Mass Transfer II

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Lecture No. # 15

So, in the previous lecture, we discussed T x y diagram vapor liquid equilibrium and we talked about; if we fix the pressure and temperature then the mole fraction of components is fixed in both the phases -liquid and vapor. We talked about tie lines. We discussed the due point curve, bubble point curve starting with a superheated vapor of binary component system. If we cool it, start cooling it; then we get this on due point. If further cool it we have this bubble point curve. So, today what we do for distillations, we also have different approach to address a variety of problem. For example; in state of working on T x y we can also have H x y diagram enthalpy x y diagram, so that essentially they are two approaches to design this distillation column, one is based on T X Y and one is based on H x y. So, we take up this a new you know new type of curve H x y and we will see how we can construct this curve.

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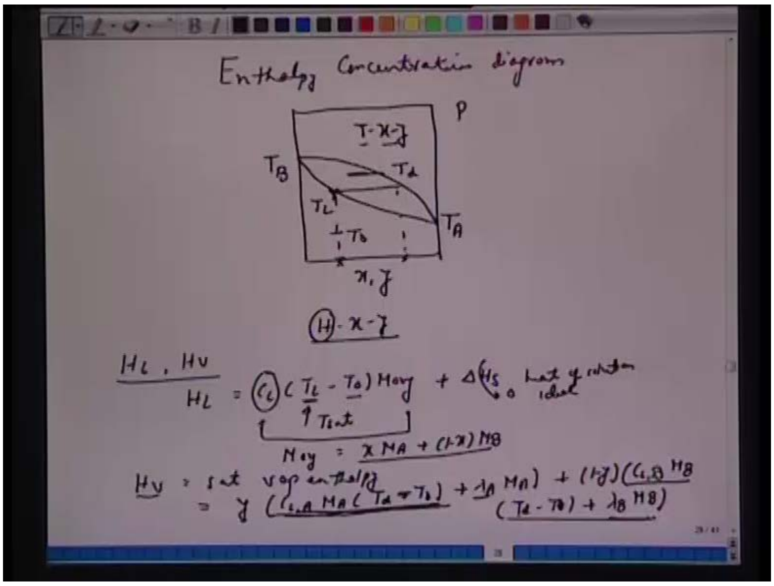

Enthalpy Concentration diagram

$\boxed{H}$-x-y

H_L, H_V

$$H_L = \boxed{C_L}\,(T_L - T_0)\,M_{avg} + \Delta H_S \quad \text{heat of solution, ideal } 0$$

$\uparrow T_{sat}$

$$M_{avg} = x M_A + (1-x) M_B$$

H_V = sat vap enthalpy

$$= y\,(C_{L,A} M_A (T_d - T_0) + \lambda_A M_A) + (1-y)(C_{L,B} M_B (T_d - T_0) + \lambda_B M_B)$$

So, now we have this enthalpy concentration diagram. So, here just like in the previous the lecture we had this T x y diagram. So, we had X Y T here of component B and burning temperature component A and we said that if a fixed pressure here and we choose a temperature then the mole fraction Y in the vapor phase and the mole fraction X in the liquid phase are fixed. So, similar to this T x y diagram, we can also have H X Y diagram. Because once the temperature is fixed and mole fraction are fixed; one can calculate the enthalpy. So, before we calculate H x y; let see how we define H L enthalpy of a saturated liquid and H V enthalpy of a saturated vapor. So, H L is defined as C L T L minus T 0 in to molecular weight average molecular, plus we can have del H s, which is heat of solutions.

Generally, for ideal solutions heat of solution is taken to be zero, so for ideal solutions we do not have this term. So, what it is essentially, we have binary components and the temperature of T L T zero is a reference temperature. So, if H L is saturated or enthalpy H L represents the enthalpy of a saturated liquid then T L is T sat, so essentially we heat. This is a sensible heat component and we heat this fluid say from some temperature T zero all the way till T L. So, H L equal C L T L minus T zero M average, where M average will be X into M A plus 1 minus X into M B. So, essentially we have some kind of weighted average here. So, H L enthalpy of the saturated liquid is nothing but specific heat of the liquid C L multiplied by T L minus T zero in to molecular weight.

We are neglecting this heat of ideal solutions. Similarly, we have H F H V saturated vapor enthalpy and the way it is defined here is Y or calculated C L A molecular weight A T D minus T zero plus lambda A M A . So, let us do what we have written here, we are essentially taking this pure component A and we heat to the temperature T D, so where T D is the temperature let say saturation temperature here. All it means; we have taken this component of A pure component. We have heated till T D it liquid gets vaporize so lambda A into M A and then it is getting mixed with component B, so 1 minus Y C L B.

We have molecular weight M B plus sorry multiplied by the temperature. So, we have T D minus T zero plus lambda B in to M B. So, these two components here and here these are unmixed liquids. So, essentially what all it means the two components A and B they are heated from temperature T zero to T D then the component B gets vaporize, so we have this component lambda M B, where lambda is added heat of vaporizations for component B and lambda is latent heat of vaporizer for component A. So, the two components are heated vaporized and then they are mixed to obtain this saturated vapor enthalpy.

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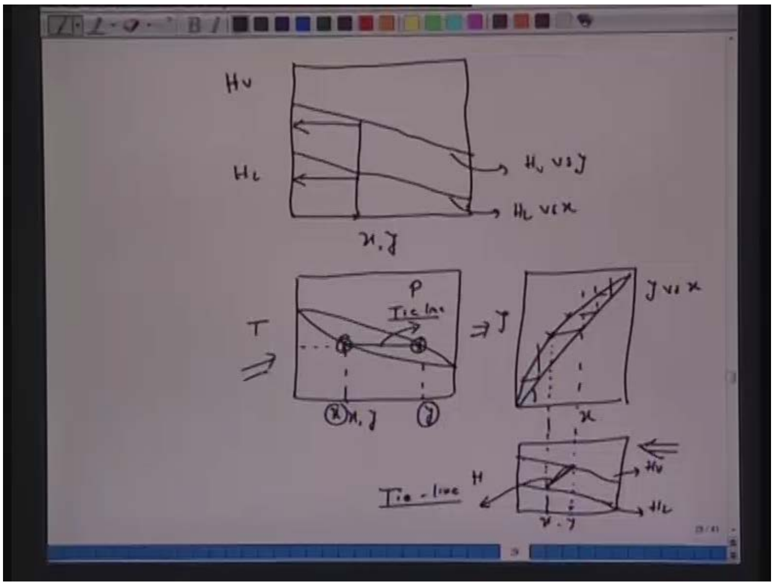

So, essentially with this we can obtain H x y diagram. So, we have X Y and we had so if you fix the mole fractions of component A in to vapor to the liquid phase we can obtain curve like H L saturated enthalpy of the saturated liquid and we can have H V not necessary linear or parallel H V enthalpy of the saturated vapors. So, if we fix the mole fraction X then we have H L and corresponding to this mole fraction we can have this H V. So, this is H L verses X this curve and we have H V verses Y. So, now if have now let us if you recall the previous graph for T X Y diagram, if you plot T x y diagram . So, we have T temperature here and X and Y and if you choose a tie line that means this come Y mole fractions this is an equilibrium with X.

So, if you have Y and X fixed here for a given pressure and temperature we can also generate you recall Y verses X diagram. So, essentially we can also have equilibrium curve like Y verses X. So, we have Y here and Y X here and we know we can take the component projections from here X here we can bring Y to this 45 degrees lines, we can take then we can extent here. So, if you take it here you can extend here to obtain this coordinate, similarly we can obtained some other components other coordinates. So, we have y verses x and we have T x y diagram. Now, here also if we take this projection of

X and Y and we construct this H X Y diagram, which we have, done right here H X Y so this would be H V curve this would be H L.

So, if we take these projections here H L this Y right here and we take these projections for coordinate X here we can see that whatever we connect this to this will become our tie line. So, now let us go back to this figure and the figure here. For this Y and X at this temperature this is the tie line. And if we fix X and temperature enthalpy of this component is fixed here for this liquid, liquid phase saturated liquid phase. Similarly, fixing Y and fixing this temperature, we have fixed the enthalpy and the two we are trying to mark on this curvature. How do we do this? X we have taken the projection here from the top and Y we have taken the projection here, at this saturated H V curve and H L curve and we connect to make this as tie line .

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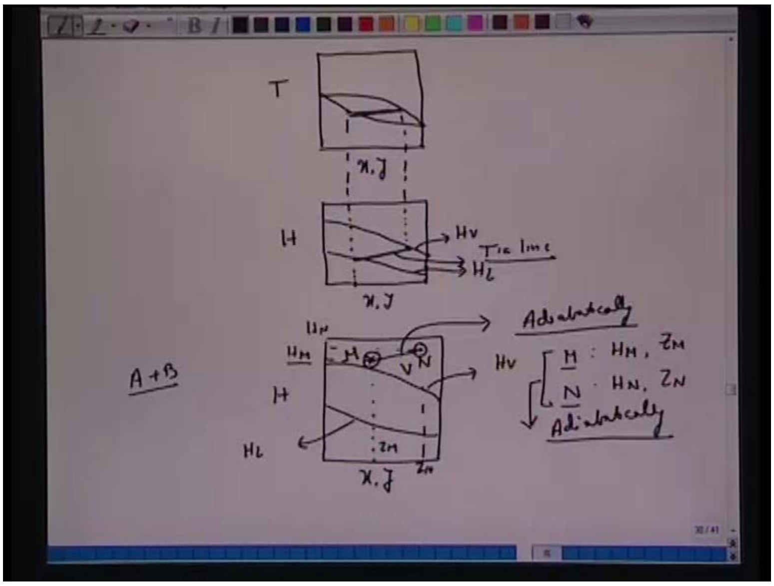

We will like to redraw this one top of the other. So, let us start with T x y diagram again T x y diagram. So, we have this tie line and we take projections on this H x y diagram. So, we have H, we have x y, we have this H V, which we have calculated or we have obtained from that expression, which we had earlier H V H L. All it means; now if you take this Y here and we take this X coordinate here, we can draw these two lines this would be the tie line representing the equilibrium component. So, this tie line is essentially is same as a tie line we have here that is one thing. Now, right so and similarly if we choose let us reconstruct H X Y diagram again here. So, if we have H V and we have this H L. Let us take two coordinates here, one is M and one is N. Now, if you fix M, so that means coordinate is marked here say Z M H M and we choose N whose coordinate is mark as H N and we have this Z M.

Now, if we mix these two fluids, so that means fluid with the enthalpy of H M it is a binary components consisting of A and B and another way of enthalpy H N with the mole fraction Z N. If we mix these two streams for these two fluids adiabatically then one can show that the resulting component, resulting fluids enthalpy will be on this straight line, so this what we trying to proof here, that if you mix M whose coordinate is H M and Z M, N is coordinate is H N and Z N, so here we have chosen M N, which is superheated vapors, so this is saturated vapor, saturated liquid and this is this reason is further vapor phase. So, this calculation should hold good for any two points on this H X Y diagram. So for example; so if we choose M here and N here and we mix these two fluids adiabatically then we can write material balance, we can write energy balance like this. So, we have now P equals M plus N.

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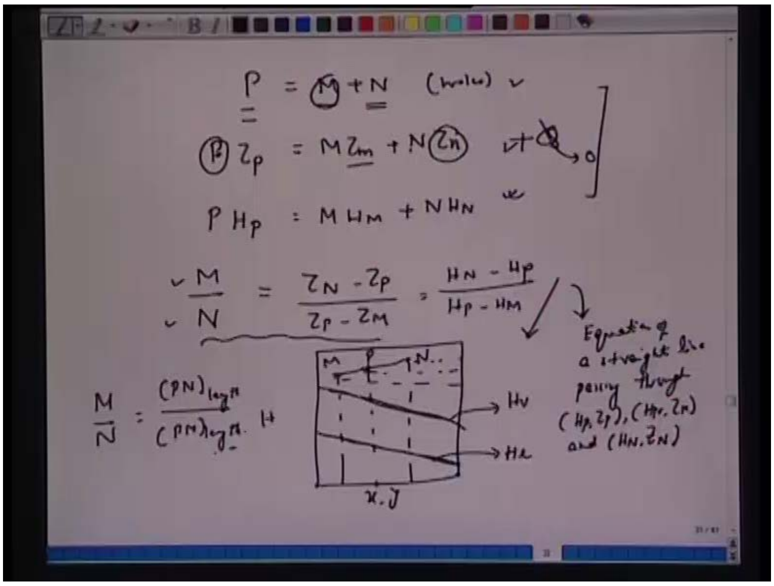

$$P = M + N \quad \text{(moles)}$$

$$P Z_P = M Z_M + N Z_N$$

$$P H_P = M H_M + N H_N$$

$$\frac{M}{N} = \frac{Z_N - Z_P}{Z_P - Z_M} = \frac{H_N - H_P}{H_P - H_M}$$

$$\frac{M}{N} = \frac{(PN)_{\text{length}}}{(PM)_{\text{length}}}$$

Equation of a straight line passing through (H_P, Z_P), (H_M, Z_M) and (H_N, Z_N)

So, we are talking of some moles of N is mixed with moles of N to give moles of P. Now, if you make a species balance P into Z P equals M Z M plus N Z N. So, Z N would be a mole fraction of A in this binary mixture of A N and Z M is a mole fraction of A in the binary component of binary fluid of M and when we mix these two we have this fluid P, which is nothing but M plus N and this has a mole fraction of A as Z P. So, this is a species balance this would be a total balance we can also make enthalpy balance P H P here M H M plus N H N. So, with these three equations, one for the total balance, one for species balance and one for energy balance we have one can show that we can get a ratio of M by N Z N minus Z P over Z P minus Z M equal to H N minus H P over H P minus H M.

Now, let us go back to this curve again, so we have H X Y diagram. So, instead of T X Y we have this H X Y diagram saturated vapor curve and saturated liquid curve. In this space any where we have two components M and N. We are mixing these two fluids adiabatically, that means there is no heat loss here Q zero. If you mix these two marbled coordinates from this equations it is easy to see that the coordinate of P will be on this straight line joining between M N, see this what we have this is Z M, this is Z N, this is Z P. So, Z N minus Z P and Z P minus Z M this ratio will be same as M by N and M plus N we have seen this equal to P. So, this nothing but equation of a straight line passing through H P, Z P, H M, Z M, and H N Z N.

So, whatever we have the relation for M by N from first to you can also obtain the relation in terms of H N minus H P, so this would be H N here, this would be H P here, this would be H P. So, one can show by the coordinate geometry at this P lies on a straight line between M and M by N, which means if you lo at here again H N minus H P over H P minus H M is nothing but the length of P N. So, H N minus H P this would be the same ratios as the length of this P N over this P M to length. So, what we have done now so far that we started with H X Y diagram. We said that just like we have T X Y diagram, we fix the temperature, we know the mole fraction X and Y pressure is fixed enthalpy of this binary components of A and P, A and B corresponding to X and corresponding to Y will be fixed, one can calculate knowing the sensible heat and the latent heat of vaporization.

We calculate the sensible heat of the liquid know the specific heat capacities C L the temperature is raised cold feat from T 0 to all the way till the saturated curve, so C L into T L minus T 0 multiplied by the molecular weight, so you have raised that fluid temperature to the saturated level or to calculate the enthalpy what we did we said that we have A and B both of them are raised to this saturated vapor curve that temperatures heat. So, the mole fractions of A and mole fraction of B in that proportional it is raised to that temperature mixed them adiabatically. First we have to heat it to the saturated temperatures vaporize them and then mixed together in that case we get H V curve. Once we have H L and H V curve, you know H x y diagram is ready.

Now, we are saying that in that plot any where if you choose two points, which is M and N here that means now we are mixing the two fluids A plus B with a coordinates or properties mole fractions Z M enthalpy H M. We have another A plus B, which has mole fraction Z N of A and marbled volatile components and enthalpy H N, if you mix that two together without any loss of energy adiabatically then we have the mixtures, which will be now P M plus N, so 50 moles of 40 60s, if we have 100 moles and the enthalpy of this fluid the new mixed fluid which you have now, if we plot on the same H x y diagram should lie on the straight line between M N. this what mixing rule we have.

We are going to make use of this property to do some more calculations on H x y diagram. So, let us try to understand this mixing rule again, because this is what we are going to do a time and again we have distillation column several trace, one vapor leaves, one tray goes to the next tray liquid trickles down from one tray to another tray. So, one can make this energy balance to show that we have two fluids, which are getting mixed together to have two new different streams, which are leaving the trays. So, there also one can do this mixing rule what we have done now. It is very important that we understand the coordinates of different components different streams on this H x y diagram the way we have done on T x y diagram.

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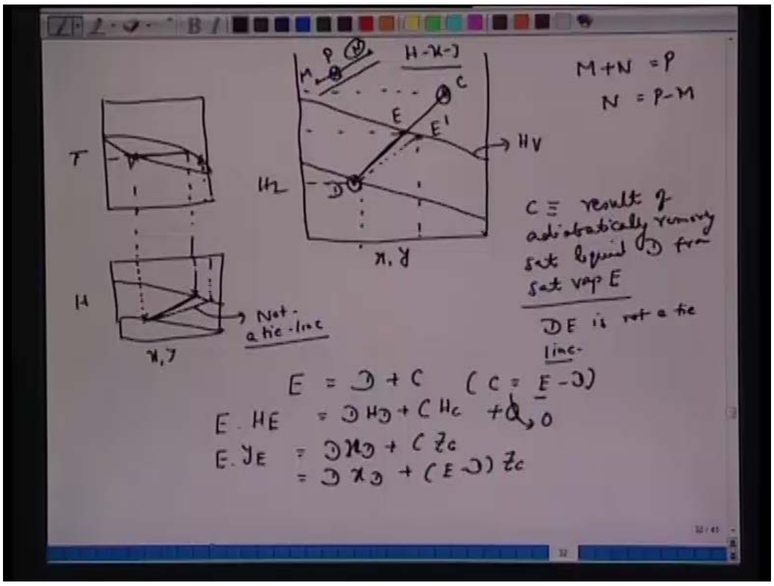

M + N = P

N = P − M

C ≡ result of adiabatically removing sat liquid D from sat vap E

DE is not a tie line.

$$E = D + C \quad (C = E - D)$$

$$E \cdot H_E = D H_D + C H_C + Q, 0$$

$$E \cdot y_E = D x_D + C z_C$$

$$= D x_D + (E - D) z_C$$

So, let us do this mixing rule again. We have this H x y diagram. So, this is x, this is y. We have this enthalpy H L, we have this saturated vapor H V. Now, here as you said that on this anywhere this H x, y diagram we can take two streams we choose P and N in the earlier example both were superheated vapors, so we mix the two our third components with new mixed mixture will have the enthalpy, which will lie on this statement. This how we got the equation of the line. This is two with anywhere on this two points, which means now if we choose say C, and draw any straight line say it cuts this curve on E and this curve on D. One can say that what is the C, it is a result of adiabatically we are removing saturated liquid D.

So, if we take this saturated vapor E from this, if we remove this saturated liquid D, we should be able to show that resulting mixer will be C or if you choose this C, superheated vapor mixed with this saturated liquid D one can show that we are going to get. So, whatever we have now applied this mixing rule A M and N gives rise to P one can also say that from P, if we remove M we can get the same things writing like M plus N equals P or N equals P minus M. So, similarly here one can say that this E saturated vapor or we have here E is nothing but mixing the saturated liquid D, and superheated vapor this C or C is produced, if we remove this D component, D you know this coordinate here or the fluid of this specification D from E by adiabatically will get E.

So, let us write down here that C is result of adiabatically removing saturated liquid D from saturated vapor E and also make a note that this D E is not a tie line. So, this also very important that we do not P is not necessary the tie line. We will talk about this later may be the tie line is D E prime. The tie line only if this component here this mole fraction is in equilibrium with this mole fraction and that has to come from T x y diagram. So, if this is a T x y diagram then this is a tie line we have this Y component this is X here mole fractions. If we now plot take the projection on H x y diagram which we have earlier here. So, if this is your H P this is the H L you take this here it will intersect here and if you take the projection here this is an intersects here.

If we draw this line here then this will be a tie line, because this Y and X they are saturated compositions of saturated vapor and saturated liquid at the same temperature. So, in this case not necessarily this D E will be a tie line, because they may be different temperatures. If I take this point here and take some other temperature here and then take the projections on this and then we draw this line is not a tie line, because they two components not a tie line, because these two components here mole fractions corresponding to this and mole fraction corresponds to this they are not the same temperature.

So, it is it is very important that what we are trying to say here we understand that we are applying a mixing rule it is only a mass balance total mass balance or it is totally species balance. We are saying that if you add C and D we will get E, if we subtract D from E we will get C, if we subtract C from E we will get this components and not necessary this D or E they are at they are the equilibriums, so not necessary this would be the tie line. It is possible that it could be on tie lines if they have the same temperature as given from here and once again we can do the calculation, which we did earlier that this E can be seen as D plus C or we can also write as C as E minus D. So, that is what we say C is a result of adiabatically removing saturated liquid D, so saturated liquid D from saturated vapor E, but not necessary the same temperature.

If they are the same temperature of course it would be a tie line. Right now we just apply a mixing rule E equal D plus C. We can also write E into H F H E equals D H D plus C H C. So, these are the respective enthalpies of E and D. All we have done, we have just apply energy we can say it is adiabatically mixing so this is zero here. We can also make a balance for species balance Y E, so this would be D X D plus C Z C. You can always arrange this D X D plus C as E minus D into Z C.

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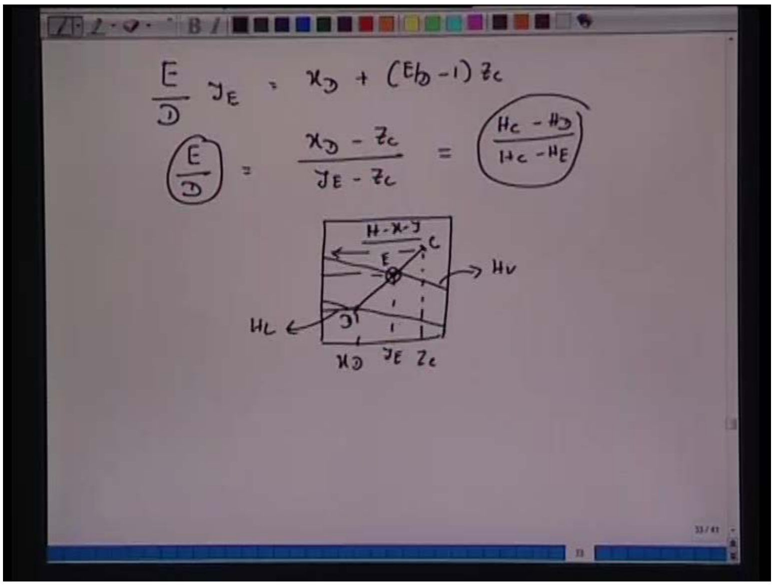

$$\frac{E}{D} y_E = x_D + \left(\frac{E}{D} - 1\right) z_C$$

$$\boxed{\frac{E}{D}} = \frac{x_D - z_C}{y_E - z_C} = \boxed{\frac{H_C - H_D}{H_C - H_E}}$$

And then one can show that we get E by D Y E equals X D plus E over D minus one Z C or E over D can be we written as X D minus Z C over Y E minus Z C. This will also be equal to H C minus H D over H C minus H E. So, look at this E by D equals H C minus H D over H C minus H E. This is what we are trying to say here that on H x y diagram. We have H V and we have H L we have constructed this from T x y diagram knowing the sensible heat, latent heat of vaporizations for component A and latent heat of vaporization for component B we have constructed this two curve and we choose two components two fluids E and D and if we subtract D from E we will get C or if we subtract or if we add C to D we are going to get E and we are saying that this are not E D need not be tie line.

So, this is your Z C this is your X D we have Y E and we have three enthalpies corresponding to this mole fractions. So, far what calculation we have done we have created H x, y diagram that is one. Once we have H x, y diagram then we apply this mixing rule. Anywhere on this H x, y diagram if we choose two components two fluids A plus B either they are saturated vapor saturated liquid, one of them is vapor, one of them is saturated liquid does not make a different we are all going to apply a mixing rule. Take these two components and mix them, the resulting mixture coordinates enthalpy of the resulting mixtures will lie; has to lie on the straight line joining the two components this we get from the mixing. This we did for H x, y and we did it also for Y x, y diagram E on D x, y diagram.

There also if we take the two components apply this mixing rule for the mole, total moles and for the species balance one can show that we will get the similar scenario that we have a straight line and the two components, which are going to mixed they lie on the same straight line as that of a resulting mixture, because we are going to make use of this in our next calculations. So, now based on this now we start the first unit operations, of course we are in the distillations, but we have also single stage vaporizes we call it flash drum and it is a one stage flash drum, which is going to be the block, we will start from this single stage as a building block for the distillations.

So, essentially what you have in a single stage flash drum that you take a liquid, so feed a certain composition say Z F and it is a cold feed one has to heat it, so you have to supply heat Q bring it to this some saturated liquid and there we should be pressurized so that you can flash it to the lower pressure and the you can have larger separations. If you recall in our previous lectures, we talked about effect to the pressures. So, if we have T x, y diagram at certain pressures and if we increase the pressure then we said that most of the ideal fluids or the binary components fluids there separation will be smaller. In other words, this envelop of T x, y diagram will become smaller.

So, for the same temperature now we have small separations. If we decrease the pressures then if you do not; if they are no quick spots or the components are behaving as ideal fluids than we have this larger separation. So, where we want to have this distillations separation in single stage operation vaporizer or flash drum generally what is the practice that you take a fluid heat it bring to a saturated temperatures and it should be pressurize at high pressures, so that now you can throttle it and flash it to the vapor and the liquid then you will see a separation X Y with the single stage. If we understand this and draw it on our T x, y diagram on H x, y diagram, then you will see that when we take up the larger distillation column where the different stages trays this will act as a building block.

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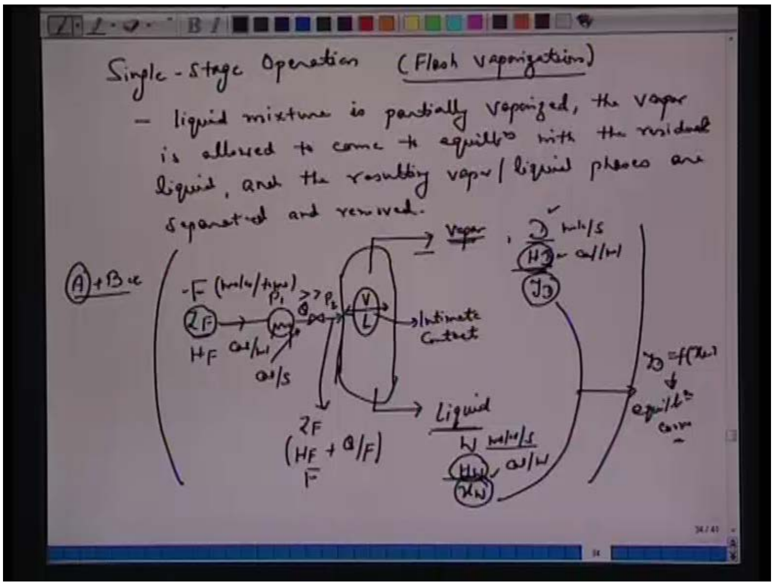

Single - Stage Operation (Flash vaporization)

- liquid mixture is partially vaporized, the vapor is allowed to come to equilib^m with the residual liquid, and the resulting vapor / liquid phases are separated and removed.

So, let us start this single stage operation or single stage vaporizer, which is nothing but flash vaporizations. So, we have this single stage operation, which is nothing but flash vaporization. Essentially what we have here liquid mixture is partially vaporized. The vapor is allowed come to equilibrium with the residual liquid and the resulting vapor liquid phases are separated and removed. So, let us draw this schematic of this or single stage operation or flash vaporizations, so essentially we have a flash drum here. It is a very simple device a flash drum in which L feed is or liquid is brought in. So, let us say the feed flow rate is F moles per unit time some moles per second composition of this fluid this feed is Z F.

So, we have binary components A and A plus B and when we say Z F, Z F is the mole fractions of more volatile components A as the convention, so 1 minus Z F is a mole fraction of less volatile components. So, Z F and this fluid once we have F X Z F in enthalpy of this fluid is H F calorie per mole. Now, this fluid in general it is cold so it is brought way heated. So, where we are giving this heat Q at say certain rate calorie per second. So, the heat is given to this fluid Q and we said earlier this fluid is actually pressurized, so the pressure up steam is P 1 or this boiler pressure is P 1 it is throttle to P 2 before it is flash into this.

Now, let us examine this state of this fluid, which enters the column or after throttle. So, here this mole fraction of the feed is Z F, which means the mole fraction will remain the same here is Z F total mole fractions it will not change here. Enthalpy will be however H F plus Q over F, because we have increased the enthalpy we have added heat here we are adding heat at the rate of Q calorie per second and molar flow rate is F moles per second. So, now the enthalpy of the fluid, which enters the drum this H A plus Q F feed rate is same as F moles per second. We talked about that this fluid has to be pressurized to relatively higher pressure, so that now we can throttle bring down to a lower pressures P 2 and then we can achieve larger separations.

So, now after this so when we flash then there is a vapor and this liquid; two liquid two comprages there brought in intimate the contact with this and then the vapor is separated from here and the liquid is separated or drain from here. So, it is a very simple device and we will see that the analysis here that is more important. Whatever we do the analysis on T x, y diagram or H x, y diagram that becomes our very basic very fundamentals to do the calculations for distillation trays wise. So, we have the liquid, let us it is withdrawn at the rate of W moles per second vapor drawn as at flow rate of say S moles per second or moles per time enthalpy of this liquid is H F saturated liquid, and here enthalpy of this vapor; saturated vapor is H D calorie per mole fractions let us use X W and let us use the mole fractions Y D the vapor phase.

Now, we said that H D and H W these are the enthalpies of saturated vapor and liquid respectively. That means once we have this vaporizations or flashing two phases they have been brought in intimate contact sufficient time has been given, so that the leaving streams are in equilibriums. In that case only H D and H W these are the saturated enthalpies of these are the enthalpies of the saturated phases here. Otherwise; these two is coordinates they will not necessarily fall on this equilibrium curve. We will draw this. So, let us try to understand this flash drum once again. We have the feed here F moles per unit times it is brought in.

It has a composition Z F enthalpy H F, here we heat this liquid to saturated state to bring it supply the heat at a rate of calorie per second liquid is pressurize, so that it is throttle brought to brought down to the pressure P 2. We have this face separations vapor and liquid, vapor is withdrawn from here liquid is withdrawn from the bottom after giving sufficient contact time between the two phases, so that we have the two leaving streams vapor and the liquid they are in equilibrium. So, let us assume that we have D moles per second molar flow rates and we have W moles per second the liquid flow rate, enthalpy is H T enthalpy is H W, we have the mole fractions Y D mole fraction of X W, except when we say that they are in equilibrium now Y D can be written is a function of X W by this equilibrium curve or vapor liquid equilibrium curve, because two steams living are in equilibrium.

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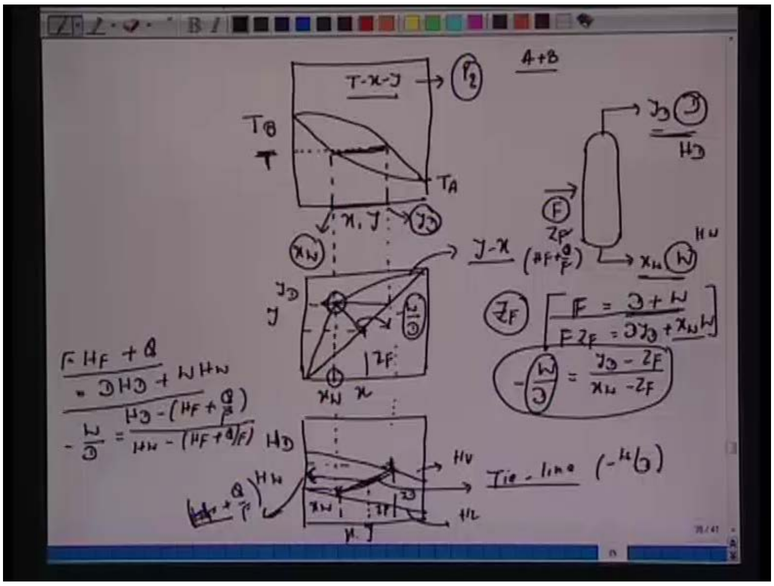

Let us draw this on T x y as well as H x y diagram. So, for this component A plus B we have this T x y diagram T x y diagram. So, let us see that we have this vapor liquid T x y diagram and this is note that at a pressure P 2, so P 2 is a downstream pressure of this flash drum, because liquid has been throttle to the pressure P 2 then the two phases have been separated. Now, this if the flash drum temperature is somewhere here T and the two streams, which leave from the flash drum they are in equilibriums then we can say that this is a tie line and this component here will be Y D and this component will be X W.

So, this is the meaning of this equilibrium for a given pressure P 2 fix the pressure, T is a temperature of the flash drum here in between T B, T A, A is more volatile than B A plus B binary components, we have fixing Y D and X W corresponding to this flash temperatures, so this is your T x y diagram. Now, let us plot just underneath this Y X diagram. We have done this earlier, so 45 degree lines. Now, if you take this projection here on the Y 45 degree line both this way, take X all the way till here, it intersects here this would be the coordinates of X plus component with X W and this would be Y D and this point will be on this Y X diagram; Y verses X diagram, because we are saying that two streams which are leaving the flash drum they are in equilibriums.

So, we have this point here coordinate is X W and Y W and we must note that this coordinate also corresponds to this temperature T here T x y. Underneath this now what happens, let us before we draw this H x y diagram. Let us look at what happens to Z F mole fractions of component A in the feed phase. So, if we have this flash drum here the feed was brought in F with component Z F and we have Y D total flow rate is D, we have X W total flow rate molar flow rate is W. It is not bring in enthalpy right now, because we are working on T x y diagram.

Now, look at this mixing rule F equals D plus W and this we did earlier and we can also write F multiplied by Z F equals Y D multiplied by D plus X W multiplied by W. So, let us rewrite may be F equal to D plus W F Z F equals D Y D plus X W in to W. Now again, we are applying the two mixing rules, which means if you fix a coordinate of D and W the coordinate of feed F will be on the straight line between D and W . So, from this one can obtain one can show that will get minus W by D equals Y D minus Z F over X W minus Z F . It is not difficult to show that here if you put Y D equal to Z F this mole fractions of the feed Z F, which is in between Y D and X W this would be on the 45 degree lines, because we put Y D equal to Z F X W will also will come in to Z F. So, this is your Z F it compositions, that means if you draw this line here slope of this line will be minus W over D, which is same as this .

So, let us try to understand here that we are trying to say that two fluids D and W can also be seen as mixed or coming out of this F. If you take F and it is all adiabatic. So, we writing material balance F equal to D plus W and there is no loss of the species F Z F equal to D Y D plus X W Y, that means the coordinate of this F has to be on a straight line joining T and W. So, this mole fraction is Z F here, we put in this equation of straight line minus W by D Y D minus Z F over X W minus Z F will be substitute Y D equal to Z F, we will get X W as Z F. So, here if we substitute with this coordinate at 45 degree line here connect these two points and can obtain minus W by D.

In other words, if you take this line and then you take a slope of minus W by D you will obtain this Z F or starting from Z F, if we take this slope of minus W by D you will obtain Y D and you will obtain X W. Similar, exercise one can also done on this H X Y diagram So here. We have X and we have Y here. Now, we take the projections of this Y, so this stream is saturated, a stream which is leaving here Y D is equilibrium with this W this coordinates comes here. If we take X W here all the way for this liquid, we have a saturated liquid connect this would be a tie line, that is one thing because two leaving streams were in equilibriums we have Y X from this tie line all the way projections we do it here this will also be a tie line. So, this coordinate is now X W, this coordinate is Y D. Here we have H D and this is H F plus Q over F.

So, this was enthalpy of this fluid here. Let us write down H T. We have H W and here we have this H F plus Q over F. Say this here is actually is actually this is H D here and this one is H W. Now where is this coordinate Z F just like you said that Z F equals D plus W we can also write enthalpy balance F H F, so we have F H F plus Q this is incoming to the flash drum. This equals D H D plus we have W in to H W and from this and the first equation F equal to D plus W. you should be able to obtain that again we have minus W over D as H D minus H F plus Q over F over H W minus H F plus Q over F.

So, one can again apply this mixing rule. There is no heat loss that means a coordinate of this Z F, if we mark it here this will correspond to this coordinate here this will has to correspond to H F plus Q over F. The full fact that we are mixing or we are separating F into D plus W as could as we mix D plus W to obtain F adiabatically. So, if we know this coordinate here we know the coordinate here we mix a draw this as a tie line mark this Z F on this the coordinate enthalpy coordinate has to be the enthalpy of this entry, fluid which enters H F plus Q by F and here also the slope of this line will be minus W by D that also comes from this geometries.

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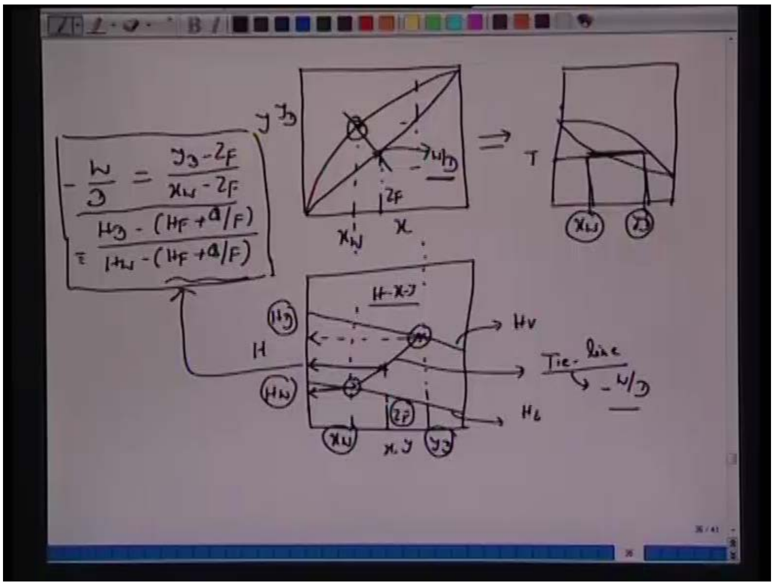

$$-\frac{W}{D} = \frac{y_D - z_F}{x_W - z_F} = \frac{H_D - (H_F + Q/F)}{H_W - (H_F + Q/F)}$$

We will redraw this line H x y diagram again. So, we have this Y X, we got Y D and we got this X W and the two streams where in equilibrium, so we have this point here. Just underneath we want to take projections on H x y diagram. So, we have this H V saturated vapor enthalpy curve and we have saturated liquid enthalpy curve, take all the way this projection for Y till here to obtain H D, take this X W all the way till here you obtain H W. So, we have X W and we have mark Y D. We have H W and we have H D. If we draw these two lines, this would be the tie line, because two streams which we are leaving where in equilibriums, remember this also came from P x y diagram. So, if we have this T x y diagram this was Y D and this was X W and this is the temperature.

So, the liquid flash of this temperature we have this two leaving streams Y D and X W, which we mark from this and we take this projections and we mark here. Where is the feed here and here well when we make this mixing rule here for the enthalpy for the species balance we said that we have the slope of the coordinate geometries minus W by D A amounts of liquid and the vapor leaving two streams can be shown to be equivalent to Y D minus Z F over X W minus Z F and this will also can be shown to be equal to H D minus H F plus Q by F over H W minus H F plus Q over F. So, going back to the mixing rule how we get Z F make use of this coordinate geometry. We know the mole fractions Z F on the feed F is 45 degree line; that means if you connect this, this would be minus W by D.

In other wards, if I fix Z F and take the slope of minus W by D, I will hit y D in x W or if I take Y D X W take the slope of minus W by D, I will reach this Z F or if I just take Z F and connect with x D, Y D, X W curve we will get this line slope would be minus W by D. The similar argument here, where is a feed, if I choose feed Z F in between x W here then the coordinate of this will be H F plus Q by F, because that is a mixing rule. We are mixing we are taking a feed, which has enthalpy of H F plus Q by F is now separated in two streams D and W two are in equilibrium fall on the line; on a straight line and this given the equation of the slope of this line is given by minus W by D. So, this is a tie line and the slope of this line will be minus W by D from here so this relation will be obtained.

So, it is very important that we understand that T x y diagram whatever we have done here in terms of marking the coordinates is as good as H x y diagram, where we have marked the coordinates of two streams, which are going to leave, given the feed state composition Z F and the enthalpy of this fluid as H F plus Q by F here. Now, in this case we have assumed that two streams vapor and the liquid they leave in equilibriums. So, that means when the feed was brought the superheated, this heated fluid pressurize liquid and it was flash after throttling. We gave enough time good mixing between the two phases vapor and liquid, so that the two leaving streams are equilibrium that means one temperature T and Y D and x W they are on the tie line T x y.

So, when we take a projection on Y X, we mark this point Y D and x W. Where is a feed, well we choose a feed as Z F, which is entering and we connect with this line on the equilibrium curve the slope of the curve will be the receives of W and D that comes from the coordinate geometries minus W by D. It take further projections on H x y diagram, we should also be able to convince your self that now the tie line, which you join between the H V and H L corresponding to Y D and X W and corresponding to the enthalpy of H D and S W, there the slope of the tie line will also be minus W by D, because two leaving streams are in equilibriums.

There are cases when there in a non-ideality or non-equilibriums and it is possible that two streams may not leave in equilibriums and then the several possibilities of non-equilibriums, which we will like to redraw and see on this H x y diagram or on T x y diagram you can have different scenarios of non-equilibriums, which we take up in the next lecture.