Machinery Fault Diagnosis and Signal Processing

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Lecture - 35
Noise Monitoring

In the previous lecture, we had an introduction to Noise and Sound. And in particular regarding the sound pressure level in decibels and then, how to add decibels and then, what happens when the for a spherical source or for a point source in 3 dimensions; how the SPL reduces by 6 decibels for every doubling of the distance. And then we did discuss about certain conditions as to the fields of Noise.

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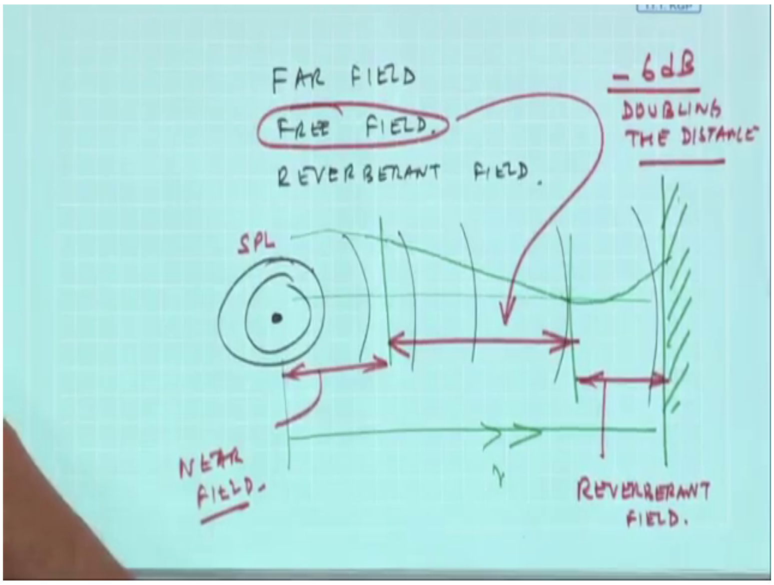

Far Field Free Field and Reverberant Field, etcetera. See, when I have noise source, it is radiating in all directions; sound.

But what happens, once it comes to the boundary; because of reflections and you know if you see here, with every doubling of the distance; the sound pressure level will decrease. And then, as you come close to the boundary, this is going to increase. And here also there will be some laws. So, the region where, the sound pressure level follows the rule.

That for every doubling, the distance, the sound pressure level will decrease by 6 decibels. Now, but when you come close to the boundary, there will be increase and this is what is known as the Reverberant Field and very near to this surface, this is the Near Field. So, when you are doing a noise monitoring of a machine, it is good that we always do the measurements in the free field. But in reality when am talking about noise monitoring in machines, in reality what happens? We will have many obstacles.

So, if you want to find out the noise radiated by a machine; it is ideal to put it in a Free Field environment.

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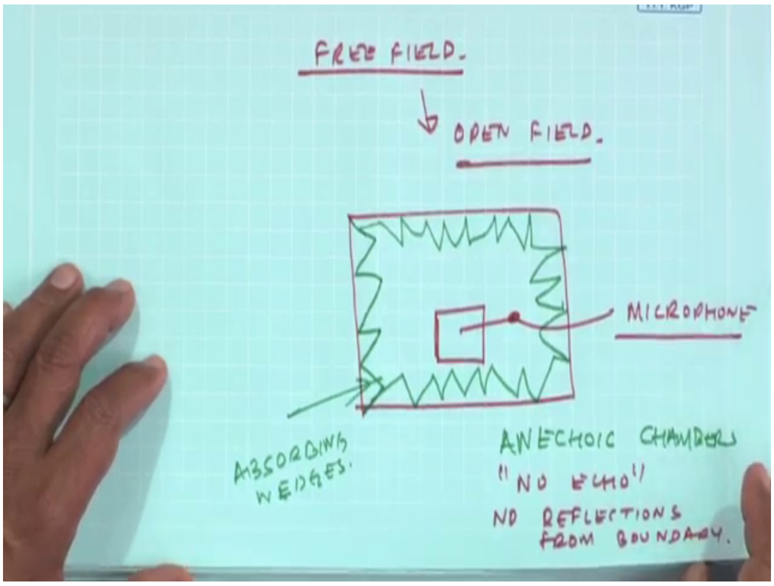

A good example of Free Field is an Open Field like a large football field, in the center of field where you are doing measurements or in chambers which are specially constructed with wedges. Towards the end of the previous class, I had showing you a picture of a car in a hemi anechoic chamber. These are all absorbing wedges such chambers are known as Anechoic Chambers. That means, no echo; that means no reflections from the boundary.

So, the reverberation effects are not there and everything which is going out will not get reflected back. So, I can have my machine, who's SPL, I am going to measure at some distance by an instrument like a Microphone. I measure in a Free Field environment.

There is an why this is important from a CBM point of view is, if a machine is producing noise and if I measure it in any other environment; when it is not free field. The environment is going to contaminate the levels of produced by this machine. So, but in practice, in real world in machines shops or in factories, it is difficult to get these free field environment for doing any measurements.

Another thing, we must have realized that when I add 2 SPL.

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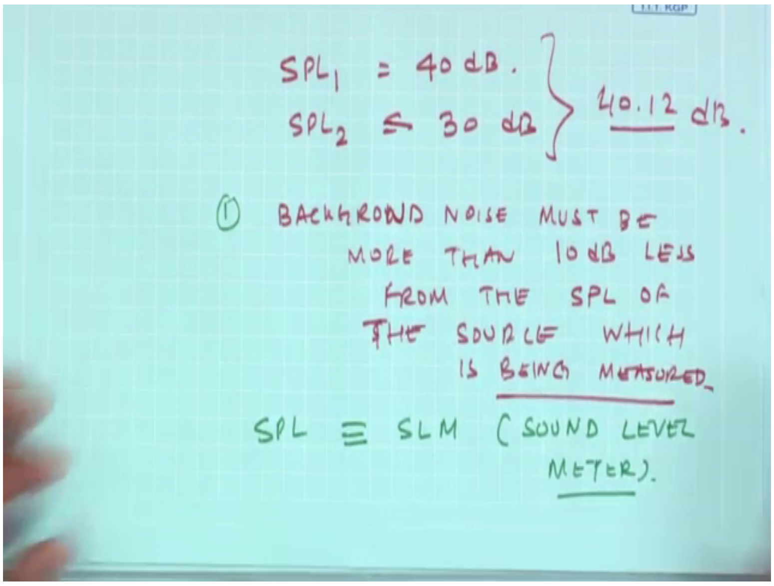

SPL 1 as may be 10 may be you know, 40 decibels. Say if SPL 2 is something less than 30 decibel; my net effect would go only 40 point something 1 2 decibel.

So, if the in noise monitoring this is very very important that the Background Noise Must Be More Than 10 dB Less From The SPL Of The Source Which Is Being Measured. So that means, if you are doing noise monitoring of a machine; suppose, the machine itself produces 40 decibels and with the machine of we must see that the background is less than 30 decibels.

So, in effect the background is not going to affect the overall level add to the overall level of the measurements. So, this is a very very important rule which every noise control engineer follows, when they have to measure the noise produced by machines form one can purposes. So, this is one thing which one has to very very careful while you measure this SPL. By the way just to let you know, SPL is measured in an instrument known as an SLM, that is Sound Level Meter.

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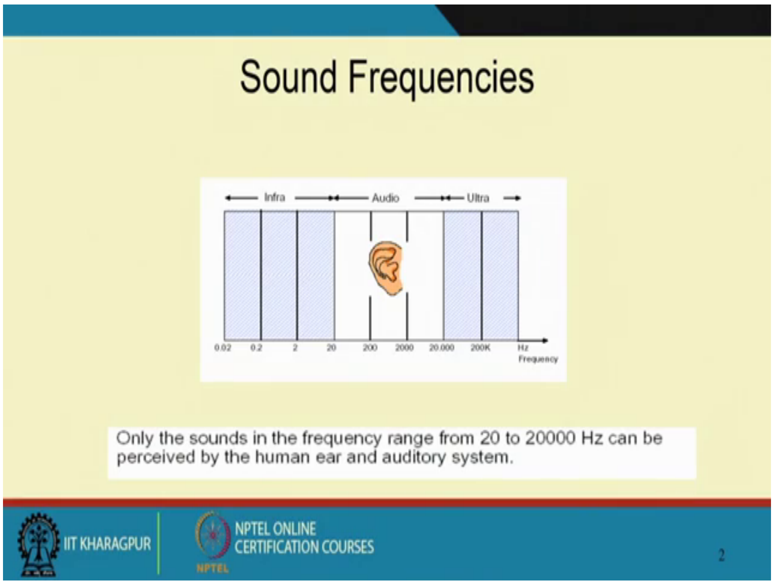

So, as you see here, the frequencies which human-being hear, are from 20 hertz to 20000 hertz; beyond 20000 hertz, we have the ultrasonic noise and below 20000 hertz, we have the infrasonic noise. But as you will realize, God has made our ears and our ears is highly non-linear. It is not a linear instrument.

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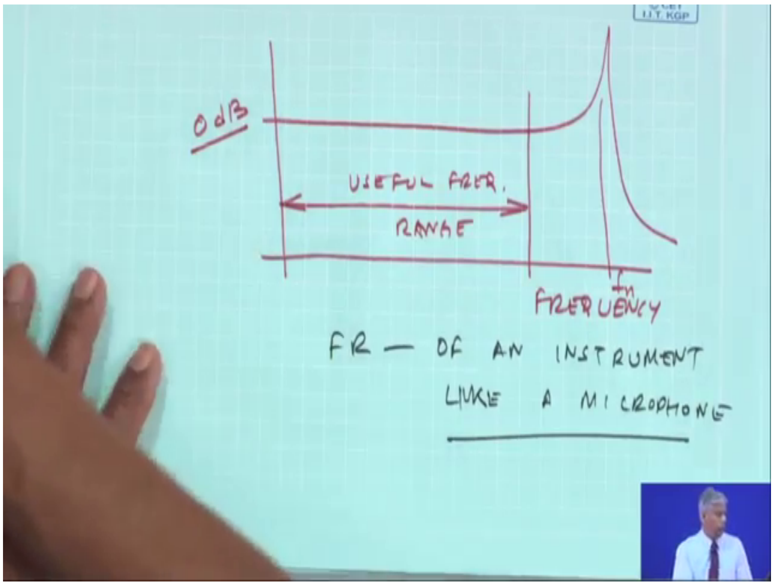

If I had a microphone, with frequency. The frequency response of the microphone would be something like this; flat till its resonant frequency have fn and we say, this is the Useful Frequency Range and dB scale output when it is 1. So, this is 0 decibel. But our human ear, this is for an FR frequency response Of an Instrument Like say a Microphone; our human ear is not like this.

So, we will see.

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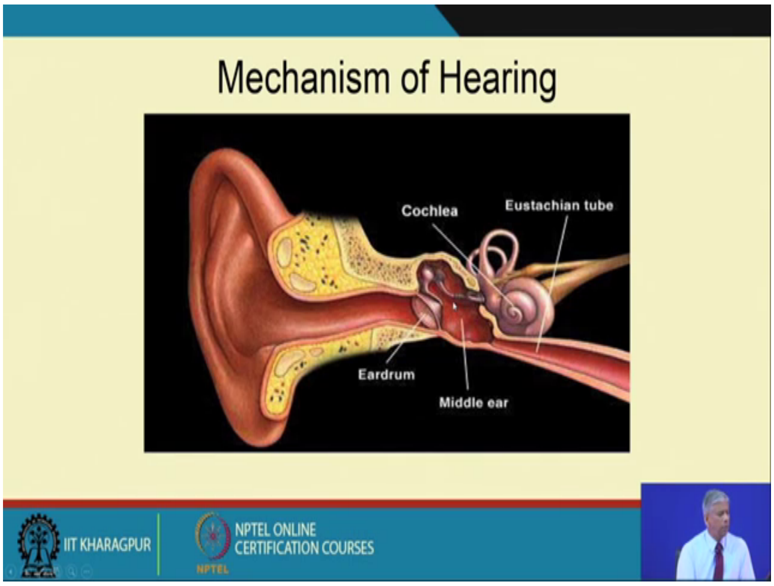

The mechanism of human hearing. So, this is the outer ear, we have the Ear canal here. And this is the Eardrum. So, Eardrum is actually a very thin membrane which is subjected to this fluctuating pressure p and then there are you know this series of 3 bones and then, we have an tube and then, there are certain hair cells which will deflect based on the sound pressure being transmitted and then we will have neurons attached to it to give a senses of hearing.

So, everything from the outside world is actually incident; the pressure ways on this ear drum and then, depending on you know, how good your hearing is; some can hear for high frequencies, some will lose hearing because this hair cells get damaged some could get permanently damaged and so on; will not go into the details of this. But prolonged exposer to a high level could damage your inner ear in the cell in which is not repairable.

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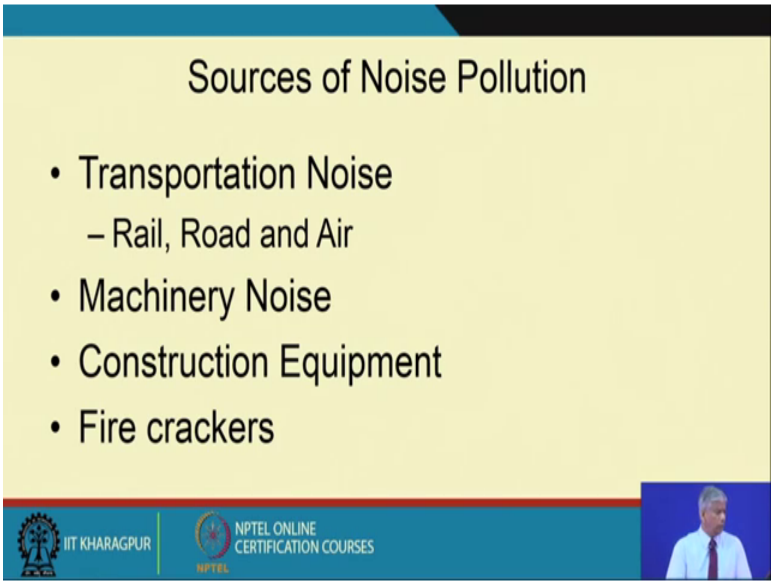

So, that is the reason, when we have noise all around us; 1 has to be careful that our ears which has been given gift to us by god our well protected. They do not set in a get in to the permanent damage mode.

So, people toward today, are talking about noise pollution in transportation systems in the Railways, in the Automobiles, in Aircrafts. We are talking about Machinery noise being loud construction equipment. Of course, in our country like India, we talk about Fire crackers during Diwali festival and so on.

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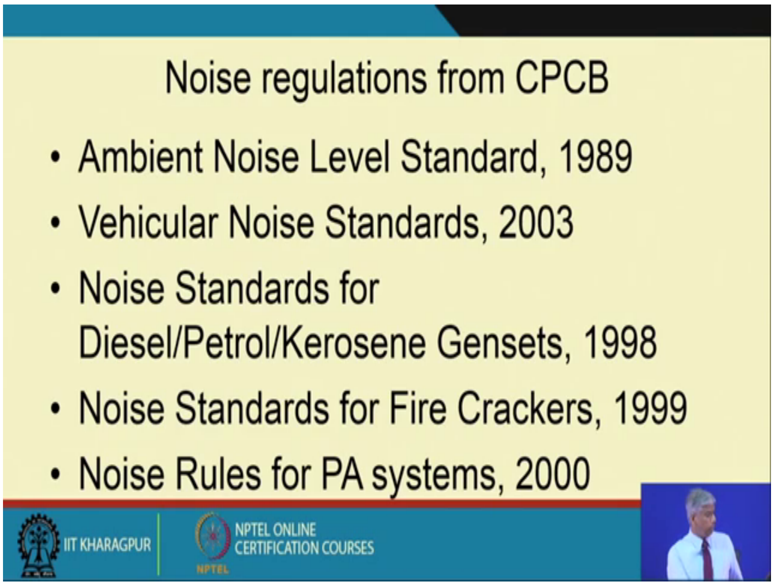

So, there are certain standards given by the Central Pollution Control Board of our country and this standards, one can refer to in CPCB website or other guidelines that some of the rules are there. Since 89, 2003 etcetera, etcetera. So, these at towards the end represent the year in which they have come into existence.

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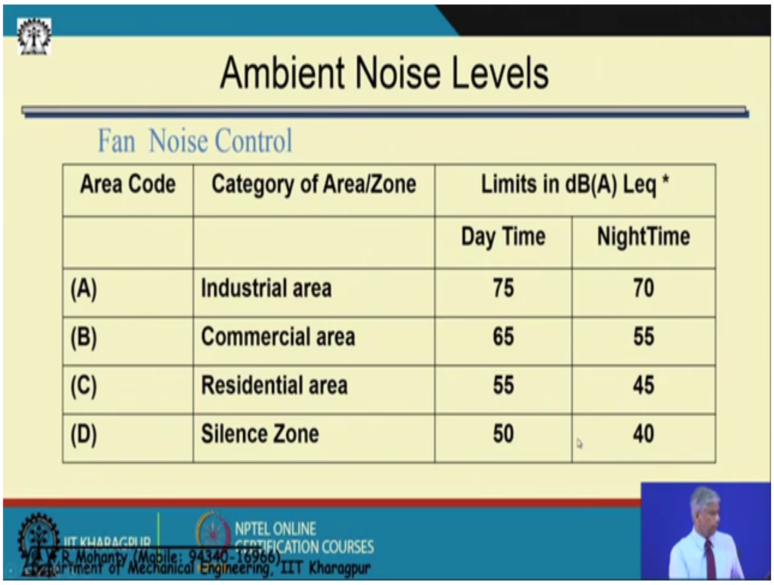

So, just for Fan Noise Control, I will just show you that we have 4 zones here; which is known as the Industrial area, Commercial area, Residential area, Silence Zone. What is the equivalent time, I will come to the a weighting just in a little bit.

What is the overall level to which the sound level should be? You know in a residential area, in the night time, it should be somewhere around 45 or less and because why do we have this? Because this is going to set in a permanent damage to our hearing and prolong exposer.

So, one has to be careful about this. But in CBM, we are talking about noise control or noise monitoring from as a main stool monitor the health of a machine or as a means to find out which area of the machine in this making more noise.

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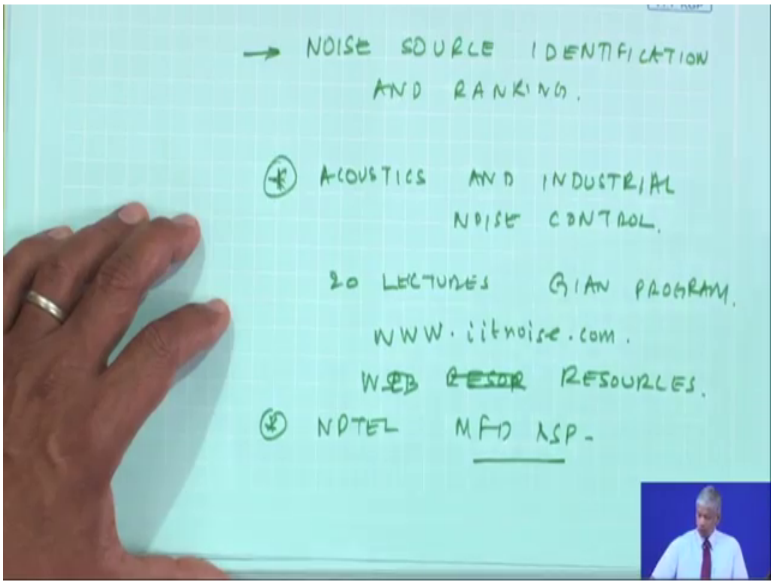

And to do that, there is a technique called Noise Source Identification And Ranking. By the way, I must tell the students here that though this is the course on machinery fault diagnosis and signal processing. The reason I am taking this 2 classes, noise and noise monitoring is for the fact that you know noise and vibration go hand in hand and this noise will, from a machine will draw our attention to that machine.

So, a little background about SPL and then, we will see about noise source identification and ranking by the way, those of you want to know more about Acoustics and Industrial Noise Control, we also have about 20 hours of Lectures under the Gian Program on the same topic and the details about them can be found in my website iit noise dot com and if you go the resources, web resources you will see; resources you will see the links to this Acoustics and Noise Control. And also for an previous lecture, 40 lectures on NPTEL on Machinery Fault Diagnosis and Signal Processing.

So, just if you want to have more information about Acoustics and Noise Controlling, you can refer to my website and see our Gian Program, where we have about 20 hour lectures on Acoustics and Industrial Noise Control.

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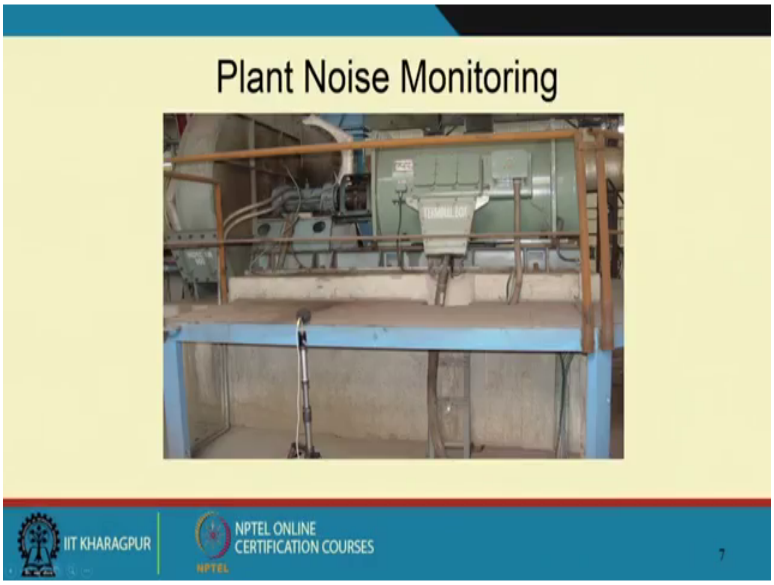

Now, this is we how a Plant Noise Monitoring is done. The microphone is put on a tripod and there are certain standards of noise monitoring and that is typically the standards says we have to rotate a distance.

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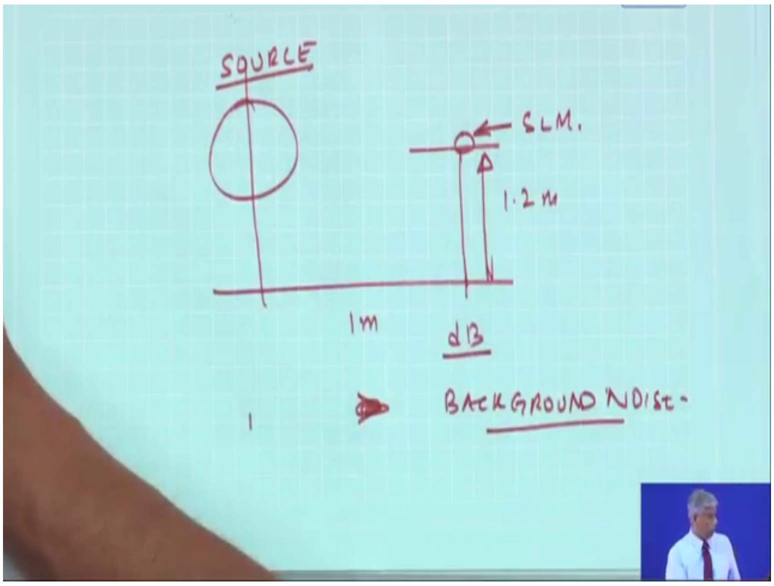

This distance is specified usually 1 meter and then, this is my machine. In a free field environment and this about somewhere about 1.3 meter and this is your SLM and this is your source and then, we can you have to measure the SPL and dB or dB A something which I am going to come to. And of course, the background noise should be, Background Noise must be greater than 10 dB below the actual level of the machines.

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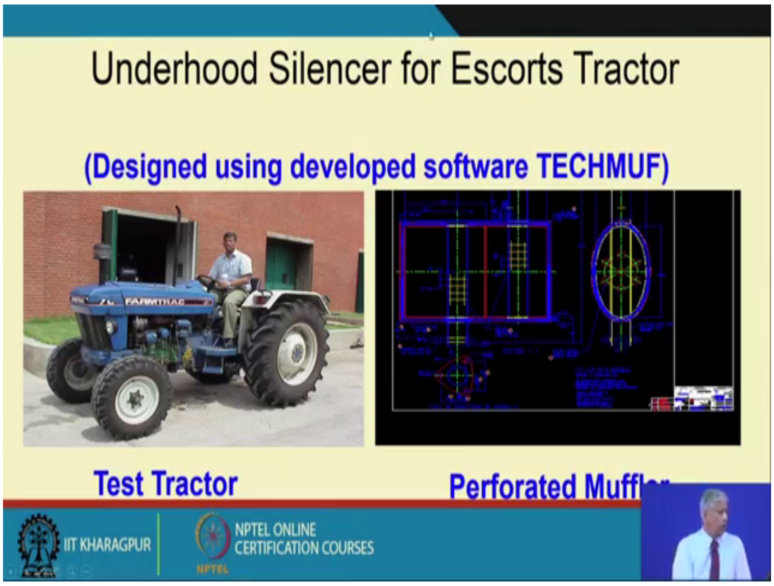

Of course, you know, we are doing many projects for noise reduction one such is a Tractor muffler.

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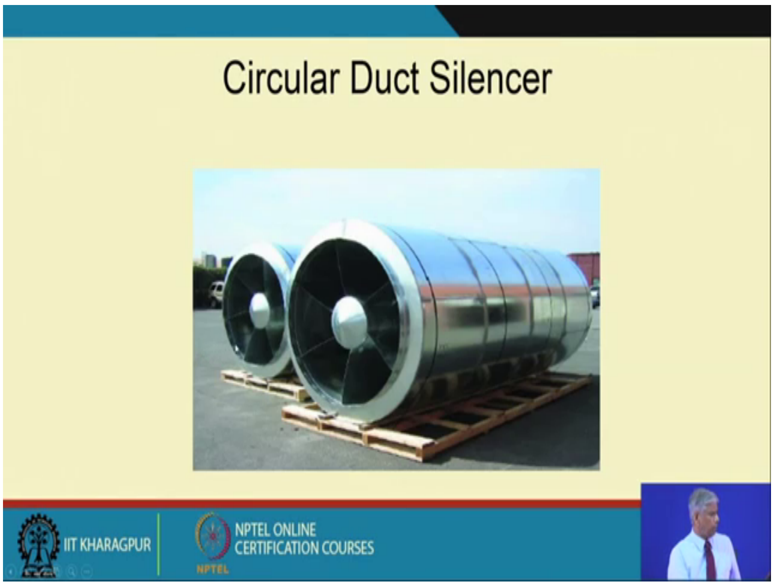

Silencers people use in the duct lines to reduce the noise etcetera. I will again not go into details of noise control in this lecture.

But just to give an idea.

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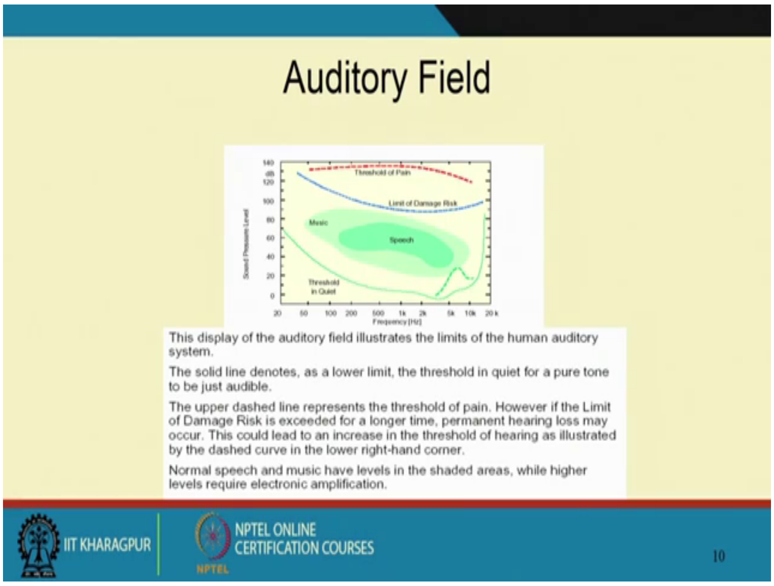

But one most important thing, we must know about this sound processor level is the human Auditory Field; you will see everything here is a function of frequency. The speech one people talk is somewhere predominantly less than 5000 hertz.

Music based on the membrane or biased instruments in the string instruments; they can go all the way from 50 hertz to about you know 12 kilo hertz and this is the threshold in quietness you know it is not a linear level and then, the blue line is the list of damage risk, limit of the damage risk at high levels we will have prolonged exposer of for years to more than this level you create a damage to our ears.

And beyond this level, we will have a sensation of pain. So, one has to be very very careful though the energy is insignificant from a thermo dynamically speaking thermodynamics point of view, but this levels are so damaging to our human ear that one has to be careful about and as we can get a clue, our human ear is not at all linear; it is sensitive at different frequencies.

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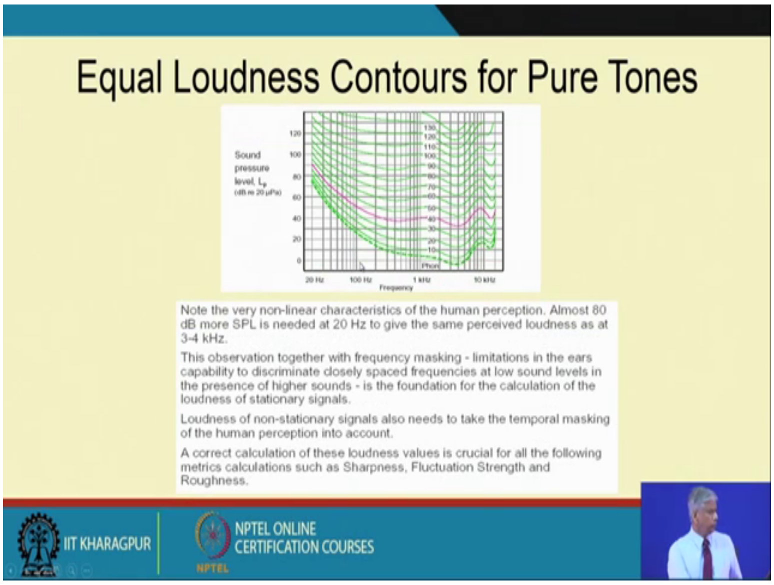

So this is how the Equal Loudness Contours for Pure Tones occur we need to increase the sound pressure level at low frequencies compared to high frequencies to get these same senses of loudness or hearing.

So, that means, our human ears hear responds to different sound levels, differently at different frequencies and for the same sound level, they perceive differently at different frequencies and this frequency response of a human ear is actually put in the measurements which we do with the microphone. For example, so, this is.

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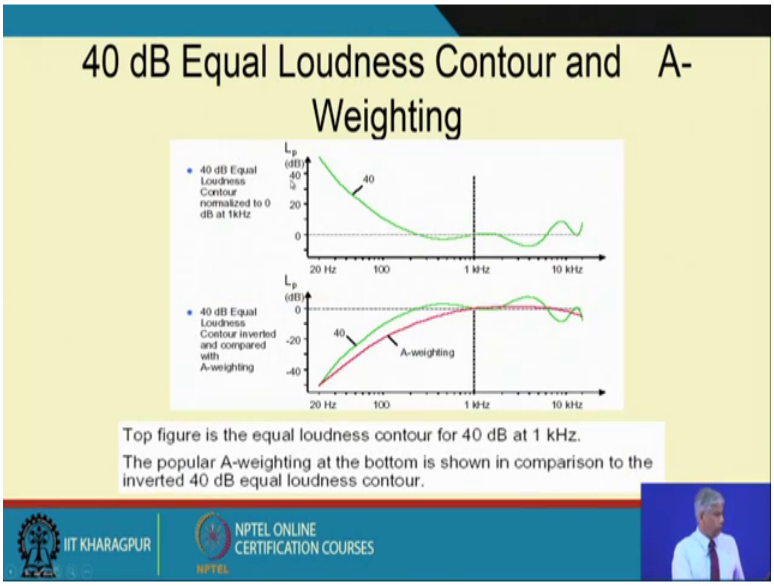

Could next slide here, this say for a 40 dB equal loudness contour, our human ear actually perceives it this way. So, we hear, we have to increase the level to get the same perception.

So, this is actually our human ears. The green curve, actually the human ears perception of any sound. So, to account for that we have developed what is known as this.

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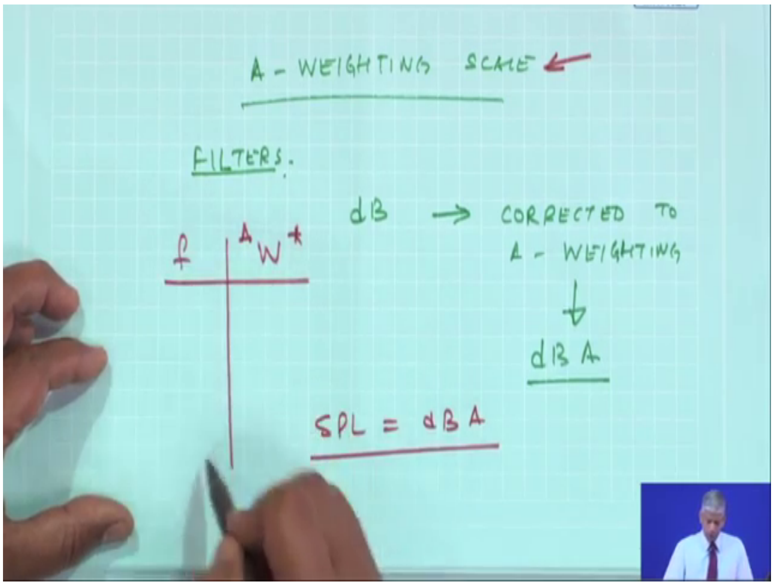

A Weighting Scale which is inversely adopted, by we, I do not mean IIT Kharagpur, but you know everybody in the world I have. So, standards people use a weighting scale where in to any measurements; suppose, we had a microphone I would have measuring this level, straight level. So, I will subtract certain values from these measured values at corresponding frequencies; when I come to frequencies I will talk about certain filters.

So, this is what is known as a weighting curve. So, any measurement which has been done in decibel and then, corrected to a weighting is actually then represent in dB A. So, decibel in the A scale. There are of course, B scales, C scales; theses are used for higher levels. Actually the international standard now is you know everybody represents SPL in dB A.

And this is just nothing but an weighting scale. And these weights, A weights is a function of frequencies. There are you may see in handbooks, people have equation given equation for this a weighting, but then traditionally, people had used filters. So, what is an Octave filter?

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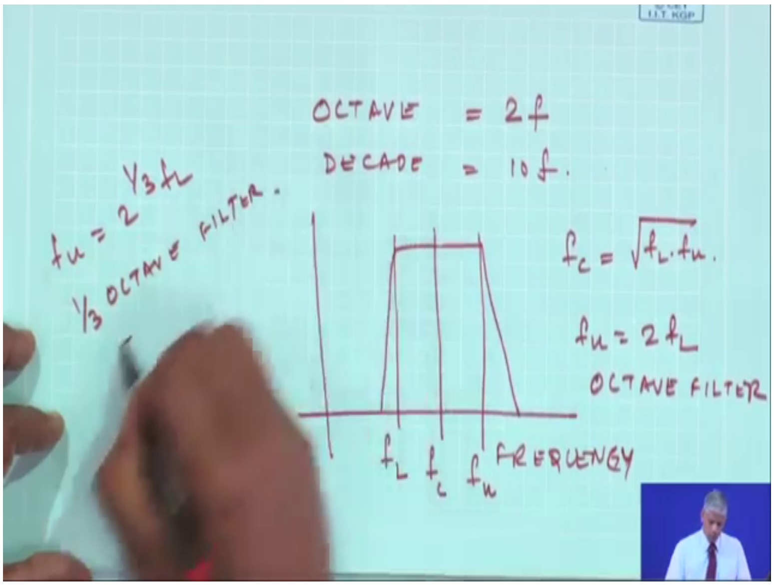

Or what is an Octave? Octave is nothing but 2 times f, twice the frequencies of Octave. Decade is 10 times frequency. So, if I have a signal in the frequency domain a noise signal and I try to put a filter around it. This, this filter will have a low Frequency. This will have a upper frequency. This will have the center frequency.

So, center frequency is nothing but the geometry mean between fl and fu. So, if fu is twice of fl this becomes what is known as an Octave Filter. If fu is 2 power 1 by 3 fl, this is known as 1/ 3 Octave Filter. So, the grossly speaking, you know I have this audio band from 20 hertz to 20 kilo hertz.

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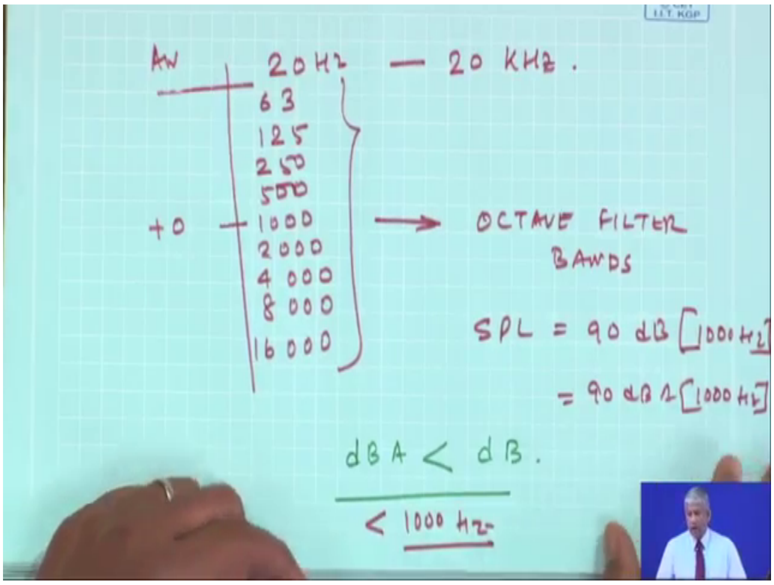

If I stay the first frequencies, 125 hertz or may be 63 hertz and this becomes 250 the next octave band, 500 is a next octave band, 1000; because they are all doubling 2000, 4000, 8000, 16000.

So, you see the entire audio band could be made out of such Octave Filter Bands. For every such Octave Filter Band, this we will look in the handbook, the a weighting values are given, you know will be more in these low frequencies and good rule to remember is, it is 0 at 1000 hertz. So, the value of SPL suppose, it is 90 dB at 1000 hertz. It will be also 90 dB A at 1000 hertz.

And if you see predominantly, if your dB A, for the same signal dB A value is much less than dB; what can you say just looking at this 2 numbers, anybody; this means what? Because you see here dB A values are much lower because we have to subtract this amount.

So, this is predominantly and then, particularly at higher frequencies; they are little more or almost equal. So, predominantly these signals are less than 1000 hertz and let me tell you in engineering noise control, many of the noise control issues are actually reducing this.

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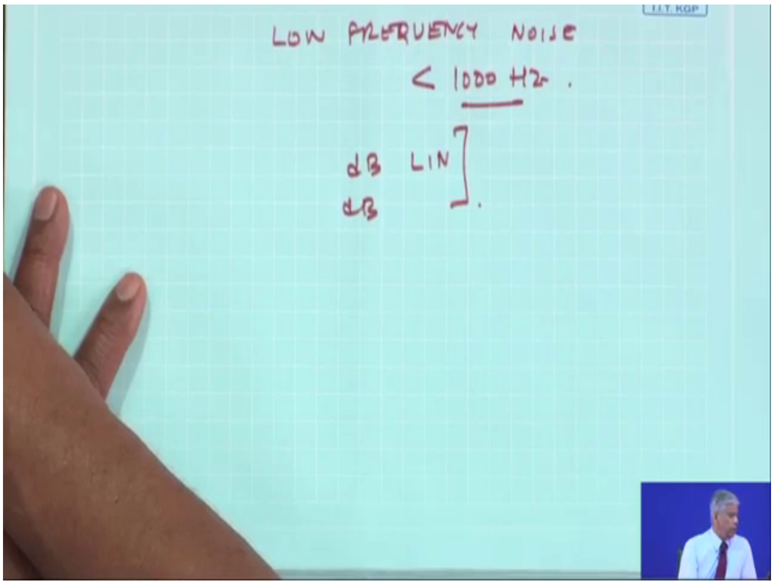

Low frequency noise, noise which is less than 1000 hertz. I will give you an example here.

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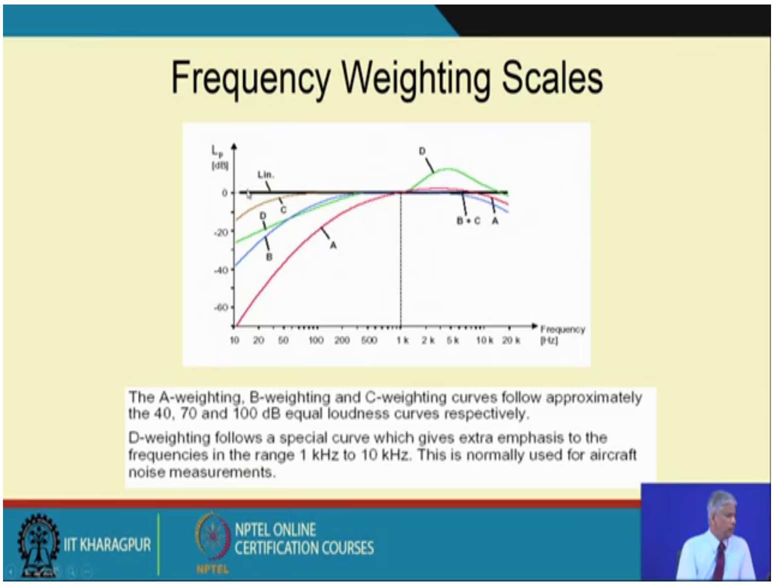

So, before coming to that example. So, this is my linear scale dB, dB LIN. dB LIN or dB, they are the same thing. Then I can have dB A scale which we use throughout in the industry and dB C is used for a 100 loudness curves particularly when you are talking about aircraft noise, you know people talk about dB C and so on.

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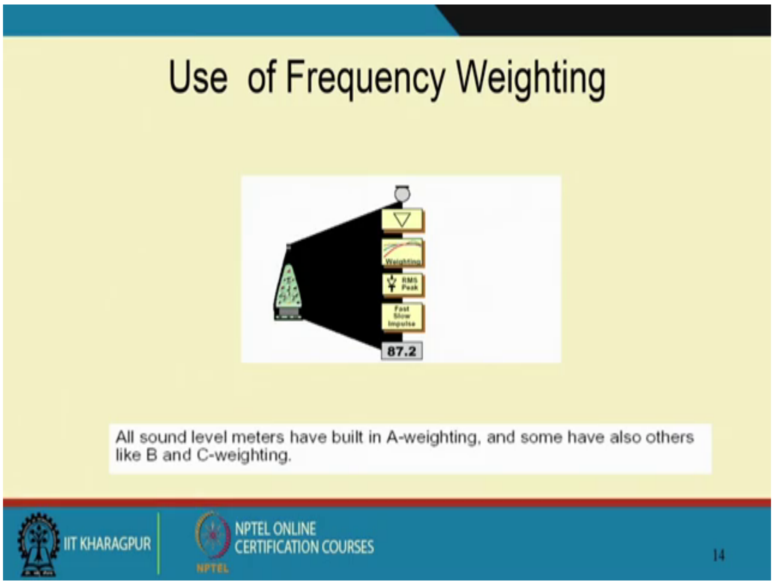

And then, Frequency Weighting are actually put in the sound level meter. So, we have the microphone. We have pre amplifier, this weighting curves. Then, we have an RMS speech detector and the integration time whether it is fast, slow, impulse and so for any signal, we get the number either in 87.2 it could be dB, dB A, dB B, dB C. So, such sound level meters are available or noise monitoring of equipment.

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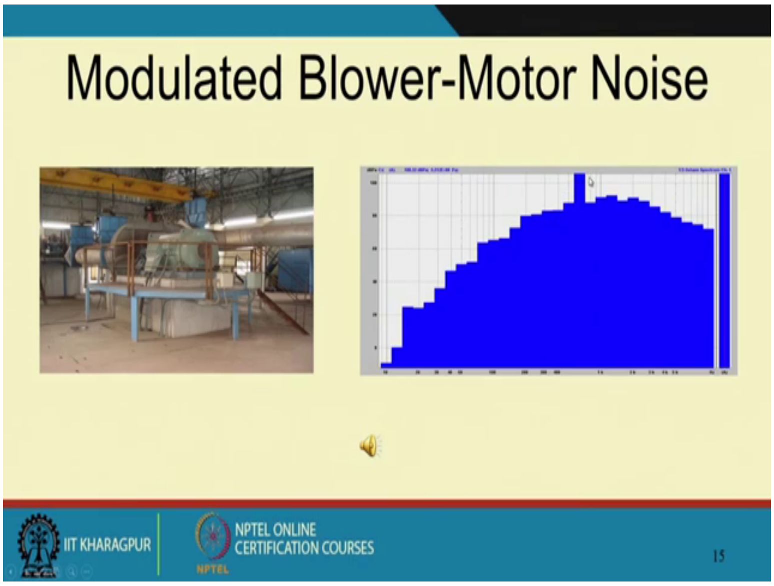

I just want to show you this.

So, this is the same Blower which is being used in a steel plant to get fresh air to the blast furnace because they have to be fed at a fast rate. So, this Blowers help in accelerating the flow of air into the blast furnace and if you will predominantly see, this blower made a lot of noise and when we went to the plant, this was around you know 110 decibel.

It is very loud for new worker to stay around in this place and if you will see this spectrum which has we have been measuring are actually represented in the 1/3 Octaves Bands and this is predominantly, the frequencies very very loud. This is somewhere around 630 hertz which happened to be the Blower vein (Refer Time: 26:52) which gets modulated; because of the other low frequency noises. So, you will see predominantly any noise control or noises monitoring you do, these are the low frequency noises one has to come across.

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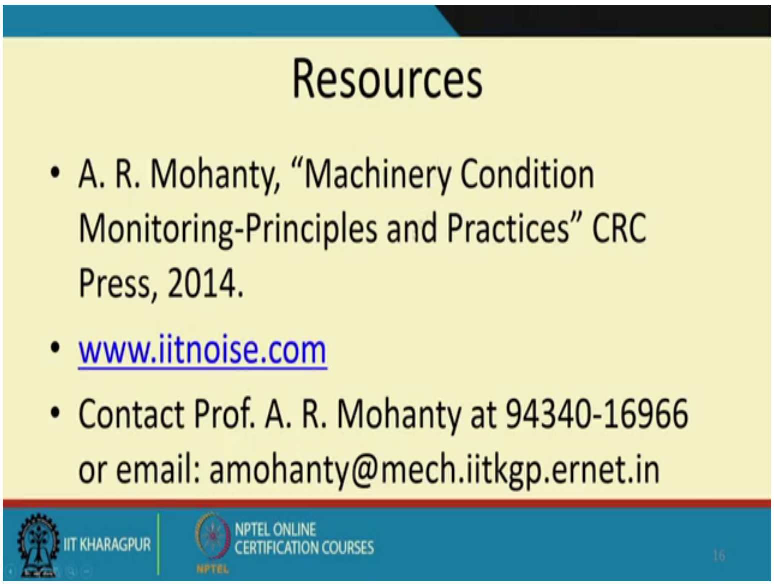

So, as I was telling you, if you can go to this iit noise dot com, we can see on our Gian website, resources 20 lectures on Acoustics and Noise Control.

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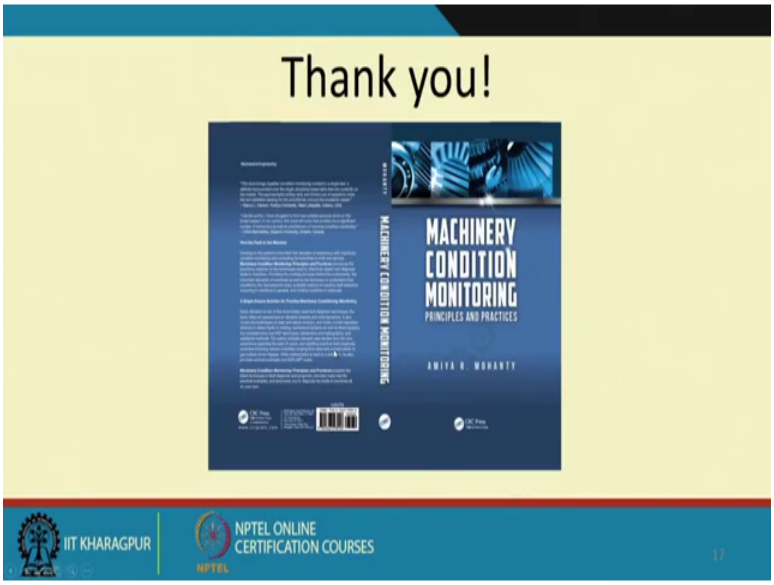

And if you will go to my book, you will see an example as to how we can find out the noise source in refrigerator using the sound intensity probe.

Thank you.