Acoustic Materials and Metamaterials
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Lecture – 10
Principles of Noise Control

Welcome, to the last lecture of this week which is lecture 10. So, this is also the last lecture in the module for studying about the fundamentals of acoustics. And, after this lecture will straight away go and start studying the different Acoustic Materials.

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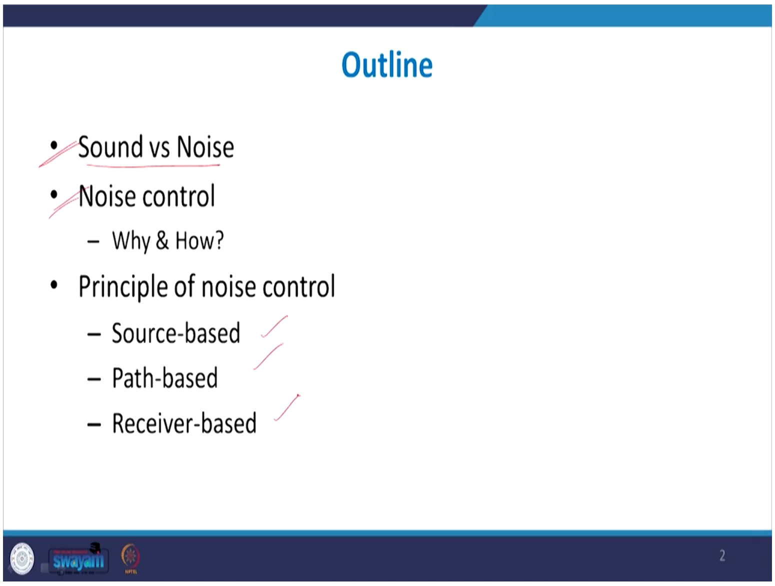

So, the title of this lecture is Principles of Noise Control and this is the outline for the lecture. So, first of all we will see so, why do we do noise control. So, we will see what is the difference first between noise and a sound and then we will study what is the basic principle of noise control.

So, it is source based, path based and receiver based. So, we will go through just the basic details without getting more in to the detail. So, we will only go through some briefly through the principles, because we need to know we need to have a brief knowledge about it. So, that we know what is the purpose of an acoustic material and how different acoustic materials prove to achieve different type of noise control. So, let us begin.

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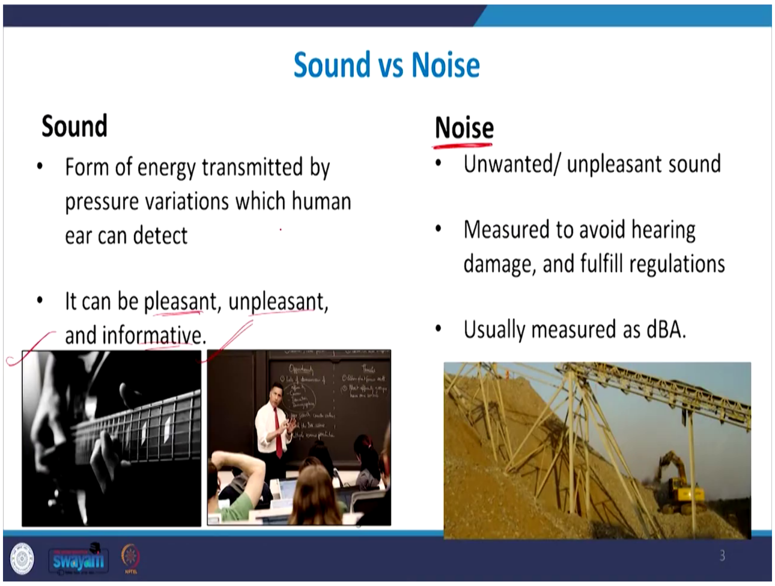

So, now, we know that sound in general is a form of energy that is transmitted in the form of pressure fluctuations, which reach our ear and this we sense as a sound. So, for example, there is a teacher who is teaching in a class and the students are sitting. So, the whatever sound that is coming out; the students are listening to the lecture and in that case we do not need to control this kind of sound. In fact, we need to make sure that the students can students are able to hear the teacher well; I mean provided they are good students they want to study. So, they would like to listen to the teacher.

So, this is not a noise for them they want to hear this sound, because it is giving them some information. In the same way suppose, we are some people are rock and roll fans, some are good music; some are fans of certain music bands. So, they go to their concerts and they listen to such music bands perform. So, such musicians performing; so, here also the sound that is coming from the instrument or their singing, that is not some unwanted sound they do not want to control such sound. In fact, amplifiers are used throughout the arena so, that large crowds can hear the sound at a very loud music; they, can hear such loud music.

So, there the sound becomes a source of pleasure. So, sounds can be pleasant, it can be unpleasant; it can be informative depending on what is the context. So, sound in general is just a form of energy, which reaches our hear and we get some sensation.

But noise term is specifically coined for that kind of sound waves which are not wanted and which are unpleasant, something that needs to be controlled. So, for example, let us say as a resident; I am living in my quiet home and a construction is going just next by and even at the night time the construction goes on the day time also. So, that noise becomes very irritating. So, it is so, that I do not call as sound that is like a noise so, it is unwanted for me. And, hence I would like to do something. For example, I if I have the money and the resource; I would like to soundproof my building. So, that no noise from the outside enters inside and it disturbs me so, such kind of noise becomes unwanted.

Similarly, in most of the machinery plants, manufacturing plants. So, the machinery noise from some of the component is really very rough sound, it is very irritating to ears and usually what people want is to do a quiet machine design. So, depending on the context some sounds, they are enhanced for example, music some or when so, when the auditoriums is designed or a classroom is designed it is designed so, that the human speech is enhanced. So, we can listen to the speaker or we can listen to some singer singing, but the unwanted machineries noise is something which is always done to control. So, that is the control that we do.

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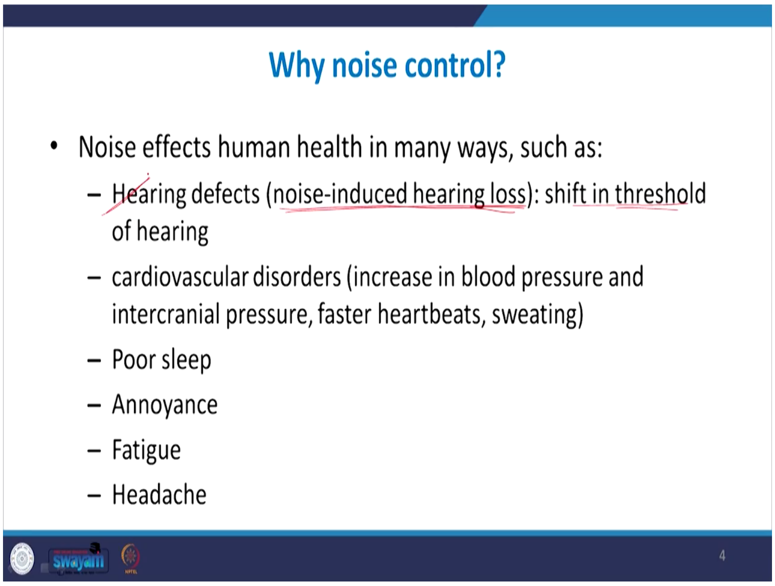

So, why noise control again? First of all, because not every noise not every sound wave is wanted. So, the noise first of all has got many harmful effects. The first effect which is very obvious to us is that, if you are listening to some sound and it is loud in nature, it can cause hearing defects. And a long term exposure of sound so, sometimes you see that some loud music is playing. So, once it plays you it feels like you know ear is paining or some loud construction is going on. But once the construction stops after a few hours, your ear regains to its original state and then you can hear fine. So, you think that, so, this was just a momentarily thing when then so, now, noise was there, then I was getting this discomfort in my hearing, but when the noise went away I can hear fine. So, why do we do noise control? But that is not the actual case.

If you are continuously or repeatedly exposed to such noise so, it has been found that this needs to noise induced hearing loss. So, with a repeated exposures so, suppose a person is working in a quiet environment and the decibel levels of his office space is between 60 or 65 not more than that. And, then we have another worker who is working in some textile loom industry. So, his every day expose to a sound that is more than 90 dBs.

Then over a few months or over a few years, what when you do their hearing test; you will see that the person who has been continuously living in a quieter environment will have much better hearing and the person who is been continuously living in this noisy environment, the hearing will start to degrade and he will not be able to hear quiet sounds. So, he his hearing threshold is going to increase. So, that is called as the noise induced hearing loss, it causes a shift in our threshold. So, many such hearing defects are caused by noise. And, other than that it also has many health effects.

So, high level of noise or continuous noise can lead to many cardiovascular disorders such as increase in the blood pressure or increase in the heart rate, faster heartbeats, sweating, etcetera. Then a night time noise is the prime reason for poor sleep and sleep disturbance and continuous noisy environment can cause annoyance and fatigue, headache.

It can also and specially like in the areas for example, a student who is in the library or you know in the classroom or the office workers, where they have to concentrate on a certain task and there is continuous noise or some intermediary noise. Then the noise will hamper with their ability to focus or concentrate. So, their performance is going to reduce. And similarly, noise always interferes with communication.

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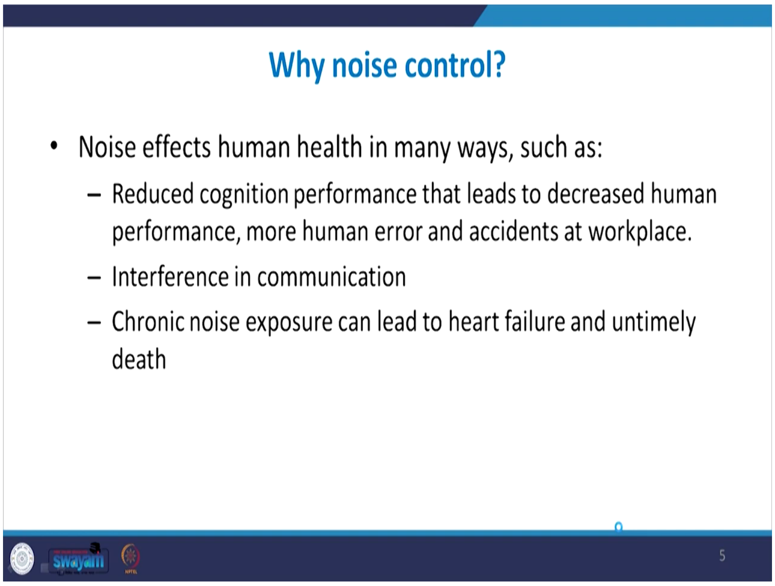

So, for example, again in the I will give you the example of a classroom; a teacher is teaching and you have some construction going out outside or a heavy vehicle passing by, the noise will interfere with the speech or the communication. So; obviously, in many such situations noise control is desired.

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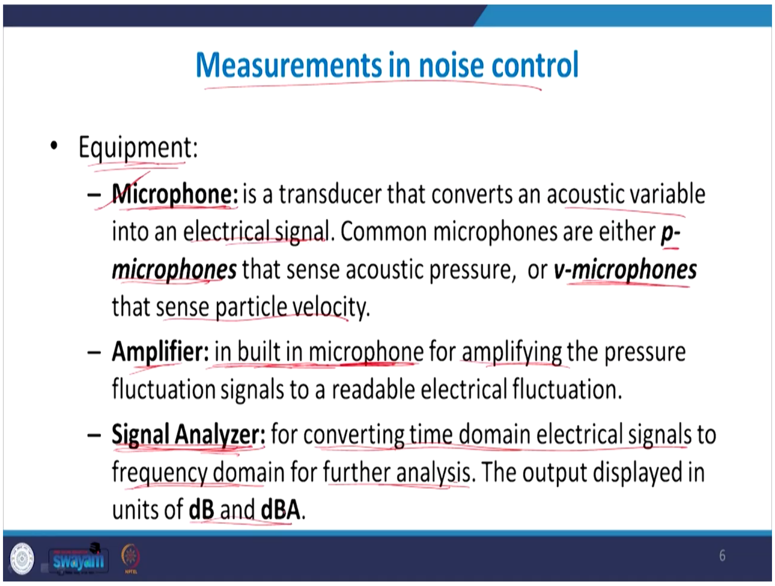

So, when we study about noise control and what are the principle of controlling noise; first of all we will study that what is the basic equipment used to measure the noise. And once the noise is measured and we identify these are the these are the sources which are creating more noise or this is the frequency, where the maximum noise is present and the control strategy can be devised accordingly. So, how to measure the noise? The basic equipment used for measuring noise is a microphone.

So, microphone is simply a transducer which converts an acoustic variable into electrical signals. So, acoustic variable; the most common acoustic variables are either the acoustic pressure or the particle velocity. So, we have both types of microphones; we have the p-microphones which measure a sense acoustic pressure then we have v microphones which sense particle velocity and then whatever value is measured is converted into a is converted or shown as a fluctuating in the voltage signals. So, it is converted into electrical signal.

Now, we know that the fluctuation so, this acoustic pressure or this particle velocity is a very small quantity, these are just very small minute fractions; to make the output more readable in nature we need a amplifier always attached with a microphone. So, in old days or some of the olden model, the olden model microphones so, though old model microphones they do not have a amplifiers. So, we have a microphone and then we have cables attached to it and then we have a signal conditioner or a amplifier. So, an external amplifier is added, because whatever signals we are getting to make the output more readable, because the fluctuations are going to be very minute small fractions.

To make it more readable, the entire fluctuation is amplified and we get a more readable output. But most of the modern microphones now, have a built in mic so, built in microphones with an amplifying so, they are in built in the microphones the amplifier. And, the third and then this microphone in amplifiers set up is then finally, this gives you so, microphone and amplifiers set up gives you how the that a particular acoustic variable for example, let say how the acoustic pressure is varying with time and it give some more some readable output.

But, we know that we need to do spectrum analysis to get a more detail of what are the frequencies where we have more most amount of sound or most amount of intensity. So, we need to have a signal analyzer and this does Fourier analysis. It converts the time domain electric signals to frequency domain which can be further analyzed. So, the output is a dBA spectrum.

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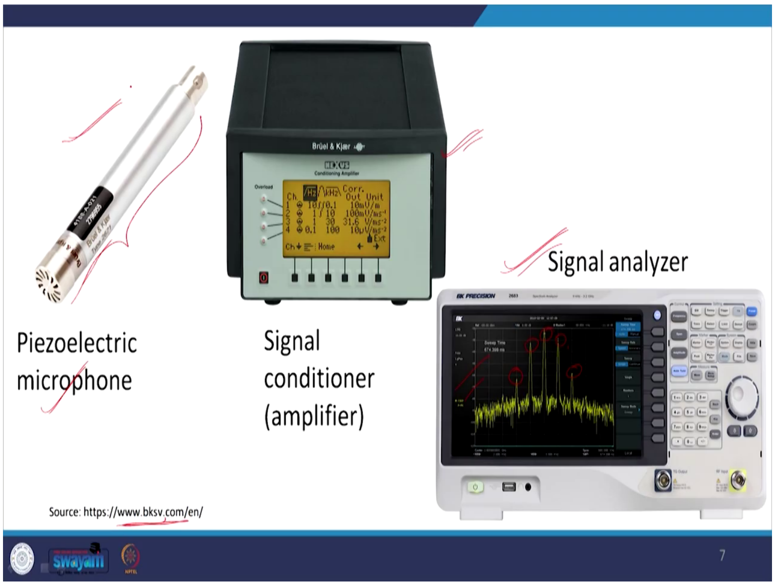

So, this shows a standard setup here. So, as you can see this is a Piezoelectric microphone, which here this the microphone that I am showing its a courtesy of BKSV. It is rule and care a very famous company, that manufactures most of the acoustic equipments. So, this is a pre amplified microphone with a pre amplifier. So, it is pre polarized we call it. So, it already has a amplifier built in, but even if it does not or if it has. You can always attach it to an external signal conditioner and apply certain gain values to get more readable output which is finally, attached to a signal analyzer where you can see the spectrum, how the decibels are varying with respect to various frequencies and you can point out that, these are the crucial critical frequencies which needs to be controlled and so on. So, you can look at the spectrum.

Now, having all these equipments together, it is very cumbersome. So, that is why for acoustic engineers the favorite equipment is the sound level meter.

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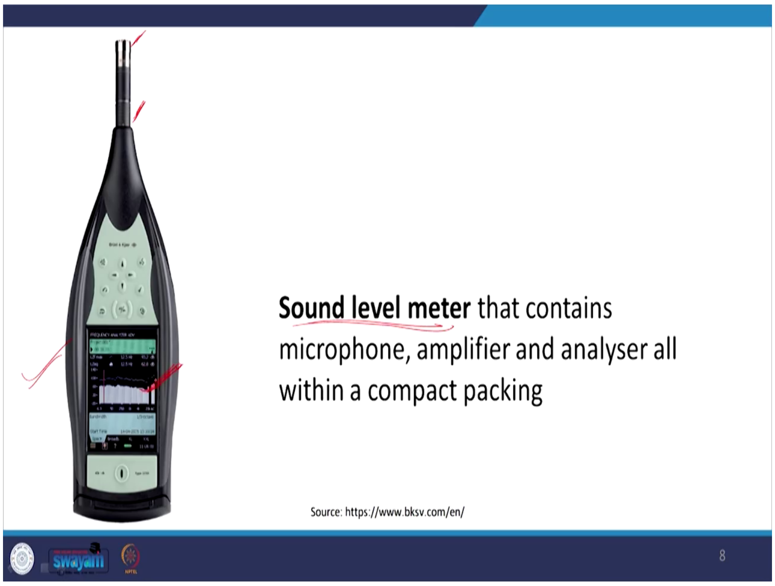

So, the sound level meter is all the 3 components combined together in a single small box. So, it is a portable way of doing sound level measurement. So, the microphone is here at the head which is pre polarized and pre amplified and then you have an inbuilt spectrum analyzer and you can see the output on the display screen.

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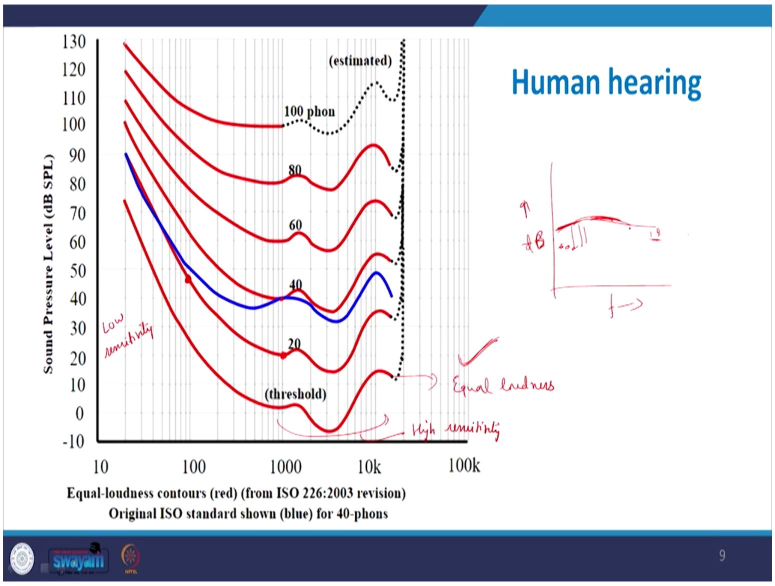

Now, as I had been pointing out before in, before that the human hearing it is frequency dependent. So, not all sounds they are heard at the same level. So, this shows this is the graph of human hearing. So, what it shows is that; this is the graph for equal loudness. So, a all the points within one single line will be perceived by the human ear to have the same loudness. So, as you see here at 1 hertz sorry; 1000 hertz, a 20 dB sound will sound like 20 dBs.

At 1000 hertz this is 40 dB sound will sound like 40 dBs, but if you go towards the backward side then you can see that at lower frequencies, let say at 100 at 100. So, a 20 dB sound sounds like a it is 20 dBs loud at 1000 hertz, but it is a 45 or a approximately 50 dB sound which is, which sounds almost the same loud as a sound of 20 dB at lower frequency.

So, the sensitivity is low here. So, this is the region of low sensitivity. And, this is the region of high sensitivity. So, you need a much higher magnitude sound to get the same sensation of loudness compared to, but even a lower magnitude of sound in this particular range will give you that much amount of loudness.

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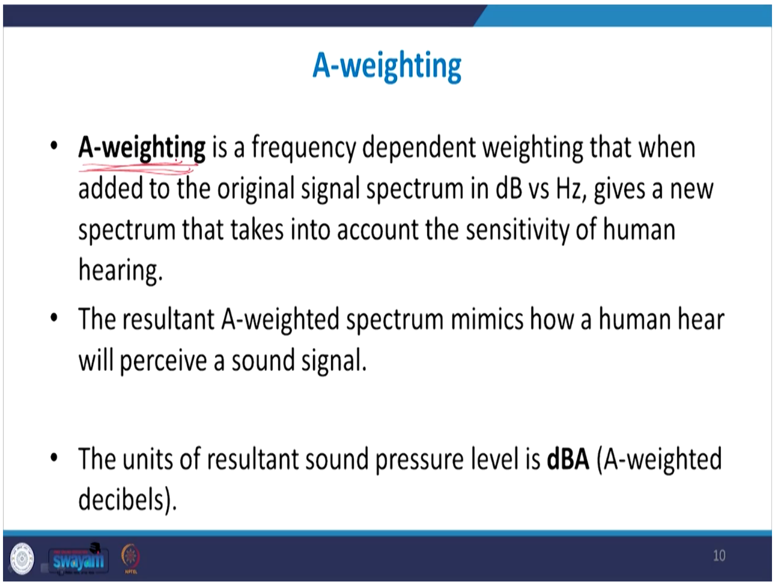

So, as you can see this is human hearing which is highly frequency dependent and that is why, whenever a spectrum of a signal is obtained; it is obtained as dB versus frequency. So, what we do here is that we apply a filter to these dB levels and that filter is called as A-weighting. So, this is the most common filter applied in noise control applications. So, what it does is that the function of this filter is that, as you can see here; suppose we have a constant spectrum or whatever spectrum we have; frequency verses the intensity in decibels. So, because this is the region of low sensitivity it will subtract those the filter will subtract the levels here and then a little bit of subtraction here and add the levels here to obtain an equivalent spectrum. So, the main purpose of applying this filter is to mimic, how the human hear will actually hear it.

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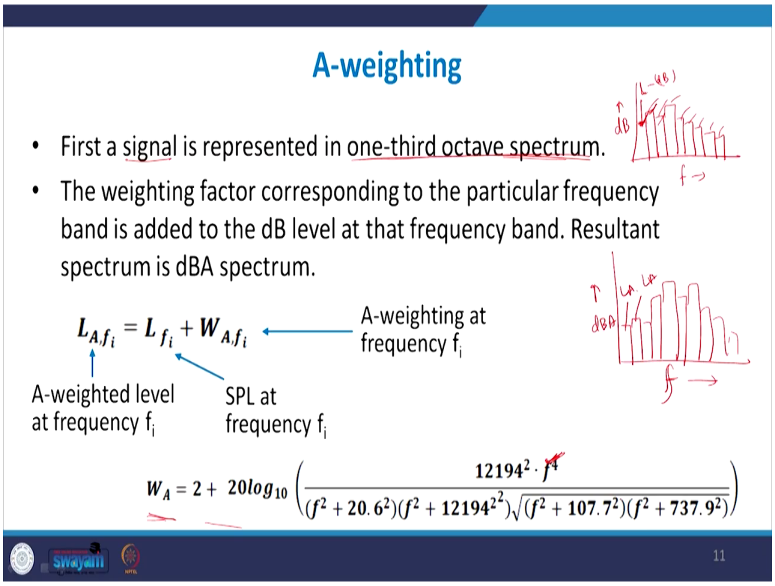

So, how it is calculated? This A-weighting; first what we do is that, we take a signal ,we represent it in one-third octave spectrum. Once it is represented is one-third octave spectrum which means suppose this is the original signal and whatever value we are getting one-third octave spectrum so, at every band we are getting some L as a dB in the units of dB. So, individual levels we are getting at the individuals band. Then what we do? We apply some weighing factor and this is the way to calculate the A-weighing factor so for every particular frequencies.

So, this is a frequency dependent weighing factor. Usually it has a negative value for lower frequencies, because that is the low sensitive region. So, you use this formula you get the weighing factor and then you add that weighing factor and those frequencies. So, every band you calculate the weighting factor and then you add that factor to the original level and then you get a new sort of level, whatever be the new level this is in dBA and this is in hertz frequency or hertz. So, now, these are the individual A levels at various bands.

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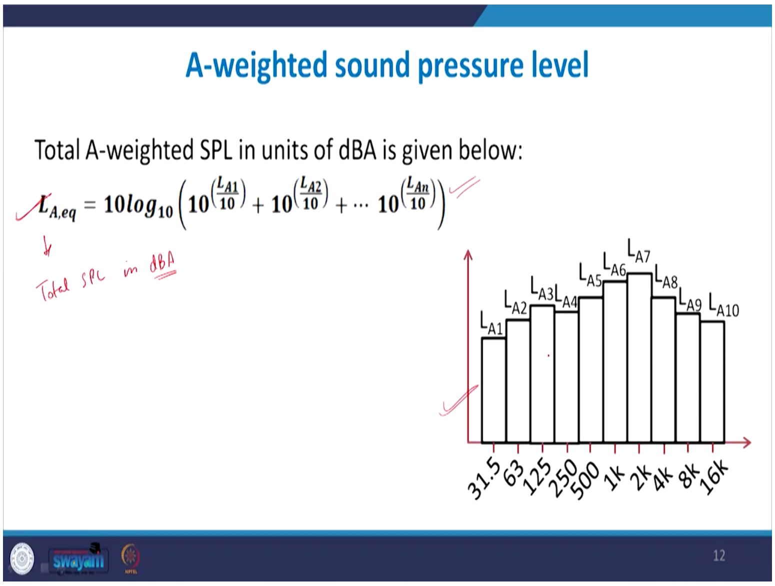

So, when you add them and then you can combine them. So, if this is the kind of resultant wave form you are getting so, you representing as one third octave spectrum and in the individual bands; you are adding some weighting factors then you are getting the A levels at individual bands.

Then we use the same equation that we derived in the last class on how to if we have different sounds at different frequencies and different levels the total equivalent sound becomes 10 log 10 brackets, 10 to the power L A 1 by 10 plus 10 L A by 2 by 10 and so on. So, the individual levels so, here A 1, A 2, L A 1, L A 2, L A 3, L A 4 these are the individual A weighted levels at the different frequency bands and they are combined together to get the total SPL, total SPL in dBA.

So, the take away here is that for the noise control applications, the decibel the decibel spectrum is converted into A weighted decibel spectrum by applying some different weighting factors at every band.

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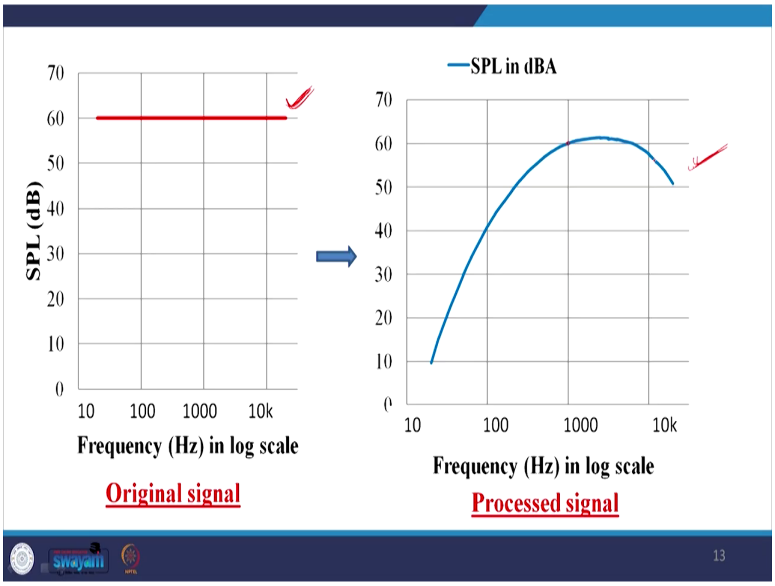

And, the purpose is to mimic a human hearing. So, let us see if we have some signal. This is a signal which is a uniform it is like a white noise or a 60 dB signal, uniformly distributed throughout all the frequencies and this is passed. Then if you use that formula for A weighing, A weighting factors we apply this a weighting then the resultant spectrum we get is this.

So, original dB this kind of dB spectrum gets converted into this in the A weighted A weighted spectrum. So, as you see this is more, this is more how the human ear will hear. So, although the sound may be something like this, but for a human ear it will sound lower at high at these low frequencies and then at exactly 1000. It will sound like a 60 dB and then it will increase and then decrease. So, it will it mimics how the human ear hear. So, low sensitivity regions the levels are minimized and at high sensitivity regions levels are increased. So, now, we have studied what are the instruments used, how the measurement is taken and how it is analyzed. So, it is usually analyzed as the dBA or the A weighted decibels varying with frequency.

So, let us quickly review, what is the principle of noise control. Now, we know that in the they are 3 main players in noise in any noise control problem. So, first of all we have a source; the source is generating the noise and then we have a particular path. So, the noise for example, if I am teaching here and I am speaking then my sound can be travelling to the listener either through the air. But suppose I am speaking and at the same time, I am tapping my foot then the structure will start vibrating the.

So, this tapping of the foot will be carried forward through structure, because a structure the foot tapping will then vibrate the structure that I am standing on and then it will be structure bone. So, there can be different way of reaching to the listener. So, there are different paths through which the sound wave can propagate from the source and reach the listener.

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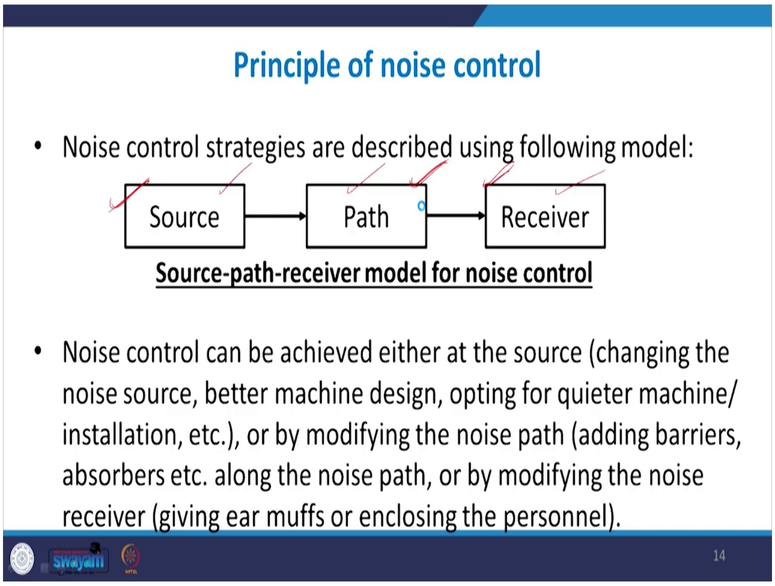

So, there are three main players we have. We have the source which generates the noise, the path through which the noise propagates and finally, it reaches the receiver or the listener. So, the noise control strategy is therefore, divided into source based, source based path based and receiver based. So, here what we can do is that, we can either apply some noise control at the source and this is probably the best practice.

So, what you can do? Let say you have a manufacturing plant you have some machinery installed and it is making a lot of noise. Even I will give you another general example; let say we have a car we have the typical IC engine car and the engine is the main source of noise. So, here the IC engine is making. So, there can be many ways to control this noise and make the car less noisy, but the best way would be simply remove that IC engine and put electric motor, make it electric vehicle.

So, here you are changing the source itself, you are modifying the source and when source changes then the noise stops being created. The generation of the noise is stopped at the origin itself and that is one way of controlling the noise. So, we are modifying this source, either we are changing the engine type or making it more electrical, because in general the machines that operate mechanically they are more noisier compared to those that use that are electrical in nature.

So, electric motor is more quiet compared to a mechanical IC engine. So, we can change the source itself make it more quieter or let see if you have in a plant, we have a machinery that is loose. So, it is a loose fitting machinery and it is vibrating and the vibrating surface is creating a lot of noise.

Then we can change the machinery we can install a new machinery which has no loose parts and therefore, no extra noise due to vibrating, due to the vibrations. So, this can be one way do doing noise control. Then the other way can be that suppose in certain situations we are not able to change the source.

Then the other way could be to apply some noise control treatment and the path. So, let us say I am a listener here, there is a receiver or there is a source and there is a receiver. We place some material in between, we place walls in between them. So, initially there was an in a manufacturing plant, we had a machinery and we had some personal working and it was an open, it was an open room then later some walls were created in between the machinery and the listener or the personal; then in that case these are blocking how the sound wave propagates. They are acting as a obstacle to the sound wave propagation so, these are path based treatments.

And, the third and the last resort is that we apply some treatment at the receiver end. So, maybe we can give him or her some headphones to cancel the noise, some ear mufflers and so on. So, these are the three basic ways of doing noise control; source based, path based and receiver based.

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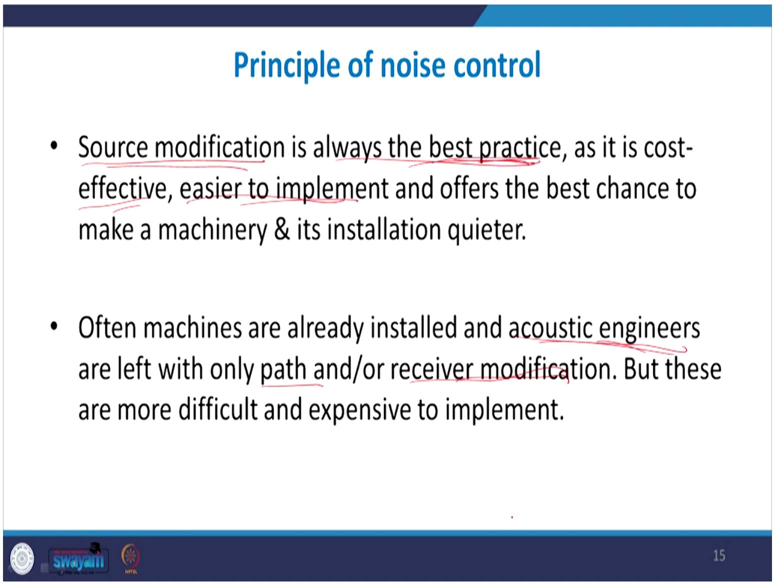

So, as pointed out the source modification is always the best practice, because here we are just cutting down what is creating the noise; the noise is reduced. So, this is the best practice the most cost effective and easier to implement, but it is not always possible to do it and in fact, most of the times the acoustic engineers when they come to a plant or a industry then the machinery is fixed and maybe it is, because of the limitation in resource that they cannot buy a new machinery or it is due to the limitations in technology that a quieter machine for that particular application is not available.

So, in that case it is then they left with path and receiver modification, which are more difficult and expensive; so, the most the best way is source modification.

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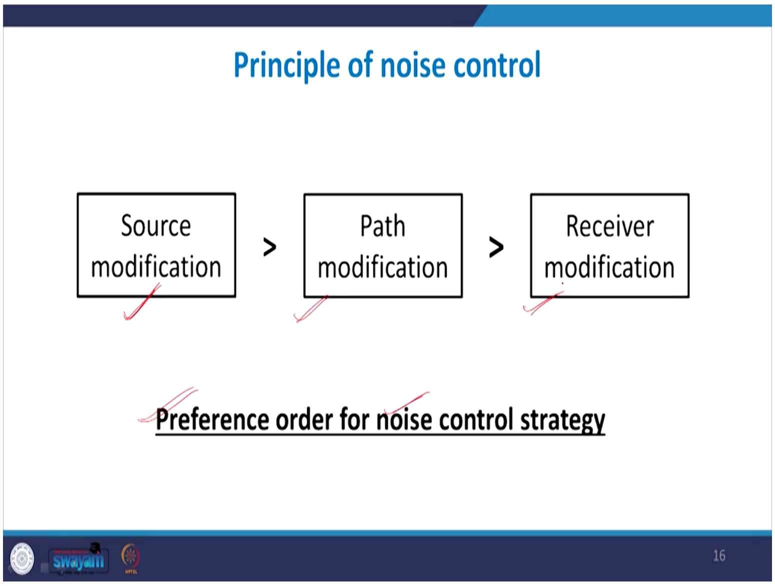

So, this is the preference order for noise control strategy. First start with source modification, then go for path and then go for receiver modification.

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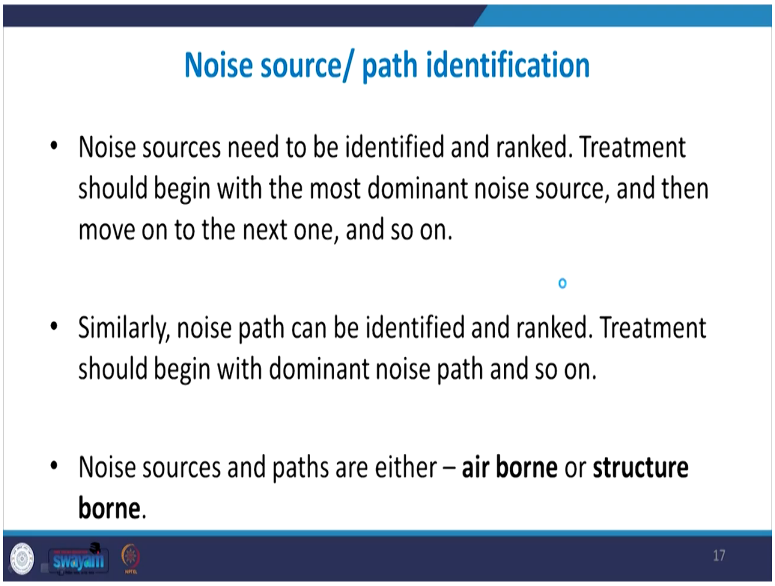

So, when we are doing the this modification, to do the modification; first of all we need to identify what are the most dominant noise sources and what are the most dominant paths. So, I will not go into the detail of noise source identification methods and noise path identification methods that are used and I will be I will in the slides and at the end of the course, I will be giving you a many reference books that you can do to so, some further reading on how this techniques are implemented. But the main idea here is that whenever you have to control the noise, then first of all you start by identifying what are the major noise sources. So, let say if it is a large plant with so many machineries and so many components all of them creating some individual noise, that you can start and you can start to measure what is the individual contribution of each noise source.

Then when you find out that, this is the most noisy source you start ranking them. So, rank one gives goes to the most noisy source followed by rank 2, 3, and so on. So, you rank them and then you start with applying treatment to the most dominant one. So, the most noisy source has to be controlled fast, followed by the second most noisy and so on and similarly, for the path the most dominant path the path through which the maximum sound intensity is propagated that has to be controlled first on modified first followed by the less dominant paths.

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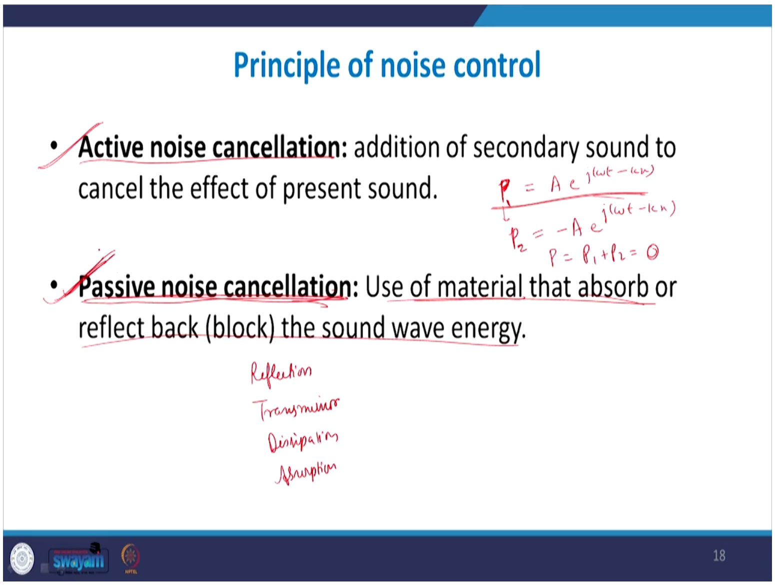

And, there are two major methods of controlling noise. One is active noise cancellation, the second one is passive noise cancellation. What is meant by active noise cancellation is that suppose we have some here we have a microphone and an actuator and a speaker to take it in general terms. So, the pressure is measured at the point where it has to be minimized. So, the measured pressure suppose comes out to be some A e to the power g omega t minus K X. So, the microphone can measure the pressure at that point and it can drive an actuating mechanism, which will generate a speaker and the speaker can then create a negative wave front, which is minus A e to the power j omega t minus k x. So, the total noise will then be P P1 and this is P 2.

So, it will the total pressure will cancel each other out. So, this is the typical active noise cancellation where the pressure is already; as the acoustic pressure is present they measure the acoustic pressure and then a negative amplitude wave is given to cancel out the effect of that. But it is very much dependent on the location and its very costly. In this particular course we are studying about acoustic materials and the acoustic materials they use the principle of passive noise control.

So, this is the noise control where materials are used. So, here no additional pressure is added to the medium instead some materials are given there as a boundary and then they control either the reflection, transmission and the dissipation, absorption. So, they manipulate the sound waves as it passes through the material and that is how the noise is controlled. So, this is what where the materials are used passive noise cancellation.

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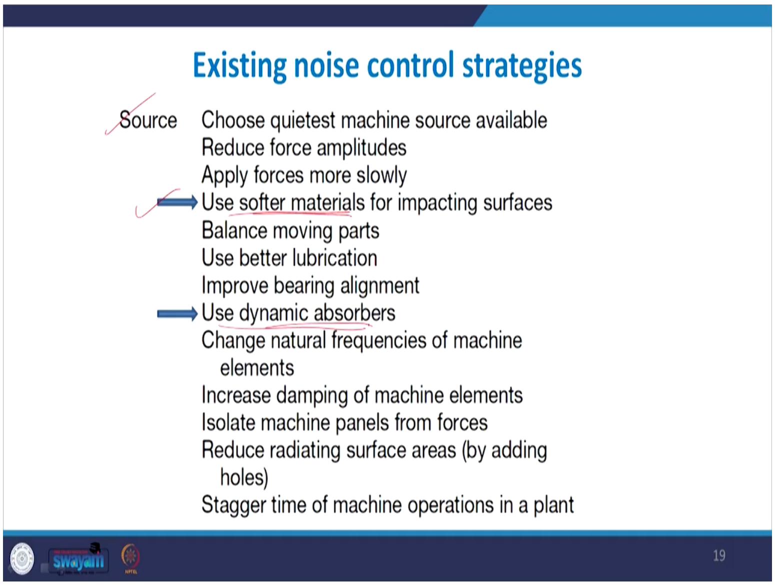

So, it is just a overview of the various existing noise control strategies here.

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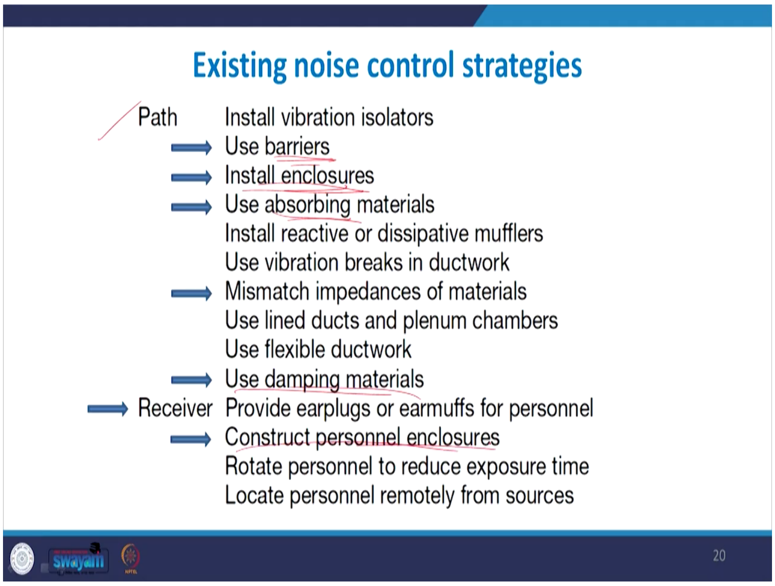

If you see into these slides this one so, lot of strategies are there. But in most of this strategies the use of materials is very common. You know using the material either to absorb the sound to enclose the sound or to block the sound. So, various materials are being used.

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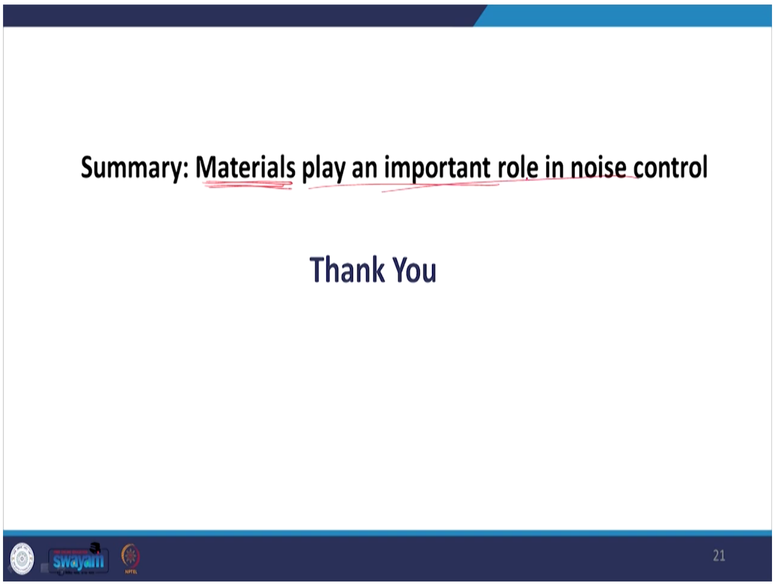

So, the summary here is that noise control can be source path or receiver based, but in majority of the cases use of materials, it plays some important role in noise control. So, with this I would like to end this lecture on the principles of noise control and next week we will start with acoustic materials.

Thank you.