NOISE CONTROL IN MECHANICAL SYSTEMS

Prof. Sneha Singh

Department of Mechanical and Industrial Engineering

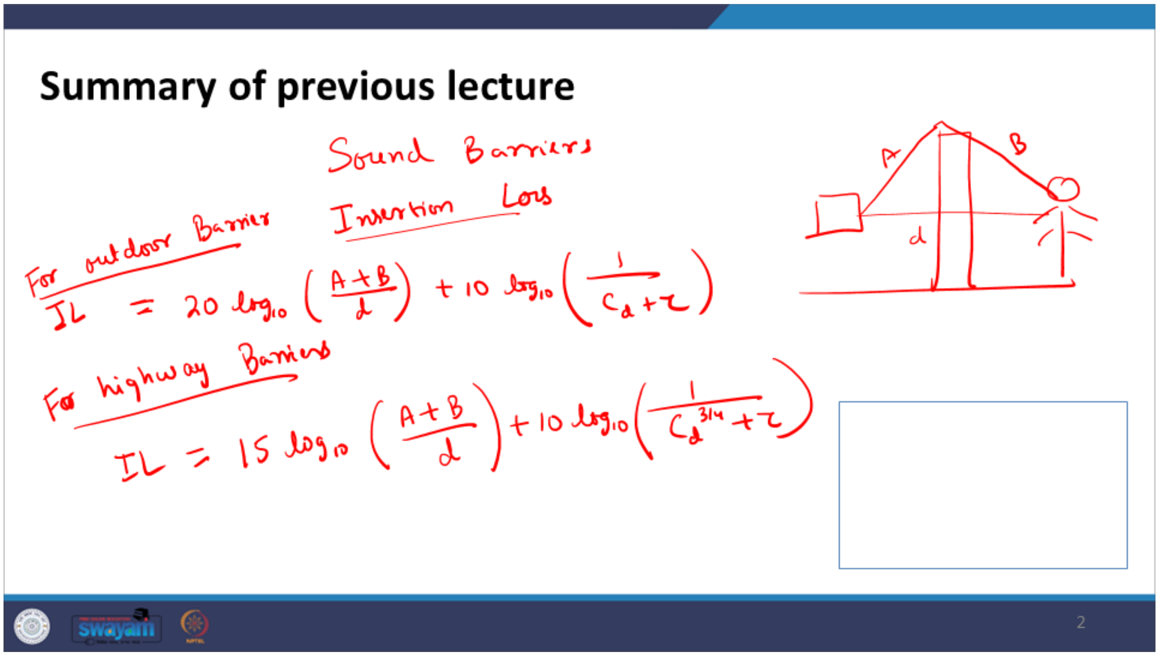
IIT Roorkee

Week:7

Lecture:034

Lecture 034: Acoustic enclosures

Hello and welcome to this lecture course on noise control in mechanical systems with me, Professor Sneha Singh. In the previous lectures, we started our discussion on sound barriers, and we will continue that. One particular application of sound barriers is to use them as an enclosure. this lecture will focus on acoustic enclosures, where they are made of sound barrier materials. To summarize, we discussed sound barriers and how we use insertion loss to measure their performance, and the insertion loss of a typical outdoor barrier was given in the last class.



This is a very important equation:

$$IL = 20\,log_{10}\left(\frac{A+B}{d}\right) + 10\,log_{10}\left(\frac{1}{c_d + \tau}\right)$$

τ being the transmission intensity coefficient of the material used for the barrier, given that this is the noise source, this is the barrier in between, and this is your listener, and this is your shortest distance 'd' between them, and this value is A. and this value is B, OK. for highway barriers, which is one of the common applications, the insertion loss had a small tweak to suit the empirical measurements, and hence the tweaked formula just for the highway barriers was this.

$$IL = 15\,log_{10}\left(\frac{A+B}{d}\right) + 10\,log_{10}\left(\frac{1}{{c_d}^{3/4} + \tau}\right)$$

where c_d is the diffraction coefficient due to the barrier.

Let us see what acoustic enclosures are, their working principle, and their performance measurement. What is an acoustic enclosure? It is a confined space made of barrier materials and is designed to contain or encapsulate a particular source or a receiver completely.

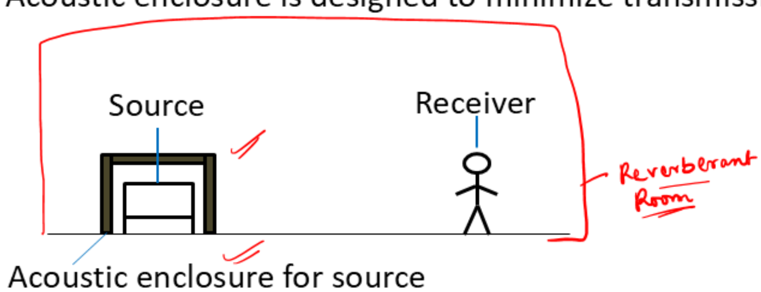
Outline

- Acoustic Enclosures
- Working Principle of Acoustic Enclosures
- Performance of Acoustic Enclosures

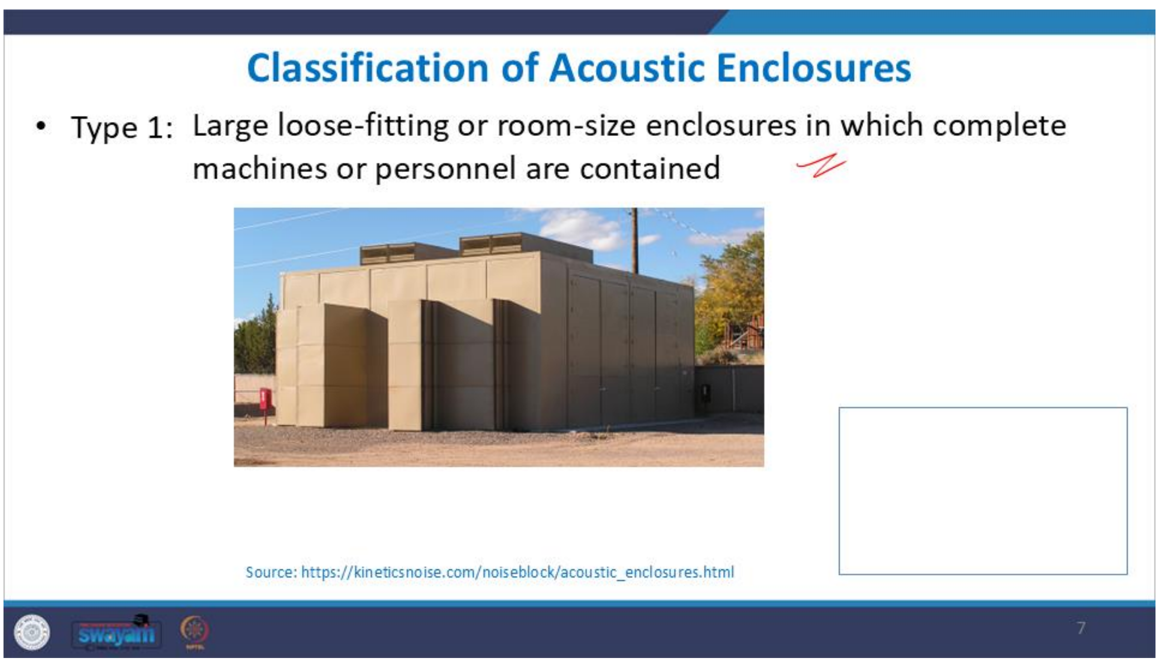
Barriers can be thought of as like partial enclosures. They are partially blocking the sound, but the sound waves, if suppose some reflecting elements are there, the sound waves can still have other ways to reach the receiver.

Acoustic Enclosures

- **Acoustical enclosure** is a confined space made out of materials that are sound barriers and that is designed to contain or encapsulate the sound source or receiver.
- Acoustic enclosure is designed to minimize transmission through it.



And hence they are usually used in the outdoor free field environments. But suppose we have a diffuse environment some let us say some somewhere inside a factory floor setup. for this diffuse field environment, we cannot use such partial barriers. What we can do is we can use the same barriers and make a box out of it. We have a box type of thing which is completely enclosing the source or completely enclosing the receiver and hence it is being effective in a reflective environment. It is not only cancelling the direct ways of the sound to reach the receiver. Now, it will be able to even block all the other indirect ways or the reflected pathways to which the sound can reach the receiver. You can either enclose the source completely. You have the acoustic enclosure for the source as given here and it is usually in a reflective environment setup. Considering that they are in some kind of closed room, a reverberant environment, some closed rooms. And then you have to in order to cancel the sound waves reaching from all the paths direct as well as reflected you are completely enclosing the source or you can completely enclose this receiver within this environment or you can do both. In a typical factory setup where there are lot of machineries and then there is a control room where all personals are there who are working to operate these machineries from time to time. The best way to protect the personnel could be to construct enclosures in these factory setups.

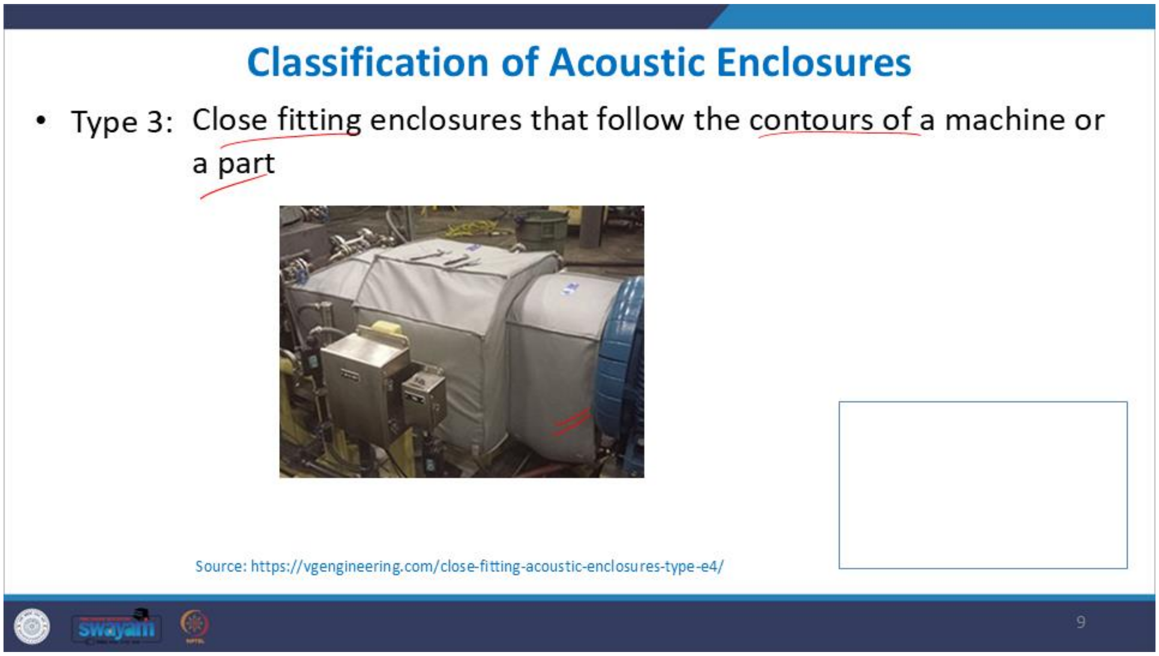


There are various types of acoustic enclosures that are available. The very first type could be, and most of these are in relation to industrial machinery and industrial plants.

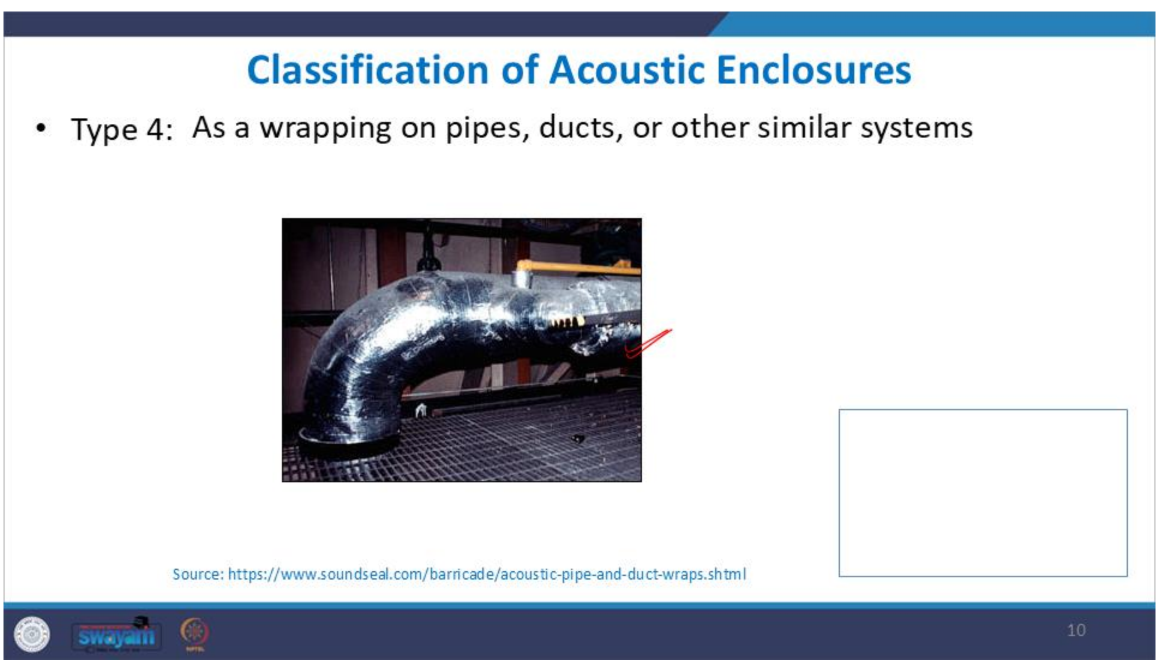
The very first type is, you have large loose-fitting or room-sized enclosures in which complete machinery or personnel are contained. You can have some factory where you keep all the, heavy machinery together on a work floor and, all the heavy machinery is kept together in a single building which is completely enclosed. The entire machinery, is enclosed in a separate large room which is made of good barrier material. That becomes your enclosure. In the same way, if you suppose you have machinery in a lot of places scattered around, even in the outdoor areas. A better thing would be where you cannot, you do not have all the heavy machinery, together in the same confined space, but rather they are scattered around. You cannot build individual enclosures for this machinery because it is very costly or not very practical. Then, in that case, what you can do is that you can have all the personnel and their control rooms all situated together, and then you can enclose these personnel in these large room-sized enclosures.

Then, otherwise, what you can do is you can build small enclosures. This is usually used to enclose small machinery or some small noisy part of a large machinery setup. This is a typical figure from my own published paper where we had built an enclosure based on a natural jute composite. Because we wanted to measure an IC engine, but it was so noisy that we, the experimenters, had to be protected from the noise of that machinery. Because we were making the measurements in a very reflective, reverberant environment. To protect us, we first used mufflers, the mufflers were effective, but not that much.

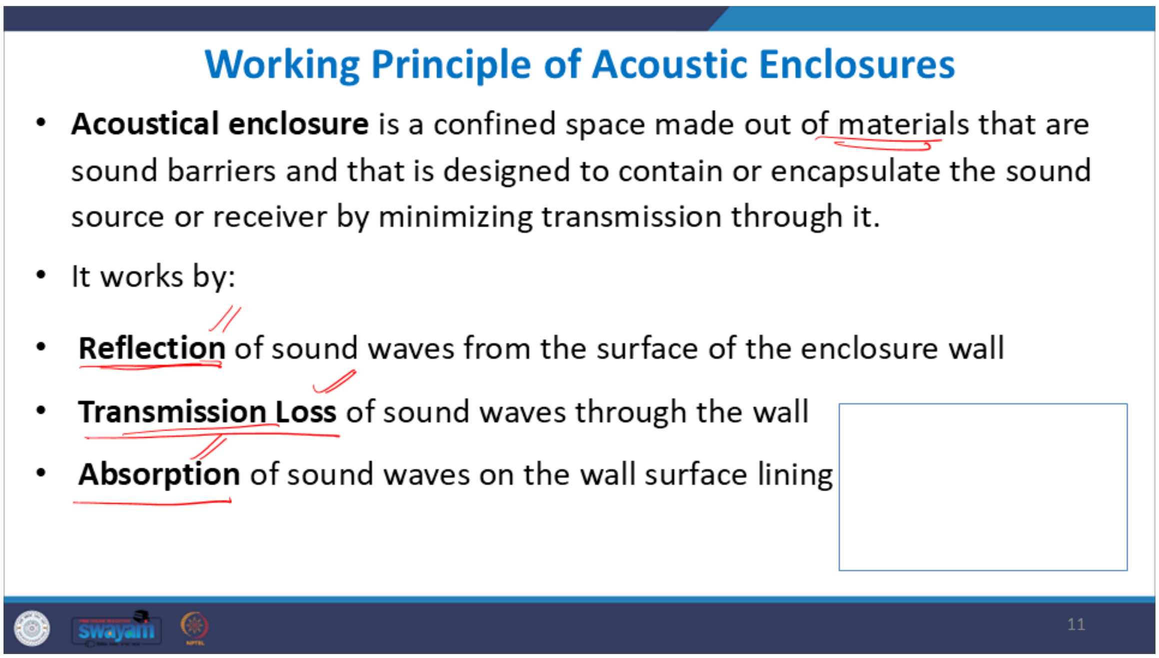
Then what we did was we also enclosed the machinery that had to be measured in this small enclosure. Here, because this could be more costly. You can just enclose a small part of the machinery that is noisier using some small enclosures.



Then, the other option could be, if you have some machinery and you want to save material even further you do not want to have large rooms built specially to enclose the machinery, nor small boxes or small sub-rooms for components of the machinery, then you can go for some close-fitting enclosures that follow roughly the contours of the machine or the part, something like this.

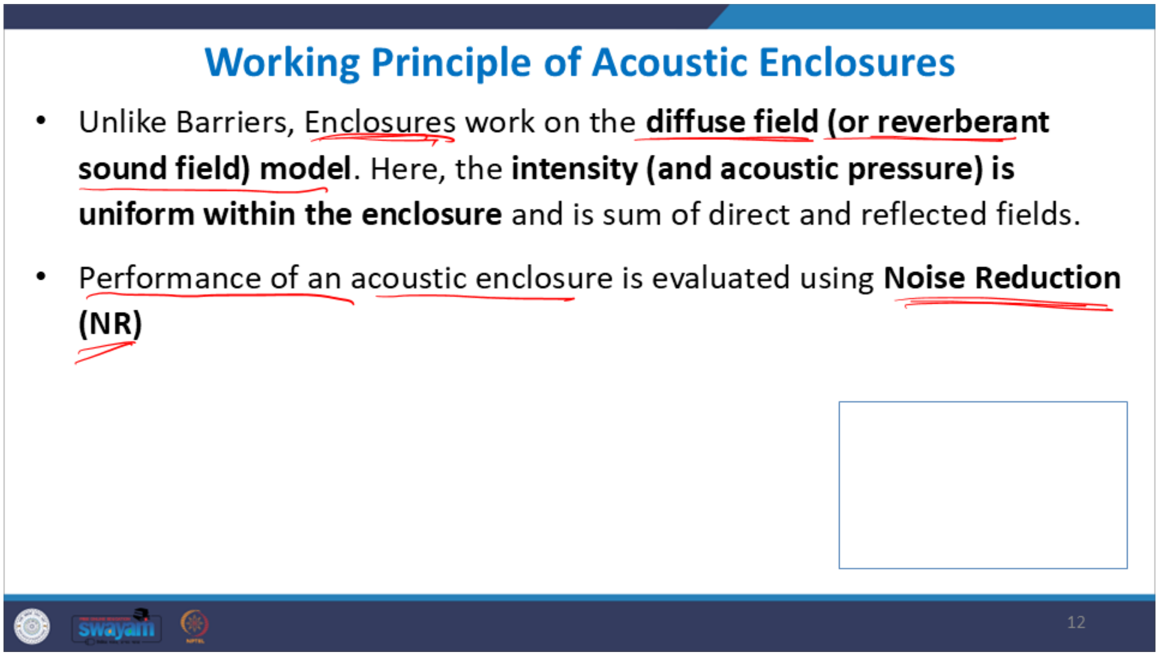


Even, the ducting and piping systems in many mechanical systems are a great source of noise because they generate noise based on the fluid flowing through them. The fluid flowing through these pipes and machinery generates noise due to the flow of the fluid itself, and then it also generates noise because of the vibrations of the piping system. Both fluid-based and mechanical-based noises are generated in these various piping and ducting systems of machinery. You can simply have some insulating wrappings that can act as enclosures for these pipes. These are the typical types of enclosures used in factories and industrial setups.

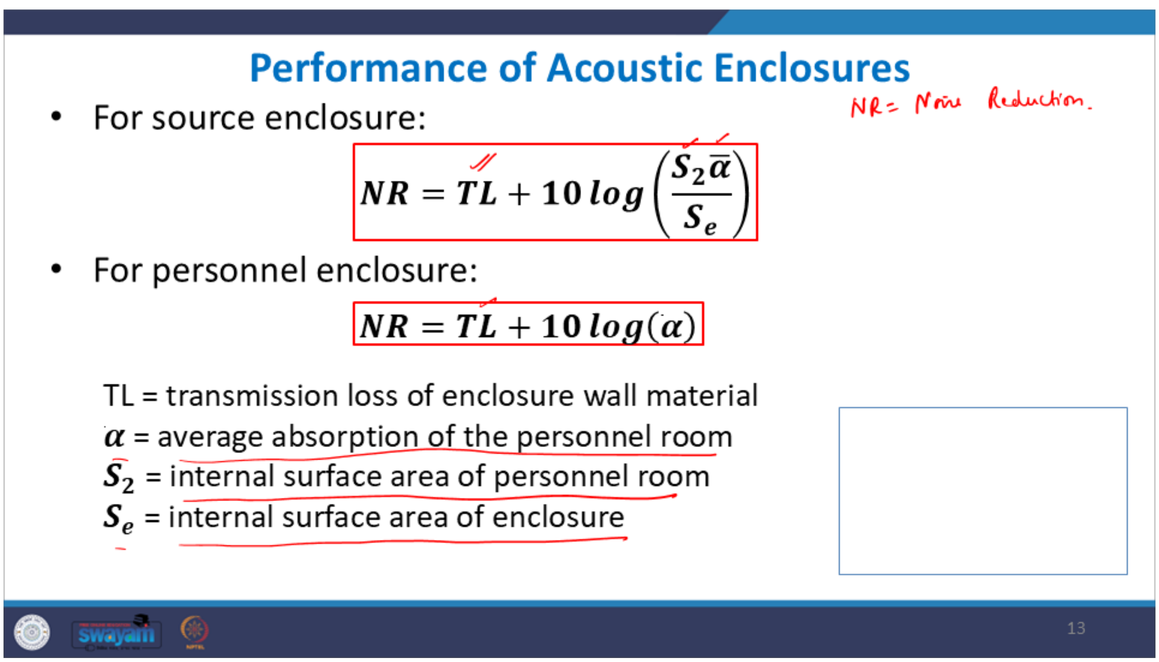


What is the working principle? Again, they are made of barrier materials. What they do is, whenever sound waves hit them, they reflect back or pass through them. Most of the sound waves are reflecting back whatever remaining are passing through it and are going, through absorption and transmission loss so that when they reach the other end of the material the transmission is minimized.

These enclosures as I explained to you. Barriers are used in the open field environment and enclosures are sort of a complete sort of box built of barriers to entirely enclose the source or the receiver and they are used specially for this diffuse field or reverberant sound field environment. And in this environment like for example, an outdoor barrier we measure it through insertion loss, the performance indicator for an acoustic enclosure is noise reduction or NR in decibels.



What is noise reduction? It is the difference between the SPL measured before passing through the enclosure and the SPL measured inside the enclosure.



The performance of acoustic enclosures can be measured in terms of their noise reduction. And there is a separate formulation for the noise reduction of the source enclosure and the personal enclosure. In fact, for the source enclosure, the noise reduction is the transmission loss of the material that is being used to build enclosure plus 10log10 times of this particular quantity, which is $S_2\ \bar{\alpha}$ by S_e.

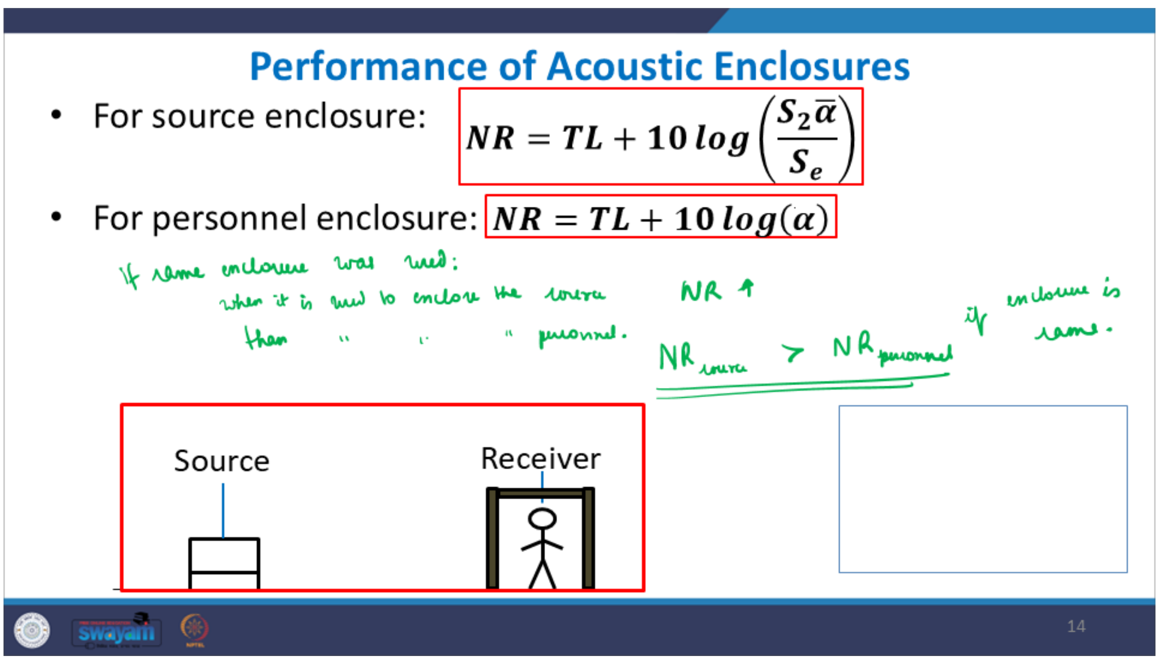
$$NR = TL + 10\ log\left(\frac{S_2\bar{\alpha}}{S_e}\right)$$

S_2 is the internal surface area of the personal room and S_e is the internal surface area of the enclosure and $\bar{\alpha}$ is the average absorption of the personal room.

For the personal enclosure in that case the noise reduction is given by

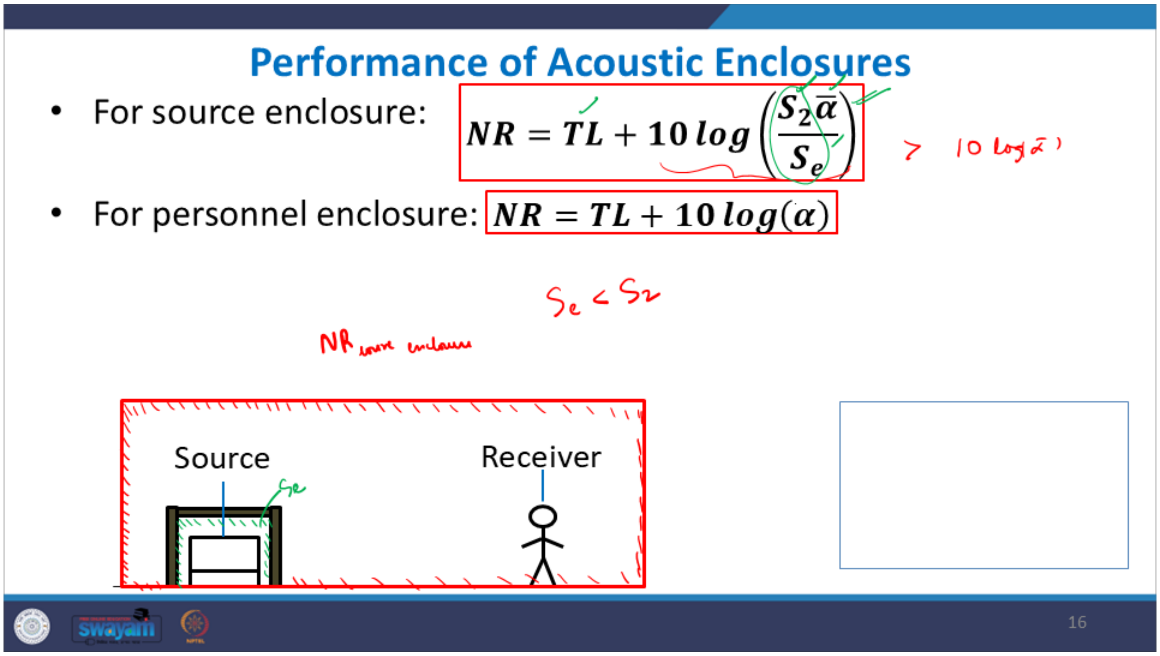
$$NR = TL + 10\ log(\bar{\alpha})$$

Now, if you see these two formulations again in terms of how these enclosures are used.

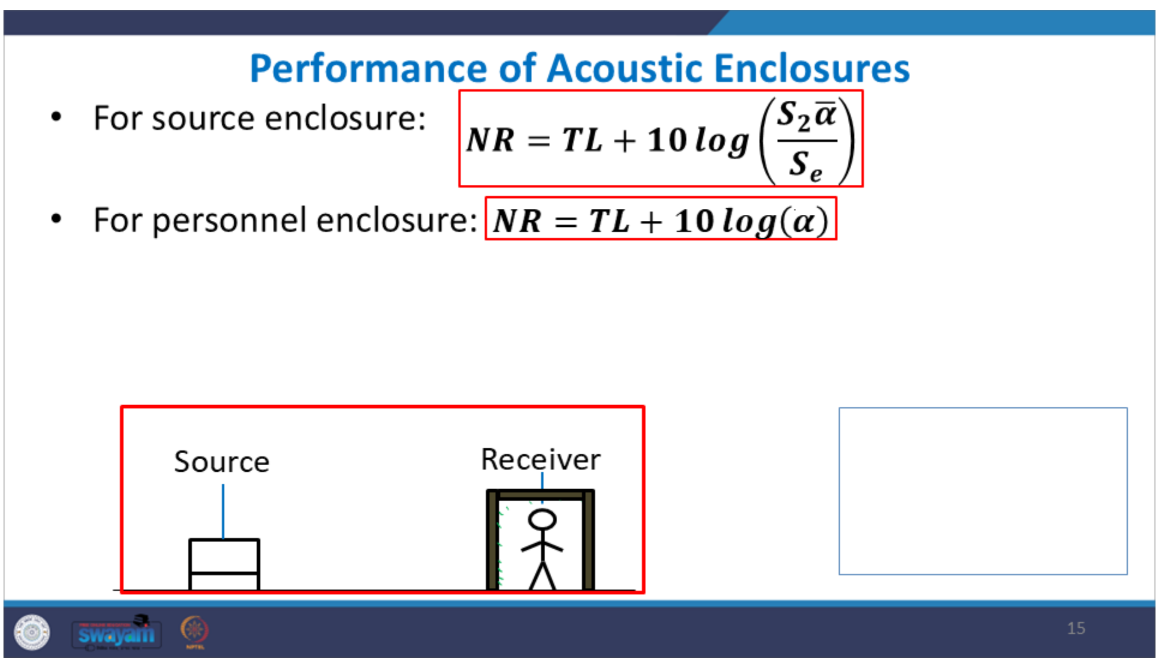


let us say in a factory floor, when you have enclosure on the personnel then in that case, let us start first with the enclosure on the source.

What happens is this is your source enclosure. In this case, this will be your S_e, the internal surface area of your enclosure. And what would be the S_2, which is the internal surface area of the personal room? This entire thing here, the entire surface area of this big factory room in which the personal and the source are present together, this will become your S_2.

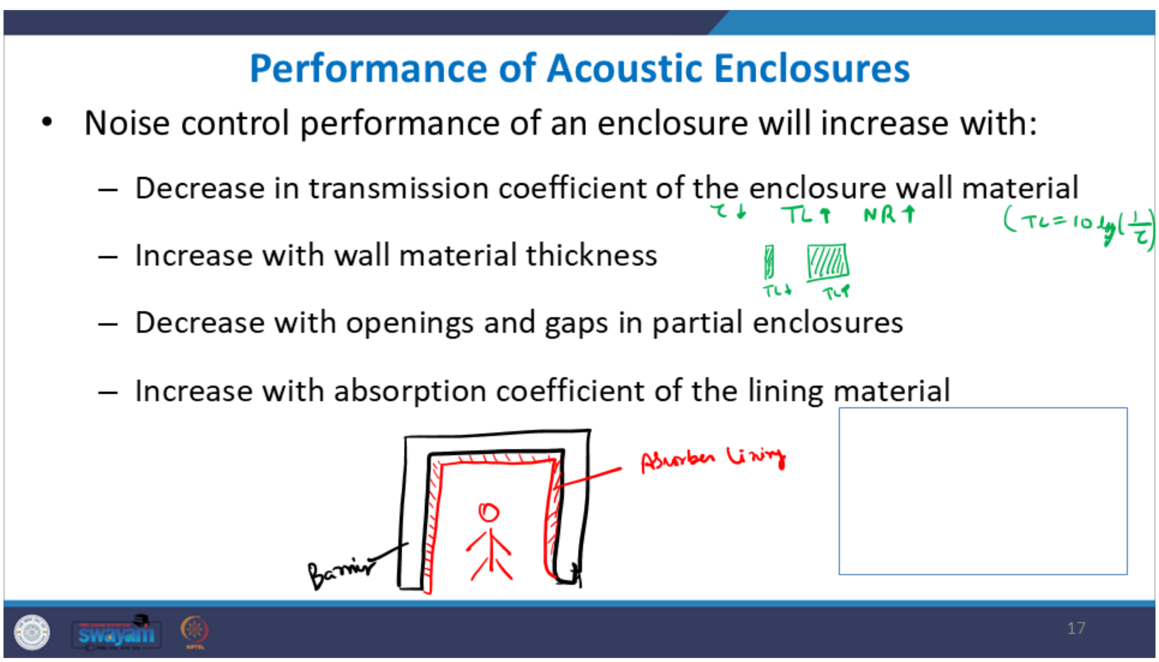


In general, what happens is that these enclosures are installed where some personnel are present and the machinery sources are also present together. In that case, suppose when you cover the source with the enclosure, then the internal surface area of the enclosure will always be smaller than the overall area of the factory room over which the personnel are working. In that case, this quantity over here would be greater than $10\,log(\bar{\alpha})$. Whatever noise deduction you get from the source enclosure is here, and suppose instead of that, the personal enclosure was there.



This is the general kind of equation which is valid both for the source and the personal, but in the case of personal enclosure, what happens is that this is your internal surface area of the enclosure and the personnel room. Here, those don't come into the picture. It is just $\bar{\alpha}$. What happens is that this quantity, in general, is greater than 1 because S_e is always smaller than S_2, the way the enclosures are made. The enclosures would obviously be smaller than the overall factory room over which it is being installed, and hence S_e is always smaller than S_2. What we conclude from here is that suppose you had the same enclosure. The conclusion here is that if we had same enclosure was used. Which means that the dimensions of the enclosure were same, the material used for building the enclosure was same, everything about that enclosure was same. But in the first case, when it is used to enclose the source, NR is greater than when that same enclosure is being used to enclose the personnel (refer slide 14). The NR because of the same enclosure when used on the source would be greater than the NR when it is being used on the personnel. Used on the source would be greater than the noise reduction due to the enclosure being used on the personnel if enclosure is same. Basically, covering the source, so more generic way, suppose you have a factory floor and the machinery source is being operative on that closed reverberant factory floor and personnel is also there working nearby, then it is more effective to directly close the source rather than keep the source open and try to close the personnel.

Let us now also look at this equation and see what are the factors that affect the overall noise reduction achieved by an acoustic enclosure. obviously, these things would affect the noise reduction of an enclosure (refer slide 16).



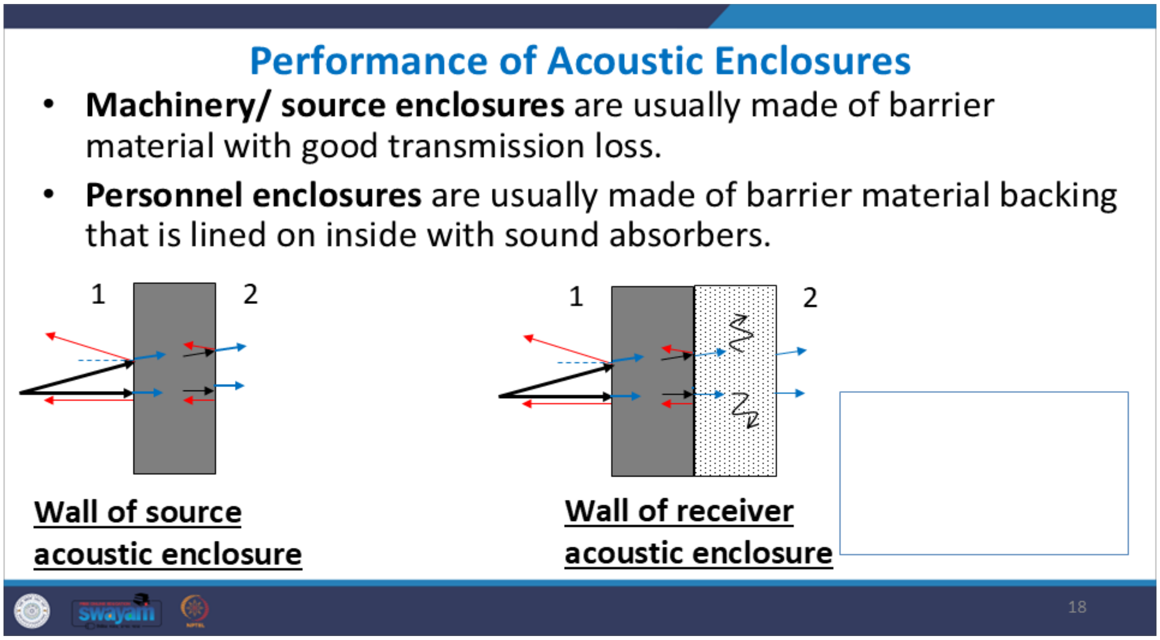
First of all, if you decrease the transmission coefficient, so if τ decreases, then transmission loss is going to increase. Why? Because transmission loss is

$$TL = 10\log_{10}\left(\frac{1}{\tau}\right)$$

when the transmission intensity coefficient is decreasing, obviously the transmission loss is going to go up. Which means that the noise reduction that is being achieved by the enclosure is going to go up. The performance is going to increase or enhance with the reduction in the transmission coefficient of the material used for these enclosures. It is also going to increase with increase in the wall thickness because as you keep increasing the thickness the same material is being used but the amount of transmission loss is directly proportional to the thickness of the material because thinner material will have a smaller TL than the same material with a much wider thickness this will have a higher transmission loss. With the increase of the thickness also the material will become a better enclosure and these are very common sense to understand as well. Then if you decrease the openings and the gaps in these partial enclosures because each opening becomes a pathway for leakage of the sound waves because whenever there is an opening or a hole overall at that patch where the opening or the hole is present that is effectively having a τ of 1 which is all the sound waves are transmitting through it and there it is not able to stop it the transmission loss is ideally almost zero or very low value so these are going to just bring down your overall transmission loss. They will most importantly create some alternate pathways that the sound waves can take and reach out.

The purpose of enclosure will not be served because the name itself suggests enclosure. It is about enclosing the source or the personnel completely, completely encapsulating them and with any gaps or openings that purpose is not served because the sound waves will now get some pathways to go ahead and go and pass through these enclosures. In the same way usually, a typical absorption. supposes your enclosure is made in such a way that it is made of some barrier material let us say. And on the top of that there is a lining of porous material. This is your total let us say a typical absorber that you have made.

More specifically let me come to this one. Let us say this is your typical enclosure wall this shows the cross-sectional view of your enclosure wall and this material is a barrier material because it has a higher transmission loss and can block the sound waves but in general when these enclosures are used so typically the treatment is that you also especially when you are using it on personnel, you line it with some absorber’s absorber lining inside. especially when you are using it for personnel. This is the barrier material these are the absorber lining and this is how typically these enclosures are built in particular when used on the personnel. When you increase the absorption coefficient of the lining material, your noise control performance also enhances.



As already mentioned, the various kinds of machinery and source enclosures are usually made of a good barrier material that has a very high transmission loss. But in the case of personal enclosures, these barrier materials are usually aligned with some sound absorbers to further enhance their capacity. And with this, I would like to conclude this lecture.

Thank you for listening.