DEDICATED TO

MY PARENTS AND

TAMO DILIP

A MANUAL IN THE SELECTED AREAS OF AUDIOLOGY FOR ALLIED PROFESSIONALS

Register No. 8410
Tanuja. E.

An independent project submitted in part fulfilment fo
of Master of Science (Speech and Hearing),
University of Mysore, 1984

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

CERTIFICATE

This is to certify that the Independent Project entitled "A Manual in the Selected Areas of Audiology for Allied Professionals" is the bonafide work in part fulfilment for M.Sc., in Speech and Hearing of the student with Reg.No.

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CERTIFICATE

This is to certify that the Independent Project entitled " A Manual in the selected Areas of Audiology for Allied Professionals" has been prepared under my supervision and guidance.

GUIDE

DECLARATION

This Independent Project is the result of my own study undertaken under the guidance of Dr.(Miss) Shailaja 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 unit for any other Diploma or Degree.

Mysore
Dated: REG. NO.

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CHAPTER-I

INTRODUCTION

INTRODUCTION

The term 'audiology' was coined by Norton Canfield. It is a relatively new field of study having within its purview various aspects of hearing both normal and abnormal. It came into existance subsequent to world war II. In India, its advent was even later in the mid 1960's when formal training programs took their roots. Since then there has been considerable interest in the utilization of the services of the new group of professionals, in the welfare of the consumers of such services. In order that the professional services are properly utilized, the tools employed by the professionals and the ways and means to keep them in proper order as to yield proper results must be known by the group of people who offer such services and by those who make use of such services. The latter group may be a very diverse group consisting of allied professionals medical, paramedical, administrators and teachers, parents and service organizations.

The profession Audiology has grown considerably both in terms of the sophistication and in terms of the extent of its - application. There is an onslaught of new information on tools, techniques and tests. Thus the professional offering audiological services must upgrade his knowledge and those allied professionals who make use of his services to refer to for getting a better idea as to the requirement of this profession. At present, very few indigenous publications are available to serve as source material. This manual is intended to provide information on some aspects of the tools,tests, techniques etc. that face within the purview of audiology.

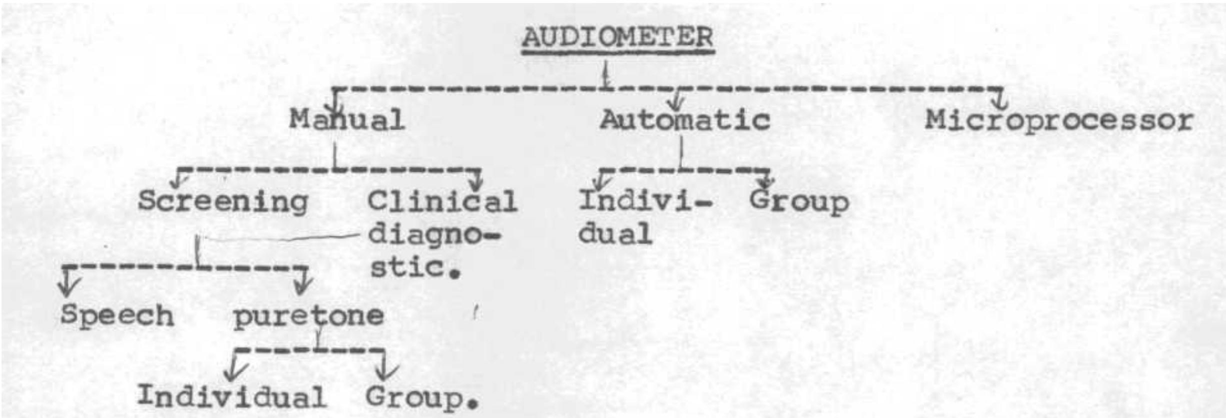
CHAPTER-II

AUDIOMETERS

AUDIOMETERS

Audiometer is an instrument for the measurement of hearing acuity. (IS:9098-I979)

Audiometer can be classified as follows:-



International Electrotechnical Commission (IEC:1976) classified Audiometers as:

Type 1, Type 2, Type 3, Type 4 and Type 5. Type 1,2 and 3 are diagnostic type, have the facility of both A.C and B.C. whereas type 4 & 5 are screening type having only A.C. facility, but avoided to use such descriptive terms.

ANSI (S_3.6-1969) classified pure tone audiometers as wide-range audiometer, narrow range audiometer and limited range audiometer, based on testing facilities available both AC and BC or only BC and also intensity and frequency range it covered.

IS (9098-1979) classified audiometer as pure tone audiometer and diagnostic audiometer.

Audiometer is undergoing a lot of developmental changes. Some of its developmental advancements are given in the Appendix (H).

Parts of the Audiometer:

1) On/Off switch: An audiometer may receive the power supply either by AC. or DC. Some have facilities for both, while purchasing a battery operated audiometer, the recurring expenditure in the replacement of the battery must also be taken into consideration.

2) Attenuator: The attenuator or the hearing level dial indicates the level of the stimuli - pure tone or speech and the level of the noise being presented. In a screening audiometer where facility for masking is not provided, there may be a single attenuator to control the intensity of the tone being presented. For audiometers equipped to provide masking noise two attenuators, are to control the level of the tone and are to control the level of the noise are available so that the level of the tone and the noise presented simultaneously may be controlled independently of each other.

For audiometers having two channels, two attenuators to control the level of the signal in each channel are provided. One of these may serve to attenuate or amplify the noise.

Normally, the attenuator is marked in hearing level in dB ranging from 0dB to 100dB, 0 dB being indicative of the signal/noise at its softest and 100 dB being indicative of loudest signal/noise that the instrument is capables of producing. The lowest hearing level tested may be -10 and the level of the signal could be increased to 110 dB or 120 dB. The minimum upper limit of 120 dB and 70 dB for type I and Type IV audiometers. For type II and Type III audiometers, the upper limits are 110 dB and 100 dB respectively. The lower limit is -10 dB for all four types of audiometers (IEC 29C).

The range on the attenuator dial from the lowest to the highest digit could be in steps of 5 dB i.e. the level of the signal pure tone or speech,can be increased from 0 to 5 to 10 etc upto the maximum. In some audiometers, the attenuator may be marked in ldB steps, i.e. the level of the tone speech could be increased or decreased by 1 dB at a time.

It is important toAnote that from the range from the lowest to the upper limit i.e. -10 to + 100, the attenuator is applicable to the pure tones inthe range of the middle frequencies such as 500 Hz to 4000 Hz. At higher (6000Hz, 8000Hz) and lower (125 Hz, 250 Hz), the range is more limited. Similarly compared to the range available for air conduction testing, the range for bone conduction is more limited. These limits are normally indicated for the attenuator dial. Similarly, the effective level for masking noise may be indicated on the attenuator so that the tester is aware of the noise level required to mask a pure tone at threshold level.

The attenuator lenearity i.e. if there is a corresponding change in the output values consequent to the manipulation of the attenuator is in the clockwise and anticlockwise direction throughout the full range is an important aspect of calibration. To check the output SPL, the attenuator is kept constant at the recommended level i.e. 60 dB HL or 70 dB HL (ANSI,1969) (IS:9098, 1979).

3) Frequency dial:- Every audiometer has the facility to choose the test tone for presentation to the tester. The range of frequencies provided depend on the type of audiometer. For Type 1 and 2, the range is from 125 Hz to 8000 Hz at octave intervals with additional frequencies of 750, 1500, 3000 and 6000 Hz (IEC 29C), for type 4, only discrete frequencies i.e. 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz and 6000 Hz are included (IEC 29C). For type 3, 125, 750, 1500 Hz are excluded. The frequency of the tone being presented at a given time may have a digital.

The frequency range listed above is normally the same irrespective of whether the signal is a continuous tone, pulsed tone or warble tone.

For calibration purposes, the deviation is the indicated frequency must be checked. The permissible error is ± 3% for all except the two or three frequencies at the extremes (250, 6000 and 8000 Hz) which can have an error of ±4%. In addition, harmonic distortion, 2nd, 3rd and higher harmonics must be checked.

4) Tone switch:- To present the signal, a tone switch is provided whenthe switch is depressed the selected pure tone is fed through the earphone and the bone vibrator. The tone switch in recent audiometers are normally of the 'off' type i.e. unless it is depressed, no signal will be presented. In earlier audiometers the tone switch was called as the tone interruptor since whenthe switch was depressed, the tone which was normally 'on' was interrupted.

The tone switch has to meet certain requirements. It must not produce any audible elicks, it must be easy to operate. For more details the national standards may be refferred to.

5) Masking Noise:- Audiometers have provision for masking noise to be presented to the nontest ear whenever there is a likelihood of the test signal crossing over to the nontest ear from the test ear.

Type 4 and 5 audiometers need not provide for masking noise (IEC 29 C).

Facilities for presenting the masking may be through the contralateral earphone, through the ipsilateral earphone or through the bone vibrator. For type 3 audiometer, masking noise facilities through the contralateral earphone only may be available and for types 1 and 2 all 3 means are recommended (IEC 29C).

Type of masking noise may be one or more of the following broad band noise, narrow band noise, speech spectrum noise. For Type 1 and 2 audiometers both narrow band and speech weighted noise (or broad band noise) are recommended (IEC 29c) For type 3 audiometer only narrow band noise is recommended.

6) Earphones:- Each audiometer is equipped with two earphones, one marked red to be used for the right ear and the other marked blue to be used for the left ear. The two earphones mounted in earcushions are connected by means of an adjustable headband. The two earphones must be matched.

A single earphone may suffice for a screening Type of audiometer such as the type 5 or IEC (29C).

The earphone frequency response must be flat throughout the frequency range of interest. Further its impedance must match that of the audiometer.

7) B.C.Vibrator:- Audiometers are equipped with B.C. vibrators, exception may be for Type 4 and 5 audiometers. For both single channel and dual channel audiometers, a single B.C. vibrator attached to a head band are provided.

The vibrator must meet certain requirements. It should have a circular contact tip area of 1.75 $\pm$ 5 mm^2. The head band must exert a force of 5.4 N.

The B.C. vibrator must be calibrated periodically.

8) Output Selector Switch:- By means of this switch, the signal may be presented through the red/blue earphone or through the B.C. vibrator. It is important that there is no cross talk i.e., the signal should be presented only in the earphone chosen, right or left but not in the other. This may be checked by keeping the earphone through which the signal is going through away from the ear withthe contralateral earphone kept over the ear.

Discussed above are the parts of an audiometer that are common of an audiometer that are common to almost all the audiometers. Whenever exceptions have been permitted,these have been mentioned.

In addition to the above audiometers the more versatile clinical diagnostic ones are provided with the followingi-

a) Test signal indicating device.

*

b) Patient signal indicating device.

c) Auxiliary output for loudspeakers.

d) Input for external signal such as speech from a taperecorder or microphone.

e) Reference tone for alternate or simultaneous presentation.

f) Communication between the tester and testee.

g) VU meter

Automatic, Manual Microprocessor:

The three types of instruments differ in the manner in which the signal is presented and the response is recorded, decisions with respect to signal presentation and criteria for response. A comparative statement is given below:

Manual	Automatic	Microprocessor
Stimuli is presented by the tester	Stimuli is presented automatically.	Stimuli is presented automatically.
Recorded manually on a graph (Audiogram) or numerically)	Automatically traced on the graph meant for this purpose	Bisplay and print out of the responses (numerals) onthe paper meant for this purpose.
Tester decides when to present the signal	Tester starts the instrument and subsequently the signal is presented continuously at a predetermined rate.	Stimuli presented according to program predetermined.
Stimuli presented at discrete frequencies.	Instrument for discrete frequencies end continuous frequencies available.	Stimuli are presented at discrete frequencies

1.	2.	3.
Changes the intensity of the stimuli, testee does not increase or decrease the intensity.	The intensity of the stimuli is increased or decreased depending on whether the testee releases or presses on a hand-held switch. Tester does not change the intensity of the stimuli.	Neither tester or testee change the intensity of the signal.
Can be single channel or two channel	Single channel instrument	Can be single channel or two channel.
Rechecking of thresholds done by the tester.	Does not have provision for rechecking thresholds recorded or unrecorded.	Retests, unestablished thresholds.

Speech Vs Pure tone Audiometer:

In speech audiometer, it is the speech stimuli that is used to evaluate the auditory function. The speech source may be either discs or recorded types or the stimuli may be given through live-voice by means of a microphone. The stimuli may be presented through earphones or through loudspeakers. The advantage of the former is that information regarding each eat may be obtained separately? the latter may be preferred at the time of hearing aid evaluation. It is now more common to have the pure tone and speech circuit in the same chassis so that the same audiometer may have facilities for both speech and pure tone tests.

Screening Vs diagnostic audiometer:

Screening audiometer serves the purpose of identifying hearing loss. It has got facility for only AC testing with limited range of frequency and intensity. It may be individual or group type.

Diagnostic audiometer on the other hand is more versatile. It has got facility for both pure tone and speech testing and in its more elaborated form includes facility for special tests also. It is required to be uses in sound treated room. It is primarily meant for diagnostic purposes in clinical and medical settings.

Individual vs Group Audiometer:-

With individual type audiometer, one can test only one subject at a time, Whereas group audiometer is capable of testing a group of person simultaneously. Using a proceduce in which reliable information is obtainable from each individual. Compared to group audiometer, individual type audiometer provides more accurate result but it is more time consuming.

Most of the clinical audiometers are of individual type.

Selection of Audiometer:

Selection of a particular type of audiometer depends upon the purpose of use. If only puretone testing is required, it is good to buy one of the simple audiometers built only for simple pure tone testing. If it is for routine clinical examination, it is preferable to buy one which has provision for pure tone speech and some of the special testing facility.

Audiometers should be purchased from manufacturers who will provide reliable maintanance and calibration services. While buying we should ask for operational and servicing manual of the instrument and also a cover to protect instrument from the dust. Specifications of its accessories must be well noted as it is necessary to mention it clearly while buying spare parts.

Thus it is important that we select the audiometer which is most appropriate to serve the purpose.

CHAPTER-III

AUDIOGRAM

AUDIOGRAM

Introduction:

An audiogram is helpful for evaluation of auditory problems. Determination of the type of hearing loss can be obtained by comparing airconduction and boneconduction thresholds and also it helps in determining type of rehabilitation needed for an individual.

Puretone audiometry consists of airconduction (AC) and boneconduction(BC) testing. For AC testing, puretone signals are presented through the earphone with the frequency ranging from 250 Hz through 8000 Hz at octave intervals. BC testing consists of presenting puretones ranging from 250 Hz to 4000 Hz by means of a bone vibrator placed on the mastoid, behind the ear or on the forehead. For each specific frequency, the tones are varied in intensity by means of an attenuator dial on the audiometer to find out the lowest level at which the individual could barely detect the presence of the signal. This particular level of hearing is termed as threshold level of the individual. This measurement is essentially similar for both AC and BC.

Hearing test results particularly those of puretone audiometry are presented in the form of a graph. Thus an audiogram can be defined as the graphic representation of hearing as the test results. This term was first used by Fowler and Wegel (1944). Hearing test results can also be recorded numerically.

Specifications of An Audioqram:

An audiogram form consists of identifying informations such as name, age and sex of the testee, registration number, audiometer used, symbol keys and also provision for recording other test batteries such as speech audiometry and special test results in addition to the graph. A sample is given in page number (22).

Construction of the graph:

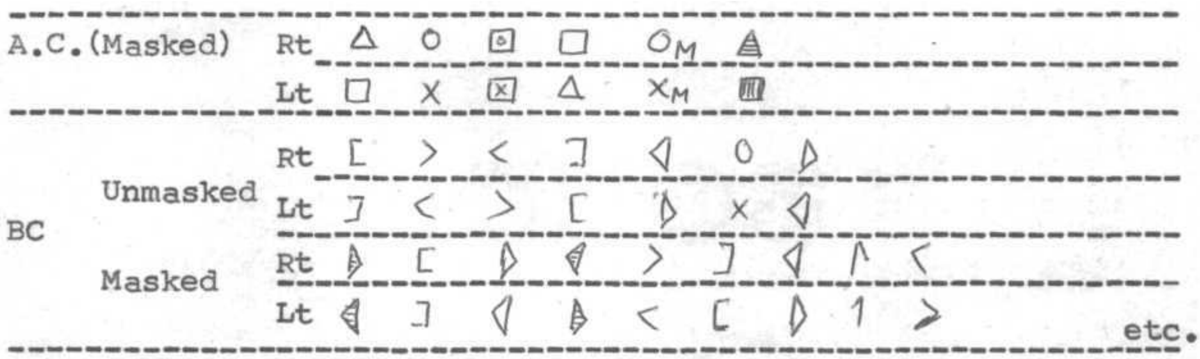
For puretone hearing testing, frequencies is expressed in Hertz (Hz) and intensity in decibel (dB). A graph frequency Vs intensity, is drawn to record the test results. ASHA(1974) recommended that frequency to be represented by the horizontal line (abscissa) and hearing level by the vertical line (ordinate) of the graph. The digit of the hearing range in the audiogram correspond to the digit range given in the intensity dial of the audiometer. The same holds true for frequency also.

The size of one octave on the frequency scale should be equivalent to 20 dB on the hearing level scale (ANSI S3 6-1969, ASHA-1974). Also it is recommended that the lines representing octave interval of frequency scale and 10 dB interval of hearing level scale have equal darkness and thickness. The lines used for inter-octave frequency be finer and lighter than that of octave frequencies (ASHA 1974).

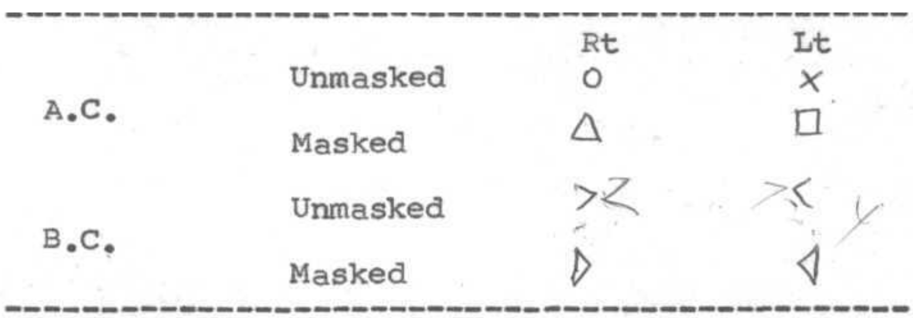
Although no standard specifies the frequency and intensity range, an audiogram generally have frequency range of 125 Hz to 8000 Hz at octave intervals and an intensity range of 0 to 100 dB which may sometimes extend from -10 dB to 110 or 120 dB depending upon the audiometer. 0 dB in the audiometer dial is not the absolute zero of the sound pressure level, but rather a reference sound pressure level which represents normal hearing level for normal hearing adults. It is equivalent to 0.0002 dynes/cm^2 for puretones. Thus a line at 0 dB HL is some sort of normalizing line which represents normal hearing. The point above this line indicates hearing that is better than standard norm and point below it indicates hearing. The range of hearing level dial may extend below 0 dB i.e. -10 dB indicates that individual who shows threshold of -10 dB have hearing which is more sensitive than average. Audiometers are calibrated directly in dB relative to a standard representing threshold of normal hearing. The audiometric zero reference standard used today are ASA(l951), ISO(1964) and ANSK1969).

Symbols used:-

There exists a wide variety of symbols and symbol systems adopted by different clinicians. But there is no universal agreement regarding which symbol system is to be adopted. It may create confusions and misinterpretations when audiograms - are exchanged among different centers which adopt different symbols (ASHA 1974). To be aware of the different existing symbols, it is worth reviewing the results of the survey conducted by Martin and Kopra (1970) on audiometric symbols. Some of the selected samples are listed below:



Based on their survey, Martin and Kopra (1972) proposed a symbol system which is give below:



Also there are symbol systems recommended by Thompson (1946), Fowler (1951) and Smith (1966) in the literature.

Jerger (1976) proposed a symbol system specially made for scholarly publications. In addition to pure tone symbols, he included the symbol for other test results also such as sensory neural acuity level (SAL) and acoustic reflex threshold (ART).

	Unmasked	Masked
A.C.	○	●
B.C.	△	▲
SAL	◇	◆
ART	□	▨

Jerger (1976) claimed that the symbol system proposed by him, minimizer number of symbols used thus eliminating the problem of colour coding.

There are different opinions regarding the use of B.C. symbol. Some prefer to use separate symbols for forehead and mastoid placement (ASHA,I974) and some other eg: Martin and Kopra (1972) prefer to use symbols common to both. Jerger (1976) recommended the use of a common symbol for both masked and unmasked B.C. threshold.

To avoid possible confusions of using different symbols. ASHA (1974) recommended a symbol system for universal use which is following:-

Modality		Rt	both	Lt
AC	Unmasked	O		X
	Masked	Δ		□
BC	Unmasked	<		>
(Mastoid)	Masked	[		]
BC	Unmasked		V	
	Masked	┐		┌
A.C.Sound field			S	

No response symbol

Modality		Rt	Both	Lt
AC	Unmasked	↙O		X↘
	Masked	↙Δ		□↘
BC	Unmasked	<↙		>↘
(Mastoid)	Masked	[↙		]↘
BC	Unmasked		V↓	
(Forehead)	Masked	┐↙		┌↘
AC Sound Field			S↓	

(Symbol system of Audiogram recommended by ASHA 1974)

Recorded hearing threshold levels in the audiogram should be connected by solid lines for air conduction and broken lines for bone conduction. The latter should be connected only when

It is not necessary to use colour coding but if employed red shall be used for right ear symbol and connecting lines. Blue for left ear symbol and its connected lines (ASHA,1974, Newby, 1965).

While placing symbols, it was recommended that AC symbol shall be placed on the intersecting point of vertical and horizontal axis at the approximate level. BC symbols should be placed adjacent to the frequency axis. Also left ear symbols should be placed at the right side of the frequency axis and vice versa. When the threshold of masked and unmasked right and left AC threshold are at the same level, left ear symbol should be placed inside the right AC symbol eg.(BC symbols should be placed adjacent to but not touching AC symbol when AC and BC thresholds overlap, unmasked symbols must be placed closer to frequency axis and masked threshold surrounding but not touching (ASHA, 1974).

Single or separate:-

According to Newby (1965), some clinicions employed a common audiogram for both the ears while some other used separate audiograms for each ear appearing side by side. Jerger (1976) suggested the use of two audiograms on the grounds that using separate audiogram for the two ears minimized the number of the symbols used and eliminated the problem of colour coding. Moreover it is easier to visualize airbone gap is bilateral conductive loss, when separate audiograms are used. Also, it avoids cluttering of symbols that occurs when AC and BC hearing threshold level for both left and right ear occur approximately at the same level.

Audiogram and Standard:

At earlier times, ASA (1951) was the only audiometric standard available. So it was not necessary to record it on the audiogram. But with the development of ISO (1964) standard, confusion arose regarding audiometric calibration. ASA (1951) and ISO (1964) differ in the scale they adopted thus direct comparison of audiograms are not possible, eg. If an audiogram obtained with an audiometer calibrated at ASA 1951, shows 15 dB HL, the same with an audiometer calibrated at ISO (1964) standard would show 25 dB HL. It is when threshold measurement are made for the same individual at the same time. Thus although the value differs, hearing level of the individual essentially remain the same. Thus, if standards at which the audiometers are calibrated are unknown, comparison of audiogram is not passible.

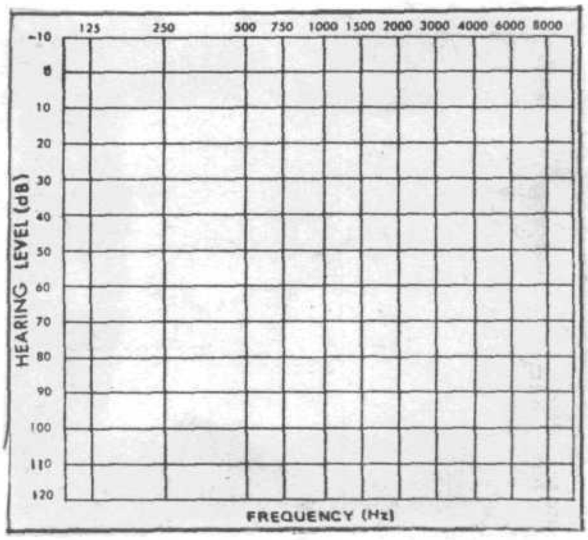
Thus at a time, many audiogram forms contained both ASA (1951) ordinate and an ISO (1964) ordinate to make ordinate

AUDIOGRAM

NAME . . . . AGE . . . . SEX M/F Case No......

TESTED BY......... TEST NO . . . . DATE . . . . . .

AUDIOMETER USED . . . . . .



SPEECH AUDIOMETRY

	RIGHT	LEFT
PTA		
SRT		
PBMAX		
PBMAX IN NOISE		
SPEECH AWARENESS LEVEL		

KEY TO SYMBOLS

	RIGHT	LEFT
AIR CONDUCTION : UNMASKED	O	X
MASKED	△	□
NO RESPONSE	↙O	X↘
BONE CONDUCTION *:		
UNMASKED	[	]
MASKED	⌐	¬
NO RESPONSE	[↓	]↓
FIT	f	
SOUND FIELD	S	
NO RESPONSE	S↓	

SPECIAL TESTS

EAR	RIGHT				LEFT			
FREQUENCY (HZ)	500	1000	2000	4000	500	1000	2000	4000
OLSEN & NOFFSINGER'S TONE DECAY TEST								
STAT								
ABLB								
SISI(PL-dBHL)								
STENGER								

*CONTRALATERAL EAR MASKED

of choice to some audiogram form provide conversion table in terms of dB to add or subtract to convert one standard to other (Newby 1965). Nowadays ISO (1964) is more widely used. However the audiometers calibrated to ASA (1951) standard may still be in use, thus it is essential to mention the audiometric zero reference level prominently on the audiogram form.

Audiogram Interpretation:

An audiogram can be interpreted under the following headings!-

1) Types of hearing loss
2) Pattern of hearing loss and
3) Degree of hearing loss

l) Types of Hearing Loss:

The information regarding the types of loss: conductive, mixed or sensorineural type can be obtained from the audiogram by comparing AC and BC thresholds. The gap between AC and BC threshold is termed as airbone gap which is critical in determining the type of loss.

a) Conductive Loss:

A conductive loss is demonstrated by the presence of hearing loss by AC but normal hearing by BC (Newby, 1972). The existing airbone gap must be atleast 10 dB HL. If such a gap exists when both AC and BC thresholds are within normal limits, it is termed as minimal conductive hearing loss. AC loss generally does not exceed 60 dB HL (Feldman 1963) because beyond this level, the whole skull vibrates resulting in direct stimulation of the cochlea. Thus if the threshold level exceeds 60 dB HL, problem cannot be purely conductive.

b) Sensori-Neural Hearing Loss:-

The audiogram shows greater loss for the high frequency with lower frequency being normal or near normal. BC thresholds are approximately same as that of AC threshold within 10 dB airbone gap.

c) Mixed Hearing Loss:-

In this type of hearing loss both AC and BC thresholds show poorer hearing than normals. But the loss of BC is not as much as that of AC (0Neill and Oyer 1970). AC thresholds may be relatively flat or dropping off in high frequencies with a dropping audiometric configuration.

2) Pattern of Hearing Loss:

There is no standard as such regarding the pattern of hearing loss. However various authors such as Carhart (1945), Davis (1978), Hodgsm (1980) have described different pattern.

The following patterns are generally recognized:

1) High frequency hearing loss
2) Low frequency hearing loss
3) Flat hearing loss
4) Trough or Saucer shaped hearing loss
5) Corner audiogram
6) Irregular audiogram

1) High Frequency Hearing Loss:

High frequency hearing loss is characterized by presence of slope from low frequency to high frequency with a loss at least 25 dB HL through the speech frequency or a total loss of hearing beyond 3000 Hz or both (Johnson 1966). The slope should be at least 15 dB between 500 Hz and 4000 Hz (Anderson). It has been classified into two types, gradual and sharp type.

Gradual type:

In gradual type, the loss begins at low frequency with a gradual increase in the high frequency. At 500 Hz, a threshold of 25 dB HL or greater and change in per octave by 10 dB. The difference between the highest and the lowest threshold was no more than 35 dB (Stephens and Rintelmann 1978).

Sharp type:

It is characterized by normal or near normal hearing in the low frequency with a threshold at 500 Hz of 30 dB HL or better. Between 500 Hz and 1000 Hz or between 1000 Hz and 2000 Hz, there is a drop in the threshold of at least 20 dB. The difference between lowest and highest thresholds was greater than 40 dB (Stephen and Rintelmann 1978).

This pattern is associated with sensory-neural hearing loss. There is a pattern known is conductive high tone hearing loss where the problem is purely conductive in nature. Here AC threshold shows high frequency loss when BC threshold remain unaffected (Anderson).

Although no two individuals show exactly similar type of hearing loss, some of the typical types of audiogram which are generally associated with particular disease condition can be identified (Fig:1-16). Some of the hearing loss conditions when high frequency hearing loss is often seen are presbycusis, noise induced hearing loss, ossicular discontinuity, etc.

2) <u>Low Frequency Hearing Loss:</u>

This audiometric patterns shows significant loss at low end mid. test frequencies with relatively normal or near normal hearing in the high frequency region (Ross and Matkin 1967, Davis Johnson 1966). Johnson, 1966* defined it as reduced threshold in the low frequency with a rising curve through the speech range and into the higher frequency. Davis (1978) termed it as rising low frequency hearing loss.

This is often seen in conductive hearing loss cases but it may be seen in some Sensori-neural loss conditions also such as Meniere's disease at its early stage.

3) Flat Hearing Loss:

In this pattern, there is approximately equal degree of hearing in all test frequencies. The magnitude of the difference not exceeding 5-10 dB (Johnson 1966, Davis 1978). It is frequently associated with conductive hearing loss such as serous Otitis media. Also seen in condition of collapsed ear canal and moderately advanced condition of Meniere's disease.

4) Trough or Saucer Shaped Loss:

This pattern is demonstrated by better hearing at low and high frequencies with poorer hearing in mid. or speech frequency range, Johnson (1966), when the threshold difference between poorest and best thresholds are great, the audiogram appear as V-shape, but when mild, appear as saucer shaped. This type of hearing loss is often seen in some SN loss conditions such as rubella and also in Malingerers.

5) Corner Audiogram:

This pattern occurs is profound deafness. Corner audiogram is characterized by presence of response to only low frequencies such as 250 Hz or 500 Hz that too when presented at very high level or maximum limit of the audiometer. They usually do not respond to mid or high frequency at highest intensity that could be presented by the audiometer. (Davis 1978, Hodgson 1980).

It is usually seen in congenital hearing loss, viral disease and drug induced hearing loss.

6) Irregular Loss:-

When the audiogram does not fit into any of the above categories, the pattern is often termed as irregular loss (Hodgson, 1980).

Audiometric pattern yielded valuable information when correlated with type of hearing loss. But considering only this factor in diagnosis will be misleading as there are exceptional conditions. So this information only supplements to the other information as far as diagnosis is concerned.

3) Degree of Hearing Loss:

Degree of hearing loss indicates to some extent. The degree of difficulty experienced in communication by the individual. It is usually obtained by comparing AC threshold value with that of standard norms. Although audiometric zero level is considered as average response of normal young adults, there are individual variations in normal hearing range. Those individuals whose threshold fall between -10 to 20 dB HL are usually considered to have hearing within normal range (ANSI,1969). Thus hearing level greater than 26 dB HL represents hearing loss and severity is graded depending upon degree of hearing loss.

Goodman (1965) prepared a scale of hearing impairment which relates hearing threshold level (HTL) with degree of impairment and also HTL in terms of probable handicap and needs. It is as follows:-

HTL in dB	Descriptive term	Probable Handicap and needs
10 to 26	Normal limits	
27 to 40	Mild hearing loss	- difficulty in hearing faint speech. Needs favourable seating arrangement, lip reading and hearing aid.
40 to 55	Moderate hearing loss	- Hear conversational speech at a distance of 3-5 feet. Needs:Hearing aid, auditory training, lip reading, favourable seating, speech conservation and correction

(1)	(2)	(3)
55 to 70	Moderately severe hearing loss	- difficulty understanding speech at normal Conversational level especially in group discussion. Needs: That is needed by moderate loss plus language therapy.
70 to 90	Severe hearing loss	- Hear loud voice at a distance of 1 feet and able to identify environmental sounds but difficulty in distinguishing consonant sounds Needs: Special education for deaf, may enter regular classes at a late time
90	Profound hearing loss	- May hear loud sound but does not rely on hearing for communication. Needs: Special education for deaf, some may enter regular high school.

(HTL = average of 500 Hz, 1000 Hz and 2000 Hz Ref: ANSI 1969)

(Ref: Green Puretone air conduction testing in Handbook of Clinical Audiology by Katz, 1978).

Ohe of the limitation of this guideline is it neglects the type of hearing loss which is crucial in determining rehabilitational needs. Also the individual may show only mild hearing loss by puretone threshold but may have complete loss of ability to understand speak at any level as in case of tumor condition (Davis,S and Green S 1979). However an estimate of speech handicap can be made by considering speech frequencies. Fletcher (1950) recommended to use only two frequency average while predicting hearing loss of speech regardless of the shape of the AC curve on the audiogram.

Degree of hearing loss is often used to categorize the person into deaf or hard of hearing. Those individuals whose hearing loss is less than 85 dB HL are labelled as hard of hearing and those exceeds 85 dB HL as deaf Davis (1978). This classification is crucial factor in determining their of rehabilitational needs. Those who are deaf need full time special education whereas the hard of hearing can be put in regular classroom by providing some special facilities.

The patient's need for hearing aid and the requisite power use can be determined by considering hearing threshold level and pattern of hearing loss. Hearing loss upto a degree of 80 dB HL may be benefitted from hearing aid. For those with profound hearing loss, speech perception may be limited but the hearing aid may help to increase awareness of environmental sounds. Those individual who show flat loss are generally better benefitted from amplification but those of high frequency it is less beneficial because of the limitation of hearing aid.

Audiogram can be very useful provided it is recorded accurately and unambigously. It supplies pertinent information about the patient regarding the problem.

TYPICAL AUDIOGRAMS

Fig: I

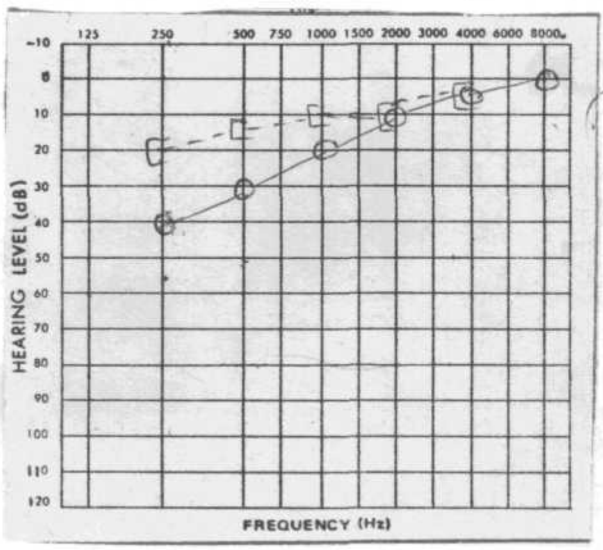
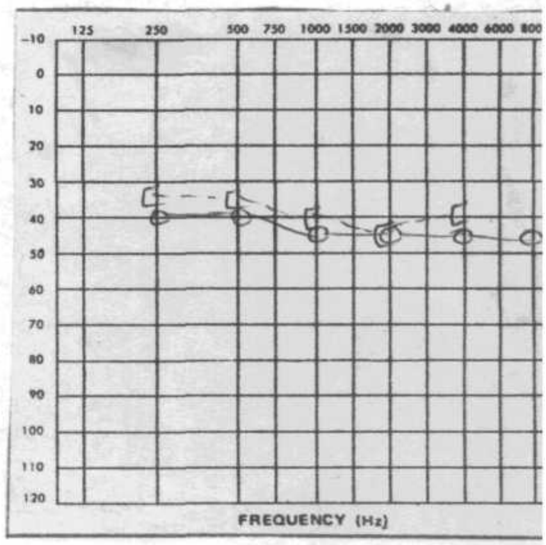


Fig: 2.



Early stage of Meniere's disease

-Low frequency conductive hearing loss

-History of vertigo and Tinnitus

(Goodhill and Gugger heim 1971)

-Moderately advanced stage of Meniere's diseas

-Flat frequency hearing loss sensory type.

(Goodhill and Gugger heim 1970

Fig 3

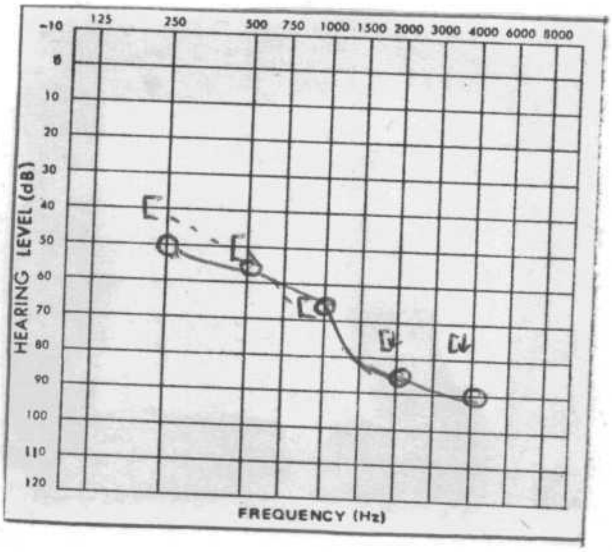
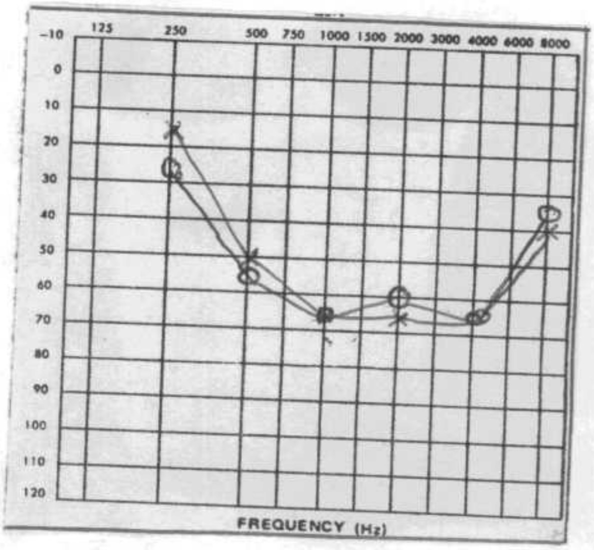


Fig 4 .



-Advanced stage of Meniere's disease -Maternal rubella and Malinger

-Saucer shaped audiogram (Prescord 1978) .

-Severe Hearing loss

-Usually accompanied by marked vestibular hypoactivity, poor speech discrimination and presence of recruitment (Goodheill and Guggenheim 1971)

At

Fig : 5

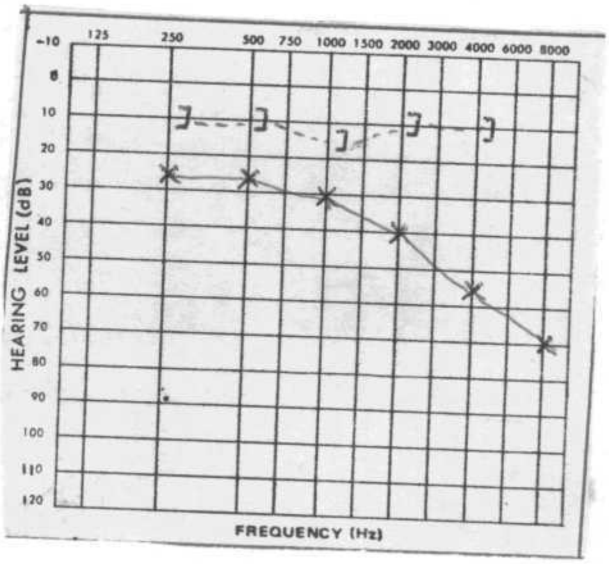
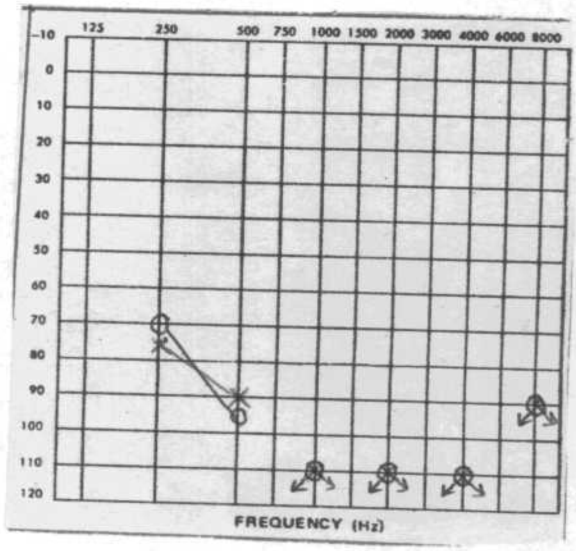


Fig : 6



-Ossicular discontinuity
-High tone conductive hearing loss
(Anderson)

-Congenital hearing loss and viral disease

-Corner audiogram
(Davis J 1978)

Fig 7

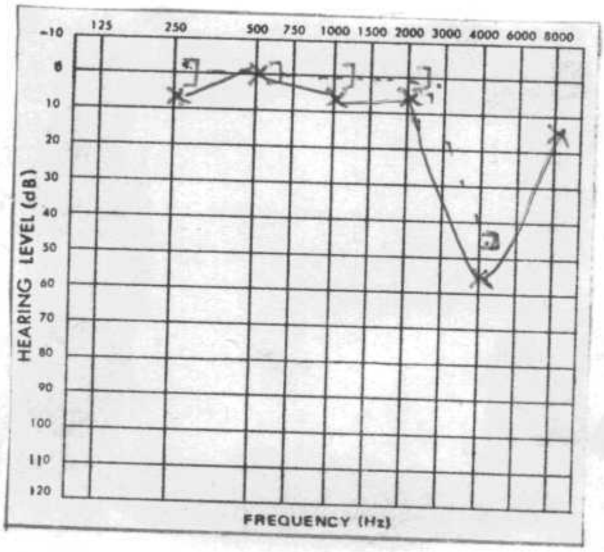
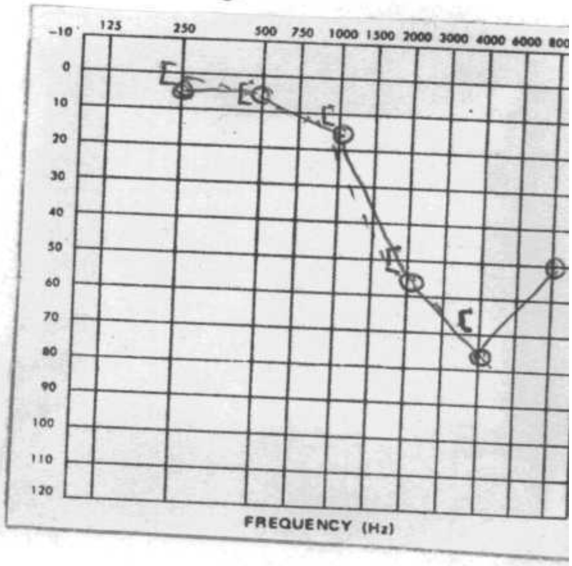


Fig 8 .

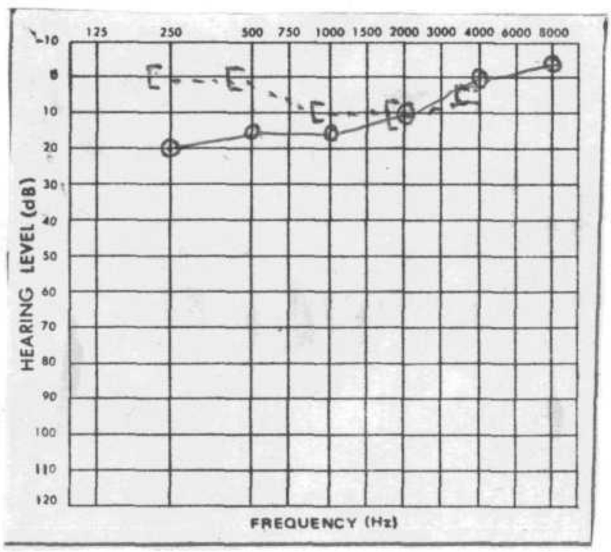


-Noise induced hearing loss
-Dip at 4 KHz for both AC & BC
-History of tinnitus and exposure to high intensity noise

(Goodheill & Guggenhaim 1971)

-Noise induced hearing loss further deteriora
if remain untreated.
Drop at 2000 Hz also due to persistance o
acoustic trauma
(Goodhill and Guggeenht
1971)

Fig: 9.



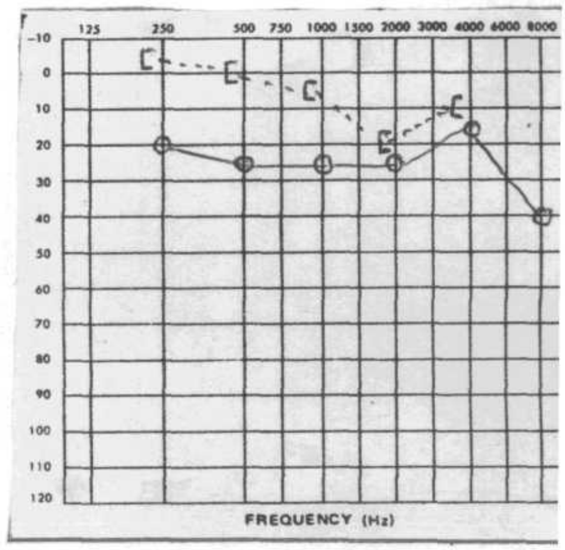
-Early Otosclerosis

-Normal sensoryneural reserve

-Early stapes fixation

-Induces slight stiffness silt in AC audiogram without affecting BC threshold (Carhart 1971)

Fig: 10



-Otosclerosis

-Incomplete stapes fixati free from SN Hearing loss

-Mild AC loss and distortion of BC audiogram.
(Carhart 1971)

Fig 11

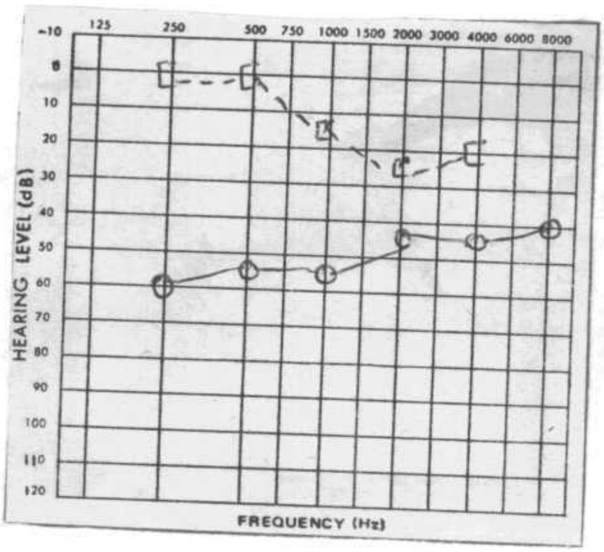
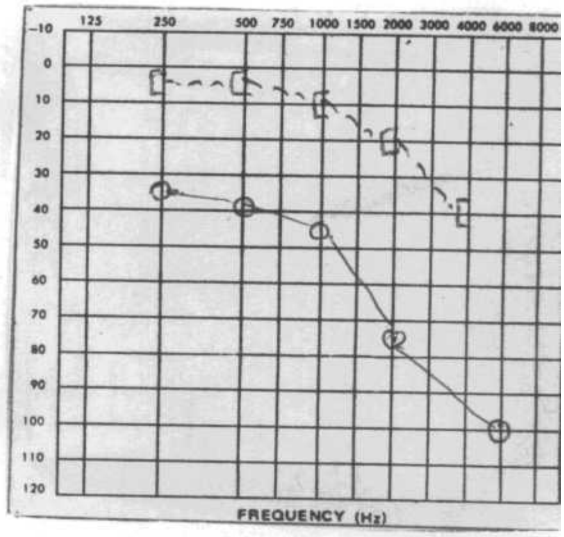


Fig 12

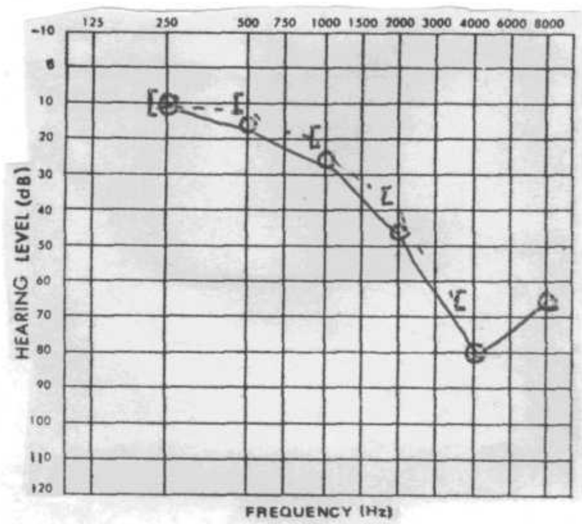


-Otosclerosis
-Complete stapes fixation in an ear
-Free from SN loss
-Marked loss of AC hearing
-Typical mechanical distortion of the BC audiogram
(Carhart 1971)

-Otosclerosis with cochlear involvement
-Superimposed upon conductive loss

(Goodhill and Guggerhaim 1971)

Fig 13



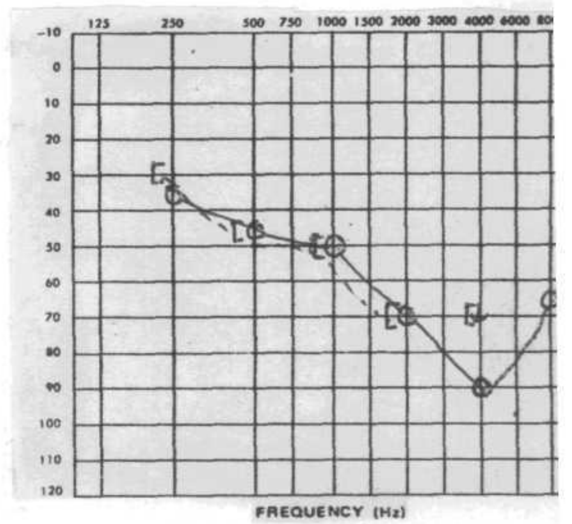
-Sensory presbycusis

-High frequency hearing loss

-Usually bilateral

(Katz 1978)

Fig - 14.



-Neural presbycusis

-Gradual high frequency hearing loss

-Usually bilateral

(Katz 1978)

Fig 15

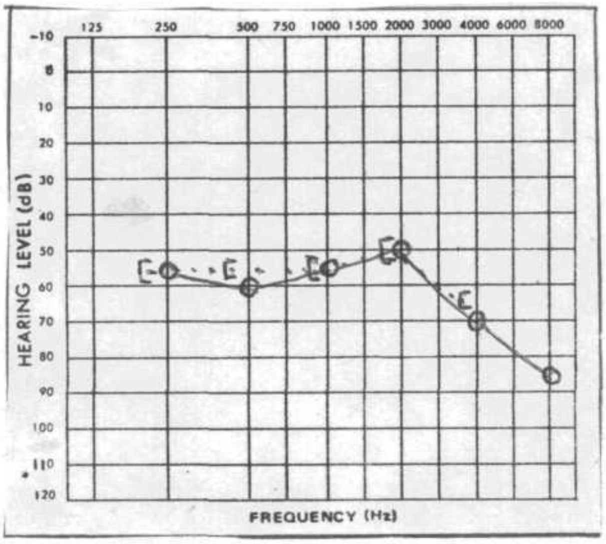
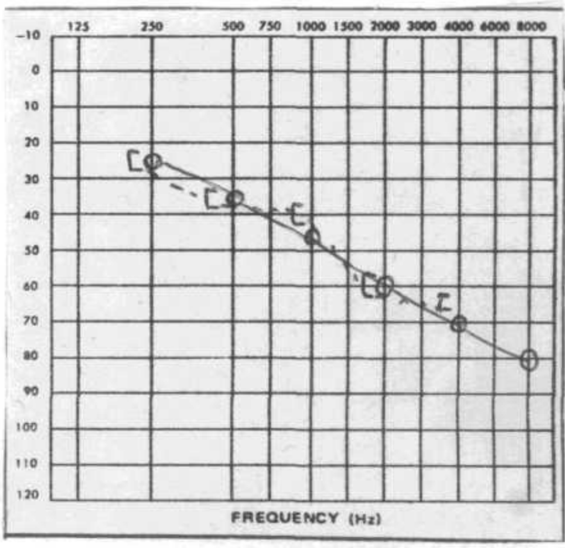


Fig 16.



-Strial atrophy
-More hearing loss at high frequency
-Usually bilateral
(Katz 1978)

-Cochlear donductive Presbycusis
-High Frequency hearing loss of gradual type
-Usually bilateral
(Katz 1978)

CHAPTER-IV

EARPHONE AND EARCUSHION

EARPHONES AND EARCUSHIONS

Earphones:

Earphones are electroacoustic transducers which convert electrical signal into acoustical signal. There are two types of earphone namely external type and internal type.

External type:

External type are mounted in rubber cushion and placed facing the external canal. External type earphones are generally used to deliver audiometric airconduction signal. It enables to test to each ear separately. They are selected on the basis of good long term stability, flat frequency response and ability to deliver high intensity signals. There are a variety of earphones. They differ in terms of impedance characteristics, frequency response, output sound pressure level etc. To name a few, telephones : TDH-39, TDH-49, TDH-50, TDH-140, permoflux PDR-1, PDR-9, PDR-10, Western Electric 705-A, Telex-1470, Beyer DT-48, Pederson type B-228 etc. Among them TDH-39, and TDH-49, both mounted on MX-41/AR cushion are commonly employed in hearing testing.' It is important to recognize different types of earphones as they differ in characteristics and each audiometers is supplied with specific type of earphones. So when replacement is needed, it is essential to select the particular type as specified by the audiometer, it will affect calibration of the audiometer. Thus earphones should not be exchanged between audiometers.

Insert type:

Insert type, extend into the external auditory meatus with the help of an earpiece (earmould).

Insert type receivers have limited frequency response and in most of them output drops sharply in the frequency range above 2000 to 3000 Hz (Laybarger, i972). Also they present calibration problems. They are used in hearing aid and in some audiometers for delivering masking noise. It increases intraaural attenuation by 15-20 dB thus reducing chances of overmasking.

Ear Cushion:

The earcushions are enclosers of external type earphones. Thus used/to fix earphones on the ear. They are made out of rubber and have specific shape and size. Two types of earcushions are generally recognized. They are:

1. Supraaural earcushion
2. circumaural earcushion.

Supraaural cushion covers only the outer part of the pinna and seal againts the skull. Thus circumaural cushion occupies a larger volume than supraaural cushion. The letter is approximately 6 CC which approximates the volume of NBS-9A standard coupler. The specific volume of circumaural cushions are not known as there is no standard coupler developed to measure the same. Examples:

Supraaural cushion : MX-41/AR

Telephonies model D-51 etc.

Circumaural cushion,: Aural Research, AR-100, Auraldomes, Radsen ME-10, Rudmose RA-125, Otocup etc.

The supra-aural cushion MX-41/AR (as specified by ANSI-1969) are most commonly used for hearing testing. It is a two piece foam. Cushion made out of Buna rubber (base) and sponge neoprene (cap). Performance of different MX-41/AR cushion may differ due to material compound, molding processes effectiveness of the cement connecting the two pieces aid aging characteristics of the sponge materials. To overcome this problem. Telephonics developed one piece Model 51 earcushion, comparison were made between MX-41/AR and Model 51 and they found no significant difference in their performance. But there was strong indication of Model-51 giving more consistent results with improvement of comfort also (Michael and Bienvenue 1980).

It is recommended, 3/4 inch as diameter of the opening of the hole of earcushion (ANSI 1962). If the dimension is less than 3/4, it may lead to alteration of output at certain frequency range even if the audiometer and the earphone are in good condition. But commercially available! earcushions are found to vary from 1/32 inch to 1/8 inch less than recommended value (Dirk and Wilson 1976).

Earphones and earcushions are available as specific assembly. Most earphones can be mounted in either supra-aural or circum-aural cushion. Sometimes they are available as single unit eg; sharpe HA-10.

Specific combination either supra-aural or circum-aural has its own advantages and disadvantages. Some of them are mention below:-

Earphone-supra-aural cushion combination:

Advantages:

It can be easily calibrated by using the standard coupler NBS-9A, thus approved by various standards such as ANSI, SI6-1962.

Disadvantages:

1) They become uncomfortable after wearing for longer time which may affect the performance.
2) They donot attenuate ambient noise as effectively as that of circumaural earphone which is demanded in some situations such as school screening and industrial screening.
3) This type of cushion deforms the flesh around the canal entrance and constricts the opening. It results in lowering

of the resonant frequency of the system which varies with pressure applied to the cushion which is in contact with the pinna (Villchur 1969).

Earphone-Circumaural Cushion Combination:-

Advantages:-

1) It provides greater attenuation of ambient noise thus advantageous for testing in noisy situation.
2) It improves the comfort of the wearer.
3) There is less likelihood of the energy leakage.
4) They have low impedance in lower frequency region. Thus at this frequency range output measured on a flat plate coupler goes well with the real ear measurements made by supra-aural earphones investigated (Show 1966b).

Disadvantages:

1) It cannot be calibrated to NBS-9A, standard coupler. No standard coupler has been developed to calibrate the circumaural earphone as yet. Thus its use is not justified in routine audiometric testing. Its use is limited to laboratory investigations where careful calibration can be performed.

2) At frequencies above 2000 Hz, circumaural earphone response varied depending upon type of earphone and cushion, applied force and placement of earphone on coupler (Show and Thiesson, 1962).

Speaks (1969) investigated difference in performance between circumaural cushion (CZU-6) and supra-aural cushion (MX-41/AR) on threshold sensitivity for speech. The result revealed that supra-aural cushion shows slight superiority of performance but at suprathreshold level hearing 80 dB, performance were the same. Thus speech discrimination was unaffected by the choice of cushion.

Need for Evaluation:-

Recalibration are not necessary when either earphone cords or cushions are replaced (Joseph, Paul and Charles) but it is essential to establish calibration data when earphones are replaced as they may alter calibration of the audic meter. As earphones differ in their response characteristics, it is essential to have a knowledge of specification of each earphone in use.

(Appendix-'F' shows comparison of characteristics of some of the earphones).

When old earphones are worn out, it replace it with new ones, it is essential to transfer norms from old and new earphone. This process results in slightly different sound pressure value. This norm value represents normal human thres depending on the earphone in question. Thus a new model of earphone should undergo audiologic evaluation to establish reference normal hearing threshold prior to use. Reference threshold level provided for standard earphone ANSI S_3.6-1969. Corresponds to the normal hearing threshold for ear frequency (Fig.1)

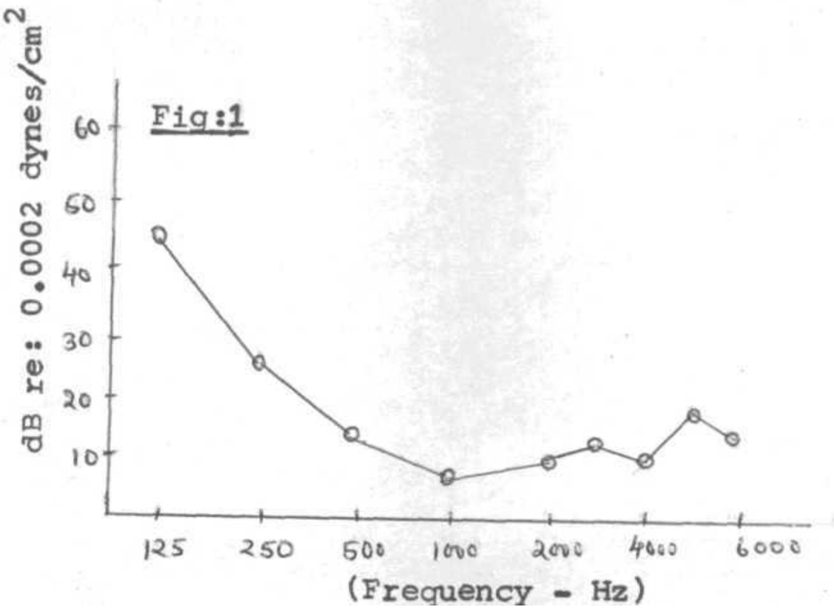
This values can be transferred to values which are applicable to other new earphones. It is usually done by using loudness balance procedure between standard and new earphone. Thus reference threshold level for new audiometric earphone.

A comparison of different earphones (TDH-39, TDH-49, and DT-48) were made and results revealed that a real ear difference of 2 dB was found between TDH-39, TDH-49 and 5 dB between TDH-49 and DT-48 (Without equilizer)(Hugo Fasti, 1979).

Earphones and Occlusion Effect:-

Occlusion effect is a phenomenon in which subject experiences increase in sensitivily of BC threshold as he closes his external auditory meatus. This condition can also be created by using earphones. The effect of various types of earphones on average occlusion effect are given in the graph (Fig.II).

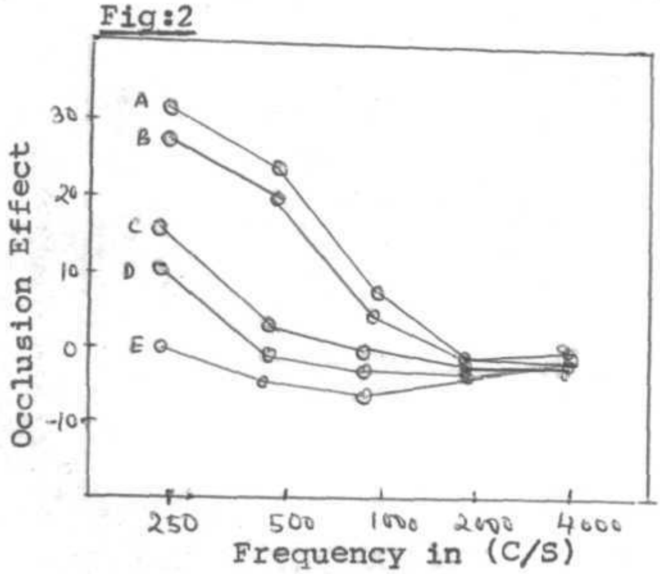
Fig:1



Normal Threshold level ref: 0.0002 dynes/cm^2 for AC via a TDH-39 earphone fitted with a MX-41/AR cushion ANSI S_3.6-1969

(Handbook of Perception Vol.IV : Hearing)

Fig:2



A - PDR-10 earphone is firm rubber cuff

B - TDH-39 phone is firm rubber cuff & plastic backing shell

C - Circumaural earphone series H-10

D - Noise free Mark-II built in phone

E - Loudspeaker mounted is approximately 7" spherical enclosure

(Ref: Jerger 'Modern development of Audiology', 1979)

Method of Evaluation:

The reference threshold level of a standard earphone may be transferred to the values which are applicable to other new earphones. It can be carried out using either objective method or subjective method.

Subjective Measurement:

In subjective method, two methods of measurement are available. Suprathreshold loudness balancing method and threshold loudness balancing method. Suprathreshold' loudness balance method is usually employed while comparing earphones having same physical characteristics. Threshold balancing method is used for comparing earphones having different characteristics. The latter method has been adopted by environmental acoustic laboratory for all psychoacoustic comparison of earphone and even for those which are physically similar (Michel and Bunvenue 1980).

l) Suprathreshold loudness balance method:

Here comparison is made between output of a standard earphone and the earphonein question. Both earphones are attached on a headband and a tone is presented alternately between the ear at a level above the threshold level. Subject are asked to make the balance judgement and values obtained are recorded. ANSI specification for Audiometers S_3-6-1969 prescribes this loudness balance to be done by not less than 6 subjects with otologically normal ears at a hearing level between 20 and 40 dB SL, covering a frequency range of 125, 500, 1000, 1500, 2000, 3000, 4000, 6000 and 8000Hz.

IS;909 (1979) recommended balancing to be done at mild or moderate level by 10 otologically normal subjects with the age range of 10-25 years whose threshold donot exceed 15 dB at test frequencies.

Donald Causty and Lucille B Beck (1974) reported calibration data of Telex 1470 earphone using a standard earphone (WE-705-A) and a transfer standard earphone(TDH-39). Here use of the transfer standard earphone is to avoid problem of difference of hearing acuity between two ears. First balancing was made between standard ear phone (WE-705-A) and transfer standard earphone (WE-705-A). The judgement was then repeated between transfer standard earphone (TDH-39) on the same ear and earphone in question (Telex 1470) which replaced the standard earphone on the opposite ear.

The test employed Bekesy handswitch control in tracking loudness balance and conducted on 12 normal subjects. Eleven frequencies were tested in a random order among subjects except the frequency 1 KHz which was presented at the beginning or end of the frequency series. The frequency order was identical between earphones for the same subject. Results revealed that Telex 1470 earphone was more sensitive in the midrange of the frequency than the other earphones.

ii) Threshold loudness balance method:

In this methods, threshold measurements are taken for each earphone and comparison is made by comparing the threshold values of standard earphone and earphone in question.

Michel and Bunvenue (1981) reported using this method while obtaining calibration data of Telex 1470-A earphone using TDH-39 as standard earphone. Both earphones were mounted in MX-41/AR cushion. 10 subjects were selected on the basis of stable hearing within 20 dB HL (ref. ANSI S -6 - 1969). MAICO Model MA-18 audiometer was used which accepts 10 of TDH-39 and Telex-1470-A earphones. The test was conducted on a mechanically isolated test room, noise level of which is within the permissible level of ANSI S_3-1-1977. Threshold for both earphone eas taken on the same day to avoid threshold variation and sequence of presentation were randomly varied.

The data developed was in close agreement with the data obtained with coupler measurements. But significant difference from previously reported subject's performance were noted especially at high frequency.

Objective Measurement:

Artificial ear or coupler method is the one most commonly employed. The artificial ear consists of a condenser microphone and a 6.6 CC coupler. The latter was chosen as it approximates volume under an earphone for a human ear (Corliss and Burkhard 1953). The 6 CC coupler simulater the human ear impedance. The two coupler IEC coupler and the Zwislocki coupler (Zwislocki , 1970,1971) appear to more closely approximate acoustic impedance of human ear but the audiometer standards still relates its threshold values to the NBS-9A coupler.

Procedure:-

The earphone is placed on the coupler. The output is read in voltage and then converted to dB. Alternately it can be read directly in dB re: 20μ pa. After initial placement of the earphone on the coupler, introduce a low frequency tone (125 or 250 Hz) Readjust the earphone on the coupler until the highest intensity is read. The output may then be compared to the expected output per frequency.

According to the ANSI (1969) specifications to get the preference threshold level for other earphone couplers, the respective signal voltages required by the standard earphone and comparison earphone to produce equally loud tones are applied to

The respective earphone. When attached to the standard coupler

Thus, the magnitude of the pressure generated in the coupler by the comparison earphone corresponding to the standard reference pressure generated by the standard earphone can be determined.

Evaluation of Ear cushion:

Acoustic performance of new earcushion can also be evaluated by comparing it againts a standard earcushion.

Michael and Bienvenue (1980) reported comparison data of a newly developed one piece earphone cushion againts the conventional 2 piece MX-41/AR cushion. The former was conducted on 10 subjects. Both the earcushions were mounted on a TDH-39 earphone and acoustic performances were compared using threshold loudness balance and coupler measurements. Results revealed that the one piece earphone cushion does not differ significantly in acoustic performance from the piece MX-41/AR cushion. In addition there is a strong-indication that the one piece cushion will afford more consistent performance between units, more long term stability and better wearer comfort than the conventional MX-41/AR cushion.

Michael and Bienvenue (1976) reported calibration data of a circumaural headset designed for hearing testing. Two sets of TDH-39 and TDH-50 earphones were used. One set mounted in Telephonies circumaural headset, another set mounted in a conventional audiometric headset using supra-aural MX-41/AR earcushions 10 subjects were taken comparison was done by using threshold loudness balance method.

Data show that the circumaural earcup affords significantly more attenuation to background noise than does the conventional MX-41/AR supraaural cushion in all frequencies. In addition, subjective comfort evaluation strongly favour the circumaural earcup over the MX-41/AR cushions. Also it afford significantly more consistent threshold data then the conventional MX-41/AR headset and this circumaural earphone assembly can be calibrated on a flate plate for audiometry.

Cushions cannot be replaced by larger or smaller ones without disturbing calibration. Recalibration is not necessary when cords and cushions are replaced. Cushions should be changed when cracks, buffles or crevices developed. Changing a new earphone necessitates calibration because replacement of unmatched ear-phones may bring about error in calibration.

CHAPTER-V

SOUND TREATED ROOM

SOUND TREATED ROOM

Valid and accurate auditory test results can be expected if the instrument it is proper calibration and testing is carried out in the environment which is quiet enough for threshold measurement. The latter condition is generally difficult to obtain in the ordinary room environment. Thus special acoustical facilities are necessary to meet such a condition. A room which meet this condition is often termed as sound treated room. Thus sound treated room provides a quieter sound environment which permit determination of subjects hearing threshold without interference of the extraneous noise. If such a condition is not met, there is likelihood of getting elevated threshold indicating poorer hearing than is actually the case thus leading to misleading diagnosis.

There are existing national and international standards such as ASA (1951), 1.SO-389( ), ANSI(1977), which specify the maximum ambient noise level permissible in audiometric testing rooms. An audiometric room should meet such criteria. The standard applies to AC audiometry with the specified earphones and cushions.

Measurement of Noise Level:

Measurement of ambient noise level must be made before the sound treatment and after the sound treatment. Measurement of sound level at the chosen location helps as to how much reduction is required. This is essential in selecting appropriate sound treatment procedure. After the construction is over, final noise measurement must be made to see if the level is adequately achieved or not.

Such a measurement can be made using a condenser microphone and a sound level meter fitted with octave filter set. The noise level may be measured at Octave frequencies from 125 Hz to 8000 Hz or the C-scale of the sound level meter. Noise measurements must be made at regular intervals to ensure that the noise level does not increase significantly when second or final measurements are made. While measuring, microphone should be placed where subject is to be seated and measure under least favourable condition eg. with usual noise source operating.

It is easier and more economical to plan acoustic treatment before the construction of the building. But most often it may have to be converted from the existing structures. In the latter condition suitable modification will be made. To construct a sound treated room, good design should be prepared before the actual construction begins. But only good design does not ensure the desired results. The plans should be properly carried out in actual practice under the supervision of qualified personnel such an acoustic engineer.

During construction, the following factors should be taken into consideration.

Location:

Whenever possible select a relatively quietor place. It is a preferable to be sway from corridors, waiting rooms, busy hall ways, elevators, etc (ONeill and Oyer 1966). If there is loud noise source near the audiometric rooms, we have two alternatives either to choose an alternate location of audiometric room or shifting of the noise source. Here we must consider expenses involved and one which proves least expensive and most satisfactory test situation should be selected within the space available.

Space and Dimension:

Hearing testing can be conducted in single room or double room situation. The choice depends upon the purpose of the test. One room situation may be adequate for basic puretone audiometry whereas it is essential for speech audiometry to be conducted in two-room situation. In one room situation subject, tester and instrument, all are in the same room whereas in two room situation tester and equipment are in the adjacent control room.

The size of the room depends upon the need. For puretone testing, it may range from a small telephone booth type which accommodates only the person being tested to a room in which both tester and subject can be comfortably seated. In size it can range from 3 x 2½ feet to 8 x 8 feet (ONeill and Oyer 1970). The dimension of an ideal single room may be 6'(W)x6'6"(L)x6'6"(H). In case of double room, if there is provision for free-field testing i.e. sound field test via loudspeaker, room should be large enough for a person to sit at least one meter from the loudspeaker (Sivian and White 1933). A relatively small room may be chosen if speech audiometry via only earphone need to be done. When free-field testing is required, the dimension may be 10'(w)x9'6"(L) and 6'6"(H). The control room may have a minimum inner dimention of 4'(w)x6'6"(L) and 6'6"(H). The test room may have a dimension of 6'(W)x6'6"(L)x6'6"(H) if only puretone audiometry and speech audiometry through earphone has to be carried out. One room testing suit permits simpler and more direct instruction and reinforcement (Hodgson 1980).

Acoustical Treatment:-

a) Walls:-

A single brick wall with two sides cement mortar plaster is adequate if the ambient noise is of moderate level. The total thickness of the wall may be 9"or 10". But if the ambient noise level is excessively high, it is advisable to have double walls, if separated by an airgap of 4" or more as it provides more isolation (William B.Snow 1963). If it is a hard wall (Plaster, Wood wall, asphalt tile floor) sound reflection is present. So it is essential to cover with sound absorbing material to absorb sound and reduce reflection. However it provides reduction of noise only by 5-10 dB. Heavy drapes or acoustic tiles should be used.

b) Ceiling and Floor:

The ceiling must be of higher density material. For double wall construction, the outer wall should be have the concrete slab and the inner wall should support the false ceiling. The space between the concrete roof and false ceiling may be filled with sound absorbing materials. For control room also, it is advisable to have a false ceiling with a sound absorbing material to reduce reverberation. The floor may be covered with carpet.

c) Door and Entrance:

The doors connecting the room must be solid and tight enough to avoid leakage. It may be made up of teak wood frame covered with teak wood planks thus providing an airgap between the planks. The airgap may be filled with the sound absorbing material such as glass wool or fine river sand. A thick rubber linning along the edges of the door will be helpful in avoiding leakage. Sometimes double doors are used, one opening into the room and the other opening out.

The threshold of the door should not be high so as to accommodate the wheelchair if nonambulatory patients need to be tested.

d) Observation Window:

The window provides visual communication between the subject and the tester. It should be placed in such a way that it provides a clear view of the test room and the subject. The subject may be able to see the tester but not the manipulation of the instrument. In single wall construction, an observation window of 24"x18" may be sufficient. This should be provided with two layers of ¼" glass sheet separated by maximum available air gap. The glass panes should be placed obliquely, not parallel to avoid standing wave. Two separate windows of the same size should be provided in case of double wall construction.

Moisture absorbing material must be placed between the glass to avoid window from fogging in very cold places (Martin 1981).

Observation window is required only in the two room situation.

Ventilation:

If it is an air-conditioned room, long inlet and outlet ducts that are heavily lined with noise absorbing material must be used. It helps to keep the noise at minimum level but care should be taken not to introduce noise through the ventilation system. Provision of adequate supply of fresh air is essential. Fans may be used. Attempts should be made to keep the temperature and humidity within tolerable limits.

Lighting:-

Amount of light should be pleasant to the subject and it should be placed in such a way that it should be adequate for good viewing of the subject by the tester simultaneously avoiding any reflection. Either incendencent or flourescent light can be used for this purpose. Incendencent light is preferable as it produces less noise compared to flourescent light.

Vibration:

Vibration does not have direct influence on hearing measurement. But if there is intense vibration, it may produce annoyance to the patient. So vibration should be damped. It can be detected by placing one's elbow on the arm of the chair or on the table where the subject is likely to Occupy.

Electrical Connections:

Jacks must be provided to provide electrical connection between the test room and the control room. Use of pipes and holes should be avoided as it may introduce noise.

Prefabricated Sound Room:

Good sound treated room are expensive to construct demanding constant supervision. Thus in this condition, it is economical and convenient to consider prefabricated sound room which is a portable sound treated room. It is available commercially elsewhere however they are not yet available in India. Made of steel panels, they can be more easily installed. Both one room and two room suits are available. It is free standing, not touching any wall of the room. Its performance is standardized and consistent. It can guarantee a certain amount of noise reduction.

However, manufacturer guarantee only the amount of attenuation, the room will provide but not the noise level within the sound room after installation. Thus these booths should be placed on low ambient noise area. As it has limited attenuation of low frequency, it is preferable to place where noise level is less than 40 dB (A) (Knight 1981). From the point of strength of the floor on which it is placed, weight is the another factor to be considered. A booth can weigh upto 2000 Kg.(Knight/ 1981). Adequate light and ventilation should be provided.

Conclusions:

To obtain the valid testing, it is essential that hearing measurements are conducted in the appropriate test environment. Special attenuation and supervision is necessary to meet such a criteria. The amount of reduction of noise is determined by comparing the existing noise level and national and international standards. To see that an audiometric test room meets the requirement we have to be aware of the maximum permissible noise level as per standard. The specifications given by ASA, ISO and ANSI are given in the appendix (A-E).

However it is not needed to meet such a test environment for screening programs such as school screening as a relatively quiet room is sufficient for this purpose.

The measurement should be made often to check if the environmental noise remain sufficiently low or to detect increase of noise level.

CHAPTER-VI

CALIBRATION.

CALIBRATION OF AUDIOMETERS

Electronic equipment may lose their precision and accuracy over time. It is only when the equipment gives precise and accurate information that the results of the measurement can be reported with confidence periodic calibration of the equipment is necessary even though there is no obvious damage. When the instrument is used for a long period of time. Exposure to heat, dust, humidity etc. and shock hazards can adversely effect the functioning of the equipment. Periodical check on the calibration ensure that the instrument is functioning as desired.

Parameters to be checked:

To calibrate the audiometer, the parameters to be checked must be known. For a pure tone audiometer, the parameters to be checked would be in the frequency intensity and time domain specifically the following have to be checked.

1. Output SPL for each earphone at each of the frequencies with the input constant; where speech audiometry capabilities are available, output SPL for the speech channel using speech spectrum noise.
2. Linearity of the attenuator dial(s)
3. Frequency deviation.
4. Haramonie distortion.

5. Rise delay time of the signal.
6. Output SPL of the masking noise.
7. Where narrow-band noise is provided, the bandwidth and the slope.
8. Frequency response of the earphones used.
9. Output of the bone vibrator and its harmonic distortion.
10. Increment size, where facilities for the SISI test are available.
11. Accuracy of the VU meter where provided.
12. For the tone decay test, where the test tone is continuously on, the output level must not vary more than by - 1dB.

In most of the above it is the acoustical check that is indicated, in some, electrical measurements are recommended.

In addition to the above, where input to the audiometer is by means of a microphone and/or a tape recorder, calibration procedures would include these also.

In order to ensure that all the essential features of the instrument are checked, it is best to refer to the national international standards on the performance requirements of the audiometers. These publications discuss specifically the features as well as the procedures for audiometric calibration.

Instruments:-

For calibrating manual audiometer several instruments are required for acoustical and electrical measurement. These are as follows:-

1. Artificial ear/coupler
2. Sound Level Meter with associated Octave/1/3 Octave filter set.
3. Condenser microphone - pressure type (if free-field testing is done appropriate microphone for this purpose would also be required).
4. Pistonphone
5. Level recorder
6. Frequency counter
7. Cathode ray oscilloscope
8. Audio frequency analyzer
9. Artificial mastoid
10. Pre-amplifier.

A majority of the equipment listed are not indigenously manufactured. The instruments listed above have to be inter-connected, the type and number depending on the parameter being evaluated. These would be for laboratory use. Some companies abroad also manufacture a few portable, compact units to check such aspects as the output SPL, rise-delay time. There are several companies abroad such as Bruel & Kjaer, Tracor RA-310, Quest, etc. which manufacture one or more of these instruments. While purchasing these, care must be taken to see that they can be used with the existing instruments if any and that they meet the national/international standards.

Instruments required for calibration is for objective calibration, acoustical or electrical measurements. For subjective or biological calibration, a group of normal hearing subjects and the audiometer is question suffice. However one foreign manufacturer. Quest has come up with a product which can be used to keep the earphones on, thus eliminating the need for a group of subjects.

Method of Calibration:

Two methods of calibration are generally recognized: subjective method and objective method.

Subjective method:

Using this method, the output of the earphones and the bone vibrator may be checked. Variations of this method are reported. They are:

1. The examiner keeps a record of his threshold obtained

with the standard audiometer. Then he checks the threshold with the audiometer to be calibrated. The difference in threshold obtained with the two audiometers constitute the correction to be incorporated in recording the threshold.

2) In normal hearing subjects with no problems of the ear, present or past are tested using the audiometer in question. The thresholds taken for each test frequency are averaged. The magnitude of the deviation from the audiometric zero is used as a correction factor, the rational being that the normal subjects' thresholds are equivalent to the audiometric zero and the thresholds above. These are necessarily due to the error of calibration.

These two methods described above can be used for checking the calibration of the earphones.

For the bone vibrator, one of the subjective method is use of 6 to 10 normal hearing individuals as subjects and test for both Air-Conduction and Bone-Conduction thresholds. An audiometer with Air-Conduction system in proper calibration shall be use for this purpose. Assuming that in normal hearing individuals, AC and BC thresholds are equivalent, any deviant of BC threshold from that of AC threshold is taken as error and the particular value obtained are used as correction factor (AMA 1951).

The difficulty encounter using the above procedure is the difficulty to get true threshold because most of the audiometer do not extend their intensity limit below 0 dB. To overcome this problem. Roach and Carhart (1956) recommended to make use of sensorineural hearing loss individuals as subjects instead of normal hearing subjects.

Difficulties in using the subjective method are in getting the requisite subjects with normal hearing or with sensorineural hearing loss. Its shortcomings are that other aspects of the performance of the audiometer cannot be checked. Hence the utility of the subjective method is highly limited.

Objective Method:

The subjective method using a group of normal hearing subjects may suffice for day today use. But electroacoustic and electrical measurements are a must once a guartor. The instruments required and the aspects to be checked have been discussed above. The pertinent national standards for audiometer calibration must be referred to at the time of calibration.

Audiometer calibration is necessary before it leaves the factory and subsequently thereafter. The equipment required for this purpose being very expensive not all centers can afford to have them. So far those which does not have such facilities, subjective calibration is the alternative approach.

After checking the output SPL of the earphones, a correction chart can be prepared so that the correction can be incorporated at the time of recording the testee's threshold. The correction will be in the same direction as the error i.e. if the audiometers output is higher than what it should be then the threshold recorded will be recorded as being higher by a corresponding magnitude. Eg:- Measure output is 87 dB and expected output is 81 dB, then 5 dB should be added to the threshold as correction factor. It must be noted, however, that a correction is introduced only when the deviation exceeds a prescribed value. According to Hodgson (1980) correction values are as follows:-

Error	Correction value
2.5 dB or less	No correction
2.6 to 7.5 dB	5 dB
7.6 to 12.5 dB	10 dB
12.5 and above	(serious malfunctioning thus should not be used).

Correction chart must include the correction for each earphone and each test frequency where deviation is observed.

CALIBRATION CHART

Frequency in Hz		250	500	1000	2000	4000	6000	8000
AC	Rt							
	Lt							
BC								

For audiometers having adjustable potentiometer, a correction chart need not be made. Instead, the potentiometer can be adjusted so that the obtained SPL is the same as the expected SPL.

Relevant information regarding expected output SPL of earphone as per ANSI (1969) standard is given in the Appendix-G.

Calibration of the audiometer is very important to obtain accurate test results. In addition to it daily and weekly listening check also should be supplemented. It is important that the audiometer be well maintained. As expenses are high, many centers do not have facility for equipment for calibration. For them they should make an attempt to get it calibrated wither by sending to factory or nearby centers where such facilities are available.

CHAPTER-VII

SPEECH AUDIOMETRY

SPEECH AUDIOMETRY

Speech audiometry is an integral part of audiological evaluation. Speech stimuli are conventionally used to get two measures, the speech reception threshold and the speech discrimination score. The former is the intensity level at which the subject is able to repeat 50% of the stimuli presented to him. The lattern, the speech discrimination score is expressed in percentage of the correct repetition of 25 or 50 words at suprathreshold levels.For this purpose, word lists have been developed - two syllable ones to get the speech reception threshold and monosyllabic ones to get the speech discrimination score.

Through speech discrimination testing, it is possible to evaluate the functional integrity of the auditory system. The poorer the speech discrimination score, greater is the involvement of the sensori-neural mechanism. Along with other test results, speech discrimination scores can be used in the differential diagnosis of cochlear and retrocochlear lesions. Disproportionately poor discrimination scores are indicative of a phenomenon called phonemic regression (Gaeth, 1948). The two measures of speech audiometry have prognostic value for otological surgery and utility of sensory aids.

Speech stimuli can be used to get the threshold of detectability i.e., the level at which an individual can detect. The presence of the signal. This level may be termed as the speech awareness threshold or speech detection threshold. This may be obtained when speech reception threshold is not possible to get on account of profound hearing loss or limited linguistic ability on the part of the subject.

Test Stimuli:

Various stimuli have been used in the determination of speech reception threshold. They are as follows:-

1. Spoken digits (Fletchar& Steinberg, 1929)
2. Spondaic words (Hudgins et al 1947? Hirsh et al, 1952)
3. Sentences (Hudgins et al, 1947)
4. Connected discourse.

For the purpose of speech discrimination testing, the stimuli used are:

1. Monosyllables (Egan, 1948? Hirsh et al, 1952)
2. Nonsense syllables (Fietcher,1929? Pederson, 1970)
3. Synthetic sentences (Jerger, Speaks and Trammell, 1968).

In case of SRT testing, 'spondaic words' are the most widely used test stimuli, and 'monosyllabic words' in case of speech discrimination testing (Carhart, 1970).

Presentation of the stimuli:

The stimuli for establishing the speech reception threshold may be presented in 2 dB or 5 dB steps. At each level 2-6 words (spondees) may be presented. When 5 out of the 6 words are repeated correctly, the presentation level is attenuated in 2 dB steps with 2 words being presented at each step. SRT is defined as the lowest level where both responses were correct minus 1 dB for every word repeated correctly below this level (Rintelmann et al, 1973).

For speech discrimination testing, generally, the lists of words are presented at 40 dB SL (ref: SRT). A level lower than this is utilized for cases wherein the presentation level exceeds the discomfortable level or the level is not available in the audiometer. In order to make sure that the test stimuli are presented at the level which is indicated on the attenuator dial, a calibration tone should be recorded at an average level of the tests stimuli and the tone level on the VU-meter should be kept at 'O'. In case of monitored live voice testing, the tester should have sufficient practice to peak the carrier phrase at '0' on the VU meter. .

When speech discrimination testing is done to obtain PI functions, then the lists are presented at different sensation levels, such as 10 dB, 20 dB, 30 dB, 40 dB and 50 dB SL (Ref: SRT).

Recorded Vs. Live voice testing:

When speech stimuli are presented either through the earphones or through the loudspeakers, it may done so by means of a taperecorder using recorded tapes or by means of a microphone with the examiner presenting the stimuli orally. Recorded and turntables were used earlier, but they are rarely if ever used in recent times.

The use of recorded stimuli is recommended as the intertest variations due to fatigue etc. on the part of the person testing may be kept to a minimum. However, live-voice testing may be chosen whenthe stimuli have to be presented at a slower rate etc.

It is normal practice to precede the test word with a carrier phrase viz.'say the word...' 'you will say....'. It has been found that the discrimination scores can be higher by as much as 16% (Gladstore and Siegenthaler, 1971).

Closed Vs Open set tests:

In the closed set tests, the test stimuli presented is one of a set of alternatives such as in a multiple choice type. In the open set type, on the other hand, the subject is asked to repeat or write down the stimulus word presented. The subject's response will be dependent on the extent of his vocabulary. Hodgson(l980) reported that closed set tests, yield 10% better scores.

Earphone Vs Sound-Field Presentation:

Speech stimuli can be presented under earphones or in sound field. The former is the choice when information of diagnostic value is intended to be obtained. The speech reception threshold and the speech discrimination score are obtained separately for each ear. When one ear is much better than the other, the better ear must be masked to obtain the speech reception threshold and/or the speech discrimination score. Speech stimuli may be presented to both ears simultaneously when special tests are administered. The stimuli may be identical but presented to the two ears at different intensity levels. The stimuli may be different in the two ears in any of several ways (a) the words may be low-pass filtered and high-pass filtered each being presented simultaneously to the the two ears; (b) the two ears may be presented with two different words but having one syllable in common? (c) the stimuli may be superimposed with competing messages spoken by one or more talkers or by noise. Additional modifications from the conventional procedures of presenting stimuli (unmodified) to each ear, include accelerating the speech signal. Different techniques of accelerating the signal may be employed, but the purpose of this to get stimuli that taxes the auditory system sufficiently to reveal disorders such as central auditory dysfunction. Such disorders are difficult to diagnose.Using the conventional, undistorted stimuli. Similarly, when stimuli are presented with a slight lag, the effect seen with normal subjects is not seen with patients having temporal lobe lesions.

Normally the speech stimuli are presented through the earphones. Sometimes, the stimuli may be presented through the bone vibrator of the audiometer. This may be done to predect the post stapedectomy discrimination scores.

Test stimuli for children:

Tests standardized for use with children are reported. These include simple commands (Keaster, 1942), monosyllabic words (Siegenthaler and Haspiel 1966, Pursant Le Zak, 1954) and standard spondiac words (Meyerson, 1947). Pictures representing test items may be used. Natural objects have also been used (Munsur 1953; Sortini and Flake, 1953). For speech discrimination testing, PB-K lists (Haskins, 1949) have been widely used. As in SRT testing, picture identification tests have been used for discrimination testing. WIPI (word intelligibility by picture identification) which consists 25 picture plates each with four pictures can be used for children with limited vocabulary (Ross and Lerman, 1970). Other tests are: an adaptive speech discrimination test for children and sound effect recognition test.

Tests for children have also been prepared in Indian languages Standardized pictures. SRT test in Kannada language for children is available (Rajshekhar, 1976; Hemalatha, 1982).

Interpretation of SRT:

The extent of hearing loss for speech is estimated by SRT. A close relationship exists between the SRT and Pure-tone average of 500, 1000 and 2000 Hz (Carhart, 1946; Harris, 1946; Fletcher, 1950; Graham, 1960). Carhart (1971) reported that SRT was in good agreement with the average of pure tone thresholds of 1000 Hz and 500 Hz.

SRT level serves on the reference level for the suprathreshold speech tests. It aids in checking the validity of pure tone test results. A wide discrepancy between the SRT and pure tone average is one of the useful indicator of pseudohypacusis. SRT is also used to determine the amount of amplification needed.

Interpretation of the SRT tests results is also done by obtaining 'articulation intensity function' using spondee words and this is often referred to as 'speech audiogram'. The advantage of using 'speech audiogram' is that the results correspond closely with the pure tone audiogram. Speech audiogram not only provides information about estimating amount of amplification but also about the amount of expected improvement of speech understanding.

Interpretation of discrimination scores:

The percentage of words correctly identified in discrimination tests, is computed. The score, thus, can range from 0% to 100%. For greater utility, this range can be broken up further as follows:-

90% to 100% - - Normal limits.
75% to 90% - Slight difficulty.
60% to 70% - Moderate difficulty.
50% to 60% - Poor discrimination, difficulty following conversation.
Below 50% - Very poor discrimination,difficulty in following running speech (Goetzinger, 1978).

The above categories were based on difficulty in speech understanding, Hopkins and Thompson (1967) gave another method of classification of the scores in terms of pathology as follows:

90-100% - Normal limits or conductive loss
50-80% - Mixed impairment, presbycusis with no cochlear impairment.

22-48%	-	Cochlear involvement
22% or less	-	Retrocochlear involvement (Hopkins and Thompson, 1967).

Discrimination score of 90 tp 100% is generally obtained with individuals having normal pure tone sensitivity. But there is no one-to-one relationship between the two as there could be normal pure tone sensitivity with poor discrimination ability, for example, (1) disproportionately low speech discrimination scores indicate phonemic regression mentioned earlier (Gaeth, 1948) and (2) in retrocochlear lesion such as acoustic neuroma, discrimination scores are disproportionately poorer than pure tone sensitivity. Further, deterioration of scores with progression of the disease could be observed which may not be seen with other audiometric measures.

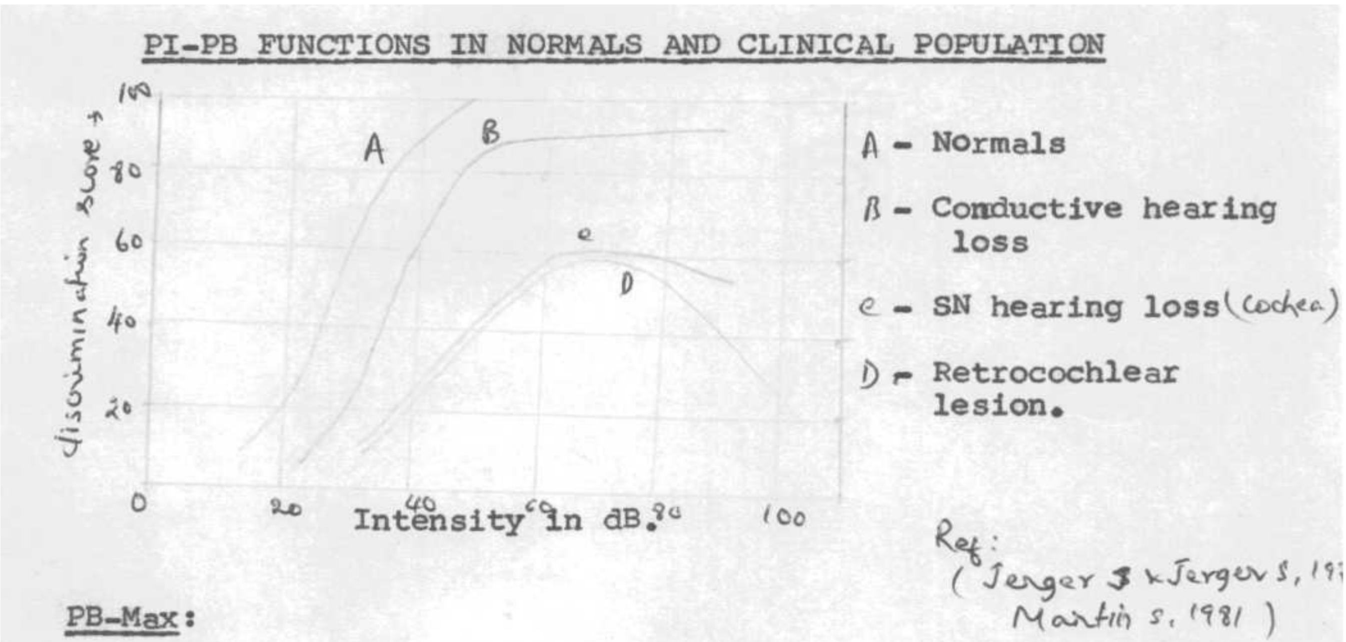
The speech discrimination scores must be interpreted along with other test results.

Performance-Intensity (PI) Functions:

Discrimination scores can be determined at different sensation levels. When the percentage of scores is plotted as a functions of intensity a PI function is obtained and this is also referred to as 'articulation curve'.

PI functions aids in the differential diagnosis. For normals the plateau of the articulation curve is seen at 100%

score. In case of conductive hearing loss, the shape of the PI function is similar to that of normal hearing subjects but is shifted to right. 100% discrimination score is not obtained in patients with sensorineural hearing loss. Further a 'roll over phenomenon' i.e. increase in intensity of the stimuli bring about an increase in discrimination score and after a certain level further increase in the presentation level brings about a reduction in scores, is observed. In case of retrocochlear pathology a marked roll over effect is seen (Davis and Silverman, 1960; Jerger and Jerger, 1971)



PB-Max:

PB-Max is used to indicate person's discrimination ability. The level at which maximum discrimination is obtained is called PB-Max. However, the use of PI-PB functions are recommended than just discrimination score at a particular presentation level.

CONCLUSION:

Speech materials used for the speech audiometry should be standardized. Type of stimuli and factors affecting discrimination should be taken into account at the time of administration. As language may differ from place to place, familiarity of the language also should be considered. If not cautious of such factors, it may loose its validity. When speech audiometric tests are carried out appropriately, they may be valuable tools to the audiologist.

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APPENDICES

APPENDIX 'A'

Values of Octave band sound pressure levels for ambient noise above which hearing threshold level measurements should not be carried out without further noise abatement.

Lowest hearing level to be measured is 0 dB (ISO-389)

Octave band center frequency Hz	Sound pressure levels (re 20 P2) in octave bands dB	
	Ears Uncovered	Ears covered with TDS-39 earphones with Mx-41/AR earphone cushions
35.1	80	80
63	70	70
125	55	57
250	39	44
500	19	26
1000	13	28
2000	11	37
4000	13	44
8000	18	41

contd...

Limits of acceptable ambient sound pressure levels when an octave band analysis only is carried out.

The lowest HL to be measured is 0 dB (IS0-389)

Octave band centre frequency Hz	Sound pressure levels (re 20 Pa) in Octave bands dB	
	Ears un-covered.	Ears covered with TDH-39 earphones with MX-41/AR earphone cushions.
31.5	73	73
63	58	59
125	43	47
250	28	33
500	9	18
1000	7	20
2000	6	27
4000	7	38
8000	10	36

APPENDIX 'B'

Maximum permissible ambient sound pressure levels (re 20 Pa) in 1/3 octave bands whenthe lowest HL to be measured is 0 dB (ISO-389)

1/3 Octave band centre frequency Hz	Sound pressure levels in 1/3 octave band dB	
	Ears uncovered	Ears covered with TDH-39 earphones with earphone cushions Mx-41/AR
31.5	78	78
40	73	73
50	68	68
63	63	64
80	58	59
100	53	55
125	48	51
160	43	47
200	37	42
250	32	37
315	28	33
400	18	24
500	11	18
630	9	18
800	9	20
1000	8	23
1250	7	25
1600	6	27
2000	6	32
2500	7	35
3150	7	38
4000	8	40
5000	9	38
6300	10	36
8000	15	39

APPENDIX - 'C'

ANSI - 1977

	125	250	500	750	1000	1500	2000	3000	4000	6000	8000
1/3 octave band levels ears not covered.	23.3	13.5	9.5	7.5	9.0	5.5	3.5	3.5	4.0	9.0	15.5
1/3 Octave band levels ears covered with earphone mounted in MX-41/AR cushion	29.5	18.0	1S.5	17.5	24.5	24.0	29.5	34.0	37.0	36.0	40.0

Permissible ambient noise levels in sound treated rooms

APPENDIX 'D'

Maximum permissible ambient SPL is 1/3 octave bands (Lhex in <3B) for AC and BC audiometry as per ISO/Dp 8253 (1983)

Lirax re: 20 Pa in dB for test frequency range in Hz

Midfrequency of 1/3 octave band in Hz	125-8000		250-8000		500-8000	
	AC	BC	AC	BC	AC	BC
31.5	56	55	66	63	78	
40	52	47	62	56	73	
50	47	41	57	49	68	
63	42	35	52	41	64	
80	38	30	48	39	59	
100	33	25	43	35	55	
125	28	20	39	28	51	
160	33	17	30	21	47	
200	20	15	20	15	42	
250	19	13	19	13	37	
315	18	11	18	11	33	
400	18	9	18	9	24	
500	18	8	18	8	18	
630	18	8	18	8	18	
800	20	7	20	7	20	
1000	23	7	23	7	23	
1250	25	7	25	7	25	
1600	27	8	27	8	27	
2000	30	8	30	8	30	
2500	32	6	32	6	32	
3150	34	4	34	4	34	
4000	36	2	36	2	36	
5000	35	4	36	4	35	
6300	34	9	34	9	34	
8000	33	15	33	15	33	

APPENDIX - 'E'

Maximum ambient Noise Level in Sound Treated Room as per ASA (1961)

Frequency in Hz,	Octave band in Hz	SPL in dB ref:0.0002dynes/cm^2
125	75-150	40
250	150-300	40
500	300-600	40
1000	600-1200	40
2000	1200-2400	47
4000	2400-4800	57
8000	4800-9600	67

APPENDIX - 'F'

Comparison of the specifications of the TDH-39, TDH-49, TDH-50 and Telex 1470A.

Types of ear phones - Parameters.	Telephonics TDH-39	Telephonics TDH-49	Telephonics TDH-50	Telex-1470-A
Impedance	10 (Standard	10	60	
Continuous power rating	300 milliwatts at any single frequency from 100 to 8000 Hz	300 MW. at any single frequency from 100 to 8000 Hz	300 MW at any single frequency from 100 to 8000 Hz	10 50 300 $\pm$10%
Sensitivity	100$\pm$ 4 dB SPL output with 1 MW input at 1 KHz	106$\pm$2 dB SPL output with 1 MW input at 1 KHz	106$\pm$2 dB SPL output with 1 MW input at 1 KHz	106$\pm$3 at 1 KHz with 1 M.W input.
Distortion	less than 1%	less than 1%	Less than 1%	Less than 1%
Linearity	Linear for power input from 0 to 400 MW	Linear for power input from 0 to 400 MW	Linear for power input from o to 400 M.W.	
Earphone type	Dynamic	Dynamic, moving coil	Dynamic moving coil	
Reference	0 dB SPL	0 dB SPL	0 dB SPL	.0002 dynes/CM^2
Frequency response	20-20000 Hz	20-20000Hz	2O-2OOOOHZ	20-10000Hz
Maximum output				136 dB SPL to 1 KHz

APPENDIX - 'G'

Reference Threshold Level for Various Earphones (Ref: Threshold level) re:.0002 Microbar dB.

Frequency	TDH-39	TDH-49	Permoflux PDR-1	705-A	Perfmoflux PDR-8	Permoflux PDR-10
125	45	47	46.5	45.5	44	51
250	25.5	26.5	26.0	24.5	25	28.5
500	11.5	13.5	11	11	11.5	10
750	8	8.5	-	-	-	-
1000	7	7.5	7	6.5	6.5	6
1500	6.5	7.5	7	6.5	5.5	6.5
2000	9	11	9	8.5	7.5	6.5
3000	10	9.5	10	7.5	8	9
4000	9.5	10.5	13.5	9	9	9
6000	15.5	13.5	8.5	8	17	18.5
8000	13	13	11	9.5	13	14

(* Data based on measurement made on NBS-9A coupler with earphone fitted with MX-41/AR cushion)

Ref:- ANSI (1969) Specifications of Audiometers) % ! ;

APPENDIX 'H'

ADVANCE IN DEVELOPMENT

Year		
1875	Telephone receiver (it makes possible use of earphone in Audiometer)	Alexander Graham Bell
1878	Acoumeter (-utilized telephone receiver first attempt to develop puretone audiometer)	Hartman
1879	Electric sonometer(-inspired first use of the term audiometer)	D.E.Hughes
1885	Application of binaural receiver in audiometer	Jacobson
1890	B.C.Vibrator	Gradings.
1899	Audiometer which has a logarithmic and intensity	Seashore
1904	Phonograph in audiometer	Sohier Bryant
1914	Electric Generator	Stefamine
1919	Otandian (of Germeny - first audiometer which could produced puretones of any described frequency and of measurable intensity	
1921	Vacuum tube audiometer - utilizes interruptor switch	Gutman
1922	Western Electric IA Audiometer(-first commercial clinical audiometer)	Wegel & Fowler
1924	Provision of both AC and BC make available in audiometers.	Knudsen and Jones
1940	Several commercial audiometers appeared in market.	
	- Vacuum tubes are replaced by transistors in many audiometers.	

contd..

1947	Automatic self-recording audiometer	George Von Bekesy
1962	Use of noise in audiometer	B.Langenbeck
1927	WE 4C audiometer first speech audiometer (screening)	
1950	Speech audiometer commercially available.	