EFFICACY OF TUTORIAL ON PURE TONE AUDIOMETRY

Reg. No. M0114

An Independent project submitted in part fulfillment for the first year M.Sc (Speech and Hearing) to University of Mysore

All India Institute of Speech and Hearing
Mysore-570006

May- 2002

Dedicated to,

Dear Mai, Babuji

&

Sangi

With all my love

CERTIFICATE

This is to certify that this independent project entitled "EFFICACY OF TUTORIAL ON PURE TONE AUDIOMETRY" is a bonafide work in part of fulfillment for the degree of Master of Science (Speech and Hearing) of the student (Register No.M0114)

Dr.M. Jayaram
Director
All India Institute of
Speech and Hearing.
Mysorc-570006

Mysore,
May, 2002

CERTIFICATE

This is to certify that this independent project entitled "EFFICACY OF TUTORIAL ON PURE TONE AUDIOMETRY " has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any degree or diploma.

Guide

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Mysorc-5 70006

Mysore,
May,2002

DECLARATION

This Independent project entitled "EFFICACY OF TUTORIAL ON PURE TONE AUDIOMETRY" is the result of my own study under the guidance of **Mr.Animesh Barman,** Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and not been submitted in any other University for the award of any degree or diploma.

Mysore,

May, 2002 **Reg. No. M0114**

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INTRODUCTION

The sense of hearing is perhaps the most important and the least cared for sense organ of all the five senses of the human body. The hearing abilities of man has made it possible for him to communicate through verbal language. The acquisition and monitoring of speech, the detection of potential danger, the elementary feeling of existing in a living universe, all depend upon the auditory modality.

Through out the waking life, the ear receives an uninterrupted stream of messages which are screened, stored and acted upon. How precious hearing is becomes clear only when it is lacking.

Hearing impairment affects the communication of an individual. In children it produces a delay or deviant speech and language development. Man's needs for communication with his fellow men is possibly his greatest need and the fulfillment of his other needs depend upon, or at least is greatly facilitated by his ability to hear.

Apart from this, hearing loss also affects language acquisition, especially, when the hearing loss occurs within the critical period. This is a period from five months to two years which is the best period for learning and most important for the acquisition of speech. Since we know that speech and language is the key stone of modern society, lack of adequate speech and language, causes devastating effects.

Hearing loss and the constraints imposed by hearing impairment not only affect the life of a hearing impaired child but also affects the lives of his or her family members. After much expectation about the child, when the parents realise that their child has a hearing impairment, a series of emotional reactions occur. These emotional reactions can manifest as shock, anxiety, anger, depression, guilt, resentment etc. They will be in a state of panic and confusion. Parents are faced with a multitude of problems. In addition to the concerns like providing appropriate hearing aids, initial auditory training, educational placement, speech therapy and corrective treatment required for the child, they arc faced with strong feelings related to guilt, denial, anger, feelings of incompetence, self doubt and chronic sorrow.

Loss of hearing has also been seen to cause more social and adjustment problems than the loss of other human capacities such as that of visions, smell or even motor abilities like in the case of paralysis. This is because, a person with hearing loss, loses his ability to communicate and becomes a recluse in society.

All of us at some time or the other are affected by some disease or another in our lives. The faster these diseases are identified and earlier the proper treatment is initiated, the better are the results, but if they are neglected or ignored, they could turn out to be fatal to the person or can cause serious handicap that he would have to live with for the rest of his life.

Loss of hearing is one of the most common physical impairment because the 'car' like any other organ is liable to damage from various sources, and this damage can occur in any part of the ear. As the saying goes "prevention is better than cure", one must try to prevent hearing loss.

Prevention includes primary, secondary and tertiary prevention. Primary prevention is composed of preventive initiatives inorder to prevent the occurrence of hearing loss. Secondary prevention relates to premature discovery of hearing loss and prevention of deterioration whereas tertiary prevention aims at limiting its consequences once they have already taken place.

Primary prevention can be propogated through public awareness measures. Increased public awareness can have positive effects on the implementation and planning of Hearing Conservation Programmes. This can be achieved with the help of audiologists also. It is their duty to develop interesting modes to convey valuable information to the public like what has been developed by Roshni (1991) titled 'Audiologist satisfies the Layman's doubts on hearing, hearing loss and rehabilitation'. Public awareness can be created using various modes, the main ones being the mass media and through public education. Through the mass media, it can be done via television, radio, magazines, posters, slogans, contests (on various aspects of speech and hearing), puppet shows, comics, cartoons, dance, drama, songs etc.

Public education can be carried out through exhibitions, home visits, itenerant services, workshops, professional lectures, seminars, symposium, demonstrations, pamphlets. One such pamphlet was developed by Monica (1995) titled 'Prevention of hearing loss-material for public education pamphlet.' Booklets, brochures, visual mode can also be used for public education. Two such have been developed by Luna (1995) titled 'Quest on audiology; learning through visuals' and also the project work named 'Hearing loss; Causes, prevention and management; A pictorial presentation' developed by Neelu. (1991). Audiovisual modes like the independent project work of Gopalkrishna (1994) titled 'Audiovisuals on Audiometers and Audiograms' and the one developed by Venugopal (1994) named 'Slides and audiotapes on normal and abnormal structures of the ear' can also be used. The efficacy of this mode (Audio visual) was later checked by Rajcsh (1997) as part of his independent project entitled, 'Efficacy of audio visuals on normal and abnormal conditions of ear' and also by Ayasakanta (1995) as part of his independent project called 'Efficacy of Audiovisuals on hearing loss a field study.'

Public education can also be carried out through street plays like the one developed by Sindhu (1997) titled 'Inactable play and its role in increasing public awareness', the efficacy of which was later determined by "Anusha (1998) as part of her independent project named 'Efficacy of street play'.

Secondary prevention strategies include hearing screening through means like High risk register (HRR). One such has been developed by Sunil (1993) entitled 'Infant screening with high risk checklist'. Prevention strategies also include detailed assessment by means of different subjective procedures like Behavioural observation audiometry and Pure tone audiometry and different objective procedures like Acoustic immittance measurements, Brain stem evoked response audiometry, Otoacoustic emission etc. So it becomes a must for a professional to gain sound knowledge about these assessment procedures.

Tutorials are the best means of gaining intensive instruction in any area. This has motivated many people to develop tutorial in different areas like, the tutorials on Pure tone audiometry by Kavita (2001) and Acoustic immittance measurements by Uma (1999), Clinical masking by Perumal (1998) developed at A11S11 as part of their independent project. The information in a tutorial is carefully selected and delivered in an organised and structured manner. It also evaluates the user's knowledge through different kinds of questions which gives him or her an immediate feedback of the performance. It thus acts as an effective guide for students and experts linked with the particular field.

It is not only important that several tutorials are developed but also their efficacy in imparting information should be determined.

The tutorial of which the efficacy was studied aimed at providing intensive information regarding Pure tone Audiometry.

Among the great number of tests employed in the field of audiology, Pure tone Audiometry is one of the most basic standard behavioural procedure for describing auditory sensitivity. It is the most reliable method to assess person's hearing sensitivity. Pure tone audiometry is used to determine if hearing loss is present or not .If present, it gives idea about severity and configuration of hearing loss. The application of Pure tone audiometry is not limited to hearing assessment alone. It provides preliminary idea regarding site of lesion .It helps in making decision about line of treatment i.e. whether the person require medical, or surgical or rehabilitative management. It also helps in prognosis of hearing improvement for particular otological disorders. By doing pre and post treatment hearing assessment we can assess the amount of hearing improvement taken place due to treatment. Also to quantify the degree of hearing handicap for medicolegal purpose .

From the above discussion it is clear how important is for students and professionals in this field to know about these measurement procedures in depth. The tutorial under study has been developed keeping this in mind.

Inordcr to gather information about the efficacy of this tutorial or how much it is helpful for the beginners in the speech and hearing field, a set of questions were put up with respect to each chapter. Responses of students then obtained so as to get an immediate feedback regarding the efficacy of the tutorial.

NEED:

The tutorials developed at AIISH should fulfil the criteria of being comprehensive and easy to understand. It must include sufficient information for the students. So it was essential to know whether any modifications were required and it would also bring into light the various precautions that have to be taken prior to the development of such manuals in the future.

AIM:

Thus this independent project has been developed to serve the following purposes:

1. To evaluate **the** efficacy of the tutorial on Pure tone audiomctry developed at AIISH.
2. To find out which mode of exposure (visual or audio visual) to the manual is the most beneficial.
3. To find out whether any modification is required to the existing material to improve the efficacy.

METHODOLOGY

The project has been taken up to study the efficacy of tutorial on Pure tone Audiometry and also to check the effective mode of presentation. To carry out this study, the methodology used is given below.

SELECTION OF SUBJECTS:

The following criteria was considered for selection:

1. All the students belonged to 1st B.Sc Speech and Hearing who had very little or no knowledge regarding Pure tone Audiometry. Because this tutorial has been developed with the intention of imparting knowledge to the beginners in this field and also this is relevant for this field and students belonging to this field would pay more attention and motivation to acquire more information regarding the same. Thus it would help to enhance the reliability of efficacy of the tutorial.
2. All those students who had English as their medium of instruction during their pre-university course were selected because the medium of instruction of the course and the text was also in English.
3. The students had no sensory impairment like visual (if present, corrected) or hearing problems.

Keeping this criteria in mind 30 students were selected and was divided into two groups randomly with 15 in each group of which one group underwent the visual mode of presentation (V) and the other underwent the audiovisual mode of presentation **(AV).**

SELECTION OF CHAPTERS:

The tutorial on Pure tone Audiometry developed by Kavita (2001) includes the following chapters.

1. Historical aspects
2. Pure tone air and bone conduction testing.
3. The Audiometer
4. The Audiogram.
5. Factors affecting air and bone conduction testing.
6. Transducer
7. Clinical masking.
8. High frequency audiometry.
9. Bekesy audiometry.
10. Pure tone audiometey in difficult to test population.
11. Calibration of Pure tone audiometers.
12. Standards relevant to pure tone audiometry.

The chapters selected for the study are as follows:

I. Historical aspects

II. Pure tone air and bone conduction testing.

III. Factors affecting air and bone conduction testing.

IV. The Audiometer

V. The Audiogram.

VI. Transducer

VII. High Frequency audiomtry

VIII. Clinical masking.

Selection criteria:

Only those chapters that were felt most essential by the professionals for the beginners of this field were selected.

DEVELOPMENT OF QUESTIONNAIRE:

The questionnaire was developed based on the material provided in the tutorial. Ten questions were set for each chapter, the questions were in the form of binary choice (True/False) along with another option i.e., 'Don't know'. This option was included so as to avoid the false positive responses. A total of 80 question were set. The questions also included those that were already given in the tutorial after each chapter, either in their original form or in a modified form.

PILOT TRIAL OF QUESTIONNAIRE:

The questionnaires developed for chapter were shown to the IIIrd B.Sc, I st M.Sc and II nd M.Sc students before administering it to the subjects and their opinions were considered in order to make sure that the questions were easy to understand and also to avoid ambiguity. After necessary modifications, the questionnaires were shown to some of the teaching professionals for approval.

COLLECTION OF DATA:

The data was collected in 3 phases:

(1) Pre-exposure scores:

Both the groups (V & AV) were given equal time (15 mins) to answer the questions before the exposure of the manual on a particular topic. The students were given instructions about the mode of answering. They were advised not to guess, instead to indicate, 'Don't know'. They were assured that the experimenter had no intention to assess their intelligence or aptitude.

The pre-exposure questionnaire required the subjects to give their identity on the right hand side so that it helped the experimenter to compare pre and post exposure scores obtained by each subject.

(2) Presentation of text:

Both the groups were exposed to the manual. The subjects were seated in a classroom in such a way that they could have a clear view and optimum audibility when the material was presented. The text was presented to group V only in visual mode i.e., projecting the text on screen and for group AV it was presented in audiovisual mode i.e., projecting as well as the experimenter reading it aloud simultaneously at a normal rate of speech (160-180 words per minute) with out giving any clarification if asked for.

The subjects were also asked to note down their suggestions and modification regarding each chapter in order to improve the efficacy of the tutorial.

(3) Post-exposure scores:

The respective questionnaires for the selected chapters were distributed to the students immediately after their exposure to the manual. The post exposure questionnaire had the same set of question like the pre-exposures questionnaire but the sequence of questions was changed so as to avoid the chance factor.

The post-exposure questionnaire also required the subjects give their identity on the right hand side. The students were given lesser time (approximately 10 mins) to answer this test, as they were familiar with the questions.

The students were exposed to one chapter per day because exposure to too many chapters in a day would have been very tedious.

Scoring pattern:

For each correct answer 1 mark was given and wrong answers including 'Don't know' was given no mark. The same was applicable to both pre and post exposure scores. The maximum score one can obtain is 10 and minimum score of 0.

Statistical Analysis:

The two sets of scores (pre and post) and the differences between them was tabulated chapter wise for further statistical analysis in terms of mean, standard deviation and t-value. Paired t-test was used to determine significant difference between the pre and post exposure for visual and audiovisual mode of presentation.

RESULT AND DISCUSSION

The project has been taken up with the aim to assess the efficacy of tutorial on "Pure tone Audiometry" the data obtained was analysed using suitable statistical procedures.

1. Pre and post exposure scores obtained in the visual mode:

Table 1 shows the mean, SD, range and t-value for each chapter. The graphical representation of prce and post exposure scores is shown in Figure 1.

The mean of the pre exposure scores range from 0.93 to 4.66 which clearly indicates that the subject had some knowledge in all the chapters as this test was administered after 3 months of their admission to this course during which they might have got some exposure pertaining to the chapters which were included for the study.

The subjects obtained lowest score in the chapter that deals with high frequency audiometry. This chapter was unique for them as high frequency audiometry (HFA) is not regularly administered clinically therefore chances of acquiring knowledge about HFA was less.

Mean of post exposure scores range from 5.93 to 8.6 Post exposure scores obtained for first four chapters and VI chapter showed almost similar but not substantial, improvement compare to pre-exposure scores. This may be attributed to the following facts. The chapter I which deals with historical aspects involved several authors and years which would have been difficult for any subjects to remember after single exposure. Where as for the other chapters it could be due to uses of more technical terms, lengthy text material and also minimal use of graphical representation which would have made difficult to grasp and memorise those new concepts.

The chapter on high frequency audiometry showed maximum improvement. This could be due to the fact that the base line itself was less and retrieval from short term memory to score well as the text was very less to remember. The scores obtained on V and VIII chapter showed substantial improvement which could be attributed to the simple language used to explain, less usage of mathematical calculations and also usage of more graphical representation.

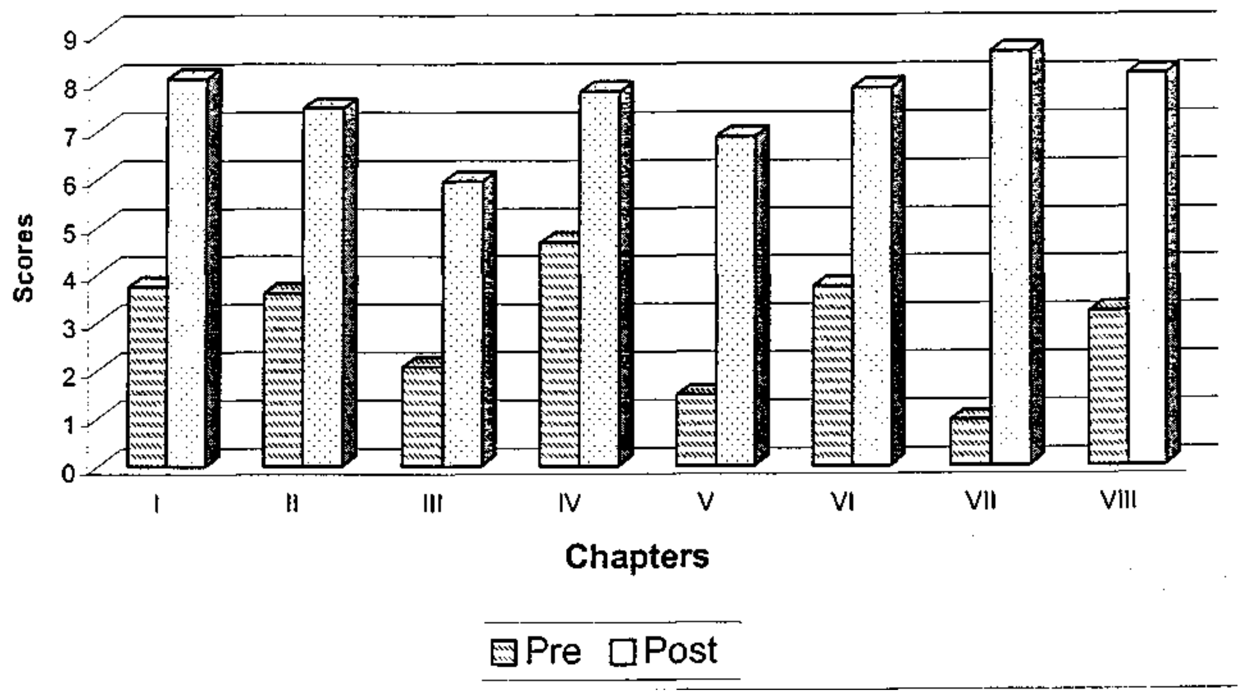
However, pre and post exposure scores did show improvement in knowledge which is statistically significant at 0.01 level as evident from table 1.

Table 1.Showing the Mean, S.D and range of pre and post exposure test score for visual mode of presentation

(Group V) along with the t-value

Chapter	I		II		III		IV		V		VI		VII		VIII	
	Pre	Post	Pre	Post	Pre	Post j	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	3.73	8.07	3.6	7.46	2.06	5.93	4.66	7.8	1.46	6.86	3.73	7.86	0.93	8.6	3.2	8.13
S.D	1.28	1.39	1.29	1.12	1.27	1.33	1.83	1.26	0.83	1.40	1.53	0.99	1.83	1.76	0.94	1.24
Range	2-6	5-9	2-6	6-9	0-5	4-8	2-8	6-10	0-3	5-9	1-6	6-9	2-5	6-10	0-6	6-10
t-value	9.1327		11.047		12.019		9.32		15.466		15.101		13.539		19.819	

Fig.1. Showing mean of pre and post scores obtained in visual mode of presentation



II. Pre and post exposure score obtained in the audio visual mode:

Table 2 shows the mean, S.D, range and t-value for each chapter. The graphical representation of pre and post exposure are shown in figure 2.

The mean of pre exposure scores range from 1.46 to 4.6 which indicates that the subjects had some knowledge on all chapters as explained before. The chapter which deals with transducer had obtained lowest score followed by chapter on high frequency audiometry which could be attributed to the minimal acquaintance of subjects about these chapters as explained earlier.

The mean of post exposure score range from 6.33 to 8.8 some what similar trend of improvement was observed for audio visual mode as that of visual mode of exposure. Here also it was noticed that the chapter on high frequency audiometry has obtained highest improvement due to the fact as discussed earlier.

The scores obtained in chapters II, IV, V and VIII indicated that there was good improvement in knowledge after exposure, which could be again attributed to the fact of simple language used and usage of graphs etc.

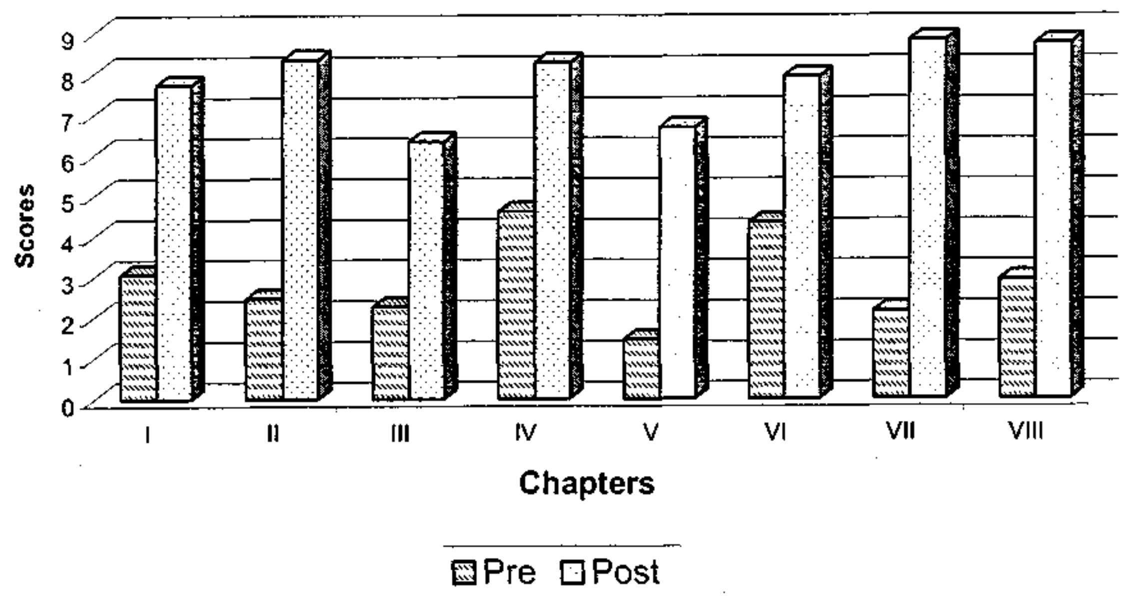
The chapter 111 and VI showed minimal improvement which would be due to inclusion of more technical terms, lengthy text etc.

However, it is evident from the table 2 that there has been significant improvement(at 0.01 level)in knowledge as can be seen from the post exposure scores in comparison to pre-exposure scores.

Table 2.Showing the Mean, S.D and range of pre and post test score for audio visual mode of presentation (Group AV) along with the t-value

Chapter	I		**II**		III		**IV**		**V**		**VI**		**VII**		**VIII**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Mean	3.06	7.73	2.46	8.33	2.26	6.33	4.6	8.26	2.93	8.73	1.46	6.66	2.93	8.73	2.13	8.8
S.D	0.88	1.03	1.06	1.71	1.33	1.49	1.29	1.83	0.88	0.88	1.59	1.44	0.88	0.88	1.40	1.65
Range	1-4	6-10	1-5	4-10	1-4	4-9	3-6	6-10	0-5	4-9	4-6	6-10	2-5	7-10	0-4	6-10
t-value	14.642		12.571		7.810		8.69		11.856		7.126		14.349		23.869	

Fig.2. Showing mean of pre and post scores obtained in audio visual mode of presentation



III. **Comparison of improvement (difference of pre and post exposure scores) obtained in visual and audiovisual mode:**

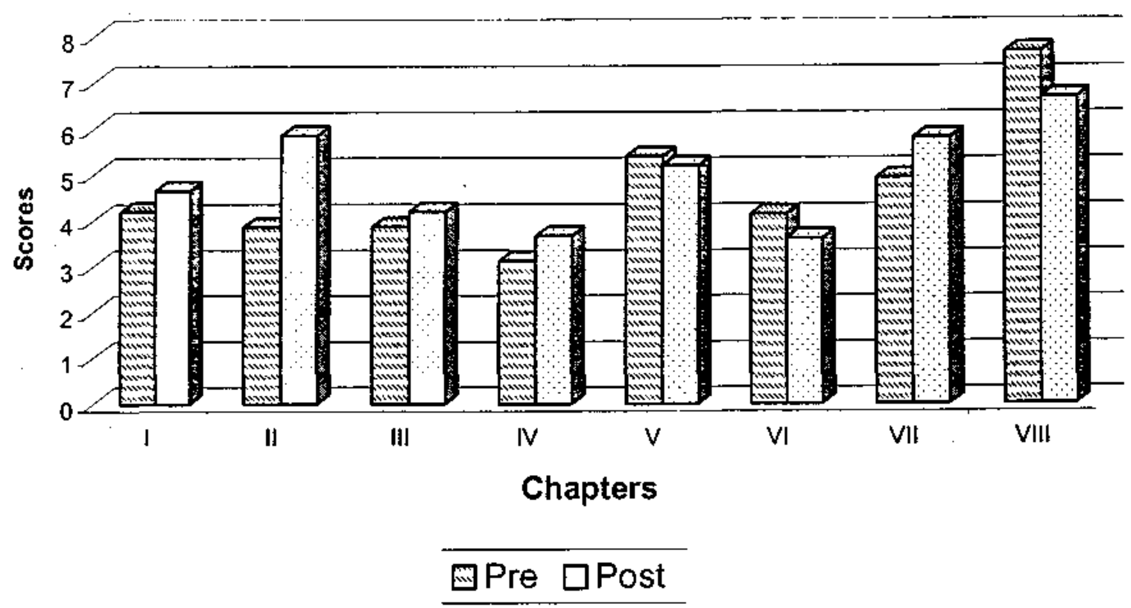
Table 3 shows the mean, S.D., and range of improvement obtained in visual and audiovisual mode along with t-value. The graphical representation of improvement (difference of pre and post exposure score) obtained in both mode of exposure as shown in fig 3.

As it is evident from table, majority of the chapters have obtained slightly greater improvement in audiovisual mode than visual mode of exposure though it has failed to reach significant level this could be attributed to the advantage of multisensory approach over the unisensory approach that facilitate better learning.

Table 3 Showing the Mean, S.D and range for the difference score (pre and post) for both group V and AV along with t-value

Chapter	**I**		**II**		**III**		**IV**		**V**		**VI**		**VII**		**VIII**	
	V	**AV**	**V**	AV	**V**	**AV**	**V**	**AV**	V	AV	**V**	**AV**	**V**	**AV**	V	**AV**
Mean	4.2	4.66	3.86	5.86	3.86	4.20	3.13	3.66	5.40	5.2	4.13	3.6	4.93	5.80	7.66	6.66
S.D	1.70	1.23	1.35	1.80	1.24	1.78	1.30	1.63	1.35	1.69	1.06	1.95	0.96	0.94	2.19	1.79
Range	1-7	3-7	1-5	2-7	3-6	1-7	2-5	1-6	3-7	3-8	3-6	1-6	3-6	4-8	5-10	4-10
t-value	0.767		4.472		0.717		0.953		0.367		0.790		2.694		1.732	

Fig.3. Showing mean improvement score (post - pre) for visual and audio visual mode of presentation



IV. Modifications to improve the efficacy of existing material:

In general, the students found the text as comprehensive and informative and they appreciated the usage of simple language and good diagrams and illustrations in certain chapters.

However, they put forth certain suggestions and also based on own experience the experimenter would like to suggest a few modifications that could be made to the existing material to add to its efficacy. They are given below.

1. Historical Aspects:

- Information with regard to names and years could have been better expressed in tabular form.
- Easy learning strategy like mnemonics could have been used.

2. Puretone Air and Bone conduction testing

- More simpler explanation regarding technical terms should have been provided.

3. Audiometer

The pictures of different types of audiometers should have been included in the text.

4. Factors affecting Air conduction and bone conduction testing

Factors affecting air conduction and bone conduction could have been tabulated for better grasping. Again, technical terms like ambient noise, Carhart notch etc., should have been supported with more explanation.

5. **Clinical Masking:**

Tabular form of all the formulae in a systematic order should have been provided so as to avoid confusion.

6. High frequency audiometry

Information regarding procedure of High frequency audiometry could have been included in the chapter for better insight into the subject.

Therefore these points should be considered while developing a tutorial.

SUMMARY AND CONCLUSION

Pure tone audiometry, being one of the basic and essential tools in the field of audiology, one must be well versed with the subjects. The tutorial studied is the easiest way to attain intensive instruction regarding the same. To make sure that it serves its purpose effectively the efficacy of the manual had to be determined.

The main purpose of this study was to:

- Study the efficacy of the tutorial.
- Influence of mode of exposure (visual or audiovisual).
- And also to put forth some suggestions for the betterment of the tutorial.

To achieve these aims, questionnaires were developed for 8 chapters that were selected and were administered to 30 first year B.Sc. students so that the pre and post exposure scores could be obtained. Out of 30 students, 15 subjects were exposed to visual mode of presentation and the other 15 subjects were exposed to audiovisual mode of presentation.

The results indicated that there is significant improvement in post exposures scores in all the chapters when compared to pre exposures scores for both visual and audio visual modes.

The overall data obtained as shown in table 4 demonstrates a t-valucs of 9.458 and 12.378 for visual and audio-visual mode respectively which is also statistically significant at 0.01 level. Thus it clearly indicates that the tutorial has been highly effective in both the modes.

The two modes of exposure i.e., visual and audiovisual modes of exposure for each chapter did not show any significant difference in terms of post exposures scores.

The overall data also did not show any significant difference even at 0.05 level which is evident in table 5.

Thus from the combined analysis of each chapter in both the groups, we can infer that the tutorial was found to be highly effective, informative and useful to improve the knowledge in the subject, no matter which modality of exposure is given.

The overall impression of the subjects was that the tutorial was good and that the language was easy to understand and was highly informative. However they opined a few suggestions for improving the efficacy of the tutorial and development of tutorials in the future.

- More tables and graphs can be provided for the information to be grasped easily.
- More examples could be included so that the concept becomes clearer.

Table 4. Showing the overall Mean, S.D and range of pre and post test score for group V and AV along with the t-value

	Visual Mode		**Audio + Visual Mode**	
	Pre	Post	Pre	Post
Mean	2.92	7.58	2.90	7.84
S.D	1.29	0.84	1.08	0.91
Range	0.93-4.66	5.93-8.6	1.46-4.6	6.33-8.8
t-value	9.458		12.378	

FigAShowing the overall mean score of pre and post exposure obtained in visual and audiovisual mode of presentation

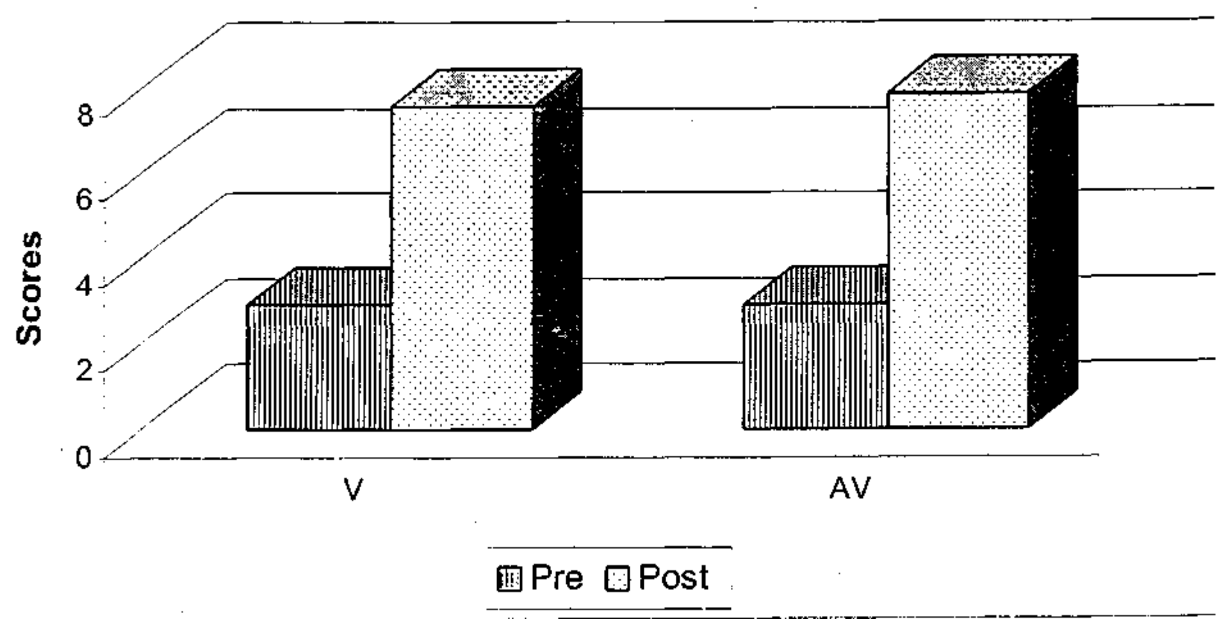
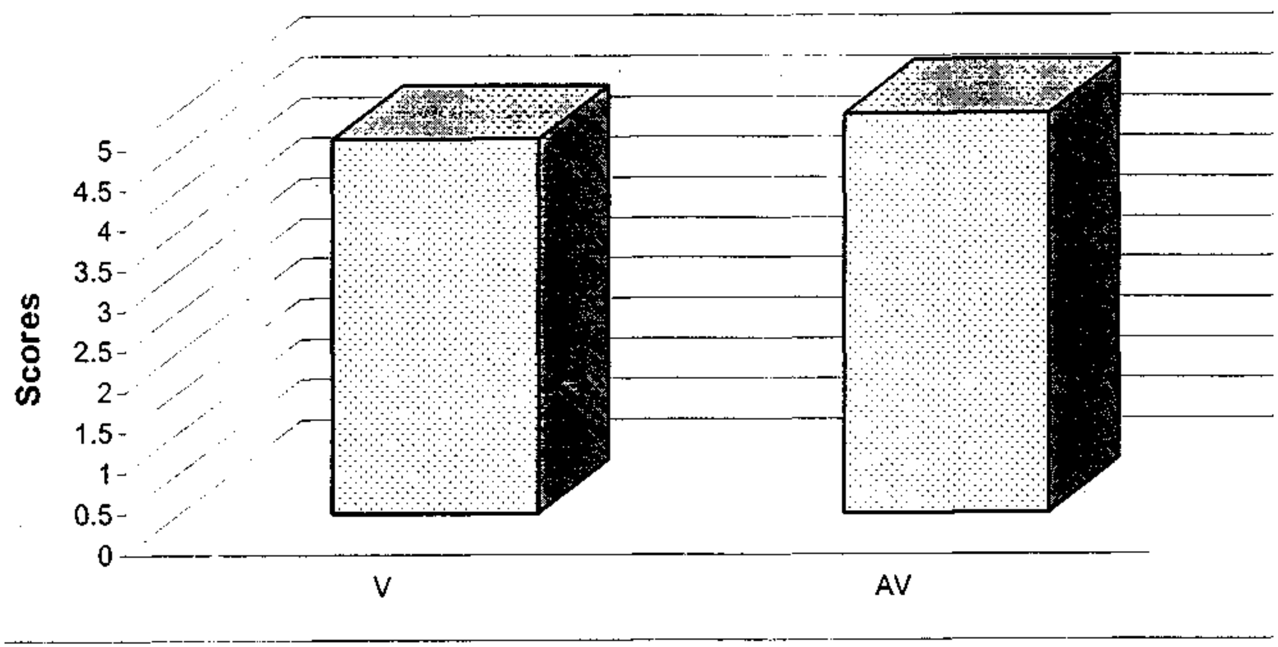


Table 5.Showing the Mean, S.D and range for improvement in score (post - pre) test for both group V and AV along with the t-value

	Group A	Group B
Mean	4.64	4.95
S.D	1.40	1.11
Range	3.13-7.66	3.6- 6.66
t-value	0.94	

Fig.5.Shows overall improvement of scores(post-pre) for visual and audiovisual mode of exposure



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APPENDIX -1

HISTORICAL ASPECTS

Historically considerable work has been devoted to the development of methodology for the clinical evaluation of human hearing. Much effort and attention were given to the establishment of tests intended to assess the type and to quantify the amount of hearing loss.

Although true diagnostic differentiation through various audiometric measures did have its beginning about half a century ago, attempts to test the power of hearing by using of instrumentation were made much earlier in the 1870's.

THE WHISPER TEST:

This was one of the earliest tests of hearing to determine whether the patient had normal hearing. The examiner used either spoken voice or whispered voice at a specified distance from the patient and determined whether the patient responded appropriately or not.

Disadvantages:

(1) Whispers have been measured from 20dB to 65dB SPL at 3 feet distance, depending on the talker,

(ii) It is not possible to determine which ear is responding to the whisper / spoken voice,

(iii) Frequency composition of the whisper was concentrated in the lower frequency region,

(iv) With increased advancement in technology, it became more important to determine extent of hearing loss and to differentiate site of possible pathology (ie EE/ME/IE).

THE WATCH-TICK & COIN CLICK TESTS

These were also some of the earlier tests administered to assess hearing. The physician holds his watch next to the patient's ear and asks the patient to inform him when he ceases to hear the tick, as the doctor moves the watch away. Hearing loss is expressed in terms of a fraction, of which, the distance in inches that the patient can hear the, watch tick is the numerator and the distance the normal ear can hear the watch tick is the denominator.

Disadvantages:

(i) To administer such a test to a patient with any amount of hearing loss, the physician must posses a fairly noisy watch,

(ii) The information is obtained in a crude way.

The coin click test consists of the physicians' dropping a large coin, on a hard surface. The patient is instructed to report whether he hears the coin "ring" or only a dull thud. Hearing the coin "ring" indicates that the high frequency hearing acuity is normal, while, if he hears a thud he is presumed to have high-frequency hearing loss.

The disadvantages of this test were:

(i) It yields no information as to which frequencies are affected or the extent of loss,

(ii) It cannot be used successfully in monaural testing.

THE TUNING FORK TESTS

Reports concerning the use of tuning forks to test hearing appeared in the 19" century. Weber described the reference or lateralisation of response to the poorer ear with a tuning fork applied to the skull of the patient with unilateral conductive deafness. Later Rinne reported on comparisons of bone conduction (BC) and air conduction (AC) tuning fork responses to differentiate conductive from sensorineural (SN) deafness. Finally Schwabach related the results of comparing the length of time that a hearing impaired patient heard an activated tuning fork placed on the skull to the response time of those patients with normal hearing. These tuning fork tests serve as the foundation for basic audiological tests in their assessment of the air conduction and the bone conduction response, the comparison of these two responses, and the consideration of a given response to "normal".

1875-1914 THE TUNING-FORK AUDIOMETER

The credit for die development of the audiometer like many other scientific advancements, cannot be awarded to any one man of genius. In 1875, Clarence J Blake along with Politzer reported certain physiological investigations on hearing, which were vital to the development of the telephone. Later in 1878 by January, Arthur Hartman devised the "acoumeter" (German word : Hormesser) which utilized a telephone receiver for the purpose of testing hearing. Puretones were selected by placing a tuning fork in the primary circuit of an induction coil, interrupting the circuit at regular intervals. There were several variations that followed in the next 35 years but they were never in general clinical use by otologists.

In 1879, D.E. Hughes in England described an "Induction balance" originally used to analyze metals, but applied with a tuning fork to the testing of hearing. He called this instrument an "electric sonometer".

Other version of the "induction coil" audiometer using either tuning forks or a buzzer as a sound sources were Jacobson's audiometer (1885) and Cheval's audiometer (1890).

Seashore (1899) developed an audiometer, which represented an important advancement over earlier types in that he used a series of coils to provide inductance steps that increased the loudness in the receiver, according to the Weber-Fechner law.

The general disadvantages of these instruments were as follows:

(i) Early instruments were bulky and difficult to keep in running order.

(ii) They were limited in their diagnostic scope : only tuning forks with a frequency of 1000 c/s or less could be used effectively,

(iii) The output intensity had no psychophysical referent.

(iv) It told nothing about the hearing for speech and was therefore limited in diagnostic value.

1914-1919 - THE ELECTRIC GENERATOR

In 1914, A Stefanini of Italy constructed an instrument,which made the modern audiometer possible. It was an electric generator producing an alternating current with a complete range of frequencies. However, it was never applied clinically.

On the basis of Stefanini and his principles Lee W Dean and Cordia C Bunch applied the electric generator to the first clinically useful "Pitch range audiometer" in 1919. It was so called because it produced all the tones between 30 and 10,000 c/s. The intensity of tones could be varied from below threshold of audibility upto threshold of pain. However, it was never available commercially.

Schwartz in 1920, introduced the "otaudian" an electrical audiometer which had a series of controls for selecting the desired frequency and intensity along with a loud speaker arrangement.

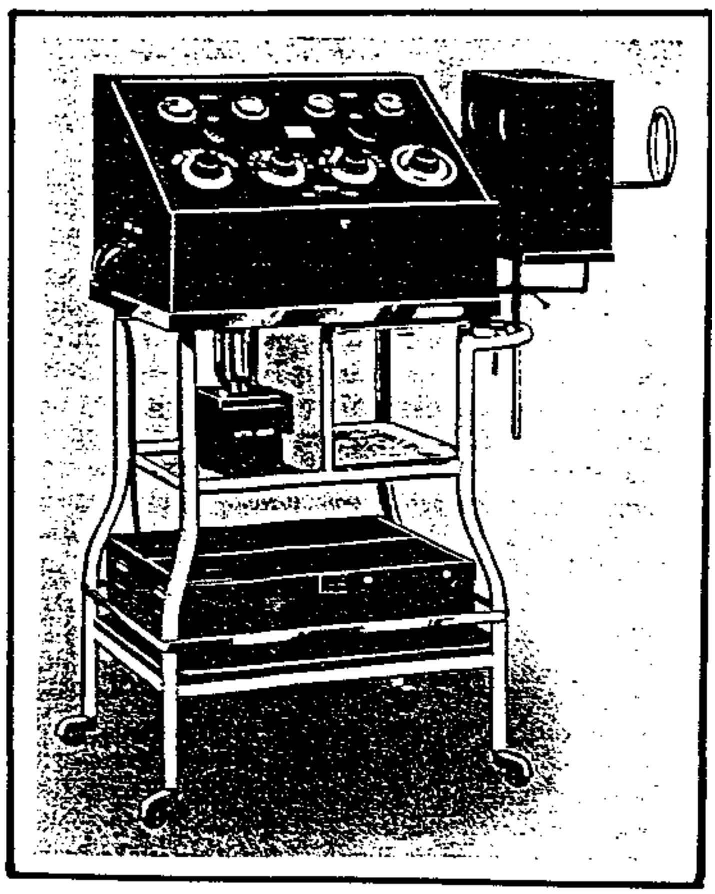


Figure 1 : The Otaudian (Schwartz 1920)

The advantages of these tests were:

1. They tested a wide range of frequencies.
2. There were controls which were specified.

The disadvantages of these instruments were:

1. They were not available commercially.

1921-1940 - THE VACUUM TUBE AUDIOMETER

After Dean and Bunch's contribution, it remained only for the application of the vacuum tube to make audiometers commercially feasible. The instrument hereafter utilized vacuum tubes to obtain oscillating electric currents of almost any desirable frequency.

The first commercial clinical audiometer was presented in 1922 by otologist Fowler and physicist Wegel, the Western Electric 1A, it generated 20 octave and semioctave frequencies from 32 through 16, 384 c/s and had a logarithmic attenuator, they also described charts called "audiograms" for plotting hearing sensitivity relative to a straight line for "normal hearing". The Western Electric 1A Audiometer was not widely used because of its prohibitive price of $ 1500.

The Western Electric 2A soon succeeded the 1A. Unlike the 1A which produced a sweep frequency output from 32 to 8192 c/s, the 2A presented only the octave frequencies from 64 to 8192 c/s. A further model, the 3A, used complex noise stimulus but never found favor among otologists.

The use of a bone-conduction receiver in connection with a pure-tone audiometer was reported by Jones and Knudsen (1924). Their "audioamplifier" used not only air conduction and bone conduction but also a speech circuit. Jones and Knudsen's audioamplifier was later modified and produced by the Sonotone corporation as the Sonotone Jones-Knudsen Model 1 Audiometer.

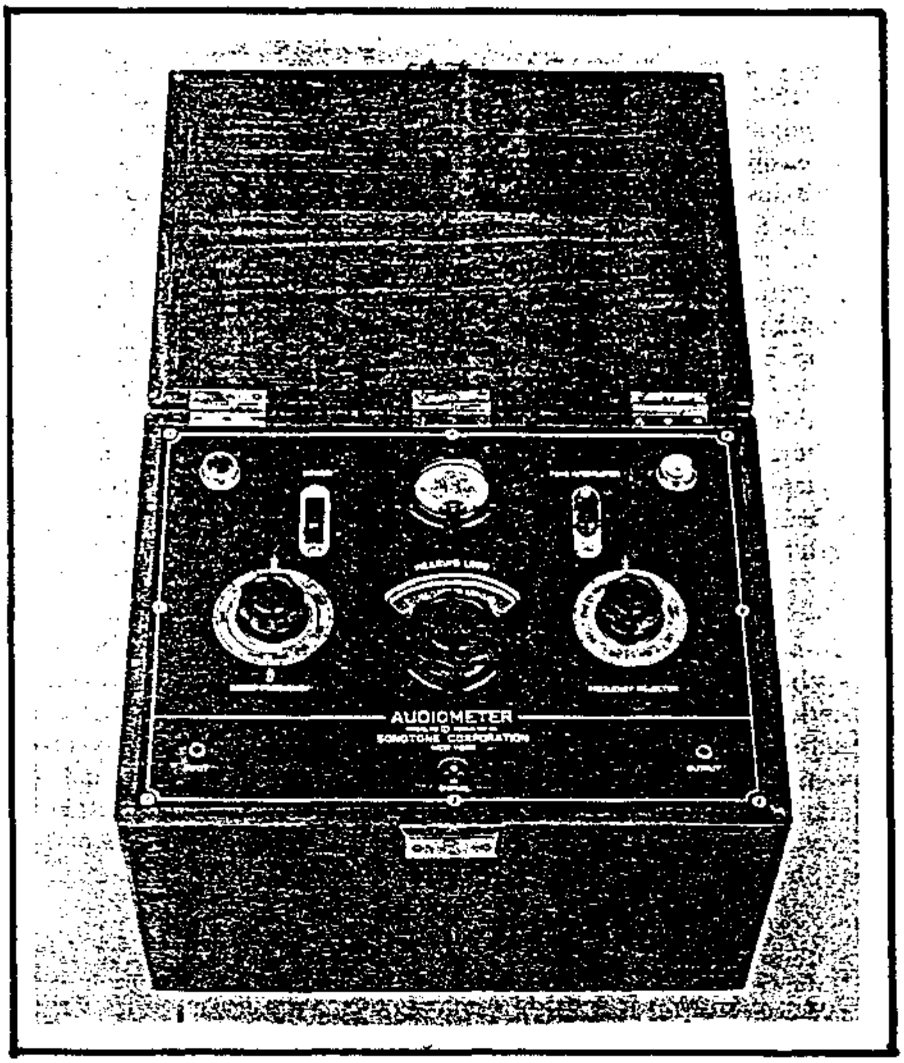


Figure 2: Sonotone Jones-Knudsen Model 1

The advantages were:

1. The introduction of the group audiometer.
2. These instruments were commercially available.
3. They provided more facilities & controls.
4. Speech audiometry was introduced.
5. It created a pathway for the diagnostic audiometer.

1940 ONWARDS

By the middle of the 20th century, audiometric testing included the use of both pure tones and speech. Towards the 1940's audiometers began to be available commercially. These advancements have been largely in the way of refinements of general principles and in the use of circuitry for test variations. In addition, transistors are currently replacing vacuum tubes in many instruments.

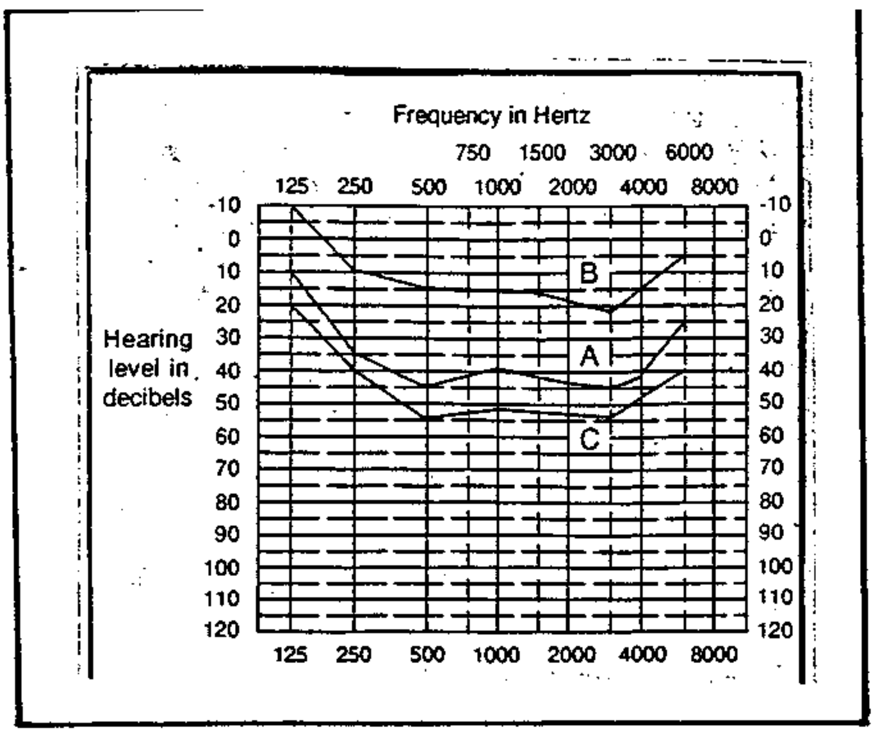
In 1947, Nobel Prize winner, Dr. Georg Von Bekesy introduced the automatic- self-recording audiometer, in which the tone fluctuates around the threshold under the subject's control.

In 1950, German otologist B. Langenbeck used filtered bands of noise in experiments with noise audiometry.

PURE TONE AIR AND BONE CONDUCTION TESTING

RATIONALE USED FOR THE FREQUENCY RANGE OF PURE-TONES USED IN PURE-TONE AUDIOMETRY

The range of frequencies for air conduction testing is generally 250-8000Hz while that for bone conduction testing is 250-4000Hz. Any sound, however complex can be shown to be a combination of pure-tones, including speech. The overall intensity level of conversational speech is approximately 65-70 dB SPL. Pascoe (1978) determined the sensation lever with respect to the minimum sound pressure level for audibility of the speech stimulus at the 3 rd octave bands centered at 125,250,1000,2000,4000, & 8000 Hz. The study was done on normal-hearing listeners, so the sensation level can be considered equivalent to hearing level.



Graph 1 : Speech spectrum on an audiogram format.

As can be seen from figure, the hearing level for speech at each frequency when the speech has an overall level of 65 dB SPL is approximately 20 dB at 125 Hz, 40 dB at 250 Hz, 55dB at 500 Hz, 52dB at 1000 Hz, 55dB at 2000 Hz, 50 dB at 4000 Hz & 40dB at 8000 Hz.

Audibility of the entire speech range is not essential for good speech-recognition ability in quiet. However, normal-hearing listeners would have to utilize high frequency sensitivity in noisy situations when low frequency hearing is masked by the noise. Persons with high frequency hearing loss on the other hand cannot efficiently utilize their high frequency hearing in noisy situations (Hirsh et al, 1954). In a study by Skinner & Miller, (1983) highest speech recognition score was obtained with the widest bandwidth (266-6000 Hz). Thus, frequencies above 4000 Hz are important for hearing-impaired listeners in quiet & noise as well as for normal hearing listeners in noisy situations.

- Another rationale for testing 250 Hz &500 Hz is the detection of many conductive pathologies yielding a stiffness-loaded middle ear or outer-ear system as in the case of otosclerosis & otitis media.
- Testing 4000 & 8000 Hz is to assist in differentiating between noise induced & other high frequency sensory neural hearing losses.
- Also, these tests are often used in suggesting site of lesion or general anatomic location of the pathogenic condition.

Thus although people are seldom called upon to listen to pure tones it is* reasonable to use such stimuli to test hearing.

AIR CONDUCTION MEASUREMENT:

The air conduction route i.e., the AC route comprises of the outer ear, the middle ear & the inner ear. The total auditory system, including the conductive portion & the sensory neural portion (i.e., the outer & middle ear, the cochlea & eighth cranial nerve respectively) are involved in air conduction testing. The stimuli for this test are delivered through earphones or insert receivers or in sound field through speakers.

Purpose of Air Conduction Testing:

(1) To determine the type of hearing loss present by comparison of the air & bone conduction thresholds

(2) To determine the magnitude of hearing loss

(3) To detect the presence of functional hearing loss by comparison of the pure-tone average with the speech-recognition threshold.

(4) To monitor the effectiveness of medical intervention by comparing pre & post treatment AC thresholds.

(5) To predict auditory handicap & phoneme-recognition ability.

(6) To assess the need for & the benefit from amplification.

BONE CONDUCTION MEASUREMENT

Bone-conduction threshold measurement is an integral part of basic audiological evaluation. In bone-conduction testing an oscillator or vibrator is positioned on the masteoid process of the temporal bone or on the middle of the forehead. Electrical energy is delivered to the oscillator to drive it into vibration against the skull thereby causing the skull bones to vibrate. The vibrational energy is transmitted directly to the cochlea, bypassing the outer and middle ear, which make up the conductive portion of the auditory system. The bone conduction threshold assesses the integrity of the cochlea & eighth cranial nerve, which represent the sensory neural portion of the auditory pathway.

Bone conduction hearing from airborne sound does not occur until the intensity of the sound exceeds the air-conduction threshold by at least 60 dB (Dirks, 1985)

The purpose of bone conduction testing is:

(1) To determine the type of hearing loss present by comparison of the air & bone conduction thresholds.

(2) Bone conduction testing measures the sensorineural sensitivity.

CONVENTIONAL PURE TONE THRESHOLDS.

According to the American National Standards Institute (ANSI, 1973), the threshold of hearing is the threshold of audibility which can be obtained under two conditions denoted by the minimum audible pressure (MAP) & minimum audible field (MAF). This threshold is defined as the "minimum effective sound pressure level of the signal that is capable of evoking an auditory sensation in a specific fraction of trials" (ANSI S3.20-1973) i.e., to say if 3 trials are given & there is a positive response twice, then the minimum level at which there is consistency in the two positive responses out of 3 trials is considered the threshold.

There are many psychophysical methods based on which thresholds are obtained. Some of them are:

I. Method of limits

II. Method of adjustment

III. Descending run method

IV. Method for clinical determination of pure tone threshold measurement.

[A] Hughson-Westlake(1944)

[B] Carhart-Jerger modified Hughson-Westlake (1959)

[C]ASHA (1978a) Guidelines for manual pure tone threshold audiometry,

[D]ANSI (S3.21 -1978) Method for manual pure tone Audiometry.

I. Method of limits:

It was given by Fechner in 1860 & is one of the classical psychophysical methods for measurement of threshold. Series of stimuli that are either ascending or descending in intensity are presented. This is done because the threshold varies as a function of the direction of the run/ trial. The amount of increase (i.e., increment) in intensity is fixed or equal.

Instructions;

1) The patient is instructed to respond whenever & as soon as the tone comes on regardless of how faint it is & to stop responding as soon as the tone goes off. The subject is also instructed that first one ear & then the other ear will be tested.

2) The mode of response can be any of which is overt, for example, raising and lowering the finger, hand or arm, pressing & releasing a signal light switch.

3) A spoken response, however, is the least acceptable as silence is desirable in the test environment.

Method:

1. Ascending ran: Sound is first presented at a level known to be below threshold & then is increased in fixed, equal increments until the subject perceives the sound (i.e., a first positive response is obtained).
2. Descending run: Sound is initially presented at a level known to be well above the threshold, & then is decreased in fixed, equal increments untill the subject no longer perceives the sound (i.e., a first negative response is obtained)

3. The descending and ascending runs are alternated and a minimum of at least 6 runs is administered.

4. Each run is initiated & terminated at a different intensity in order to prevent the subject from standardizing the response by counting the number of stimuli given before changing the response.

Calculation:

The absolute threshold is determined for each run by calculating the series of transition points denoted by (t), which is the midpoint between the last negative and the first positive response in an ascending run or the last positive & first negative response in a descending run.

The over all threshold is the average of the T values (for at least 6 runs)

Disadvantage

Errors of anticipation & habituation may constitute the persistence effect.

1. Anticipation: Subject changes response before applicable e.g. In ascending run the subject may say "no" for the first few stimuli & then say yes before the stimulus is heard because it is anticipated.

2. Habituation: Subject continues to respond to the stimuli in the same manner, even when response is no longer applicable e.g. In descending series subject says "yes" out of habit, even when stimulus is no longer heard.

Altering the direction of runs & using large no of runs minimizes the effect.

II. Method of adjustment:

In this, the testee has control of the intensity of the stimulus by depressing/ releasing a switch, which will increase or decrease the intensity. He has to adjust the intensity of the stimulus until it is just barely audible. He is instructed to manipulate the switch so that the continuously changing stimulus varies between just audible & just not audible. A mid point of these two values is usually taken as threshold.

III. Descending method:

The instruction is similar to that used for the method of limits, the tester presents a stimulus that is easily heard & serially decreases the intensity with each tonal presentation until the testee no longer reports hearing the tone. The process is repeated several times & the lowest level at which the observer reports hearing the tone 50% of the total time is taken as threshold of hearing at that frequency.

A. Hughson-Westlake Method (1944):

It is similar to psychophysical "Methods of limits" in that it represents only the ascending version.

Instruction: Same as that for method of limits.

Method: The stimulus is presented in ascending order from a level where sound is inaudible to the lowest level where sound is audible.

Calculation: Threshold is defined as the lowest level at which the sound is audible in more than half of the ascending trials.

[B] Carhart-Jerger Modified Hughson-Westlake (1959):

Carhart & Jerger (1959) revised the Hughson-Westlake method.

Instruction:

The instruction is the same as mentioned earlier.

Method:

A tone is presented well above threshold, i.e., at 30-40 dBHL, if the subject appears to have normal hearing sensitivity, & at 70dBHL if a moderate hearing loss appears to be present.

If the initial level still yields a negative response, then the intensity is increased in 10-15 dB steps until a positive response is obtained.

The duration of pure-tone stimuli is 1-2 s & the stimuli are separated by toneless intervals.

After the first response, the intensity is decreased in 10-15 dB steps until response is obtained.

When inaudibility is reached, the threshold search is begun. The intensity is then increased in an ascending series of 5 dB steps until a response is obtained.

When a response is obtained, the intensity is decreased 10-15 dB & another ascending trial of 5 dB increments is begun.

Interpretation:

The criterion for threshold is the lowest intensity at which 3 positive responses are obtained on an ascending run.

Advantages:

5-dB increments in ascending run increase the reliability since moment to moment fluctuations (i.e., changes) in auditory sensitivity are generally less than this increment size [Carhart & Jerger (1959)].

The brief tonal duration enhances reliability by maximizing "on effect" phenomenon & minimizing adaptation [Carhart & Jerger (1959)].

"On effect": Refers to the fact that the auditory system responds most vigorously at the onset of a tone.

Adaptation: For a sustained tone when there is a reduction in responsiveness (either due to perceived decrease in loudness or change in tonality) even when the tone is not intense enough to yield fatigue.

Separation of stimulus by toneless intervals permits full recovery from adaptation, if present.

[C] ASH A (1978a) GUIDELINES FOR MANUAL PURE-TONE THRESHOLD AUDIOMETRY

The ASHA guideline for manual pure tone threshold audiometry is essentially based on the recommendations of Carhart & Jerger (1959) & Reger (1950). The guidelines indicate that variations in procedure may be necessary for **difficult -to -test populations.** The procedure is as follows:

1. Instructions: Instructed to respond whenever & as soon as the tone comes on regardless of how faint it is & to stop responding as soon as the tone goes off. The subject is also instructed that first one ear & then the other ear are tested.

2. The mode of response can be any which is overt, for example, raising & lowering the finger, hand or arm pressing & releasing a signal light switch.

3. A response should not be considered as one unless the latency of the response is consistent & the subject responds approximately to the termination and initiation of a tone. If the latency of the response to the first tone in an ascending run is delayed, the response to the tone that is 5 dB higher should be with out hesitation.

4. Subjects should be instructed if false-positive responses or false negative responses are obtained. False positive responses can be minimized by

varying the interval between audible stimuli, employing pulsed on warble tones, or by having the subject report the number of pulsed tones presented at a given level.

5. The subject is familiarized with the tone by one of the two methods. In the first method, the attenuator is set at lower limits & the intensity is slowly & continuously increased until a response occurs. In the second, the tone is presented at 30 dBHL & at 50 dBHL if no response occurs at 30 dBHL. If there is no response at 50 dBHL, the tone is increased in 10dB steps until a response occurs.

6. The duration of tone is l-2seconds

7. The inter stimulus interval is varied but is never less than the duration of the stimulus.

8. After the first response, the tone is decreased by 10 dB whenever the subject responds & increased by 5 dB whenever the subject fails to respond.

9. The threshold is defined as the lowest intensity at which the subject responds at least half the times & at least 3 times on ascending runs.

10. Variations in technique should be recorded on the audiogram, for example, descending method, pulsed tone, warbled tones, substituted.

11. The audiometers & earphones must meet the specifications in ANSI S3.6-1969.

12. The ambient noise levels in the test environment must meet the specifications in ANSI S3.1-1977.

13. The tester should check for cerumen blockage or collapsed canals with or without earphones. The tester should place the headphones, so that the grid is directly over the entrance to the ear canal. Hair should be manipulated so that it is not trapped underneath the headphones & other obstacles such as earrings should be removed.

14. Diagnostic testing should be done at the following octave frequencies: 250, 500, 1000, 2000, 4000, 8000 Hz. Testing is also done at 125 Hz when a low frequency hearing loss is present. The interoctave frequency is tested whenever the difference in threshold between two adjacent octave frequencies is at least 20 dB

15. The better ear should be tested first. The order of test frequencies employed should be

(a) 1000, 2000, 4000 & 8000, retest at 1000, then 500, & 250 Hz or

(b) 1000, 500, & 250Hz retest at 1000 then 2000, 4000 & 8000 Hz respectively.

[D] ANSI S.3.21-1978- METHOD FOR MANUAL PURE TONE AUDIOMETRY

The ANSI is only slightly different from ASHA (1978 a).

It initially recommends presentation of tone at 30 dBHL for every one; if no response occurs increase by 20 dB & by lOdB there after until a response occurs. An Alternative method is setting the attenuator at the lowest intensity level & then slowly & continuously increasing the intensity until a response occurs. The tone is then turned off for at least 2s & then presented again at the same intensity.

If no response occurs when the tone is presented again, the complete procedure is repeated again.

Yantis (1985) According to him this method is preferred by many audiologists Since this approach is less time consuming, the intensity range around threshold is decreased & some of the behavioral characteristics associated with **functional hearing loss & loudness recruitment may be detected more easily.**

FACTORS AFFECTING AIR CONDUCTION TESTING

There are a number of factors that can influence measures of pure tone threshold. A clinician should be aware of these and take the necessary steps to lessen them or compensate for their effects. A general overview of the various possible sources of error in audiometry may be structured as follows:

A. PATIENT VARIABLES

B. INSTRUMENTATION AND ENVIRONMENTAL VARIABLES

C. CLINICIAN VARIABLES

They may be further classified as

A. PATIENT VARIABLES

1. Physiological factors
2. Psychological factors
3. Pathological factors
4. Physical factors

B. INSTRUMENTATION AND ENVIRONMENTAL VARIABLES

1. Equipment Operation
2. Temperature and Ventilation
3. Calibration
4. Ambient Noise Environment

C. CLINICIAN VARIABLES

1. Placement of headphones
2. Placement of bone vibrator
3. Method of testing
4. Visual Cueing
5. Linguistic factors

6. Rapport
7. Frequency Sequencing
8. Ear selection
9. Listener / Tester position

A. PATIENT VARIABLES

1. Physiologica1 Factors

There are 4 major physiological factors that may affect the testing procedure;

a. Physiological noise
b. Adaptation effect
c. Temporal integration
d. Central masking

a. Physiological noise

Internal noise or physiologic activity linked with vascular, digestive and respiratory functions can establish a "masking floor" below which signal detection is absent even though the organism may be capable of sensation. Random acoustic or neural energy generated within the system including tinnitus can contribute to this result.

b. Adaptation

This is another physiologic phenomenon, which may influence the test result. It is the gradual reduction of the activity in the sense organ when exposed to a constant stimulus of long duration. Using stimulus, which has a duration that is short, can eliminate this.

c. Temporal Integration

This occurs when the duration of a tone pulse influences its audibility and loudness. Nearing thresholds the tone pulse duration must be at least 0.5 sec for maximum audibility

d. Central Masking

This is a phenomenon when the masker presented to one ear causes a threshold shift of signal at the other ear even when the masker signal is too low for it to cross over to the signal ear. This contralateral effect of the masker is most likely due to an interaction of the masker and the test signal within the central nervous system probably at the level of the superior olivary complex. There is an effect or shift of around lOdB due to central masking.

2. Psychological factors

a. The result of the test is greatly influenced by the ability and willingness of the testee to co-operate. This ability may be influenced by factors such as fatigue, worry, anxiety, insecurity or an uncomfortable test room.
b. Distracting events in the test room may also disturb the listener's ability
c. The motivation of the testee during the test
d. False responses may occur which are of two types, false positive and false negative. To reduce or eliminate these effects, the clinician should reinstruct the case, change the method used to obtain thresholds, vary interstimulus intervals, use warble tones etc. Learning effect and psychoacoustic testing learning effects are also present to some degree. In simple detection task learning period is usually quite short, which allows the listener sufficient training before actual testing is started.

3. Pathological Factors

a. Adaptation:

Some patients with marked adaptation associated with retrocochlear pathology will display large intrasubject variability in thresholds, appropriate modification should be employed. To reduce this, such as

a. Use of short stimulus duration
b. Use of lengthened interstimulus intervals
c. Use of ascending approach to obtain the threshold

Collapsed Ear Canal

In some elderly patients, the mastoid process may be ossified, possibly leading to bone conduction thresholds that are more than 15 dB poorer than the air-conduction thresholds at low frequencies. Also, in some there may be ear canal collapse because of decreased skin elasticity in the cartilagenous part of the external Auditory meatus. A quick way to confine whether a potential problem exists is to retest with the earphone elevated slightly, from the pinna. If threshold improves, canal wall collapse must be considered.

The various management techniques have been suggested in case of collapsed ear canal

(i) Place pads of gauze or tissue behind the pinna so that the pinna and the posterior canal wall are forced backward when the earphones are replaced.

(ii) Others have recommended inserting into the canal a thick-walled plastic tube, ear stopple, stock earmold or probe tip like those used in immittance audiometry

(iii) Other suggestions include open ear retest in calibrated sound field and substitution of circumaural for conventional supraaural cushions

(iv) Use of insert earphones to test.

4. Physical Factors

a. Standing Waves

The average length of the ear canal is approximately 1.5 inches. The wavelength of an 8000 Hz tone is also approximately 1.5 inches. When an 8000 Hz tone is delivered via the ear phone into the ear canal, and the distance between the tympanic membrane and the earphone diaphragm is approximately 1.5 inches, the reflected wave from the tympanic membrane will be 180 degrees out of phase with the incident wave and cancellation of the wave will take place. This may also occur at around 6000 Hz. Therefore, whenever there is a disparity between the 4000 and 6000 or 8000 Hz thresholds, the presence of standing waves should be suspected and the clinician should readjust the earphones.

B. INSTRUMENTATION AND ENVIRONMENTAL VARIABLES

1. Equipment Operation

a. Inaccurate thresholds may be obtained if the earphone plugs are not plugged into or are incompletely plugged into the correct jack.

b. If there is excessive winding of the phone leads

c. If the earphones are placed on the wrong ear
d. If the transducer and stimulus buttons on the audiometer are incorrect and if the amplifiers have not been activated properly for sound field-testing.
e. Clinicians should be especially suspicious of equipment problems in cases of asymmetrical or unilateral hearing loss or when normal hearing thresholds are obtained despite the patients reporting hearing loss.

f. Make sure that the audiometer is receiving power and that the electric supply is proper for the instrument being operated.
g. Earphone contamination is another common problem Talbot (1969) concluded that the potential for infection was present although there was no evidence of patients incurring infections from the cushions.

The most common way to disinfect earphone cushions is to wipe them off with an ethanol sponge.

2. Temperature and Ventilation

a. High temperature exceeding 85° F and lack of ventilation in the booth can affect accuracy of the pure tone thresholds, especially in children. Wilber, (1979).

3. Calibration

a. Lack of accuracy in pure tone thresholds can also stem from inadequate calibration.

4. Ambient Noise

Ambient noise is another source of inaccuracy in audiometric measurement. The noise levels at each octave band should meet specified standards. (Refer to the chapter titled "Standards relevant to puretone audiometry). The table shows the maximum permissible noise levels at each octave band in the audiometric booth used for testing done at 0 dBHL in sound field or by bone conduction.

C. CLINICIAN VARIABLES

1. Placement of Headphones

The clinician should ensure that the earphone diaphragm is against the entrance of the ear canal. Variations by a few millimeters up and down or forward and backward can give rise to measurable variation in sound levels reaching the eardrum. The earphones must also fit snugly to reduce the problem of leakage of stimulus around the earphone.

In sound field audiometry, large variations in test sound level may arise in the test room if it is not anechoic. Also, the speakers should be placed at a distance of 1 meter and an angle of 45° from the patient.

2. Visual Cues

Visual cues, such as looking down or making certain body gestures every time the tone is presented or relating to tonal presentation should not be given.

3. Rapport with the patient

A friendly and understanding attitude increases the motivation of the patient.

5. Linguistic Factors

a. Instructions

Instructions should be clear and the clinician should check if they are understood.

The patient may need to listen to some tones or words before the test begins.

The exact phrasing of the instructions is not as important as making sure some concepts are understood.

In order to make sure that the patient understands what he is to do, the audiologist should ask him to repeat the instruction.

b. Language used

The clinician should explain instructions in a language familiar to the testee and tester.

c. Contact:

The clinician should make use of appropriate content words and his length of sentence chosen should not be too long.

5. Ear selection

Normally the test should begin with the ear that appears more sensitive. The presumption is that the better ear will not need retesting in the event masking must be used after the poorer ear is evaluated. .Also individuals use better ear advantage for the better ear usually perceives day to day sounds.

6. Frequency Sequencing

The testing should usually begun at 1000 Hz for three primary reasons

a. 1000 \\z is identified perceptually as a pitch familiar to most listeners
b. Thresholds obtained at this frequency tend to be more reliable.
c. All individuals usually have some amount of residual hearing at this frequency.

7. Listener Position

If threshold tests are conducted in a single room, the listener must be seated so that movements of the examiner can not be directly observed but those of the listener are visible to the examiner. It is also important that acoustic radiation does not emanate from the chassis of the audiometer.

8. The personality motivation and experience of the clinician are factors, which may also affect the testing.

Factors Affecting Bone Conduction Testing

Some specific factors which affect bone conduction testing alone are:

A. Bone vibrator placement

The bone vibrator must be placed on the mastoid process no closer than a thumbs width to prevent acoustic radiation. Mastoid placement is also recommended over frontal bone forehead placement because the reference level in ANSI S3.26 (1981) are based on mastoid placement and the dynamic range is larger for mastoid than forehead placement. The frontal site is advantageous in that it has smaller inter and intra subject variability and it excludes the contribution of the middle-ear inertial-ossicular component of bone conduction.

1. Headband tension

Hearing sensitivity changes sufficiently with change in headband tension, which is less when the tension is around 750 gms. The recommended value, as per the ANSI (1969) Standards, for the headband tension of the bone vibrator is 550 gms or 5.4 N.

2. **Surface area**

More the surface area, more the acoustic radiation. Also, there are more chances of getting tactile sensation at higher levels. Hence the ideal surface area or the contact area of the bone vibrator is 1.75 $cm^2 \pm 25$ mm^2 ANSI (1969).

3. Type of Bone vibrator

The type of bone vibrator may also influence the bone conduction testing. For example, the old radio ear B-70 series has a contact area larger than the recommended value. Also, acoustic radiations or aerial radiation at high frequencies is a common problem associated with the B-71 and B-72 bone vibrator.

B. Occlusion effect

The occlusion effect is the improvement in the bone conduction threshold when the external ear is covered by an ear phone or when the ear canal is occluded by a finger, ear insert, earmold, ear protector over the unoccluded bone conduction threshold (Studebaker (1979). The occlusion effect occurs primarily at low frequencies and is an average of 20 dB at 250 Hz, 15 dB at 500 Hz, 10 dB at 1000 Hz and 0 dB at 2000 Hz and above (Goldstein and Hayes, 1965 ; Martin, Buttler and Burns, 1974).

C. **Effect of Middle Ear Pathology on Bone Conduction Thresholds**

1. Ossicular Fixation

The bone conduction threshold is often elevated at frequencies around 2000 Hz in patients with ossicular fixation, referred to as the carharts notch (Carhart, 1950). The elevation occurs because of the loss of the middle-ear inertial-ossicular component of bone conduction. The carhart notch occurs approximately at 2000 Hz since, in humans, the ossicular chain resonates at 2000 Hz. The classical carhart notch usually shows a bone conduction thresholds of approximately 15 dBHL.

2. Otitis Media

In otitis media, the bone conduction thresholds are decreased at the low frequencies and increased at high frequencies (Huizing, 1964; Hulka, 1941; Naunton and Fernandez, 1961; Liden and Kim, 1984). According to Huizing (1964), Hulka, (1941), Naunton and Fernandez, (1961) the attenuation in bone conduction threshold is related to resonance changes because of mass loading of the middle ear system.

D. Physiological Factors

1. In geriatric, ossification of mastoid area leads to a decrease in the bone conduction sensitivity due to which the BC thresholds may be poorer than AC thresholds by more than 15dB .
2. In some patients with mastoid abnormalities, good bone vibrator placement may be difficult. In such cases, the clinician should place the vibrator on the better mastoid or move the bone vibrator around the mastoid process or on the forehead with the tone continuously on until a site is reached where the tone is loudest.

THE AUDIOMETER

The audiometer is an electronic device for measuring hearing ability or lack of it. In its simplest form, it is a pure tone generator. Valid testing of hearing sensitivity for pure tones requires a minimum amount of equipment & an appropriate testing environment. According to IS: 9098-1979 the audiometer is an instrument for the measurement of hearing acuity.

Audiometer can be classified as follows: -

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

a. Typel,

b. Type2,

c. Type3,

d. Type4,

e. Type5.

Type l, 2 & 3 are the diagnostic type & have the facility of both AC &BC, where as Type 4 & 5 are screening type having only AC facility.

Table 1 : Classification of audiometers according to IEC

SI. no	Parameters	Typel	Type2	Type3	Type4	Type5
1	Intensity Range					
	Maximum	120 dB	110 dB	100 dB	70 dB	70 dB
	Minimum	-10 dB	-10 dB	-l0dB	-10 dB	-10 dB
2	Frequency Range					
	Lowest	125 Hz	125 Hz	Exclusion of 125 Hz, 750 Hz & 1500 Hz	500Hz	
	Highest	8kHz at octave interval frequen -cies of 750 Hz.	8000 Hz with aditional 1500 Hz 3000 Hz & 6000 Hz.(IEC 29C)		6 kHz. others 1000, 2000, 3000, 4000 Hz.	
3	Noise					
	Transducer for masking noise facility	Contralateral earphone Ipsilateral earphone & bone vibrator		Masking noise available through earphones only	Not provided for masking noise.	
	Type of masking noise.	Narrow Band and Broad band		Narrow Band only		
4	Transducer					
	Earphones:	2 earphones mounted in Supra/circum aural cushions				Single earphone
	Bone vibrator	Available			No bone vibrator	

(IS:9098-1979) classified audiometers as pure tone audiometers & diagnostic audiometers. The pure tone audiometer has the facility to test using pure tones whereas the diagnostic audiometer has both, speech and pure tone testing facility.

According to ANSI (1969), the specifications for audiometer covers two major types of instruments-Pure tone audiometers & speech audiometers. Audiometric instruments are further categorized into wide, limited, &narrow range devices.

(I) The wide range device is defined as one, which covers a major portion of the human auditory range in both frequency & Sound pressure level. It is similar to the diagnostic audiometer. It includes one or two earphones, a bone vibrator & provisions for masking of the non-test ear.

(II) Limited Range: It is restricted in frequency & output & could be compared to a screening audiometer. Facilities for testing bone conduction & for masking may be omitted.

(HI) Narrow Range: It is further restricted to perhaps only 2-3 frequencies at just few sound pressure levels. They are for screening purposes.

The speech audiometer is defined as an instrument that enables the monitoring of spoken material at controlled sound pressure levels. The speech source may be live voice, disc or tape.

According to Newby,(1972). Pure tone audiometers can vary from simple portable models for school testing to elaborate 'research' audiometers, with which it is possible to administer all kinds of special advanced tests, in addition to the standard measures. According to him, they are of two main types: discrete frequency & sweep frequency. The former provides tones only at octave & mid-octave steps as the frequency dial is turned; the latter type provides a tone that is continuously variable in frequency.

Pure tone audiometers

A common type of audiometer, which is sometimes portable, tests hearing sensitivity by air conduction & by bone conduction. The testable frequencies for these audiometers include 125, 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, & 8000 Hz. The range of intensities begin at -10 dB & goes to 110 dBHL at frequencies between 500 & 6000 Hz & slightly lower maxima at 125, 250 & 8000 Hz. Usually only the range from 250 through 4000 Hz may be tested by bone conduction. The maximum testable hearing level for bone conduction is considerably lower than for air conduction, not exceeding 50 dB at 250 Hz & 70 or 80 dB at 500 Hz & above. **The Maximum output for BC is lower than that for AC because the power required to drive a bone conduction vibrator is greater than for an air conduction ear phone.** Additionally when the bone conduction vibrator is driven at high intensities, harmonic distortion takes place, especially in the low frequencies. A masking control is also provided for introduction of noise to the non-test ear during masking.

Automatic Audiometers

These are audiometers that allow a patient to track his or her own auditory threshold while it is automatically recorded in the form of a graph on a special form. During automatic audiometry, patients hold a switch that they press whenever they hear a tone. The tone is automatically increased in intensity for as long as the switch is released. The tones may be in the form of discrete or sweep frequency steps.

Computerised Audiometer

A computer may be programmed to control all aspects of administering puretone air & bone conduction stimuli, recognize the need for masking, determine the appropriate level of masking, regulate the presentation of the masker to the non test ear, analyze the subjects responses in terms of threshold determination criterion & present the obtained threshold values in an audiogram format at the conclusion of the test computerized audiometry may be performed on a device that is microprocessor- controlled which allows it to be remotely operated by a computer.

Stach (1988) states that it is used successfully to a great extent for military, industrial & educational applications than for individual diagnostic purposes.

Further classification of audiometers can be on the basis of

(i) Screening Vs Diagnostic

Screening audiometer

It is used for the purpose of identifying hearing loss. It has got facility for only AC testing with limited range for frequency & intensity. It may be individual or group Type.

Diagnostic Audiometer:

It is more versatile. It has got facility for both pure tone & speech testing & in its more elaborated form includes facility for special tests. It has primary meant for diagnostic test in clinical & medical settings.

(ii) Individual Vs Group:

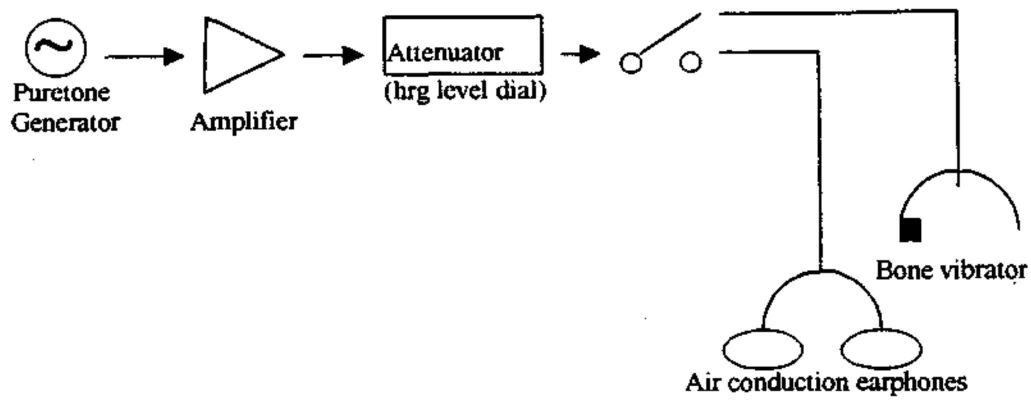
Individual Audiometer:

In this type one can test only one subject at a time. It provides a more accurate result than the group audiometer but the procedure is more time consuming.

Group Audiometer:

This is capable of testing a group of persons simultaneously, using a procedure in which reliable information is obtainable from each individual.

Figure 8 : Block Diagram Of A Pure tone Audiometer



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. Battery operated audiometers are also available. Currently most commercial audiometers come with a provision of uninterrupted power supply (for a certain duration of time). The switch may have markings like on/ off, AC, DC, Batt, Power etc.

***(2).* Attenuator**

The attenuator or hearing level dial indicates the level of the stimuli-pure tone or speech & the level of 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 provided, one to control the level of the tone & one to control the level of" the noise, so that the simultaneous presentation of the 2 tones 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.

Normally, the attenuator is marked in hearing level in dB ranging from -10 dB to 100 dB or 120 dB, -10 dB being indicative of the signal or noise at its softest & 100 dB or 120 dB being indicative of the loudest signal or noise that the instrument is capable of producing.

The hearing level control may be graduated in steps of 1,2 or 5dB i.e., the level of the signal pure tone or speech, can be increased from 0 to 5 to 10 to 15 to 20 etc. when 5 dB steps are set up to the maximum

It is more important to note that for the range from the lowest to the upper most limits i.e. -10 dB to +100 dB or 120 dB, the attenuator is applicable to the pure tones in the range of the middle frequencies such as 500 Hz to 4000 Hz. At higher (6000, 8000 Hz) & lower (125Hz, 250 Hz) the range is more limited. Similarly compared to the range available for air conduction testing, the range for bone conduction testing is more limited. 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 linearity (i.e. if there is a corresponding change in output values consequent to the manipulation of the attenuator) is in the clockwise &

anticlockwise direction through out the full range and is an important aspect of calibration. To check the output SPL, the attenuator is kept constant at the recommended level i.e., 60 dBHL or 70 dBHL (ANSI 1969) (IS: 9098-1979)

3. Frequency Dial:

Every audiometer has the facility to choose the test tone for presentation to the testee. The range of frequencies provided depends upon the type of audiometer.

The frequency range listed above is normally the same irrespective of whether the signal is a continuous tone, pulsed tone or warble tone. However a high frequency audiometer can have a facility to check hearing acuity upto 20 kHz at octave and mid octave frequencies

For calibration purposes, the deviation of the indicated frequency must be checked. The permissible error is ± 3% for all except the 2 or 3 frequencies at the extremes (250, 6000, 8000 Hz) which can have an error of ± 4%(ANSI-1972. In addition, harmonic distortion, 2^{nd} & 3^{rd} & higher harmonics must be checked.

(4) Tone Switch:

To present the signal, a tone switch is provided. When the switch is depressed the selected pure tone is fed through the earphone & 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 interrupter since when the 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 clicks, it must be easy to operate.

(5) Masking Noise

Audiometers have provision for masking noise to be presented to the non test ear when ever there is a likely hood of the test signal crossing over the non test ear from the test ear. Facilities for presenting the masking may be through the contralateral earphone, through the bone vibrator. Types of masking noise may be one or more of the following, broad band noise, or narrow band noise, speech spectrum noise.

(6) Ear phone:

Each audiometer is equipped with 2 earphones, one marked red to be used for the right ear & the other marked blue to be used for the left ear. The two earphones are mounted in supra/circum aural ear cushions and are connected by means of an adjustable headband. The two earphones must be matched.

The earphone frequency response must be flat through out the frequency range of interest. Also, impedance must match **that** of the audiometer. •

(7) B.C. Vibrator:

Audiometers are equipped with B. C. vibrators. For both single channel & 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 ± 25 mm^2 (ANSI-1972, IEC 373-1971). The headband 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 through the BC vibrator, insert receiver or free field.

Discussed above, are the parts of an audiometer that are common to almost all audiometers. In addition to the above, the more versatile clinical diagnostic ones are provided with the following:

(a) Test signal indicating device

(b) Patient signal indicating device (Talk back)

(c) Auxiliary output for loudspeakers

(d) Input for external signal

(e) Reference tone for alternate / Simultaneous presentation

(f) Communication / between tester and the testee.

(g) V.U. meter.

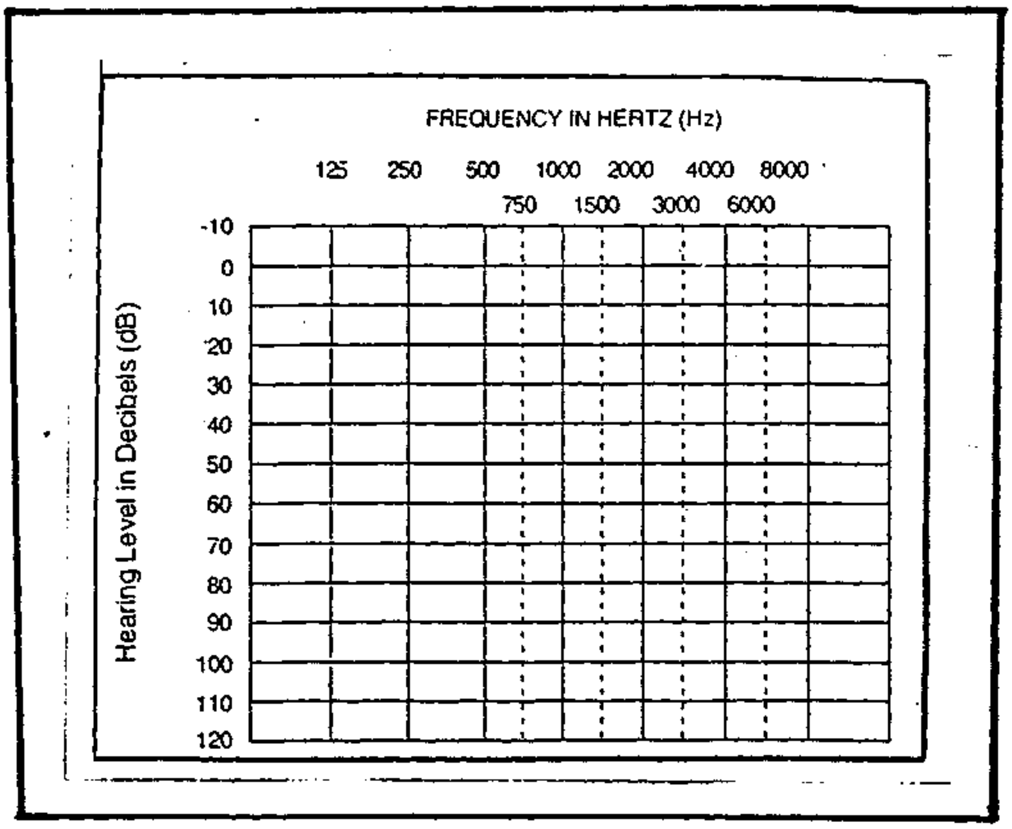
Given below is a table summarising the various parts of the audiometer and their functions

Table 2 : Summary of the various parts of an audiometer and their functions

Control	Purpose
1. Power switch	Activates device
2. Frequency selector	Selects frequency for test
3. Hearing level control	Selects test level
4. Output selector	Selects desired Transducer
5. Interrupter control	Turns signal 'on' & 'off
6. Mode selector	Select pulsed/continuous
7. switch for masking	Turn on masking noise
8. Attenuator for masking	Controls level of masking

THE AUDIOGRAM

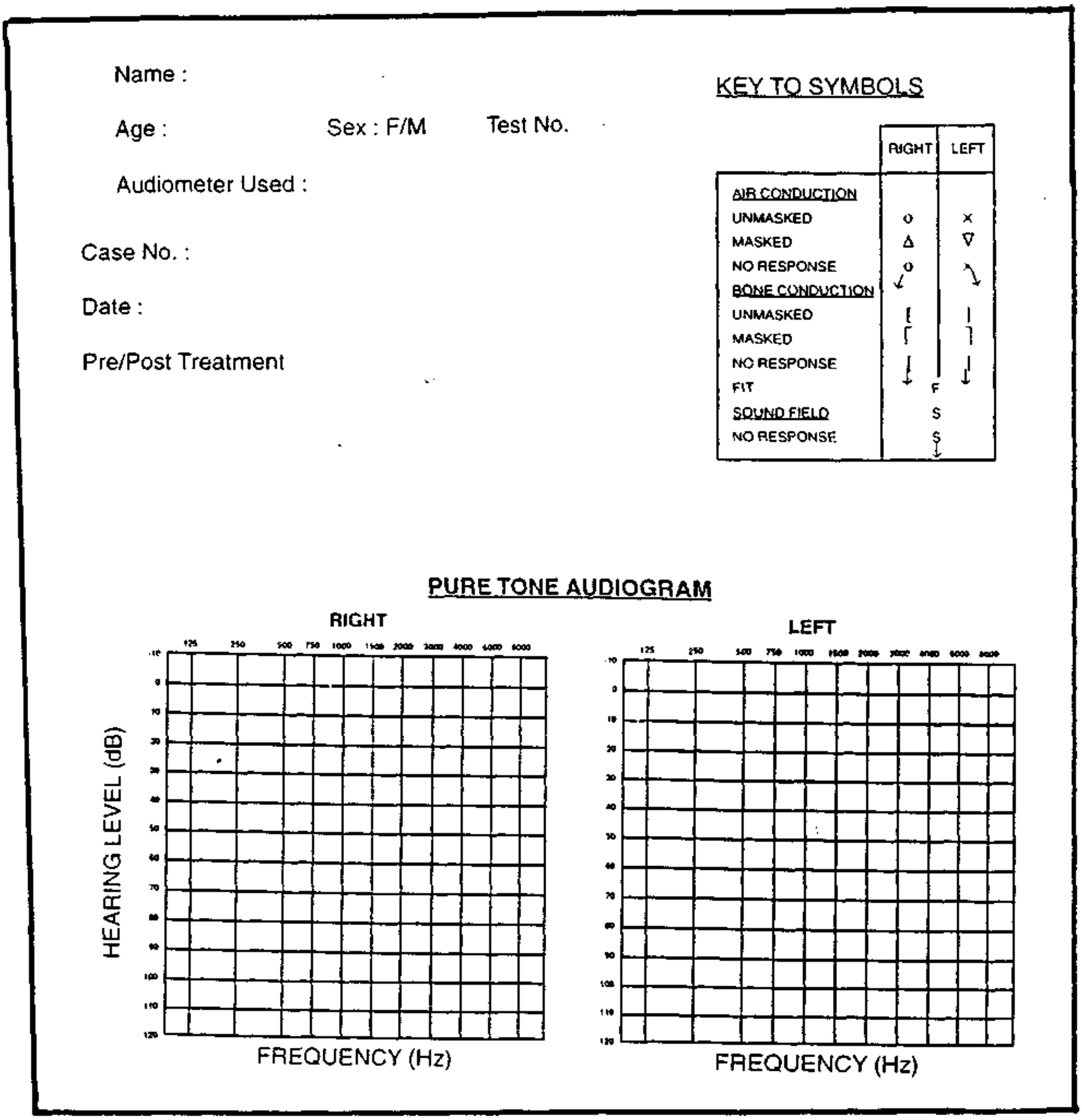
Pure-tone sensitivity can be measured by air conduction and by bone conduction. The audiogram is a graph showing the hearing sensitivity for air and bone conducted sounds of an individual. Thus an audiogram can be defined as the graphical representation of an individual's hearing sensitivity, the results of which can also be recorded numerically. The graph has two dimensions; the frequency of the tone in Hertz (Hz) or cycles per second (cps) is represented along the abscissa and hearing threshold level (HTL) in decibels (dB) along the ordinate. The figure below is an example of a graph, which is used to plot an individual's threshold



Graph 2: An Audiograph depicting frequency along the abscissa and intensity along the ordinate

Specifications of an Audiogram

An audiogram form consists of identifying information 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.



Graph 3: An Audiograph with specifications like Key to the symbols, personal information etc.

Construction of the graph

A graph of frequency versus intensity is drawn to record the test results. ASH A (1974) recommended that frequency be represented by the horizontal line (i.e. the abscissa) and hearing level by the vertical line (i.e., the ordinate). The digit of the hearing range in the audiogram corresponds 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 interoctave frequency should be finer and lighter than that of octave frequencies (ASHA 1974).

Symbols Used

The symbols used in the audiogram form , should, as far as possible, conform to a standard specification to prevent any discrepancy. Additionally, a key to the symbols should be provided whenever possible so that there is no confusion regarding the interpretation.

Standard symbols are used to indicate HTL's for each ear at the appropriate 5 dB step, separate symbols being used for air conduction and bone conduction thresholds. Also, different colors can be used to differentiate between the ears, red denoting the right ear and blue the left.

Table 3: Audio metric symbols recommended by ASHA (1990).

Modality	Response: Ear Left	Response: Ear Unspecified	Response: Ear Right	No Response: Ear Left	No Response: Ear Unspecified	No Response: Ear Right
Air conduction earphones						
Unmasked	X		O	X↘		O↙
Masked	□		△	□↘		△↙
Bone conduction-mastoid						
Unmasked	>	^	<	>↘	^↓	<↙
Masked	]		[	]↘		[↙
Bone conduction-Forehead						
Unmasked		v				
Masked	┌		┐			
Air conduction- sound field	*	S	Ø	*↘	S↓	Ø↙
Acoustic-reflex Threshold						
Contralateral						
Ipsilateral						

The above figure shows a typical audiograph form with the symbols being approved by the American Speech-Language Hearing Association (ASHA, 1990)

A combination of both masked and unmasked symbols can be used depending on, for which frequencies' masking was actually employed, but it is customary not to include unmasked symbols if these results were repeated with masking. Thus, the symbols shown should represent true hearing sensitivity.

If the patient does not respond by air-conduction or bone conduction to the maximum hearing level at a given frequency, an arrow is drawn pointing towards the specific direction from the appropriate symbol at the hearing level, as shown. For example

Customarily, solid lines of the appropriate color connect the air-conduction symbols, which mark the points of hearing threshold level across the audiogram. The bone conduction thresholds may not be connected by lines or may be connected by dashed lines (Newby,1972). However, universal agreement does not exist concerning the direction or placement of some symbols and no-response arrows. Some authors believe that the direction of the symbols should be reversed from the way they appear on the sample audiogram i.e., for bone conduction thresholds of the right ear, the no-response arrows and brackets should appear to the right of the frequency line and point to the right. Others, however, believe that the no response arrow or bracket should head to the left for the right ear and to the right for the left ear. The logic for this backward use of symbols is that the arrow or bracket represents the pinna of the patient and that as the patient sits facing you, the right pinna is to your left; therefore the symbol for the right ear should be to the left of the frequency line on the audiogram and the no response arrow should point downward towards the left. This logic, however, does not hold well, if the patient sits with his back to the examiner.

Interpretation

There are two aspects where the interpretation of the audiogram is important. They are:

A. AS AN AID TO DIAGNOSIS

B. AS A GUIDE TO REHABILITATION

A. AS AN AID TO DIAGNOSIS

The audiogram provides information about the person's air and bone conduction sensitivity. Based on this information we can further classify the hearing loss as

(i) Type of hearing loss

(ii) Pattern of Hearing loss

(iii) Degree of Hearing loss

(i) Type of Hearing loss

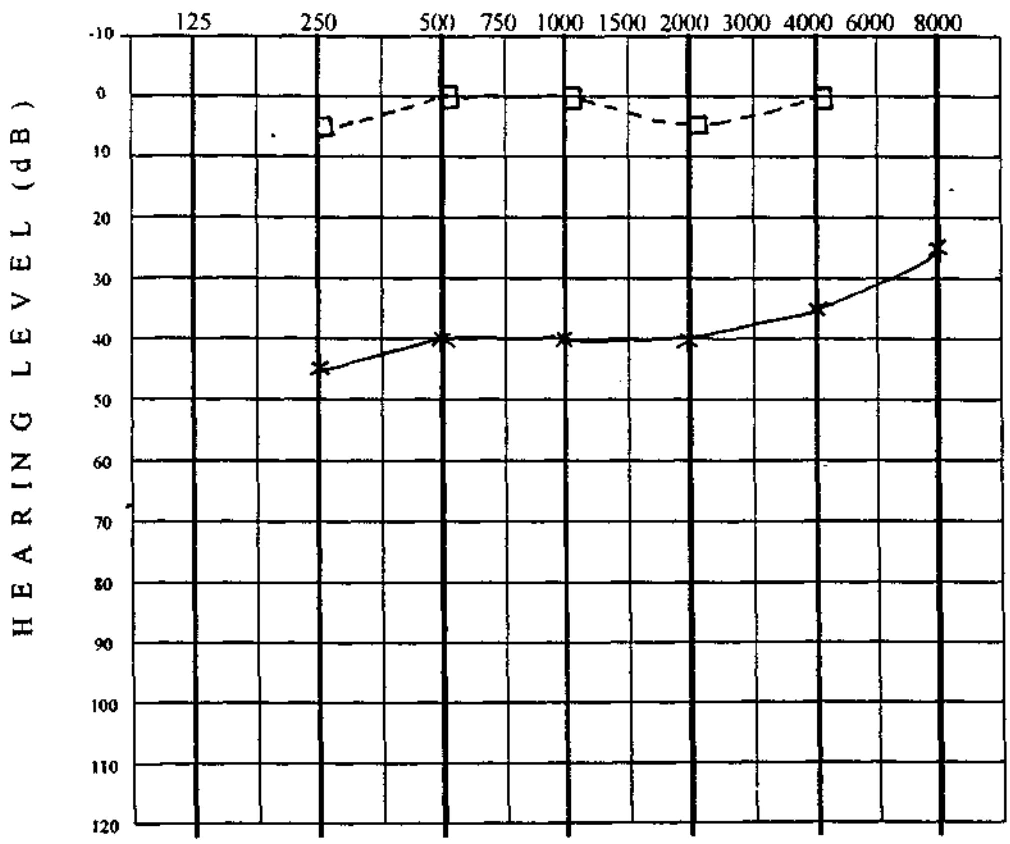
Hearing loss can be diagnosed as conductive, sensory-neural or mixed in type. The course of treatment prescribed will be based on this diagnosis and it depends not only on the hearing test results but also on the results of the physical examination and the patient's medical history.

a. Conductive Loss

A patient with a conductive hearing loss should show losses by air conduction but normal hearing by bone conduction. The existing air-bone gap must be at least 10 dBHL. If such an air bone gap (ABG) exists when both air conduction (AC) and Bone conduction (BC) thresholds are within normal limits, it is termed as minimal conductive hearing loss. AC loss generally does not exceed 60 dBHL (Feldman, 1963) because beyond this level, the whole skull vibrates resulting in direct stimulation of the cochlea. Thus, if the threshold level exceeds 60 dBHL, the problem cannot be purely conductive.

Generally in a conductive impairment the air conduction losses will be fairly equal at all frequencies, with perhaps slightly greater loss for lower frequencies. However, diagnosis should be made by comparing the AC and BC curve.

In conductive hearing loss damage to either the middle ear, which transmits sound energy efficiently, or the Eustachian tube, which maintains equal air pressure between the middle ear cavity and the external canal, could result in a mechanical defect in sound transmission. In pure conductive hearing loss there is no damage to the inner ear or the neural pathway.

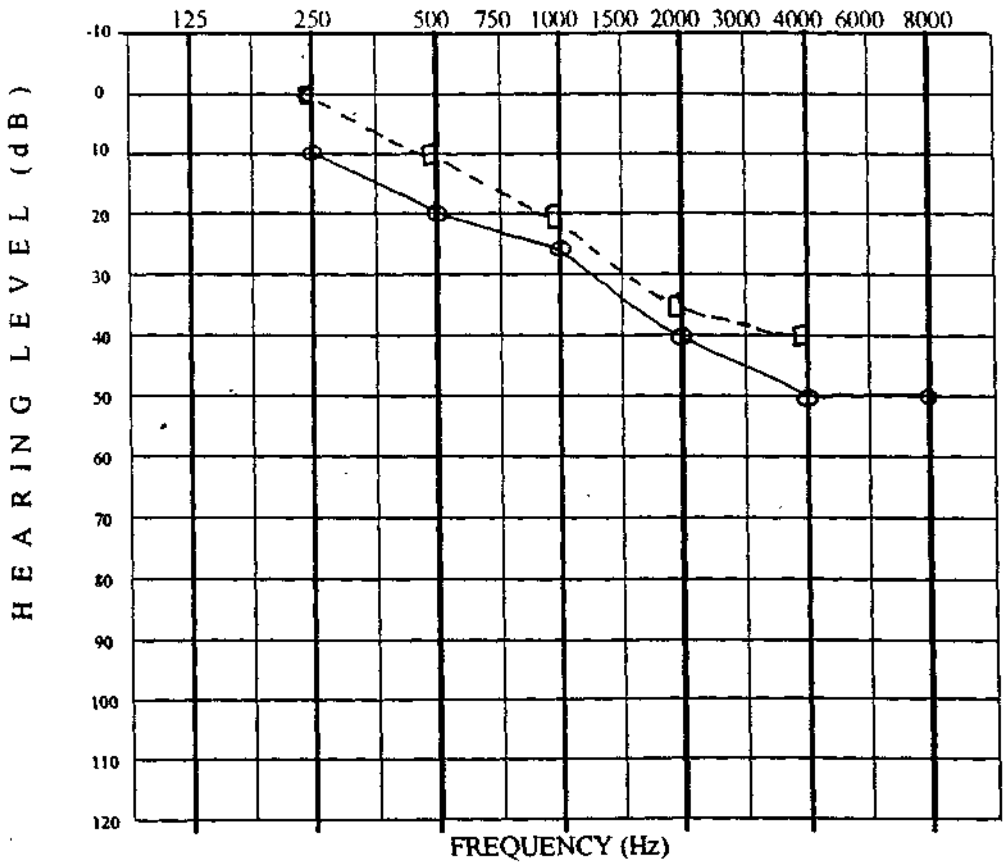


Graph 4: An Audiogram depicting conductive hearing loss.

b. Sensorineural Loss

A sensorineural (SN) hearing loss is present if the bone conduction thresholds are outside the normal limits. The air bone gap does not exceed 10 dB and the air conduction thresholds are outside the normal limits i.e., greater than 25 dBHL. Thus a SN loss is characterised by poor bone conduction thresholds, and essentially ,equally poor air conduction thresholds.

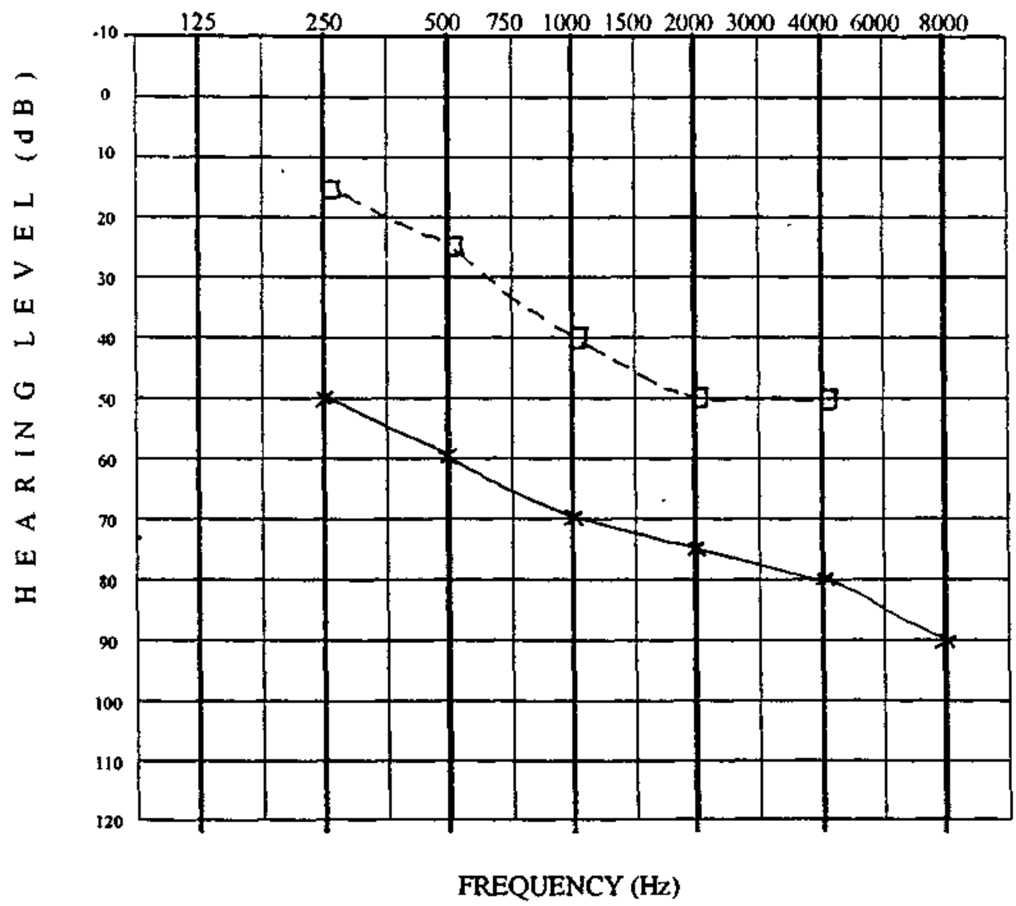
The term sensorineural has dual character and suggests two separate areas, which may be affected. The "sensory" hearing loss is applied when the damage is localised in the inner ear. "Neural" hearing loss is the correct term to use when the damage is in the auditory nerve.



' **Graph 5: An audiogram depicting sensori neural hearing loss.**

c. Mixed hearing loss

A mixed hearing impairment is present if the bone conduction thresholds are outside the normal limits, i.e., greater than 15 dBHL, significant air bone gaps exceeding 10 dB are present, and the air conduction thresholds are outside the normal limits signaling a problem in the outer/or middle ear in addition to the problem in the sensorineural mechanism, indicated by the poor bone conduction thresholds.



Graph 6: An audiogram depicting mixed hearing loss.

d. Functional Hearing Loss

The patient may neither seem to hear or respond; yet the handicap may not be caused by any organic pathology in the peripheral or central auditory pathways. The hearing difficulty may have an entirely emotional / psychological etiology, or it may be superimposed on some mild organic hearing loss, in which case it is called a functional or psychogenic overlay. In some cases it may be feigned or simulated and the patient is conscious of the deception. It is commonly encountered with a background service, social circumstances involving a pension, rejection for enlistment, compensation in a legal action or social maladjustment

e. Central Hearing Loss

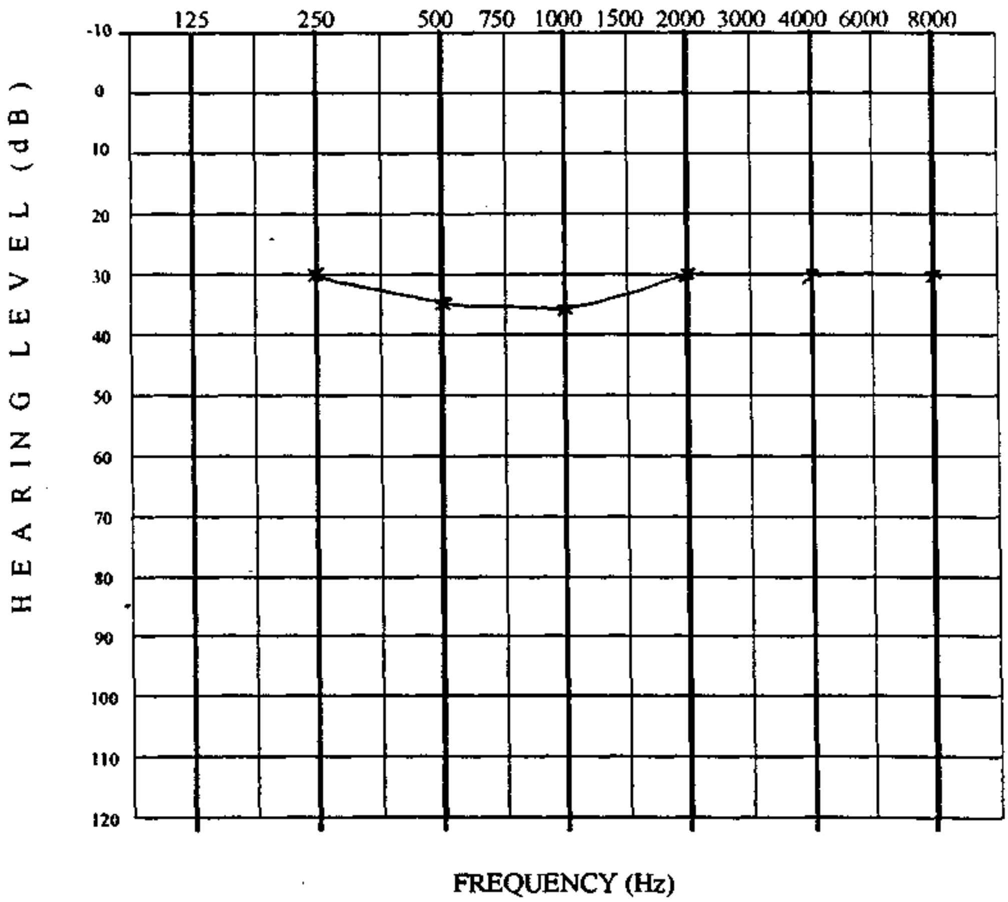
Some patients cannot interpret or understand what is being said and that the cause of the difficulty is not in the peripheral mechanism but some where in the central nervous system. In this loss, the problem is not in lowered pure tone thresholds but in the patient's ability to interpret what he hears.

(ii) Pattern of Hearing Loss

The Audiometric configuration with respect to the positive or negative slope of the air conduction threshold i.e., classified as flat, gradually sloping, sharply sloping, precipitously sloping, rising, trough, saucer, notch, corner and miscellaneous type.

a. Flat Audiogram

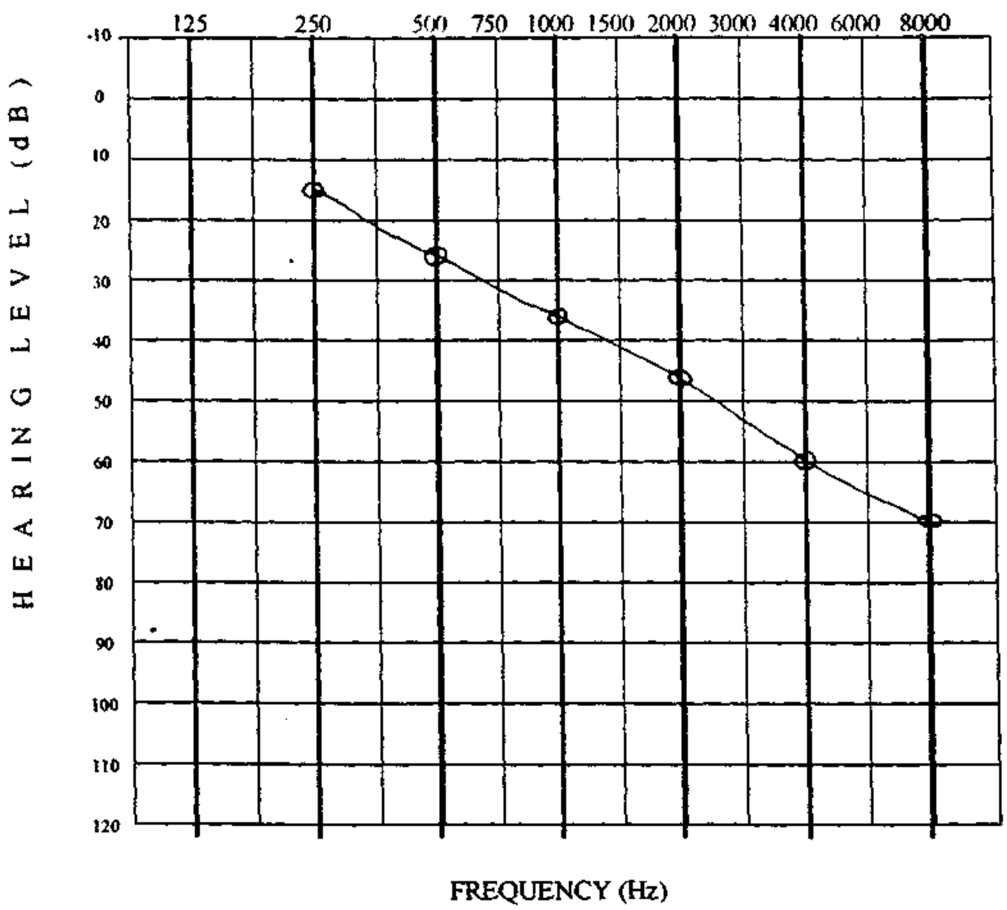
In this there is approximately equal degree of hearing in all test frequencies, the magnitude of difference not exceeding 5-10 dB (Johnson. 1966 ; Davis, 1998). It is usually associated with conductive hearing loss such as Serous Otitis Media, Collapsed Ear Canal, Moderately advanced condition of Meniere's Disease.



Graph 7: An Audiogram depicting a flat pattern

b. Gradually sloping Audiogram

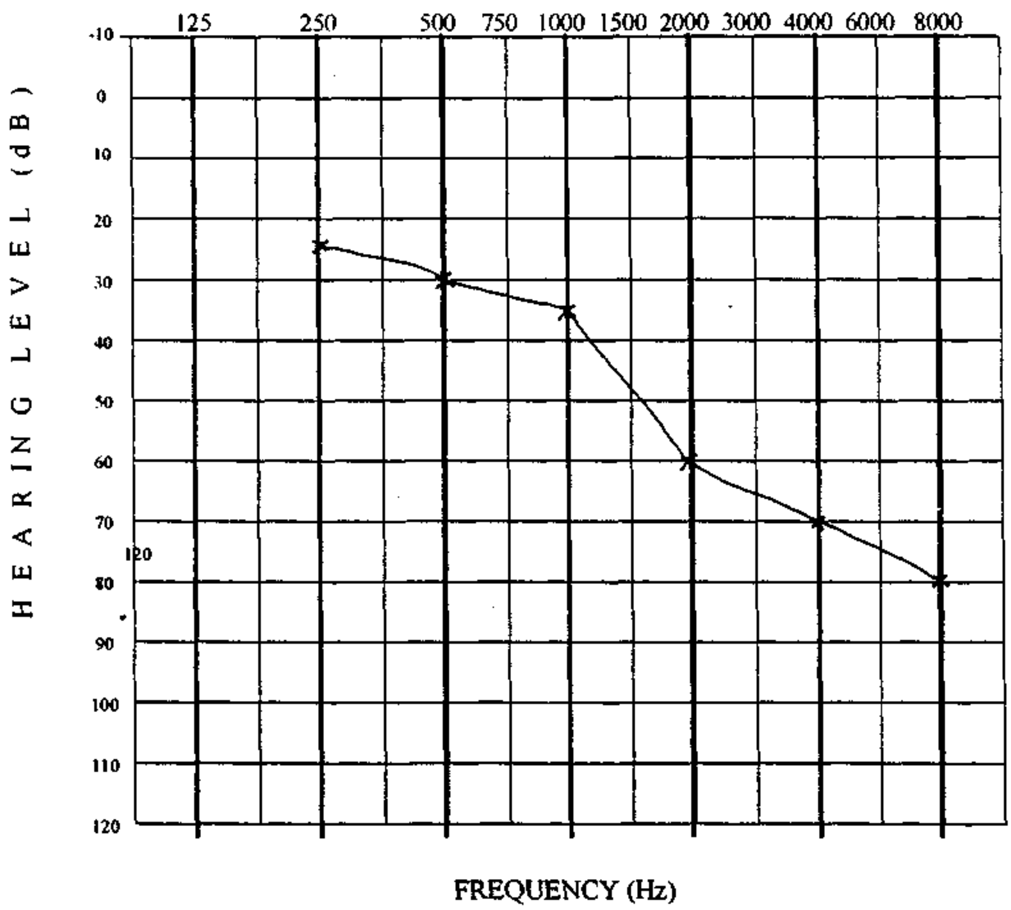
In the gradual type, the loss begins at low frequency with a gradual increase in the high frequency. At 500 Hz, a threshold of 25 dBHL or greater with an increase in threshold of around 5-12 dB per octave. The difference between the highest and the lowest being no more than 35 dB (Stephens and Rintelmann, 1978).



Graph 8: An Audiogram depicting a gradually sloping pattern.

c. Sharply sloping Audiogram

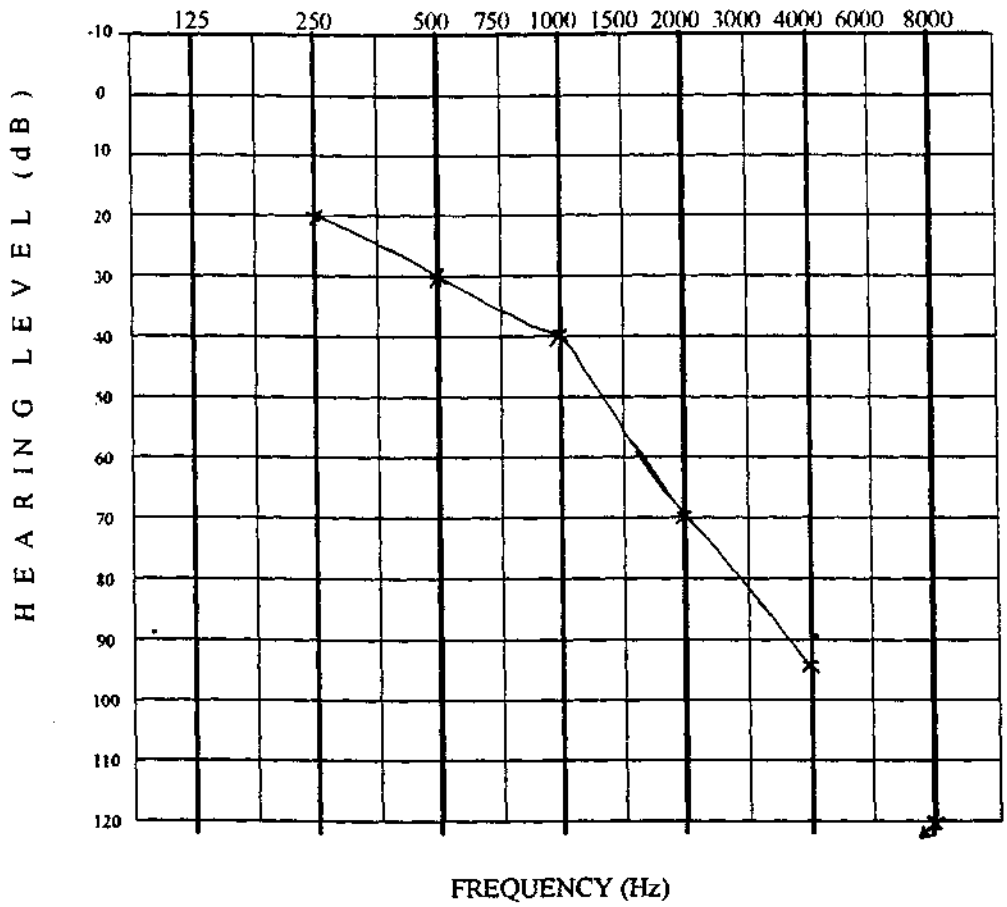
It is characterised by normal or near normal hearing in the low frequency with a threshold of 30 dBHL or better at 500 Hz. Between 500 and 1000 or 1000 and 2000 there is a drop in threshold of at least 20 dB and the difference between the highest and lowest thresholds is greater than 40 dB (Stephen and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



Graph 9:An Audiogram depicting a sharply sloping pattern.

d. Precipitous sloping Audiogram

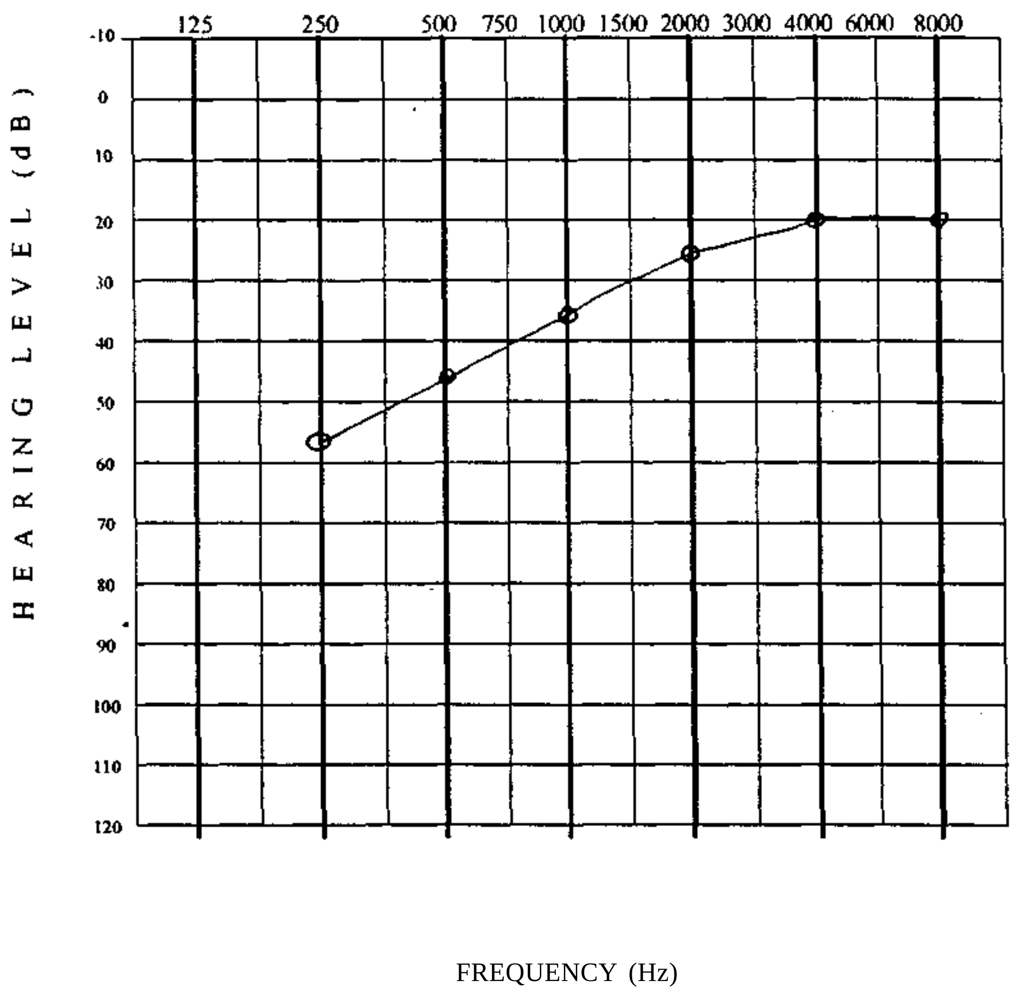
This initially shows a flat or gradually sloping pattern with the threshold suddenly increasing at the rate of 25+ dB per octave.



Graph 10: An audiogram depicting the precipitously sloping pattern

e. **Rising Audiogram**

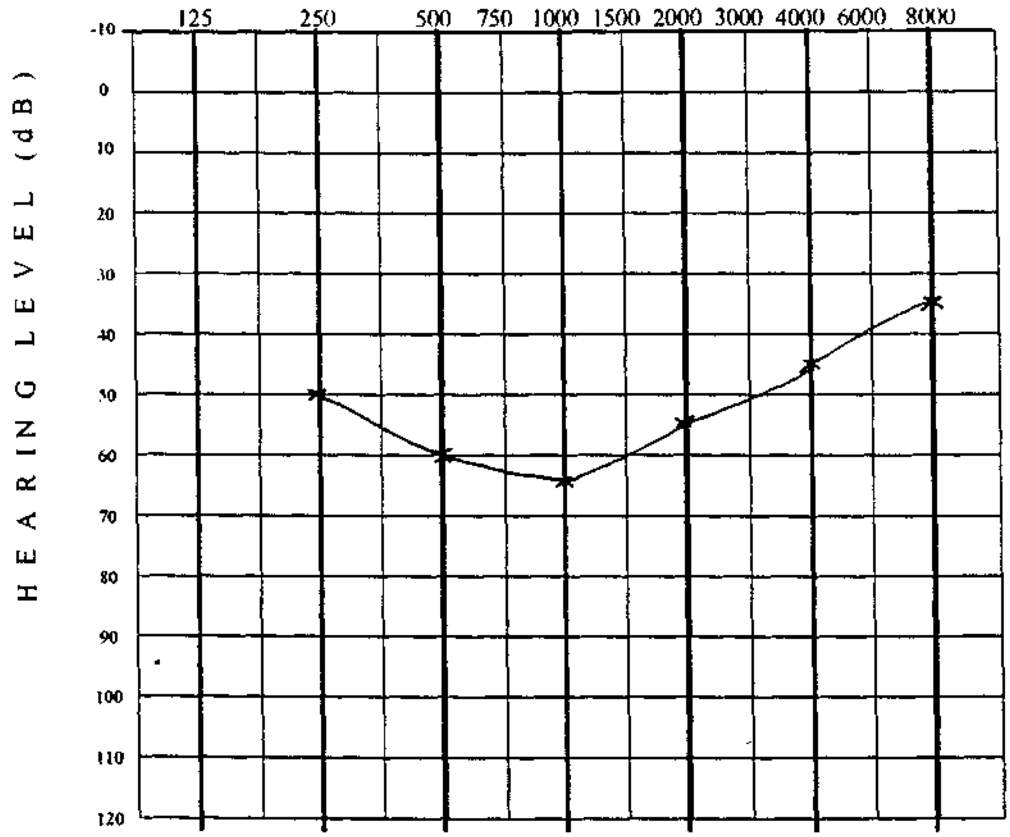
This audiometric pattern shows significant loss at low and mid-test frequencies with relatively normal or near normal hearing in the high frequency region (Ross and Matkin, 1967 ; Davis and Johnson, 1966). It is usually seen in conductive hearing loss cases but it may be seen in some SN loss conditions such as Meniere's disease at an early stage.



Graph 11:An Audiogram depicting a rising pattern

f. Trough Audiogram

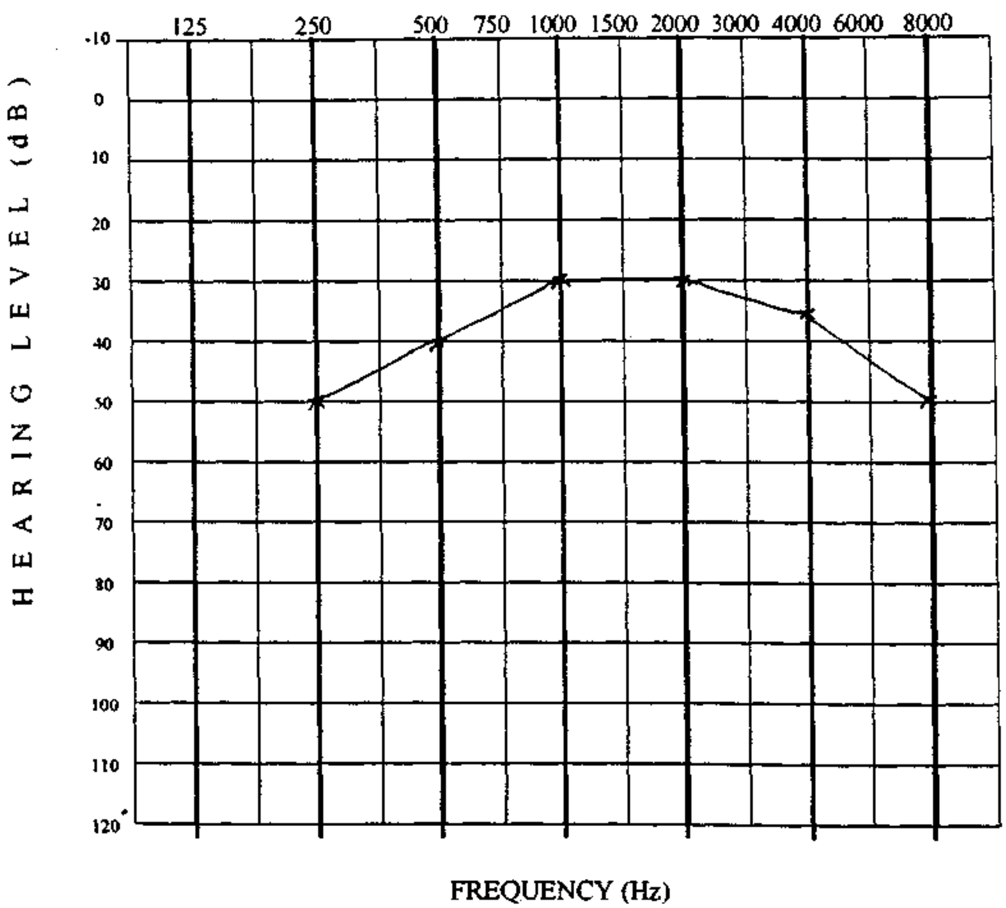
In this pattern there is greater loss at the mid frequencies of around 20 dB or greater than at the extreme frequencies. It is typically seen in some children with Rubella.



Graph 12:An Audiogram depicting a trough pattern

g. Saucer Audiogram

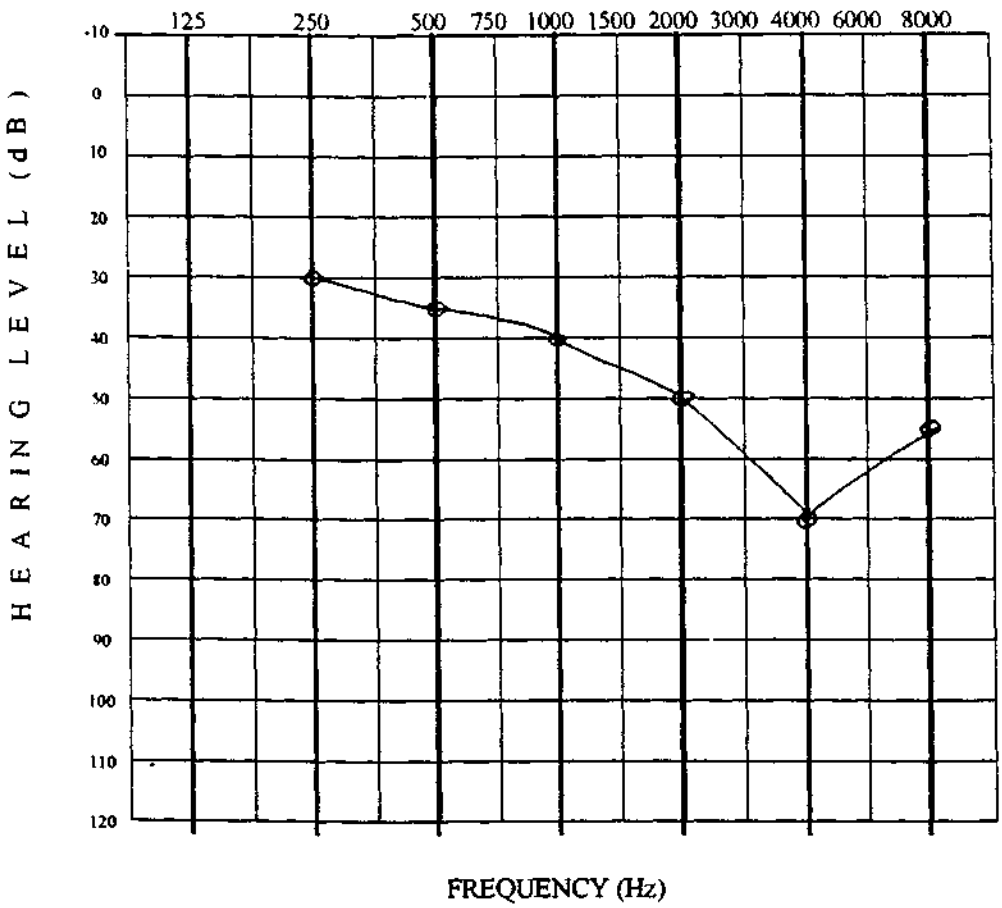
This is the opposite of the trough pattern in that there is 20 dB or greater loss in extreme frequencies than at the mid frequencies. It is often associated with malingerers.



Graph 13:An Audiogram depicting a saucer pattern

h. Notch type Audiogram

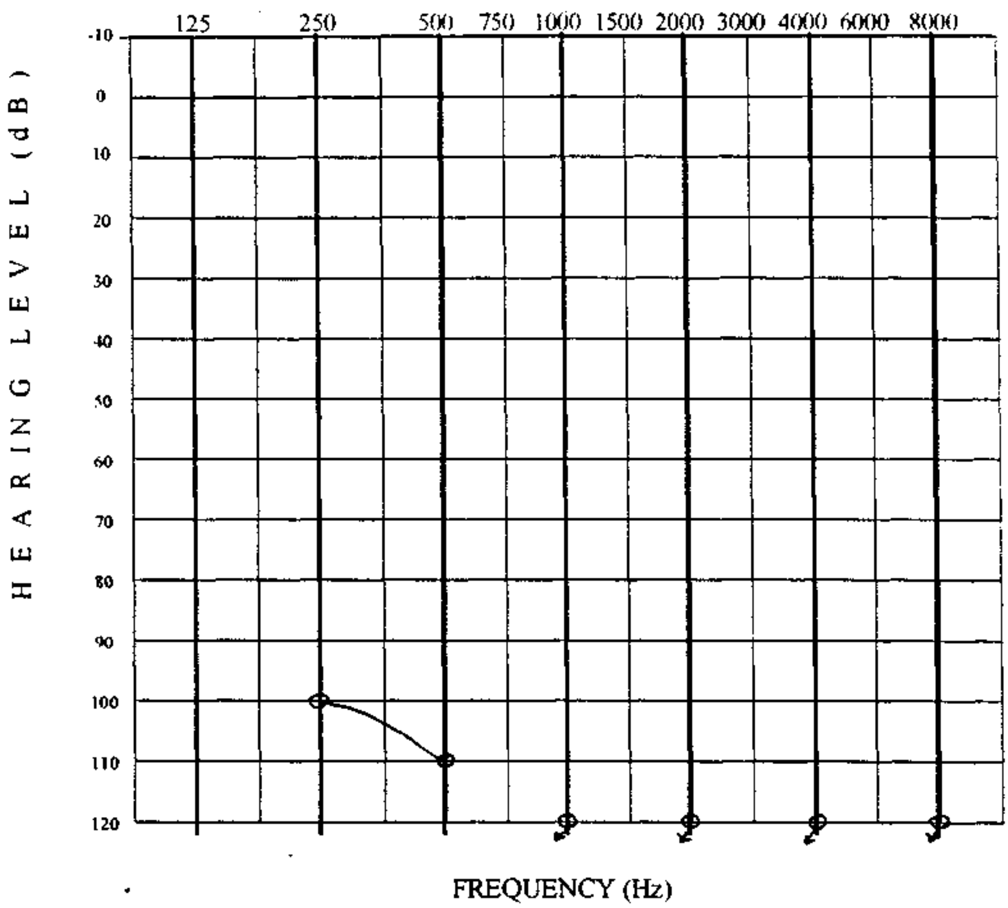
This type is characterized by a sharp dip at a single frequency with recovery at the immediately adjacent frequencies. A notch at a high frequency is usually associated with noise exposure or head trauma etc.



Graph 14: An Audiogram depicting a notch pattern

i. Corner Audiogram

This pattern occurs in profound deafness. It is characterised by the presence of a response to only low frequencies such as 250 Hz or 500 Hz when presented at very high levels.



Graph 15:An Audiogram depicting a corner pattern

j. Irregular/ Miscellaneous Audiogram

The audiogram does not fit into any of the above categories (Hodgson, 1980).

(in) 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 the average response of a normal young adult; there are individual variations in the normal hearing range.

Classification of hearing loss can be made on the basis of magnitude of hearing impairment. Goodman (1965) prepared a scale of hearing impairment, which relates the hearing threshold level with degree of hearing impairment.

Hearing Threshold Level	Degree Of Loss
0 to 25	Normal
26 to 40	Mild
41 to 55	Moderate
56 to 70	Moderately severe
71 to 90	Severe
90 & above	Profound

Table 4: Classification of degree **hearing loss by Goodman (1965)**

Clarke (1981) then modified the Goodman's classification, & this classification more or less follows that adopted by ANSI.

Average Threshold Level (dB)	Suggested Description
- 10 to 15	Normal hearing
16 to 25	Slight hearing loss
26 to 40	Mild hearing loss
41 to 55	Moderate hearing loss
56 to 70	Moderately severe hearing loss
71 to 90	Severe hearing loss
90 & above	Profound hearing loss

Table 5: Classification of degree hearing loss by Clarke (1981) (Modified Goodman)

10 20 30 40) 50 60 70 80 90 100 110 120)

	Profoundly deaf					Clarke (1957)
	Slight deafness	Partial deafness	Severe deafness	Profound deafness		Dale (1962)
Class A: Not significant	Class B: Slight	Class C: Mild	Class D: Marked	Class E: Severe	ClassF: Extreme	Davis and Silverman (1970)
Normal	Mild	Moderate	Severe	Profound		Paul and Hardy (1953)
Normal	Mild	Moderate	Moderately severe	Severe	Profound	Goodman (1965)
Normal	Class1: Mild losses	Class2: Marginal Losses	Class3: Moderate losses	Class4: Severe losses	Class 5: Profound losses	Streng etal. (1955)
Normal	Hard of hearing	Educationally or partially deaf	Deaf			Streng etal. (1955)
Hard of hearing						VanUden (1957)

Table 6: Hearing level (loss) in dB re: ANSI-1969.

A classification of the degree of hearing impairment, which classifies hearing loss in terms of percentage, was given by the World Health

Organization. Based on this, the ministry of health and welfare notification no.4.2/83 HW dated 06.08.86, gave a classification as follows.

Sl.no.	Category	Classification	dB level	Speech & Discrimination	%of hearing loss
1	I	Mild hearing impaired	26-40 in better ear	80-100% in better ear	Less than 40%
2	II	Moderate Hearing Impaired	41-55	50-80%	40 - 50%
3	III	Severe hearing impaired	56-70	40-50%	50 - 75 %
4	IV	a.Near total deafness	91 dB& above	No discrimination	100%
		b. Profound hearing loss	71-90 dB	Less than 40%	75-100%
		c. Total deafness	No hearing	No discrimination	100 %

Table 7: **Classification of percentage of hearing loss given by the ministry of health and welfare (1986).**

B. AS GUIDE TO REHABILITATION

The audiogram may be interpreted as a guide to rehabilitative needs. It is useful in pointing to the need for rehabilitative measures such as a hearing aid. It helps to differentiate between children who are deaf and need full time special education and children who are hard of hearing who can fit in to the framework of regular a classroom.

Hearing level dB 1951 ASA reference	Hearing level dB 1964 ISO reference	Probable handicap and needs
Less than 30 dB	Less than 40 dB	Has difficulty hearing faint or distant speech; needs favorable seating and may benefit from lip-reading instruction.
30 to 45 dB	40 to 55 dB	Understands conversational speech at a distance of 3-5 feet, needs hearing aid, auditory training, lip-reading, favorable seating, speech conservation and speech correction
45 to 60 dB	55 to 70 dB	Conversation must be loud to be understood there is a great difficulty in group and classroom discussion, needs all of the above plus language therapy, and may be special class for hard of hearing.
60 to 80 dB	70 to 90 dB	May hear loud voice about 1 foot from the ear, may identify environmental noises, may distinguish vowels but not consonants; need special education for deaf children with emphasis on speech. auditory training and language; may enter regular classes at a later time.
More than 80 dB	More than 90 dB	May hear loud sounds, does not rely on hearing as a primary channel for communication; needs special class or school for deaf; some of these children eventually enter regular high school.

Table 8: indicating relations between hearing level in dB and probable handicapped and their needs.

The magnitude of hearing loss can also be expressed in terms of percentage; there are two basic methods to compute **percentage of hearing loss**

(i) AMA method

(ii) AAOO method

(i) AMA method

It was published under the aegis of the American Medical association. In the AMA method, only 4 frequencies on the audiogram are given consideration: 500,1000, 2000 and 4000 cps. These frequencies are weighted in their importance to the total speech-hearing function, as follows: 500 cps 15%, 1000 cps= 30%, 2000 cps= 40% and 4000 cps=15%. Losses in dB at each of these frequencies are assigned percentage values according to a chart which is used in conjunction with the pure tone audiogram. Losses for each ear are converted to percentages, and a formula is applied for computing binaural percentage loss.

Disadvantages

1. It speaks little about the person's communicative ability.
2. It also does not shed any information on the ability to compensate for his loss by means of a hearing aid.

(ii) AAOO method

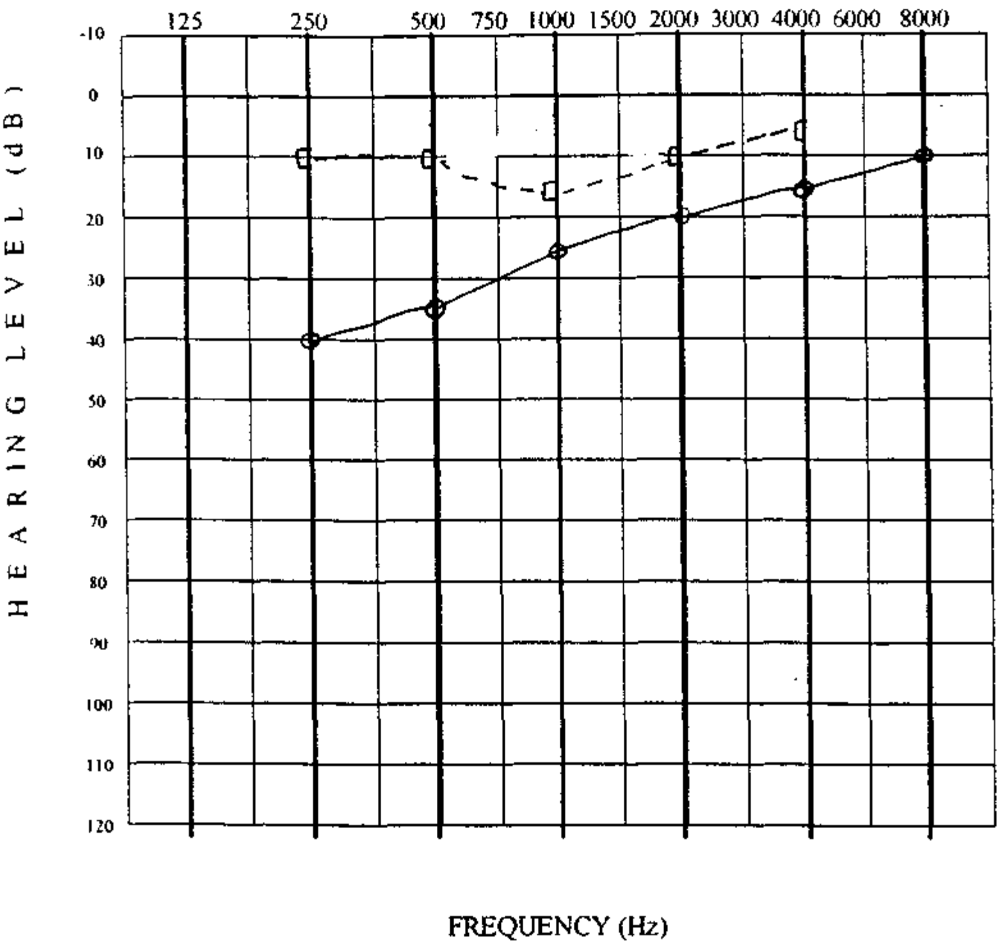
It was given by the American Academy Of Opthalmology and Otolaryngology. In this method only the speech frequencies are assigned any percentage values. Percentage impairment is computed for each ear separately by averaging the air conduction hearing levels at 500,1000 and 2000 Hz. Subtracting 26 dB from this average and multiplying the remainder by 1.5%. The binaural percentage impairment is computed by multiplying percentage impairment of the better ear by 5, adding this product to the percentage impairment of the poorer ear, and dividing this sum by 6.

Importance of **the** audiogram

The audiogram may be useful in the following ways:

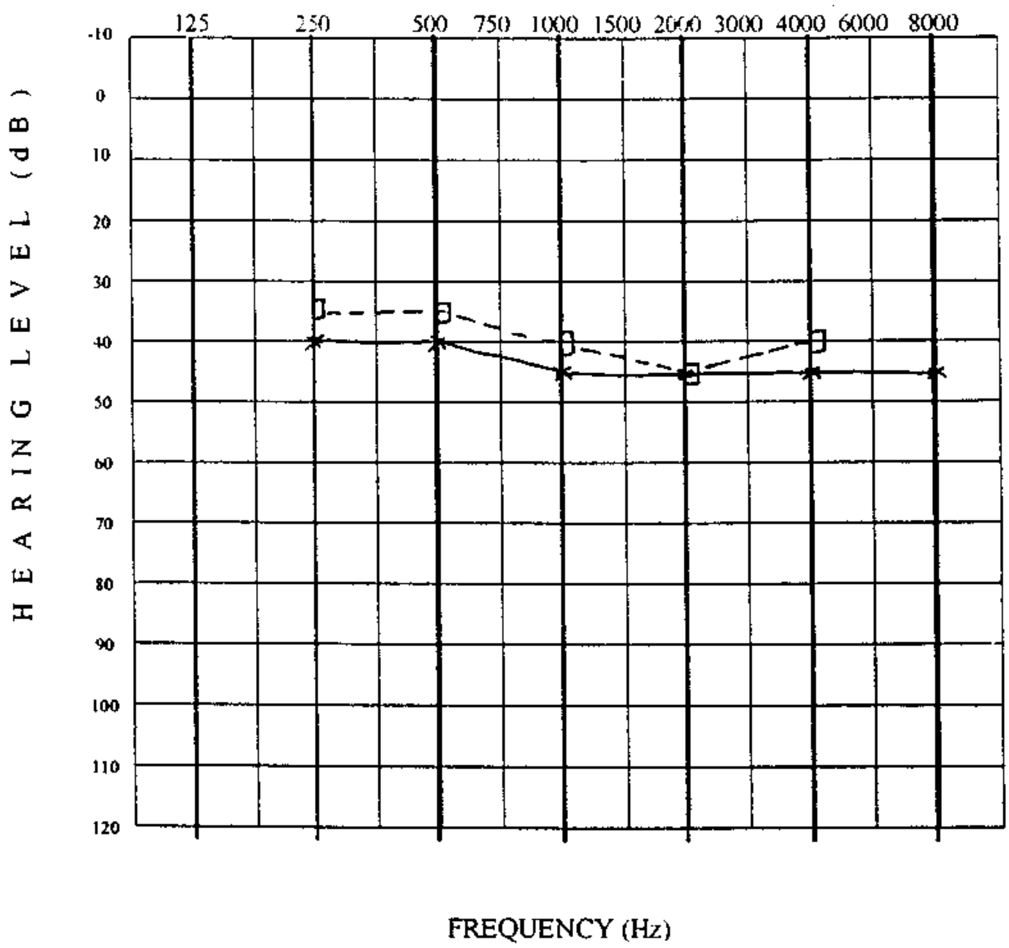
1. To illustrate patterns of hearing sensitivity for tones as a function of frequency.
2. To decide if an individual has hearing loss or not.
3. To determine if the loss is of conductive, mixed or sensorineural type.
4. In identifying the nature of the problem.
5. In Quantifying the amount of hearing loss in determining the amplification needs of an individual.
6. To compare air and bone conduction sensitivity.
7. To present the results of other related pure tone tests.

Typical Audiograms



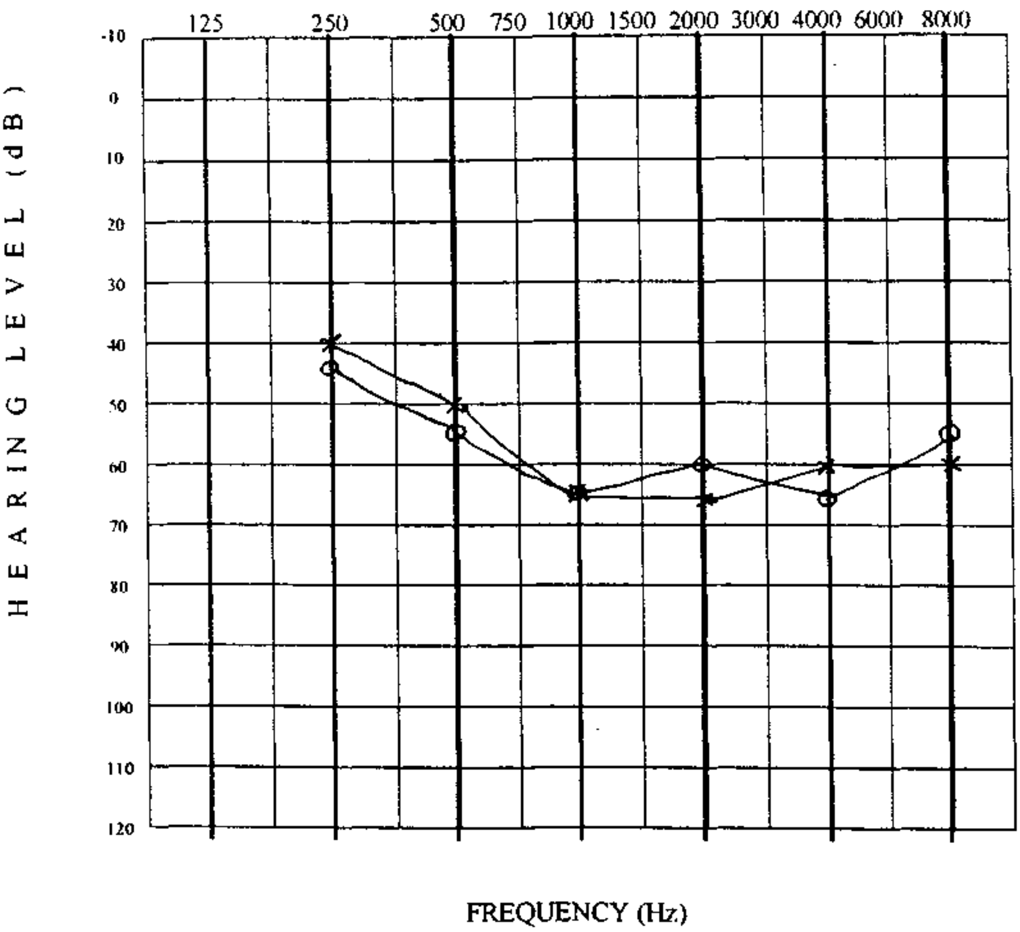
- Early stages of Meniere's disease.
- Low frequency " hearing loss.
- History of vertigo and Tinnitus.
- (Goodhill and Guggerheim ,1971)

Graph 16: Early stage of Meniere's disease



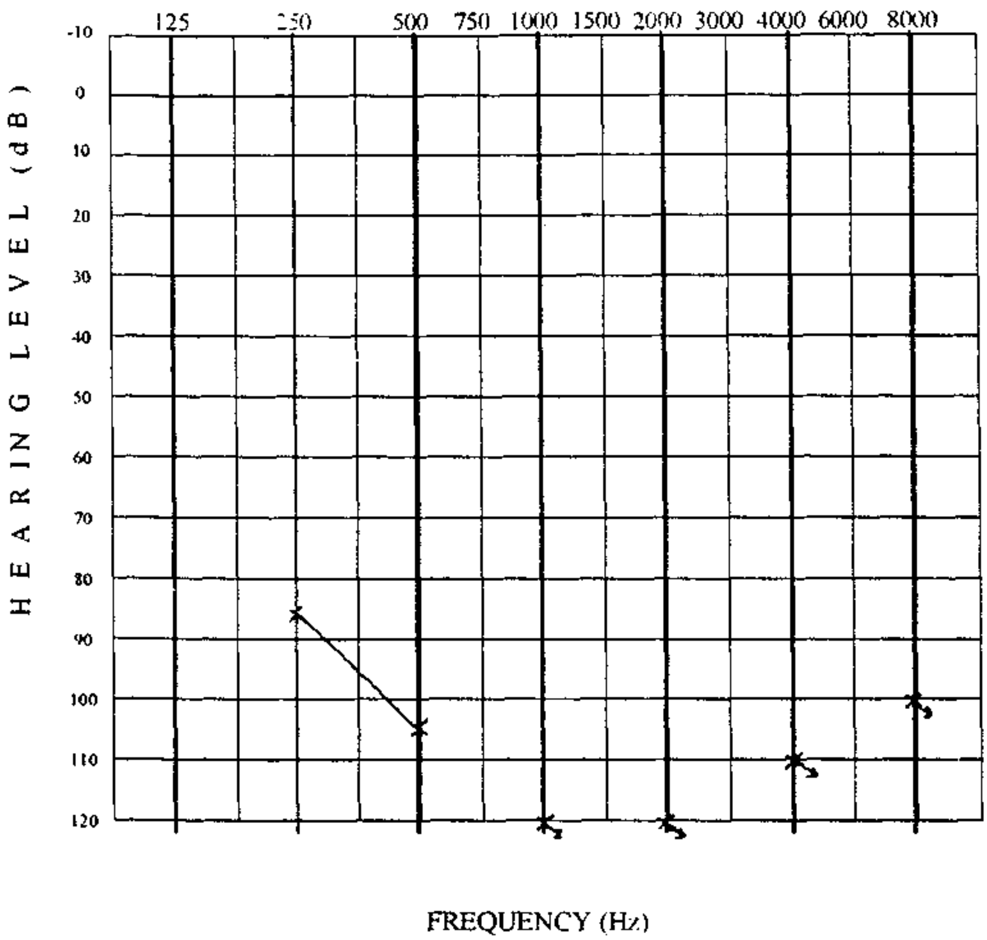
- Moderately advanced stage of Meniere's disease
- Flat frequency hearing loss of sensory type
- (Goodhill and Guggerheim, 1971)

Graph 17: Moderately advanced stage of Meniere's disease



- Maternal rubella and Malingerers
- Saucer shaped audiogram
- (Prescord,1978)

Graph *19:* Maternal rubella



- Congenital hearing loss and viral disease
- Corner audiogram

(Davis J, 1978)

Graph 20: Congenital hearing loss

TRANSDUCERS

Bone Conduction Vibrators

The requirements for the physical characteristics of an idealized bone receiver were generally well described by Lierle & Reger (1946). The characteristics being,

(i) A mechanical design that will stand up under continued & rough usage without change in calibration

(ii) Extension of the frequency range to values near or coincident with the normal upper limits of audibility

(iii) Freedom from overtones

(iv) Freedom from the effects of differences in pressure when the vibrator is held against the head. & a wide a.c.-b.c. differential.

Sanders & Olsen (1964) have reported undesirable harmonic distortion at low frequencies for a hearing aid-type vibrator.

Both national & international standards recommend that bone vibrators used in audiometry have a plane circular contact tip area of 1.75 $cm^2 \pm 5\ mm^2$. The old radioear B-70 series vibrators have contact tip larger than recommended by current standards. The newer radio ear B-71& B-72 vibrators contain contact tips corresponding to the current standards for bone conduction audiometry.

The physical output of the B-72 is significantly greater at 250 Hz than other bone conduction traducers. The figure on the next page shows examples of the frequency responses of two bone- conduction vibrators.

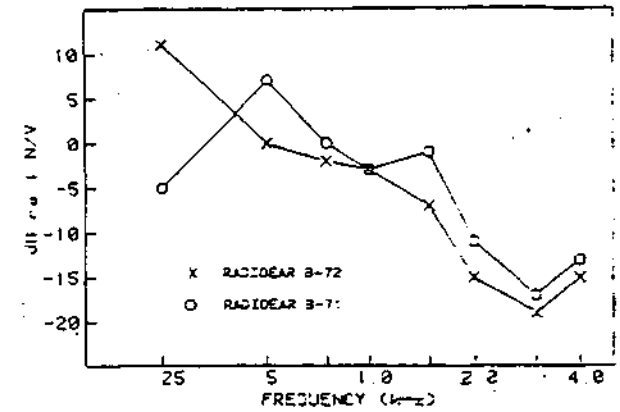
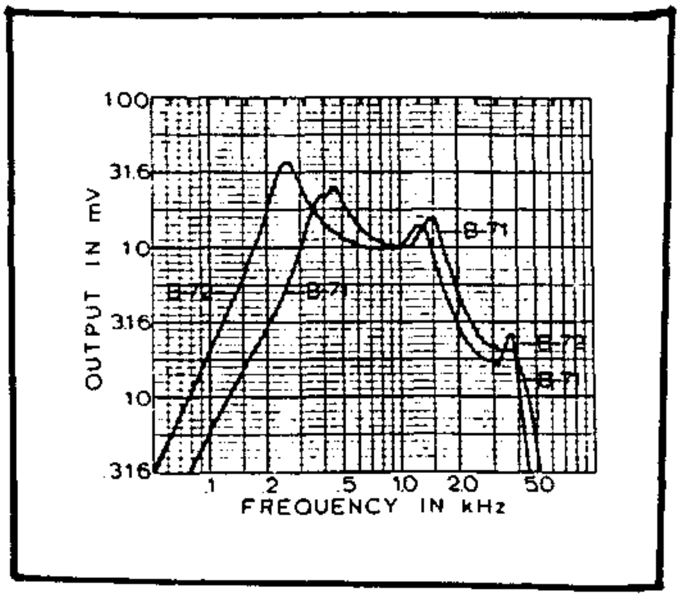


Figure 9.5. Frequency response of Radioear B-71 and B-72 bone vibrators in dB *re* 1 N/V as measured on a Bruel and Kjaer 4930 artificial mastoid.

Graph 25: Frequency Response of B-71 and B-72 bone vibrators in dB re: 1N/V as measured on a Bruel and Kjaer 4930 artificial mastoid.

The resonance of the B-72 vibrator is found at a lower frequency (250 Hz) than for the B-71 vibrator. Thus the output is greater for the B-72 at 250 Hz; increasing the potential dynamic range for testing & reducing the harmonic distortion.

Frequency response curves were obtained for a radioear B-71 bone vibrator with a revised Bruel & Kjaer model 4930 artificial mastoid. 3 resonant peaks which decreased in amplitude as frequency increased characterized the curves for each vibrator. The maximal output volatage variations of the artificial mastoid were ≤ 2 dB for each vibrator at all audiometric frequencies (± 3 %), except for the B-72 at 4000 Hz where the variation was 6.9 dB



Graph 26: Comparison of the frequency response curves of the B-71 and B-72 bone vibrators

According to Shipton et al., (1980) and Haughton (1982), the mechanical behavior of the B-71 Vibrator may also lead to unsatisfactory acoustic radiations at the high frequencies of 3000 and 4000 Hz. Frank and Holmes (1981) investigated the influence of acoustic radiation produced by bone vibrator at 4000 Hz on bone conduction testing, using a radioear B-70A, B-71 and B72 vibrator. Results indicated that the B-70A and B-71 produced minimal acoustic radiation. However, the B-72 was found to have excessive acoustic radiation which would be sufficient to influence BC thresholds and produce an invalid high frequency air bone gap. These authors suggest that the test ear of the patient be occluded by a small ear plug when bone conduction testing is conducted at these frequencies. Thus the air conducted signal will be attenuated in the ear canal and eliminate the influence of air radiation of the bone conduction thresholds.

This suggestion is reasonable because the occlusion effect bone conduction is minimal or absent at these high frequencies. Haughton, (1982) observed that acoustic radiation for the B-71 vibrator could be reduced by enclosing the vibrator in a more rigid case.

Ear Phones

Ear phones are electroacoustic transducers, which convert electrical signal into acoustic signal. There are two types of earphones namely external type and internal type.

External Type

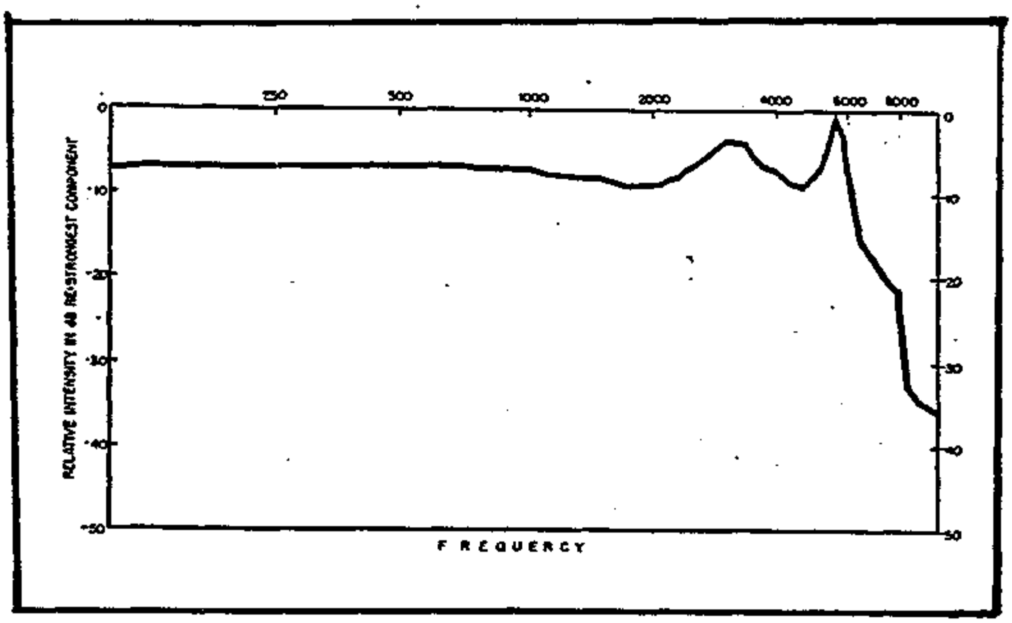
These types are mounted in rubber cushions and placed facing the external canal. External type earphones are generally used to deliver audiometric air conduction signals. Each ear may be tested separately. They are selected on the basis of good long-term stability, flat frequency response and ability to deliver high intensity signals. There are a variety of earphones that differ in terms of impedance characteristics, frequency response, sound pressure level etc. Some of the more, commonly used ones are the telephonic series: TDH-39, TDH-49, TDH-50, TDH-140, Permoflux series PDR-1, PDR-10.

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

Types of ear phones-parameters.	Telephonies TDH-39	Telephonies TDH-49	Telephonies TDH-50	Telex-1470-A
Impedance	10 (standard)	10	60	50 ±10% 300
Continous 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	
Sensitivity	100 ± 4 dB SPL output with 1MW input at KHz	106 ± 2 dB SPL output with 1MW input at KHz	106 ± 2dBSPL output with 1MW input at KHz	106 ± 2dBSPL output with 1 MW.
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 0 to 400 MW.	Linear for power input from 0 to 400 MW.
Earphone Type	Dynamic	Dynamic, moving coil	Dynamic, moving coil	Dynamic
Reference	0 dBSPL	0 dBSPL	0 dBSPL	0.0002 dynes/cm^2
Frequency response	20-20000 Hz	20-20000 Hz	20-20000 Hz	20-10000 Hz
Maximum output				136 dBSPL to 1KHz

Among them TDH-39 and TDH-49 both mounted on MX-41/AR & P/N 510C017-1 cushions are commonly employed in hearing testing. Selection of a particular earphone is specific to the audiometer and will affect the calibration of the audiometer.

ANSI S3.6-1989 specifies the dB SPL values equivalent to audiometric zero at the audiometric frequencies for various supra-aural earphones as measured in an NBS-9A 6cc artificial ear. These reference levels were based on large survey of hearing levels. The TDH-39, TDH-49 and TDH-50 earphones, mounted in an MX/41AR & P/N 510C017-1 cushion are mostly supplied with the audiometer.



Graph 27: Frequency response of an external type ear phone (TDH50) in response to a broad band spectrum

Internal type

They are also called the insert type. They extend into the external auditory meatus with or without the help of an earpiece. These type have limited frequency response and in most of them output drops sharply in the frequecy range above 2000 to 3000 Hz (Lybarger, 1972). They also present calibration problems they may also be used for delivering masking noise. Also it increases IA by 15 to 20 dB, thus reducing chances of over masking.

They are often substituted for traditional supra aural earphones, I particularly in cases of masking dilemma, incases of collapsed ear canals and when testing in noisy environment.

Etymotic research developed the ER-3A insert ear phones which is commercially available. Wilber et al., (1988) obtained mean output levels across five studies of the ER-3 A at threshold in dB SPL, using a 2cc coupler. The technical specification and limits for the E-A-R TONE 3 A **are** as follows

Impedance 10Q, 500, 30OΩ

1KHz sensitivity 102.5dB SPL in DB-0138 (HA-2) coupler

@0.1Vrms(10Ω)
@0.2Vrms(50Ω)

103.5 dB SPL in DB-0138 (HA-2) coupler

@ 0.49 V rms (300Ω)

Limits : ± 3dB

Distortion : < 3 % measured @ 500 Hz, 118.5 dB SPL

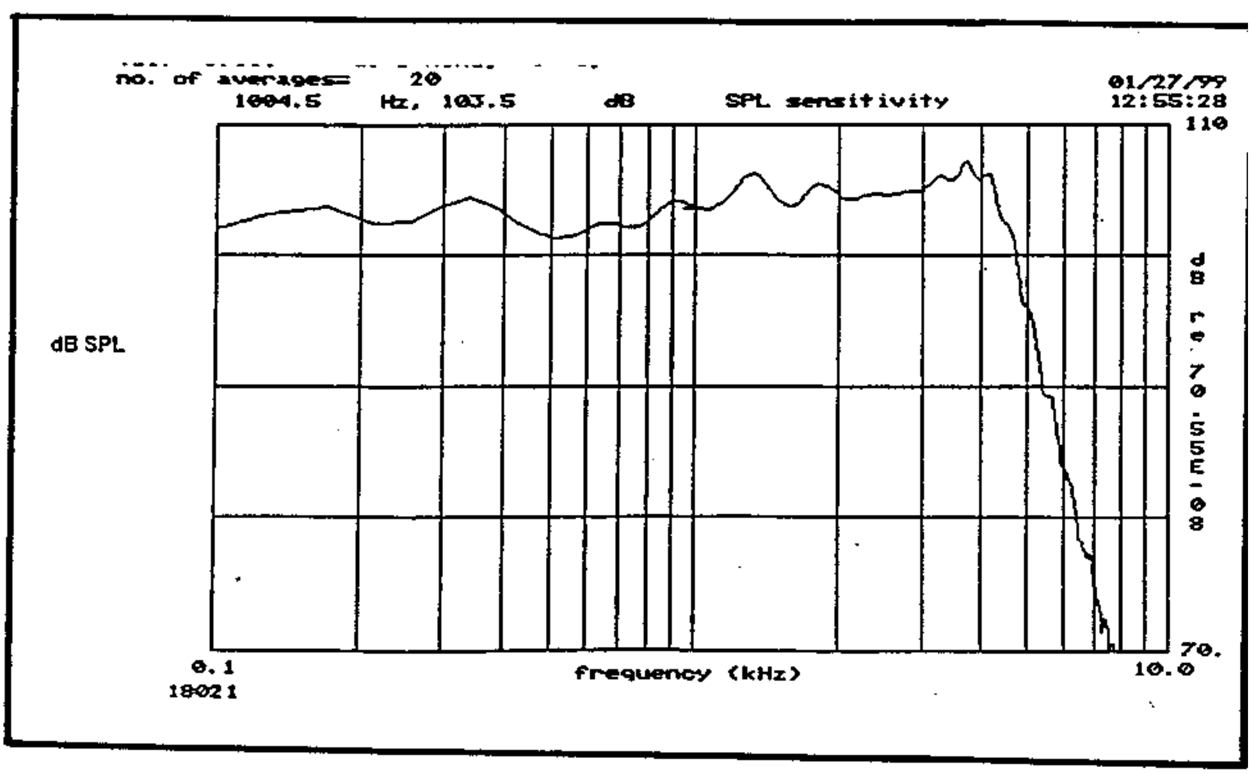
Maximum output: meets or exceeds 110 dBHL at standard audiometric frequencies between 500 to 4000 Hz.

Safe Operating limits: maximum continues sine wave drive:

2.5Vrms(10Ω)

5.0Vrms(50Ω)

13.75 Vrms (300Ω)



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Graph 28: Frequency response of an interna type earphone (ER-3A)

Ear cushions

The enclosures surrounding the external ear type earphones are called ear cushions. They are made of rubber and have specific size and shape. They are

1. Supra aural type
2. Circum aural type

r

Supra aural cushion

It covers only the outer part of the pinna and seals against the skull for example: MX 41/AR Telephonics Corp. P/N 510C017-1

Circum aural cushion

It occupies a larger volume than supra aural cushion. It is approximately 6 cc which is similar to the volume of the NBS-9A standard coupler. The specific volume of the circum aural are not known as there is no standard coupler to measure the same. Example : Aural research AR 100, Aural domes.

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. The cushion is made out of Buna rubber and sponge Neoprene (cap). Another model of the supra aural cushion is the model 51. Comparisons between the MX-41/AR and the model 51 revealed more significant difference in their performance. However, there was a strong indication of model 51 giving more consistent results with much improvement of comfort also. (Micheal and Bienvenue, 1980) similar to this model 51 is the telephonics corp. P/N 510C017-1 which is most often being used presently with TDH series.

It is recommended that 3/4″ be the diameter of the opening of the hole of the ear cushion (ANSI 1962). If the dimension is less than 3/4" it may lead to alteration in the output at certain frequency. Specific combinations of either supra aural or Circum aural have their own advantages and disadvantages. Some of them are :

Ear Phone - **Supra Aural Cushion Combination**

Advantages

1. It can be easily calibrated using the NBS 9A coupler, thus approved by various standards such as ANSI, ISO, etc.

Disadvantages

1. They become uncomfortable after wearing for long time which may effect the performance.
2. They do not attenuate ambient noise as effectively as that of circum aural ear phone.
3. It might deform the flesh around the canal entrance and constrict the opening which results in lowering of the resonant frequency of the system (Villchur, 1969)

Ear Phone Circum Aural Cushion Combination

Advantages

1. It provides greater attenuation of ambient noise, so it is more advantageous in noisy situations.
2. It is more comfortable for the wearer
3. There is less likely hood of energy leakage
4. It has low impedance in the low frequency region

Disadvantages

1. It can not be calibrated using the NBS 9A, standard coupler. No standard coupler has been developed to calibrate the circum aural ear phone as yet. Its use is limited to laboratory investigations where careful calibrations can be performed
2. At frequencies above 2000 Hz, circum aural ear phone response varies depending upon type of head phone and cushion, applied force and placement of earphone on coupler (Shaw and Thiesson, 1962)

Artificial Ear

It is a coupler used to calibrate air conduction ear phones. A standard convenient way of indicating the sound generated by an ear phone is to measure, using a precision microphone, sound pressure produced in a precisely machined cavity of specified dimensions. This is accomplished by "coupling" the ear phone to the measuring microphone by an enclosed volume of air.

In ear phone calibration for audiometry a 6cc coupler is used because it approximates the volume of air enclosed between the earphone diaphragm and the tympanic membrane of the ear when the ear phone is placed on the ear.

The artificial ear is made of heavy steel body with the cavity at the center. The cavity volume can be changed from 6cc to 4cc or 2cc by placing a steel cylinder.

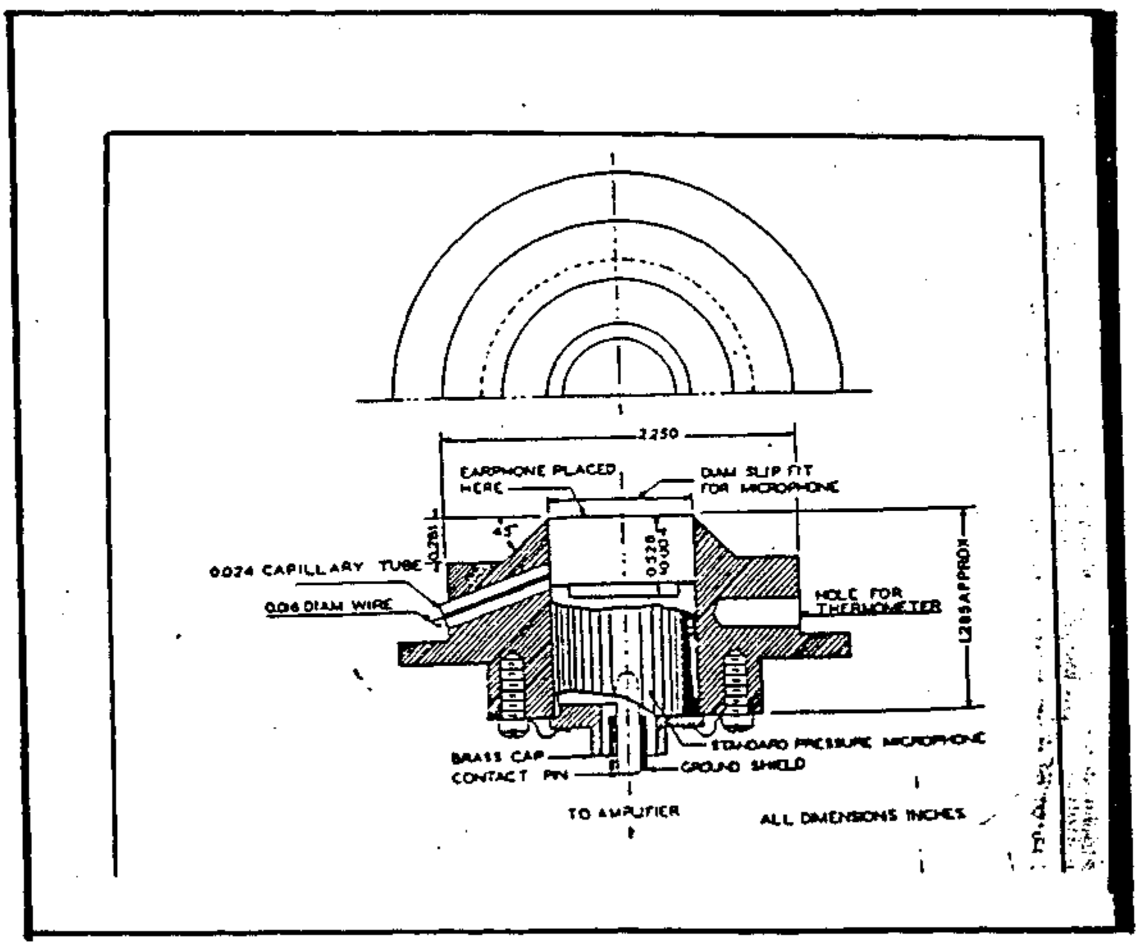


Figure 10: NBS - 9A coupler

The whole steel body is mounted on a wooden base isolated from the table with a mechanical suspension. The lower part has a provision to fix a 1" condenser microphone and preamplifier. Head band tension is provided by a ebonite cup and spring loaded tension with the scale from 0 to 1000 gms.

ANSI S3.6-1969 standard specification for audiometers designates the national bureau of standards (NBS) 9A coupler as a standard for this purpose. The NBS 9A coupler used in conjunction with a sound analyzer for measuring ear phone response is called an "Artificial Ear". It provides for making measurement of an ear phone mounted in supra aural cushions.

However Burkhard and Corliss (1954) pointed out that the impedance characteristic of a 6cc coupler probably simulates the impedance of human ear over a small part of the frequency range. Because the 6cc coupler does not replicate the impedance of the human ear, it can not be considered a true artificial ear.

There are further disadvantages as well such as the present 6cc NBS 9A is known to have a natural resonance at 6000 Hz (Rudmose, 1964) This interferes with the measurement of output of an audiometer and ear phone around that frequency.

Also the size of the coupler, its shape and the hard walls permit the possibilities of standing waves at the frequencies above 6000 Hz.

Insert ear phone are being used increasingly with audiometric equipment. The 9A coupler is not appropriate for assessing performance of this type of ear phone. The coupler usually specified for this purpose is the 2cc coupler described as HA-1 in ANSI 3.7-1979. It should be noted that output measured with a 2cc coupler can not be compared directly with that measured on a 6cc coupler Wilber, 1985.

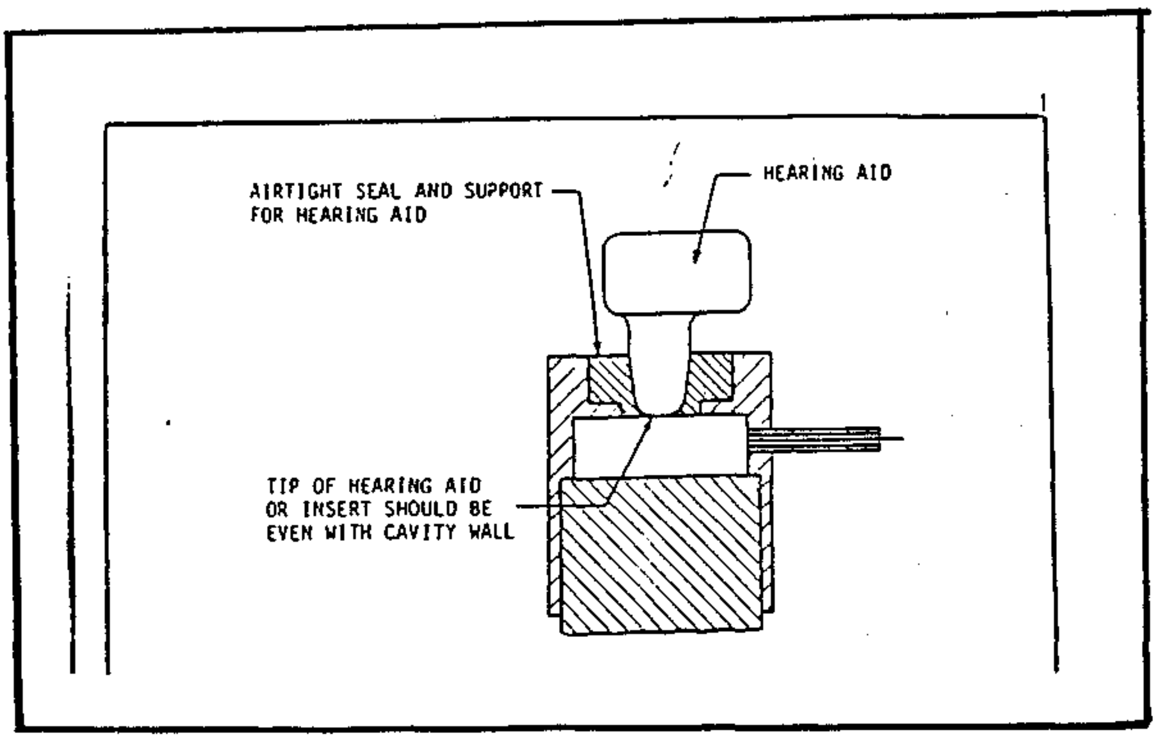


Figure 11: The HA -1,2cc coupler.

Artificial Mastoid

It is a mechanical coupler used to calibrate bone conduction vibrators. The output of the bone vibrator should be measured in a device resembling the average human head with respect to its mechanical impedance characteristics. Under such conditions it is assumed that the force developed at the output of such a mechanical device is equal to the force at the output of the skull to the cochlea. The specifications according to IEC/ANSI is based on the characteristic of the mechanical impedance of the human mastoid (Dadson, Robinson and Grieg, 1954 ; Coliss and Koidan, 1955)

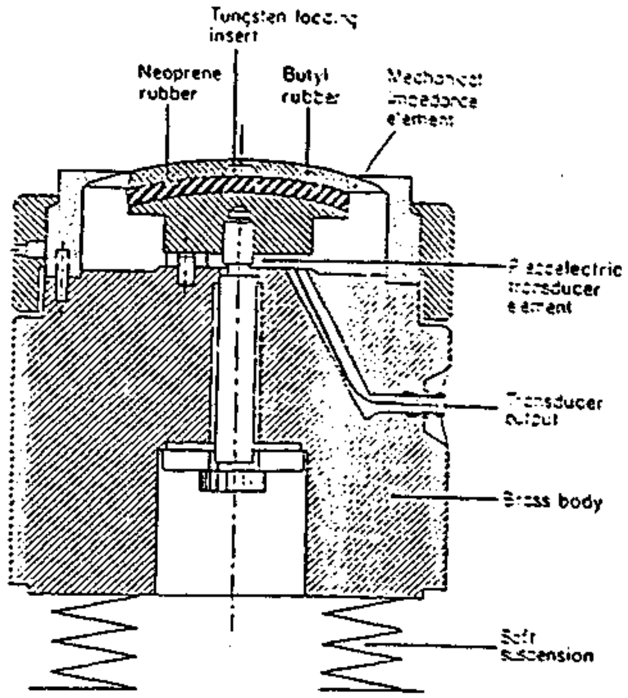


Figure 12:Artificial mastoid

It mainly consist of a cylindrical mass of 6.5 kg by weight which corresponds to the weight of the human head. The central part of the steel mass is provided with a layer of silicon butyl rubber. A crystal bymorph is fixed to convert the vibration received from the bone vibrator in to electrical signal. To provide the headband tension arrangement is made with a spring load on arm. The tension on the arm can be adjusted using a spring balance. The complete system is mounted on a steel base separated from the base with a suitable suspension.

Two artificial mastoids have been available in the united states, the Beltone 5A model and the Bruel & Kjaer 4930. In Europe and consulting the IEC the standard 4009 was commercially available. Currently only the B&K 4930 artificial mastoid is commercially available. However, according to Dirks, Lybarger, Olsen and Billings (1979), no available artificial mastoids meet the ANSI S3 13-1972 and the IEC 373 (1971) standards.

HIGH-FREQUENCY AUDIOMETRY

High frequency audiometry is threshold estimation at frequencies above 8 kHz (to 20 kHz) either through AC or BC. Specialized equipment and unique calibration procedures are required for high frequency audiometry. It may have both diagnostic and rehabilitative ability (Fausti et al., 1979; Berlin, 1982). There are commercially available audiometers for testing this frequency range. The transducers for these audiometers are the Senheisser HDA 200 earphones which permits testing till 20,000 Hz and the KH-70, Oticon A20 bone vibrators permit which testing till 16 kHz.

Clinical Applications of High Frequency Audiometry

(i) Differentiation between noise induced hearing impairment and other high frequency sensorineural hearing impairment such as Presbycusis (Laukli and Nani, 1985)

(ii) Early detection of ototoxicity (Dreschler, Van der Hulst, and Tange, 1984 ; Tange, Dreschler and Van der Hulst, 1985 ; Tonndorf and Kurman, 1984)

(iii) Measurement of speech recognition ability in persons with significant hearing impairment at the routine audiometric frequencies with good speech intelligibility and articulation (Berlin, 1982).

(iv) It is important in the prediction of sensorineural component, before it affects the speech frequencies,

(v) It has also been used to predict the prognosis of the treatment or surgery in different conductive hearing losses (Laitila, et. al., 1997, Mair and Laukli, 1985, Mair and Hellmo, 1994).

CLINICAL MASKING IN PURE TONE AUDIOMETRY

In its simplest term masking may be referred to, as, the noise which is presented to the non test ear (i.e., NTE) to elevate threshold in that ear. It may be defined as " Masking is the term given to the psychoacoustic phenomenon where the threshold of audibility is raised by the presence of another auditory stimulus".

WHY IS MASKING NECESSARY

Masking is used in order to make certain that the test tones are perceived only in the ear that is being tested, i.e., to prevent the responses of the non test ear from contaminating the responses of the test ear.

Therefore masking should be done in order to prevent the occurrence of

(i) Cross hearing or

(ii) Shadow curve

(i) Cross hearing

In unilateral hearing loss cases or asymmetrical bilateral hearing loss cases, when we present a tone to the poorer ear, it may Be transferred and heard in the better ear well before reaching the threshold of the poorer ear. This is called cross hearing.

According to O'Niell & Oyer (1970) this transfer may be due to

(a) Aerial radiation or radiation through air transmission

(b) Through the headband or earphone.

(c) Bone conduction or transmission through bones of the skull which is well accepted & used in clinical masking

(ii) Shadow curve

From the above paragraph we come to know that the possibility exists that, the patient is hearing the tone in the NTE or his "good" ear even though we are presenting tone to the poorer ear. The response curve, thus obtained, by participation of the NTE with out masking is false & gives rise to a shadow curve.

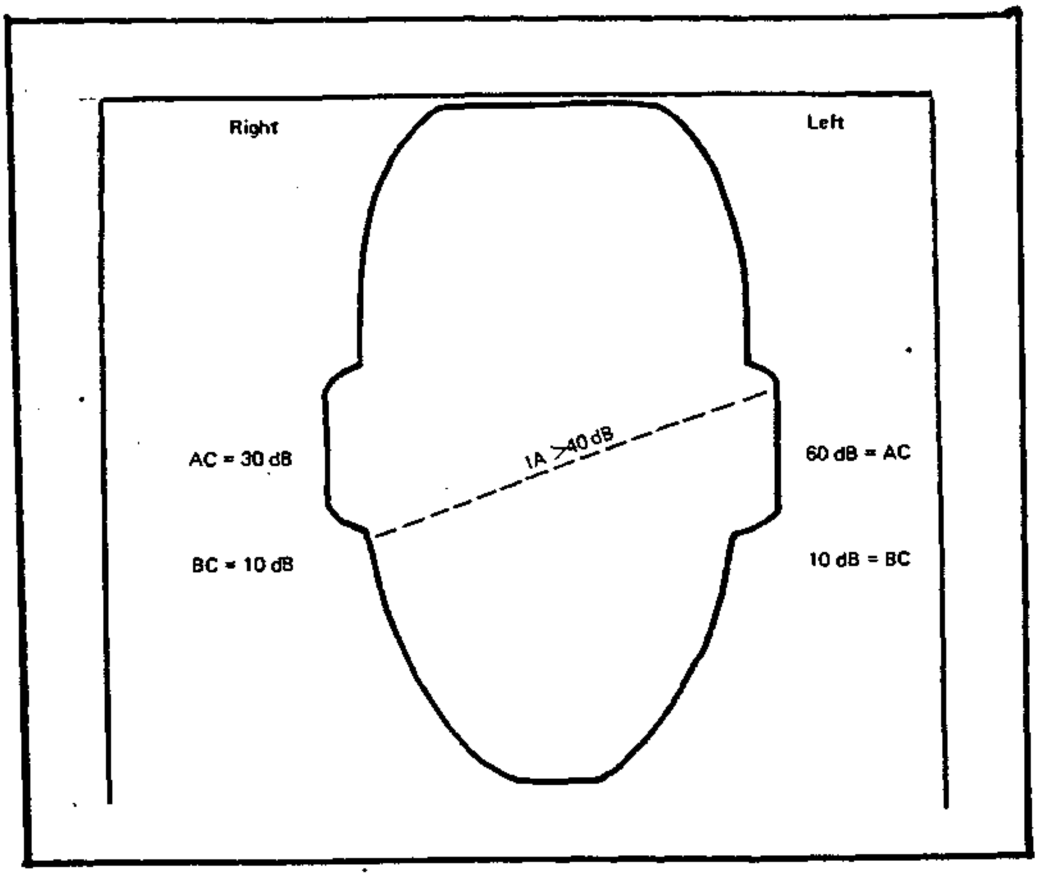


Figure 9: An example of cross hearing

This phenomenon of cross hearing & of the shadow curve depends on the following factors:

(i) Presentation level of the test signal (PL)

(ii) Inter-Aural Attenuation (LA)

(iii) Threshold sensitivity of the non test ear (BCNTE)

$$\text{i.e., } PL - IA \geq BC_{NTE}$$

- cross hearing will take place.

The IA varies depending on the mode of sound transmission & transducer used.

Accordingly the minimum IA that has been calculated is as follows

Headphones: 40 dB

Ear insert: 70 dB

Bone vibrator: 0 dB i.e., because the test signal stimulates both cochleae with approximately equal intensity regardless of the placement of the bone vibrator.

WHEN TO MASK?

The decision about 'when to mask' will vary depending on whether, we are masking the air conduction or the bone conduction.

For Air Conduction

It is necessary to mask AC whenever the air conduction presentation level at the test ear exceeds the bone conduction threshold of the opposite ear by more than the smallest inter aural attenuation value (Studebaker, 1967).

Symbolically it is represented as

$$PL - IA \geq BC_{NTE}$$

The minimum IA for headphones is 40dB therefore

$PL-40 \geq BC_{NTE}$ or $PL- BC_{NTE} > 40$ dB

For example: Consider a left ear with threshold 45dB & a right ear with threshold OdB. If the headphones are being used, the IA is 40 dB. Therefore the presentation level i.e., 45 dB is greater than the BC of the non test ear i.e., 45 dB is greater than the BC of the non test ear i.e., -5dB. Therefore by applying the formula we get

$= PL- BC_{NTE}$

$= 45-(-5)$

$= 45+5$

$= 50$ i.e., > 40 dB therefore masking is required.

For Bone Conduction

Studebaker (1964) recommends masking should be used any time the bone conduction thresholds are better than air conduction thresholds in the ear being tested by more than 10 dB . Symbolically that is,

$$PL - BC_{NTE} \geq 10.$$

Since, bone conduction involves the stimulation of both cochleae the question of which ear to mask becomes difficult to answer. For this reason it has been suggested that the Audiometric Weber test be used to determine which ear to mask during bone conduction testing, which is, the ear to which the individual lateralises.

It is expected that tones will be referred to the poorer hearing ear in a conductive loss to the better ear in a sensorineural loss & to the midline in a symmetrical loss.

METHOD FOR MASKING.

There are several methods used for masking, however, the "plateau seeking method" given by Hood is the most preferred method.

Hood (1960) first reported this technique. It is called threshold shift procedure, shadowing method. It consists of the following steps.

1. Whenever the danger of cross hearing is indicated calculate minimum effective masking level & introduce noise in the better ear.

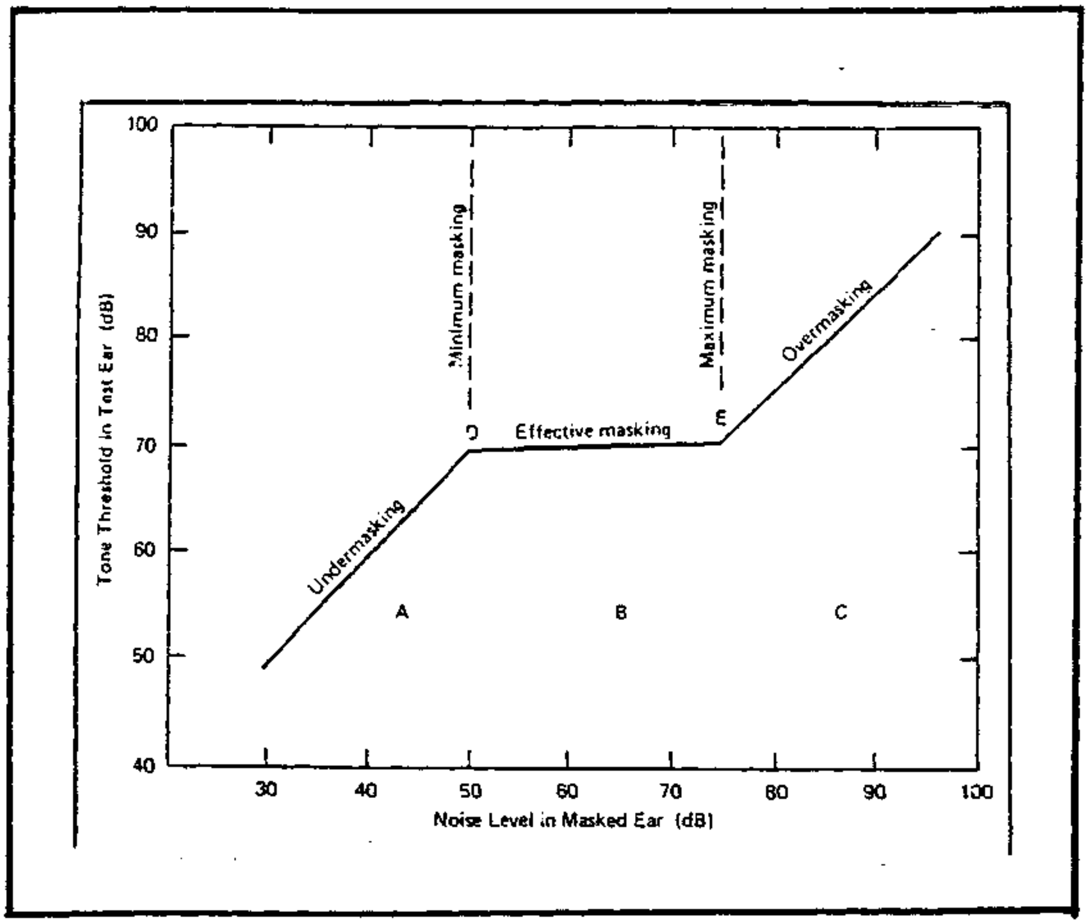
2. Reestablish threshold in the test ear, if there is no threshold shift non-test ear is not participating. If there is a threshold shift, note down the level at which the subject responds & the level of the noise and proceed to the next step

3. Increase the level in the non-test ear by 5- 10 dB & again note the level at which he responds & the level of the noise.

4. The process should be repeated until the subject shows no further shifts of the threshold with increase in noise in the better ear. When the level of the noise can be increased several times (20-30 dB) with out

shifting the threshold in the test ear, the 'plateau' has been reached. The level at which plateau was reached is the threshold.

5. Further increases in noise will shift the threshold again. This is due to over masking.



Graph 24: Indicating Hood's plateau seeking method

occulsion effect resulting in a change in the S/N ratio. Hence occlusion effect needs to be added to the minimum effective masking level when air bone gap in the NTE is absent

(B) The Maximum Effective Masking Level. (Max.E.M.L.)

It is the highest level of noise that can be presented to one ear via a transducer before the noise crosses the skull & shifts the threshold of the opposite ear (Martin, 1975). In order to calculate the Max.E.M.L. we must try to avoid over masking which can be defined as,

When ever the level of effective masking presented to the masked ear minus the patients' inter-aural attenuation is above the bone conduction threshold of the test ear, a sufficient amount of noise is delivered to the inner ear of the test ear to elevate it's threshold. This is called over masking & is given by the formula

$$EM_{NTE} \geq BC_{TE} + IA$$

Maximum effective masking level is equal to the threshold of the test ear by bone conduction i.e., BC_{TE} plus the IA minus 5 dB (Martin 1975).

$$Max.EML = BC_{TE} + IA - 5$$

APPENDIX - II

Name:

Pv2-Test

Time: l5 min

HISTORICAL ASPECTS

State true / false / don't know

1. The electrical audiometer was introduced before the Tuning Fork audio meter.

   (T/F/Don't know)

2. Fowler & Wegel introduced the first commercial clinical audiometer.

   (T/F/Don't know)

3. Magnitude of hearing loss can be determined by whisper test.

   (T/F/Don't know)

4. The Sonotone Jone - Kundesen Model 1 Audiometer does not have facility for speech testing.

   (T/F/Don't know)

5. Tuning Fork tests serve as foundation of Audiological test

   (T/F/Don't know)

6. 0TAUD1AN audiometer was introduced by Katz.

   (T/F/Don't know)

7. The vacuum tube audiometer was introduced during 1921-1940

   (T/F/Don't know)

8. In audiometric testing pure tone, speech and noise are included by 20th century.

   (T/F/Don't know)

9. Automatic self-recording audiometer was introduced by Bekesy.

   (T/F/Don't know)

10. Conductive and Sensorineural hearing loss can be identified by Rinne test.

    (T/F/Don't know)

Name:

Post-Test

Time: 10 min

HISTORICAL ASPECTS

State true / false / don't know

1. The electrical audiometer was introduced before the Tuning Fork audio meter.
(T/F/Don't know)

2. Fowler & Wegel introduced the first commercial clinical audiometer.
(T/F/Don't know)

3. Magnitude of hearing loss can be determined by whisper test.
(T/F/Don't know)

4. The Sonotone Jone - Kundesen Model 1 Audiometer does not have facility for speech testing.
(T/F/Don't know)

5. Tuning Fork tests serve as foundation of Audiological test
(T/F/Don't know)

6. OTAUDIAN audiometer was introduced by Katz.
(T/F/Don't know)

7. The vacuum tube audiometer was introduced during 1921-1940
(T/F/Don't know)

8. In audiometric testing pure tone, speech and noise are included by 20^{th} century.
(T/F/Don't know)

9. Automatic self-recording audiometer was introduced by Bekesy.
(T/F/Don't know)

10. Conductive and Sensorincural hearing loss can be identified by Rinne test.
(T/F/Don't know)

Name:

Pre-Test

Time: 10 min

PURE TONE AIR AND BONE CONDUCTION TESTING

State true / false / don't know

1. Bone conduction testing is done to determine the magnitude of hearing loss.
(T/F/Don't know)

2. Testing at 4000 and 8000 Hz is to assist in differentiating between noise induced and other high frequency sensory neural hearing loss.
(T/F/Don't know)

3. The range of frequencies for Bone Conduction testing is generally 250-8000 Hz.
(T/F/Don't know)

4. Bone conduction testing measures the sensorineural sensitivity.
(T/F/Don't know)

5. Hughson - Westlake method was modified by Carhart and Jerger.
(T/F/Don't know)

6. Air conduction test helps to find out auditory handicap.
(T/F/Don't know)

7. The overall intensity level of conversational speech is approximately 65-70 dBSPL.
(T/F/Don't know)

8. The air conduction route comprise of the outer car and inner ear.
(T/F/Don't know)

9. The duration of presentation of tone is 2-3 sec.
(T/F/Don't know)

10. Threshold of hearing is obtained under MAP & MAF conditions.
(T/F/Don't know)

Name:

Post-Test
Time: 10 **min**

PURE TONE AIR AND BONE CONDUCTION TESTING

State **true / false / don't know**

1. Bone conduction testing is done to determine the magnitude of hearing loss.
(T/F/Don't know)

2. The range of frequencies for Bone Conduction testing is generally 250-8000 Hz..
(T/F/Don't know)

3. Testing at 4000 and 8000 Hz is to assist in differentiating between noise induced and other high frequency sensory neural hearing loss.
(T/F/Don't know)

4. Air conduction test helps to find out auditory handicap.
(T/F/Don't know)

5. Bone conduction testing measures the sensorineural sensitivity.
(T/F/Don't know)

6. Air conduction test helps to find out auditory handicap.
(T/F/Don't know)

7. The air conduction route comprise of the outer car and inner ear.
(T/F/Don't know)

8. The overall intensity level of conversational speech is approximately 65-70 dBSPL.
(T/F/Don't know)

9. Threshold of hearing is obtained under MAP & MAF conditions.
(T/F/Don't know)

10. The duration of presentation of tone is 2-3 sec.
(T/F/Don't know)

Name : **pre test**
Time 15m

State true or false or Don't know

Factors affecting Air and Bone conduction testing

1. Central masking is a psychological factor. (T/F/ Don't know)

2. Standing wave usually occurs at 6000Hz. (T/F/ Don't know)

3. For sound field audiometry, the test room need not be anechoic. (T/F/ Don't know)

4. Head band tension of the bone vibrator should be 6.4N according to. ANSI(1969) (T/F/ Don't know)

5. More the surface area of bone vibrator lesser the acoustic-radiation. (T/F/ Don't know)

6. High temperature exceeding 85 degree F can affect accuracy of measurements. (T/F/ Don't know)

7. The occlusion effect is seen more for higher frequencies. (T/F/ Don't know)

8. The elevated bone conduction threshold at around 2000Hz is referred as Jerger's notch. (T/F/ Don't know)

9. In geriatric, ossification of mastoid area leads to a decrease in bone conduction sensitivity . (T/F/ Don't know)

10. Ambient noise of audiometry room should be OdBspl for reliable measurements. (T/F/don't know)"

Name : **post test**
Time 10m

State true or false or Don't know

Factors affecting Air and Bone conduction testing

1. Head band tension of the bone vibrator should be 6.4N according to ANSI(1969) (T/F/ Don't know)

2. For sound field audiometry, the test room need not be anechoic.

   (T/F/ Don't know)

3. Standing wave usually occurs at 6000Hz. (T/F/Don't know)

4. Central masking is a psychological factor. (T/F/ Don't know)

5. The occlusion effect is seen more for higher frequencies.

   (T/F/ Don't know)

6. In geriatric, ossification of mastoid area leads to a decrease in bone conduction sensitivity . (T/F/ Don't know)

7. More the surface area of bone vibrator lesser the acoustic-radiation.

   (T/F/ Don't know)

8. Ambient noise of audiometry room should be OdBspl for reliable measurements. (T/F/don't know)

9. High temperature exceeding 85degree F can affect accuracy of measurements. (T/F/ Don't know)

10. The elevated bone conduction threshold at around 2000Hz is **referred** as **Jerger's notch.** **(T/F/ Don't know)**

Name:

Pre-Test

Time: 15 min

AUDIOMETER

State true / false / don't know

1. In type V audiometer both AC and BC testing is available

   (T/F/Don't know)

2. The diagnostic audiometer has provision for masking the nontest ear.

   (T/F/Don't know)

3. In puretone audiometer, the intensity range is -10 to 110 dBHL at all test-table frequencies.

   (T/F/Don't know)

4. The power required to drive a bone conduction vibrator is lower than for an air conduction ear phone.

   (T/F/Don't know)

5. A patient can trace his or her own auditory threshold in Automatic Audiometry.

   (T/F/Don't know)

-4-

6. Attenuator is used to control frequency level the audiometer.

   (T/F/Don't know)

7. The frequency range provided in an audiometer depends on the type of audiometer.

   (T/F/Don't know)

8. Output selector switch is used to select desired transducer.

   (T/F/Don't know)

9. Type I, II & III are diagnostic type of audiometer.

   (T/F/Don't know)

10. The pure tone audiometer has provision to use pure-tone and speech as test stimulus.

    (T/F/Don't know)

Name:

Post-Test

Time: 10 min

AUDIOMETER

State true / false / don't know

1. The diagnostic audiometer has provision for masking the nontest ear.

   (T/F/Don't know)

2. The power required to drive a bone conduction vibrator is lower than for an air conduction earphone.

   (T/F/Don't know)

3. In lypc V Audiometer both AC and BC testing is available

   (T/F/Don't know)

4. A patient can tract his or her own auditory threshold in Automatic Audiometry.

   (T/F/Don't know)

5. In purctonc audiometer, the intensity range is - 10 to 110 dBHL at all test-table frequencies.

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6. The range of frequency provided in the audiometer depends on type of audiometer.

   (T/F/Don't know)

7. Output selector switch is used to select desired transducer.

   (T/F/Don't know)

8. The pure tone audiometer, has provision to test using pure-tone and speech.

   (T/F/Don't know)

9. Attenuator is used to control frequency level the audiometer.

   (T/F/Don't know)

10. Type 1, II & III are diagnostic type of audiometer.

    (T/F/Don't know)

Name:

Pre-Test

Time: 15 min

AUDIOGRAM

State true / false / don't know

1. Mid-octave frequency lines are usually darker.

   (T/F/Don't know)

2. "•" is the symbol for left ear masked AC threshold, as recommended by ISO.

   (T/F/Don't know)

3. If a person has a puretone average of 55 dB he is said to have moderate hearing loss.

   (T/F/Don't know)

4. Rising type of audiogram is seen in cases with early Meniers.

   (T/F/Don't know)

5. Traugh pattern of hearing loss represents greater hearing loss at mid frequencies.

   (T/F/Don't know)

6. According to Feldman, AC loss generally doesn't exceed 65 dBHL in conductive hearing loss.

   (T/F/Don't know)

7. The term "sensory" hearing loss is applied when the damage is localised in the auditory nerve.

   (T/F/Don't know)

8. In mixed hearing loss both AC & BC are affected.

   (T/F/Don't know)

9. Sauccer audiogram is seen in cases with Acousticnuroma.

   (T/F/Don't know)

10. In an audiogram bone conduction threshold should be connected by solid lines.

   (T/F/Don't know)

Name:

Post-Test

Time: 10 min

AUDIOGRAM

State true / false / don't know

1. " U" is the symbol for left ear masked AC threshold, as recommended by ISO.

(T/F/Don't know)

2. If a person has a puretone average of 55 dB he is said to have moderate hearing loss.

(T/F/Don't know)

3. Mid-octave frequency lines are usually darker.

(T/F/Don't know)

4. Traugh pattern of hearing loss represents greater hearing loss at mid frequencies.

(T/F/Don't know)

5. According to Feldman, AC loss generally doesn't exceed 65 dBHL in conductive hearing loss.

(T/F/Don't know)

6. Rising type of audiogram is seen in cases with early Meniers.

(T/F/Don't know)

7. hi mixed hearing loss both AC & BC arc affected.

(T/F/Don't know)

8. In an audiogram bone conduction threshold should be connected by solid lines.

(T/F/Don't know)

9. The term "sensory" hearing loss is applied when the damage is localised in the auditory nerve.

(T/F/Don't know)

10. Sauccer audiogram is seen in cases with Acoustic nuroma.

(T/F/Don't know)

Name:

Prc-Tcst

Time: 15 min

TRANSDUCERS

State true / false / don't know

1. Clinically, B-72 is the most commonly used bone vibrator.

   (T/F/Don't know)

2. The B-72 vibrator has acoustic radiations at around 3000 - 4000 Hz.

   (T/F/Don't know)

3. Bar phone converts acoustic signal into electric signal.

   (T/F/Don't know)

4. Ear phone with circumaural ear cushion attenuate ambient noise more effectively than earphone with supra aural cushion.

   (T/F/Don't know)

5. The resonance of B-72 vibrator occurs at frequency less than 250 Hz.

   (T/F/Don't know)

6. Insert receiver increases the inter aural attenuation by 15 to 20 dB.

   (T/F/Don't know)

7. Artificial car is used to calibrate bone vibrator.

   (T/F/Don't know)

8. A 6cc coupler is used to calibrate earphone.

   (T/F/Don't know)

9. Earphone with circumaural ear cushion has high impedance in low frequency region.

   (T/F/Don't know)

10. A 6 cc NBS9A coupler is known to have a natural resonance at 6000 Hz

    (T/F/Don't know)

Name:

Post-Test

Time: 10 min

TRANSDUCERS

State true / false / don't know

1. Earphone with circumaural ear cushion attenuate ambient noise more effectively than earphone with supra aural cushion.

   (T/F/Don't know)

2. Earphone converts acoustic signal into electric signal.

   (T/F/Don't know)

3. The B-72 vibrator has acoustic radiations at around 3000 - 4000 Hz.

   (T/F/Don't know)

4. Clinically, B-72 is the most commonly used bone vibrator.

   (T/F/Don't know)

5. Insert receiver increases the inter aural attenuation by 15 to 20 dB

   (T/F/Don't know)

6. Artificial ear is used to calibrate bone vibrator.

   (T/F/Don't know)

7. The resonance of B-72 vibrator occurs at frequency less than 250 Hz.

   (T/F/Don't know)

8. A 6 cc NBS9A coupler is known to have a natural resonance at 6000 Hz.

   (T/F/Don't know)

9. A 6cc coupler is used to calibrate earphone.

   (T/F/Don't know)

10. Earphone with circumaural ear cushion has high impedance in low frequency region.

    (T/F/Don't know)

Name:

Pre-Test

Time: 15 min

HIGH FREQUENCY AUDIOMETRY

State true / false / don't know

1. In High frequency audiometry threshold is estimated at frequencies above 10 kHz.

   (T/F/Don't know)

2. In high frequency audiometry only AC thresholds are measured.

*

   (T/F/Don't know)

3. High frequency audiometry helps in early detection of ototoxicity.

   (T/F/Don't know)

4. High frequency audiometry is not useful to predict the prognosis of treatment in conductive hearing loss cases.

   (T/F/Don't know)

5. Calibration of high frequency audiometry is unique.

   (T/F/Don't know)

Name:

Post-Test

Time: 10 min

HIGH FREQUENCY AUDIOMETRY

State true / false / don't know

1. In high frequency audiometry only AC thresholds are measured.

   (T/F/Don't know)

2. High frequency audiometry helps in early detection of ototoxicity.

   (T/F/Don't know)

3. In High frequency audiometry threshold is estimated at frequencies above 10 kHz.

   (T/F/Don't know)

4. Calibration of high frequency audiometry is unique.

   (T/F/Don't know)

5. High frequency audiometry is not useful to predict the prognosis of treatment in conductive hearing loss cases.

   (T/F/Don't know)

Name:

Pre-Test

Time: 15 min

CLINICAL MASKING

State true / false / don't know

1. Cross hearing can occur in cases with bilateral asymmetrical hearing loss.
(T/F/Don't know)

2. Minimum IA for insert receiver is 75 dB.
(T/F/Don't know)

f 3. AC masking is done when PL-40 < BCNTE-
(T/F/Don't know)

4. The method given by Hood for masking is also called shadowing method.
(T/F/Don't know)

5. The formula for maximum effective masking level is BCn; + 1A + 5
(T/F/Don't know)

6. In the audiometric wcber test the car in which person doesn't laleraliscs to be masked.
(T/F/Don't know)

7. The energy lost as sound travels from one ear to the other ear is called cross hearing.
(T/F/Don't know)

8. The response curve obtained by the participation of nontest ear, without masking is called shadow curve.
(T/F/Don't know)

9. Masking is done to find out the real (or to improve) threshold of the better ear.
(T/F/Don't know)

10. Plateau occurs during effective masking.
(T/F/Don't know)

Name:

Post-Test

Time: 10 min

CLINICAL MASKING

State true / false / don't know

1. Minimum IA for insert receiver is 75 dB.
(T/F/Don't know)

2. Cross hearing can occur in ears with bilateral asymmetrical hearing loss.
(T/F/Don't know)

3. The method given by Hood for masking is also called shadowing method.
(T/F/Don't know)

4. AC masking is done when PL-40 < BCNTE.
(T/F/Don't know)

5. In the audiometric weber test the ear in which person doesn't lateralises to be masked.
(T/F/Don't know)

6. The energy lost as sound travels from one ear to the other ear is called cross hearing.
(T/F/Don't know)

7. The formula for maximum effective masking level is BCTE + IA + 5
(T/F/Don't know)

8. Plateau occurs during effective masking.
(T/F/Don't know)

9. The response curve obtained by the of non test ear, without masking is called shadow curve.
(T/F/Don't know)

10. Masking is done to find out the real (or to improve) threshold of the better ear.
(T/F/Don't know)

APPENDIX - III

Name:

Pre -Test

Time: 15 min

HISTORICAL ASPECTS

State true / false / don't know

1. Magnitude of hearing loss can be determined by whisper test.

(T/F/Don't know)

2. Tuning Fork tests serve as foundation of Audiological test

(T/F/Don't know)

3. Conductive and Sensorineural hearing loss can be identified by Rinne test.

(T/F/Don't know)

4. The electrical audiometer was introduced before the Tuning Fork audio meter.

(T/F/Don't know)

5. OTAUDIAN audiometer was introduced by Katz.

(T/F/Don't know)

6. The vacuum tube audiometer was introduced during 1921-1940.

(T/F/Don't know)

7. Fowler & Wegel introduced the first commercial clinical audiometer.

(T/F/Don't know)

8. The Sonotone Jone - Kundesen Model 1 Audiometer does not have facility for speech testing.

(T/F/Don't know)

9. In audiometric testing pure tone, speech and noise are included by 20th century.

(T/F/Don't know)

10. Automatic self-recording audiometer was introduced by Bekesy.

(T/F/Don't know)

Name:

Post-Test

Time: 10 min

HISTORICAL ASPECTS

State true / false / don't know

1. Magnitude of hearing loss can be determined by whisper test.
(T/F/Don't know)

2. Tuning Fork tests serve as foundation of Audiological test
(T/F/Don't know)

3. Conductive and Sensorineural hearing loss can be identified by Rinne test.
(T/F/Don't know)

4. The electrical audiometer was introduced before the Tuning Fork audio meter.
(T/F/Don't know)

5. OTAUDIAN audiometer was introduced by Katz.
(T/F/Don't know)

6. The vacuum tube audiometer was introduced during 1921-1940.
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7. Fowler & Wegel introduced the first commercial clinical audiometer.
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9. In audiometric testing pure tone, speech and noise are included by 20th century.
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