Principles and Applications of Building Science
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Lecture – 13
Building Acoustics – Basics

In this module we will look at the Basics of Building Acoustics. We will talk about basics of sound, what fundamental things need to be understood before getting on with environmental acoustics as well as building acoustical design. We will primarily cover the basics of sound waves.

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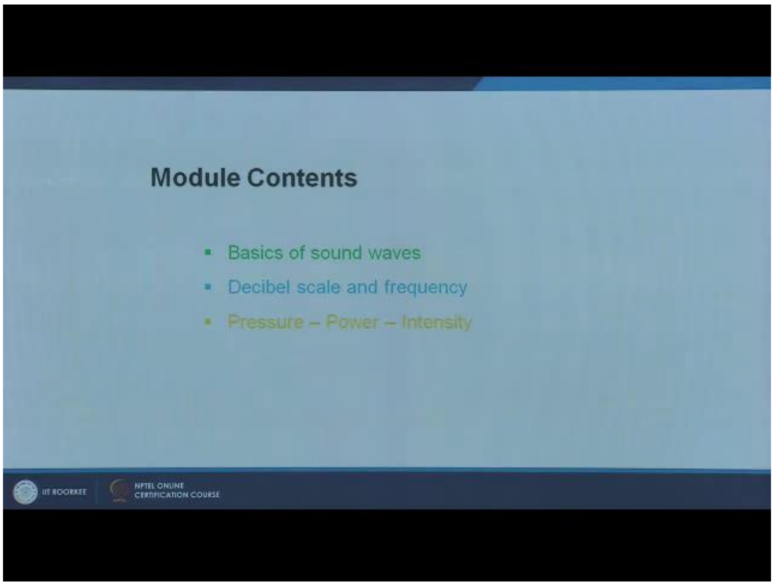

We will talk about the decibels scale which we commonly refer as dB sound is expressed in decibels, and the frequency spectrum, sound spectrum. Then we will look at the difference between sound pressure, sound power and sound intensity.

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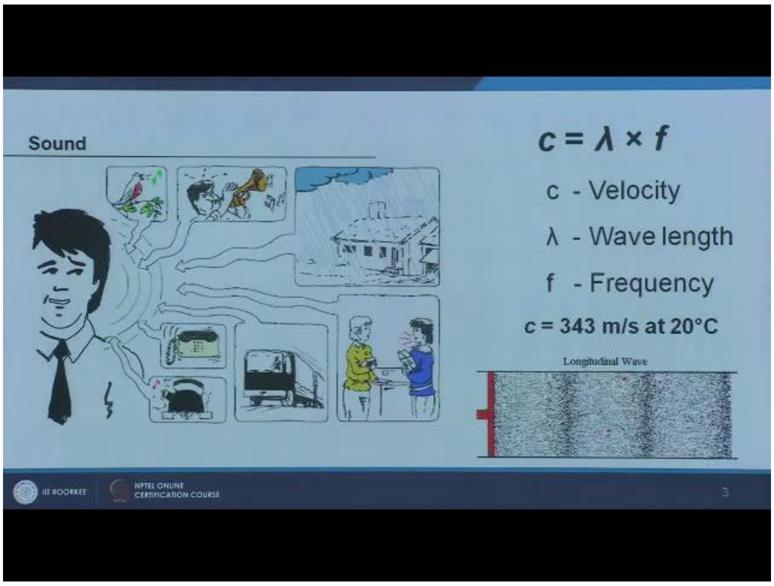

So, as we know we deal with sound in the in terms of wave propagation it is a longitudinal wave. We have compressions and rarefaction some propagates as longitudinal waves. So, we have three parameters; one is a velocity which is dependent on the wave length and frequency of sound, at room temperature typically it is around 340 to 343 meter per second that is a velocity of sound. So, velocity as well as wave length and frequency they are related in terms of velocity is expressed as wave length in to frequency. So, what is sound? Typically it is a compression rarefaction, it is reaching you by propagating through a medium we studied the (Refer Time: 01:36) experiment during our school. Sound does not propagate through vacuum, so it needs a medium to propagate. Then properties of the medium as well determine the propagation of sound.

So, there is a sound source, there is a path and there is 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. Typically we call it air borne or when it propagates through the structure we called structure borne. Then it reaches human ear where the ear is the receiver. So, three components typical components are involved as per sound is concerned. When the sound level exceeds certain threshold value we perceive it as noise.

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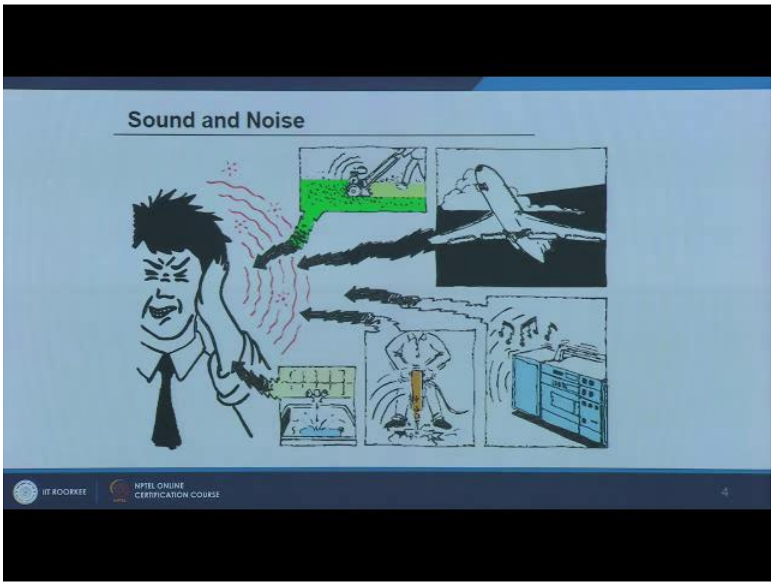

Typically it is unwanted sound or undesirable sound. One person sound can be other person's noise, so the threshold typically varies depending on the source depending on the path and depending on the receiver, the nature of source as well. Velocity of the sound depends up on the density of the medium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

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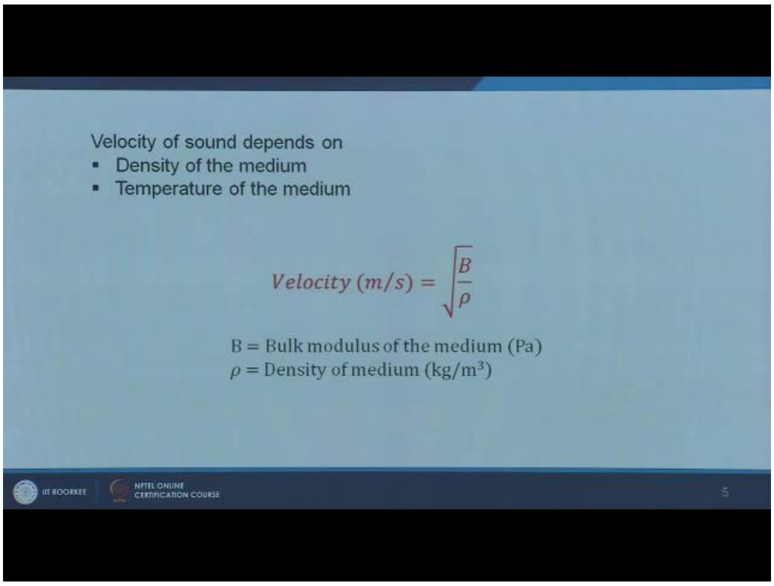

Typically it you need bulk modulus as well as the density of the medium. Then you can talk about the velocity. As well there is a similar equation or expression which relates temperature of the medium with the velocity of sound.

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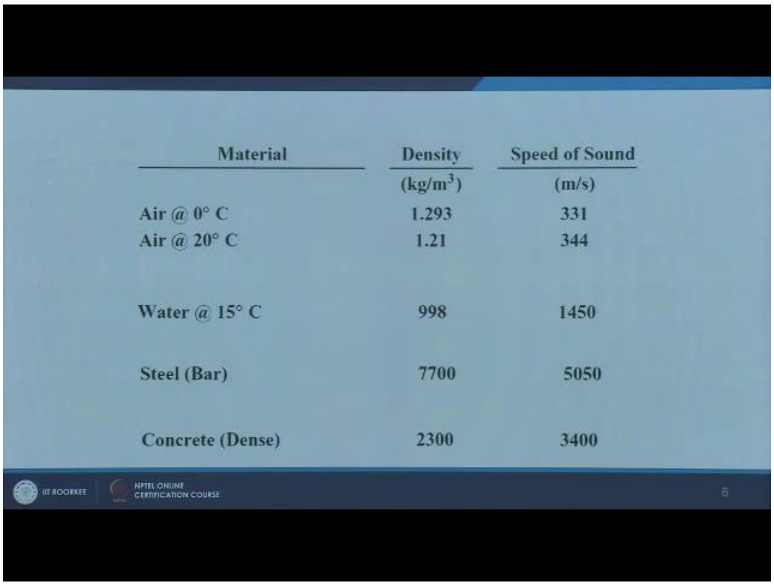

Material	Density (kg/m^3)	Speed of Sound (m/s)
Air @ 0° C	1.293	331
Air @ 20° C	1.21	344
Water @ 15° C	998	1450
Steel (Bar)	7700	5050
Concrete (Dense)	2300	3400

If you take simple examples air at 0 degrees, density is close to 1.3, speed of sound is around 331 meter per second. As you increase the temperature further the speed of sound slightly goes up. Water, the density is different it is higher, with the higher density the sound speed of sound increases. Take a material like concrete 2300 kg meter per cube. The velocity of the sound is pretty much higher than what you see in air. Material like dense material like metal steel bar with a high density then the speed of sound is really high.

So, how do you express sound? We always talk about sound pressure, sound levels, moment you say level it is like a comparative term. We do not always pressure is measured in pascals, but sound you know is not expressed in pascals. Typically you get to you know here terms like 40 dB, 60 dB, 80 dB. So, these are like levels not the direct pressure value.

So, why do you need to develop this first? When there is a wide range within which the numbers are varying. For example, in this case of sound which we are talking about human ear can perceive quite a wide range of sound pressures. So, this kind of pressures this wide variation in pressure if you are expressing directly it is a too much of long numbers, say it ranges from 10 power minus 5 to something like 10 power 3 in terms of pascals. So, we need a relative term to express.

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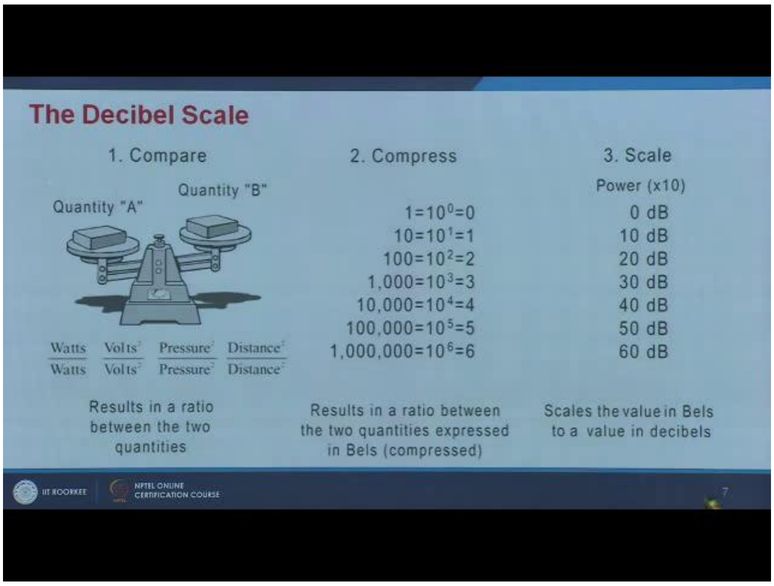

So, we always express quantity A and how much quantity B is in terms of relative. In relation two quantity A, so if it is watts there is a reference watt, if it is a pressure there is a reference pressure. So, typically we are expressing it as ration. So, then we can compress it and then scale it. In this process we are comparing compressing and then scaling it so we end up with the decibel scale that is what we call as dB. We will look little more in detail of this.

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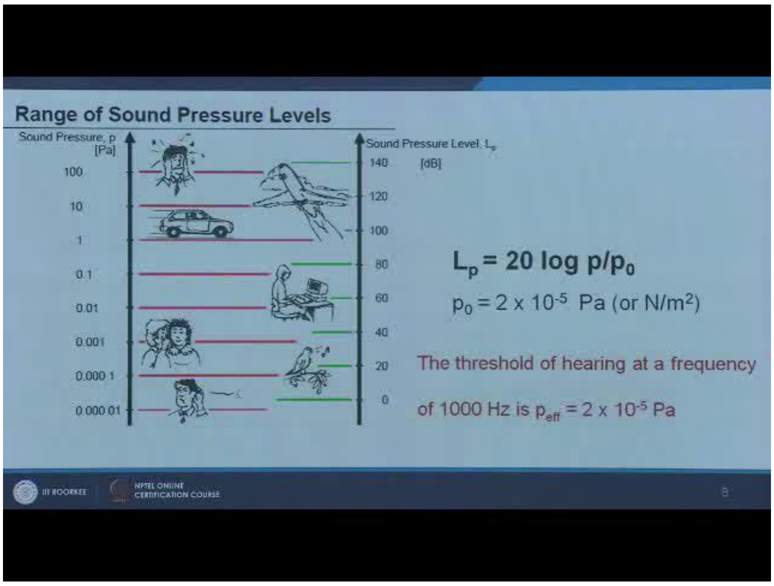

As I said the minimum perceptible sound levels varies somewhere as slow as 10 power minus 5 pascals and it can go you know as high as more than 100 pascals. Of course, you will have hearing related problems there will be short term long term impacts if you are exposed to very high sound pressures.

So, in order to simplify this range you are expressing it in terms of decibel, the minimum audible or perceptible sound level is a scale that is the scale a that we looked here quantity A then we are waiting it with respect to what the actual sound pressure is. For example, like a whisper this is 10 power minus 3 if you express it in terms of dB it would come somewhere close to 30 to 35 decibels.

Like a jet propulsion it will be around 10 to 20 pascals it can be higher than it will relate to around 100 decibels. So, this is what actually we are doing in terms on converting pressure in terms of pressure levels. There are other terms like power and intensity we will look at them. So, the basic thing is we have L p, moment you see L this is level, p is pressure and this is sound pressure level this is equal to 20 log p by p reference p naught is p reference which is in to 10 power 5 pascals or Newton per meter square. This is a threshold of hearing at 1000 hertz frequency.

We will talk more about frequencies, this is like typically a center frequency we call or we will look at frequencies more in detail. But this is what it means this is the p reference or the minimum threshold of hearing, below which you cannot here. So, this starts from

0 and then goes all the way up to. It can be as high as one 40 dB or further more you will actually start losing your hearing ability if you are exposed to very high intensity sound or even intensities of around 100 110 dB for quite a longer duration there will be temporary and permanent hearing impairments.

I am going to show you one example, this is a physical measurement of sound that we took and then we will proceed with what are the terms and parameters that we need to look at.

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As you see in this graph this is a sound pressure level this is on 22nd October it is 2014, what you see here is sound pressure level there is dBA I will come to this term a little while couple of slides this would come, this is decibel sound pressure level and what do you see here is the time. So, this is somewhere from 5:45 to 6:5, this is 20 minutes recordings here you will see the following thing this is like split in to 20 minutes this is the first 20 minutes this is the second 20 minutes the same day. This is the environmental or ambient noise level recorded from a terrace of a house.

What we find here, the sound pressure level somewhere varies around 55 decibels, dBA here. Typically this is a suburban area residential area. So, there are not many extra you know extensive noise sources it is around 55 decibels dB, this is a CPCB central pollution control board limit, I will show you the you know desirable limits that they have given or permissible limits they have given. So, CPCB limit here.

So, around you know 5:50 there is a slight increase there are certain high intensity sounds, certain continuously increasing sounds I have highlighted some of them. As you go in time there are lots of peaks whatever I have shown in dots versus these stars. So, eventually if you see as the time grows ideally as the time increases like you go from 5:45 you go down to 7 o clock 8 o clock in the night, ideally the sound pressure level has to come down because the vehicle or traffic would come down after the peak hours it has to decay down. In this case what happens there is a slight increase here it has gone up above the limit which is prescribed then it is going further up here, here you are getting something close to 85 dB.

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Around 6:45 it is touching 95 dB you are also getting continuous levels here plus certain peak values. Around 7:30 you are getting sound levels as high as 120 dB. You are wondering what these numbers, you know what these things correspond to which recording it is. It is a residential area in a suburb it is a Diwali.

So what happens here, it was quite here at this point people started doing the crackers these are like continuously cracked, these are like rockets specific instances of crackers. You get as high as 120 decibels some of these sounds are that intensity. This is what actually we do. This is a pollution control board limit. Every year you get to see this in newspapers like, this much level it went up to up above the prescribed level. Of course, you also have the air pollution levels going up.

Just to touch space we were talking about sound pressures and sound pressure levels. This is typically a man made event, series of manmade events we are experiencing somewhere between 55 decibels to as high as 120 decibels in terms of sound pressure level just to touch space of what it actually is. Now is this all enough to understand about the sound pressure and sound pressure level the characteristics of sound. Already we had a good indicator of how much variation the sound itself is causing.

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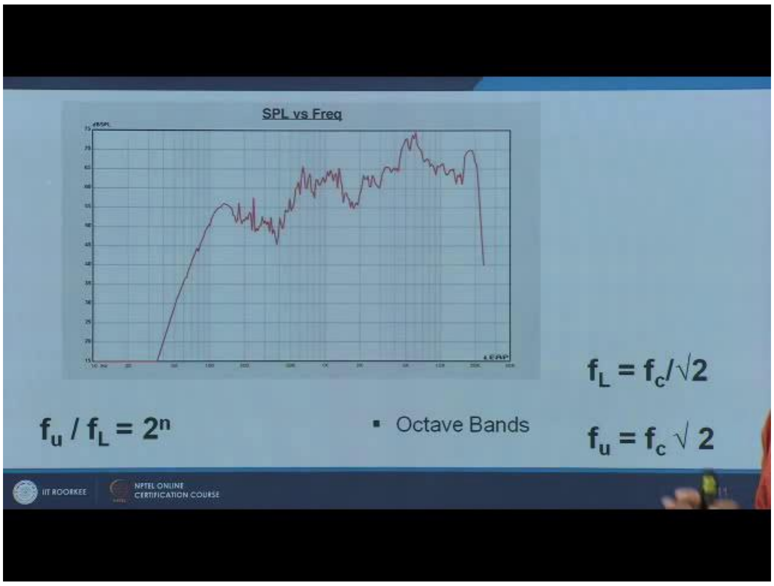

But sound is like wide spectrum within which lot of variations can happen. In order to get a closer look of the characteristic of the source itself or the propagating medium and the receiver characteristics we need to split it in to specific segments which we call as frequency spectrum. There are different types of frequency splitting; the simple thing or most common thing we use is octave band that is 2 is to 1. So, you have a center frequency for example, you have a central frequency of 500, the next central frequency would be into 2000, then it would be 2000, 4000.

Typically our interest would lie somewhere between 31.5 hertz to 16,000 hertz and some cases it would go from 16 hertz to 20,000 hertz or 20 kilo hertz. This is typically for building applications we refer from 63 and half hertz on the lower end that is of low frequency it can go as high as 16,000 hertz, but mostly we stop around 8000 hertz for our specific observation. How do you split this octave bands? As I said different types this most commonly used is octave band. If you want to further split it up you can split it up to third octave bands. So, each octave get split into three I if I have you more details about it.

So, using this simple relations you can find out n is a which octave, it is this is upper limit and lower limit of the spectrum, then if you want the center frequency when I was taking about 500 hertz 1000 hertz these are center frequencies of bands. So, if you want the lower limit from the center frequency you can find the lower as well as the upper limit.

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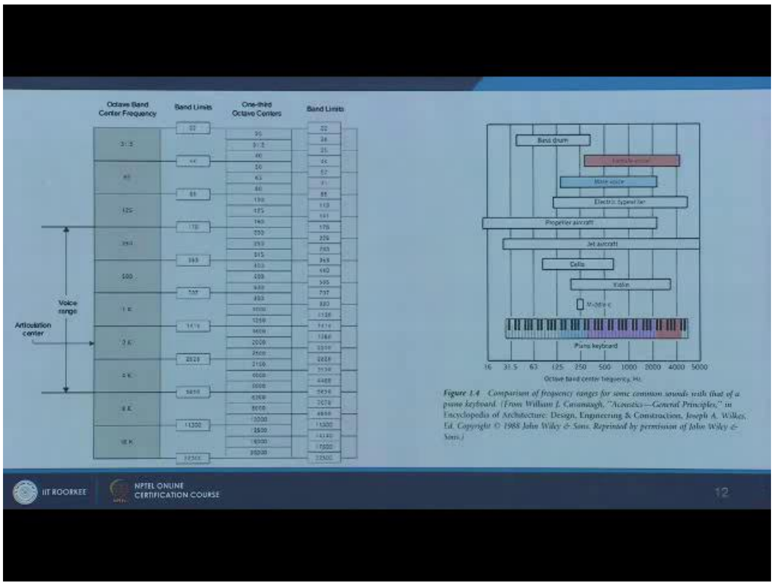

So, what is all about this octave and third octave? Let us start from say 31.5 we will go up to 16 kilo hertz, so this is one band in this band the upper limit is 22 to 44 hertz, if you split that further in to three octaves so you have one third octave band where 25 31 and half and 40. So, three center frequencies are obtained. Then the next frequency is 63 that is this in to 2 which we saw earlier this is single octave in to 2 then you get this you can split it further in to 3. Then you have 125 all the way it goes to 16 kilo hertz.

Now while splitting the single signal in to multiple spectrums what we actually obtain, we are able to find out which source has what type of characteristics. Now talking about this not all sources have similar frequency characteristics if you look at this is a piano keyboard like any instruments if you are able to appreciate music you will know you will be have a low mid and high frequencies, typical piano keyboard this is what you know you will have the middle see and just spread of it.

Each instrument, each source, any particular noise signal sound signal we will have a frequency spectrum. If you take violin for example, the prominent frequency lies somewhere between 150 hertz it goes up to close to 3500 hertz. On the other hand, if you say a bass drum this is a low frequency side. Typically music systems we talk about you know woofer and twitter; twitter goes on the high frequency, woofer goes on the low frequency we will start feeling the vibrations itself. The bass drum gives you more in the low frequency, whereas violin gives slightly on the mid and high frequency. Whereas, if you see something like a Jet Air Craft take off you have a 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.

Now, look at this it is like male and female voice; male voice slightly goes to the lower frequency spectrum it is start somewhere from 120 5 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 spectrum than 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 on the wave length of the sound 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. So, if you have to design a say for example, a indoor acoustical design has to be done you have an auditorium or a classroom, you have to really understand which frequency there is a prominence of sound mean, which prominent frequency the sound is getting emitted. Only if you know that you will be able to give a proper treatment. Similarly for a environmental noise you want to design a noise barrier you want to arrest the sound you want to do sound proofing the first idea you should have is about the sound pressure level, how much intense the sound is. And number two which frequency is 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.

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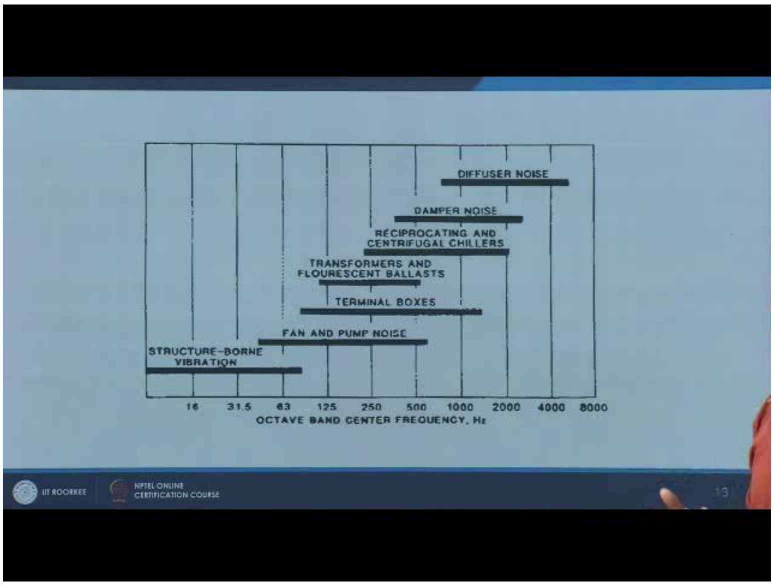

In continuation with the previous slide I have put certain frequencies, the frequency spectrum of some of the mechanical equipment. This is a octave band again here you find different mechanical equipment these are associated with air conditioning system HVAC system, it starts from fan and pump noise typically fan and pump noises lie in the low frequency spectrum. It can go as low as31 and half to around 500.

Imagine you want to provide treatment for a fan or pump, if you find that the fan is emitting more than desirable noise then if you have to provide treatment your treatment material as well as the strategy should be attending to treat the frequency spectrum between 31 and half hertz to around 500 or say 1000 hertz. This should be your area in which treatment the material should be effective in this particular range, your treatment should hold effective here. On the other hand if you go with dampers or diffusers it is on slightly on the mid and partly high frequency ranges. Again the treatment that you need to give for diffusers or dampers should be on mid and high frequency ranges, you do not have to worry about the low frequency.

As the frequency levels further comes down if you can see the structure bone vibrations are present here. Imagine you are in your sound system you are going for a woofer there is a bass drum which is being played the woofer is really loud then you will start feeling the vibration. This is a typical thing you notice in PS systems as well some of the systems good in low frequency you will feel the vibrations.

These are typically structure borne vibrations when it comes to sound propagating through your building envelope or any particular structural system you can feel it in the relatively low frequency range. Some of these things are really not audible, say for example when it goes further below 16 hertz you will not be able to hear it, but you will be able to feel it. Instead of using a sound measurement you will be doing vibration measurements for really low frequency like 3 hertz 5 hertz and all that. These are not audible ranges; the audible range is between 16 hertz to primarily 16,000 hertz sometimes to 20,000 hertz.

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Getting back to our example these are the same crackers sound that we were talking about. Three different frequency spectrums I have put, this is 250 hertz, this is at 1000 hertz and this is at 8000 hertz. Different time lines indicated in different colors. To highlight why we need this particular frequency spectrum related analysis, what you find here at different spectrum the distribution of sound pressure level this is sound pressure level considerably varies. The same sound pressure level at different frequencies you will find a considerable difference as well as with respect to time.

In case you want to impose a regulation, you want to give a treatment you want to give protect or insulate a particular system or a building you will have to really have an understanding of where which frequency spectrum the sound is getting emitted.

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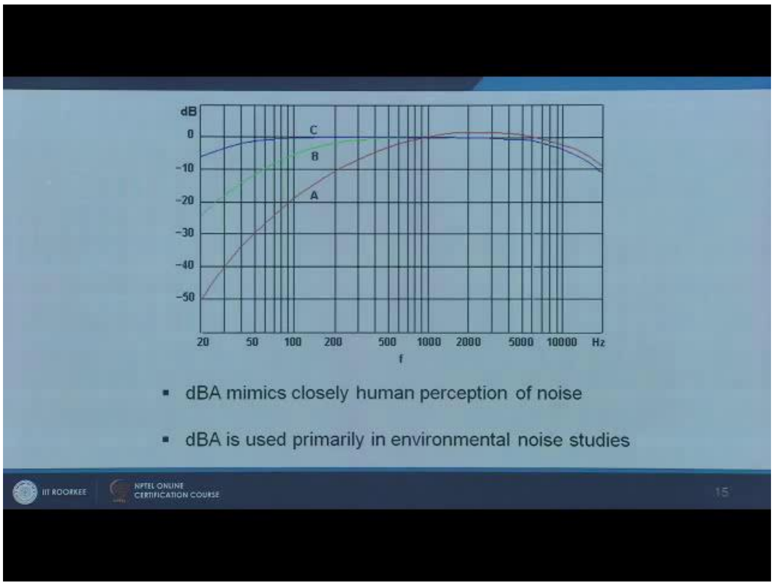

Now we were talking about the source characteristics. Let us take a look at the receiver characteristics. We had source path and receiver, moment you come to receiver that is the human ear; the human ear is not sensitive equally to all the frequencies. Let us take a frequency from 20 hertz all the way to 10,000 or even 20,000 hertz. The frequency spectrum in which the ear is more sensitive the ear is actually sensitive to 1000 hertz and above as it comes down below 1000 hertz that is as you go towards low frequency this is where you start perceiving. That is even louder sounds are perceived to be less loud. I am using the term loud I will come to that term in the next line.

But before that imagine you have a sound pressure of 100 decibels at 1000 hertz if you without telling you that this is 100 dB if I am asking a set of people to mark how much decibel it is or to tune another source to that particular level they will be most probably tuning it to more or less 100 decibels at 1000 hertz frequency. Imagine I am doing the same exercise at 100 hertz frequency or 120 hertz frequency the person is going to perceive it to be 20 decibels lower than what it actually is. So, you would be probably telling that this is a 80 dB sound instead of saying that it is a 100 dB sound.

As you further go down in frequency, say if you go as low as 20 hertz you are going to perceive it as just 50 hertz you know 50 dB sound at 20 hertz. What you know actually is in 1000 hertz the same 100 decibels here also it is the same 100 decibels, but you will perceive it 50 decibels lower than what it actually is. As you go higher there is a slight increase that is for example, a 2000 hertz the same 100 decibels sound the healthy human ear would perceive it slightly 2 or 3 dB higher than what it actually is. But they again after say 5000 to 6000 hertz it eventually starts coming down, not as low as this slightly lower. So this particular line this red line represents the response of human ear. This red line typically represents how human ear perceives sound.

So, there is a weightage factor here. As I said if you have 100 dB you can apply this particular curve and find out how human ear would actually perceive the sound. This is represented as A and that is what typically we call dBA. It can be written dB within bracket A or dBA. Typically it mimics how human ear perceives the sound. When I take a instrument when I measure the sound level the spectrum each frequency I am counting I am making a table after that the conventional way of doing it was I used to apply this correction factors at each of these frequency and scale it down or slightly up toward the human ear actually will be perceiving.

So, keeping this in mind a dBA scale today the sound levels meter today have a built in filter, so if you switch from dB to dBA they will apply this correction factor and tell you what dBA is actually. Sound pressure again is a cumulative number, you can measure it in different frequency and then integrate it to one number finally we call it dBA. When we are talking about different loud sounds, so you know sound at 100 dB at 1000 hertz versus the same 100 dB at 20 hertz they are not equally perceived as equally loud so we have a quantity called loudness. We know quite well about loudness.

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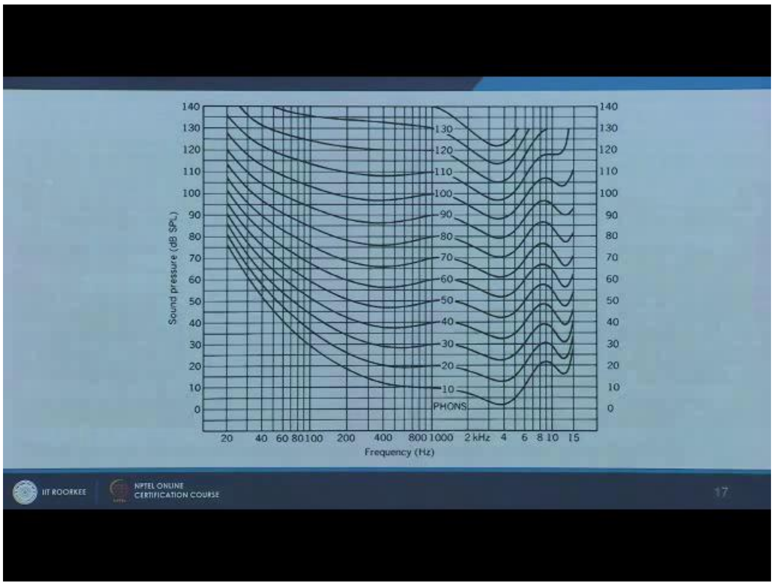

There is a chart which was proposed by Fletcher and Munson, he drew equal loudness contours at each of these frequencies how much the equivalent sound pressure level are, how equal the sound levels. For example, it is expressed in phones, this is frequency, you have the sound pressure level here and these are perceived to be equally loud. Say at 1000 hertz this particular say 10 dB, at 20 hertz even the 75 dB sound will be perceived to be equally loud as this particular number.

So, this is like equal loudness contour. In fact, this A and I did not talked about B and C weighting these are similar weightages used for specific applications say if you have to work with air craft noise typically you refer to be weighted some pressure level. C is more or like linear, we also refer to linear sound pressure level that is more or less unweighted sound pressure level there is no weightage. The actual thing is taken more or less we refer linear as z weighted C weighted is also more or less equal to the linear sound pressure level. There is not much of weighting which is given.

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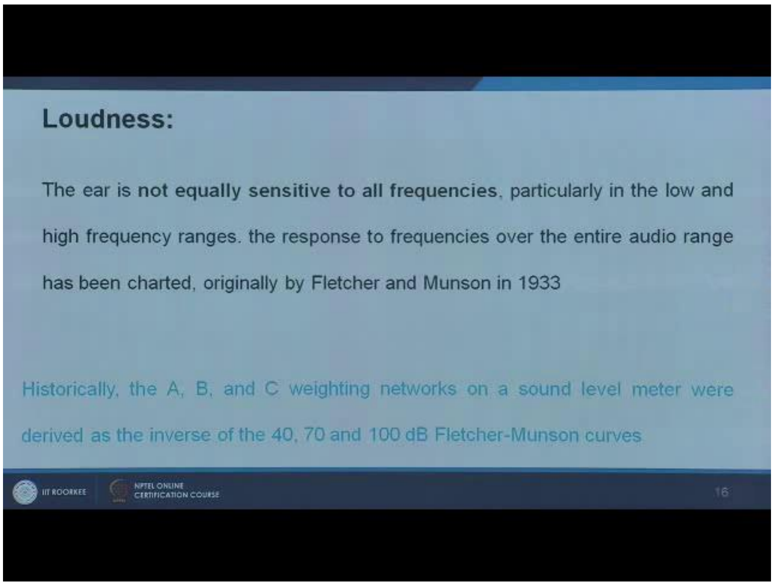

This A, B, C are other types of weighting are primarily derived as a inverse of this Fletcher and Munson equal loudness curve.

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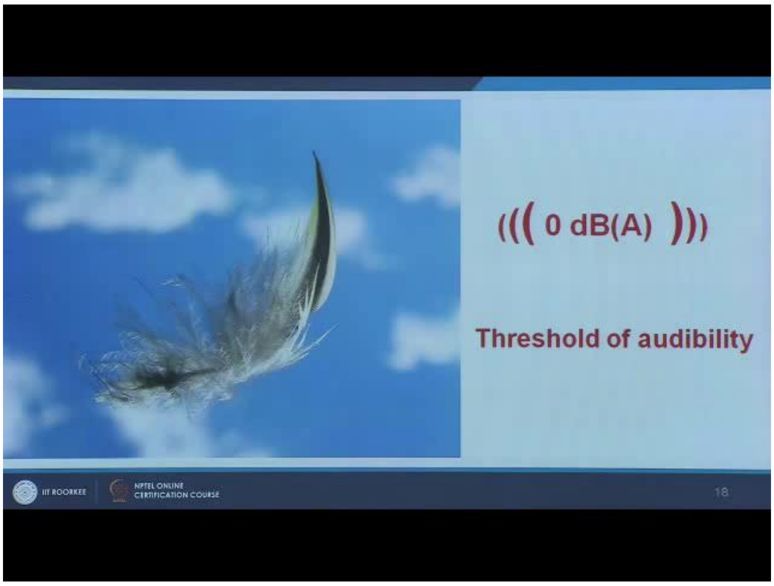

To quickly brush up the sound pressure level, the threshold of audibility typically you do not hear anything. There is nothing like you know even in a very peaceful quite environment you will not be able to measure 0 decibel, because air itself is exerting some pressure frictions. It will cause a minimum amount of 20 25 or at least 30 dB sound will be there present in any space.

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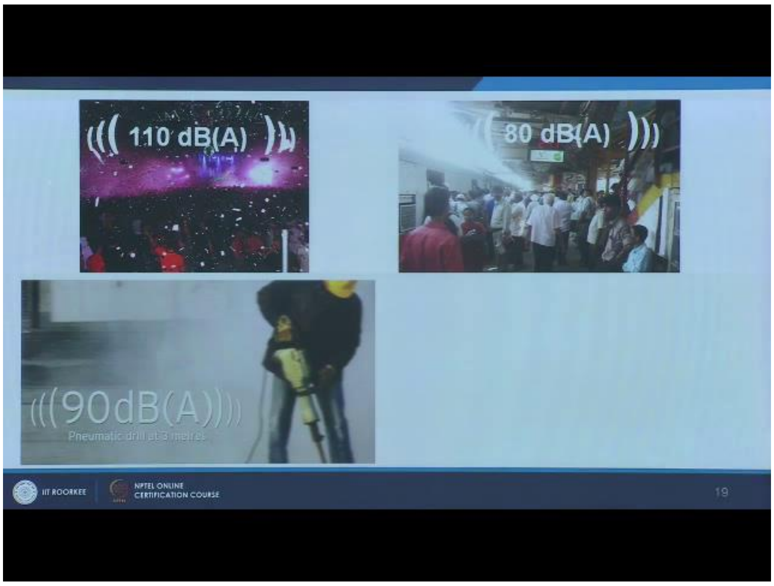

Then typically a rock show you can expect as high as 110 115 dBA. Railway platform and the train is stationery again when the train moves it is different it can go to 80 85 dBA. Pneumatic drill, I have put that at 3 meters as you get closer or as you get further the sound pressure varies. So, we will look at the distance corrections in a little while around 90 dBA. Typically an office environment you need it quite, when I say quite you will be expecting something around 35 to 40 dBA where you are at peace you do not get disturbed by any other sound pressure.

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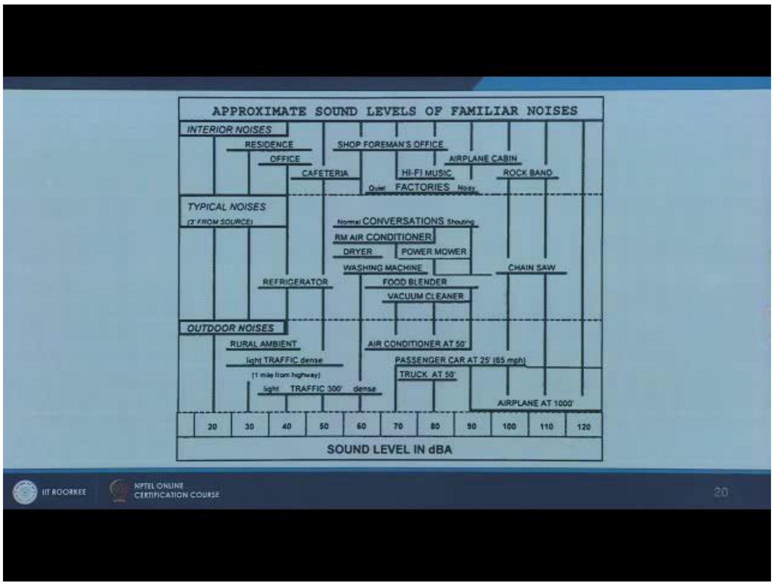

Typical sound levels, outdoor noises like rural ambient area it will be some somewhere between 30 to 40 dBA. And as you go up air plane at 1000 foot height you will still be able to find depending on the air craft and the turbulence's it can be somewhere between 90 to 120 dB. Typical house hold appliances like washing machine, dryers, chain saw is pretty you know it is a high frequency. Then it will also have higher sound pressure level. You have instruments within an air plane cabin rock band, hi-fi music cafeteria like you know this is for a quick reference you can build it with multiple sources.

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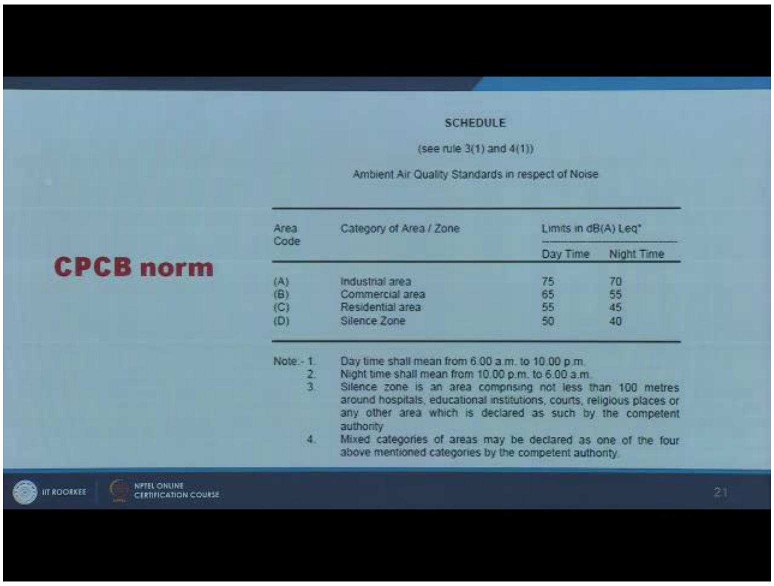

What is our pollution control? What is our pollution control we will talk about it gives a simple table where different areas zones are defined; four different zones are defined industrial area, commercial, residential and silence zone. Silence zone could be an hospital or a school. Limits of dBA sound pressure level Leq I will talk about Leq little while. They have given for day and night time typically for example if it is an industrial area day time can be maximum 75 dBA, it should not exceed 75 dBA, whereas at night time it should be slightly lower so 70 dBA. If it is like a residential zone day time maximum permissible is 55 nights time it should come down to 45.

See you are conducting a pro show in a residential area typically you will not be permitted as per pollution control board rules, because you are going to produce 80 to 90 dBA sound while the maximum permissible is 45. If it is silence zone day time is 50 night time is just 40 dB. So, that is why what the prescribed values are. Lot of outdoor activities need to comply with this. Simple example is you are working for a company there is a construction activity going on, you need to monitor the construction noise level both day time and night time, you are report it to central pollution control board only then you will be given clearance for your construction. There is a frequency every month every quarter you have to be reporting this noise levels. Typically for construction highway projects, even metro operations any train operation this things has to be measured and reported.

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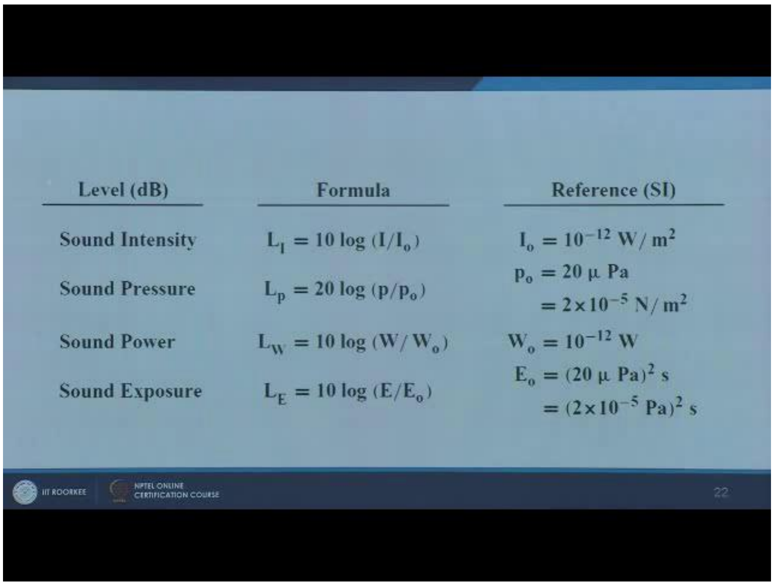

So, we also talked about three other quantities; first we were talking about pressure we also talked about intensity and sound power. Pressure we now know it is 20 log p by p reference; p reference is 2 in to 10 power minus 5 Newton per meter square. There are two other quantities; first let us look at sound power. When you buy a speaker typically for your music system you will ask how many wattage, how many watts your speaker is, so this is power. We will talk about the relationship first is sound power. So, again power in terms of acoustical terms we will refer it as sound power level. Sound power level is 10 log W by W reference W is a power; W reference is 10 power minus 12 watts.

Again you know it is relative scale intensity. In intensity level 10 log I by I reference again I reference intensity reference intensity is 10 power minus 12 watt per meter square. We will come to the exposure quickly.

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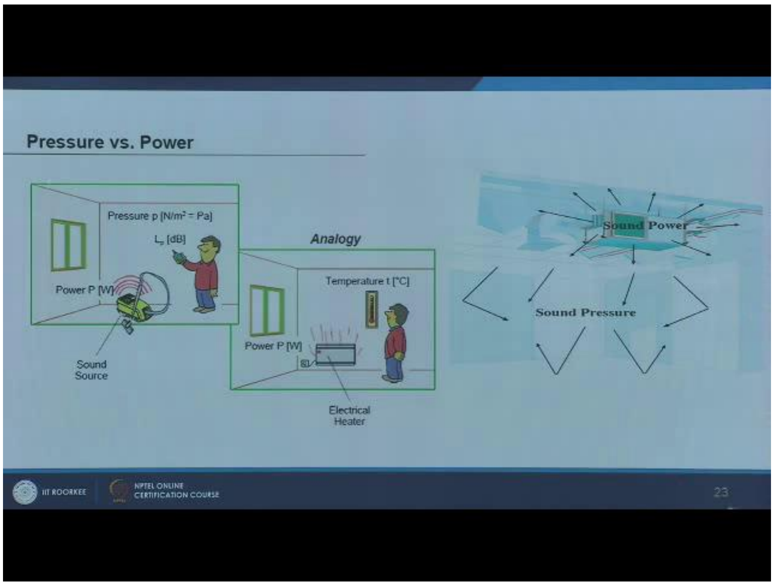

So, what is it differ from pressure and power? When you have a sound source it is having a power, when it is emitting there is a medium this is source this is path and it can be receiver can be an instrument or human ear. So, source path and receiver you perceive it as pressure. A simple analogy is you have a radiant heater it has certain power, power consumption we talk about it has certain power, it emits the heat radiant heat we are talking about the heat transmission heat transfer, it emits heat and then you start perceiving it through a censor or through your human body in terms of temperature.

So, this can be equated here, there is power here and what you perceive is pressure. It needs a medium in terms of compression and rarefaction it trans propagates and then it reaches you it causes your tympanum to vibrate in your ear which senses it as the pressure quantity. So, you have a 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.

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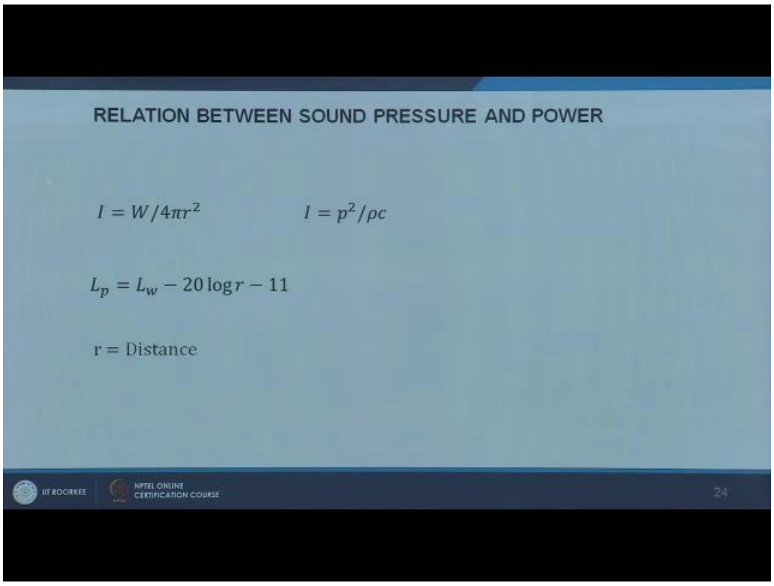

We will refer further to it as sound pressure level. We will look at some of the relationships. First let us take a look at how to find out the relation between sound power and sound pressure. First of all why do we need to know this most of the equipment say like I told you the speakers when you buy you buy it with the power rating, you have a fan, you have a mechanical equipment, you have a motor you have a pump any test you know certificate or the data sheet will give you the sound power levels.

So, first when you know the power you actually have it in the data you have to then calculate as an acoustician you have to calculate what the sound pressure is or sound pressure level perceived, because human is of importance where that is why we are doing this design calculations. Typically intensity is W watts per 4 pi r square.

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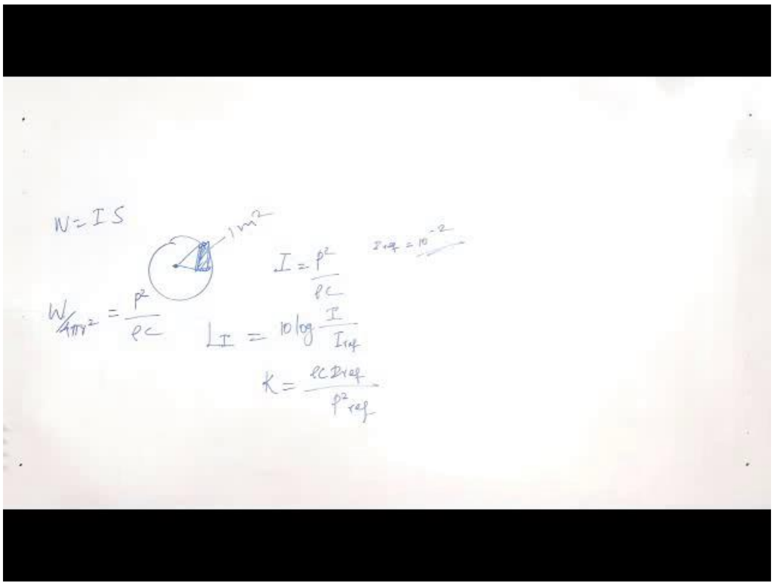

So, you take a spherical propagation you have the source here it propagates all across, so if you take a particular area then if you take the whole thing it is W by 4 pi r square this is where you can find the intensity. Then again similarly intensity can also be said as p square this is pressure, rho c is specific acoustic impedance, rho is a density c is a velocity so you get acoustic impudence here. If you equate this and this both the right hand side like just W by 4 pi r square will be equal to p square by rho c. If you take log and equate it you will get a equation like this L p that is sound pressure level will be equal to L W minus 20 log r minus 11. Here this is a sound power level r, here is a distance and this is a constant.

So, what do you understand now? If I am telling you that the sound power level of a particular pump or a motor is going to be 100 decibel. In terms of sound power level say if it is 100 decibel as a distance varies you are going to get a difference in the sound pressure level. You have to observe this is negative sign. So, as the distance increases the sound pressure level is going to come down, as you go further the sound pressure level will drop down there is a constant here. We will look at further about the sound propagation in the next module, but quickly this is a relationship.

Then the next thing is how sound pressure relates with the intensity. As we looked at here, intensity is p square by rho c rho c is specific acoustic impedance.

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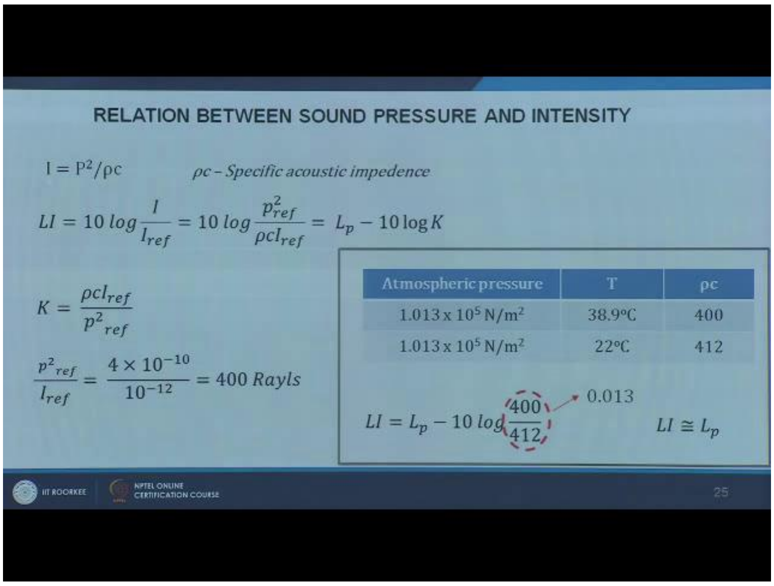

So, now, you can write this as if I want to calculate LI that is intensity level this will be 10 log I by I reference. This is a logarithmic scale, so if I need to if I know the intensity I need to find out the intensity level this will be I by I reference. We know that I reference is 10 power minus 12, this is a number here I reference is 10 power minus 12. Then this equation will become p square by rho c I reference. Let us keep I reference here, so this will become p square by rho c I reference. If you write it off you can term this whole thing as a constant called K which will be equal to rho c I reference by p square reference. This is reference intensity this is p square reference that is your s reference sound pressure. This is termed as K, take a negative sign this become inverse of it.

Now, we know both p square references as well as we know I reference, p square reference is 2 in to 10 power minus 5. So, if you substitute you will get the number 400. The only thing left is rho c if you want to substitute value for rho c you will need the pressure as well as temperature. Let us take air as a medium a typical atmospheric pressure let us take a temperature around 39 degrees you get a rho c value, this can be calculated rho c value is around 400 that is the acoustic impedance provided is 400, while the temperature reduces you get around 412 that means impedance increases.

So, if you substitute both these values say let us first take 400, if we substitute 400 here it is already 400 this will become 1, so the whole thing is 0. Now, LI will be equal to L p that is sound pressure will be equal to intensity. Even if the temperature drops down the rho c value impedance value goes up you are getting 412, if you substitute you will get something around 0.01 which is negligible if you take logarithm it will be a very negligible number, even then sound pressure will be more or less equal to sound intensity.

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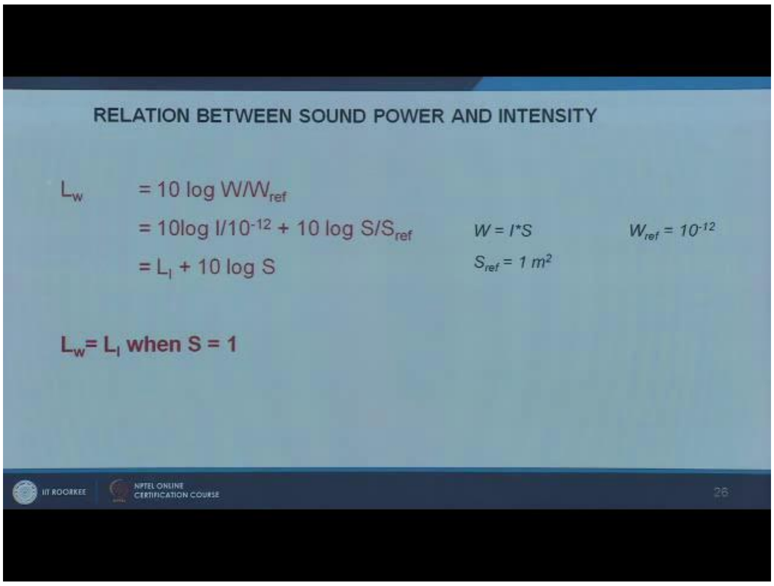

The relation between power and intensity similarly you have sound power level is W by W reference, W is the sound power by W reference again 10 power minus 12. This W reference W can be expressed as I intensity in to surface area if you substitute this number here it will become I by I reference in to yes, so this becomes plus 10 log of S by S reference. So, this will be surface area by reference surface area.

If you take reference surface area as 1 meter square typically if you say this particular patch is 1 square meter then this will be equal to LI that is sound intensity plus 10 log of S. So, indirectly what it means if the surface area is 1 meter square then sound intensity will be equal to sound power. So, this basic relation between sound pressure sound power and sound intensity we have to be remembering.

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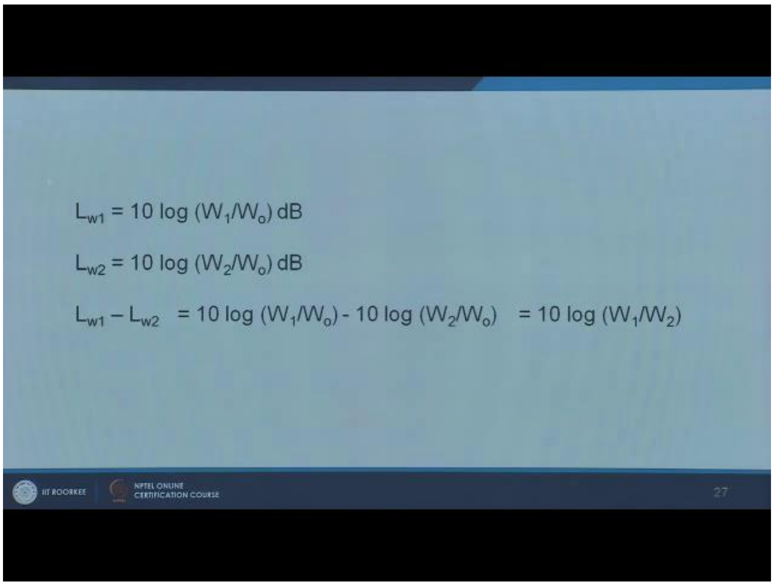

The last thing is how do you add or subtract sound power levels. So, you have 2 fans, 2 pumps, we will look more about decibels additions, but quick thing to look at you have 1 sound power level the second sound power level 10 log W by W reference. Say you will have W 1 and W 2, so you can find out two levels then you subtract it which ideally means in logarithm it will be W 1 by W 2. You know W 1 minus W 2, this is reference this is reference so finally W 1 by W 2. With this ratio you will be able to find what are the difference between l W 1 and l W 2.

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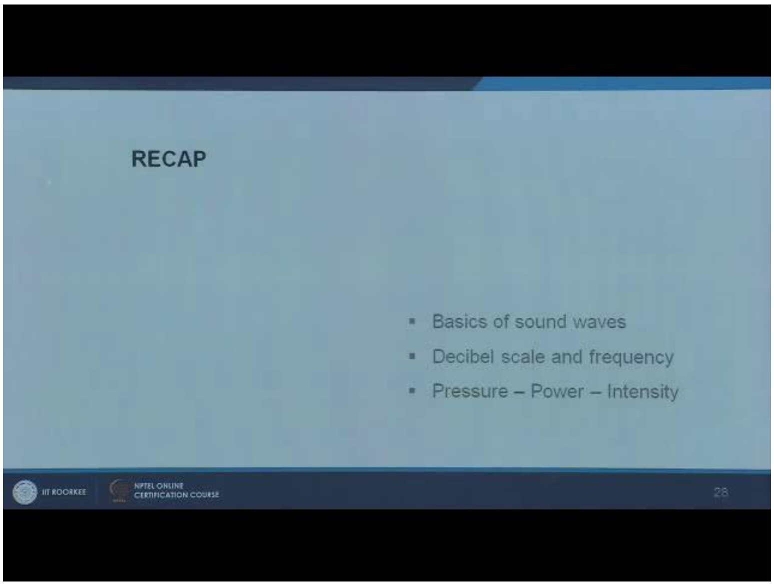

As a part of this session we looked at three important things; one is we talked about basics of sound waves, their propagation. Then decibel and frequencies levels, what is the decibel scale, why do we need it, and then what is the frequency spectrum how to calculate the limits of frequencies, and how common sounds have their frequencies spectrum. And at last we looked at three relations; that is the relation between sound pressure and power, sound power and intensity, and how they relate to each other.

Thank you.