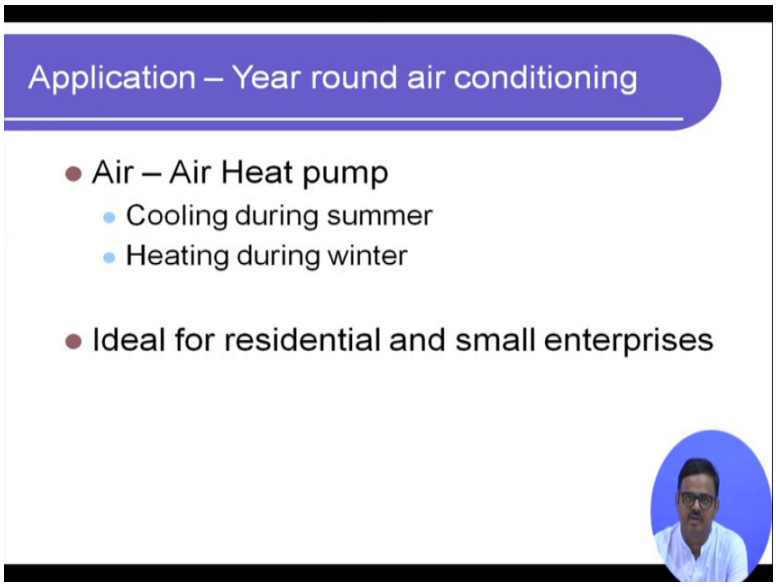
Energy Conservation and Waste Heat Recovery
Prof. Anandaroop Bhattacharya
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 48
Heat Pumps – II

Welcome back to the next lecture of Energy Conservation and Waste Heat Recovery. Today, what we will do is we will continue with our discussion on Heat Pumps.

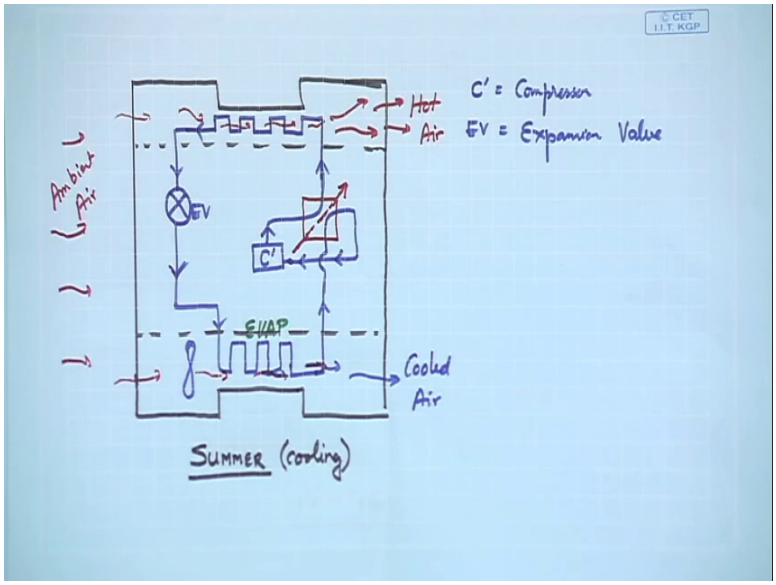
(Refer Slide Time: 00:30)



If you recall yesterday we started with our discussion on heat pumps, what a heat pump is essentially the fact that it is a way of upgrading the quality of energy that is available to us at a low temperature. And so what it happens is you upgrade that energy using a heat pump and of course, it does not come for free, we use a vapor compression cycle which is a normal refrigeration cycle except here the difference between refrigeration and heat pump is our aim here is to have thermal energy at a higher temperature compared to refrigeration where we remove heat at a lower temperature.

But essentially the way the cycle works is the same, it is a vapor compression cycle and what we first did was with that introduction we went over and discussed the first example which is air to air heat pump that is that can be used for year round air conditioning.

(Refer Slide Time: 01:32)



So, let us just recap by taking a look at the sketches that we drew in the last class this was a heat pump which we say it was so this was this is a room that is used for this was a heat pump that is being used for year round air conditioning.

So, in summer what we would like to do is we would like to have cooling. Now where does where now we have ambient air which is at an elevated temperature and which needs to be cooled down. So, in a typical vapor compression cycle, the way where you get cooling or the location where you get cooling is where you have the evaporator in their cycle where the refrigerant converts itself at a low pressure from liquid to vapor.

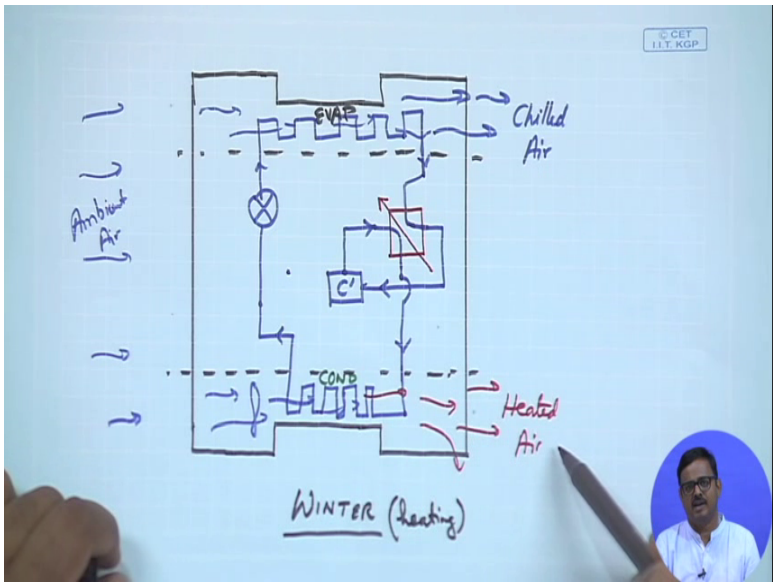
Therefore, what we do is we have the evaporator unit inside the room and we have the warm ambient air go over the evaporator and therefore, what comes out is cool air which we can use to cool down the room. So, essentially this is pretty much the way the normal room air conditioners work, what happens in at the other end where you have the condenser; it is the same ambient air which is used for as the fluid or the cold fluid rather for condensing the refrigerant from at high pressure, from vapor to liquid and as the refrigerant condenses while going through this heat exchanger, it gives up heat which is taken up by the ambient air and what comes out of the condenser unit is heated air.

Now, remember this heated air can be used for a lot of other purposes, if you are talking about a small industrial unit this hot air can have a lot of applications, right. So, on one

hand we get cooling on the other hand we also get heated air which at high temperature. So, it is high grade thermal energy which can be used for other purposes.

Now, in winter what happens is this 4 way switch turns the other way. So, therefore, the flow loop is reversed and what goes into the compressor is actually the refrigerant that is coming out of this heat exchanger. So, essentially what happens is the evaporator and condenser switches.

(Refer Slide Time: 03:52)



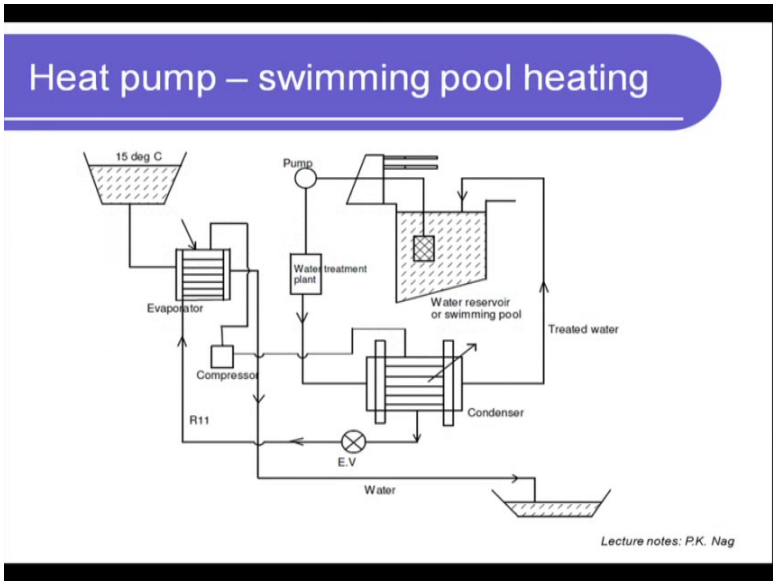
The heat exchanger inside the room becomes a condenser and the heat exchanger outside becomes the evaporator.

So, therefore, what do we get here? So, same thing except the ambient air now is cold because it is winter outside and we would like to heat it up. So, that we have more comfortable conditions inside the room. So, as this ambient air which is at a lower temperature goes over the condenser it picks up heat and comes out as heated air, which can now be used to you heat up the room and make it more comfortable. And simulate the evaporator end what happens is yeah it is cold air outside, but once it comes it cold air, but it again gives up heat. So, that the refrigerant can evaporate and therefore, what comes out is chilled air it is even at a lower temperature which is even lower than the outside ambient.

Now, this chilled air can also have a lot of other purposes a lot of other applications. So, therefore, on one hand for room air conditioning we are getting heated here, but simultaneously we are also getting chilled air which can be used for other purposes and we will see one example later where we will where we will have an application, where the chilled air and heated air in such a unit can be used simultaneously.

So, this is where we stopped in the last lecture quick recap and then we will move on to one more such application.

(Refer Slide Time: 05:28)



And this one is an example of water heat pump. So, this the example that we are talking about is used for heating the swimming pool or this is one example of heating a swimming pool there can be other examples of water heat pump.

So, here what do we have? So, if you look at this is the swimming pool whose water needs to be warmed. So, we want a heated swimming pool heated heat it to the extent where it is comfortable for the body typically in cold countries we are talking about let us say an indoor swimming pool or in a hotel.

So, how are we going to do that well from our knowledge we know that the if we want to heat up something we have to use the fluid or the or the or the heat exchange fluid that comes out of the condenser in a heat pump, right.

So, first let us talk about just the heat pump unit which is the vapor compression unit. We have the condenser here, we have the expansion valve here, we have the evaporator here, and compressor here. So, what comes out of the compressor as before is high pressure or refrigerant vapor at high pressure and high temperature which comes to the condenser where there is an isobaric condenser that is condensation at the same pressure, then what comes out therefore, out of the condenser is condensed refrigerant at the high pressure.

Now, in this process it gives up heat which is now picked up by the fluid in this case water. So, the swimming pool water is pumped through the condenser and so that when it comes out it is at an elevated temperature and this water goes back. So, this is how the recirculation loop is the circulation loop is completed. So, the water reservoir is a swimming pool from where it is pumped into the condenser after some water treatment and from the condenser it is fed back to the swimming pool at an elevated temperature and this is how we are maintaining the temperature of the swimming pool water clear.

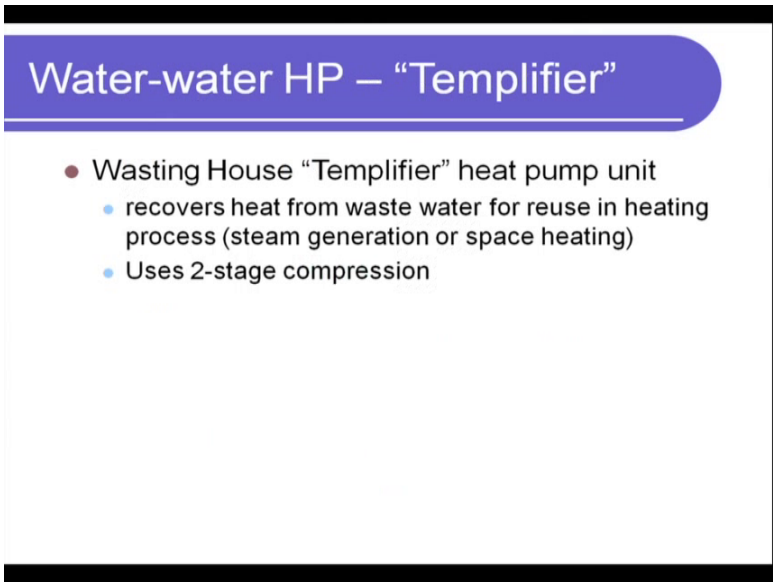
Now, what happens at the evaporator unit here also we take similar water which is at 15 degree centigrade. So, the same water here at the indoor water at that temperature in winter. So, these 15 degrees is not very comfortable for swimming right. So, that is what we are heating up using the using the heat that or that is that we are getting from condenser.

Now, over here in the evaporator we use the same water at 15 degree centigrade and when it comes out of the evaporator, it is at a lower temperature and which we can collect somewhere here and use the chilled water from some other application all right.

So, this is one application using a water; water heat pump and an example that we showed is for swimming pool heating, the water that is available to us in winter is at a lower temperature around 15 degree centigrade which is not comfortable for a swimming pool. So, therefore, we use a heat pump where this water at 15 degrees is used to condense and therefore, condense the refrigerant and as it does. So, it picks up heat the temperature goes up and the heated water is now fed to the swimming pool at the evaporator end what comes out is even chilled water, but that chilled water has a so has some applications which can be and it can be used for that.

So, here; so, therefore, we have discussed water; water heat pump. Let us look at one more such example where we are going to talk about process heat recovery.

(Refer Slide Time: 09:15)

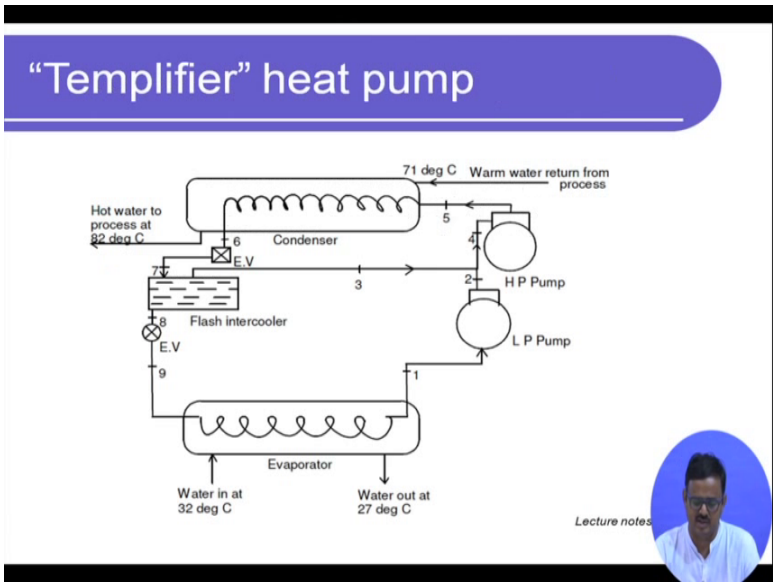


And this water-water heat pump the example that we are going to take is an unit con ‘Templifier" which is quite well known which was first put in wasting house.

So, wasting house Templifier heat pump unit it recovers heat from wastewater for reuse in heating process. So, again similar concept, but in this case it is a water-water heat pump. The previous one that we saw was definitely it was water, but the refrigerant that was used was still a refrigerant. So, in that case it was a liquid water heat pump I am sorry if I for if I you know mistakenly took the or say that the swimming pool was a water-water heat pump, it was water-water in the sense that it was water used as a fluid both in condenser and refrigerator, but still the fluid flowing through the refrigerant the flowing fruith flowing through it flowing through the vapor compression loop was still a refrigerant.

In this case; however, both the fluids are water and as we will see it uses a 2 stage compression.

(Refer Slide Time: 10:19)

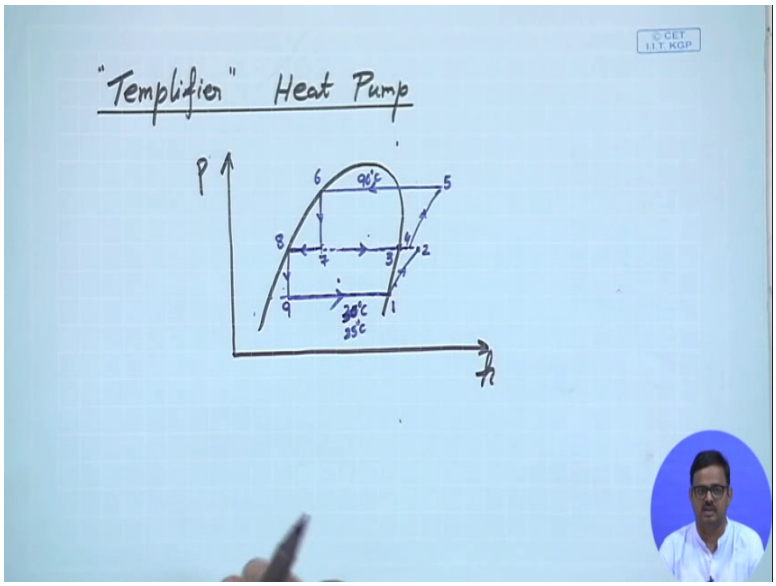


And I am showing going to show you a schematic over here as to how it works. So, we have waste warm water it is warm at 32 degree centigrade, but then not good enough, right 32 degrees is a low temperature it is not very high grade thermal energy that we have, right.

So, views it in an evaporator and it is a 2 stage compression and then what happens is in the condenser unit, you have water coming in and then hot water you can get at 82 degree centigrade all right and then you have a flash intercooler you have an electric sorry expansion valve 2 expansion valves and so on because you have a 2 stage compression.

So, let us look at this cycle a little more carefully and using our knowledge try to draw a PH diagram or a TS diagram.

(Refer Slide Time: 11:12)



So, let me first write down here what we are going to analyze is the ‘Templifier” Heat Pump. It is a templifier heat pump and what we are going to do is look at the thermodynamic cycle based on what we saw. So, I am going to switch between the paper and the screen. So, that we can correlate the 2 and then try to see. So, let us look at the screen once more and spend a few seconds looking at this at the cycle.

So, what we will do is now we will draw the PH diagram of the templifier unit. So, this is pressure and this is enthalpy that we look to draw the vapor dome. This is how it looks like in the PH diagram as we know and we will keep it like this and then let us try and see; what are the different points on this ph diagram.

So, let me first draw the draw the cycle and then we will go point by point. So, this is how the cycle works and we will see how let us name the points, now this is point number 1. So, if we look at the screen over here the point number 1 is the exit of the evaporator then point, number 2 is the exit of the low pressure condenser I mean low pressure compressor, point number 4 is the exit of the high pressure compressor. So, let us name those points 2 and sorry the inlet of the high pressure compressor is 4, the exit of the high come pressure compressor is 5.

So, let us look over here again and make sure that we are doing it correctly 1, 2, 4 and 5 what is 3? 3 is the exit of the first expansion sorry 3 is the exit of the flash intercooler.

So, we are going to write down 3 over here which is this point the rest is going to be simple 5 and then 6 will be this point 7 here, 8 here and 9 here.

So, once again let us correlate the 6 is going to be the exit of the condenser which is what is seen over here, 7 is the exit of the first expansion valve, then 8 is the entry to the second expansion valve, 9 is exit of the second expansion valve. So, 6 7 8 9 and which is what we have seen here 6 7 8 and 9.

So, this is how what we are seeing is the “Templifier” unit represented on a Ph diagram let us put the arrows. So, this is the cycle or the refrigerant cycle which is going through this, all right. So, the 2 stage compression is required because in the “Templifier” unit the temperatures that we have is at evaporator for over here it is around I believe 35 degrees and over here the temperature because it is giving up heat it is almost about 90 degrees. So, this is what it is I am sorry this is not 35 this is thirty because the inlet of the water over here is around 32 exit is around 27 no I am sorry I am wrong this will be 25 degrees or less clear.

So, that is why. So, this is the; what is picking up the heat by extracting it from the; you know from the water that enters at 32 and leaves at 27 clear. So, this is how it is, all right. So, once again this is 25 degrees 25 to 90 it is a big jump and therefore, we need a 2 stage compression a single stage compression would have been difficult clear.

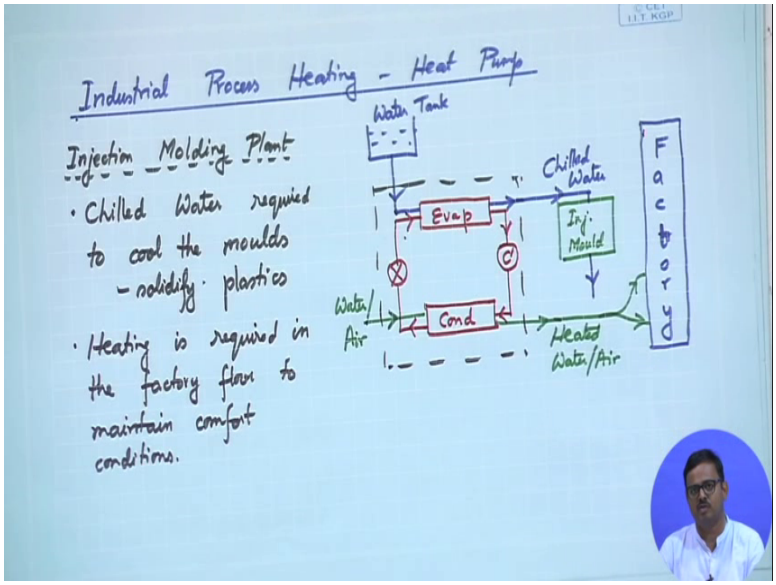
So, once again I want to take a moment over here and acknowledge one person who is my former teacher for what I learned from him. As you see in this figure as well as a previous one the reference I have written is lecture notes of Professor PK Nag; Professor PK Nag was my teacher when I was a bachelor student at IIT, Kharagpur and this topic of waste heat recovery I first learned from him. So, I would like to take this opportunity to express my gratitude to professor PK Nag, he is no more with us, but the lessons that I learned from him has stayed with me till now and probably will stay with me forever all right. So, I wanted to just pay my respect to my Guru, all right.

So, this was the Templifier unit that can be used for as a this is also a liquid-liquid heat pump in this case water-water heat pump and this is what is being used in wasting house. Where waste water is being is used for some other application at a higher temperature, let us move on to another application. So, this heat pump actually is a has lots of applications it has been used in various configurations across the world. So, I mean I am

just showing some applications over here I mean there are the numbers of applications are really endless.

So, remember I said that I am going to show one more example where we can use both for space heat pump for both space heating as well as the chilled fluid for some other application.

(Refer Slide Time: 18:31)



So, let me do that and what I will do is this is another example of I would say Industrial Process Heating using Heat Pump well is not just heating it is cooling also and the example that I am going to talk about is an Injection Molding Plant injection molding I write it as MOLD many people write it as a MOULD is say American and British spelling.

So, this is where you know the injection molding is done prime sometimes using plastic sometimes using something else or molten metal. So, what do we need? So, if you recall in any injection molding process you need to cool down after it has been cast, in the mold you need to cool it down, that it can take the form or and shape right. So, you need cooling and plus especially in winter or in cold countries this is done in a factory where you need to maintain ergonomic conditions and therefore, you need to you need space heating for that for the factory or the for that plant.

So, how can we do that? So, heat pump is actually a wonderful application or rather a wonderful technique to attain or achieve simultaneously both these objectives. So, let us write down something. So, injection molding where what I would says Chilled Water required to cool the moulds. So, I would say solidify plastics all right in the components being molded that is obvious and I would say that also say that heating is required in the factory floor if I may call it so to maintain comfort condition. So, this is essentially what is happening so; however, how are we going to do it I think right now by now I think all of us are pretty I think we can all guess as to how we are going to do it.

So, let us first draw the vapor compression unit the heat pump components and then see what we will do. So, the first thing that I am going to do is I will say this is evaporator this is condenser this is my expansion valve and this is my compressor C prime clear. So, what happens evaporator exit gets to come compressor then it comes to condenser condenses the refrigerant then flows through the expansion valve and enters evaporator.

So, fair enough no questions about that this is my unit. So, this is my expansion valve now what happens is that I have let me say this is my factory floor and I would draw here is my injection mold. So, what do we need we need to cool the injection mold and then we need to heat up the factory fair enough let me just put a boundary around this.

So, therefore, what happens let me say I have some cooling water tank over here water tank I will let this fluid flow into the evaporator and then what comes out of the evaporator will be chilled water, which goes to the injection mold and then what comes out of the injection mold is in a heated water or normal water at room temperature or elevated temperature and then what I will do through the condenser again let me use a different ink.

Let us say I am going to pass air or water does not matter and then this one comes out at an elevated temperature and can be used for heating. If it is heated air it can be directly fed into the factory floor if it is heated water that we are using so let me write it can be water or it can be air. If it is air directly so this is heated water or air. If it is heated water then what we will have this heater you know this room heaters which circulate heated water or warm water that is what we are going to use in the factory floor and if it is air then of course, it is already warm air which can be directly fed into the factory.

So, this is an example for use of a heat pump in an injection molding plant. Now output from the condenser which is at a higher temperature can be used to heat up the factory flow to maintain organic or comfort conditions and the output from the condenser which typically chilled water is being circulated across the injection mold. So, that it cools down the mold and solidifies the plastic and therefore, whatever we are trying to manufacture actually takes shape and comes out in their shape and form. So, with that with that example we will conclude this lecture and in the next one we will take off from here and probably look at one or 2 more examples so.

Thank you very much and see you in the next class.