A MANUAL FOR NOISE INDEPENDENT

REGISTER NO.8

ANINDEPENDENT PROJECT SUBMITTED AS PART FULFILMENT
FOR

FIRST YEAR M.Sc (SPEECH AND HEARING) TO THE UNIVERSITY

OF MYSORE

All India Institute of speech and Hearing: Mysore-570006

1982

!

Dedicated To,

My Amma, Appa

and Akka.

C E R T I F I C A T E

This is to certify that the Independent Project entitled **"A Manual for Noise Measurement"** is the bonafide work in part fulfilment for M.Sc, in Speech and Hearing of the student with Reg. No.8

Director,

All India Institute
of Speech & Hearing,
Mysore - 570 006.

C E R T I F I C A T E

This is to certify that the Independent Project entitled **"A Manual for Noise Measurement"** has been prepared under my Supervision and guidance.

Guide.

DECLARATION

This Independent Project is the Result of my own study undertaken under the guidance of Dr.(Miss)Shailaja Nikam, Professor of Audiology and Head of the department of Audiology, All India Institute of Speech and Hearing,Mysore and has not been submitted earlier at any unit for any other Diploma or Degree.

Mysore: Reg.No. 8

Dated:

ACKNOWLEDGEMENT

I am highly indebted to Dr.(Miss).Shilaja Nikam, Professor and head, Department of audiology, All India Institute of Speech and Hearing, Mysore, for her valuable guidance, constant concern and resourceful help.

I extend my thanks to all members of the Electronics department, who helped me to collect the literature concerned by providing the manuals on instrumentation.

My special thanks to Mr.G.A.Lathe, Research Assistant in Noise Trauma Cell, department of Audiology, All India Institute of Speech & Hearing, for his guidance and help.

I extend my appreciation to Miss.Malini, Miss. Parinatha, Miss.Tanuja and Miss.Latha Gopala Krishnan, for their help, during various stages of the study.

I specially thank students of III year B.Sc, for their encouragement.

I am most grateful to Mr.Srikanth,M.A. Miss.Falguni Pathak, Miss.Pushpa without whose help this manual would not have been completed.

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Chapter -l

Introduction

Prolonged exposure to excessive noise can speed the process of gradual hearing loss. An extremely loud noise Can cause immediate loss, of hearing, but on the other hand, the loud noise, though not so extreme may still hurt and can be dangerous because it is more common. The noise we "get used to" and endure for many ears is more likely to cost na our hearing than are the high levels.

The concern over excessive noise in industrial environments has increased significantly in the last few years. Part of this concern stems from the recognition that pollution of any type is damaging to the individual's welfare. More important is the mounting evidence that excessive noise causes not only hearing damage, accelerated deafness and decreased working efficiency, but other psychological stress and physiological damage.

How the noise affects the performance of the individual must be given greater importance, especially in the industrial concern several studies have been recently done on the possible effects of noise on the performance and efficiency of people at work.

Summarization of such studies are as follows:-

a) Broad Bent (1957) reported that steady noise with out meaning does not affect the performance unless the noise level exceeds 90 dB (A), but yet the consistency is not clear.

b) Cohen (1969) found that intermittent and impulse noise are more disrupting than steady noise.

c) High frequency noise above 2000 Hz appears more disrupting than low frequency noise below 2000 Hz (Broadbent and Harris, 1957).

d) Noise does not change the rate of work; but rather increases the variability of the work; there may be work pauses compensated by increase in work rate (Carpenter.A., 1962).

e) Noise increases the number of errors made at work rather than the total amount of work (Broadbent).

f) Regarding the complexity of tasks Boggs and Simon found that complex tasks more are affected by noise than,simple tasks.

Considering the above literature one is clear that noise has adverse affects and has to be controlled or minimized. Noise control is a means of obtaining an acceptable noise environment, at a receiver, consistent with economic and operational considerations.

the receiver may be a person, a group of persons, an entire community or a piece of equipment whose operation is affected by noise and vibration. When the word "acceptable" is used, questions such as the following are raised: Acceptable under what conditions? Acceptable to whom? The answere to these questions mainly depend upon the measurement of noise as such* Thus, several attempts have been made to device methods for measurements. This requires the knowledge of noise measurements..

Prior to embarking on a measurement program, one should establish clearly why and for what conditions the data is needed (Bruce, 1971) and also, the investigator should have a prior adequate knowledge as to what instruments are to be utilized for such noise measurements.

It should be kept in mind that the measurement of noise from the source, etc is not an end process in itself. Thus, noise measurement involves a much complex process of data analysis. In a broad sense, data analysis refers to the extraction of useful information from the data.

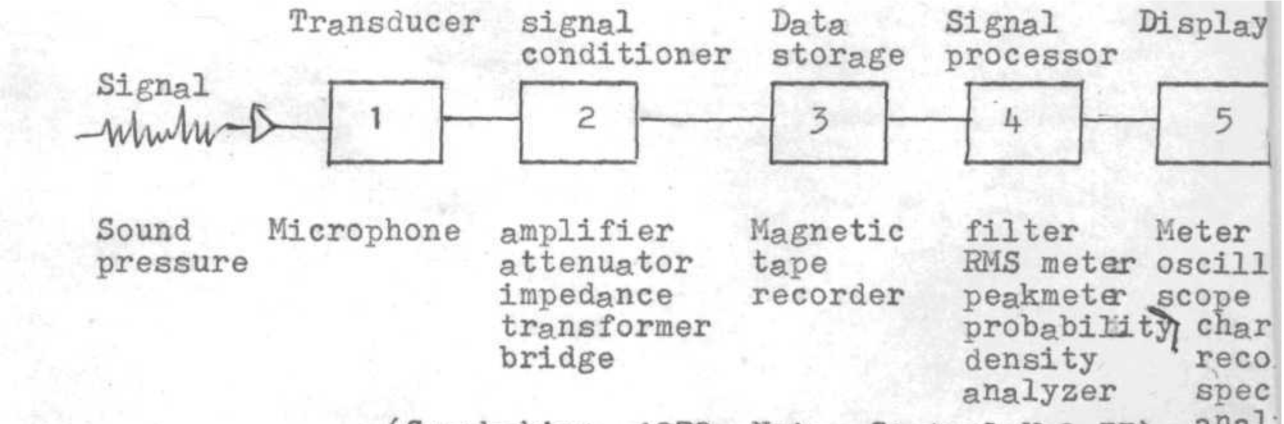
In connection with the above mentioned factors, this manual is written for the people who wish to solve a noise control problems which is done mainly through noise measurement and analysis. The purpose of this manual is to provide guidance about the Various instruments and methodology involved in noise measurement and secondly, prior knowledge about the instrument and measurement methodologies aids the assessment to be made as accurately and objectively as possible.

Chapter -2

Instrumentation for Noise Measurement

This chapter deals with basic instruments used for the purpose of noise measurement. When ever measurements are made, the Round from the source is picked by the microphone which converts the acoustical signal into electrical signal. The electrical signal is small and hence it has to be amplified which is done through an amplifier - Now the amplified input passes through the weighting networks (A, B, C, or D) or an octave band filter set - the output from the filter is amplified again rectified and now the level is indicated on a meter - The value obtained on the meter is called level which is expressed in dB's (Fig. l)

An idealized instrumentation set up to illustrate this_situation_is_shown_in_Block_diagram Figure 1.



(Crockshire, 1972, Noise Control Vol.II)

A brief description of the diagram:-

In this set up, (1). the transducer consists of microphone. It converts the acoustic signal into electrical signal. (2) The signal conditioner modifies the signal such that it is easy to have direct read out on the meter. The signal conditioner may consist of any one of the following; amplifier, attenuator, impedance transformer or bridge - depending upon the noise characteristics a signal, conditioner is then used to either amplify, attenuate, or transform the signal. Next is the (3) data storage - is utilized based on the purpose of measurement - for eg. whenever a detailed noise analysis should be made to determine the spectral characteristics, the noise signal is taped and analyzed in the laboratory.(4) Signal processor is used depending upon the type of signal (noise) - It consists of filters, RMS meter, peak meter, etc. The other instrument shown in the diagram supplement the sound level measurement. (5) The display unit may consist of -

(a) Graphic level recorder - an automatic recordings of level during the noise measurement may be done by graphic level recorder - this gives a graphic representation of the sound pressure level as a function of time.

(b) Oscilloscope: gives the visual representation of the on going noise signal in their wave forms.

(c) Spectrum analyzer is used to measure the band pressure level in different frequency bands.

Although these components of a measuring system are shown as discrete units, a number of their functions can be combined into one instrument. For eg. a sound level meter is normally equipped with particular type of microphone. More detailed discription of the functions and characteristics of these instruments are given in the later part of this chapter.

A. 1.1. Microphone characteristics: The microphone used for the measurement purpose should have the following-

1) sensitivity.
2) variation of response with frequency and the ambient conditions.
3) directional properties.
4) non linear distortion.
5) Impedance.

The relative importance of each of these characteristics depends on the requirements of the measurement system.

l) Sensitivity:-The sensitivity of the microphone is the ratio of the electrical output to the acoustic input. The electric output is commonly given in volts and the acoustic input in terms of sound pressure.

It is clear that as the sound pressure amplitude increases, the output voltage amplitude also increases. The ratio outputvoltage to the input pressure is called the sensitivity or Mp.

ie.Mp=E/p.

For very low sound pressure amplitude, noise will exceed the voltage generated by the microphone and this forms the lower limit of measurements. At very high sound pressure amplitude, the voltage generated is not proportional to the diaphragm displacement. Nonlinearity thus sets an upper limit for the usage of the microphone When the pressure amplitude exceeds the nonliaearity, the damage to microphone will occur. Hence the microphone should be used with in two limits - ie range between the upper limit and lower limit is called the dynamic range.

(2) Variation of response with frequency and ambient conditions:

Practically, most of the microphones are constructed to work under normal temperature, humidity and atmospheric pressure; Any deviation from the normal temperature, humidity and atmosphere causes marked changes in the response of a microphone.

When the microphone is used at the temperature that is considerably different from the ordinary room temperature, the temperature coefficient of the microphone should be used; this coefficient is given by the particular company.

The change of response with respect to humidity, usually less than 0.5dB between 0-90% relative humidity is indicative of stability of the microphone(Lipscomb, Kent Williams 1978).

Atmospheric pressure variations that occur near the sea level do not generally affect response of the microphone significantly; changes in the atmospheric pressure as great as those experienced by air craft can cause significant changes; thus while measuring air craft noise, changes in atmospheric pressure should be considered.

(3) Directional Properties:-

The variation in response with respect to the direction of arrival of sound is called the directional pattern: Based on these, the microphones are classified as directional and omni directional microphone. The directional microphone is the one which responds more to the sounds arriving from the particular direction than the other direction.

Some microphone responds equally to the sounds coming from any directions- this type microphone is said to have omni directionality or non-directionality.

This directivity pattern is frequency dependent ie. when ever the frequency of sound signal is below 2000 Hz , the microphone responds essentially for all directions of sound incidence. But at higher frequencies the size of any microphone becomes comparable to the wave length of the sound and as a result on the directivity also.

The directivity pattern is important under conditions 1) measurement made in a free field or nearly free field conditions and 2) measurement made close to the noise source.

Basic types of directivity pattern of microphone response:

Free Field response:

- when the direction of travel of the wave of the sound is perpendicular to the diaphragm the response is called the Perpendicular incidence response and the direction is labelled 0 .
- Grazing incidence response is obtained when the direction of sound wave is parallel to the face of the diaphragm and is represented as 90^o.
- random incidence response is the average response of the microphone for sound that strikes the diaphragm with all angles of incidence.

- When a microphone is placed on a small chamber, the distribution of sound pressure on the microphone diaphragm is different from the distribution that occurs in a free field. This is called the pressure response of the microphone

Random response is used for measurement.

1. Which are made at a distance from a source in a reverberant or a semireververant room.
2. When the direction of arrival of sound is not well defined.
3. When the source of the sound and the microphone change in relative orientation.

4. Nonlinear distortion: As the amplitude of sound pressure is increased the output of a microphone increases correspondingly. At sufficiently high level, the microphone output level will no longer increase proportionately to the sound pressure and it is then said to be nonlinear.

The allowable nonlinearity in noise measurement is' 4 to 5% of harmonic distortion; For high sound used for measurements have less than 1% distortion of all sound levels upto 120dB.

The nonlinearity may lead to the damage of the microphone; so it is important to know the damage point when exposed to noise of very high intensity levels.

5. **Impedance**: Impedance characteristics of a microphone is of significance, 1) in determining how a microphone should be connected to a given instrument and 2) to find out the effect of such connection on the overall output. For eg: A microphone with high impedance when connected to the instrument with low, impedance would cause large reduction in sensitivity. 3) The impedance of a microphone varies over the normal frequency range so that care must be taken that the connection does not introduce an unwanted change in response Vs frequency.' Impedance mismatch should be avoided.

The other factors like transient response, disturbing effect, size, ruggedness and inherent noise level should also be considered.

A 1.2 Types of microphone:-

It is impractical to construct a microphone with all characteristics. Thus we have different types of microphone that would fulfill certain requirement more. As we all know the microphone is a crucial part of any measuring and several different types are currently available. The three major types of microphone that are currently available are:-

a) pressure microphone.
b) Velocity or pressure gradient microphone and
c) Microphones that are the combination of the above two classes.

Table 1 (below) indicate the type and classes of microphone and their characteristics in terms of the directivity:

Type of mic	Mic that belongs to the class	Type of response pattern
(a) Pressure microphone	Carbon microphone condensor microphone Dynamic microphone Piezo electric microphone	Non directional Non directional Non directional Non directional
(b) Velocity microphone	Ribbon microphone	Directional
(c) Pressure & Velocity microphone	Not available	Directional

(a) Pressure microphones:-

When the sound waves strikes the diaphragm of the microphone, it moves in wards and out wards causing pressure variations, thus in the pressure operated microphone, the electrical output is due to the pressure variation; In this microphone, the pressure acting on the diaphragm is equal on all sides and hence they are non-directional.

(b) Velocity microphone / Pressure gradient Microphone:

The velocity microphone is also called as pressure gradient microphone. As we have stated earlier, the pressure variations are caused by the movement of the diaphragm; Now this pressure variation causes a to and for movement of the air-consequently high pressure is caused during compression of layers and low pressure at rarefaction - the electrical output is thus dependent upon the periodic pressure variation and not on the pressure. This sort of microphone that works on periodic pressure variation/periodic velocity variation is called the velocity microphone. The velocity microphone responds to only to sounds coming along its axis as its action depends upon the ribbon(diaphragm) which moves to and fro. Thus these velocity microphone exhibit directional properties.

Though various types of microphones are available the most commonly used microphone is the pressure microphone, for reasons such as:

- They are used for calibration of the audiometer and the ear-phone.
- They have the most uniform frequency response when closely coupled to the source.
- They are used for the noise measurement with a moving sound source.

When the measurement is made in a reverberation room, a pressure microphone is often used due to its non directionality (Williams - 1978).

Under this category, the most commonly used microphone in the noise measurement are- condensor,electret and piezo electric and hence the description are given only for these microphone.

A. 2.1 Condensor microphone:

In the condensor microphone the incident pressure wave causes the microphone to deflect slightly and consequently the diaphragm moves along the back plata; this Causes change in the capacitance between the diaphragm and a flat electrode positioned parallel to and behind the diaphragm. Thus the acoustic energy is converted in terms of change in capacitance and this has to be converted to electrical energy, there are several methods through which the change in capacitance may be converted to an electrical signal. They are: 1)maintain or constant charge on the Capacitor by a polarizing voltage. 2) Using the microphone capacitance to establish the frequency of the oscillator so that the frequency is modulated by the capacitance.

Types of condensor microphone:

The widest frequency range for the pressure response of a condensor microphone is obtained when the diaphragm is critically damped. The high frequency range for the pressure response can be extended by simply dicreasing the size of the diaphragm. In other words the smaller diameters generally provide higher limits for the frequency and the dynamic ranges at the expense of a lower sensitivity. Thus based on this concept, the condensor microphone are of different sizes with respect to the diameter, for eg. 1 inch, ½ inch, ¼ inch and 1/8 inch. Figure 2 gives the visual representation about the frequency response characteristics of the different size microphone.

Figure - 2

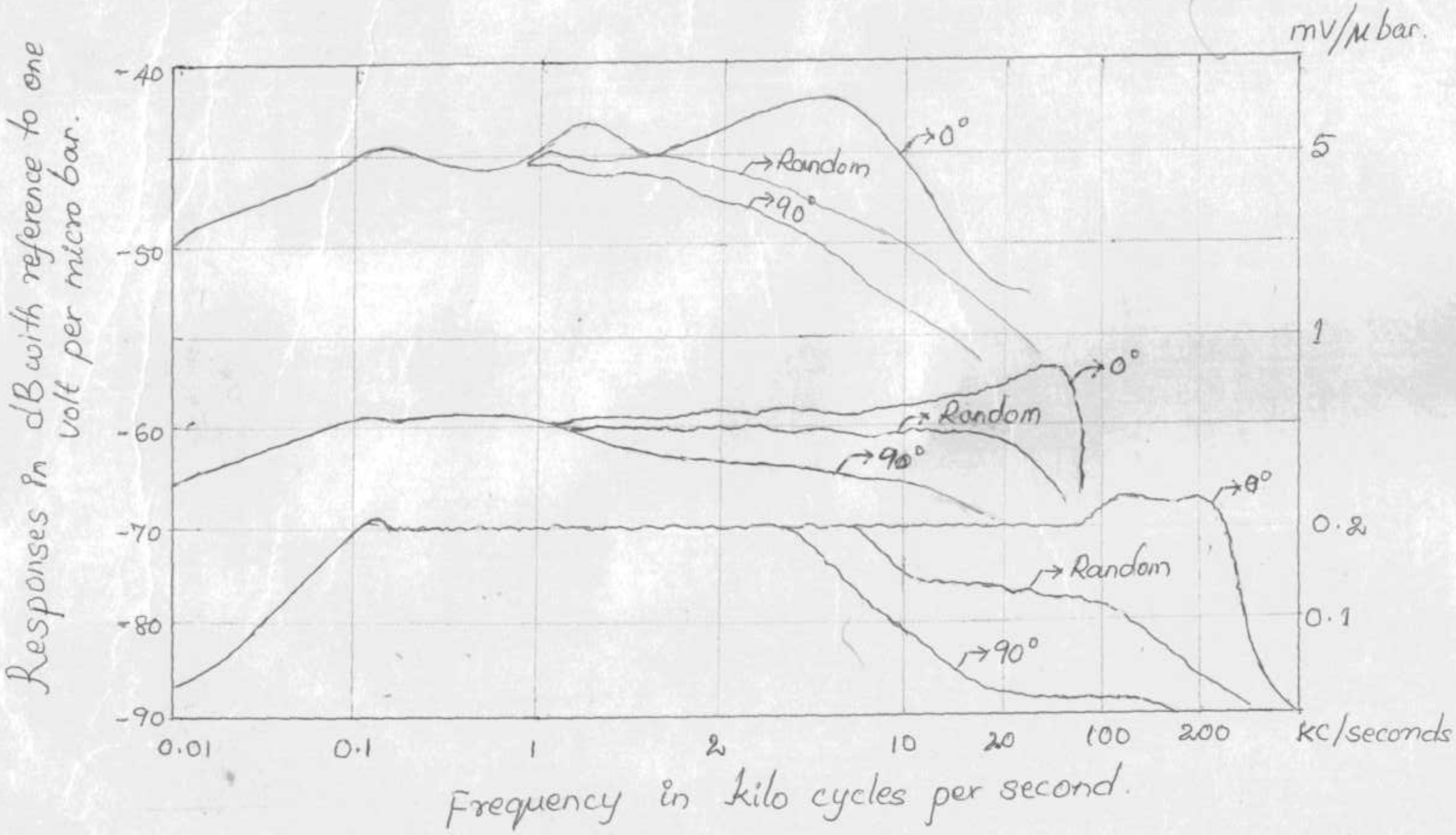


Fig.(2) THE FREQUENCY RESPONSE OF THE MICROPHONE IN TERMS OF DIRECTIVITY FOR VARIOUS SIZES (DIAMETER) OF THE MICROPHONE IN FREE FIELD CONDITION

From the figure(2) one can deduce that the smaller the diameter, the higher the frequency range- ie ¼ "has a frequency range upto 200Kc/sec compared to ½ and 1" microphones.

Advantages:

1) Since they are small, condensor microphone create minimum disturbance in the sound field in which they are kept especially at high frequencies.

2) The condensor microphone gives a wide frequency range depending upon the size of diaphragm as stated earlier. Thus the existance of the condensor with varying sizes of diaphragm helps in the measurement over wide frequency range.

3) Condensor microphone have excellent longterm stability and a very uniform sensitivity as a function of temperature ie. 0.008 dB/^{o}C between -50°C and 150^{o}C.

4) They are resistant to changes in humidity usually less than O.5dB between 0 and 90% relative humidity.

5) The change with respect to the effect of ambient pressure change-0.0003dB/mm Hg is indicative of its suitability for extended long term monitoring situations.

6) The condensor microphone have low sensitivity to the mechanical vibrations of the unit as a whole.

7) These condensor microphones can be easily calibrated.

Disadvantages

1) It has low capacitance which results in high impedance particularly at low frequencies. Hence the output from the condensor microphone cannot be connected directly to any measuring system with low impedance as it results in impedance mismatch.

2) The high impedance of a condensor microphone makes it susceptible to troubles from electrical leakage caused by the high humidity. This requires the microphone to be operated at sufficiently high temprature than ambient temprature so that no appreciable leak occurs.

3) The condensor microphone has a thin diaphragm which when exhibited to very high intensity may damage it.

4) The air leak from leakage path of the condensor microphone reduces the low frequency response of the microphone. In order to prevent this the hole is vented to the atmospheric pressure at the point of measurement.

5) The condensor microphone is sensitive to the moisture. At times condensation can appear as a result of rapidly moving the microphone from a cold to the warm environment. The condensation manifests itself in popping or noise.

A.2.2. Electret Microphpne:-

The condensor microphone is modified by Sessler and West (1963, 1966) - ie. self polarizing condensor ' microphone is called the electret microphone. Rather than operating with an air gap between the diaphragm and a parallel electrode, an electret microphone employs a solid dielectric stretched over a back plate . Because the dielectric material (electret foil) is prepolarized there is no need to supply the constant polarization voltage required in a condensor microphone. An electrical voltage is produced when the electret foil moves relative to the back plate as the result of an incident sound wave.

Advantages and Disadvantages of the electret microphone:

Significant advantages of the electret microphone are: i) elimination of the D.C bias voltage, 2) simple rugged construction and 3) large capacitance.

Electret microphone vary considerably in their long term stability and sensitivity as a function of temprature, for eg. their temprature coefficient could be 0.03 dB/^{0}C from 0° to 55^{0}C and sensitivity may vary by $\pm$ dB over an extended time period. As a result, there arenot as well suited as condensor microphones to performing the measurements in an environment that experiences moderately large temprature variations. Electret microphone also differ some what from condensor microphone in their frequency response ie their linear response at high frequency is considerably less than a condensor microphone with the same diameter diaphragm. However, the electret microphone does not suffer as significant a loss in sensitivity as the diaphragm size is reduced.

A.2.3. Piezo Electric Microphone:-

The basic piezo electric microphone consists of the following- A diaphragm is used as a force collector. The piezo electric material is placed behind the diaphragm so that force excerted on the diaphragm strains the crystal and consequently results in the production of voltage which is proportional to the sound pressure level by the piezo electric action.

Advantages:-

1. This type of construction is more rugged than either an electret or condensor microphone because the piezo electric material behind the diaphragm and tends to support it.
2. It has a high capacitance and hence no need for the preamplification of the output signal.
3. The performance of the microphone is unaffected by the changes in the temprature and the effect of the atmospheric pressure.

4. These microphones have a wide dynamic range.
5. These microphones are cheaper comparatively.

Disadvantages:-

1) The piezo electric microphone has a very low acoustic output.
2) These microphones are highly subjected to vibration changes.
3) When Rochelle salt is used, the serious limitation is the irreversible change at temprature above 55.6 C.
4) Exposure of unprotected Rochelle salt results in the distruction of the crystal due to the humidity changes.
5) ADP used in this sort of microphone is not as active as the Rochelle salt and also it renders in the stability of the microphone over a long period of time.

Having considered the different type of microphone, one can conclude that an ideal microphone should have the following characteristics:-

a) microphone should Cause negligible diffraction of the sound field (its dimension should be small compared with the smallest wave length of interest.
b) It should have high acoustic impedance compared with the fluid so that little energy is extracted.
c) It should have low electrical noise.
d) Its output should be independent of temprature

humidity, magnetic fields, static pressure and wind velocity and it should be rugged and stable with time.

e) Its sensitivity should be independent of the sound pressure level.

f) Its frequency response should be flat ie. if the output of a microphone shows only small variations in amplitude between its upper and lower frequency limits, it is said to have flat frequency response.

g) It should introduce a Zero phase shift between the sound pressure and the electrical output signal.

B. Preamplifier:-

As stated earlier, the electrical output of the microphone cannot be directly connected to the measuring system. The low internal capacitance of microphone requires a high input impedance in the succeeding stages in order to ensure a minimum loss in sensitivity due to loading. For the purpose of the impedance matching a preamplifier with High impedance is thus introduced, between the transducer and the measuring system (Sound Level Meter - SLM) - the cathode follower is used in serving this purpose of preamplification.

In a basic measurement procedure, the noise from a source is picked up by the microphone and preamplification is done if required - At this stage the sound signal only is collected. No information regarding its intensity is known. To obtain the correct information about the intensity of the signal, a measuring system is used - called the sound level or sound pressure level meter.

C. Sound Level Meter:-

The sound level meter is the instrument used for measuring sound pressure. The sound level meter consists of the following elements:

1) a transducer (microphone) to sense the sound wave pressure and convert pressure fluctuations into an electrical voltage.

2) an input amplifier to raise the electrical signal to a usable level.

3) a calibrated attenuator to adjust the amplification to a value appropriate to the sound level being measured,

4) an indicating instrument (meter) to display the measured level.

5) Weighting networks to modify the frequency characteristics of the instruments response.

6) an output amplifier and calibrated output attenuator.

7) an output jack to carry the signal to additional instrumentation for further analysis.

8) Portable external filters may be added to the basic system. (Lipscomb 1978).

Figure - 3

Block Diagram of the Sound Level Meter

As indicated in the fig 3 the SLM unit is described here with respect to its components.

Microphone converts the sound signal into identical electrical signal- the output of electrical signal is quite small, hence it must be amplified before it can be read on the meter. After the first amplifier, the signal may pass through a weighting network (A)B,C,D). It is however worth while to note that all of the weighting networks do not have equal utility.

SLM and the Weighting networks:-

The frequency response characteristics of a sound level meter is controlled by the weighting networks -

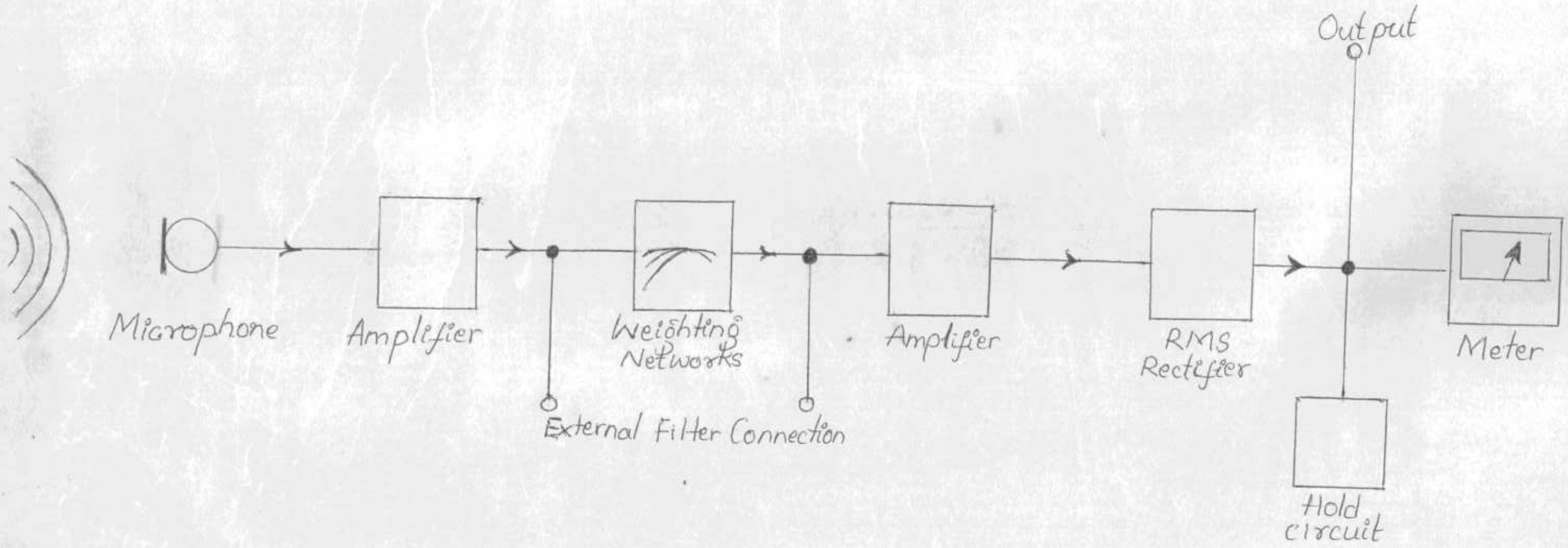


Fig.(3) THE SOUND LEVEL METER

This simple electrical weighting networks of SLM provide a degree of frequency analysis of sounds. They give certain weight or importance to sounds in certain frequency range than in other frequency ranges.

Originally these networks designed to approximate the loudness level sensitivity of the human ear for puretones. Although the network responses corresponds to particular loudness contours for puretones (Fletcher and Munson), they do not give the loudness level of the complex tones. Hence the weighted sound levels are expressed in decibels and not in phons. Thus the weighting networks A,B,C corresponds to the loudness contours in the following way: The A network approximates the equal loudness contour at low SPL's, the B network at medium SPL's and the C network at the high levels. Figure 4 (below) shows the frequency response characteristics of the SLM weighting networks (USA Std. 1961).

Figure -4

From B & K
Manual (1972)

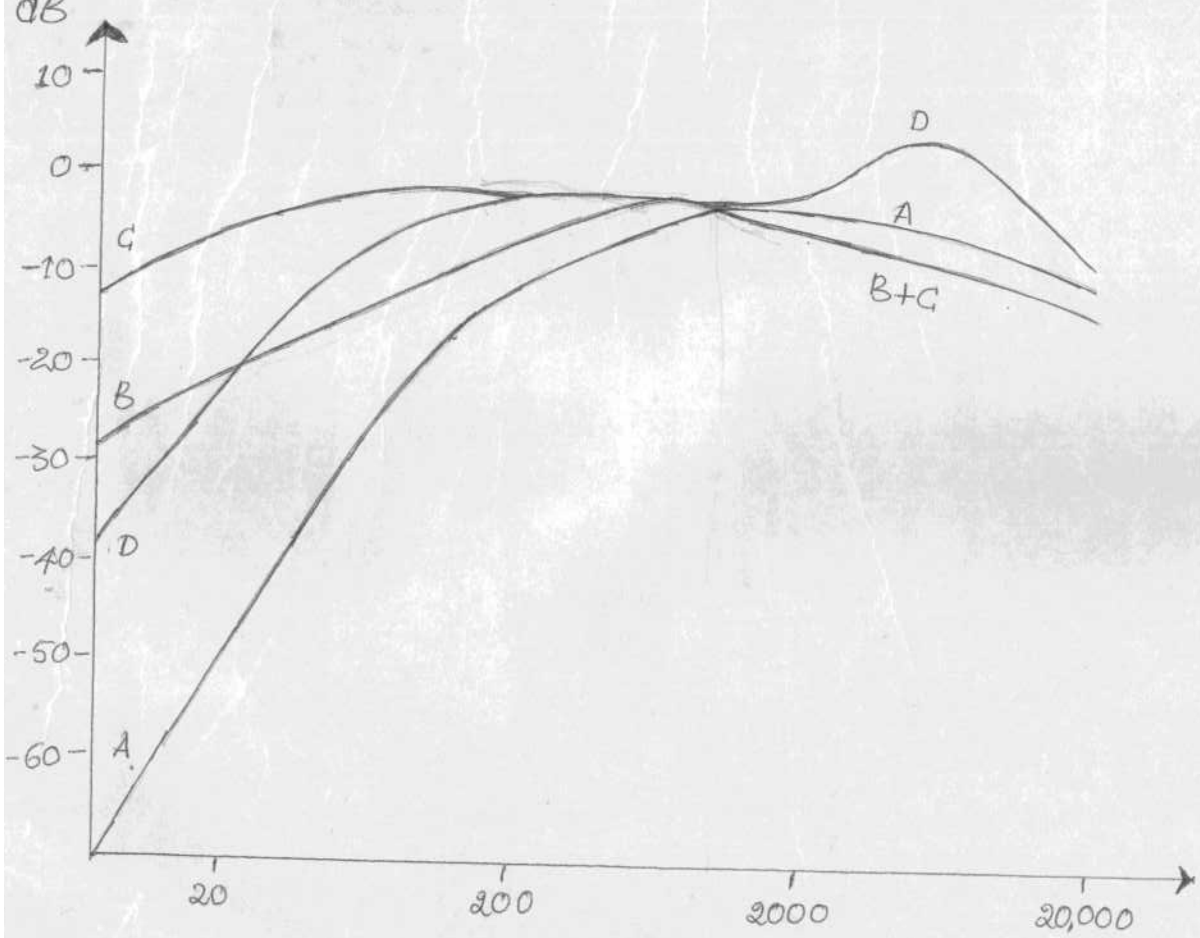


Fig (4)

From B$K manual (1972)

A weighting networks:-

The most commonly used weighting networks for both indoor and out door noise measurement is the A weighting networks. The A. weithing networks approximates the 40 dB phon contour. From fig 4 it is illustrated that the frequency response of the A-weighting network decrease with the decreasing frequency.

The A weighted networks are used 1. to specify the Federal standards for daily occupational noise limits. 2. environmental noise intrusions are evaluated in the light of A weighting networks.

The U.S. environmental protection agency (EPA) (1974) expressed its reason for selecting the A weighted sound level as the appropriate measure of environmental noise: "The A weighting, standardized in the current sound level meter specifications has been widely used for the transportation and community noise description. For many types of noises the A weighted sound level has been found to correlate as well with the human response as more complex measures such as calculated perceived noise level or the loudness level derived from the spectral analyses.

In order to use available standardized instrumentation for direct measurement the A frequency weighting is only suitable choice at this time." (Lips comb 1978).

The above two criteria depict the importance of A weighting in the sound level measurement. Even though a particular measurement situation may dictate a different procedure, generally it can be that the A - weighting response will give the required information.

B Weighted networks:-

The B weighting approximates the 70 dB contour in the loudness contour curve. The B weighting is rarely if ever used.

C weighted network:-

This approximates a 100 dB contour curve and this has a flat frequency response. This weighting network is generally assumed to be a good approximation to a linear response or the sound pressure level. This net work is used occassionally when the low frequenc/energy content of the source is being overly discriminated against by the low frequency roll-off of the A-weighted filter, ie. certain annoying noise sources with a large percentage of their energy below 200 - 250Hz, may have a misleading low A weighted sound levels - For this type of source (for eg. diesel loco motive, etc.) a C weighted sound level is informative.

D Weighted network:-

These networks have yet to gain complete universal acceptance. They are designed primarily to yield a single number subjective measure of air craft noise, Cunniff (1977) mentioned two facts regarding the D weighting networks which must always be kept in mind:-

1. It was developed for noise measurement around air port only.
2. It is not adopted by any inter national standard group as mentioned earlier.

Although it is available on some sound level meters, the D weighting network is currently used only rarely and for very specific measurement applications.

The measurements obtained by using A weighted net works are represented as L_A Similarly B, C, and D network readings may be presented as L_B, L_C and L_D respectively. Usually a difference in readings of level with the C weighting and A weighting network (L_C - L_A) in dB is called Harmonic index. This values gives some basic idea of the frequency distribution of the noise; for eg. if A weighted sound level (L_A) is less than C weighted sound level (L_C), it may be said that the source contains a large amount of low frequency energy, provided the other physical conditions being the same.

An alternative to the network is an octave or third octave filter which may be attached externally. After additional amplification (2nd stage), the signal will now be high enough to drive the meter , (Details about indicating can be got from the chapter on precautions of measurement) after its value has been determined in the RMS detector. The value read on the meter is the sound level in dB.

What is RMS? EMS means root mean square which is a special kind of mathematical average value. It is of importance in sound measurements because the RMS value is directly related to the amount of energy in the sound signal.

In summary, the basic characteristics of the SLM is thus as follows:-

The block diagrams names each characteristics- defines it and states the ideal response of the sound level meter.

The 'acoustical response' that is response Vs. angle of incidence of sound wave is ideally such that the instrument is equally responsive to waves arriving from all direction. This characteristics is mainly controlled by the size and the shape of the microphone and the instrument case.

The 'Weighting response' is ideally suph that there is no error in the approximation to the perceived response Vs. frequency. It is controlled by the electrical circuits that include amplifiers, attenuators and weighting networks.

The detection response is dependent upon the pressure time relation or wave form of the sound signal and must be controlled such that the instruments reading is proportional to the mean square pressure level of the signal reaching the detector circuits. It is controlled by the electrical circuits which includes squaring and averaging components and by the dynamic response of the indicating meter.

The sound level meter are of different types (Manjula, 1979).

1. Precision sound level meters - with microphone and weighting networks.
2. Sound level meter with octave filter set type.
3* Sound level meter with its output terminals allowing the noise signal to be recorded or monitored on an external recording device if required eg. level recorder.
4. Impulse precision sound level meter.

According to IEC standard, the four types of sound level meters are: as given in the table II.

Table II indicating the types of SLM (IEC std. Kundett Inter Noise 77)

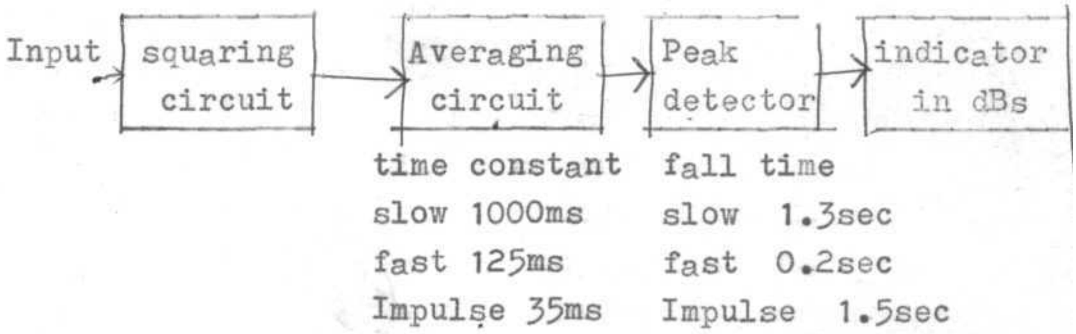
Sound level type	microphone used	Description	Application
0	½"	Standard	Laboratory reference standard
1	1"	Laboratory	Laboratory application and field use under closely contro-lled conditions
2	1"	General purpose	field applica-tions. .
3	1"	Survey	field noise surveys.

Impulse sound level meter:

While measuring impulse sounds like gunshot, impul sound level meter is required. The impulse sound level meter is based on the detection response as stated earl

Ordinarily the detector unit of the SLM consists o squaring output circuit, expotential average circuit and indicating meter. These 3 circuits follows the weighting network. Thus the signal from the weighting networks is squared and fed to an averaging circuit having an expotential response with specified time constant. The average result is displayed in dB. Expotentials response consists of 1. fast at 12.5ms and 2. slow at 1 seconds.

The impulse sound level meter differs from the ordinary detector unit of the SLM in that a peak detector with controlled fall time is introduced into the chain between the averaging circuit and the indicator. (Fig 5)



The main purpose of the peak detector is to hold the signal of short duration for sufficient duration to allow the indicator to respond and to be read. Thus the peak detector in the impulse sound level meter serv the following purposes:

1) To measure a short duration signal that occurs only once for eg. a vehicle passing by.

2) To describe the effects of loudness, roughness and noisiness observed on sound with low periodicity.

3) To measure the sounds of impulse character.

D. Frequency Analyzer:-

When the sound to be measured is complex consisting of a number of tones, or having continous spectrum the single value obtained from a sound level meter reading often is not sufficient for evaluating understanding the problem; It may be necessary to determine the sound pressure distribution according to frequency. It is true that by the judicious use of weightigg network in a sound level meter, one Can know something about the frequency component, but this knowledge is very qualitative and crude. Other than being informative in a crude sense, this type of analysis is unacceptable when more detailed information is required about the special characteristics of the sound source. Thus the electric filters have been developed for use in conjunction with SLM to provide a more accurate assessment of the noise source in terms of its frequency content or distribution. The instrument used for this purpose is called the spectrum analyzer.

In general, there are 3 types of noise analyzers:

1. Octave, half octave and third octave band widths,
2. Constant band width and
3. Constant percentage narrow band (Jones, 1967).

D.1. Octave band analyzers:-

The most practical widely used analyzer for industrial noise studies is the octave band analyzer. As indicated by the name, the upper cut off frequency is twice the lower cut off frequency. For a half octave analyzer, the upper cut off frequency is/2 times the lower and for one third octave band analyzers the ratio is 3 : 2. A commonly used set of octave pass bands in. commercial equipment is 20 to 75, 75 to 150, 150 to 300, 300 to 600, 600 to 1200, 1200 to 2400, 2400 to 4800 and in excess 4800Hz.

This analyzer 1. provides sufficient data on industrial noise to evaluate its physiologic significance; 2. to provide a basis for noise control. The major advantage of this octave band analyzer being the small number of bands makes it possible to perform an analysis in a reasonable length of time and also the band are wide enough to reduce tha problem of transient components affecting the stability of the meter.

Constant band width analyser:

This instrument has a fixed band width that is a specific number of cycles wide. Common band widths range between 5 and 200Hz. Because of the transient . nature of industrial noise and the narrow band width of the analyzer, this instrument is rarely used in industrial noise studies.

The constant band width analyzers are preferable in acoustic measurement for the following reasons:

1+ Slight instability in noise producing machinary mostly produce a constant percentage type frequency deviation rather than constant absolute type, where by measurement errors introduced by such instabilities are basically the same over the complete range of measurement.

2. The ear responds to sound in much the same way as a constant percentage band widths analyzer having a band width of about 1/3 octave.

Constant percentage band width analyzer

Its band width is a fixed percentage of the mid band frequency. Thus for the low frequency the band width will cover a wider range of frequencies. This instrument has the same limitations as the constant band width analyzer, but it can be used for noise control problems.

Among the three types of analyzer the most commonly used one is the octave band analysis. The other analyzer available are the Band rejection filter analyzer and the impact noise analyzer.

Band Rejection filter analyzer is made use of in the distortion or noise meter. It is most used widely used to test the electronic components for distortion, hum and noise. It can also serve to measure the acoustical distortion.

E. Data Storage - Magnetic Tape Recorder:-

The magnetic tape recorder has become a very useful for the Noise (acoustic engineer both in research and in development.

The essential features of tape recorder (for noise measurements) are:-

- The recorder must be absolutely dependable so that there is no risk of losing data, because of the improper functioning.

- It should be having a flat frequency response that is approximately equal or greater than that of SLM's.

- It must have an amplifier with high gain and high input impedance.

- Simultaneous play back system should be there.

The magnetic tape recorder can be used to perform the following functions in the field of noise measurements (Peterson, 1967).

a) To keep reproducible records of progressive changes in a sound. These changes may be a result of the application of successive noise control procedures; for eg-

b) To record a noise for analysis by a number of techniques, when the particular approach to be used is not at first obvious and it is not convenient to use the original source repeatedly.

c) To record the sound waves that varies with time; samples can then be selected from the. recording for analysis to obtain the change in spectrum as a function of time.

d) To record noise in the field for detailed study in the laboratory, where complex instrumentation systems can be used.

e) To record a short duration sound, which can their be played back repetitively to simplify analysis.

f) To monitor over long periods to catch intermittent sounds, which their can be separated for analysis.

g) To record noise that are erratic or intermittent possibly by binaural techniques, to aid in tracking down sources.

h) To record a noise to permit a 2:1 frequency translation for convenience in analysis.

i) To record a transient noise in order to change the time scale by a factor of 2 or to invert the time scale for ease of graphic recording.

j) To permit subjective or objective comparison among sounds recorded at different times.

k) To permit observation of the subjective effects of altering a signal for eg: by filtering, clipping or adding noise.

l) As a measurement system with a recorded signal as the source and a recording channel as the detector, for example, in the measurement of reverberation characteristies.

Although high quality magnetic tape recorders are satisfactores for many applications in the noise control problems, their characteristics are not ideal. Some of the limitations are considered here under the following headings, a) response Vs frequency, b) flutter, c)inherent noise and hUm. d)distortion e)print through.

a) Response Vs frequency: The uniformity of response Vs frequency for a tape recorder is determined by tape speed, magnetic-gap length, gap alighment, nature of head and tape equalization and amplifier response. Since it is easier to maintain good high frequency response at the . higher tape speed, the higher speed is generally to be preferred.

b) Flutter:- The tape does not slide by the magnetic gaps at an absolutely uniform speed and the reproduced signal is then modified by fluctuations in the relative time scale; unless such fluctuations are very small, they are audible when certain types of sounds are reproduced. For general application to noise recordings, therefore, only the better quality tape recorders should be used; Then it is possible to obtain and maintain over long periods flutter values less than about ¼%, which is ordinarily satisfactory; when tape recorders are used in the field, it is sometimes necessary to use a storage battery and a converter to supply power to the recorder;

c) Inherent noise and hum: Noise level in a high quality magnetic tape recorder is satisfactory for most noise recording applications.

d) Distortions:- Distortion level sets an upper limit and the inherent noise level set a lower limit to the range of signal levels that can be handled satisfactorily. This range is sometimes called dynamic range and in a high quality tape recorder, it is 50dB or more, which is adequate for most noise recording purposes;

e) Print, through: Adjacent turns on a reel of recorded tape may affect each other by reason of the magnetized state of the properties, some transfer of recording may occur so that 'echoes' appear. Echoes of both positive and negetive delay can obviously occur, and the process by which this echoes are produced is called the print through. These echoes can ordinarily be held to less than the inherent noise if the recorded level is kept below the distortion point provided the tape is not exposed to the magnetic field and also to high temperatures.

F. Display unit or recorder: Sound level meters and the measuring amplifier used in noise measurements have indicating meters from which steady noise levels can be read directly. Thus the information available is not subjected for future use and comparison. Moreover, the noise emitted from the traffic noise and the air craft fly overs etc, tend to change with time; Hence the single measurement value of this noise is not adequate and it becomes often advantageous to have a record of time history. The above criteria demands an automatic recording of the data which can be achieved by one of the following. Graphic level recorder / oscilloscope.

F.1. Graphic level recorder:-

This instrument is designed to convert sound signal input to static sound pressure indication on a time basis. It is used to record the measured frequency spectrum directly on pre-printed frequency calibrated recording Paper. The graphic level recorder produces a permanent chart record of the level of an applied signal at frequencies as low as 7Hz. For the noise and vibration measurements, the output from a SPL meter / vibration meter or analyzer is fed to the graphic level recorder which gives the graphical relationship of the signal with respect to frequency as a function of time.

The Graphic Level Recorder can be used to record the sounds levels over periods of time of airport flyover noise, near high ways/residences and also it is used in the calculation of the reverberation time.

The graphic level recorder, depending upon the instrument to which it is coupled, gives the particular information concerning the noise under measurement. Thus the graphic Level recorder may have the following combinations.

- The graphic level recorder connected to the output of Sound level meters records the Sound pressure level as a function of time.
- The combination of graphic level recorder and the beat frequency oscillator yields the frequency response characteristics ideal for plotting frequency characteristics of analyzers, weighting networks, microphones etc.,
- The graphic level Recorder used with an analyzer records the frequency spectrum of the noise (amplitude Vs frequency).

F.2. <u>Oscilloscope</u>:

When the signal concerned is of too short duration, the graphic level recorder may not be quick enough to document the event. In such a case the need for the Oscilloscope is emphasized as a means of observing the waveform of an acoustic signal from a SLM.

In the noise measurement procedure, an oscilloscope is used 1) to find out the temporal pattern of noise. 2) to determine the noise level from the voltage (represented on Y axis) and finally to understand the wave form pattern of noise.

G. Noise Dosimeter:-

Industrial noise Can be continuously or intermittently distributed and can occur as a steady state, fluctuant or as impulse noise. Measurement of the occupational noise should include both A weighting and measurement of total energy during the day. Ordinarily sound level meter indicating the momentary sound level are sufficient only at continuous steady state noise. . When the sound levels Vary, noise dosimeter must be used which are capable of continuous registration and integration of the sound energy from which the equivalent sound level Leq can be calculated.

Rosenblith and Stevens (1974) dilineated three crucial factors in the development of a rationale hearing damage risk criterion. 1. spectral distribution of sound/noise, 2. temporal pattern of exposure and 3. acceptable level of improvement of hearing - these criteria laid the foundation of audio dosi metry.

Description of Dosimeter:-

The dosimeter was designed to successively accumulate a weighted sound energy over durations of 10 seconds. The weighting function was essentially flat from 500Hz to 1000Hz; Beyond l000Hz the weighting function rose at the rate of 3dB/0ctave until the upper cut off frequency was 500Hz; A damage risk criterion could be formulated in terms of data gathered with such a meter , The newly enacted federal legislation directed toward noise exposure control has stimulated interest in the use of audio dosemeter as monitoring device;

Basically three different types of sound level dosemeters are used: They are

1. Stationary noise dosemeter.
2. Earborne dosemeter.
3. Focket size personal noise dosemeter.

The first was described earlier; the latter will be discussed here in detail.

(One of the first personal pocket borne dosemeter described by Lagerholm & Foremalum(1967,1970) and later on several portable pocket dosimeter have emerged on the market.

In some of the major investigations which have contributed to the knowledge of the relationship between the occupational noise and hearing damage, the noise measurement are made with the microphone kept close to the worker's ear; (Krylin 1960,Horngren et al 1971).

Thus, later models of pocket borne noise dose meters have been devised to permit measurements with microphone close to the ear;

It is, however, difficult to measure occupational noise as well as to analyze the importance of the different Variables of the measured such as frequency, intensity and exposure time with respect to hearing damage. Thus, for example, when using the SLM, errors in reading can occur depending on the response time for the meter if the sound contains impulse (Wilkerson 1974).

This problem of measuring noise correctly attends the use of dosi meter (Martin 1974).

Ear Bourne Sound level dosimeter:-

Commercially available pocket bourne dosimeters record the total energy dose, It is not possible to determine whether the noise recorded has been of moderate level and of long duration or of short duration, with a high level; Here the earborne sound level dosimeter is described which measures the time the noise exceeds the preset levels.

The sound that reaches the ceramic microphone is transformed into an electrical signal which is proportional to the sound pressure. The microphone has a flat frequency response upto 10kHz; close to the microphone is the impedance transformer to transform the high ohmic signal into a signal less sensitive to disturbances;

According to international recommendations, the signal is A filtered, with the resistors R_1 and R_2, the amplification can be adjusted in the subsequent operational amplifier.

The amplitude of the signal is felt by the level detectors. When the amplitude exceeds the preset levels of the level detector, the light emitting diode is switched on and remains on with constant light intensity as long as the amplitude of the signal is high enough.

When the input signal U°_1 is changed by 0.65mV, it causes a change in the voltage across the diode U which is about 80% of the voltage step. The 0.65mV shift corresponds to a change in input sound level of about 0.2 dB at 80 dBSPL and 0.1 dB at 100 dB SPL.

The light from the light emitting diode darkens a & spot with a diameter of 2mm on a photo-graphic film. For the total system the response time is determined by the microphone and the weighting network (A). This means that the system can easily handle impulse sound with a duration down to 1ms. Both the diode and the film are enclosed in a casette.

The darkness of the spot on the film is a measure of the time of amplitude has exceeded the preset levels.

The dosimeter can be miniaturized and the complete device will then have the same size as that of the hearing aid and can be placed in the same way behind the ear with microphone at the entrance to the ear canal; Such a mini dosimeter includes only two preset level detectors.

Advantages of the SLD (Dosimeter):-

- Compared to the other sound measuring devices, the dosimeter enables sounds of different kinds, impulsive as well as continuous to be recorded for periods during which the pressure peak exceed the preset sound level.

The response time thus enables estimation of the distribution of sound energies peak sound pressures, the total equivalent sound level (L eq) in dB (A) as well as a rough estimation of the non-exposure time below 85 dB (A).

- The position of the microphone at the enterance of the ear canal makes the measurement of the actual SPL entering the ear Canal possible and thus eliminates the disadvantages of other measuring methods, concerning the evaluation of the baffling effect and the distance effects.

- This device facilitates the new possibilities of prospective studies of individual total daily exposure to all kinds of noise including impulse noise.
- It does not disturb the wearer.
- It does not weigh more than an earborne hearing aid.
- It gives values from which L eq and the mean SPL can be calculated.
- It can be worn under the earmuffs.

Accessories:–

1. Calibrator - a).Piston phone, b) sound level calibrator,

(a) Piston phone:- It consists of an air cavity one side of which couples tightly to the microphone and the other side of which is formed by two pistons driven by an electric motor; The alternating movement of the piston which varies the volume of the cavity is accurately known and,thus produces an accurate known alternation in the instantaneous pressure at the microphone diaphragm. The piston phone usually provides calibration at only one frequency (250Hz). The intensity of the sound is 124 dB. This high level allows correct calibration even in a very noisy surroundings.

(b) Sound Level Calibrator: It has a built in oscillator which produces a precisely known sound pressure level (114 dB) at five USASI preferred frequencies (125, 250, 1K, 2K).

2. **Noise Cone(Nose Cone):** It is a protection grid to reduce wind noise or also dynamically induced noise during out door measurement. It has a stream lined shape in order to give the least possible resistance; It also improves Omnidirectivity; used in ventilating ducts.

3. **Adaptors:** These are the electro acoustic actuators; They make it possible to use microphones with different diameter diaphragms namely ½", ¼ ", 1/8" with SLM and gives better frequency response and ominidirectivity.

4. **Random Incidence conect.or:** It makes precise measurements possible upto 10KHz on sounds having variable or random incidence.

5. **Wind Screen:** Of particular concern for outdoor measurement is the use of wind screen. The pressure fluctuations characterizing the sound wave are modified by the turbulence of air passing over the microphone diaphragm and suffering a velocity change and by the interference between the variations in the air pressure caused by the wind velocity changes and the turbulence. (Skode 1966). The influence of these factors may be reduced by covering the microphone diaphragm with a wind screen. The wind screen presents a large resistance to the wind itself but has a very small acoustic impedance.

result accurate acoustic measurements may be made under less than calm atmospheric conditions where direction is not of great concern. It is recommended that a windscreen be used for all outdoor measurement, and it is good practice to use them for indoor measurement since they protect the microphone cartridge from contaminants such as dust and dirt.

6. **Rain cover:** This has been designed in order to allow permanent out door installation of the microphone (eg. air field) even in the extreme weather conditions.

7. **Probe microphones:** Can be used for measurement of SPL inside the ear with ear protectors in intricate machinery and small ducts.

8. **De-humidifier:** It contains silica gel for the de-humidification of the microphone.

9. **Floor stand:** It is a tripod stand with height of about 50 to 140cm; It is used for supporting SLM during long term measurements and to eliminate the baffle effect of the body in the sound field;

10. **Rotating microphone boom:** For sound measurements in building acoustics to determine the diffused sound field.

11. **Extension corrector:** It is a flexible rod of 46cms and can be connected to the instrument in the place of

the microphone. This is used when remote control of the microphone is needed; especially.

(a) When the site of the sound field is too small to accomodate SL meter.

(b) When SL meter may disturb the field;

When the length of the extension connector is not enough, extension cable can be used.

12. Carrying Case: It is a compact case to enable the easy transportation of the sound level meter.

13. Turbulence screen: When an air blows by a microphon develops turbulence on the down stream side and cause fluctuations in ambient pressure which generates noise. Thus a turbulence screen is used which attenuates the noise thus produced by air turbulence. It is a tube with an axial silt covered with several layers of specially selected damping material, with stream lined nose cone in the front.

Advantages of having various accessories available depends upon the purpose of the measurements, the comple xity of the measurements and the environment in which the measurements are to be made.

This chapter deals briefly with various instruments generally used in noise measurement. The preceeding chapter gives the factors considered in selecting the instrument based upon purpose.

Chapter -3

Factors Considered in Choosing Instruments For Measurement

The purpose of this chapter is designed to show the experimenter how to select a particular instrument or combinations of instrument which best fits his requirements.

The first concern of ours in the field of noise measurement is the choice of microphone and hence it needs lots of emphasis.

The choice of Microphone: For most sound level measurements the microphone usually supplied with a sound level meter is well suited; However, for special applications, other types of microphones may prove more satisfactory especially under the conditions that are mentioned below; Thus when choosing a microphone for a specific purpose, one should consider, the following factors (Baranek):-

A. Expected properties of sound field.
   1. Free field or closed chamber;
   2. Density and wave velocity in the medium;
   3. Important range of sound pressure level;
   4. Important frequency range.

B. Desired precision of measurement.
   1. Sensitivity tolerance;
   2. Frequency distortion tolerance;

3. Phase distortion tolerance;
, 4. Non-linear distortion tolerance;
5. Self-noise tolerance.

C. Environmental conditions of measurement.

1. Background noise level;
2. Temprature;
3. Humidity;
4. Atmosphetic pressure;
5. Wind;
6. Strong electro magnetic fields;
7. Mechanical shock;
8. Weight and Space limitations.

The various factors thus should be considered in selecting the use of microphone are:

1. Low sound levels:- A microphone used to measure low sound levels must have low 'self-noise' and it must produce an output voltage sufficient to overide the circuit noise of the amplifier in the sound level meter. The type of microphone (Rochelle salt) supplied with the sound level meter is very good in this respect and the sound levels down to about 24 dB can be measured with it.

2. High Sound Levels:- Most microphones including Rochelle salt units, are not designed to operate with sound level meters at sound levels in excess of 140dB.

Above this level, crystal, magneto-striction, condensor or ceramic microphones may be employed. In sound fields of high levels, it is usually necessary to insulate the instrument used in conjunction with the microphone against the high levels to avoid microphonics. In order to reduce the effects of microphonics on the signal to noise ratio, it may be advantageous to introduce an additional attenuator (pad) in the circuit of sound level meter. The added pad may also make it possible to extend the use of the sound level meter, with the Ro chele salt microphone with which it is supplied, to higher levels.

3. Low frequency noise:- The ceramic and condensor type microphones are well suited for measuring low frequency noise. With either of these microphones, measurements may be made down to only a few Hz if special amplifiers are used. Most of the SLM with these microphones are designed tocover the frequency range to 20Hz and even at 10Hz the response is down only by 10 dB. The 20Hz limit is adequate for almost all types of low frequency noise.

4. High frequency noise:- The primary requirements on the microphone for accurate measurements on the microphone of high frequency sounds are small size and uniform frequency response at higher frequencies. For

measuring overall sound levels the high frequency characteristics is not so important because most machinery noises do not include strong high frequency components* If these noises are to be analyzed and accurate measurements of band pressure levels at high frequencies is important, the microphone performance must be good or accurately known. The condensor microphone system can be used for measurements upto 10,000Hz and measurements rarely need to be made on air borne sounds at frequencies higher than this.

5. Humidity:- Long exposure of any microphone to very high or very low humidity should be avoided. The ceramic microphones are, however, are not damaged by extremes of humidity.

Rochelle salt may be permanently damaged if exposed to excessively high humidities ie. above about 85%. For this reason the Rochelle salt crystals in microphone of this type are given a protective coating. Nevertheless it is wise to avoid unnecessary exposure. A Rochelle salt microphone should not be stored for long periods in a very dry atmosphere, since it can dry out.

Dynamic microphones are relatively unaffected by high humidities.

While a condensor microphone unit is not damaged by high humidities, its operation may be as a result of leakage across the condensor. For proper operation it is necessary (essential) that very little electrical leakage occur across the microphone. The exposed insulating surface in the microphone has been specially treated to maintain this low leakage even under conditions of high humidity - in spite of this precaution, the leakage may become excessive under some conditions. Then it may be advisable to keep the microphone at a temprature higher than the ambient temprature to reduce the leakage. The heat of the Vaccum tubes in the condensor microphone preamplifier is sometimes utilized, there fore, to keep the temprature of the microphone above that of the surroundings.

6. High Temperature:- The maximum temperature to which a Rochelle - Salt microphone can be exposed without permanent damage is 132°F (55.6°C); a safe upper limit is about 113°F (45°C). Therefore when sound level measurements are made at high temperatures, condensor, dynamic or ceramic microphones, some of which are designed to operate at temperatures as high as l67°F (75°C), are sometimes used. High temperatures tor extremely low temperatures) also affect the life of batteries in the sound level meters.

7. Varying temperature:- Allthough most noise measurements are made in indoors at average room temperature some measurement conditions expose the microphone to much higher or lower temperatures. When these conditions are encountered, it is essential to know the temperature limitations of the equipment.

The microphones are usually calibrated at room temperature. Actually, the microphone sensitivity varies with temperature, although under normal circumstances this variation may be negligible. When a microphone is connected directly to a sound level meter the variation is relatively small. However when the microphone is connected by means of a long cable, the Variations is quite significant. This variation is the result of the change of thecapacity of the crystal with temperature.

The temperature co-efficient of sensitivity of a typical condensor microphone system is about 0.04 dB per ^{o}F. For the dynamic microphone the variation depends on frequency. Over much of the frequency range the variation is of the order of 1dB per a 50^{o}F change in temperature.

8. Hum Pickup:- Dynamic microphones are sometimes used for measurement purposes because they are readily used with long cables. But if they are used, care must be

taken to avoid hum pickup, which is the induction of undesired electrical signals from the external magnetic field of equipment such as transformer, motors and generators. Ceramic or condensor microphone are relatively free from this undesirable effect.

9. Cable Extensions:- For the most accurate sound measurements, only the microphone should be put into the sound field, and the measuring instruments and the observers should not be near the point where sound pressure is to be measured.. For this reason and also for the situations when it is impossible or impractical for the observer to be near the microphone, an extension cable is ordinarily used to connect the microphone to the instruments. If the microphone is attached directly to a preamplifier, long cables can be used without any deleterious effects.

A correction for loss in sensitivity is necessary, however, when a ceramic microphone is used directly with an extension cable. The correction is about 7dB when 25 feet cable is used between the microphone and the instrument, so that 7 dB should be added to the indicated level to obtain the level of the microphone. For longer Cables the correction is greater.

If a long cable is used between a dynamic microphone and the input transformer of a sound level meter, no correction is necessary (the cable should be skilled and twisted). For this reason dynamic microphone must be placed at a long distance from the instrument*

10. Wind effects:- The microphone should also be kept out of any appreciable wind, if possible. Wind on the microphone produces a noise which is mainly of the low frequency. This added noise may seriously upset the measurement, particularly when the microphone has a good low frequency response. If it is not possible to avoid the wind on the microphone, a wind screen should also be used which helps to attenuate the wind noise by 20 dB.

11 . Direction of arrival of sound at the microphone:

As stated earBer in the chapter I, the response of the microphone mainly depends upon the direction at which the sound wave arrives at the microphone, some microphones are designed to have directional properties at all frequencies; However, most of the microphone used for noise measurements are essentially omni-directional or non directional at low frequencies ie+ below about 1kHz. But at the higher frequencies, the size of the microphone is comparable to the wave length of the sound in air and hence these microphones will show directional effect at the higher frequencies.

This variation in response pattern of the microphone in terms of the direction of the sound should be considered in the placement of the microphone for the noise measurement. Thus the microphone is usually positioned in such a way that the microphone exhibits a flat/uniform frequency response;

The variation of the response of the microphone in terms of placement of microphone considered in two conditions.

(a) Measurement at a point not close to the source.

(b) Measurement at various points with varying distance from the source(noise source).

(a) When the noise measurement is made in a reverberant room at a point not near the noise source, we have sound waves arriving at the microphone from all directions. Thus a microphone responding to sounds from all directions is called the supposed to have 'random incidence response'. Under such conditions, it is often necessary and desirable to keep the microphone pointing away from the hard surface; This is done to avoid the high frequency sound reflection from the hard surface which is perpendicular to the plane of the diaphargm(O incidence). However, the reflection of high frequency sound can be eliminated with use of the acoustic absorbing material placed on the reflecting surface.

(b) In this condition, the microphone position is oriented in such a way that a line joining the microphone and the source is at an angle of about 70 from the axis of the microphone.

12. Position of the microphone: In general, the location of the microphone mainly depends upon the nature/type of noise measurement, for eg: The microphone is kept near the source for the measurement of noise from the machine. Moreover, the characteristics of the noise field should be clear before deciding on a definite location for the microphone. The noise measurements should be made at various points of location of microphone for an accurate specification of the sound field especially, when the apparatus produces noise that in highly directional.

It becomes quite often important to explore the noise field especially when the noise measurement is made for the speech interference level determination or the establishment of the deafness criteria.

Moreover to find out the account of noise exposure of an individual, the microphone should be placed at the earlevel of the operator and the measurement is thus made.

II. Use of weighting network:

The following are the level ranges that are suggested in accordance with the use of the network.

for eg: under 55dB - A
55-85dB - B
above 85dB -C

Normally the A and B weighting networks are used with in the range given above; But sometimes it is used above that level especially when noise is measured at some distance from the source.

The C network is used for all measurements at high sound levels(85dB or higher)

III. Effects of Room and Nearby Obiects:-

1) Effects of observer and Meter case on measured data:- The observer can affect the measured close to the microphone. When the measurements are made in a live room and not close to a surface, the effect is usually not important. But if the measurements are made close to the source, the observer should stand on side of the direct path between the source and the microphone.

When the measurement is made in an anechoic chamber the instrument and the observer should be in the other room. With only the source, the microphone the extension cable and a minimum of supporting structure in that room.

In practical noise measurement the errors due to the presence of an operator may occur particularly during the outdoor measurements. For this kind of application, the angle of incidence should be kept within $\pm$ 30^{o} relative to the reference direction of the microphone, if the sound source is well defined (Young 1962).

Study done by Brinkmann and Obermayr (1977) about the influence of the operator on an SLM reveal three important points:-

1) Deviations from flat frequency response of about $\pm$ 2dB to $\pm$ 3dB may occur when a SLM is held in hand, especially when the measurement is made with tonal components.

2) More accurate measurements can be carried out with . a SLM mounted on a stand. A distance of atleast 2m from the microphone would be required for the frequency response to be flat within $\pm$ 1dB. This can be done by the use of extension rod from the source which reduces the distance between the SLM and the observer.

If SLM is mounted on one side the observer standing beside and not behind the instrument then the accuracy can be noticably increased.

3) When precision measurements are needed a microphone of 20 mm diameter or less must be mounted on a stand and connected to an instrument by an extension cable. No operator may be within a radius of 4m from the microphone - this reveals good frequency response.

The metre case itself may also disturb the sound field at the microphone. This effect is not noticed below l000Hz and again, on most noises, little error on measuring the overall level is seen, when the microphone is left on the instrument. Whenever you make use of analyzer along with SLM, it is necessary to separate the microphone from the source through an extension cable.

2. Room Design: When an acoustic out put has to be measured from the source, the space in which the source is present have a significant effect on such measurement. The measurement room-, should be well treated in such a way that the standing wave does not exist. In spite of it, persistence of small standing-wave pattern can be measured by finding out the maximum and minimum decibel readings; If the differences are more than 6dB, the level should be taken as 3dB below the maximum reading that occur frequently.

This standing wave pattern should not be confused with the normal decrease in level with distance or with the directvity of the source.

3. Effect of Nearby objects: All unnecessary objects should be removed from the measurement room. This is a must because objects in the room reflect the sound waves just as do the walls of the room. When it is empirical to follow this principle, it is essential to treat the objects with the absorbing material.

Whenever noise measurement is made, no change should be made in the usual location of equipment, but the placement of the microphone should be optimal such that acoustic shadow cast by a nearby object is minimal.

4. Environmental consideration: One of the major importance is the influence of external factors upon the measurements ie, how the environment affects the readings.

(a) Barometric pressure:- It is found the barometric pressure can affect the calibration of the instrument. For eg. A piston phone that generates a sound pressure level of 124dB SPL at the atmospheric pressure of 760mm Hg would generate a SPL af 123dB at 677mm Hg.

(b) Temperature: The two elements that are sensitive to temperature changes are the batteries and the microphone. As the temperature decreases, the life of the batteries decreases. Thus when you are dealing with noise measurement, one should know how much longer reliable measurements can be made with the same batteries. This is especially true with sub zero temperatures.

Some microphones are practically in sensitive to temperature: for eg: Condensor microphone can retain its caliberation within 0.5dB over an operating range of $-40^0$to 150^0C The ceramic piezo electric microphone is also quite stable over a range of -40 to 60 C. But a Rochelle salt microphone is very sensitive to the temperature.

(c) Humidity: - Microphones are found to be sensitive especially condensor microphone. If the moisture enters the space between the electrode and the diaphragm, a 'Gacking' or popping sound is heard in electrical output This condensation can be dried out by placing the microphone under a light bulb for 5 to 10 minutes.

The modern ceramic microphone may be used in relative humidities of 0 to 100%.

5. Background Noise:-

Ideally when noise measurement is made from the source the resultant SPL level should indicate only the direct air borne sound from the source, without any significant contribution from noise produced by other sources* To determine whether the background noise in a space influences the SPL, one should turn off the noise source and measure the background noise level. This measurement should be carried out through the same instrument that is used to measure noise from the source.

If in any frequency band, the difference between the background noise level and the source noise level is greater than 10dB, the background noise level will not significantly affect the noise level from the source.
If the difference is less than 10dB, then the measured noise level should be corrected to obtain source noise level, (Table - 3) .

Table-5: Connection for the Background noise.

SB difference between BGNL and SNL	dB to be subtracted from the total noise level in order to get the noise level oving to ghe source.
8-10	0.5
6-8	1.0
4.5-6	1.5
4-4.5	2.0
3.5	2.5
3	3

If the difference is less than 3dB then the appropriate measurement cannot be made. If the background noise level cannot be lowered, the microphone placement near the source would increase the difference between the two noise levels.

Wind Noise:

When ever the outdoor measurements are made, the frequency response characteristics of microphone is affected mainly by the flow of wind. Consequently, turbulence develops on the down stream side and causes fluctuations in the ambient pressure resulting in generation of noise; The magnitude of the noise increases with the increase in wind speed.

Knowing the turbulent noise reduction for a given microphone wind screen combination, one may determine whether or not the measured noise level is caused by the wind or comes from the noise source. To determine this, measure noise level with and without the wind screen:

(1) If no change occurs when the measurement is made with and without wind screen, the desired noise level is being measured.

(2) If the change in noise level when the wind screen is used is smaller than the turbulence noise reduction, then the measurement (i) without wind screen determines the noise levels and the measurement (ii)with the wind screen determines the levels of the noise source.

Chapter- 4

Noise Measurement Procedure

Why Noise Measurement?

Few points regarding the need and utility of noise measurement are given here. They are:-

1. Noise measurement is done whenever you choose a site, especially for: construction of audiometric rooms, or to check up the noise levels in an audiometric room periodically.
2. To study the adverse effect of noise, one must be sure as how much noise (intensity) is acting upon to produce such an effect.
3. From industrial point of view, this noise measurement is a must economically,for eg. loss in industry or compensation to be paid for the worker for hearing loss consequent to noise exposure'from the particular industry.
4. Noise control.
5. Study of the ambient noise in a community is a necess because a theatre or a chowltry in a residential area may create disturbances.

One can and must have a clear idea that the noise assessment procedure, like many other assessment procedures, consists of comparing an actual or proposed noise exposure with a noise exposure that is on the borderline' acceptable and unacceptable. Yet the task is never, as simple as comparing, say, a car's speed with the posted speed limit.

In the first place, noise is not always easily measured. Even when adequate instrumentation is available,a measurement procedure must be defined to take into account the place or places that microphone should be sited in relation to the noise source and the manner in which the source must be operated to display a representative noise output. Extraneous factors that might affect the results must be within the defined limits(bounds).

(Depending upon the purposes of the measurements and the desired accuracy of the result a wide range of measurement techniques and sound level descriptors should be understood. So it is the purpose of this chapter to categorize in basic terms, some of the measurement fundamentals employed in the assessment of both indoor and outdoor acoustic environments.

Measurement Procedure:

Each noise measurement made according to various procedures put forward by some standards varies from country to country. However some general conditions that are relevant are given below. The goal of noise measurement is to make valid, accurate and through measurements of noise situation under study. The following points are nighly relevant.

1. THE PURPOSE FOR WHICH MEASUREMENTS ARE MADE AND WHAT INFORMATION IS REQUIRED-WETHER THE OVERALL LEVEL IS ADEQUATE OR NARROW BAND ANALYSIS FOR NOISE REDUCTION OR MORE SOPHISTICATED ANALYSIS FOR RESEARCH.

The noise measurement being made can Vary from simple sound level measurement to a detailed measure involving frequency analysis, computation of the data to express the results in the desired units. The use of appropriate method depends on.

a) What the noise problem is and
b) the ultimate use of the data obtained for future references.

The various methodologies involved in noise measurement helps us to distinguish between measurements on noise source individually and measurements in noisy environments where various sources contribute on noise simultaneously.

2. THE TYPE OF NOISE SOURCE UNDER CONSIDERATION WHETHER AMBIEKT NOISE, TRAFFIC NOISE, AIRCRAFT NOISE ETC.

3. THE TYPE OF NOISE THAT IS TO BE MEASURED WHETHER IMPULSE, CONTIGUOUS, INTERRUPTED ETC.

Noise that creates concern can either be a steady noise or an impulsive noise.

Steady noise are more easily analysed. Intensity fluctuations in steady noise may take place at irregular intervals and involve only a narrow range of frequencies at one time. The impulse noise on the other hand are composed of mainly sharp bursts of sound. Each burst begins to die away before the succeeding one is generated, producing the overall effect of a rapid rise to a maximum intensity followed by a somewhat slower decay (Gloring) let us consider under this heading as to how these two types of noise are measured and the instrument involved in such measurement.

3.a. Measurement of steady noise:

Both overall noise level and octave and levels must be measured whenever noise exposure evaluation of steady noise is made the overall sound levels of steady noise are measured with sound level meter. The 'C response or flat response scale of a sound level meter measures average overall sound pressure level in decibels relative to 0.0002 dynes/Cm^2.

The meter indicator responds to irregular fluctuations present in the steady noise and usually donot remain fixed in one position while the measurement is being made. Because of these fluctuations the average of several readings taken at the measuring point is recorded as the overall sound pressure level of the noise at that location.

The 'A' scale of sound level meter may be used as a screening method to determine the need for a detailed octave band analysis. When ever the A scale reading minus 5dB exceeds the hearing conservation criterion octave band analyzers should be completed. The use of 'A' scale in this manner will eliminate conducting octave band analyzers of noise level at locations where the noise levels may be borderline.

If a noise is of steady type, the aim of the investigation is to obtain an estimate of the noise level. The read out provided by the instrument of a precision sound level meter or an octave band analyzer, using its fast and slow characteristics may be quite satisfactory (Manjula, 1979).

3.b. Measurement of non-steady noise:

A noise with a level that fluctuates over a range greater than 10dB during observation should be classified as nonsteady, either impulsive or fluctuating. An impulsive or fluctuating noise having a pulse repetition rate of greater than 10 pulses/second may usually be classified as quasi-steady noise, and procedures outlined in steady noise measurement should be followed.

i) Fluctuating or intermittent noise: Continuously or intermittently fluctuating noises often must be measured with a sound level meter. And also use of a Graphic level recording is normally preferred than the meter reading or statistical distribution analyzer should be used.

ii) The Impulsive npise: The sound level meter and the octave band analyzer donot measure the impulse sound correctly. In the measurement of impulses the parameters of interest are the unfiltered peak pressure level, the pulse rise time the donation of the pressure wave and the frequency spectrum of the pulse.

Thus in the impulse measurement, the sound level meter should have additional characteristics like a good phase response, a flat frequency response(100Hz-70KHz) and a rise time less than 10µ seconds; impulse sound level meter is used in such instances.

4. THE PLACE WHERE THE MEASUREMENT IS TO BE MADE WHETHER INDOORS OR OUTDOORS AND THE POSITION OF THE SOURCE IN THE ENVIRONMENT AS SUCH.

4.A. INDOOR MEASUREMENT

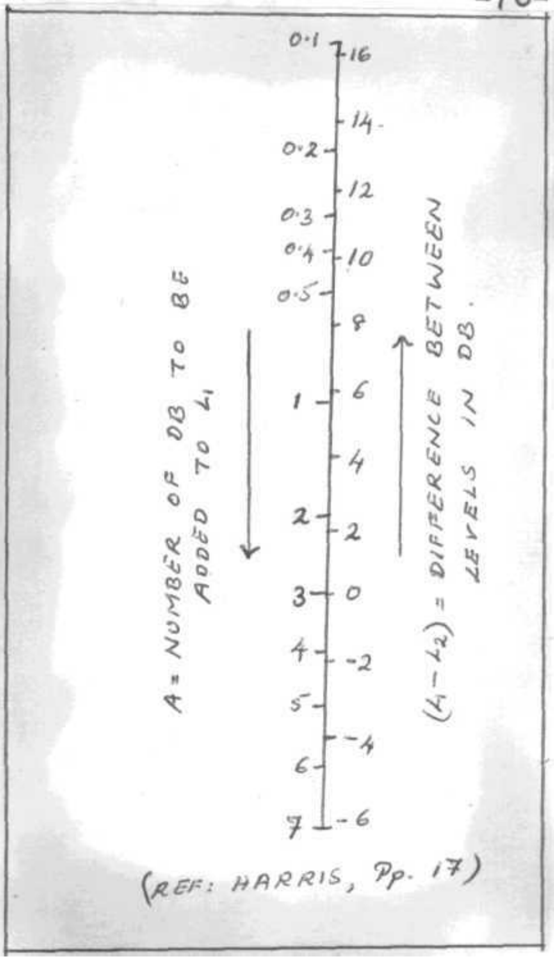
Five measurement conditions may be identified as occuring most commonly, in the field. They are:
1) Perpendicular incidence(O) ii) Omni directional incidence (iii) pressure (iv)graving incidence and (v) random incidence.

To determine the sound field directly from the single source with no reflections, a perpendicular incidence field measurement should be made with the free field microphone. If the total sound from a large number of sources spperated at various angles is to be measured, an omni directional microphone should be used. This also applies to the indoor measurement such as that would be found in a factory environment. Under certain conditions a random incidence corrector should be used as well.

When indoor measurements are to be made in a reverberation room(measurement of acoustic power for example) a pressure microphone must be used. Because of the highly reverberant character of the sound field, the sound direction can be ignored. The pressure microphone, with its relatively uniform random incidence response is acceptable for such a measurement condition.

4 a) Free Field Measurement: Here the measurement is carried out in a free field that is the sound field in an area for from the reflecting surface. Sound pressure measurements are made in a free field at a fixed distance from various angular directions(Harris 1972). By integrating the overall power flowing at various angular direction, one can obtain the total power.

Two steps in the calculation of sound power level:
i) Findout the average sound pressure level from various points in the field at a particular distance, say 'n' times. This is computed by combining the first two values, find out the combined level from Table-1 and then combine this new value with third value, etc.



(REF: HARRIS, Pp. 17)

ii) Subtract from the total combined level the averaging constant 'N' which varies depending upon the number of points at which the measurement is made for e.g.,

No. of points (array)	N
20	13
12	10.8
8	9
6	7.8
4	6

4.b) Reverberant field method or Diffuse field method:

In recent years reverberant room technique has been widely used for measurement of sound power. In this method, the sound power measurements are made in a highly reverberant room where diffuse conditions are approximated. In such a diffuse condition, the sound pressure level are approximately equal throughout the room except very near the source.

4.b. Variables in the reverberant method: Diffuseness the field governs the accuracy in this method and the diffuseness in turn is a function of the room dimensio its shape and absorption and the type of noise itself (H.H.Scott 1973) and the frequency.

4.b.l. The room dimension: The minimum volume of the test room depends on the lowest frequency at which the measurement is made i.e., the lower the test frequency, the larger the volume of the test room.

At the same time the volume of the room should not be much larger as air absorption may cause an undesirable reduction in the uniformity of the reverberant room especially is the highest frequency bands. Thus in this case, the effects of air absorption should be included in the determination of the sound power.

4.b.2. Shape of the room: The shape of the room is either rectangular or non-parallel surfaces. When the room is rectangular, the diffuse characteristics is obtained with the length, width and height in the ratio 2 :l:4 .

If the room is not rectangular, no surface of the room should be parallel. These nonparallel surface with irregular boundaries tend to increase the diffusion.

Another tool to improve the measurement diffusion is not a rotating diffuser; i.e., large rotating or oscillating vanes are sometimes used to increase the uniformity of the sound field(J.Tichy 1979).

4.b.3. Absorption: The equivalent absorption area affects the minimum distance to be maintained between the source and the microphone and thereby it influences the diffuseness of the field. The absorption area should therefore be neither too large nor too small.

In order for the diffuse condition to prevail the absorption co-efficient should not be greater than 0.06 Yet the highest value of the absorption co-efficient should not exceed 0.16.

4.C. Semi reverberant field method: It is the sound power determination in the actual environment which are neither free field nor reverberant field. The sound power level that is measured is compared with the sound power level of the source measured in a free field room for accuracy. Yet this method is not dependable as the above two methods.

4.D. Anechoic hemispherical space: The determination of the sound in the hemispherical space is based on the premise that the reverberant field is negligible at the position of the measurement and that the total radiated sound power is obtained by a space integration of the sound intensity over a hypothetical test hemisphere centered on the source of noise. The surface of the test hemisphere should be in the far field of the source. Many points of measurements are choosen depending upon the accuracy required and the directivity the more directive the source, the greater the number of points at which the measurements should be made.

In order that the measurement be carried out in a far field, the hemisphere radius should be equal to at least two major source dimensions or four times the average source, height above the reflecting plane whichever is larger.

4.E. Anechoic full space: Sometimes the noise source under test is not associated with a hard surface and perhaps is small enough to be placed near the centre of an anechoic chamber. In this case, it is necessary to determine the space average mean square sound pressure level over a test spere-here the test area is doubled.

4.F. Sound pressure measurements under field conditions; In those cases where the noise cannot be moved from its location into a special test environment, the measuremen must be Carriedout in a situation where the walls and ceiling are not highly absorbant and the room is not highly reverberant. A hard floor is almost always present.

In this case, the room should be large enough so that microphone can be placed in the far field of the source without being too close to the room boundaries. And noise source should be mounted as it is normally used.

4.B. OUTDOOR MEASUREMENT:

Whenever outdoor measurements are to be made, metrological data such as wind direction, humidity and temperature etc. should be given due consideration.

5. PLACEMENT OF THE MICROPHONE WITH RESPECT TO THE SOURCE:

5.a. Placement of the microphone in a free field condition

It should be used at normal incidence so as to obtain increased intensity, it should be connected to sound pressure level meter through cable extension to reduce or eliminate the diffraction effects. It should be at a distance not less than twice or five times the largest dimensions of the machine under test, i.e., at least not less than 3 feet from the source.
(d= $\lambda/4$, where λ is the lowest frequency to be measured)

5.b. Placement of the microphone in a reverberant field:

Since the energy distribution is almost uniform in a diffuse field, random in6idence response of the microphone is utilized.

The position of the microphone should be selected such that it is atleast $3/4\,\lambda$ away from the corners and edges of the chamber, $\lambda/4$ from the walls where λ is the wave length of the lowest frequency of interest. This is done mainly because, the sound pressure level is greater near the corner edges and walls than the rest of the chamber.

As stated in the free field method, the microphone should be placed at a distance of 3 feet the average sound pressure level should be considered and the number of positions required depends upon the width of the spectrum of the sound source.

5.C. placement of the microphone in a large or small room: The placement of the microphone (as stated earlier) may not be possible if the room isnot sufficiently large but no room surface should be less than one major machine. In this case, the sound pressure level in each of the four corners of the floor is measured and averaged. Thus the average sound power level in the central position of the room is the average sound pressure level from the corners minus 9dB.

5.D. Placement of the microphone in anechoic hemispherical space: The microphone should be no closer to the room boundaries than $\lambda/4$ where λ is the wavelength of the lowest frequency of interest and the radius of the test hemisphere must be 0.6metres (2 feet) approximately. When the hemisphere is more than 0.15 metre, atmospheric effects are likely to influence the measurement.

6. SELECTION OF THE APPROPRIATE INSTRUMENT SO AS TO GET THE NECESSARY INFORMATION.

7. USE OF DIFFERENT WEIGHTING NETWORKS:

Earlier it was suggested that to determine the sound level at a particular location due to a noise source, a sound level meter to be used. There is infact much more than that (Lipscomb). Different sound levels are obtainable from a measurement of the same source if different electronic weighting fitters are employed. Under these conditions we measure the weighted sound pressure level, most commonly called the sound level. It is however worth while to note that all the weighting network donot share the equal utility.

The 'B' weighting network-originally presented as how individuals respond to sounds of moderate intensity is rarely if ever used.

The 'C weighting network is assumed to have a good approximation to a linear response or the sound pressure level and is commonly used when the low frequency energy is discriminatively predominant.

The 'D' weighting network is designed primarily to provid a single member subjective measure of aircraft noise.

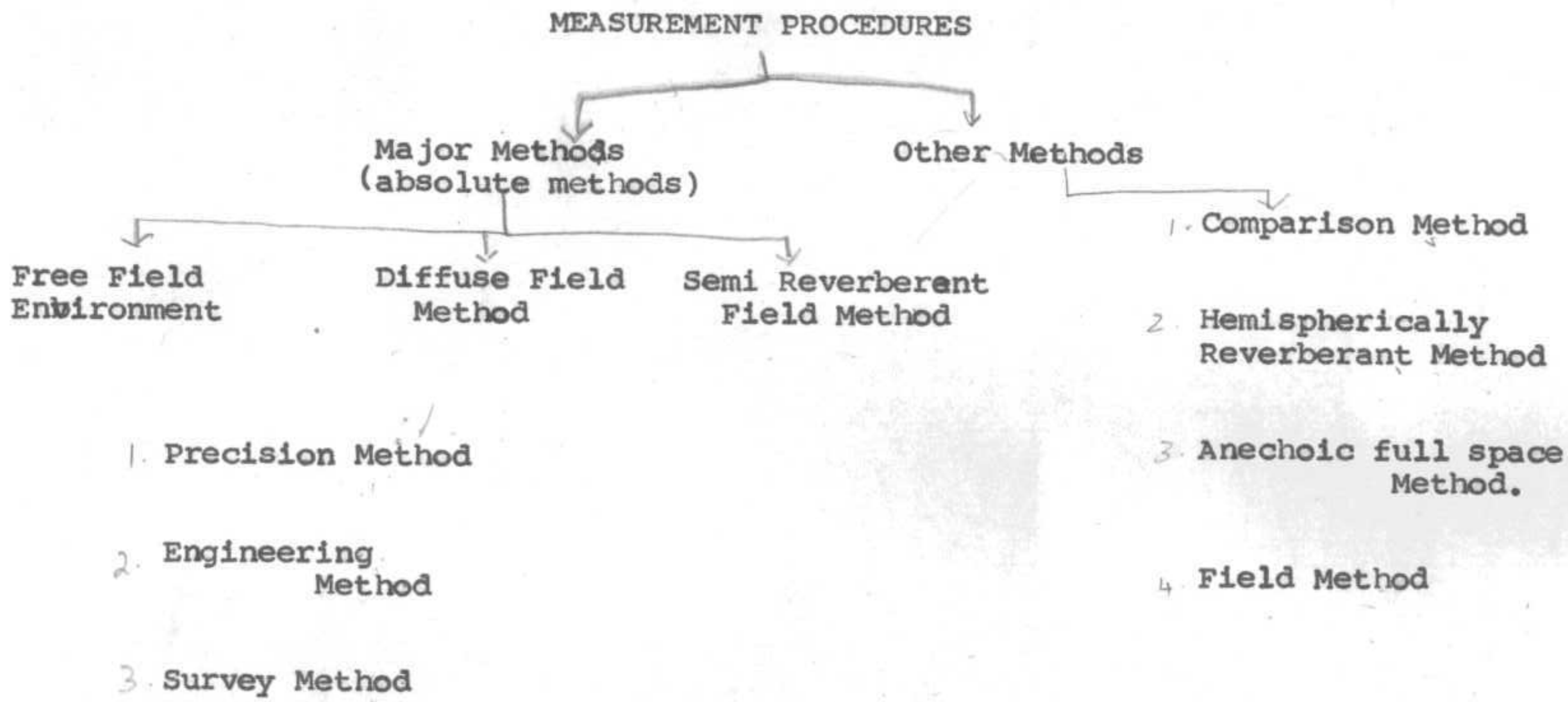
The most commonly used weighting network for both indoor(occupational) and outdoor(environmental)noise measurement is the 'A' weighting network(EPA).

The measurement of sound level from a noise source can give a crude approximation of the frequency distributions of the sound. For e.g., If the 'A' weighted sound level is considerably less than the source contains a large amount of low frequency energy that is below 500Hz. If the 'A' weighted and 'C weighted levels are nearly the same, most of the acoustic energy is likely to be in the frequency range above 500Hz. This analysis only gives basic information is worked for. Detailed analysis can be obtained with , the spectrum analysis.

8. USE OF THE FAST OR SLOW SCALE.
9. METER READING.
10. OTHER FACTORS:
    a) Look for name, make, type and serial number.
    b) Applied connections to a particular measurement with certain instruments.
    c) Any special instrumentation if required especially for measurement of impulse noise etc.
    d) Check for calibration for all the instruments.
    e) Make the sketch of the instrument that is utilized.

METHODS OF NOISE MEASUREMENT

Having considered the various methods of sound power measurements, the overall methods of measurement is emphasized here. Thus the absolute methods are divided into.


MEASUREMENT PROCEDURES
Major Methods (absolute methods)
Other Methods
Free Field Environment
Diffuse Field Method
Semi Reverberent Field Method
1. Precision Method
2. Engineering Method
3. Survey Method
1. Comparison Method
2. Hemispherically Reverberant Method
3. Anechoic full space Method.
4. Field Method

i) Survey Method ii)Precision Method and iii)Engineering Method. Let us consider the importance of these methods individually.

i) SURVEY METHOD: This method requires the least amount of time and equipment.

Measurement procedure: The sound field is described by the sound level as measured by sound level meter. Readings of sound level meter give the sound pressure level weighted according to a standardized frequency response curve. In these cases use of 'A' or 'C weighted network is recommended although the use of other networks such as "linear" may be appropriate. For many practical purposes sound level 'C is a fair approximation to the overall sound pressure level. The 'A' weighted sound level is useful for the assessment of human response.

Advantage: It may be used for the comparison of the noise sources of similar characteristics.

Disadvantage or Limitations:

(i) This method is generally of the limited value if the connective measure to reduce the noise to be evaluated.

(ii)Itis not useful for the measurement of impulse noise,

(iii) No detailed analysis of the acoustics is made.

(ii) ENGINEERING METHOD:

Measurements of sound pressure level or sound levl are supplemented by measurements of band pressure levels. The acoustic environment ia analyzed to determine its effect upon the measurements. The measuring points and the frequency range are selected according to the characteristics of the noise source and the environment in which it operates. The time dependence of the level during the period of observation may be recorded.

Advantage: This method provides information that is usually sufficient for tabulating engineering action in many situations such as in connection with noise abatement programme.

Disadvantage: Not suitable for the measurement of the impulse noise like the previous method.

(iii) PRECISION METHOD:

This method gives us a detailed description of the noise problem as much as possible. Measurement of sound pressure level or sound level are supplemented by the measurement of the band pressure levels. Records are made over an appropriate time interval in accordance with duration and fluctuations of noise. The acoustic environment is Carefully analyzed and measuring points and the environment. If possible the effect of the environment on the measurement is quantified by carrying out the measurement under controlled experimental conditions such as a free field or reverberant room. The utilization of this method is called for in a complex situation where a thorough description of the noise field is required this being the major advantage of this method.

Chapter - 5

Data Analysis

The earlier chapter dealt with measurement procedures, indoor and outdoor. The result obtained from such procedures may not in themselves be adequate for all purposes. Further analysis may be necessary to get the information on the frequency characteristics of noise. This is especially important in terms of noise control and further measure. Thus data obtained from such measurement is subjected to data analysis. Data analysis may also be thought of the estimation of certain properties or measures of a signal. These measures can be derived from the total signal or the filtered versions of the signal. The latter yield measures that are a function of frequency.

A measure basic to nearly all signal analysis in sound and vibration is called the spectral analysis - ie., the process of determination of the energy power in a signal as a function of frequency is called the spectral analysis. The analysis of spectrum is based on the two characteristics:

(a) the type of signal and

(b) the type of analysis.

(a) The type of signal:- This includes the stationary and the nonstationary signals.

a.1. stationary Signal:-

This can be either periodic or random; This signal has a power spectrum that does not change with time. The examples of the random signal are noise from the water falls or from an air conditioning system; the periodic signal can be either pure tone or sine wave.

a.2. The Non-stationary Signal:-

They are also called the transient signal which include the impulsive signals. This type of signal exists for relatively short time period.- eg. of this gun shot. The impulse category include signal that vary slowly in time; for eg. the sound on the ground from an air plane flying over head.

This type signal presents different type of analysis. For stationary signals, the power spectrum is desired while for the transients, the energy spectrum is desired- the energy spectcum is the power spectrum integrated over time.

(b) Type of Frequency analysis:- Main types of frequency, analysis are used in the analysis of noise signals:

1. Constant percentage band width and
2. Constant band width.

According to the first method the filter band width is a constant percentage of the centre frequency of the pass-band, whatever its absolute Value, will increase as the frequency increases. This analysis is used in procedures for the estimation of the subjective responses of the humans to the environmental noise. The acoustic measurements for purposes of estimating loudness annoyance and subjective response generally do not require such detailed knowledge of the spectrum of the noise source. The analysis of air craft noise measure ment is normally carried out with constant percentage band width, as the air craft fly over noise varies relatively slowly with frequency.

In the latter method ie. the constant band width method, the filters have a constant band width completely independent of the centre frequency to which the filter is tuned. This techniques gives 1) a detailed spectrun analysis which is required for the noise reduction procedure.

2) Discriptive analysis of the sources with many distinct harmonics (gear trains), which emit puretones(jet engine and electric motors) and rotating machines.

3) Identification of multiple resonance or harmonics which occur at constant frequency analysis.

4) Changes in amplitude in the spectrum with greatest precision.

The other methods include.

3. Sequential analysis:

This type of analysis is based on the two parametres ie the time and the band width ie the time taken for the sequential analysis depends on the band width of the signal. For eg. a narrow constant band width analysis will therefore take very much longer than the octave or 1/3 octave constant percentage band width analysis.

Sequential analysis can be contiguous and continuous band analysis, depending upon whether the analysis is carried out in bands which have a fixed centre frequency or in bands whose centre frequency sweeps contineously through the analysis range.

In This method of frequency analysis, the frequency analyzer is used-the output from the frequency analyzer are presented to the RMS rectifier and the read out device. The RMS value is calculated by the formula

$$A_{rms} = \sqrt{1/T \int_0^T a^2(+)\,dt}$$

where T=averaging time
a= instantaneous value.

To obtain the results of a certain accuracy in this analysis, it is important to increase the time over which the data is averaged as the band width of the analysis is decreased ie a narrowband width analysis have to be averaged over a relatively long time period.

4. Statistical distribution analysis: (Fig 5)

It is not sufficient to describe the sound level history by any measurement taken at any single instant time, (especially environmental traffic noises etc.) In this case, a statistical description is clearly required the sound level of the fluctuating signal can be determined statistically.

When it is desired to carry out a statistical analysis of the variation in noise level with time, a method of analysis which can be done automatically by connecting a statistical distribution analyzer to the level recorder (Drock 1971)

A statistical analysis yields two kinds of report.

(a) Cumulative histogram:- The graph obtained gives the representation of noise level Vs amplitude in terms of percentage. This is called the cumulative probability plot. Based on the graphic, one can determine L_{10},L_{50},L_{90} etc. (Fig. 6a)

(b) Distribution histogram: This Calculates the proportion time the sound level spends in each of the amplitude intervals. This type of graph can be obtained from the level recorder or alpha numeric printer. The shapes of these histograms varies widely from one type to another. To get an alphanumeric printer, a noise level analyzer. The print out intervals can be set to values from a few

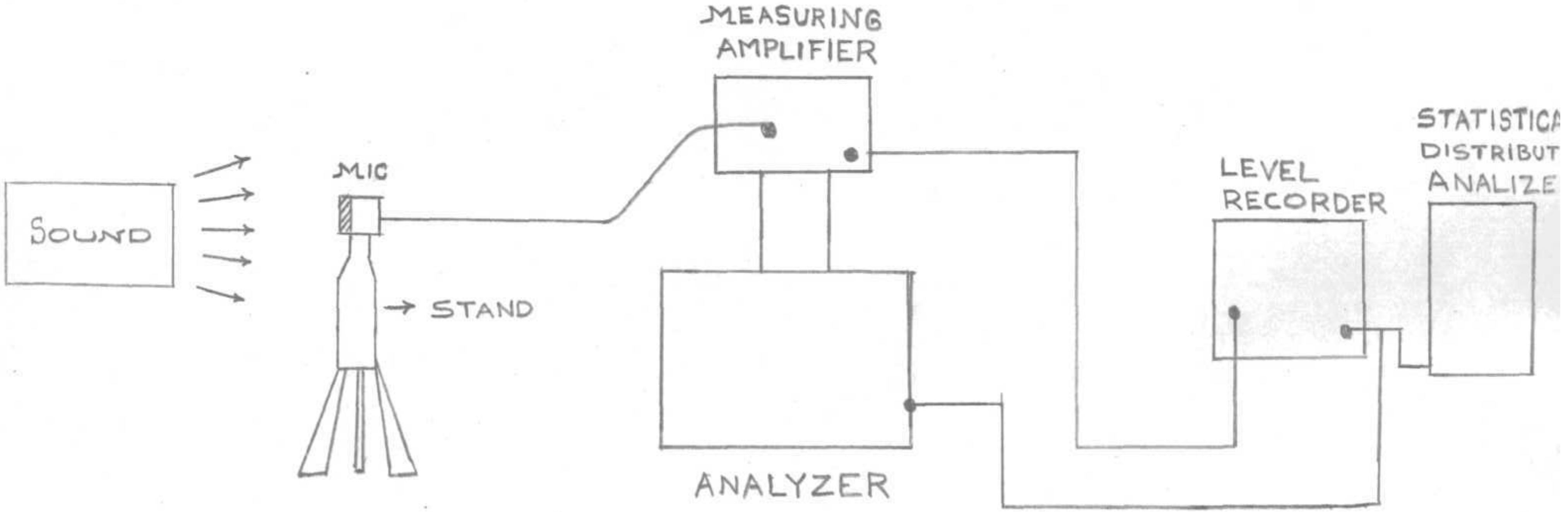


Fig-5- INSTRUMENTAL SETUP FOR STATISTICAL DISTRIBUTION ANALYSIS

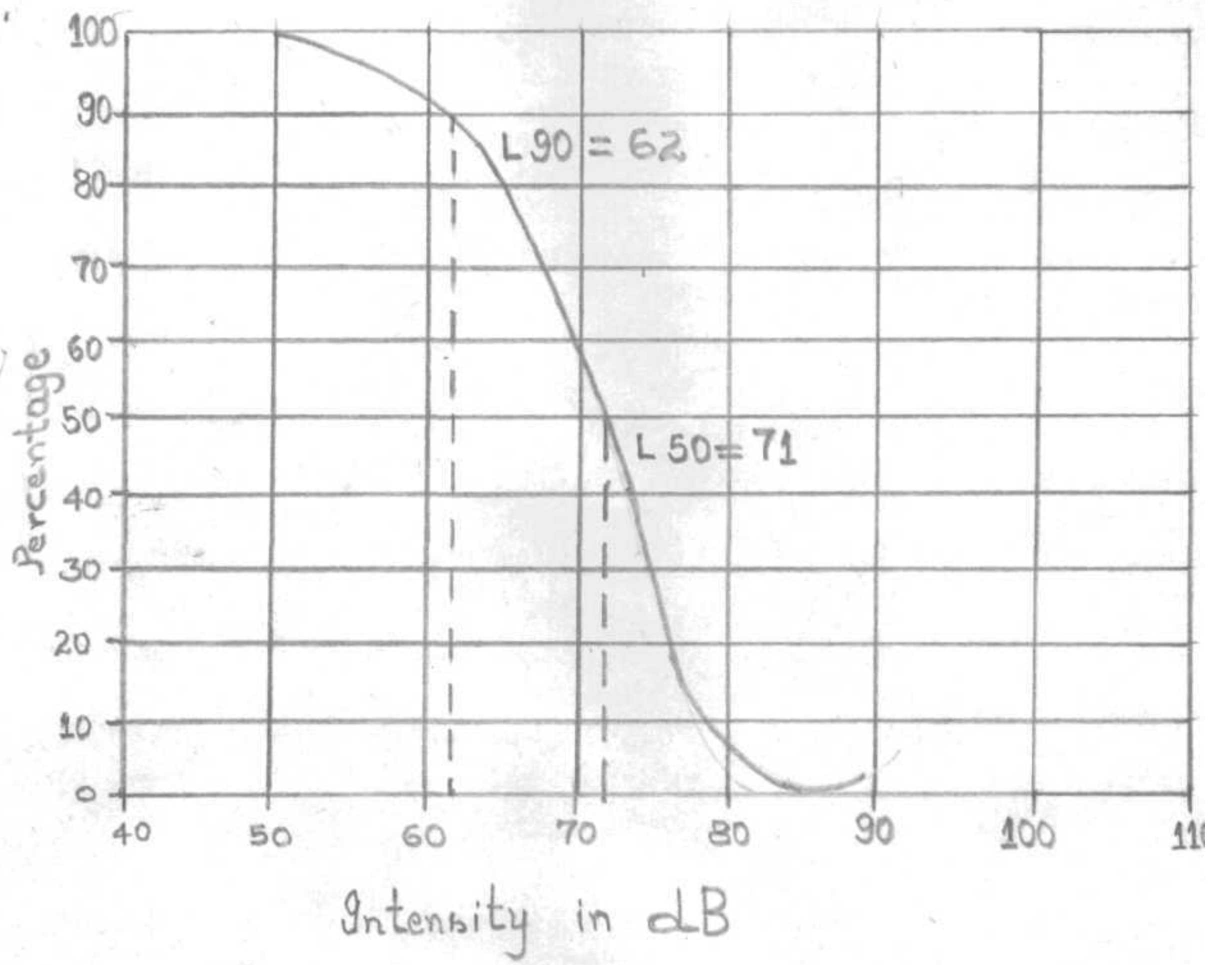


Fig - 6[a] - Cumulative histogram

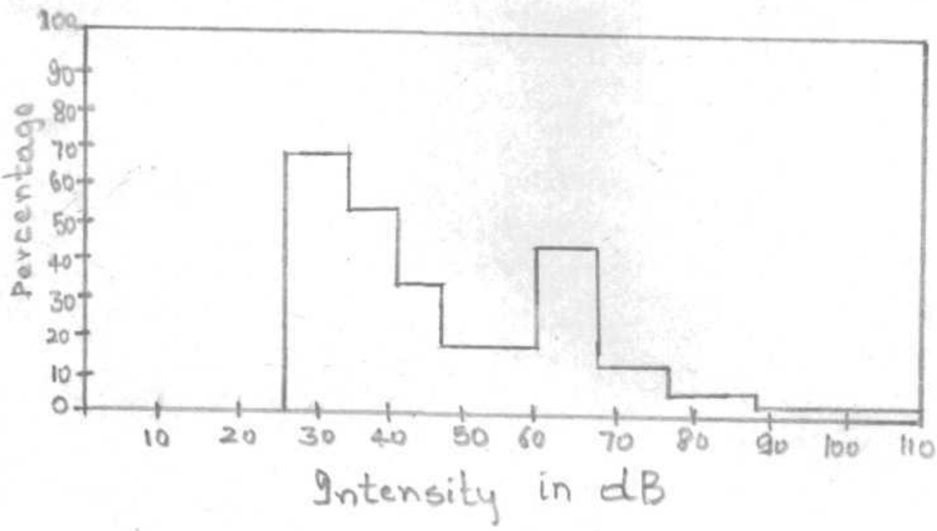


Fig - 6[b] - Distribution histogram

seconds to one hour, or can be controlled by noise level analyzer to take place at the end of measurement period ehich have a duration of few minute to 180hours From the print out one can obtain value of L_{50}, L_{90}, L_{10} Leq etc. - a printout of noise distribution in % starting at 26dB, S is the lowest level the noise level analyzer can measure.

5. A further method of frequency analysis is called the real time analysis or parallel analysis. Special techniques are required for the measurement and analysis of acoustic impulses and transient pressure changes and also for the evaluation of their perceived loudness, annoyance hearing damage risk. The difficulties encountered in these signals are mainly due to the fact that they aften contain high frequency spectum level at low frequencies, usually non repetitive and of very short duration.

Frequency analysis described earlier analyzed the data through a filter of required band width, through the frequency range of interest. A through it may be perform automatically, this sequential method requires the total time which is equal to the measurement time multiplied by the number of filters used and this suitable for the frequency analysis of steady noise on the signal varying only slowly with time, for signals like transient, technique capable of analyzing all the data all of the

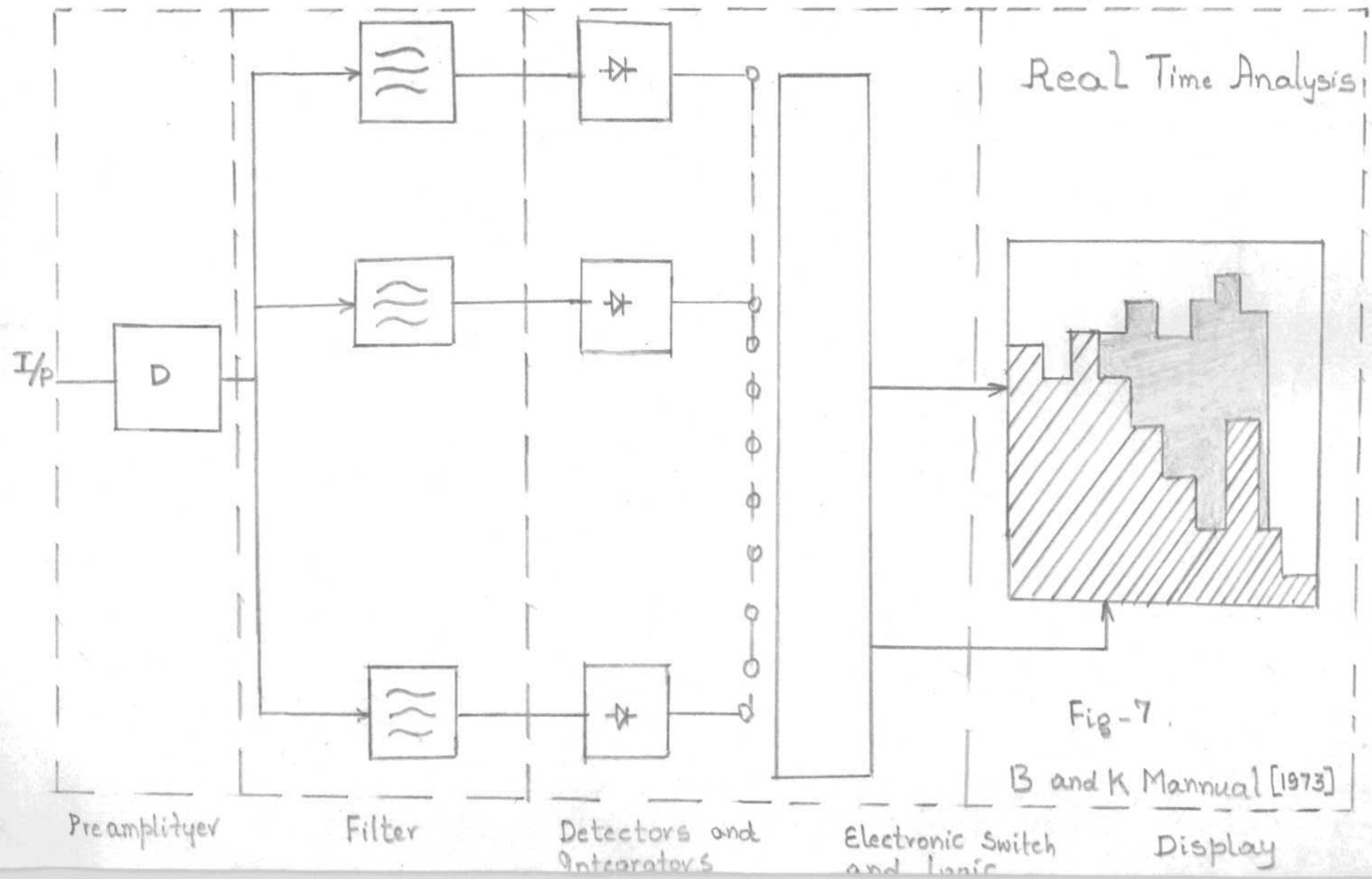

Real Time Analysis
I/P
D
Preamplifyer
Filter
Detectors and Integrators
Electronic Switch and Logic
Display
B and K Mannual [1973]

Fig-7

time should be employed, so that rapid changes can be detected. This is done by presenting the signal simultaneously to the input of all the filters in the chosen analysis range, and feeding the output to a contineous display device where they are displayed as a complete spectrum (Fig. 7)

The analysis done in this way is called the real time analysis.

Advantages of Real time analysis:

- It gives a very rapid system for automatic data processing.
- It is useful for both noise investigation process and for noise monitoring process.
- There dimensions plots about frequency intensity and time can be obtained.
- The important parameters describing the time varying impulse eg. rise time, shape and peak amplitude can be obtained simultaneously.

Few points regarding the noise analysis:

If the noise is steady and contineous, only the SLM, the sound and vibration analyzer and the graphic level recorder are required.

If the noise is intermittent, the SLM and the tape recorder will be needed.

Where there is high intensity noise, the condensor mic must be used with SLM.

Finally to measure impact or impulsive type noise, the tape recorder and the oscilloscope with

Chapter - 6

Conclusion

A manual for noise measurement has been prepared to be used as a guide, by anyone who wished to make noise measurements.

In this manual the reader is introduced to the idea of what noise measurement is and why we do it.

He is informed about the basic instrumentation and its selection. The factors that control accurate and meaningful noise measurement results are discussed. Certain precautions and do's and dont's are also suggested.

We have however not included any information on on the various standards adopted regarding measurement procedures. This is due to the fact that there are several such standards and they vary considerably from country to country and are a result of complex socio-economical, political considerations.

The information regarding the representatives of the instrumentation is available in the Directory of equipment and hence no details are given in this context.

The adresses from where the insttruments can be procured can be easily obtained from the Standard directories available on the subject.

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