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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

UNIT – 1 - BUILDING SERVICES III– SAR 1302

INTRODUCTION

Acoustics is a science of sound, which deals with origin, propagation and auditory sensation of sound, and also with design & construction of different building units to set optimum conditions for producing & listening, speech, music, etc.

There are three domains in acoustical study that deals with building physics or the architectural acoustics.

- Wave Acoustics
- Ray or Geometric Acoustics
- Statistical Acoustics

Wave Acoustics- where a sound is taken into a wave front and the wave propagation where particular fluctuations of the wave, the pressure fluctuation has to be taken into account.

Geometric or the ray acoustics where the wave front or the sound wave is generally categorized **as a line diagram.** So, a line actually replaces the wave in a logical and understanding format inside a room. So, the reflection, refraction or maybe the absorption of the sound has been translated in terms of a ray.

Geometrical Acoustics or ray **acoustics** is a branch of **acoustics** that studies propagation of sound on the basis of the concept of rays considered as lines along which the **acoustic** energy is transported.

The same laws of reflection and refraction hold for sound rays as for light rays.

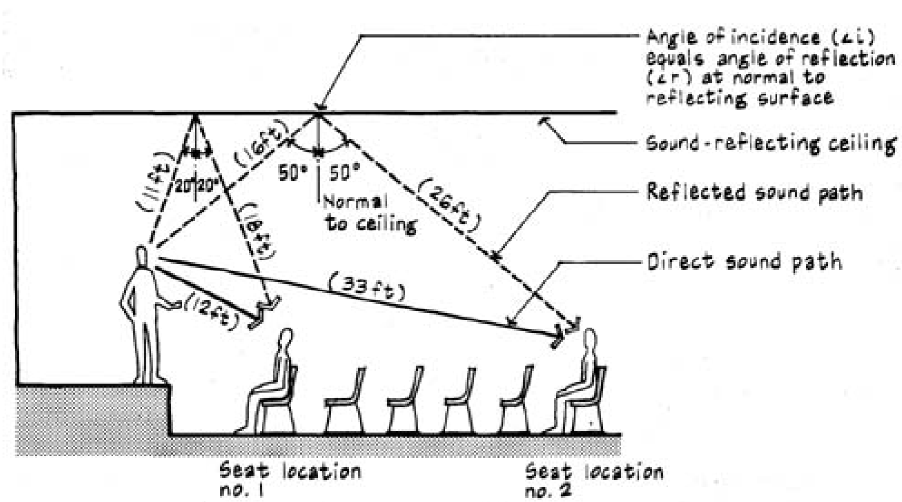


Fig.1.Ray diagram

Statistical Acoustics a particular sound there are various amount of frequencies and various types of the sound pressure levels or maybe the sound intensity levels. So need some kind of a statistical techniques to be handled to deal with lot of frequencies and the sound pressure.

To give a certain type of sound with a certain type of quality and in a certain area, for that we need some kind of a statistical techniques to be handled to deal with lot of frequencies and the sound pressure.

This statistical acoustics is directly implemented in any kind of material testing and also categorize the character of the interiors of building.

In physics, **sound** is a vibration that propagates as an acoustic wave, through a transmission medium such as a gas, liquid or solid.

Sound is in the form of energy.

It travels in the waves through elastic media and fluctuation of pressure and displacement of air particles.

A sound wave is a wave of alternating high-pressure and low pressure regions of air.

<u>Types of wave motion</u>

Longitudinal and transverse waves

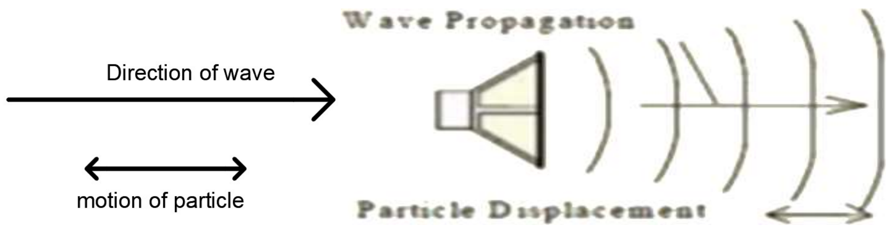


Fig.2.A loudspeaker generates longitudinal waves in which particles
Oscillate parallel to the direction of wave propagation.

Transverse waves

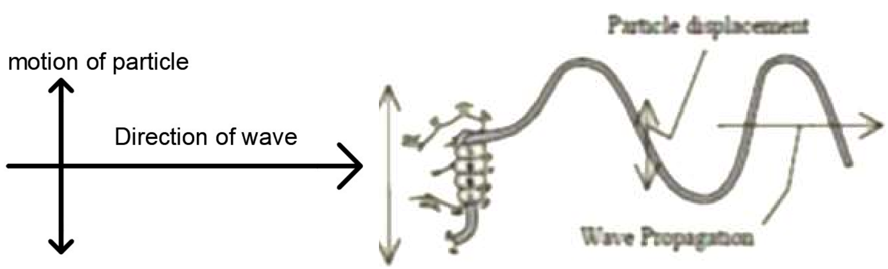


Fig.3.The hand shaking the rope generates a transverse wave in which particles
Oscillate perpendicular to the direction of wave propagation.

Sound (or noise) is the result of pressure variations, or oscillations, in an elastic medium (e.g., air, water, solids), generated by a vibrating surface, or turbulent fluid flow. Sound propagates in the form of longitudinal waves, involving a succession of compressions and rarefactions.

We have three parameters; one is a velocity which is dependent on the wave length and frequency of sound, at room temperature typically it is around 340 to 343 meter per second that is a velocity of sound.

<u>Velocity – (speed of sound)</u>

The speed of sound is the distance travelled per unit of time by a sound wave propagating through an elastic medium. In dry air at 20 °C (68 °F), at sea level, the speed of sound is 343 metres per second (1,125 ft/s)

Sound does not propagate through vacuum, so it needs a medium to propagate.

There is a sound source, path and a receiver. It can be any source, it can be equipment, it can be a bird, and it can be some event which is happening. Then there is a medium of propagation.

Sound propagates through the air is the medium called as air borne. Where the sound transmits through the structural components called as structure borne.

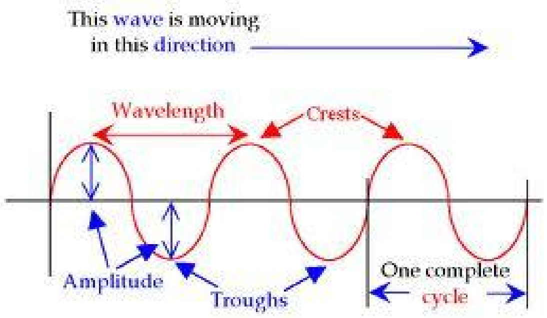


Fig.4.Sound waves

<u>Amplitude – (Height of Waves)</u>

The amplitude (A) is the maximum extent of a vibration or oscillation in a propagating wave motion, measured from the position of equilibrium.
At any point on the wave, the vertical distance of the wave from the centerline is called the amplitude of the wave. The amplitude of the peak is called the peak amplitude. The more intense the vibration, the greater the pressure variations, and the greater the peak amplitude. The greater the amplitude, the louder the sound.

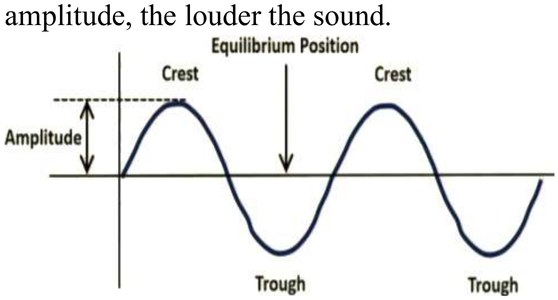


Fig.5.Sound waves(Amplitude)

<u>The amplitude of the motion is also having 3 types:</u>

- Peak Amplitude
- Peak to Peak Amplitude
- Root Mean Square Amplitude.

<u>Peak Amplitude</u>

The extent of a vibration between the crest to the position of equilibrium in a propagating wave move motion is called **Peak Amplitude.**

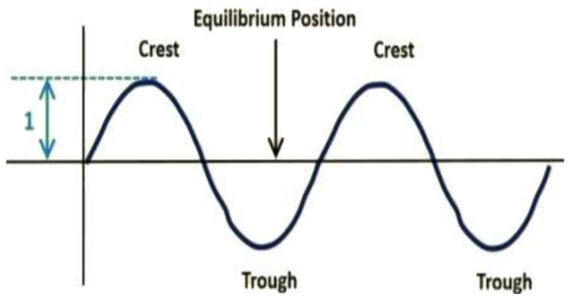


Fig.6.Peak Amplitude

<u>Peak-to-Peak Amplitude</u>

The extent of a vibration between the crest to trough in a propagating wave move motion is called **Peak-to-Peak Amplitude.**

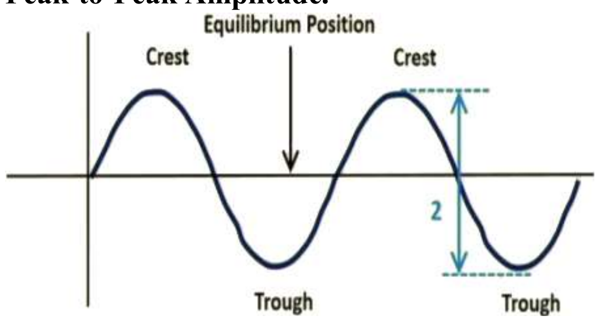


Fig.7.Peak –to-peak Amplitude

<u>Root mean square amplitude</u>

The square root of the squared average values of the wave form is called **Root-mean-square amplitude.**

the root mean square value - the square root of the squared
average, of the total propagation by integrating this particular in a period of time T.

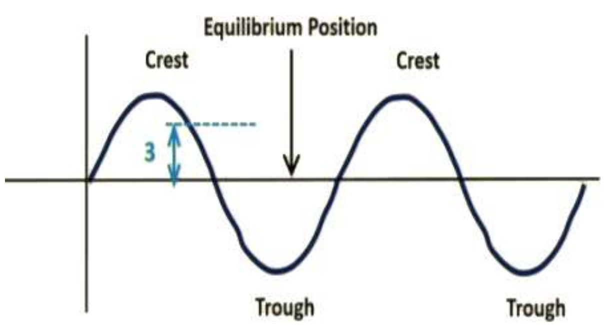


Fig.8.Root mean square Amplitude

<u>Time Period</u>

The time needed for one complete cycle of vibration to pass a given point is called **Time Period.**

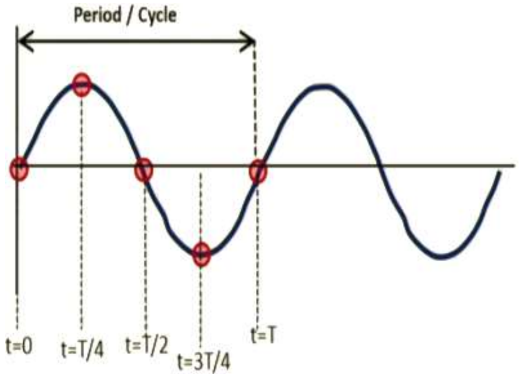


Fig.9.Time period

FREQUENCY

Frequency – (No of Cycles / second)

Frequency describes the number of completed wave cycle that pass a fixed point in unit time. Usually frequency is measured in cycles per second (cps) or hertz unit.

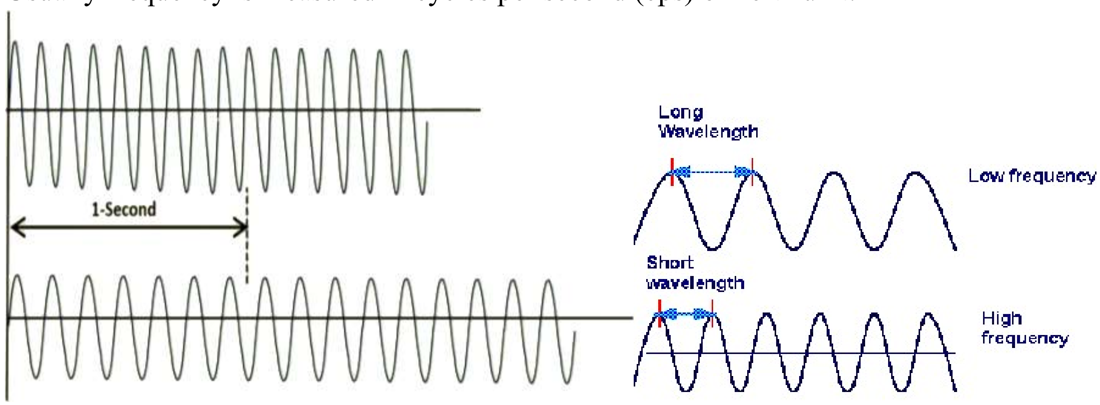


Fig.10.Frequency

Distance covered by the particular unit time is the frequency times the wave length. So then the velocity of the propagation of the wave is -in one second.
Velocity of propagation = frequency (number of cycles) x wavelength.

FREQUENCY

The sound source (the loudspeaker) vibrates back and forth many times a second. The number of cycles completed in one second is called the frequency. The faster the speaker vibrates, the higher the frequency of the sound. Frequency is measured in hertz (abbreviated Hz.,) One Hertz equals one cycle per second. The higher the frequency, the higher the perceived pitch of the sound. Low-frequency tones (say, 100 Hz) are low pitched; high-frequency tones (say,10,000 Hz) are high-pitched. Doubling the frequency raises the pitch one octave.
The frequency is the number of cycles per second(1 Hertz = 1 vibration/second).

Wavelength (λ) **– (Distance)**

When a sound wave travels through the air, the physical distance from one peak (compression) to the next is called a wavelength. Low frequencies have long wavelengths (several feet); high frequencies have short wavelengths (a few inches or less).

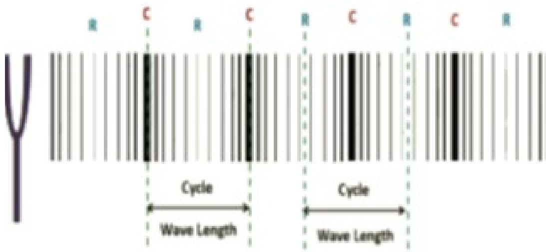


Fig.11.Sound wave propagation in Air

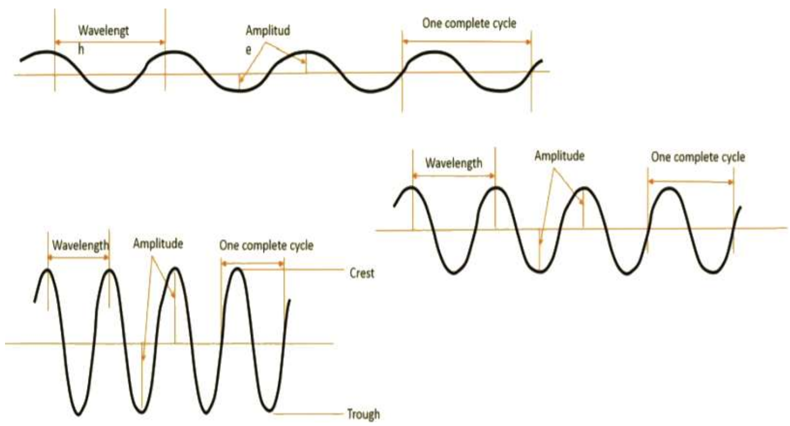


Fig.12.Variation of frequency, Amplitude &Wavelength

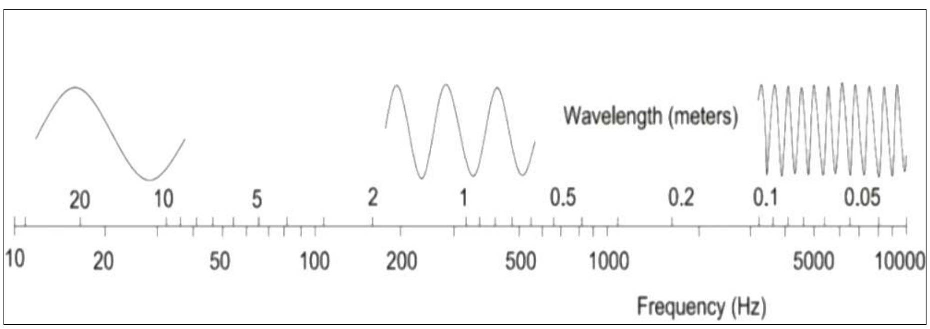


Fig.13.Nomogram of Frequency & Wavelength

This is a nomogram where we can see an extended version of the frequency in the lower axis of the x and the wave length in the upper axis. From the figure we can understand the intimate relationship between frequency and wavelength in a wave propagation.

<u>Pitch</u>

Pitch is perceived as how "low" or "high" a sound is and represents the cyclic, repetitive nature of the vibrations that make up sound.

For simple sounds, pitch relates to the frequency of the slowest vibration in the sound (called the fundamental harmonic). In the case of complex sounds, pitch perception can vary. Sometimes individuals identify different pitches for the same sound, based on their personal experience of particular sound patterns. Selection of a particular pitch is determined by pre-conscious examination of vibrations, including their frequencies and the balance between them.

The brain interprets the frequency in terms of the subjective quality called **Pitch.**

<u>There are two type of tones</u>

Pure tone
Complex tone
A sound with a single frequency or only a particular frequency is called a **pure tone.**
For example, a vibrating object like tuning fork or maybe a guitar string is a pure tone. It involves only one frequency.
Complex tone -where there are two or more than two frequencies mixed together.
A complex tone consists of two or more simple tones, called overtones. The tone of lowest frequency is called the fundamental; the others, overtones.
So these different frequencies super impose with each other.

<u>Loudness</u>
Loudness is an attribute of a sound that depends primarily on the pressure amplitude of the wave. Frequency is also factor.
Hearing range usually describes the range of frequencies that can be heard by humans or other animals, though it can also refer to the range of levels. The human range is on average from 20 to 20,000 Hz, although there is considerable variation between individuals (range declines with age), especially at high frequencies, where a gradual decline with age is considered normal. Sensitivity also varies with frequency, as shown by **equal-loudness contours**.

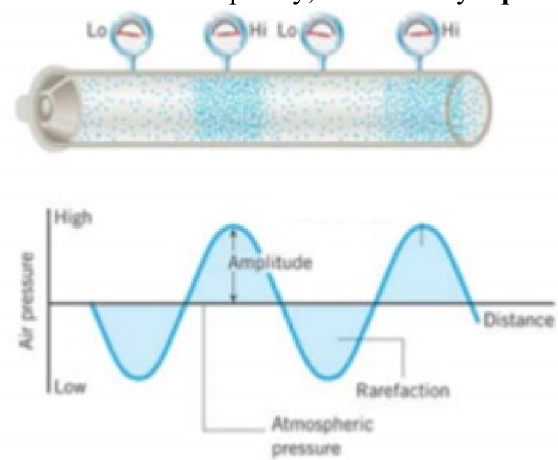


Fig.14.Sound wave(loudness)

<u>Equal loudness contour</u>
An equal-loudness contour is a measure of sound pressure (dB SPL), over the frequency spectrum, for which a listener perceives a constant loudness when presented with pure steady tones. The unit of measurement for loudness levels is the phon, and is arrived at by reference to equal-loudness contours.

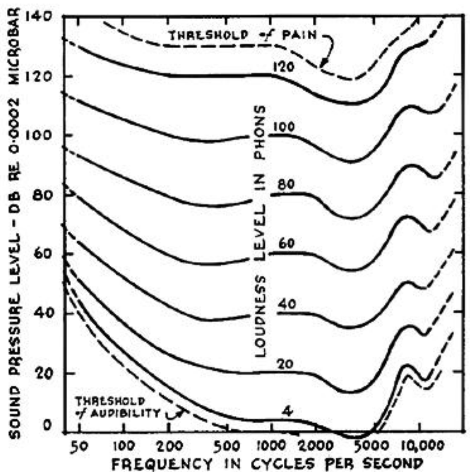


Fig.15.Equal loudness contour

Intensity is the amount of energy that is transported past a given area of the medium per unit time is known as intensity of the sound wave. The greater the amplitude of vibrations of the particles of the medium, the greater the rate at which energy is transported through it.

Sound intensity

Sound intensity is defined as sound power per unit of an area. It depends on the distance from the sound source and the acoustic environment in which the sound source is. Sound intensity is a vector quantity and describes the amount and direction of the sound energy. The unit for sound intensity is [W/m^2]. It is calculated as a product of the sound pressure and the speed of particles.

"human ear is capable of detecting sound waves with a wide range of frequencies, ranging between approximately 20 Hz to 20 000 Hz. Any sound with a frequency below the audible range of hearing (i.e., less than 20 Hz) is known as an infrasound and any sound with a frequency above the audible range of hearing (i.e., more than 20 000 Hz) is known as an ultrasound."

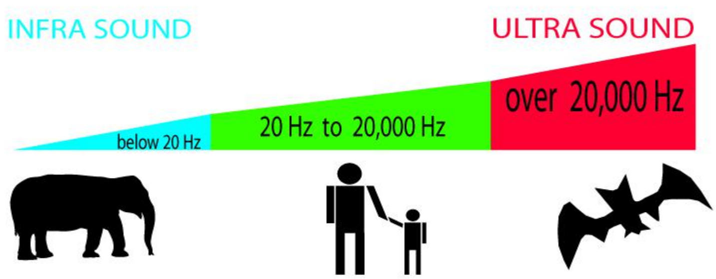


Fig.16.Audible frequency range

The creatures produce low-frequency **noises** between 1 to **20 Hertz**, known as infrasound, that help them keep in touch over distances as large as 10 kilometers.

<u>Speech and music frequencies</u>

Speech normally carries the mid frequency. The male voice has little lower frequency than the female voice. Speech frequencies ranges from 200Hz to 2KHz.

Music frequencies ranges little wider than the speech frequencies. It ranges from 63Hz to 16Khz. The sound pressure level (dB levels) are ranges from 20dB in the mid frequencies to 90dB in the lower frequencies in the case of drums and bands.

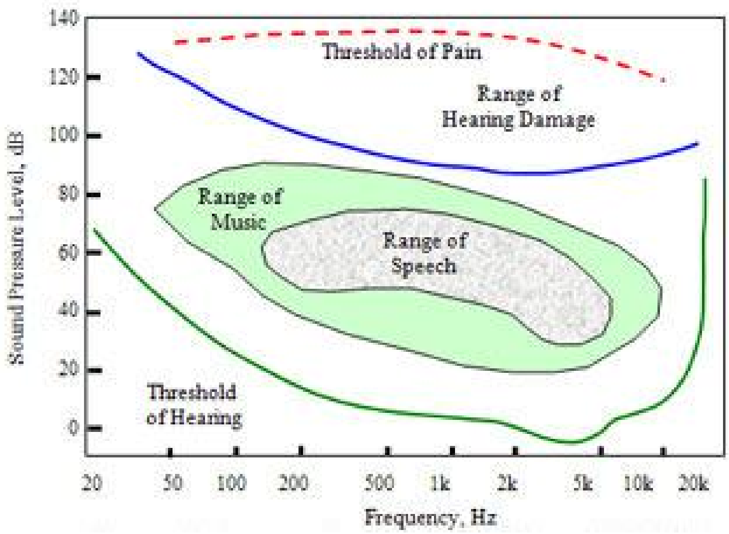


Fig.17. Speech and music frequencies

When the sound level exceeds certain threshold value we perceive it as **Noise.**

Typically it is unwanted sound or undesirable sound. One person sound can be other person's noise, so the threshold typically varies depending on the source depending on the path and depending on the receiver, the nature of source as well.

Velocity of the sound depends up on the density of the medium as well as the temperature of the medium.

Material	Density (kg/m^3)	Speed of Sound (m/s)
Air @ 0° C	1.293	331
Air @ 20° C	1.21	344
Water @ 15° C	998	1450
Steel (Bar)	7700	5050
Concrete (Dense)	2300	3400

Speed of the sound -Sound travels faster in solids as compared to liquids and faster in liquids as compared to gases.

<u>dB scale (logarithmic scale)</u>

A direct application of linear scales (in Pa) to the measurement of sound pressure leads to large and unwieldy numbers. In addition, as the ear responds logarithmically rather than linearly to stimuli, it is more practical to express acoustic parameters as a logarithmic ratio of the measured value to a reference value. This logarithmic ratio is called a decibel or dB. Here, the linear scale with its large numbers is converted into a manageable scale from 0 dB at the threshold of hearing (20 μPa) to 130 dB at the threshold of pain (~100 Pa). Fig -shows the dB scale equivalent to pressure levels. Surprisingly wide range of sound pressures - a ratio of over a million to one. The dB scale makes the numbers manageable.

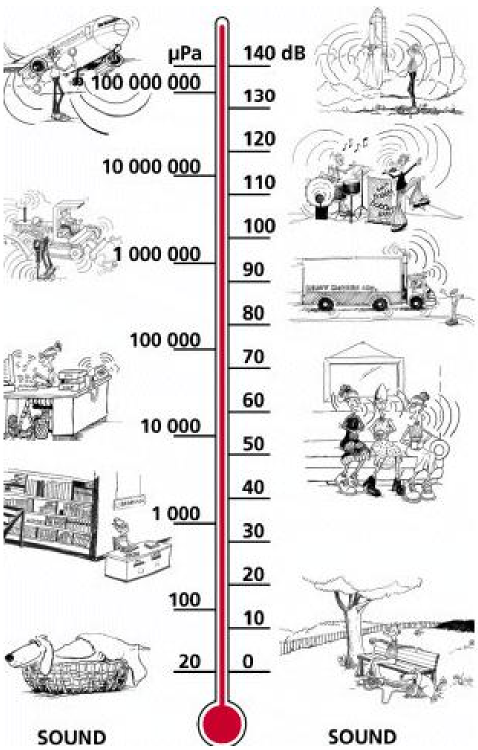


Fig.18. dB Scale

Sound power is the characteristic of a sound source, it is independent of the distance and, therefore, a practical way of comparing various sound sources. Sound power can be measured in different ways (by sound pressure or by sound intensity).

Sound pressure or **acoustic pressure** is the local pressure deviation from the ambient (average, or equilibrium) atmospheric pressure, caused by a sound wave. In air the sound pressure can be measured using a microphone, and in water with a hydrophone. The SI unit for sound pressure p is the pascal (symbol: Pa).

Sound pressure level (Comparative term)

Sound pressure level (SPL) or sound level is a logarithmic measure of the effective sound pressure of a sound relative to a reference value. It is measured in decibels (dB) above a standard reference level. The standard reference sound pressure in the air or other gases is 20 µPa, which is usually considered the threshold of human hearing (at 1 kHz).

<u>Difference from pressure and power-</u> When there is a sound source it is having a power, when it is emitting there is a medium - source, path and it can be receiver can be an instrument or human ear. So, source path and receiver you perceive it as pressure.

A simple analogy is there is a radiant heater it has certain power, it has certain power, it emits the heat radiant (the heat transmission or heat transfer), it emits heat and then start perceiving it through a censor or through your human body in terms of temperature. So, this can be equated, there is power perceive it as pressure. It needs a medium in terms of compression and rarefaction it propagates and then it reaches you it causes your tympanum to vibrate in your ear which senses it as the pressure quantity. Sound power that is a source it can be anything says mechanical equipment, propagates through the room and then it reaches you. So, what you measure or what you perceive is a sound pressure.

Octave bands

Sound is like wide spectrum within which lot of variations can happen.In order to get a closer look of the characteristic of the source itself or the propagating medium and the receiver characteristics need to split it in to specific segments which was called as frequency spectrum.

There are different types of frequency splitting- octave band (2 is to 1). for example, central frequency of 500, 1000, 2000, 4000 so on. For building applications refer as 63 and half hertz on the lower end that is of low frequency it can go as high as 16,000 hertz. But mostly it was around 8000 hertz for our specific observations. Further it can split up to third octave bands. So, each octave gets split into three.

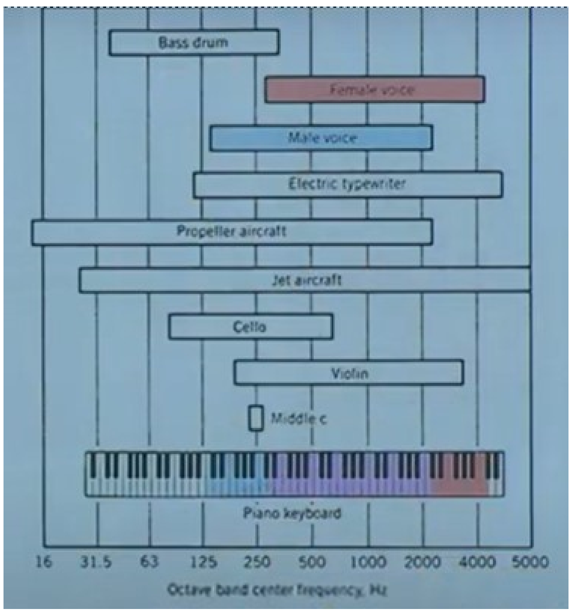


Fig.19. Comparison of frequency range

Knowing about this not all the sources have similar frequency characteristics. For example piano keyboard will be having the low mid and high frequencies.
Each instrument, each source, any particular noise signal sound signal we will have a frequency spectrum.
Violin for example, the prominent frequency lies somewhere between 150 hertz to 4000 hertz.
bass drum -33 hz to 280hz.(low frequency side).
Jet Air Craft -really wide spectrum, it ranges from a very low frequency to a very high frequency.
Propeller air craft- it is more on the low
frequency compare to higher one.
male and female voice- male voice slightly goes to the lower frequency spectrum somewhere from 125 hertz goes all the way to slightly more than 2000 hertz, whereas female voice does not go that low, but it has a slightly higher frequency spectrumthan the male voice. So, if you take multiple

numbers of sources we will be able to split what frequency spectrum they actually are emitting the sound levels.

This has lot of implications, but primary implication the sound propagation depends mainly on the frequency and the wave length of the sound. Where frequency determines the wave length, frequency is a number of cycle, wave length is the distance between the compressions or rarefactions.

The frequency of the sound has a strong impact on the way the sound propagates.

For example - design for indoor acoustical - an auditorium or a classroom, you have to really understand which prominent frequency the sound is getting emitted. Only if you know that you will be able to give a proper treatment.

Similarly, for an environmental noise you want to design a noise barrier you want to arrest the sound you want to do sound proofing-

1. the first idea you should have is about the sound pressure level; how much intense the sound is.

2. And in which frequency spectrum the sound is getting emitted.

So, if you know these two characteristics then you will be able to effectively contain or treat the sound source.

This wide frequency spectrum has lot of implications:

- The primary implication of the sound propagation depends mainly on the frequency and the wave length.
- The frequency of the sound has a strong impact on the way the sound propagates.

While designing an indoor acoustical design has to be done for an auditorium or a classroom:

- really to understand which frequency there is a prominence of sound mean,
- which prominent frequency the sound is getting emitted.
- Then will be able to give a proper acoustical treatment.

Sound field

Spherical Propagation - how the propagation of the sound occurs. The propagation of sound is spherical; it is from a point source is in a spherical way. So, in air or in space it is going in a spherical way. So, from this particular point s source is going in 3 dimensions in this spherical way.

So, if you are very near to the source, intensity is high, if move away from the source, your sphere is bigger, radius is bigger, surface area is bigger and the intensity is decreasing.

The *sound intensity* from a *point source* of sound will obey the *inverse square law* if there are no reflections or reverberation. A plot of this intensity drop shows that it drops off rapidly.

Inverse square Law - The decrease in intensity with increasing distance is explained by the fact that the wave is spreading out over a circular (2 dimensions) or spherical (3 dimensions) surface and thus the energy of the sound wave is being distributed over a greater surface area. The diagram at the shows that the sound wave in a 2-dimensional medium is spreading out in space over a circular pattern. Since energy is conserved and the area through which this energy is transported is increasing, the power (being a quantity that is measured on a per area basis) must decrease The mathematical relationship between intensity and distance is sometimes referred to as an inverse square relationship. The intensity vanes inversely with the square of the distance from the source So if the distance from the source is doubled (increased by a factor of 2), then the intensity is quartered (decreased by a factor of 4).

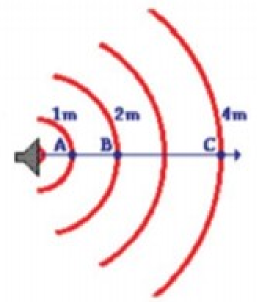


Fig.19. Inverse square law

The *sound field is an area where the sound exists*. When measuring the sound pressure, it is very important whether the sound field is *free or diffused*.

Free-field

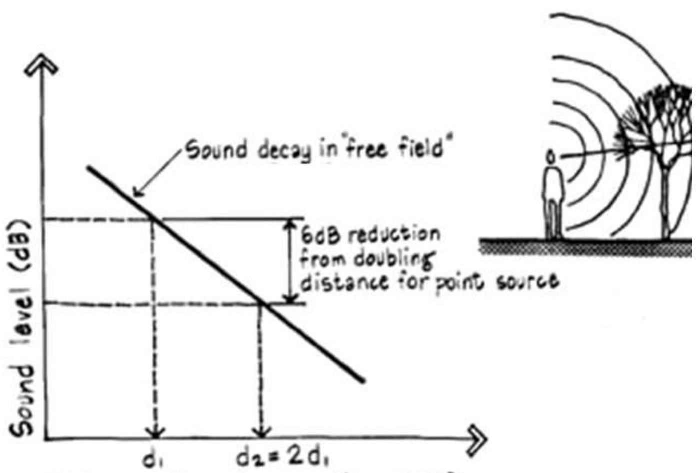


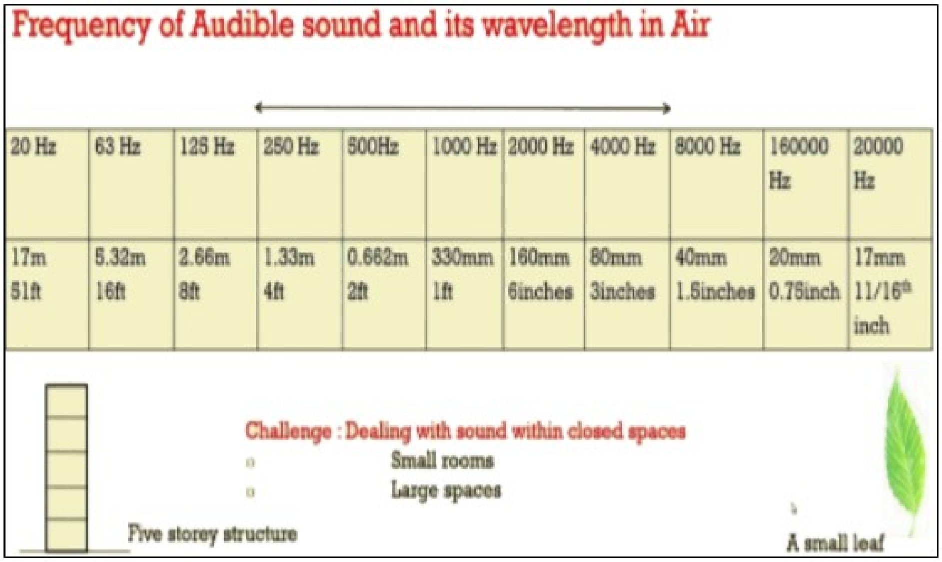
Fig.20. Free field

Free sound field- it can be found in a space where there is no reflection. It can be simulated outside or in an isolation room, where all the sound that strikes the walls is absorbed. The main property of the free sound field is that the sound spreads spherically.

Free-field conditions occur when sound waves are free from the influence of reflective surfaces (e.g., open areas outdoors, anechoic rooms).

Under free-field conditions, sound energy from **point sources** (e.g., warning siren, truck exhaust) spreads spherically and drops off 6 dB for each doubling of distance from the source.

Line sources of vehicular traffic consist of successive point sources which reinforce each other. Sound energy from **line sources** spreads **cylindrically**, not spherically, and drops off only 3 dB for each doubling of distance.



20 Hz	63 Hz	125 Hz	250 Hz	500Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	160000 Hz	20000 Hz
17m 51ft	5.32m 16ft	2.66m 8ft	1.33m 4ft	0.662m 2ft	330mm 1ft	160mm 6inches	80mm 3inches	40mm 1.5inches	20mm 0.75inch	17mm 11/16th inch

Fig.21. Frequency of audible sound and its wavelength in air

An audible range, which is of the order of 20 Hz to 20000 Hz frequency. 20 Hz is the order of 17 meters or 51 feet, which is equivalent to a five-storey structure. And for 20000 Hz, which is of the order of 17 millimeter of wavelength, which is 11/16 th inch, which is small distance.

Now, particularly when we deal with our rooms, spaces where we need to communicate, it is mostly speech, music, orchestra, or a performance where we need to take our sound, whichever is originated from the source to the receivers (whoever are spread inside). So, knowing this wavelength is very important, we usually consider our speeches to music from 250 Hz to 4000 Hz, and can move further to 8000 Hz and maybe down to 63 Hz.

<u>The interaction of sound with solid surfaces:</u>

Reflection

Diffusion (scattering of sound)

Diffraction (bending of sound)

Absorption

Transmission

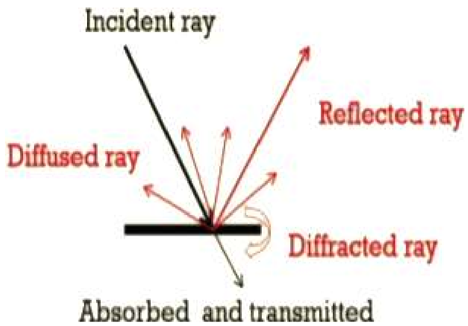


Fig.22. interaction of sound with solid surfaces

The incident ray is falling on an object and, it is getting reflected directly, which is called **specular reflection**. Some of it gets diffused, and some of it can bend and go beyond that particular object, where it is falling on, so that is diffraction and some gets absorbed and transmitted.

Reflection

The reflection of sound follows the law "angle of incidence equals angle of reflection", sometimes called the law of reflection.

The same behaviour is observed with light and other waves, and by the bounce of a billiard ball off the bank of a table.

The reflected waves can interfere with incident waves, producing patterns of constructive and destructive interference. This can lead to resonances called standing waves in rooms

It also means that the sound intensity near a hard surface is enhanced because the reflected wave adds to the incident wave, giving a pressure amplitude that is twice as great in a thin "pressure zone" near the surface.

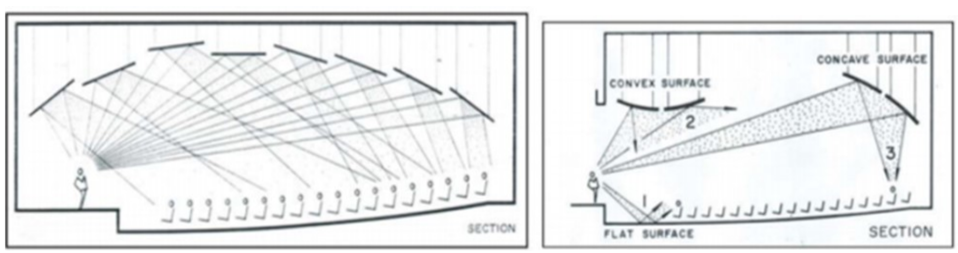


Fig.23. Reflection

Ray diagram or Geometric Acoustics

It is a simple way by demonstrate within the spaces which deal for acoustics, though there are certain limitations, it is considered that sound reflects as represented by ray diagrams.

Limitations

Sound reflects as represented by ray diagram only when the surfaces which hits is very large compared to the wave length.

Source is considered as a static which may not actually true. Detailed study may not be possible with respect to diffusion or scattering of sound.

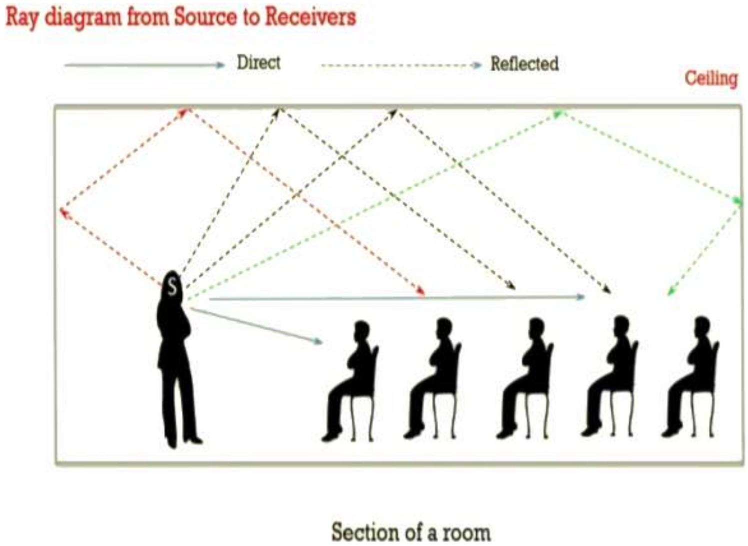


Fig.24. Section of a room

In this ray diagram the source is there, the direct sound is shown in a continuous line and the reflected sound in dotted line, the two different locations the sound traveled from the source are different.

So, the direct path is D1, and the reflected path to D1 is the reflected path (R1a)+ reflected path (R1b). Similarly, at location 2, it is R2a and R2b, and that is what is reaching him after a short span of time after he has heard D2. So, the path difference is R1a + R1b - D1 for the listener 1, and R2a + R2b- D2, in case of listener 2.

So, this path difference should be heard within a certain time, so that these can help in strengthening or better hearing at location 1.

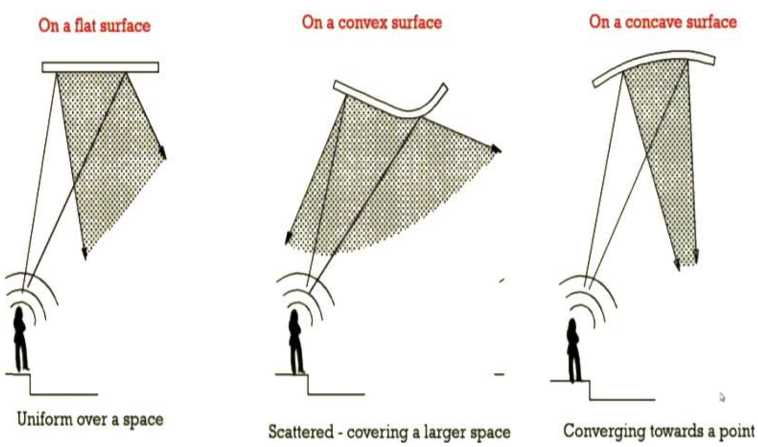


Fig.25.Shape of reflector determines the sound path

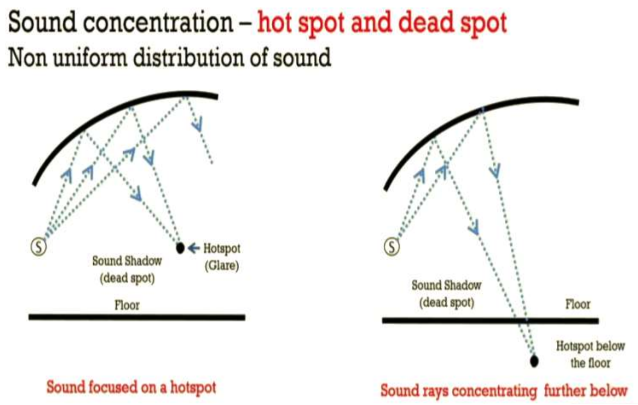


Fig.26.Hot spot and dead spot

Hot spot -sound concentration can create some points within the floor where there will be a glare. So, all the sound from the source will go and concentrate in that particular area, which is called the **hotspot.**

Dead spots The entire sound energy which was supposed to get distributed into the other areas, there no sound has reached particularly from the reflected sound rays. So, that creates a sound shadow area, or **dead spots**, beside or surrounding a hotspot.

<u>**Diffusion**</u>

Diffusion implies the scattering of sound or random distribution of spreading of sound from a surface on to which it is falling.

So this diffusion is happening in all directions. Surface irregularities, breaks, projections, wedges, instead of continuous reflective surfaces, can cause diffusion.

Inside our spaces- for example- curtain, blackboard edges, the chairs, tables; any material which is projected out, like a book rack within a classroom; all can take part in the process of diffusion of sound.

Diffusion helps in uniform distribution of sound in the space, and it also implies uniform decay of the sound within the room. it distributes the sound energy equally towards the receivers all from the front till the back. Adequate diffusion is critical for obtaining an even distribution of reverberant sound in a listening space. Sound reflection from flat surfaces causes glares, while diffused sound helps avoid direct sound to the receiver.

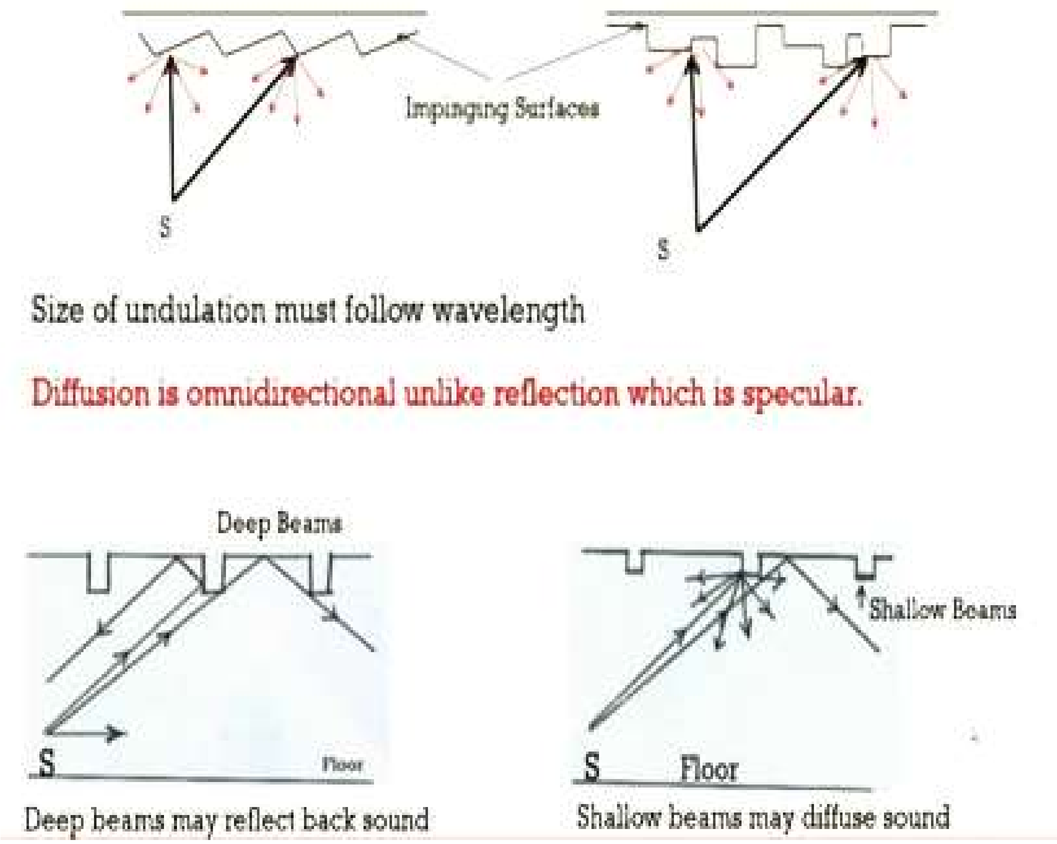


Fig.27.Diffusion

Transmission

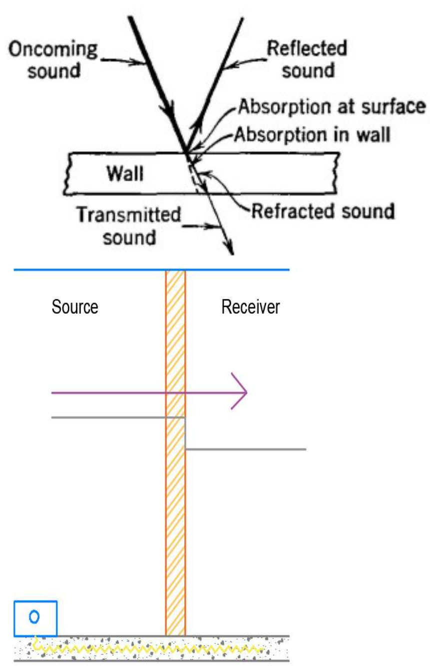


Fig.28.Transmission

There are two types of transmission one is called the airborne sound transmission and, one is called the structure borne sound transmission.

In airborne sound transmission, Sound energy penetrate the boundary element and reaches the other part. Where as in the structure borne sound, sound will travel through the material itself or the envelope material of the building. And there will be gradual loss of the sound energy and, when it propagates from one point to the other point.

Diffraction

An acoustical phenomenon which causes sound waves to be bent or scattered around such obstacles as corners, columns, walls, and beams

Also a phenomenon where sound passes through an opening resulting in a change of propagation, as influenced by the ratio of the sound wavelength to the size of the opening

the **bending of waves** around small* obstacles and the spreading out of waves beyond small* openings.

The fact that you can hear sounds around corners and around barriers involves both diffraction and reflection of sound. Diffraction in such cases helps the sound to "bend around" the obstacles.

Diffraction is nothing but **bending of sound**. Why can we hear a sound behind a wall, source is not seen, we can hear some of the sound. That is because sound can bend and go into the receiver's ears.

From the below image- when incident wave is falling and is getting guarded by a barrier, the upper part of the incident wave is traveling, whereas the lower part is hit and it may reflect back. This upper part, which is moving by compression and rarefaction is not present in this particular zone (this particular zone is devoid of it). So, the energy will push these areas and will allow the sound to pass to this area, which is nothing but diffraction.

Though one will listen very nicely in the particular zone hence will correspondingly listen (receive) at a higher energy level (in case of direct sound), or lower energy level (for diffracted sound).

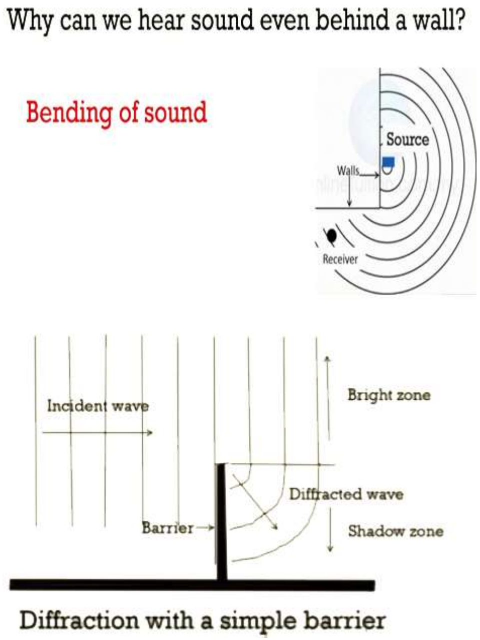


Fig.29.Diffration

Absorption

- The property of a surface by which sound energy is converted into other form of energy is known as absorption.
- In the process of absorption sound energy is converted into heat due to frictional resistance inside the pores of the material.
- The fibrous and porous materials absorb sound energy more, than other solid materials.

When sound waves hit the surface of an obstacle, some of its energy is reflected while some are lost through its transfer to the molecules of the barrier. The lost sound energy is said to have been absorbed by the barrier. The thickness and nature of the material as regards its softness and hardness influences the amount of sound energy absorbed.

Absorption co-efficient

- The effectiveness of a surface in absorbing sound energy is expressed with the help of absorption coefficient.
- The coefficient of absorption `α' of material is defined as the ratio of sound energy absorbed by its surface to that of the total sound energy incident on the surface.
- **A unit area of open window is selected as the standard.** All the sound incident on an open window is fully transmitted and none is reflected. Therefore, it is considered as an ideal absorber of sound.
- Thus the unit of absorption is the open window unit (O.W.U.), which is named a "sabin" after the scientist who established the unit.

Absorption Coefficient

The effectiveness of acoustical material to absorb sound depends on its thickness, amount of airspace, and density. It is the ratio of ABSORBED: INCIDENT sound energy

$$\alpha = \frac{Sound\ energy\ absorbed\ by\ the\ surface}{Total\ sound\ energy\ incident\ on\ the\ surface}$$

The amount of sound absorbed at the surface of a material is described by an absorption coefficient (a). The absorption coefficient relates to sound reflection, where a high equals low reflected energy and a low a equals high reflected energy.

Marble slate has an absorption coefficient of 0.01 (almost no absorption and high reflection). Some specially constructed sound rooms score as high as 1.0 (total absorption and no reflected energy).

The absorption coefficient of a material typically increases with frequency. At low frequencies, porous materials absorb less sound, so that materials must be thicker to be effective. The overall performance of a sound-absorbing material is often described by the Noise Reduction Coefficient (NRC). The NRC is the arithmetic average of the absorption coefficient at 250, 500, 1000, and 2000 Hz.

Sound absorption differs from sound insulation. Sound absorption relates to sound reflection, whereas sound insulation relates to the amount of acoustic energy able to pass through material. The sound absorption provided by a 10 centimetre-thick (4-inch thick) fiberglass acoustical blanket is high, but its insulation quality is low. Sound is able to travel through the material to the other side. By contrast, a lead wall absorbs almost no sound but it is a very good insulator.

NRC stands for **Noise** Reduction Coefficient and is a standard rating for how well a **material** absorbs **sound**. The **NRC** rating of a **material** can be viewed as a percentage. The **NRC** figure ranges from 0.00 (perfectly reflective) to 1.00 (perfectly absorptive).

NRC value which is an average absorption coefficient of four different frequencies, 250 500 1000 and 2000. If there is any material there will be the noise reduction coefficient, for example -the NRC value is 0.8, 0.94, means it's a good absorbing material. It indicates the materials absorbing performance, but it is an average value.

Reverberation

is the persistence of sound after the source of sound has stopped. It is due to the repeated reflection of sound waves remaining between the enclosing surfaces. Reverberation Time Reverberation time is defined as that time required for the sound in a room to decay 60 dB. This represents a change in sound intensity or sound power of 1 million (10 log 1,000,000 = 60 dB). In very rough human terms, it is the time required for a sound that is very loud to decay to inaudibility. Sabine Reverberation The idea that there exists a characteristic time for sound to die out in a room originated with Wallace Clement Sabine.

Sabine measured the reverberation time, the time it took for the sound level to drop 60 dB, for varying amounts of absorptive materials.

The empirical formula he discovered, now called the Sabine reverberation time, is

$$T_{60} = .049 \frac{V}{A}$$

where T_{60} = reverberation time,or the time it takes for sound to decrease by 60 dB in a room (s)

V = volume of the room (cu ft)

A = total area of absorption in the room (sabins)

$= S_1 \alpha_1 + S_2 \alpha_2 + S_3 \alpha_3 + \cdots + S_n \alpha_n$

The standard unit of absorption, now called the sabin in his honor, has units of sq ft. The metric sabin has units of sq m. In metric units the Sabine formula is

$$T_{60} = 0.161 \frac{V}{A}$$

RT = (0.16 × V)/A -------Unit seconds (for matric)

RT = (0.05 × V)/A -------Unit seconds (for feet and inches)

where V = volume of room (m^3), A = total absorption in room (m^2).

Reverberation time

When the source is switched off, the reverberant sound field would persist for a little time as it gradually decays. The time taken for the sound field to drop by a factor of a million *(*10^6*)*, i.e. a drop in sound level of 60 dB, is referred to as the *reverberation time* (RT). The length of this time depends on the size of the room and the room surfaces. A little energy is lost at each reflection. With hard surfaces it will take more reflections, thus a longer time for the sound to decay. In a larger room the sound travels a longer time between reflections, there are fewer reflections in unit time, thus RT is longer.

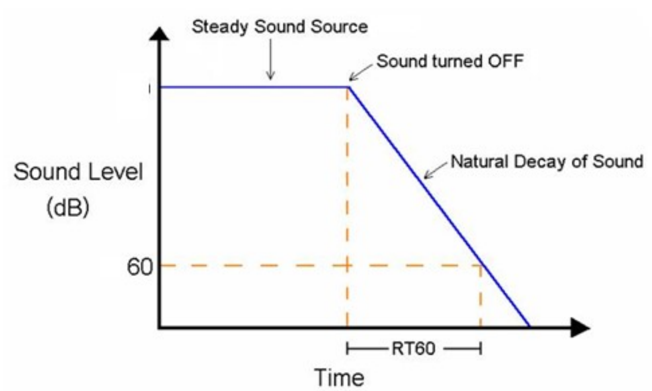
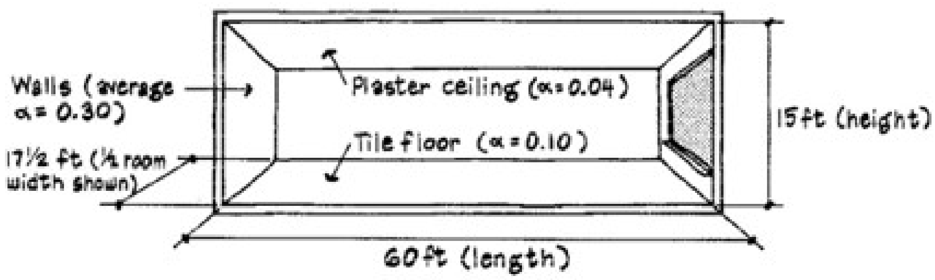


Fig.30.Graph showing reverberation time

EXAMPLE PROBLEM (REVERBERATION TIME)

A classroom 60 ft long by 35 ft wide by 15 ft high has sound absorption coefficients α's of 0.30 for walls, 0.04 for ceiling, and 0.10 for floor. All α's are at 500 Hz.



Find the reverberation time T at 500 Hz in this space with no occupants and no sound-absorbing treatment.

1. Compute the room volume V.

$$V = 60 \times 35 \times 15 = \boxed{31{,}500 \text{ ft}^3}$$

2. Compute the surface areas S.

Ceiling	$S = 60 \times 35 = 2100 \text{ ft}^2$
Walls	$S = 2 \times 35 \times 15 = 1050 \text{ ft}^2$
	$S = 2 \times 60 \times 15 = 1800 \text{ ft}^2$
Floor	$S = 60 \times 35 = 2100 \text{ ft}^2$

3. Compute the total room absorption a using $a = \Sigma S\alpha$.

	S	α	a (sabins)
Ceiling	2100	× 0.04 =	84
Walls	2850	× 0.30 =	855
Floor	2100	× 0.10 =	210
		Total a =	$\boxed{1149 \text{ sabins}}$

4. Compute the reverberation time T using $T = 0.05 \dfrac{V}{a}$.

$$T = 0.05\,\frac{V}{a} = \frac{0.05 \times 31{,}500}{1149} = \frac{1575}{1149} = \boxed{1.37 \text{ s}} \text{ at 500 Hz}$$

<u>Absorptive materials</u>

There are three basic types of absorbers, the absorption being due to different processes:

<u>Types of acoustic absorbers</u>

- Porous absorbers
- Membrane absorbers
  Perforated panel absorbers
- Cavity resonators

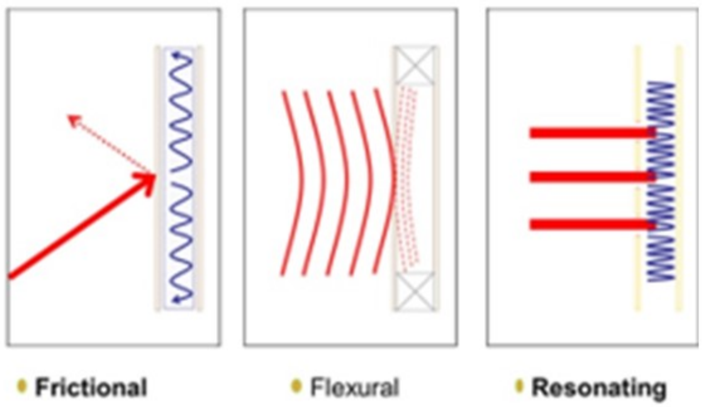


Fig.31.Methods of sound absorption

1. Porous absorbers, such as mineral wool, glass wool, fibre board or plastic foams which have anopen cell structure (Fig.a). Vibrations are converted to heat by the **friction** of vibrating air molecules and the cell walls. These are most effective for high frequency (short wave) sounds. If the thickness (b) is less than quarter wavelength (b < λ/4), they have little effect. If such a sheet is fixed at some distance from a solid surface (Fig.b), it will have almost the same effect as a thicker absorber. In this case, the maximum amplitude of both the incident and the reflected wave would occur within the porous material.

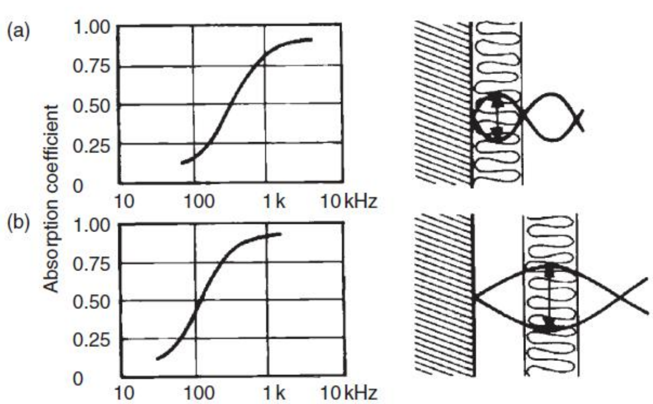


Fig.32. Porous absorbers: (a) fixed to a solid wall, (b) spaced out e.g. by battens

Take simple 50 mm or 25 mm thick cushion, it is absorption or alpha value absorption coefficient it is not very well performing in the low frequency. In these foam material, by increase the thickness or the spacing between wall. For example- 50 mm or 100 mm space, air gap then mounts and there will be improve the performance in **the low frequency also**.

By simply mounting it on the wall surface, a thin 50 mm cushion standard panels boards then the performance in the high frequency, but not performed in low frequency.

Cushion or a Foam - have very good absorption in the **mid and high frequency range.** Take the cushion material the microstructure it has air porous in it. Then normally the acoustic signal or the sound energy is getting converted into heat energy inside these porous.

Porous absorbers

- More efficient at high, **rather than low frequencies**
- Efficient improves in **the low frequency with increased thickness and with distance to their solid backing.**
- Perforated, fissured, or textured materials
- Available as acoustic boards, hangers, geo-acoustic tiles.
- Other variant-Plasters, sprayed fibrous materials, blankets,
- foam boards, carpets and fabrics.

2.Membrane absorbers may be flexible sheets stretched over supports, or rigid panels mounted atsome distance from a solid wall. Conversion to heat would occur due to the rapid **flexing** of the membrane and repeated compression of the air behind it. These will be most effective at their resonant frequency, which depends on the surface density of the membrane, the width of the enclosed space and on the fixing and stiffness of the membrane or panel. Most such absorbers are effective **in the low frequency range**.

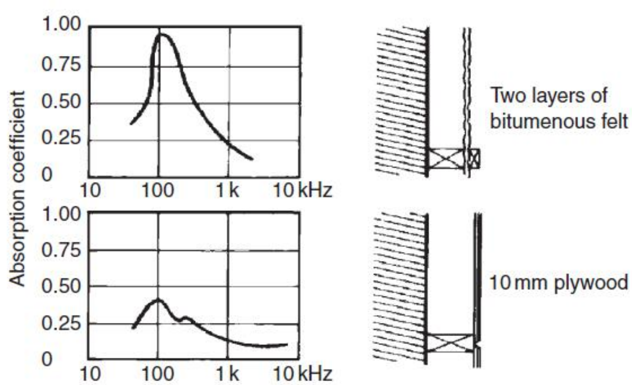


Fig.33.Membrane type absorbers

3. Cavity (Helmholz) resonators are air containers with a narrow neck. The air in thecavity has a spring-like effect at the particular **resonant** frequency of the enclosed air volume. **These have a very high absorption coefficient in a very narrow frequency band.** Large pottery jars built into stone walls with their opening flush with the wall surface are the original examples from Greek amphitheaters.

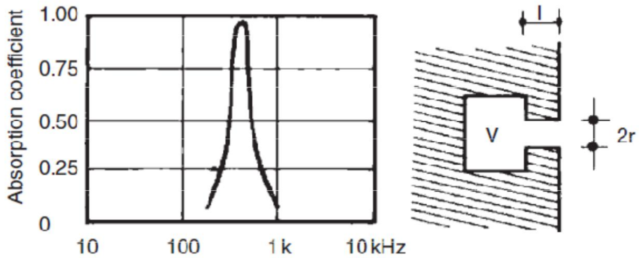


Fig.34. A cavity resonator absorber

Cavity resonators

- Individual Cavity Resonators -Classifications Individual Cavity Resonators Individual Cavity Resonators- Standard concrete docks. using regular concrete mixture, but with slotted cavities
- Perforated Panel Absorbers
- Slit Resonators Isolation blankets (or alternative) covered with slits, the whole system forming a resonator

They are sound-absorbing panels which are designed to provide low-frequency absorption (250 Hz).

Applied in music practice rooms, radio/TV studios etc.

Resonant panels absorb energy from sound waves by vibrating at a frequency determined by the geometry and damping characteristics of the panel.

To decrease the resonant frequency, use wide spacing between supports (> 7 (1), thin panel materials (e.g.. plywood, hardboard), and 'deep' air-space behind panels.

To increase the resonant frequency, use close spacing between supports, thick panel materials (or perforated, thin panel materials with sound-absorbing material located close behind the panel), and shallow or narrow airspace behind panels.

Cavity (Helmholz) resonators these are typically box shaped absorbers, these are also called Helmholtz Resonators, working principle is they actually trap the acoustic signal, it can be specific boxes like this, or it can be panels with perforated, in which each of these perforations is going to act as an acoustic cavity, inside which the signals or the incoming signals can be trapped. This signal can be, have simple white or this can be lined for improved absorption, and these are typically **well performing in the mid and low frequency range.** Of course, it depends on the width of the cavity; that is the diameter or the cross section of this whole thing as well.

4. Perforated panel absorbers

Combine all three of the above mechanisms ,The panel itself may beplywood, hardboard, plasterboard or metal and many act primarily as membrane absorbers. The perforations, holes or slots with the air space behind them act as multiple cavity resonators, improved by some porous absorber. Most of the broad-spectrum commercially available acoustic materials (e.g. ceiling tiles) fall into this category.

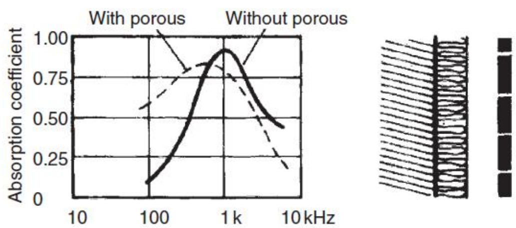


Fig.35. A perforated panel absorber

<u>Slit Resonators</u>

The glass wool, foam backing behind this by using different types, they can also be separately suspended in the form of specific boxes, which act as **resonating cavities**, it can be individual cavities which can arrest, in **very low frequency sounds**, typically used in **recording studios**, where low frequency creates a lot of problem, because of the smaller volume of the room as well as a type of sound signals which are generated.

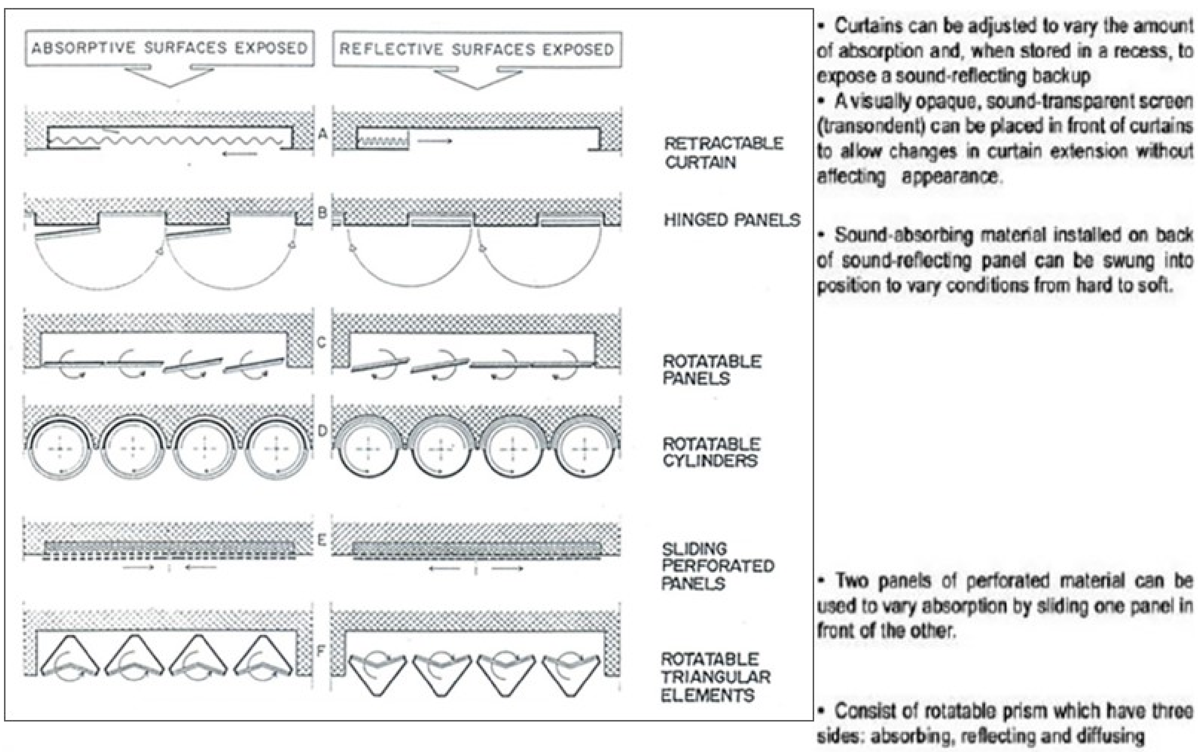


Fig.35. Variable sound absorbers

<u>Variable Sound Absorbers</u>

• When the reverberation time must be varied to satisfy the requirements of different activities in a room, the sound
absorbing treatment can be designed to be adjustable.
• Surfaces or furnishings can be designed to expose either sound-absorbing materials or sound-reflecting materials.
<u>They are of the following types:</u>

- Retractable Sound

-Absorbing Curtains
- Sliding facings
- Hinged panels
- Rotatable elements

<u>Acoustic Boards</u>

Advantages

- Trade catalogs contain detailed specifications
- Easy installation and maintenance
- Flexible absorption

Disadvantages

- Difficult to conceal joints between units
- Soft structure subject to damage
- Paint redecoration harmful to absorption

Sound-absorbing materials are commercially available for installation in a spaced regular pattern. When these units (or panels) are installed with all edges and sides exposed, they can provide extremely high absorption per square foot of material because at least six surfaces will be exposed to sound waves.

Suspended spaced absorbers can be used where a uniform or continuous application of conventional sound-absorbing materials is not feasible (e.g., industrial plants with extremely high ceilings)

• For walls, use fibrous materials with protective open facings (e.g., perforated or expanded metal, perforated hardboard, metal slats), fabric-covered panels, or shredded-wood form board. • Use membrane-faced or ceramic tile materials for humid environments such as swimming pools, locker rooms and kitchens. • Lightly tint or stain, rather than paint, sound-absorbing materials, because painting can seriously diminish the sound-absorbing efficiency by clogging the openings. For many situations spray applications can achieve a thinner coating than brushes or rollers.

Acoustic Hangers or baffles- a system of fiber-board panels that are wrapped with insulation and are hung freely using wire or rope.

Geoacoustic Tiles- special prefabricated units for random application on walls and ceilings.

Diffusers- absorptive material that have, irregular surfaces, or angled or curved fronts, so when mounted on a wall or the ceiling they stop parallel wall interference and prevent standing waves.

Acoustic Blankets- Also referred to as "Isolation Blankets". Materials manufactured from rock wool, glass fibers, wood fibers, hair felt, etc.

Acoustic Foam Boards- High density blankets with covering: also act as diffusers.

<u>Properties Of Acoustic Materials</u>

• Fire resistant
• Termite resistant
• Withstand heat and moisture
• Easy to handle
• Pleasing appearance
•Good structural strength
•Good absorption coefficient
• Uniform absorption
• Uniform resonance
• Durable and economical

Acoustical Boards

- Regular perforated tile
- Fissured tile or panel
- Random perforated tile
- Texture and patterns tile or panel
- Slotted tile or panel
- Membrane faced or ceramic tile materials
- Shredded wood fiber board
- Glass fiber
- Smooth sprayed material.
- Rough sprayed materials.

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DEPARTMENT OF ARCHITECTURE

UNIT – 2 - BUILDING SERVICES III– SAR 1302

ACOUSTICS

OUTDOOR NOISE

Outdoor noise comes in many varieties:

- Industrial
- Loudspeaker
- Construction work
- Road Traffic
- Trains
- Air crafts
- Radios and microphones
- Machineries and equipment's
    - Outdoor mechanical equipment for air control in buildings, fans, pumps and much more.
    - Many larger municipalities have noise standards, requiring noise levels not to exceed 65 dB(A) during daytime and not to exceed 55 dB(A) after 10 PM.

Outdoor noise level

Outdoor/Environmental noise is the summary of noise pollution from outside, caused by transport, industrial and recreational activities.

Noise is frequently described as 'unwanted sound', and, within this context, environmental noise is generally present in some form in all areas of human activity. The effects in humans of exposure to environmental noise may vary from emotional to physiological and psychological.

Noise at low levels is not necessarily harmful; environmental noise can also convey a sense of liveliness in an area, and is not then always considered 'unwanted'. However, the adverse effects of noise exposure (i.e. noise pollution) could include: interference with speech or other 'desired' sounds, annoyance, sleep disturbance, anxiety, hearing damage and stress-related cardiovascular health problems.

Table .1-Permissible outdoor noise levels for Indian context

Category of Area/Zone	Day time (limits in dB(A) Leq	Night time (limits in dB(A) Leq
Industrial area	75	70
Commercial Area	65	55
Residential Area	55	45
Silence Area	50	40

Permissible outdoor noise levels – (Ambient noise standards given by Central pollution controlboard of India)

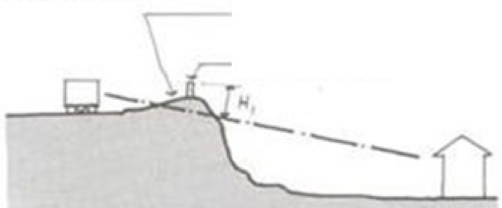
Day time: 6.00Am to 10.00Pm, Night time :10.00Pm to 6.00Pm. Silence zone is defined as an area comprising not less than 100 meters around hospitals, educational institutions and courts.
Leq - Equivalent Continuous Sound Level

<u>Outdoor Barriers:</u>

Outdoor barriers can be used to reduce the environmental noises, especially
high – frequency sound energy such as tire "whine" from cars and trucks.
The low – frequency sound energy, such as engine "roar" can readily bend over and around the barriers.

Better

Elevated roadbed plus shielding of grass-covered earth berm and thin-wall barrier can provide useful attenuation. However, elevated highways more than 500 ft away can produce almost the same noise levels as highways at grade because the line of sight will not be blocked.



Better

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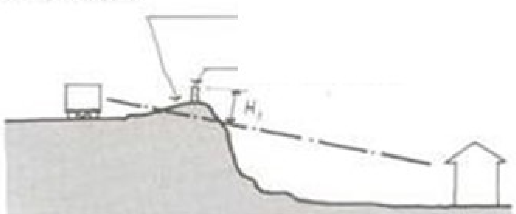


Best

Roadbeds below grade can interrupt the direct sound path from source to receiver even further, thereby providing greater attenuation by diffraction. Roadbed depressions of 12 ft or more usually are needed to control highway noise. Note that the height H_2 above the acoustical line of sight for the example roadbed below grade is greater than the height H_1 for the example elevated roadbed.

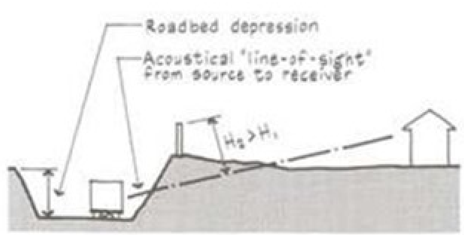


Fig.36.Outdoor Barriers

Noise barrier-it can be some objection, object which is protecting the propagation or preventing the propagation of sound from the source to the receiver. It does direct reflections, it also scatters the sound, it depends on the surface treatment and the edge finish there are something called edge diffraction's which will happen. Instead of the straight path part of it is get reflected, part of it gets of the barrier because of diffraction and some of it gets diffracted back. So, typically develop a something called shadow zone within which the barrier is effective. Shorter the barrier the shadow zone will be much lesser as the barrier height increases the shadow zone will be more.

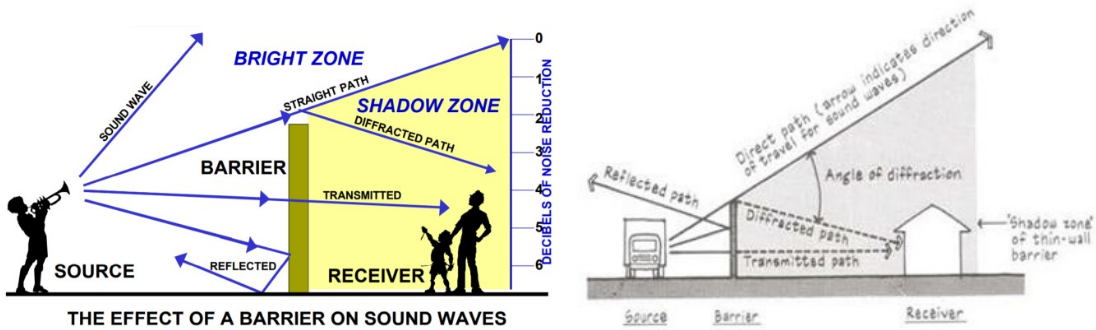


Fig.37.Noise Barriers

Shown above are the sound paths from source to receiver, interrupted by a thin-wall barrier. The arrows indicate the direction of travel for the direct, reflected, diffracted, and transmitted sound waves. The greater the angle of diffraction, the more effective the attenuation of the barrier.

<u>Checklist for Effective Use of Barriers</u>

1.Place barrier as close as possible to either the source of sound or receiver.

2.The greater the height of the barrier above the direct path from source to receiver, called the acoustical line of sight, the greater the attenuation.

3. Barrier should be solid (> 4 lb/ft2 density) and airtight. However, the TL of the construction materials used need not exceed the attenuation from diffraction effects over and around the barrier. Example barrier materials are: 1 1/2-in-thick fir, 1 1/4-in-thick plywood, 4-in-thick concrete panels or concrete block.

4. Treat barriers that face each other (e.g., deep road cuts) with sound-absorbing materials, or tilt the barriers. For example, vertical sound-reflective barriers on opposite sides of a road can be greater than 10 dB more effective when treated with sound-absorbing materials.

- As the distance of the source increases or the distance of the receiver increases the effectiveness of barrier considerably varies.
- For the effectiveness of barrier, we will know about that it depends strongly on the frequency. If you have a high frequency sound emitted from this point it gets reflected or scattered away, whereas low frequency sound which has high wave length; and high frequency sounds have a low wave length (inversely proportion). Low frequency sounds get diffracted and then they get back to this. So, typically environmental noise barriers are much effective and made on high frequency range, but if you have to make it effective for low frequency you need a special treatment or special design of barriers in order to curtail low frequency sounds.

A self-protecting building

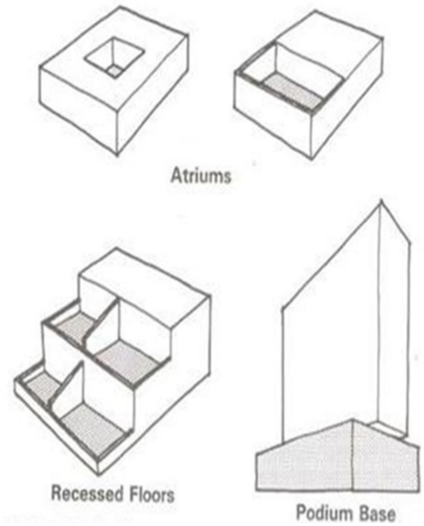


Fig.38.Self –Protective Built forms

A self-protecting building has external elements which act as barrier screens by interrupting the acoustical line of sight to nearby noise sources. This feature can protect acoustically weaker elements such as windows and doors. Examples of self-protecting atriums, recessed floors, and podium bases are shown below. Be careful when designing wide podium bases because they can restrict access to upper floors for fire-fighting and rescue operations.

Balconies and Overhangs

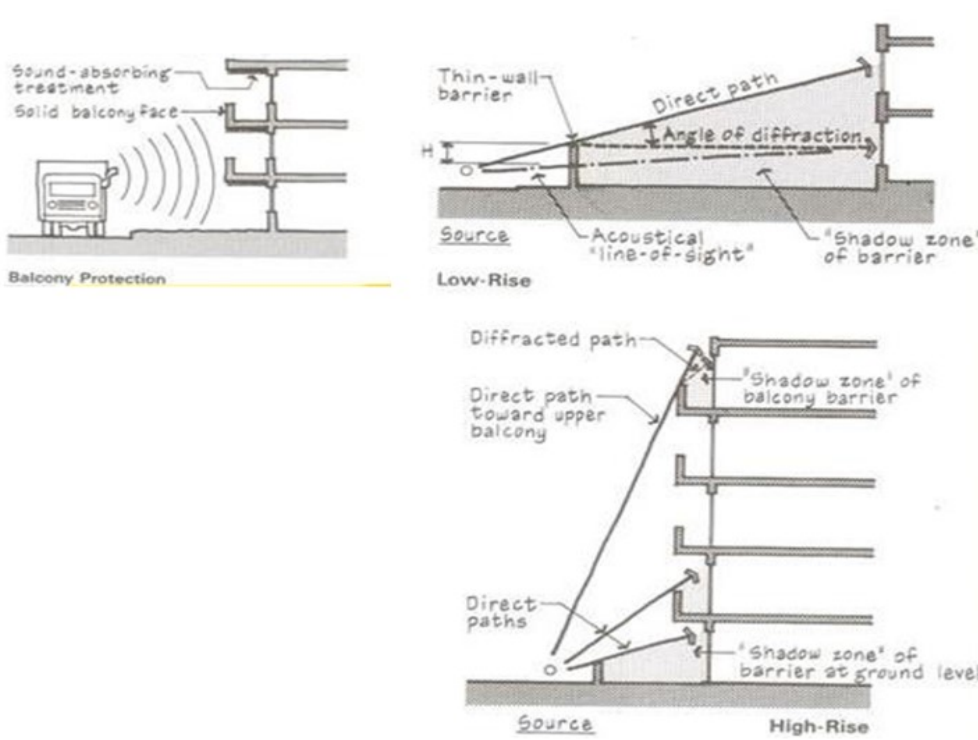


Fig.39.Balconies and over hangs

Balconies and Overhangs Balconies and overhangs can be used to isolate buildings from surface transportation noise. Isolation can be improved if the underside of the overhang is treated with sound-absorbing material. Balconies with solid railings should be used in front of windows. Open railings should be closed with weather-treated 112-in-thick plywood, 1/8-in-thick moulded polycarbonate, or glass. Solid balconies and overhangs with sound-absorbing treatment can reduce noise transmitted to interiors by 5 to 10 dB.

Openings for ventilation should be in the shadow zone as close to the floor as possible. Barriers near the noise sources also can be effective for low-rise buildings.

Orientation of Buildings:

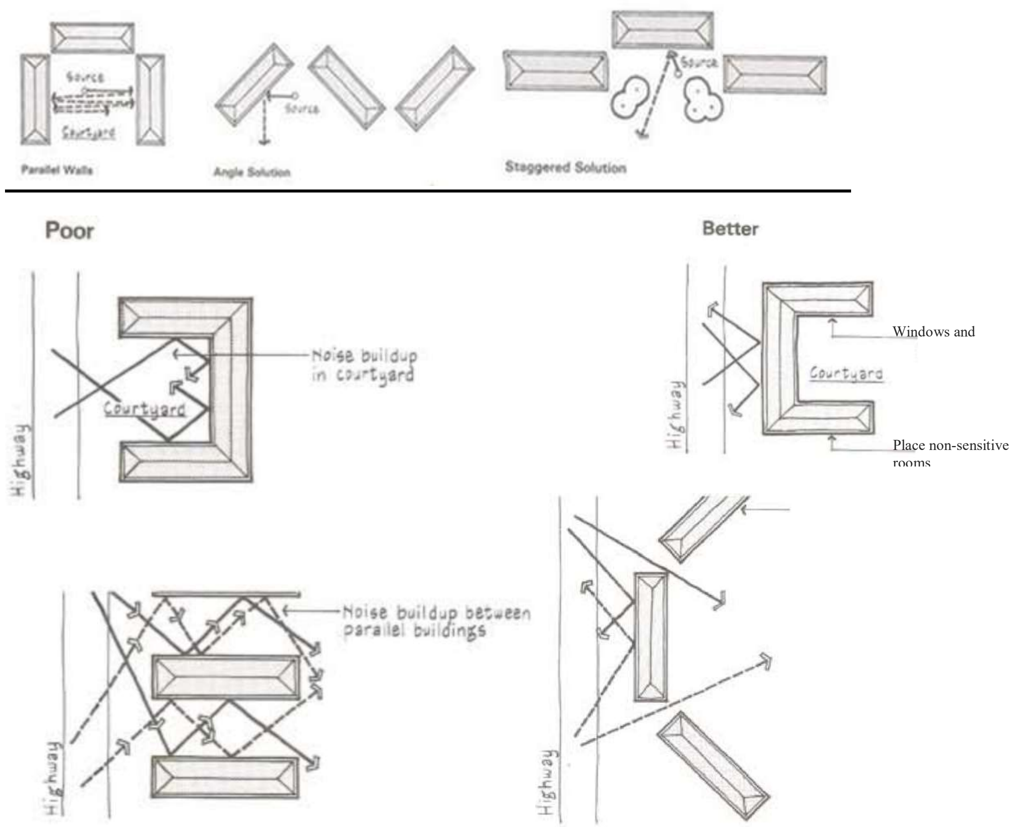


Fig.40. Orientation of Buildings

Courtyards can be sources of considerable noise. The buildings shown above have a central courtyard enclosed by parallel walls. The hard-surfaced parallel walls cause flutter echoes which intensify the noise in the courtyard. By angling or staggering the buildings, noise build-up can be reduced.

Courtyards directly facing streets can confine vehicular noise between reflective surfaces, causing build-up of sound energy. The preferred orientations, locate courtyards so they will be shielded by facing away from traffic noise. Sound levels at the sides of the buildings can be 3 dB lower than at the front; sound levels at the rear can be 10 dB or lower. Consequently, openings and sensitive areas should be located on sides which will be shielded from noise sources.

Earth Berms:

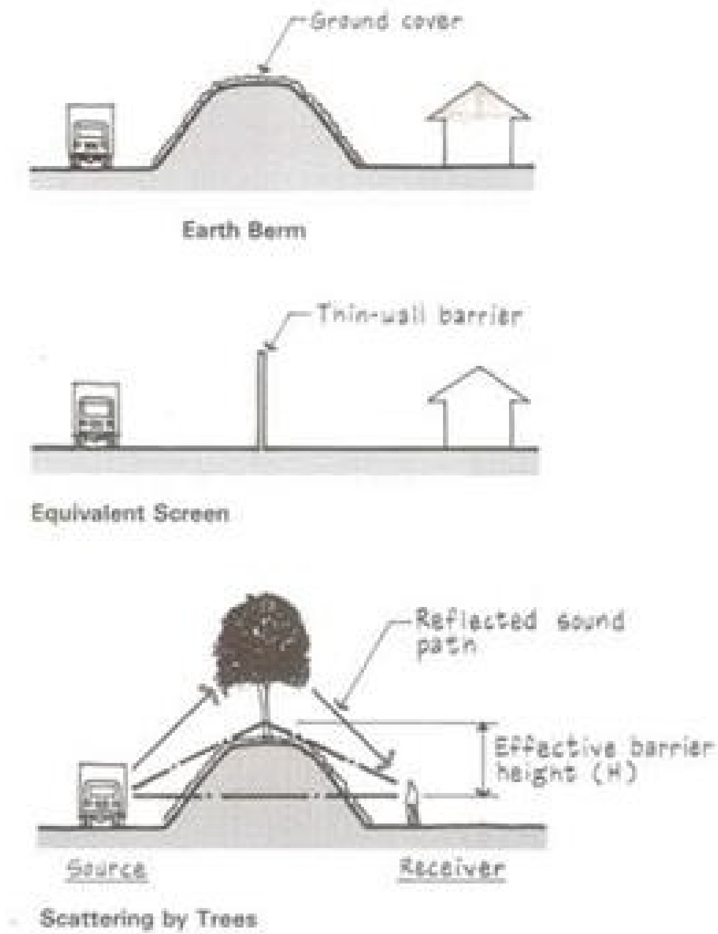


Fig.40.Earth berms

Earth berms, completely covered by grass or other sound-absorbing plant material, can be effective isolators, reducing noise by 5 to 10 dBA. They can be as effective as reflective thin-wall barriers or lower berms which have thin-wall barriers along their tops.

The effectiveness of earth berms can be reduced by reflective top surfaces (e.g., asphalt or concrete bicycle paths and walkways) and deciduous trees, which can scatter sound energy, thus reducing attenuation by 5 dB or more at frequencies greater than 250 Hz (fir trees > 4000 Hz).

Attenuation from Vegetation:

Attenuation is a simple term which we use to find out how much the sound pressure levels are cut.

Poor Isolation

A single row of trees has no value as an acoustical barrier! Paradoxically, when a single row of trees is added to solve an existing noise problem, the situation may seem worse.

Preferred Isolation

Many rows of trees have some value as an acoustical barrier. However, the attenuation from dense plantings more than 100 ft deep will be limited by the flanking of sound energy over the top of the canopy of trees.

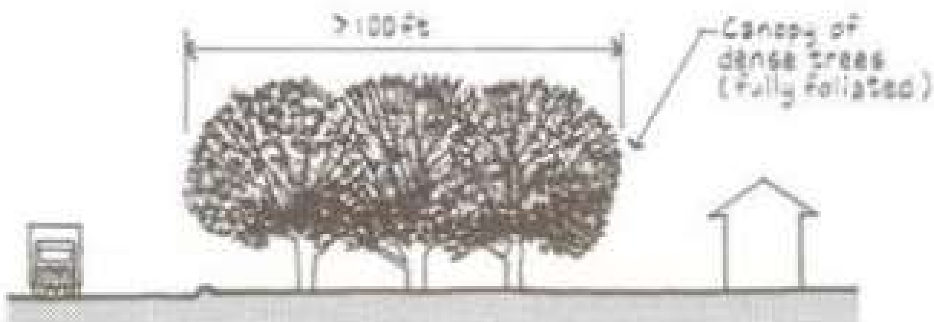


Fig.41.Attenuation from Vegetation

Temperature and Wind Effects

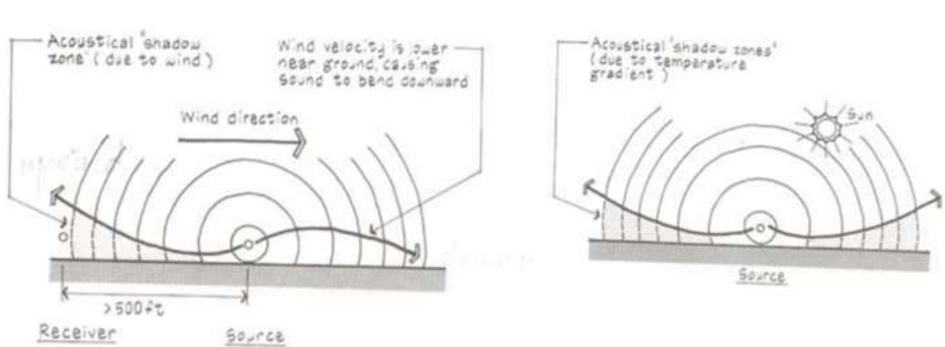


Fig.41.wind, Temperature effects

Downwind from the source, sound is normally bent toward the ground increasing its sound level.

Upwind, sound is bent upward causing a shadow zone where the sound level will be reduced.

For example, at distances greater than 500 ft, as shown above the upwind mid-frequency attenuation can be about 10 dB for winds of 10 mi/h.

On a clear, calm day the effect of temperature gradients (due to warmer air near the ground) can cause sound to bend upward as shown by the sketch above.

Environmental noise propagation varies with respect to the wind speed and the wind direction say if there is a point source here it is emitting, this is a windward side as it propagates against the wind it tends to bend up, as it propagates away from the wind it tends to bend down.
If you look at the old roman amphitheaters these principles where nicely applied the source versus the audience, the source versus the receivers, the windward and leeward sides were carefully considered because there were no amplification systems they considered carefully above the bending of sound across the wind.

Again it varies with the temperature differential between the ground and the atmosphere. So, as the temperature decreases for instance then the sound tends to go up as a temperature increases it tends to bend down.

Ground Interaction

Ground interaction; say for example sound propagating from source to receiver through a glossy surface or a say concrete surface or metal surface. Then there is a lot of reflected sound whereas if it is passing through grass or vegetation, then there will be a lot of diffraction and absorption will be happening.

INDOOR NOISE

Acoustic transmission in building design refers to a number of processes by which sound can betransferred from one part of a building to another. Typically, these are:

Airborne transmission - a noise source in one room sends air pressure waves which induce vibration toone side of a wall or element of structure setting it moving such that the other face of the wall vibrates in an adjacent room.
Structural isolation therefore becomes an important consideration in the acoustic design of buildings. Highly sensitive areas of buildings, for example recording studios, may be almost entirely isolated from the rest of a structure by constructing the studios as effective boxes supported by springs. Air tightness also becomes an important control technique. A tightly sealed door might have reasonable sound reduction properties, but if it is left open, only a few millimeters its effectiveness is reduced. The most important acoustic control method is adding mass into the structure, such as a heavy dividing wall, which will usually reduce airborne sound transmission better than a light one.

Flanking transmission - a more complex form of noise transmission, where the resultant vibrations froma noise source are transmitted to other rooms of the building usually by elements of structure within the building.

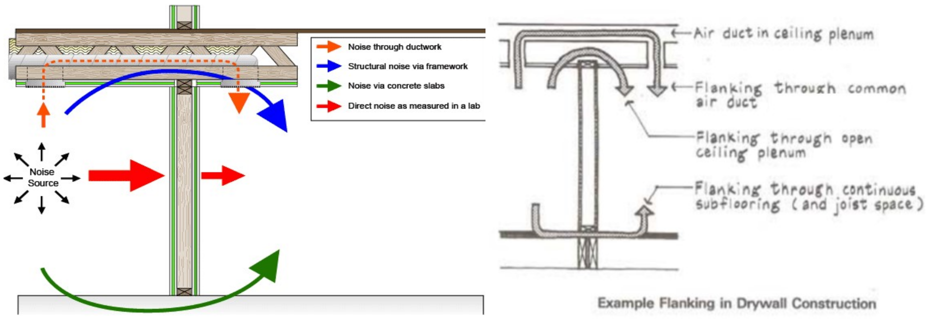


Fig.42.Flanking transmission

Sound energy can bypass constructions through indirect paths (called flanking).
Example flanking paths, which can seriously degrade the TL of common barriers, are: open ceiling plenums and attics, continuous side walls and floors, air duct and pipe penetrations, joist and crawl spaces, and many others.
Some of the potential flanking paths in wood frame gypsum wallboard constructions (called drywall) are shown by the section illustration below. To achieve the full sound isolation potential of common barriers, flanking paths must be prevented by careful design of all connections, penetrations, and adjacent framing systems.

Airborne Sound Insulation by Partition

Airborne sound can be transmitted in a receiving room via some or all of the paths (A) to (D) as shown in figure.Path (A) is called the **direct path**.
All transmission paths other than path (A) are together termed the **indirect** or **flanking transmission**.
This indirect transmission becomes increasingly important when the insulation requirement of the separating partition is about 35 dB upwards.

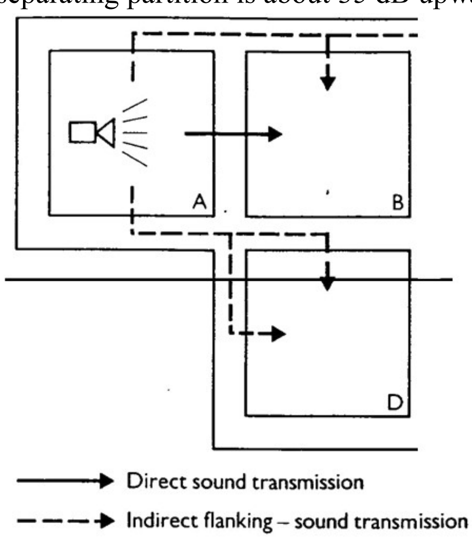


Fig.43.Paths of sound transmission between adjacent rooms

Impact transmission - a noise source in one room results from an impact of an object onto a separatingsurface, such as a floor and transmits the sound to an adjacent room. A typical example would be the sound of footsteps in a room being heard in a room below. Acoustic control measures usually include attempts to isolate the source of the impact, or cushioning it. For example, carpets will perform significantly better than hard floors.

Impact Sound Insulation: the insulation against noise originating directly on a structure by blows orvibration e.g. footsteps above, furniture being moved, drilling and hammering the structure.

impact noises are erratic and can be caused by walking (hard heel footfall), rolling carts, dropped objects, shuffled furniture, slammed doors, and the like.

Impacts on floors, are radiated directly downward. They also can be transmitted horizontally through the structure and be reradiated at distant locations.

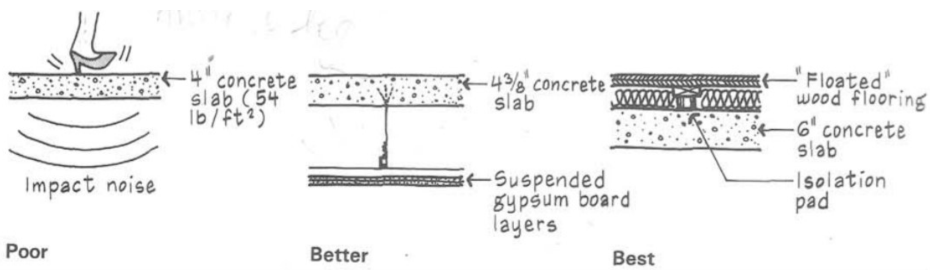
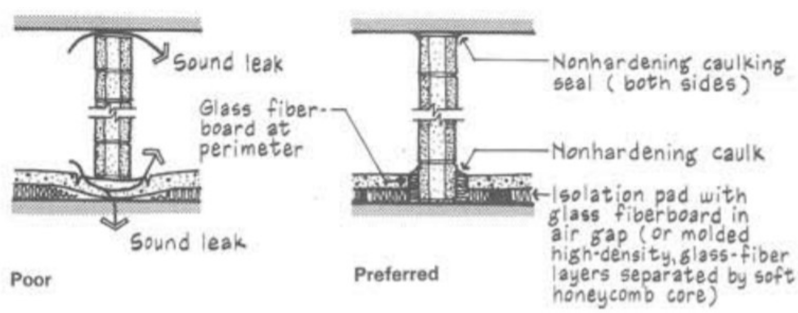


Fig.44.Impact noise isolation

<u>Floated Floors</u>



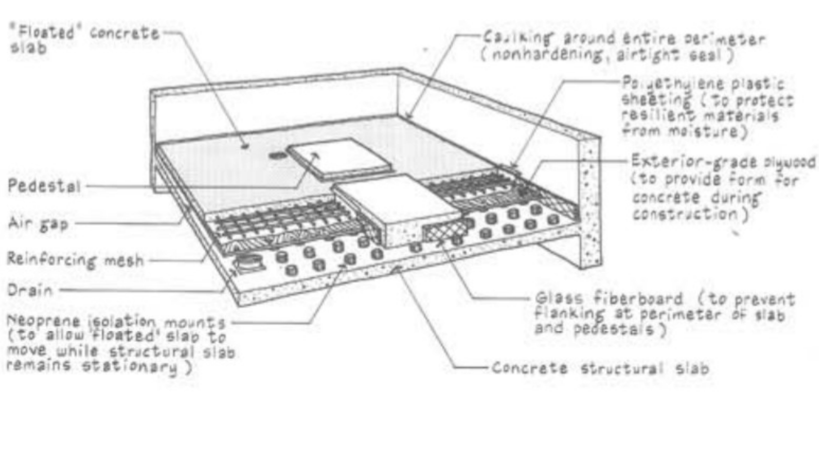


Fig.45.Floated floors

Shown are details of an example floated floor. Floated floors are complicated constructions requiring careful design, specification, and supervision during installation. Basic concrete floated-floor systems consist of recompressed glass-fiber or neoprene isolation pads installed under plywood forms with a moisture barrier completely covering the forms.

Where wood forms are not desired or permitted due to fire safety codes, lift slab systems can be used. In these systems, steel-reinforcing mesh is placed on the isolators and, after the concrete slab has cured, the slab is raised to its final height by jackscrews at the isolator pads (or springs). Polyethylene moisture barriers, covering the entire structural slab and perimeter of the floated slab, are used to help break the bond between concrete layers during lifting operations.

<u>Floor Ceiling Construction ForImpact Isolation</u>

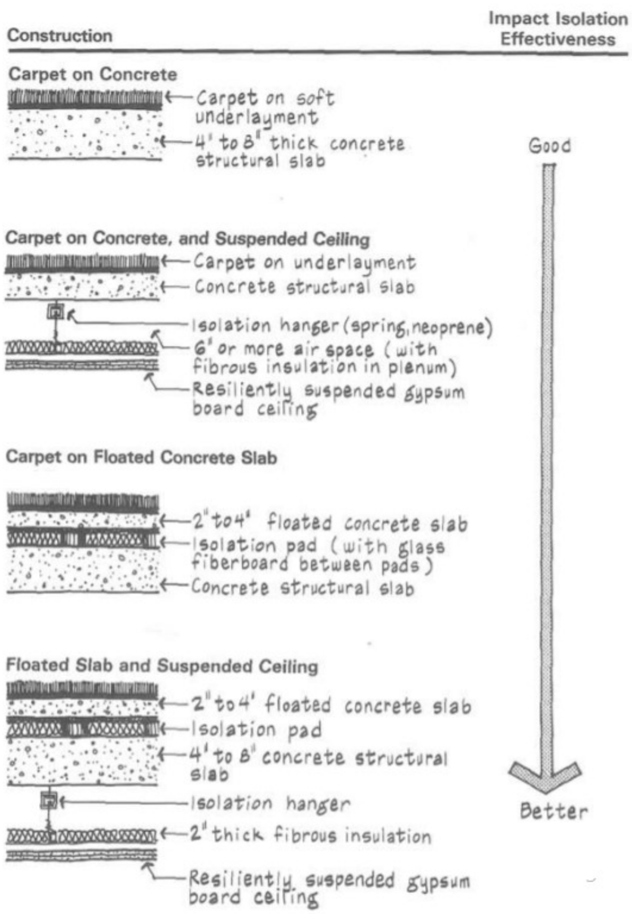


Fig.46.Impact isolation effectiveness

Carpeting and resilient rubber floor tiles can be used to cushion impacts. They are most effective as isolators of mid- and high-frequency impact noises such as 'clicks' from footsteps. However, low-frequency 'thuds" from things being dropped still may be transmitted through constructions having these surfaces. Elaborate constructions, such as concrete slabs with suspended ceilings and floated floors, may be required to achieve high values of impact isolation over the entire frequency range.

Floor -Ceiling Constructions

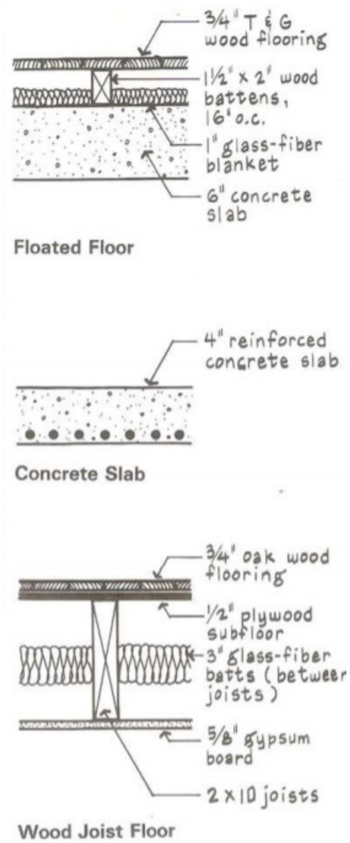


Fig.47. Floor -Ceiling Constructions

To prevent 'squeaking' floors in wood joist constructions, be sure nails are the proper size and properly spaced, install building paper or felt layer between subfloor and finished floor, and use only seasoned wood.

To block flanking through joist spaces, install joists parallel to party walls. In addition, cut subflooring at wall (> 1/4-in gap) to interrupt flanking path for airborne sound and vibrations. Flanking of sound energy through continuous wood frame floor constructions limits common wall STC to 40; through continuous 6-in concrete slabs to 50.

Plenum Barriers

Gypsum board, lead sheet, and mineral fiber can be used as vertical barriers to prevent flanking through ceiling plenums.

As shown below, these barriers can close off plenums by extending from the top of partitions to the overhead structural slab.

As also shown, mineral fiber can be overlaid horizontally above suspended sound-absorbing ceilings, extending 4 ft or more on both sides of the wall-ceiling intersection.

When installed this way, mineral-fiber blankets (>2.5 lb/ft3 density) can significantly reduce the transmission of flanking sound through exposed-grid panel ceilings. Ceiling-attenuation ratings can be increased more than 5.

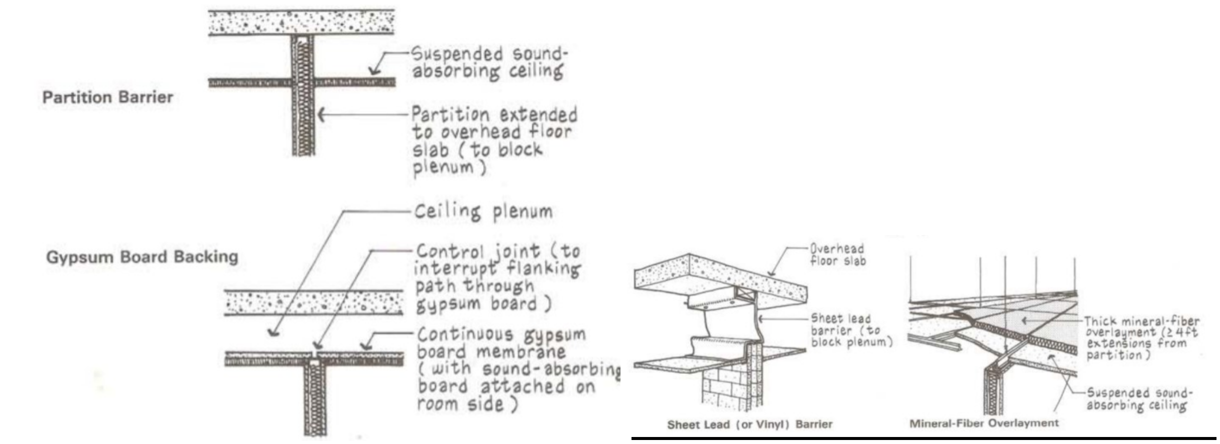


Fig.48.Plenum Barriers

Isolation by complex walls

In the example constructions shown below, the TL performance of an 8-in-thick brick wall is increased by breaking the direct sound transmission path. Isolation can be significantly improved by dividing the wall into two separate walls of equal weight (two 4-in-thick brick layers separated by a 4-in airspace) or by resiliently supporting a 1 / 2-in-thick gypsum board layer with vertical furring attached to the original 8-in-thick wall.

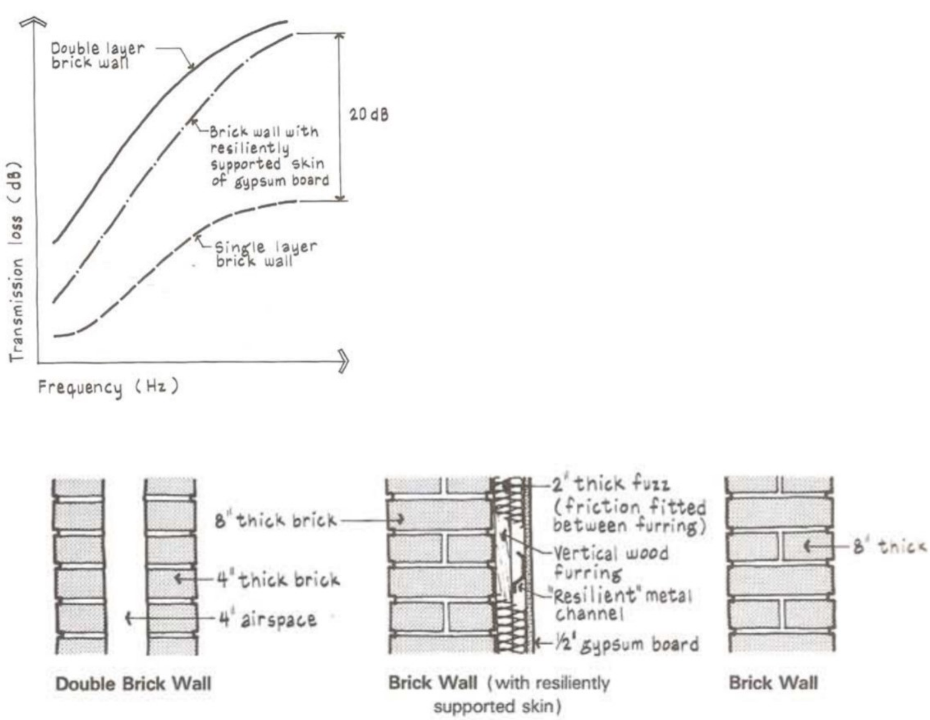


Fig.49.Isolation by complex walls

Checklist for Achieving High TL with Masonry Constructions

1. Set blocks in firm bed of mortar and be sure all joints are tightly filled and not porous.
2. Use heavy block or medium-weight block with sand- or mortar-filled cells.
3. For single walls, seal airtight at least one side with plaster, gypsum board supported by furring, three coats of latex block filler, or a thick application of epoxy paint.
4. To improve single walls, add a gypsum board layer resiliently supported, with low-density glass fiber or mineral fiber in the airspace (> 2 in wide) between the block and the gypsum board, or install a resilient layer without fibrous insulation on the unsealed side of the wall. (Be careful because TL at low frequencies can be reduced by resonance effects of gypsum board layers when they are installed on both sides of a wall without sound-absorbing material in the cavity airspaces.)
5. Where especially high TLs are needed, avoid stiff wire ties, which can reduce TL of double-wall constructions by more than 7 dB.

Sound Insulation

It is important to avoid confusion between **sound absorption** and **sound insulation**.

(a) Sound absorption is **the prevention of reflection of sound**or alternatively, a reduction in the sound energy reflected by the surfaces of a room.

(a) Sound insulation is **the prevention of transmission of sound**or alternatively, a reduction of sound energy transmitted into an adjoining air space.

Transmission loss

Sound Transmission Class (or STC) is a number rating of how well a building partition (such as ceilings, floors, doors, windows, exterior wall etc) attenuates airborne sound.
According to the mass law for homogeneous building materials, such as glass, wood, and concrete, the TL and sound transmission class rating (abbreviated STC) increase by about 5 for each doubling of surface weight (in pounds per square foot). STC is a single-number rating of TL performance for a construction element tested over a standard frequency range. The higher the STC, the more efficient the construction is for reducing sound transmission.
STC data for a variety of building constructions listed below have considerable scatter about the theoretical mass law curve. Nevertheless, the trend clearly indicates that heavier materials provide better sound isolation. This is the fundamental principle of sound isolation for architectural acoustics.
The TL of a wall can be increased by separating the wall layers with an airspace to form a double-wall construction.
For the wood stud constructions shown below, TL increases as the width of the cavity airspace increases.
Further increases in TL can occur if sound-absorbing material is added to the airspace because absorption reduces the build-up of sound in the airspace.
The double-stud construction breaks the direct sound transmission path through the studs from layer to opposite layer because there are two independent framing systems separated by 1 in or more. This construction technique widely separates both sides of the wail, so the full benefit of the cavity absorption can be achieved.

Fundamentals of Sound Isolation

With no isolation, the doorbell produces 70 dB at a few inches away.
When the doorbell is surrounded by a 3/4-in-thick enclosure of low-density, porous glass fiberboard (called fuzz), the transmitted noise is reduced by only 3 dB.
Porous sound absorbers are very poor isolators because air molecules can readily pass through them. They absorb sound but do not prevent its transmission.
When the doorbell is surrounded by a 1/2-in-thick plywood enclosure with an airtight seal around its edges, the noise is reduced by 28 dB (from 78 dB within the enclosure to 50 dB outside). This is a tremendous change in noise level and would be perceived by most observers as about one-fourth as loud. The plywood enclosure is an effective barrier because it is solid, has sufficient mass, and is sealed airtight around the edges. The seal is essential because even a very small opening can noticeably increase the transmitted sound.
When the doorbell is surrounded by a 1/2-in-thick plywood enclosure fully lined with 3/4-in-thick fuzz, the noise is reduced by 29 dB. However, the noise outside is further reduced to 43 dB because the sound-absorbing lining reduces the buildup of reflected sound energy within the enclosure by 6 dB.

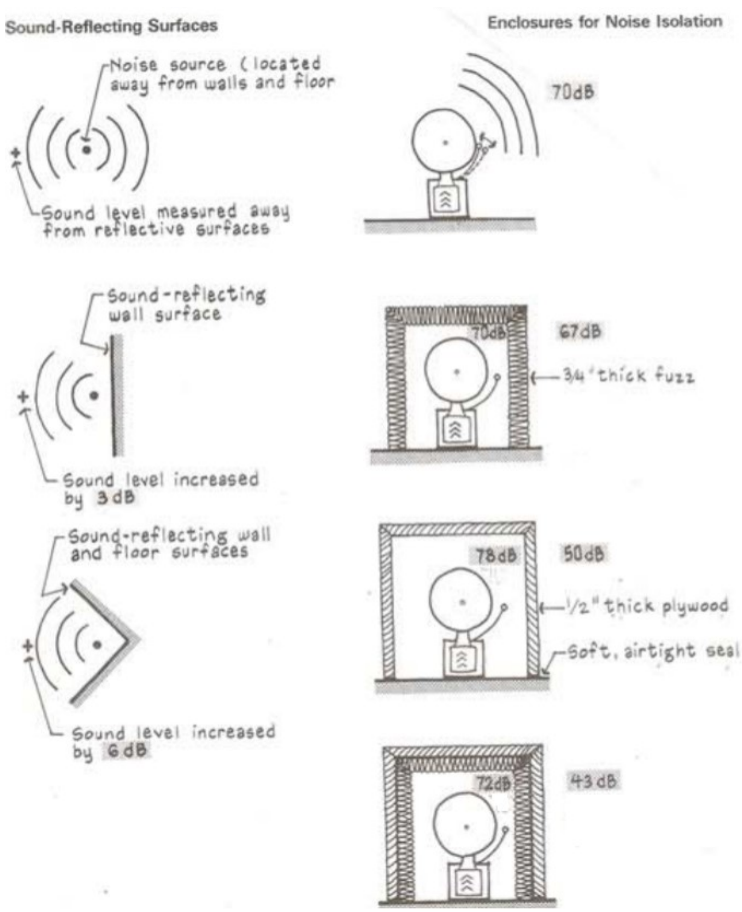


Fig.50.Sound Isolation

Vibration of Building Elements

Sound waves impinging on building elements, such as walls, floor, or ceiling, produce back-and-forth motion. The magnitude of this motion or vibration depends on the weight (or mass) of the building element the greater the weight, the greater the resistance to motion and the less sound energy transmitted.

Sound Leaks

Sound leaks, like water leaks, must be prevented because sound will travel through any size opening with little loss.

For sound, the more effective a solid construction is as a sound isolator, the more serious the sound leak.

Consequently, when sound isolation is required, always seal cracks and open joints in partitions, avoid back-to-back electrical outlets, and eliminate all other potential sound leaks.

The example partition shown at the right has sound leaks along both the head and floor tracks. By caulking the perimeter of the gypsum board base layer on both sides, the TL can be increased by more than 20 dB.

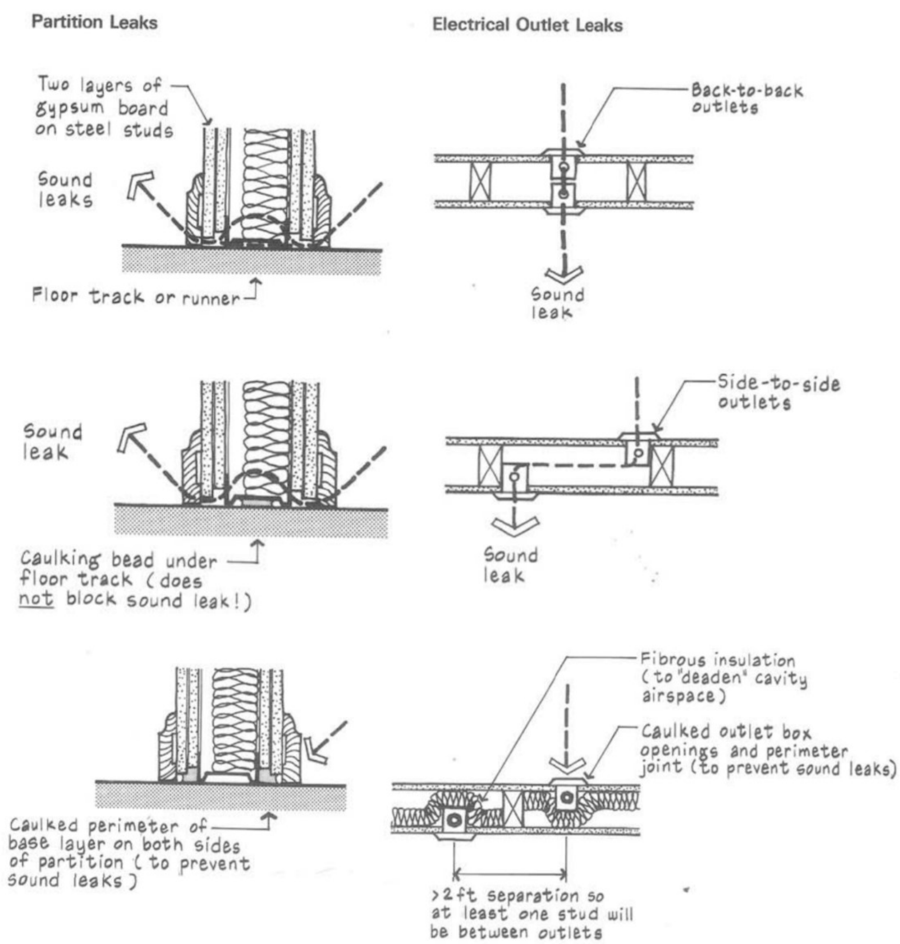
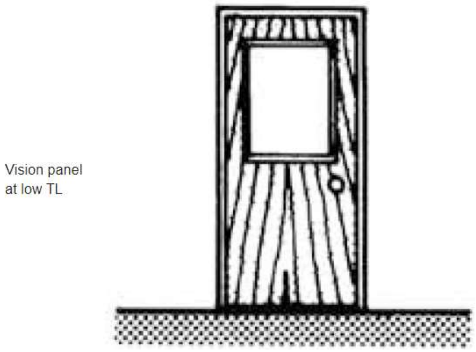
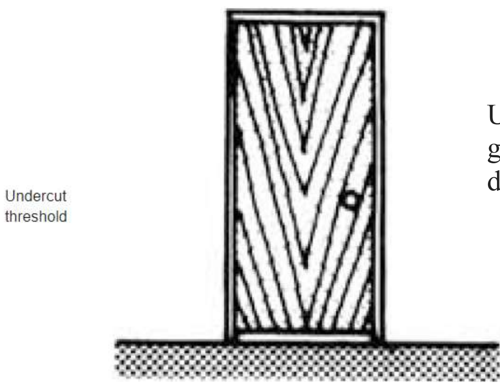


Fig.51.Sound leaks

Example leaks in doors and corrective measures are presented below. When doors must provide high sound isolation, use solid-core wood (or fiber-filled hollow metal) doors which are gasketed around their entire perimeters in order to be airtight when closed, or use proprietary "acoustical" doors, which come from manufacturer complete with gasketing and stops.



Use at least 1/4-in-thick glass, laminated glass, or two separate panes of glass.



Use threshold gasket or effective drop seal

Fig.52.Sound Leaks-Corrective measures

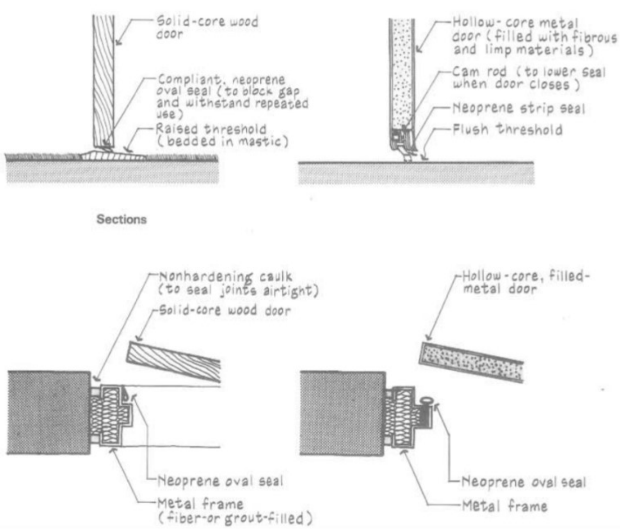


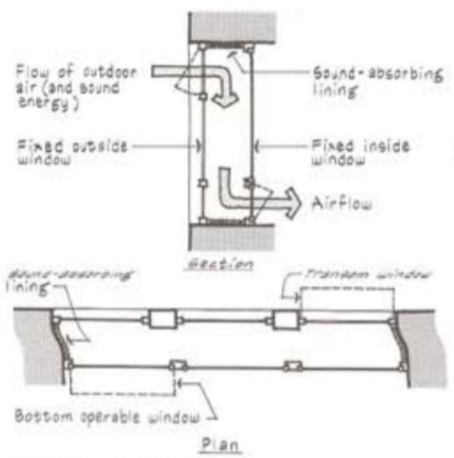
Fig.53.Doors

Doors

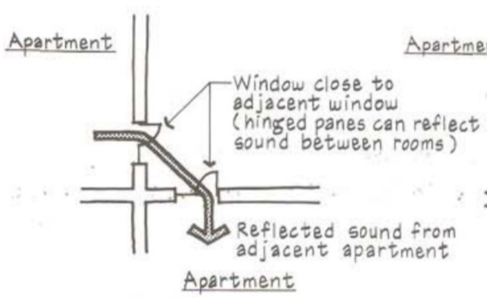
To be effective as a sound barrier, a door must be heavy (high lb/ft2) and gasketed around its entire perimeter to be airtight when closed.
Slightly greater than normal pressure will be required to close the door against soft, airtight seals.
Doors that are louvered or undercut to allow air movement will be nearly useless as sound barriers.
Gasketed hollow metal doors filled with fibrous materials and dense limp materials, such as sheet lead or lead-loaded vinyl, have higher STC performance than gasketed solid wood doors of identical weight.

Operable Windows

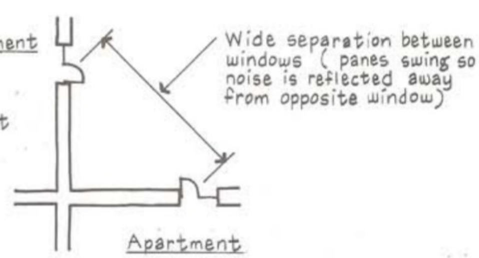
The noise reduction can be significantly increased if double-window combinations with offset openings are used. Shown is a double-window design having an operable external transom and an operable inner bottom pane. When closed, the TL is comparable to that of a conventional double window, if airtight seals can be achieved.



Ventilation Window



Poor Window Layout



Preferred Window Layout

Single Pane

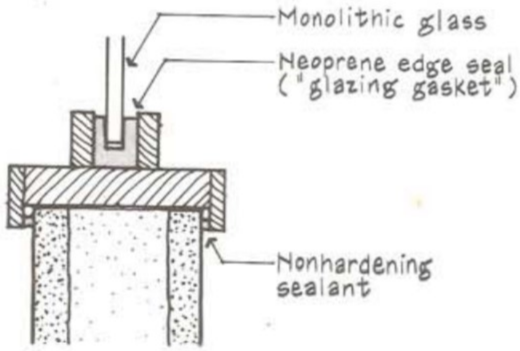


Fig.54.Windows

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

UNIT – 3 - BUILDING SERVICES III– SAR 1302

DESIGN OF PERFORMING SPACES

Design of auditoriums

The auditorium, as a place for listening developed from the classical open-air theatres.

An auditorium is a room built to enable an audience to

- Hear and
- Watch performances.

Key Factors for Auditorium Acoustics

1. Location.
2. Buffer Zones around Auditorium.
3. Doorway STC.
4. Reverberation Analysis for Auditoriums.
5. Auditorium Background Noise.
6. Balcony Design.
7. Sound Systems for Auditoriums.
8. Orchestra Pits.

1. Location

For new auditoriums, the building should be planned as far away as possible from any potential noise sources such as highways, train tracks or industrial areas. Airport noise may also be particularly problematic in some locations. If this is the case, perform an Auditorium Sound Study prior to construction to ensure an adequate OITC is specified to prevent disruption inside the space.

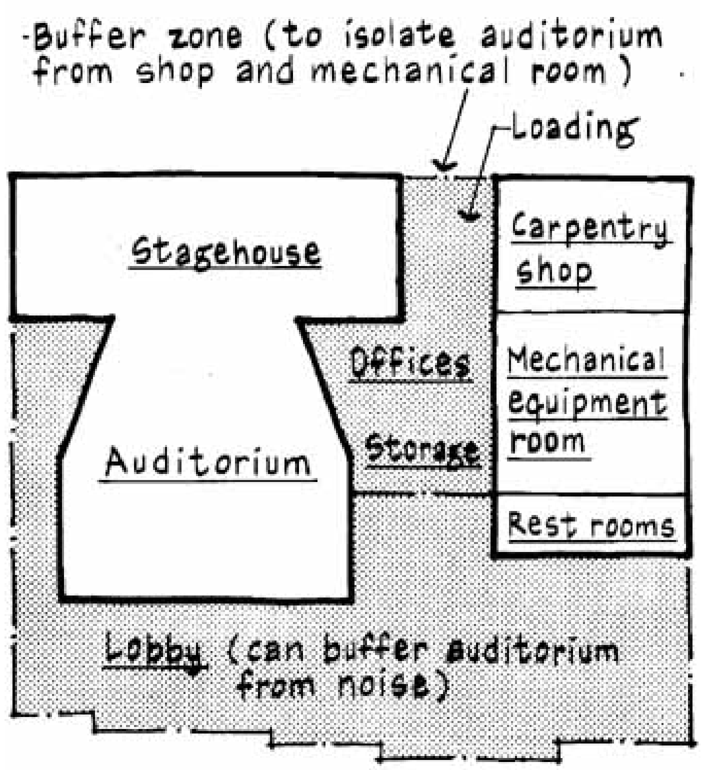

What do you mean by OITC?

Outdoor/Indoor Transmission Class (OITC) is a number rating of the sound transmission loss of a constructed assembly tested with lower frequencies to represent sound typical of modes of transportation. OITC is of relevance to designers interested in how effectively their design will shield occupants from sound generated exterior to the structure.

2. Buffer Zones around Auditorium

Isolate the auditorium from the rest of the building and potential noise sources by creating buffer zones.

Hallways and lobbies should separate the main auditorium from restrooms, mechanical equipment, dressing rooms etc. Surrounding space should be used for storage or offices that will be empty while the auditorium is in use.

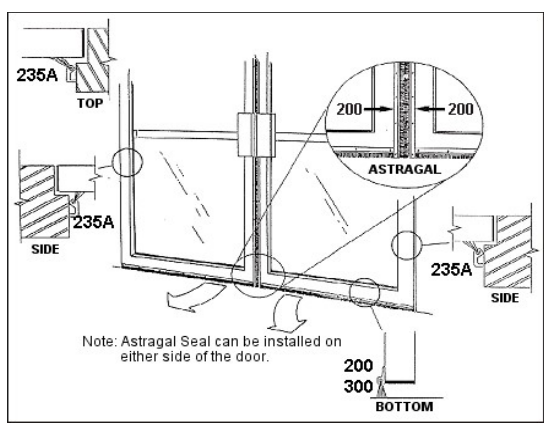


3. Doorway STC

All doors should be solid-core, with airtight seals to inhibit outside noise from slipping in. Select STC-rated doors if the performance space is critical. While apartment doors may only require STC 32, we suggest STC performance in the 35-40 range. If double doors are used, ensure that an Astragal is installed in the center, and sufficient rubber gasketing is used to prevent flanking.

Sound Transmission Class

STC stands for Sound Transmission Class, which is the measurement used to calculate the effectiveness of soundproofing materials in reducing sound transmission between rooms.



4. Reverberation Analysis for Auditoriums

To combat reverb in a large room:

1. Build with sound absorbing material and include sunken panels, undulations and other small irregularities in the walls.
2. Consider specialty treatments, such as stretched fabric wall systems, custom-designed and installed for auditorium spaces.
3. Sound reflecting materials should be used for the bulk of the building process (thick wood, thick gypsum, concrete).
4. Hang thick, fabric curtains along walls to minimize hard surfaces.
5. All aisles should be carpeted to reduce foot-traffic noise.
6. Always use fabric seating. Avoid metal and plastic.
7. Create a checkerboard pattern alternating between sound reflecting and sound absorbing materials along the ceiling.

NOTE: A basic acoustic analysis simply uses the room geometry and acoustic absorption coefficients to determine the expected reverberation time in the space. See a simple example below.

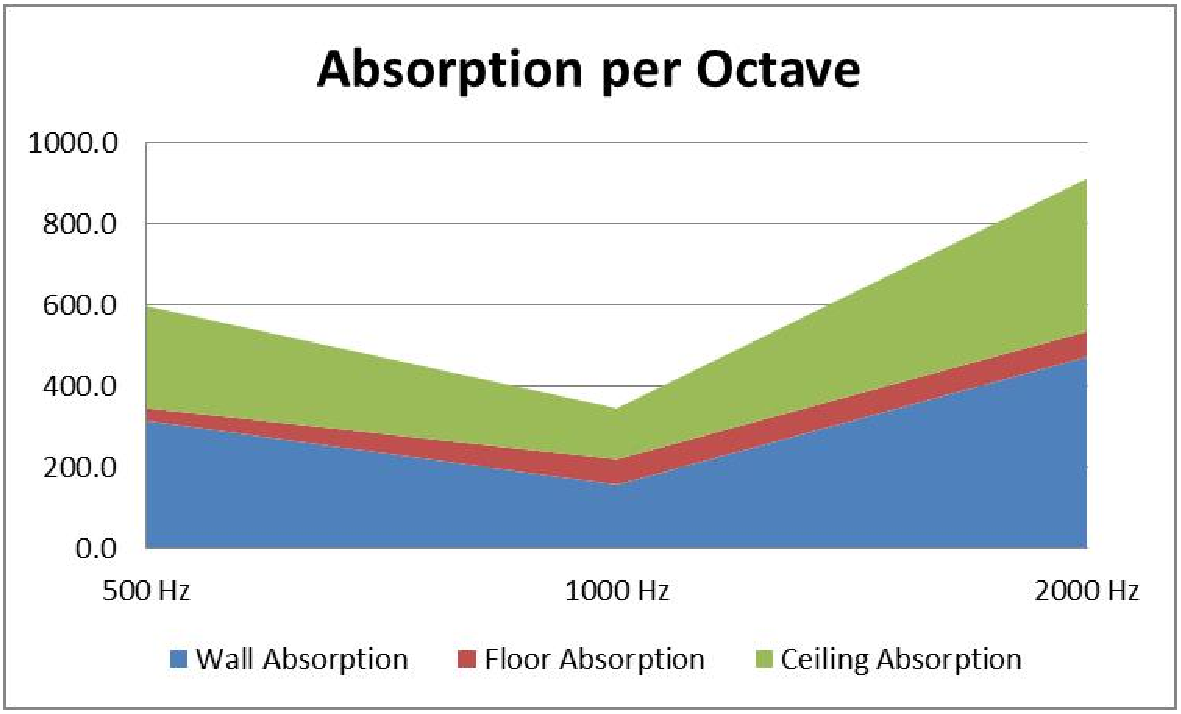
Room	Lobby

Primary Room Geometries	
Length (ft)	29
Width (ft)	10
Height (ft)	15
Volume (ft^3)	4350

Surface	Material	Coefficient of Absorption	Area	Sa
Wall 1	Drywall	0.15	435.00	65
Wall 2	Drywall	0.15	435.00	65
Walls 3 & 4	Drywall	0.15	300.00	45
Floor	Tile	0.2	290.00	58
Ceiling	Drywall	0.15	290.00	44
			Baseline Sabins	277

Sabins Calculations	
RT60=.05*V/Sa	
Estimated RT60	0.79

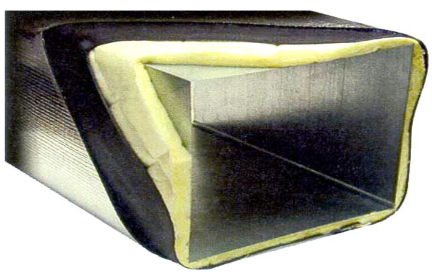
A more advanced analysis requires looking at specific frequency bands, often broken down into the 1/3rd octave bands. This is often required for auditoriums and other performance venues that may have more specific requirements.



5. Auditorium Background Noise

Install sound absorbing duct liners and mufflers to reduce HVAC noise. HVAC design shall ensure that the NC (Noise Criteria) level is at or below NC-35. Critical spaces may require an NC level of 40.

NOTE: NC levels can be compared to similar dBA levels, if that is a preferred system for your acoustic consultant or mechanical designer.



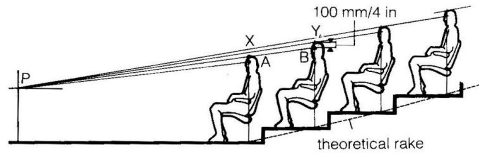
6. Balcony Design

Balconies should be included where possible to reduce the distance between the farthest seats and the stage. The overhang should be of small depth and be fitted with sound absorbing material.

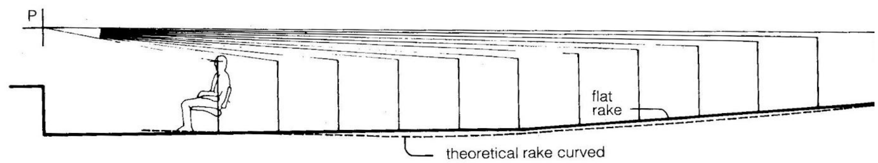
7. Sound Systems for Auditoriums

Speakers should be placed just above and in front of the proscenium opening or arch. The controls for these speakers should be positioned in a central location of the seating area rather than in a separate room in the back of the auditorium.

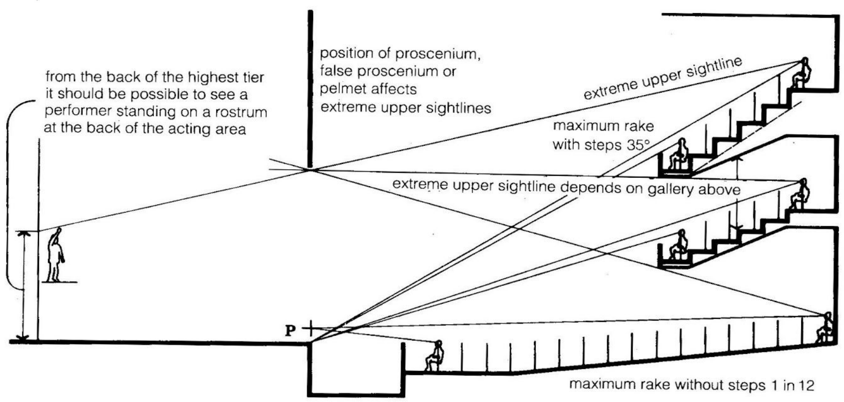
3:2. Method of calculating sightline with low P



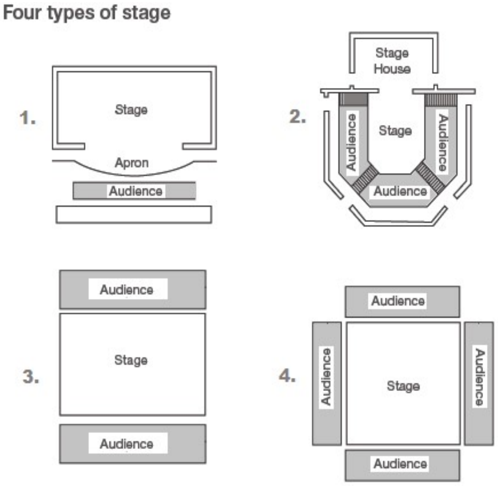
3:3. Theoretical rake curved. Maximum gradient of aisles without steps 1 in 12

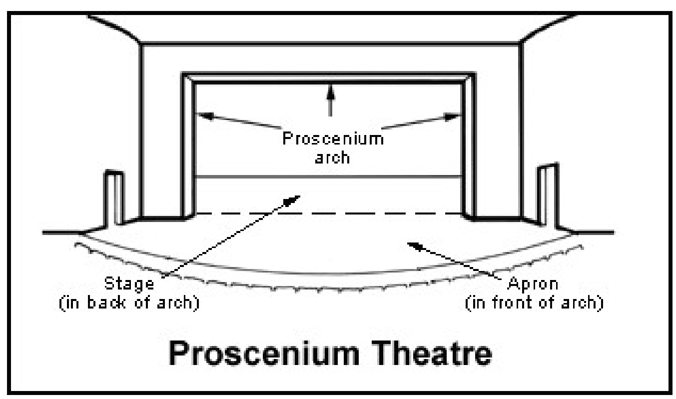


3:4. Vertical sightlines



Four types of stage

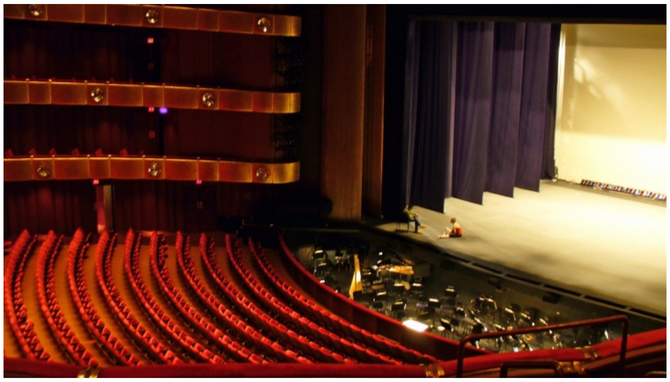


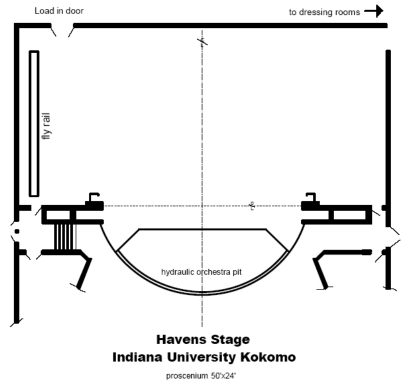


8. Orchestra Pits

If the auditorium has an orchestra pit, soundproof curtains should be installed that can be opened and closed as the conductor chooses to control the noise level.

General auditoriums play host to a wide range of performances and events which will have no chance of success if audiences aren't able to hear them. Consider this list the next time you're working on a general auditorium to create the ideal acoustics.





Auditorium Acoustics

The design of various types of auditoriums has become a complex problem, because in addition to its

1. Various strategies,
2. Sometimes conflicting,
3. Aesthetics,
4. Functional,
5. Technical,
6. Artistic and
7. Economical requirements

An auditorium often has to accommodate an unprecedentedly large audience.

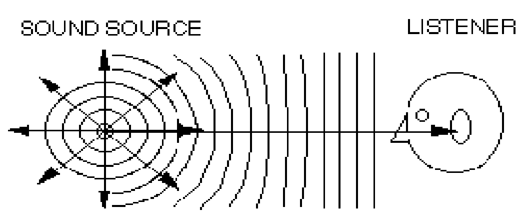
Auditorium acoustics:

There are two criteria's to be considered while designing Auditoriums.

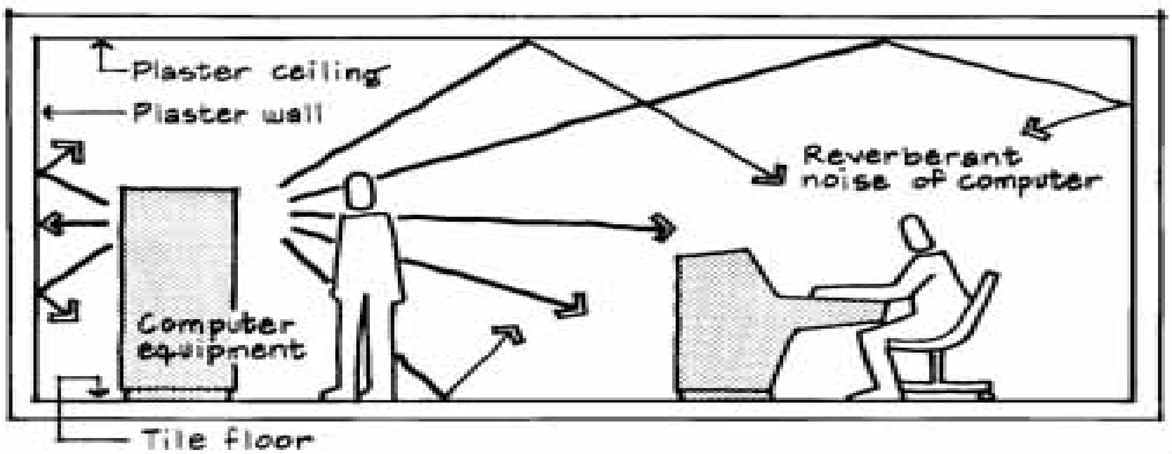
1. The acoustics factors which affect the functioning of the Auditoriums
2. The basic dimensions for audience comfort with respect to the acoustics.

<u>Behavior of sound & its effects:</u>

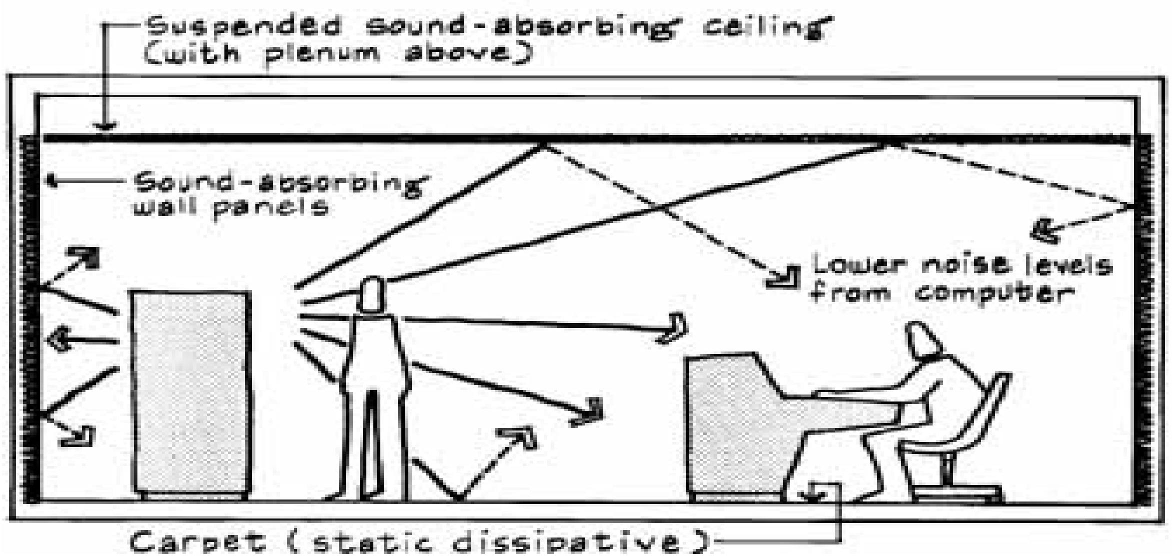
- The behavior of sound plays an important role in acoustical design of buildings and in sound insulation.
- When a sound originates from any source either a speech or music, it is transmitted from the source in all directions.
- The sound continues to travel till it strikes on a surface such as floor, wall, ceiling or any other barrier from where a part of it is reflected back, a part being diffused, another part being absorbed by the surface where it dies out in the material or transmitted to the other side of the barrier.



Room with No Acoustical Treatment



Room with Sound-Absorbing Treatment



Room with no Acoustical treatment results in the following Acoustical Defects:

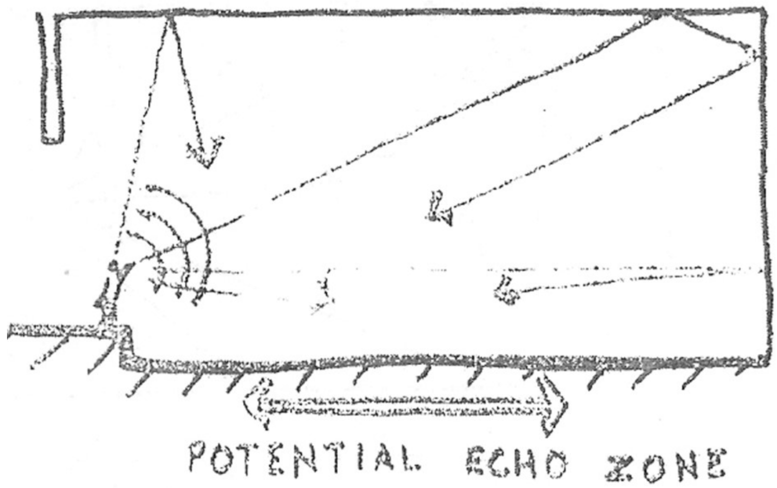
1. Echo
2. Reverberation
3. Sound Foci & dead spots
4. Insufficient Sound Volume
5. High background noise

ECHO:

When the difference in the arrival time of the direct sound and the reflected sound from the same source is more than 60 milliseconds, we hear the sound as two distinct sounds. Echo is a long delayed reflection

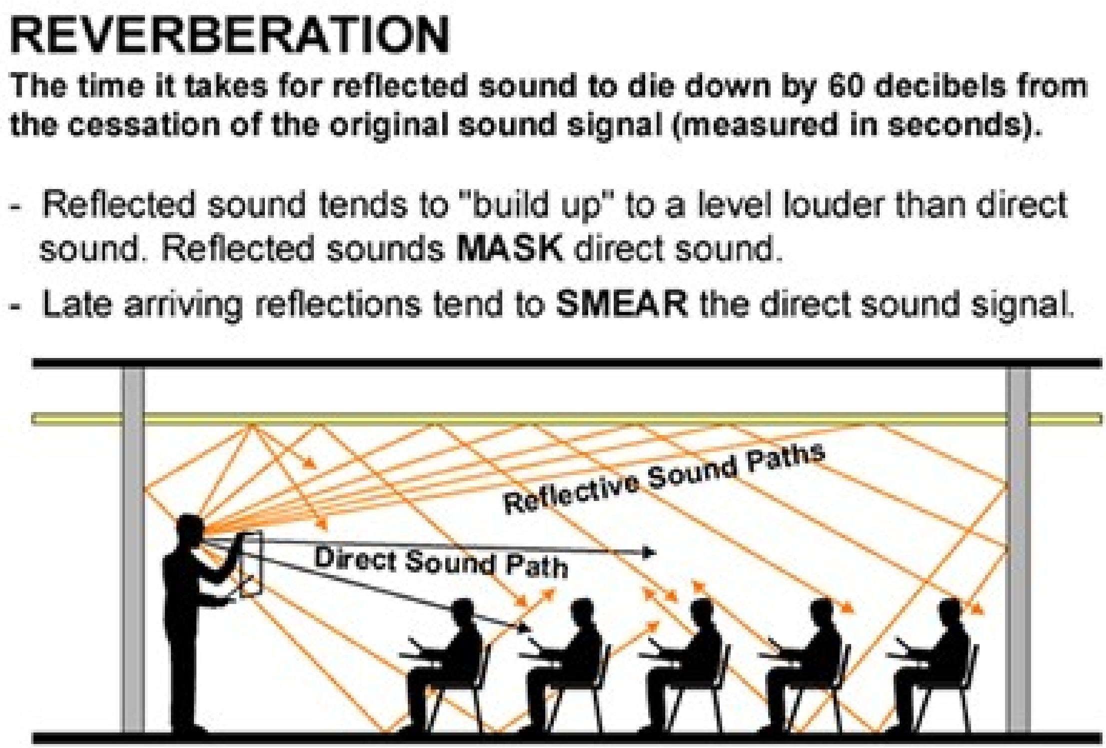
When a sound becomes trapped in repetitive pattern in between parallel surfaces is called

"Flutter Echo"



REVERBERATION:

The sound from the source does not die immediately.



This prolongation of sound even after the sound from the surface is stopped Reverberation.

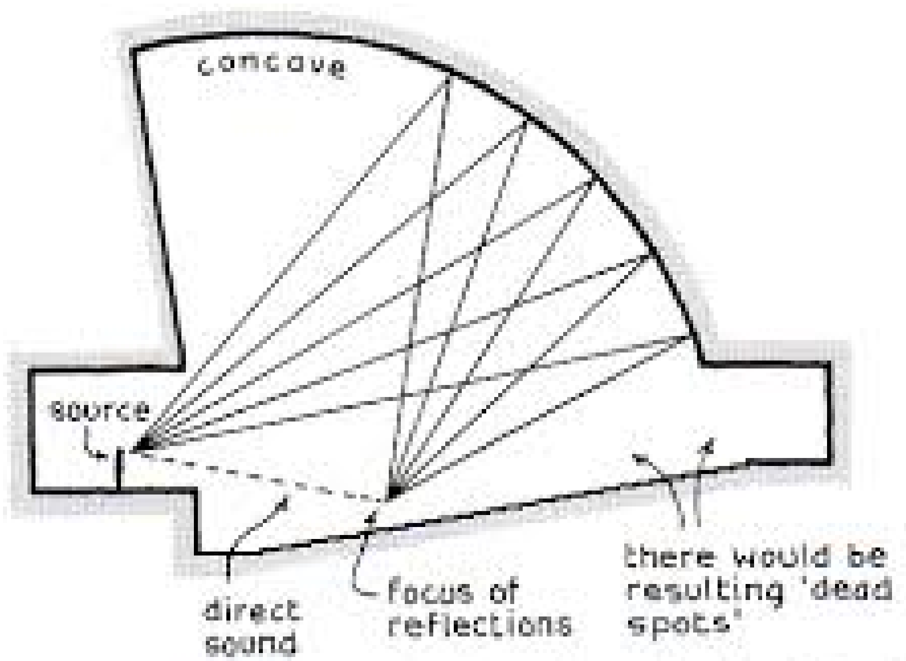
SOUND FOCI &DEAD SPOTS:

In case of concave shaped reflecting surfaces or domed ceilings, there is a possibility for reflected sound rays to meet at a point called Sound focus.

These spots of unusual loudness or intensity is known as “Sound Foci”

Dead spot is a defect which is a side effect of sound foci.

The spots of low intensity causing unsatisfactory hearing for the audience are called “Dead spots”



6.8 Concave ceiling causing discernible echo and preferential foci – any resemblance to an existing opera house is, of course, purely coincidental

Insufficient sound volume:

In a large Auditorium it is desirable that the speakers voice from the stage should be easily audible in all parts of the hall at a uniform intensity or loudness.

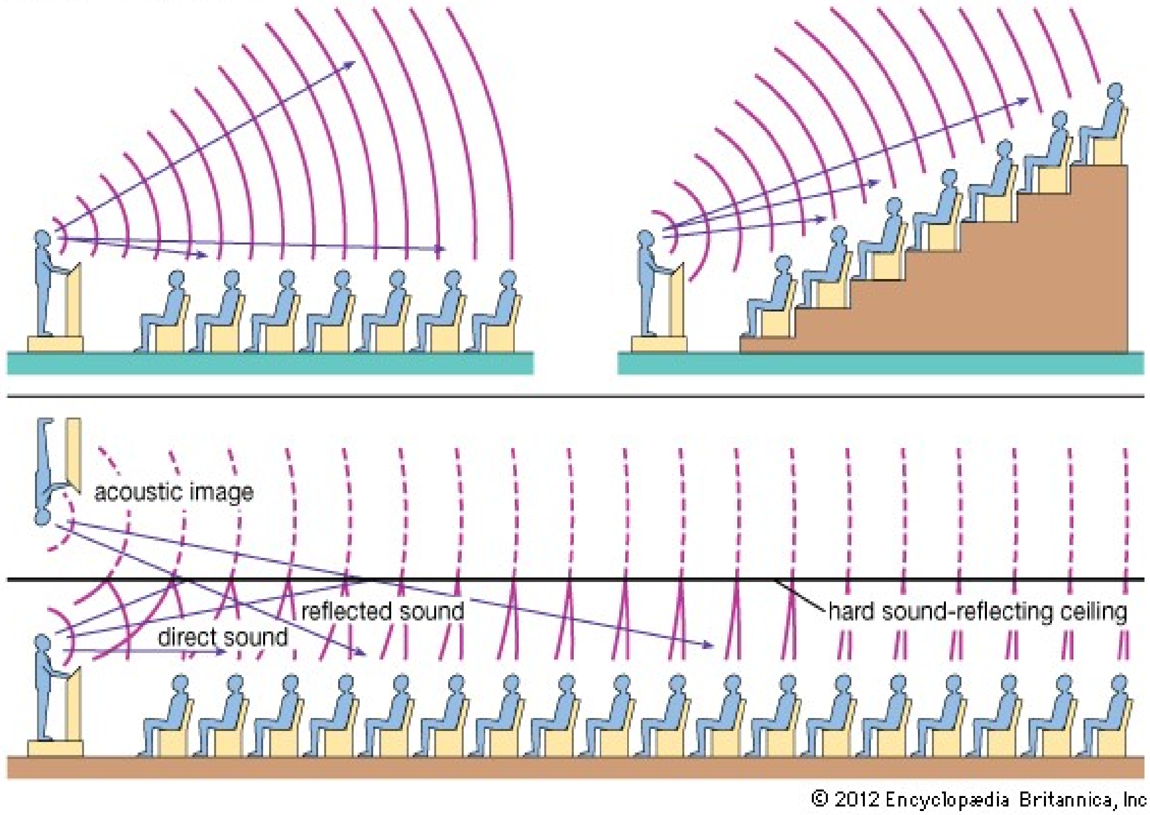
To achieve this the sound waves should get properly reflected and uniformly spread over the interior of the enclosure.

High background noise/ nuisance:

This defect is caused mainly due to poor sound insulation and due to poor planning

The exterior noise is carried inside through loose door, window openings and ventilator.

Distribution of sound

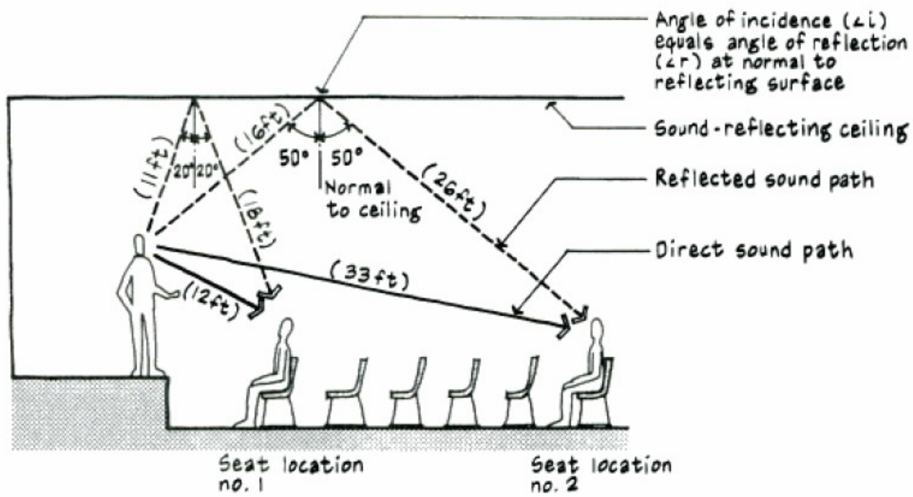


	Defect	Causes	Recommendations
1	Excessive reverberation	Insufficient absorption	Add absorbents
2	Echo	- Unsuitable shapes - Remote reflecting surfaces - Surfaces are smooth and hard.	- Avoid unsuitable shapes - Make offending surfaces more absorbent.
3	Sound foci	Concave reflecting interior surface	Avoid curvilinear interiors & use absorbents n focusing areas.
4	Dead spots	Irregular distribution of sound	Provide even diffusion of sound by means of suitable diffusers.
5	Insufficient sound volume	- Lack of reflections close to source of sound. - Excessive absorption	- Arranging hard reflecting surfaces near the stage or the sound source - Providing sufficient amount of absorptive materials to give optimum reverberation time. - Use of loudspeakers for large halls or limiting the length of the hall. - Avoiding provision for deep balconies. - Use of adequate no. of windows or door openings.
6	High background noise	- poor sound insulation - badly fitted doors & windows - noisy air- conditioning system/other equipments	- construction with required sound insulation - proper fitting doors & window with sound insulation - adequate noise insulation for air-conditioning/other equipments

RAY-DIAGRAM GRAPHICS

An inexpensive protractor to measure angles, a pencil, scale, and paper are all the equipment required for ray-diagram calculations. Shown below is an auditorium section with sound path differences calculated to front and middle-rear audience locations from a typical source location.

Path difference = reflected path − direct path



Example Ray-Diagram Measurements (Distances are shown in parentheses on above drawing)

Front location no. 1:

Path difference = (11 + 18) − (12) = 17 ft

Excellent for speech and music because path difference is less than 23 ft.

Middle location no. 2:

Path difference = (16 + 26) − (33) = 9 ft

Excellent for speech and music because path difference is less than 23 ft.

Sound amplification systems:

Sound amplification system are used for the following purpose:

• To reinforce the sound level when the sound source is too weak to be heard.

• To provide amplified sound for overflow audience.

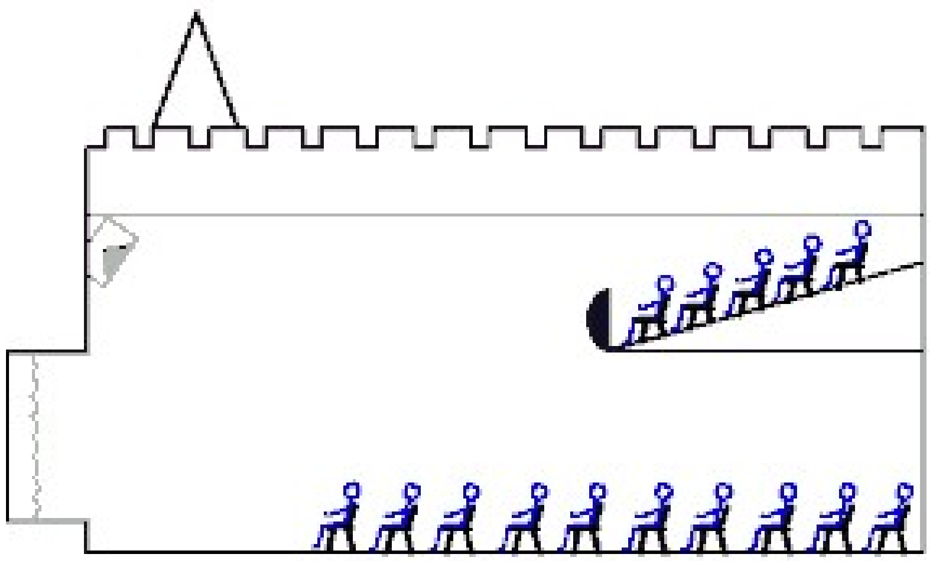
• To minimize sound reverberation.

• To provide artificial reverberation in rooms which are too dead for satisfactory listening.

Types of loudspeaker system

- **Centrally located system**
- **Distributed system,**
- **Stereophonic system,**

The centrally located system with a single cluster of loudspeakers\ over a sound source. This system gives max. Realism as the amplified sound comes from the same direction as original sound.



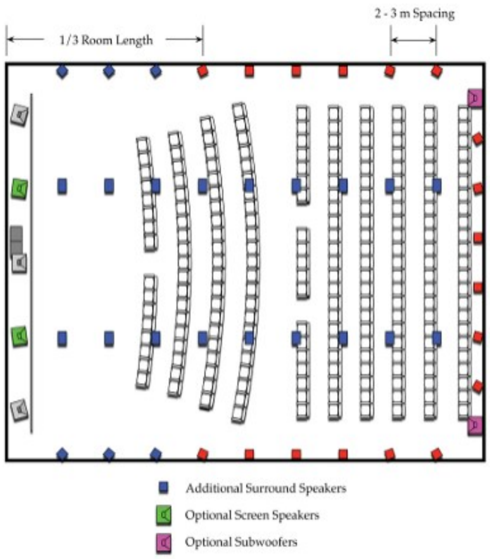
The distributed system, using a number of overhead loudspeakers located throughout the auditorium.

This system should be used when:

- Auditorium height is too low to install central system.
- When majority of listeners do not have an adequate sight line of central loudspeakers.
- When sound has to be provided for overflow audience in large halls.

The stereophonic system, with two or more clusters of loudspeakers around the proscenium opening or the sound source.

Stereophonic system preserves the illusion that, the sound is coming from the original , unamplified source.

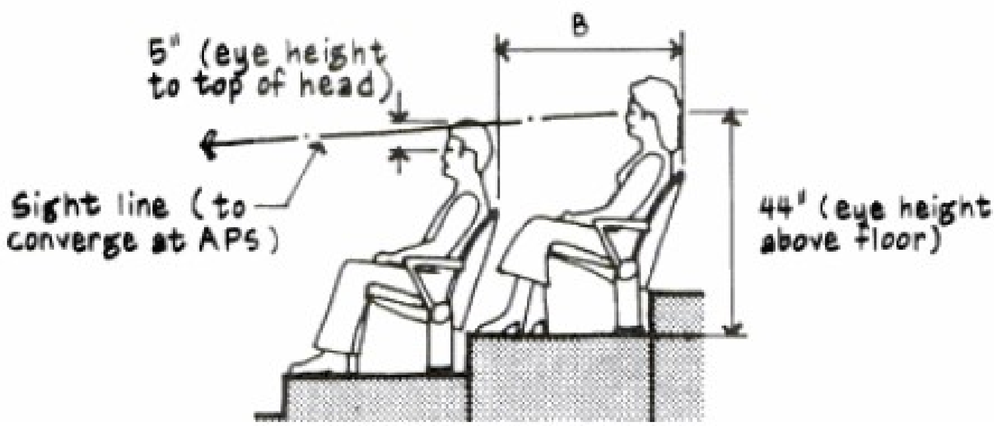


SIGHT LINE BASICS

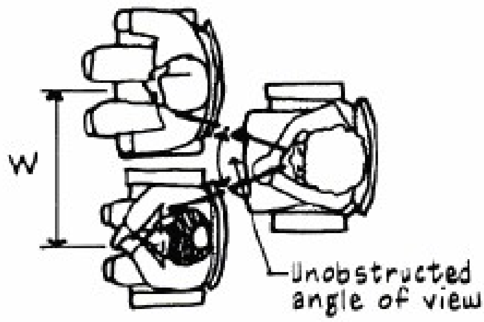
Sight line:-

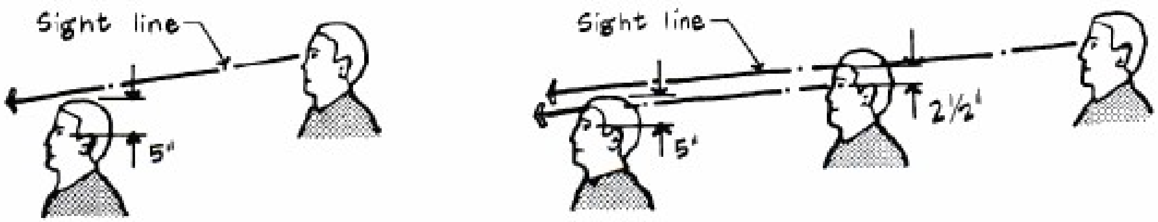
Straight lines drawn from eyes of seated occupants to stage area.

- Unobstructed sight lines from all seats to the front of the forestage allow full view of performers & unobstructed propagation of the direct sound.
- Sight lines are normally drawn to converge at a point on stage called the **arrival point of sight** (APS).
- Laterally staggered seating layouts can achieve satisfactory **every-other row vision** for back –to back seat dimensions.
  - 40″ for continental seating
  - 36″ for radial & Parallel seating



Average Seating Dimensions



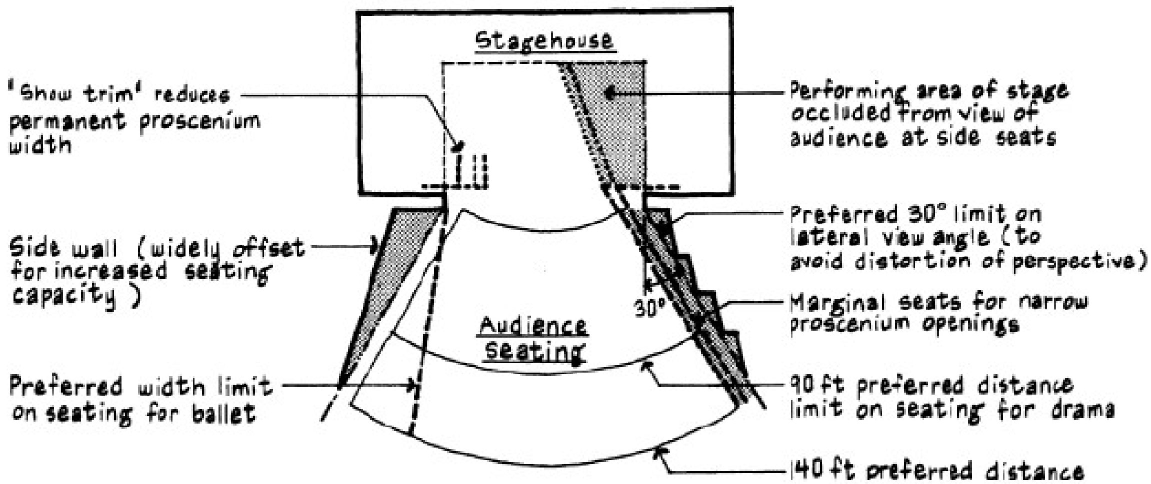


Every-Row Vision — **Every-Other-Row Vision**

Note: To achieve liveness within a reasonable room volume, the back-to-back seat dimension *B* and center-to-center seat dimension *W* should be as small as possible consistent with the requirements for comfort and life safety.

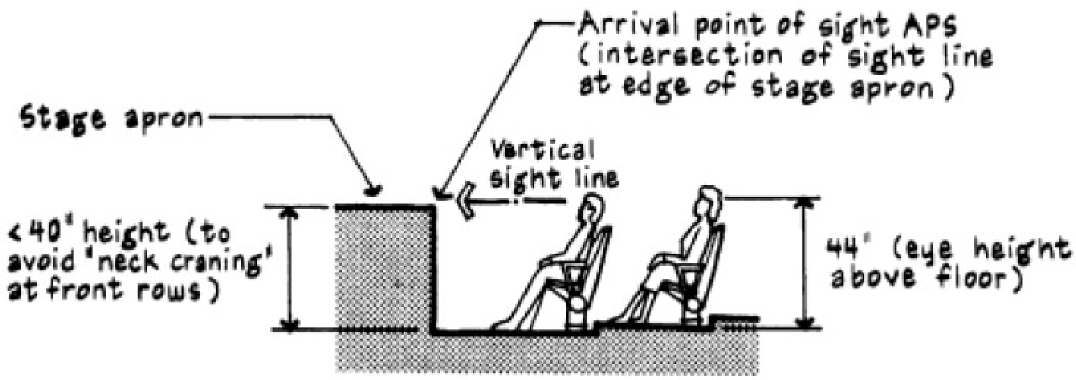
Sight line layouts:-

- For proscenium theatres, lateral sight lines should be within a "view angle" of 30°
  (View angle is measured from the perpendicular at the end of the proscenium opening.)
- Floor & balcony slopes should be designed so that seated audience has an unobstructed view of the performance.
- Balconies should not have excessive floor slope > 26°
- Top balcony should not be more than 65′ above the stage to avoid vertigo.
- Proscenium arch should not obstruct the view of bottom 7′ of the back stage wall



Plan View

Detail at Stage



Section View

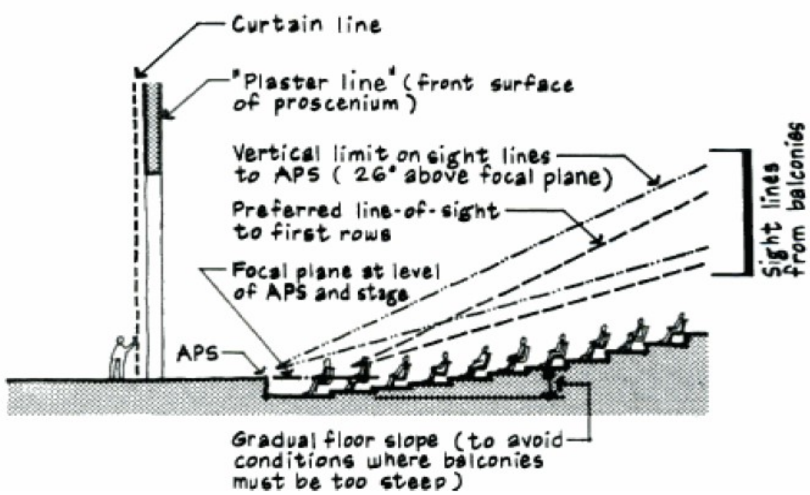


Diagram 12.1 Sightlines for seated spectators

Key to diagram:

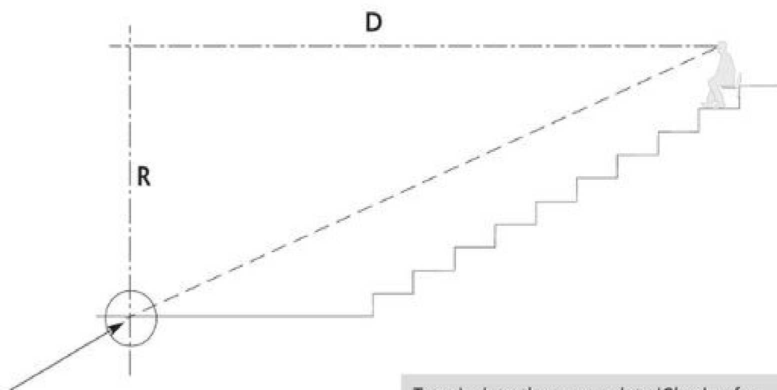
C = the 'C' value

D = the horizontal distance from the eye to the point of focus

N = the riser height

R = the vertical height to the point of focus

T = the seating row depth

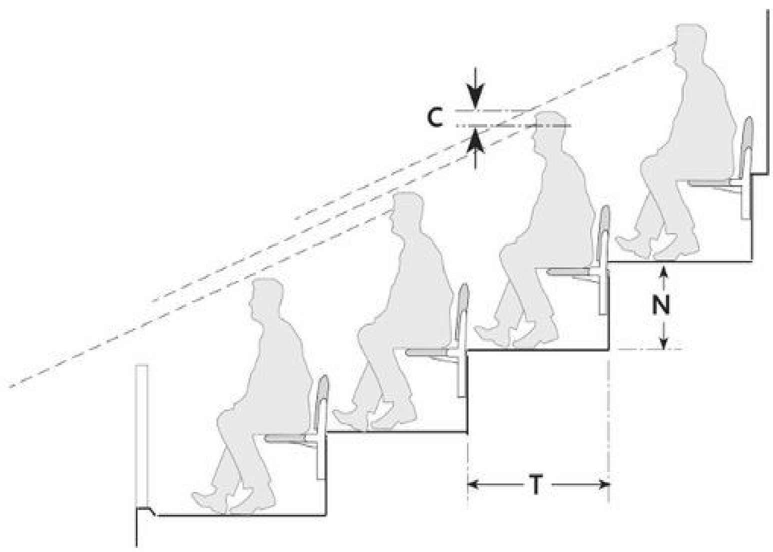


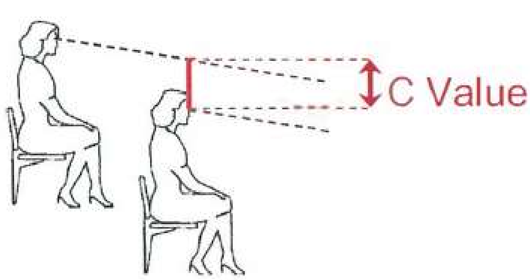
point of focus

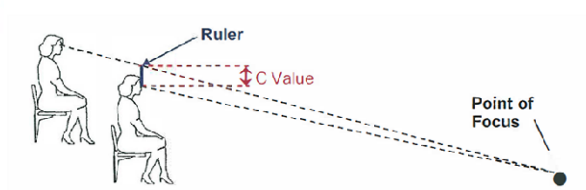
typically the nearest touchline, or outside lane of running track, or boundary of area of activity

To calculate the appropriate 'C' value for the sport to be viewed, the following formula applies:

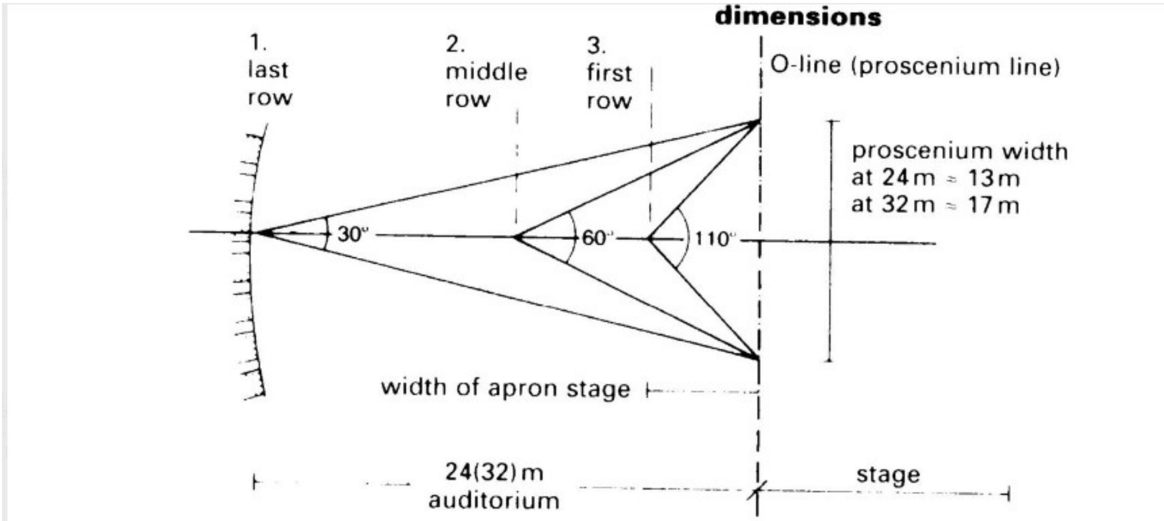
$$C = \frac{D\,(N + R)}{D + T} - R$$



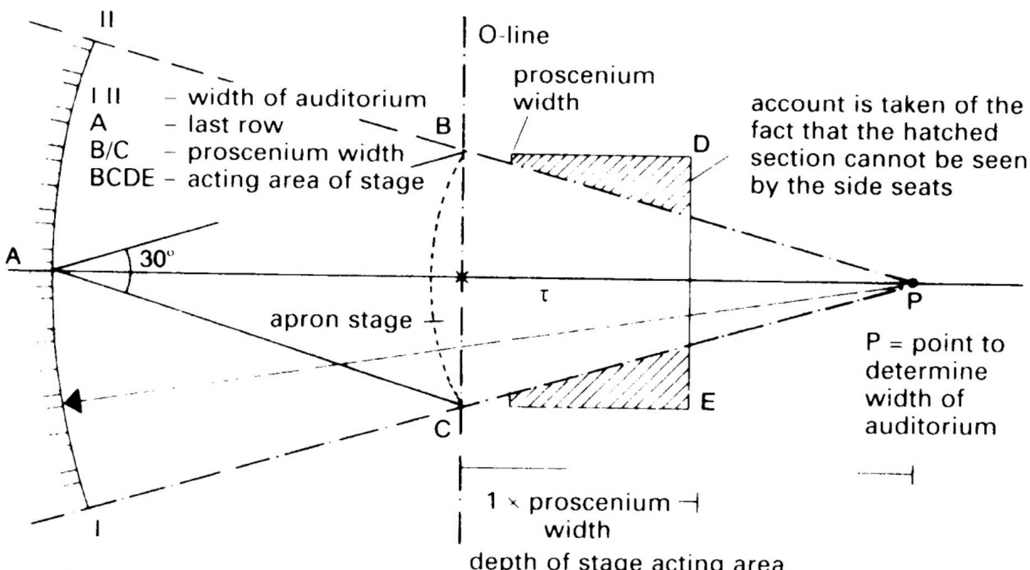




- Good view without head movement, but slight eye movement of about 30°
- Good view with slight head movement and eye movement of about 60°

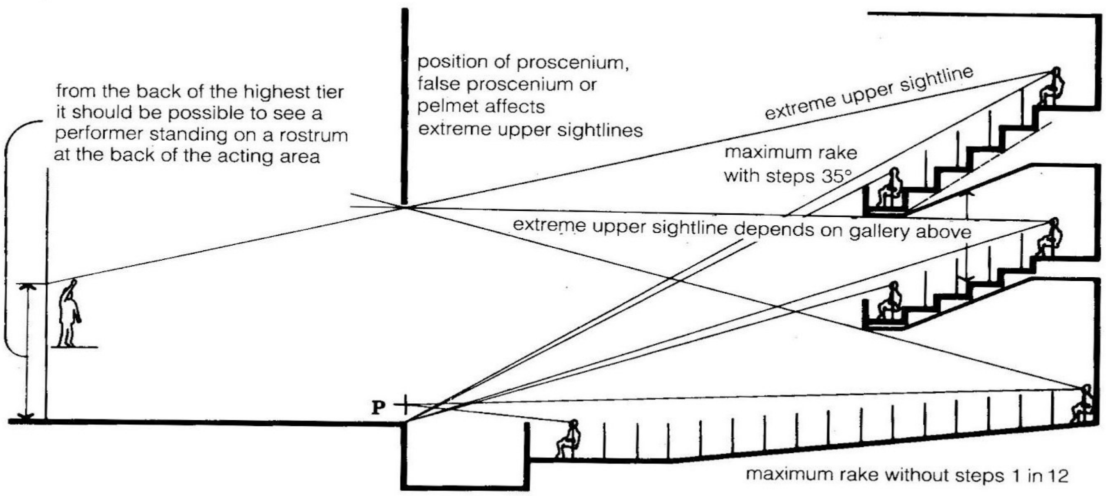


Proportions of the traditional auditorium (view)



Auditorium width

Vertical sight line



BALCONIES

Balconies allow more of the audience to be seated close to the stage and limit the slope of the orchestra seating.

Balcony floors have steeper rakes than the orchestra floor, but the slope can be calculated using the same equations.

The slope should not be greater than 30◦ and the top of the balcony should not be more than 65 feet above the stage to avoid vertigo. Figure 20.2 shows a typical balcony configuration.

Balcony overhangs must be controlled to allow the reverberant sound to reach the seats beneath them. For speech, balcony overhangs can be deeper without undue degradation.

FIGURE 20.2 Balcony Design

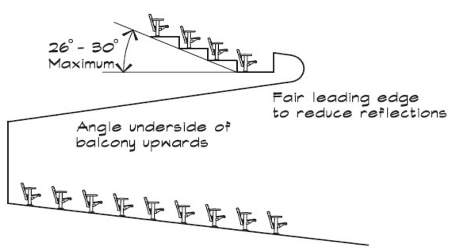
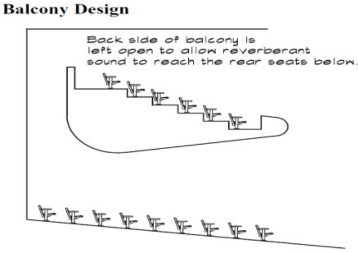


FIGURE 20.3 Flying Balcony Design



A slightly convex under-balcony ceiling can help redirect sound into the shielded area. Likewise a rising leading edge at the front of the balcony is also helpful. Where the balcony overhang is very deep, both direct and reverberant sound have difficulty penetrating.

A sound system can augment the direct sound, using loudspeakers located on the underside of the balcony. A concave or semicircular-ceiling cavity under the balcony can help generate a localized reverberant field to offset the effect of a deep overhang.

In rare instances, halls have been built with a flying balcony, separated from the rear wall of the room as in Fig. 20.3. This allows the sound to flow around the upper balcony to reach the rearmost under-balcony seats. It is an expensive solution, since it presents structural challenges, even when beams support the balcony from the rear.

Ceiling Design

The ceiling of an auditorium or theater is more complicated than those found in a lecture hall.

When auditoria are designed for speech, strong overhead reflections are preferred, whereas for music, a ceiling that diffuses the sound and aids in the sense of envelopment, or feeling surrounded by the sound, is best. A flat ceiling can yield excellent results for speech if it is not too high and if the floor rake is sufficient. In auditoria and lecture halls, particularly when the floor is flat or slightly raked, a shaped ceiling is helpful. This type can be designed

by dividing the surface into angled planes or separately supported reflectors, so that there is an even distribution of reflected sound over the audience.

FIGURE 20.4 Design of Proscenium Reflectors

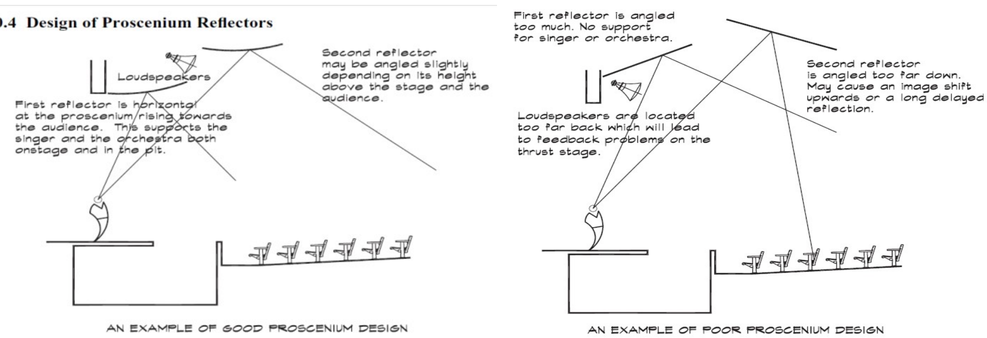


FIGURE 20.5 Design of Projection Screens

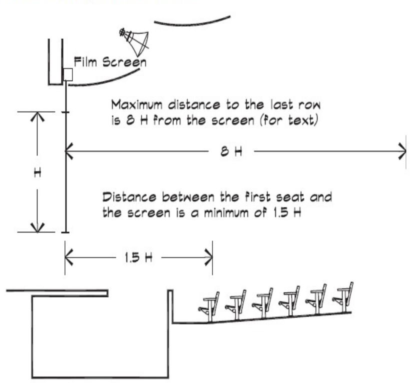
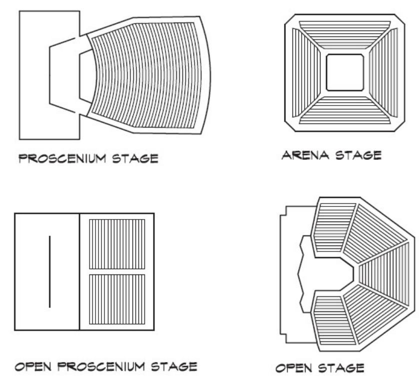
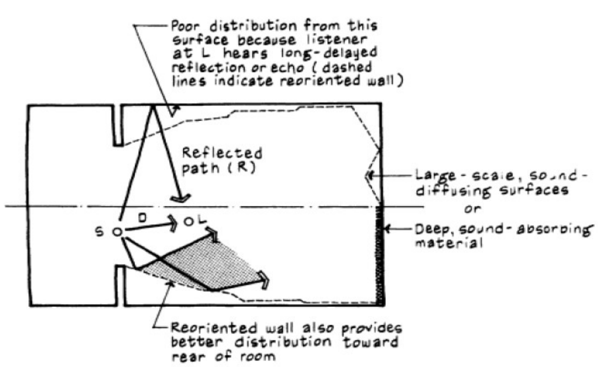


FIGURE 20.6 Basic Stage Forms Used in Theater Design

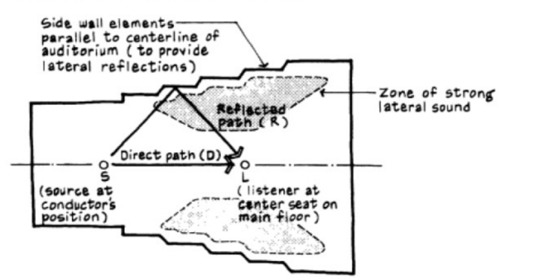


Side walls Design

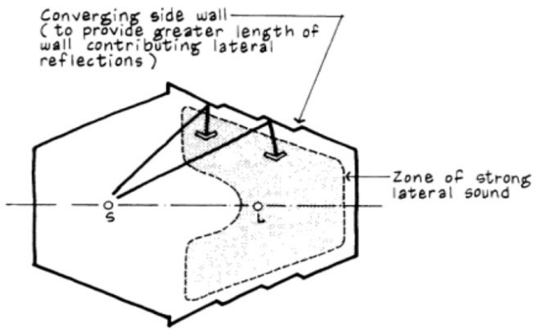
Rectangular Shape (Dashed lines indicate preferred orientations for a lecture room)



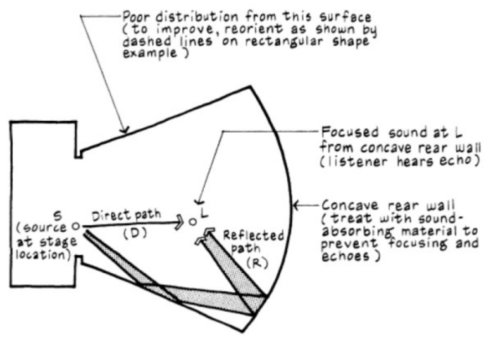
Stepped Shape (Alternate elements of side walls are parallel to provide lateral reflections toward audience for music hall)



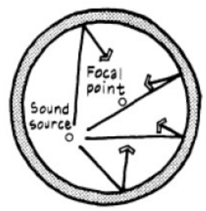
Reverse Fan Shape (Side walls at rear reflect sound toward audience for definition of music)

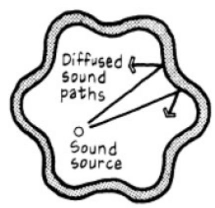


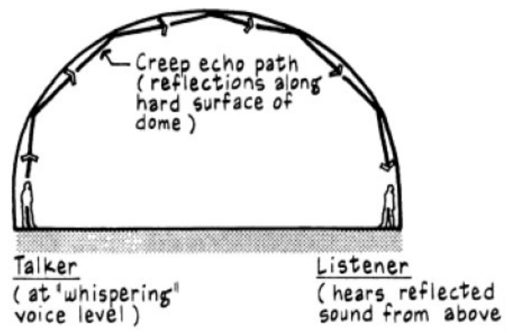
Fan Shape (For lecture room)



Problem	Solution
Focused sound	*Surface undulations*: Large-scale, random-sized surface undulations can provide diffusion to minimize focusing of reflected sound energy (e.g., convex brick surfaces at M.I.T. Chapel, Cambridge, Mass., Eero Saarinen, architect).

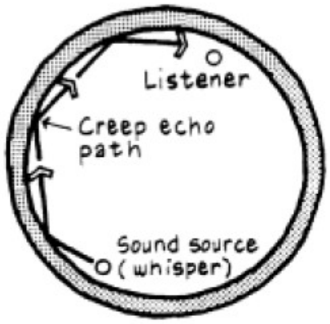


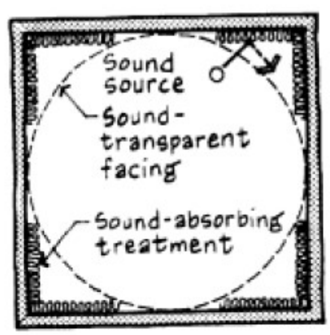




Creep Echo from Dome

Creep	*Sound-absorbing treatment*: Acoustically transparent material (e.g., spaced wood slats or open metal grille) conceals actual enclosure, which can be treated with deep sound-absorbing material to reduce reflected sound energy and creep echoes.





Concert Halls

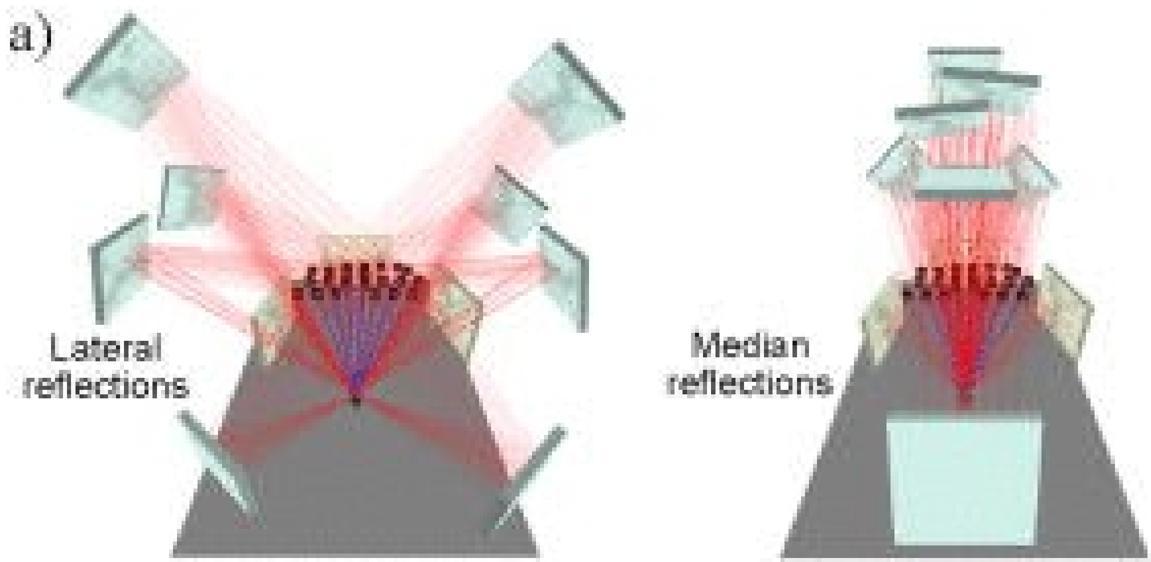
Concert halls are rooms designed specifically for music in which the musicians and the audience occupy the same space. Classic concert halls are roughly rectangular and have one or more shallow balconies. In good concert halls the number of seats ranges from 1700 to 2600, with the best halls averaging around 1850. Above 2600 seats, the chances of success are much reduced and the preferred capacity is between 1750 and 2200.

GENERAL DESIGN PARAMETERS

The Listening Environment

The ideal listening environment for live music depends to some degree on the type of music being played. There are, however, a number of common elements about which there is general agreement.

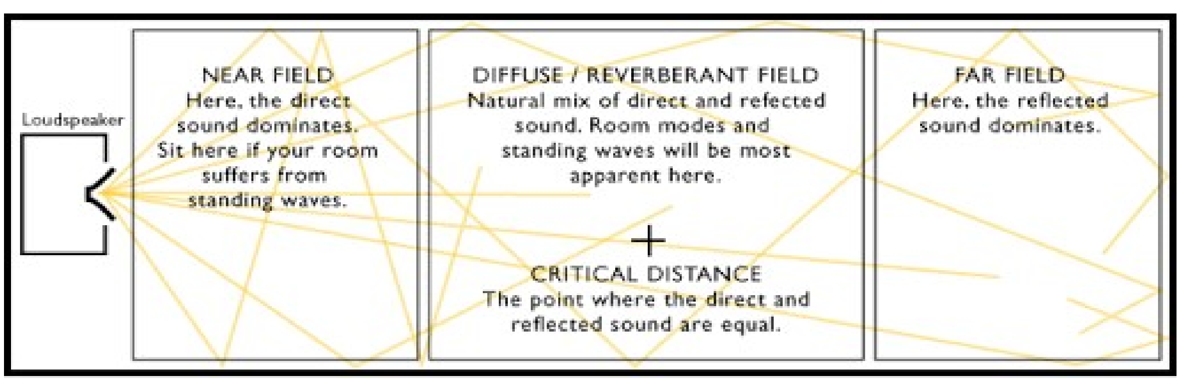
1. The audience should feel enveloped or surrounded by the sound. This requires strong lateral reflections with a significant fraction of the energy arriving from the side.



2. The room should support instrumental sound by providing a reverberant field, whose duration depends on the type of music being played. A reverberation time that rises with decreasing frequency below 500 Hz yields a beneficial sense of musical warmth.

3. There must be clarity and definition in the rapid musical passages so that they can be appreciated in detail. This requires reflections from supporting surfaces located close to the source or receiver so that the initial time delay gap is short.

4. Sound must have adequate loudness that is evenly distributed throughout the hall. When the number of seats becomes excessive (above 2600 seats), loudness and definition are reduced. In small auditoria the loudness must not be overbearing.

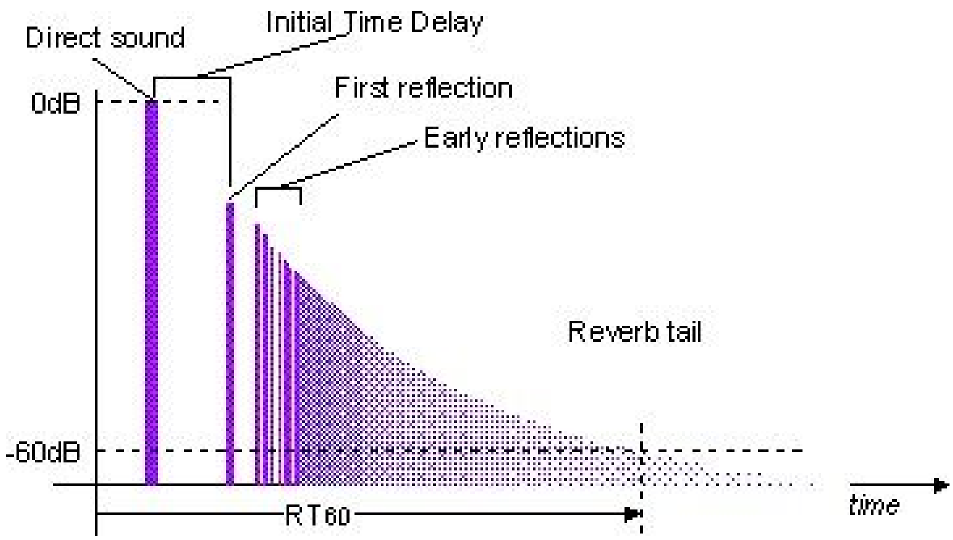


5. A wide bandwidth must be supported. Musical instruments generate sounds from 30 Hz to 12,000 Hz, which is much broader than the speech spectrum. The room must not color the natural spectrum of the music.

6. Noise from exterior sources and mechanical equipment must be controlled so that the quietest instrumental sound can be heard. Background noise levels should not exceed NC 20 in small halls and NC 15 in large concert halls.

7. The detailed reverberation characteristics of the space should be well controlled with a smooth reverberant tail and no echoes, shadowing, coloration, or other defects.

8. The performers should have the ability to hear each other clearly and to receive from the space a reverberant return that is close to that experienced by the audience.

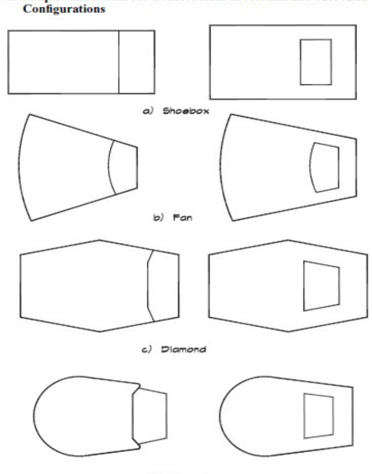


Hall Shape

The most commonly encountered shapes in concert hall design are summarized in Fig. 19.1.

The most consistent performer is the rectangular or shoebox floor plan.

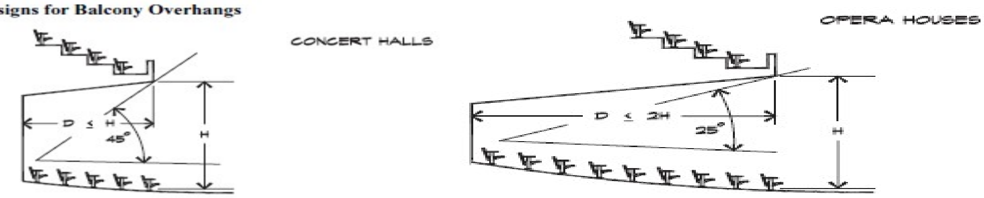
FIGURE 19.1 Simple Plan Forms for Concert Halls in Normal and Surround Configurations



Balconies and Overhangs

A balcony brings the audience closer to the musicians and improves sight lines, while dividing the room vertically into separate spaces. Under a deep balcony there is less reverberant energy and the listener has less sense of envelopment and a lower reverberation time.

FIGURE 19.3 Designs for Balcony Overhangs



An opera is a theatrical piece that tells a story totally through the music. We get the word opera from the Latin and, later, from the Italian, a noun formed from the word operari, "to work." The style evolved in Italy around 1600.

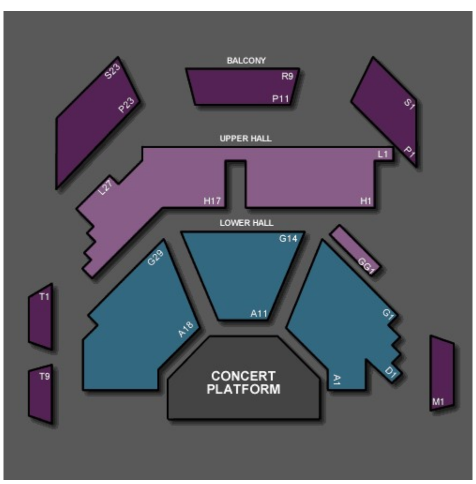
Platforms

Space must be provided for the musicians in a configuration where they can hear and be heard. The amount of floor space provided for the orchestra is a compromise between comfort and acoustics.

This is not to say that acoustical excellence requires us to torture the musicians, but smaller stages generally yield better sound.

Beranek (acoustical researcher) recommends 20 sq ft (1.9 sq m) per musician, which yields a platform size of 2000 sq ft (190 sq m) for a 100 piece orchestra. Platforms in many of the best halls are considerably smaller.

Vienna Musikvereinssaal has 1750 sq ft (163 sq m); Amsterdam, 1720 sq ft (160 sq m); and Boston, 1635 sq ft (152 sq m).



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Pits

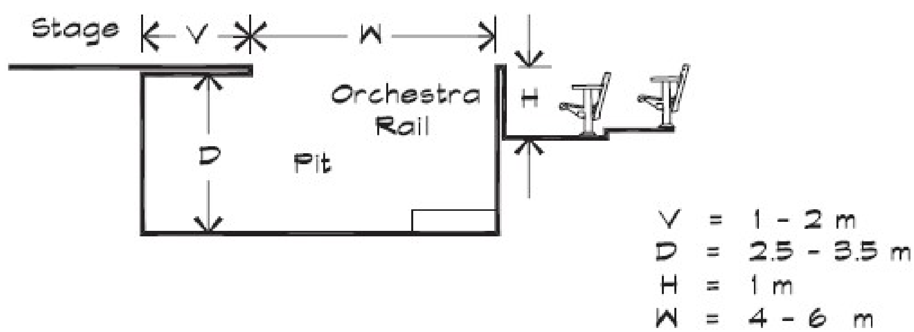
An orchestra pit is not normally part of a pure concert hall, but is quite important in opera halls and multiuse facilities. A pit functions to reduce the loudness of the orchestra relative to the singers and to provide a place where the musicians can be viewed by the conductor while being out of the sight of the audience. The musicians in the pit should be able to hear each other and the singers. The singers in turn must be able to hear the orchestra so that each can adjust their level to the other. Pit levels can be very high, particularly when the pit is partially enclosed. Absorbent materials lower the pit levels but also lessen the communication between players.

Pit design is difficult since the desired amount of level control depends on the size of the hall, the size of the orchestra, the ability of the singers, and the type of music.

The space required is a little less than that necessary for a platform, about 16 to 18 sq ft (1.5 to 1.7 sq m) per musician.

Pit orchestras tend to be smaller than concert orchestras with a few exceptions. The pit in the Metropolitan Opera House in New York, with an area of 1420 sq ft (132 sq m), accommodates up to 95 musicians and is approximately 25 ft (7.6 m) deep from the back wall to the front railing (Beranek, 1996).

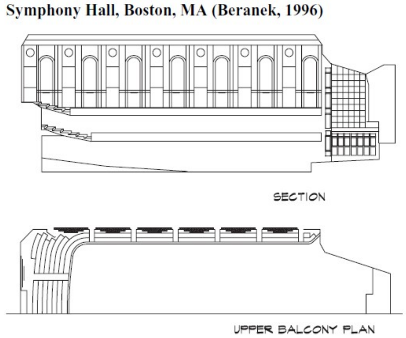
FIGURE 19.5 Typical Opera Hall Pit Dimensions (Barron, 1993)

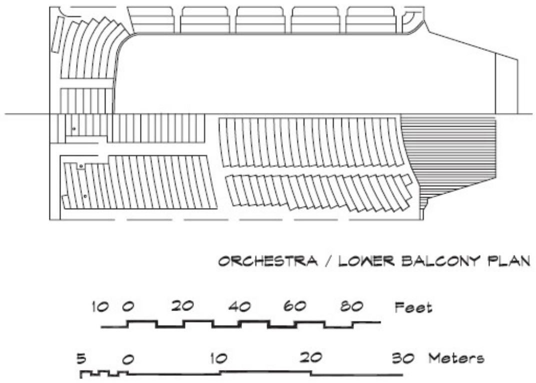


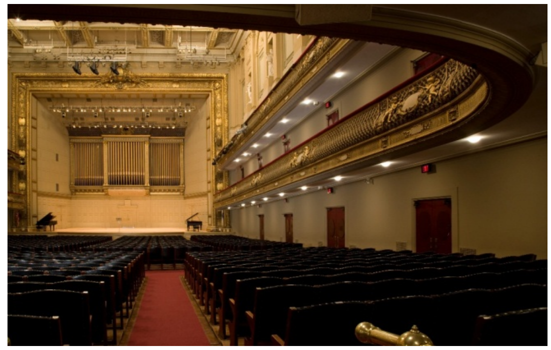
Boston Symphony Hall, Boston, MA, USA

Boston Symphony Hall, shown in Fig. 19.17, was designed by Wallace Clement Sabine in the late nineteenth century, and opened in 1900. It has a classic shoebox shape, with a 54” (1.37 m) high raised platform, surrounded by a shallow shell at one end. The central feature of the orchestra enclosure are gilded organ pipes that span the rear wall of the shell and provide a reflecting shelf above the backs of the musicians. Around the sides and across the rear of the hall are two narrow balconies.

FIGURE 19.17 Symphony Hall, Boston, MA (Beranek, 1996)







At Sabine's suggestion, the architects topped the hall with a coffered ceiling to provide the best possible acoustical experience to every seat in the house.

Wallace Clement Sabine (The father of modern architectural acoustics)

Wallace Clement Sabine (June 13, 1868 – January 10, 1919) was an American physicist who founded the field of architectural acoustics.

RT60 = 0.49 V/SA. The modern unit of sound absorption, the Sabin, is named after him, and is considered the most important quantitative tool in architectural acoustics today.

Sabine concluded that the Fogg Lecture Hall's reverberation time was too long–a spoken word would remain audible for 5.5 seconds, as opposed to the optimal reverberation time of 2.25 seconds–so there was too much resonance and echo. He solved the problem by outfitting the space with sound-absorbent materials to reduce the "echo effect."

Broadcasting studio

Sound isolation is a technique that prevents sound from entering or leaving a studio space. Acoustic treatment, on the other hand, involves absorbing or diffusing certain frequencies to achieve a balanced sonic environment within the studio.

Sound isolation

The property **of blocking off outside sound through use of materials** that reduce sound transmission from the exterior environment into the interior environment. The internal and external noise sources can greatly affect the noise levels in a building. It is therefore essential to control such noise problems to the acceptable noise levels in order to maintain a good acoustic environment.

Site Selection

The required internal and external noise climate in a broadcasting studio set up **depends a lot on the site location.** All the perceived noise levels in a **chosen site** depends on the **intensity of the noise source and should be measured to ascertain** the range of the background sound level. Such external and internal noise sources should be **well controlled** to achieve the desired noise levels. It is important to **predict the nature of any future developments that are likely to take place around the site**. These developments would greatly affect the noise climate and hence sound control precautions should be comprehended early enough to avoid later disappointment.

Site Planning

In the overall planning and design of broadcasting and television studios, there should be proper orientation of the building to reduce noise exposure of occupied and critical spaces. The **noise sensitive spaces** such as studios should be placed as **far away** as possible from external and internal noise sources. The architect should attempt to give a **significant separation of quieter** areas from, noisier ones.

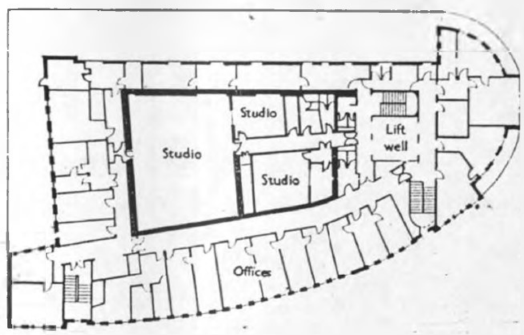


Fig. 2.1 Plan of Broadcasting House London. (Parkin & Humphreys , London 1969 (Pg. 201.)

Internal Planning

In the internal planning of a broadcasting and television studio centre, quieter studios should be separated from noisier areas by less critical spaces acting as barriers to the exterior noise; for instance use of offices to shield the quieter studio spaces from external noise in the Broadcasting House. Studios require quiet ambient background (25-30 dB) and hence buffer spaces are preferred between them and other noisy spaces. Adequate sound insulation both from the interference of outside noise and between adjacent internal areas and the studios must be provided. Any spaces above any studio should be **provided with resilient floors** to reduce any impact sound transmission to the studio. The studio should have **suspended ceiling to increase sound insulation** from spaces above it.

Background Sound Levels

Background noise levels are taken to determine the best position of a building on site. The **quietest part of the site can be found out by the noise survey.**
The acoustical environment in an occupied space is the **resultant of the noise** arriving at the space from both internal and external noise sources.
Internal noise sources in a studio may be caused by mechanical systems, electrical services, circulation services and human traffic, while the external noise sources may be caused by traffic, aircraft, and railway or nearby machinery.
It’s mandatory **to maintain an ambient acoustical background for studio spaces at 25-30dB**. This range should be maintained and any unwanted noise should be isolated from these spaces to achieve a good indoor acoustic environment.
The noise control procedure of site selection, building orientation, internal planning, selection of plant and equipment and use of building materials and suitable structure should be strictly followed. There is often a change of external noise climate with time, usually increasing year after year. This may be due to progressive developments around the building location. Such **future developments** should be ascertained early enough to avoid significant effects on the level of the noise climate.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

UNIT – 4 - BUILDING SERVICES III– SAR 1302

ELEVATORS AND ESCALATORS

Definition of Lifts

- Vertical transport equipment that efficiently moves people between floors (levels, deck) of a building, vessel or other structure.
- Generally powered by electric motor that drive by traction cable and counterweight systems like a hoist or hydraulic pump.

Importance of Lifts

- **Rapid development:** buildings design nowadays built vertically /higher because of high land cost.
- **Basic needs** : to bring building user from one level to higher level in building
- **Comfort needs:** working efficiency for office building or large organization.
- **UBBL**: building with more than 6 storey must provide lifts system.
- **Fire requirements:** provide fire lift to be used during fire.

Lift Categories According to the Function

Trade Lift

- Crucial to the good performance to clients of the building.
- Between 6 – 23 people.
- Speed of elevator 200 – 2000 ft/ min.
- Examples : offices, shopping mall and hotels

Hospital Lift

- Used in hospital & treatment center
- Designed for transporting large carts or furniture.
- Speed of elevator 100 – 350 ft/ min.
- Two sides of front and back doors for loading and unloading facilities.
- Door width between 900 – 1100mm

High Residential Lift

- For high rise residential buildings such as flat, apartment or condominium.
- Needs regular maintenance because high frequency of its use every day or possibility of vandalism.

Institution Lift

- Used in library, office, classroom or lecture hall located at high altitudes.

Store Lift

- Used to transport heavy goods but depends on types of good transported.

- Elevator speed 50 – 150ft/min.
- 5000 lbs normal, load haul 20000 lbs.
- Usually used in shoppping complex, airports, hotels, warehouse

Lift of Cars

- Used specifically to lift a car in multi storey car park or showroom.

NOTES :

The six types of elevators had to be in the form of pull (traction) and hydraulics.

Form of traction is more commonly used for high velocity.

Hydraulic type only used to transport goods where waiting time is not concerned.

Characteristic of Lifts

Lift needed for the building more than 6 storey.

Installation must be in accordance with the regulation in UBBL.

Suitable speed 100 – 150ft/min. Too fast will result in a nervous breakdown to the user. If too slow will cause lack of function.

User Requirements:

Good System – quiet equipment, smooth journey, good condition and safe at every moment.

Waiting time – minimum waiting time at any level.

Aesthetics – Button panel clear and easily reached at appropriate level. Complete instruction. Decorative lighting and comfortable.

Movement of door – door movement is quiet and fast.

Components & Installation of Lifts

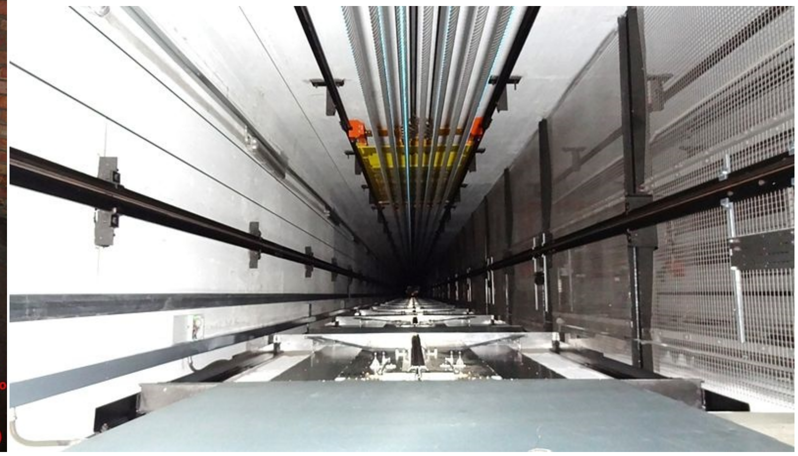
Lift sub-system

Control Motion – includes motor, gear, engines, brakes and power supply.

Control System - to get control the movements of the lift.

Door Control – contained motor connecting lift car doors, platforms gates and door safety devices.

Safety Control – contain the safety gear, speed controller for the first balance, heat and lack of power.



Lift Components

LIFT CAR

- Platform where passengers or goods is transported.
- Constructed with steel or iron attached with steel frame.
- Fire resistance

Equipment to be provided – door, floor panel indicators, button of request, phone, emergency button, lighting, ventilation and enough emergency supplies.


Elevator hoist ropes on top of a lift car   A modern internal control panel.

Lift shaft

- Constructed with reinforced concrete.
- To accommodate the loading and fire resistance.
- Size of lift shaft space is determined by the number of user.

Selection Factor

GENERAL REQUIREMENTS

- **Utility** – The function must be identified whether for commercial, office of hospital.
- **Capacity & number of lifts** – depends on the access building pattern and building size.
- **Speed** – depends on the number of stops, numbers of user and transport cost.
- **Type & size of lift gate** – depends on the use or function.

PHYSICAL REQUIREMENTS

- **Size of lift shaft** – depends on lift cargo capacity

- **Depth of lift shaft** – depends on the speed of elevator
- **Area of space in lift** – depends on speed of elevators.
- **Mechanical room size** – depends on type and size of the lift equipment.

OTHER REQUIREMENTS

- Electrical panels and power outlets.
- Ventilation fan and lighting in engine room.
- Steps down and power sockets in the wells lift (lift pit).
- The structure for lifting the machinery room.
- Maintanence works.

Building type	Waiting time (second)
Office building Central town Commercial	25 – 30 30 – 45
Residential building Luxury Medium type Low cost Hostel	50 – 70 60 – 80 80 – 120 60 – 80
Hotel Class A Class B	40 – 60 50 - 70

Function	Lif capacity (lbs)	Min. Speed (ft/min.)	Building height (ft)
Office Building Small size Medium size High scale	2500 3000 3500	350 – 400 500 – 600 700 800 1000	0 – 125 126 – 225 226 – 275 276 – 375 > 375
Hotel	2500 3000	Same as above	
Hospital	3000 3500 4000	150 200 250 – 300 350 – 400 500 – 600 700	0 – 60 61 – 100 101 – 125 126 – 175 176 – 250 > 250

Residential	2000 2500	100 200 250 – 300 350 - 400	0 – 75 76 – 125 126 – 200 > 200
Commercial	3500 4000 5000	200 250 – 300 350 – 400 500	0 – 100 101 – 150 151 – 200 > 200

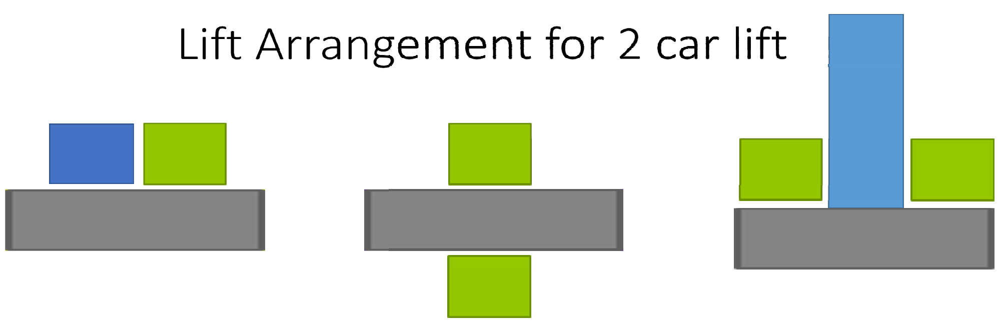
Location & Lift Arrangement

LIFT ARRANGEMENT

- To ensure there is **no interference** between passengers who wish to get into the lift.
- Should be carefully planned so can easily get into lobby and travel distance is reasonable.
- Maximum **travel distance 150 – 200ft**
- System layout depends on the number of elevator cars that use the elevator
- Normally the elevator is set in the layout or zoned.

BENEFIT

- If there is high traffic , the usage is at optimum level
- Waiting time will be shorten.

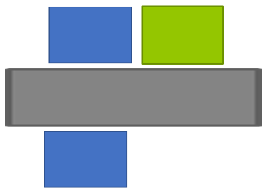


Side by side arrangement – width of corridor = width of car lift

Opposite arrangement of corridor = width of car lift ment – width of corridor = width of car lift

Not good arrangement

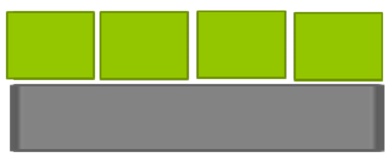
Lift Arrangement for 3 car lift



Opposite arrangement – width of corridor = 1.5 – 2A, where A is width of lift

Side by side arrangement – width of corridor = 1.5A, where A is width of lift

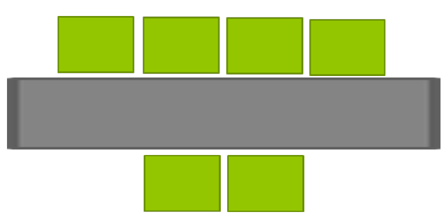
Lift Arrangement for 4 car lift



Opposite arrangement – width of corridor = 1.5 – 2A, where A is width of lift

Side by side arrangement – width of corridor = 1.5A, where A is width of lift

Lift Arrangement for 6 car lift



Opposite arrangement – width of corridor = 1.75 – 2A, where A is width of lift

Side by side arrangement – width of corridor = 2A, where A is width of lift

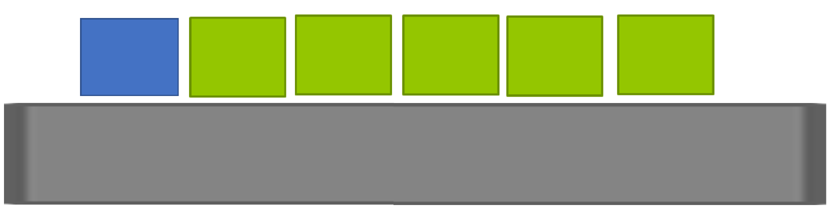
Lift Arrangement for 6 car lift

Weak
arrangement for
6 car lift

Lift Arrangement for 6 car lift

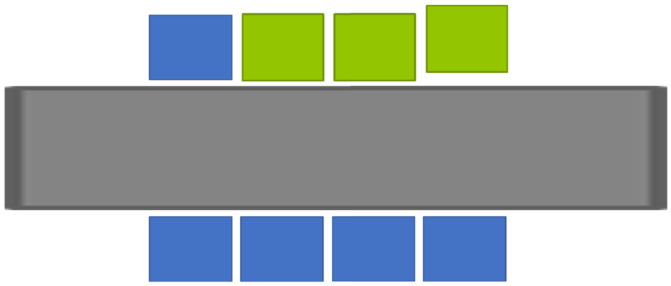
Weak
arrangement for
6 car lift

Lift Arrangement for 6 car lift



Weak
arrangement for
6 car lift

Lift Arrangement for 8 car lift



Opposite arrangement - width of corridor = 2A, where A is width of lift

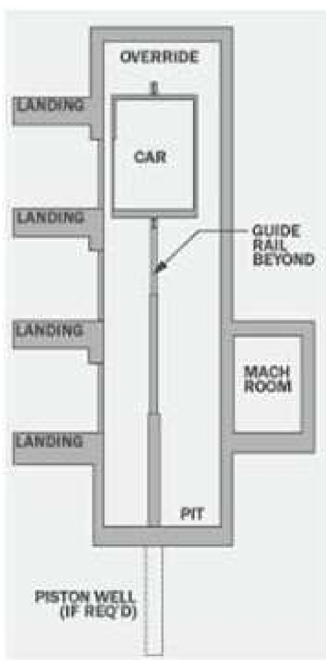
According To Hoist Mechanism:

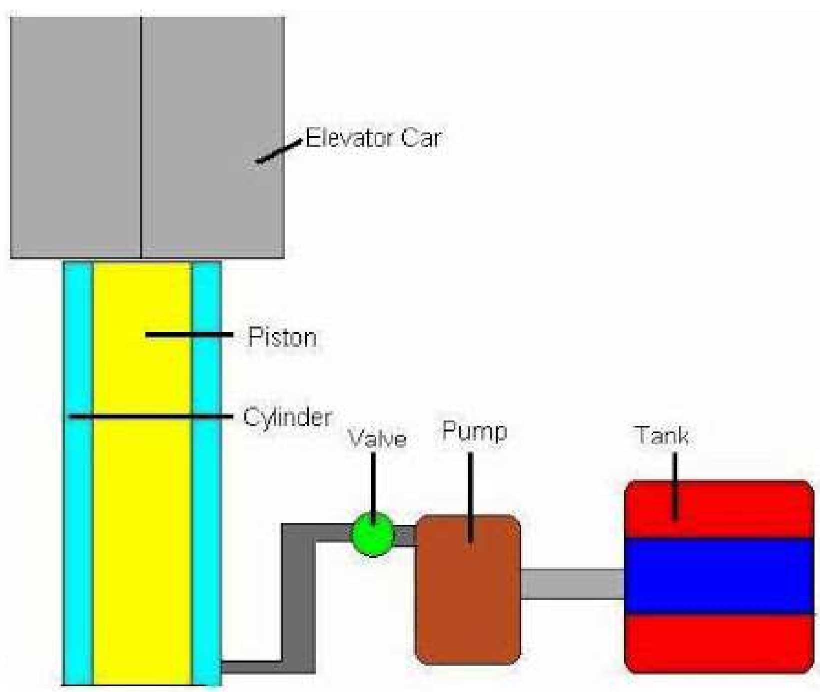
Elevators will be classified according to hoist mechanism to 4 main types as follows:

1. **Hydraulic Elevators**
2. **Traction Elevators**
3. **Climbing elevator**
4. **Pneumatic Elevators**

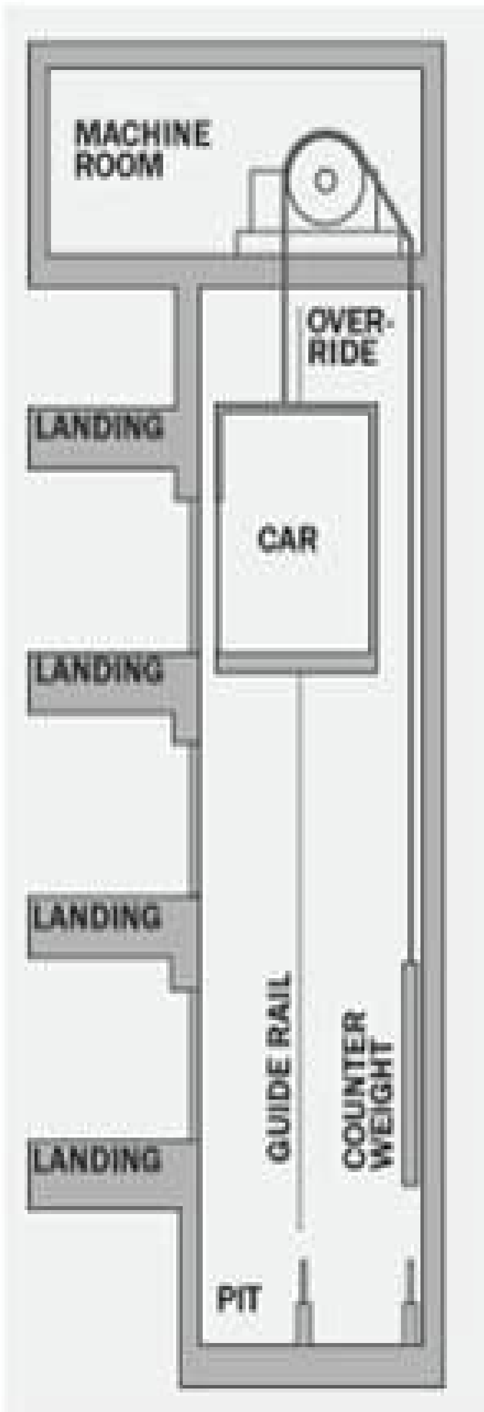
Hydraulic Elevators (Push Elevators

Hydraulic elevators are supported by a piston at the bottom of the elevator that pushes the elevator up. They are used for low-rise applications of 2-8 stories and travel at a maximum speed of 200 feet per minute. The machine room for hydraulic elevators is located at the lowest level adjacent to the elevator shaft.



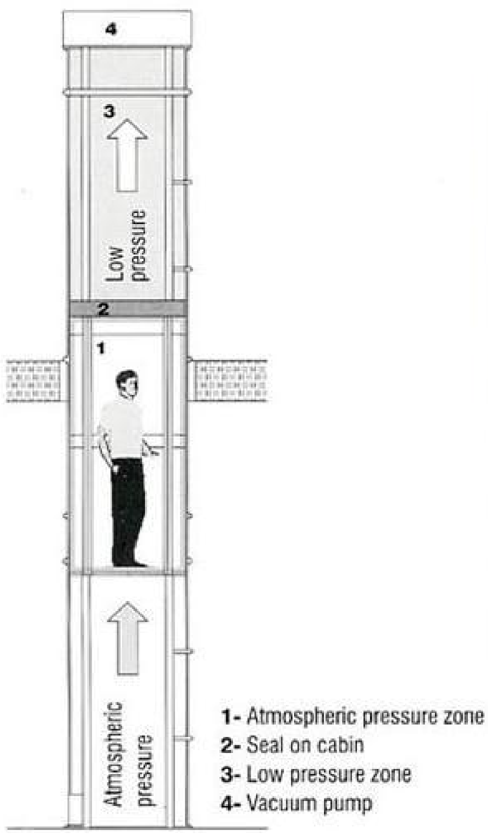


Traction elevators Traction elevators are lifted by ropes, which pass over a wheel attached to an electric motor above the elevator shaft. They are used for mid and high-rise applications and have much higher travel speeds than hydraulic elevators. A counter weight makes the elevators more efficient.



Climbing elevator
They hold their own power device on them, mostly electric or combustion engine. Climbing elevators are often used in work and construction areas.

Pneumatic Elevators
Pneumatic elevators are raised and lowered by controlling air pressure in a chamber in which the elevator sits. By simple principles of physics; the difference in air pressure above and beneath the vacuum elevator cab literally transports cab by air. It is the vacuum pumps or turbines that pull cab up to the next Floor and the slow release of air pressure that floats cab down. They are especially ideal for existing homes due to their compact design because excavating a pit and hoist way are not required.



VERTICAL TRANSPORTATION: LIFT

Factor of Safety

The minimum factor of safety for any part of the lift shall not be less than five.

Number of Lifts and Capacity

The number of passenger lifts and their capacities, that is load and speed, required for a given building depend on the characteristics of the building.

- Number of floors to be served by the lift.
- Floor to floor distance.
- Population of each floor to be serve.

- Maximum peak demand; this demand maybe unidirectional, as in up and down peak periods, or a two-way traffic movement.

PRELIMINARY LIFT PLANNING

The three main factors to be considered for lift installation:

- Population or the number of people who require lift service.
- Handling capacity of the maximum flow rate required by these people.
- Interval or the quality of service required.

Population :

- If a **definite population** figure is **unobtainable** an assessment should be made from the **net area** and probable **population density**.
- If a definite population figure is unobtainable an assessment should be made from the net area and probable population density.
- Average population density can vary from about one person per 4 m2 to one person per 20 m2.

Load		Car Side		Lift Well		Entrance
Persons (1)	kg (2)	*A* (3)	*B* (4)	*C* (5)	*D* (6)	*E* (7)
4	272	1 100	700	1 900	1 300	700, *Min*
6	408	1 100	1 000	1 900	1 700	700, *Min*
8	544	1 300	1 100	1 900	1 900	800
10	680	1 300	1 350	1 900	2 100	800
13	884	2 000	1 100	2 500	1 900	900
16	1 088	2 000	1 300	2 500	2 100	1 000
20	1 360	2 000	1 500	2 500	2 400	1 000

- If **no indication is possible** population in the region of 5 m2 per person for general office buildings is usually assumed.

Quantity of Service :

Type of Building	*Handling Capacity*
Office — Diversified tenants	10 to 15 percent
Office — Single tenant	15 to 25 percent
Residential	7.5 percent

Quality of Service or Acceptable Interval

20 to 25 seconds	Excellent
30 to 35 seconds	Good
34 to 40 seconds	Fair
45 seconds	Poor
Over 45 seconds	Unsatisfactory

NOTE — For residential buildings longer intervals should be permissible.

No. of Floors	Speed
4 to 5	0.5 to 0.75 m/s
6 to 12	0.75 to 1.5 m/s
3 to 20	1.5 m/s to 2.5 m/s
Above 20	2.5 m/s and above

DETERMINATION OF TRANSPORTATION OR HANDLING CAPACITY DURING THE UP PEAK

The **handling capacity** is calculated by the following formula:

$$H = \frac{300 \times Q \times 100}{T \times P}$$

H = Handling capacity as the percentage of the peak population handled during 5 min period.
Q = Average number of passengers carried in a car.
T **= Waiting interval** in seconds, and
P **= Total population to be handled** during peak morning period.
The waiting interval is calculated by the following formula:

$$T = \frac{RTT}{N}$$

N = Number of lifts.
RTT **= Round trip time**

The **round trip time** is the cycle **time** taken by the **elevator** to pick up the passengers from the main entrance, deliver them to the upper levels and then return back to the main entrance

6.2.9.2 An example illustrating the use of the above consideration is given below:

Gross area per floor	1 100 m^2
Net usable area per floor	950 m^2
No. of landings including ground	15
Assuming population density	9.5 m^2 per person

Probable population in

$$P = \frac{14 \times 950}{9.5}$$

Upper floors	1 400 persons
Taking 20 passengers lift with 2.5 m/s the calculated *RTT*	165 s

$$Q = 20 \times 0.8 = 16$$

a) Taking No. of lifts, $N = 4$

$$T = \frac{RTT}{N} = \frac{165}{4} = 41 \text{ s}$$

$$H = \frac{300 \times Q \times 100}{T \times P} = \frac{300 \times 16 \times 100}{41 \times 1\,400}$$

$$= 8.3 \text{ percent}$$

b) Taking No. of lifts, $N = 6$

$$T = \frac{165}{6} = 27.6 \text{ s}$$

$$H = \frac{300 \times Q \times 100}{T \times P} = \frac{300 \times 16 \times 100}{27.6 \times 1\,400}$$

$$= 12 \text{ percent}$$

The value of Q depends on the dimensions of the car. It may be noted that the car is not loaded always to its maximum capacity during each trip and, therefore, for calculating H the value of **Q is taken as 80 percent of the maximum carrying capacity of the car.**

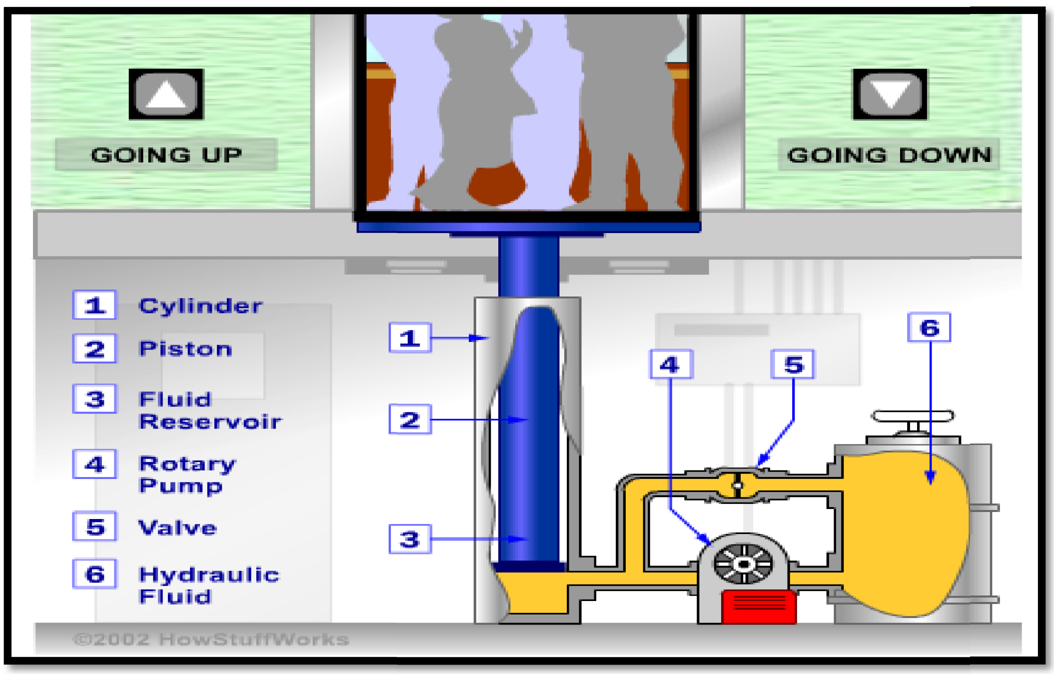
<u>BASIC PRINCIPLE OF LIFT WORKING :</u>

- **Hydraulic Lift :**

Hydraulic elevator systems lift a car using a **hydraulic ram**, a fluid-driven piston mounted inside a cylinder.

The hydraulic system has three parts:

- A **tank** (the **fluid reservoir**)
- A **pump**, powered by an **electric motor**
- A **valve** between the cylinder and the reservoir



- **The Cable System :**

In roped elevators, the car is raised and lowered by traction steel ropes rather than pushed from below.

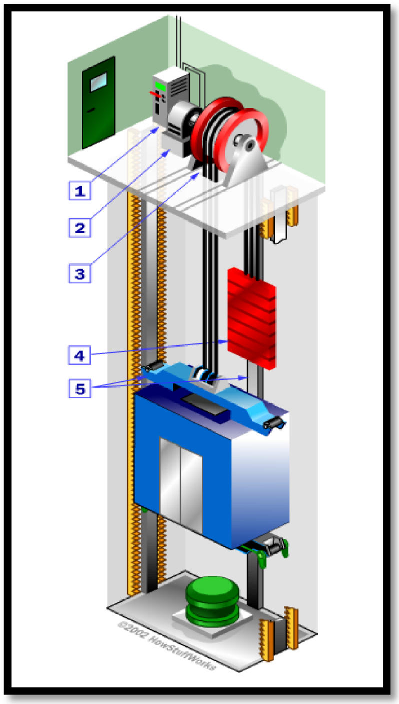
Main parts of cable system are :

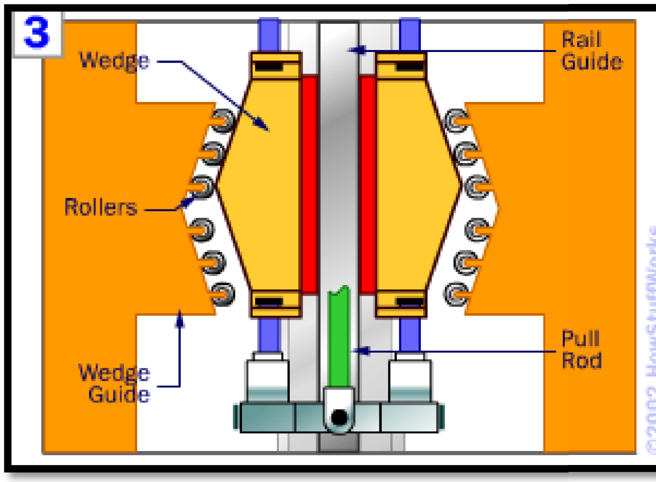
- Control System – (1)
- Electric Motor – (2)
- Sheave / Pulley – (3)
- Counterweight – (4)
- Guide Rail – (5)

Sheave, motor & control system are placed in machine room

Safety Systems: <u>Safeties</u>

- Activated by a **governor** when the elevator moves too quickly.
- Governor systems **positioned at the top** of the elevator shaft.





Escalators and moving walks

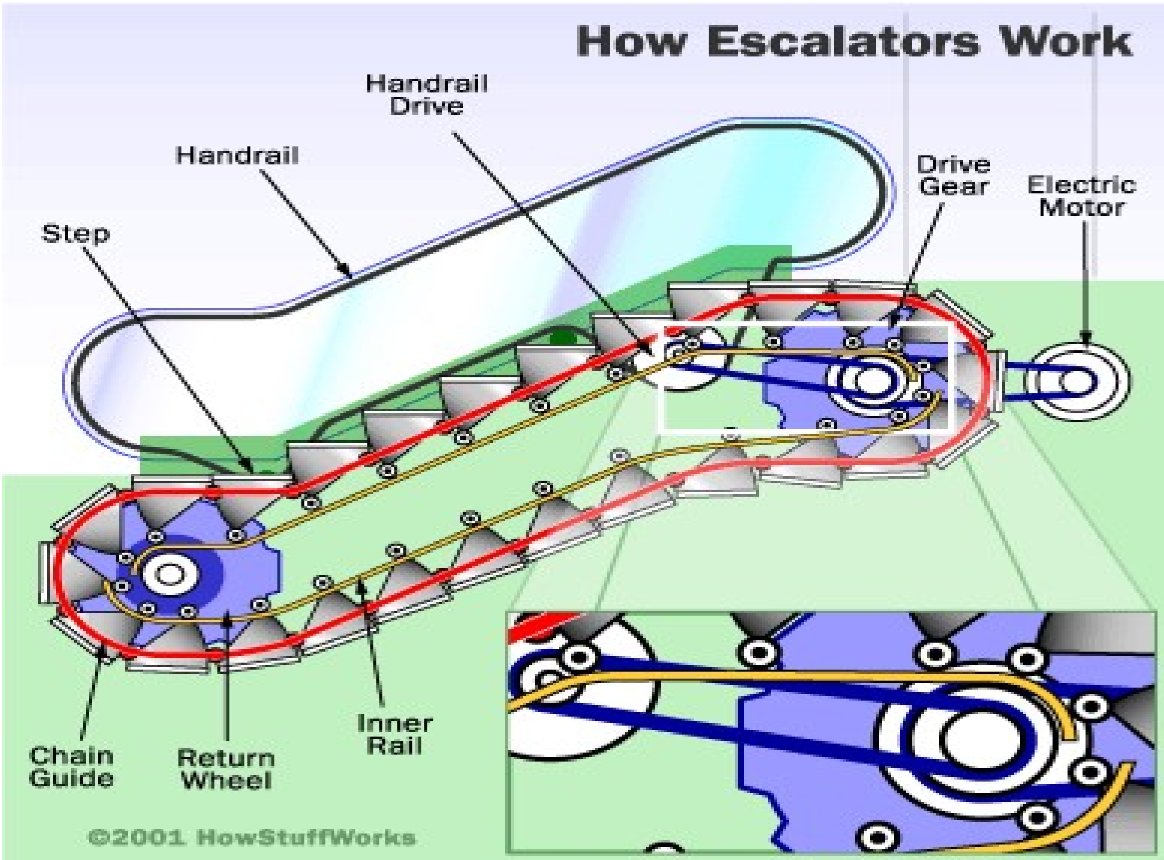
Escalators are load carrying units designed to transport people, between two landings. They are driven by an electric motor and a drive system that moves steps and handrails at synchronised speeds. The escalator is supported by a truss which contains all the mechanical components, such as the drive unit, brakes and chain.

Escalators typically travel at speeds of around 0,5 m/s – fast enough to provide rapid displacement while not disregarding comfort and safety. They are used both in commercial buildings and in public transport facilities such as airports, metros and railway stations. For the transport of trolleys between two floors, inclined moving walks are used. At airports, horizontal moving walks are installed to move passengers more quickly to their destination.

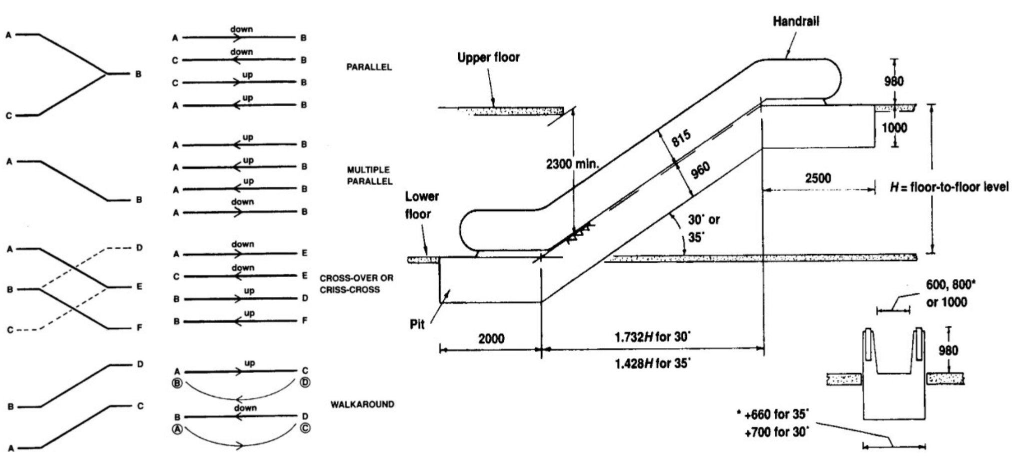
Basic Operating Guidelines -Escalators

Regularly (at least monthly) apply a silicone friction reducer on skirt panels Document any unusual noises or vibrations. Remove any debris Monitor for broken comb teeth Always remove the start-up key from the "on" direction. If an escalator or moving walkway makes an automatic emergency stop, perform a detailed equipment check before returning to operation.

Do not permit overloading of passengers or freight. Do not permit the use of an inoperative escalator as a stairway



An **escalator is a conveyor transport device for transporting** people, consisting of a staircase whose steps move up or down on tracks that keep the surfaces of the individual steps horizontal Where large numbers of people are anticipated, such asairports and railway terminals, department stores and shopping malls, several escalators will be required and can
be grouped in a number of ways to suit the building functions
The angle of inclination is normally 30o, but may increase to 35o if the vertical rise does not exceed 6 m and the speed is limited to 0.5 ms-1



Step Speed

Escalator speeds vary from about **90 feet per minute to 180 feet per minute** (27 to 55 meters per minute) An escalator moving 145 feet (44 m) per minute can carry more than 10,000 people an hour – many more people than a standard elevator.

TRAVELATORS

A **moving walkway, moving sidewalk, or travelator is a** slow conveyor belt that transports people horizontally up to the practical limitations of about 300 m.

They work in a similar manner to an escalator. In both cases, riders can walk or stand. The walkways are often supplied in pairs, one for each direction.

They are particularly useful in large railways and airports terminals, as well shopping complexes, and may be inclined up to about 15o where a level differential occurs.

Speed range between 0.6 and 1.3 ms-1, limitations being imposed because of the difficulty in getting off.

Combine with walking, the overall pace could be about 2.5 ms-1.

Materials for travelators must be flexible or elastic and include reinforced rubber or composites and interlaced steel plates or trellised steel.

The latter two have the facility to deviate from the conventional straight line.

Dumb Waiter Elevators Standard Specifications:-

Dumbwaiters are small freight Elevators (or lifts) not intended to carry People or live Animals, but for Objects.

Small lifts installed in Hotels' Kitchens for transferring cooked hot food, raw materials etc. to various pantries at all floors in multi-storied hotels, large households, marriage halls, restaurants, etc. Dumbwaiters for kitchens are usually made of stainless steel so that they are not affected by steam, hot food, water, etc.

Dumbwaiters are also used in hospitals and departmental stores to carry stores to various levels in the building. These can also be of S.S. or M.S or GLASS.

PARTICULARS OF LIFTS

1) Type of lift (Passenger, goods, service or dumb waiter)........................
2) Number of lifts required.....................
3) Load: number of persons...............kg......
4) Rated speed.....................m/s
5) Travel..............................m
6) Serving...........floors......entrances.......
7) Number of floors served.....................
8) Method of control..................(*see* **7.2**)
9) Position of machine room..................
10) Sizes of lift well(s)....................
11) Position of counterweight..................
12) Internal size of lift car.....................
13) Construction, design and finish of car bodywork..............................
14) Car entrances:
    a) Number, size and type of doors
    b) Power or manual operation
15) Car light..............................
16) Call indicator..............position indicator in car........................
17) Lift Landing Entrance:
    a) Number, size and type of doors or gates or shutters (for goods lifts)
    b) Location of landing entrances in different floors, if the car has more than one opening.
18) Electric Supply:
    Power..................volts ac/dc...............
    phase..................
    Cycles............, wire system..................
19) Whether neutral wire available for control circuit?
20) Lighting..............volts ac/dc..............
    cycles.................
21) Are premises subject to Lifts Act/Rules?
22) Proposed date for commencement on site........................
23) Proposed date for completion..................
24) Additional items, if required....................
25) Booklet giving complete details of maintenance schedule and circuit diagram where so specified........................