Mass Transfer Operations I
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Module - 4
Absorption
Lecture - 3
Packed Tower Design Part 2

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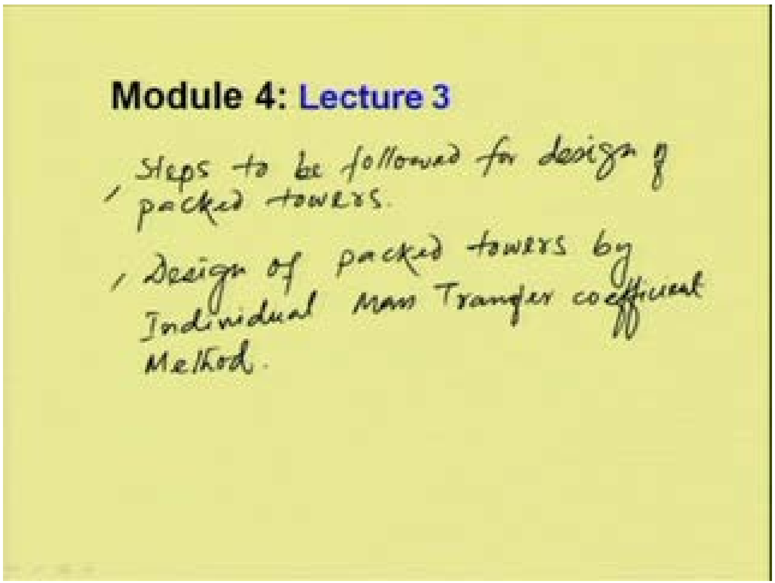

Welcome to the third lecture of module four. In the previous lecture, we have discussed the absorption towers packed and plate plate towers are used for absorption, and we have started with the steps to be followed, followed for design of packed towers. And some of the design procedures are discussed previously, and we consider design of packed towers by individual mass transfer transfer coefficient method.

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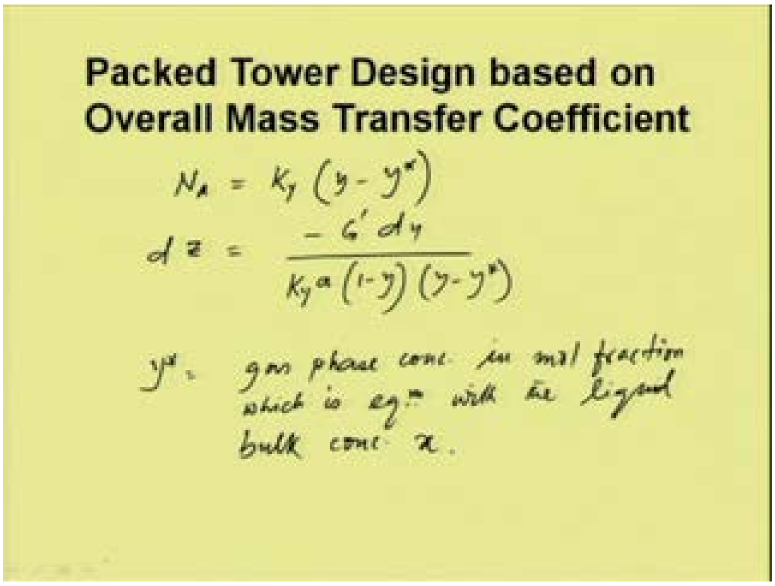

In this lecture, we will discuss packed tower design by overall mass transfer coefficient methods, and also by height of transfer unit methods. So, let us consider packed tower design based on overall mass transfer coefficient method. Now, if we express the overall flux N A is equal to capital K y into y minus y star; capital K y is the overall mass transfer coefficient for the gas phase, and then we can write dz is equal to minus G dash dy divided by capital K y a into 1 minus y into y minus y star; y star is the gas phase concentration in mole fraction, which is equilibrium, equilibrium with the liquid bulk concentration x.

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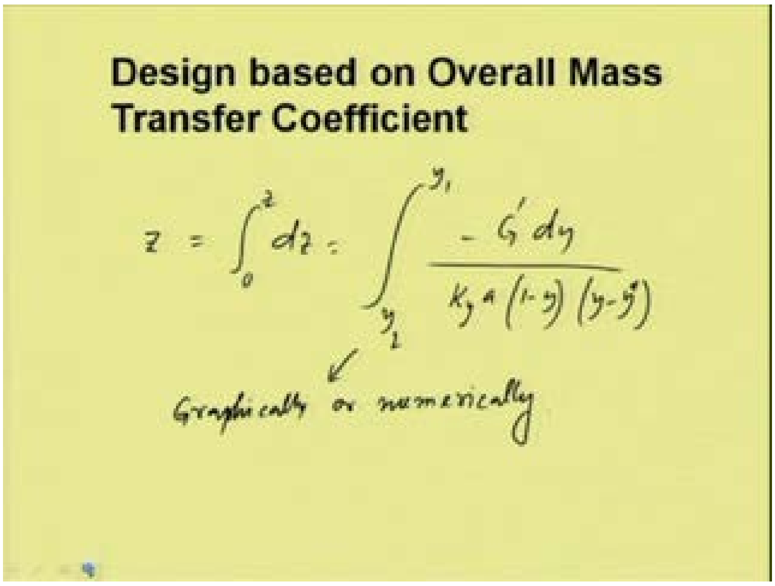

Now, the required packed height, we can obtain by integration of this equation. So, z would be equal to integral 0 to z dz would be integral y 2 to y 1 G dash dy by capital K y a 1 minus y y minus y star. So, now this integration can be done either graphically or numerically.

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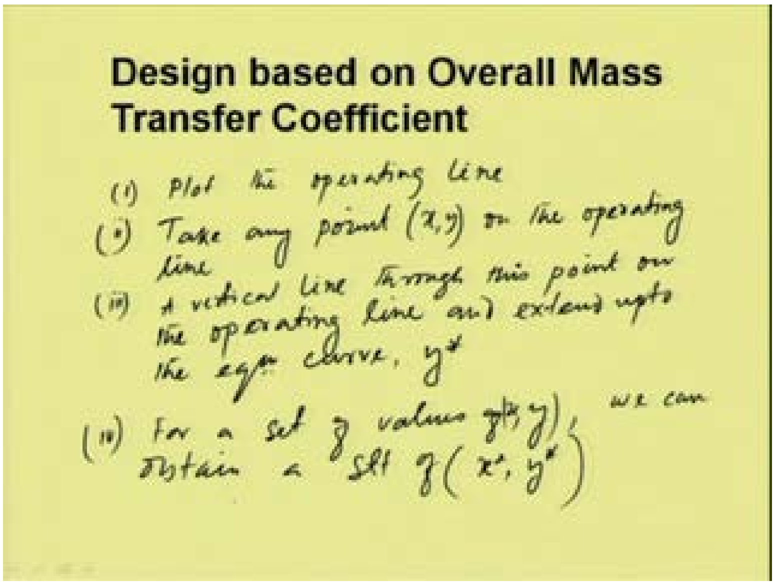

So far graphical integration we can follow the procedure, first plot the operating line, and then take any point x, y on the operating line, then we can draw a vertical line through this, through this point on the operating line, and extend up to the equilibrium curve curve which meets at a point y star. For a set of values of x, y we can obtain a set of set of x star y star, and then we can obtain the value of the integration.

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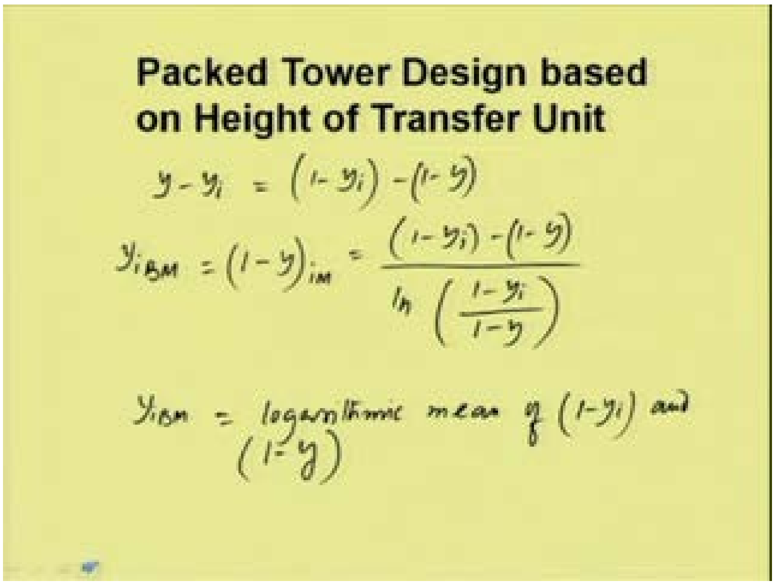

So, now we will consider another method which is packed tower design by height of transfer unit, we know that y minus y i is equal to 1 minus y i minus 1 minus y. So, y i B M is the log mean concentration gradients, we can write is equal to 1 minus y i M is equal to 1 minus y i minus 1 minus y divided by ln 1 minus y i divided by 1 minus y, y i B M is equal to logarithmic mean of 1 minus y i and 1 minus y.

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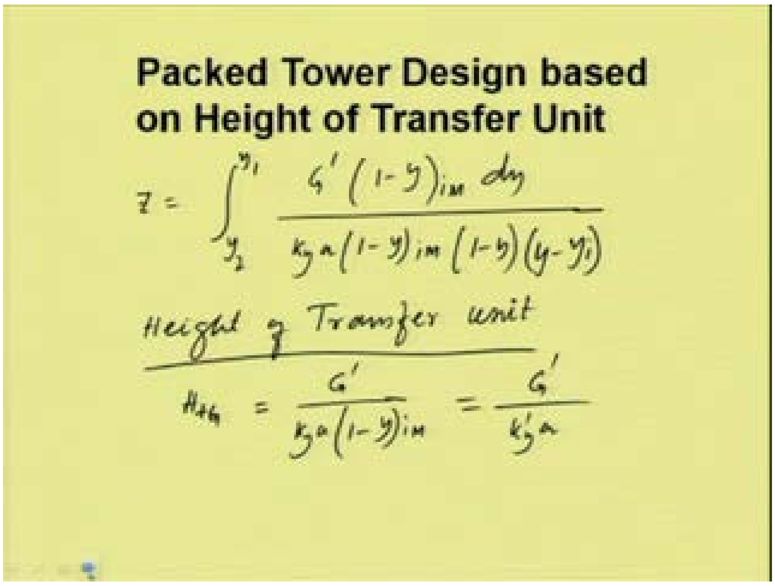

Now, we can calculate the height of the packing z, we can write z is equal to integral y 2 to y 1 G dash 1 minus y i M dy divided by small k y a into 1 minus y i M into 1 minus y y minus y i. We can define the height of transfer unit height of transfer unit unit, we can define h t G is equal to G dash divided by k y a 1 minus y i M. We can this will be G dash divided by k y dash a.

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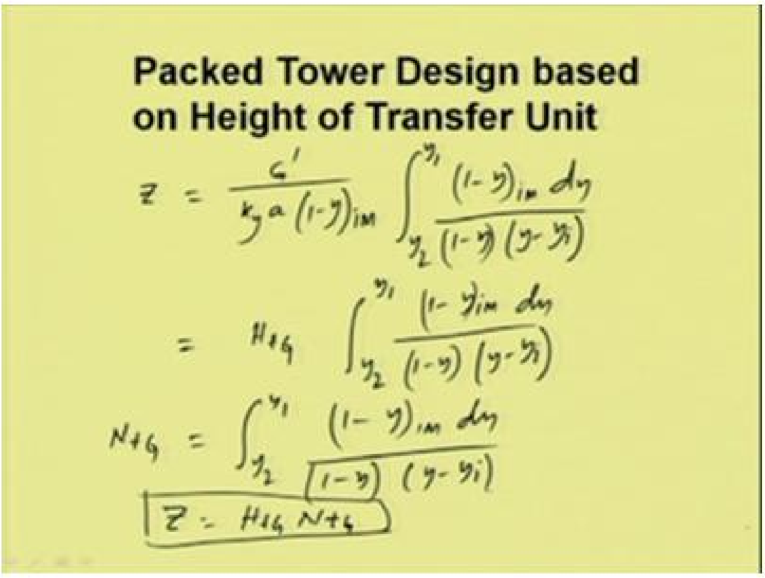

So, this equation of z we can write z is equal to G dash by k y a 1 minus y i M integral y 2 to y 1 1 minus y i M dy divided by 1 minus y into y minus y i. So, this we can write H t G integral y 2 to y 1 1 minus y i M divided by 1 minus y into y minus y i. The integral of this part can be termed as or defined as N t G. So, N t G is equal to integral y 2 to y 1 1 minus y i M by into dy divided by 1 minus y into y minus y i. Therefore, z is equal to H t G into N t G. So, this is the equations of packed height in terms of height of transfer unit and number of transfer unit.

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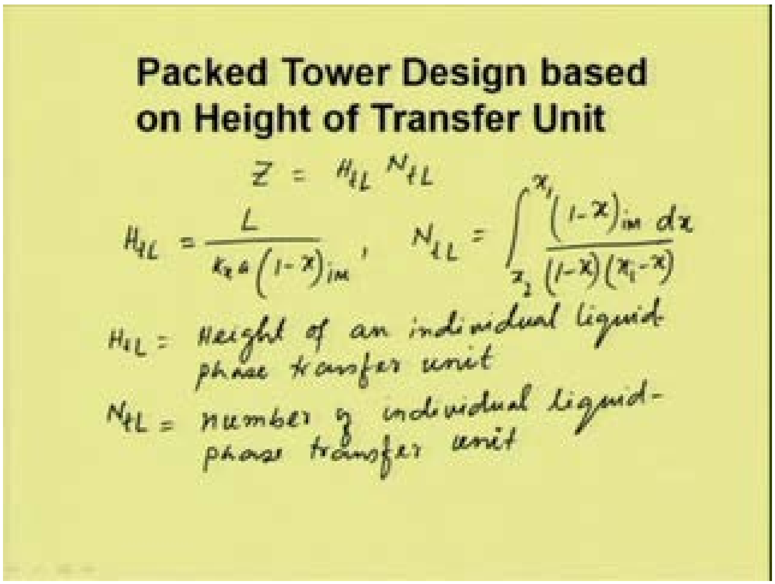

Now, this relationship we can apply for liquid concentrations as well. So far liquid concentration, we can write the counter part of this equation is equal Z is equal to H t L N t L. So, H t L is defined as is equal to L by k x a into 1 minus x i M, and N t L can be written as integral x 2 to x 1 1 minus x i M divided by 1 minus x into x i minus x into dx. So, H t L is basically height of an height of an individual liquid phase transfer unit, and N t L number of number of individual liquid phase transfer unit liquid phase transfer unit. So, this is in terms of the liquid phase concentration of the species, we can define the height of transfer unit and number of transfer unit, and then we can calculate the packing height.

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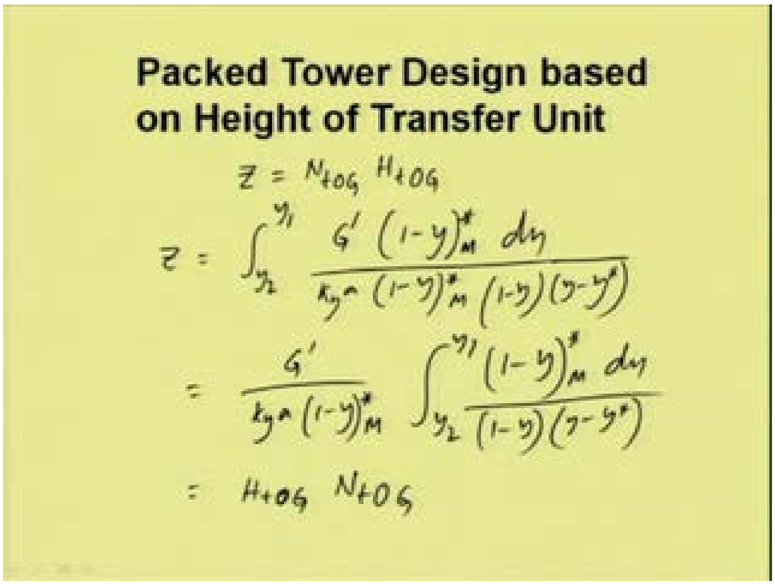

Now, for some cases the equilibrium distribution curve is straight, and the ratio of the mass transfer coefficient is constant. Z is equal to N t OG into H t OG, where Z is equal to integral y 2 to y 1 G dash into 1 minus y star M dy divided by k y a into 1 minus y star M into 1 minus y into y minus y star. This we can write G dash divided by k y a into 1 minus y star M integral y 2 to y 1 1 minus y star M dy divided by 1 minus y into y minus y star. So, this part is known as H t OG and this is N t OG.

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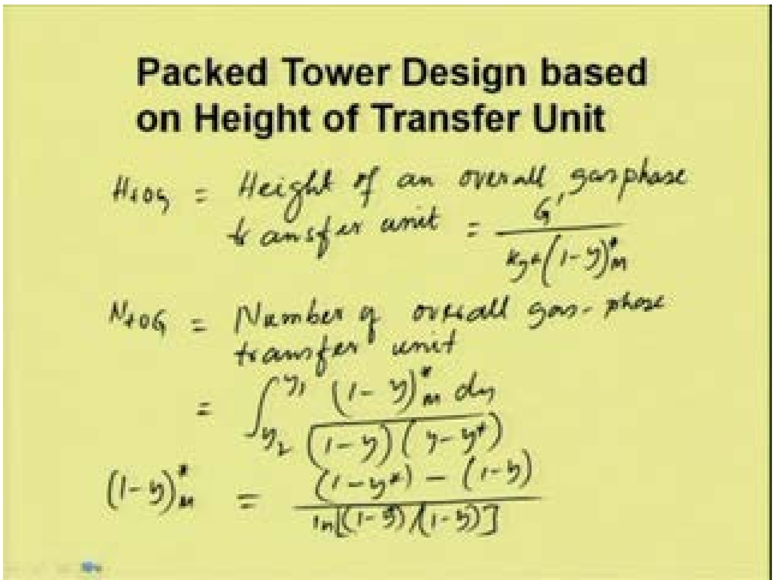

So, this is based on the overall mass transfer coefficient H t OG is equal to height of height of an overall gas phase transfer unit unit, which is equal to G dash divided by K y a into 1 minus y star M. And N t OG is equal to number of overall gas phase transfer unit which is equal to integral y 2 to y 1 1 minus y star M dy divided by 1 minus y into y minus y star. And 1 minus y star M is equal to log mean concentration gradient 1 minus y star minus 1 minus y divided by ln 1 minus y star divided by 1 minus y.

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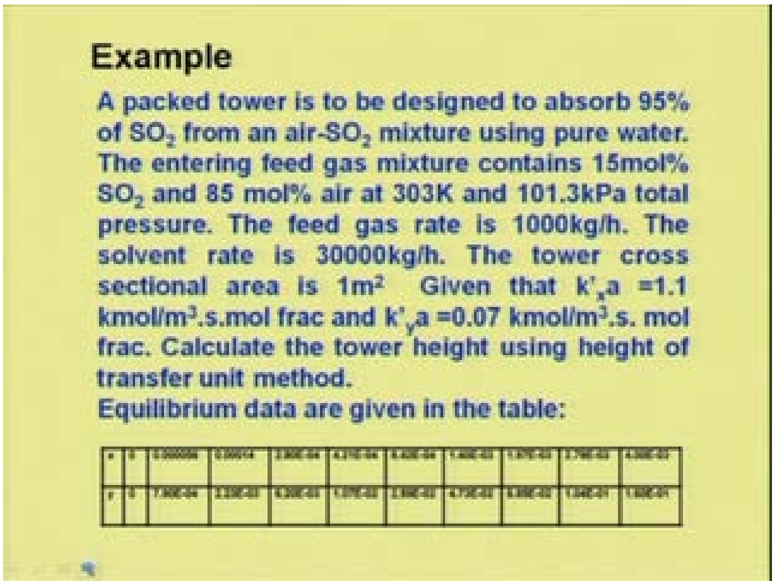

Let us take an example to calculate the packed tower height. We will consider the similar example as we considered in our previous lecture, and in this case the value of all the parameters remains almost similar as we can see the equilibrium data is also same for the system and this is a packed towers is to be design to observe 95 percent of sulfur dioxide form an air ratio to mixture using pure water. The entering feed gas mixture contains 15 mole percent sulfur dioxide and 85 mole percent air at 303 kelvin, and 101.3 kilo pascal total pressure. The feed gas rate is given 1000 K G per hour, the solvent rate is also given 30000 K G per hour the tower, cross sectional area is 1 meter square and it is given that k dot x a is 1.1 K mole per meter square second mole fraction, and k dot y a is equal to 0.07 K mole per meter cube second mole fraction, calculate the tower height using height of transfer unit method.

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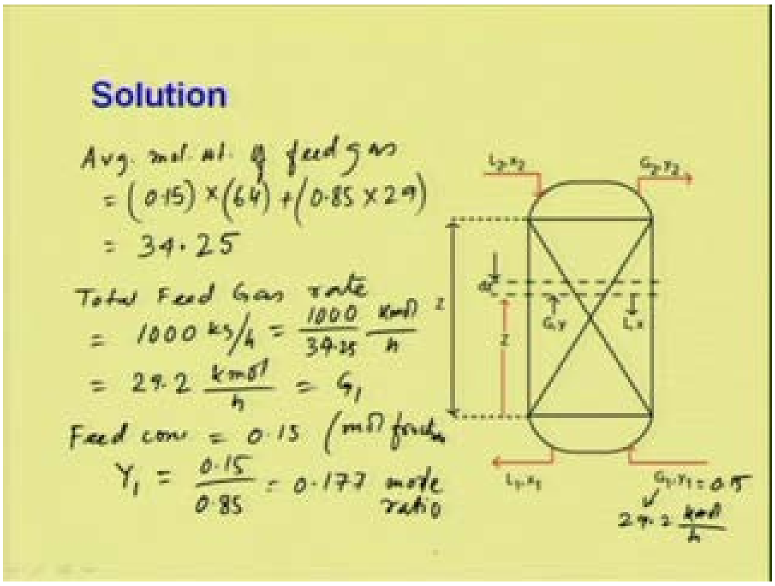

So, the last method which we have discussed we will follow the similar procedure, here this is the factors and all the symbols as we discussed earlier in the derivations are remain same. So, now we will calculate the average molecular weight of the feed gas, average molecular weight of feed gas is equal to 0.15 15 mole percent into 64 plus 85 percent is air into 29. So, this will give 34.25, then total feed gas rate total feed gas rate we can calculate which is given 1000 K G per hour which is equal to 1000 divided by 34.25 this will be kilo mole per hour. So, this is equal to 29.2 K mol per hour, this is we can define as G 1 - this G 1 is 29.2 K mol per hour.

Now, feed concentration is given feed concentration is equal to 0.15 mole fraction that is this one 0.15. So, we can calculate capital y 1 is equal to 0.15 by 0.85 is equal to 0.177 this is mole ratio.

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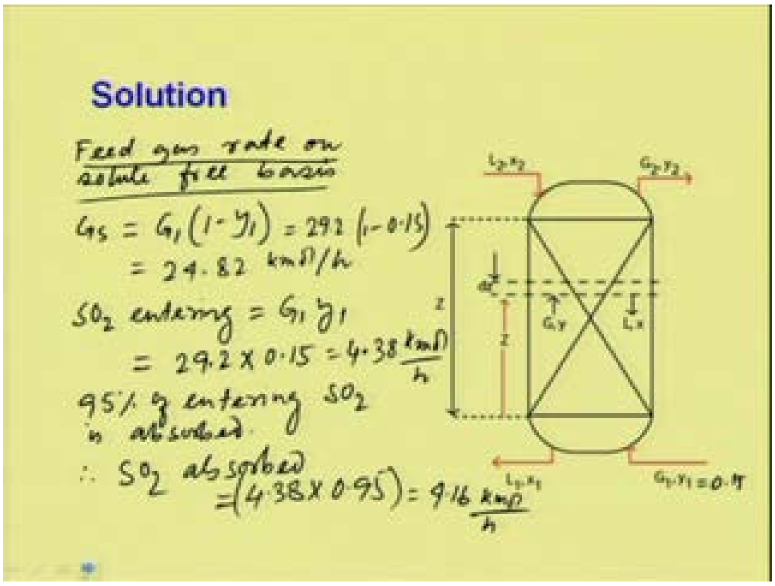

Now the feed gas rate on solute free basis, we can calculate feed gas rate on solute free basis. So, that is G s is equal to G 1 into 1 minus y 1 which is equal to 29.2 into 1 minus 0.15 which will give 24.82 K mol per hour, and the entering SO 2 is equal to G 1 y 1 which is equal to 29.2 into point y 1 is 0.15. So, 1 5 which is 4.38 K mol per hour, now 95 percent of entering entering sulfur dioxide is absorbed absorbed.

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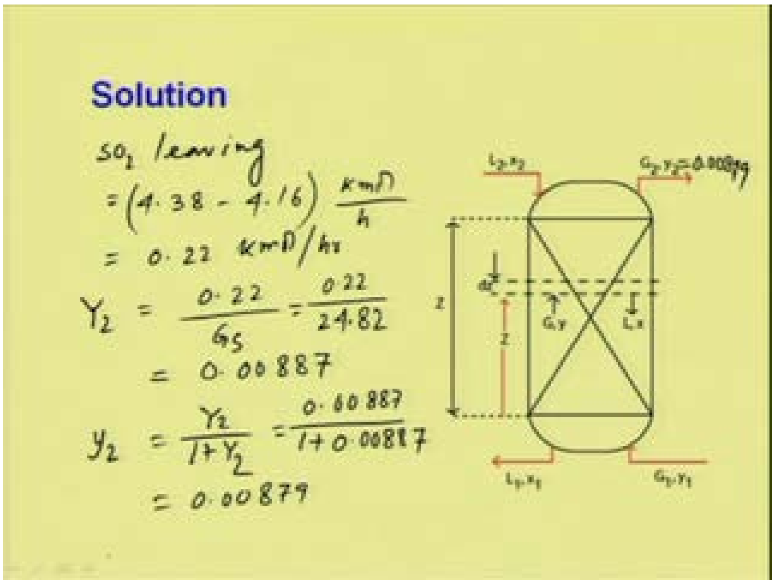

Then S o 2 which is absorbed is equal to 4.38 into 0.95 is equal to 4.16 k mol per hour. So, this is the amount absorbed, so the amount leaving from the tower. SO 2 leaving is equal to 4.38 minus 4.16 K mol per hour, so which is equal to 0.22 K mol per hour. Now we can calculate the gas phase concentration at the exit, Y 2 is equal to 0.22 by G s is equal to 0.22 by 24.82 which is equal to 0.00887. Similarly y 2 will be capital Y 2 by 1 plus y 2 which is equal to 0.00887 divided by 1 plus 0.00887 which is equal to 0.00879. So, this is the exit concentrate 0.00879.

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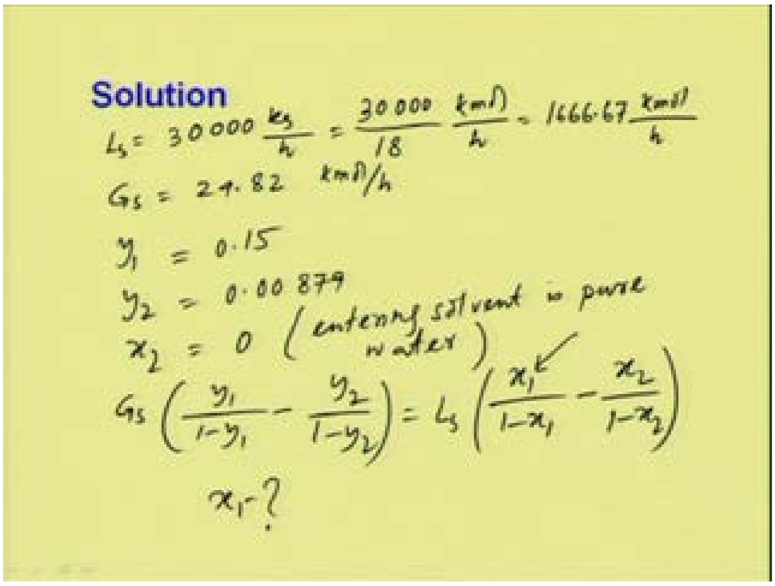

Now, we know that L s is given 30000 K G per hour. So, which is equal to 30000 by 18 K mol per hour, this is the pure water rate which is equal to 1666.67 K mol per hour. G s we have calculated G s is equal to 24.82 K mol per hour, and y 1 we know that 0.15, y 2 is 0.00879, and x 2 also known which is 0, the entering solvent solvent is pure water. So, x 2 should be 0, G s into y 1 by 1 minus y 1 minus y 2 by 1 minus y 2 will be L s into x 1 by 1 minus x 1 minus x 2 by 1 minus x 2. Now, if we substitute we know all the parameters except x 1, x 1 is unknown.

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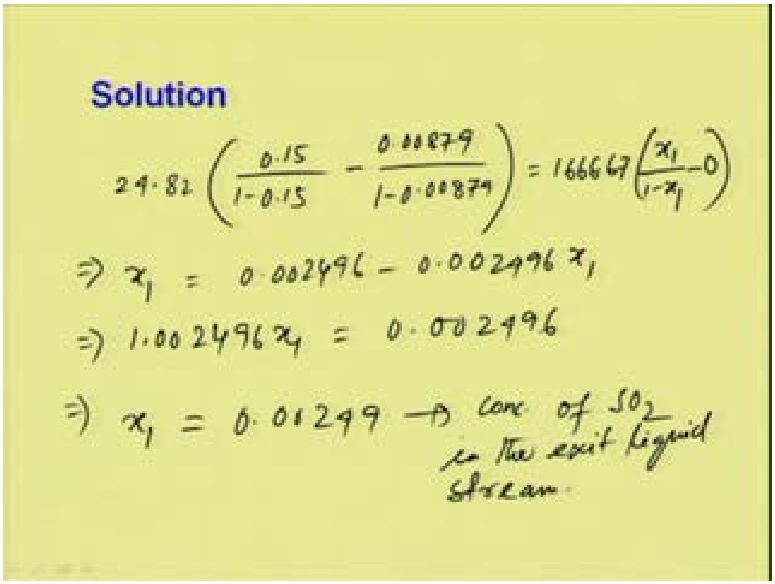

So, if we substitute this parameter it will be 24.82 into 0.15 divided by 1 minus 0.15 minus 0.00879 divided by 1 minus 0.00879 is equal to 1666.67 into x 1 by 1 minus x 1 minus 0. So, from this we can calculate x 1 would be 0.002496 minus 0.002496 x 1. So, from this x 1 1.002496 x 1 would be 0.002496. So, x 1 after solving it will be 0.00249. So, this is the concentration; concentration of SO 2 in the in the exit liquid stream.

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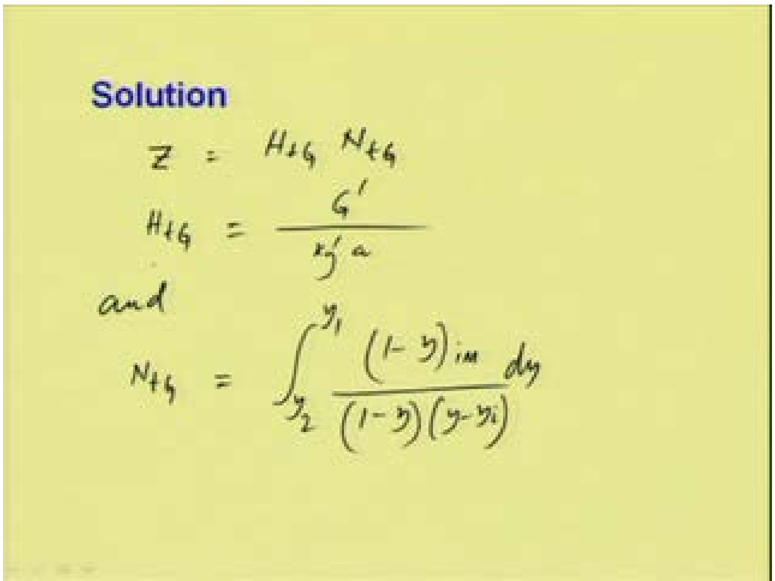

Now, if we use the method of overall height of transfer unit to calculate the packing height, we know that z is equal to H t G into N t G. So, H t G is equal to G dash by k y dash a, and N t G t G is equal to integral y 2 to y 1 1 minus y i M divided by 1 minus y into y minus y i dy.

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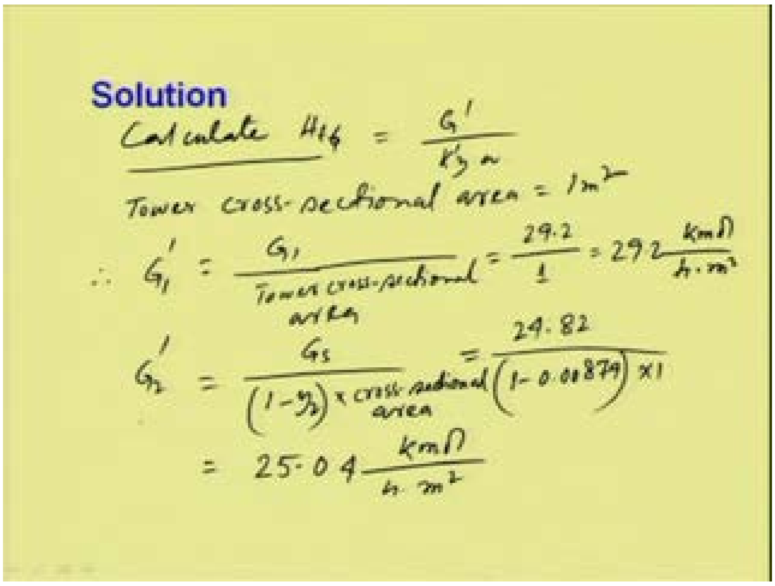

Now, let us calculate H t G calculate H t G, which is equal to G dash by k dash y a, we know tower cross sectional area - cross sectional area is 1 meter square, now we will calculate G 1 dash would be G 1 divided by tower cross sectional area, which is equal to 29.2 divided by 1 which is equal to 29.2 k mol per hour meter square. Similarly, G 2 dash we can calculate G s divided by 1 minus y 2 into cross sectional area, which is equal to 24.82 divided by 1 minus 0.00879 into 1, which is equal to 25.04 k mol per hour meter square.

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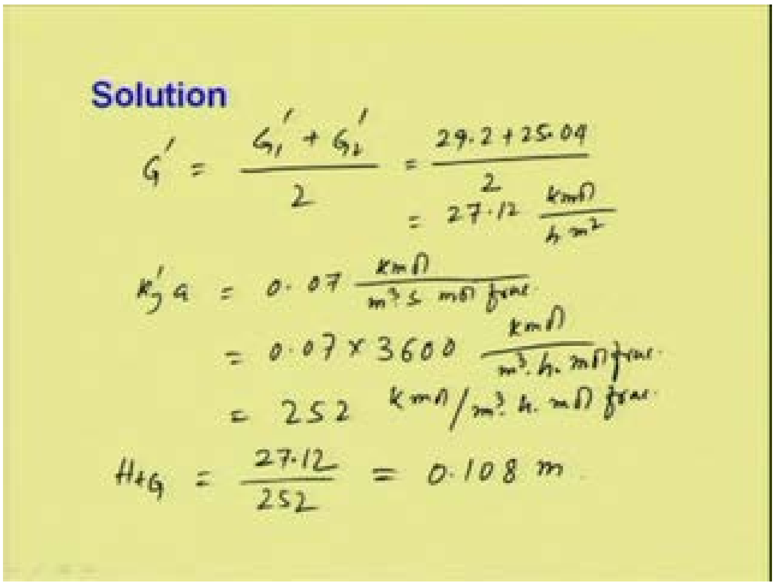

Now, if we take the average of this two that will be your average d G dash over the tower. Therefore, G dash will be G 1 dash plus G 2 dash by 2 which is equal to 29.2 plus 25.04 divided by 2 is equal to 27.12 k mol per hour meter square. It is given that k y dash a is 0.07 K mol per meter cube, second mole fraction. So, we can convert it to 0.07 into 3600 k mole per meter cube hour mole fraction, which is equal to 252 k mole for meter cube hour mole fraction. So, now H t G we can obtain 27.12 G dash divided by K dash y a, which is 252 is equal to 0.108 meter, this is H t G.

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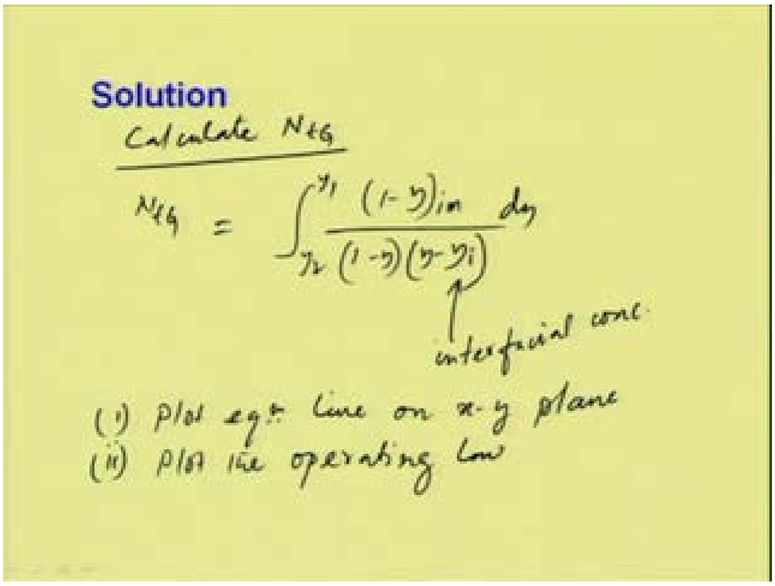

Now, we will calculate N t G; N t G we know that it is equal to integral y 2 to y 1 into 1 minus y i M divided by 1 minus y into y minus y i into dy. Now, we have to evaluate this integral, then to evaluate this integral we need to know the interfacial concentration; interfacial concentration, as we followed earlier we will follow similar procedure - first we will plot the equilibrium line, plot equilibrium line on x y plane, and then plot the operating line.

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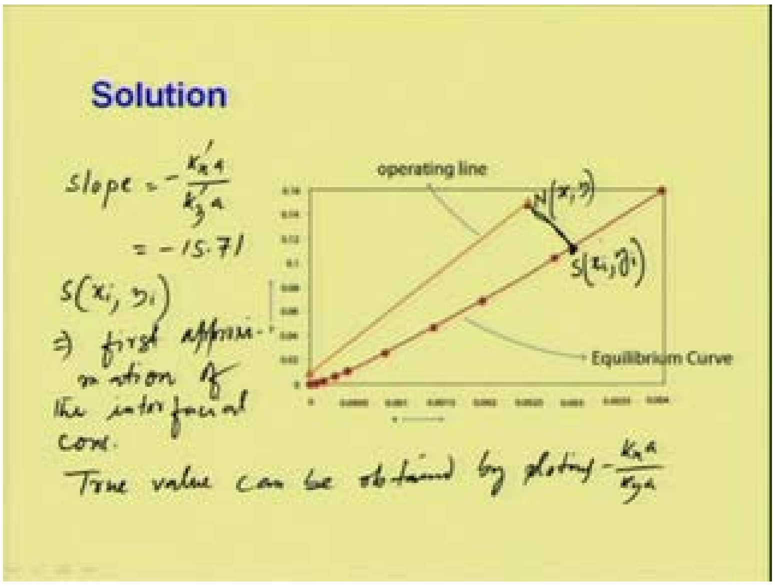

So, this is the equilibrium data which are given x and y, and this is the equilibrium curve, and this is the operating line curve based on the data given, we can look at any point at this location say N. And this is x, y on operating curve, then we draw a line from this curve with a slope is equal to minus k x dash a divided by K y dash a, which is equal to as per the given value is 15.71. And from this point, we plot a curve with that slope, which will meet in this point as at S, and this S point we will get this is x i and y i, and this is the first approximation S (x i, y i), this is the first approximation, approximation of the interfacial concentration concentration, then the true value can be obtained can be obtained by plotting minus k x a by k y a with the slope of this, and which will meet at some point on equilibrium curve.

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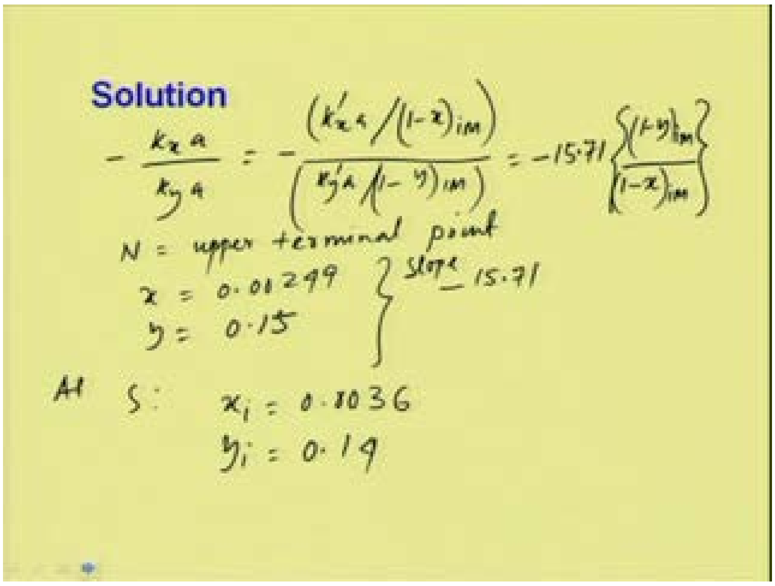

Now, minus k x a divided by k y a is equal to minus k x dash a divided by 1 minus x i M divided by k y a dash divided by 1 minus y i M. So, which is equal to minus 15.71 into 1 minus y i M divided by 1 minus x i M. So, point N is the upper terminal point, N we consider in the previous one is the upper terminal point terminal point point. So, the value at this point is x is equal to 0.00249, and y is equal to 0.15. So, if we plot the with the slope of 15 minus 15 point from this point minus 15.71, then it will meet at point S here x i and y i - the value of x i y i is equal to at S x i is 0.0036 and y i is equal to 0.14. So, with these values we can calculate k x a and k y a.

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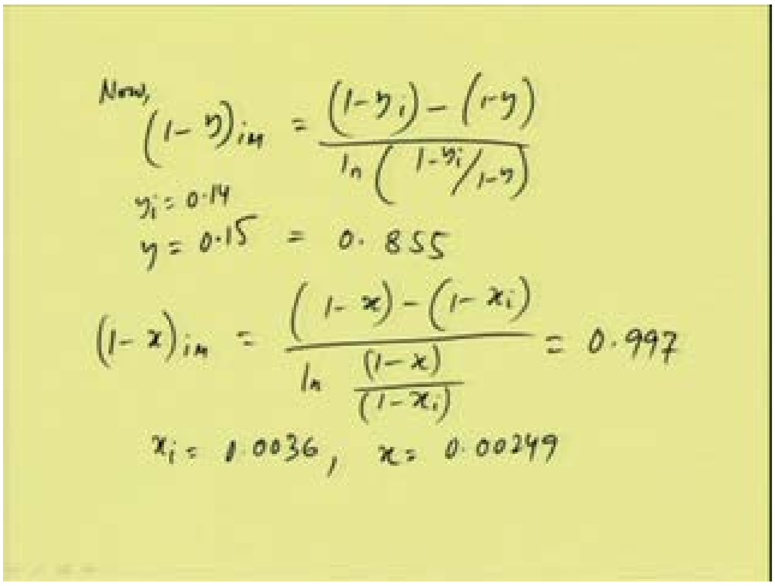

Now, we can calculate 1 minus y i M is equal to 1 minus y i minus 1 minus y divided by 1 ln 1 minus y i divided by 1 minus y. So, if we substitute it will be 0.855, where y i is 0.14 and y is equal to 0.15. Now, we can calculate 1 minus x i M, this is 1 minus x into 1 minus x minus 1 minus x i ln 1 minus x divided by 1 minus x i. So, the values of x i is 0.0036 and x is equal to 0.00249. So, we substitute this will be 0.997.

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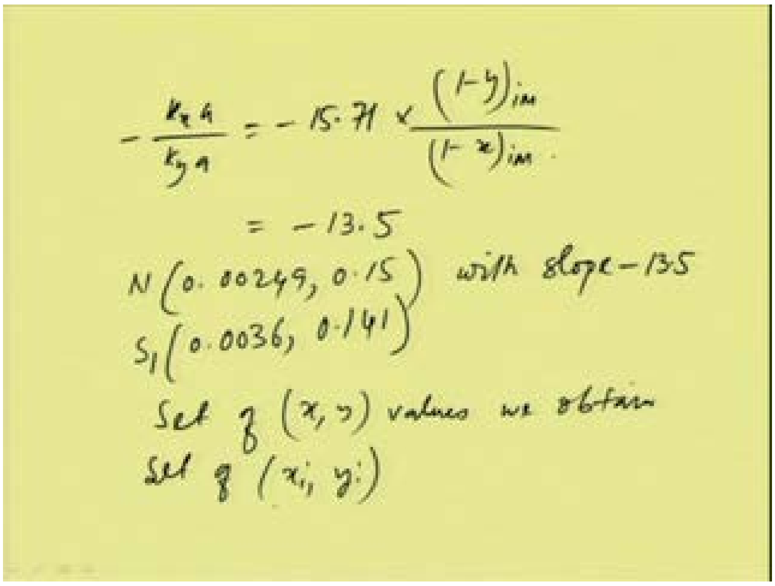

Minus k x a divided by k y a is equal to minus 15.71 into 1 minus y i M divided by 1 minus x i M, after substitution this will be minus 13.5. Now, if we start from point N, which is equal to 0.00249; that is the upper terminal 0.15 with slope slope minus 13.5 will give the true value which meet at S 1. So, that meeting point would be at S 1 suppose from this point it meets some nearer to this point S 1 which is nu x i y i. So, this S 1 0.0036 is and 0.141. Now, set of say x y values, we obtain set of x i, y i.

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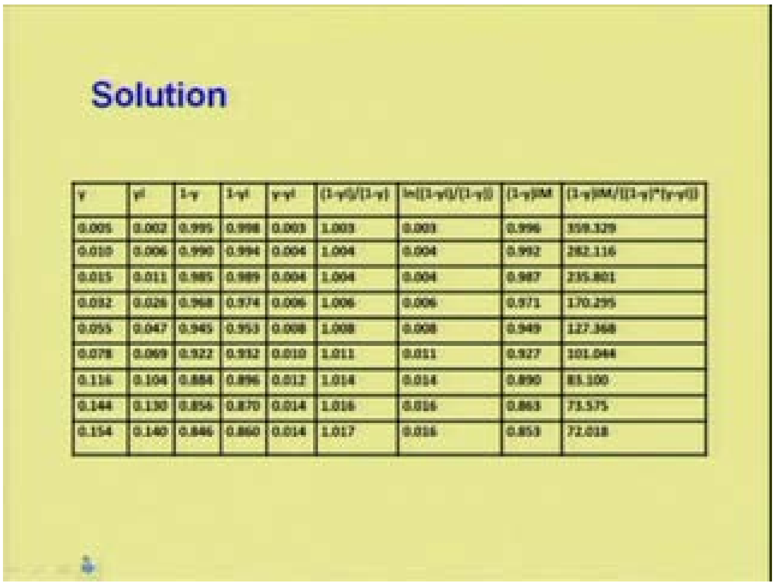

Solution

y	yi	1-y	1-yi	y-yi	(1-yi)/(1-y)	ln[(1-yi)/(1-y)]	(1-y)iM	(1-y)iM/[(1-y)*(y-yi)]
0.005	0.002	0.995	0.998	0.003	1.003	0.003	0.996	359.329
0.010	0.006	0.990	0.994	0.004	1.004	0.004	0.992	282.116
0.015	0.011	0.985	0.989	0.004	1.004	0.004	0.987	235.801
0.032	0.026	0.968	0.974	0.006	1.006	0.006	0.971	170.295
0.055	0.047	0.945	0.953	0.008	1.008	0.008	0.949	127.368
0.078	0.069	0.922	0.932	0.010	1.011	0.011	0.927	101.044
0.116	0.104	0.884	0.896	0.012	1.014	0.014	0.890	83.100
0.144	0.130	0.856	0.870	0.014	1.016	0.016	0.863	73.575
0.154	0.140	0.846	0.860	0.014	1.017	0.016	0.853	72.018

So, this is shown in the in this table, we have different y values and we have y i values, and we have calculated the difference and then we have calculated the integral term.

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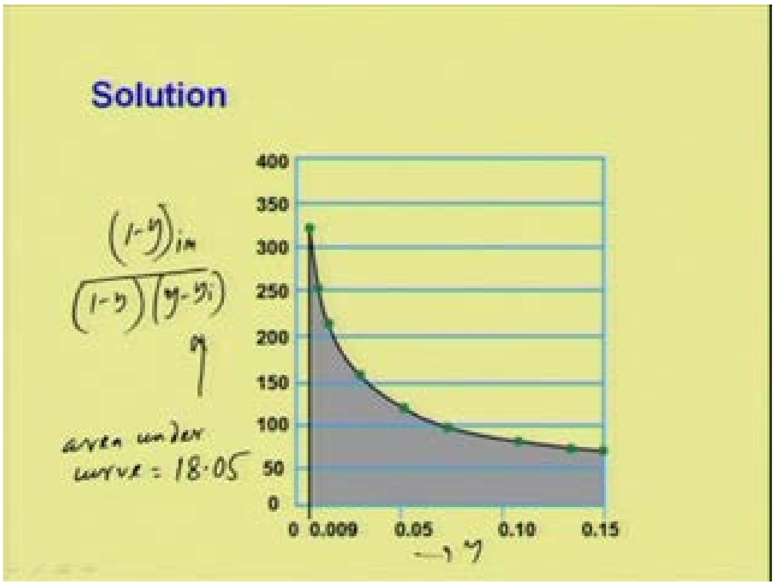

If we plot this versus y, this is basically 1 minus y i M divided by 1 minus y into y y minus y i. So, this is in this axis, and this is in this is y. So, if we plot this, then it will give the value area under the curve, which is N t G. So, area under the curve under the curve is equal to 18.05.

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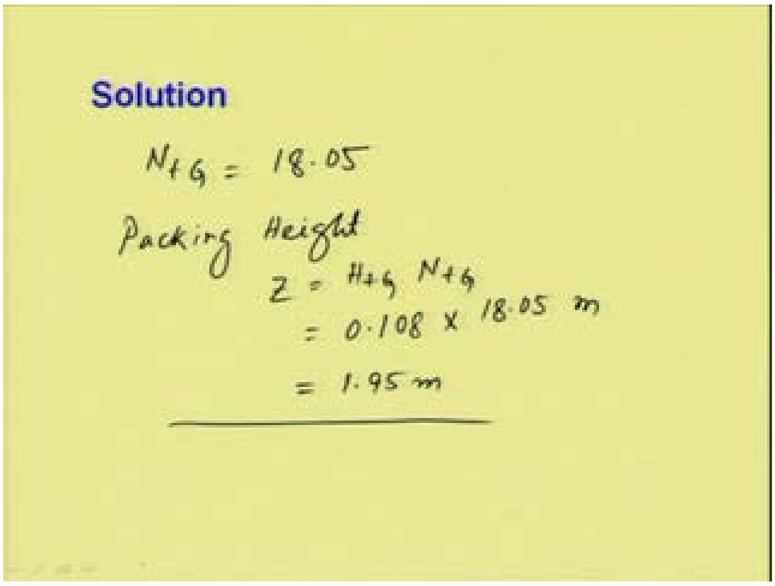

So, N t G t G is equal to18.05. So, packing height, which is Z is equal to H t G into N t G which is equal to 0.108 into 18.05 meter, which is coming about 1.95 meter. So, this is the method, by which we can calculate the packing height required for a particular operation.

Thank you.