MARINE ENGINEERING

By

Prof. Abdus Samad

IIT Madras

Lecture59

HVAC-VCRC components

good morning everybody. Today's lecture is continuation of the previous lecture that is like refrigeration cycle and their diagram and TS diagram and basic understanding of formulation. so today's lecture will start with components. refrigeration cycle you have seen the components like compressor you have, then you have condenser. condenser releasing heat, then you will have one throttle valve,

then you have evaporator okay so after condensing it will be liquid this is liquid and this is gas okay and after compression it will be gas at high temperature this is gas as at high temperature when temperature is reduced, so it will be forming liquid. Now it is having, you can see four basic components. One is compressor. This is compressor.

compressor normally to be positive displacement type. in if you can remember the previous lectures where we told that positive displacement type compressor or pump it will be having higher pressure development capability and low volume handling capability okay so in this case we need very lower amount of volume but higher amount of pressure we have to develop that's why normally people will be using positive displacement type compressor so positive displacement type compressor will have several type one will be reciprocating type Another can be scroll, volute, scroll type, then screw type. So, there are many types of positive displacement type compressors are there. So, any one type can be used.

For very small application or very small system, so scroll or reciprocating type compressor will be used. But in bigger cases where high volume flow rate you have to handle, in that case you can use centrifugal pump. So, it will have higher volume flow rate capability, pressure development will be lower. So, in that case, maybe multiple staging will be required to develop the required pressure at a higher volume flow rate. What about the condenser and evaporator?

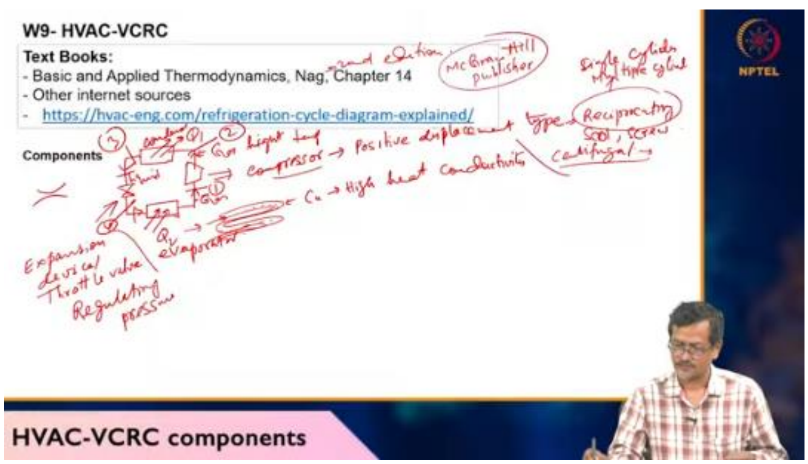
evaporator is taking heat from atmosphere and this is actually copper coil. Copper pipes and fluid or refrigerant will be passing through this pipe. and outside refrigerant, you put outside this pipe you put your food item or fruit item whatever you want to cool okay so this it will reduce your temperature sufficiently and this is copper normally so copper because high heat conductivity high heat conductivity again evaporative side like if it is an air conditioner then hot normal air will be passing over the coil so air temperature will be going down in the refrigerator system your refrigerator also small amount of air will be blown very slowly but here flow rate will be higher air flow rate but in normal domestic refrigeration system or fridge normally we say that fridge will be having lower volume flow rate in air okay Condenser also it will be a copper pipe.

Again heat will be dissipated in the atmosphere. So this is the condenser. This is actually an evaporator. so many times the condenser will be air cooled or water cooled air cooled condenser like domestic refrigerant refrigeration system or fridge this will be air cooled but if you say big industrial system the condenser will be normally water cooled also possible if you go to any cold storage and other big uh big shopping malls they are cold storage outside some building you can say lots of water splashing happening over pipes so that is a condenser for your refrigeration system so they are reducing temperature using water splash So water will take lots of heat.

Again splashing will create evaporation. Evaporation again because of phase change will take lots of heat from the pipe and the temperature will be lower. So expansion device. This is an expansion device or we say throttle valve. expansion device or throttle valve we say it will be regulating pressure and flow rate so regulating regulating pressure so pressure let us say I have to put number let us say 1 2 3 4 so 4 3 to 4

pressure will be changing enthalpy not changing okay so in that case you are changing pressure and flow rate also you can control how much because as per your requirement, you can change your flow rate okay so two type of uh expansion valve or throttle valve will be there special one means like you create restriction in your pipe so that fluid flow rate will be reduced in the specific zone okay and two types will be there one will be variable type another will be like constant restriction so like for example domestic refrigerator very low cost systems the they may not have many options but if you have a high quality or high-end refrigerator or air conditioning system there will be multiple options actually very variable restriction variable flow rate so because they will be optimizing your energy requirement and noise production okay In compressor system, the name is compressor. So, it will not be handling any liquid. So, normally you have to give gas or after evaporator, everything should be gas.

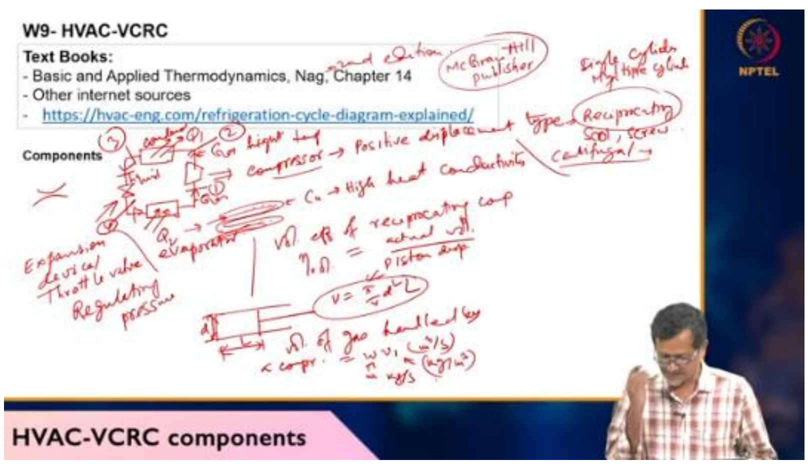
Then you are putting that gas into compressor system. Then you are compressing releasing heat releasing heat in condenser it is passing through throttle valve throttle valve it will be reducing flow rate and it will be changing pressure but enthalpy will be same because you are not adding or removing any energy from in the throttle valve okay then evaporative system it will have the coil copper coil so it will be absorbing heat from surrounding surrounding or if it is a air conditioning system then air will be blowing over the coil so air will be cooled down and it willcirculated inside your room okay reciprocating system also there will be a single like reciprocating pump or compressor it will be having single cylinder or multiple cylinders if you have single cylinder then it will very small system multiple cylinders means maybe an intercooler may be there so that you can reduce uh temperature in between compressor and you can improve the performance of the compressor so that your power performance improves volumetric efficiency uh of reciprocating compressor volumetric efficiency



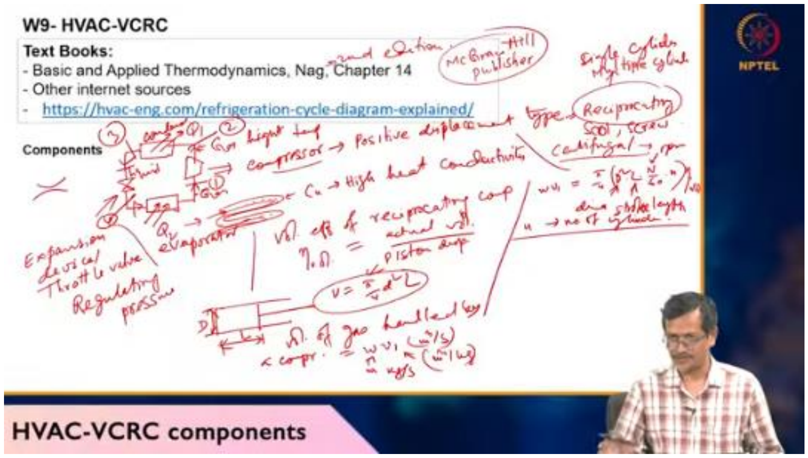
reciprocating here in this system we vapor compression system you see the term is compression is there and compressor is the heart of the system if compressor function any problem in the compressor that means whole system will fail okay so the volumetric efficiency of compressor eta volume eta volume equals actual volume divided by piston displacement displacement so you can remember that reciprocating pump or compressor okay so actual volume means what you measure using instrument and you see how much volume flow rate you are getting okay that is your actual volume flow rate but piston displacement volume means like you if you know diameter you know stroke length forward-backwards motion that length l so this volume equals pi by 4 d square into l okay so this is piston displacement So, if you know actual volume, how much it is delivering, how much piston is delivering, piston is moving. So, that ratio is called volumetric ratio.

And why the actual volume will be lower? Sometimes piston will have certain leakage also. Because of leakage, volumetric efficiency will be lower. If it is sealed properly, then volumetric efficiency will be very much higher. But weird out any compressor piston, so their volumetric efficiency will be lower.

So, the volume of gas handled by a compressor equals omega V1 meter cube per second. Omega has a mass flow rate in kg, a mass flow rate a kg per second, volume is kg per meter cube. Specific volume, the specific volume will be meter cube per kg, meter cube per kg. Now, WV1 equals pi by 4 d square L, d I should write capital D, d square L n by 60 into small n. eta volume okay so here cylinder diameter already i have shown in figures cylinder diameter this is stroke length stroke length n gth n is rpm revolution per minute small n is your number of cylinder



And eta volume, already we defined volumetric efficiency. In this way, we can calculate volume of gas handled by a reciprocating compressor, which is having multiple cylinders, maybe, or one cylinder also possible, because based on value of n, we can calculate. And whenever you are calculating, you have to see the units. Units must be balanced, left side or right side. Okay, these topics are taken from P.K. Nag book.



So multi stage compressor if you have seen single-stage compressor system. So now if we put it to multiple stages then the system performs much better. So how this will work? You have so you have one evaporate condenser system. Then you have one compressor.

This is the condenser. Condenser releasing heat Q1. and after condensation fluid is going to one throttle valve throttle valve then it is going to one evaporator section from evaporator it is going to again compressor this loop already you are familiar with okay so numbering i'll put putting later i have another loop actually another compression system evaporator system then from evaporator throttle valve is here okay so you can say multiple stage two compressors are there and they are pulling one evaporator section evaporator okay so heat is being given there q2 uh heat is taking from surrounding and this is called direct contact heat exchanger This one direct counter heat exchanger and M1 mass is circulating here, M2 mass circulating here.

So two cycles are there, top cycle, bottom cycle, top cycle mass circulation or refrigerant cycle, the top cycle has refrigerant circulation rate M1 dot and bottom cycle M2 dot. and now put the numbering and numbering before compressor 1 here 1 after compressor 2 then it is going to 1 direct after heat exchanger it is going to 3 then 3 to 4 after compression 4 to 5 it is going condenser 5 to 6 it is going 6 to 7, 7 to 8. You can see the top cycle is reducing certain temperatures. That temperature, that heat, that top cycle releasing a certain amount of heat, that heat is being used by the bottom cycle.

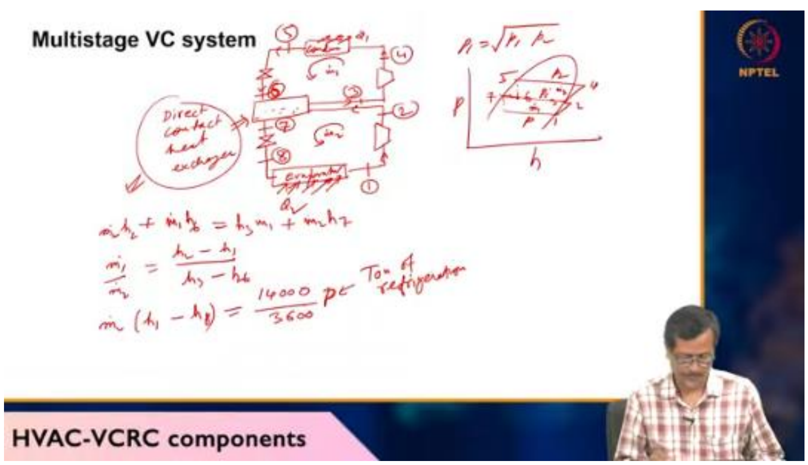
So, that you are getting more effectiveness in evaporation. And what will be the intermediate pressure? Pi equals P1 P2 square root. pH diagram I will draw here. So 1 to 2 compression system.

1 to 2 compressor. 2 to 3. 2 to 3 what is happening? It is absorbing certain amount of heat. 3 to 1.

3 to 4 again Expansion compression happening 3 to 4, 4 to 5. What happened? 4 to 5 heat release happened. Then 5 to 6 throttling happening.

Then 6 to 7 again some temperature increases happening in bottom fluid. 7 to 8 throttling happening. 821 the process is becoming complete p1 this is p2 intermediate pressure is pi okay and this is mass m1 dot this is mass m2 dot okay so two cycles we have different mass flow rate in the cycles okay now if you see the direct contact heat exchanger so their heat balance i'll do there m2 h2 here m2 after compression m2 h2 plus fluid is entering here another entering is coming from 6 so m1 dot h6 equals fluid exiting exiting 3 h3 m1 dot plus exiting 7 also M2 dot H7 so total heat balance I have done total amount of fluid entering total amount of fluid exiting so M1 dot by M2 dot if you rearrange the equation it will be coming like H2 minus H1 H3 minus H6 now M2 dot

H1 minus H8. You can see the evaporator effectiveness. It will be like 14,000 divided by 3600 into P. You have to remember the formula. P is your ton of refrigerant of refrigeration. okay so from here you can calculate empty value or you can say p is a capacity okay okay another topic is cascade system cascade system where two fluid will be separated 40 degrees centigrade let's say condenser temperature

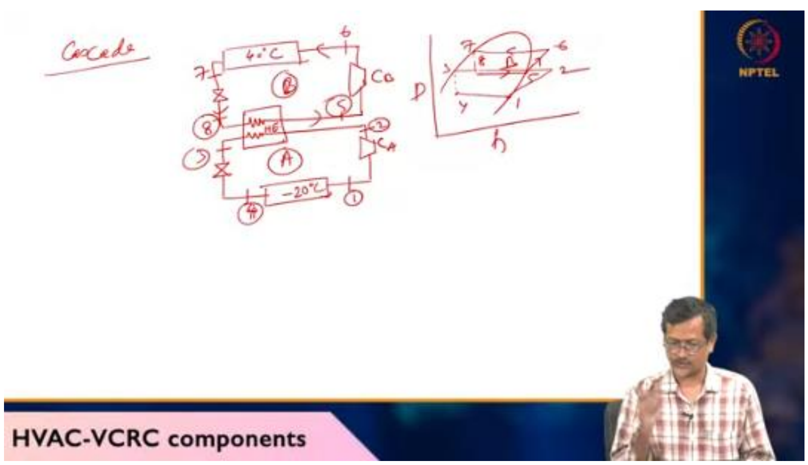


okay on condensing will be happening constant pressure constant temperature and we have one compressor system compressor means like now this is turbine compressed compressing here okay uh then it is going to one heat exchanger throttle valve is here okay then another i have heat exchanger heat exchange happening Throttling will be happening. Then evaporation will be happening. Then I have one compressor here. So I can have multiple stages.

This is called cascading system. So let's say this is one cycle. This is two cycle or a cycle, b cycle. I put minus, just my own name, minus 20 degree. Just example temperature.

So it may not be, only fixed 40 and 20 degree. it may go to minus 180 degree also okay this is see compressor a compressor b and if i want to draw in ph diagram so ph diagram will be little bit tilted actually saturation curve okay so six to seven compression happening six to seven six to seven then seven to eight throttling happening throttling this i'll put dotted line seven to eight uh seven to eight then eight to five eight to um eight two it is going to five okay eight to five uh six five okay eight to five then my compressor okay this is top cycle this is b now bottom cycle bottom cycle it would be taking heat from top cycle top cycle condenser evaporator is bottom cycles condenser right so this is heat exchanger h e means heat exchanger okay now top cycle temperature should be lower okay two after compression two then before compression one then three two to three three to four okay so you can see this uh bottom cycle condenser temperature

Oh, this is pressure. So, it does not matter. Oh, this is pH diagram. Till now, we discussed only VCRC, Vapor Compression Refrigeration System. VCRC, Vapor Compression.



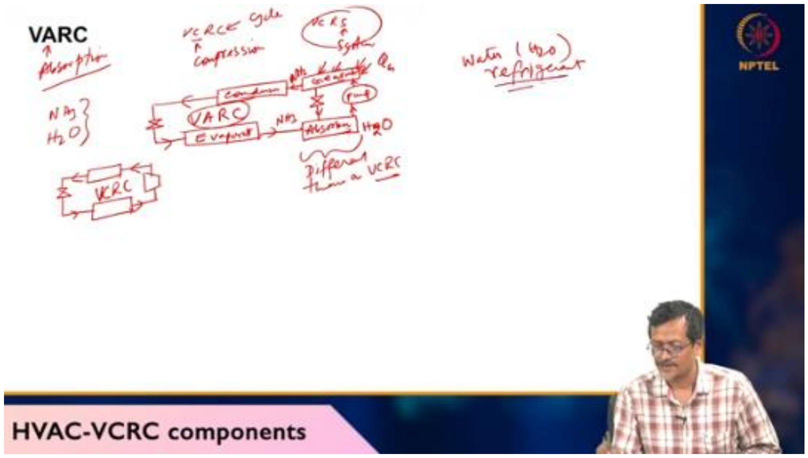
This is compression. This is cycle. Sometime I write VCRS also. S means system. So now I will discuss VARC, Vapor Absorption System.

Basically two types of systems will be there. One will be ammonia refrigerant system. Another will be water refrigerant system. How the system looks like? It will have again condenser.

condenser fluid will be throttled then it will going it will be going to evaporator okay up to this it is common as this is VARC vapor absorption system now vapor compression system you can remember I have throttle valve condenser hen evaporator compressor okay uh because you can see the resemblance v crc okay you can see the resemblance this left side part almost same right side part for vrc will be different how there will be observer absorber then there will be one generator then from absorber to generator one pump must be there okay fluid will be pumped to generator and from generator one throttle valve will be coming here and it will be coming to absorber okay so you can see this right side part this part is different than a VCRC okay now what how this ammonia and water refrigerant will be working so in this case if it is ammonia let's say ammonia is circulating so what will happen ammonia circulating ammonia in evaporator it will be evaporated it will go to absorber absorber will be absorbing ammonia absorber means it will be water absorber will contain water so water will be absorbing lots of ammonia vapor when it is absorbing it will create low pressure so when it is creating low pressure so normal ammonia liquid ammonia will be evaporating then this ammonia and water mixture whatever you got you have to pump to generator generator you get give lots of heat

in general you are giving lots of heat and you are isolating water and ammonia vapor okay done then ammonia what will do ammonia will move towards condenser okay ammonia is moving towards condenser and it is going to throttle valve throttle valve evaporator again ammonia going to absorber absorber will be absorbing ammonia okay now what is this throttle of second throttle valve from generator to absorber. generator to absorber means after releasing ammonia, this higher amount of water, the water will be coming down to absorber again. So, the whole system will be continuing. So, if we have water as a refrigerant, in that case what happens?

In that case, water or H2O refrigerant in this case what happens water water is absorbed by by lithium bromide solution libr solution libr okay so water will be circulating lithium bromide will be absorbing in the same process as ammonia cycle is there okay now formulation for vapor absorption refrigeration system cop and other parameters so source t1 from source it is going to generator generator generator to condenser then absorber evaporator Then you have QE region of TR. TR means refrigerant.

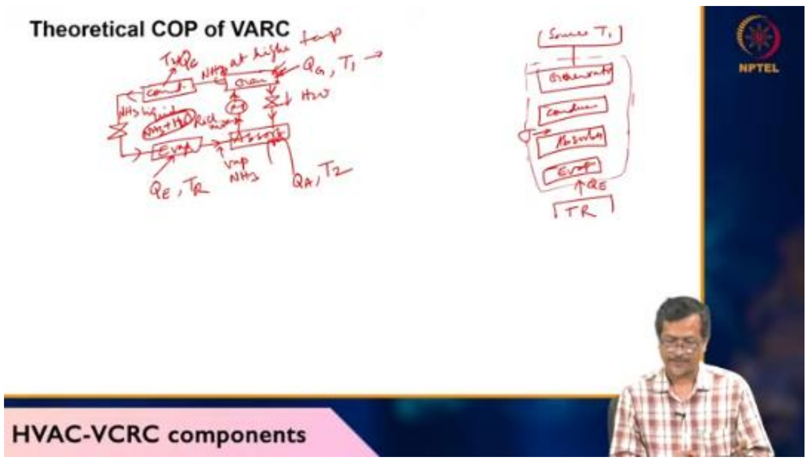


So I have to draw this vapor absorption system again. Condenser, condenser, generator. Then condenser to throttling valve. Then evaporator system. then evaporator to generator absorber so absorber to generator it will be going through a pump and generated to your absorber again come when it is coming back it will be coming back through one throttle valve okay so whenever you are drawing for your exam you should give proper

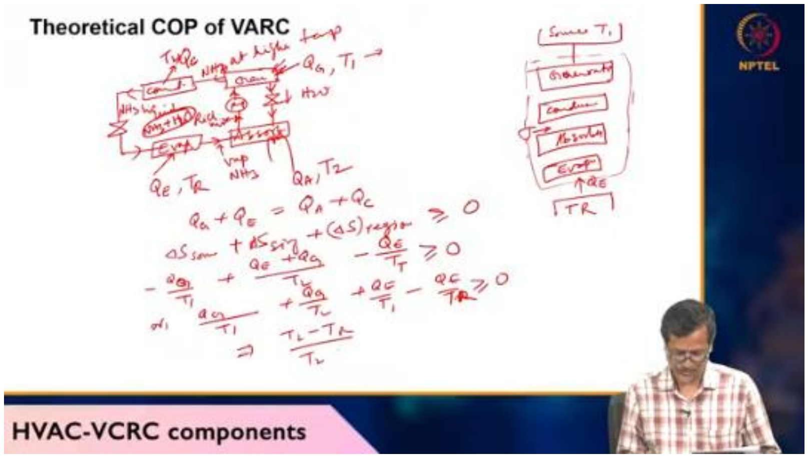
arrow direction also so that you can get full marks and evaporate is taking heat q e at temperature t r refrigerant temperature refrigeration temperature and let's say ammonia circulating and ammonia liquid here after condensation and after throttling ammonia will be absorbing heat then to be creating vapor vapor ammonia then when it is pumping it is rich mixture mixture when it is coming down there will be basically water okay and from generator ammonia going ammonia at higher temperature okay so condenser releasing heat qc at T2 temperature we are assuming the generator is getting heat so at high temperatures fluid water and ammonia will be separated so QG and temperature T1 and pump one pump is here so the pump will be pumping liquid things it will not work in the gas or steam so only liquid would be pumped okay The absorber is having cooling water also will be coming. So this is QA at temperature T2.

So this is the ammonia plus water cycle. Now I will make one control volume here evaporator. condenser then pump will be working here so vapor absorption system only air basically mechanical energy input will be there from pump other parts are getting like waste energy this vapor absorption system good thing is that like it will be taking heat or releasing heat from in the surrounding and especially like solar air conditioning system they are in basically heat is required in generator section when you where you are separating your ammonia and water or water and lithium bromide so heat is required so that heat may come from your waste heat sources anywhere there is any waste heat you can use solar power plant there can be small amount of heat that can be working also and electricity requirement in pump is very lower amount but in vapor compression system electricity requirement will be very high and it is not depending on any other waste heat or other heat okay So heat absorbed QG source T1 by generator and QE evaporator heat absorbed from TR rejected heat QA and QC.

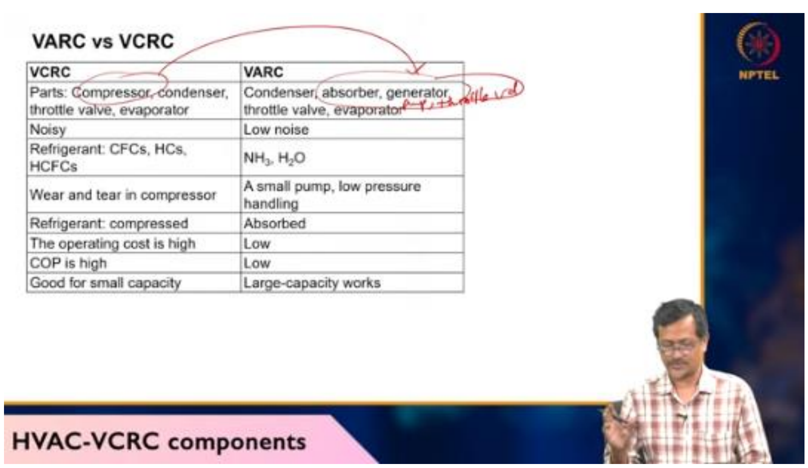
QA at absorber and QC at your condenser. So absorber also rejecting and condenser also rejecting. But heat is getting absorbed in generator and evaporator. Now heat balance you can do QG plus QE heat absorbed equals QA plus QC. And second law of thermodynamics says del S source equals del S sink plus del S region.

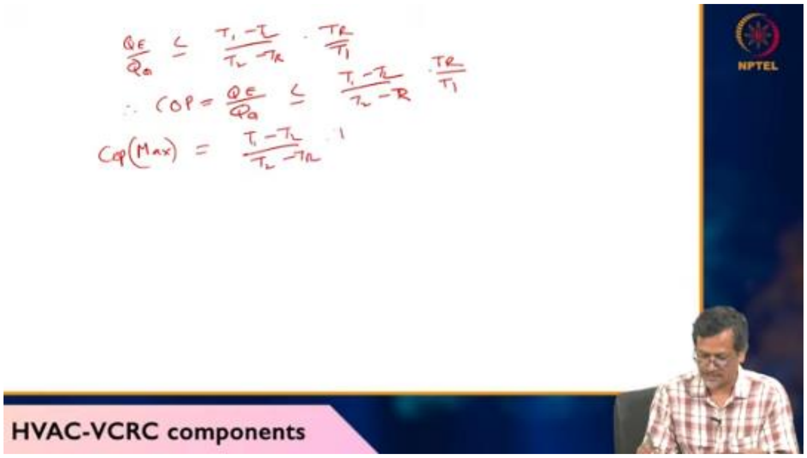


greater than equals zero okay so minus qg by t1 plus qe plus qg t2 minus qe by tr greater than equals zero so or qg by t1 plus qg by t2 QG by T2 plus QE by T1 minus QE by TR greater than equals 0. from there we get T2 minus TR. T2 TR QE less than equals T1 minus T2 T1 T2 QG so QE by QG QE by QG less than equals T1 minus T2 T2 minus TR TR by T1 so COP equals QE by QG less than equals T1 minus T2 by T2 minus TR TR by T1 so maximum COP equals T1 minus T2 T2 minus TR



TR by T1 this is your formula for your maximum COP you can get from your vapor absorption refrigeration system okay now you see vapor absorption and vapor compression system we discussed what are the difference actually so vapor compression system you can remember it is having compressor condenser throttle valve and evaporator basically some more other system also there but basically key parts are there compressor condenser throttle valve evaporator but in vapor absorption system actually you replace this compressor and you put absorber generator and one extra throttle valve also you added actually one pump and one extra throttle valve also okay so this section uh is replaced by this one okay uh and vapor compression when you're talking about the compressor is actually noisy so because it is using a huge amount of energy and it is compressing gas so it is more noisy but vapor absorption system less noisy refrigerant normally CFC, HC, HFC will be used vapor absorption normally NH3 or H2O as a refrigerant so here you can remember H2O is refrigerant when lithium bromide LIBR is your absorbent H2O will be absorbed by LIBR So this is absorbent. And ammonia absorbent will be water.

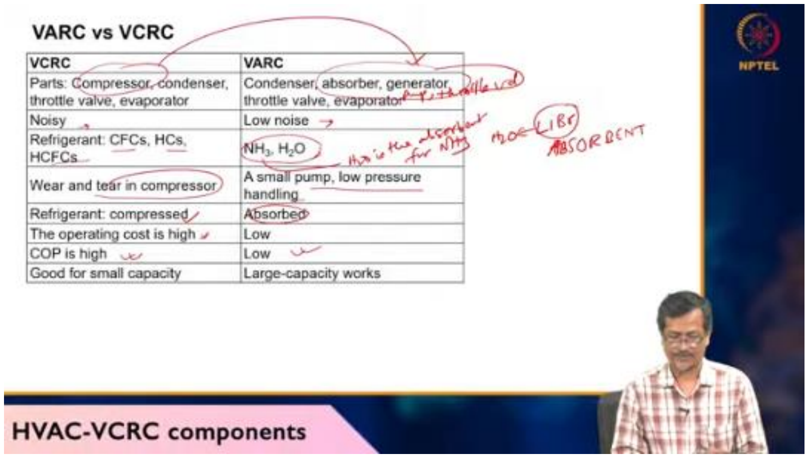




Water is the absorbent for ammonia. b a n t okay so h2 is absorbent correct okay so h2 is the absorbent for industry a the spelling is n t okay Wear and tear in compressor, wear and tear will be higher in compressor because this is taking lots of energy and this is the main part of the system and will be working continuously. Small pump, low-pressure handling for vapour absorption system. Refrigerant in vapour absorption, vapor compression system is compressed but in vapour absorption system is absorbed.

This is difference from the name itself it is there. The operating cost for vapor compression system is higher because one compressor is continuously working but VARC or absorption system in that case only small pump is working. The other pump is a non-moving element so life will be longer. COP for vapor compression system is higher but VARC is having lower. For vapor compound systems window air conditioner or split air conditioner, normal application is very commonly used.

But for very large applications, a vapor absorption system is used. The vapour absorption system is already heavier. So, small application room air conditioning is not suggested to use this vapor absorption system. So, another term is the cryogenic system. So if you go to IIT Kharagpur website, I think they have masters in programming cryogenics.



So cryogenics is used for rocket propulsion, fuel and other aspects. So science of low temperature. The term is coming from Greek word cryos and genic. So frost creation or production. So low temperature science is called cryogenics.

So it can produce minus 180 degrees centigrade temperature also. Okay, so commonly application liquefaction of nitrogen, oxygen or any gas you can create liquid, carbon dioxide liquid you can create using this low temperature. Again one single compression system, the vapor compression absorption system will not create that temperature. you have to do cascading. one will be maybe reducing 50 degree, another 50 degree, another 50 degree.

that way 2-3 stages you can make and then you can create such low temperature. producing and storing superconducting conductors studying low temperatures phenomena and many other things done through cryogenics technology thank you very much for today's lecture next day we'll start uh for we'll start sensible heating and cooling and humidity related thing and we'll solve some problem and of course the chapter thank you very much