MARINE ENGINEERING

By

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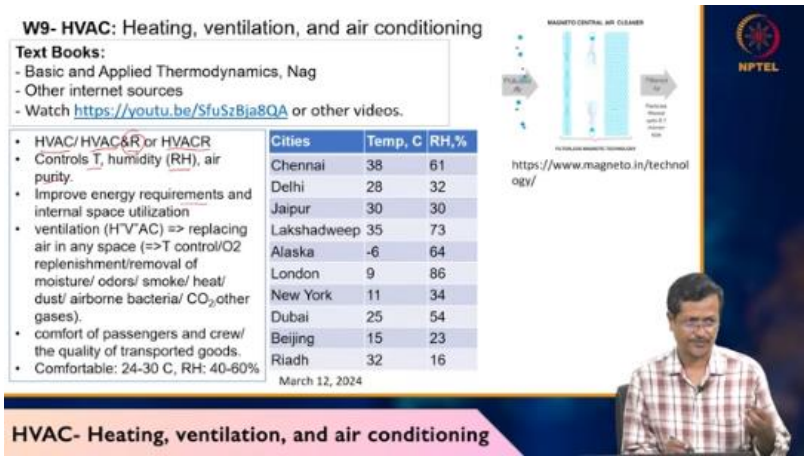
Lecture56

HVAC- Heating, ventilation, and air conditioning

good morning everybody. Today our new week, this week I will discuss about HVAC, heating, ventilation and air conditioning systems. So heating means increasing temperature, ventilation means you have to remove pollutant gas with low amount of oxygen or any pollutant is there, so you have to remove and air conditioning means temperature may be able to increase or decrease. So these three things basically will be there. Then initially I will discuss about general aspect of the HVAC system, why we need this one for a shipping or offshore vehicles or offshore any structure or let us say offshore platforms.

Then we will discuss ventilation and later we will go for air conditioning details, mathematical analysis and we will discuss about performance. Your psychrometric chart also so that you can understand why psychrometric chart or moisture in air also very important for your comfort in room. Now HVAC they will be saying HVAC or HVAC and R air conditioning and refrigeration HVACR so different way they will be explaining. And it will be controlling temperature, humidity basically and air purity. Air purity means like if you have any odour or anything.

So it will be removing. Improving energy requirement. these days lots of research are going on how to reduce energy consumption from your refrigeration system and how to design a building. that it will require less amount of heat or energy from electrical source or other sources. Ventilation system, so where V term is there, that is actually ventilation, it will be replacing air in any space.



So, it will be controlling temperature, oxygen. Replacing removal of moisture odour is there smoke is there heat dust airborne bacteria carbon dioxide other gases all these things will be removed through ventilation mechanism so ventilation mechanism you have seen like the ventilator fan you are very familiar with or if you open your window also air will be circulating so that is also on ventilation purpose so the comfort of passengers and crew in the the quality of transported goods so many goods will be there so medicine will be there many products will be there chemical product which needs lower temperatures in that case also ventilation is very much important ventilation and air conditioning hvac is very much important and comfortable temperature for room comfortable temperature 20 to 24 to 30 degrees centigrade relative humidity will be 40 to 60 percent later we'll discuss in detail Here, I will explain a little bit simpler term. You say I was in Aberdeen.

Aberdeen temperature, when that maximum temperature, very high temperature becomes 30 degrees. So, the Scottish people, their faces become red actually. Because they feel that it is very hot. And we feel very much comfortable. that depends on person to person.

some South Indian student was there in Aberdeen. So, some South Indian student was there in Aberdeen. So, in summer time also, they will be putting heating system on. Because normally South India temperature higher and Scotland temperature is very low. So summer time it is very much comfortable still feel colder.

Even I was also feeling colder during summer time. Relative humidity normally it will be 40 to 60 percent. So lower relative humidity what will you do? It will be drying your skin. Especially during winter season, if you are in North India or West Bengal, that side, because of drying skin, if you scratch your screen, you can see white sort of thing will be coming up.

And sometimes screen will be broken and crack will be created. And sometimes blood will also be coming up. because of dry skin. So, in that case, moisturizer you have to apply, right? Lots of companies are doing business because of this dryness.

And what about if relative humidity is more than 60%? So, what is happening in Kolkata? if in especially in during august humidity will be very high okay so during humidity very high actually you feel suffocated because of high humidity and clothes will not get dried quickly it will be smelly uh lots of skin disease may also come up okay so very high humidity very low humidity also not required so you have to put optimal level of humidity let's say normally people say 40 to 60 degree but 60 percent not degree And comfortable temperature 24 to 30 degrees centigrade. So many people will be putting AC at 20 also.

Many will be putting at 29 around. So based on your percent to percent it varies. Geographical location. Scottish people if they are putting air conditioner definitely they will be putting at 20. In Chennai normally we will not be putting 20.

We will feel very much cold. normally we will be putting higher maybe 25 around. relative humidity anyway it will be auto controlled by your uh air conditioning system okay it will be maintaining so later we'll discuss how to maintain that relative humidity how mechanically it is working okay if you see this temperature and humidity in different cities i have taken from uh google just google weather so chennai 38 degree temperature relative humidity 61 percent so you see the temperature is very high Right. if you reduce temperature, then actually relative humidity will be changing.

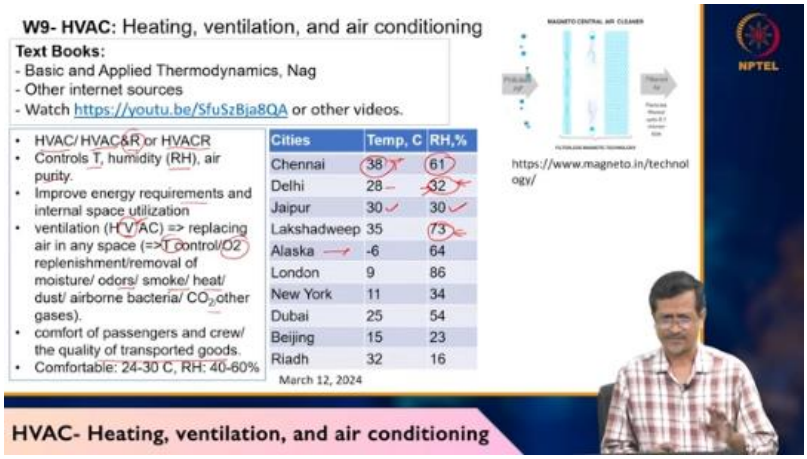
in that case, actually you have to take some action. You have to remove some moisture. Then you have to, you can make your room or any cabin you can make comfortable. Delvee 28, 32% level. It is very low.

in Delhi side same air conditioning mechanism may not work. Delhi side you can use actually desert cooler. So desert cooler in Delhi side if you are from Delhi you may be knowing that lots of water vapor will be going into air and when air is getting lots of moisture temperature will be lower. But in Chennai, people do not use that desert cooler because Chennai humidity is already high, 61%. If you are adding more humidity, you are increasing humidity much higher, then temperature will be going down, but your humidity will be high.

So, that will make much more uncomfortable. So, that is why Chennai people will not be using your desert cooler. But Delhi side, UP side, Rajasthan side, they will be using desert

cooler in summer time. It is very much effective there. okay jaipur if you see 30 degree temperature relative humidity 30 so again you have scope to increase relative humidity when you are increasing relative humidity actually temperature will be dropping so you will feel comfortable luxury because see again relative humidity higher so you have to reduce relative humidity there okay and if you see alaska temperature already negative so reducing temperature doesn't make any sense actually you have to put some heating system okay to make it comfortable

In Chennai, normally this normal passenger vehicles, they will not have any heating system. But if you go to colder countries like UK, so there will be a car heater inside the car, the car heating system will be there. So, you will feel comfortable inside the car. London temperature presently 9 degree actually, but relative humidity will be very high. So, if you are reducing relative humidity, your temperature will be down approximately



So it will not help. So you have to do some mechanism. So you have to increase temperature. If you increase temperature actually automatically humidity will be down. So that mechanism can be used.

So later I will discuss how things will work. But I want to explain you that different cities, different location, geography location they will have different temperature and humidity. And we have different humidity and relative humidity and temperature comfortable zone. So within zone, if we are making our room, then it will be very much comfortable. If you are going outside zone, it may not be comfortable or it may be creating some other issues.

For example, breathing, suffocation also will be coming if moisture is very much high. Or moisture is very much low, then again dryness will be there. So you can see this Riyadh, 16% relative humidity, Saudi Arabia. So it is very low. But luxury London is 86%.

It is very high. So during rainy season especially continuous rain will be there for several days. Sometime the humidity will be going to 90% or more actually. So in that case your cloths will not get dried. So it will be very much smelly.

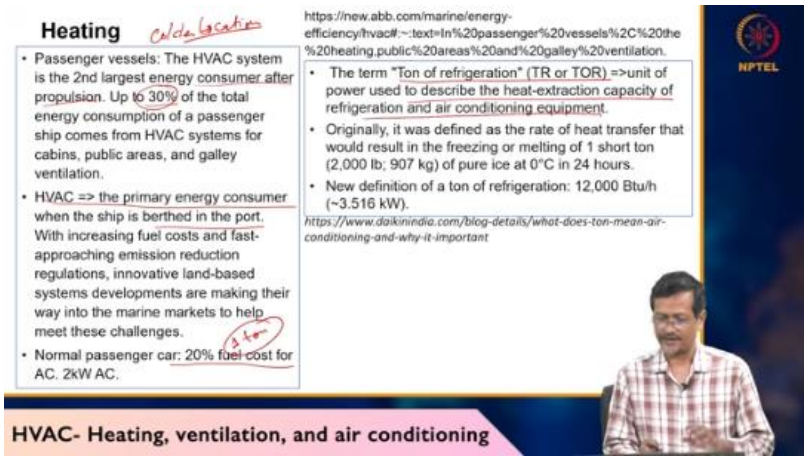
So in that case you should control your relative humidity. So both you have to control relative humidity plus temperature. okay and other thing are there like for example dust smoke other thing like bacteria virus anything is there in atmosphere in air so that also you have to control so right side one picture i have shown here how things are working like the polluted air is here and quality will be going through certain mechanism you can see here then you are getting filtered air okay so this is our actually collaborated magneto magneto one company in delhi So they are making this air purifier. So you can go through their website and you can check what they are doing.

Now heating, especially in colder countries. So heating means especially colder countries, colder locations. Okay, so passenger vessels HV system is second largest energy consumer after propulsion system. So normal one car, normal passenger car in Chennai, it will be using 20% of your fuel if you are switching on your AC. Okay, for your passenger ships also up to 30% energy can be consumed by your air conditioning or HVAC system, heating, ventilation, air conditioning altogether.

In some cases you have to heat, you have to increase room temperature, in some cases you have to reduce temperature, again you have to control moisture also. So altogether about 30% energy can be consumed by system. HVAC is the primary energy consumer when ship is berthed at the port. When it is not moving, propeller is not moving actually, so that time it will be taking the maximum amount of energy. Normal passenger car, 20% fuel cost.

Normally, 2 kilowatt power will be required. 1 ton refrigeration system or 1 ton air conditioning system will be used. About. Thumb rule. So the term ton of refrigerant you can see the definition.

So you should remember the definition actually very much important whenever you want to buy in a refrigerator or your air conditioning system they will say sir what is the tonnage. So you have to know that one approximately. Unit of power used to describe heat extraction capacity of refrigeration and air conditioning system. Here I will tell you one thing. Refrigeration and air conditioning mechanism almost same mechanically.



Later we will discuss. There will be one evaporator coil, condenser coil, compressor coil, all these things. So mechanism is same. Refrigerator you are creating very low temperature. But in your air conditioning system you are creating temperature around 20 to 30 degree within that range.

Normal air conditioning in India I have seen. So minimum will be 18 maximum will be 30 or around. So within that range you can control actually. So normal room temperature for comfort room temperature will be like 25 to 30 degrees centigrade and for your food storage in refrigerator minus 1 to 4 degree. Food storage in your freezers.

It will not be minus 1 normally. It will be normally 4 degree around. But if you are going to deep freezer then it will be much more negative also. But deep freezer it will have less than 0. Deep freezer.

So all the refrigerators they will have one defreezer condition also where you can create ice also. You can put your food items, meat, fish. So those items must be frozen below 0 degree. So minus 15-18 degree centigrade temperature will be there. Dry ice if you want to produce, dry ice, dry ice.

So, in that case your temperature will be like minus 70 degree centigrade, dry is means carbon dioxide you are making solidified and minus 70 to minus 200. So, if you are liquid making liquid gas minus 70 to 200 minus 200 degree centigrade. So, making liquid gas liquid air let us say nitrogen and other. um molecules you want to make liquid nitrogen or liquid oxygen so in that case within that range you have to work so this is called cryogenic temperature very low temperature you're creating so later we'll discuss what is cryogenic temperature how to create it mechanically okay so why these things are required to know because one one side you are reducing room temperature and making it comfortable

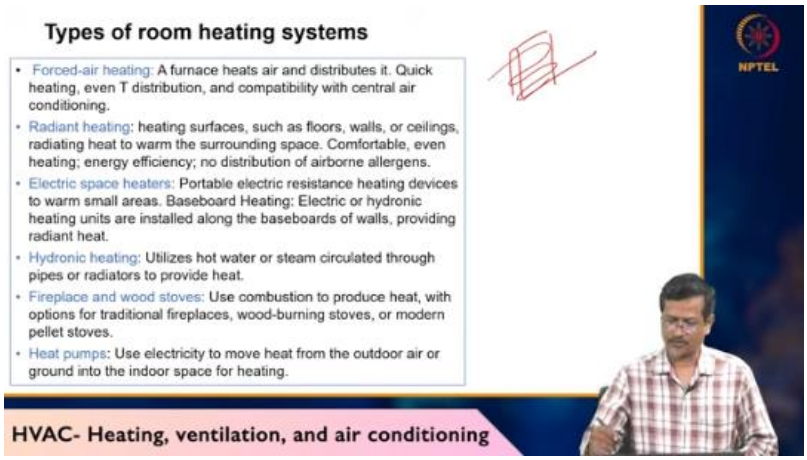
another side you have freezer passengers ship you are designing you have freezer so you have to know a food preservation temperature diffuser temperature and many cases you transport many food item and many chemical item also which needs very low temperature okay so that also you have to know for example liquefied natural gas lng so you are creating liquid so that means you are creating low temperature

okay so and your container must have all these facilities so that's why you should know the temperature ranges for this okay uh one more thing uh tone of refrigerant here uh definition is that 2000 pound 907 kg uh ice you are creating so that is called tone of refrigerant at 0 degree centigrade in 24 hours okay so this is the definition now here tone doesn't mean like 1000 kg is this short tone so in u.s they use short tone one long tone will be there another will be metric tone metric tone actually exactly 1000 kg and short term is 907 and if it's a long tone so in that case it will be 1016 that this short tone that means 907 kg and exact definition they have given now 12,000 British thermal unit this much of energy you are transferring. or 3.516 kilowatt energy you are transferring that is the new definition of tone. So tone of refrigerant means 12,000 BTU per hour.

you are buying any refrigerator or any air conditioning system, so you have to talk about tonnage of refrigerants. So, type of room heating system. So, one is that forced air heating system. So, you have one furnace and you blow air. So, whole room will be, air will be circulated and temperature will be controlled.

Another is radiant heating system. I was in the UK, in Scotland. So, there they had one radiation, radiant system. So, inside there will be some coil. Hot fluid will be passing through the coil.

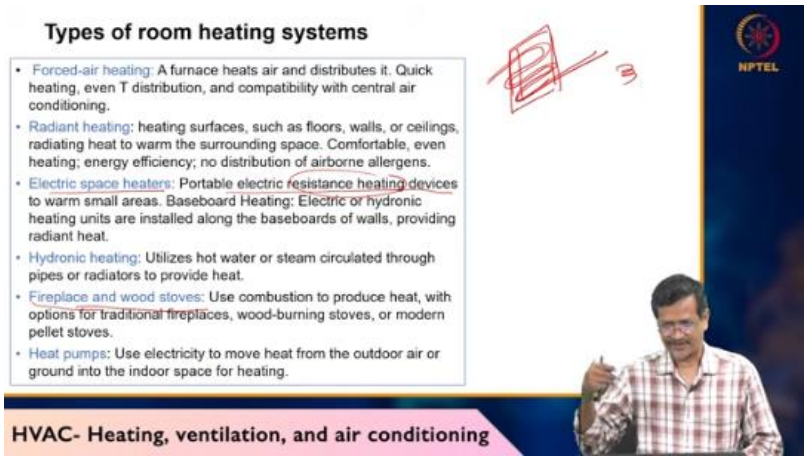
Coil means pipe actually. Through this hot fluid will be passing through this one and this one metal sheet. When hot fluid passes through this one metal sheet will be heated up and this will radiate heat inside the room continuously. gradually room air temperature will be going up. In South Korea I was there so they had floor heating system.



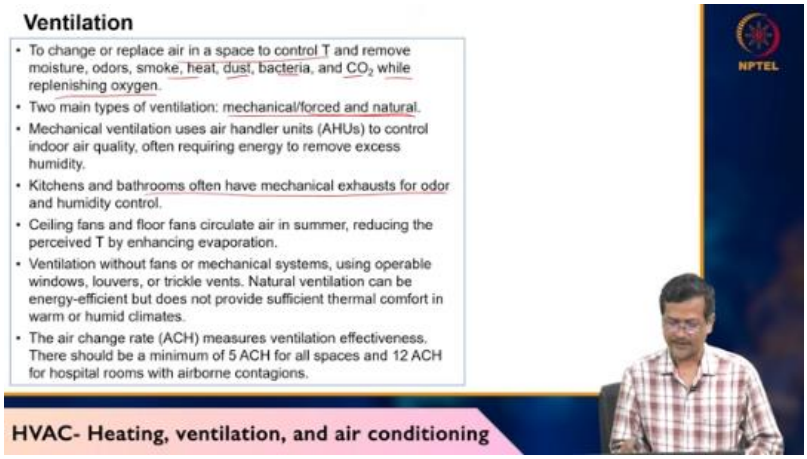
So the floor they will have some coil or some heating mechanism. So floor will be heated up slowly floor will be radiating heat. And because of high temperature, the hot air particle will be moving up. So, whole room will be heated up gradually. And in North India side, if you see during winter season, they will be putting simple coil.

Like electric coil they will be putting and some curves way so that you can get heat directly. So, electric space heater they say. portable electric resistance heating device so resistance city that one actually okay there is a nominee in the future northerner side people will be using during winter season okay uh some many other types of heating also fireplace heating are there for example older houses if you see in colder countries there will fireplace inside room so there will be burning coal or wood and there will be increasing room temperature uh There will be heat pump also in some cases somewhere heat source is there. So you pump or make some natural circulation system so the room temperature will be increasing gradually.

So and many cases people will be using your exhaust heat to increase temperature. So exhaust heat you pass through some pipe and the radiated heat will be inside room. So radiated heat will be increasing temperature but the exhaust gas you are not putting inside room rather uh that heat you are using for heat room heating purposes but everywhere you are not heating room for example some vessel is there in chennai you are not hitting the room because temperature already high but when vessel is moving towards colder countries so there you may need heating room okay ventilation so to change or replace air in space to control temperature remove moisture odor smoke heat dust bacteria carbon dioxide while replacing oxygen So two main types of ventilation system, mechanical and forced ventilation or natural circulation will be there.



So mechanical ventilation like you have air handling unit, you have fan, normal like your toilet system, there will be fan or many rooms also will be having fan, ventilator fan. So that room air will be pushed out of the room so that fresh air can come from other sources. Let us say door will be open and from door it will be entering. So kitchen and bathroom often will have mechanical exhaust fan. This will be controlling odour and humidity.



okay ceiling fan and floor fan circulates air in summer reducing passive temperature by enhancing evaporation so ceiling fan actually it will be circulating more so once air circulation is there so more evaporation will be there so because of evaporation will feel more comfortable so ventilation without fan mechanical system so door or window you keep open so that will create natural ventilation that is also possible okay so that used one term air changes rate okay normal air conditioning system like whatever air is running here also so there will be five air changes normally uh so five times one time two times three five times air will take from room after that it will be pushing out to the room okay but in many cases like hospitals there will be 12 years many times changing will be there okay So, now air conditioner type. So, whenever we are talking about room air conditioning

system, normally we say in general respect we say like reducing room temperature. But if you say western country like say Scotland where I was there.

So, air conditioning does mean that you have to increase room temperature. Room cooling does not make any sense because already outside temperature lower. So, if you open the window already room will be cooled. So central air conditioning system will be there. So if you see, if you go to your Phoenix Mall, that's outside IIT.

Phoenix Mall, it will be centrally air-conditioned. One air-conditioning machine is there for a library or even offices also. In our department also, they are putting new air-conditioning pipelines. So, one centralized plant is there. From there, you are transporting your cold fluid to the rooms.

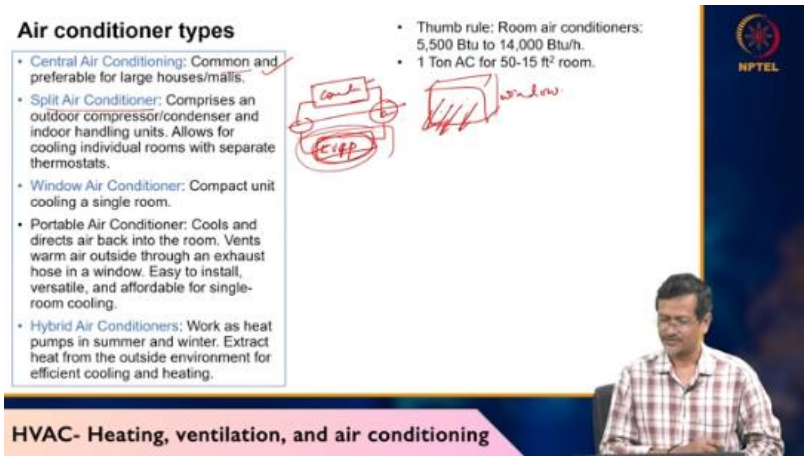
That will be central air-conditioned. Or new academic buildings also, they are having central air-conditioned. Instead of putting individual air conditioner in each room, they put centralized one system. Another is split air conditioner. Centralized means very big system, very big houses, very big malls, school or let us say big building, NSE building.

So, there you are putting one machine and you are cooling whole building. And split air conditioner. So, these are split air conditioner. In this room, split air conditioner means normally air conditioner will have one condenser. So, in split air conditioner, we will have one condenser and one evaporator coil.

Something more will be there, I am not showing now. So, condenser means, let us say above the building, sometimes we will be seeing some boxes there. So, that is called a condenser. So, that will be releasing heat. And evaporator means inside pipe like here some air is coming, cold.

So, from there, cold air is pushed here. means hot that heat it is taking and it is pushing out to the condenser okay so split condition means two unit condenser will be outside building and evaporator part will be inside your room but another is that window air conditioner in my office room i have one windows small air conditioner okay so inside everything will be there your condenser your evaporator another really all the mechanism will be put inside one box So this is called window air conditioner. The split air conditioner is that it is silent because maximum noise will be coming from condenser and one compressor will be there. So those noise making and difficult part it will be outside building and evaporate part which is not making such noise for example this room is not making noise right only small air blow noise is coming.

This split air conditioner will not give any noise and peaceful cold room you are creating. But window air conditioner, all the compressor, condenser, all mechanism will be there in one box and will be delivering air inside your room. that is why it is noisy. So many people will not like window air conditioner. They will be liking split air conditioner.



But window air conditioner is very small you can make and you can put in small rooms. This is one compact unit. You do not have to put separately condenser and other parts in some other places. The small unit you put here. So, portable air conditioner window also one portable air conditioner actually.

Hybrid air conditioner also possible and many cases air conditioner possible using your vapor absorption system. Later we will discuss vapor absorption system. Actually basically two types of air conditioner system will be there. One will be vapor compression system. So normally window air conditioner, your split air conditioner will be vapor compression system.

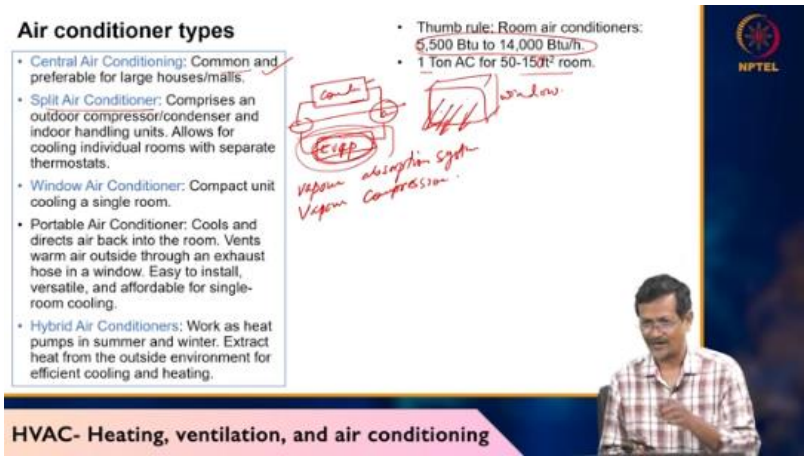
And vapor absorption system will be for big malls and cold storage system. There will be vapor absorption system because it will be very heavy. But very light and compact system if you want to make then vapor compression system is better. So, thermo rule is that for room air conditioning system like this much of range of heat will be removed. So, your tonnage will be like 1 ton around.

So, 1 ton around room like normal office room will be like this room is bigger actually. But if we see my office room is smaller room. So, there will be 1 ton refrigerant AC will be enough. For big room ton will be higher. Okay, 50 to 150, not 15, 150 square feet, this is thumb rule actually.

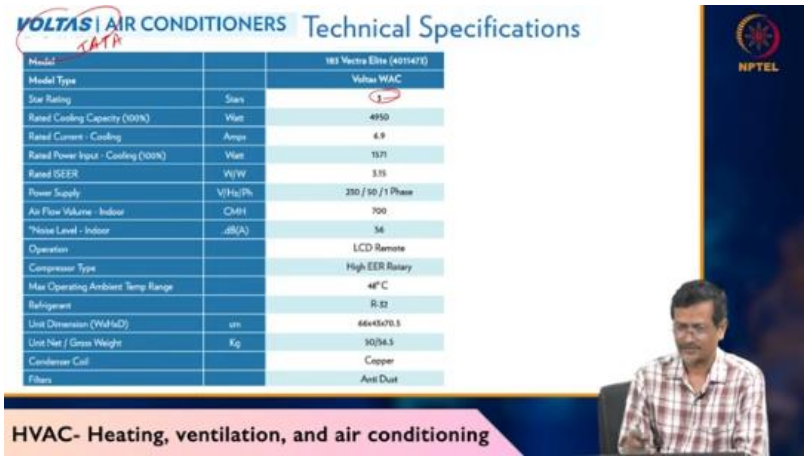
If you go for actual calculation, then you have to do actual dimension you have to take. But normally you say, sir, how big your room? Sir, one bedroom is there, queen size or king size cot is there. So, then your SC shop people say, sir, you take one ton or two tons. But if you want to go for exact calculation and building design or shape design something.

So, in that case then you have to see whether room is insulated properly, windows are designed properly, windows if there are lots of leakages there, your air conditioner cooling but lots of heat will be wasted. So, room windows must be designed properly, ceiling must be designed properly, walls must be insulated properly so that heat should not go out or in. So lots of things are there. But we are not going to design the reorganizing system based on this room size and other things. Rather we will go for mechanical system.

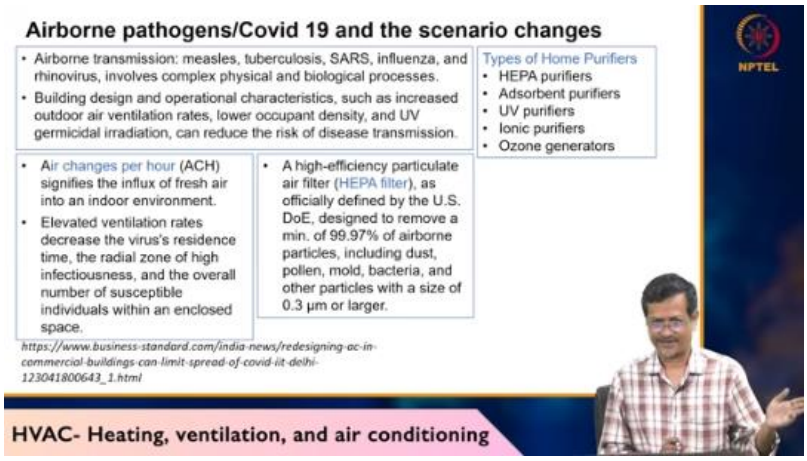
How reorganizing system will be working. How we will make comfortable room. So here I have given one example just I took from internet. One Volta company they are selling product Tata. I think Tata product this one.



They are selling product in India. You can see this one. Star rating. So higher star rating is better actually. This is more energy efficient.



then cooling capacity 4950 watt ok so this much of heat they can remove rated current 6.9 ampere cooling power input ok then noise level also very low you can see operation LCD maximum operating ambient range temperature 48 degree centigrade also they can work ok and refrigerant later we will discuss what is R32 Freon I think you may be knowing right r12 uh you may be knowing already because this is a chloroflow carbon type so r32 is there are 134 is there so many types are there later we'll discuss different types of refrigerant okay and yeah so anti-dust filter also there so this is one type of window air conditioner actually okay so it's nothing related to ship that's trying to show this what the air condition looks like airborne pathogens, COVID-19 and other scenario changes. So, in 2020, when COVID started, scenario was different. Now, the scenario is different because the air conditioning system, it will be recirculating air, room air.



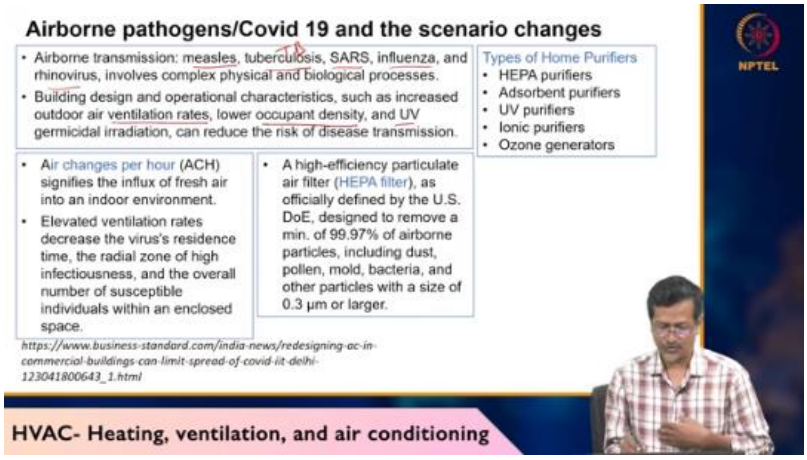
it will be recirculating room air means air. it is taking room air, cooling it, again sending, again it is taking back, sending. So several times it will be doing this one, after that it will be sending out to the atmosphere. Now when it is doing this one, so if there is some virus,

it will be recirculated, it is creating air turbulence. So one person is having some COVID virus, it will be reaching to others.

So that becomes challenge for the designers or air ventilation or HVC system engineers. And airborne diseases like measles, tuberculosis, SARS, Influenza, rhinovirus, influenza, rhinovirus, measles, tuberculosis, tuberculosis TB and COVID-19 SARS, SARS-CoV-2 you can say. So, these are airborne viruses. Airborne viruses, it will be if you have any moisture particle, air droplet, water droplet, liquid droplet, it will be residing liquid droplet and it will be moving, right?

When air conditioner is working and recirculating, it will be taking one virus from here and it will be sending to others. Then what to do? the building design operational characteristics, they said like increased ventilation rate, lower occupancy density. lots of people are there. So, possibility that more virus will be transmitted.

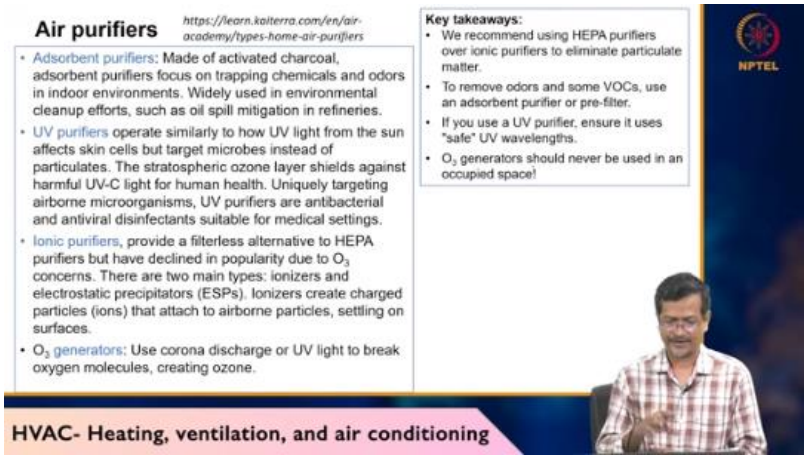
So, reduced number of occupant. uv ultraviolet ray you can use so actually we are working with one royal academy of engineering project for designing uv waste air filter design where we are doing like this we have one channel we are taking room air and inside channel we have put all this uv virus uh uv light sense uh uv lights okay when air is moving through this uv lights uh all the germs will be killed or deactivated virus it is lifeless anyway right so when virus will be moving through this uv section it will be deactivated or i mean it will be killed you can say killing rate we say it will be killed and when air is going out if any virus is there you are getting without virus or bacterial pairs okay so that we are trying to design actually So many companies also jumped into that business. Previously it was there, so we are trying to design and optimize the system actually.



And one system is there already, a high efficiency particulate air filter. So lots of small source heaps will be there and when air passing through this one so very small particle also will get trapped and it will be dropping very much higher pressure also but it is still fine when you are talking about virus spread. So this high efficiency particulate air filter it will be around 99.97% effectiveness is there but particle size 0.3 micrometer or larger it will be stopping. But if some particle size much lower, then it will be having difficulty.

some virus or bacteria will be larger size, virus may be much lower also that can get transmitted. But UV is one effective method. So, we are trying to develop certain technology. So, types of home periphery like HEPA periphery will be there, adsorbent periphery is there, UV periphery is there, ionic periphery is there, ozone generators also there. One company like Delhi in Magneto, our collaborator with this project.

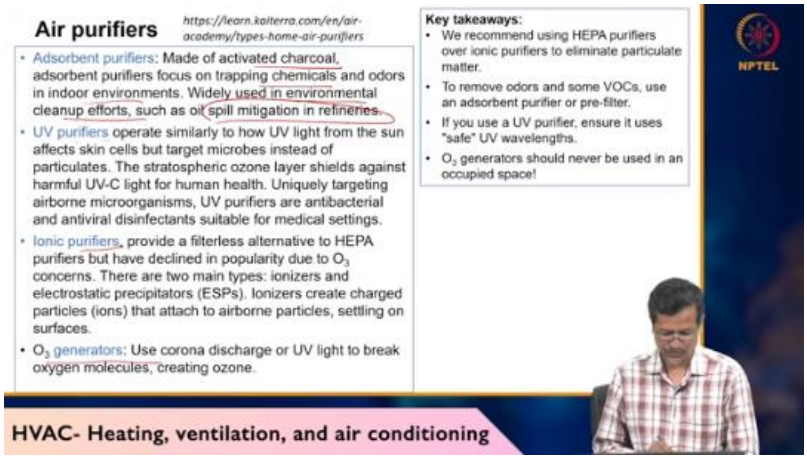
So they are also trying to develop ionic based purifier and UV already were working together. air purifier. Air purifier means here you are not controlling temperature or moisture. Here actually you are purifying air for dust or another thing. Absorbent purifier. So it may be made of activated charcoal.



So it may be trapping chemicals, odors, indoor environment. Widely used in environmental cleanup effort such as spill mitigation, refineries. charcoal is used for your desalination system also for odor removal purpose. UV purifier also there I already told. Ionic purifier is there.

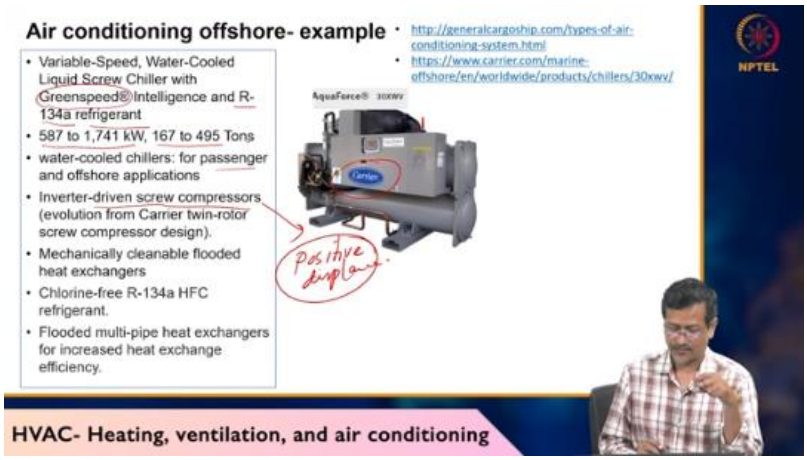
Oxygen generator is there. Use corona discharge of UV light to break oxygen molecules creating ozone. So, air conditioner for offshore, one example here I have taken, like carrier company, big air conditioning company, so they make offshore. And I found some other companies also there, they make especially for ships, your boats, especially offshore

applications. So, they may have specific criteria, especially material and other things must be considered.



Because offshore is very much salty, so any material randomly you select and you design, it may not work. okay so for example one example is given here green speed one their technical term i mean name they have given so r134a refrigerant they are using and this much of cooling they are creating 167 to 495 tons so very big actually very large shipping applications is water cool chiller so chiller means like condenser part will be water cooled for passenger offshore application inverter driven screw compressor Here compressor system they have specified screw compressor means like positive displacement. So what happens in the organic system we need one compressor. The compressor will be producing very high pressure but low volume flow rate.

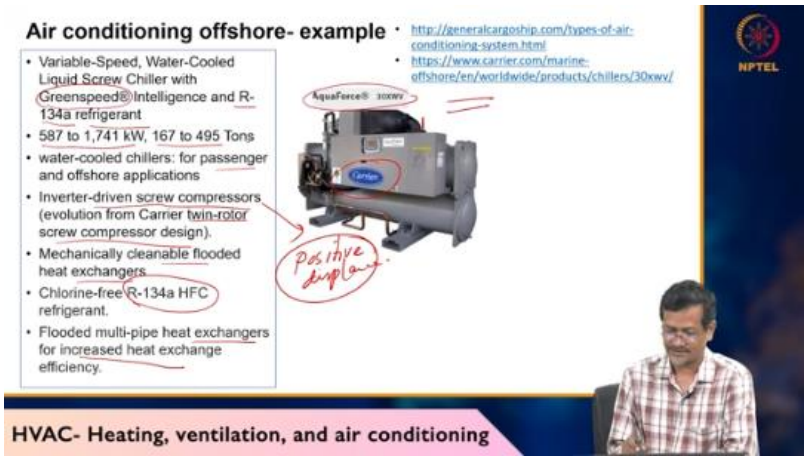
When it is producing higher pressure low volume flow rate we go for a positive displacement type compressor. So, you can remember this pump lecture. So, when volume flow rate lower and pressure rate higher or head higher. So, in that case we go for positive displacement type. So, here in compressor system for air conditioning or refrigeration system, the compressor will be positive displacement type.



And screw compressor is a positive displacement type compressor. So, they are using twin screw, twin rotor screw compressor they are using. Mechanically cleanable flooded heat exchanger. Chlorine free. This one R134A. Later we will discuss in details about refrigerants.

Multipipe heat exchanger also they are using. So you can go through the again heat exchanger lecture. What is multipipe? Heat exchanger multiple pipes will be there. So cooling rate will be much higher.

So their Aquaforce 3.0. This is their product actually. This picture shows. now i told that there will be two type of basically two types of refrigeration system one will be vapor compression one vapor absorption many other types also there but let's first focus on vapor compression how does it work so vapor compression system will have one compressor compression term is there that means one compressor must be there so let's draw one compressor first okay so compressor what is it is doing It will be compressing refrigerant and condenser. After condenser, there will be one throttle valve and evaporator.



So, I will put name 1, point marker, state 1, state 2, state 3, state 4. Now, I will be putting this one in TS diagram. Again, you draw this similar to Rankine cycle, one vapor envelope drawing. Your compressor, this is compressor. This is throttle valve.

or expansion valve. So TS diagram condenser will be reducing temperature. This is your compressor. Then four, one, two, three. So, now you can see this one just opposite of your Rankine cycle actually.

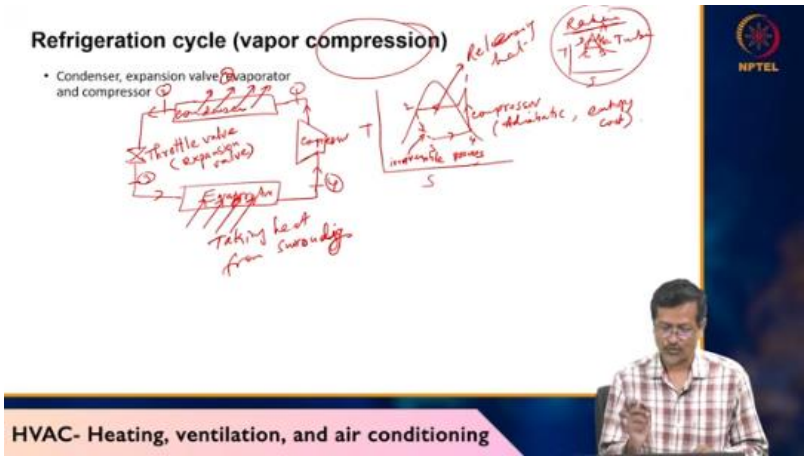
If I can draw TS diagram Rankine cycle, I had like this, right? So, A, B, C, D, Rankine, okay? So, Rankine cycle you can see compressor, instead of compressor in Rankine cycle I had turbine, okay? So, compressor we are giving power to compressed air when turbine we expanded fluid right so it is similar to uh just opposite of franken cycle actually you can see but two to three is called expansion valve and it is irreversible process okay this is irreversible process so two to three is irreversible process

1 to 2, 1 to 4, 4 to 1 compressor we are assuming let us say adiabatic or entropy constant. 1 to 2 is your condenser. So that means it is releasing heat. So 1 to 2 is releasing heat. and evaporator what is happening it is taking heat from surrounding okay evaporator taking heat from surrounding so here evaporator this room is cool right so this evaporator is taking heat from this room

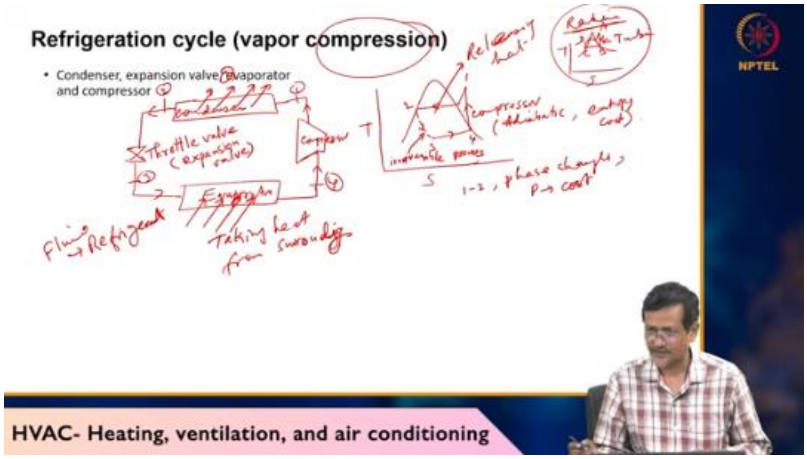
So, evaporator is nearby here, but condenser, it will be outside the building. And throttle valve, so condenser and compressor will be outside building. Compressor because compressor will be noisy, motor will be there, then screw compressor or scroll compressor will be there. So, those will be continuously running. Because of that one, some noise will be coming.

So, condenser and compressor will be outside building if it is split air conditioner. But if you are thinking about window air conditioner, then everything will be together in one box. Very small compact system. Now TS diagram you understood. 2 to 3 throttling happening or expansion happening.

So there entropy increasing but irreversible process. 4 to 1 compression happening. Because of compression gas temperature will be rising. So compression then you have to reduce temperature. So 1 to 2 you reduced.



Heat will be released. when reduced actually you made liquid compressor compressed your refrigerant the fluid is flowing fluid called refrigerant okay so when fluid is flowing through the loop that fluid is called refrigerant refrigerant one to two phase change occurring constant pressure okay so one to two phase change occurring P constant. Right? 2 to 3 pressure changing but phase change not occurring.

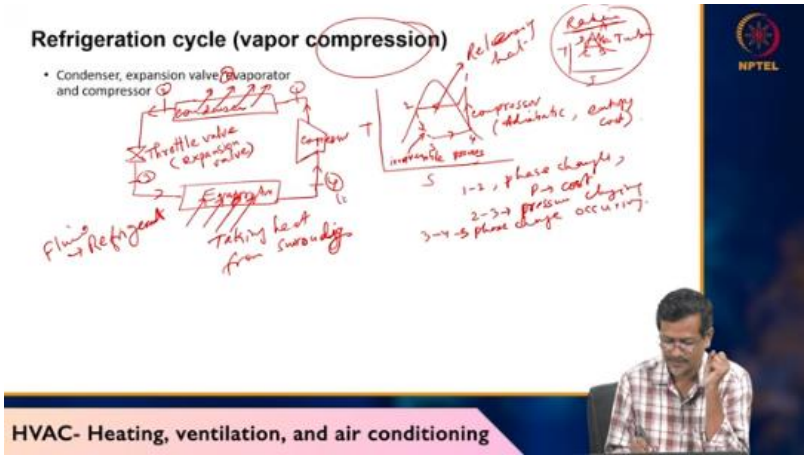


2 to 3 irreversible process pressure changing. And 3 to 4 what is happening? 3 to 4 is evaporation happening. Evaporation happening means you are giving temperature from room. Room temperature is taking and phase change occurring.

So 3 to 4 phase change occurring. 3 to 4 phase change occurring. Now the system 3 to 4 phase change occurring means you created gas evaporated steam or gas created 4 to 1 compressed it compressed means you increase temperature condenser release heat again you make liquid at higher pressure, you are making liquid. When it is going through throttle valve, pressure changing.

So, pressure changing and it is going to your evaporator system. Then evaporator systems at lower pressure, lots of evaporation will be happening, vapor will be coming out. So, that will be taking lots of latent heat. When latent heat is taking, so latent heat it will get from the room or if it is fridge, From food item, it will take latent heat.

And food item will be cooler. Room is cooler. Then it is liquid again. This at 4, it is liquid. So 4 is, it is vapor.



Right? So 4 to 1, compressing vapor. Okay? It is clear now.