INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-13
Compound Compression with Intercooling-2

with
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Hello, I welcome you all in this course of refrigeration in air conditioning today we will continue our discussion on compound compression with intercooling. Today we will cover multi pressure systems.

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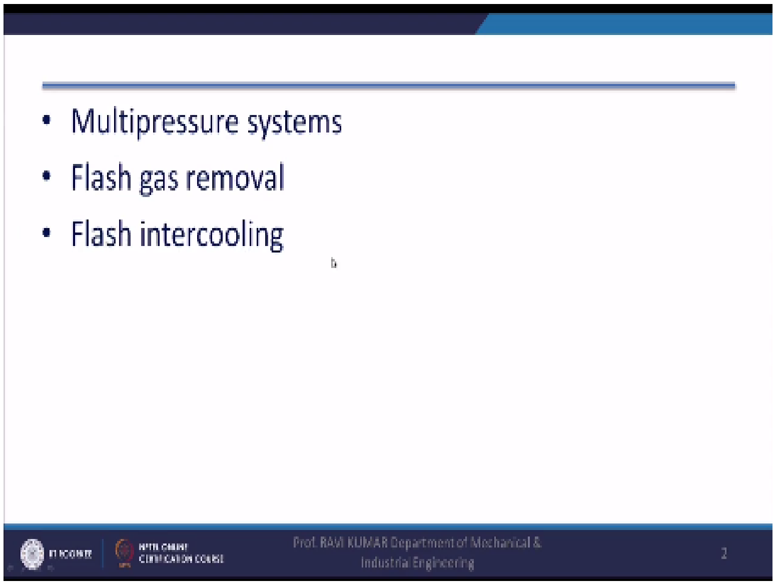

Flash gas removal and flash intercooling for the intercooling of a compressor.

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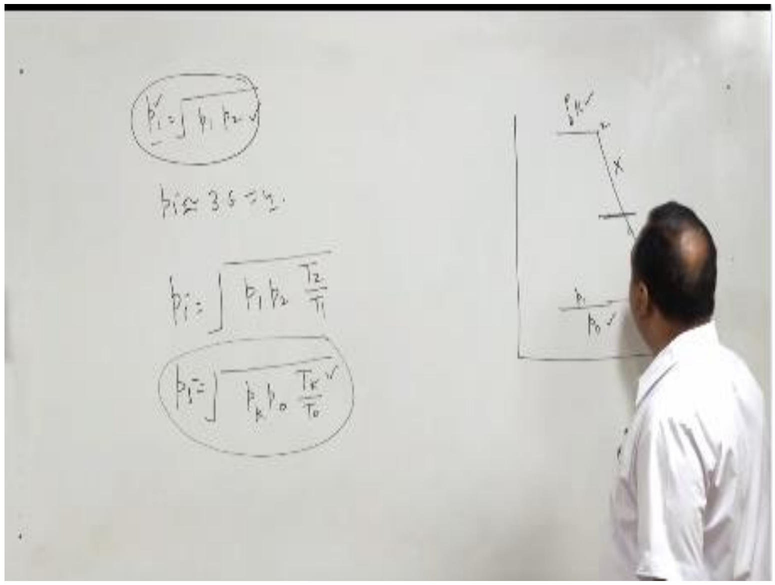

Especially when air also ideal gases used we have derived one equation that if the compressor is operating between two pressures P_1 and P_2 then we have derived the equation if intercooling is required intercooling has to intermediate a pressure under $\sqrt{P_1P_2}$ this is P_1 and this is P_2 and it will come somewhere here. We also discuss that this is well it only for ideal gases where perfect intercooling is taking place perfect intercooling means after intercooling the temperature is equal to the initial temperature.

But this does not happen in refrigeration system first of all refrigerant cannot be considered as an ideal gas, right. So this expression can give us any value close to the this intermediate optimum pressure, intermediate pressure but this will not give us the exact intermediate pressure. But normally in refrigeration systems ideal case the work done in both the compressor should be equal, but here what we do we do not maintain exact value for example, if Pi is approximately 3.6 we take as 4, right.

So we rounded off to the higher values and normally it is seen that the intermediate pressure predicted by this equation is approximately 10 to 20% less than the intermediate pressure for a refrigeration system. So in order to reduce this gap investigators have suggested that instead of taking P_1P_2 we should multiply this with T_2/T_1 in some of the books P1 is taken as P_o pressure of evaporator and P_2 is pressure of condenser P_k subscript k for condenser o for evaporator in that case intermediate pressure is going to be equal to P_1P_2 sorry, P_kP_o and T_k and T_o and these temperatures are absolute temperatures.

Now this intermediate pressure is close to the real value of intermediate pressure in multi compression systems. Now in multi compression system where the compression takes place in two stage or more than two stage the intercooling is done after each stage intercooling is done, flash intercooling is done flash intercooling is preferred because flash for flash intercooling we do not have to give extra arrangement for water line.

Now first of all intercooling is required is clear let intercooling is required to minimize the work input to the compressor and in case of ammonia why I said in case of ammonia. Because what happens in case if we look at the pressure enthalpy diagram for any gas.

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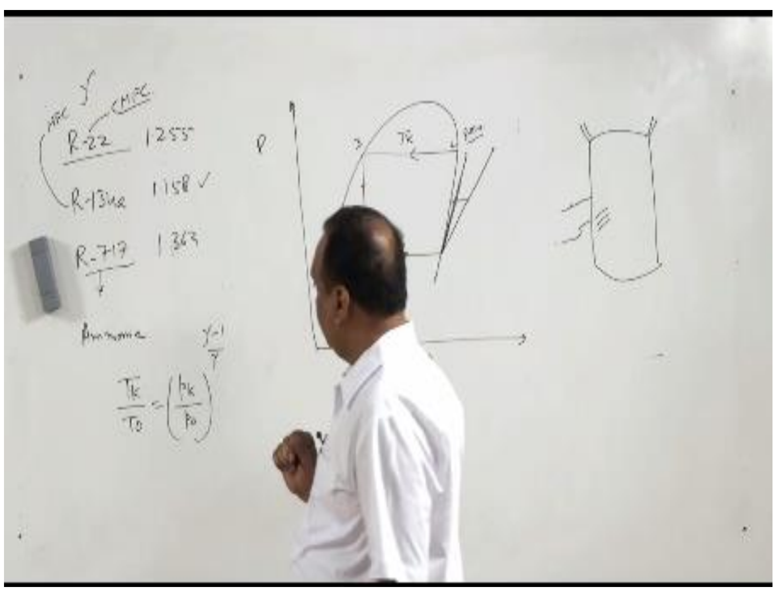

The value of R22 so value for γ for R22 is 1.255 for R134a is it is 1.158 for R717 it is 1.6 sorry 1.363, now if you look at this figures then we can easily find that during a simple cycle, during a simple cycle 2,3,4 when the compression is taking place and we are taking R134a as the working substance the constant entropy line is going to be close to the saturation line, because T_2/T_1 or here T_k/T_o we can take this T_k or T_o in some of the books it is written T_h and T_l also.

So $T_k/T_o=(P_k/P_o)^{\gamma-1/\gamma}$ so the moment we increase the value of γ this ration increases when this ratio increases means when T_1 is fixed temperature of the vapour coming from the evaporator is fixed temperature of the vapour leaving the compressor increases. It means the slope of this curve reduces so if we take for example, R134a if the value of γ is less right, so this ration will also be less in that case T_2 will be somewhere here, this is for R134a.

So R717a is ammonia it is hydrofluorocarbon and this is CH chloro hydrofluorocarbon so this all I will discuss in details well take up the topic refrigerants how the normal glycerin is done but let us focus on this numbers R22, R134a and R717 this is ammonia so for ammonia, ammonia the value of γ is 1.363 so $T_k/T_o=(P_k/P_o)^{\gamma-1/\gamma}$ so if we are increasing the value of γ even we are increasing the value of γ, the value of this ratio is also increasing and the value of T_k will increase because the value of T_kT_o is constant, it means when the γ is increase this line will have less instillation and we will land up somewhere here.

Because super heating is taking place in this reason, so if we take in the case of ammonia intercooling it will be very effective in comparison to the case R134a where the compression line is very close to the search vision line that is why in small capacity units like domestic refrigerator, domestic refrigerator you must have seen there is a hermetically sealed compressor, in hermetically sealed compressor it is a sealed unit wielded unit in fact and it has two wires coming out for the power supply and where two puts.

The electricity is supplied through this wire to the motor and motor and compressor they are on the same shaft, the refrigerant which enters the compressor also used for cooling the winding of the motor and the properties of refrigerant should be such that it does not harm the insulation of the coils of the coils of the motor. So for this type of applications normally R134a and previously R12 was used. If you use any other refrigerant which has value high value of γ there is a possibility that the proper cooling will not be there inside the hermetically sealed compressor and the wildings will be burned out.

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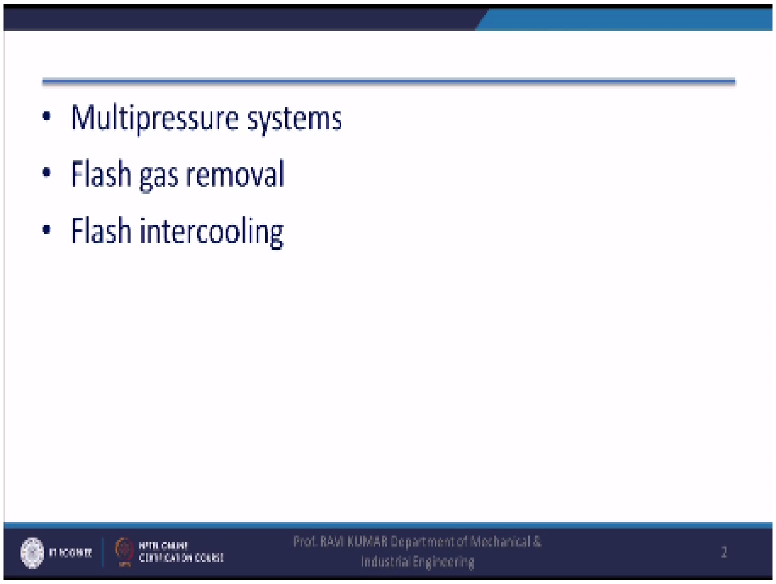

Now we will start with flash gas removal, in case of flash gas removal what happens in a tow pressure system.

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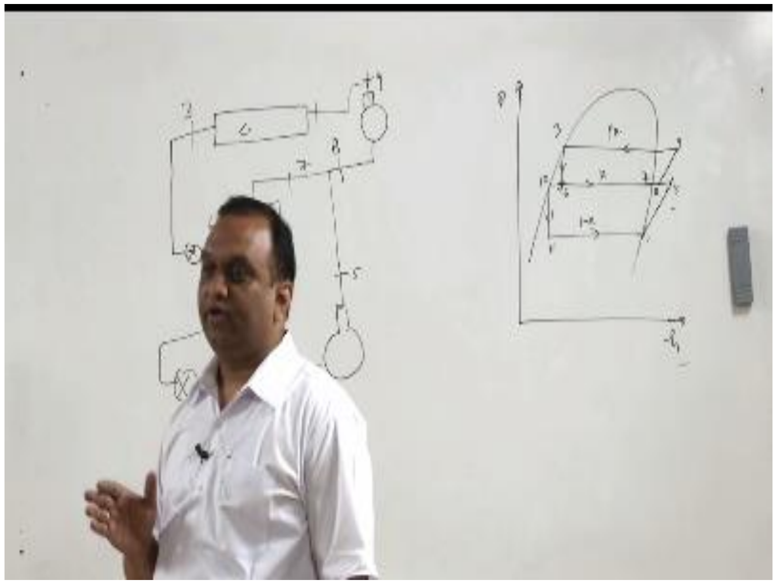

In a two pressure system where here we can take P_1 or P_o and this is P_k it is simple vapour compassion refrigeration system. During an expansion flashes of refrigerant takes place so suppose the refrigerant entering suppose if it is a low capacity plant and capacity it use are used as expansion devices so the refrigerant entering the capillary U will be liquid but slowly the flashing will take place, okay and after expansion to certain length the amount of vapour becomes sustention and if we remove this vapour the idea is if we remove this vapour.

Because what is happening this vapour will get expended again this vapour will be compressed, so in order to avoid this if flash gas removal system is provided in the system so if I draw an evaporator in a typical vapour compression system and there is a condenser between evaporator and condenser a flash gas removal system is provided. Now vapour emerging from the evaporator it is state 1, right and this vapour will get compressed and state 2.

Now we will have multi compression system so it will, let us say it is 3, so it is compressing getting compressed and we are at in state 3. Now liquid refrigerator is coming from here sorry, this is already 3 is already there so 4 will take 5, 5 at 3 liquid refrigerator is already there so liquid refrigerant is getting expended in a expansion valve after expansion the flashing will take place or it will mixture of liquid and vapour.

So we will arrange one expansion here and after expansion the refrigerant will enter a flash chamber it will not go to the evaporator it will go to the flash chamber now flash chamber is nothing but is vessel of relatively very large diameter so that all the kinetic energy of the vapour is lost and the stratification of the fluid takes place I mean bottom, at the bottom position the liquid is accumulated and in the upper position the vapour is there after this expansion the liquid is remaining in the bottom side and vapour will reaming at the top side.

This vapour is in saturation state at some intermediate pressure so intermediate pressure it is in saturation state now this vapour is taken away from here and mixed with the vapour coming from the compressors so we will say it is 6 now expansion has taken up to here expansion has taken up to here so this point is 6 this point is 346 so this is now this point is 6 this point is 7 after expansion it is entering the flex chamber so this point is 6 now here separation is taking place here separation is taking place here it is pure liquid and here in this sphere not sorry saturated vapour.

So the saturated vapour is coming here that is a state 7 and saturated liquid is reaming at the bottom of the flex chamber now this vapour saturated vapour is getting mixed with the super heated vapour so mixing of super heated vapour at 5 is taking place both are at the same pressure this has to be ensured so there is a regulating because also here so that these two pressures are same they are not same than imbalance in the system will take this and mixing of these two vapours takes place one vapour is saturated another is super heated so mixture will been slightly super heated.

And we will get state 8 state 8 now in second stage instead of compression vapour at this state, state vapour will be compressed from this state so this is state 8 state vapour will again go to the compressor now this mixture I will label at a state A will go to the another compressor and it will be compressed up to the state line as it is shown here the state A it will be compressed and we will get the straight line after the state line it will straight away go to the condenser, condenser straight line and it will be condensed to a state 3 and remaining refrigerant which is available in flesh chamber.

The liquid refrigerant will go to the evaporator and it will expanded so 6 it is 7 8 9 10 and this 11 so liquid refrigerant it will go to the evaporator and it will get expanded their 10 and 11 and then 11 to 1 now during 10 to 11 suppose the part of the vapour is evaporated x expression of the vapour is evaporated so refrigerant available for this heat revolve is only 1 – x however this refrigerant is available at a relatively lower temperature so this type of arrangement if there is a multi pressure system where more than one compressor is used.

This type of arrangement is always preferred or it is recommended because it is the energy consumed by the compressor.

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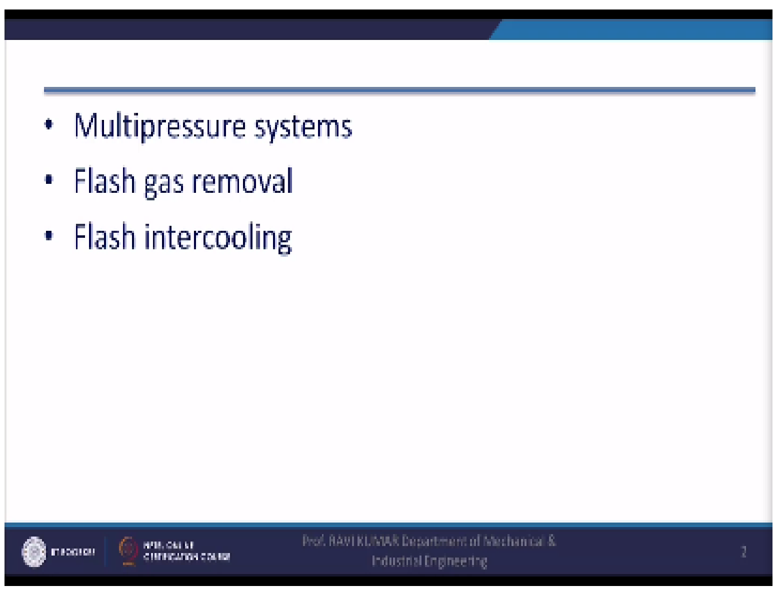

Now flash intercooling this is flash gas removal but how intercooling can be done with the gas flash gas removal we will try another diagram for flash gas removal.

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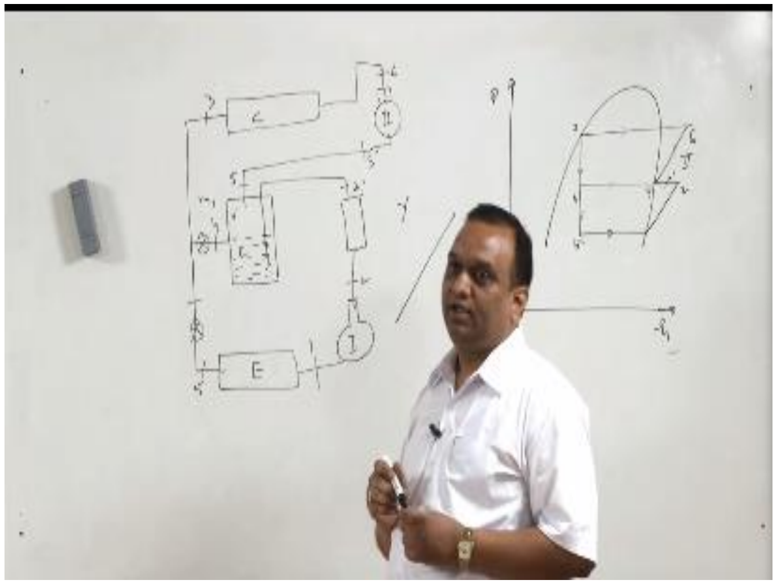

Again there is a single evaporator and single compare compressor system so evaporator and sorry, evaporator and single condenser system so there is one evaporator and one condenser vapour coming from the evaporator is going to a compressor so a state 1 to state 2 so vapour this is saturated vapour so saturated vapour coming from the evaporator is going to a compressor of state 2 again we have a flash intercooler now flash gas removal arrangement is used as a flash intercooler so in this flash intercooler again the expansion is taking place and vapours are coming to flash gas chamber.

This is a flash gas removal and there is a stratification here we have vapour and the bottom side whereas liquid and this process can be shown somewhere here right so let us say this is a state 3 and this is state 4 so this is state 3 and this is state 4 from a state three the liquid refrigerator is available at a state 3 and it coming to the flash chamber after expansion into the wall in the flash chamber stratification of vapour takes place now for the purpose of intercooling the vapour coming from compressor is bubbled through the flash chamber in flash gas removal it is it was directed with the.

Vapour from the flash gas flash gas flash chamber in that case we were getting slightly these super heated vapour at the entry of the second compressor but here the vapour is coming from the compressor they have bubbled through the liquid refrigerant so any vapour emerging from here if this, this is vessel the fluid in the vessel is instauration state so any vapour emerging from here will be saturated vapour now this is 5 so we are getting 5 here and from 5 it goes to the compressor again 5 and after compression we get 6 and from 6 after second compressor this is first compressor.

In second compressor it goes to the condenser and condensation takes place now in this arrangement the reaming vapour suppose m1is taken here so 1- m1 will go to the evaporator and here also expansion will take place so reaming part will go to the evaporator and refrigerating effect will be attain from let us say 4 this is 5 6 so 4 and 4 5 or same 4 6 5 this is 5 this is 4 5 so expansion is taking place here and then vapour is entering into the vapour and refrigerating effect is attain now here in this case in flash intercooling the output of the compressor is send to the flash chamber where this super heated vapour is mixed with the saturated vapour now in this course because these super heating of this vapour is taking place here some of the refrigerant will be evaporated some of the refrigerant will be evaporated.

In flash gas chamber and that refrigerant will come into the second compressor so the Maslow rate in the second compressor will higher than the Maslow rate in the first compressor now if we take example of ammonia, ammonia has very high latent heat so if this super heating taking place in case of ammonia small amount of ammonia will be evaporated but if we take is of a for example R134a R130 ammonia has latent heat more than 6 to 7 times the latent heat of R134a so R134a substantial amount of vapour will be evaporated if d super heating takes place and R134a so and that will increase.

The work of the compressor in second stage so this type of intercooling been not draw benefits in the case of R134a but it is very useful for the refrigerant like ammonia because ammonia has very has a high value of γ that is why level of super heating is or degree of super heat is high in case of ammonia and if this type of arrangement is made flash intercooling type of arrangement is made then lot of energy came the saved in compression of refrigerant now in order to this in ammonia type of system so water cooling is also done water cooling is also done because all the cooling cannot be done here.

So water cooling is also done so water cooling arrangement is also made so we get somewhere 2- and 2- goes to here then we get another stage two dash and the fluid available at two dash goes to the flash chamber so we have covered today the multi pressure systems flash gas removal system how the flash gases are removed from the system and flash intercooling system because in a multi stage system that two types of cooling system water cool intercooling system and flash intercooling system and in case of ammonia refrigerant we can apply both type of systems now in the next lecture we will start with multi evaporator systems.

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