Mass Transfer Operations I
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Module - 4
Absorbtion
Lecture - 5
Mass Transfer Coefficients
Correlation and HETP Concept

Welcome to the fifth lecture of module 4. We are discussing absorption.

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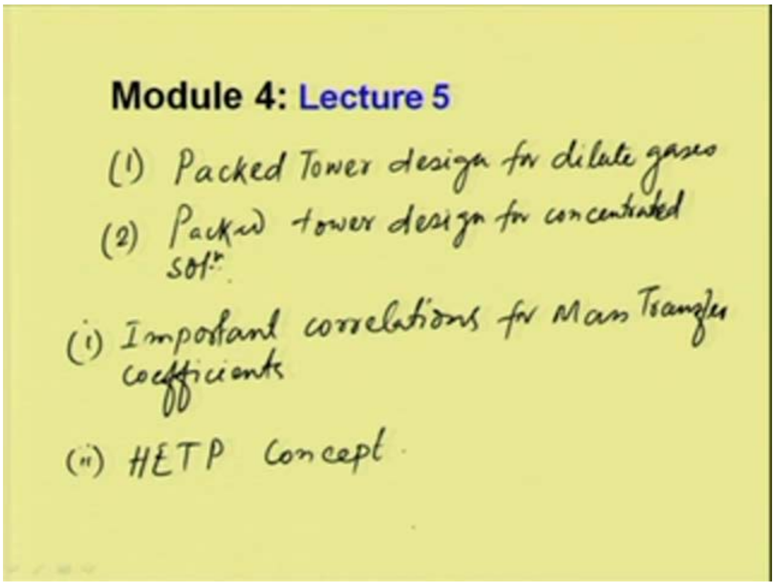

In the previous lecture, we have mainly considered two things; one is packed tower design for dilute gases, and second thing we have discussed, packed tower design for concentrated. So, for dilute solutions, we generally consider the mole fractions of the solute both in gas as well as liquid phases, should be less than 0.1 that is 10 percent, and above that we should consider concentrated solution. So, these two methods we have discussed, and we have seen the examples how to solve different problems. In this lecture, we will discuss the correlations, some of the important correlations for mass transfer coefficient and second thing we will discuss HETP concept that is height equivalent to a theoretical plate HETP concept.

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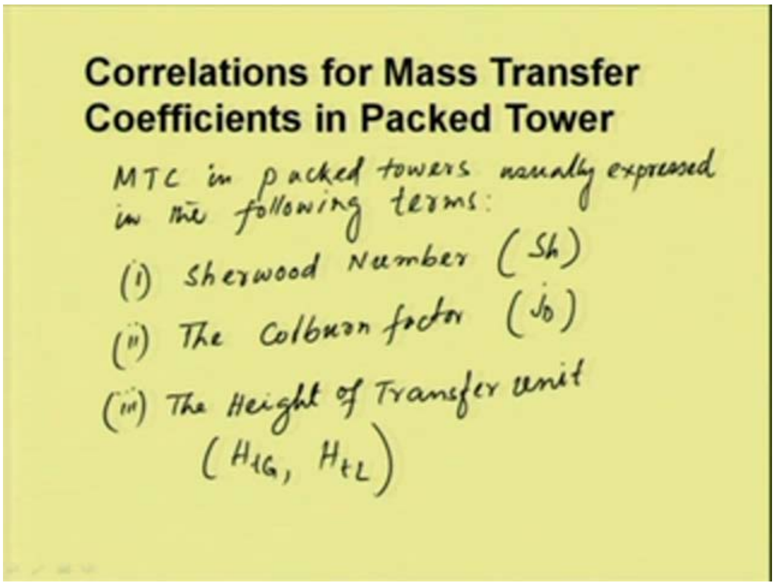

So, let us consider the first thing correlations for mass transfer coefficients. The mass transfer coefficient that is MTC mass transfer coefficients in packed towers generally expressed, usually expressed in the following terms. What are those Sherwood number S h and secondly the Colburn factor which is defined as j D, the height of transfer unit height of transfer unit which is H t G or H t L.

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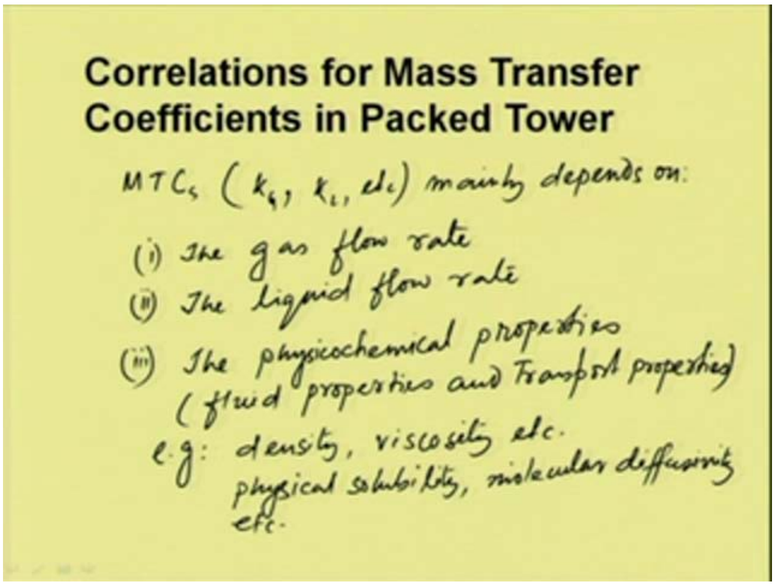

The mass transfer coefficients generally k G, small k G, k L etcetera mainly depends on the gas flow rate, second the liquid flow rate and third the physicochemical properties that is fluid properties and transport properties. So, the fluid proprieties like for example, density, viscosity etcetera and the transport properties like physical solubility, molecular diffusivity etcetera.

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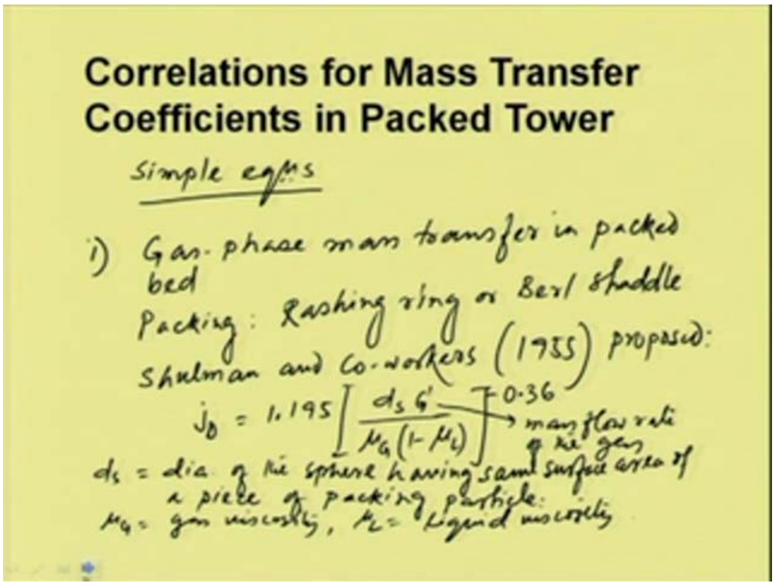

So, there are several correlations available in the literature, which are derived mainly from the experimental data for different systems. So, some of the important equations we will discuss here. So, very simple equations, one is for gas phase mass transfer in packed bed. Here the packing used is Rashing ring or Berl Shaddle and Shulman and Coworkers in 1955 proposed the equation, proposed the following equations j D is equal to 1.195 d s G dash divided by mu G 1 minus mu L whole to the power minus 0.36 d s is the diameter of sphere having the same surface area of a piece of packing particle and mu G is the gas viscosity, mu L is the liquid viscosity and G dash is the mass flow rate of the gas. G dash, this is the mass flow rate of the gas.

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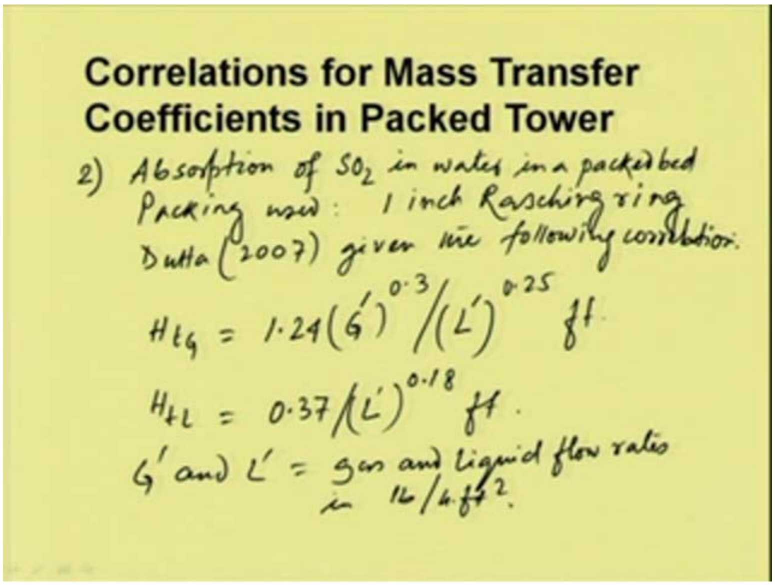

Let us consider another system absorption of SO2 in water, in a packed bed. The packing used is 1 inch Rasching ring and there is a correlations which is given by Dutta 2007, following correlation H t G is equal to 1.24 G dash to the power 0.3 divided by L dash to the power 0.25 feet and H t L is equal to 0.37 divided by L dash to the power 0.18 feet where G dash and L dash, gas and liquid flow rates in pound per hour feet square.

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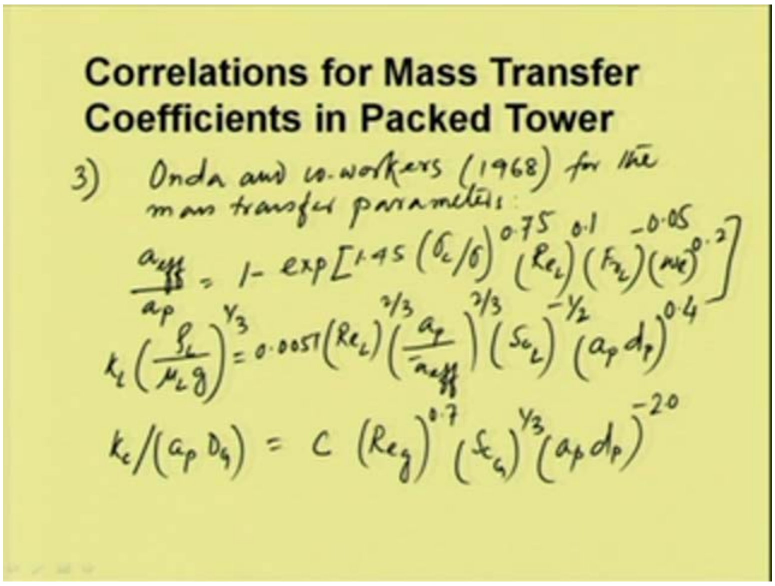

So, another correlation which is given by Onda and co-workers in 1968 for the mass transfer parameters, a effective divided by a p is equal to 1 minus exponential 1.45 sigma c by sigma to the power 0.75 Reynolds number to the power 0.1 Froude number to the power minus 0.05 and Wave 1 number to the power 0.2. So, each number we will discuss later and k L into rho L divided by mu L into g to the power one third is equal to 0.0051, Reynolds number to the power two by three a p by a effective to the power two third Schmidt number to the power minus half a p d p to the power 0.4. Another correlations for k c, k c divided by a p D G is equal to c, c is a constant Reg to the power 0.7 Schmidt number to the power one third a p d p to the power minus 2.

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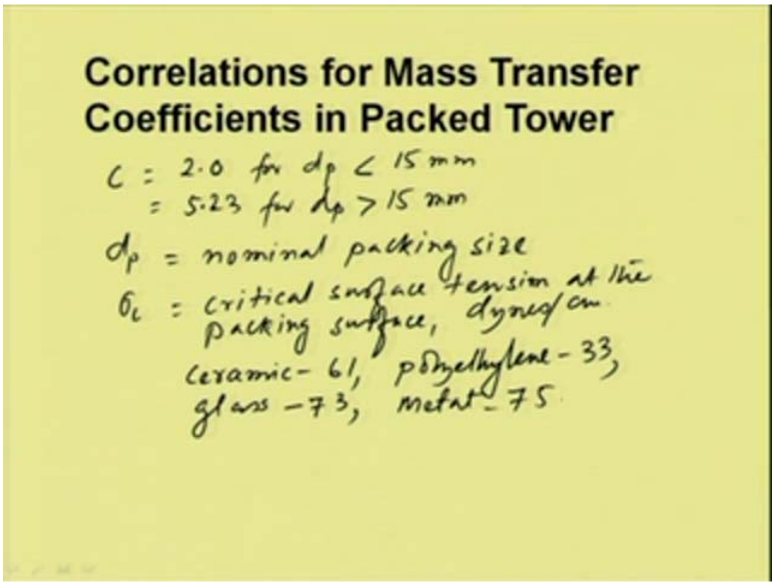

So, here this c, c is equal to 2.0 for d p less than 15 millimeter and this equal to 5.23 for d p greater than 15 millimeter, d p is the nominal packing size, sigma c is the critical surface tension at the packing surface in dynes per centimeter and it varies like for ceramic it is 61, polyethylene 33, glass 73 and metal 75.

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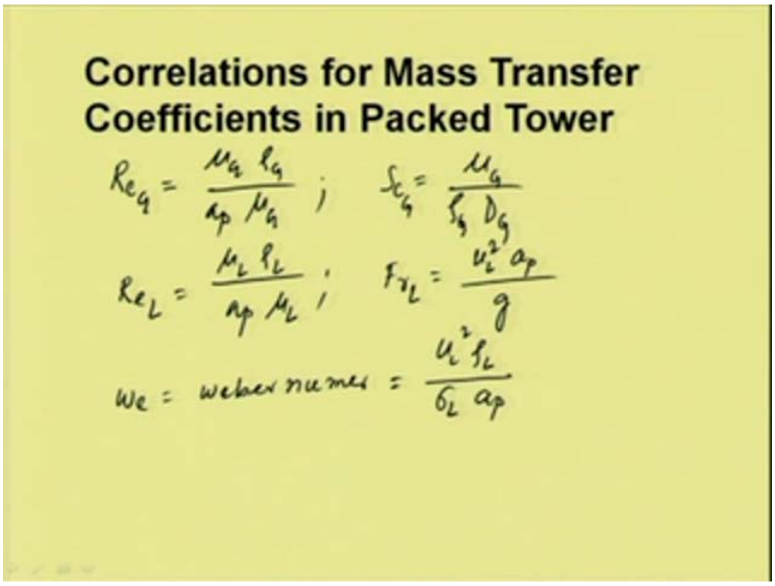

Re G is equal to mu G rho G by a p mu G. Schmidt number is equal to mu G by rho G into D G. Re L is equal to mu L rho L divided by a p by mu L, this is G, this is equal to u L square a p divided by g, weber number is equal to, weber number which is equal to u L square rho L by sigma L a p.

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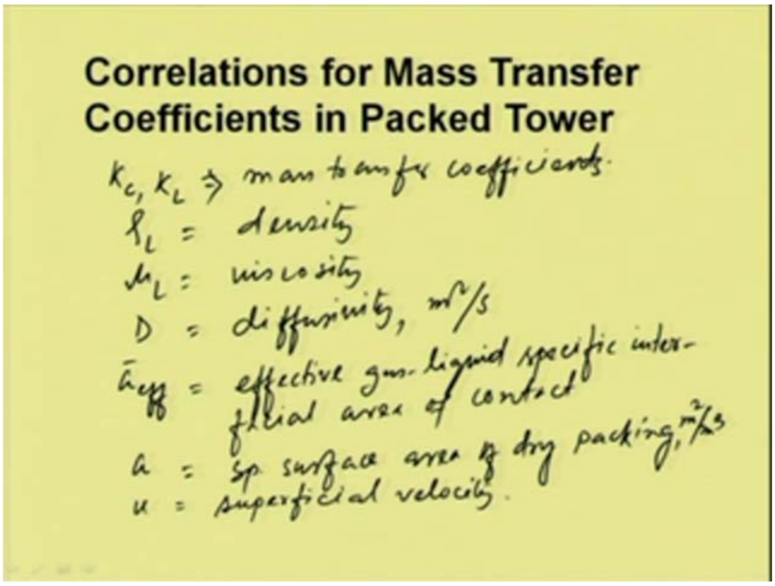

So, here k c and k L which is the mass transfer coefficients, rho L is the density, mu L is the viscosity, D is the diffusivity meter square per second, a effective is the effective gas liquid specific inter facial area of contact and a is the specific surface area of dry packing, specific surface area of dry packing say meter square per meter cube and u is the superficial velocity.

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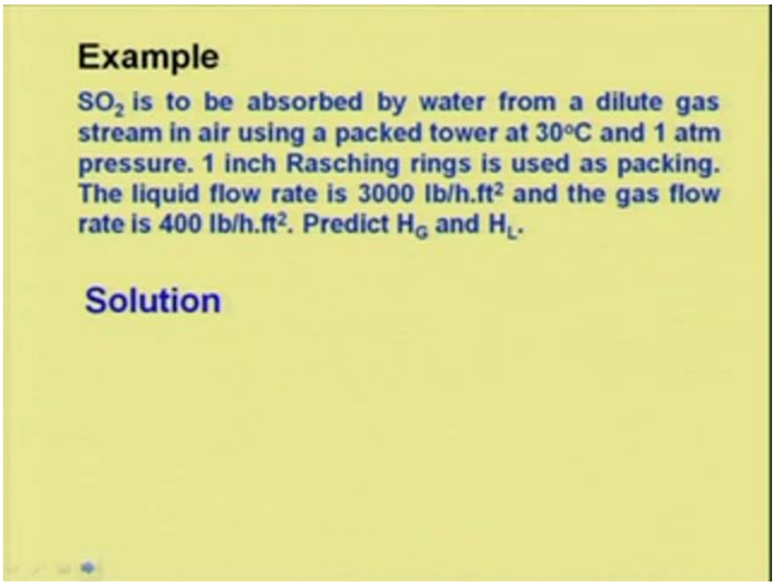

Now, let us take a very simple example, how to calculate the height of transfer units H G and H L. So, if we take the example sulphur dioxide is to be absorbed by water from a dilute gas stream in air using a packed tower at 30 degree centigrade and 1 atmosphere pressure 1 inch Rasching rings is used as packing, the liquid flow rate is 3000 pound per hour feet square and the gas flow rate is 400 pound per hour feet square. Predict H G and H L.

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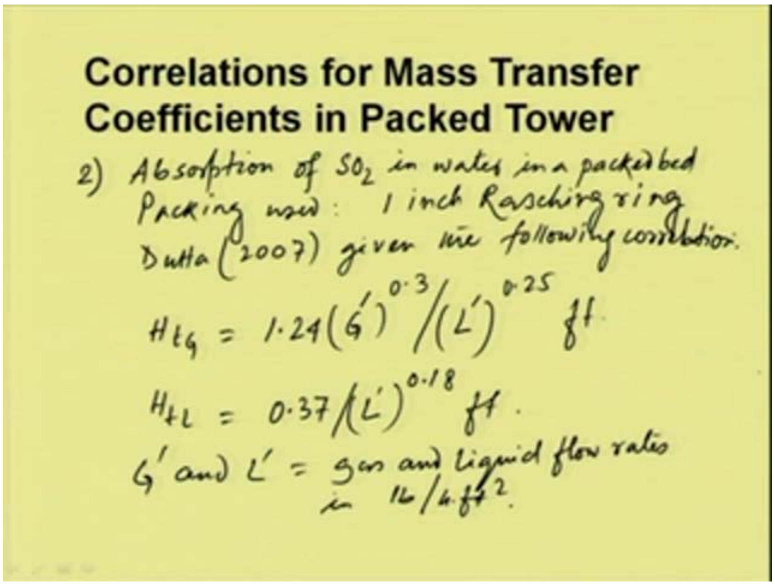

So, if we go back and look into the correlations given for H G and H L which is for 1 inch Rasching ring and absorption of sulphurdioxide H G equation is given and it is given that liquid and gas flow rate.

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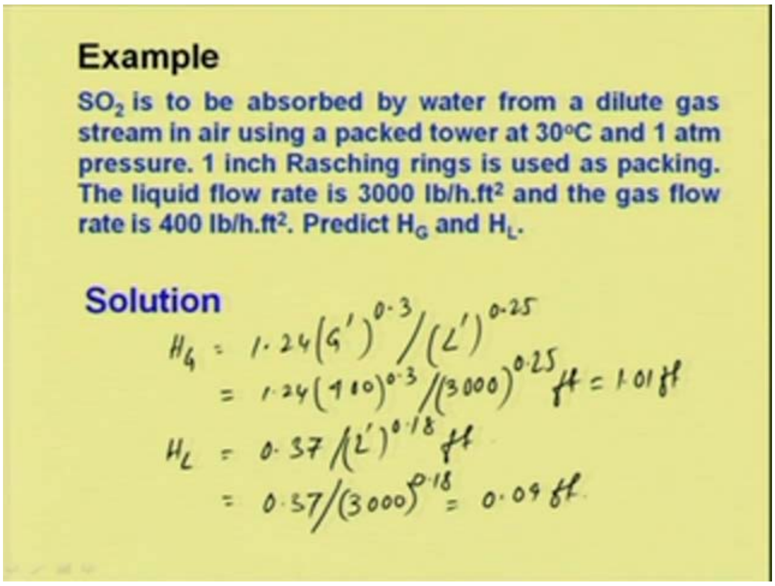

So, if we write these equations H G is equal to 1.24 G dash to the power 0.3 divided by L dash to the power 0.25 which is equal to 1.24, G dash is 400 pound per hour feet square to the power 0.3 divided by liquid flow rate is 3000 is to the power 0.25, this much feet. So, it is equal to 1.01 feet. H L which is 0.37 divided by L dash to the power 0.18 feet.

So, which is equal to 0.37 divided by 3000 to the power 0.18 which is equal to 0.09 feet. So, similar systems can be solved using this correlations and for other systems as well.

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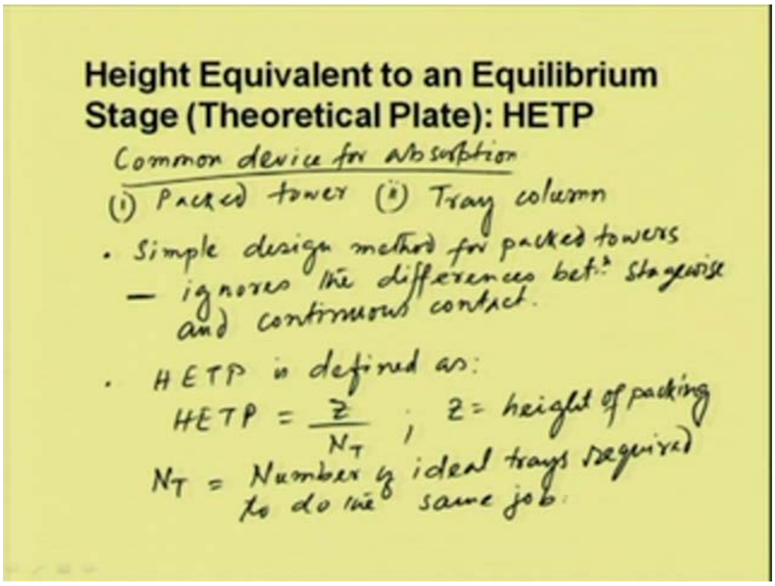

So, now we will discuss height equivalent to an equilibrium stage or theoretical plate. The common device for absorption, we have discussed before for absorption is packed tower and second is tray column. This HETP method is a simple design method for packed towers which is developed long before and this ignores the differences between stage wise and continuous contact. So, HETP is defined as HETP is equal to z divided by N t, z is equal to height of packing and N t is equal to number of ideal stage or trays required, number of ideal trays required to do the same job. So, it is the ratio between the height of packing and the number of ideal stage required for a given job.

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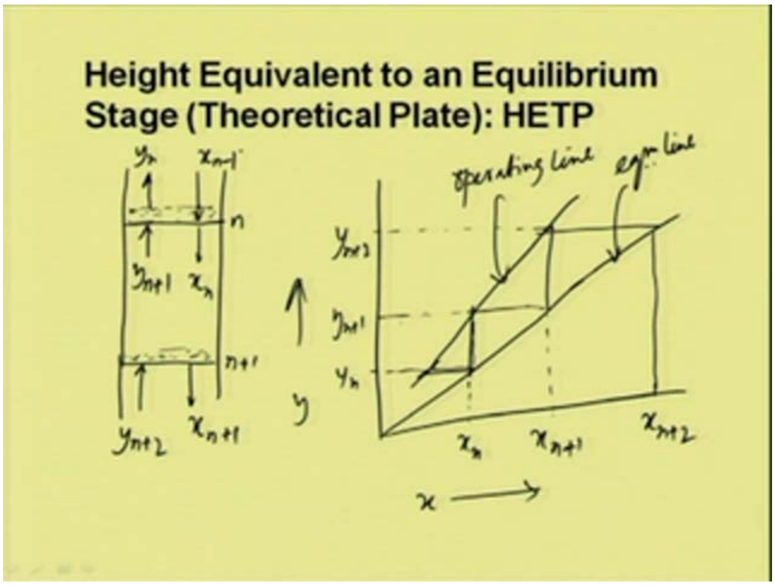

Now, let us consider the following figures. We have two different trays and this is named as nth tray, this is n plus 1 and say there is a liquid hold off on the tray. So, the liquid which is entering to nth plate is x nth minus 1 and which is coming out from this tray is y n, the gas which is coming out and the liquid which is coming out from this tray towards the down is x n and the gas which is entering to this plate is y n plus 1 and the gas which is coming to the n plus 1 stage is y n plus 2 and the liquid which is coming out from this is x n plus 1.

Now, if we plot the equilibrium curve and the operating line curve. So, this is y n plus 2 this is y n plus 1, this is y n plus 1 this is y n and corresponding to this is x n and this is x n plus 2 and this is x n plus 1. So, x and y. So, this is equilibrium line and this is operating line.

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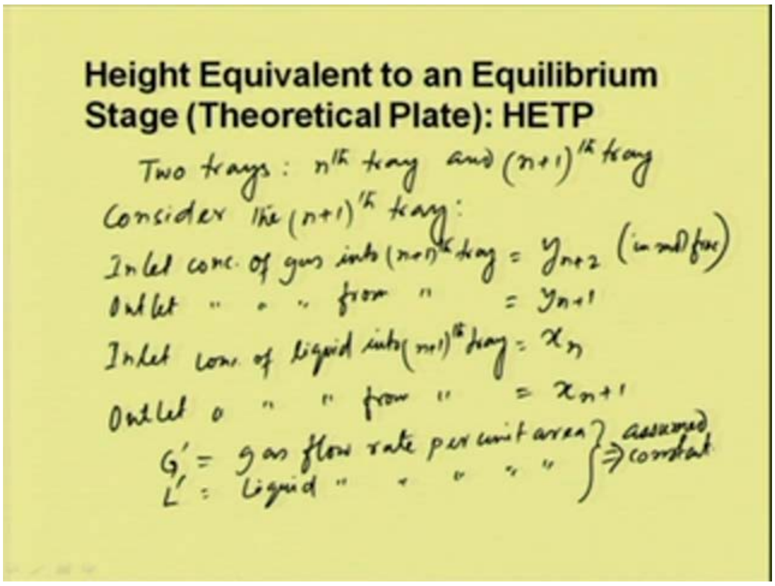

So, here we have used two trays, nth tray and n plus oneth tray. Now, if we consider n plus 1 tray and if we do the balance, consider the n plus oneth tray inlet concentration of gas into n plus oneth tray is equal to y n plus 2, This is in mole fraction. Outlet concentration, concentration of gas from this tray is y n plus 1. Inlet concentration of liquid into n plus oneth tray is equal to x n and outlet concentration of liquid from this tray is x n plus 1 and let consider G dash gas flow rate per unit area and L dash liquid flow rate per unit area. So, both assumed constant.

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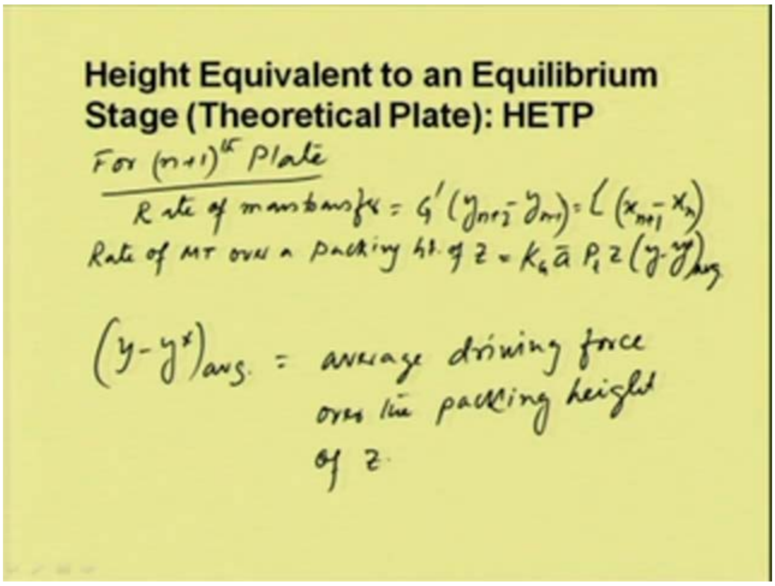

Then if we do the mass balance over n plus oneth tray for n plus oneth plate. So, rate of mass transfer is equal to G dash y n plus 2 minus y n minus 1 would be equal to L dash x n plus 1 minus x n. And rate of mass transfer over a packing height, height of z would be equal to k G a bar p t z into y minus y star average, where y minus y star average is equal to average driving force over the packing height of z.

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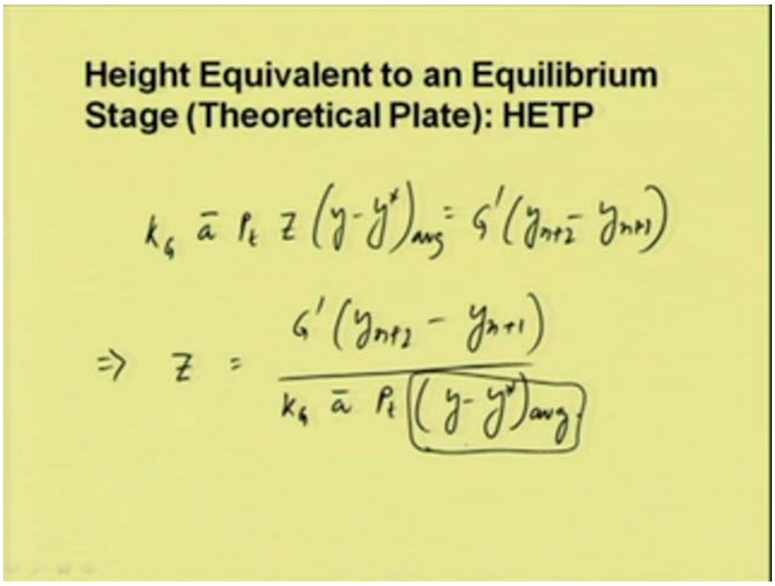

So, then if the rate of mass transfer on a tray is same as the rate of mass transfer over a packing surface we can right k G a bar p t into z y minus y star average would be G dash y n plus 2 minus y n plus 1. So, from which z we can calculate, it is G dash y n plus 2 minus y n plus 1 divided by k G a bar p t y minus y star average, it is reasonable to take this y minus y average as a log mean overall gas phase driving force between the point P and Q.

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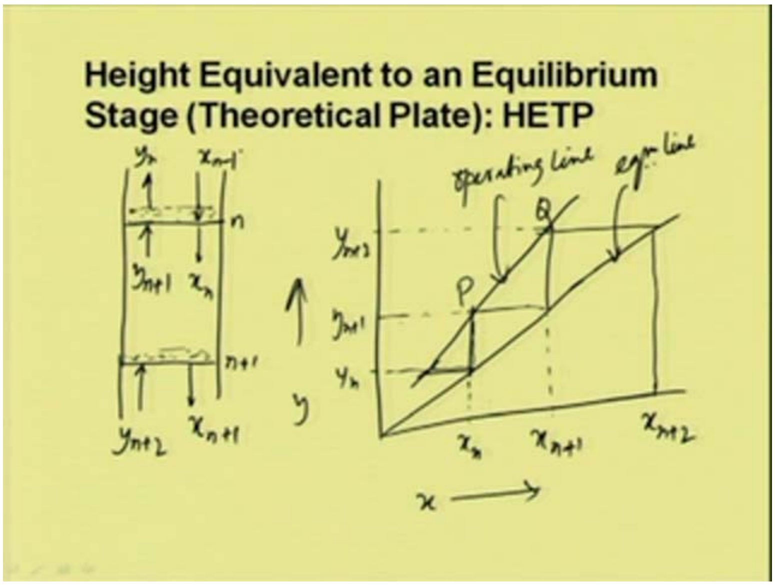

So, between this, this is operating line. So, between this point P and Q, it is reasonable to take the log mean overall driving force for y minus y star average.

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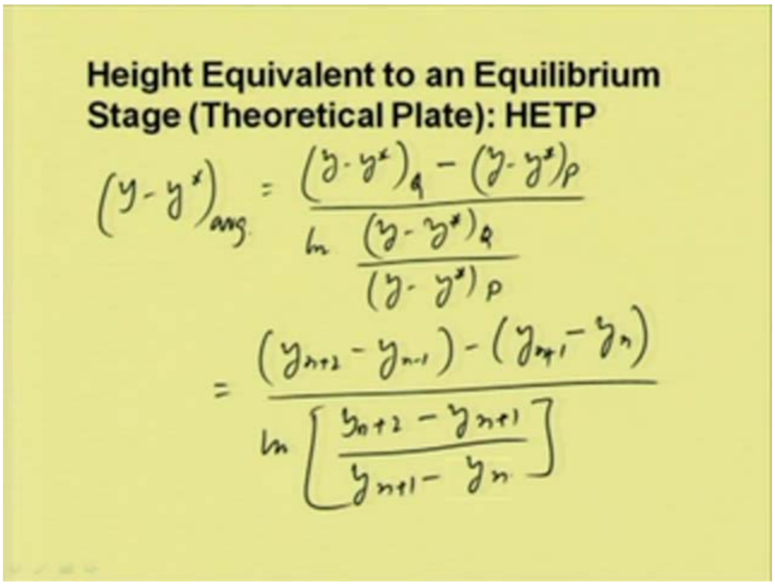

So, if we take that y minus y star average would be y minus y star Q minus y minus y star P divided by l n y minus y star Q divided by y minus y star P. So, this would be y n plus 2 minus y n minus 1 minus y n plus 1 minus y n divided by l n y n plus 2 minus y n plus 1divided by y n plus 1 minus y n.

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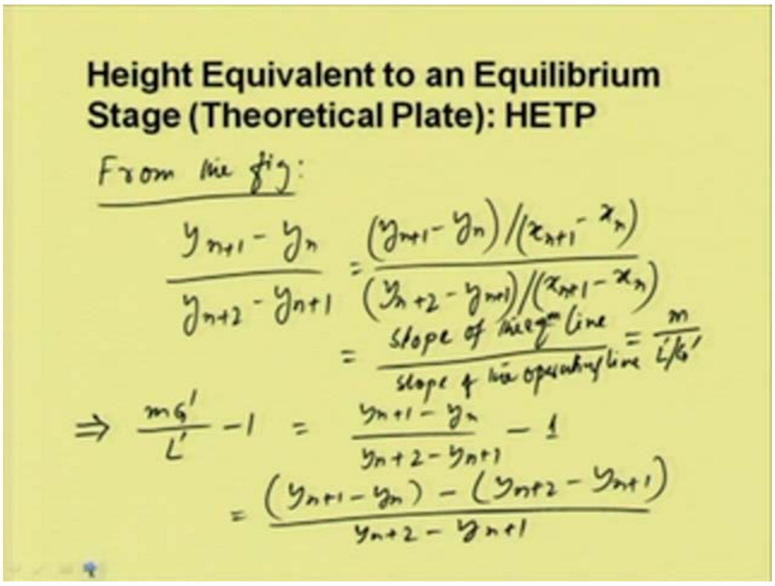

So, from the figure we can write y n plus 1 minus y n divided by y n plus 2 minus y n plus 1 is equal to y n plus 1 minus y n divided by x n plus 1 minus x n divided by y n plus 2 minus y n plus 1 divided by x n plus 1 minus x n. So, which is equal to slope of the equilibrium line, line divided by slope of the operating line. So, which is we can write m by L dash by G dash.

So, from this we can write m G dash by L dash minus 1 is equal to y n plus 1 minus y n divided by y n plus 2 minus y n plus 1 minus 1. So, which is equal to y n plus 1 minus y n minus y n plus 2 minus y n plus 1 divided by y n plus 2 minus y n plus 1.

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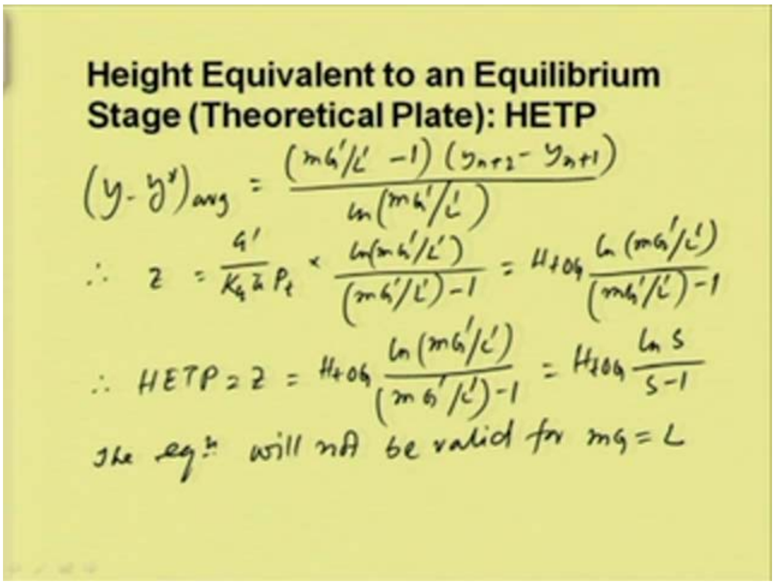

Now, we can substitute this in the equations of y minus y star average is equal to m G dash by L dash minus 1 into y n plus 2 minus y n plus 1 divided by l n m G dash divided by L dash. So, therefore, z would be G dash divided by capital k G a bar p t into l n m G dash by L dash divided by m G dash by L dash minus 1. So, which is equal to H t o G L n m G dash by L dash divided by m G dash by L dash minus 1. Therefore, HETP which is equal to z you can write is equal to H t o G l n m G dash by L dash divided by m G dash by L dash minus 1, which is we can write H t o G l n of the stripping factor S divided by S minus 1. The equation will not be valid for m G equal to L.

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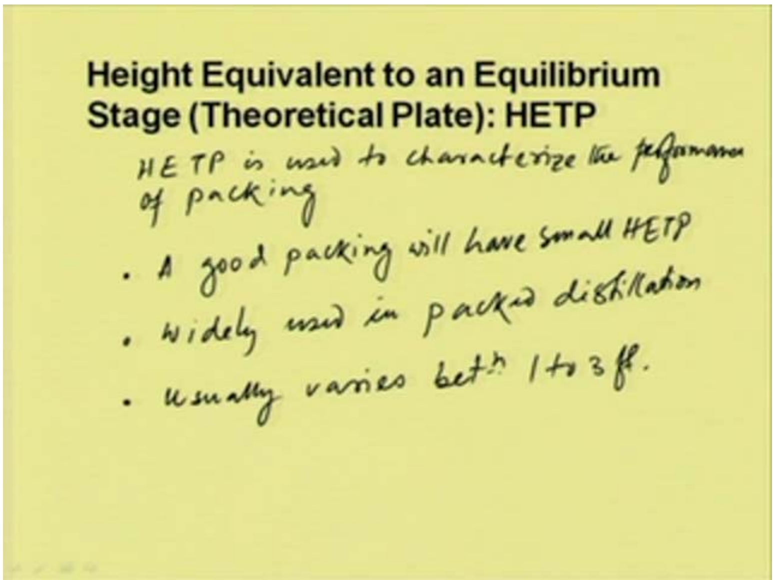

This HETP is generally used to characterize the performance of packing, HETP is used to characterize the performance of packing. So, the a good packing will have small HETP. This is widely used in packed distillation and its usually varies between 1 to 3 feet.

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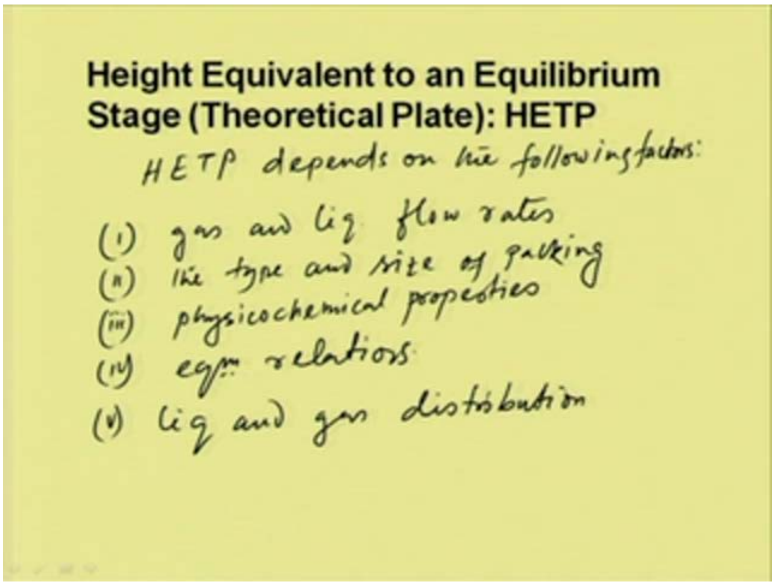

This HETP depends on the following factors, one is the gas and liquid flow rates, second the type and size of packing, physicochemical properties, the equilibrium relations and the liquid and gas distribution.

Thank you