

IMMITTANCE AUDIOMETER: GUIDELINES FOR PURCHASE,
INSTALLATION AND MAINTENANCE

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DEDICATED TO

ACHAN AMMA

FOR BEING THE STRONGEST

FOUNDATIONS OF MY LIFE

DECLARATION

I, hereby declare that this independent project entitled, "IMMITTANCE AUVIOMETER: GUIDELINES FOR PURCHASE, INSTALLATION ANV MAINTENANCE" is the result of my own study under the guidance of Dr. (Miss} S. Nikam, Professor and Head of the Department of Audiology. All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or deggree.

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CERTIFICATE

This is to certify that the independent project entitled, "IMMITTANCE AUDIOMETER: GUIDELINES FOR PURCHASE, INSTALLATION AND MAINTENANCE" is a bonafide work done in part fulfilment for first year degree of Master of Science (Speech and Hearing) of the candidate with register number M 9477.

*Mysore
1995*


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*This is to certify that the independent project
entitled "HINNITANCE AUDIOMETER: GUIDELINES FOR PURCHASE,
INSTALLATION AND MAINTENANCE" has been prepared under my*

supervision and guidance..

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INTRODUCTION

The development of impedance audiometry during the past decade has enhanced the diagnostic sensitivity of the audiological test battery and also added new scope and dimension to clinical audiology. Within a very short span of time, measurement of impedance characteristics of M.E. has progressed from a sophisticated research tool to a clinical procedure applicable to all patients.

The term 'acoustic immittance' refers to acousted impedance, to acoustic admittance or to both quantities (ANSI, 1981). Acoustic admittance is the general term expressing the ease with which sound energy flows through a system and acoustic impedance represents the total opposition to the flow of sound energy. These two are reciprocal quantities.

The direct measurement of the acoustic impedance properties of the M.E. offers a means of objectively determining the integrity and mobility of the ear drum, ossicles, intra-aural muscles and their various attachments, as well as the air space of tympanic cavity. An efficient transfer of energy from an air medium with a low impedance to a fluid medium with a high impedance, such as the cochlea, establishes a need for an

impedance-matching transformer. In our auditory system, the M.E. provides this function. The development of pathology in the M.E. alters this critical function of the M.E. and subsequently results in a loss of hearing. The electro-acoustic measurement is really a measurement of how well the M.E. is performing its impedance matching function.

The history of clinical acoustic immittance measures is well over 100 years old. According to Feldman (1970) the first attempts at objective assessment of the M.E. function using acoustic impedance measures were performed by Lucae in 1867. Historically early clinical acoustic immittance measures were restricted to measures of the resting state acoustic impedance of ear drum. With the reserach in diagnostic audiology reaching new frontiers the clinical application of acoustic immittance techniques has expanded into many areas encompassing almost all aspects of diagnostic audiology. Acoustic immittance measures have been applied to screening as well as diagnostic tests, to the diagnosis of peripheral and central disorders of the auditory system and to the estimation of auditory sensitivity in patients for whom behavioural audiometry is equivocal. It is an objective test, is not time consuming, is non-invasive and is relatively easy to administer.

Different types of impedance meters ranging from screening to computer-assisted multiple probe frequency immittance instruments are commercially available for diagnostic application. Hence a clinician should have information regarding the type of instrument best suited for his/her individual needs and the procedure for purchase and installation. It is also very essential to know the calibration procedure and other environmental requirements for the proper maintenance of the instrument.

The present study aims at discussing the guidelines for purchase, installation, and maintenance of an immittance audiometer.

HISTORICAL NOTE AND DEVELOPMENT

The era of impedance audiometer began nearly 100 years ago. The first attempts at objective measurement of middle ear function using acoustic impedance measures were done by Lucae in 1867. There is vast literature on the measurement of acoustic immittance measures dating back to early 1900s. Immittance measurements clinically employed today are based on the 1940s studies and technological creativity of Otto Metz. The table below summarises the important landmarks in the development of impedance audiometer.

Table 1

Year	Investigator	Finding
1	2	3
1867	Lucae	First attempt at objective assessment of M.E. function
1934	Schuter	First mechanical acoustic coupler
1934	West	Development of an electro acoustic device which was coupled to the ear with a telephone receiver cap
1935	Troger	Troger's bridge
1938	GeffScken	Using Troger's bridge, calculated the impedance at various frequencies

1	2	3
1939	Waetzman and Keibs	Used thermophone method
1944	Metz	Modified Schuster type bridge
1945	Schuster	Mechanical acoustic impedance bridge
1946	Otto Metz	Used electro-mechanical bridge (Metz bridge) to measure acoustic impedance
1952	Johansen	Theoretical discussion of the effects of mass, stiffness and resistance
1957	Metz (Denmark)	First commercially available electro-acoustic impedance bridge
1960	Terkildsen and Nielson	Gave an electro-acoustic impedance measuring bridge for clinical use. Responsible for the proto type of Z061
1960	Madsen Company	Produced electro-acoustic bridges Z070 and Z072
1963	Zwislocki	First commercially available mechanical impedance bridge capable of directly measuring the component of impedance at the ear drum
1968	Denzil Brooks	Developed gradient concept as a measure of quantifying the "rounding off" of the tip of the tympanogram
1969	Anderson <u>et al.</u>	Published monograph on elevated reflex threshold and reflex decay in patients with acoustic tumour
1969	Gunnar Liden	Delineated the basic types of tympanograms

1	2	3
1970	Grason-Stadler Company	Developed an electro-acoustic counterpart of Zwislocki impedance bridge
1970	Jerger and Jerger	Synthesized clinical experience with a basic impedance battery
1970	Griesen and Rammssen	Pointed out values of distinguishing ipsilateral and contralateral acoustic reflexes in brainstem disease
1973	Grason Stadler Company	Commercially produced mechanical impedance instrument
1974	Niemeyer and Sesterhan	Predicted hearing level from acoustic reflex threshold based on bandwidth effect
1975	Lovette	An objective otoscope "compact admittance measurement device"
1975	onchi	Developed electro-acoustic instruments
1976	Onchi	Electro-acoustic device for detecting acoustic threshold
1977	Jerger and Jerger	Gave patterns of abnormality in brainstem disease based on relationship between two ipsilateral and two contralateral thresholds
1977	Colletti	Multifrequency tympanometry
1982	Hayes and Jarger	Gave rise of signal averaging technique
1984	Stach and Jerger	To analyse suprathreshold characteristics of acoustic threshold

1	2	3
1983	Endo S. Shibahara, Y. Sakuma, M. Takasuka, T. Kawamotok Okitsut	Studies using mechanical middle ear model
1984	Teele and Teele	Acoustic otoscope
1987	Wada, H. Kobayashi, T.	Studied impedance using mechanical middle ear model
1989	Wada, H. Kobayashi, T. Suetake, M. Tachizaki, H.	A newly developed sweep frequency apparatus, which measured middle ear dynamic characteristics
1991	Holte, L. Margolis, R.H. Cavanaugh, R.M.	Developmental changes in much frequency tympanogram
1992	Hiroshiwada, Toshimitsu Kobayashi, Hisashi Tachizhi	Diagnosis of middle ear disease with ear drum preformation by a newly developed sweep frequency measuring apparatus

As knowledge increased regarding immittance testing microprocessing technology was advancing at a rapid rate. The technology available today has allowed this field to far surpass the vision of its creative predecessors. The days of manually balanced bridges gave way to microprocessor systems which today are able to rapidly analyse the amplitude and phase of reflected probe tone signals based on the

immittance characteristics of the middle ear system. It is now possible to store calibration data and test data in memory for recall. It is also possible to *offer* smaller more durable and affordable instrumentation which feature flexibility.

INSTRUMENTATION FOR IMMITTANCE MEASUREMENT

The measurement of acoustic immittance provides a measure of the efficiency of the middle ear system, as seen at the tympanic membrane. A majority of the immittance measuring instruments employ a probe which either enters the ear canal or is placed against the entry to the canal in such a way that an hermetic seal is obtained while tests are being performed. The probe contains a small transducer which is energised by an oscillator so that a probe tone of selected frequency is produced. The manufacturer shall provide specific information regarding the dimensions of the probe and any associated tubing that might be used between the probe and the instrument. ANSI (1987) states that along with a 226 Hz probe tone, manufacturer can supply additional probe signals also.

The signal is delivered to the ear through a loud speaker. The reflected signal in external auditory meatus is picked up by a microphone and fed to an AVC circuit which electronically modifies the energy of probe signal delivered to the ear. The energy of the probe signal or the current delivered is varied to maintain a constant reference SPL (eg. 85 dB SPL) in external auditory meatus. The instrument which uses AVC circuit to maintain this constant reference SPL is called an immittance meter. Other kind of instrument is an impedance bridge where the rotation

of a variable control manually modifies the level of probe tone.

The energy of probe signal required to maintain a reference SPL in a hard walled cavity will vary depending on the volume. Larger the volume, greater is the energy required. In a cavity with a compliant wall the energy required to maintain a reference SPL will also depend on the compliance of the wall. Higher the compliance of the wall, greater is the energy required. In external auditory meatus the energy of the probe signal required will vary depending on the admittance at the probe tip. Greater the admittance, greater is the energy required, i.e., an ear with greater admittance acts like a large cavity. Thus the admittance can be expressed in terms of equivalent volume. The instruments are calibrated to display the equivalent volume depending on the energy of the probe signal required to maintain a reference SPL. Some instruments express admittance in ml or cc, whereas others express in numbers. A majority of the commercially available instruments measure only magnitudes of acoustic admittance (Y). A few instruments measure the components of admittance, i.e., susceptance and conductance. ANSI 1987 standard specifies that, with a probe signal frequency of 226 Hz, the instruments shall have the capability for measuring acoustic-admittance value of

atleast 2×10^{-9} to 5×10^{-8} m³/Pa S (0.2 to 5 cgs acoustic Pa S/m³ (200 to 5000 cgs acoustic ohms)).

The instrument also has an air pump to vary the air pressure in external auditory meatus during tympanometry. The probe has three small apertures for microphone, loudspeaker and air pump. According to ANSI S₃-39-1987 standard, the maximum limits of air pressure shall be -800 da pa to +600 dapa as measured in the 0.5 mm cavity and minimum air pressure range shall be at least -600 to +200 dapa. If air pressure produced by the instrument can be changed automatically, the rate at which the pressure change occurs shall be measured in each of the specified cavities and stated by the manufacturer. The manufacturer also shall state the direction in which air pressure is changed for each test (negative to positive, positive to negative or both). The air pressure in the external auditory meatus shall be indicated by an analog or digital display. The accuracy of the display shall be specified by the manufacturer as well as its limitations with regard to atmospheric pressure and altitudes above sea level.

Acoustic stimulus for reflex measurements can be presented either through probe or through an earphone coupled to the opposite ear. ANSI .(1987) standard states

that when fixed frequencies are provided, they shall be selected from the following frequencies: 125, 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000 or 8000 Hz. If the maximum output for an instrument is lower than the hearing level (HL) or SPL values given in the table, the total harmonic distortion for the output capability of the instrument shall not exceed the values stated in the table below.

Table 2
Maximum total harmonic distortion for pure-tone acoustic reflex activating signals (ANSI, 1987)

Stimulus	Supra-aural earphones		Insert/probe type earphones		
Frequency (Hz)	200 & 8000	500-6000	500	1000-3000	4000
Stimulus level (dB)					
HL	90	110	85	100	75
SPL	--		95	100	75
Maximum total harmonic distortion	3%	3%	5%	5%	5%

If you are using broad band noise as activating stimulus, when presented through insert earphones or probe type transducers it shall have a uniform acoustic pressure

spectrum level (within +5 dB relative to the level at 1000 Hz) over the frequency range of 400-4000 Hz. The manufacturer shall also specify the band width slope characteristics, and pressure spectrum level for the noise with tolerances.

Table 3

Minimum range of stimulus level control for type I and II aural acoustic immittance instruments (ANSI, 1987)

Stimulus	250	500-2000	4000	6000	Broad band noise
Supra-aural earphones (dB HL)	50-90	50-120	50-120	50-100	50-115
Insert or probe type earphones (dB HL)		50-100	50-80		
Insert or probe type earphones (dB SPL)		60-110	60-90		50-100

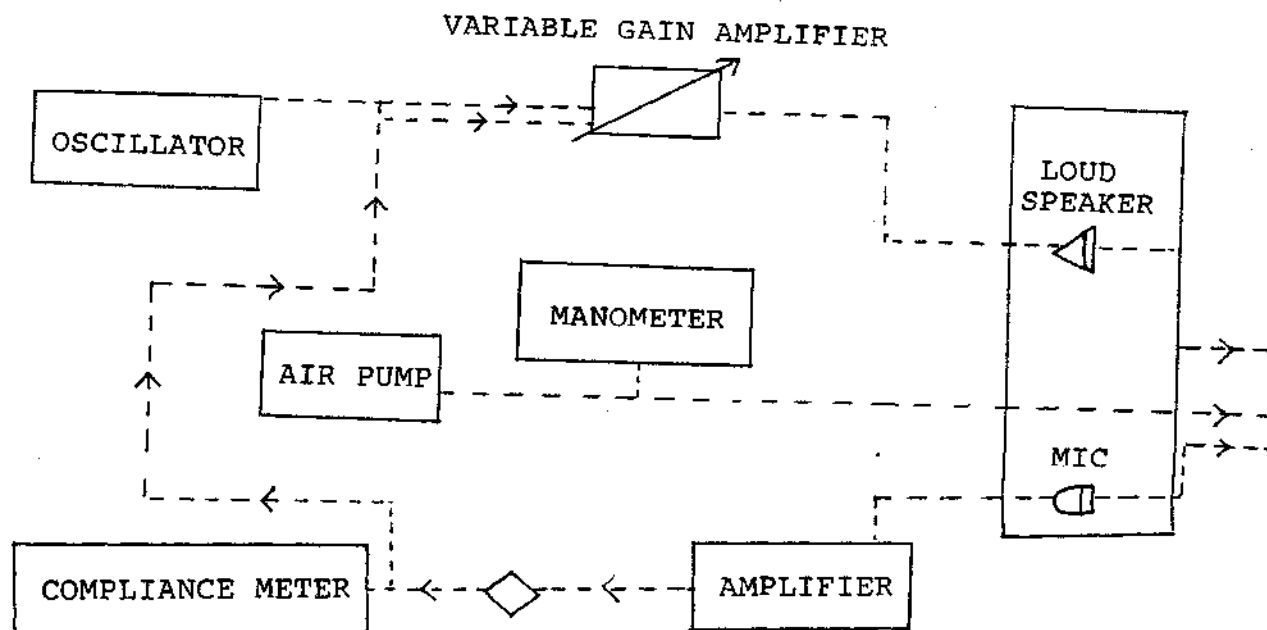


Figure 4: Block diagram of instrumentation

Types of immittance audiometers

1. Two types of instruments are in use. They are impedance bridges and impedance meters.

Impedance bridge compares the sound pressure level in the ear canal (Volts) to a preset standard SPL. Changes in the acoustic admittance caused by changes in the ear canal pressure can be measured by balancing the ear canal sound pressure level with the standard. The amount of sound pressure needed to rebalance the bridge is inversely proportional to the change in acoustic admittance (Wiley and Block, 1994).

The electro-acoustic admittance meter has a feedback circuit to maintain a constant SPL in the ear canal regardless of changes in the acoustic admittance (Wiley and Block, 1994). Some meters measure the acoustic compliance expressed in ml of equivalent volume, while others measure the acoustic conductance and acoustic susceptance.

2. GoYin (1991) has divided the impedance instruments into three categories. They are;

- a. Screening instruments for educational or dispensing setting.
- b. Clinical instruments of medical settings.
- c. Research instruments for advance research applications.

1. Screening impedance instruments

These have the advantage of portability. They incorporate the basic functions for tympanometry and acoustic reflex with simple and quick test protocols. They reveal the presence or absence of a reflex at pre-programmed stimulus levels. They might have a low resolution display or no display at all. They are not designed for testing with a variety of test parameters. The screening instruments also carry a lower price than clinical instruments.

2. Clinical impedance instruments

They are more versatile than screening instruments. These can be further divided into analog and digital instruments.

Analog instruments do not store data and they record in real time on paper. Digital instruments either have a computer integrated into them or can be connected to an external computer. The data acquired can be stored in the computer memory and can be manipulated later, if required. This perhaps is one of the most powerful features of the computer based instruments.

Research impedance instrument

These instruments are used to support some particular investigation and are not commercially marketed.

3. A different classification is given by ANSI (1987). The four different types of acoustic immittance instruments specified are type 1, 2, 3 and 4. Type 1 has the greatest range of functions and capabilities and type 4 provides minimum functions and capabilities. Type 4 may have capability for tympanometry alone, for static acoustic immittance measurements alone, for acoustic reflex measurements alone, or for any combination of these.

Table 5

Summary of minimum mandatory characteristics, functions and capabilities required for type 1, 2 and 3 acoustic immittance measurements

Characteristic, function or capability	1	2	3
Probe signal			
Sinusoidal, 226 Hz	+	+	+
Pneumatic system			
Manual control of air pressure			
Automatic control of air pressure	+	+	+
Manual or automatic control of air pressure			
Analog or digital output proportional to air pressure			
Graphic display or indicator	+	+	+
Static acoustic immittance			
Measurement plane	+		
Compensated	+	+	
Proportional analog or digital output	+		
Graphic display or indicator	+	+	+
Tympanometry			
Measurement plane	+		
Compensate	+	+	
Proportional analog/digital output	+		
Graphic display/indicator	+	+	+

Acoustic reflex activating system				
Noise activating signal	+			
Pure tone activating signals	+	+		
Pure tone or noise activating signal				+
Contralateral presentation of stimulus	+			
Ipsilateral presentation of stimulus	+			
Contralateral or ipsilateral stimulus			+	+
Manual control of stimulus level	+			

PURCHASE AND INSTALLATION

Consideration for procurement of inunittance audiometer

Selecting an impedance instrument today can be a challenging task with the availability of specialised instruments and recent advances in electronic technology. Today, there are more impedance instrument manufacturers than ever before. In addition, the impedance instruments available are quite diversified. When it is time to replace an aging impedance instrument or to purchase a new one for practice expansion, several points should be kept in mind which help make the selection process a bit easier. The four critical elements should be included in purchase decision-making are;

(i) technology, (ii) capital budgeting, (iii) competitive advantage, (iv) non-financial resource requirements.

(i) Technology

Technology always important, has taken on an added dimension because of the rapid rate of technological change being experienced in the industry. To evaluate any technology consider the following issues.

- How will the equipment be used ? What testing will it be used for ?

- What attributes are important ? Speed ? Volume testing ? Ease of use ? Low service requirements ? Durability ? Portability ? Image ? Marketing application ?
- Is the technology used state of the art ? Where are technological changes likely ?
- What is the expected life span of the technology used in the test equipment ?
- Can the equipment be upgraded to include technological advances or changes in industry standards.
- Does the manufacturers offer a guarantee or warranty ? For how long ? Does it cover parts and labour ?
- What have been the service requirements of the equipment being evaluated ? How much time do repairs require and are loaners available ?
- What is the manufacturer's commitment to older equipment no longer sold ? Are parts and service readily available ?
- How stable is the manufacturer ? Will they be around to provide parts and service as the

equipment ages ? If not, can the equipment be serviced or repaired ?

(ii) Capital budgeting

Equipment purchases are an investment. The economic consequences of investing in equipment must be closely evaluated. It is critical to consider;

- The impact of any purchase on one's cash flow.
- The long term value of the investment.
- Opportunity cost, i.e., the cost of not investing in alternative equipment or another activity.
- Financing alterations
- The tax consequences

(iii) Competitive advantage

Equipment purchases can provide the hearing health professional with significant competitive advantages. Equipment can produce cost advantages. It also can help differentiate a business and its services from those of the competition.

(iv) Resource requirements

The acquisition of new equipment often has unexpected costs: time, funds, change. These costs may be associated with the installation or actual use of the

equipment. One should plan for these costs. Consider these potential resource requirements.

- Are there any special installation requirements ?
- Is training required before the instrument can be used productively ?
- Will its integration into the office change operations ?
- operation ?

A basic eight point framework for effective purchase decision-making is suggested by Jelonek (1988). Its purpose is to ensure that professionals make the best investment possible and realise the highest return on their funds and time spent.

1. Clearly define the purchase objective

Your goal may be to replace an unreliable ten year old immittance audiometer, at the same time, add new testing capabilities and expand your services.

2. Establish if the purchase of specific equipment is consistent with your general business goals

The type and brand of equipment purchased by your office should support your primary business objectives and

marketing positioning. Hence the first step is to honestly make a list of requirements for utilisation of the impedance instrument, both for its use today and in the future. Consider the following questions:-

What requirements are really wanted in this instrument ?

- Is this instrument being purchased to satisfy only today's measurements needs or should future needs be considered ?
- If a satellite location is possible in the near future, should a portable or at least transportable impedance instrument be considered ?

Next, you separate the requirement list into two parts; (1) the critical needs list, those needs that absolutely must be met and (2) the desired features list, those needs that are not critical but would be nice to have.

Armed with a list of requirements, the hearing care professional next should consider measurement needs. For example, if majority of a hearing care professional's referral is from a local paediatrician whose primary interest is whether or not fluid is present in the middle ear space, that person's diagnostic priorities may be quite different from a hearing care professional whose

referrals come largely from an otologist seeking detailed site of lesion information to assist in accurate diagnosis and appropriate treatment of more complex pathologies.

3. Calculate the total cost of purchasing the equipment

The cost of equipment includes the sales price, interest, sales tax, shopping and installation charges.

4. Calculate the financial value of getting the equipment

Equipment is an asset that increase the business. Of great importance is the revenue generating potential of the equipment. You need to calculate the direct and indirect revenues that the purchase will provide. Ask yourself what services the equipment will provide ? Are they bill able ? What will you charge per test ? How many will you do for a fee each month ? Equipment may not generate direct revenue, though it can create good will or represent a basic cost of doing business.

5. Consider alternate uses of cash and time

A major element in any equipment purchase is the opportunity cost. You need to evaluate the alternate uses of funds and staff time.

6. Evaluate the risk involved in getting or not getting the equipment

The primary risk in a purchase is financial. Can you afford to commit the cash without depleting your reserves ? If your revenue projections fall short, will your cash flow situation deteriorate ? Do you have the reserves to cover one to two months of lease or debt payments if revenues are down ? The risks involved in not purchasing the instrument is often greater than those related to purchasing it.

7. Compare brands or models, identify the equipment which best needs your objectives

In comparing alternative brands, focus on the four elements of the "good by" - technology, capital, budgeting, the competitive advantage and non-financial resource requirements.

8. Outline a plan for equipment installation, training and marketing

In evaluating the output needs, you should look a variety of factors:-

1. Is a hard copy print out of test results necessary ? If so, what format should it take, strip chart or 8 1/2" x 10" standard paper ?

2. Will it be desirable to save the data to computer ?

3. Will it is useful to integrate impedance findings with other test results in a combined reports ?

4. Will it be necessary to review and analyse the data in ways other than it was obtained and recorded after the patient has left ?

Working with an authorised dealer

Almost all impedance instruments sold for hearing care today are purchased through authorised dealers in India. This factor is due to relatively small size of the market and the inability of most manufacturers to generate sufficient sales volume to support a full field sales and service organisation. Thus, the dealers represents a number of manufacturers and product lines. A dealer can be an important resource to the hearing care professional, serving as a source of information on available products, making instruments available for demonstration purposes, and most importantly, being available for service and ongoing support after the sale is consummated. Most dealers have at least one individual trained in specific area to meet the specialised needs of the consumer. Since most dealers are locally owned and

staffed, they can quickly and efficiently respond to the purchaser's needs.

Procedure to purchase the equipment

Before buying any equipment one must have detailed information regarding the instrument. These are,

- (i) name of the instrument as given by company
- (ii) estimated cost
- (iii) accessories that might be required
- (iv) justification of the use or need of the instrument in the department.

(v) Invoice should be collected before requisition is made to the higher authorities, for the acquisition of the instrument.

Performa invoices

These are supplied by the manufacturer or company which gives the cost of the instrument and accessories including sales tax and mail charges depending upon the type of delivery mode of the equipment. The cost mentioned in the invoice is only estimated, need not be same as the equipment is actually delivered in the institute. This is because there may be variation in the price of that equipment over the time and hence if there is gap between the period of asking for equipment and

finally receiving the equipment there may be some price differences.

As the next step the committee concerned either approves or rejects the requisition depending upon the sanctioned budget from the ministry or sanctioning authority and the urgency.

Quotation

If the equipment is approved quotation are called from firm and the manufacturer of the equipment. Quotation can be called for non-proprietary equipments. As specific data will be given in the advertisement for quotation or will directly inform to the firm concerned and the firm will have to send invoices and detailed information to the institute before the last date given in quotation. The information will be sent in a sealed cover.

Opening of the quotation

Once the last date for receiving quotation expired, the offices personnel of the institute opens the quotation in the presence of people from the respective company and the head of the institute. The lowest quoted figure or cost of the equipment given by the firm is

accepted provided that instrument meets the user's requirements and the equipment is ordered from this particular firm. In Government set up there are formalities to be performed. In the official procedure it is required that at least three quotations can be called for the purchase of an instrument. Sometimes high cost equipment also can be purchased depending upon quality. Proper justification has to be given if a low cost instrument not purchased.

Payment

As the equipment is delivered from the manufacturing company, payment is done either through bank or you pay directly from the organisation to the manufacturing company. Usually in government setup 90% of the equipment cost is paid soon after the delivery of the equipment and 10% paid later after assessing the performance of the equipment over a period of time.

Non-indegenous equipment

Before purchase of equipment from foreign manufacturers are has. to get NOC (No Objection Certificate) from DGTD (Director General of Technical Development) and NMIC (Not Manufactured in India Certificate) has to be taken from the Department of

Commerce. This is a directory which keep information regarding all the manufacturing companies in India. Another approval, CCP (Custom Clearance Certificate) is obtained from CCE and I (Chief Controller of Export and Import). This is done to make way for equipment without any problem at the customs.

Installation of immittance audiometer

While installing an immittance audiometer, you have to ensure the following:

1. Qualified personnels such as an audiologist and electronic engineer are present.

2. The role of the stabiliser is very important while installing an impedance audiometer. Stabilisers are electrical devices incorporating step up or step down transformers which augment or attenuate voltage flow to the instrument as per voltage requirement. Step up stabilisers ensure upgrading of voltage signal from 110 volts to 220 volts as required in Indian set up, where as step down stabilisers have the reverse function.

3. Test environment

There are several important factors to be considered when deciding the place of installation of the

apparatus. The first consideration would be to place the equipment in a convenient room which is readily accessible to those who use it. If the instrument is used for testing patients, it is of advantage to install the apparatus close to the place where patients are seen.

The surface on which it is placed should not be subjected to vibrations. The temperature and humidity conditions should be conducive for its normal functioning.

Frequent movement of the delicate apparatus will probably result in malfunction and cause kinds to break-off and depts to appear. Portable immittance instruments may be considered in set-ups which require frequent carrying of the equipment from one department to the other.

A sound treated room is an ideal testing environment. But this is not a necessary condition. The room should be sufficiently spacious with good ventilation and diffused lighting for the comfort of the patient . Testing room should contain less of disractions as head movements and other body movements might interface test results. These measures will ensure

good co operation from patient which is essential for valid hearing measurements (Murthy, Jacob, 1970).

Powerline interference can arise from non-equipotential power ground circuits. These potential differences are created by ground currents in ground circuits with poor connections, inadequate wire diameters, high contact resistances and also by circulating currents in building structure. The minimisation of these interference problems requires exceptional care in wiring and system design.

Thus, while installation of the equipment is a necessary key step in the establishment of an immittance audiometry facility, a vigilant maintenance is crucial to

its efficient functioning.

MAINTENANCE OF IMMITTANCE AUDIOMETERS

Proer maintenance and calibration of the audiometer is a must to get valid and reliable test results. Following guidelines would ensure conditions conducive for the proper functioning of the immittance audiometer.

Power supply

Before operating the impedance instrument, make sure that the working voltage is within permissible limits. For this purpose, it is preferable to have a voltage stabilizer through which the instrument receives its power supply. The use of a voltage stabiliser would ensure safety of the instrument in the event of voltage fluctuation.

Cleanliness

The instrument must be kept clean prevent collection of dust, oily substances, drops of water, etc. on the instrument. Wipe the panels and the housing care with dry cotton or a dry piece of cloth. Whenever necessary, a small, smooth painting brush may be used to remove dust. Avoid use of solvents such as spirit, soap or water in cleaning the immittance audiometer. Avoid rough handling while cleaning the instrument. The probe tips also should be cleaned and wiped properly.

Physical damage

Prevent the occurrence of any breaks, cracks or cuts on the immittance audiometer and its accessories (dials, knobs, cords, head bands, earphones). Avoid dropping of headphones, probe tube, etc.

Electrical connections and wiring

Proper insulation of the wires, switches, etc. is a must for the prevention of electrical shock check for any loose connection of jacks, cords, etc. Do not hang the earphones at the end of the cords like pendulum.

keeping away insects and rats which may nibble at the wiring. The use of insect repellants would be desirable.

Some dos and donts that help in maintenance

Dos

a. When the instrument is not in use, switch off the power supply and disconnect the immittance audiometer from the mains and place the dust cover over the instrument.

b. If the instrument is not likely to be used for a long duration, keep them stored in a place devoid of dust and dampness.

c. When they are being stored, faulty parts or accessories should be labelled as such for convenience.

d. Take necessary steps to minimise the effects of vibration and shock during transportation. It is ideal to retain and use the original cartons and the packing material. Where this is not available, pack the instrument with shock absorbing materials such as foam, thermocool, etc.

Don't's

a. Do not expose the instrument to large variations in temperature and humidity.

b. Do not drop transducers.

c. Do not allow the cords to get tangled.

d. Do not subject the instrument to vibration.

e. Do not change the transducers such as earphones, probe tube, etc without ensuring that they

match the instrument.

f. Do not shift the instrument from place to place frequently unless it is of a portable type.

Eventhough these guidelines would ensure conditions conducive for the proper functioning of the instrument, this does not mean that the instrument is working normally. In order to check that the instrument meets performance requirements, its calibration should be checked.

Calibration of immittance audiometer

Use of calibrated equipment is a pre-requisite for an accurate audiological evaluation. Failure to calibrate the instrument at appropriate intervals may be a major cause of unreliable test results. To ensure accuracy the signal- parameters, the instrument must be checked on its acquisition and regularly thereafter.

The following schedule for calibration can be used.

- a. A daily listening check to detect any gross deviation.
- b. Periodic electro acoustic evaluation.

Preliminary check up

Before calibrating the immittance audiometric, check for the following .

i) The working voltage is within permissible limits.

ii) All the jacks, cords and plugs are in place and there are no loose connections.

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iii) There is no visible damage on the instrument, its controls and its accessories. Damage if any, should be rectified before checking the calibration.

iv) The earphone is the type that match the instrument.

v) The head bands have adequate tension.

vi) The instrument is not delivering any electrical shocks.

a. Daily listening checks

These are the subjective calibration procedures. Check the instrument, as it is routinely used. The following steps may be taken to determine if the instrument is in calibration.

1. Switch on, allow warm-up time according to the instruction manual supplied by the manufacturer.

3. Check if the indicators function correctly.
4. Connect the 2 cc cavity to the probe and see if the compliance reading is the same.
5. Ensure that the signals are coming through the transducers.
6. Ensure that the operation of the alternator brings about a variation in the signal level.
7. Also assure that the pressure in the external canal can be varied by operating the alternator.

One should have these daily listening checks as well as periodic tests of one or two persons with known acoustic immittance to check immittance, tympanogram and acoustic reflex levels to catch any gross problems. However, it is essential to carryout electroacoustic evaluations periodically, to ascertain the integrity of the instrument.

Electro acoustic calibration

Much "how to calibrate" information is available in the manuals that accompany acoustic immittance devices, as well as the pieces of equipment used in checking or calibrating equipment. Although many of us

seem to live by the slogan "When all else fails, read the manual", the first step in learning how to check calibration should always be to read the appropriate manual. The clinicians should be aware of the required tolerances and calibration for the particular instrument.

The parameters to be calibrated and the brief calibration procedure are given below.

- a. Probe signal
- b. Manometer system
- c. Monitoring system
- d. Reflex activating system.

a. Probe signal calibration

Regardless of the specific probe signal frequency, the user should determine that the probe signal is accurate in frequency, at the specified level and free of unwanted distortion and noise. Measurements of the probe signal characteristics are performed in a standard HA-I (2 and 3) coupler.

Frequency check

The frequency output from the immittance audiometer is best checked by using an electronic counter. The output can be directly connected to the

frequency counter. By this one can easily determine if the output from the instrument corresponds to the dial reading or electronically displayed number. ANSI (1987) specifies that the frequency of probe signal shall remain within $\pm 3\%$ of the nominal value.

Block diagram of instruments needed for calibration of frequency out of an immittance audiometer:

Figure 6



Distortion measurement

This can be carried out by giving the electrical output from the instrument to the distortion factor meter. The total harmonic distortion shall not exceed 5% of the fundamental when measured in a 2 cc coupler (ANSI, 1987).

Block diagram of instruments required **for distortion measurement.**

Figure 7



Output SPL

To check the output SPL proceed as follows.

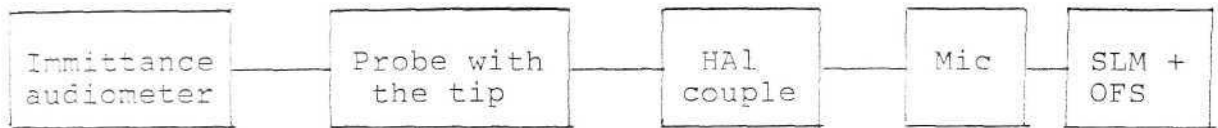
- Calibrate the SLM using a piston phone or sound level calibrator.
- Connect a condenser microphone of pressure type (eg. B & K 4144) to a 2 cc coupler.
- Connect the coupler to the calibrated SLM.
- The SLM should be set into 'slow response' and 'external filter' mode and it should be connected to an octave filter set.
- Place the probe with an appropriate tip to the coupler.
- Switch the instrument on and select a probe tone, eg. 226 Hz.
- The attenuation of SLM should be set into 80 dB.
- The frequency chosen on the octave filter set should correspond to the frequency of the probe tone selected.
- Check the reading on the SLM.

- The reading should correspond to the intensity specified by the manufacturer/stands, if not

internal calibration is required.

- Continue the same procedure for all the probe signals.

Figure 8: Block diagram of instruments for the calibration of output SPL of immittance audiometer



(b) Manometer system

The pneumatic system. should be evaluated to determine the rate of air pressure changes and the accuracy of the graduated steps on the air pressure indicator. Manometer accuracy should be within the tolerance specified by the standard and can be determined with a U-tube manometer graduated in calibrated units. Connect the probe to a manometer or 'U' tube, and then determine the water displacement as the immittance device air pressure dial is rotated. If an X-Y plotter is used to record the output as a function of air pressure changes, the correspondence between the manometer readings and the pressure readings on the recorder chart must be determined. The air pressure should not differ from that

stated on the device by more than \pm dapa or \pm 15% of the reading whichever is greater ANSI (1987) states that the air pressure should be measured in emities of 0.5 to 2 cm³. IEC (1986) stresses that the response of the measuring instrument should be at least three times faster than the rate of pressure change.

c. Acoustic immittance monitor system

Regardless of the variables and units of measurement, the acoustic immittance or acoustic impedance value indicated by the instrument must correspond to known values for fixed cavity volumes over the range of interest. The exact test cavities and tolerances should conform to those required in ANSI (1987). If an external recording device is used (eg. X-Y plotter) the meter calibration must be consistent with the recording device. That is, the value indicated on the acoustic immittance meter must correspond with the appropriate value marking on the chart paper for a specific calibration cavity.

The acoustic immittance of an enclosed volume of air is dependent on environmental conditions such as temperature, humidity and atmospheric pressure. If standard conditions do not exist at the measurement site, then a

correction factor must be made. Variations in temperature and humidity, however, have a negligible effect on calibration. Most immittance measurements are performed at room temperature, and, variations in temperature from 20°C to body temperature (37°C) unit in a minimal change in the acoustic immittance of a volume of air. Similarly, changes in relative humidity from 0 to 100% do not significantly change the acoustic immittance of an enclosed volume of air. In contrast, changes in atmospheric pressure and, therefore, in elevation can have a marked effect on calibration. Thus a correction for elevation has to be made.

Another issue is the potential of an artifact or interaction between the activating signal and probe tone. ANSI (1987) states that the manufacturer should specify the stimulus level at which there is an artifactual response, synchronous with the presentation of the acoustic reflex activating stimulus. The possibility of an artifactual response is especially relevant for ipsilateral reflex measurements. ANSI (1987) also specifies that it is critical that the clinician determine what the artifact-free limits of the measuring device are because reflex measurements are so important in evaluating uncooperative or immature patients. The presence of an ipsilateral artifact is easy to determine

by placing the probe in the 0.5 cm³ calibration cavity and presenting the ipsilateral activating stimulus over the intensity range of the instrument. If the measurement is free of artifact, the meter needle will remain stationary for all presenting levels. If a deflection of the meter needle is observed, that is coinciding with stimulus presentation, then an artifact is present. The artifact effectively limits the operating range of the instrument. The limits should be kept in mind while evaluating the patients.

d. Response time of the instrument

The initial latency, rise time, terminal latency, fall time and the drift are the temporal characteristics to be measured. A recommended procedure for determining the temporal characteristics of an acoustic-immittance instrument involves measurement of the output of the instrument in response to various load immittances. The basic load immittance shall be similar to that of a standard 2 cm acoustic coupler. Load immittance either will be held constant or changed instantaneously.

e. Acoustic reflex activator system

The required measures include frequency accuracy, output levels, attenuator linearity and harmonic

distortion for both contralateral and ipsilateral acoustic reflex signal.

Contralateral signals are evaluated in a standard NBS-9A (6 cm) coupler or an artificial ear and the ipsilateral signals are measured in a 2 cc coupler. The calibration of stimulus level either in dB SPL or dB HL is straight forward for signals presented through air cum aural earphones. If ipsilateral signals are specified in dB HL, however, the manufacturer must use the procedure used to derive the refernce equivalent threshold levels. The proposed IEC (1986) standard further cautions that the levels of ipsilateral stimulus will vary, depending on the ear volume of the ear canal under test. Ipsilateral stimulus levels for children, therefore, may be higher than those measured in 2 cm coupler. According to ANSI (1987) the sound pressure level of sonal activators should be within ± 3 dB of the stated value for frequencies from 250 Hz to 4000 Hz and within ± 5 dB for frequencies of 6000 and 8000 Hz and for noise.

Calibration of ipsilateral stimulus level.

- Connect a condensor microphone of pressure type to the coupler.
- This should be then connected to SLM and OFS.

- Connect the probe with the appropriate tip on an HA, coupler.
- Select the frequency on the immittance audiometer as 500 Hz and the intensity as 70 dB.
- SLM should be in slow mode and external filter setting. Attenuator setting should be at 70 dB.
- Set the octave filter to the frequency corresponding to that chosen on the immittance audiometer.
- Present the stimulus continuously and check the SLM reading to see if the instrument: is in calibration.
- Continue the same procedure at all frequencies.

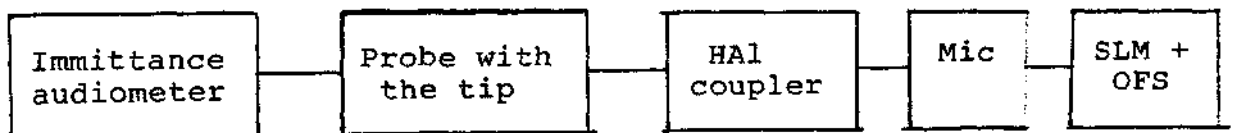


Figure 9: Block diagram explaining the instruments involved in calibration of ipsilateral stimulus level.

Calibration of contralateral stimulus level

The transducers used for contralateral stimulation is either a supra aural earphone or an insert or probe

type receiver. The procedure is the same as ipsilateral calibration except for the instruments used, the following diagrams explain the instrumentation used for calibration of earphone, insert receiver and prototype receivers.

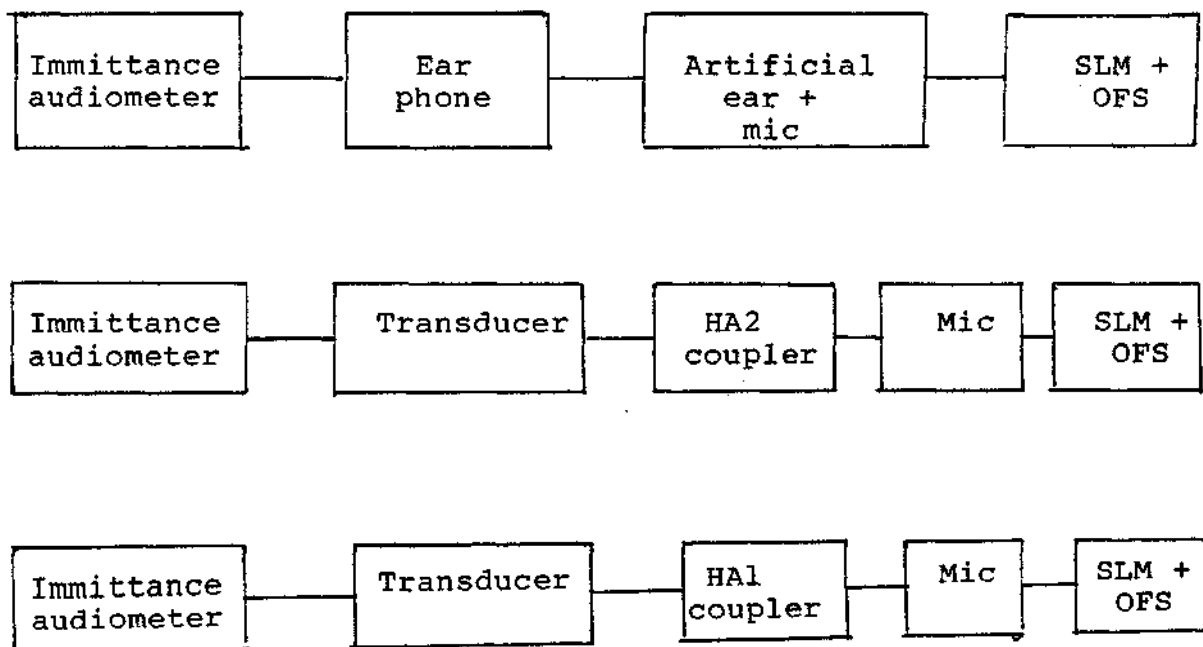


Figure 12: Calibration of probe-type receiver

Noise bands should also be checked if they are to be an activating stimulus. Broad band noise should be uniform with ± 5 dB for the range between 250 to 6000 Hz for supra aural earphones. This can be checked by sending the output through the transducer connected to a coupler, a microphone and then to a graphic level recorder. The frequency of the social activator may be measured electronically directly from the acoustic immittance device using a frequency

counter. Frequency should be $\pm 3\%$ of the stated value, harmonic distortion should be less than 3% at all specified frequencies for earphones and 5% or less for the probe tube transducer or insert receiver.

In summary acoustic immittance devices should be checked very carefully. Failure to do so may lead to variability in measurement which may invalidate the immittance measurement.

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