Mass Transfer Operation-2
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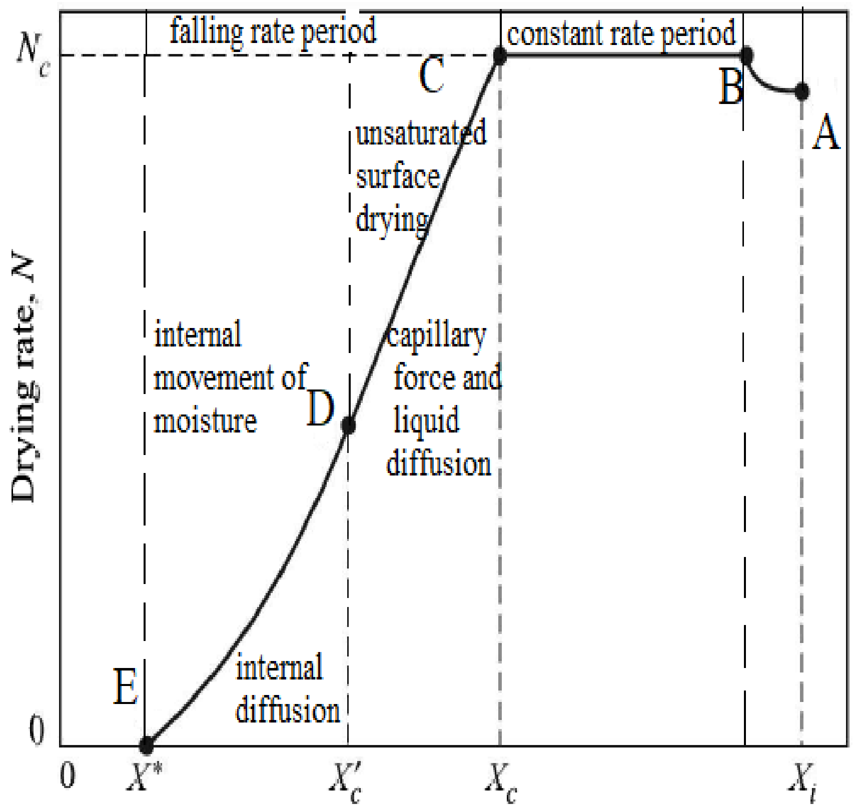
Lecture 9
Drying Time Calculation from Drying Time Curve

Welcome back to mass transfer operation-2 course. In the last class we discussed the details about the continuous dryer and in this class we will be discussing the drying time calculation from drying time curve.

Movement of moisture within solid:

- Liquid Diffusion: Due to concentration gradient between depths and surface falling rate period. Diagram.
- Capillary movement: Unbound moisture in granular and porous solids moves through the capillaries → surface tension.
- Constant drying rate period: As drying proceeds, at first, moisture moves by capillary to the surface rapidly enough to maintain a uniformly wetted surface and drying rate is constant.
- Vapour Diffusion: If heat is supplied to one surface of a solid while drying proceeds from another, moisture may be evaporated beneath the surface and diffuse outward as vapour.
- $N = -\frac{S_S}{A}\frac{dX}{dt}$
- Let X_i is initial moisture content of solid,
- X_f is final moisture content

Calculation of drying time: Constant drying conditions



Movement of moisture within solid:

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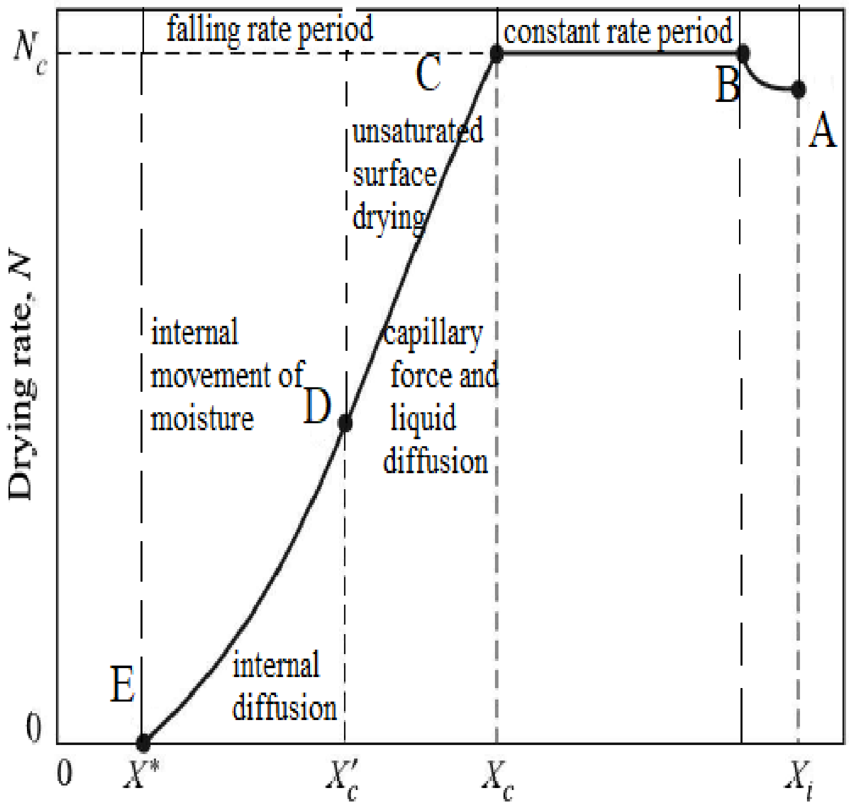

- $\therefore \int_0^t dt = -\int_{X_i}^{X_f} \frac{S_S}{A} \frac{dX}{N} \rightarrow$ t = $-\frac{S_S}{A} \int_{X_i}^{X_f} \frac{dX}{N} = \frac{S_S}{A} \int_{X_f}^{X_i} \frac{dX}{N}$

- t = $\frac{S_S}{A} \int_{X_f}^{X_c} \frac{dX}{N} + \frac{S_S}{A} \int_{X_c}^{X_i} \frac{dX}{N}$

- * Drying rate remains constant at N_C till X_C from X_i.

- 1. **Constant rate period:**

- $t_C = \frac{S_S}{A} \int_{X_c}^{X_i} \frac{dX}{N_c} = \frac{s_s(X_i - X_c)}{AN_C}$

- 2. **First falling rate period:**

- integral can be evaluated graphically ($\frac{1}{N}$ vs X)

- **Special case 1:**

- $N = mX_C + b$

- $N_C = mX_c + b$

- $N_f = mX_f + b$

- $m = \frac{N_C - N_f}{X_C - X_f}$
- $t_f = \frac{S_S}{A} \int_{X_f}^{X_c} \frac{dX}{N}$
- $= \frac{S_S}{A} \int_{X_f}^{X_c} \frac{dX}{mX + b} = \frac{S_S}{Am} ln(\frac{mX_C + b}{mX_f + b})$
- $= \frac{S_S}{A} \frac{X_C - X_f}{N_C - N_f} ln(\frac{N_C}{N_f})$
- Drying rate at $N = 0$ at equilibrium moisture, $X = X^*$
- $\therefore 0 = m X^* + b \rightarrow b = - m X^*$
- $\therefore \frac{N_C}{N_f} = \frac{mX_C - mX^*}{mX_f - mX^*} = \frac{X_C - X^*}{X_f - X^*}$
- $t_f = \frac{S_S}{A} \frac{X_C - X_f}{N_C - N_f} ln(\frac{X_C - X^*}{X_f - X^*})$
- $t_f = \frac{S_S}{A} \frac{X_C - X^*}{N_C} ln(\frac{X_C - X^*}{X_f - X^*})$
- $\boldsymbol{t = t_C + t_f = \frac{S_s(X_i - X_c)}{AN_C} + \frac{S_S}{A} \frac{(X_C - X^*)}{N_C} ln(\frac{X_C - X^*}{X_f - X^*})}$
- **Special case 2:**
- $N = bX^2 \rightarrow N_c = bX_c^2 \rightarrow b = \frac{N_C}{X_c^2}$
- $t_f = \frac{S_S}{A} \int_{X_f}^{X_c} \frac{dX}{bX^2} = \frac{S_S}{Ab} \int_{X_f}^{X_C} X^{-2}\, dX = \frac{S_S X_c^2}{AN_C} \left[\frac{1}{X_f} - \frac{1}{X_C}\right]$
- $\boldsymbol{t = t_C + t_f = \frac{S_s(X_i - X_c)}{AN_C} + \frac{S_S X_c^2}{AN_C} \left[\frac{1}{X_f} - \frac{1}{X_C}\right]}$

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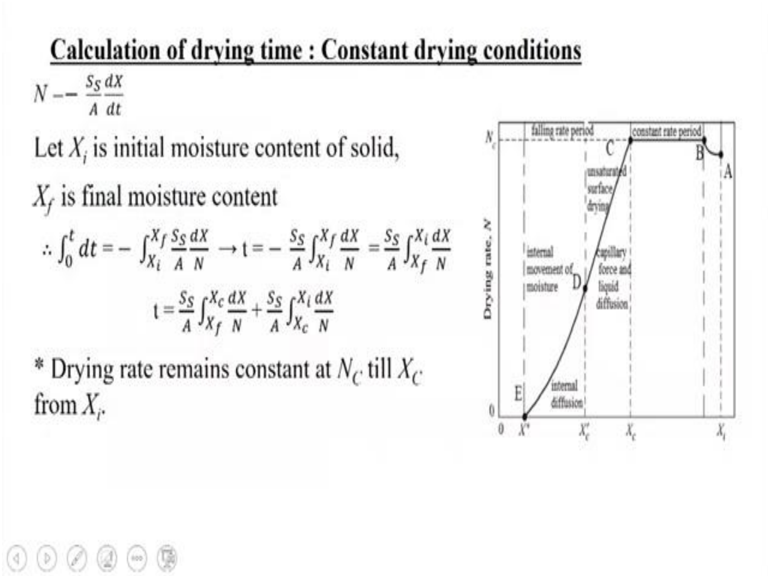

And calculation of drying time like a constant drying condition we have already discussed this one still we are recapturing those like this Flax is equal to say minus S by A into dX by dt where x is the initial moisture content and say we can say this one X to p be the final moisture content. Then whenever integrating this equation from 0 to t with respect to minus Ss by A dX by N will be getting this t in terms of we can say Ss by A and this one in terms of this N, and drying time remains constant at Nc till Xc this one from Xi like this from Xi means they say we will start from here and Xc is we can say this one when constant drying rate stops.

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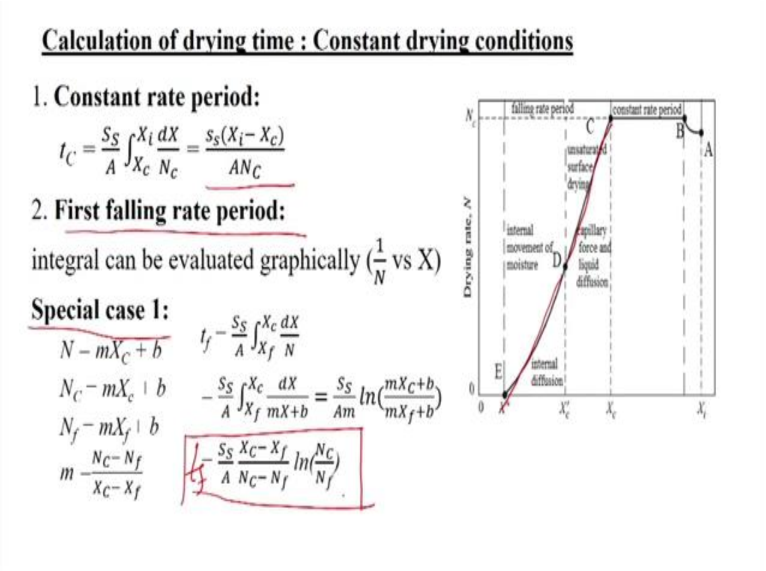

Now we will be discussing about the constant rate period time. The tC is equal to Ss by A NC into Xi minus Xc and for falling rate period we can say this one there may be two falling rate like First falling rate period than second falling rate period like this. Say we can say this one they may be first falling rate period maybe we can say drying rate is proportional to moisture content then this first falling rate period this Tf will be like this Ss by A into Xc minus Xf by Nc minus Nf into ln Nc by Nf. So that will be we can say this one time for first falling rate period.

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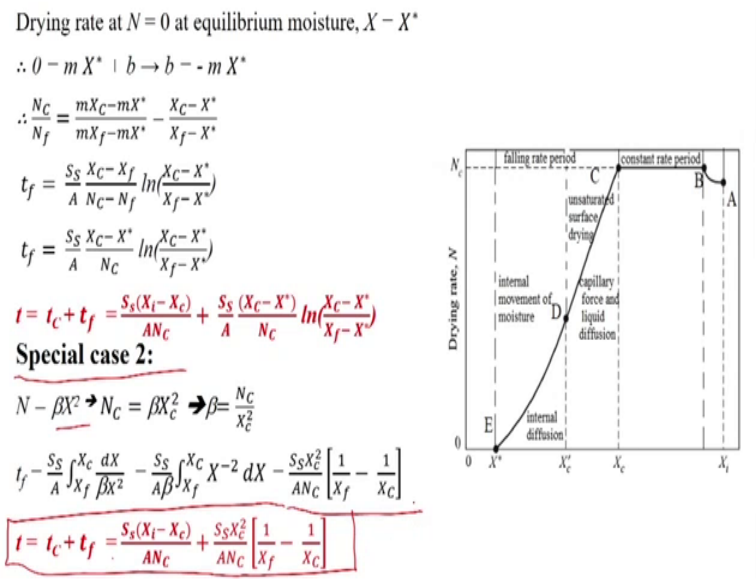

If the falling rate period is square of this we can say this one moisture content then it will be like this say tf will be this Ss by A into Nc into Xc square into 1 by Xf minus into 1 by Xc.

Then we can say that total time for this drawing will be like t constant rate period and t final rate period that is we can say this one tf so that will be Ss by ANc into Xi minus Xc plus Ss by ANc into Xc square into 1 by Xf minus 1 by Xc. So these are the, we can say this are the regular cases.

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Problem 4

A wet solid having 32% moisture (dry basis) is to be dried on a tray dryer to a final moisture of 1%. The solid loading is 30 kg dry solid per m^2 tray area. There are two critical moisture values X_{c1} = 0.183, and X_{c2} = 0.097. A laboratory test gives a drying rate of 4 kg/m^2 h in the constant rate period. In the first falling rate period, the drying flux is linear in the moisture content; in the second falling rate, the drying flux varies as the square of the moisture content. The equilibrium moisture is negligible. Calculate the drying time if the drying conditions are the same as in the laboratory test. Mention any assumption made.

Now we will be discussing one case where the 2 drying rate this one falling rate periods are there with first falling rate will be proportional to X and second falling rate will be proportional to X Square. So the problem is like that a wet solid having 32 percent moisture that is on dry basis is to be dried on tray dryer to a final moisture of 1 percent. So this is the requirement of the system like final moisture content will be 1 percent.

The solid loading is 30 kg dry solid per meter square area that is we can say Ss by A is equal to 30 kg per meter square. There are two critical moisture values that is Xc1 that is equals to 0.183 and Xc2 is equal to 0.097. A laboratory test gives a drying rate of 4 kg per meter square hour. In the first falling rate period the drying rate is linear in the moisture content. In the second falling rate the drying Flux varies as the square of the moisture.

The equilibrium moisture is negligible. Means we can say this one X equal to 0. We need to calculate the drying time if the drying conditions are the same as in the laboratory test so we need to mention any assumption if we have made.

So we will be doing this one step by step calculation but here we will be doing one thing that say the falling rate period are here two different falling rate period. Like the fast falling rate period will be fallowing this linearity and second falling rate period will be proportional to X Square.

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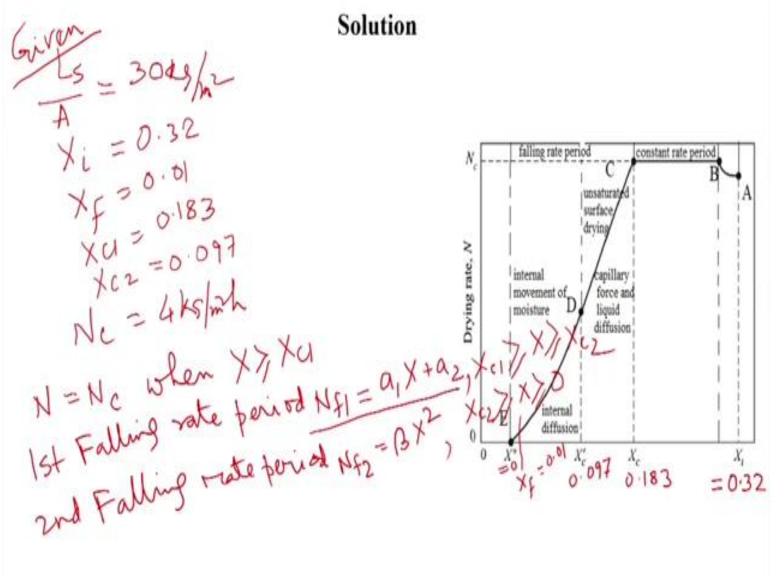

Let us start with the solving the problem like this we can say, we will be writing this one this Ls by A that is we have this one 30kg per meter square and Xi that is given as 0.32 and Xf that is given as 0.01 and Xc1 that is 0.183. These are all given and Xc2 is equal to 0.097 and Nc that is also supplied that is 4 kg per meter square hour. So these are all given in the problem itself.

Now we need to get the co-relations having all this X values along with the flux values or we can say the drying rate values like this this N is equals to we can say this one Nc when we can say X is greater than equal to Xc1 and first falling rate period say this one first falling rate period. Say we have this Nf1 that is equals to you can say this is linearly proportional to the X values so we can say is equals to say a1 into X plus a2.

So this X1 that is given as 0.32. So Xc1 that is given as a 0.183. So Xc2 is given as 0.097. So somewhere this X, f actually is given as 0.01and this X star is equals to 0. This is equals to 0 it is given in the problem. For second falling, falling rate period Nf2 is equals to say you can say beta into X square.

So for first falling rate period it is mentioned that for this case say we have say X c1 that is greater than equal to X greater than equal to Xc2. For second rate falling period we have this Xc2 greater than equal to X greater than equal to 0. So these are the conditions these are given. So we will be mentioning the conditions like this.

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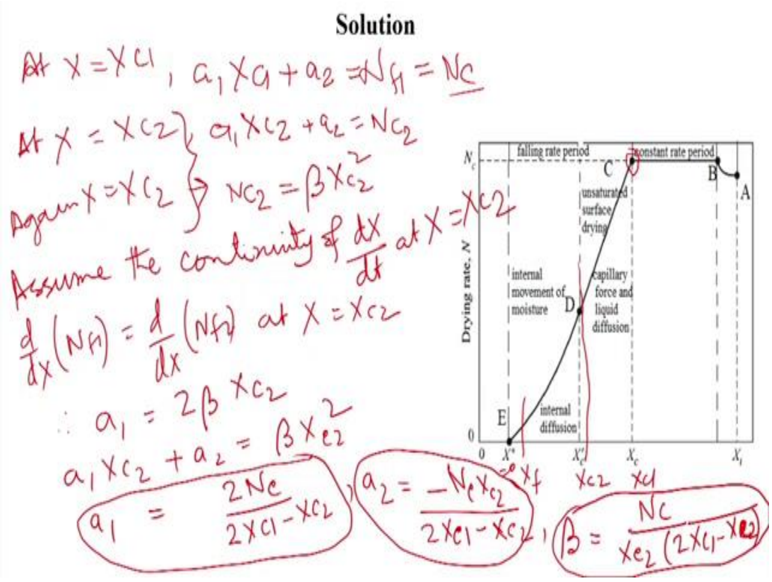

At X is equals to Xc1 we have this a1 Xc1 plus a2 that is equals to Nf1 and that is also equals to Nc because that is we can say this one here it is it is the this one at the beginning so we can say it is nothing but Nc. And X is equals to we can say at X is equals to Xc2 where we can say this one Xc2 and this one as Xc2 a1 into Xc2 plus a2 is equals to Nc2. Again at X is equals to this in this again at X is equals to Xc2 here also we can say we have this Nc2 that is square of this moisture content then we can say this is equal to beta into Xc2 square.

So we have this one and we need to assume this one that continuity this one we assume, we assume the continuity of dx dt. So at X is equals to Xc2 like this some Xc2 that is Xc2 that is Xc1 that is Xi then somewhere it is Xf that is X star equals to 0. So then we can say this one dx into Nf1 is equals to d dx of Nf2 at X is equals to Xc2.

So from there we will be getting like this a1 is equals to 2 into beta into Xc2 and a1 into Xc2 from the above equation plus a2 is equals to you can say this one beta into Xc2 square or a1 will be equals to 2Nc that from the above equation we will be just by manipulation we will be getting 2Xc1 minus Xc2 and a2 will be equal to minus Nc into Xc2 divided 2Xc1 minus Xc2 and beta will be equal to Nc divided by Xc2 into 2Xc1 minus Xc2. So now we have this a1, a2 and beta. So we have all this three values.

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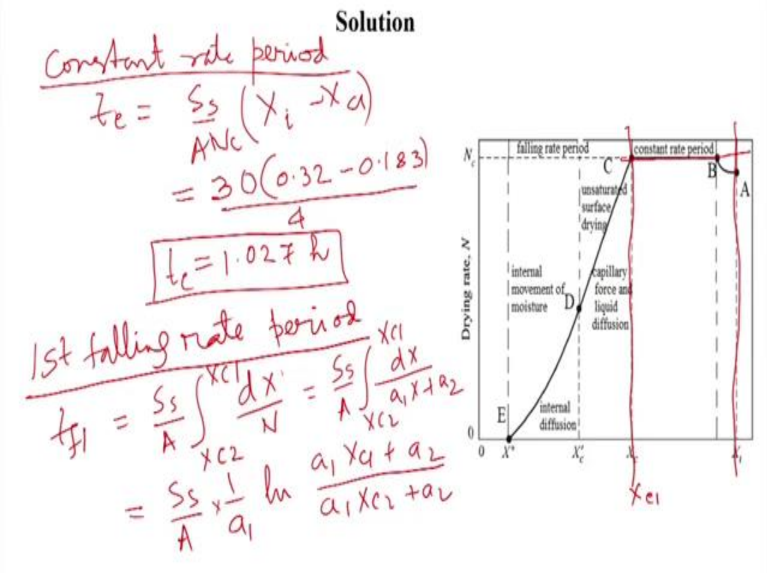

Now we need to calculate the drying time for different period like this we will start with constant rate period. So drying time calculation for constant rate period that is very easy to calculate constant rate period, first for this rate period we can say from Xi to Xc1 So Xc1 from Xi to Xc1 for drying time calculation like this tc will be, tc is equals to say Ss by ANc into Xi minus Xc1.

So that will be like this Ss by A we know this one this is 30and Xi is equals to 0.32 and Xc1 is equals to 0.183 divided by Nc is equals to 4 so it will be becoming as in terms of hour that is 1.027 hour. So this is we have got, obtained as tc is equals to 1..027 hour. Now we have 2 falling rate periods, so for first falling rate period tf1 that is equals to Ss by A into integration Xc2 to Xc1 dx by N though you have this one the minus Ss by A into integration Xc1 to Xc2 but the, to make this positive we have changed the limits that will be nothing but we can say is equals to Ss by A into Xc2 to Xc1 dx by a1 X plus a2.

So from there we will be getting that is equals to Ss by A into 1 by a1 into ln A1 Xc1 plus a2 divided by a1 Xc2 plus a2. Just by manipulating this a1 value and a2 value in this equation we will be getting this a final form of this tf1 will be like this.

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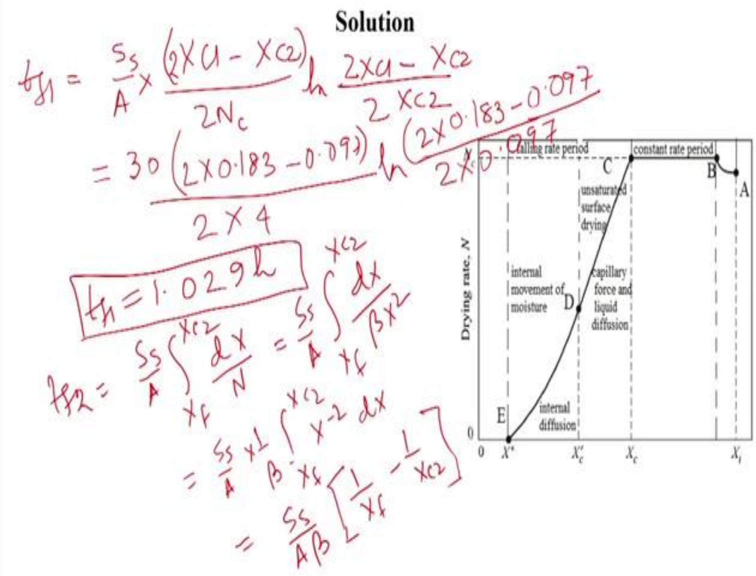

So tf1 will be is equal to just by putting this a1, a2 values in this equation we have this Ss by A into 2Xc1 minus Xc2 divided by 2Nc into ln 2Xc1 minus Xc2 divided by 2 Xc2 and all the values are now known to us we will be putting this value to get the first falling rate time. So it is Ss by A is equals to 30 then Xc1 is say that is 2Xc1 2 into 0.183 minus Xc2 is 0.097 divided by 2 into Nc is equals to 4 into ln 2 into 0.183 minus Xc2 is equals to 0.097 divided by 2 into 0.097.

So it is coming out as 1.029 hour. So first falling time is 1.029 hour. Now we need to calculate the second falling rate period time. So for that also we need to do one , we need to get the expression for this one but in this case you should this initial condition will be the final condition of the first falling rate period. So it will start from Xc1 to Xc2, So that is why we can say tf2 will be like this Ss by A into integration Xf to Xc2 that is dx by N we told that this is the drying rat is proportional to the square of this moisture content beta into X square.

So we will be putting this N is in place of N we will putting beta X square so we will be writing this one Ss by A this integration Xf to Xc2 dx by beta into X square. So that will be like this is equals to we can say Ss by A into 1 by beta and integration Xf to Xc2, X (())(20:02) minus 2 into dx.

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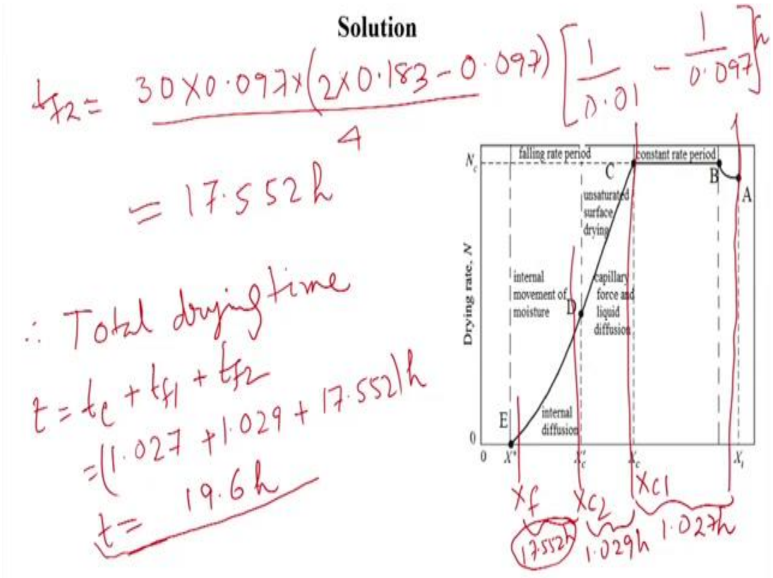

That is coming out as a, Ss by A into beta and into say 1 Xf minus 1 by Xc2. That is we can say this tf2 if we put all this values we will be getting like this, so tf2 will be tf2 will be say 30 into 0.097 into 2 into 0.183 minus 0.097 divided by 4 into 1 by the final one is 0.01 minus Xc2 is equals to 0.097 that is in hour. So that will be coming out to be 17.552 hours.

So the total time there for we can say the total drying time t is equals to constant drying period then first falling rate then second falling rate. So that is coming out to be 1.027 plus 1.029 plus 17.552 this hours that is coming out to be 19.6 hours. So this total drying time is 19.6 hours. So here we say out of this three drying times saythe first drying time we can say this one from Xi to Xc1 then from Xc1 to Xc2 then from Xc2 to Xf.

So it takes only 1.027 hour this takes 1.029 hours but his Xc2 to Xf it took 17.552 hours. So that is I say at end the drying rate actually becomes very slow due to we can say this one the less drying force it takes more time. So where as the total time is 19.6 hours.

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Problem 5

A wet solid having 25% moisture is to be dried at a rate of 1000 kg/h to 1% moisture in a continuous counter current dryer. The drying air enters at 100°C at a rate of 12,000 kg/h (dry basis) with a humidity of 0.025 kg per kg dry air and the dry solid leaves at 60°C. The temperature of the wet solid entering the dryer is nearly the same as the adiabatic saturation temperature of the air leaving the dryer.

Following data and information are available:

Gas-phase mass transfer coefficient for drying of the solid, k_Y = 150 kg/m^2 h; effective surface area of the solid = 0.065 m^2/kg dry solid; specific heat of the solid, c_{ps} = 0.96 kJ/kg K; critical moisture of the solid is 8%; the equilibrium moisture is negligible. All moistures are on wet basis. Calculate the drying time.

Now we will be discussing about another problem that say for this constant continues dryer the drying time calculation we will be doing this one and this is a very interesting problem also. Wet solid having 25 percent moisture is to be dried at a rate of 1000 kg per hour to 1 percent moisture in a continues counter current dryer. The drying air intercept 100 degree Celsius at a rate of 12,000 kg per hour dry basis with a humidity of 0.025 kg per kg dry air and the dry solid leaves at 60 degree Celsius.

The temperature of the wet solid entering the dryer is nearly the same as the adiabatic saturation temperature of the air leaving the dryer. That is we can say that is we can assume also. The following data and information are available for this drawing operation. The gas-phase mass transfer coefficient for drawing of the solid ky that is a150 kg per meter square hour, effective surface area that is a star a prime is equal to0.065 per meter square per kg. Specific heat the cps of the solid is0.96 kg per kg Kalvin and critical moisture of the solid is 8 percent the equilibrium moisture is negligible.

All moisture are on wet basis we need to calculate the drying time. So in this case as this is continues counter current dryer so definitely we have different drying zone here also from the problem we assume that the drawing there are three drying zone that is one either zone 1 and zone 2 and zone 3. Where zone 3 is the we can say this one only heating of the final dryed product to the, we can say desired temperature.

And in zone 1 the, we can say this one the initial drying starts and in zone 2 it is we can say this one temperature remains almost constant throughout the drying period. So we will be solving this one systematically.

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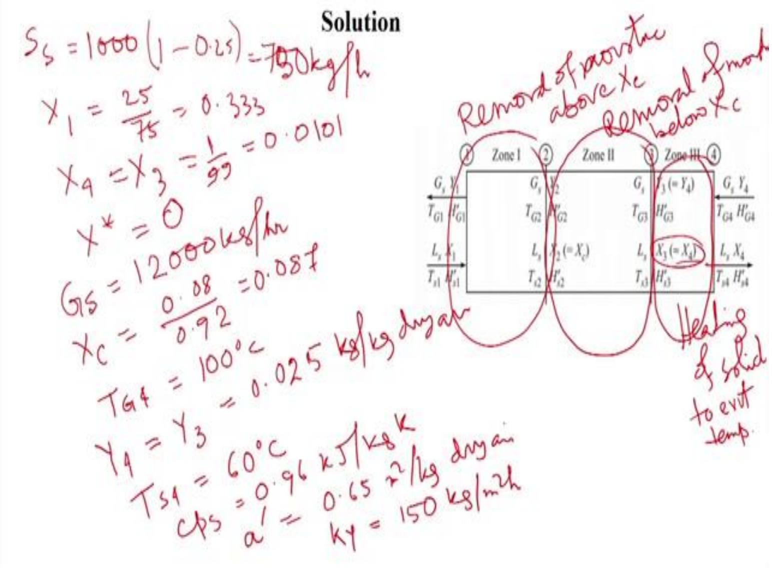

So whatever the data points we have just will be first jot down those. Like this we can say this one is this zone 1 that is we can say this one revolve of moisture above Xc that is we can say this one revolve of moisture above Xc and in zone 2 that is we can say this one revolve of moisture below Xc and in zone3 here we can say this one only heating of the solid to exit temperature.

So this three zones, so whatever the given parameter we have in the problem we will now first jot down all this Ss is actually given as say 1000 is the flow rate of this wet solid with this we can say this 25 percent moisture content. So it is 1 minus.25 so we can say it is 750 kg that is per hour. Than X1 will be definitely say 25 by 75 that is will be0.333 and X4 where it will be X4 or X3 both are same when it is executive actually from their because you see after that the moisture content does not changes. So that is X3 and X4 both are same.

So that is we can say this one that is equals to X3 also is equals to so that is 0.0101 like this and X star for this means it is equilibrium moisture content that is 0 almost 0. So we can assume this one as zero and gas flow rate this drying gas flow rate is given as 12,000 kg per hour and Xc is given as 0.08 by 0.92 that is equal to 0.087 and TG4 that is also given as we can say 100 degree Celsius and y4 that is equal to y3 also is equal to0.025 kg dryer and Ts4 is equal to 60 degree Celsius and cps is equals to 0.96 kilo joule per kg kelvin.

And a prime where specific area is given as 0.65 meter square per kg dryer and mass transfer cooperation value ky is given as 150 kg per meter square hour. These are the parameters given in this problem.

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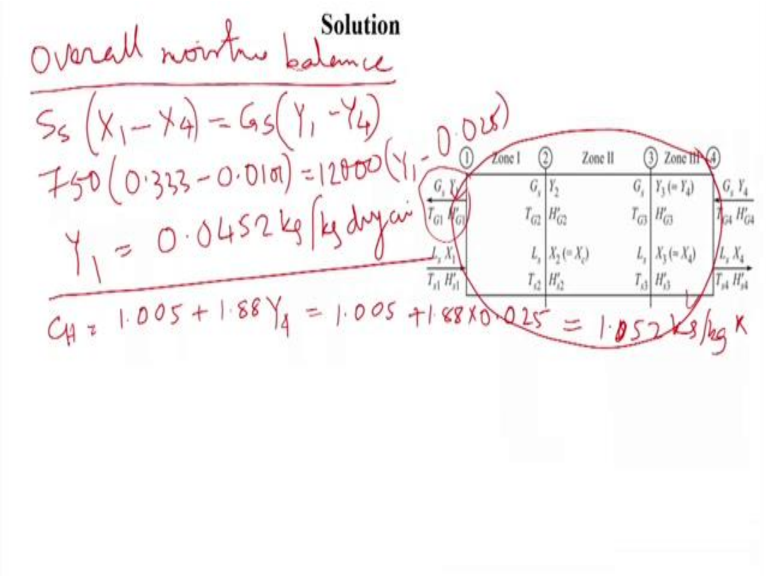

So we will be doing now overall moisture balance to get this y1 value that is first that is unknown parameter we will be calculating this one from this if we do the warm moisture balance across this enter dryer. So we will be doing this warm moisture balance like this. So we will be taking this Ss into X1 minus X4 here Ss ls both are same is equals to Gs into y1 minus y4 so that is we can say this one 750 into X1 is equals to 0.333 minus X4 is equals to 0.0101 and Gs is given as 12,000 y1 we do not know minus 4 is given as0.025 so from here we will be getting this y1 is equal to 0.0452 kg per kg dryer.

So now we have got this y1 that is we can say this one this moisture content of this drying air which is leaving the dryer. So we have got this y1 now. Now humid heat actually of the air Ch in zone 3, we will be starting here actually. So we can say this one Ch, Ch is equals to say 1.005 plus 1 .88 into y4 that is we can say 1 .005 plus 1.88 into that y4 is equal to 0.025. That is coming out as 1.052 kilo Joules per kg dryer per kelvin.

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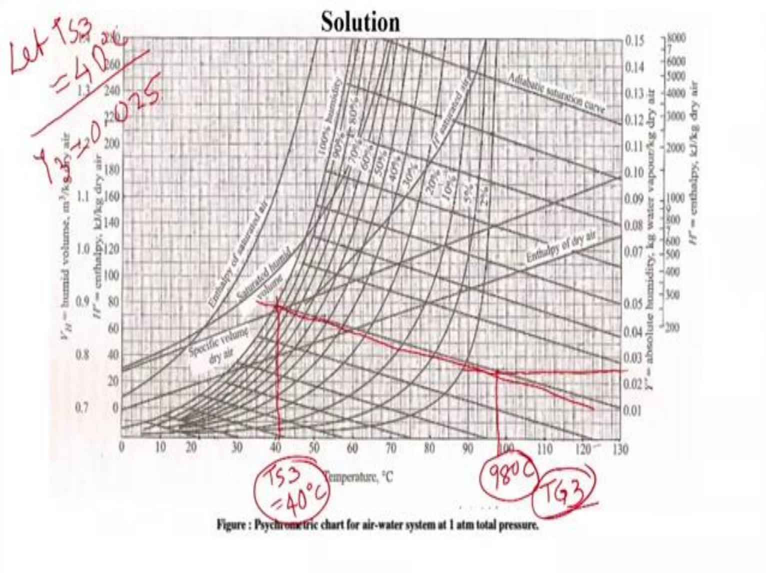

Now actually we need to take the help of this psychologic chart to get this Tg 3. So we will be doing like this we need to assume say for this one say let Ts 3 will be assume let Ts 3 that is we assume on 1 value actually we are assuming now like 40 degree Celsius. For the time being we are assuming this Ts3 is equals to this 40 degree that is nothing but we can say this one automatic saturation temperature.

So we will be taking this one at 40 degree Celsius like this here and then we will be taking this we can say y3 actually is given as point y3 that is given as 0.025 that is already given 0.025 let us take this one this line and 0.025 this line. So here we see we can say this one let us take this is 98 degree Celsius. So that is we can say this one Tg3 that is Tg3. So let us take this one is Tg3 whether we are our assumption is correct or not we can get this one from the enthalpy balance also. It is for the, we can say for simplicity we have assume this one we assumed as this Ts3 is equal to 40 degree it may be rare temperature also but it is Celsius for that we will be getting Tg3 at as the 98 degree Celsius.

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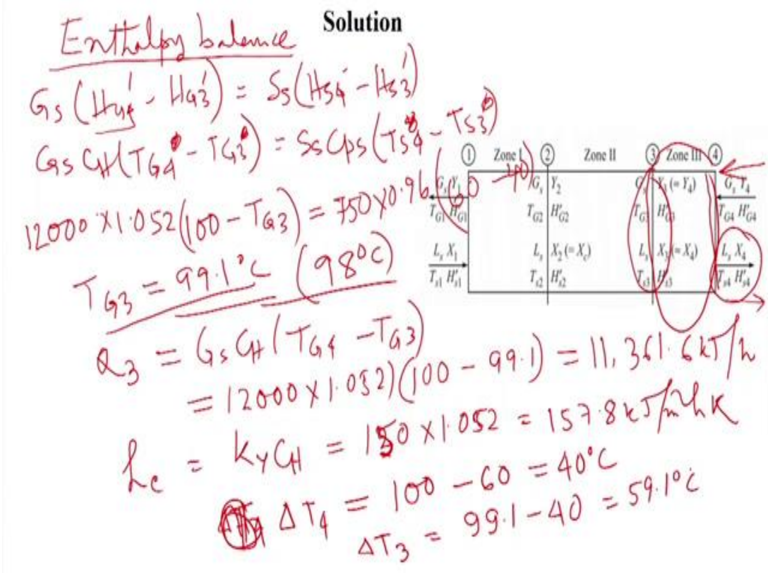

For that let us take so this will be doing the enthalpy balance to Nco whether this Tg3 is correct or not. Let us do the enthalpy balance very easily you can do this one. In this zone 3 we will be doing this one that Gs into Hg4 prime minus Hg3 prime is equal to Ss into Hs4 prime minus Hs3 prime. Here you see this except this we can say this one again we can say this one we can convert this into a in terms of H we can see we can write in the time the form of a Ch into temperature like this or Gs into Ch into Tg4 prime minus Tg3 prime is equals to Ss into cps into Ts4 prime minus Ts3 prime.

So here you see this Gs is equals to we can say this 12000 into Ch is equal to 1.052 into Tg4 is equals to is given already as 100 degree Celsius Tg3 prime will be getting Tg3 say than it is equals to Ss is given as 750 cps is given as 0.96 and Ts4 is given as 60 and Ts3 is given as 40. So now from here we can say Tg3 so these are not prime values actually so Tg3 is equals to we can say this 99.1 degree Celsius and from this psychometric chart we got 98 degree Celsius.

So we can say may be both are almost similar. So we can assume that the Tg3 is equals to say 99.1 degree Celsius. Now in zone 3 so in zone 3 w can say this one Q3 whatever the heat flow actually is there is equal to we can say this one Gs into Ch into Tg4 minus Tg3, so that comes out as 12,000 into 1.052 into this is Tg4 is equal to 100 minus Tg3 99.1.

So that is coming out as 11,361.6 kilo joules per hour and we have this Lc is equals to Ky into Ch. So that we have this one Ky is equal to 150 into Ch is equals to 1.052. So that is, so 157 this is 150 that is 157.8 so kilo joules per meter square per hour Kalvin. Now we need to get the temperature driving force so for that we have this one in this in this station 4 or wherever we can say this one hot drying solid is exiting and drying gas actually is entering there we say delta T4 that is we can say is equals to say 100 minus 60.

So this is 40 degree Celsius and here in station 3 this is we can say this is on temperature driving force delta T3 is equal to say, we can say 99.1 minus 40 so it is 59.1 degree Celsius.

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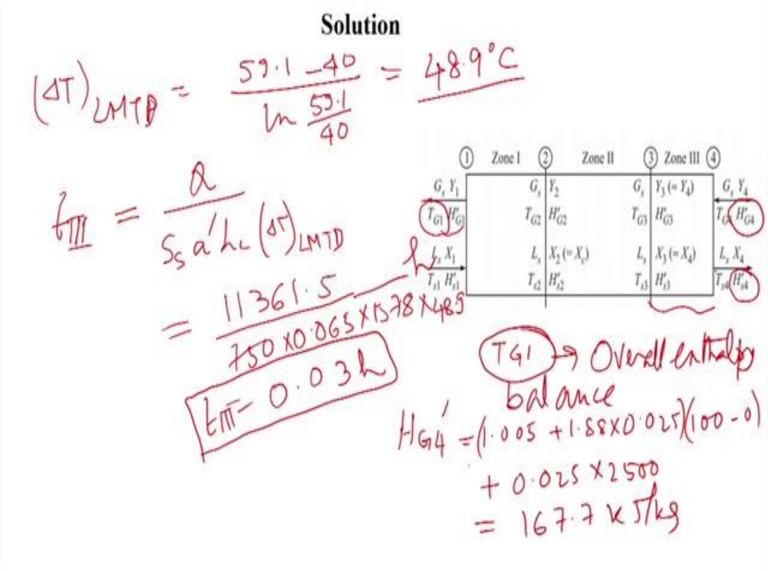

So from here actually we will be getting that say LMTD delta T LMTD will be like this 59.1 minus 40 divided by ln 59.1 by 40. So this is coming out as 48.9 degree Celsius in this zone we can say this one temperature drying force is 49 degree Celsius and say we know this we have already this one this T3 in the previous class we have already derived that is in T3 this is Q by Ss into a prime into Lc into LMTD that is equals to Q is equals to 11,361.5 divided by 750 into a is 0.065 into Lc is given as 157.8 and LMTD is 48.9.

So that is coming out in hour that is we got this time as 0.03 hour. So this T3 is 0.03 hour. Now we will be going to this zone 2. So in zone 2 first we need to get Tg1 because this temperature is actually is not known we need to do by some this we can say indirect method we will say for this getting for this Tg1 we need to do the overall enthalpy balance in zone 2 from there actually we will be getting like this before that actually we need to calculate this, suppose we need to get Tg1.

So calculation of Tg1 for that we will be doing say overall enthalpy balance. We need to get this from this overall enthalpy balance before that we need to get this one we have already derived this one for enthalpy value for gases enthalpy values for solids. This Hg4 prime that will be like this 1.005 plus 1.88 into say y prime that is into 0.025 into temperature gradient this 100 minus T0 is equals to 0 plus this y prime 0.025into 2500.

It is coming out as 167.7 kilo joules per kg. So that is Hg4 prime, however it is entering here.

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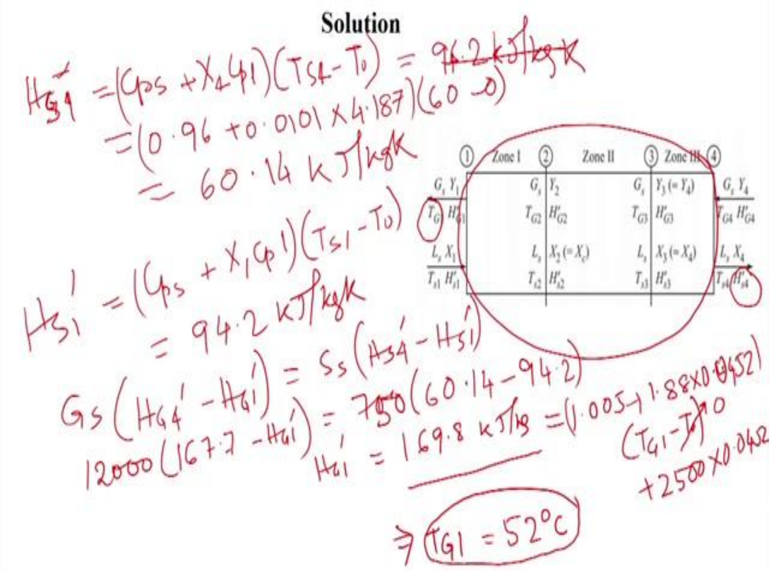

Similarly for getting this Hs4 prime we have another formula we will be using that for Hg for gas which is solid actually Hs4 prime that is whatever is coming out this we can say drying solid the enthalpy value will be like this cps plus X1 into Cpl into Ts1 minus T0 but doing this one 0.96 plus pint 96 plus 0.0101 into 4.187 into 60 minus 1, 0. So it is coming out as 60.14 kilo joules per kg Kelvin and for Hs1. So we have this cps plus that will be actually X4, X1 into cpl into Ts1 minus T0.

It is coming out as 94.2 kilo joules per kg Kelvin. Now we will be doing the overall enthalpy balance of course the entire dryer so we will be getting like this Gs into Hg4 prime minus Hg 1 prime is equals to Ss into Hs4 prime minus Hs1 prime. So we will be putting all this values to get this Hg1 prime that is not actually available. So we will be doing this one 12,000 into Hg4 prime we have already got this value 167.7 minus Hg1 prime is equals to 750 into that is we have this 60.14 minus 94.2.

So from here we will be getting this Hg1 prime that we will be getting as 169.8 kilo jul per kg. So that is we can say this that will be equal to just using this formula 1.005 plus 1.88 into y1 prime that is we can say this one 0.4, 0452 into Tg1 minus Tg0 plus 2500 into y1 prime that is equals to 0.0452. That is equal to we can say this one we will be putting this is equal to, here you see T0 is equal to 0 degree Celsius.

So we will be putting here 0. So now from this equation 169.8 is equal to 1.005 plus 1 0.88 into 0.0452 into Tg1 plus 2500 into 0.0452. So from there we will be getting Tg1 is equal to you can say 52 degree Celsius. Now we see this gas temperature is now known this Tg1 is known. What will be the Ts1 for that actually we can say this and humidity this y1 prime is already obtained as 0.0452.

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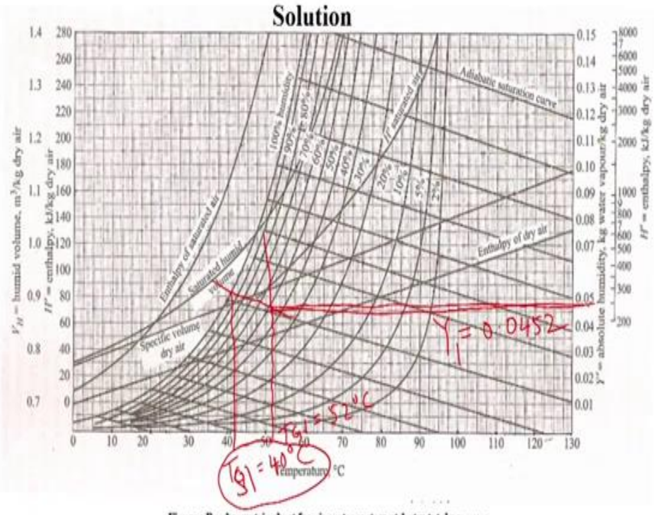

Figure : Psychrometric chart for air-water system at 1 atm total pressure.

So we will be going to this one in psychometric chart, so we have this Tg1 is equals to gas temperature we can say this one 52 degree Celsius. So 52 degree Celsius at Tg1 and 0452 like this we have this we have this one. So from here if we follow this adiabatic saturation line we will be getting we can say this one temperature as like this are, let us take it is say Tg this on Tg1, Ts1 that will be equal to we can say let us say 40 degree Celsius.

So for 52 degree Celsius Tg1, Tg1 is equals to 52 degree Celsius with y1 is equal to 0.0452 we have Ts1 is equal to just 40 degree Celsius.

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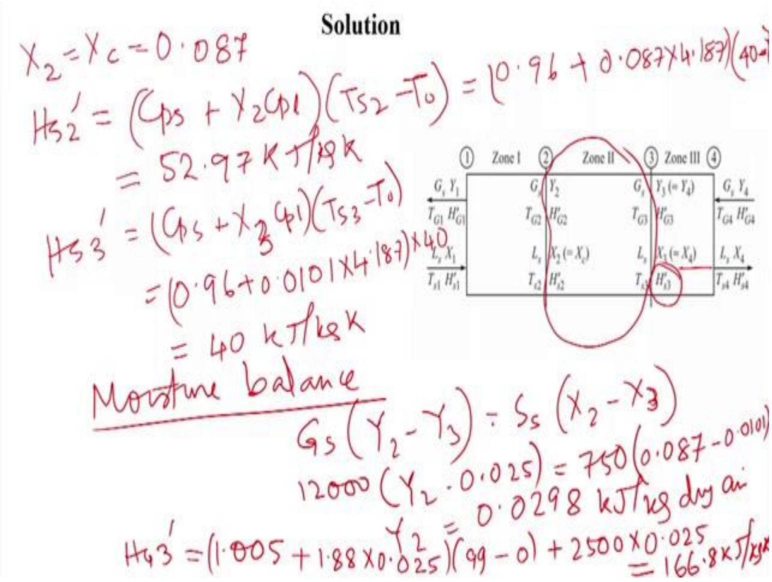

Now we will be getting this X2 values that is we can say this one X2 that is nothing but this we can say this one Xc that is we have already this one obtained as 0.087. We have this value and from there actually we will be getting Hs2 prime that is that is we can say this cps plus X2 into cpl that is liquid water into Ts2 minus T0 that is we can say this one will be getting as 0.96 plus X2 0.087 into 4.187 into Ts2 that is assume this as 40 and Ts0 is equal to 0, 40 minus 0.

So from here actually we will be getting Hs2 prime is equals to 52.97 kilo Joules per Kg kelvin, and similarly this Hs3 prime we will be calculating by this like cps plus X2 into cpl into Ts3 minus T0 so here we can say it is say cps that is 0.96 plus Hs3 that is will be X3 actually that is 0.0… and X3 X4 both are same 0.0101 into 4.187 into 40.

So that is coming out as 40 okay kilo Joules per kg Kelvin. Now we will be doing the moisture balance in this zone 2, in the moisture balance so we will be doing, moisture balance like Gs into y2 minus y3 is equal to Ss into X2 minus X3. So this is 12,000 into y2 minus 0.025 this is y3 we have is equal to 750 into X2 we have 0.087, 0.087 and X3 that is X4 both are same 0.0101.

So from here we will be getting y2 that is equal to we can say 0.0298 kilo joule per kg dryer and now we can calculate this Hg3 prime that is equal to just by putting by this value this we will be getting 1.005 plus 1.88into this y3 that is 0.025 into 99 minus 0 that is y3 that is minus 0 plus 2500 into y3 0.025. So that is coming out as 166.8 kilo joules per kg Kelvin.

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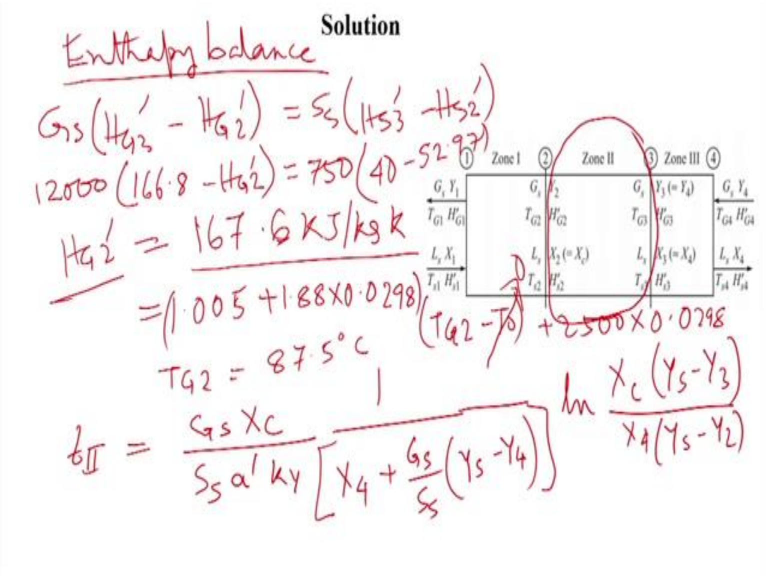

So now we have and we need to get this one this Tg2 that is not this one we do not have Tg2 value we will be calculating this one. So we will be doing the enthalpy balance Gs into Hg3 prime minus Hg2 prime is equal to Ss into Hs3 prime minus Hs2 prime that is we can say 12,000 into Hg3 prime we have just calculated 166.8 minus Hg2 prime we do not know is equal to 750 into Hs3 prime is 40 minus Hs2 prime is 52.97.

From here actually we will be getting Hg2 prime. So that is coming out at 167.6 kilo joules per kg Kelvin. So there actually we can say this one this is nothing but just by using the equation in terms of this temperature we will be getting like this that is equal to 1 point for gas actually 1.005 plus 1.88 into y2 that is 0.0298 into Tg2 we do not know Tg2 minus T0 that is 0 degree plus 2500 into y2 that is 0.0298.

So from this equation 167.6 is equal to 1.005 plus 1.88 into 0.0298 into Tg2 minus T0 that is 0 plus 2500 into 0.0298 we will be getting the Tg2 is equal to say 87.5 degree Celsius. So we have Tg2 so whatever the Ts actually will be we can say this one this Ts that is we can say Ts is equal to 40 degree Celsius.

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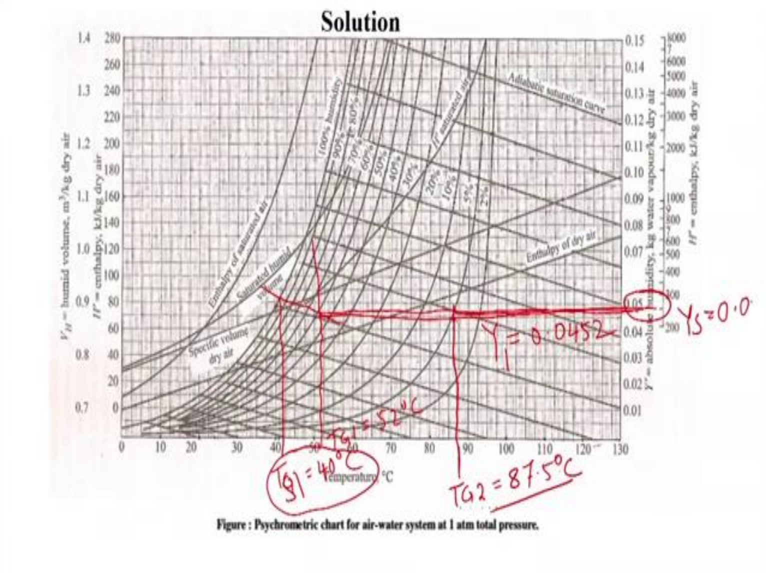

We know suppose this Ts1 is actually 40 degree Celsius and now we have Tg2 is equal to 87.5 degree Celsius, so this 87.5 degree Celsius like here so we can say if we have this the Tg2 is 80 Tg2 is equal to say 87.5 degree Celsius and Ts1 actually we have this 40 degree Celsius and say whatever will be the ys. It will be like this so ys will be is equal to say 0.05.

So now we need to get this t2 whatever the time for this second joules time require to dry the second joules so t2 we can say this one Gs into Xc by Ss into a prime into ky into 1 by X4 plus Gs by Ss into Ys minus y4 into ln Xc into Ys minus y3 by X4 into ys minus y2.

Now all the values are actually known to us we will be getting all this values and we will be putting then we will be getting.

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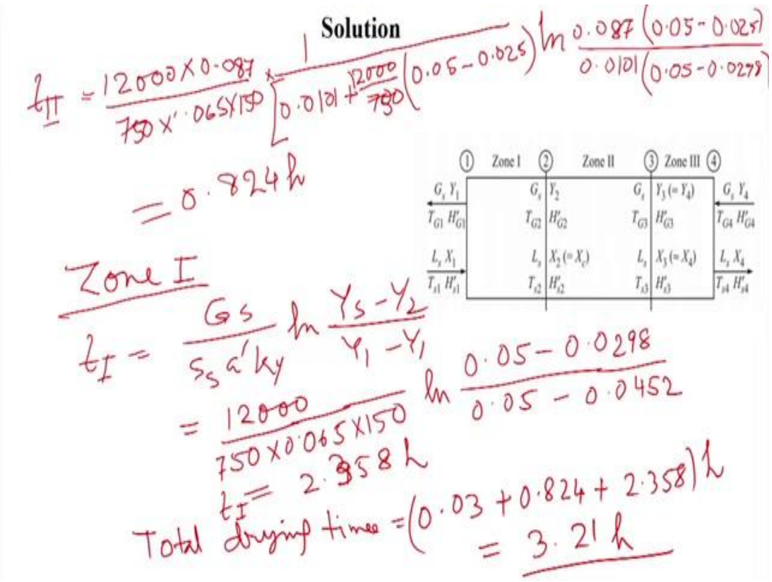

So the time required in this zone 2 t2 will be 12,000 into 0.087 divided by 750 into 0.065 into 150 into 1 by 0.0101 plus 12,000 divided by 750 into 0.05minus 0.025 into ln Xc that is 0.087 into ys that is 0.05 minus y3 0.025 divided by X4 that is 0.0101 into ys that is 0.05minus y2 that is 0.0298.

So this is coming out at 0.824 hour. Now we will be calculating the time for zone 1 so that is for zone1 we have this total time T1 is equal to Gs by Ss into a prime into ky into ln ys minus y2 by ys minus y1. So here Gs is equal to 12,000 by Ss means 750 into a prime is 0.065 into ky is equal to 150 into ln ys is equal to 0.05 minus 0.0298 divided by 0.05 minus 0.0452.

So it is coming out as 2.358 hour. So this is T1, so total time we can say this one total drying time will be total drying time is equal to we can say T1 plus T2 plus T3 that is we have this 0.03 plus 0.824 plus 2.358. So that is total 3.21 hour. So this total drying time is obtained as 3.21 hour.

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So thank you we will start this next topic that is liquid-liquid extraction in the next class