Energy Conservation and Waste Heat Recovery
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Lecture - 49
Heat Pumps - III

Welcome back to the next lecture on Energy Conservation and Waste Heat Recovery. And today what we will do is, as you know over the last two lectures we were discussing about heat pumps for waste heat recovery. So, today we will just look at one more example and then conclude this lecture with a summary of what we discussed.

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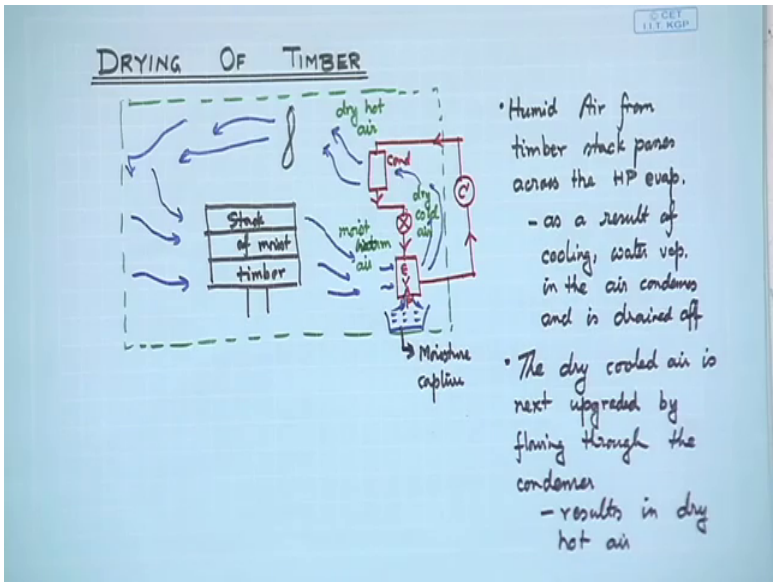

So, the last one that we are going to talk about is again and is an example of air and this is used for drying of timber. Think about it, for drying what do we need? For drying of timber or let us say; even in the paper mill for drying of paper yarns or even textile industry for drying of textiles. We need, if we are talking about air drying we need hot air and that air also has to be dry the air cannot have moisture content.

So, this is going to be a challenge how do we first dehumidifier the air and then heat it up and so on. So, one of the way exactly in the in the order that I described how do I dehumidify the air first and then heat it up heat pump again is a wonderful technique using the vapor compression cycle heat pump can be used; how, let us look at this let us think about let us consider a stack of timber like this; this is pictorially represented in this

manner in a very simple manner like this and let us say this is my stack of dry timber which needs to be dried.

So, what I will do over here is as I said I am going to use a vapor compression cycle once more. So, let me draw that vapor compression cycle again here I have a compressor let me say here I have my condenser then my expansion valve and then my evaporator and then the outlet of the evaporator goes to compressor. So, this is my vapor compression cycle as we know what do; I need I have air and I need hot dry air to come and dry this timber. So, this is a stack of moist timber. So, I need to dry this how will I do it is the next question. So, what I will do is I have room m air I will first draw the loop and then we will talk about it.

So, this air actually passes through the evaporator and after the evaporator it is directed towards the condenser. So, remember this is a sequential is the same fluid first is goes to the evaporator then it goes to the condenser probably we will have a fan over here to drive it back here. So, let me first draw some boundaries. So, the compressor and probably even the expansion valve can be or can be outside. So, what needs to be inside this timber drying unit is this.

So, what is happening? So, the first thing is let me say let me write down each of them one by one; the humid air from timber stack passes across the heat pump evaporator now as it does what happens the temperature drops down below the dew point and therefore, it loses the moisture. So, I would say that as a result of cooling. So, cooling of this moist air water vapor in the air condenses why because the temperature falls below the dew point and is drained off.

So, below the evaporator, you will have a collector where the water drains off. So, I would write here as I would name this as moisture capture. So, then I would say is the dry cooled air is next upgraded. So, it is next upgraded; how by sending it through the evaporator I, sorry, by sending it to the condenser. So, as it goes to the condenser it picks up heat from the refrigerant and this temperature goes up by flowing through the condenser.

So, here what it does is it gives up heat and therefore, the temperature goes up sorry, it absorbs heat because a refrigerant gives up heat and. So, the temperature goes up. So, result is results in dry hot air. So, let us quickly write this down this one is what its dry

hot air, what is this? This is also dry, but this is dry cold air this one is moist hot air. So, the dry hot air as it pass coming out of the condenser when it passes through the stack it dries the moisture or it dries the timber and therefore, picks up moisture. So, what comes out is a moist hot air I would say hot or probably it also loses some heat to the moist timber. So, it will be warm air let.

Let me correct this and say this is warm air its moist warm air which flows to the evaporator where the temperature cools down to below the dew point. So, the moisture separates out and is captured below and what comes out of the evaporator is dried and cooled air. So, I have I have got the dry part, but then I also need to heat it up where it is when which is done by passing it over the condenser and the output there is dry hot air which I can used to for the drying of my timber.

So, the same principle can also be used for a paper yarn manufacturer they also use for drying their yarn they also use heat pump. So, this configuration in different form, but it is the same principle that if you have a drying application where you want to use a gas or air you first pass it through the evaporator when you pass it through the evaporator, you can separate the moisture out because the temperature you have to design the evaporator such that the temperature of that gas in this case air goes below the dew point under those conditions. So, therefore, the moisture condenses and is separated out and what comes out of the evaporator of the heat pump is dry air.

But remember just dry is not enough we have to heat it up as well. So, therefore, the same dry air at a lower temperature coming out of the evaporator is upgraded by passing it over the condenser. So, as it passes over the condenser, it picks up heat from the refrigerant, it heats up itself and what comes out. Therefore, is hot and dry which is what we need for our drying application clear. So, that is the overall principle of operation of heat pumps for drying applications. So, what I showed here is again I repeat that it is for a stacked stack of timbers, but you can think of a same application using the same principle maybe in a different form for drying of paper drying of fabrics and so on clear,.

So, that kind of brings us towards the end of our discussion on heat pumps.

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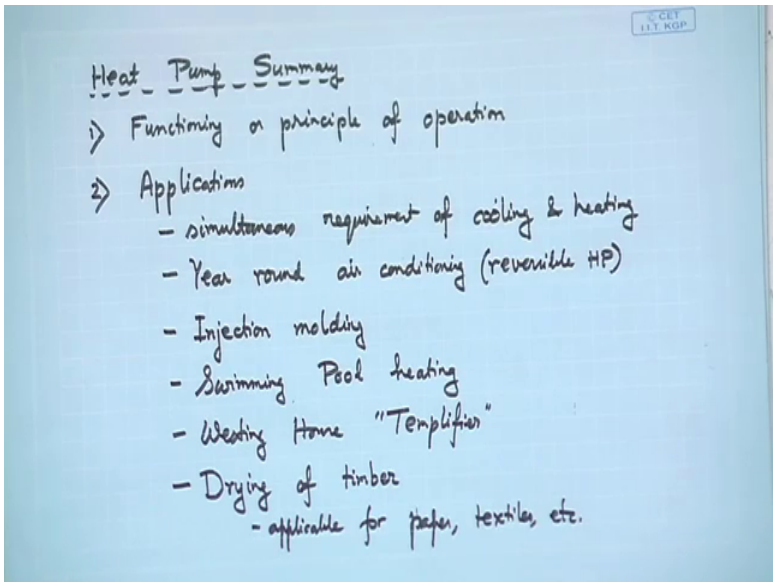

So, let us do a quick recap and see what all we studied. So, heat pump summary if we want to tabulate. So, we started by saying that how does the heat form heat pump work. So, I would say functioning for principle of operation clear. And we said that the functioning of the principle of operation is basically a vapor compression refrigeration cycle by which the fluid at a lower temperature a waste heat at a lower temperature can be upgraded to a higher temperature of course, it does not come for free, because in a heat pump using a vapor compression cycle you need compressor which needs electrical power, right.

So, you have to spend energy and only then can you upgrade the heat from a lower temp upgrade thermal energy from a lower temperature to higher temperature clear. So, we know that and so, we or rather we have flow of heat from a lower temperature to direct to a higher temperature only when we have external work done on a system, right and this is what is done. So, that is the principle of operation of a heat pump next what we did was we went straight away into applications. So, we saw that heat pumps is ideal when you need simultaneously. So, simultaneous requirement of cooling and heating how can we and what are the different ways that we can do it or what are the different scenarios under which you need both heating and cooling.

We can think of our factory where you need 2 processes one requires heating another requires cooling or you can have a single process stream wherein at one location you

need you need it to be cooled and then later, you need it to be heated right and we saw examples of that. So, then what we did was we looked at few specific examples those were generic scenarios one of them was year round air conditioning, right. So, this was a reversible heat pump that we talked about. Remember we talked about a reversible heat pump where using a four way switch we were able to you know we were able to switch the evaporator and condenser or switch the evaporator and condenser or rather use the heat exchanger that we have inside the room as an evaporator in summer.

So, that it leads to cooling and as a condenser in winter. So, that it leads to heating. So, we looked at this application and it was a wonderful example of heat pump again remember that in summer while; we will while we had cooling bypassing the hot outside air over the evaporator we also had additional or air at a still higher temperature the condenser end. So, that can be used for various purposes. So, heated air that is thermal energy at high quality has lots of applications you can use it for washing clothes if it is a domestic application you can use it for some process if it is an industrial application where you need heated where you need heating clear.

Similarly, during winter while we were getting heated air inside the room or inside the small industrial unit we are also getting chilled air at the evaporator end and this chilled air can also find applications another example that we talked about was that of injection molding where what did we use where the output where we were we could think of using water. For example, at room temperature whatever we have using a heat pump the same water goes over the evaporator and leads and gives rise to chilled water. The chilled water can be circulated around the injection mold. So, that the plastic gets solidified and we get the product in the form and shape that we want.

At the condenser end again the room temperature water can be used as the fluid at the heat exchange fluid. So, that what comes out is heated water that heated water can be used for factory space heating or we can also use air as the fluid in the condenser where you get directly heated air which we can directly provide to the factory floor in case of water heated water we will pass it through some of these room heaters that use re-circulating hot water or hot fluid clear. So, injection molding was one industrial example that we looked at what else we looked at a swimming pool example swimming pool heating, again here this was during winter we took an example where the water in winter

is probably at around if let alone would be around 15 degree centigrade and all which is not ideal for swimming it is not an ergonomic temperature.

So, what do we have to do we have to heat it up if we are talking about in industrial sorry of an indoor swimming pool or a swimming pool inside a hotel or even outside it is. So, we have to heat up the water. So, how do we want to do that again use a heat pump use a refrigeration cycle and use this room or use this water at 15 degree centigrade that we have as the working fluid in the condenser not the working fluid, sorry, as the heat exchange fluid in the condenser the working fluid in the condenser is a refrigerant, right.

So, therefore, what comes out will be heated water which is pumped back to the swimming pool and this is how this loop is continuous and. So, the swimming pool water is re-circulated through the condenser or pumped through the condenser and this is how we get hot water for swimming and at the evaporator end again the same water at ambient temperature can be used as the heat exchange fluid and what will come out is chilled water which again can be used for various applications, we can think of ways to use chilled water. So, that was another example.

One wonderful application which has been there for many years; now is the westing house templifier right in templifier what we do we use its water; water again and we use a 2 stage compression it is a 2 stage compression therefore, 2 compressors and 2 expansion valves we also drew the thermodynamic PH diagram to show the different points of because it is a 2 stage cycle. Now why do we need a 2 stage cycle because remember the water which is available to us, the wastewater is at 32 degree centigrade and what we desire to have is a temperature around above eighty degree centigrade.

So, the temperature gradient is very high. So, temperature gradients of the water itself are the up gradation of water itself is very high. And therefore, the temperature gradient of the refrigerant at the evaporator and condenser is even higher it is around 25 degrees at the evaporator and it is 90 degrees or above with the condenser. So, because of this large delta T, we do not want to use a single compressor to go through this large pressure ratio rather; therefore, we use it in 2 stages; there is a low pressure; low pressure compressor and then there is a high pressure compressor. So, 2 stage compression.

So, cycle gets a little complicated, but that does not matter. Finally, that I mean from the refrigeration cycle point of view, yes, it makes it complicated, but for our application

what we are looking at finally, we are going to use the evaporator for cooling and the condenser for heating right. So, as before we use water from or waste water from a process and heat it up again by flowing it to the condenser and we get water at 80 degrees and above.

So, this is how we upgrade water available to us at 32 degree centigrade to eighty to eighty degree centigrade or higher and the last application that we talked about was an example of drying of timber this can be of we saw it as timber, but also applicable for paper textiles, etcetera. So, drying of timber what do we use we would like to use air drying in this case. So, what are the characteristics of the; what the qualities of air that we need we need the air to be hot and we need the air to be dry we need the air to be hot. So, that the moisture trapped in the timber can evaporate and be carried out by the; and can evaporate and be carried out and we need the air to be dry because the air should be able to absorb the moisture that is inside the timber.

So, therefore, what we do is the air that is available to us or that comes out of the timber is going to be moist air. So, we need to first remove the moisture the way we done we do it is again using a heat pump and we pass that moist air through the evaporator. So, as it flows to the evaporator its temperature goes down. And therefore, it releases the moisture and the moisture is captured and the dry air is the product of the that is coming out of the evaporator the dry air, then goes to the condenser where it picks up heat becomes heated and therefore, the product coming out of the condenser is hot and dry air which is now used for drying of timber.

This is what we discussed in this lecture itself. So, I am not going through a very detailed recap because this is something that we studied very very recently. So, this kind of sums up the heat pump summary clear one passing node a thermoelectric generators that that is part of a direct that is a direct conversion device also works on the refrigeration or a similar principle, it does not have a condenser evaporated, etcetera, but there also you have a hot junction a cold junction and a external worked on it done, on it due to electric current flowing through the thermoelectric modules. So, you can think of it also as a heat pump.

So, if you say let us see; you have a cold fluid and you have it at the cold end of the thermoelectric generator and you have at the hotter end you have; you can upgrade it and

have and heat it up. So, it is the other way, because in this case it is no longer thermoelectric generator, but here you have to apply additional energy you are not generating electricity, but you are applying additional energy, but through an electric current that flows through the thermoelectric in this case the thermoelectric cooler. So, therefore, what happens is you give rise to a temperature gradient and use the hot end for upgrading the quality of your waste heat.

So, this is just a passing remark thermoelectric generator is what we what is part of this course and there the focus is on electricity generation because of a temperature gradient across the thermoelectric module, but the other way other application other way the thermoelectric module can be used is also as a cooler or refrigerator, where actually the electric current is the input as an external energy the external energy that is the external work that is done on the system similar to compressor work here. And as a result you have a cold end you give rise to a temperature gradient and the temperature gradient can be used for up gradation of the waste heat that is available at a lower temperature.

So, with that concluding remark we will wrap up our section and discussion on heat pumps. I hope you; I think heat pump from your basic understanding of applied thermodynamics you would have learnt, but in this course or in this few lectures what we tried to do was look at it from the context of waste heat recovery and the focus of this module was primarily on applications. Where the heat pump principle which is known to us we saw few applications where it is used in various industries for residential heating and cooling and for various for swimming pool heating and also for other industrial applications.

So, we will conclude our discussions on heat pumps and in the next class we will take up a new topic which is incinerating plant or incineration plants, so till then.

Thank you very much, and see you in the next lecture.