Distillation
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Module - 5
Distillation
Lecture - 11
Fractional Distillation: Ponchan and Savarit Method

Welcome to the eleventh lecture of module 5. We are discussing distillation; so let us have some recaps of our previous lecture.

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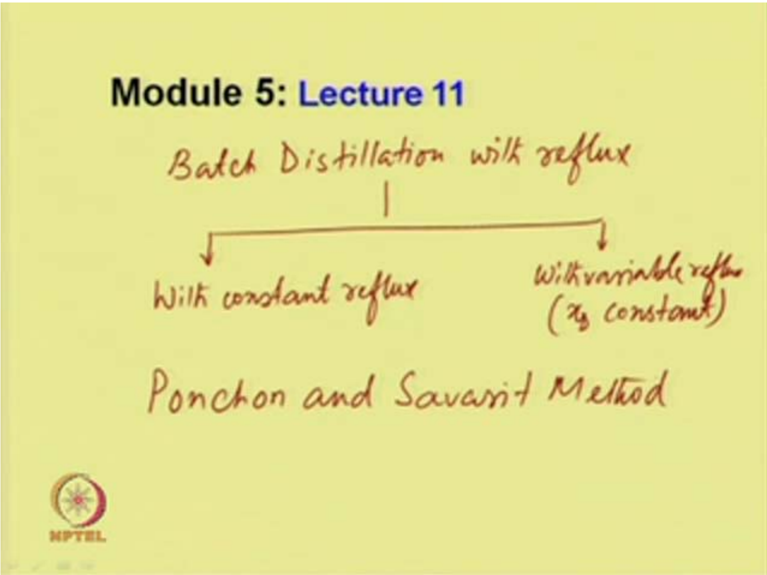

In our previous lecture, we have discussed the batch distillation with reflux, batch distillation, and we have discussed two categories of batch distillation with reflux; one is with constant reflux, and other one is with variable reflux, and where x D the distillate composition is constant. All our distillations, we have discussed before, we assumed constant molar overflow. So, today we will discuss another method, which is known as Ponchon and Savarit method. This method was developed by Ponchon and Savarit in 1921 and 22.

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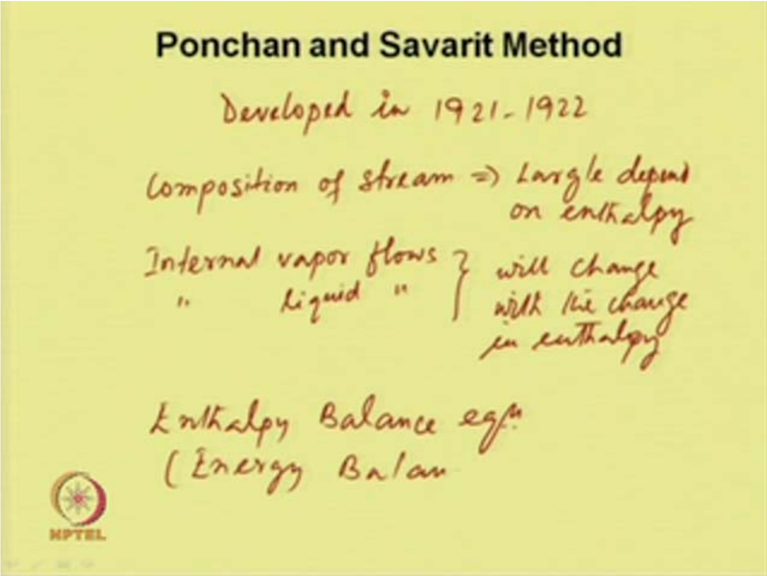

In this case with the total material balance and species mol balance, another balance which is the enthalpy balance is considered, if the composition of stream largely depend on enthalpy. Then the internal liquid and vapor flow from stage to stage will change. Internal vapor flows and internal liquid flows will change, change with the change in enthalpy.

So, earlier assumed the equimolar over flow so that the molar flow rates remains constant in each sections. So, in this case in addition to the mass and species mol balance equations we will considered another balance equations that is enthalpy balance or energy balance. The Ponchon-Savarit method is also a graphical method as we did for Mccabe-Thiele method it is also a graphical method which considers both material balance and energy balance.

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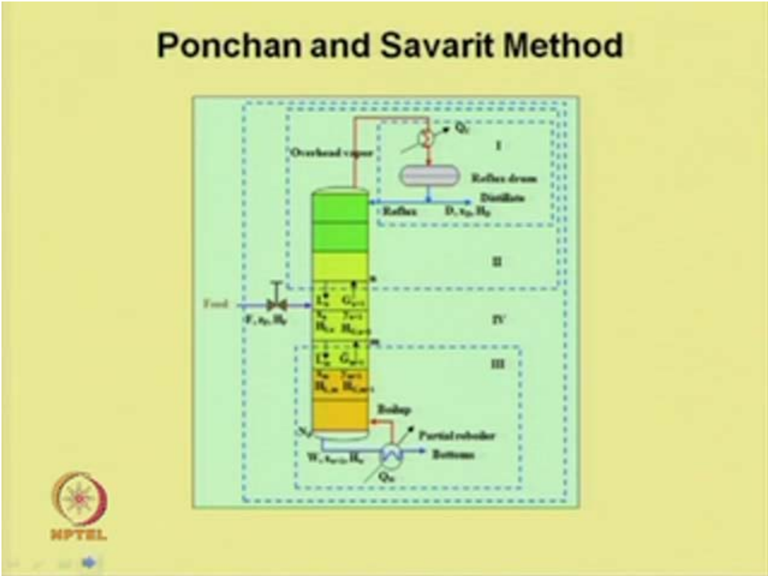

Let us considered the similar column we have taken earlier, we have divided into four sections. Section 1 which incorporates the reflux drum, distillate and the reflux and the condenser over here and in section 2 which we have considered above the feed plate which is the rectifying section and then section 3 is below the feed plate that is stripping section and then we have overall column balance which is section 4 and say in case of distillate D is the distillate, x D is the distillate composition and H D is the enthalpy of the distillate. Similarly, each stream a liquid falling for a particular tray is Z n by L n.

Composition is x n and liquid composition is H L n, the vapor which is going out from plate n plus 1 is G n plus 1 vapor composition is y n plus 1 and vapor enthalpy is H G n plus 1. So, similarly, in the liquid stream the enthalpy liquid flow rate and compositions and the vapor flow rate and the vapor compositions are denoted. In the bottoms, which is coming out denoted by w and composition is x w plus 1 and enthalpy is H w.

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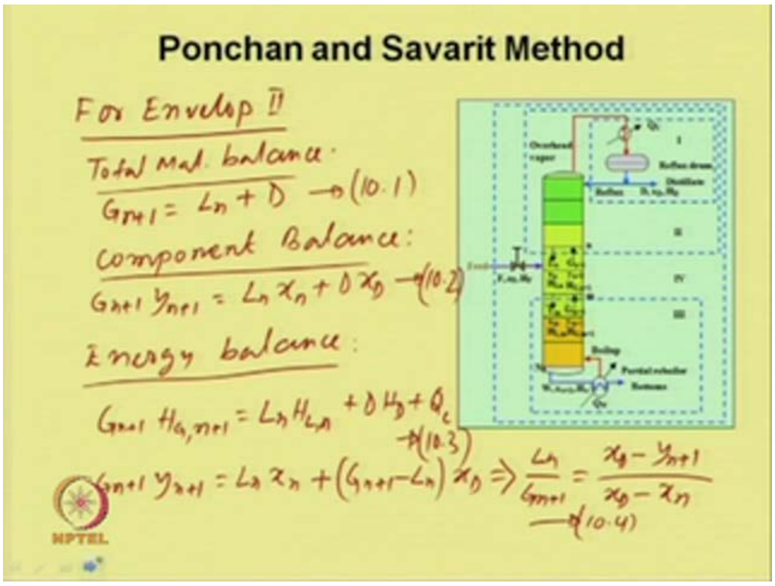

Let us considered material and energy balance equations for envelop 2. Total material balance G n plus 1 is equal to L n plus D, component balance this is a 10.1. G n plus 1 y n plus 1 is equal to L n x n plus D x D 10.2. So, the energy balance equations G n plus 1 H G n plus 1 would be equal to L n H L n plus D H D plus Q c is considering the condenser. So, this is equation 10.3. From equations 10.1 and 10.2 if you substitute over here we will have G n plus 1 y n plus 1 would be equal to L n x n.

So, from equation 10.1 and 10.2 we can write this will be equal to L n x n plus G n plus 1 minus L n into x D, so which will give L n by G n plus 1 would be equal to x D minus y n plus 1 divided by x D minus x n. So, this is equation number 10.4.

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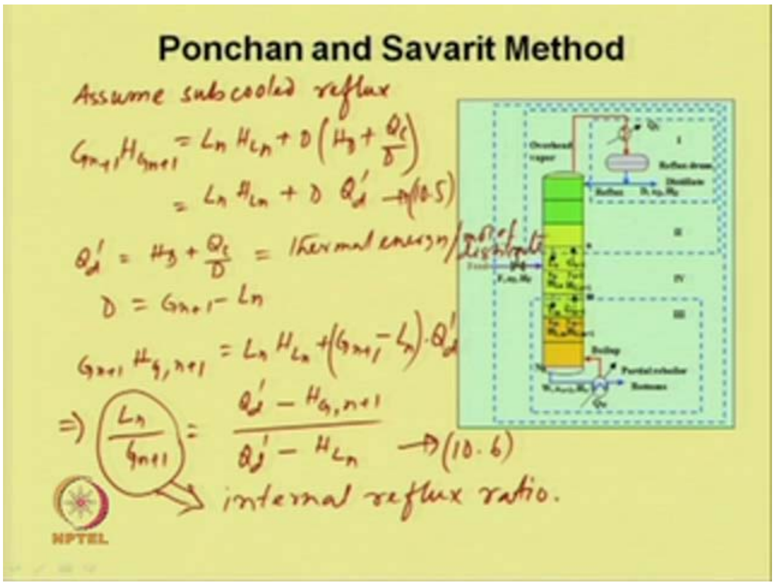

If we assume the reflux which is coming out it may be sub cooled reflux. Assume sub cooled reflux and the mol fractions is x D for 8 then we can write the energy balance equation 10.3 which we have written over here the energy balance equations.

We can write G n plus 1 H G n plus 1 would be L n H L n plus D into H D plus Q c by D is equal to L n H L n plus D Q d dash. This is equation number 10.5. Q d dash is equal to H D plus Q c by D. This is the thermal energy, energy removed from top section per mol of distillate, mol of distillate. If we put from total material balance equations D is equal to G n plus 1 minus L n. If we put in this equations 10.5 we will get G n plus 1 H G n plus 1 is equal to L n H L n plus G n plus 1 minus L n into Q d dash. If we rearrange this it is L n by G n plus 1 is equal to Q d dash minus H G n plus 1 divided by Q d dash minus H L n. So, this is equation number 10.6. So, this quantity in the left hand side L n by G n plus 1, this represents the internal reflux ratio, internal reflux ratio.

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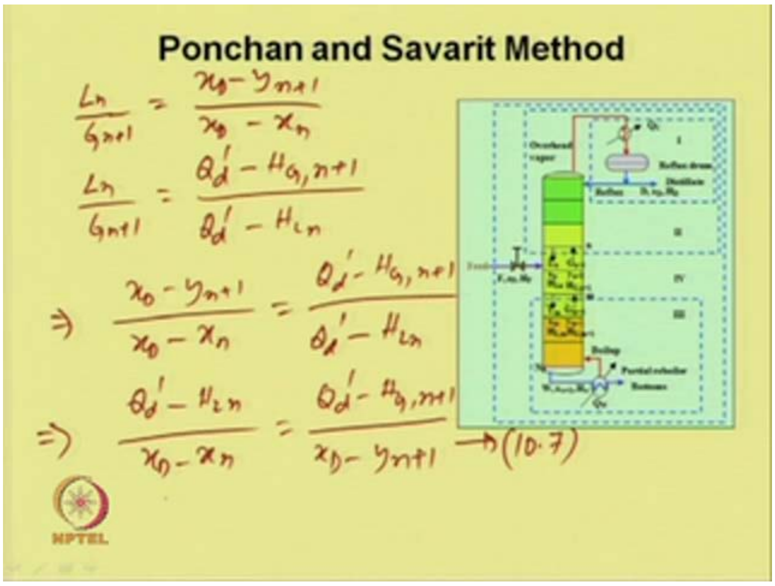

Now, from equations 10.5 and 10.3 we can write L n by G n plus 1 is equal to x D minus y n plus 1 by x D minus x n. Similarly, from 10.6 L n by G n plus 1 is equal to Q d dash minus H G n plus 1 divided by Q d dash minus H L n. So, from this two we can write x D minus y n plus 1 divided by x D minus x n is equal to Q d dash minus H G n plus 1 divided by Q d dash minus H L n. So, from this we can write Q d dash minus H L n divided by x D minus x n is equal to Q d dash minus H G n plus 1 divided by x D minus y n plus 1. So, this is equation 10.7. From this equation, the left hand side Q d minus H L n by x D minus x n can plot in the enthalpy concentration diagram over here.

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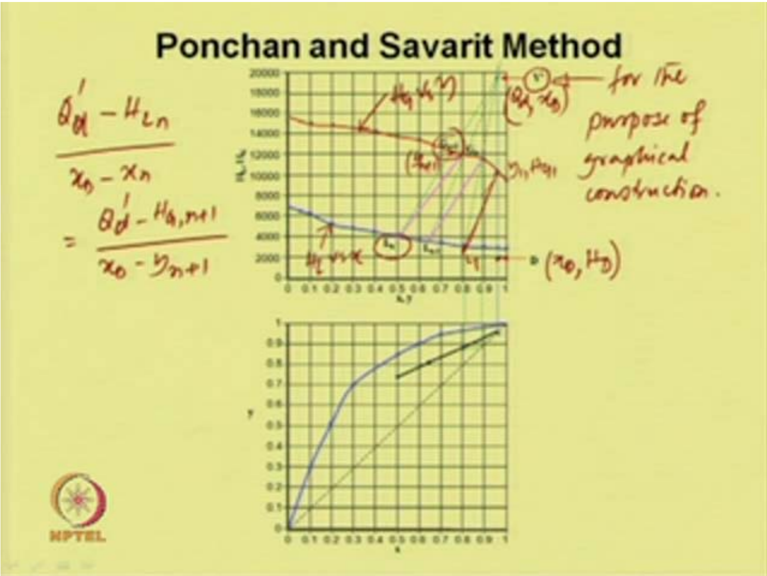

So, we can write Q d minus H L n divided by x D minus x n is equal to Q d minus H G n plus 1 divided by x D minus y n plus 1. So, all this parameters are plotted here in the enthalpy concentration diagram where this represents H G verses y and this represents H L verses x. A point on this diagram represents the composition and phase of a particular stream with the liquid vapor are mixed and the point L n here represents the liquid which is leaving for a particular plate and entering 2 n plus 1 plate and the enthalpy for this is H L n. Suppose this is a composition v dash is Q d and x D composition and then the point over here is G n plus 1 and y n plus 1.

So, the right hand side represents the slope of the line passing through the points y n plus 1 G n plus 1 and the points Q d x D and the left hand side of this equations represents the slope of the curve which is passing through the points Q d x D and H L n and x n. So, the points between Q d x D and y n plus y n plus 1 G n plus 1 and x n L n are collinear.

So, the point Q d and x D can be obtained by subtracting L n from G n plus 1 which is denoted over by point v dash. This is the point which is a fictitious points, just denoted for the purpose of this graphical construction, purpose of graphical construction. If the distillate is sub cooled then the point which is denoted over here x D H D and the lines which is passing between v dash and D which is below the x H L curve, this is x H L curve. So, this point lies below since the distillate is sub cooled. So, if we put n is equal to 1 in this equations then this point represents y 1 H G 1 and this points we will meet which is L 1.

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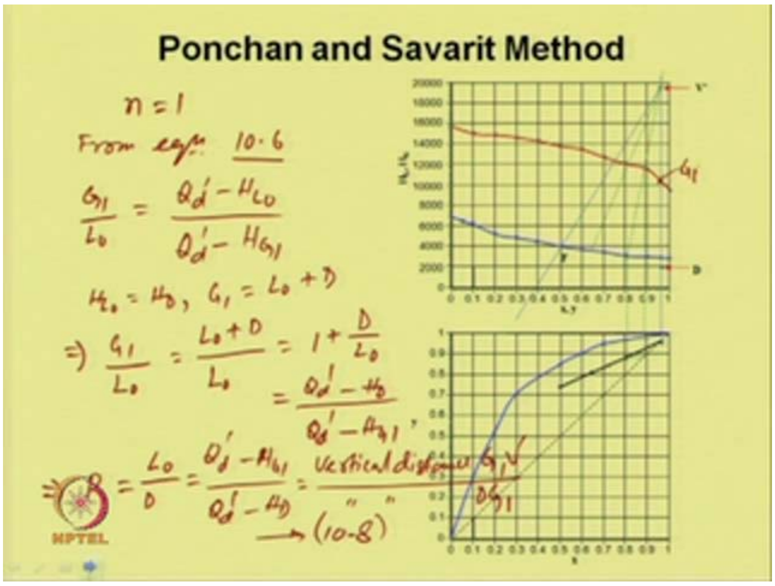

Let us considered in our earlier equations n is equal to 1 and then we will get from equation 10.6. We will get G 1 by L naught would be equal to Q d dash minus H L naught divided by Q d dash minus H G 1. Note that H L naught is equal to H D and G 1 is equal to L naught plus D. So, then G 1 by L naught would be L naught plus D divided by L naught which is equal to 1 plus D by L naught which is equal to Q d dash minus H D divided by Q d dash minus H G 1. From this we can write reflux ratio R would be L naught by D which is equal to Q d dash minus H G 1 divided by Q d dash minus H D. So, this is the vertical distance, vertical distance of G 1 which is here. G 1 and v dash, G 1 v dash divided by vertical distance D G 1. So, this is equation 10.8.

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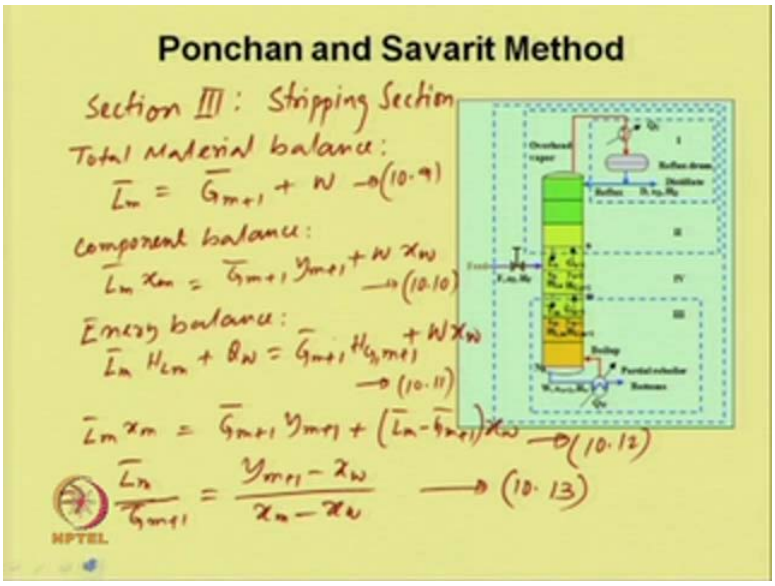

Let us consider the balance on stripping section that is section 3. Stripping section the total material balance in this section we can write, total material balance L m bar would be equal to G m plus 1 bar plus w 10.9. Component balance L m bar x m would be equal to G m plus 1 bar y m plus 1 plus w x w 10.10 and the energy balance equation which is L m bar H l m plus Q W is equal to G m plus 1 bar H G m plus 1 plus w x w 10.11. Now, from the total material balance equations if we put W is equal to L m bar minus G m plus 1 bar, then we will have L m bar x m is equal to G m bar m plus 1 bar y m plus 1 plus L m bar minus G m plus 1 bar into x w, this is 10.12 and from this also we can write L m bar by G m plus 1 bar would be equal to y m plus 1 minus x w divided by x m minus x w which is 10.13.

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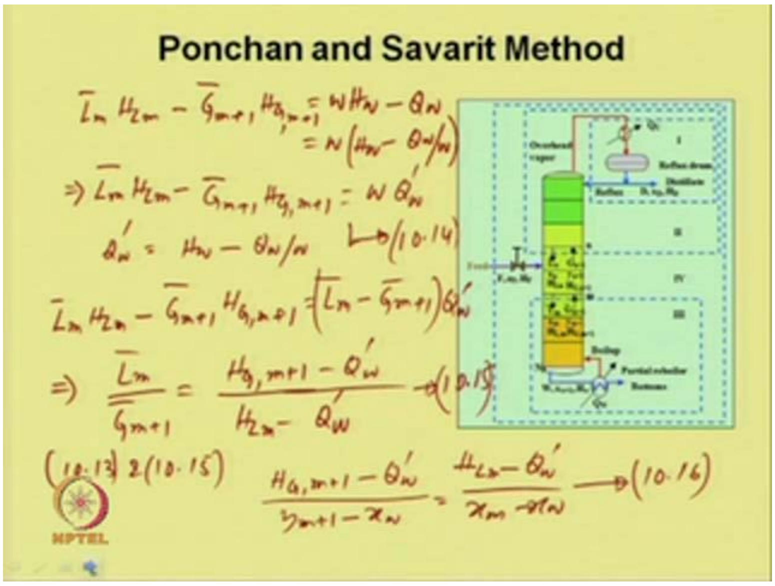

Now, 10.11 this energy balance equations we can write as L m bar H L m minus G m plus 1 bar H G m plus 1 is equal to w H w minus Q w which is equal to w into H w minus Q w by w. From this we can write L m bar H L m minus G m plus 1 bar H G m plus 1 would be equal to W Q w dash where Q w dash is equal to H w minus Q w by w.

So, this is equation number 10.14. Now from the total material balance if we put w is equal to L m bar minus G m plus 1 bar, then this equations becomes L m bar H L m minus G m plus 1 bar H G m plus 1 would be equal to L m bar minus G m plus 1 bar into Q w dash. From this we can write L m bar divided by G m plus 1 bar would be equal to H G m plus 1 minus Q w dash divided by H L m minus Q w dash, this is equation number 10.15. From 10.13 and 10.15 from this two we can write H G m plus 1 minus Q w dash divided by y m plus 1 minus x w would be equal to H L m minus Q w dash divided by x m minus x w. So, this is the equation 10.16.

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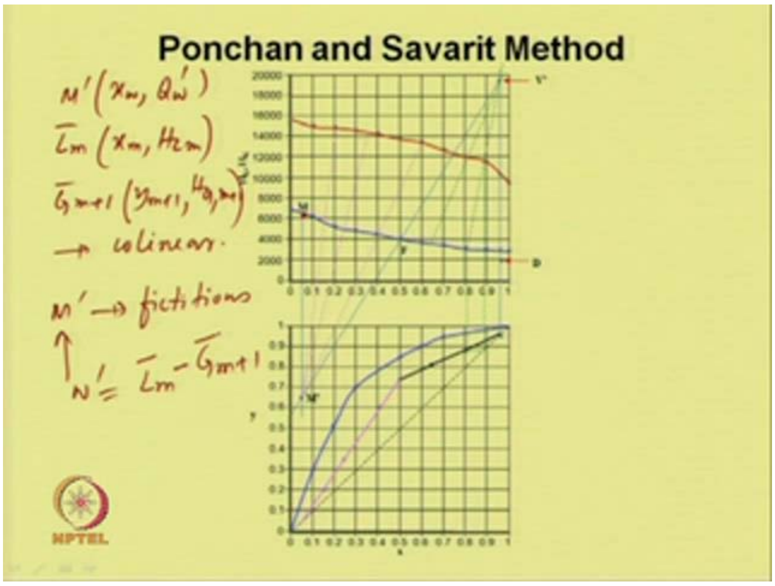

The discussions we have done in case of the rectifying section if we extend the similar discussion over here we could see we have the points over here which is m dash m is the point which is bottoms which coming out and the point m dash which is x w Q w dash and L m bar which is x m H L m and the points G m plus 1 bar which is y m plus 1 and H G m plus 1. So, this three points they are collinear.

So, the points m dash is the fictitious point, fictitious stream which concentration is x w and enthalpy is Q w dash, Q w dash is H w minus Q w by y w and the flow rate at this point is w dash which is equal to L m bar minus G m plus 1 bar, let us see how to proceed for the graphical contractions of Ponchon and Savarit method.

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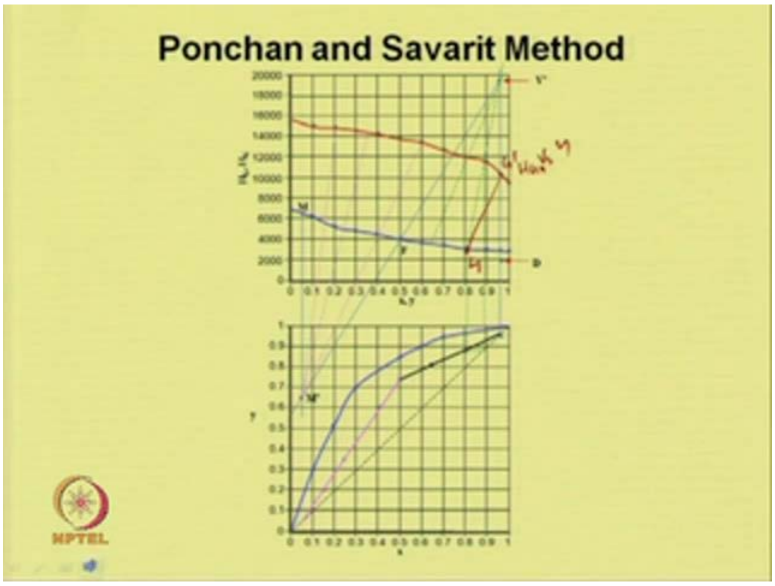

In the enriching sections we know the point v dash and we know the point distillate and if we draw a line originating from this point with a different slope above the feed plate, so the line which is drawn over here and meeting a point on a H G verses y curve at point G 1 and then with a another line which is coming over here, G 1 and the L 1 they are in equilibrium. So similarly, we can draw the line, the stage contractions in the stripping section as well which is starting from point m dash. Now, we have to locate the feed plate locations, the feed plate.

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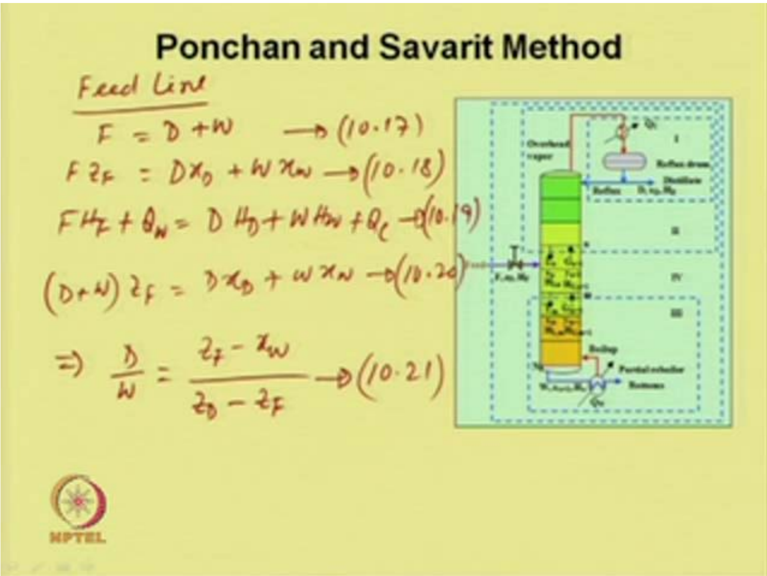

To draw the feed line we need to do the material and energy balance equation over the feed plate. So, feed line, for feed line if you do the overall material balance which F is equal to D plus w which is 10.17 and component balance F z F is equal to D x D plus w x w and the energy balance equations F H F plus Q w is equal to D H D plus w H w plus Q C. So, it is 10.19. If you substitute from 10.17 into 10.18 we will have D plus w z F would be equal to D x D plus w x w. So, which is equations 10.20. From this we can write D by w would be equal to z F minus x w divided by z D minus z F 10.21.

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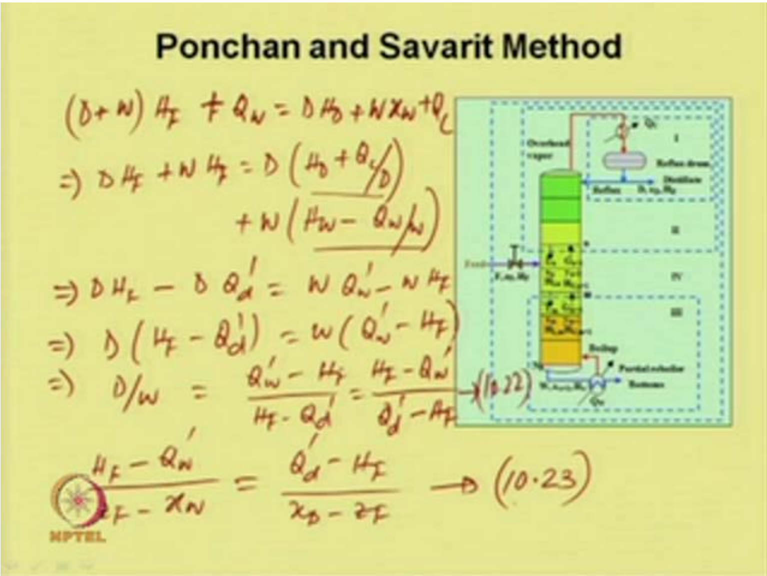

Similarly, from 10.17 and 10.19 which is the energy balance equations, we can write D plus w into H F plus Q w is equal to D H D plus w x w plus Q C and from this we can write D H F plus w H F is equal to D H D plus Q C by D plus w H w minus Q w by w. From this we can write D H F minus D, this part is Q d dash is equal to w and this part is Q w dash minus w H F. So, we can write D into H F minus Q d dash is equal to w into Q w dash minus H F. So, D by w would be equal to Q w dash minus H F divided by H F minus Q d dash or is equal to H F minus Q w dash divided by Q d dash minus H F. So, this is equation number 10.22.

From 10.21 and 10.22, 10.21 and 10.22 we can write H F minus Q w dash divided by z F minus x w would be equal to Q d dash minus H F divided by x D minus z F. So, this is equation 10.23.

Thank you for your attentions and we will continue this lecture in the next class.