INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-17
Refrigerants-2

with
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Hello I welcome you all this course on refrigeration and air conditioning and we will continue our discussion on refrigerants in the previous lecture we are discussing about the requirements of an ideal refrigerants so requirements of an ideal refrigerants can be classified as.

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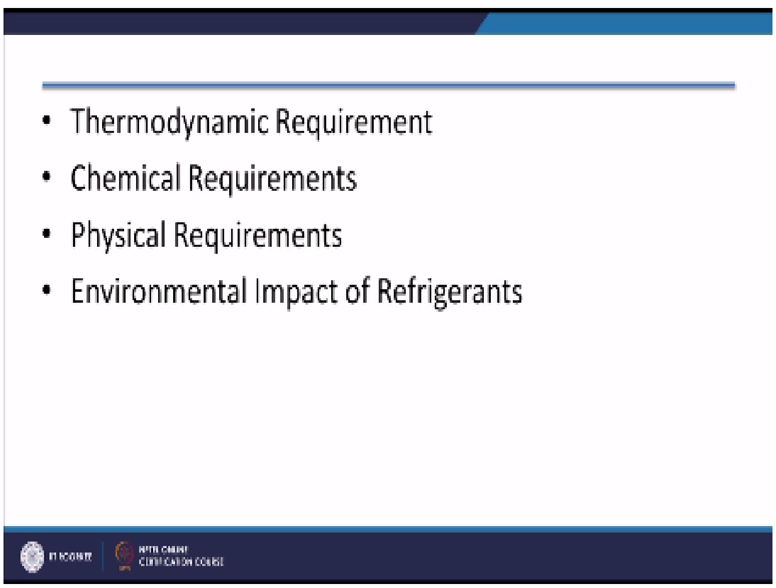

Thermodynamic requirements, chemical requirements, physical requirements and environmental impact of refrigerants this is also very important as the last one is the most important nowadays. We will start with the thermodynamic requirements.

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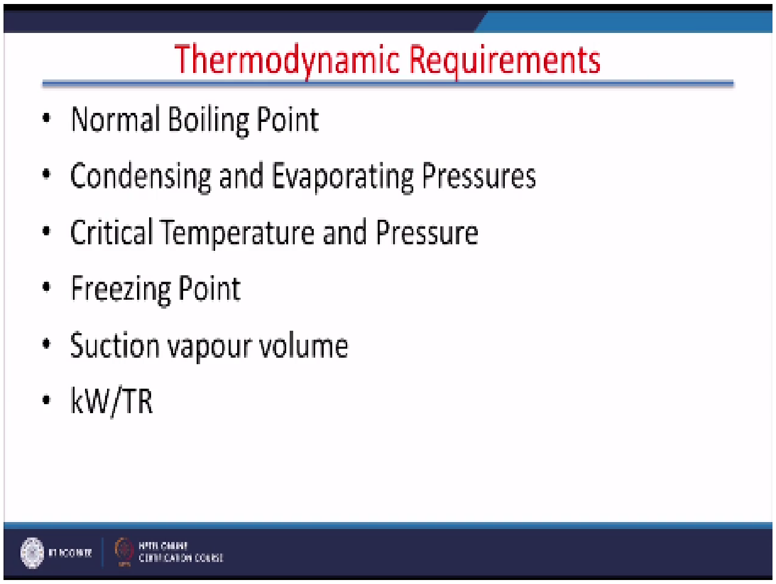

Normal boiling point of refrigerant is very important normal boiling point is, normal boiling point.

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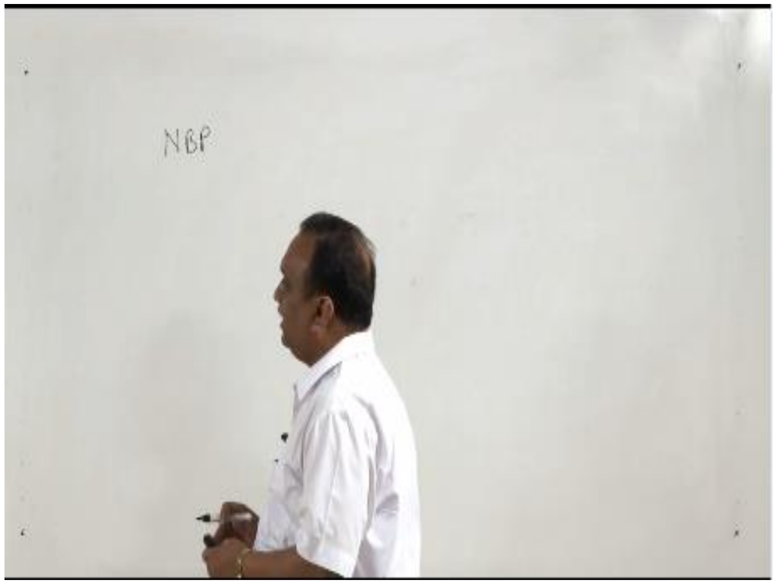

Normal boiling point of a refrigerant is the boiling point at one atmospheric pressure and in this slide I have shown.

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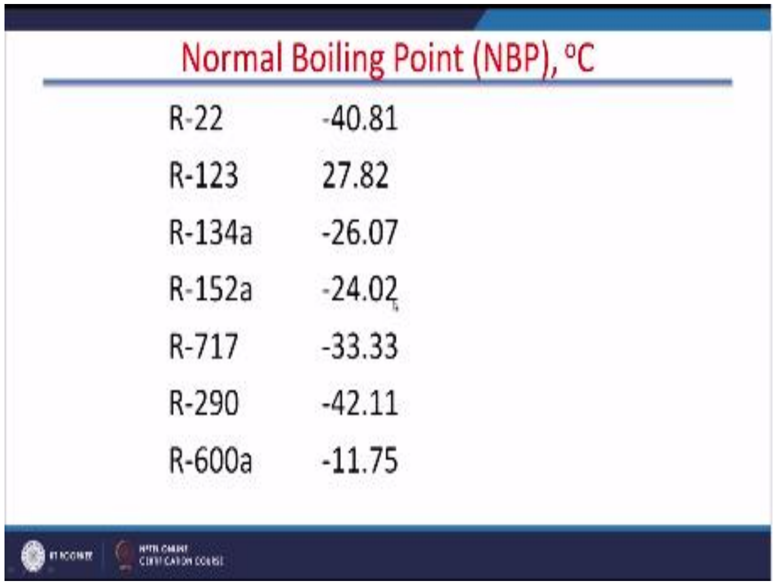

Normal boiling point of different refrigerants starting from R22 which is -40.81 point 2 600a which is a isobutane it is -11.75 so these normal boiling points decides what should be the pressure inside the system if the normal boiling point is low the system will work on high pressure and if the normal boiling point is high the system will be a low pressure system and the pressure ratio in high normal boiling point will be more and for this we will start we will do some derivation a sort of derivation with the help of clapeyron equation, so the clapeyron equation which is a derivative of Maxwell relation the clapeyron equation says that.

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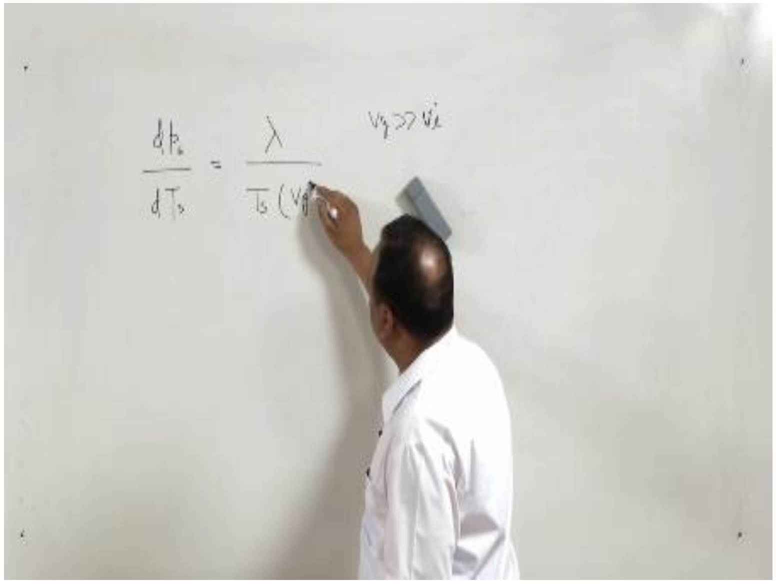

dP/dT this is saturation, saturation is equal to latent heat λ by temperature saturation temperature V_g-V_l it is applicable for the saturation condition of any fluid. Now here because V_g is much greater than V_l velocity of the liquid sorry, the volume of the liquid is much, much less than the volume of the gas, so this can always be neglected. So regarding this we will do one small derivation to find the bearing of normal boiling point on the performance of a refrigeration system.

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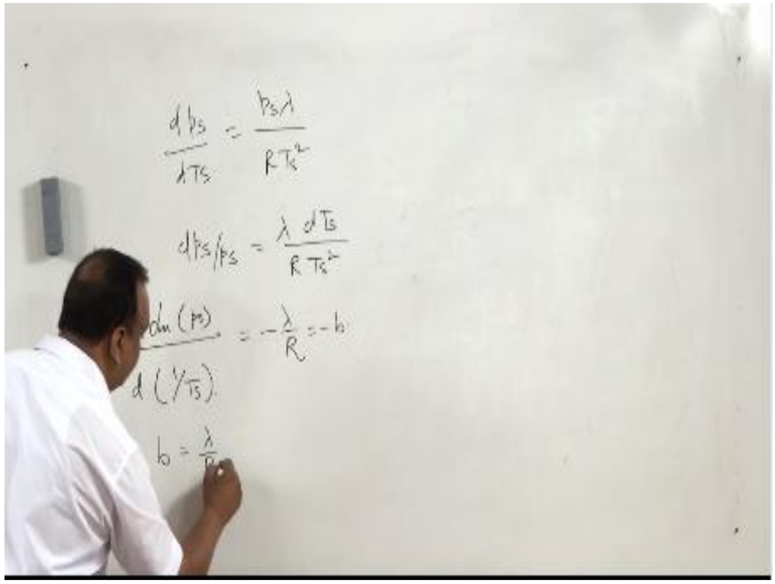

There is a Manxmen relation $\delta P/\delta T$ at constant volume is equal to $\delta S/\delta V$by Del V at constant temperature from this Manxmen relation clapeyron relation has been resolved that is dP/dT at saturation state is equal to latent heat divided by saturation temperature and specific volume of vapour minus specific volume of liquid and this is applicable during phase change. Now specific volume of vapor is much, much larger than the specific volume of the liquid so this term can be neglected and the modified form of this clapeyron equation is going to be dP/dT the $dP_s/dT_s=\lambda$ is latent heat latent heat divided by T_s and V_g.

Now here for V_g we can replace V_g by P/RT so $dP_s/dT_s = P_s \lambda/ RT_s^2$ the further arrangement of this equation will give $dP_s/P_s=\lambda dT_s/RT_s^2$ now we can further write it in differential form as d natural log of P_s / $d(1/P_s)=-\lambda/R=-b$ so $b=\lambda/R$.

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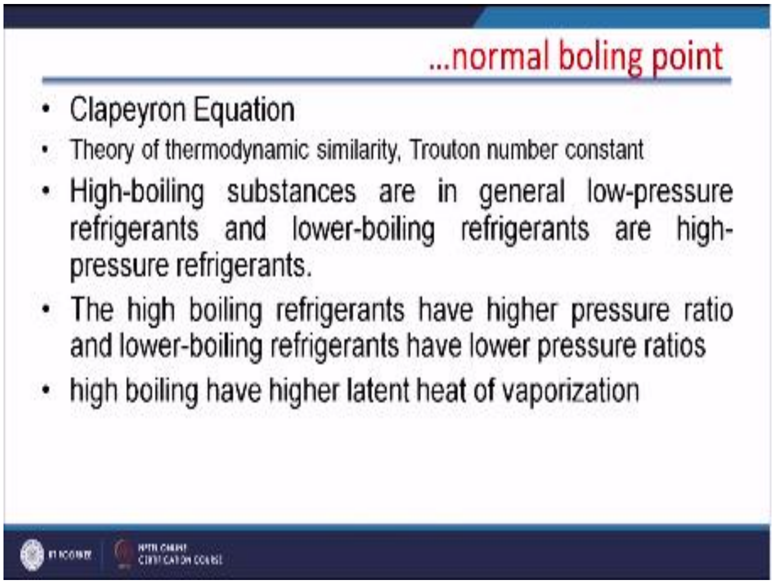

Now if you look at the theory of thermodynamic similarity which gives a number Trouton constant.

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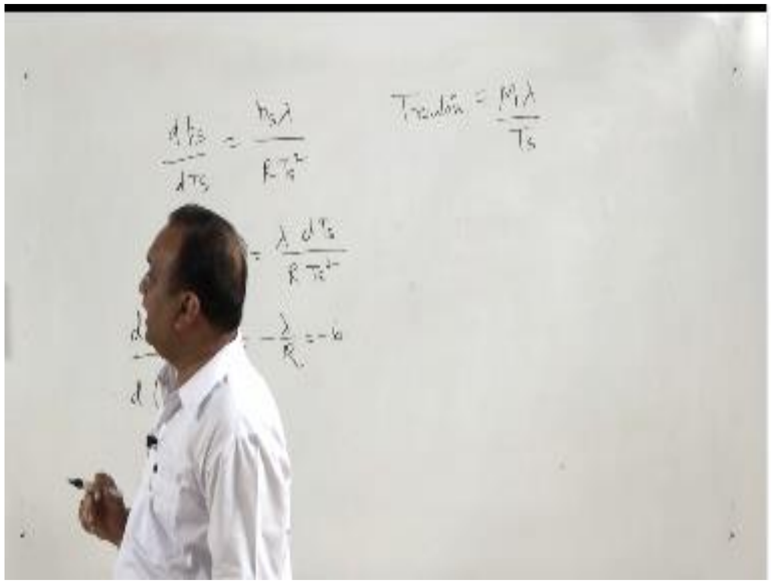

Trouton constant or Trouton dimensional number and that is equal to $M\lambda/T_s$ M is the molecular mass of the substance λ is the latent heat T_s is the saturation temperature and now thermodynamic similarity theory says that.

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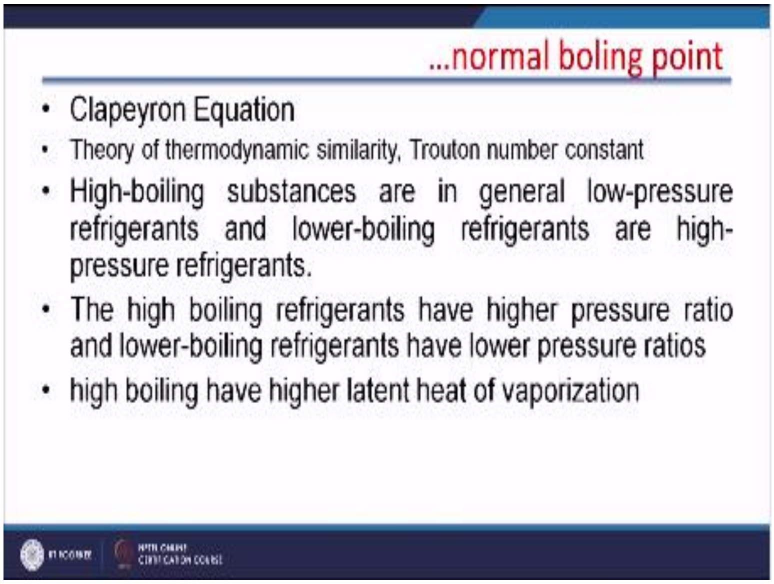

The substance of the same group will have this Trouton constant as a constant order number as a constant so here in case of $b=\lambda/R$.

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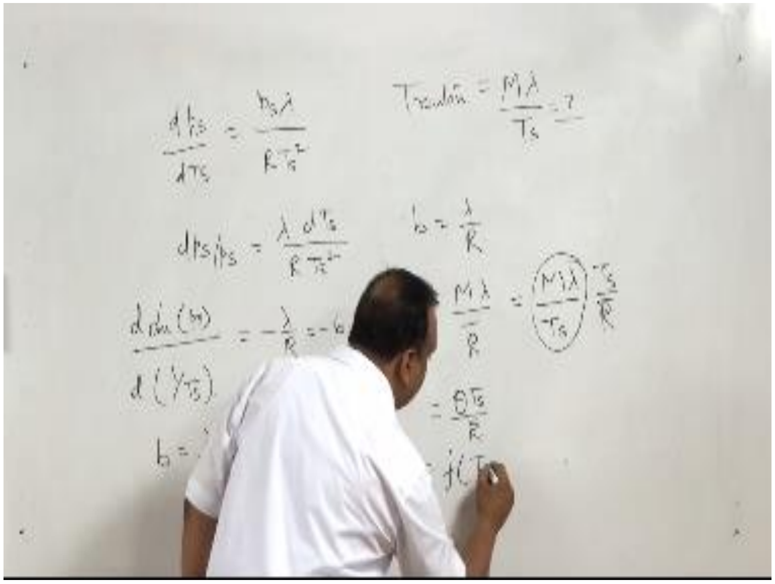

If we replace R by universal gas constant it becomes $M\lambda/\bar{R}$ universal gas constant is same for all the gases. Now it can further be written as $M\lambda/T_s$.Ts upon $\bar{R}$ now this M log M λT_s is constant is equal to $\Theta T_s/R$ now this is constant this is constant $\bar{R}$ this is constant so b is a function of T_s.

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Now regarding this equation if we integrate this we will get natural log of P_s=-b/T_s+a at one atmospheric pressure this is going to be 0zero natural log of 1 is 0 so a is equal to b/T_s so a is a rate function of T_s what do you mean to say here if we draw a curve between natural log of P_s and 1/T_s high boiling point of refrigerants will have stever slope low boiling point refrigerants will have a less steeper slope.

Now if you want to depict this on the same diagram between two temperatures this is pressure so this is the slope of low temperature refrigerant this is the slope of high normal boiling point temperature this is To and this is Tk this is To or this is Tk or high condenser temperature and you have greater temperature now this formation have somes in deciding the which refrigerants we should go for attaining the referee attic effect.

The high boiling refrigerants have high pressure ratio because the slope of this curve is high and low boiling point refrigerants have low pressure ratio. Further it can be concluded from the previous derivation that high boiling point refrigerants have higher latent heat of vaporization.

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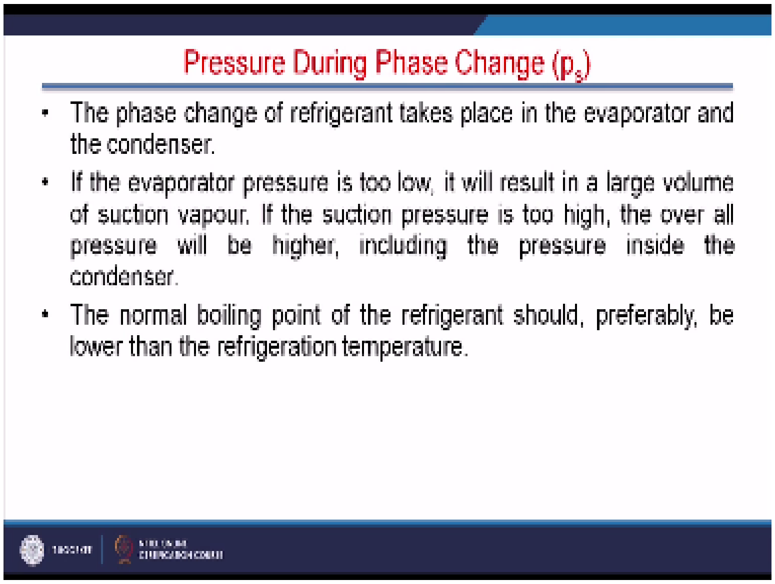

Now pressure during phase change pressure during phase change is also important deciding the refrigerant because if the pressure is high suppose in the condenser if the pressure robust design of the condenser has to be made similarly in the case of evaporator if the pressure is very low lower than the atmospheric pressure then there are chances that air may leak into the system on the same side the specific volume of the refrigerant will also be very high.

So that will increase the size of the compressor, so we have to be I mean there are many factors which decide that what order of pressure we should go into the condenser and the evaporator so in the evaporator itself the pressure should not be very low so that the specific volume of the refrigerant is high and the size of the plant is bulky and the same time if the pressure is very high then robust design of the system has to be made and that is also not I mean desired because the cost of the system will increase.

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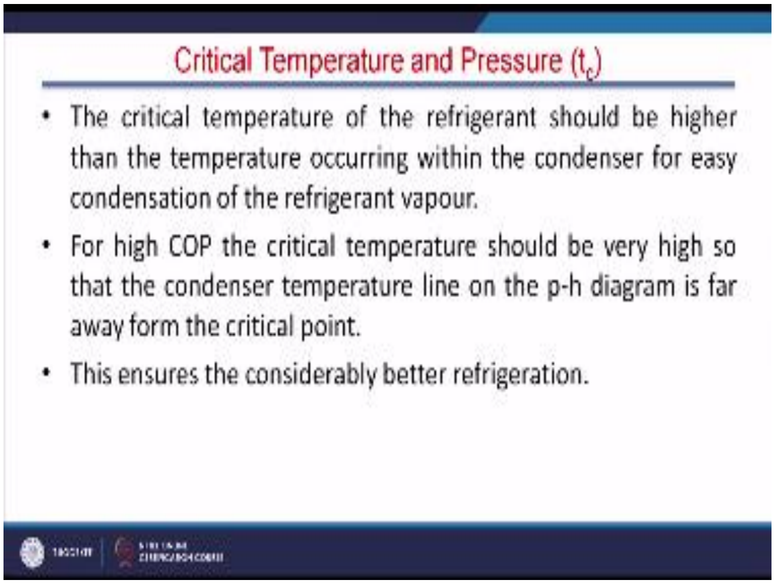

Now critical temperature and pressure for any refrigerant or for any refrigeration cycle if it is operating further from critical temperature.

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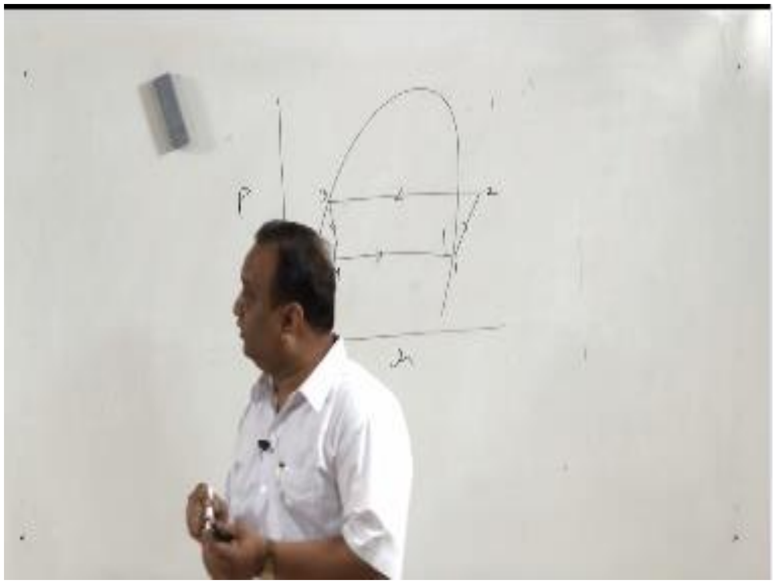

If it is operating further from critical temperature, suppose it is operating here so in this case the COP will be higher if we shift into the upward direction in that case the COP of the system will reduce so the refrigerating cycle should operate far away as far away possible from the critical point. Now freezing point, freezing point of the refrigerant has to be low.

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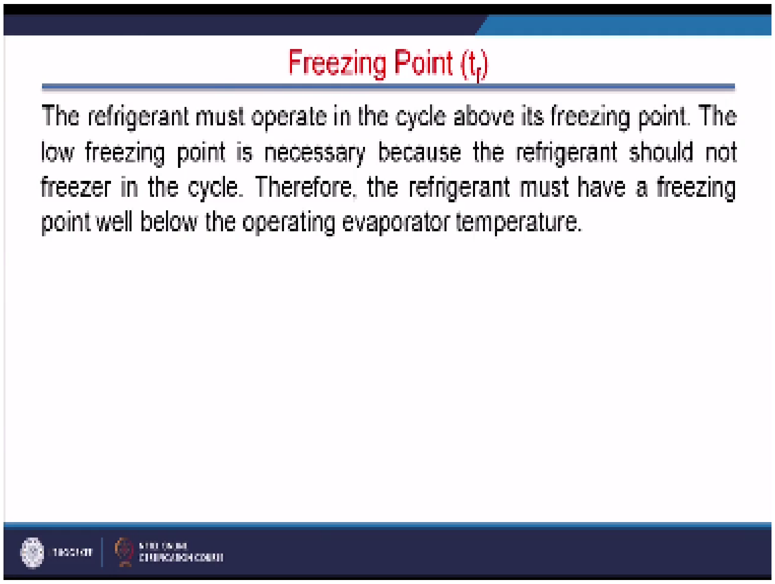

Because if the freezing point is high that will also cause problem in the operation of the system volume of suction vapor.

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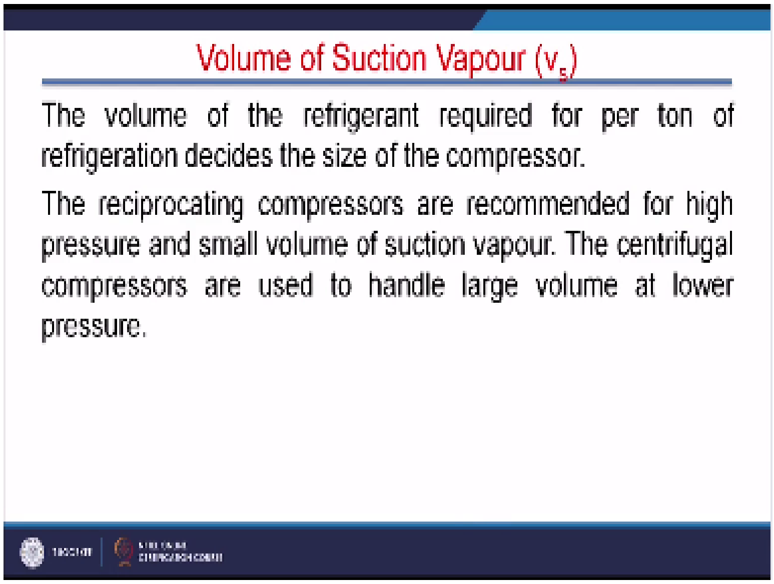

Now the volume of the suction paper regarding the volume of the suction wafer we have to compromise if the volume if the pressure in the evaporator is very low the volume will be large for handling large volume of air for large capacity systems the tentacle compressors are used. But the cost of compression increases if we go for again I am repeating if you go for higher pressure in the vaporator in that case the system will become robust and the cost of handling the vapor through the compressor will reduce.

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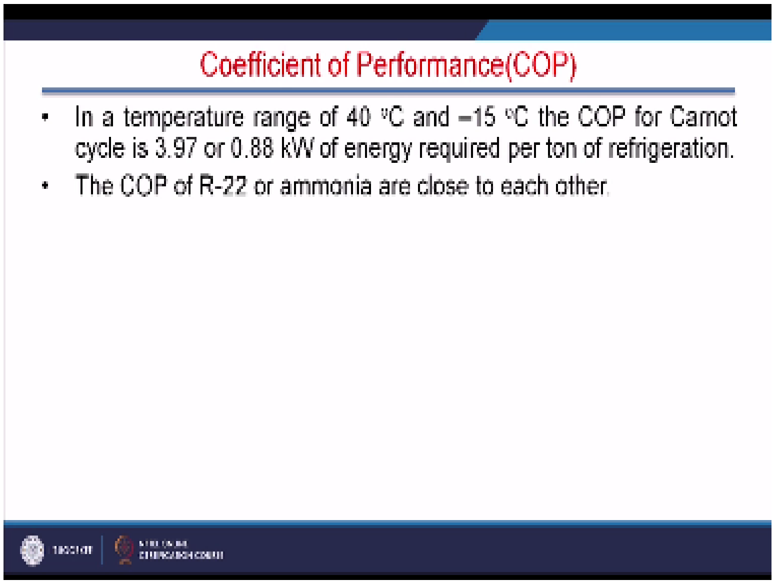

The coefficient of performance if in a temperature range of 42-5 the Carnot efficiency is given 3.97 here we can easily calculate that that comes out to be point 8 kilo watt of energy so we should have coefficient of performance nowadays I mean as per the energy point of view it has to be for example a window air conditioner.

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For window air conditioner it should be approximately equal to 3.5 so COP of the system is also very important in deciding the type of refrigerant we are going to use.

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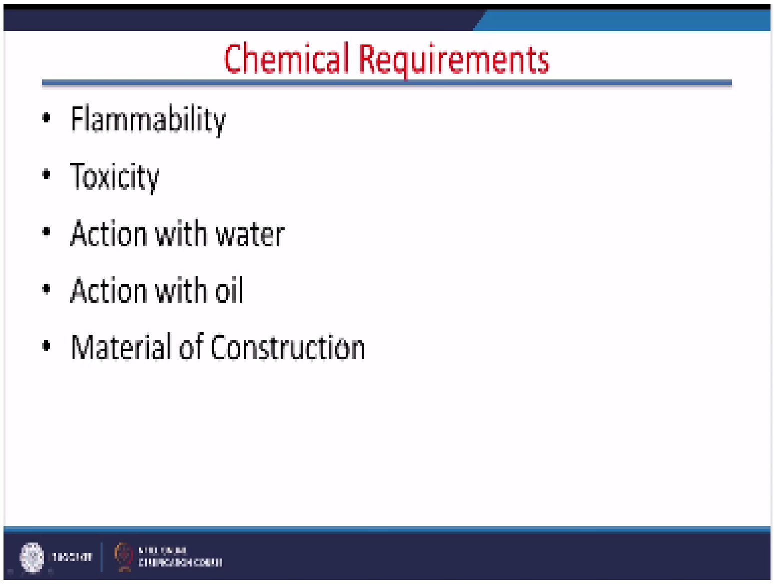

Now capital requirement the refrigerant has to be first of all chemically stable and favorability should be as low as possible and should not be it should be inflammable in an ideal case the toxicity of first I will discuss them one by one then we will discuss in details the toxicity has to be 0 in ideal case it should not act with water should not act with oil it should not act with material of construction every substance is flammable to certain extent I mean totally in favor will saying that the particular refrigerant is not favorable is not justified.

So there are classes of flammability class 1 class 2 and class 3, now class 1 indicates that.

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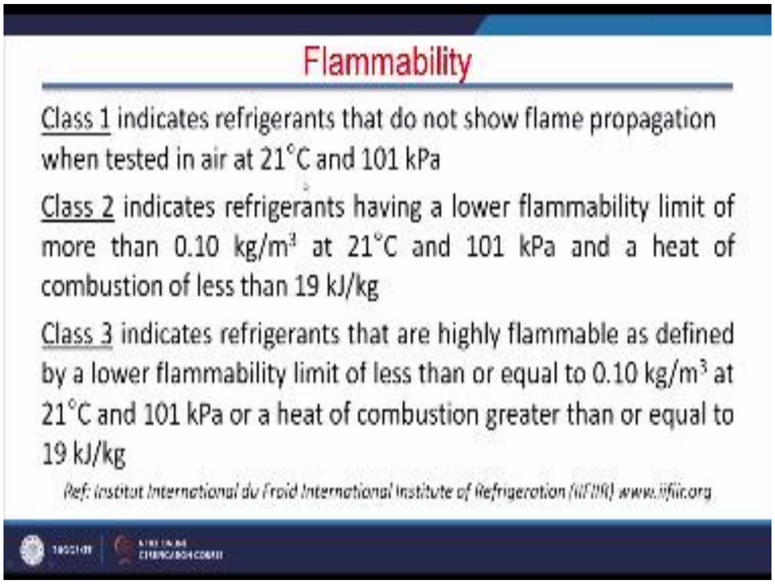

The flame propagation at 21˚C and 101 kilopascal pressure there is no flame propagation that is class one that is safe lower flammability limit of more than point 1kg per meter cube at 21°C and 101 kilo Pascal heat of combustion has to be less than 90 k kilo joules per kg these are as per the International Institute of refrigeration ɵ now class three is lower flammability limit of less than or equal to 0 point 1 kg per meter cube at 21°C and then 1 kilo Pascal pressure and heat of combustion is more than 19 kilojoules per CD so there are three classes flammability classes.

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+ 1 + 2 + 3.

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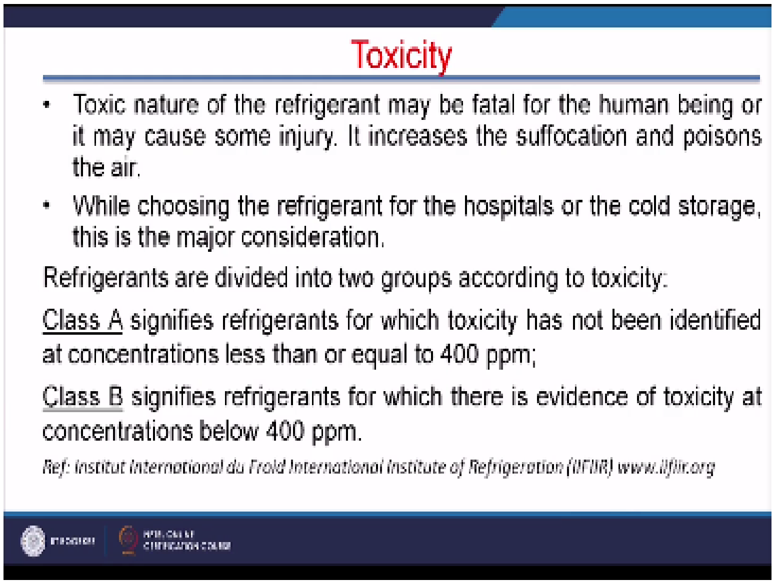

Now toxicity classes are two classes Class A and Class B is signifies the refrigerant for which toxicity has not been identified at a concentration less than or equal to 400ppm if there is no toxicity as the concentration of less than 400 ppm then it is Class A and Class B signifies refrigerant for which there is evidence of toxicity concentration below 400 ppm so 400 ppm is the borderline.

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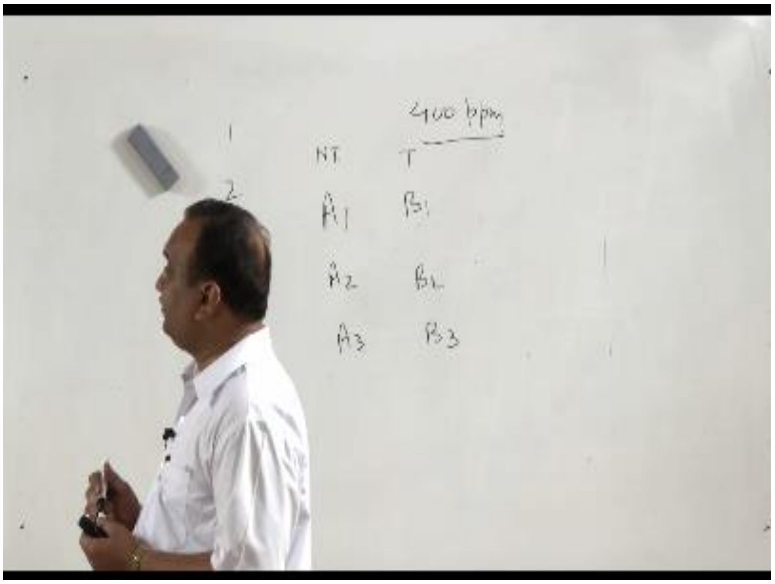

So if the toxicity is observed below the 400 ppm it is Class B if the toxicity is up is not observed below 400 ppm then it is class here so toxicity and favorability combine ding they are classified as the refrigerant class A1 A2 A3 or B1 B2 B3 here it is written that a B3 is B is toxic and a is non-toxic and flammability is 123 123 I have already explained that now chemical stability of the refrigerant is always desired during the cycle.

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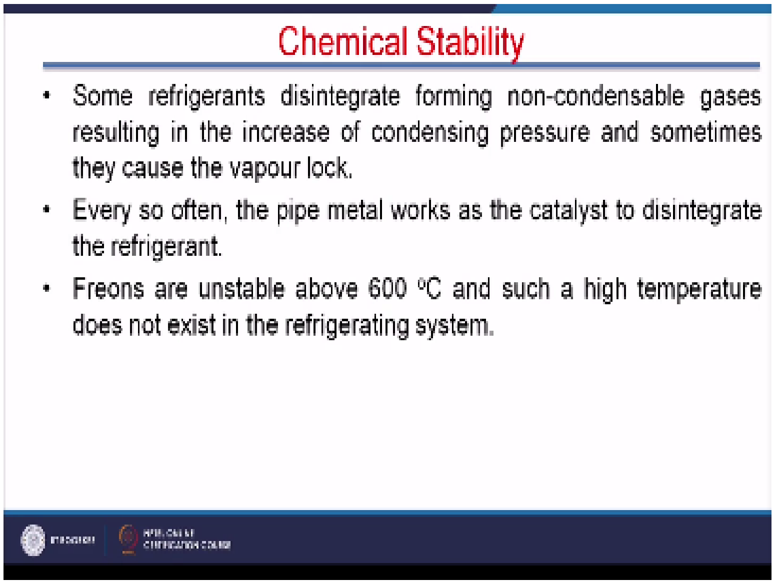

The chemical should or the refrigerant should main chemical a chemically stable the refrigerant should not accurate water or it should not be.

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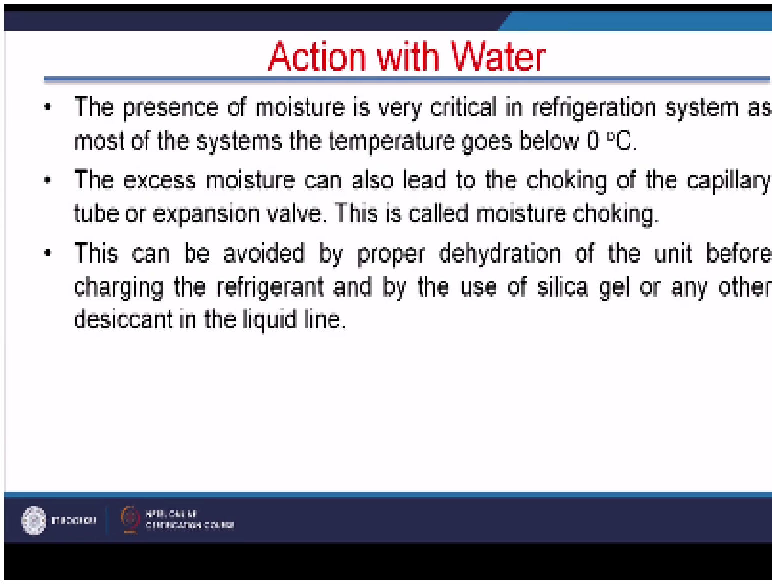

Even not only accurate whether it should not be hygroscopic in nature so that it does not absorb moisture during the cycle and if this happens this may hamper the performance of the system now action with the oil that refrigerant should not act with the oil.

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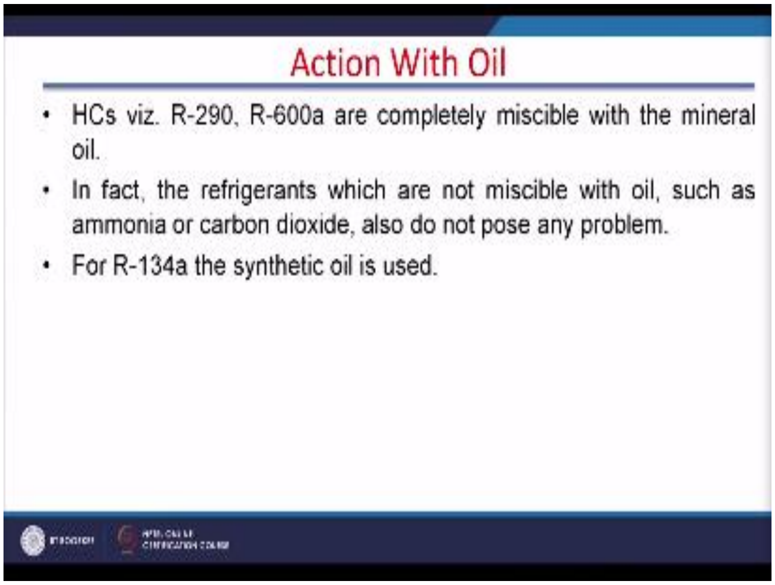

Some of the refrigerants which are hydrocarbons are completely miscible with the oils ammonia is not miscible with the oil that is the issue with the ammonia for r134a since it is not miscible with the oil while means mineral oil natural mineral oil so synthetic oil is used in case of r134a action with material that refrigerant should not act should not react with the material of the plant some issues are related with the ammonia because ammonia reacts with the copper so copper material is not used in ammonia in the refrigerant system where ammonia is used as a refrigerant now there are certain physical requirements also for a refrigerant that is thermal conductivity.

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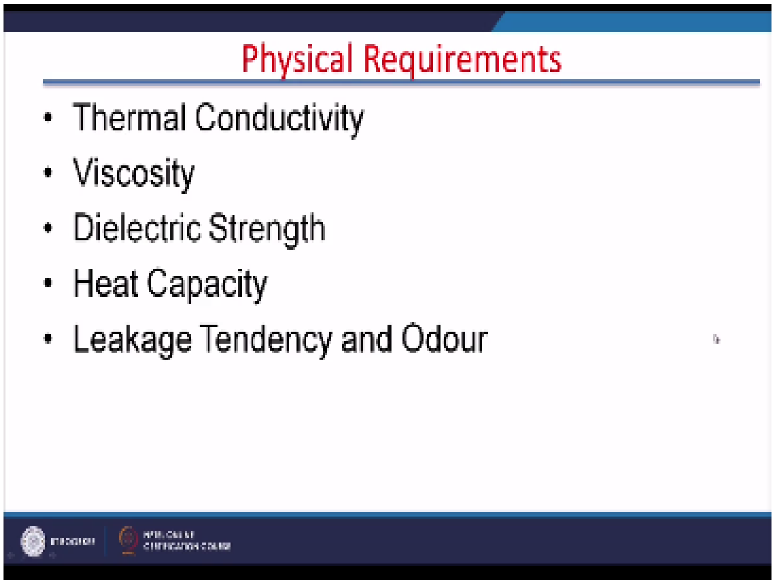

Viscosity dielectric strength heat capacity leakage tendency so reference should have very high thermal conductivity viscosity should be low it should have good direct agree strength because in small capacity system refrigerants are used for cooling the cooling coil of the compressor also so directly strength has to be low for the refrigerants heat capacity has to be low heat capacity sensible heat kept safe means this value of CP CP has to be low for refrigerant as well as possible and leakage tendency it should be minimum not especially ammonia has a leakage tendency and order I mean it should not give any bad smell otherwise order is good because through order you come to know whether there is a leakage of refrigerant or not.

But the reference should not have any order in our ideal case now secondary refrigerants I have already discussed earlier in earlier lecture but I like to explain here also that I have secondary refrigerants are those refrigerants which pic from the heat from the object.

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And discharge heat to the primary refrigerant so for example chilled water in a high capacity refrigeration system so chilled water in a high-capacity refrigeration system it picks heat from the building or different parts of the building and discharge that heat to the evaporator or the refrigerant in the evaporator or primary refrigerant so this is the function of secondary every even brine in ice making factories brain is also used as a secondary refrigerant now ozone depletion now in number of it is it was noticed in 1887 that CFCs are damaging the ozone layer.

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And causing the hole in the ozone layer and they are contributing towards the global warming as well but the damage of ozone layer was the main concern and regarding the ozone layer damage there were certain myths also like volcanoes and oceans are causing ozone depletion.

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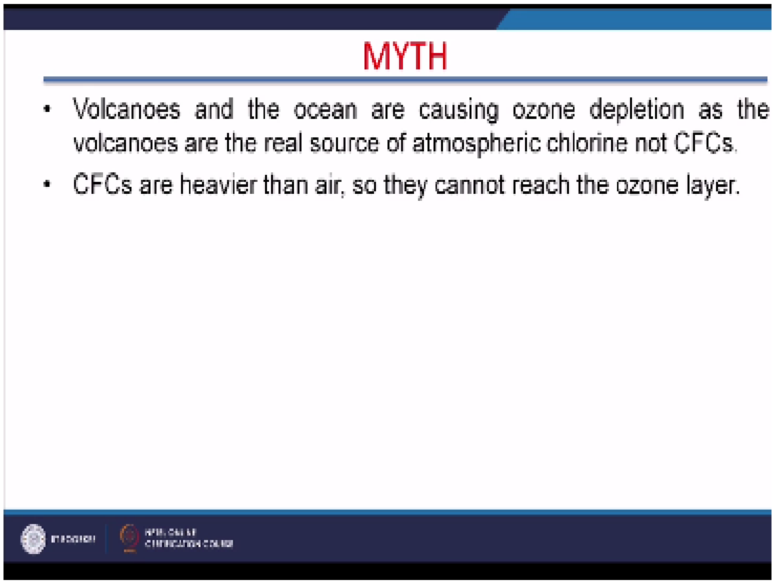

As the Volcanoes is are the real source of atmospheric chlorine or CFCs this was propagated at that time CFCs high heavier than air so they cannot reach the ozone layer but the realities few volcanoes are strong enough to penetrate the estate of a stratosphere.

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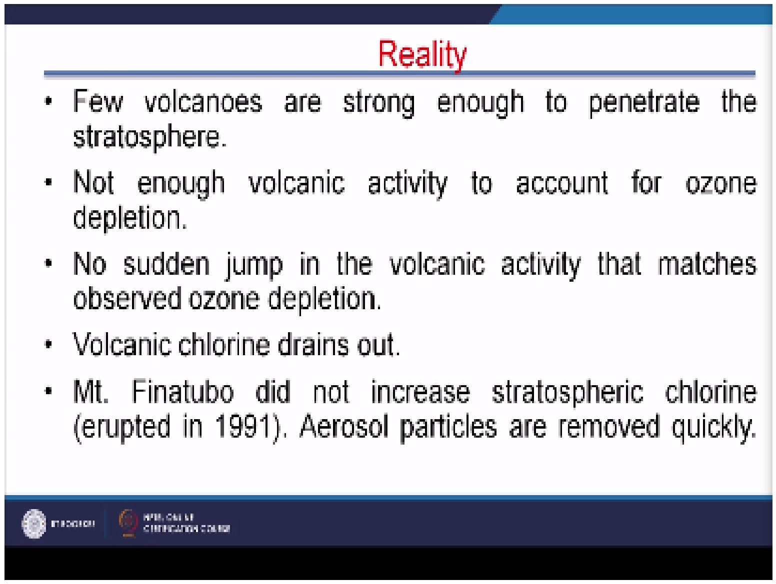

Not enough volcanic activity to account for ozone depletion no sudden jump in the volcanic activity that matches the observed ozone depletion volcanic chlorine drains out with the rains and there was an example also some data were collected at Mount Pinatubo which where the stratospherestero stratospheric chlorine was not increased after eruption of this volcano so it was later on it was established fully established that not later on I mean it was established earlier also but because there were some issues regarding the depletion of ozone layer by the chlorine coming from the oceans.

But it is confirmed now that CFCs are depleting the ozone layer and their use is banned throughout the world the manufacturing of CFCs has been stopped since 1996 and in it is totally removed from the from the market now new refrigerants have come into the market out of these refrigerants HFCs are very.

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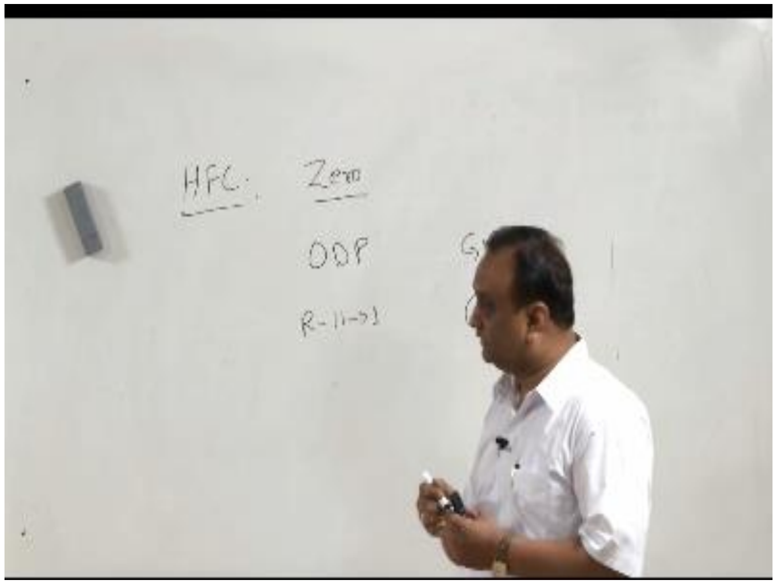

Popular now HFCs they have zero ozone depletion potential but they have global warming potential they contribute towards the global working now I will explain you how this ozone depletion potential and global warming potential are gauged the global warming potential of CO2 is considered as one ozone depletion potential of our 11 is considered as one related to these chemicals the ozone depletion potential and global warming potential of other chemicals is judged so now here is a table which is showing the ozone depletion potential and global warming.

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Refrigerant	ODP	GWP
R-11	1.0	4000
R-12	1.0	2400
R-22	0.05	1700
R-125	0	3400
R-134a	0	1300
R-410A	0	1725
R-407C	0	1600
R-507	0	3300
R-717	0	0
R-1234yf	0	4
R-744	0	1*

Potential of different refrigerants so our Levin and art well they are not being used anywhere however they have the ozone depletion protection of the order of 1 r22 has limited life I mean in advanced countries the use of our 22 is permitted up to 2020 but here in the third world countries we can go up to we have got a grace period of10 years so we can use our 22 up to 2030it has also in depletion potential only 5% threat of our 11 but now the issues are related with the global warming potential and r134a is also contributed towards the global warming the best refrigerant is you can see ammonia R717 ammonia R717.

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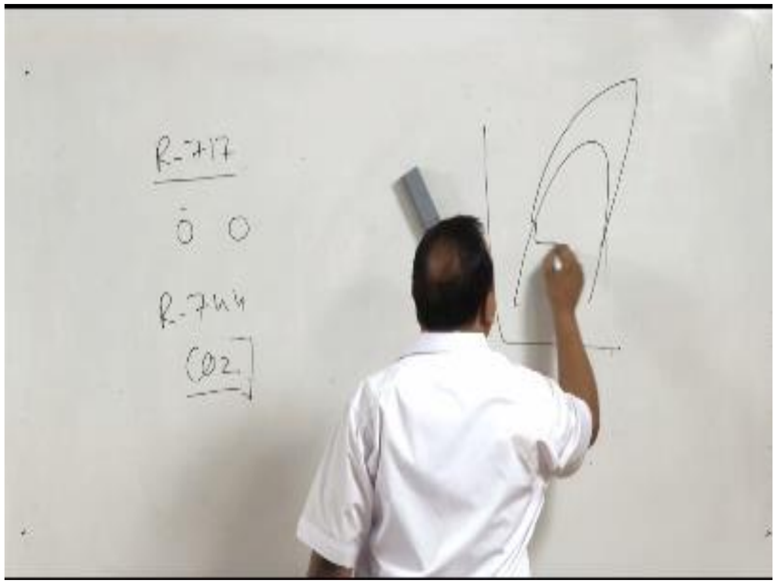

If we look at this refrigerant it is absolutely environment friendly is it has 0 ozone depletion potential 0 global warming potential toxicity is high in ammonia and that goes against the use of ammonia in many of the applications new refrigerants like our one two three four YF these this refrigerant is new in the market which has very low global warming potential and no zone depletion potential but this refrigerant is slightly favorite so some flammability related issues are therewith this refrigerant now in many areas are 77 use of our 744 our 7444 is carbon dioxide the use of carbon dioxide is explored the global warming.

Potential is of carbon dioxide is one only an ODP zero but carbon dioxide is high pressure refrigerant but it's still the possibility of this use of this carbon dioxide in mobile air conditioning is being explored otherwise because this carbon dioxide cycle is it turns out to be a trans critical cycle if we use at a normal temperature it becomes a trans critical cycle but for low temperature applications this are 744 can be used that is all about the refrigerants in this lecture and from the next lecture we will start with the absorption refrigeration system thank you very much.

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