Mass Transfer Operations I
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Module - 5
Distillation
Lecture - 3
Flash Distillation

Welcome to the third lecture of module 5, we are discussing distillation. So, before we proceed in this lecture let us have a recap on our earlier lecture we had. In the last lecture, we have discussed deviation from ideality, deviation from ideal behavior.

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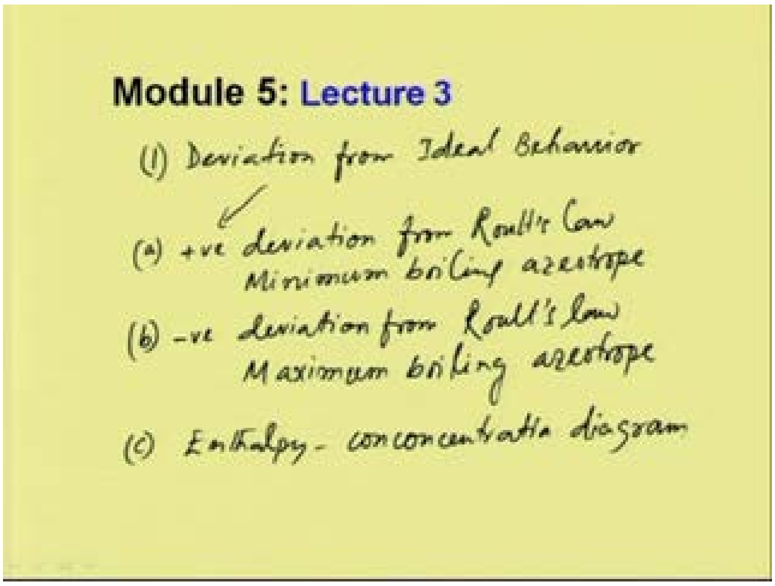

So, we discussed two cases; one is positive deviation, deviation from Roult's law. We call minimum boiling azeotrope, and second we discussed negative deviation from ideality, deviation from Roult's law, we call it maximum boiling azeotrope, and third we have discussed the enthalpy concentration diagram.

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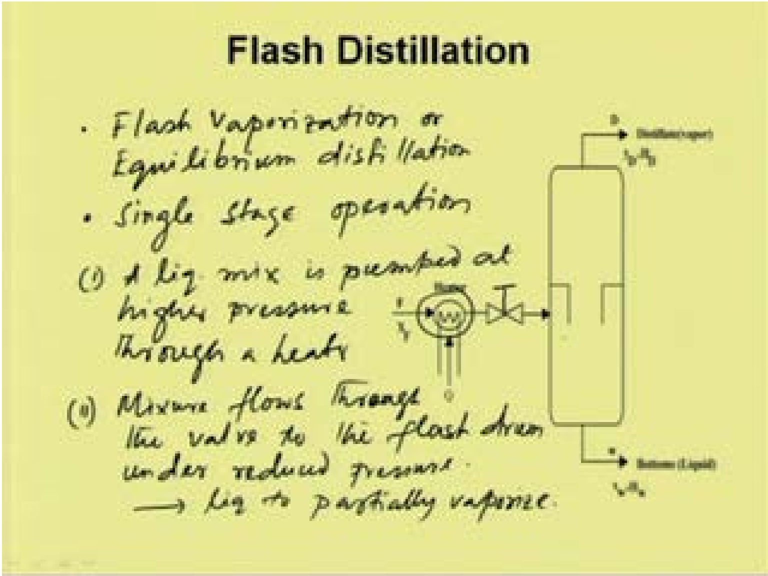

Today, we will discuss flash distillation. This flash distillation sometimes also called flash vaporization or equilibrium distillation distillation. Here, we can see a schematic of the flash distillation column. This is a single stage operation, single stage operation, where initially a liquid mixture, liquid mixture is pumped at higher pressure through a heater, which is over here, heater and the feed is pumped, it raises the temperature of the feed, and then there is a valve, is throttling valve. It is throttled mixture flows through the valve to the flash drum under reduced pressure. So, this causes the liquid to partially vaporize; as soon as it enters into the drum, the liquid and vapor separates.

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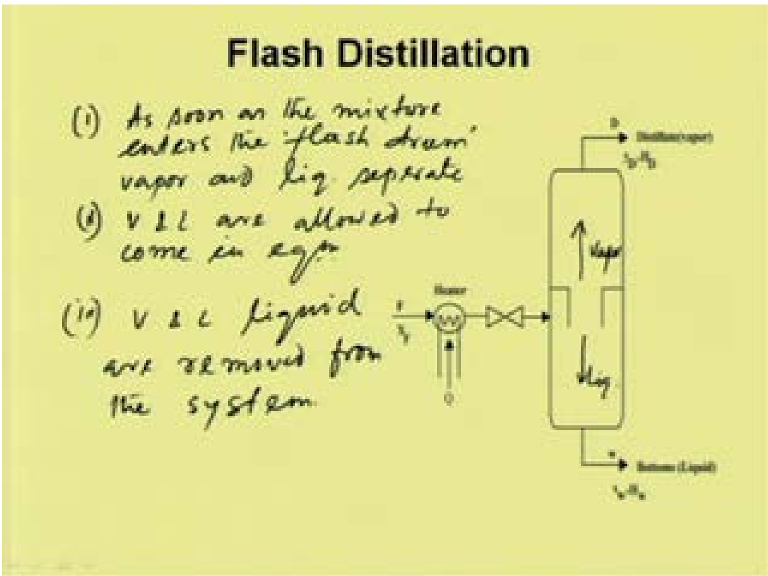

So, the vapor and liquid there, liquid goes down, vapor goes up. As soon as the mixture enters the flash drum, vapor and liquid separate. Then vapor and liquid are allowed to come in equilibrium, vapor and liquid are allowed to come in equilibrium. So, the enough space is provided and then finally, the vapor and liquid are removed from the system. This flash drum is very common particularly in petroleum industries, petroleum refining.

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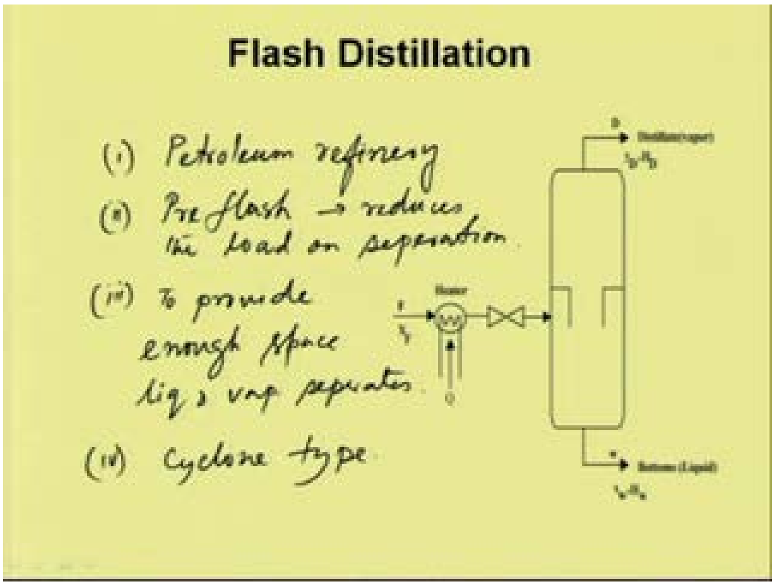

So, in many cases in distillation also they are sometimes we use the pre flash. So, it reduces the load on separation. So, in this designing of flash drum, it is very important to provide enough space, so that the liquid and vapor separates, liquid and vapor separates. In general the design of these sometimes it is of cyclone type.

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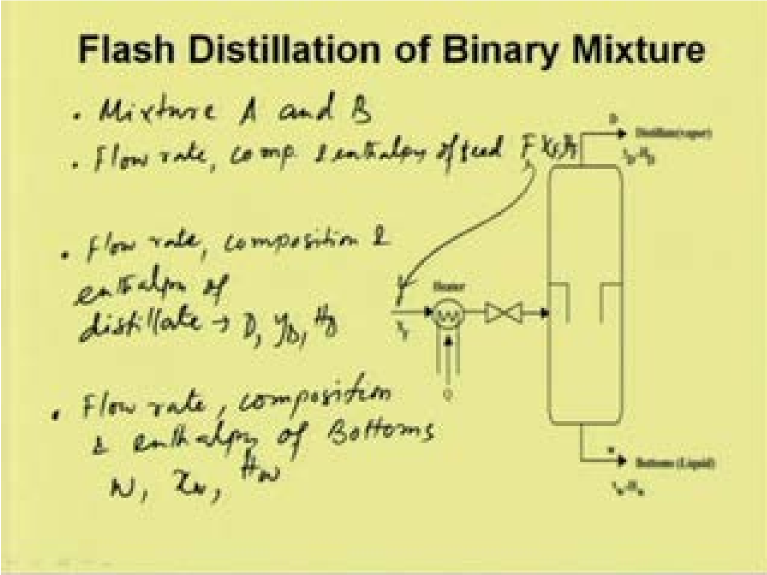

Now, we will consider a binary mixture in flash distillation and considered a mixture which contains A and B. Now, flow rate composition and enthalpy of feed, this is we can write F is the feed florid x F and h F, which is given over here. Then the flow rate composition and enthalpy of distillate which is given over here at the top, we can assume D y D y D and H D. The flow rate composition and enthalpy of bottoms, that is we can write W x W and H W.

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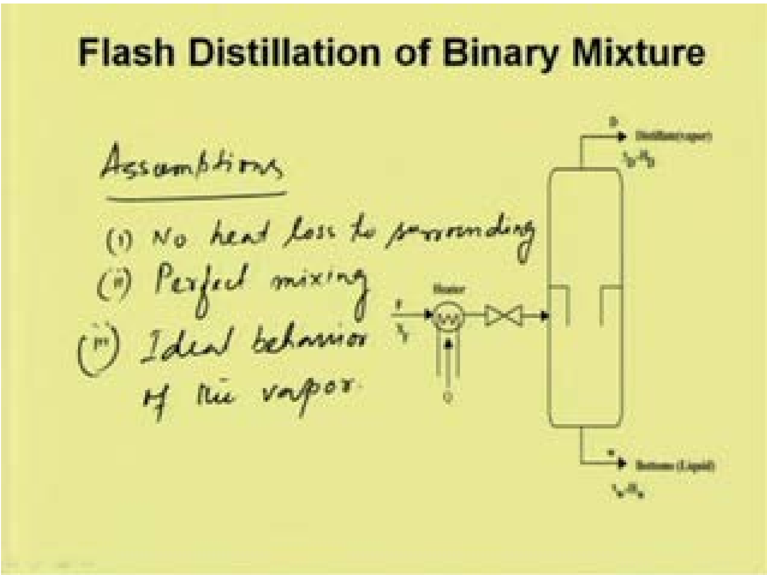

So, with this nomenclature if we do the materiel balance, first we will have the following assumptions. One is low heat loss to surrounding, perfect mixing and ideal behavior of the vapor, ideal behavior of the vapor. Now, let us do the steady state materiel balance on this flash drum.

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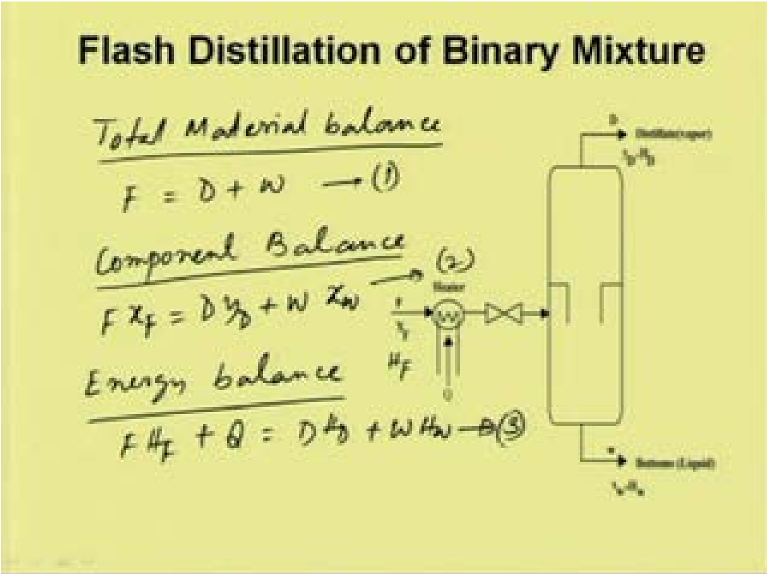

So, if you do the overall materiel balance, total materiel balance we can write F would be equal to D plus W, equation 1. If you do the component balance, balance for a we can write F x F is equal to D y D plus W x W. Similarly, we can write the energy balance equation, energy balance equation this is equation number 2. Energy balance equation should be F H F plus, this is H F plus Q would be equal to D H D plus W H W, this is equation 3.

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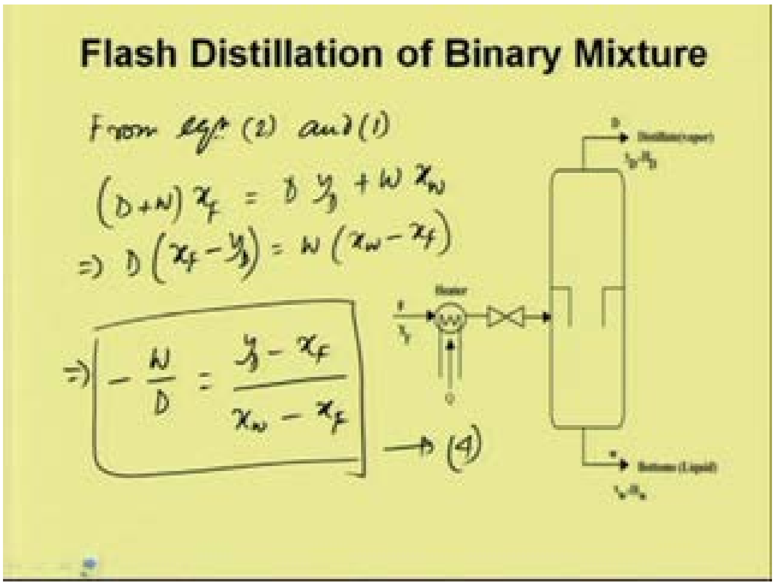

Now, from equation 2 and 1 we can write D plus W x F would be equal to D y D plus W x W. And from here we can write D into x F minus y D would be equal to W x W minus x F from which we can write minus W by D would be equal to y D minus x F divided by x W minus x F.

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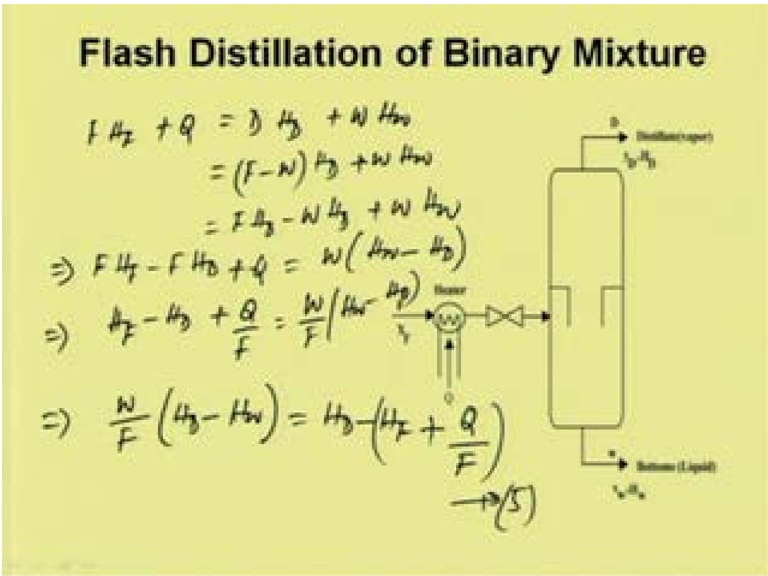

So, this is equation 4. Now, using equation 3 and 1, we can write F H F plus Q would be equal to D H D plus W H W, this is equation 3. Now, if you substitute D by F minus from the total materiel balance F minus W H D plus W H W and then we can write this should be equal to F H D minus W H D plus W H W. And we can write F H F minus F H D plus Q would be equal to W H W minus H D. So, we can write H F minus H D plus Q by F would be equal to W by F H W minus H D. And we can write W by F multiplied by H D minus H W would be equal to H D minus H F minus Q by F. So, this is equation number 5.

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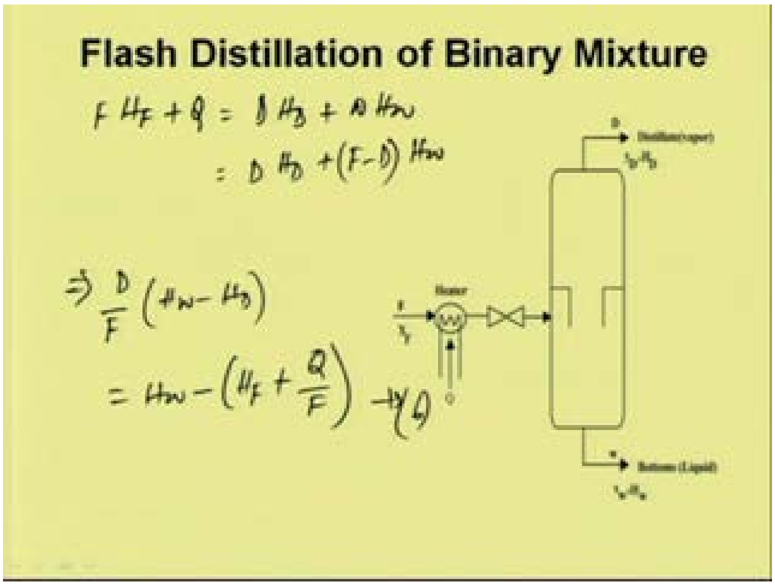

We can also write this plus this. Now, similarly if we use energy balance equation F H F plus Q is equal to D H D plus W H W. Now, if you substitute D H D plus F minus D H W and if we rearrange this equation in similar way, we can get D by F into H W minus H D would be equal to H W minus H F plus Q by F. This is equation 6.

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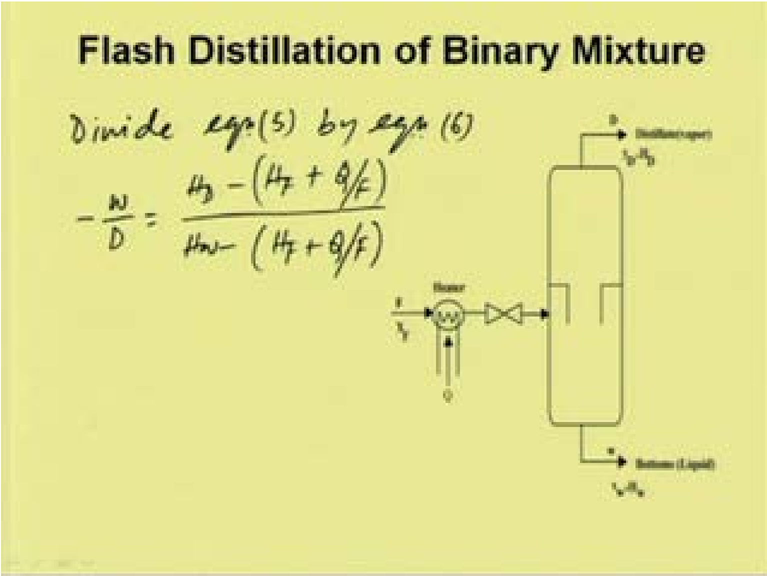

So, if we divide equation 5 by equation 6 we would obtain minus W by D would be H D minus H F plus Q by F divided by H W minus H F plus Q by F, if we look into the H x y diagram.

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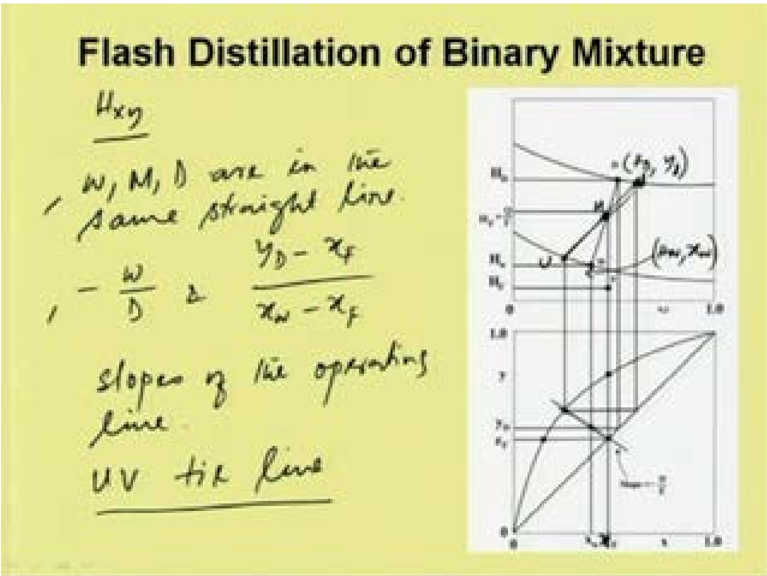

So, this points D which is H D and y D and here w which is H W x W, this point represent H W x W and the point which is given over here is H F plus Q y F and this is corresponding to x F, all these three points 1 2 and 3, say this is M and this is say W. So, W M D are in the same straight line and minus W by D and y D minus x F divided by x

W minus x F, these are the slopes of the operating line slopes of the operating line, then with this slope if we plot this line then the line connecting to this say U and V, then U and V if the effluent streams are in equilibrium U V will be the tie line.

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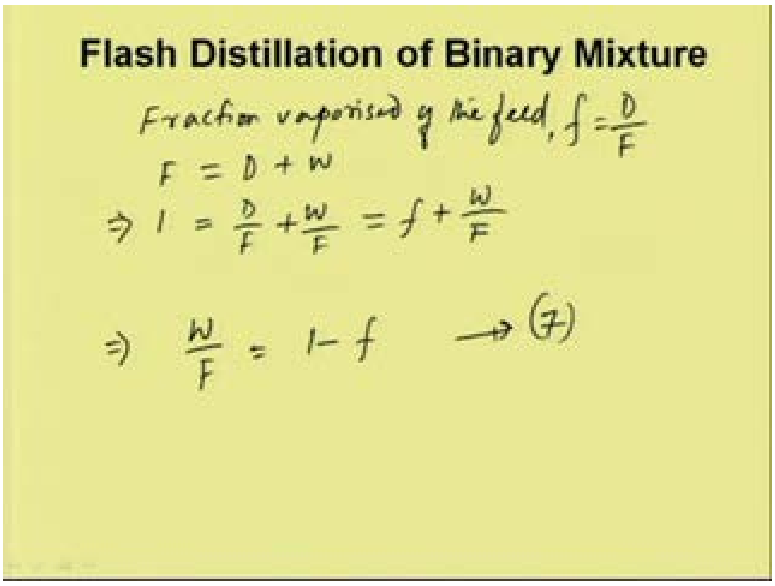

Now, we will do the another rearrangement of the materiel balance equations and we define the fraction vaporized of the feed, fraction vaporized of the feed which is defined as f small f is equal to D by F. Now, from the materiel balance equation 1 which is F is equal to D plus W, if we divide both side by F it will be 1 is equal to D by F plus W by F which we can write f plus W by F and so, from this we can write W by F would be 1 minus f. So, this is equation 7.

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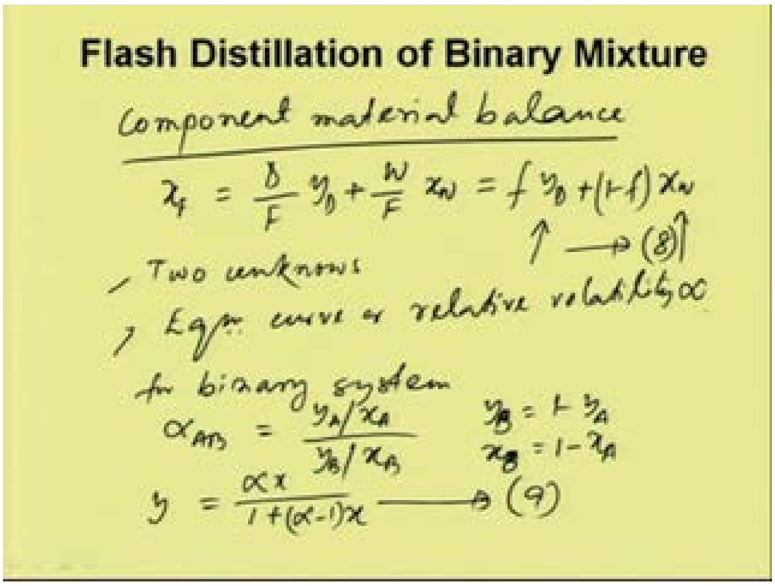

So, now for the component materiel balance we can read it an, as component material balance. Instants of fractional vaporized, we can write x F would be equal to D by F y D plus W by F x W. So, which we can write f y D plus 1 minus f x W. This is equation 8. Now, in this equation we have two unknowns y D and x W, two unknowns. So, there should be relations between these two which will give the relations between y D and x W, so that we can able to solve. So, this is provided by the equilibrium curve or relative volatility equation. The relative volatility as we have discussed for a binary system we can write alpha A B would be equal to y A by x A divided by y B by x B, where y B would be 1 minus y A and x B would be 1 minus x A. So, if we rearrange these equations it will give y would be equal to alpha x divided by 1 plus alpha minus 1 x.

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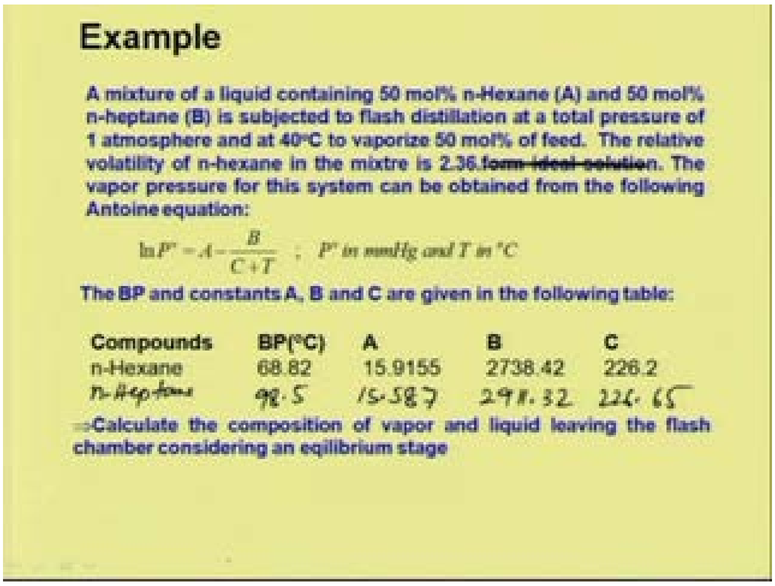

So, this is equation 9. Let us considered an example, a mixture of a liquid containing 50 mole percent n hexanes and 50 mole percent n heptanes is subjected to flash distillation at a total pressure of one atmosphere and at 40 degree centigrade to vaporize 50 mole percent of the feed. The relative volatility of n hexane in the mixture is 2.36, the vapor pressure for this system can be obtained from the following Antoine equations which this problem we have already discussed in our first lecture.

So, l n P v is equal to A minus B by C plus T where P v in millimeter H g and T in degree centigrade. The boiling point and the constants A B and C are given in the following table. n hexane is this and the value of n heptanes which is not here, n heptanes is 98.5, this is 15.587, 2911.32 and 226.65. Now, we have to calculate the compositions of the vapor and liquid leaving the flash chamber considering an equilibrium stage. The information which are given, the feed contains 50 mol percent normal hexanes and normal heptanes.

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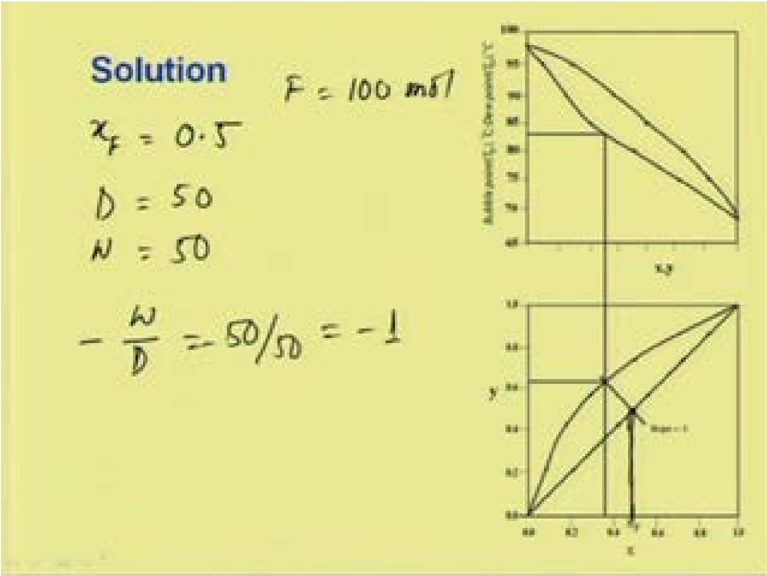

So, we have x F is 0.5 and D is 50 mol percent is vaporized, D is 50 mol if we assume feed F is 100 mol as the basis, then D is 50 mol and W is 50 mol. So, minus W by D would be minus 50 by 50. So, it would be minus 1. Now, this is the value at x F which is at 0.5 and then with the slope of minus 1, we will draw the line the equilibrium data which are obtained from the equations which is given y is equal to alpha x divided by 1 plus alpha minus 1 x.

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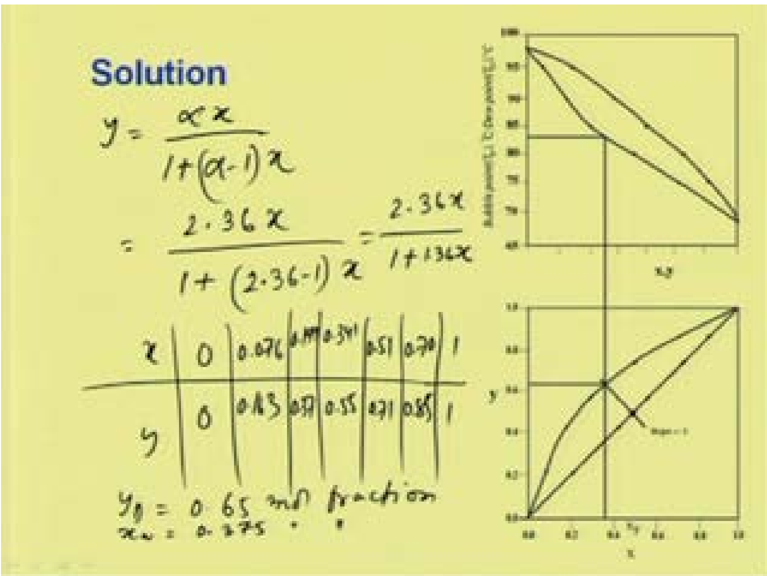

So, we can write this is 2.36 x divided by 1 plus 2.36 minus 1 x which would be 2.36 x divided by 1 plus 1.36 x. So, with this we can obtain the value of x and y. So, like if we take 0 this will be 0, if we take 0.076 this value is 0.163 and if it is 0.199 then it will be 0.37, 0.341 this value would be 0.55 and 0.51 this would be 0.71, 0.7 naught it would be 0.85 and this is 1 at 1. So, with this we can plot the equilibrium line. This is 45 degree diagonal and this is the equilibrium line. So, this is x y diagram. Now, in the x y diagram with the slope we can obtain these values and this gives a value of y D which is about 0.65 mol fraction and x W we can calculate from this point is around, x W around 0.375 mol fraction.

Now, from the (( )) equations that we have discussed before, since we have equilibrium line and we have the vapor pressure data at different temperature we can plot the bubble point and due point curve. So, this is the plot which is shown over here.

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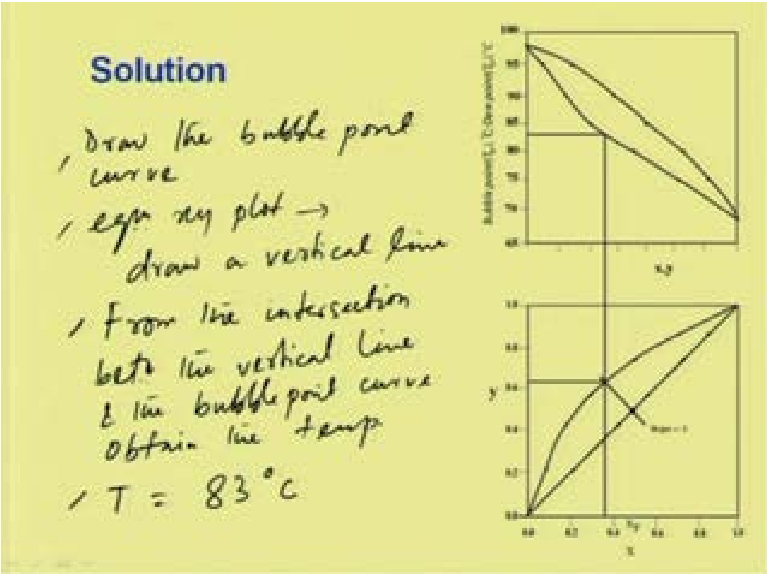

So, first we have to draw the bubble point curve curve and then the, from the equilibrium points equilibrium x y plot, draw a vertical line and then from the intersections between the, from the intersection section between the vertical line and the bubble point curve, obtain the temperature. So, the temperature is around in this case is around T is about 83 degree C.

So, thank you for your attention.