ACOUSTIC TECHNOLOGY COURSE

ENVIRONMENTAL ACOUSTICS TECHNOLOGY I

1976

Ministry
of the
Environment

Ontario

The Honourable
George A. Kerr, Q.C.,
Minister

Everett Biggs,
Deputy Minister

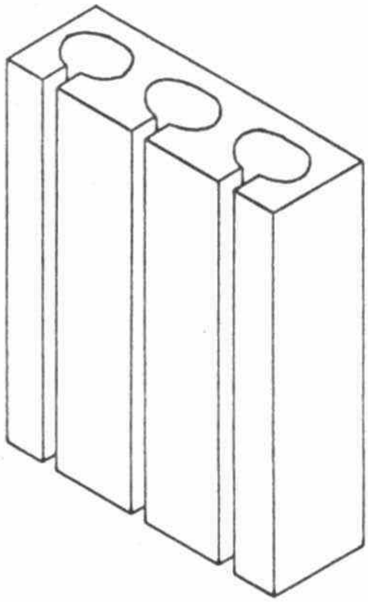

Fig. 8—Hollow blocks may also be utilized in a modification of the Helmholtz resonator called the slit resonator. This is a suggested design of such a block.

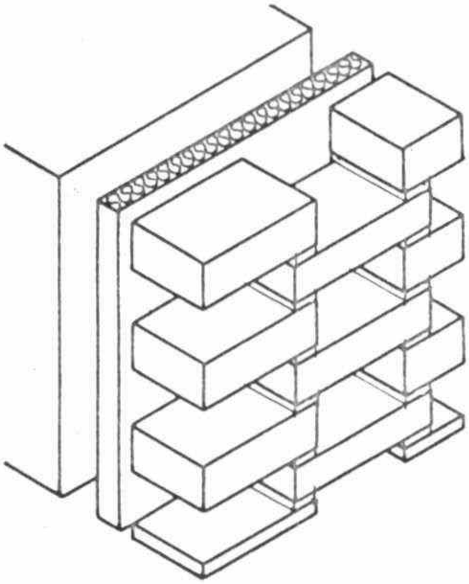

Fig. 9—Other applications of clay products where they may be employed non-structurally, as an attractive and durable facia to other sound-absorbing materials, include this honeycomb wall, built of solid blocks.

be produced having different neck lengths and different cavity volumes to have theoretical resonance frequencies covering the useful range, but it must be remembered that the absorption coefficient would be lower at the higher frequencies. One outstanding advantage of this brick is that it is a load bearing unit and may form part of a structural wall. As far as is known all non-clay sound-absorbing materials are non-load bearing and therefore represent an addition to the building.

The "SCR Acoustile', developed originally in the USA, is an adaptation of the Helmholtz resonator and is claimed to combine high sound absorption with the durability and aesthetic properties of clay. It consists of a hollow clay block having two layers of voids (Fig. 7). The face of the block is perforated with a pattern of holes, which may be uniform or random; these penetrate to the outer void which is filled with a fibrous acoustic absorbent material. The absorption coefficient is said to be 0.6-0.65.

A modification to the M-G block (developed by British Ceramic Research Association) could be made to yield a similar performance, which would be further enhanced by the use of burn-out material. It is considered that sawdust would be more suitable for this application than expanded polystyrene beads because the former tends to give a continuous pore structure whereas the latter gives a relatively closed pore structure. The porosity of such a block is about 50% compared with 90% for the fibrous acoustic materials, so that it would not be expected to have such a good absorptive performance. The face of such a block should be contoured so that it does not present a flat or concave surface.

Hollow blocks could also be utilized in a modification of the Helmholtz resonator called the slit resonator; a suggested design of such a block is shown in Fig. 8.

All examples mentioned above are products which combine load bearing properties with acoustic properties. There are other applications of clay products where they can be employed non-structurally as an attractive and durable facia to other sound absorbent materials such as mineral fibre quilts. Examples of these are a honeycomb wall built of solid bricks (Fig. 9), or perforated bricks laid on stretcher (Fig. 10), or the Italian style ornamental screen blocks. These types of walling will augment the absorption coefficient of the backing quilt, provided that the perforation area is above about 20%.

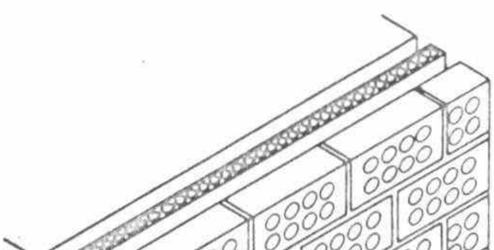

Fig. 10—Perforated bricks laid on a stretcher.

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Sound-absorbing clay products

by H. R. Hodgkinson

Most materials which are employed for their strength and durability have low sound absorption coefficients, for example brick, steel or concrete. Clay products could be particularly suitable for situations less exacting acoustically, such as entrance halls, meeting halls, churches, sports halls, swimming halls, etc., where a modest acoustic absorption coupled with an attractive appearance and a relatively vandal-proof surface, is added to the normal properties of brick surfaces.

WHEN a sound is produced in a room, the pressure waves spread from the source until they strike the interior surfaces of the room, where they are partially reflected and partially absorbed. Those waves which are reflected continue until they meet another surface, where the performance is repeated. Since most hard room linings reflect over 95% of the incident sound energy, the sound waves continue to be reflected for seconds before enough of the sound energy is dissipated to make the sound inaudible. The continued reflection of sound is called reverberation. This is defined quantitatively as the time taken for the sound energy to decay to one millionth of its initial value. The decay is exponential and on the logarithmic scale this corresponds to a decrease of 60 dB either in terms of the energy level or on the sound pressure level. The reverberation time of a room is proportional to the volume of the room and inversely proportional to the amount of absorbent in it.

The volume is important because it is a guide to the total path for sound reflected from one surface to another; the larger the room, the longer the paths and therefore the reverberation time. The amount of absorbent is a factor because it governs the amount of energy dissipated at each reflection. The issue is complicated by the fact that the reverberation time is not independent of the frequency of the sound; it is therefore usual to define the reverberation time as that measured at a frequency of 500 Hz (which is approximately the frequency of one octave above middle C on the piano).

The optimum reverberation time depends upon the use to which a room is put. For a living room it is typically 0.5 second. For an auditorium it must represent a compromise between a short time which is necessary for clarity and a long time which is necessary to give reinforcement or assistance to the speaker and performer, and to promote more uniform conditions over the seating area; for a lecture hall the time is typically 0.5-1.0 second. The time for a concert hall will depend on the size of the hall, varying from 1.2 seconds for a small hall to 2.2 seconds for the largest. It is not unusual for churches to have much longer reverberation times.

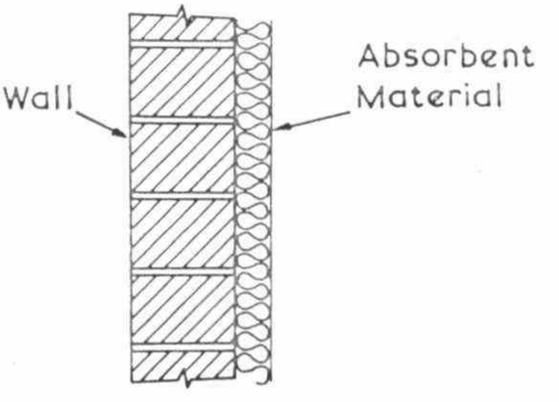

Fig. 1—Pores must be interconnected and not obstructed by an impervious facing, even painting.

It was noted above that reverberation time is dependent on the frequency; the design of the space should be arranged so that the reverberation time is reasonably constant over the frequency range 100-2000 Hz.

Sound Absorption

The sound-absorbing properties of a material are defined by the absorption coefficient. This is the fraction of the incident sound energy which is absorbed: a perfect absorber would have a coefficient of 1, and a perfect reflector would have a coefficient of 0. The absorption coefficient varies with frequency; a material could, for example, have a high coefficient over a narrow band of frequencies and little absorption above and below those frequencies; or it could have a coefficient which increases as the frequency increases. Thus, it is necessary to select different types of materials for different situations.

Sound absorbers fall into two classes: porous and impervious. In a porous material, sound energy is converted into heat by the friction of the moving air molecules in the pores of the material. In an impervious material, the sound energy is dissipated by the internal friction when the material is set into vibration. Both these types of materials can be further categorized according to whether they are flexible or rigid.

In porous materials the conversion of sound energy to heat energy is greater with higher velocities of air molecules, so it follows that the absorption of this type of material increases with increasing frequency. The pores must be interconnected and they must not be obstructed by an impervious facing, even painting (Fig. 1). Thus, open-cell plastics, felt, glass fibre, mineral wool and wood fibre are all excellent absorbers; their absorption coefficients depend on the thickness, the porosity and denseness of packing. Soft furniture, furnishings and people are also efficient absorbers, so that, for example, the reverberation time of an empty concert hall is higher than the time measured with a full audience. (This difference would be reduced where the hall was furnished with well-upholstered seats). Closed-pore plastics and foam glass, for example on the other hand, have very low absorption coefficients.

Flexible impervious absorbers work efficiently only when they resonate, i.e. when the frequency of the sound waves coincides with the resonant frequency of the panel. In this condition the motion is at its greatest. At all other frequencies their absorption is low, and so they are particularly and only useful to absorb one narrow band of frequency. This frequency depends on the mass and stiffness of the panel. Typical examples are plywood on battens and plasterboard (Fig. 2). Many proprietary absorbers consist of a combination of these two types (Fig. 3). Some typical absorption coefficients for common materials are given in Table 1.

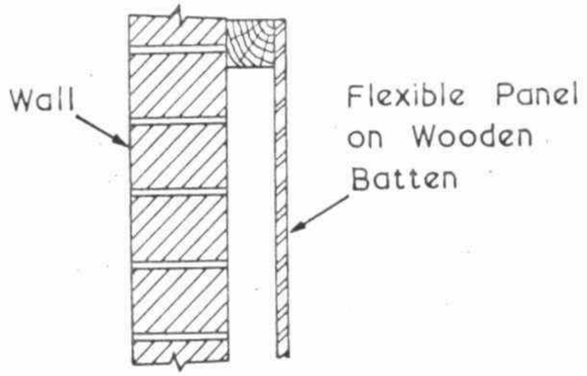

Fig. 2—Sound absorption frequency depends on the mass and stiffness of the panel. Typical examples are plywood on battens and plasterboard.

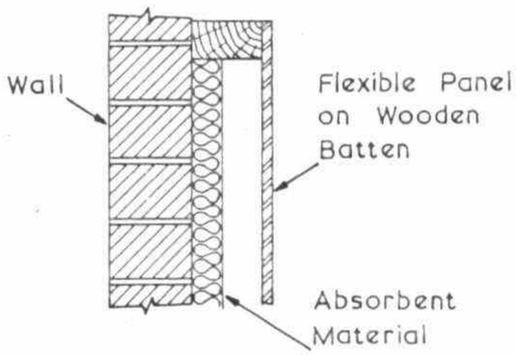

Fig. 3—Some propriety absorbers, as in this example, consist of a combination of the two types as shown in Figs. 1 & 2.

The Helmholtz Resonator

A further type of absorber is the Helmholtz resonator (Fig. 4). It consists essentially of a cavity with a narrow-necked opening. The air inside the cavity behaves as a spring acting on the mass of air in the opening; this has a resonant frequency, as can be readily demonstrated by blowing across the top of an empty bottle. Such a resonator has a high absorption around the resonant frequency and a low absorption at all other frequencies. The resonant frequency can be chosen by adjusting the size of the cavity and the size of the opening.

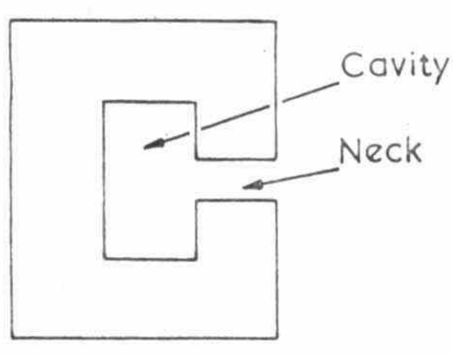

Fig. 4—The Helmholtz resonator consisting essentially of a cavity with a narrow-necked opening.

	Absorption coefficient at frequency of		
	125 Hz	500 Hz	4000 Hz
Brickwork	0.025	0.03	0.05
Concrete	0.01	0.015	0.02
Plaster on brick	0.015	0.025	0.04
Fibreboard tiles, perforated 31.7 mm thick	0.13	0.9	0.5
3.5 mm hardboard, 3 cm air space	0.12	0.15	0.15
Mineral wool, 50 mm	0.25	0.55	0.85
Plasterboard on battens	0.2	0.1	0.05
Glass fibre with 10% perforated face	0.1	0.5	0.95
Audience seated in upholstered seats	0.4	0.8	0.87

Table 1—Typical absorption coefficients of building materials.

The characteristic can be modified by fitting a porous plug to the neck or loosely filling the cavity with fibrous material. This has the two-fold effect of widening the frequency band over which the absorption is effective, but at the same time the peak absorption coefficient is lowered. The porous material should ideally be situated in the neck, but this of course detracts from the visual appearance and for this reason it is often preferred to place it within the cavity. Helmholtz resonators are

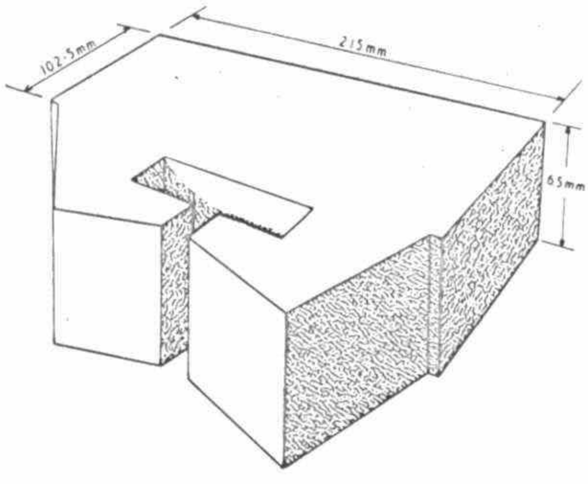

Fig. 5—An internal facing brick acting on the Helmholtz resonator principle.

most effective and suitable for low frequencies.

There are modified forms of resonator; one consists of a long slit with an elongated cavity behind. Another type is a panel perforated with small holes or slots mounted away for a rigid backing with the cavity between lightly filled with a damping material. This type is not to be confused with the porous absorber, which purely for appearance, is covered with a thin panel containing a much larger % perforation of larger holes.

Clay Products As Sound Absorbers

Most materials which are employed for their strength and durability have low absorption coefficients, for example brick, steel, concrete. It is thought that clay products are unlikely to compete with conventional sound absorbers solely on the basis of acoustic efficiency. Attempts to penetrate the market must lay special emphasis on the aesthetic properties of clay coupled with its physical attributes compared to other materials. Clay products are insufficiently versatile to lend themselves to the exacting requirements of auditorium acoustics, but could be particularly suitable for situations less exacting acoustically, such as entrance halls, meeting halls, churches, sports halls, swimming halls, etc., where a modest acoustic absorption coupled with an attractive appearance and a relatively vandalproof surface, is added to the normal properties of brick surfaces (durability, texture, color, etc.).

Several manufacturers have marketed an internal facing brick acting on the Helmholtz resonator principle. These bricks (Fig. 5) were originally developed by the Clay Cladding Company in Burgess Hill, Sussex, England. The design was originally registered, but the registration has now expired. These bricks are typically 215 mm long x 65 mm deep and have a contoured face so that the width varies from 100 to 160 mm. The cavity volume is of the order of 100-120 cm^3. The sound absorption coefficient would be expected to be of the order of 0.8. It was noted earlier that Helmholtz resonators are effective over a narrow frequency band which depends on the cavity and neck dimensions. Thus, it is possible within the standard 215 x 65 mm format to produce bricks of different other dimensions, so that one wall built of several bricks varying only in internal details could be an effective absorber over a range of frequencies. Fig. 6 is a computer design plot which shows how the theoretical resonance frequency varies with the ratio of area of neck/volume of cavity and neck length. For various acoustic reasons which it is not necessary to elaborate here, the actual measured resonance frequency is in excess of the theoretically calculated figure. As an example, whilst keeping the neck width constant to maintain the same visual appearance of the face of the brick, a range of similar bricks could

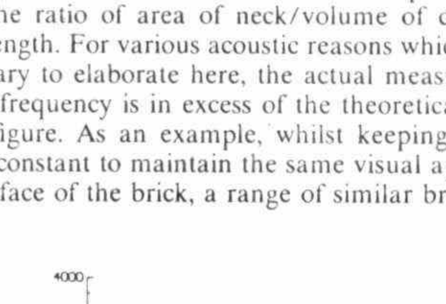

Fig. 6—A computer-designed plot shows how the theoretical resonance frequency varies with the ratio of area of neck/volume of cavity and neck length.

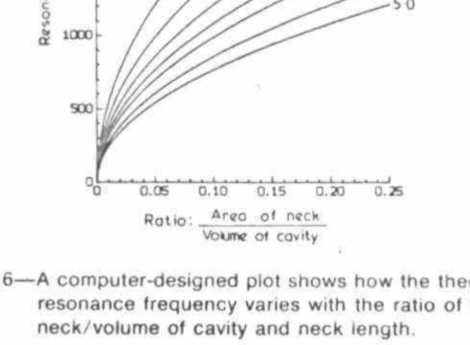

Fig. 7—'SCR Acoustile' brick is an adaptation of the Helmholtz resonator and claimed to combine high sound absorption with the durability and aesthetic properties of clay. It consists of a hollow clay block having two layers of voids.

ACOUSTIC TECHNOLOGY COURSE
ENVIRONMENTAL ACOUSTICS
TECHNOLOGY I

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Training and Certification Section
Personnel Services Branch
Ministry of the Environment
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Toronto, Ontario M4V 1P5

This course, Acoustics Technology I, is one part of the four part Acoustic Technology Certificate Course. Successful completion of this course and the Level II course is required for certification as a Noise Control Officer Level 1.

The Level I course manual and those for Levels II, III and IV may be purchased at:

Ontario Government Book Store
880 Bay Street
Toronto, Ontario

or may be ordered by mail by writing:

Ministry of Government Services
Publications Centre
3rd Basement Level
Macdonald Block
Queen's Park
Toronto, Ontario M7A 1N8

For training purposes, this manual should be read in conjunction with the Technical Publications supporting the Model Municipal Noise Control By-Law.

ACKNOWLEDGEMENT

The Noise Pollution Control Section, Pollution Control Branch, Ontario Ministry of the Environment, is entirely responsible for the scope, format and development of the course material contained herein. This manual was revised in July 1976 by:

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Uher Werke
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GENERAL INFORMATION

Identifying a lecture period

Each topic will be assigned to a part of a course identified by a three letter number.

The first letter indicates which of the four courses the topic is covered under. The four courses are as follows:

Environmental Acoustics I

Environmental Acoustics II

Environmental Acoustics III

Environmental Acoustics IV

The second letter signifies the work-day of the course. Each course lasts 5 days, thus numbers range between 1 and 5.

The third letter indicates the time during the day as coded below:

A: first morning session

B: second morning session

C: first afternoon session

D: second afternoon session

Example:

The lecture period III.4.C is in the Environmental Acoustics III course, on the 4th day, in the first afternoon session.

Evening tutorial sessions arranged as required.

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SUBJECT:

ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.1.A (Acoustics)

OBJECTIVES:

Trainee will be able to:

1. Describe the behaviour and nature of sound waves;
2. Define relationship of frequency, wavelength and speed of sound;
3. Distinguish between spherical and cylindrical wave propagation and give examples.

I.1.A.1. GENERAL DESCRIPTION OF THE NATURE OF SOUND WAVES AND THEIR BEHAVIOUR

(a) What is sound?

If a person claps his hands, or strikes a hammer, or plays the violin, sound is produced. The same sound can be heard by another person standing nearby. Sound is a disturbance which travels or propagates in the form of waves similar to waves in water.

(b) How Does Sound Travel?

Sound requires a medium to travel, and it cannot propagate in vacuum. Air, water and solids provide the mediums.

(c) Water Waves vs. Sound Waves:

When a pebble is gently dropped into a calm pool of water, a water wave is formed. This wave gradually spreads outwards. Similarly, when a sound is produced it travels outwards from the source of the sound in the form of waves. Figure I.1.A.1 illustrates this phenomenon.

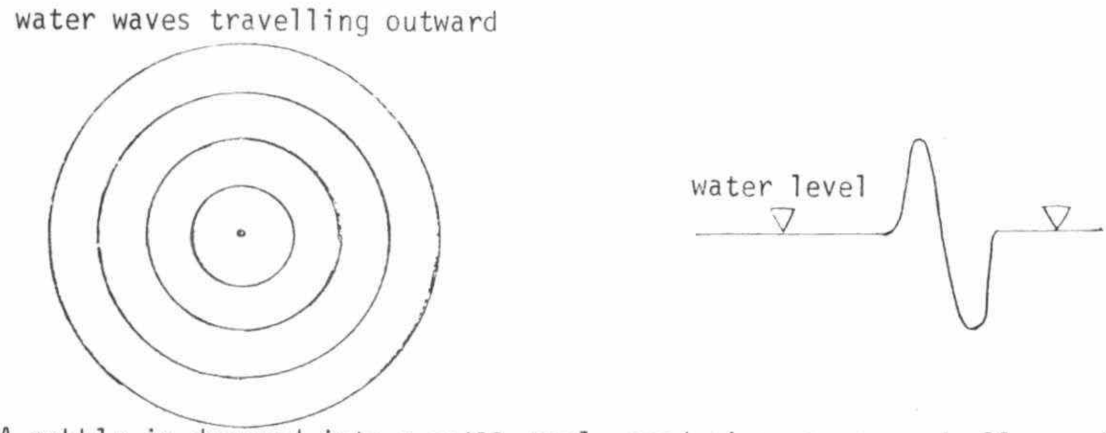
(d) Sound and Pressure:

Consider a loudspeaker generating sound. It does so by the to and fro motion of a diaphragm which in turn transmits this motion to the air adjacent to it. This results in small fluctuations in air pressure which travel outwards. These fluctuations in pressure are picked up by the ear as sound. Note that this pressure fluctuation due to sound is over and above the normally existing barometric pressure. The additional pressure due to a loud sound is very small compared with the normal barometric pressure.

EXAMPLE:

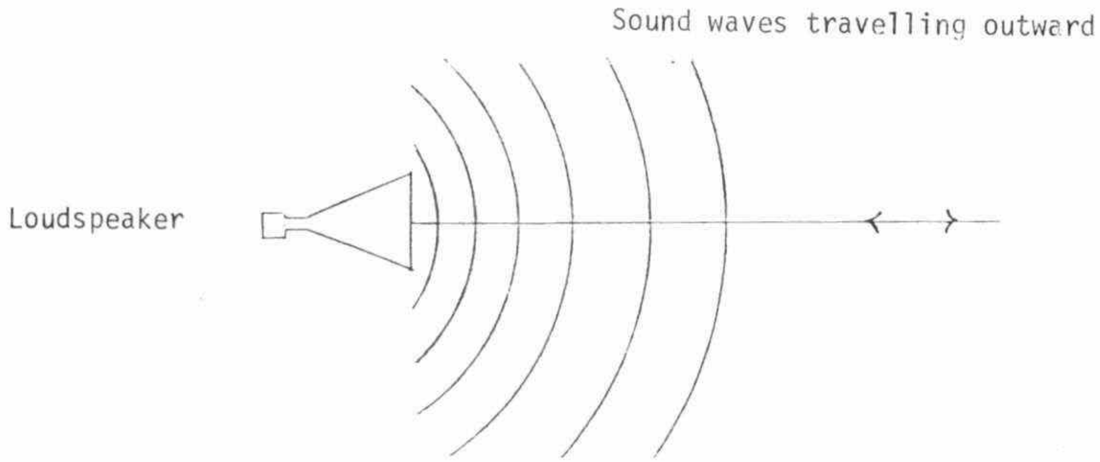
The additional pressure at a distance of 200 ft. from a jet aircraft is 10,000 times smaller than the normal barometric pressure (approximately 29 inches of mercury.)

Sound waves do not travel instantaneously, as illustrated in the example below:

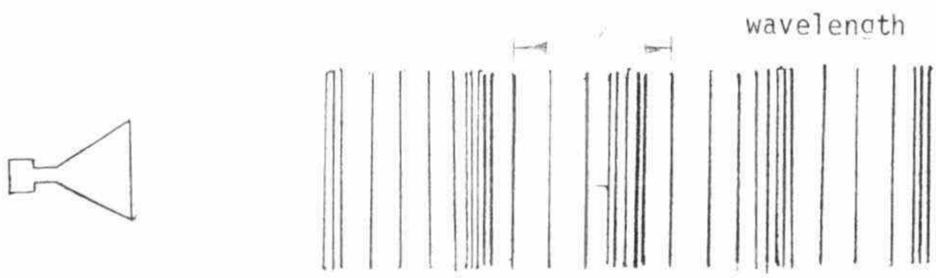


A pebble is dropped into a still pool, producing waves gradually moving outwards. As the wave travels outwards, the water itself moves up and down. (Shown on right hand side)

Figure I.1.A.1.: Generation of Water Waves



Sound from a source, like a loudspeaker also travels outwards in waves. But here, as the sound wave travels outwards air particles move to and fro in the direction of the wave. (Shown by the double arrow on the right hand side)



This to and fro motion causes alternate compression and expansion of the air. These pressure fluctuations are picked up by the ear as sound.

Figure I.1.A.2. Generation of Sound Waves

EXAMPLE:

Although lightning and thunder are generated simultaneously during a thunderstorm, the observer first notices the lightning and only later hears the thunder. The delay is caused by the time needed for the sound to travel from the thunderstorm location to the observer. (The light due to the lightning can be considered to travel the distance almost instantaneously.)

Sound travels or propagates at a certain speed known as the speed of sound. This speed depends on the medium through which it travels.

(e) Speed of Sound in Air:

During environmental noise control, we are mainly interested in the speed of sound in the air. It is related to the atmospheric temperature. At a temperature of about 20^{O} C (approx. 70^{O} F), the speed of sound in air is approximately 344 metres per second (or 1128 ft. per second).

I.1.A.2. RELATIONSHIP OF FREQUENCY, WAVELENGTH AND SPEED OF SOUND

(a) What is Frequency?

Consider the earlier example of the loudspeaker (refer to the Figure I.1.A.2). When the diaphragm of the loudspeaker moves to and fro, this generates pressure fluctuations in the air adjacent to it in the form of sound waves.

The number of times every second the air experiences these pulsations or fluctuations is known as the "frequency of the sound waves."

Obviously, the frequency of the sound waves generated is the same as the frequency at which the diaphragm moves to and fro.

(b) Units of Measurement of Frequency:

The frequency of sound waves is expressed in "Cycles per second." Cycles, in this case, refer to the pulsations of the air due to sound waves. In noise control work, a more commonly used unit is Hertz (abbreviated as Hz).

"Cycles per second" and Hertz are the same.

EXAMPLE:

If the loudspeaker diaphragm moves to and fro 125 times every second continuously, the frequency of sound waves thus generated will be 125 cycles per second or 125 Hz.

(c) Importance of Sound Frequency:

All sounds can be related in terms of frequencies. Generally, most of the everyday sounds are a mixture of different frequencies.

The human ear can perceive and distinguish between different frequencies.

EXAMPLES:

A commonly used word "pitch" closely relates to frequency. "High pitched" and "low pitched" voices in conversation generally refer to the frequency of the human voice.

A person listening to a symphony is able to distinguish between the clashing of cymbals and the tinkling of the triangle.

The sensitivity of ear to frequency plays an important role in the noise control field. Frequency analysis of the sounds from sound sources can, in many instances, point towards the problem.

(d) What is Wavelength?

Refer again to the example of the Figure I.1.A.1. It was noted that when a pebble was dropped onto the water, it generated waves which travel outwards. The distance between the two successive waves is defined as the wavelength.

When we talk about the wavelength of a sound wave, we refer to the distance between two successive points, where either the compression or the expansion is maximum (also indicated on the diagram).

Wavelength is not usually directly measured but can be determined as shown in the following section.

(e) How to Determine Wavelength:

Wavelength can be worked out from a knowledge of the frequency and the speed of the sound. It is given by the following relationship, wavelength = $\frac{\text{speed of the sound}}{\text{frequency}}$ - (I.1.A.1)

(f) Units of Measurement of Wavelength:

If the speed of sound is expressed in metres per second, and the frequency in hertz, the wavelength will be in metres.

If the speed of sound is expressed in ft. per second and the frequency in hertz, the wavelength will be in ft.

EXAMPLES:

In air, the speed of sound at $20^{o}C$ is 344 metres/sec. (1128 ft/sec.)

For a frequency of 100 Hz;

wavelength, in metres = $\frac{344}{100}$ = 3.44 metres

wavelength, in feet = $\frac{1128}{100}$ = 11.28 ft.

For a frequency of 5000 Hz;

wavelength, in metres = $\frac{344}{5000}$ = 0.0688 metres = 6.88 cms.

wavelength, in feet = $\frac{1128}{5000}$ = 0.2256 ft. = 2.71 inches

For a frequency of 20 Hz;

wavelength, in metres = $\frac{344}{20}$ = 17.2 metres

wavelength, in feet = $\frac{1128}{20}$ = 56.4 feet

Table I summarizes certain frequencies of practical interest and their corresponding wavelengths for sound travelling in air.

It is to be noted that the sound frequency increases as wavelength decreases.

Table 1: Relationship of Frequency and Wavelength in Air
(speed of sound in air at 20^{0} C = 344 m/sec. or 1128 ft/sec.)

frequency in Hz	wavelength	
	metres	feet
31.5	10.92	35.8
63	5.46	17.9
125	2.75	9.02
250	1.375	4.51
500	0.688	2.26
1000	0.344	1.13
2000	0.172	0.565
4000	0.086	0.283
8000	0.043	0.142

(g) Importance of Wavelength:

When measuring sounds in the immediate vicinity of sound sources outdoors, a knowledge of wavelength helps in selecting the best measurement locations. The distance between measurement location and the source should ideally be much larger than the wavelength corresponding to the frequency of interest.

I.1.A.3. SPHERICAL AND CYLINDRICAL WAVES:

As explained in the previous sections, sound travels in the form of waves. There are basically three types of sound waves:

(a) Spherical
(b) Cylindrical
(c) Plane

The type of wave generated depends on the sound source. The soundwaves from a loudspeaker at a distance of about 50 ft. will be of the spherical type. On the other hand,if it is from free flowing highway traffic the waves will be of the cylindrical type. At very large distances from a source (very large in comparison to the size of source) spherical waves are very similar to plane waves and may be considered as such.

SUBJECT:

ENVIRONMENTAL ACOUSTICS:- I

TOPIC: I.1.B. (Procedures)

OBJECTIVES:

Trainee will be able to:

1. Distinguish between the scope of the Environmental Protection Act, 1971 and the Industrial Safety Act, 1971;
2. Identify Municipal, Provincial and Federal jurisdiction related to noise control;
3. Describe the general philosophy of effective noise control legislation.

I.1.B.1. SCOPE OF THE ENVIRONMENTAL PROTECTION ACT, 1971 AND INDUSTRIAL SAFETY ACT, 1971

Sound waves propagate from sources of sound such as air conditioners, exhaust fans, construction equipment,etc. in all directions.

(a) How Sounds Affect People:

If these sounds are sufficiently loud or intense, they may affect people in the following ways:

1. cause annoyance
2. interfere with speech communication
3. affect interroom privacy
4. interfere with sleep
5. interfere with work tasks
6. damage hearing or health.

(b) Noise Complaints:

People affected in this manner complain of these "noises". In many instances individual municipalities or townships in Ontario will be receiving and handling noise complaints through their noise control program. This has become possible due to The Environmental Protection Amendment Act, 1974 (No. 2).

(c) Environmental Protection Act, 1971 as Amended

The Environmental Protection Act, 1971 of the Ministry of the Environment grants powers to Municipal Councils to exercise broad environmental noise control at the local level.

Environmental noise control refers to control of noise source activities outdoors in the community and in the natural environment. This control is exercised to reduce material discomfort (including annoyance) to people exposed to sounds from outdoors.

EXAMPLES:

1. Residents in the vicinity of a plant bothered due to noises of drop forge operations.
2. Apartment dweller awakened by the sounds of nearby pavement breaker operations.

Exposure to noise is also covered under another Ontario Act, the Industrial Safety Act.

(d) Industrial Safety Act, 1971

Industrial Safety Act of the Ministry of the Labor regulates noises within industrial work areas and other enclosed premises.

The control is aimed at preventing hearing damage to people exposed to loud noises indoors or at work.

EXAMPLES:

1. Drop forge operator subjected to noises from that operation in a plant.
2. Pavement breaker operator exposed to noises of that operation at the site.

(e) Environmental Protection Act, 1971, vs. the Industrial Safety Act, 1971:

The two acts address to different types of noise situations as outlined below.

1. The Environmental Act controls sounds outdoors in communities and in natural environments. The Industrial Safety Act regulates sound exposure in work areas.
2. The Environmental Act is formulated to reduce noise generated annoyance and emissions whereas the Industrial Act is primarily concerned with hearing loss hazard to those exposed to loud noises.

EXAMPLES:

In the examples given earlier the same noise problem can come under jurisdiction of both the Acts depending on the situation. In the first example of drop forge noises, the annoyance of the residents will be dealt with under the Environmental Act. The Industrial Safety Act will protect the drop forge operator from sound exposure.

Similarly in the second example, the sleep interference suffered by the apartment dweller is a concern under The Environmental Act. The noise exposure of the pavement breaker operator is controlled by the Industrial Safety Act.

I.1.B.2 MUNICIPAL, PROVINCIAL AND FEDERAL JURISDICTION IN NOISE CONTROL:

The problem of noise outdoors is a very familiar one and is deeply associated with the general activities in the communities. Industry, commerce, transportation and residential activities; all of which are vital for well being of communities, generate noises. Altogether, the three levels of Government (Federal, Provincial and Municipal) have concerns in these activities. Control of noise naturally requires participation at all three levels of Government.

(a) Municipal Jurisdiction:

As noted earlier the Municipalities in Ontario can exercise environmental noise control through the Amendment to the Environmental Protection Act. The noises that may be covered under the Municipal Noise Control By-law are listed below.

Air conditioners, power mowers, power tools, motorized conveyances, blasting and vibration,industrial and commercial noises, tire squeal, braking noises, faulty mufflers, racing vehicles, loudspeakers, street selling by outcry, loading and delivery, construction, discharge of firearms, animal noises, use of explosives, idling rail equipment on private property, car washes, all terrain vehicles, people noises, parties, gatherings, venting of high pressure gases.

(b) Provincial Jurisdiction:

The Provincial jurisdiction in noise control involves the following:

1. Approval of individual Municipal Noise By-law;
2. Certification of Municipal noise personnel;
3. Keeping record of the Municipal noise programs in Ontario;
4. Setting up standards to be used under Municipal noise control program.
5. Enforcement of the Environmental Protection Act, 1971.

The Province also assists Municipalities in adoption and implementation of the Noise By-law through technical training and advice when required.

(c) Federal Jurisdiction:

The Federal jurisdiction includes noise control over all inter-provincial transportation including aircraft and airports, trains and navigable waterways.

I.1.B.3. GENERAL PHILOSOPHY OF EFFECTIVE NOISE CONTROL LEGISLATION:

Ideally noise control legislation should be effective in abating all of the community noise problems that annoy the residents of the area. Noise control and reduction of sound intensity to attain this goal normally requires a change in the process, installation of muffler or silencer to equipment, erection of acoustic enclosures, relocation of the noise sources, change in time of operation etc. There is usually a direct or indirect cost involved in taking these steps.

A cost effective approach must be taken when abating noises. Practical control of noise aims at providing a maximum of relief from annoyance (which is not always total relief) at a minimum of cost. However, it has to be recognized that because of local, political and public opinion considerations the economic solution is not always the most practical one.

SUBJECT:

ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.1.C. (Acoustics)

OBJECTIVES:

Trainee will be able to:

1. Give the reasons for the use of logarithmic scale in sound measurements;
2. Define decibel, sound pressure level, sound power level and sound intensity level and relationships among them;
3. Indicate typical sound levels of some common noise sources in decibels.

I.1.C.1. USE OF LOGARITHMIC SCALE IN SOUND MEASUREMENTS

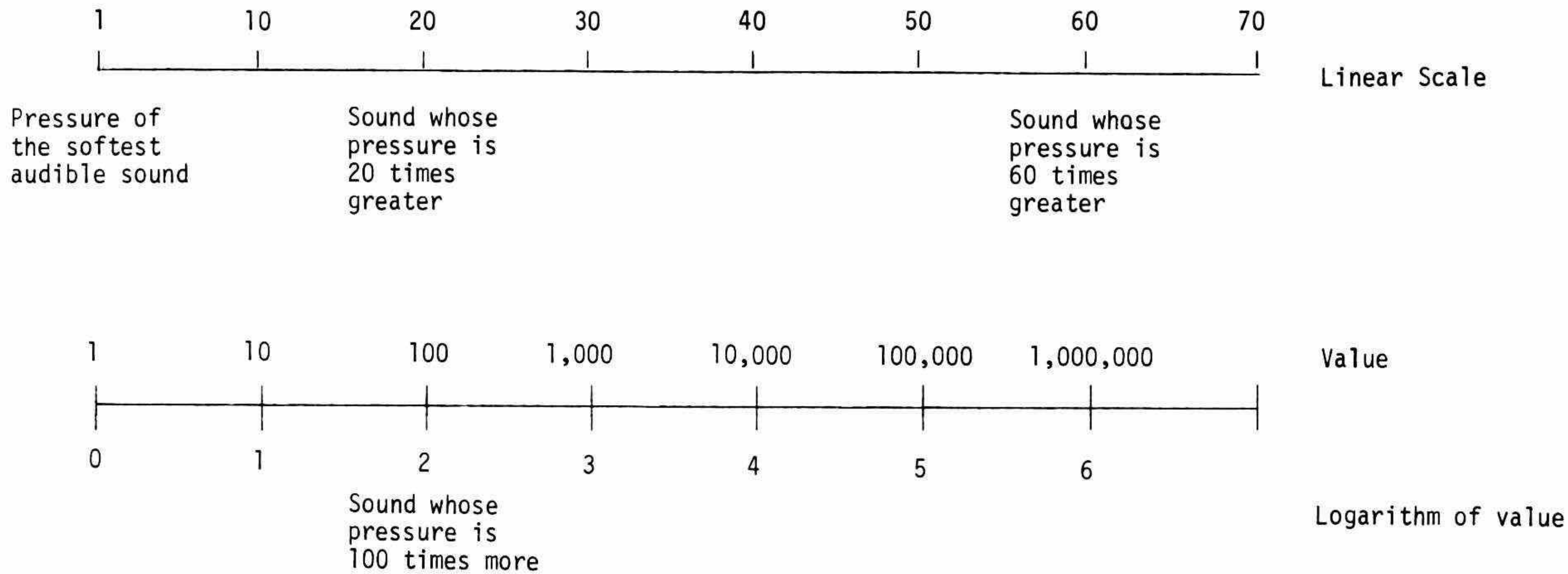
(a) Range of Noises Encountered:

The human ear is extremely sensitive. It can detect the rustle of falling leaves and yet it can withstand (to a certain degree) the roar of a jet aircraft. The ear, as we mentioned earlier is actually sensitive to pressure fluctuation. The pressure due to a jet aircraft, say at a distance of about 200 ft., is nearly 1,000,000 or a million times greater than that due to the rustling of leaves in a gentle breeze. In between these two extremes are the usual everyday sounds one is accustomed to hear, due to traffic or children in a playground,etc.

(b) Why is a Linear Scale Unsuitable to Represent all the Noises We Can Hear?

Let us try to write down those noises on a paper in their order of increasing pressure. Let us say the softest sound that we can barely hear is written at the left hand side of the linear scale in the Figure I.1.C.1. Next we write down a suitable distance away, say 0.1 inch,a sound which produces twice as much pressure. Similarly, we continue to mark the noises which cause 3, 4, 5 - etc. times as much pressure as the softest sound at 0.2, 0.3, 0.4 etc. inches from the beginning of the linear scale. Clearly, a sound marked two inches from the beginning of the line would give rise to a pressure 20 times larger than that due to the softest sound we can hear (because two inches can be divided into 20 equal parts of 0.1 inch each). If we go on at this rate, we would need 100,000 inches or 1½ miles of paper to mark the pressure due to the jet aircraft, since it is 1,000,000 times greater than that due to the softest sound. Thus, this scheme of presentation is not practical.

We could have made our scale larger, in other words we could mark the pressure due to the jet aircraft a convenient distance like, say 10 inches, from the beginning of the line. This would imply that one inch would represent 1,000,000/10 = 100,000 times the softest sound, or 1/10 inch would represent 100,000 x 1/10 = 10,000 times the softest sound. In this case we could mark the extreme sounds, but in between the two we would find it difficult to distinguish between a sound where pressure is less than 10,000 times that of another sound.



On linear scale, for every inch, 10 is <u>added</u> to previous value

On logarithm scale, for every inch, value is <u>multiplied</u> by 10

Figure I.1.C.1.: Linear and Logarithmic Scales

We are encountering a problem that is common whenever a very large range of values is to be represented. We are trying to use what is known as a Linear Scale. This means, for equal distance on the line in the Figure I.1.C.1, the value is changed by equal amounts regardless of whether we are looking at very large values or very small values. If we choose a scale which would allow us to represent the small values adequately we would need a huge length of paper. On the other hand, if we use a reasonable length of paper and we mark the largest and smallest value, we would be unable to distinguish between values which differ by a small amount.

(c) Concept of a Logarithmic Scale:

To overcome the problem we encounter when we use a linear scale to represent adequately the normal range of sounds we can hear, we use what is known as a Logarithmic Scale. Before we can explain what a logarithmic scale is, we should understand what logarithms are.

What are Logarithms?

We will not define logarithms, but will only give some examples:

Logarithm of 1 is 0. This is abbreviated as,

log (1) = 0
also, log (10) = 1
log (100) = 2
log (1000) = 3
log (10,000) = 4
log (100,000) = 5
log (1,000,000) = 6
etc.

From the above, it is clear that for numbers like: 10, 100, 1000, ... 1,000,000, ... etc. the logarithm is just equal to the number of zeroes. We also notice that while the values are going up by a factor of 10, i.e., 10, 100, 1000, ... etc., the logarithms are increasing by 1. This last fact is the key to the logarithmic scale.

If we were to plot the values on one side of a line and their corresponding logarithm on the other side of the same line it would look as shown by the bottom line in the Figure I.1.C.1.

An examination of the figure will show that for the logarithmic scale, values are spread out towards the bottom whereas they are compressed towards the top. In other words, in the 1 inch from 0 to 1, the value goes from 1 to 10. But in the 1 inch from 4 to 5 the value goes from 10,000 to 100,000.

Another reason for the use of logarithmic scale in sound measurement is that the ear responds to sounds in a logarithmic manner.

(d) How Do We Apply the Logarithmic Scale to Represent Different Sounds?

We mentioned earlier that when we say we are measuring sound, we are actually measuring the pressure fluctuations due to that sound. We also indicated that since the range of pressure due to common everyday sounds is so large, we cannot conveniently use a linear scale and we had to resort to a logarithmic scale. This is done through the use of a unit called the decibel.

I.1.C.2 DECIBEL, SOUND PRESSURE LEVEL, SOUND POWER LEVEL

(a) What is a decibel?

We have already learnt that sound is described using a logarithmic unit known as the decibel scale.

The decibel scale can be generally defined as follows:

DEFINITION

$$\text{decibel} = 10 \log \frac{X}{X_{REF}} \qquad \text{... ... ...(I.1.C.1.)}$$

In the definition we are describing the quantity X in decibel units. Later we will replace X by the acoustic units we require for describing sound level. The first step in describing the quantity X in decibel units is to divide X by some reference value of X symbolised by X_{REF}. Why is this done? First because the decibel scale is a ratio scale. Here we would say that X was so many decibels relative to X_{REF}. Thus we see that the decibel scale is not an absolute scale, and some reference must always be specified before a decibel value has any meaning. The second reason is purely mathematical in that one can only take the logarithm of a pure number. A ratio is a pure number thus the ratio of X to X_{REF} is found before taking the logarithm.

After finding the ratio of X to the reference value X_{REF}, the logarithm of the ratio is taken to give us the logarithmic scale we require. The result of taking this logarithm is a bel. However, the bel itself is not usually used as it is too large a unit for convenience. Instead one bel is divided into ten decibels. This is the reason for multiplying the logarithm by 10 in the definition.

(b) What is Sound Pressure Level?

We must now see how we can apply the decibel scale to sound pressure. Before we do this however we must decide what pressure we are going to use to describe the sound. It has already been stated that sound is small fluctuations of pressure above and below atmospheric pressure. We must somehow arrive at a single pressure reading which represents these small fluctuations. The single pressure we use is called the root mean square pressure, RMS pressure or P_{RMS} for short. This is simply a kind of average pressure found by squaring the instantaneous pressure fluctuations, finding their average and taking the square root again.

Why does this complicated squaring, averaging and square rooting have to be performed? If we performed a simple average, because the pressure fluctuations are both positive and negative (above and below atmospheric pressure) the result would be zero.

Squaring makes the negative fluctuations positive (minus times minus gives plus) and hence the averaging will give a non-zero result which is what we require. It is also found that the RMS pressure is a good representation of the fluctuating pressures associated with sounds.

The next stage before we can set up the decibel scale for sound pressure is to define the reference RMS pressure. This is defined for convenience as being approximately the lowest audible sound pressure of $20\,\mu$Pa (1 Pa = 1 N/m^2).

Now we can define Sound Pressure Level, the decibel scale of sound pressure.

DEFINITION

Sound Pressure Level (SPL), $L_p = 10 \log \frac{(P_{RMS})^2}{(P_{REF})}$ in dB ...(I.1.C.2)

where P_{REF} = 20 μPa or 0.000020 Pa

In addition to the micropascals(μPa), other units can also be employed to express reference pressure as shown below.

P_{REF} =	20	micropascals
or	2×10^{-5}	Newtons/metre^2
or	20	microNewtons/metre^2
or	2×10^{-4}	dynes/cm^2

In the definition dB is used as an abbreviation of decibel. This definition corresponds very closely to the decibel definition already given but with one very important difference, the pressure ratio is squared. Why is this?

The decibel scale is a power scale. Since pressure squared is proportional to power, then the pressure ratio must be squared before the logarithm is taken. Secondly, pressure is not a fundamental physical quantity. Energy and power are fundamental quantities and we can only set up a meaningful decibel scale using such fundamental quantities. This concept will be discussed more fully when we consider the addition of sound levels.

Sometimes when calculating it is useful to express Sound Pressure Level (SPL) in a slightly different form as in the final expression here,

$$L_p = 10 \log \left(\frac{P_{RMS}}{P_{REF}}\right)^2 = 20 \log \left(\frac{P_{RMS}}{P_{REF}}\right) \quad \text{dB} \quad \ldots\ \ldots\ \ldots(\text{I.L.C.3.})$$

(c) What is Sound Power Level

We have already defined Sound Pressure Level which is a measure of the sound reaching a measurement point from a source. Often in acoustics a scale is required to describe the acoustic power emitted by a source. This power rating is similar to that used to describe the output of a radio station or an electric heater. For convenience a decibel scale is also used in acoustics to describe the Sound Power Level (L_W) of a sound.

DEFINITION

Sound Power Level, $L_W = 10 \log \left(\frac{W}{W_{REF}}\right)$ dB........(I.1.C.4.)

where W is the sound power of the source and

W_{REF} is the reference sound power of 1 picowatt or 10^{-12} watts or 0.000000000001 watts.

(d) The Relationship between Sound Pressure Level and Sound Power Level

As we have already learnt, the Sound Power Level (L_W) is a measure in decibels of the sound power output by a source. This sound power will radiate away from the source in all directions. As this sound power radiates it will give rise to sound pressure fluctuations. As the sound waves travel further away from the source the pressure fluctuations must decrease as the available sound power is being spread over a larger area. A similar situation exists when a balloon is being blown up. The bigger the balloon becomes the more the rubber is obliged to stretch and the thinner it becomes. The sound pressure fluctuations are "diminished" and reduced in a similar manner as the available sound power is spread over a larger and larger surface area. The sound power itself remains constant whatever the distance from the source. The sound pressure fluctuations decrease according to the area over which the available sound power has been spread. Thus the relationship between the Sound Pressure Level (L_p) and the Sound Power Level (L_W) can be expressed as follows:

$L_p = L_W - 10 \log S$ ... ... (I.1.C.5.)

where S is the total surface area over which the sound power is spread (in metres^2).

We can now take this equation further for the two main types of source.

The point source

A point source can be imagined as being a point suspended in air radiating sound equally in all directions. Let us consider an observer at a distance r (metres) from this point source of sound power L_W, with no reflecting surfaces present.

First, $S = 4\pi r^2$ - the area of a sphere

<u>For a point source</u> $L_P = L_W - 10 \log 4\pi r^2$......(I.1.C.6.)

Let us also consider the effect of increasing r on the Sound Pressure Level.

Let L_{P_1} be the Sound Pressure Level at distance r_1,

and L_{P_2} be the Sound Pressure Level at distance r_2,

then, $L_{P_1} = L_W - 10 \log 4\pi r_1^2$

and, $L_{P_2} = L_W - 10 \log 4\pi r_2^2$

$$L_{P_2} - L_{P_1} = 10 \log 4\pi r_1^2 - 10 \log 4\pi r_2^2$$

$$= 10 \log \frac{4\pi r_1^2}{4\pi r_2^2},$$

Thus <u>for a point source</u> $L_{P_2} - L_{P_1} = 10 \log \left[\frac{r_1}{r_2}\right]^2 = 20 \log \frac{(r_1)}{(r_2)}$ (I.1.C.7)

From this equation it can be seen that <u>if the distance from a point source is doubled the Sound Pressure Level is reduced by 6 dB</u>.

<u>The line source</u>

A line source can be imagined as an infinitely long line suspended in air radiating sound equally in all radial directions. A similar procedure can be followed as for a point source to obtain the relationship between Sound Power Level and Sound Pressure Level for a line source. However, this involves integration techniques and will not be considered here. Only the effect of increasing r on Sound Pressure Level will be considered.

Again Let L_{P_1} be the Sound Pressure Level at distance r_1

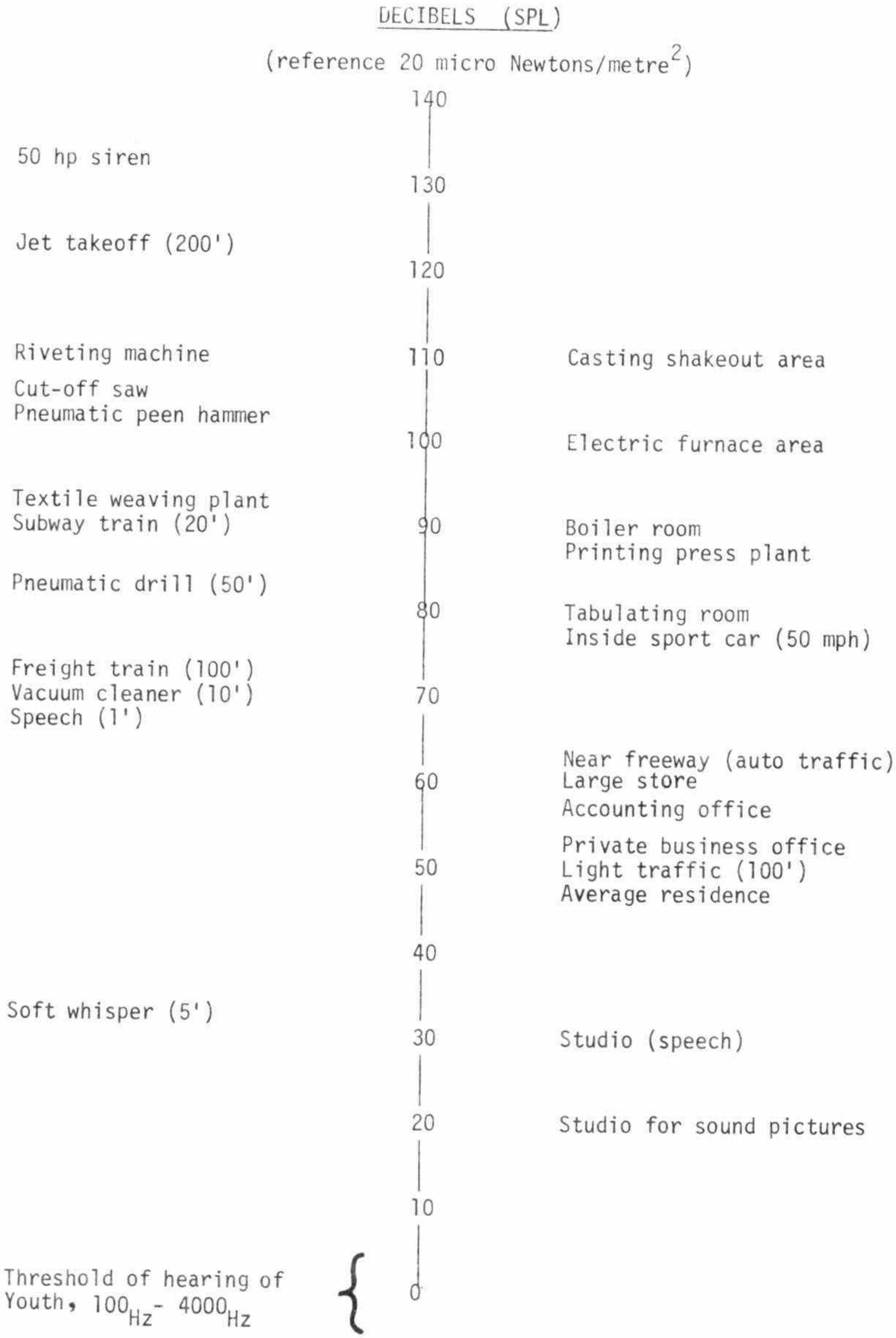
and L_{P_2} be the Sound Pressure Level at distance r_2

Thus <u>for a line source</u> $L_{P_2} - L_{P_1} = 10 \log \left(\frac{r_1}{r_2}\right)$....(I.1.C.8)

From this equation it can be seen that <u>if the distance from a point source is doubled the Sound Pressure Level is reduced by 3 dB</u>.

I.1.C.3. TYPICAL LEVELS OF SOME COMMON NOISE SOURCES

The Figures I.1.C.2 and I.1.C.3 show the sound pressure level and the sound power level respectively at noted distances for various types of common noise sources.



The sound levels are at the given distance from sound sources

Figure I.1.C.2: Typical Sound Levels in Decibels

DECIBELS (PWL)

(reference 10^{-12} watt)

195	Saturn Rocket
170	
	Turbo-jet engine with afterburner
160	Turbo-jet engine 7000-Lb. thrust
150	
	4-Propeller airliner
140	
	75-piece orchestra) peak RMS levels in
130	pipe organ) 1.8-second intervals
	Small aircraft engine
120	Large chipping hammer
	Piano
110	Blaring radio
	Centrifugal ventilating fan (13,000 CFM)
100	4' Loom Auto on highway
90	Vaneaxial ventilating fan (1500 C FM) Voice - shouting (average long-time RMS)
80	
70	Voice - conversational level (average long-time RMS)
60	
50	
40	
30	Voice - very soft whisper

Figure I.1.C.3: Typical Sound Power Levels

SUBJECT:

ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.1.D.(Acoustics)

OBJECTIVES:

Trainee will be able to:

1. Add sound pressure levels in decibels;
2. Calculate composite sound levels as a result of individual noise sources;
3. Indicate range of sound frequencies of practical interest;
4. Explain why weighting networks are used in sound measurement;
5. Name commonly used weighting networks (A,B and C).

I.1.D.1. ADDING SOUND PRESSURE LEVELS IN DECIBELS:

Anyone who has listened to a stereo knows that two speakers do not sound twice as loud as a single speaker. Disconnecting one speaker doesn't reduce the volume very much. This is because the ear hears on a type of decibel scale.

(a) How decibels add?

Figure I.1.D.1. can be used to demonstrate how decibels can be added together. Two examples given below illustrate this.

EXAMPLE 1: - Two equal sounds - add 3 dB.

50 dB + 50 dB = 53 dB and not 100 dB!

On figure I.1.C.1. 50 dB corresponds to 10^5 or 100,000. Adding two 50 dB sounds together doubles 100,000 (10^5) to 200,000. On the decibel scale this is still quite close to 50 dB, in fact it is 53 dB. In general, doubling the sound gives a 3 dB increase.

eg. 2 X 60 dB = 2 X 1,000,000
= 2,000,000 = 63 dB

eg. 2 X 73 dB = 2 X 20,000,000
= 40,000,000 = 76 dB

EXAMPLE 2: - Two very unequal sounds (at least 15 dB apart) - ignore the quieter one.

40 dB + 60 dB = 60 dB

Adding 40 dB and 60 dB is equivalent to adding 10,000 and 1,000,000 to get 1,010,000. On the decibel scale this is so close to 1,000,000 that we can ignore the lower sound level. When one sound is 15 dB or more below another, then its contribution can be considered insignificant for all practical purposes. No one will hear a bird singing next to a roaring jet engine!

(b) Addition of decibels - nomograph method:

The nomograph given in the Figure I.1.D.2. provides a quick simple and practical chart of adding decibels. The steps involved are outlined below:

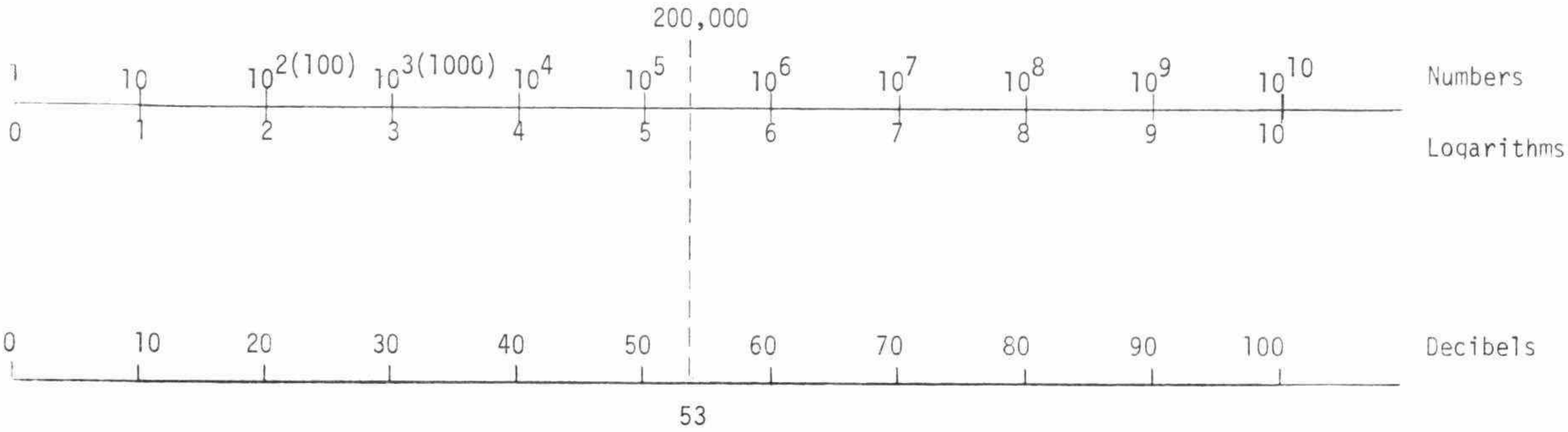


FIG. I.1.D.1. Numbers, Their Logarithms and Decibels step 1: take the difference in decibels between the two levels which are being added together.

step 2: enter this difference on the chart at the right hand side of the scale, and look up the corresponding number on the left hand side of the scale.

step 3: add the number so obtained to the higher sound level (louder sound of the two)

EXAMPLE: 63 dB and 65 dB sounds are added together using the nomograph method.

step 1: 65-63 = 2 dB

step 2: enter 2 dB on right side of scale, corresponding number on left side of the scale is approximately 2.1 dB

step 3: 2.1 dB is added to 65 dB (louder sound) giving 67.1 dB

result: 63 dB and 65 dB sounds add to 67.1 dB

MORE EXAMPLES: 50 dB + 52 dB = 52 = 2.1 = 54.1 dB
95 dB + 100 dB = 100 + 1.2 = 101.2 dB
92 dB + 93 dB = 93 + 2.5 = 95.5 dB
45 dB + 60 dB = 60 + 0.1 = 60.1 dB

(c) Accuracy while combining decibels:

At this point it may be pointed out that during most sound measurements, accuracy of better than 0.5 dB is hardly ever attained. Therefore sums that give numbers like 60.1 dB or 101.2 dB should usually be rounded-off to 60 dB and 101 dB respectively. As a general rule, round up for 0.5 dB. and above; round down for below 0.5 dB.

e.g. 60.5 → 61, 60.4 → 60. If the sums are part of a longer calculation, the extra digit should be kept until the end of the calculation before it is dropped.

EXAMPLES:

52 dB + 60 dB = 60.6 dB
→ 61 dB (by rounding off)

68 dB + 72 dB = 73.5 dB
→ 74 dB

55 dB + 63 dB = 63.6 dB
→ 64 dB

50 dB + 40 dB = 50.4 dB
→ 50 dB

56 dB + 58 dB = 60.1 dB
→ 60 dB

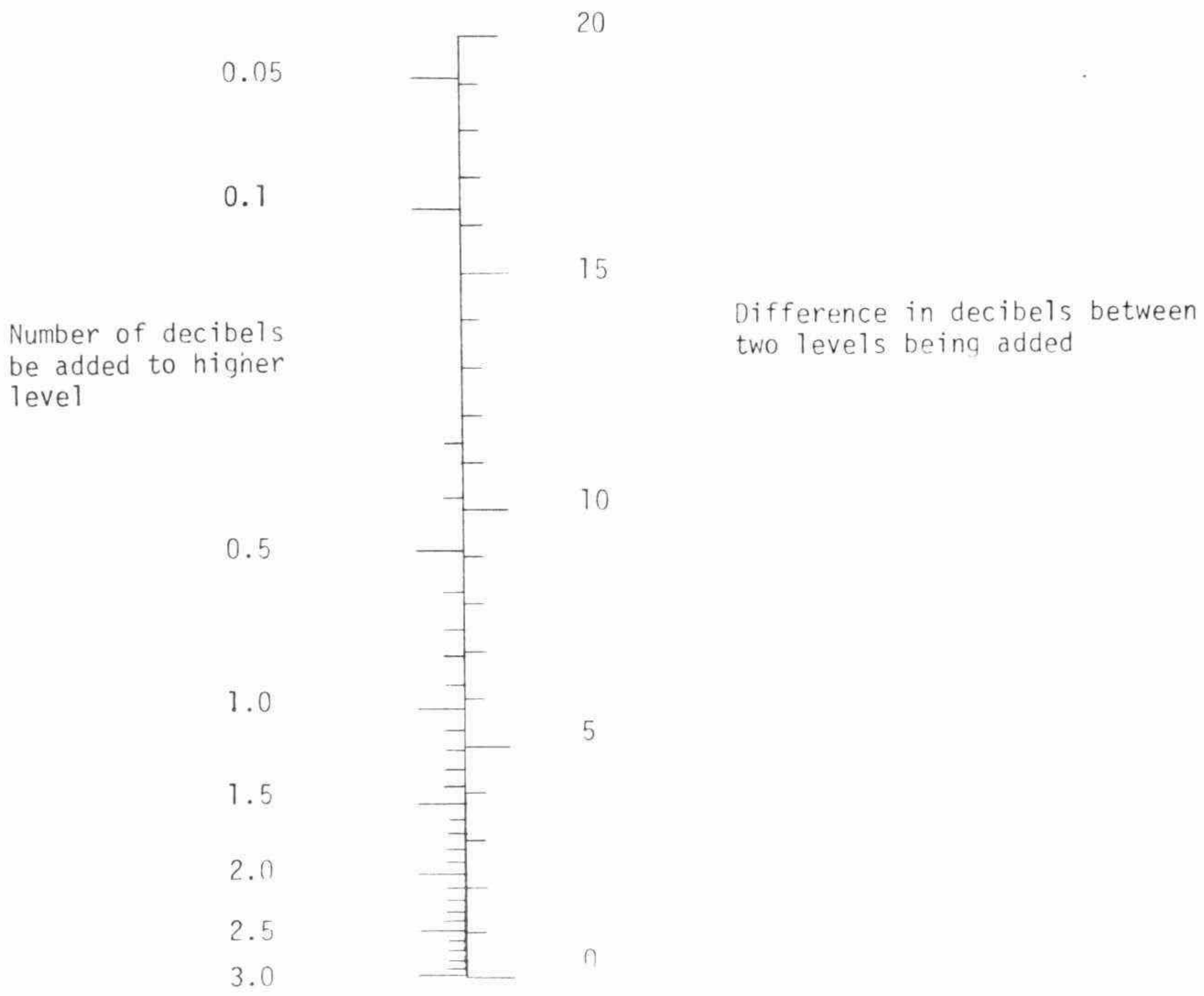


Figure I.1.D.2: Nomograph for Adding Sound Pressures in Decibels

I.1.D.2. COMPOSITE SOUND LEVELS

The nomograph method can be applied when adding sound levels due to a number of individual sound sources (more than two).

EXAMPLES:

(1) 68 dB & 72 dB & 70 dB & 70 dB & 71 dB (5 sound levels)
= 73.5 dB + 70 dB + 70 dB + 71 dB (on summing 68 & 72 dB together)
= 75.1 dB + 70 dB + 71 dB (on summing 73.5 and 70 dB together)
= 76.3 dB + 71 dB (on summing 75.1 and 70 dB together)
= 77.4 dB (on summing 76.3 and 71 dB together)
→ 77 dB

If all the levels being added are the same, the rule of 3 dB per doubling can be used.

(2) 10 machines each contributing 90 dB:
2 machines: 93 dB (on summing 90 and 90 dB together)
4 machines: 96 dB (on summing 93 and 93 dB together)
8 machines: 99 dB (on summing 96 and 96 dB together)
10 machines: 100 dB (8 machines added up to 99 dB and 2 machines added together to 93 dB)
ie. 99 & 93 dB = 100 dB

MORE EXAMPLES:

(3) 45 dB + 45 dB + 46 dB + 44 dB
= 48 dB + 40 dB + 44 dB
= 50.1 dB + 44 dB
= 51.1 dB → 51 dB

(4) 80 dB + 85 dB + 85 dB + 83 dB
= 88.5 dB + 85 dB + 83 dB
= 90.1 dB + 83 dB
= 90.9 dB → 91 dB

This could have been speeded up by noting that 85 dB + 85 dB = 88 dB reducing the problem to:
88 dB + 80 dB + 83 dB
= 90.1 dB + 83 dB
= 90.9 dB → 91 dB

Thus it is to be noted that while combining decibels, levels can be summed up in any order desired.

I.1.D.3 RANGE OF FREQUENCIES OF PRACTICAL INTEREST

(a) On high frequency side:

People vary in their ability to hear high frequency sound. Usually the limit is between 15,000 Hz and 20,000 Hz depending on age and other factors. Everyone is fairly insensitive to these frequencies.

(b) On low frequency side:

Again, people become progressively less sensitive to low frequency sound, the usual limit being drawn between 15 and 20 Hz. Sounds below these frequencies (infrasound) can often be felt and may make people extremely uncomfortable.

EXAMPLES: A piano has a frequency range from 27 Hz to 4138 Hz, with middle C being 258 Hz (International Pitch). Only very large pipe organs exceed this range.

Like music, 4000 or 5000 Hz is the usual limit of interest for noise control purposes. High frequency sound is often easy to deal with. Noise problems may involve frequencies so low that they cannot be heard.

I.1.D.4 WHY WEIGHTING NETWORKS ARE USED

In noise measurements it has been found useful to highlight certain frequencies and suppress others. For this purpose certain internationally accepted weighting networks have been designed and incorporated in measuring instruments.

I.1.D.5 COMMONLY USED WEIGHTING NETWORKS:

A,B & C weighting networks or scales (see Figure I.3.B.1).

SUBJECT:
ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.2.A (Acoustics)

OBJECTIVES:

Trainee will be able to:

1. Outline significance of the sound level meter;
2. Outline applications of sound level meter;
3. Describe principle and functioning of sound level meter;
4. Indicate the general dynamic range of sound level meters and their frequency range for different microphones;
5. Explain significance of type 1,2 and 3 sound level meters;
6. Identify limitations of sound level meters while measuring different types of noise sources;
7. Indicate why the calibration of sound level meter is important.

From previous topics we have noted that to quantify or describe different sounds, their sound levels and frequency information must be included.

I.2.A.1. SIGNIFICANCE OF THE SOUND LEVEL METER:

The sound level meter is an instrument designed to quantitatively measure sound levels and frequency content of different types of sounds. It is considered essential to standardize on an instrument by which sounds can be measured under closely defined conditions, so that results of measurements can be compared reliably.

I.2.A.2. APPLICATIONS OF SOUND LEVEL METER:

Sound level meters are used to measure a wide variety of sounds for a variety of purposes. The sounds may vary in levels and frequency content and.further.these characteristics may vary with time. The sounds may be mainly from a single source or from a combination of many sources.

Some major applications are listed below.

Sound Levels of Stationary and Mobile Sources

- stationary noise sources like compressors, air conditioners, transformers etc.
- mobile noise sources like individual trucks, automobiles, trains motor boats,etc.

Sound Levels Outdoors and Indoors

- outdoors in an open field, at a construction site, in built up urban areas, adjacent to highways,etc.
- inside a building to measure noise emitted by home appliances such as vacuum cleaners, mixers, sewing machines, stereo sets, ventilation systems, typewriters, etc.

Other applications of the sound level meter involve estimation of the hearing damage risk, evaluation of sound insulation properties of building structures (walls, doors, etc.), estimation of annoyance, land use planning and assessment.

1.2.A.3. PRINCIPLE AND FUNCTIONING OF THE SOUND LEVEL METER

(a) Principle of Sound Level Meter:

The sound level meter is a device that coverts sound to an electric signal and displays it on a meter.

The principle of operation of the sound level meter is shown in the simplified block diagram of the Figure I.2.A.1.

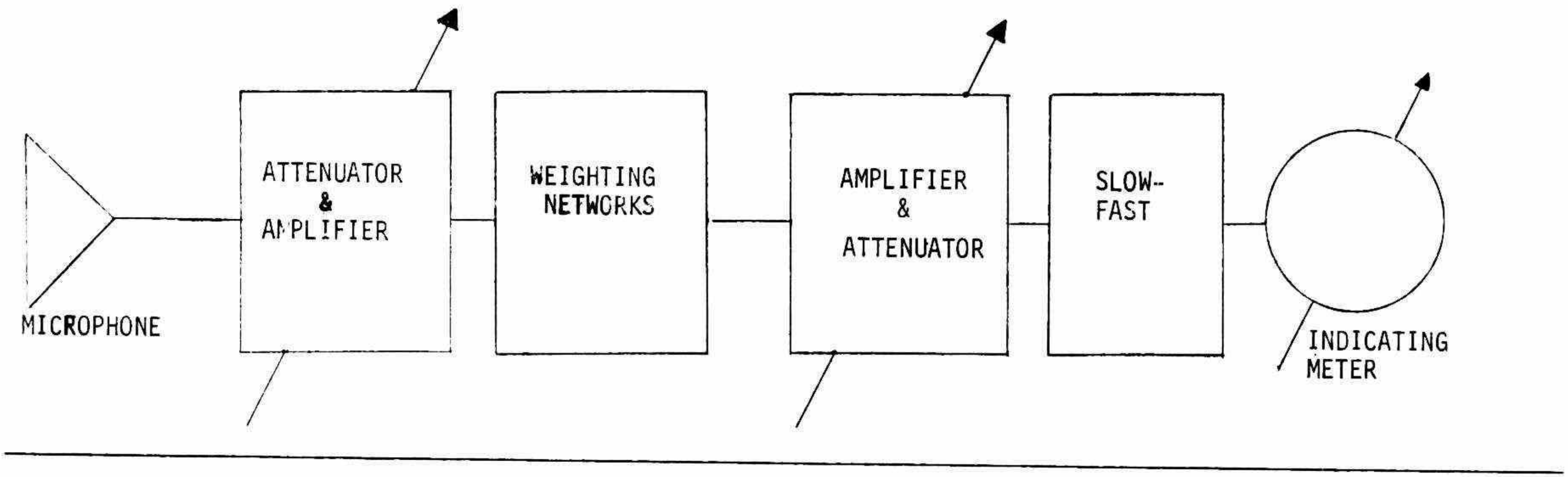


Figure I.2.A.1 Block Diagram of a Sound Level Meter.

(b) Function of Components (parts) of a Sound Level Meter:

- Microphone converts sound pressure fluctuations or sound waves into electrical signals.
- Electrical signals generated at the microphone are usually very weak. Amplifier increases them by many times into strong signals.
- Attenuator provides appropriate adjustment of the amplification of the electrical signal. The choice of attenuator setting depends on the range of sound level being measured.
- Weighting Networks are special electronic circuits built in the sound level meter to simulate frequency dependence of the human ear. To audible sounds; they highlight or discriminate against some of the frequencies present in the sounds being measured.

  A selection from four weighting networks (A,B,C and linear) is usually available, and they will be further discussed in Topic I.3.B.

- Indicating Meter displays the decibel value to obtain a reading of the sound level. The indicated level on the meter should be added directly to the setting of the attenuator. The meter scale is usually marked for levels from 0 to 10, and at least 6 dB below the "0" reference mark.

- It may sometimes be difficult to take a correct reading when the sound level to be measured is fluctuating and the needle of the indicating meter is deflecting too rapidly. The two settings "slow " and "fast" are thus provided to facilitate a selection of proper measuring condition.

  An output connection that can supply the amplified signal to another instrument for analysis is also usually provided.

A general type sound-level meter manufactured by the Bruel & Kjaer Company of the Denmark is shown in the Figure I.2.A.2.

The sound level meter is battery operated and fully portable.

1.2.A.4. THE GENERAL DYNAMIC RANGE OF SOUND LEVEL METERS AND THEIR FREQUENCY RANGE FOR DIFFERENT MICROPHONES:

Dynamic and frequency range greatly determine the capability and the limitations of a sound level meter.

(a) Dynamic Range

The dynamic range of a sound-level meter is the range of sound pressure levels, expressed in decibels, which the instrument is capable of measuring with the accuracy prescribed by the standards.

EXAMPLE:

B&K Type 2205 sound-level meter shown in the Figure I.2.A.2. has the dynamic range of 32 dB to 140 dB.

(b) Frequency Range:

The frequency range of a sound level meter indicates the range of sound frequencies within which the instrument can measure the sound pressure levels with the accuracy prescribed by the standards.

The frequency range of the instrument shown in the Figure I.2.A.2. is 20 Hz to 10 kHz (10,000 Hz)

Both, dynamic and frequency range of the sound level meter are determined mainly by the type and the size of the microphone being used.

Two types of microphones commonly used for making noise measurements are:

Condenser Microphone

It is an electrical capacitor formed by a thin diaphragm exposed to sound waves and a back plate.

Figure I.2.A.2.: The Bruel & Kjaer Type 2205
Sound Level Meter

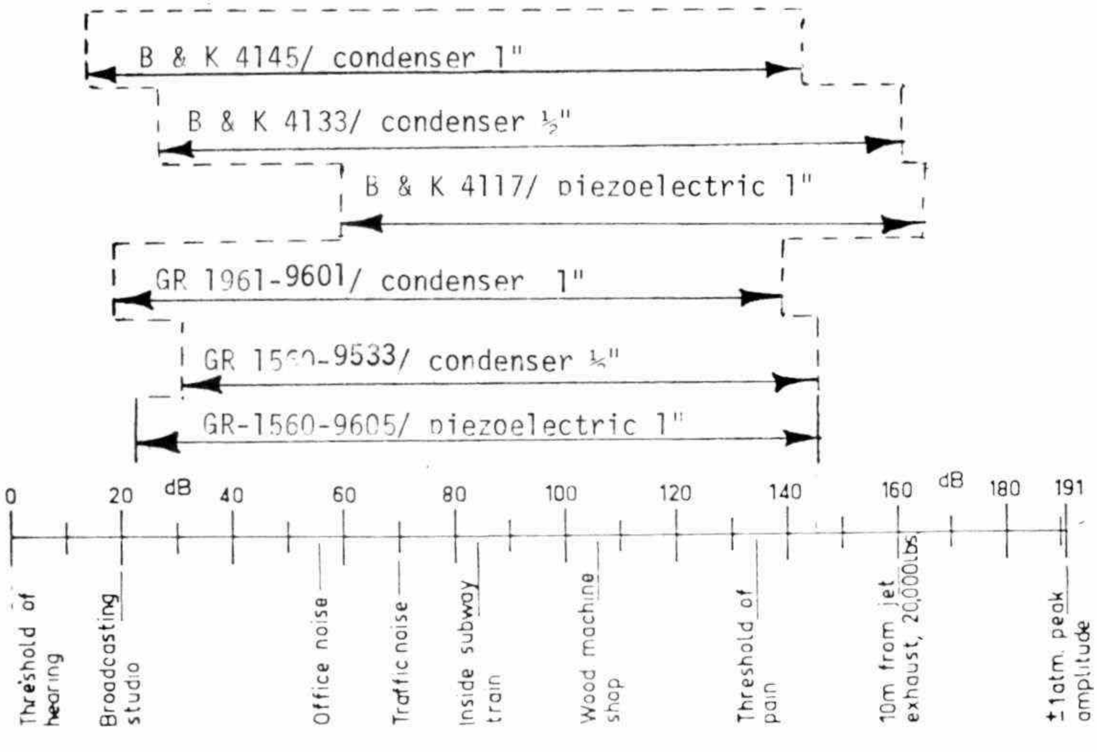


Figure I.2.A.3.: Comparison of the Dynamic Range of Microphones

EXAMPLES:

Such as B&K 4145, B&K 4133, GR-1961, GR 1560-9533 etc.

Piezoelectric Microphone

Uses piezoelectric material having the property of producing electrical charges on the surface, when the material is strained due to sound pressure variations.

EXAMPLES:

Such as B&K 4117, GR 1560-9605 etc.

1" and ½" diameter micrpohones are commonly used in noise measurements.

The approximate dynamic range for the microphones usually employed in noise measurements are compared in the Figure I.2.A.3.

Frequency range (also known as frequency response) of the microphones given in the Figure I.2.A.3. are compared in the Table 2.

Microphone Type	Frequency Range
B&K 4145/ condenser 1"	2Hz - 18 kHz (18,000 Hz)
B&K 4133/ condenser ½"	20Hz - 40 kHz
B&K 4117/ piezoelectric 1"	3 Hz - 10 kHz
GR - 1961-9601/ condenser 1"	5 Hz - 15 kHz
GR - 1560-9533/ condenser ½"	20Hz - 20 kHz
GR - 1560-9605/ piezoelectric 1"	5 Hz - 12.5 kHz

Table 2: Comparison of the Frequency Range of the Microphones.

In general, large size microphones (1" in diameter) are usually more sensitive for measuring low sound levels, whereas smaller microphones (½" in diameter) are more suitable at higher sound levels.

Comparison of frequency response for different types and sizes of microphones indicates limited high frequency response for piezoelectric types. However, because of their smooth frequency characteristic and relative superior stability at changing temperature and humidity, as well as low cost, this type of microphone has found wide application in noise measurements.

I.2.A.5. SIGNIFICANCE OF DIFFERENT TYPES OF SOUND LEVEL METERS

Because of the different types of sounds to be measured in a variety of applications, sound level meters can be divided into the following three types:

1. Impulse Type
2. General Purpose Type
3. Survey Type (THIS TYPE DOES NOT MEET THE TOLERANCE REQUIREMENTS IN MUNICIPAL USE.)

The three types of meters differ in their capabilities, and to some extent in their measurement tolerances.

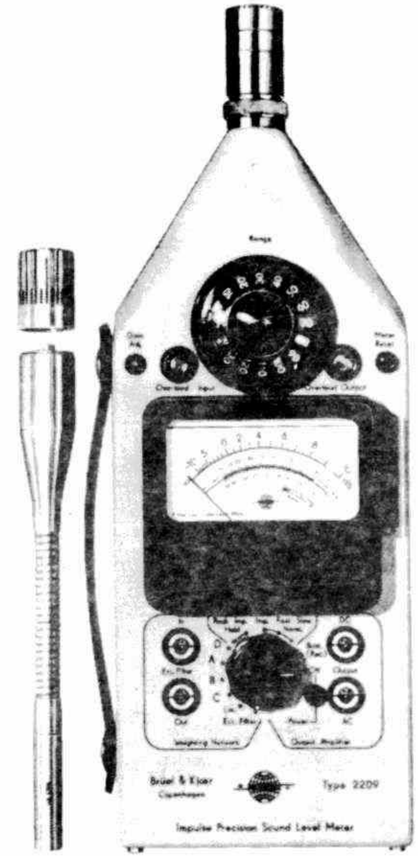
Impulse type meters generally meet the specifications of IEC 179 and 179A (for complete specifications refer to the Publication NPC-112), and may be used to measure all kinds of sounds including impulsive, quasi-steady and buzzing types of sounds, given in Table 3.

General purpose meters generally meet the specifications of IEC 123 (for complete specifications refer to the Publications NPC-112), and may be used to measure general sounds given in Table 3.

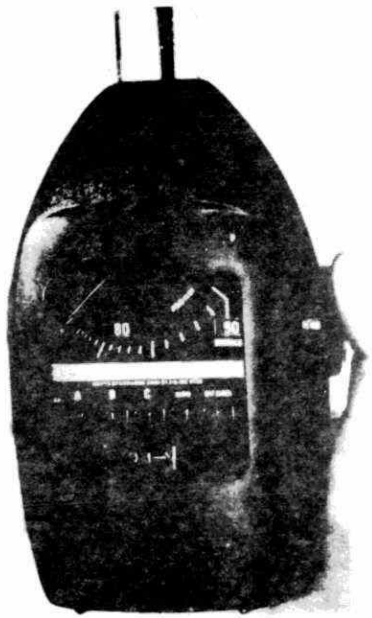
The above two types of meters are shown in Figure I.2.A.4.

Some examples of different types of sound level meters are given below.

IMPULSE TYPE: B&K 2209, GR 1933 and DA 100



Bruel & Kjaer 2209, Impulse Type



General Radio 1565-B, General Purpose Type

Figure 1.2.A.4. Examples of Two Types of Sound Level Meters

GENERAL PURPOSE TYPE: B&K 2205 (now superseded by B&K 2219), GR 1565-B (microphone remotely located from body), Scott 452 and Quest 215 (microphone remotely located from body).

Tolerance of a sound level meter varies considerably over the entire frequency range. Figure I.2.A.5 illustrates the band of typical instrument frequency tolerances expected for a general purpose meter. This tolerance incorporates microphone and weighting tolerances only, and does not include those of the rectifier and indicating meter.

I.2.A.6. LIMITATIONS OF SOUND LEVEL METER:

Applications of sound level meters are restricted mainly by the characteristics of the sounds being measured. Measurement of steady sounds, generally, does not present any special problems. However, if the level due to a sound varies considerably, it becomes difficult to determine which reading of the meter needle should be reported. Measurement of such non-steady sounds may create problems, and the results may be unreliable and misleading, if caution is not exercised.

Some examples of steady and non-steady types of sounds are presented in Table 4.

I.2.A.7. WHY IS THE CALIBRATION OF SOUND LEVEL METER IMPORTANT?

Satisfactory noise measurements depend on the use of measuring equipment that is kept in proper operating condition. Even a good sound level meter may change its sensitivity with time. In order to ensure that any important changes will be discovered and corrected, certain simple checks known as calibration have to be carried out.

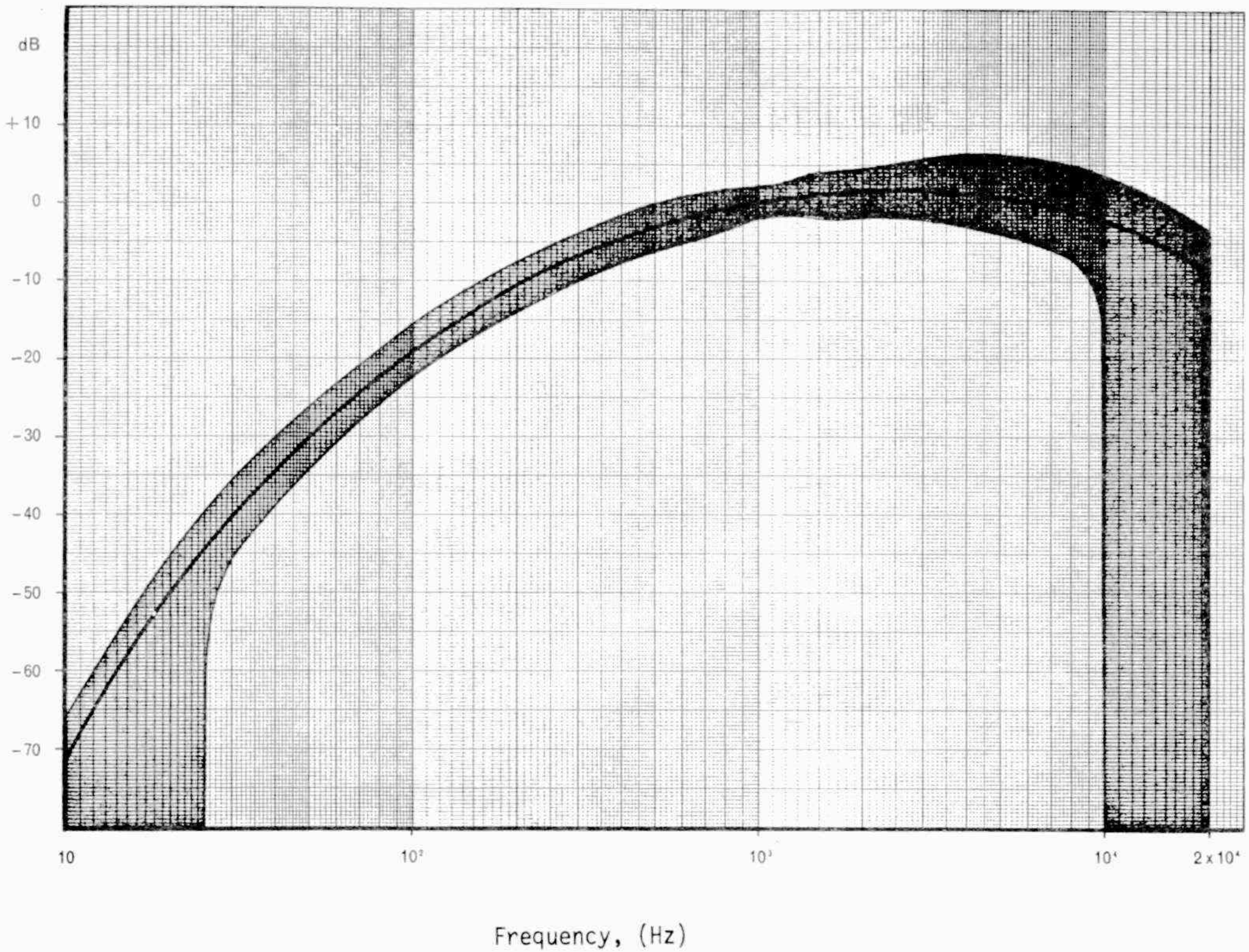


Figure 1.2.A.5. Illustration of Typical Instrument Frequency Tolerance for a General Purpose Sound Level Meter

Calibration check is performed by means of an acoustical calibrator. This is a device which produces a fixed sound pressure in an enclosure that is designed to fit over the microphone of a sound-level meter.

The acoustic calibrator offers the advantage of convenience plus the fact that the calibration checks will always be made with the same type of signal.
The simplest type of calibrators operate on a single frequency. In other types, calibrating sound signals at several frequencies are employed. A single frequency type of calibrator is shown in the Fig. I.2.A.6.
Calibration checks are applied before and after the measurements.

General Sounds	Impulsive Sounds
Without audible discrete tones Distant city Waterfall Air conditioning system (high velocity) Residential Air conditioner With audible discrete tones Circular saw Turbojet engines Muffled internal combustion engine and air compressor Fluctuating sounds Heavy traffic (nearby) Pounding surf Intermittent Aircraft fly-over Automobile pass-by Train pass-by	Isolated bursts Drop forge hammer Dog barking Pistol shot Door slamming Electrical circuit breaker Quasi-steady noise Riveting Pneumatic hammer Machine gun Ineffectively muffled internal combustion engine or air compressor Buzzing sounds Transformer Positive displacement blower Chain saw Miniature internal combustion engine Ineffectively muffled lawn mower gasoline engine

Table 3: Examples of General and Impulsive Sounds

Steady	Non-steady
Without audible discrete tones	Fluctuating
Distant city	Heavy traffic (nearby)
Waterfall	Pounding surf
Air-conditioning system (high velocity)	Intermittent
Air conditioner	Aircraft fly-over
With audible discrete tones	Automobile passing by
Circular saw	Train passing by
Turbojet engine	Impulsive
Muffled internal combustion engine, and air compressor	Isolated bursts
buzzing sounds	Drop forge hammer
Positive transformer displacement blower	Dog barking
Chain saw	Pistol shot
Miniature internal combustion engines	Door slamming
Ineffectively muffled lawn mower gasoline engine	Electrical circuit breaker
	Quasi-steady noise
	Riveting
	Pneumatic hammer
	Machine gun
	Ineffectively muffled internal combustion engine or air compressor

Table 4: Examples of Steady and Non-steady Sounds

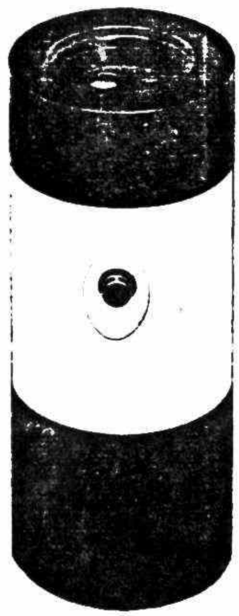


Figure I.2.A.6.: Bruel & Kjaer Type 4230
Sound Level Calibrator

OBJECTIVES:

Trainee will be able to:

1. Describe the complaint investigation procedure;
2. Indicate the procedure of handling "out of jurisdiction" complaints;
3. Recognize different categories of noise sources;
4. Describe cross referencing in complaint recording system.

1.2.B.1. COMPLAINT INVESTIGATION PROCEDURE - FORMAL

(a) Receiving Complaints

Complaints may be received by telephone, letter or by a visit of the complainant. All complaints should be recorded on a complaint form preferably in four copies.

(b) Chronological Sequence Number

Each complaint form will be numbered in sequence which will distinguish this particular complaint from any other and also keep a running total of the number of complaints received.

The first of two numbers of the sequence number will be the last two numbers of the year, and the subsequent numbers be sequential. The first complaint of the year will always be number 001 (For example, 76001).

(c) Complainant

Anonymous complaints may be accepted but should be discouraged. As it is impossible to obtain further information should this be required, it may make an investigation impossible to complete. The full name and initials with address, both residence and business phone numbers should be obtained if possible.

Source

As much information as to what is considered to be the noise source should be obtained,as possible.

Nature of Complaint

The following information should be obtained in filling out the noise complaint form (Figure I.2.B.1):

(a) Type of noise: Stationary (air conditioner, machinery etc.)
Mobile (aircraft, train, truck etc)
People noise (parties, radios etc)

Time noise occurs: Time of day
Duration
How often (every Tuesday)?

Quality of noise: Whine, screech, hum etc.

Noise Complaint Form

TOWN, CITY OR MUNICIPALITY

SEQUENCE NO.	CATEGORY

INVESTIGATION NO.

WHEN RECEIVED ______AM/PM ______________________________19___

RECEIVED BY	LOCATION

COMPLAINANT

TEL. NO.

ADDRESS

SOURCE (NAME OF COMPANY OR PERSON)

TEL. NO.

ADDRESS

NATURE OF COMPLAINT

INVESTIGATE DECISION

COPIES TO: 1. Investigation file 2. Alphabetical register of complainants 3. Alphabetical register of sources 4. Chronological sequence of complaints register

Figure I.2.B.1.

(b) Has the complainant complained before?
If so, to whom? when? what response?

Other Information

Time and date received and by whom.

Copy No. 4 of the complaint form is immediately filed in the chronological register of complaints.

Copies 1, 2 and 3 are passed to the investigator, as outlined in Section I.2.B.4.

Preliminary Investigation

The investigator will establish the general source of the noise complained of: If there is or has been, a previous investigation and if the complaint should be further investigated.

If there has been a previous investigation on this source in the same category, this complaint will be given the same investigation number and category.

If there is no existing investigation file a new file will be opened and given an investigation number and category, except when there is to be no investigation, in which case the No. 1 copy of the complaint form will be filed in a special "NOT INVESTIGATED REGISTER".

If there is to be no investigation the complainant must be advised in writing stating the reasons.

All four copies of the complaint form will be annotated with the investigation number of the complain. The complaint forms will then be filed in the appropriate file and register.

If the complainant is not interviewed, and the investigation will take longer than two weeks, the complainant should be so advised either by letter or phone of the status of the complaint.

A written record should be made in the investigation file. On completion of the investigation the complainant should be advised in writing and the file closed.

I.2.B.2. OUT OF JURISDICTION COMPLAINTS

If the source of the noise is not within the jurisdiction of the Municipality, the complaint should be forwarded to the appropriate authority and the complainant so advised either at the time of lodging the complaint or by subsequent letter.

(a) Federal jurisdiction covers the following problem areas.

(1) Aircraft Noise

Regional Supervisor of Airways,
Ministry of Transport,
P.O. Box 7,
Toronto Dominion Centre,
King Street West,
Toronto, M5K 1A5
Tel.(416) 369-3223

(2) Railway Noise

Chief of Noise Control Division,
Federal Activities Protection Branch,
Environmental Protection Service,
Environment Canada,
Vincent Massey Building,
Ottawa K1A 0H3
Tel.(613) 997-1763

(3) Highway Traffic Noise

Road and Motor Vehicle Traffic Safety Branch,
Ministry of Transport
27th Floor, Tower C,
Place De Ville,
Ottawa, K1A 0N5
Tel.(613) 995-7293

(4) All Federal Concerns (Ontario Region):
Environment Canada,
Environment Protection Service,
Ontario Region,
Toronto.
Tel.(416) 966-5840

Note 1. Shunting, loading on private property should be treated as a stationary noise source.

Note 2. Municipal by-laws may be enacted under the Railway Act to control whistling of trains.

(b) Problems concerning all Provincial jurisdiction should be referred to the MOE Regional office.

I.2.B.3. NOISE SOURCE CATEGORIES

Category: The noise source should be assigned a category as follows:

HVAC*	Heating, ventilation, air conditioner, etc.
INDP	Industrial plant
COMP	Commercial building
CDQM	Construction, demolition, quarries, mining
REDL	Residential (other than air conditioners)
PRIT	Private transportation
PUBT	Public transportation
TRAF	Traffic in general (e.g. highway noise)
OTHR	Other
RECV	Recreational vehicle
SOEJ	Federal (aircraft, train etc.)

I.2.B.4. CROSS REFERENCING IN COMPLAINT RECORDING SYSTEM

No.1 copy of the Complaint form is filed in the investigation file which is stored in numerical order of the investigation number, or in a loose leaf "NOT INVESTIGATED" register.

* This category coding is used by the Noise Pollution Control Section of Environment Ontario. Its use is purely optional.

No.2 copy of the complaint form is kept in the loose leaf register, by alphabetical order of the complainants surname.

No.3 copy of the complaint form is kept in a loose leaf register by alphabetical order of the noise source.

No.4 copy of the complaint form is kept in a loose leaf register by chronoligical sequence number.

This filing method maintains a cross reference file system with the least amount of maintenance and only ONE operating file.

SUBJECT:

ENVIRONMENTAL ACOUSTICS - II TOPIC: I.2.C. (Procedures)

OBJECTIVES:

Trainee will be able to:

1. Explain general procedure to be followed in municipal noise investigation;
2. Indicate general information sought when interviewing complainant and noise producer including investigator's assessment of noise situation;
3. Name and demonstrate the use of forms to document field measurement data;
4. Outline uses of maintaining complaint statistics.

I.2.C.1 GENERAL PROCEDURE OF MUNICIPAL NOISE INVESTIGATION :

A noise complaint investigation may be described as the work performed to analyze and report a noise situation in order to establish how to proceed further towards an effective abatement.

An investigation will normally be conducted in two phases, the first being the preliminary investigation. This involves interviewing the complainant and the noise producer, and an assessment of the situation by the investigator.

The preliminary investigation should usually be sufficient to establish whether the LOCAL MUNICIPAL NOISE CONTROL BY-LAW does in fact cover the situation. If it does, this visit may, in simple cases, be all that is needed to establish if the sound is excessive according to the by-law. In complex situations, a subsequent investigation will usually be necessary.

A useful procedure prior to interviewing the complainant and the noise producer is to take a walk around the area of the complaint. This may result in determining the actual noise source or other contributing noise sources. This walk also enables the investigator to appreciate the local environment and, as a result, he is better equipped to discuss the problem at initial interviews with the complainant and the noise producer.

The usual first step in a noise investigation is to contact the complainant. This will make the complainant aware that his/her complaint is being responded to and in most cases will enable the investigator to obtain more specific details of the complaint.

Before visiting a private residence, it is courteous to phone to ensure that a visit will be convenient. Should the investigator be delayed or unable to keep an appointment it is again courteous to phone and inform the complainant of this.

At any interview the investigator should ensure that his official position and name are known, by presenting his identification card.

As a number of separate items are covered in an investigation, various forms have been prepared to help the investigator obtain the information it is usually necessary to seek. These forms may be supplemented by additional information, at the discretion of the investigator, and the forms should, in any case, be supplemented by maps and photographs covering the area and showing pertinent locations and source(s). These forms are discussed below.

I.2.C.2 INTERVIEW OF COMPLAINANT, NOISE PRODUCER AND INVESTIGATOR'S ASSESSMENT OF NOISE:

Complainant Interview Report:

To assist the investigator in obtaining the pertinent information on a complaint, the COMPLAINANT INTERVIEW FORM (shown in Figure I.2.C.1) should be completed, though preferably not by a formal question and answer technique while with the complainant. The investigator should proceed on a line of questioning which will determine the cause of the complaint, the nature of the noise and its likely source, etc. Precise indication of the time that a noise occurs may be crucial in tracing a source. If a noise may be heard at the time of the visit, the investigator should have the complainant point it out to him. The investigator should also ensure that he has the correct name, title (if any), and initials of the complainant, the complete address and telephone number.

INVESTIGATION NUMBER

[ ]

Date: ______________

INVESTIGATION REPORT
COMPLAINANT INTERVIEW

NAME: ______________________________

ADDRESS: ______________________________ PHONE ______________

____

1. TYPE OF NOISE: (i) ______________
(ii) ______________
(iii) ______________
(iv) ______________

2. TIME(S) OF NOISE:

Noise	Continuous Yes or No	Occasional Yes or No	Usual limits of occurrence e.g. 9 a.m. - 10 a.m.
(i)			
(ii)			
(iii)			
(iv)			

3. WHEN DID NOISE FIRST BECOME A PROBLEM? ______________

____

____

4. HAVE YOU CONTACTED NOISE PRODUCER DIRECTLY? YES [ ] NO [ ]

IF YES: WAS REACTION CO-OPERATIVE? [ ] CONCERNED? [ ]

HOSTILE? [ ]

5. OTHER COMMENTS: ______________________________

____

____

Investigating Officer(s): 1. ______________

2. ______________

Figure I.2.C.1

Noise Producer's Interview Report:

The investigator during the course of the preliminary investigation will also interview the noise producer. The investigator should always enter a plant or premises through the main entrance and identify himself with his identity card and ask for a senior company official. The investigator should then state that the purpose of his visit is to investigate a noise complaint and that he is trying to locate the noise source.

To provide some guidance in the questioning of the noise producer, the NOISE PRODUCER INTERVIEW FORM (shown in Figure I.2.C.2) should be completed.

It is also useful to obtain all the relevant data about the noise source if it can be identified during the visit.

It may sometimes be advisable not to warn the suspected noise producer of the first visit made to observe the situation. A surprise visit may indicate that a laxness in procedures is a contributing factor to the noise problem; and may prevent a quick, but temporary, rectification of the noise problem prior to the investigator's arrival.

Investigator's Observations Report:

After the investigator has interviewed the complainant and the noise producer, he should make a subjective assessment of the noise and report his findings using the INVESTIGATOR'S OBSERVATIONS FORM (Figure I.2.C.3).

The subjective assessment will include what in the investigator's opinion is causing the noise and whether there is a simple solution to the problem.

A map or diagram showing land usage (and zoning if available) together with measurement locations should be added together with any photographs or sketches of the source that the investigator feels is necessary. A suggested form for this is presented in the Figure I.2.C.4. Relative location of complainant and the noise producer must be clearly indicated on this diagram

INVESTIGATION NUMBER ____________

Date: ____________

INVESTIGATION REPORT
NOISE PRODUCER INTERVIEW

PREMISES KNOWN AS: ____________ PHONE ____________

ADDRESS: ____________

____

CONTACT NAME: ____________ TITLE ____________

1. IS THE NOISE PRODUCER AWARE THAT HE IS CAUSING A NOISE PROBLEM? YES ☐ NO ☐

   IF YES, DOES HE KNOW THE NOISE SOURCE? YES ☐ NO ☐

2. DESCRIBE THE NOISE SOURCE. IF AN AIR-CONDITIONER IN A RESIDENCE, WHAT IS THE OUTPUT, MAKE AND MODEL?

   ____

   ____

3. WHAT ARE HOURS OF OPERATION OF NOISE SOURCE(S)? (THIS SHOULD CONFIRM OR DENY THE COMPLAINT HOURS). ALSO NOTE ANY CYCLES OF OPERATION.

   ____

   ____

   ____

4. CAN EQUIPMENT BE SWITCHED ON AND OFF FOR MEASUREMENTS? YES ☐ NO ☐

   IF YES, WHEN? ____________

5. CAN EQUIPMENT BE SWITCHED OFF OR REDUCED IN POWER AS A WAY OF LESSENING NOISE? (e.g. AT NIGHT) YES ☐ NO ☐

   IF YES, WHEN? AND DOES INVESTIGATOR FEEL THIS MAY HELP?

   ____

6. HAS THE NOISE PRODUCER ANY FUTURE PLANS THAT MAY ABATE THIS PROBLEM? YES ☐ NO ☐

   IF YES, GIVE DETAILS INCLUDING DATES ____________

7. WAS NOISE SOURCE OPERATING AT TIME OF VISIT? YES ☐ NO ☐

Investigation Officer(s): 1. ____________

2. ____________

Figure I.2.C.2

INVESTIGATION NUMBER

[ ]

Date: ____________________

INVESTIGATION REPORT
INVESTIGATOR'S OBSERVATIONS

1. DOES NOISE HAVE AN AUDIBLE TONAL QUALITY? YES [ ] NO [ ]
   IF YES, DESCRIBE ____________________

2. DOES THERE SEEM TO BE A BEAT? YES [ ] NO [ ]

3. DOES THERE SEEM TO BE AN IMPACT NOISE? YES [ ] NO [ ]
   IF YES, DESCRIBE ____________________

4. DOES THERE SEEM TO BE A VIBRATION? YES [ ] NO [ ]
   IF YES, DESCRIBE ____________________

5. WHAT APPEARS TO BE CAUSING THE NOISE? ____________________

   ____

6. CAN THE PROBLEM BE VERY OBVIOUSLY ABATED? YES [ ] NO [ ]
   IF YES, HOW? ____________________

   ____

7. WAS THE NOISE PRODUCER'S ATTENTION DRAWN TO THE OBVIOUS REMEDY? YES [ ] NO [ ]

8. DID THE NOISE PRODUCER SEEM WILLING TO CO-OPERATE IN ABATING THE PROBLEM? YES [ ] NO [ ]
   IF YES, HOW? ____________________

   ____

   ____

9. IS THE NOISE EXCESSIVE IN THE INVESTIGATOR'S OPINION? YES [ ] NO [ ]
   ANY SPECIAL REASONS: ____________________

   ____

10. CIRCLE CATEGORY OF PREDOMINANT NOISE: PRIT PUBT SOEJ
    HVAC INDP COMP CDQM RECV REDL OTHR

Investigation Officer(s): 1. ____________________

2. ____________________

Figure I.2.C.3

SKETCH OF MEASUREMENT LOCATION(S)

Figure I.2.C.4

I.2.C.3 FORMS TO RECORD FIELD MEASUREMENT DATA:

The measurement data collected in the field is documented on the forms (shown in Figures I.2.C.5 and I.2.C.6).If needed, measurement of full octave band and different weighting networks are recorded on the form of Figure I.2.C.5. The form shown in Figure I.2.C.6 is used for one-third octave band measurements only, and is usually employed in a subsequent investigation of a noise complaint. The important parts of these record sheets are covered below.

Instrumentation:

It is recommended that the serial numbers of equipment be noted on each investigation as a matter of good practice although they may only be required when legal action is considered or in the case of suspected instrument malfunction.

Weather Conditions:

The weather conditions at the time of the SOUND LEVEL MEASUREMENTS should be noted. Under the heading "PRECIP." note"none/rain/snow"as applicable. Local meterological office can provide most of this data. Outdoor measurements are not usually conducted when wind speed exceeds 10-12 M.P.H. Measurements are also avoided when relative humidity is high (in the range of 90%).

Noise Characteristics:

Indicate on the data sheet if the noise is tonal; impulsive or has a beat.

Intermittent:

The length of time the noise is 'OBSERVED' in a 60 minute period is noted under one of the three headings of less than or equal to 5 minutes, between 5 and 15 minutes or more than 15 minutes.

Frequency graph of Figure I.2.C.7 is used to plot both full octave and one-third actave band measurements.

SOUND MEASUREMENTS DATA SHEET (FULL OCTAVE BANDS AND DIFFERENT WEIGHTING NETWORKS)

DATE		INVEST NO.	

INVESTIGATORS 1.
2.

INSTRUMENTATION	Make	Type	Ser. No.
Sound Level meter			
Microphone			
Octave analyser			
Calibrator			

CIRCLE THE OCTAVE BAND WHERE BEAT OCCURS

MEASUREMENT CONDITIONS					
Time					
Wind Speed					
Wind Direction					
Temp.					
Precip.					
R.H. %					
Battery					
Cal. Before					
Cal. After					

NOISE CHARACTERISTIC

TONAL		IMPULSE		BEAT	
Yes	No	Yes	No	Yes	No

INTERMITTENT: Observed duration in any 60 minute period

≤5 mins.	>5-≤15 mins.	>15 mins.

No.	MEASUREMENT POSITION	Posn on diag.	Meter Response F/S	Time	dBA	dBB	dBC	dB Lin.	dB LEVEL - O.B. CENTRE FREQUENCY (Hz) 31.5	63	125	250	500	1K	2K	4K	8K	16K	COMMENTS
1																			
2																			
3																			
4																			
5																			
6																			

Figure I.2.C.5.

SOUND LEVEL MEASUREMENTS (ONE-THIRD OCTAVE BANDS)

DATE		INVEST NO.	
INVESTIGATORS	1.		
	2.		

INSTRUMENTATION	Make	Type	Ser. No.
Sound level meter			
Microphone			
1/3 octave analyser			
Calibrator			

MEASUREMENT CONDITIONS					
Time					
Wind Speed					
Wind Direction					
Temp.					
Precip.					
R.H. %					
Battery					
Cal.	Before				
	After				

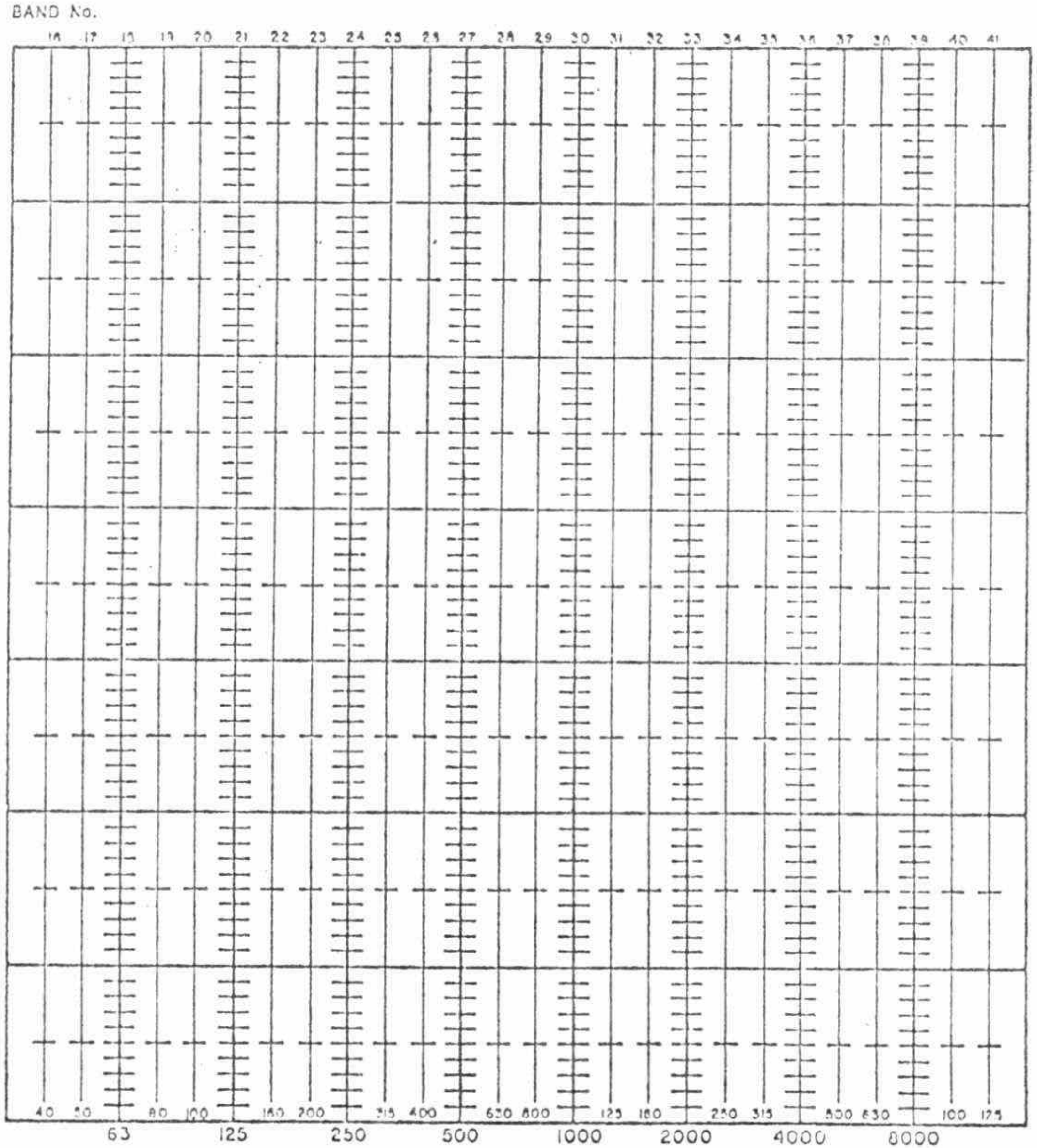
1/3 O.B. in which tone occurs is ▼

Hz.					
dB					
	adjacent bands		tonal band	adjacent bands	

No.	MEASUREMENT POSITION	Posn on diag	Meter Response F/S	Time	dBA	dBB	dBC	dB Lin.	dB LEVEL - 1/3 O.B. CENTRE FREQUENCY (Hz) 25	31.5	40	50	63	80	100	125	160	200	250	COMMENTS
1																				
2																				
3																				

No.		dB LEVEL - 1/3 O.B. CENTRE FREQUENCY (Hz) 315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	12.5K	16K	20K	
1																					
2																					
3																					

Figure I.2.C.6.



FREQUENCY IN HERTZ

Figure I.2.C.7

LEGEND

GRAPH TITLE

GRAPH NUMBER

DATE

I.2.C.4. MAINTAINING COMPLAINT STATISTICS:

The main purpose of keeping a record of noise complaint statistics is to provide basic information which can be analyzed in a number of ways to answer various questions thought to be of interest either at the time the statistics are gathered or at a later date.

Some examples of useful analysis of noise complaints are:

- the number of noise complaints received per year or per month.
- the number of complaints in each noise source category.
- the geographical areas in which the complaints most occur.
- the average length of time taken to investigate a complaint.
- the number of complex and less complex investigations.
- the number of people benefiting from noise reduction.

The main purpose of most complaint statistics analysis is to provide information which will be of use in planning manpower and instrument allocation in local noise control program. Consider the three histograms of Figure I.2.C.8 as an illustration. *HVAC and non-HVAC complaints are shown for each month in a municipality, as well as mean daily maximum outdoor temperature. Most of HVAC complaints occur during the three hottest months -- June, July and August. Non-HVAC complaints are less dependent on weather conditions although a peak effect is also noted during the same three months. The graphs clearly indicate an increased workload in summer months and hence provide a tool in planning of resources in noise control activity.

The statistics, when studied, will probably reveal ways in which the municipality's procedures, people and equipment can be better directed.

The information gained from the analysis when passed on to the Ministry of the Environment by the MUNICIPALITY

---

*HVAC = Heating, Ventilating, and Air Conditioning.

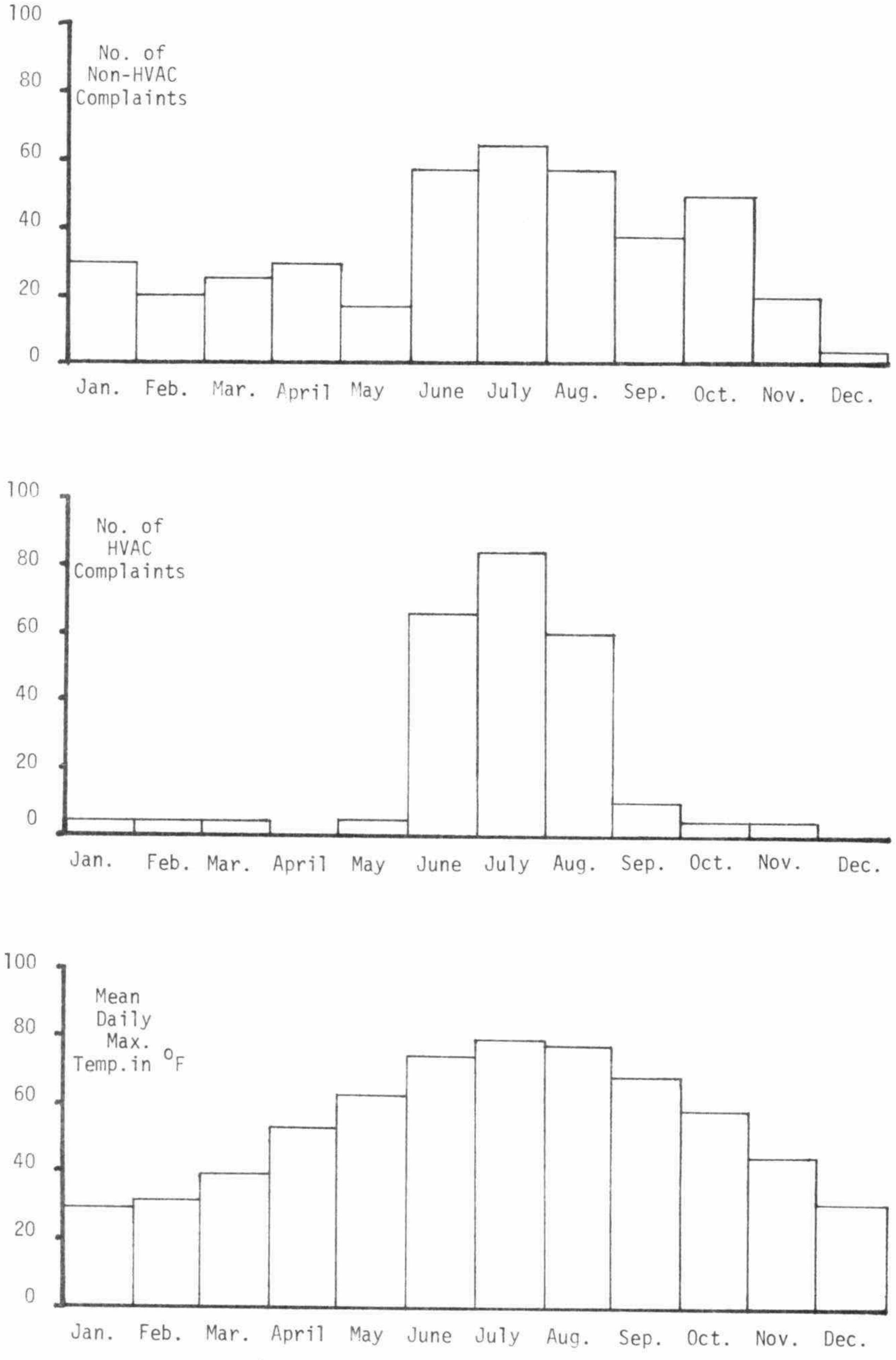


Figure I.2.C.8 : 1974 Noise Complaint Statistics of a Typical Municipality will provide an indication of the effectiveness of the noise control activities being carried out by the municipality.

The information will allow problem areas to be identified and would indicate where further action by the province, such as legislative activity directed at the manufacturing level, etc., is required.

OBJECTIVES:

Trainee will be able to:

1. Briefly describe the functioning of the human ear;
2. Give causes of hearing loss;
3. Indicate commonly accepted maximum safe exposure levels and times;
4. Outline the purpose of an audiogram and the frequencies which are of interest;
5. Name the instrument used to measure personal hearing and describe its principle of operation;
6. Describe a typical audiogram of a person with normal hearing;
7. Undergo a personal hearing test.

I.2.D.1: <u>FUNCTIONING OF THE HUMAN EAR</u>:

This description will make the least possible use of medical terms. Please consult the Figure I.2.D.1.

The outer ear is the part of the ear that is visible without surgery. It channels the sound to a diaphragm (the eardrum) which vibrates in response. The eardrum is no more than stretched skin. Water and foreign bodies are kept out of the middle and inner ears unless the eardrum is pierced or broken.

The middle ear is an area in which a system of levers, made of bone, transmit the motion of the eardrum to one end of a fluid-filled canal sending a pressure wave down the canal. To allow the eardrum to survive different static pressures exerted in the atmosphere outside the ear, the middle ear is connected by a vent to the nasal system. Swallowing opens the tube and allows the middle ear pressure to vent to the same pressure levels occurring outside the head.

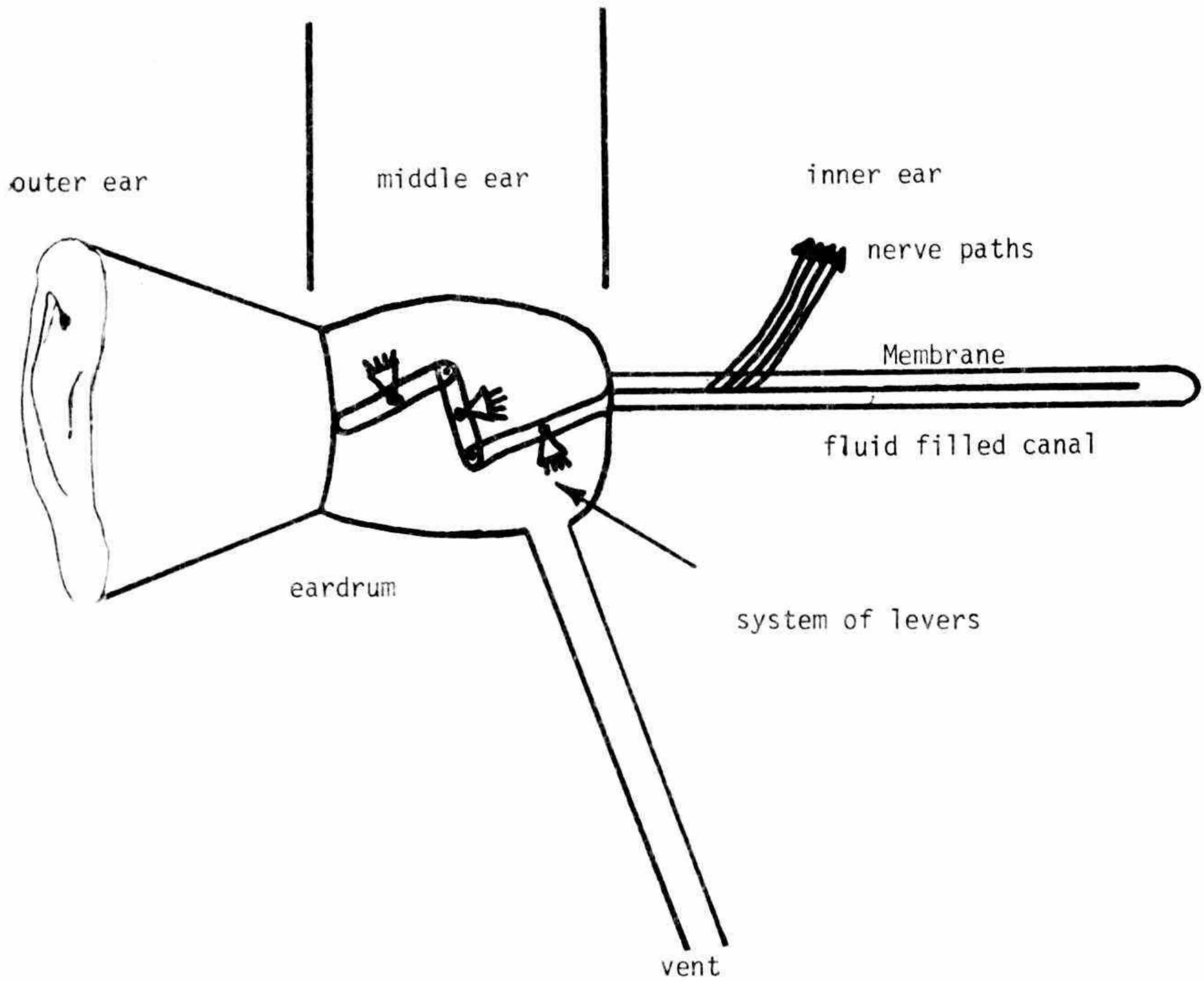


Figure I.2.D.1: Schematic of Auditory System.

The inner ear consists of a fluid-filled canal, rolled up like a snail shell in nature (but here shown extended). The pressure wave in the fluid causes a membrane in the canal to move rather like a whip; certain frequencies cause certain parts of the membrane to move. Attached to the membrane are hair cells, which are tiny transducers (nerves) resembling hairs. When they move as the membrane causes them to, an electric current is transmitted to the brain. The brain translates the signal as sound.

Our ability to detect from where a sound emanates is thought to derive principally from the fact that a sound wave reaches our two ears at different instants depending where it comes from, and probably from the fact that the frequency response of the earlobe and its environs is different for different sound wave incidences.

I.2.D.2. CAUSES OF HEARING LOSS:

1. The eardrum can be damaged by:
   - excessive pressure from sound or another source like water pressure;
   - penetration by foreign objects such as are wrongly used to clean the ear.

   A hole in an eardrum does not always seriously impair hearing.
2. The middle ear can be damaged by:
   - growths on the bones of the lever system which prevent transmission of the eardrum's motion;
   - infections.

   Middle ear damage is often reversible by an operation if the problem is in the lever system, and by drugs if there is an infection.
3. The inner ear can be damaged by:
   - excess sound destroying the hair cells;
   - infections and cancers.

   Infections can sometimes be cured, but the other problems are usually irreversible.

I.2.D.3. MAXIMUM SAFE NOISE EXPOSURE:

There are a number of different opinions about what amount of noise exposure is a safe maximum. Ontario law is rather similar to US law in this respect, and the Industrial Safety Act, 1971, covers the matter in Section III which is quoted here in full.

EXTRACT FROM THE INDUSTRIAL SAFETY ACT, 1971:

III.- (1) In this section "decibel" means decibel measured on a sound level meter conforming to standard S1.4-1971 of the American National Standards Institute operating on the A-weighting network with slow meter response.

(2) Where a person is exposed to a sound level of 90 decibels or greater.

(a) measures shall be taken to reduce the sound level below 90 decibels; and

(b) where such measures are not practicable,

(i) the duration of exposure set out in column 2 of the Table in subsection 5 shall not exceed the duration shown for the particular sound level set opposite thereto in column 1 of the Table in subsection 5, or

(ii) the person shall wear hearing protection.

(3) Where a person is exposed to a sound level of 115 decibels or greater, he shall wear hearing protection.

(4) Clearly visible warning signs shall be posted at the approaches to an area where the sound level is more than 90 decibels.

(5) The warning signs referred to in subsection 4 shall state:

(a) the daily exposure for the particular sound level permitted by the following Table; and

(b) that hearing protection must be worn when the daily exposure is more than that permitted for the particular sound level.

Column 1	Column 2
Sound Level - in decibels	Duration - Hours per 24 hour day.
90	8
92	6
95	4
97	3
100	2
102	1½
105	1
110	½
115	¼ or less
Over 115	No exposure

Table 5: Allowable Safe Levels and Exposure Duration

(6) Where hearing protection is required by this section, the protection shall be sufficient to reduce the sound level below the sound level in column 1 of the Table in subsection 5 for the exposure corresponding to that sound level in column 2 of the Table in subsection 5. .... Extract ends here.

It should be pointed out that this information from the Industrial Safety Act, 1971 is supplied here merely for interest.

I.2.D.4. PURPOSE OF AN AUDIOGRAM:

It is desirable to measure a person's hearing acuity for several reasons:

1. It may reveal, where hearing loss is found, that noise exposure is excessive.
2. It may confirm over a period of time that their noise exposure is not enormously excessive.
3. It may identify the possibility of hearing problems due to other causes.
4. It may identify people with pre-existing hearing losses and suggest reduced noise exposures for the future.
5. It may give a clue to social and work problems due to a previously undetected hearing handicap.

The frequencies of most human speech range from about 250 to 5000 Hz. Since the loss of speech communication is more important than, say, an inability to enjoy high notes in music, it is natural for hearing tests to cover the lower frequencies. In addition, hearing loss due to noise generally manifests itself in a loss in acuity around 4000-6000 Hz. Thus, for general purposes, hearing tests cover a range from 250 to 4000 or 250 to 8000 Hz. For special purposes, higher frequencies may also be tested.

I.2.D.5. PRINCIPLES OF AUDIOMETRY

Audiometry is the science of measuring the adequacy of a person's hearing. An audiometer is the instrument used in conjunction with headphones to achieve that.

The headphones are placed on the subject's head in an environment free from extraneous noise, usually a special booth.

The subject is instructed to press a button or in some other specified fashion indicate when a noise can just be heard through the headphones.

Each ear is tested separately. A pure tone of a given frequency is played into the ear and the sound pressure level at which the subject just hears it, is noted. This is repeated for tones of other frequencies, and is then performed for the other ear.

The "barely audible" sound pressure levels are compared with those for people with unimpaired hearing to arrive at "hearing loss" in decibels. Thus hearing loss at a given frequency is the difference between the sound pressure level just audible to the person being tested and that just audible to a person of unimpaired hearing.

I.2.D.6. A TYPICAL AUDIOGRAM:

An audiogram is the graphical record of a person's hearing acuity, and a typical one is shown in the Figure I.2.D.2.

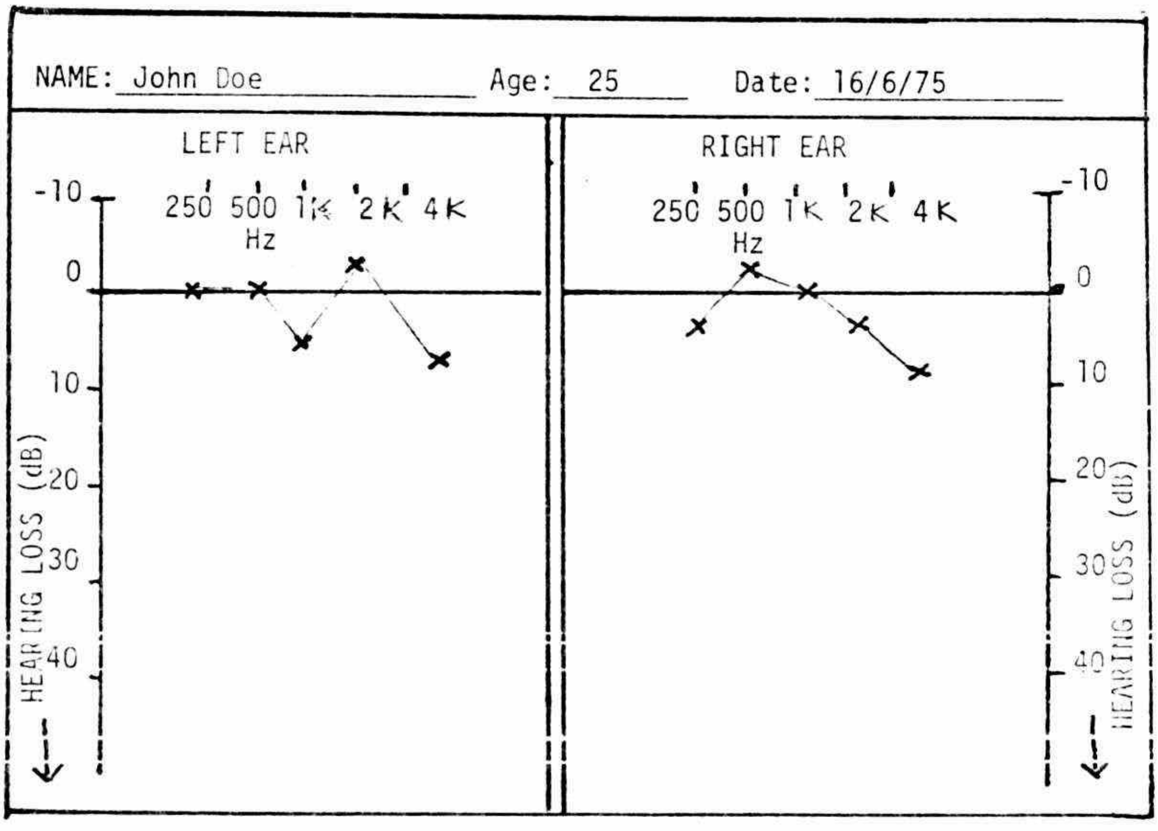


Figure I.2.D.2. A Typical Audiogram.

Here, the subject, Mr. John Doe is a young man with only the suggestion of a hearing loss in his right ear at 4000 Hz. Experimental variances will normally make us disregard a shift of 5dB or less.

Some points lie above the zero line, and while they could result from experimental error, it should be borne in mind that superior hearing is quite possible.

Persons with noise-induced hearing loss or presbycusis (hearing loss associated with age) might produce an audiogram perhaps 15dB "Lower" at 2000 Hz and 25dB "lower" at 4000 Hz. These are the order of magnitudes involved in fairly severe losses.

Some audiograms are obtained from automatic audiometers which present each frequency tone many times, and require the subject to push a button for as long as he hears the tone. By decreasing the intensity of the tone when the subject presses the button, the subject soon releases the button, and the audiogram charts both the level at which the subject first perceives a tone increasing in level, and the level at which the subject last perceives a tone decreasing in level. These are not quite the same thing. Repeating this mode of stimulus presentation results in a more complete record of hearing acuity than usual.

People going for hearing testing should not have been exposed to high sound levels immediately prior to testing.

I.2.D.7. IMPEDENCE AUDIOMETRY:

A method of investigating human hearing response that is gaining increasing favour with audiologists is impedence audiometry. This is because automatic devices have been developed which provide reliable results within a span of minutes.

The procedure consists of inserting a plug into one eardrum. When the cavity is pressurized the tympanic membrane is pushed inward to a position that may be considered hard-walled. At this point compliance will be at its lowest. Similarly, when pressure is withdrawn the membrane will move to its normal position and normal compliance will result. When the cavity pressure becomes negative the tympanic membrane will move outward to another hard-walled position. The change in compliance can easily be plotted and compared against known profiles for certain hearing problems. The tympanogram, in conjunction with an induced muscular reflex in the opposite ear, is a valid testing procedure.

I.2.D.8. PERSONAL HEARING TEST OF TRAINEES:

A personal hearing test of all trainees will be conducted during this workshop. The schedule for this test will be provided at the beginning of the course.

SUBJECT: TOPIC: I.3.A. (Acoustics)

ENVIRONMENTAL ACOUSTICS - I

OBJECTIVES:

Trainee will be able to:

1. Describe the equal loudness curves;
2. Indicate the basis of A, B and C weighting networks;
3. Distinguish between near, far, free, and reverberant field;
4. Describe and illustrate phenomena of beats, tones, impulsiveness, intermittency and intrusion.

I.3.A.1. EQUAL LOUDNESS CURVES:

Shown in the Figure I.3.A.1 are a set of equal loudness curves. These curves show the relationship between sound pressure level and frequency for sounds of equal loudness as perceived by the human ear.

Loudness Level and Loudness

Definitions:

The loudness level of a sound is measured in "Phons", each curve in Fig. 1 having a phon value assigned to it. It can be seen from the figure that the phon values of sounds at 1KHz are equal to their sound pressure levels. Thus the phon values are referred to 1KHz frequency.

I.3.A.2. BASIS OF THE A, B AND C WEIGHTING NETWORKS:

Tracing the 60 phon curve shows how the level of a sound varies as its frequency is changed to give the same loudness level. Decrease in frequency from 1KHz shows that initially the sound level must be decreased, but eventually must be greatly increased to give the same loudness. This is because ear is less sensitive to sounds of low frequencies (below approximately 125hz). Again as frequency is increased the level must initially be decreased but eventually increased to give the same loudness, indicating poor response of human ear to high frequencies (typically above 4KHz).

It should also be noted that the contours for different phon values do not have the same shape, that is the frequency characteristics of the human ear also varies with sound level. At low levels a greater increase of level is required for changing frequency than at high levels where a much smaller increase in level is required for changing frequency.

Clearly a sound level meter designed to take these effects into account to simulate human hearing must electronically approximate these curves.

This is the basis of the A, B and C weighting networks. These will be described in Topic I.3.B.

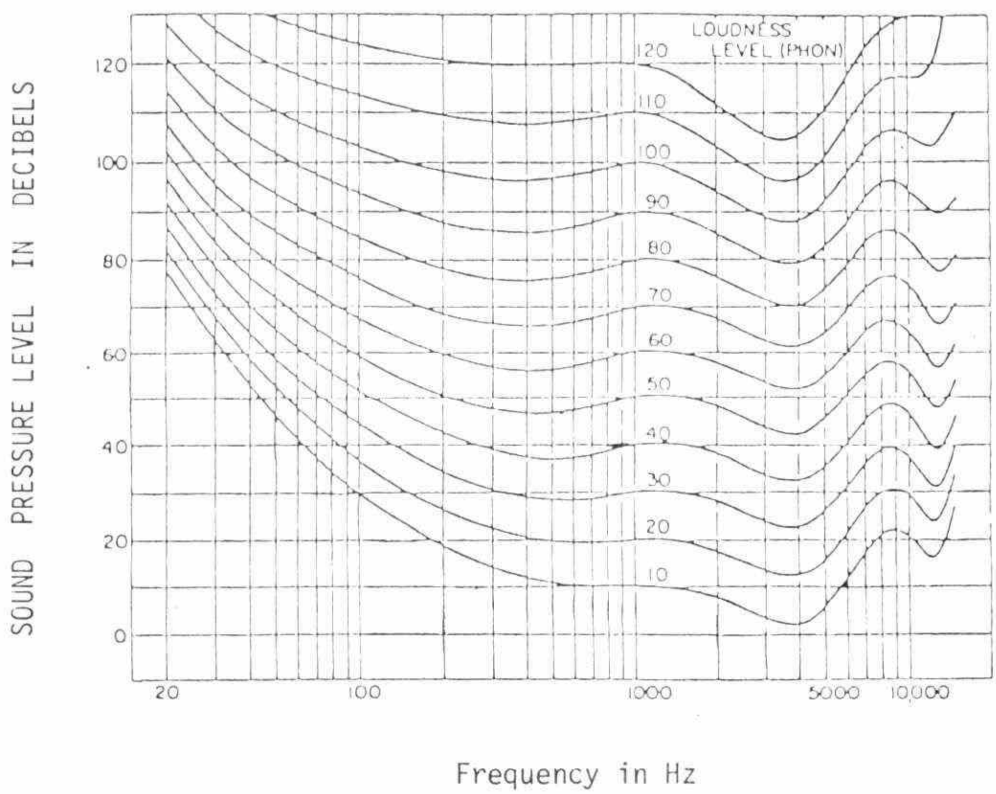


Figure I.3.A.1: Equal Loudness Curves

I.3.A.3. NEAR, FAR, FREE AND REVERBERANT FIELD:

The acoustic field around a noise source placed near an obstacle can be divided into four areas. Two of these areas, the near field and the far field are concerned with the source itself whereas the other two are determined by any obstacles near to the source. The four fields are defined with reference to the Figure I.3.A.2.

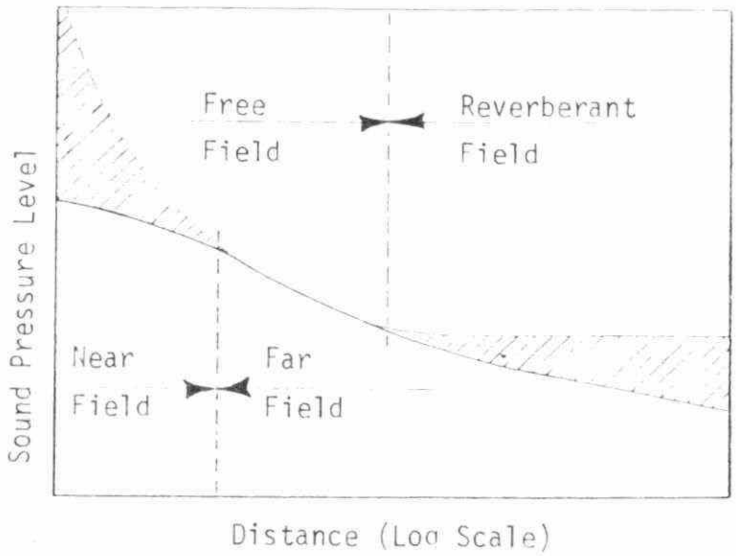


Figure I.3.A. 2: The Acoustic Field Around a Source.

The Near Field: The near field is an area close to a noise source where the sound pressure varies in a complex manner and great variations are obtained with small changes in measurement position. The near field is indicated by the shaded portion to the left of the Figure.

The Far Field: The far field is the area outside the near field where the sound pressure decreases in a simple manner with distance, and small changes in position do not produce large variations in sound pressure.

The Free Field: The free field is that area around a source where the sound travels through the air unaffected by reflections from obstacles around the source. In the free field, the sound will travel radially from the source.

The Reverberant Field: The reverberant field occurs in the area close to obstacles. In this region the sound pressure is greatly affected by reflections from these obstacles. The reverberant field is indicated by the shaded area to the right of Figure I.3.A.2.

It is clear from these definitions that sound pressure level measurements should not be taken in the near field (close to the source) or in the reverberant field (close to obstacles) because of variations of the sound pressure in these areas. Rather, sound pressure level measurements should always be taken in the overlapping region of the far field and the free field. Even in this region the sound pressure level is not constant with distance from the source, and the source to sound level meter distance should always be given in the measurement report.

It is not possible to state the extent of the near field and the reverberant field. These will depend on the particular source and obstacles in question. However, as a guideline, the following indications can be used.

To determine the extent of the near field the greatest source dimension should be taken (let this dimension be a). The near field will extend to a distance of approximately 2 x a from the centre of the source. Sound level measurements should not be taken within this radius.

The extent of the reverberant field away from any obstacle depends on the wavelength of the lowest frequency of interest in the sound from the source. In general sound level measurements should not be taken less than a quarter wavelength from any obstacle. Again as a guideline 100Hz is usually the lowest frequency of interest. At frequencies greater than 100Hz, sound level measurements should not be taken closer than 2½ ft. from any obstacle.

Note: The remarks listed above on a reverberant field do not necessarily apply inside a confined space or room. This publication is concerned with the effects of sound in the natural environment.

I.3.A.4. <u>TONES, BEATS, IMPULSIVENESS, INTERMITTENCY AND INTRUSION</u>

(a) <u>Tones</u>: tones are sound waves, at a single frequency. In general;tones are noisier than broad band sounds at the same sound pressure level. Examples of tonal sound sources are circular saws, transformers, sirens etc.

(b) <u>Beats</u>: beats are periodic (pulsing) variations of sound level due to the interaction of two tones at almost the same frequency. Examples of beating noise sources are two machines at closely the same speed, jet engines at closely the same speed.

(c) <u>Impulsiveness</u>: Sounds are said to be impulsive if they occur for a time of less than one second. Typical sources of impulsive sound are drop forges, barking dogs and pistol shots.

(d) <u>Intermittency</u>: A sound is said to be intermittent if it is not continuous, but remains on for periods greater than one second. Typical examples of intermittent noise sources are aircraft flyovers, automobile pass by and train pass by.

(e) <u>Intrusion</u>: A sound is said to intrude above the ambient sound conditions if it is clearly audible at a point of reception. Example of intrusion is factory noise audible above busy urban noise or highway noise audible above normal rural noise.

SUBJECT:

ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.3.B.(Acoustics)

OBJECTIVES:

Trainee will be able to:

1. Clearly define A,B,C, and linear weighting scales;
2. Select appropriate scales(s) for measuring different types of noise sources (with examples);
3. Indicate what octave band analysis is;
4. Indicate what one-third octave band analysis is;
5. Indicate when frequency analysis is used.

I.3.B.1. DEFINITIONS OF A,B,C AND LINEAR SCALES

As noted earlier in the topic I.3.A., electronic weighting scales are used to standardise the sensitivity of sound level meters at various frequencies.

Figure I.3.B.1. illustrates the sensitivity of sound level meters using the various weighting scales. The horizontal axis is "frequency", while the vertical axis is "sensitivity" in decibels. The scales all have the same sensitivity at 1000 Hz. Consider an example of how to interpret this graph. At 100 Hz the "C" scale has the same sensitivity it had at 1000 Hz but the "A" scale is about 20 dB less sensitive.

The different weighting scales are described below:

(a) Linear Scale:

The linear scale is equally sensitive to all frequencies, subject to the limitations of the meter electronics. This range is typically from 5 Hz to 20,000 Hz. The measurements on linear scale are indicated by dB lin.

(b) C Scale:

The C-scale is also equally sensitive to all frequencies between 50 and 5,000 Hz and it becomes progressively less sensitive outside this range. The measurements on this scale are denoted by dBC.

(c) A scale:

The A-scale is based on the curves of equal loudness for the human ear as discussed in the topic I.3.A. It is an attempt to make the sound level meter "hear" the same as a human ear. It gives a rough idea of how "loud" a sound is. These measurements are indicated by dBA.

(d) B scale:

The B-scale is almost unused today. It was used like the A-scale for some measurements, but has been almost completely dropped. dBB indicates sound levels on B-scale.

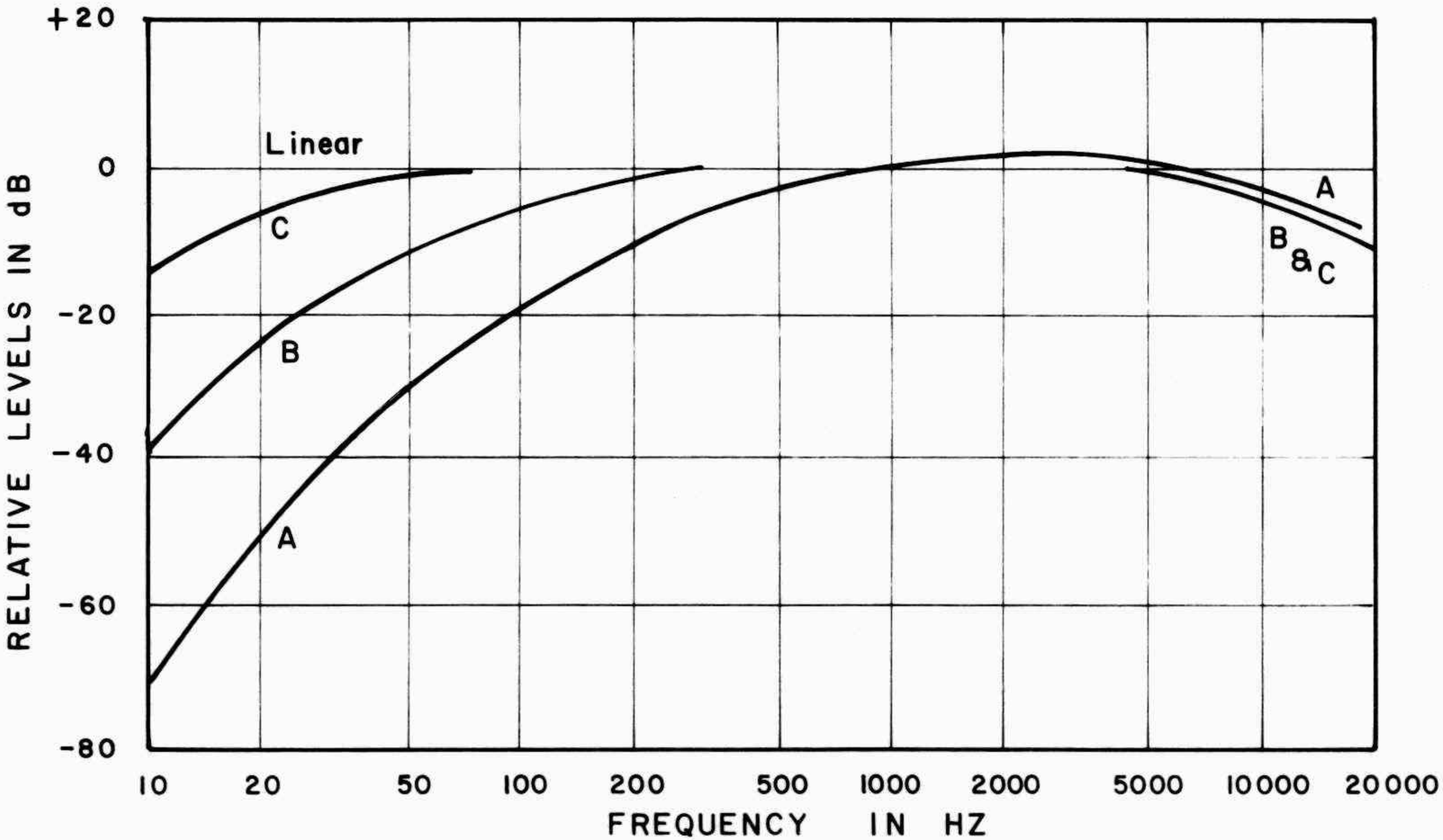


FIGURE 1.3.B.1 SENSITIVITY OF SOUND LEVEL METERS WITH A, B & C WEIGHTING NETWORKS.

I.3.B.2. SELECTING THE APPROPRIATE SCALES:

A-weighted Sound Level:

The Model Municipal Noise Control By-law (like most other noise regulations) uses the A-scale for most purposes because of its correlation with human response. For any measurement of sound to determine its effect on people (all noise measurements in other words) the A-weighted sound level is used. For complicated noise problems this may be only the start.but it is rarely neglected.

EXAMPLE:

The 40 hp blower used in the drying operation at a car wash that was investigated:gave 88 dBA and 100 dB lin. at 20'. This difference indicated that there was a lot of low frequency sound coming from the blower which did not show up in the A-weighted level.

Linear & C-Scale:

The dBC or dB lin. readings are not often used for enforcement, or evaluating "noisiness". However, in determining how big the problem is and how hard it will be to solve, this information can be extremely valuable. One point to watch with these scales is the danger of picking up wind noise. The C-scale is better than the linear scale for this since it cuts off the extremely low frequencies, where wind is a big problem.

I.3.B.3. OCTAVE BAND ANALYSIS:

Sometimes it is not enough to know just the sound pressure level. For instance, when we listen to music, it is not enough (for most of us) just to know how loud it is. We also want to know what notes are being played. This frequency information is important to our enjoyment of the music. Octave band analysis gives us some of the same information for noise.

(a) Octaves:

Musicians learned very early that people hear pitch in octaves, another logarithmic scale, but an easy one.

For a sound to go up one octave, the frequency must double. e.g. 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz..... are all one octave apart. The octave band centre frequencies used in noise control are 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, 16,000 Hz. Each octave band covers a range of frequencies around a centre frequency. Table 6 lists range of frequencies of different octave bands.

EXAMPLE:

1000 Hz octave band covers sound frequencies from 710 to 1420 Hz. 500 Hz band extends from 355 to 710 Hz etc. The difference between lower and upper frequencies (also known as lower and upper cut-off-frequencies) is the Bandwidth.

(b) Octave Filter Set:

By using an octave filter set we can make the sound level meter look at sound selectively one octave at a time. e.g. all sounds with frequencies between 88 Hz and 177 Hz are in 125 Hz octave band. Thus, the sound level meter set to a particular octave band will look only at sounds centred in the corresponding frequency range.

I.3.B.4. ONE-THIRD OCTAVE BAND ANALYSIS:

Sometimes more information is needed than can be provided with octave band analysis. As any musician can tell you, octaves are a pretty coarse scale. Much finer gradations of pitch, or frequency are possible. To give more detail, each full octave is often divided into three bands. These are called one-third or 1/3 octave bands. A 1/3 octave band analysis may reveal things which are glossed over by an octave analysis, by giving better resolution of sound.

Sound level meters are used with one-third octave filter sets to measure selectively the desired one-third octave bands.

The centre frequencies of one-third octave bands are listed in the Table 7 together with the corresponding ranges.

Lower frequency limit Hz	Centre frequency Hz	Upper frequency limit Hz
11	16	22
22	31.5	44
44	63	88
88	125	177
177	250	355
355	500	710
710	1,000	1,420
1,420	2,000	2,840
2,840	4,000	5,680
5,680	8,000	11,360
11,360	16,000	22,720

Table 6 : Range of Frequencies of Full Octave Bands.

Lower frequency limit Hz	Centre frequency Hz	Upper frequency limit Hz
14.1	16	17.8
17.8	20	22.4
22.4	25	28.2
28.2	31.5	35.5
35.5	40	44.7
44.7	50	56.2
56.2	63	70.8
70.8	80	89.1
89.1	100	112
112	125	141
141	160	178
178	200	224
224	250	282
282	315	355
355	400	447
447	500	562
562	630	708
708	800	891
891	1,000	1,122
1,122	1.250	1,413
1,413	1,600	1,778
1,778	2,000	2,239
2,239	2,500	2,818
2,818	3,150	3,548
3,548	4,000	4,467
4,467	5,000	5,623
5,623	6,300	7,079
7,079	8,000	8,913
8,913	10,000	11,220
11,220	12,500	14,130
14,130	16,000	17,780
17,780	20,000	22,390

Table 7: Range of Frequencies of One-Third Octave Bands.

I.3.B.5. WHEN TO USE FREQUENCY ANALYSIS

(a) There are three general reasons for using frequency analysis:

1. Finding out why a sound is annoying

   Sound with tonal qualities (a whine, buzz or hum) is more annoying than sound which is equally loud through a wide frequency range. The Model By-law penalizes sounds of this nature (Refer to the Publication NPC-120).

2. Figuring out what is going on

   Engineers find this information useful in finding out what is happening. For example, if there are peaks at 120 Hz. or its multiples (called harmonics), the sound is probably caused by electrical equipment. If this is expected, a scale which will clearly show up 120 Hz, 240 Hz, 360 Hz, etc. will give useful information.

   Resonance

   Many structures resonate, like a crystal goblet when it's struck, or a pop bottle when you blow across the mouth. These resonances show up as peaks at a particular frequency and its multiples (harmonics again). It is the combination of these tones that give musical instruments (and machines) their characteristic sound.

3. Deciding how to quiet things down

   It is usually much easier to absorb or block high frequencies than it is to do the same with low frequencies. Frequency analysis will give a good idea of how hard it will be to quiet something down.

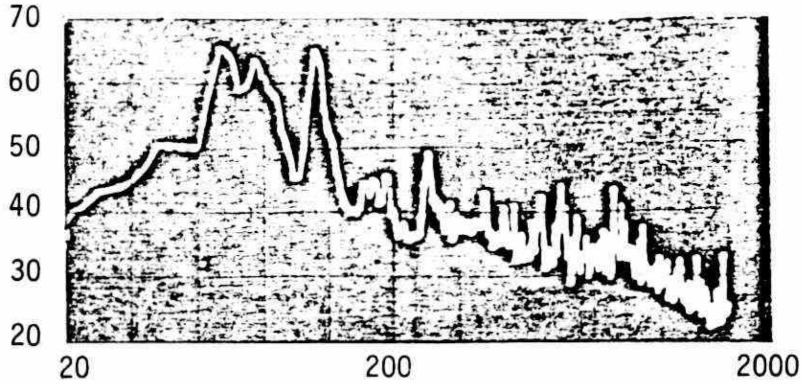
(b) Octave or 1/3 Octave?

The easiest way to explain the factors influencing the choice of filter set is with an example.

EXAMPLE:

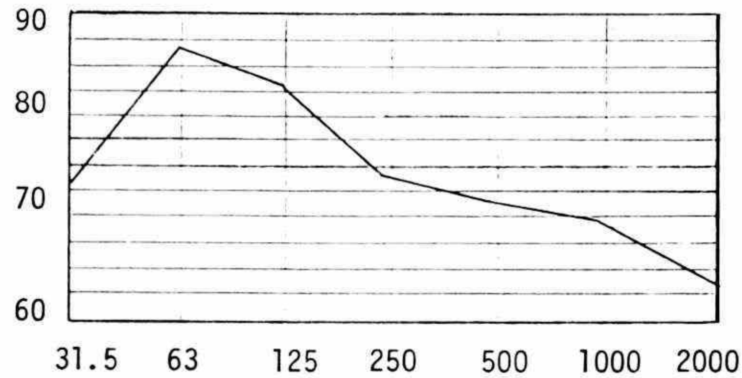
A blower used at an Ontario petrochemical plant has the frequency content shown in Figure I.3.B.2. All three graphs show level versus frequency.

The top graph shows the actual frequency spectrum of the blower. (A spectrum is just a plot of the intensity at each freqency, and the term is usually used when the analysis is more detailed than octave or 1/3 octave). Peaks



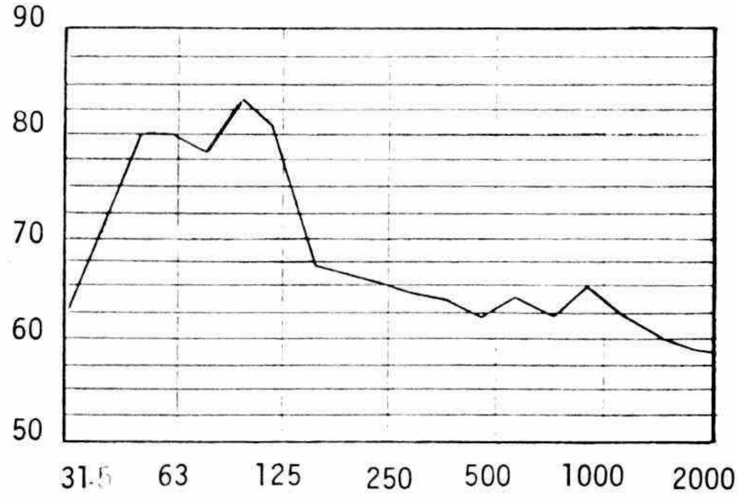
SPECTRUM

Results of spectrum analysis



OCTAVE BAND

Results of octave band analysis



1/3 OCTAVE BAND

Results of one-third octave band analysis

Figure I.3.B.2: Blower Noise Measured with Different Frequency Resolution can be seen at 56 Hz and 112 Hz. More peaks can be seen at 170 Hz, a big one at 212 Hz and at higher levels. This can be interpreted as a tone at 56 Hz. and its multiples (or harmonics).

The octave band graph shows the general shape of the spectrum with a peak near 63 Hz. This peak will be the 56 Hz tone. The 1/3 octave graph shows a peak near 60 Hz and one near 120 Hz. These will be the peaks at 56 Hz and 112 Hz. For many purposes the octave band measurements give everything that is needed. Using a 1/3 octave filter set will give more detail. If tones are a problem, this information may be useful. It may well be the inspector's ears which will decide which one is more useful. It is a trade-off between measurement time (not to mention equipment availability) and the use the information will be put to.

SUBJECT:

ENVIRONMENTAL ACOUSTICS-I

TOPIC: I.3.C.&D. (Workshop)

OBJECTIVES:

Trainee will be able to:

1. Calibrate, check and prepare sound level meter together with the accessories (tripod, windscreen, etc.);
2. Demonstrate the use of sound level meter and perform octave band analysis in the laboratory;
3. Measure and compare sound levels in the laboratory on A, B, C, and linear scales and interpret the results;
4. Demonstrate the use of prescribed data form to record above measurements.

How achieved:

Conducting a practical workshop in the laboratory with the help of sound level meters, calibrators, filters, accessories and recorded sounds.

SUBJECT: ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.4.A. & B. (Workshop)

OBJECTIVES:

Trainee will be able to:

1. Measure an industrial noise source using:
    (a) A, B, C and linear weighting scales
    (b) Octave band analysis (full and 1/3 octave);
2. Demonstrate and interpret variation of sound levels with distance;
3. Distinguish between good and bad measurement locations (study effect of directivity, reflecting surfaces etc.).

How achieved:

Conducting practical workshop at a prescribed industrial site with the help of sound level meters, calibrators, accessories and meteorological instruments.

SUBJECT:

ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.4.C. & D. (Workshop)

OBJECTIVES:

Trainee will be able to:

1. Measure individual road vehicle levels using 'A' weighting scale;
2. Demonstrate and interpret variation of sound levels with distance;
3. Distinguish between good and bad locations of measurement (study effect of directivity, reflecting surfaces etc.).

How achieved:

Conducting a practical workshop at a suitable road-site with the help of sound level meters, calibrators, accessories and meteorological instruments.

SUBJECT:

ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.5.A.& B.(Review)

OBJECTIVES:

Trainee will be able to:

1. Clarify and improve upon his understanding of the course material covered during Environmental Acoustics Technology-I, to be accomplished through questions and answers during review session.

SUBJECT:

ENVIRONMENTAL ACOUSTICS - I

TOPIC: I.5.C.& D.(Exam.)

OBJECTIVES:

Trainee will be able to:

1. Answer questions related to the acoustics theory, procedures, standards, instrumentation and measurement techniques covered during the course. Record sheets completed by trainee in the workshop periods will also be included as a part of the performance assessment.

Number	Log	Number	Log	Number	Log	Number	Log
1.0	0.00	4.0	0.60	7.0	0.85	1	0
						10	1
1.1	0.04	4.1	0.61	7.1	0.85	100	2
1.2	0.08	4.2	0.62	7.2	0.86	1000	3
1.3	0.11	4.3	0.63	7.3	0.86	10000	4
1.4	0.15	4.4	0.64	7.4	0.87	100000	5
1.5	0.18	4.5	0.65	7.5	0.88	1000000	6
1.6	0.20	4.6	0.66	7.6	0.88	etc.	
1.7	0.23	4.7	0.67	7.7	0.89		
1.8	0.26	4.8	0.68	7.8	0.89	10^0	0
1.9	0.28	4.9	0.69	7.9	0.90	10^1	1
						10^2	2
2.0	0.30	5.0	0.70	8.0	0.90	10^3	3
						10^4	4
2.1	0.32	5.1	0.71	8.1	0.91	10^5	5
2.2	0.34	5.2	0.72	8.2	0.91	10^6	6
2.3	0.36	5.3	0.72	8.3	0.92	etc.	
2.4	0.38	5.4	0.73	8.4	0.92		
2.5	0.40	5.5	0.74	8.5	0.93		
2.6	0.41	5.6	0.75	8.6	0.93		
2.7	0.43	5.7	0.76	8.7	0.94		
2.8	0.45	5.8	0.76	8.8	0.94		
2.9	0.46	5.9	0.77	8.9	0.95		
3.0	0.48	6.0	0.78	9.0	0.95		
3.1	0.49	6.1	0.79	9.1	0.96		
3.2	0.51	6.2	0.79	9.2	0.96		
3.3	0.52	6.3	0.80	9.3	0.97		
3.4	0.53	6.4	0.81	9.4	0.97		
3.5	0.54	6.5	0.81	9.5	0.98		
3.6	0.56	6.6	0.82	9.6	0.98		
3.7	0.57	6.7	0.83	9.7	0.99		
3.8	0.58	6.8	0.83	9.8	0.99		
3.9	0.59	6.9	0.84	9.9	1.00		

Table of Logarithms

Log	Number	Log	Number	Log	Number	Log	Number
0.00	1.0	0.60	4.0	0.85	7.0	0	1
						1	10
0.04	1.1	0.61	4.1	0.85	7.1	2	100
0.08	1.2	0.62	4.2	0.86	7.2	3	1000
0.11	1.3	0.63	4.3	0.86	7.3	4	10000
0.15	1.4	0.64	4.4	0.87	7.4	5	100000
0.18	1.5	0.65	4.5	0.88	7.5	6	1000000
0.20	1.6	0.66	4.6	0.88	7.6		
0.23	1.7	0.67	4.7	0.89	7.7		
0.26	1.8	0.68	4.8	0.89	7.8	0	10^0
0.28	1.9	0.69	4.9	0.90	7.9	1	10^1
						2	10^2
0.30	2.0	0.70	5.0	0.90	8.0	3	10^3
						4	10^4
0.32	2.1	0.71	5.1	0.91	8.1	5	10^5
0.34	2.2	0.72	5.2	0.91	8.2	6	10^6
0.36	2.3	0.72	5.3	0.92	8.3		etc.
0.38	2.4	0.73	5.4	0.92	8.4		
0.40	2.5	0.74	5.5	0.93	8.5		
0.41	2.6	0.75	5.6	0.93	8.6		
0.43	2.7	0.76	5.7	0.94	8.7		
0.45	2.8	0.76	5.8	0.94	8.8		
0.46	2.9	0.77	5.9	0.95	8.9		
0.48	3.0	0.78	6.0	0.95	9.0		
0.49	3.1	0.79	6.1	0.96	9.1		
0.51	3.2	0.79	6.2	0.96	9.2		
0.52	3.3	0.80	6.3	0.97	9.3		
0.53	3.4	0.81	6.4	0.97	9.4		
0.54	3.5	0.81	6.5	0.98	9.5		
0.56	3.6	0.82	6.6	0.98	9.6		
0.57	3.7	0.83	6.7	0.99	9.7		
0.58	3.8	0.83	6.8	0.99	9.8		
0.59	3.9	0.84	6.9	1.00	9.9		

Table of Antilogarithms