**NOISE CONTROL IN MECHANICAL SYSTEMS**

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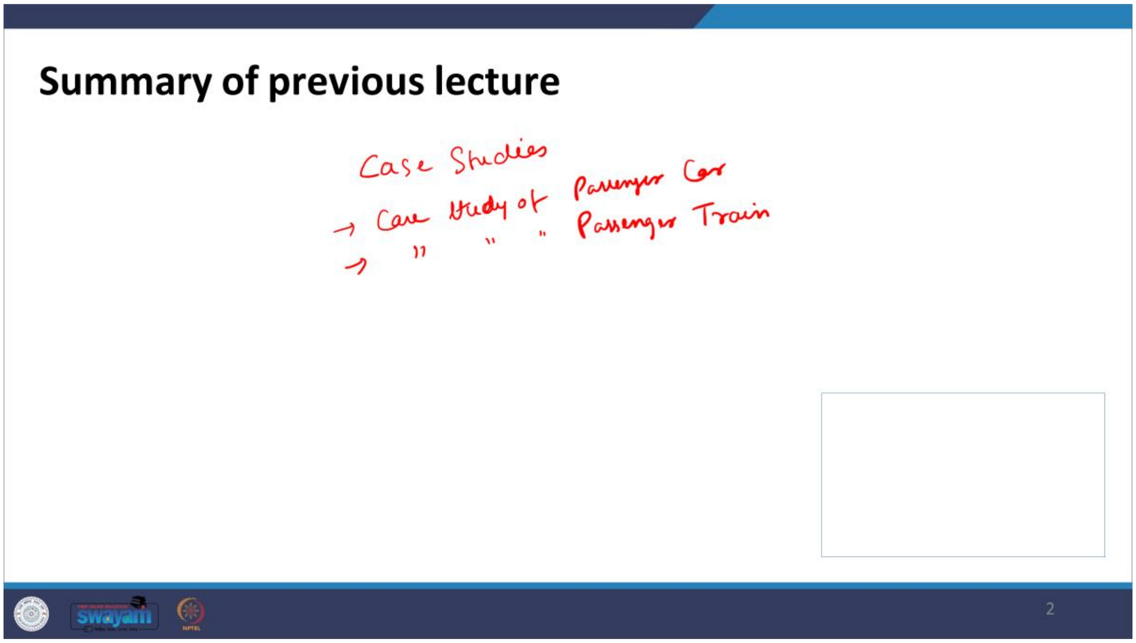
**Week: 12**

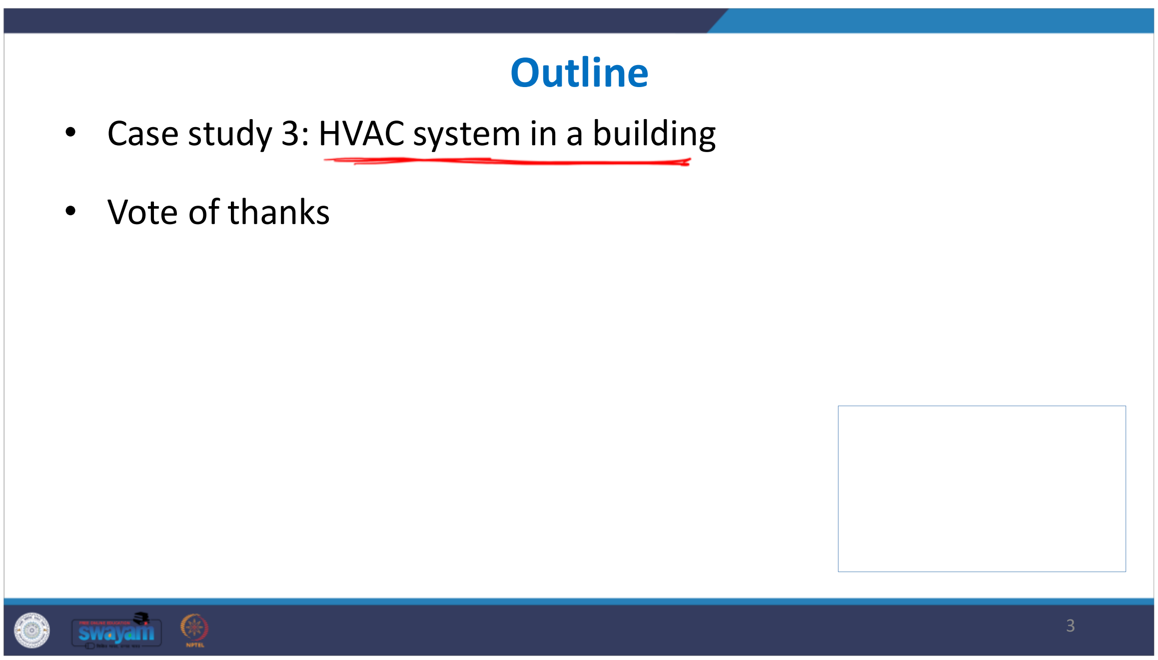
**Lecture: 59**

# Lecture 59: Case study of HVAC system and Conclusion

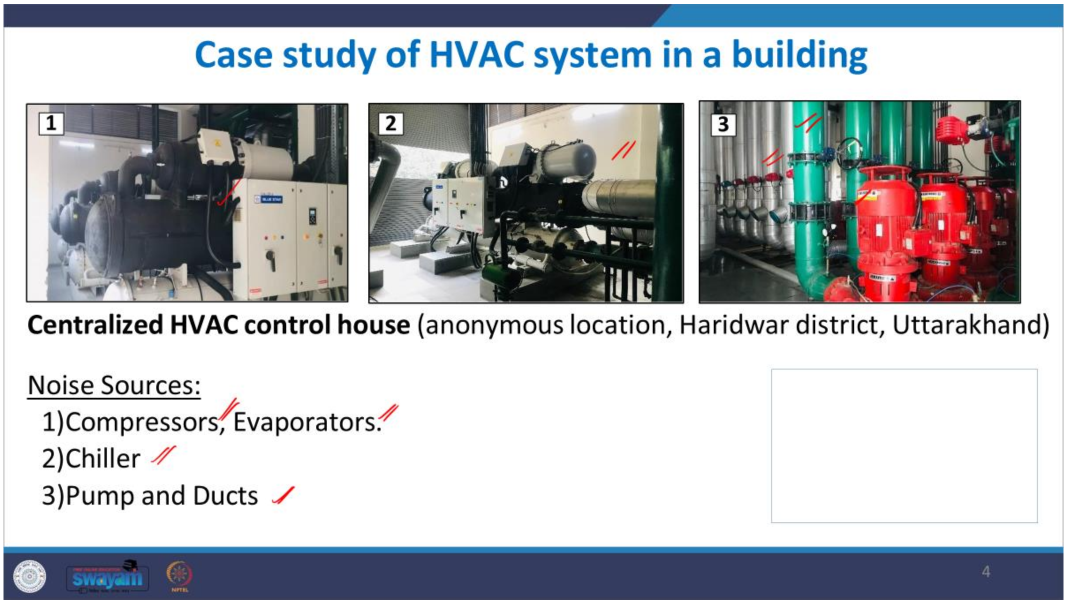

Hello and welcome to this last lecture on the course on noise control in mechanical systems with me, Professor Sneha Singh. So, we have been discussing the last module in this lecture series where we have been discussing the various kinds of case studies where we utilize our knowledge gained in this course and try to control the noise and apply this knowledge to find noise control strategies in some typical real-life mechanical systems. Within this, we have done a case study of a premium passenger car, then the case study of a passenger train.



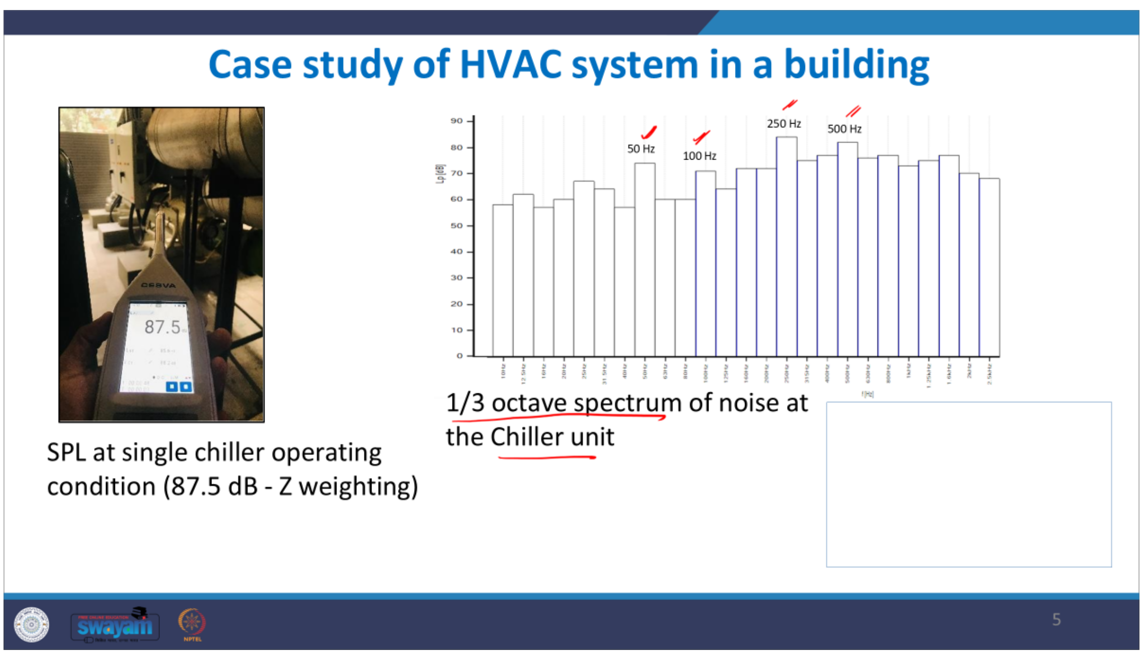

This is the last case study for this particular lecture course, where we will discuss an HVAC system in a building, the typical noise sources in that HVAC system, and how we can bring the noise level down. This will conclude with a small word of thanks.



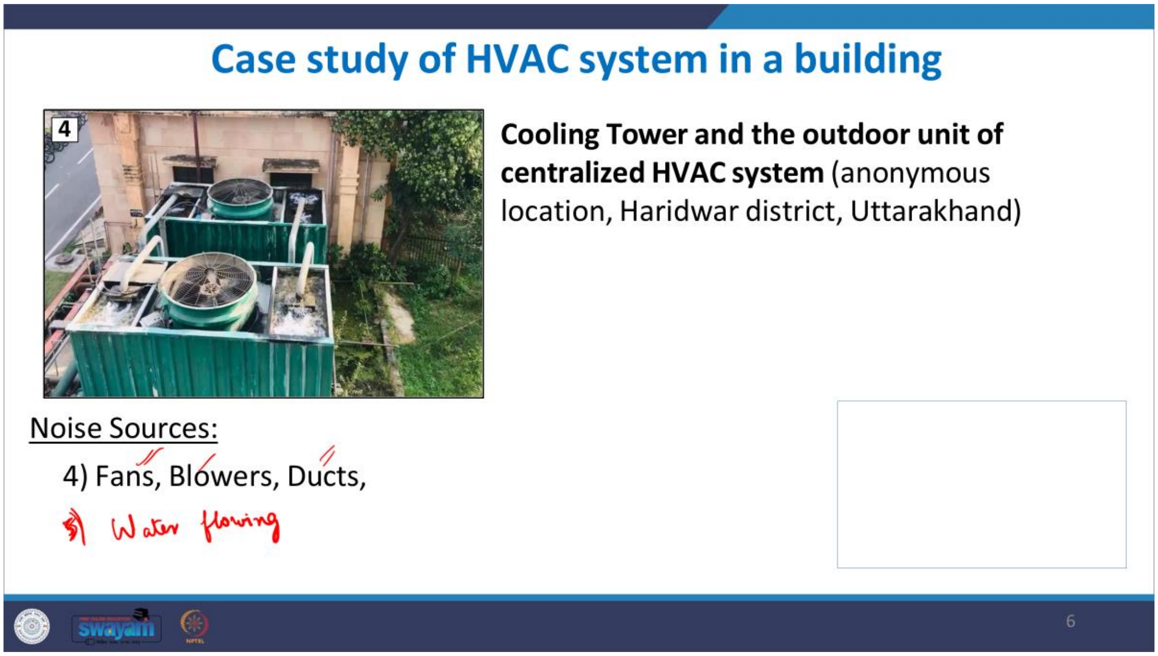

So, this is a case study of an HVAC system in the Haridwar district of Uttarakhand, and we are keeping the location anonymous to maintain confidentiality. As you can see, this is the typical HVAC plant. There is a big building that has centralized HVAC, and this is the power control house of that HVAC system for the building. There are a lot of ducts, pipes, condensers, evaporators, and chiller units. Many components are present in this big centralized HVAC system.



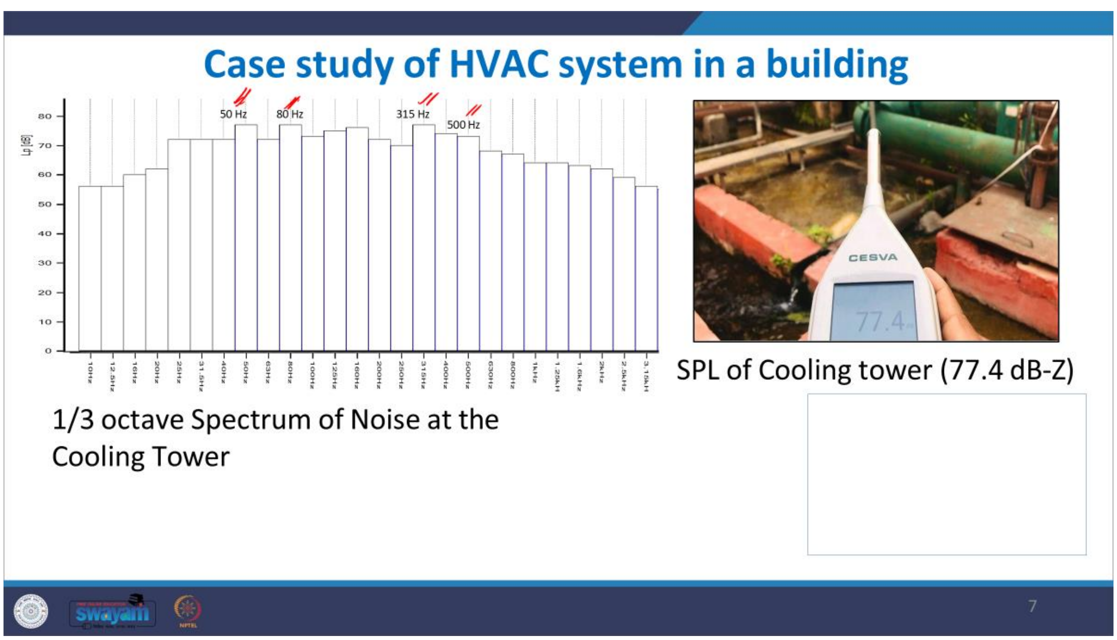

So, what are the typical noise sources? You have the compressors, evaporators, chiller units, pumps, and ducts that might be present. These include hydraulic pumps, the chiller unit, evaporators, condensers, cooling towers, etc. When we examined that HVAC system and measured the noise level, the SPL—for example, one typical noise measurement I am showing you—the SPL at a single chiller operating condition was 87.5 decibels on the Z-weighting scale. This shows the one-third octave spectrum of the noise measured at the chiller unit of the HVAC system. As you can see, the noise typically has low-frequency content.



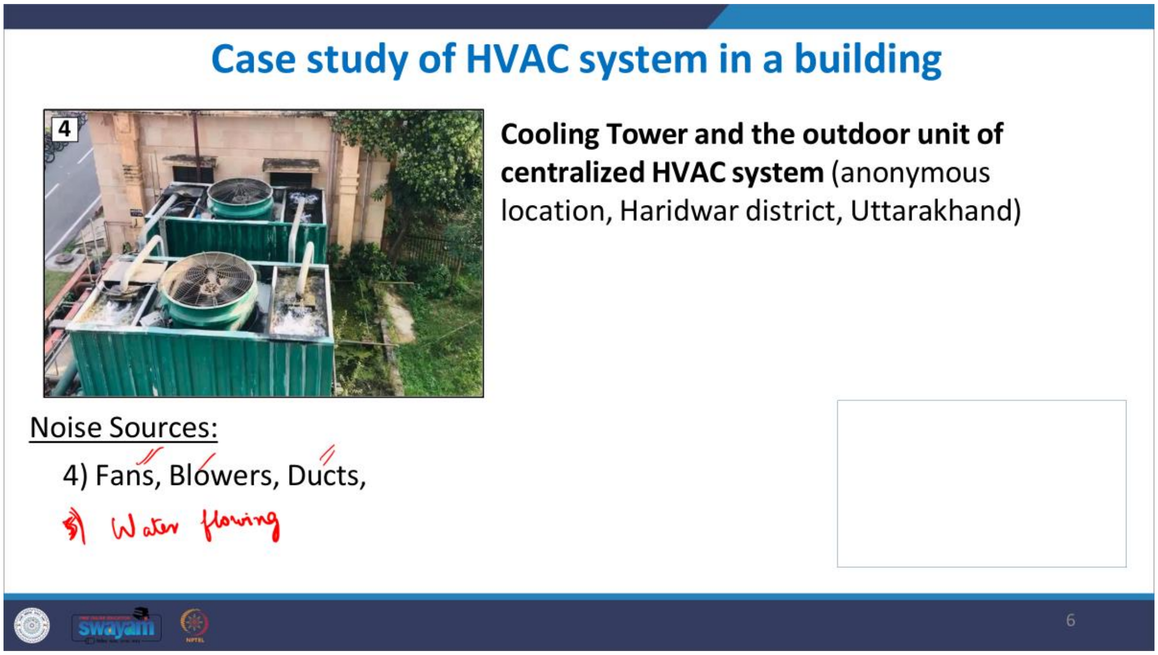

You can see the peaks are majorly in the 50 Hz, 100 Hz, 250 Hz and 500 Hz. So it is usually concentrated in the lower frequency range. And this is the outer unit of the HVAC powerhouse and this contains the cooling tower and the fans, the cooling tower and the other outdoor units for supplying the power to the complete system. In a very big building, this HVAC system is being employed and this is the outer unit for this. So here also you can see the various kind of noise sources such as you can see these fans and blowers and the ducts even you can see the water flowing that also becomes a major noise source.



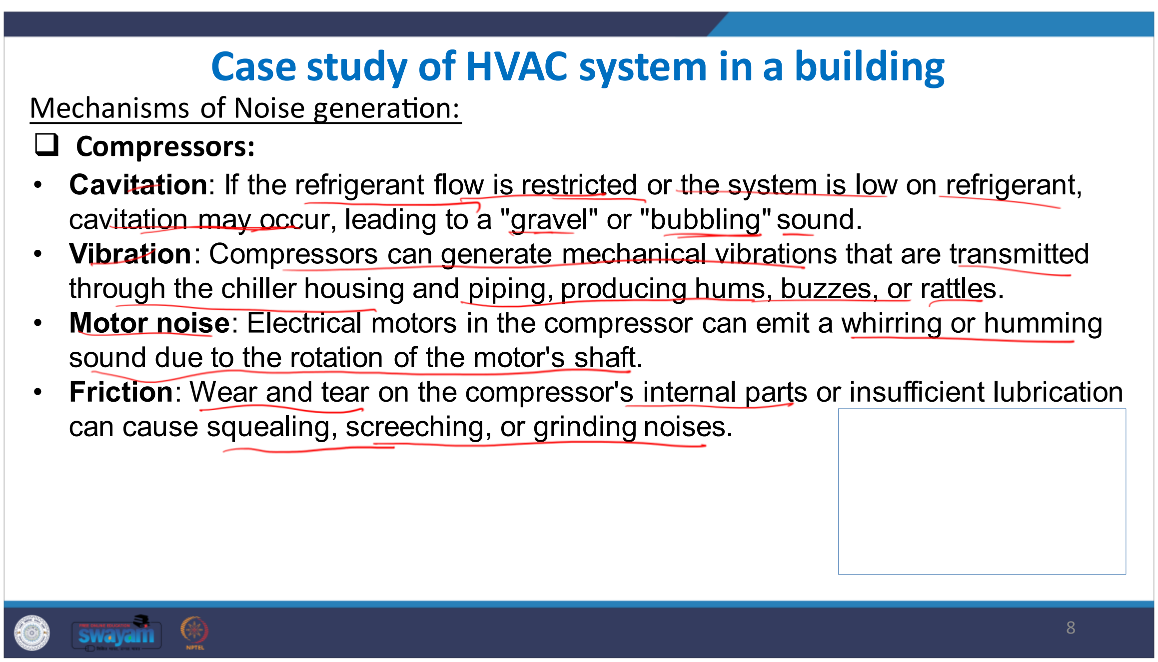

The water flowing into the cooling towers. And we measured the noise level and it was around 77.4 dB-Z and the octave spectrum of this was somewhere around, you can see the peak around 50 Hz, 80, 315 and 500. So, once again what you see is that.



Here in the outdoor unit where you know you have more of the fan noise and so the noise is both due to the structure borne as well as a lot of airborne noise. This is the fan noise and the water flowing noise.




So what you observe is that when the fan and water flowing noise is there. The overall spectrum looks a bit more broadband. The sharp peaks are not that much and you can see just these various small peaks, not very sharp, around 50, 80, 315 and 500. So, it is mostly a broadband content, whereas for the indoor units within a reverberant environment, the signal is more peaky in nature and which means that it has a higher kurtosis. So, let us see what are the mechanisms of noise generations in this typical HVAC system that can be found for sort of supporting the big buildings.

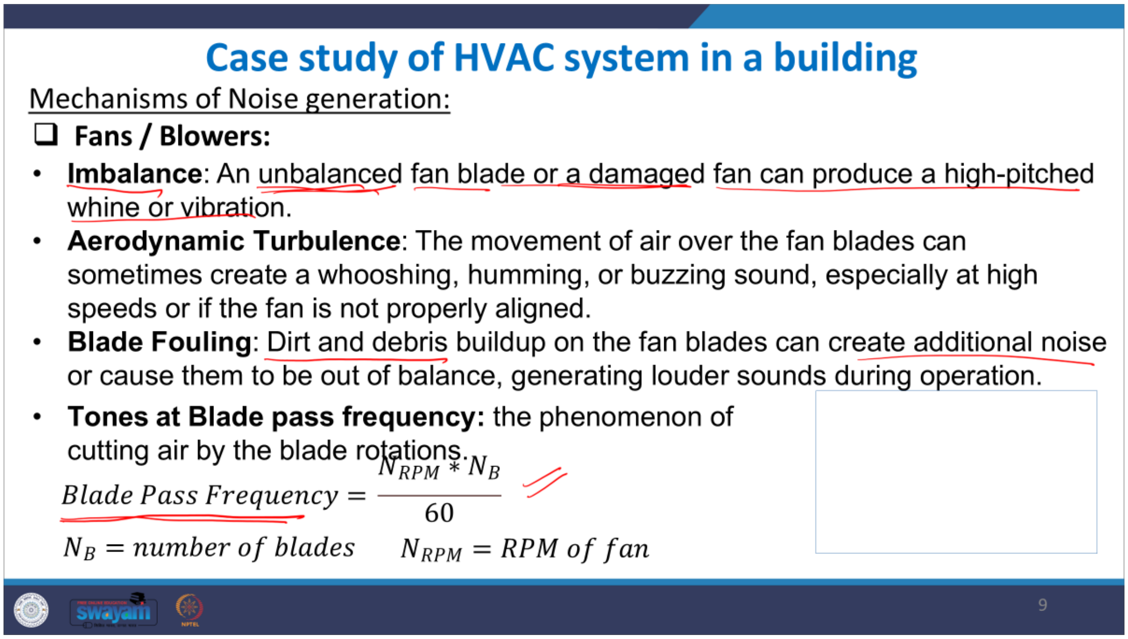


So, first of all, compressors—let us see what the mechanisms of noise generation in the compressor units are. You have Ah, because in the compressor, it typically involves, you know, the flow of the refrigerants, the pressurization of the liquids, etc. So, cavitation becomes an important source of noise. Whenever the refrigerant is flowing, it is restricted, and the flow of the refrigerant gets restricted due to some kind of obstacle that might be present within the compressor unit. Some kind of dust or dirt particle, some kind of manufacturing defect as well, or just accumulation of gravel, etc. And what will happen is that this will create more cavitation.

Cavitation can be thought of as when some kind of liquid is flowing through some kind of system, like a duct or a pipe. And there is obstruction to the smooth flow of the liquid. Then the bubbles come up—right, these bubbles come up. So, bubbling noise—you can hear that—is cavitation, the bubbling that happens. Then, the vibration when the compressors generate, in general, the mechanical vibrations that could be transmitted through the chiller housing to the various pipes, and it can produce various kinds of hums, buzzes, and rattling sounds.

Then, the motor noise. So, electrical motors in the compressor—it depends on how the compressor is operating. So, most modern compressors use electrical motors, and these electrical motors can emit some kind of whirring or humming sound due to the rotation of the motor's shaft. Then, obviously, because it is a mechanical system, it has various, you know, parts. And the parts degrade over time; they have some kind of surface roughness present, and whenever they come in contact, the wear interior and the contacting—just the mere contracting.

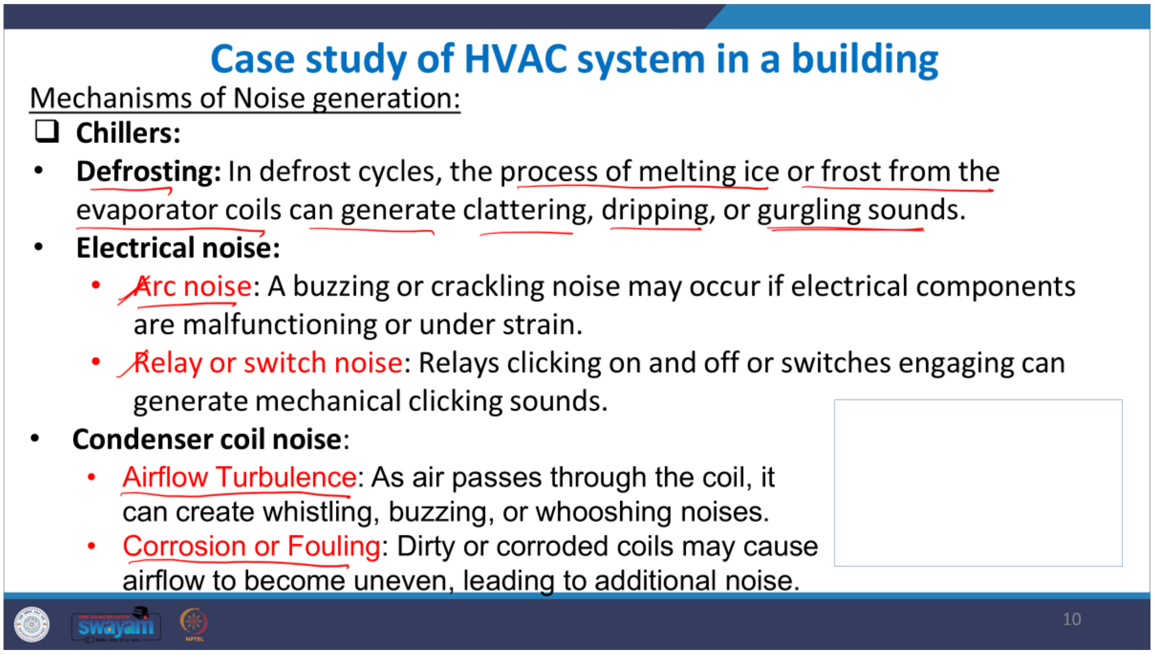
The various internal parts within the compressor can cause squealing, some kind of screeching or grinding noise, and this is the noise due to the friction between the components of a compressor. The higher this noise is, the more you can know that the compressor is getting old. And the parts are getting worn out. Some debris is collecting, the parts are getting worn out, and there is not very sufficient lubrication, which is causing a lot of friction and creating this sharp noise. Then, fans and blowers—what are the typical mechanisms? So, as you already know from the previous module, a typical fan or blower in any mechanical system creates airborne noise due to turbulence and also due to the blade pass frequency.




So, there could be additional phenomena, such as imbalance. Suppose there is some kind of manufacturing defect in the fan blade—it is, after all, a rotating machine. So, when it is rotating, due to some imbalance that might be there because of a manufacturing defect or just because the fan is getting worn out and damaged, all of this would produce some noise due to the imbalance. It would typically be a high-pitched whine or vibration and would correspond to the rotational frequency of the fan. Then, we obviously have the aerodynamic turbulence. When the movement of the air is over the fan blades, it can create a lot of whooshing, humming, or buzzing sounds, especially at high speeds or if the fan is not properly aligned and is creating a lot of turbulence in the airflow.

So, improper fan design and improper alignment of the fan blades can lead to or increase the turbulence in the air. Then, blade fouling—which simply means that the fan is getting older and the blades are being deposited with dirt and debris—builds up on the fan blades and creates additional noise or causes them to be out of balance, creating louder sounds during operation. So, this is the blade fouling noise, where, because of the dirt and debris, the noise is being created. It can act as a mass imbalance. Okay. Then, we have the blade pass frequency. So now, we have the blade pass frequency, which is like a kind of tonal noise.

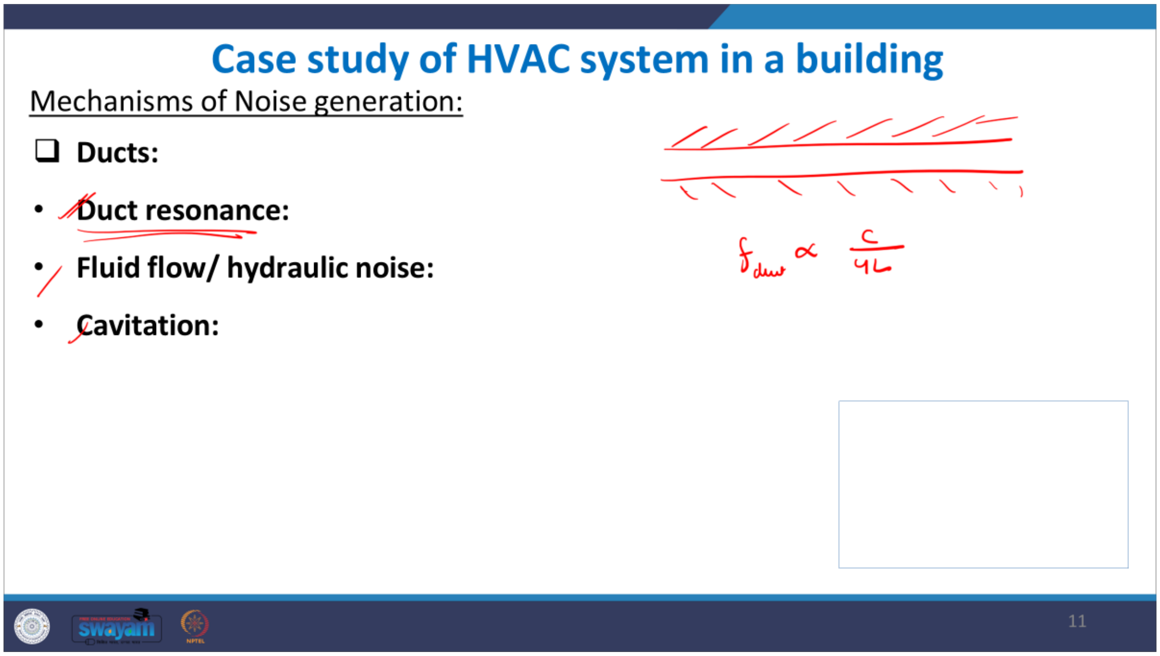
So, why is this noise created? It is simply because of the rotation of the blades. As the fan moves, the blades rotate and cut the air around it. This phenomenon of blade rotation and air cutting creates noise, which corresponds to the rate at which the air is cut by the blades, given by the blade pass frequency in this formula. So, the number of revolutions per second multiplied by the number of blades. Then, what are the mechanisms of noise generation in chillers?




Obviously, the chiller unit is responsible for cooling, and during the defrosting process, noise is generated in the defrost cycles. What happens? The process of melting ice or frost from the evaporator coils can generate clattering, dripping, or gurgling sounds. There is also electrical noise, which could be in the form of arc noise—buzzing or crackling—that may occur if electrical components malfunction or are under strain in the chiller. Okay. So, due to malfunctioning, this arc noise can be generated as buzzing or crackling.

Then, there is relay or switch noise. Relays produce clicking sounds when switching on and off, as the switches engage and generate mechanical clicking noises. Then, condenser coils can also produce noise in chillers. First, there is airflow turbulence in the condenser coils. When air passes through the condenser coil, it creates whistling, buzzing, or whooshing sounds due to airflow turbulence.

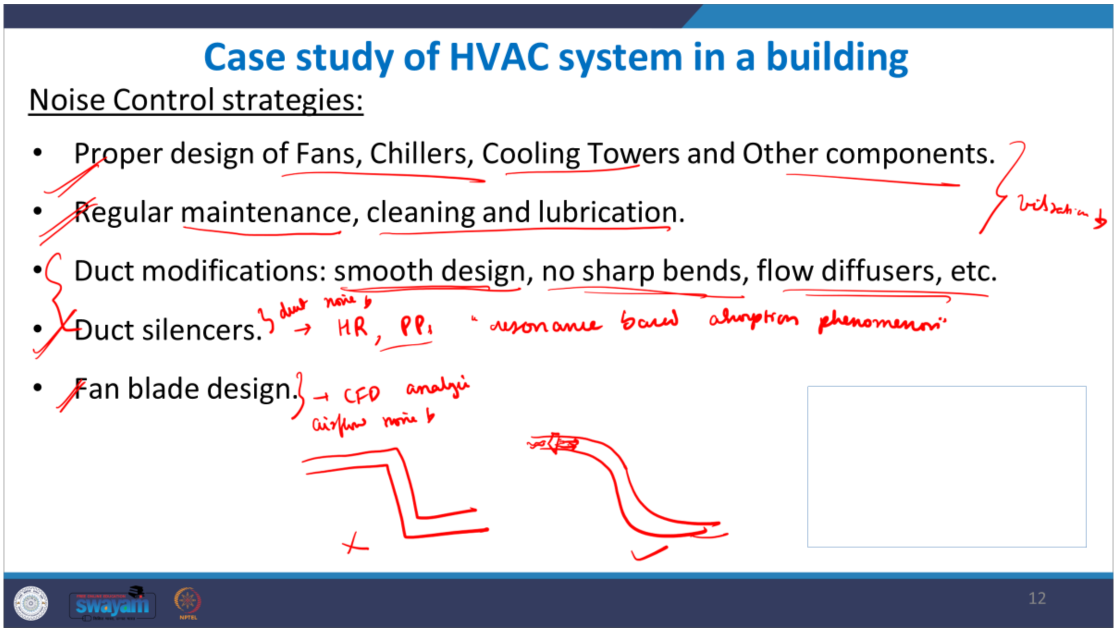
Then the corrosion or the fouling of the condenser coil because of a lot of overtime, as the dirt accumulates, the coils corrode, which may cause the airflow to become even more uneven, leading to an additional source of noise. Then, definitely, ducts are a major part of the HVAC system. So, what happens in a duct is that it is like a confined acoustic cavity. Okay, and typically, the fundamental frequency of any duct is proportional to C




by 4L, like that. Every duct has its own fundamental frequency depending on the geometry of the duct, which is typically the length of the duct. When the fluid is flowing through the duct, or when the air is flowing through the ducts, the coolants are flowing. Then, what happens is that because of the

fluid flow, sometimes the fluid flow can set the duct and excite it at its resonance frequency. When it excites the duct at its resonance frequency, sharp tonal sounds are produced by the duct. So, duct resonance becomes a very common source of noise in the ducting of the HVAC system. Then, just the phenomenon of the flow of the fluid and the hydraulic flow of the fluid creates this hydraulic noise. So, just the gushing of the water or the flow of the air itself creates noise because of the turbulence, and cavitation noise is in the form of the bubbling of the liquids. So, these are some of the major types within the ducts.

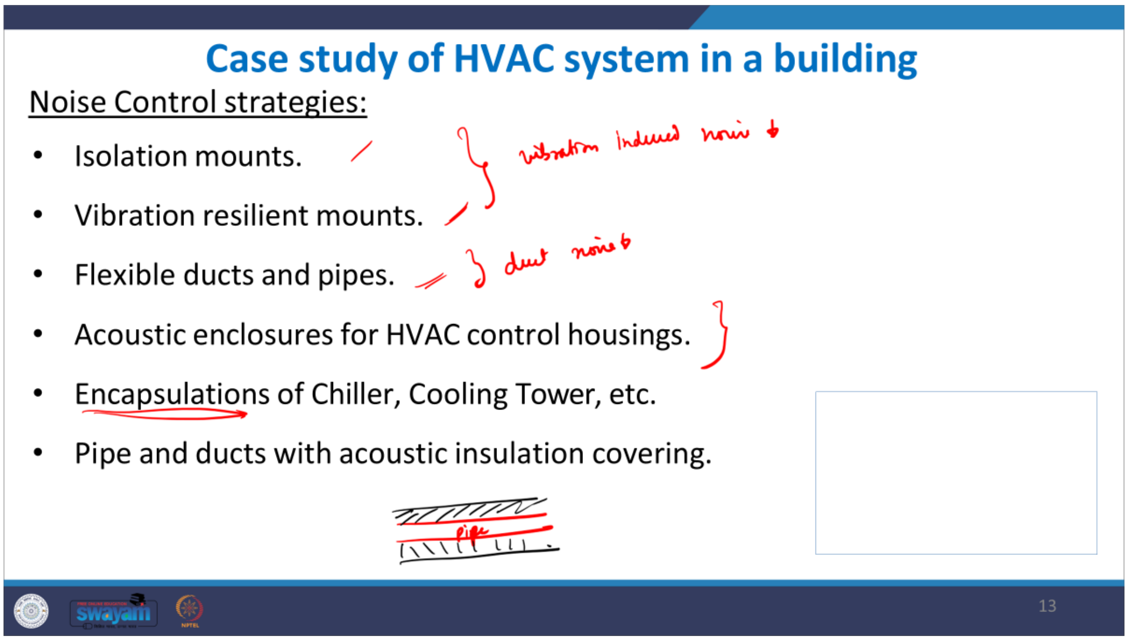
So, what are the noise control strategies? So, now we know that these are the ways in which noise is produced in the various components of an HVAC system. So, applying this knowledge, what can we say about the noise control strategies? So, the proper design of fans, chillers, the cooling towers, and various other components is definitely important. These are the generic things for every mechanical system. You need to have properly designed parts, and you need to do regular maintenance, cleaning, and lubrication to avoid noise due to fouling, imbalance, or misalignment.




Then there could be modifications done to the duct itself to tone down the duct noise. It could be that the ducts could be made smoother in design without any sharp bends, or they could have flow diffusers installed. So, when we were in the previous module when I was teaching, we had already discussed that the less resistance you offer to the flow of the air or the flow of the fluid inside a duct, the lesser will be the noise produced. So, obviously, if this kind of ducting system is there, it is going to be more noisy, whereas a duct with smoother bends is going to be less noisy. It will create less turbulence and less disturbance to the airflow.

A more streamlined design could be thought of, and then we could also have some flow diffusers installed, which could diffuse the flow. So, even if there is some turbulence here, by the time it passes through the diffusers, the flow becomes more laminar in nature. Just like in the automotive system, you have these silencers in the exhaust pipe. In the same way, you can have silencers installed in the ducts or the duct silencers, and they typically involve Helmholtz resonators and perforated panels. and various other kinds of absorption resonance-based absorption phenomena are used. So, the resonance-based absorption phenomenon is used in these kinds of silencers. Then the fan blades can be designed.

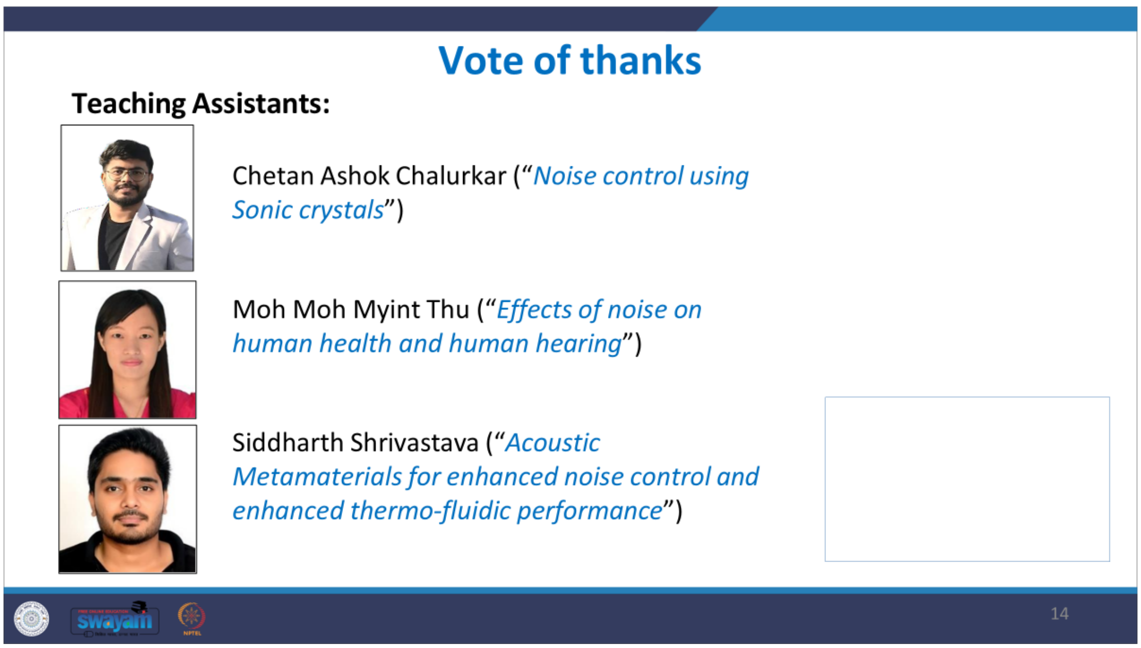
So, various kinds of CFD analysis could be done to see what fan blades lead to lesser turbulence, lead to smoother airflow, and that kind of fan blade design could be installed in the system. So, this is going to bring down the noise level of the fans. Then we can have isolation mounts, which means all the vibrating parts should be installed not directly on the ground or the hard deflecting walls, but rather through the isolation mounts they could be installed to the rest of the ground, ceiling, or any other hard deflecting surface. Then vibration-resilient mounts could also be used. Flexible ducts and piping systems could be installed once again to bring the duct noise down, and this could be installed to bring the vibration-based noise down. This will bring down the vibration-induced noise, and this is again going to bring down the duct noise.




All of this will bring down the duct noise, and this will again bring down the vibration-based noise, and this will bring down the airflow noise or simply the fan noise. So, in that way, you know, these strategies could be implemented. And because, at the end of the day, even after implementing these strategies, they may not always be feasible. Maybe the noise control design is hampering the performance of the HVAC system. So, if that is the case, when there is a clash between the noise control strategy and the performance of the device, sometimes the manufacturer would prefer the performance of the device over the noise.

So, even after these strategies, sometimes the noise level could still be up, and not every strategy may be possible to implement within the system. So, in that case, you can simply enclose it within acoustic enclosures and keep it away from the rest of the people. And then the chiller, cooling tower, and these various units could be encapsulated inside these barrier housings. The pipes and the ducts could have acoustic insulation covering. It is very common in various things.

Suppose this is your pipe or kind of duct. Then you have these acoustic insulations. That is covering these various pipes. They look like insulation tapes, but they also serve the purpose; they not only serve the purpose of thermal insulation but also acoustic insulation. Okay, so with this, we close the case study for noise control in the HVAC system, and we close the lecture series here. I would like to thank the teaching assistants for this course, who are my PhD scholars.




helped me develop the content of this course. These are Chetan Ashok Chalurkar, Moh Moh, Myint Thu, and Siddharth Shrivastava. They are all involved and will be interacting with you through the discussion forums and the websites, helping you resolve your queries. I would definitely like to thank the e-learning center at IIT Roorkee for providing me a platform to offer this online course for all the avid enthusiasts in the field of noise control. And definitely, the Indian Institute of Technology Roorkee, because I'm employed here, and they have given me the opportunity to disseminate my knowledge through the e-learning center and the NPTEL scheme.

With this, I hope you enjoyed this lecture series and thank you for listening.

**Thank You**