INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-16
Refrigerants-1

with
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Hello I welcome you all in this course on refrigeration and air-conditioning. Today we will discuss about the refrigerants which are used in refrigeration systems.

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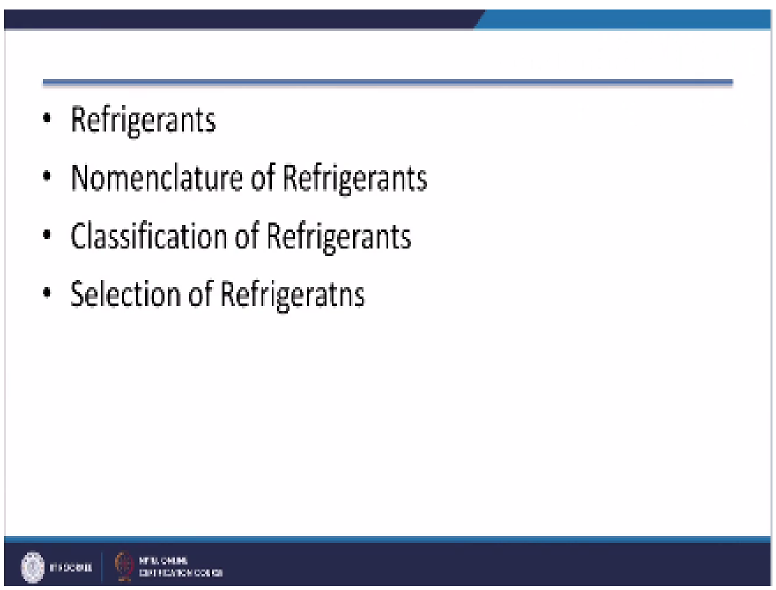

In this lecture we will cover the definition of refrigerants how the nomenclature of refrigerants is done, classification of refrigerants and selection of refrigerants.

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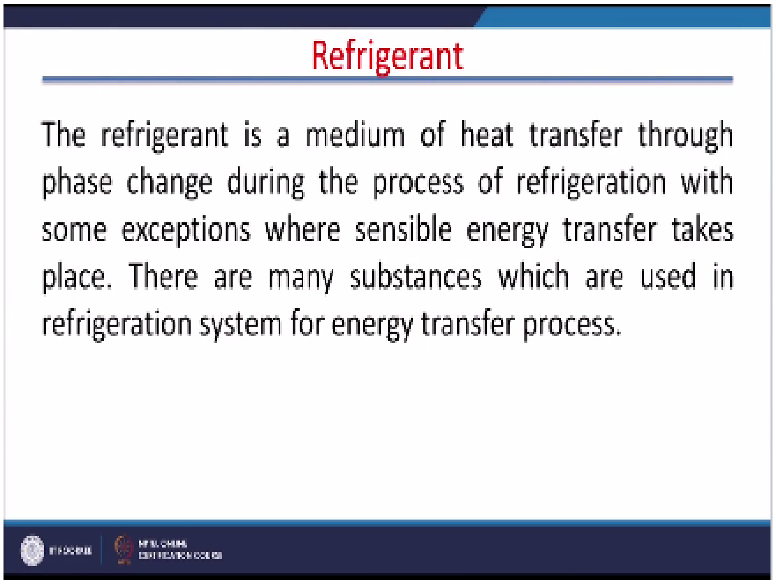

Regarding the definition of refrigerant it is the refrigerant is a medium of heat transfer through phase change during the process of refrigeration with just some exceptions where sensible energy transfer takes place. There are many substances which are used in refrigeration system for energy transfer process.

So mostly refrigerants are those fluids which are used in a refrigeration system and heat transfer takes place through the phasing.

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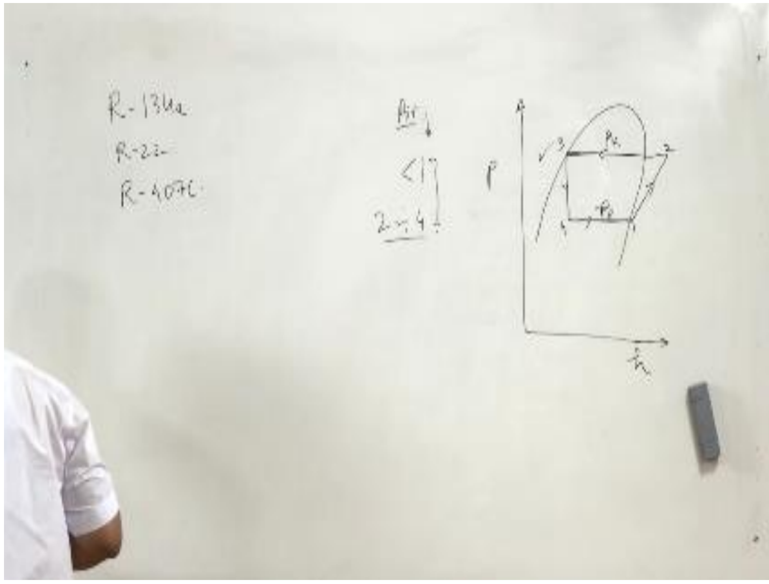

As you can see in a PV diagram mostly heat transfer takes place during phase change of refrigerants either boiling or condensation this is pressure. So 1, 2, 3, 4 refrigerating effect is attained here and that is due to phase change. During this process also condensation of refrigerants takes place.

So in most of the cases there is a phase change but there are some exceptions, exceptions like air refrigeration system. In air refrigeration system there is no phase change, but the COP of the air refrigeration system is less than 1. However, in this case the COP is most of the cases it is greater than 3 or between 2 to 3 and it can between 2 to 4 let us say nowadays it is between 2 to 4 depending upon the pressure in the condenser.

And pressure in the evaporator. Now refrigerants are same as blood in our body if there is no flow of blood in our body there is no life in the body. Similarly if there is no flow of refrigerants in a refrigerating system it means the refrigerating system is dead. So they are very important constituent of any or very important part of any refrigeration system, you must have observed in my previous lectures also we have used while expressing the refrigerants I have used some numbers like R-134A or R-22 or R-407C I have used this number alpha numeric expressions.

I have used this alpha numeric expression in order to write the refrigerants I have not written their chemical names. In fact they are chemicals and most of our driven from hydrocarbons.

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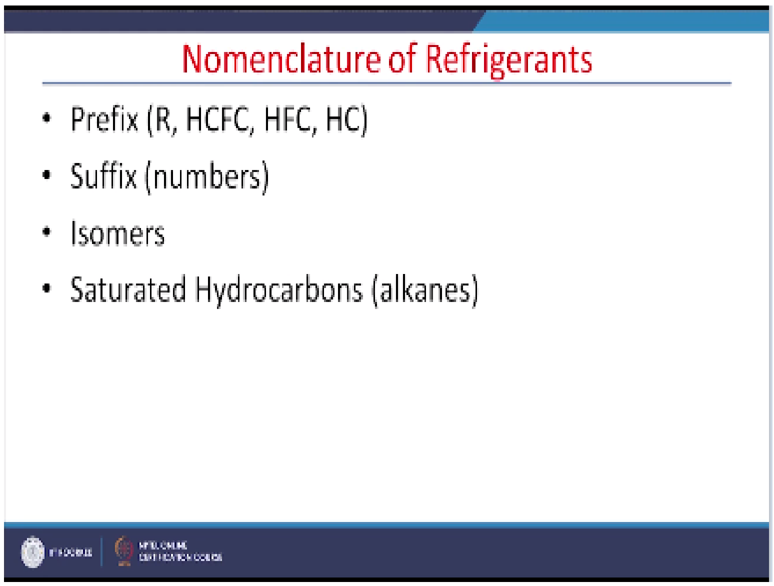

Hydrocarbon driven chemicals so in a nomenclature of a refrigerant there are two parts prefix and suffix.

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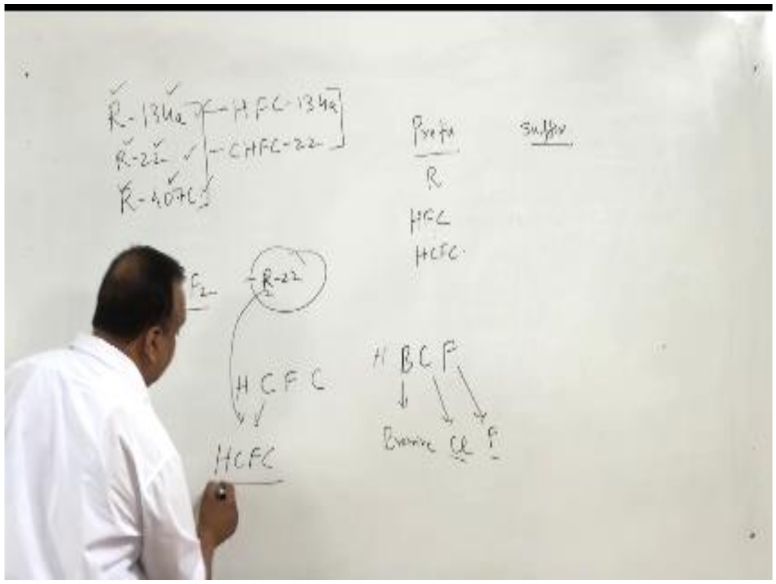

R-134A, R-22, R-407C in some of the books you will find that this is written as HFC-134A this is written CHFC-22. So these refrigerants are also written like this. Now we can classify refrigerants as prefix and suffix, prefix of refrigerant prefix and another is suffix of refrigerant. Now prefix we are using are for all refrigerants that stands for refrigerant or HFC or SCFC.

For example, if I take chloro-difluro methane chloro-difluro methane is CHClF2. Chloro-difluro methane has number 22 this is R-22 in fact. But for prefix what prefix it is done like this first of all we write C it is carbon, then carbon is preceded by in order of appearance in order of the presence of BC and F, B for bromine, C stand for chlorine, and F stands for fluorine.

So if the composition suppose for example this composition has chlorine and fluorine. So it will be like this CF sorry, it will be CF/C C for chlorine, F for fluorine, so first chlorine will appear, then fluorine will appear then carbon will appear if it is having H also this would proceed by H. So this R-22 can also be written R can be replaced by HCFC.

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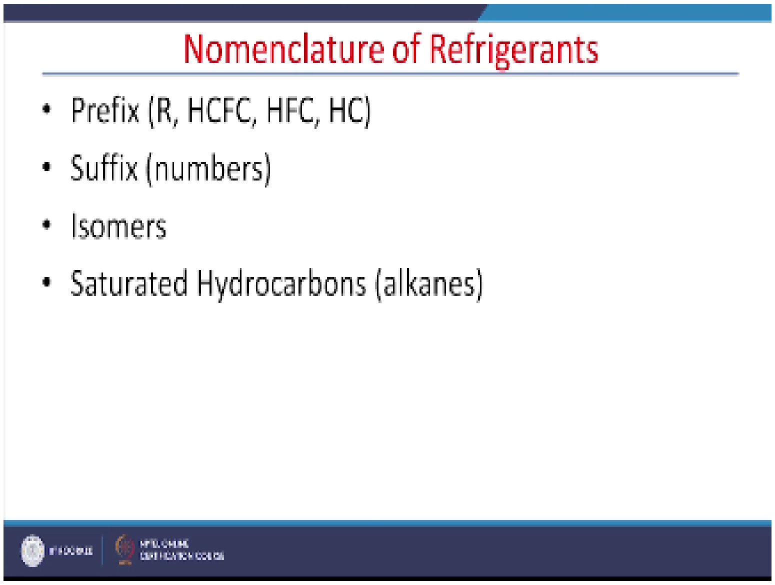

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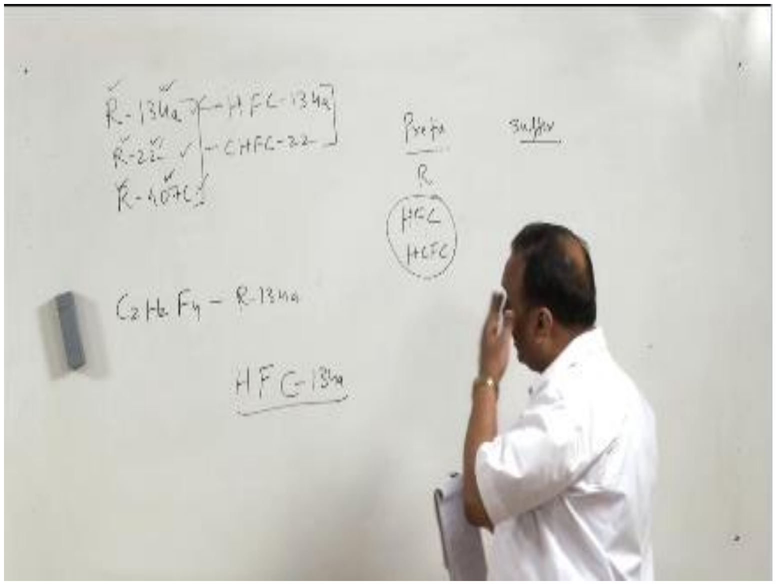

Now I will take another example like tetra fluoro ethane C2H2F4. Now C2H2F4 is nothing but R-134A. Now here in order to decide prefix it has carbon it does not have chlorine, it has fluorine and it has hydrogen also. So it is HFC-134A this is how a prefix of a in the nomenclature of a refrigerating system is decided. Now let us come to the suffix these numbers, these numbers are actually these most of the refrigerants are derivatives of saturated hydrocarbons or alkanes.

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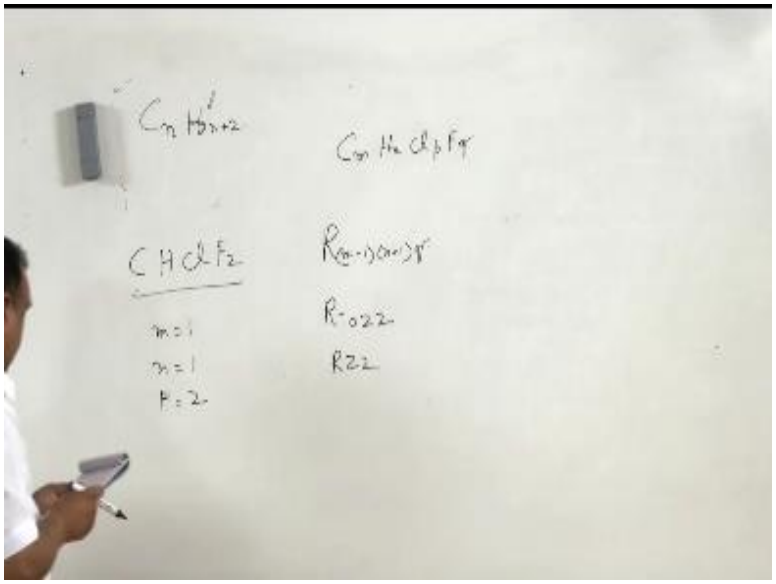

So saturated hydrocarbons are Cn and H2n + 2 they are simplest form of hydrocarbons having a single bond and the carbon is saturated with all the bonds are saturated with hydrogen that is why it is called saturated hydrocarbons. This is saturated because bonds are saturated with hydrogen. Now in a refrigerant let us go back to CHCLF2 this is R-22 we will start with CmHnCLpFq this is a generalized formula for any refrigerant.

Because but nowadays chlorine is not there in most of the refrigerants because chlorine damage the ozone layer those issues will be addressing later on. So in this case if I want to give a nomenclature to this I will write R(m-1)(m+1)F, F is q. So in this case M = 1, N=1 and F = 2. So this refrigerant is going to be R0 n = 1 so 02 NQ = 2 this is R-22.

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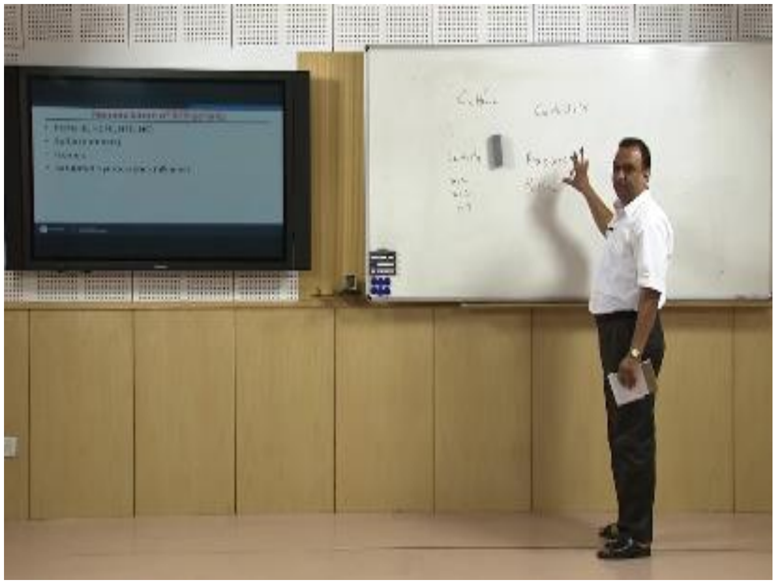

Now we can take another example also for tetra fluoro etahen. So C2H2F5F4 tetra fluoroethane, here m = 2, n = 2 and F = 4. So while doing the nomenclature we can write R(m-1) that is 2-1, n+1 that is 2+1 and F is 4 so R134. In the this refrigerant R-134 there is a subscript A, it means it is an isomer, isomers are the substances which have seen chemical formula, but arrangement of molecules is different right.

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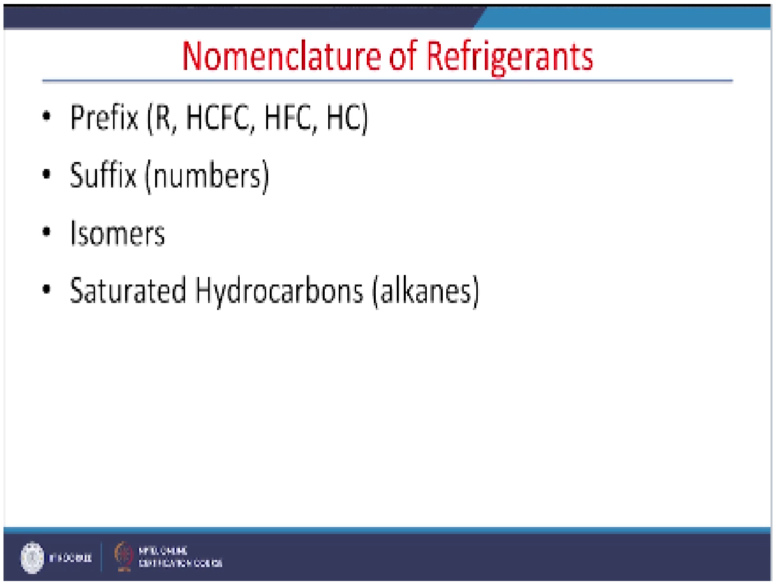

So these compounds or chemical substances they are known as isomer. So R-134A is one of the isomer of tetra fluoro ethane. So this is how the nomenclature of refrigerants is done. Now we will take the different classes of refrigerants one by one and we will discuss their nomenclature at the same place. For example, classification of refrigerants.

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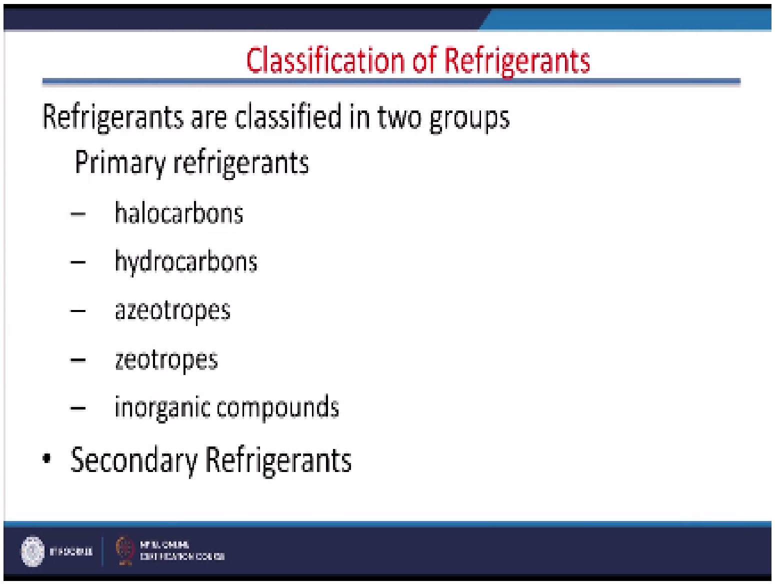

So refrigerants can be classified as primary refrigerants and secondary refrigerants, primary refrigerants of those refrigerants which are circulated in the system like R-134A or air or ammonia these refrigerants are circulated in the system so they are known as primary refrigerants. Often they are in direct contact with the substance on which the refrigerant refrigerating effect is produced. Now secondary refrigerants are those refrigerants they pick heat from the substance.

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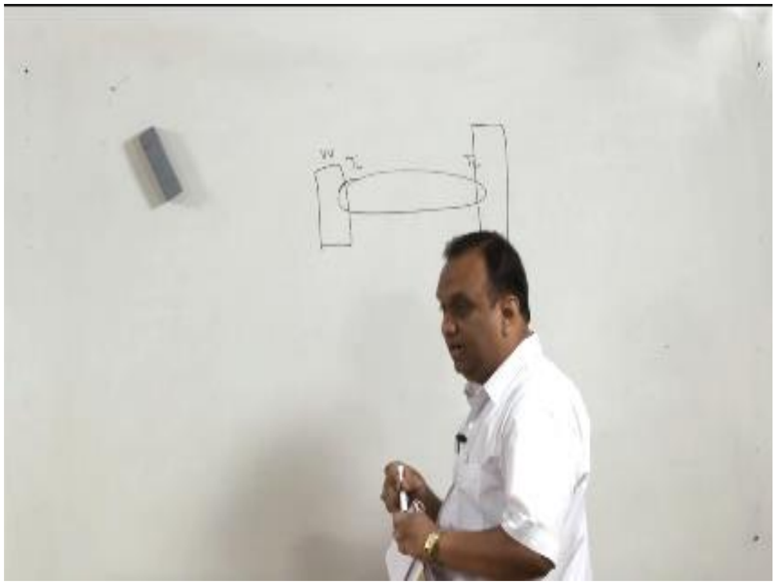

Suppose I want to pull water, so secondary refrigerant will take heat from water in a freezer and discharge heat to T versus TL this is TH and discharge heat to primary refrigerant through a heat exchanger. So it is a link between a substance and the primary refrigerant. For example, in big buildings chilled water is circulated for the cooling of large size of buildings where temperature, when the load is 800 tons of thousand tons or 1200 tons chilled water is circulated in the building.

So chilled water acts as a secondary refrigerants, so chilled water picks the heat from the room or different heat sources in the building and chilled water discharges heat to the primary refrigerant. So there is a function of secondary refrigerant in some of the applications like ice factories brine water is also used as a secondary refrigerant.

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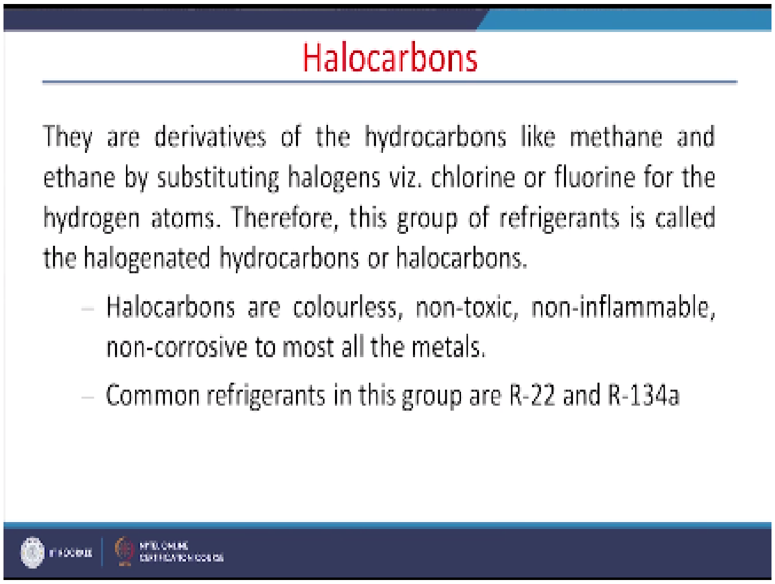

Now halocarbons, now halocarbons or halogenated carbons we have already discussed. Since halocarbons were proposed to be used as a refrigerant 90 years back and when these halocarbons space we chlorofluorocarbons.

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Now they are bent like R-12 R-11 these refrigerants they are bent because they damage the ozone layer they are responsible for the depletion of ozone layer which is vital for the life of the on the earth and they contribute towards the global warming. These refrigerants were bent but when they were introduced 90 years back they were supposed to be the excellent refrigerants.

I mean they were colorless, they were non-toxic, non-flammable, noncorrosive and they were not reacting with any metal. But later on it was discovered that they are damaging the ozone layer and causing the global warming these refrigerants were discarded. In fact chlorine present in these refrigerants this chlorine C this chlorine creates problem.

So in the ozone layer, so now we have refrigerants which are HFC, hydro fluorocarbons only one refrigerant is there which has chlorine that is CHFC that is R-22 and this refrigerant is allowed to be used up to 2020 developing countries are given grace period of 10 years. So we can go comfortably go with this up to 2030 beyond which it will not be allowed to use this refrigerants.

So most of them nowadays they are consistent effort to find a refrigerant which is eco-friendly, eco-friendly means there is no damage to the ozone layer, ozone depletion potential is zero and global warming potential is also zero.

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Now in halocarbons we are frequently used nowadays R-134A it is a ozone safe refrigerant it has zero ozone depletion potential but it has global warming danger. So in due course of time this refrigerant shall also be replaced in addition to the halocarbon, hydrocarbons can also be used as a refrigerant, hydrocarbons like methane, ethane

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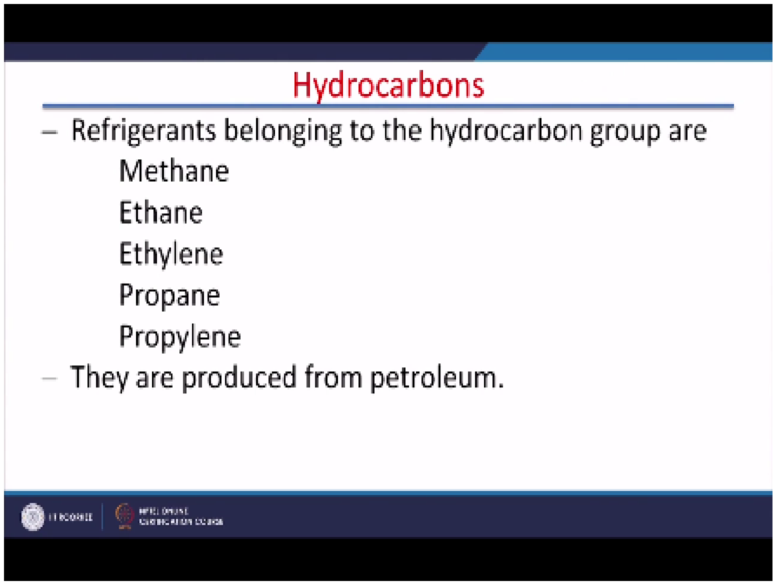

C2H6 propane, C3H8 these reference hydrocarbons can be used as a refrigerant, the benefit of hydrocarbons is their density is very low, so small amount of charge of hydrocarbons is required in the refrigeration system, and the problem with the hydrocarbons is they are inflammable. So a lot of precautions have to be taken while using hydrocarbons as a refrigerant, regarding the nomenclature.

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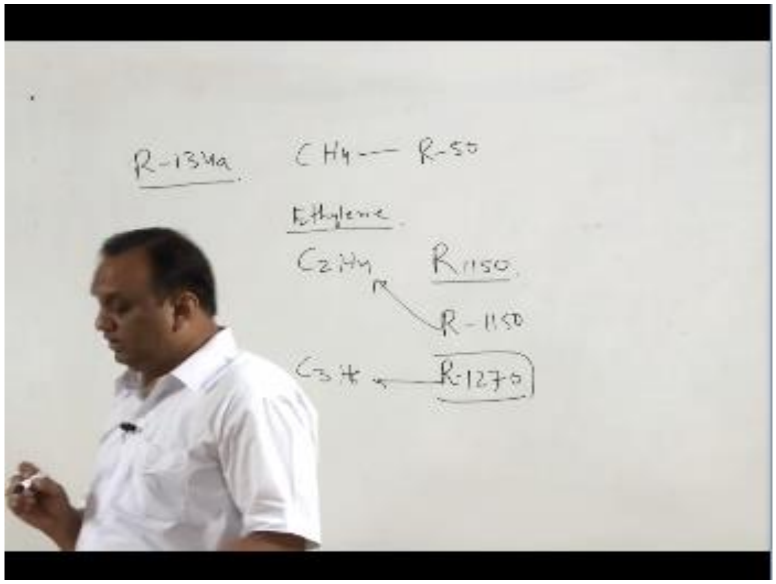

CH4 is, written as R-50, sorry! this is methane ethane ethylene, I will take ethylene, ethylene is C2H4 this is not saturated hydrocarbon, this is not a saturated hydrocarbon, and it is written as R this is 5 because 0 is added in hydrocarbons, and C2 is 1, and because it is unsaturated it is 1150 so R_{1150}, is ethylene similarly propylene, propylene is C3 S6, so pro for propylene it is going to be that is 70, you can do it by yourself now 1270, is propylene and this is ethylene. So they're all product of petroleum, this is they are inferior will so their applications are limited.

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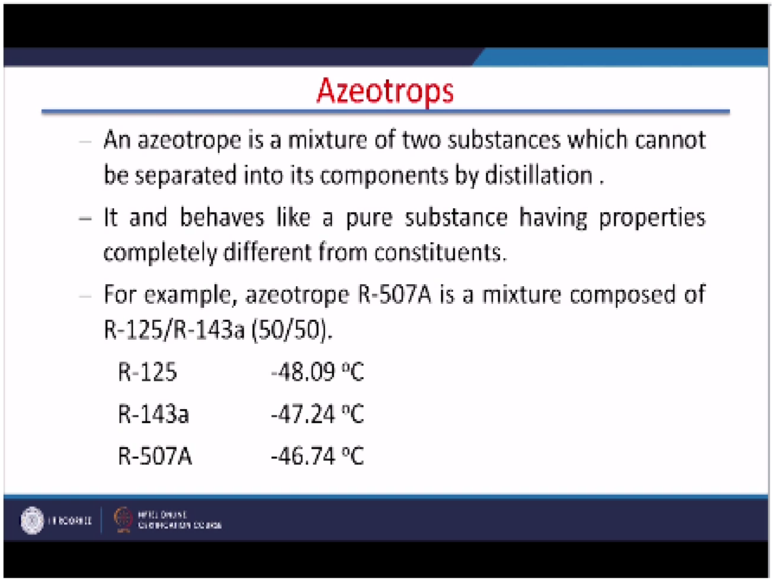

Now zoetrope, zoetrope are mixtures and there is special type of mixtures, these mixtures have if two refrigerants, if two chemicals what are zoetrope? First of all I will define if two substances which cannot be separated to compose components by distillation and it behave like a pure substance having properties completely different from constituents.

It means if we mix two substances, that normally if there is a mixture then if we do distillation then all the constituents of the mixtures, will be separated out or can be separated, but in case of zoetrope, if zoetrope, is formed first of all as you drop has one boiling point in freezing point, one boiling point, I mean it doesn't have to I mean.

Well it has single boiling point, so it behaves like a pure substance or pure refrigerant, and if you boil this zoetrope, the constraints will not be separated out and zoetrope is formed I mean in any proportion if you mix two substances, zoetrope will not be formed. So there has to be certain weight by weight a composition of the mixture, only then zoetrope will be formed so here one example of a co drop is given 507, in this case you can see it is50-50 mixture of R125 and R143a.

As you can see the normal boiling point of R125 -48.09^{0}C, normal boiling point of R143 a is 47.27^{0}C, if they are mixed in 50:50 proportion we are getting R507a, and normal boiling point is -46.74 which is higher than these two, in logically the boiling point should lie should be the average of these two but, you can see there is it is boiling point is higher than these two and five zeros even a behaves like a pure substance, now zero tropic mixture, you must have seen the refrigerate like, R407 C, now any number of refrigerant starting with four is zero tropic, any number is starting with five like 507 a, so this is a Azoetrope, zoetrope and zoetrope is the, number of it is four series so the number of the refrigerant will start with four.

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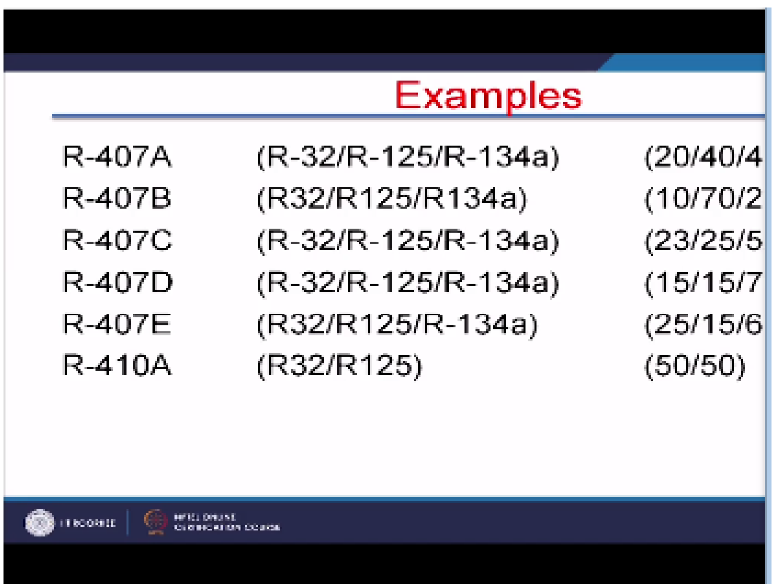

And it is called 400 in fact it is called 400 series, and their number of zoetrope are shown here 4:07 A, 4 0 7 B 4:07 C 4 0 2 7 D, E and A, now in the 407 the constituents are same R32 125 R134a, now R32 is die flora methane. Now I should explain this R 32 also R 32 it is dichloromethane.

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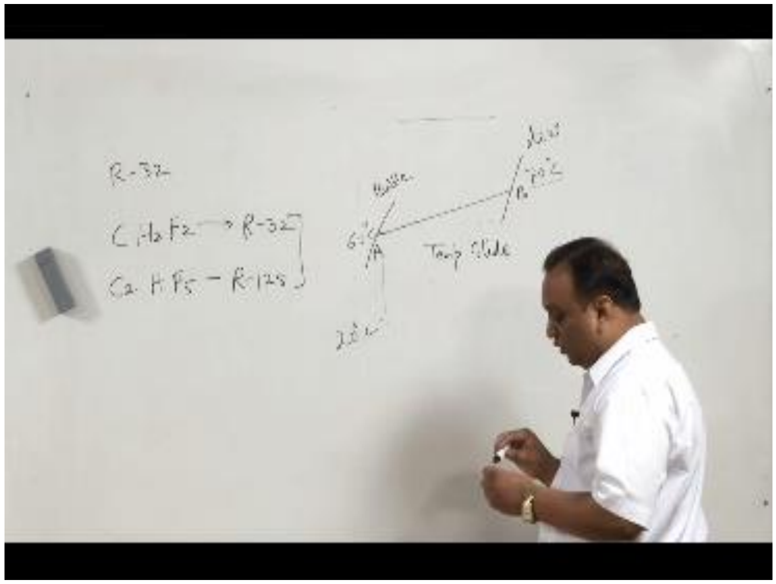

CH2 F2, so if you again if you write CH 2F 2 4 number 4 CH 2 F 2 they then it is going to be H is 2 +1 3 & 2 R 32 and similarly, R 145 it is the interferon ethane that that is C2H H5 C2H 5, Penta fluoro ethane.

So CMN-1, so it is going to be 2 - 1 that is1 this H + 1 to NF 5 R 25, now this is a die fluoro methane, and this is Penta Fluoro methane, 10 and if you mix them in50/50 proposition, then you get R410a, now R410a is seen a very potential refrigerant in the reflection industries and now most of the systems which are coming in the market especially, VRF systems they are working on 4 1 0 a.

Now I will tell you the reason later on, now another refrigerant which is popular here is 4:07 C, which has R 32 R125 and R134a as well in the proportion, of 23:25:52% weight by weight problem with the 407, see is that it has temperature Glide, now let us understand what is temperature Glide, if boiling of temperature this burning of refrigerant is taking place, it has it has two components A and B, then a will start boiling at suppose we start from the room temperature 20 ^{0}C, a has boiling point let us say 60 ^{0}C.

Another is having 70 ^{0}c, so if we keep on heating this liquid the moment 600 degree is reached, this constituents a will start boiling and this boiling temperature will keep on shifting, because a is disappearing from the fluid mixture and it will end at Point V where the boiling temperature is 70 ^{0}C, so this change in the temperature from 62 to 70 degree is known as temperature Glide, this is known as temperature Glide, and these type of mixtures they do not have any fixed boiling point or condensation point, because by definition of boiling point means the temperature remains constant during the phase change.

So this temperature is known as bubble point, and this temperature is known as dew point, because if you are cooling the vapour, first of all B will condensed at 70 ^{0} c and the temperature will keep on reducing, till completely a is condensed completely, and this variation is again known as temperature Glide.

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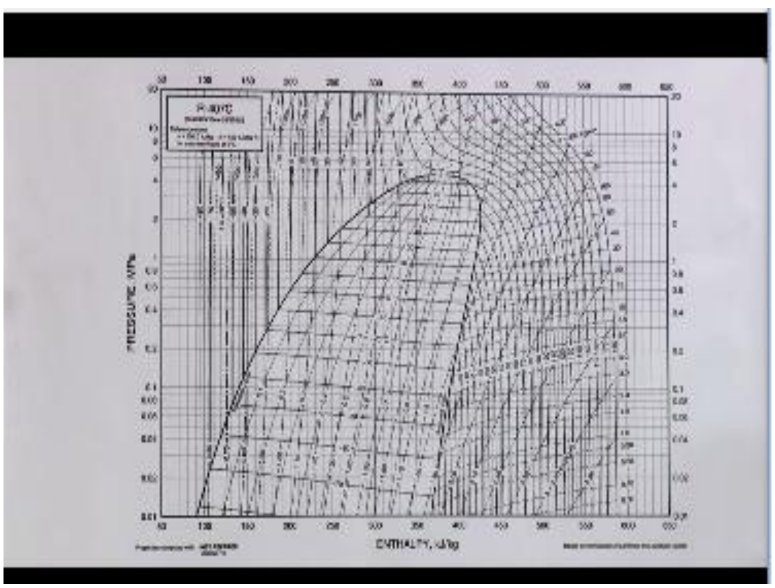

For the more clarity, I will show you the ph diagram of 4:07 C you can see this is the saturation line, saturation curve on y-axis pressure on a log scale on x-axis, there is a enthalpy at on a linear scale, there is a thick saturation line, on the left hand side there are vertical lines constant temperature line and constant temperature lines, are inclined they are not horizontal.

They are inclined because if you want to maintain the temperature constant, you will to reduce pressure for the boiling, ordering condensation if you want to maintain temperature constant, you will have to increase the pressure during the condensation, if you want to maintain constant pressure, in that case there is going to be change in temperature.

So if you want to maintain constant pressure in condenser or evaporator, there is going to be change in the pressure rest of the things in this chart are same as in the case of 134a, that is why these are the selected properties from the properties charter 407 C, you can see here this chart is based on pressure.

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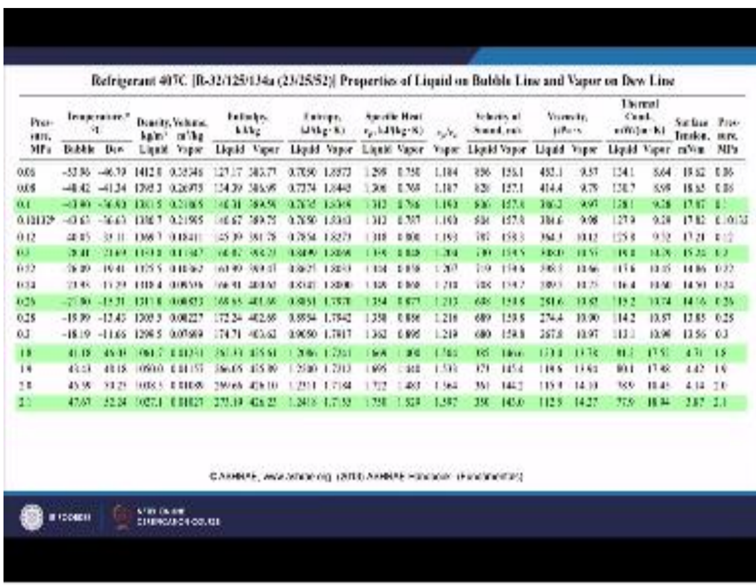

It is not based on temperature if you look at the chart of 134 a, it is based on temperature so this is a temperature based pressure based, chart and at atmospheric pressure this is bubble point and this is dew point, it means at atmospheric pressure the refrigerant the bubbles will form in the mixture, as -43.63, and bubble formation or all the liquid will be converted into the vapour at -36.63^{0}C.

And from here itself you can see there is a change the temperature of 7^0C, so 7^0C is the temperature Glide, in this case and if you look throughout the this property diagram, up to two bar pressure, the temperature Glide is of the order of 7^0C it not 70 ^{0}, 7^0C.

So that creates problem during operation of the system also, or designing also become typical but however in the case, of 410a it is also a mixture, but temperature glide is of the order of 0.1 ^{0}C. So it is near zoetrope, I mean the temperature glide in for10 a is it is a it is high pressure refrigerant the pressure, so normal boiling point of four one zero a is order of- 51 approximately, - 51 ^{0}C.

But so the system has to be robust in order to run a system which works on 410 a, but in this refrigerant because the temperature glide is of the order 0.1 or 0.2, it is near isotropic, and it is easy to deal with this refrigerant.

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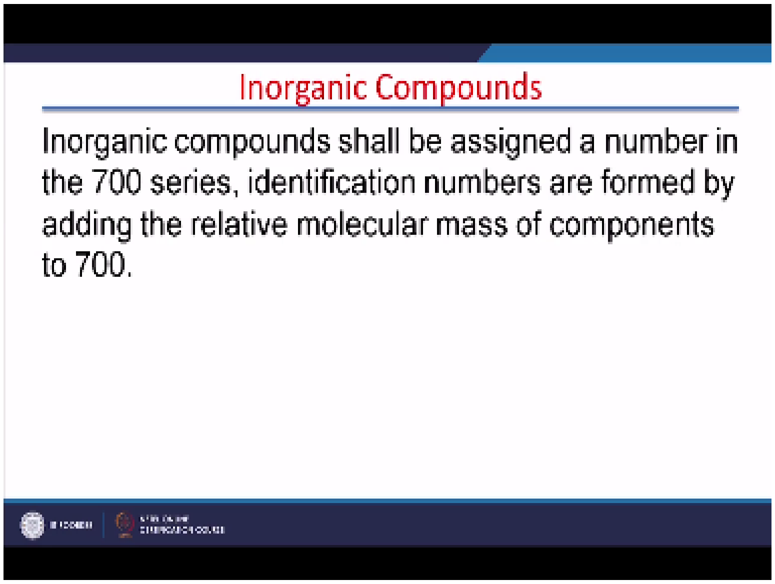

Now inorganic compounds, inorganic components like ammonia, is also used as refrigerant and in order compounds are covered under 700, series and nomenclature for in early components is very easy, I mean you start with for example.

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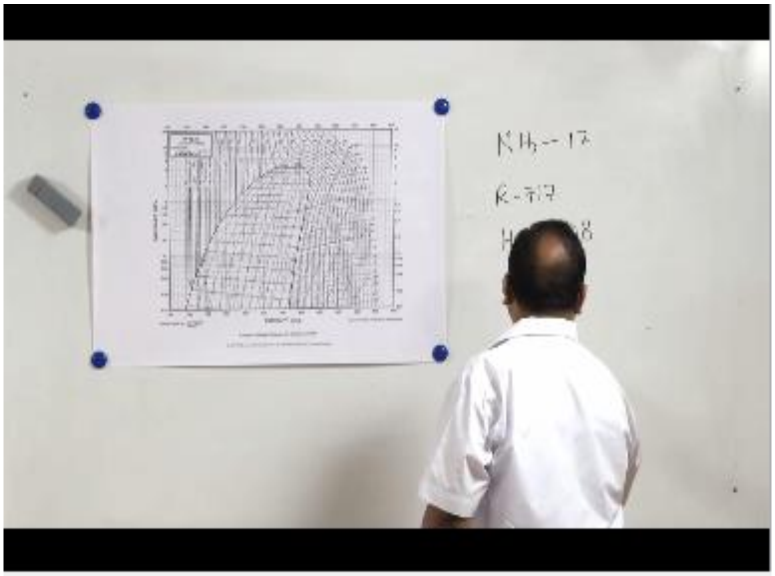

Ammonia, atomic weight is17 so it is 717, water,h2o atomic weight is 18, R718 air here you can take air R 729 and so on helium argon 740, argon so this is how the nomenclature of organic compounds are used, nowadays inorganic compounds are becoming popular, because throughout the world scientists are trying to go for natural refrigerants so inorganic use of in inorganic, is intended to be increase in fear feature. We are looking for more inorganic compounds to replace the existing chemicals in refrigeration industry.

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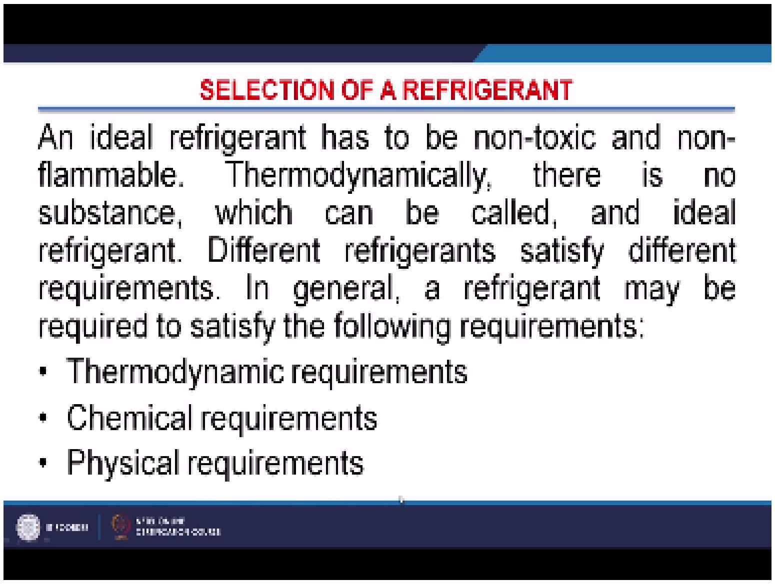

Now selection of refrigerant for selection of refrigerants the focus has to be on the thermodynamic requirement of the system, or thermodynamic requirement of the refrigerants ,chemical requirement and physical requirements, so these requirements you will discuss in subsequent lecture which is on which is also on refrigerants.

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