Applied Thermodynamics for Marine Systems

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Lecture – 23

Summer and Winter Air Conditioning

Let us continue with our discussion on the psychrometric or psychometric? processes that are common in air conditioning application. If you remember, we were discussing the by-pass factor of a cooling coil. What I said was that a cooling coil is a heat exchanger surface and basically, it is a cross-flow heat exchanger where we will have the flow of cold refrigerant through the inside of the coil and it makes the coil cool at a very low temperature and air passes over the external surface of the coil. The air which comes in contact with the cooling coil will attain its dew point temperature.

There is a certain mass flow of air past the coil or across the coil. The entire amount of air will not come to the… The surface temperature will not come down to the surface temperature of the cooling coil. If the surface temperature of the cooling coil is t_s and if the temperature of air with which it enters the cooling coil is t_a, then the temperature of the outgoing air will be somewhere in between t_s and t_a. This process is idealized in a different manner in air conditioning. It is assumed that certain portion of the air makes perfect contact with the cooling coil and has a temperature of t_s, while the other portion of air or the rest of the air does not contact the cooling coil at all and so it has a temperature t_a itself. Then, there is mixture of these two air streams and so we will have the condition of the air at the exit.

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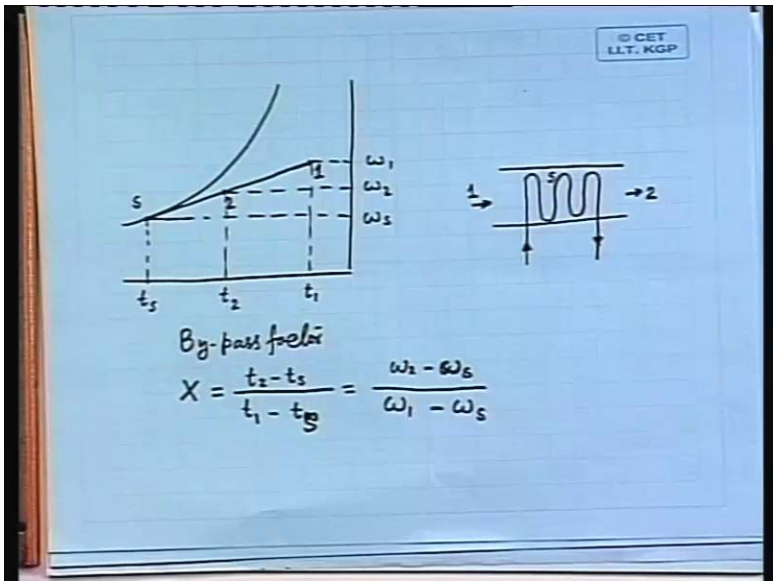

On a psychrometric chart, if we represent the process, we will have something like this. Let us say this is the dew point temperature of the cooling coil. It is known as apparatus dew point temperature and generally, it is represented by s because it is at a saturated condition. Let us say this is the temperature at which or this is the condition at which the air is drawn from outside to the cooling coil. We can represent this condition by any suitable notation; let us say we are indicating it as 1. We are assuming that certain air is there at condition 1 and another stream of air is there at condition s.

These two streams of air are mixing adiabatically to give condition 2, which is the actual exit condition of air. If we represent it schematically, let us say this is your cooling coil. This is where the refrigerant is entering, this is where the refrigerant is coming out and then, air is entering at condition 1, air is going out at condition 2 and everywhere on the body of the cooling coil, we have got condition s. One can have, this is t_s, this is t_2 and this is t_1. Similarly, one can have w_s, w_2 and w_1. The by-pass factor is generally represented by capital X, which is equal to t_2 minus t_s by t_1 minus t_s. It can be obtained by w_2 minus w_s by w_1 minus w_s. This is the amount of air which is bypassing the coil divided by the total amount of air. So, the coil by-pass factor depends on a number of parameters.

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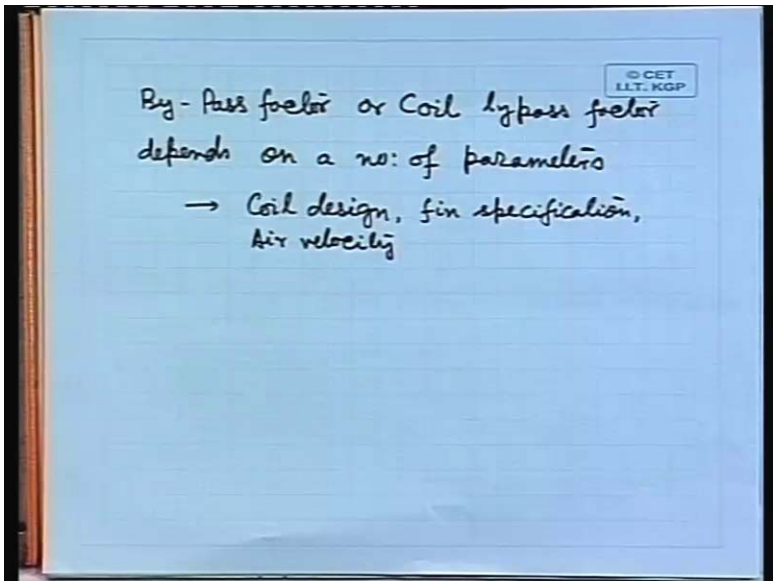

One can write, by-pass factor or sometimes it is called coil by-pass factor, it depends on a number of parameters. What are these parameters? These parameters are generally coil design and in coil design, the diameter of the coil and the number of passes of the coil will come. Then the fin specification is very important; whether you have got only a few fins or you have got a large number of fins very closely spaced, what is the fin material, etc., that is important, and the air velocity. The by-pass factor depends on these parameters. If you have got a very compact coil, which means that if you have got a large number of tube turns, large number of fins of highly conducting material and if you have got high air velocity, you will have a low by-pass factor, whereas if air velocity is low, I mean the fin density is not high, then one can expect a high by-pass factor. This by-pass factor is generally specified by the manufacturer of the cooling coil. It is a parameter which one needs for design and estimation. Knowing the by-pass factor and the apparatus dew point temperature and the temperature of the incoming air, one can determine what will be the temperature of the outgoing air and how much moisture will get separated. These useful quantities can be determined by knowing the by-pass factor of the cooling coil.

Then, we are going for the analysis of summer air conditioning. As I have said, I like to discuss the air conditioning process for different situations. Though there could be air around the air

conditioning system, the processes of air conditioning for summer and winter are different. Let us first discuss summer air conditioning.

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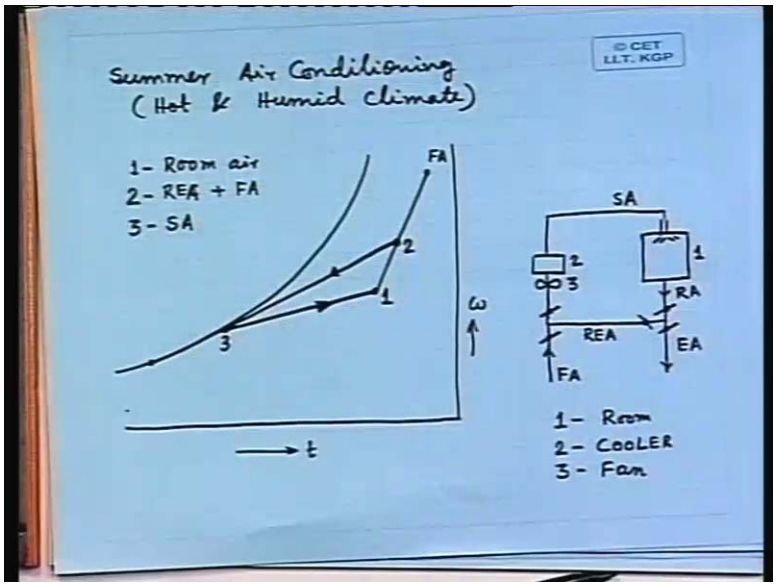

Let us see summer air conditioning, particularly for a hot and humid climate, which is the situation in a large number of places in India. We will have a cooling coil through which we will have the evaporating refrigerant. Then, we should have a vapor compression refrigeration system. The evaporator of it will be used as the cooling and dehumidifying coil. Let us see how one can achieve summer air conditioning for a hot and humid climate. Let us say that the condition of the cooling coil, the apparatus dew point temperature is somewhere here. The comfort condition will be somewhere here and then the outside air condition is somewhere here – high temperature, high humidity, outside air condition will be somewhere here.

Basically what is done is, let me draw a figure, a schematic diagram and then it will be understandable. We will have a room; this is the room. In the room, cold and dry air will be supplied. This is the room where cold and dry air will be supplied. This air has to come from a cooler or cooling and dehumidifying coil. To have this, one should have a fan and then from the room, this air has to be extracted. Part of it will go to the atmosphere and part of it will be recirculated back. Then from the open atmosphere, one has to take certain amount of air. Generally, in this path, one will have dampers to control the volume flow; one can have number

of dampers. This is how one can show schematically the arrangement. This is called supply air SA, this is the return air RA, this is exhaust air, let us say EA, this is recirculated air REA and this is fresh air FA. We can give different names also. This is 1, 2, 3. I have drawn a very simple diagram. 1 is the room, 2 is the cooler and then 3 is the fan. I have shown only a few things. There could be a number of other items, which we will discuss later on.

This is a summer air conditioning process, which I like to also describe with the help of the psychrometric chart. 1 is the room and let us also represent the room air condition as 1. Actually, I said that this is the comfort condition, if you remember. While I was describing this diagram, I told that this is the comfort condition. It is like this. When we supply cold air to the room or to the condition space, we supply it at a very low temperature and at a very low humidity, low absolute humidity or low humidity ratio; we supply the air at a very low temperature and at a very low humidity. That is obvious. We have got experience that if we stand just beside the exhaust of the air conditioner, we feel the gust of the air which is coming out of the air conditioner to the room and the air is cold enough – it is not comfortable, it is cold enough. So, we have to supply cold air because inside the room, there is enough heat load. We have to pick it up and that is why you have to supply cold air. But where human beings or occupants are there, when the air comes to that place, it will be at the comfort condition or it should attain the comfort condition. It is also assumed that when the air goes out of the room, it is having the comfort condition; that means the air that goes out of the room is having the properties corresponding to the comfort condition. This means that if we design the room air conditioning system for let us say 25 degree Celsius or 26 degree Celsius and 60% relative humidity, the air which will be going out of the room, will also have 26 degree Celsius and 60% relative humidity.

This will be the room air condition and it will also be the condition of the air which is leaving the room. Here, what we can see is that part of the room air is taken for recirculation and is mixed with fresh air, which is nothing but outside air. This is fresh air. If these two air streams mix together, we will have the mixture condition somewhere in between. This air will now pass through the cooling coil, something like this (Refer Slide Time: 19:49); this air will now pass through the cooling coil and then, it will be somewhere here. This cooling coil has some sort of a by-pass factor and so the supply air condition will be somewhere here and it will go to the room. How to represent it? Let us say this is 2 and this is 3. For this diagram, let us say this is

temperature t and omega. We can call 1 as room air, 2 as recirculated air which is again being re-circulated over the machine. Let us call it, mixture of recirculated air plus fresh air, so mixture of recirculated air plus fresh air. This is condition 2. Then 3 is the supply air, SA.

What we can see is that 2 to 3 is a cooling and dehumidifying process which is taking place in the cooling coil. The mixture of recirculated air plus the fresh air goes through the cooling coil and experiences a cooling and dehumidifying process. Then, it is supplied to the room. In the room, it undergoes a heating and humidification process. In the room itself, in general, there will be both sensible load and latent load. This will be picked up by the air and so, we will have heating plus humidification when the air passes through the room. There will be a mixture of fresh air and recirculated air and when it will be supplied to the machine or cooling coil, it will have a still higher temperature and higher absolute humidity. That is what we will have in our summer air conditioning. The recirculated air, actually this comes in the details of air conditioning, why is it needed?

The ……. first thing that inside human being will be there and so due to their respiration, one will have depletion of oxygen and increase in carbon dioxide. The need for recirculated air is not only for that but also there is generation of staleness inside the room and so air has to be freshened up. That is why certain amount of air has to be put outside as exhaust and instead, we have to take some amount of fresh air. That is what we have in summer air conditioning. But here, you see in the summer air conditioning, mainly we have one equipment – that is your cooling and dehumidifying coil. We have only one process – this is 2 to 3 and by this process, we are controlling both temperature and humidity. This task sometimes becomes very difficult. Sometimes, it is like this – let us say it is the rainy season and the outside air is heavily loaded with moisture. We have got a lot of moisture and we have to get rid of it. What can we do? Then we have to cool the air to a very low degree or the apparatus dew point temperature will be very very low.

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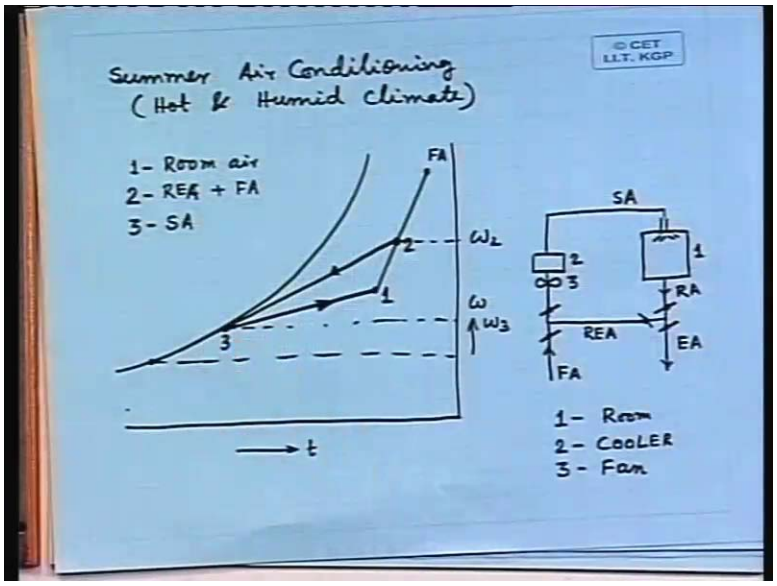

If the apparatus dew point temperature is very, very low, then only, this is the condition of air w_2 and this is w_s or let us say, taking the by-pass factor into consideration, this is w_3. So w_2 minus w_3 has to be quite large or in other words, w_2 is fixed and we have to make w_3 very large. That happens in a number of cases when we are having a lot of moisture in the air that goes through the cooling coil or may be inside the room itself and it has to pick up lot of latent heat. Inside the room, it will pick up a lot of moisture and so in those cases, it happens.

We have to lower down the dew point temperature. If we lower down the dew point temperature, we can get rid of moisture but at the same time, the supply air temperature will also fall down. That may not be permissible or that may not agree with our comfort condition. What do we have to do there? After getting rid of the moisture, we have to go for heating the air. This is called reheating of air. In summer air conditioning, particularly when it is highly humid condition, we have to go for reheating.

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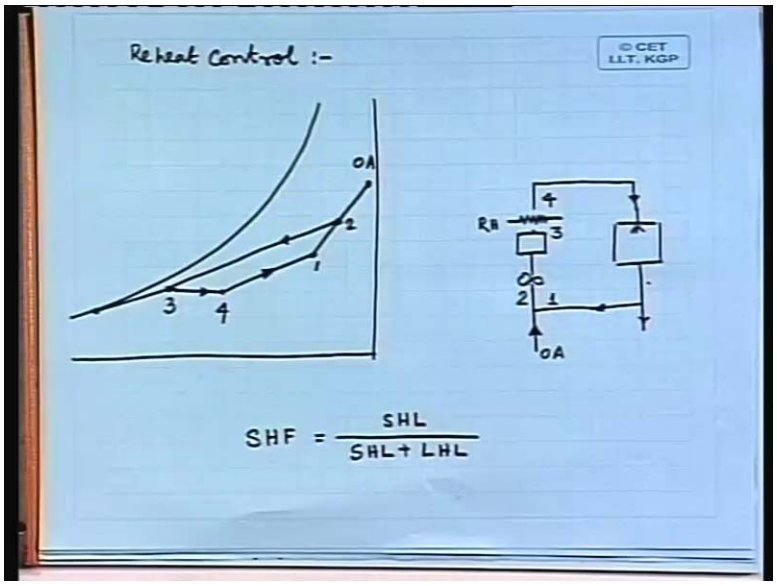

Reheat control; sometimes, it is called reheat control. Why is it called reheat control? It is because we are controlling the temperature of the supply air by the process of reheating and that is why it is called reheat control. Let me draw the psychrometric diagram first and then we will go for the other diagram. This is the apparatus dew point temperature and this is where air will be supplied. From here we will have a reheat process, which means that we will have increase in temperature without any change in the humidity and then we will have change in the room where both temperature and humidity will increase. Then, we will have outside air condition OA and this is 2. We can have 1, 2, let us call this 3, let us call this 4; 3 to 4 is the reheat condition.

If we want to represent it schematically, we will have the room and this is supply air. Then part of it will go out and the rest will be taken as recirculated air. It will be mixed with fresh air, then we are having the fan, we can have the cooling coil, we can have the reheater RH and then the air will go like this. What we can have here is this is outside air OA and room air is coming at condition 1, so this is 1. 1 and OA are mixing, which is giving 2. Here, it is 3 and here it is 4. This is what we will get in a physical system.

No, we are not assuming. You are asking whether we are assuming that in the room, the temperature difference is less, but there is no need of assuming it. Only thing is that from the comfort requirement, we need to supply the air at certain temperature and also, that is necessary

because the room has got certain load. So it is also necessary to supply it at a particular temperature.

What happens is that sometimes, particularly during humid climate, we can have lot of humid load. In that case, to take care of this humid load, one has to overcool the air so that some good amount of moisture can be separated out. If we do that, if we overcool the air also, that means its temperature is lowered to a very large extent and that may not be practicable. That is why we have some method for balancing it. We heat the air after it is cooled or after the moisture is separated. This process is known as reheating and this heater is known as a reheater. One can look into the whole situation from a different angle.

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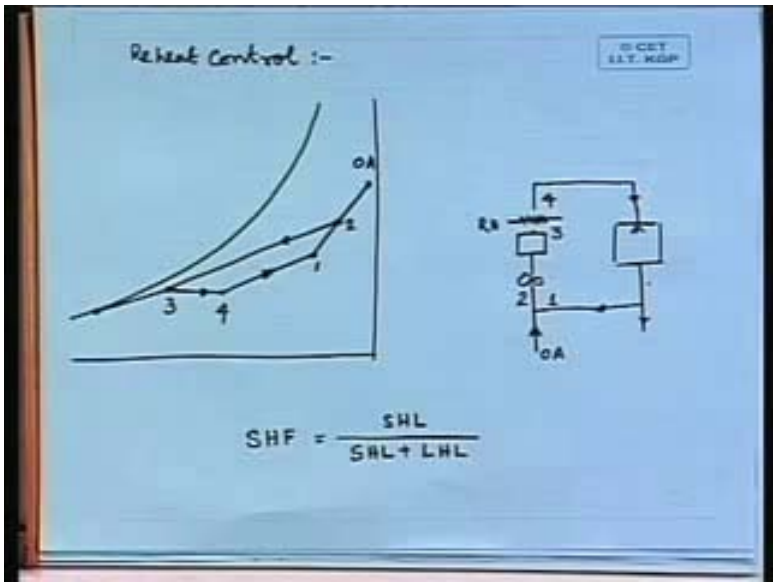

Already, I have introduced the sensible heat factor. The sensible heat factor SHF is equal to sensible heat load SHL, we call it sensible heat load, divided by sensible heat load plus latent heat load. Sometimes, what happens if the latent heat load is very high, then the sensible heat factor becomes very low. For all the processes, there is some permissible value of sensible heat factor, but our latent heat load is so large that it is lowering down and it is bringing it below the permissible level of the sensible heat factor. Then artificially, I have to bring the sensible heat factor to the acceptable value. What can I do? I can introduce artificially some amount of sensible heating. That is what has been done by the reheating process. Clear?

There must be a certain level at which this facility is used. That means the humidity level has to be at certain level.

Yeah. When humidity is very high then only we can do. What is that high level? Actually, all this depends on a number of things and a number cannot be told. It depends on a large number of things. It is like this. Let us say the outside humidity is not very high, not extremely high. But inside the room, we have a lot of humid load. Then, what we have to do is we have to go for it. Generally, a good air conditioner will have provision for reheating and we can control the room temperature with the help of reheating. This is a very convenient method of doing so. But again from the energy point of view, this is not a very good technique. Because what we are doing is we are artificially creating heat load and again that heat load is being taken care of by our machine. We need to have a heater and to consume that heat load we have to have some sort of an oversize machine. But in certain cases, we have to live with it; we cannot avoid it. This is what is called as reheat control or reheating process or controlling the air condition by the heating process. So it is called reheat control.

In certain places, one can have hot and dry climate. In hot and dry climate, one can have the cooling coil. That means a vapor compression refrigeration system and the evaporator in the form of a coil; that can be done. But whenever you are having the cooling, it will again take out some amount of moisture from the air and you probably need some sort of water sprinkling in the air itself to get back the humidity. There is another technique which can be used. One can go for evaporative cooling. As far as comfort air conditioning is concerned in India, in a number of places, those air coolers are sometimes called reject coolers are there, where one can do the cooling with water stream.

There are mechanized systems also, sophisticated mechanized systems, those are known as air washers. With air washers, we can control the desert type of climate also very easily, because the air there is going through some sort of a spray of water which is pumped and not only that, that water condition can be monitored either by cooling or heating the water. That is why I said that it is a rather sophisticated equipment and with that, we can tackle the desert climate or hot and dry climate.

Can you repeat your question?

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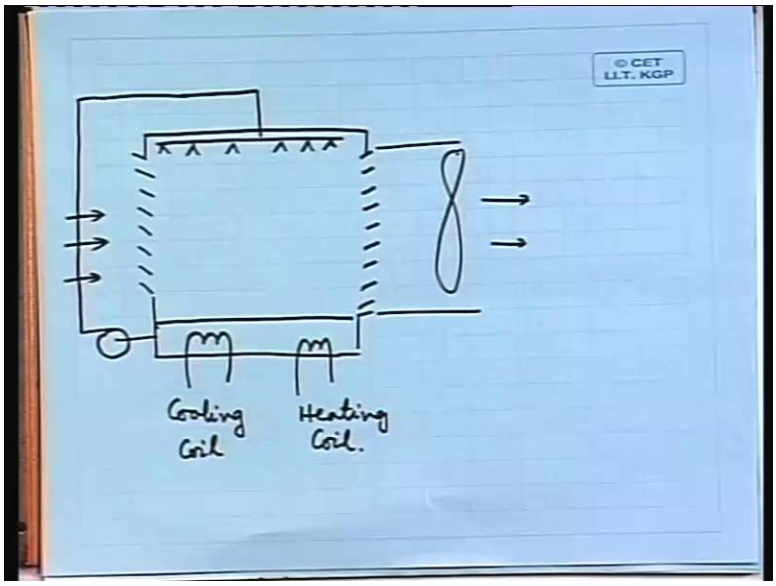

Very quickly, let me draw it so that it will be clear. It is like this. You have a system like this. This is your air washer, maybe you can have some sort of a ducting and some sort of a fan for drawing air – something like that and you have got a pump. This is air and these are number of nozzles. Here, you have the cooling coil and the heating coil. You are making contact between air and water, but you can monitor the water condition. Again, here, one can have the reheater etc., – reheater or preheater; those types of things are possible. Here, as you are using water, if any evaporation is needed to increase the moisture content of air, that is possible. But in India, the use of this air washer is limited. There are certain systems; particularly the air washers are suitable for large systems and so for large systems in certain establishments, air washers are used. This takes care of the desert climate or hot and dry climate.

[Conversation between student and professor - Not Audible (40:27 min)]

That is what I told. What you are telling is that heating coil or cooling coil is not there. Yes, that is a very cheap system. In large parts of north India, we get this and we call it air cooler or desert cooler. That is there; but what I am telling is that one can have a sophisticated, good system where temperature control, humidity control is possible with the help of air washer. In fact, the air washer is a much versatile machine compared to our vapor compression-based air conditioning system because of its versatility and because it can go for evaporative type of

cooling, it is a much versatile device compared to the conventional air conditioner. But then it is more bulky, it is noisy, it is leak-prone – has leakage problem; that is why it is not used that much.

We have discussed regarding summer air conditioning. Now, winter air conditioning, I should say, is not that critical, particularly in our condition. Mostly, we need heating and in some extreme conditions, we need heating plus humidification – not in all cases but in extreme cases, heating plus humidification. Heating is rather easier. Basically, you need a blower for circulating the air and you need some heating and for a compact system, electrical heating is there. But people may argue that that is high-quality energy, I mean heating from low-grade sources like steam or hot water heating is also there. Particularly in cold countries where room heating is a must, they will have a boiler to have the steam form and then it is circulated throughout the building.

That is why they will have a centralized heating mechanism for the room and by that, the entire room will be supplied or there can be a district heating system where steam will be generated at one place and it will be supplied to a number of consumers – that is possible, or one can have electric heater. But when heating plus humidification is needed, in that case we are having two or three different options. One option is water injection – that means you can increase the moisture content by injecting water. Now, if you have to do this, it is always advisable to increase the air temperature first and then inject water because at high temperature, it will have higher ability to retain moisture.

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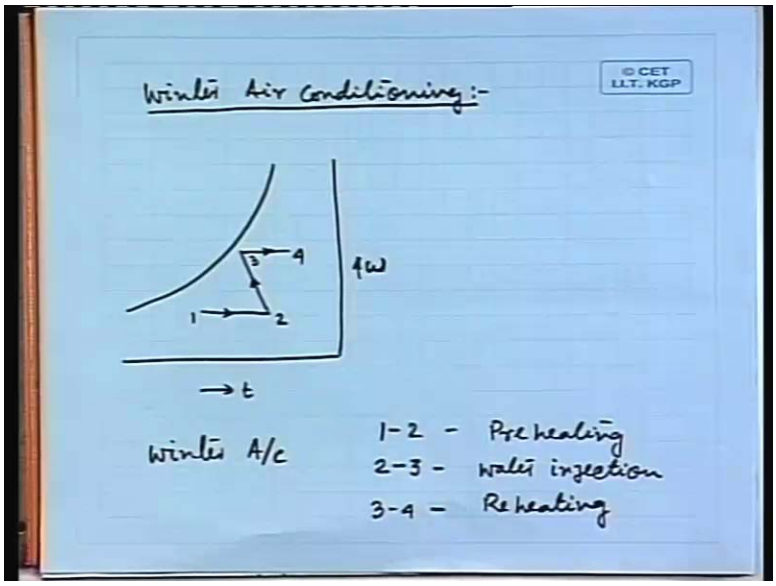

The process will probably be some type of process like this. One can think of a process like this – 1, 2, 3, 4. This side is t, this side is w. Winter air conditioning; 1 to 2 is called preheating. Generally, if any heating is there before evaporation or condensation, we call it preheating. Then, 2 to 3 is water injection. If we inject water, what will happen? Water will evaporate. During that process, the moisture content or absolute humidity will increase, but there will be decrease in temperature. This process, this curve will be similar – may not be parallel to your constant wet bulb temperature curve, but it may be at an angle with the constant wet bulb temperature curve. In some cases, if you control the process, then it can be parallel to the constant wet bulb temperature curve. So 2 to 3 is water injection and 3 to 4 is again reheating. In winter air conditioning, you can have these three or maybe these two: preheating and water injection. Depending on the situation, you can have this type of a process.

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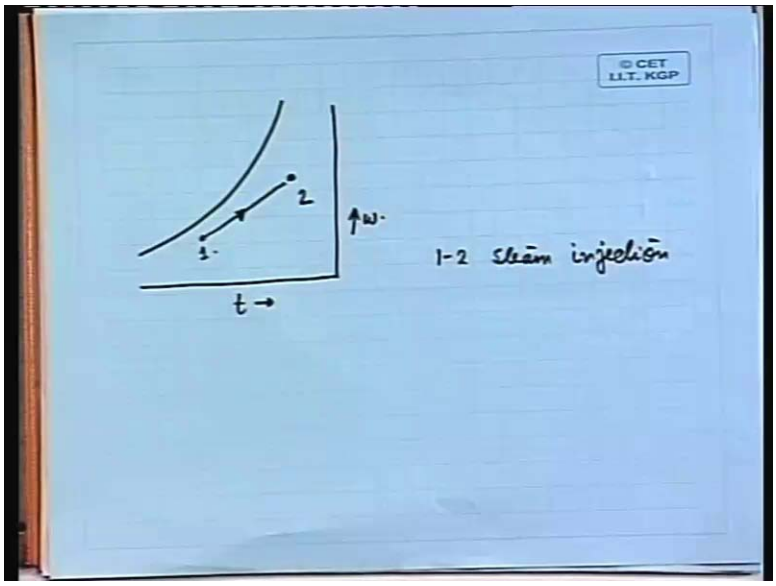

One can have another option also for winter air conditioning. The condition during winter is somewhere here; our comfort condition is somewhere here. One can have steam injection. If you inject steam, then you will increase the moisture content and you will increase the temperature also; here, t and w. This is 1 and 2. 1 to 2 is steam injection. This is also possible.

Actually, I could get what you told. See, it is again just like our cooling and dehumidifying coil. Here also, with a single process, I want to control two parameters, temperature and humidity. Here, problems will be there or may be there. What is done is sometimes or most of the time, with steam injection we also have reheating or preheating. That means temperature is controlled by at least two methods and steam injection is there to supplement humidity.

One thing is there; for humidity, one can allow a larger range for comfort feeling – that is there. Control does not become very critical for comfort condition, but for other applications like electronic fabrication etc., humidity control has to be done precisely. There, some sort of chemical processes are also used to take care of moisture control. Some sort of desiccation etc., are also used for the control of moisture content but for comfort condition, it is not very critical. In some cases, you may need to inject steam because it is giving heating plus humidification – that is possible. I think I will stop our discussion on air conditioning with this and we can go to other topics.