Thermal Operations In Food Process Engineering: Theory And Applications

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Lecture - 48
Heat Exchangers (Contd.)

Good morning we have been doing Heat Exchangers and obviously, we have come a little ahead and now we shall go on to in the previous class we said that heat exchangers with your baffles. So, that baffles and other things when they are coming then you need to get the temperature difference in the right way, 'right'.

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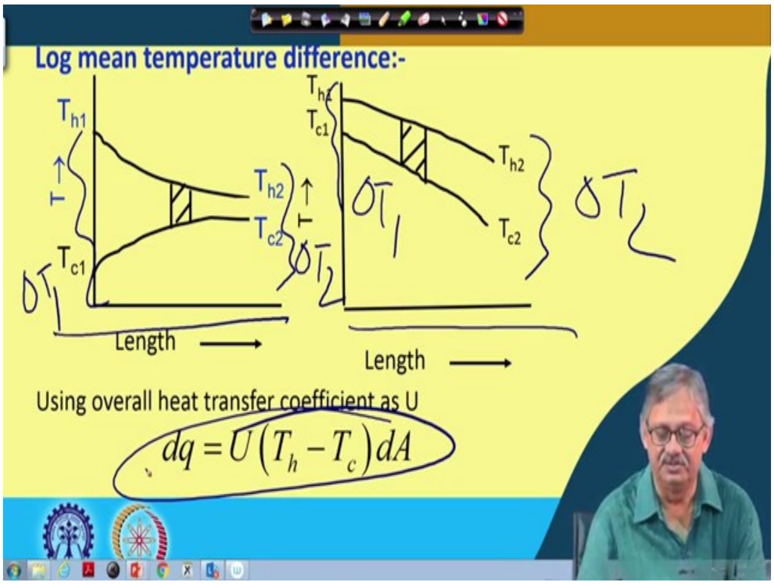

Log mean temperature difference:-

Using overall heat transfer coefficient as U

$$\boxed{dq = U(T_h - T_c)dA}$$

So, that can be done if we are doing with log mean temperature difference, 'right'. Perhaps, I am not recalling whether we started it or not; however, if we had started then let us recapitulate or go through it very quickly that log mean temperature difference for parallel flow, this is for counter flow, 'right'.

So, when it is for parallel and counter flow, so, what do we need that, let us take this is for the parallel flow and this is for the counter flow and this is for ΔT_2 this is for ΔT_1. Similarly this is for ΔT_2 and this is for ΔT_1, 'right' and the basic equation is $dq = U(T_h - T_c)\, dA$, 'right'.

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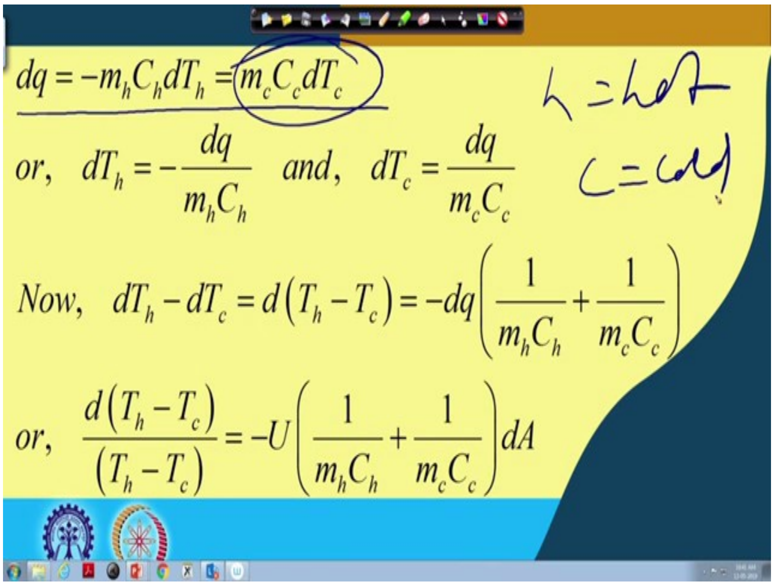

$$\underline{dq = -m_h C_h dT_h = \boxed{m_c C_c dT_c}}$$

h = hot

c = cold

$$or, \quad dT_h = -\frac{dq}{m_h C_h} \quad and, \quad dT_c = \frac{dq}{m_c C_c}$$

$$Now, \quad dT_h - dT_c = d\left(T_h - T_c\right) = -dq\left(\frac{1}{m_h C_h} + \frac{1}{m_c C_c}\right)$$

$$or, \quad \frac{d\left(T_h - T_c\right)}{\left(T_h - T_c\right)} = -U\left(\frac{1}{m_h C_h} + \frac{1}{m_c C_c}\right) dA$$

So, if that be true then, let us look at how it was done, again I am not sure whether you did it or also not. So, quickly you are doing d q = $-m_h$ C_h dh = m_c C_c dT_c where h stands for hot and c stands for cold, 'right'.

So, if this is true then dT_h = -dq / m_h C_h and dT_c = dq / m_c C_c, yes I remember that this negative we had explained why. So, if one is minus mc b dT the other is plus m_c b dT, 'right'. So, dT_h - dT_c that came to be d (T_h - T_c) and that is equal to -dq ×(1/m_h C_h and + 1/ m_c C_c). So, we can write d(T_h - T_c) / (T_h - T_c) of course, with respect to inlet and outlet is minus U (1/$m_h C_h$ + 1/ $m_c C_c$) dA, 'right'.

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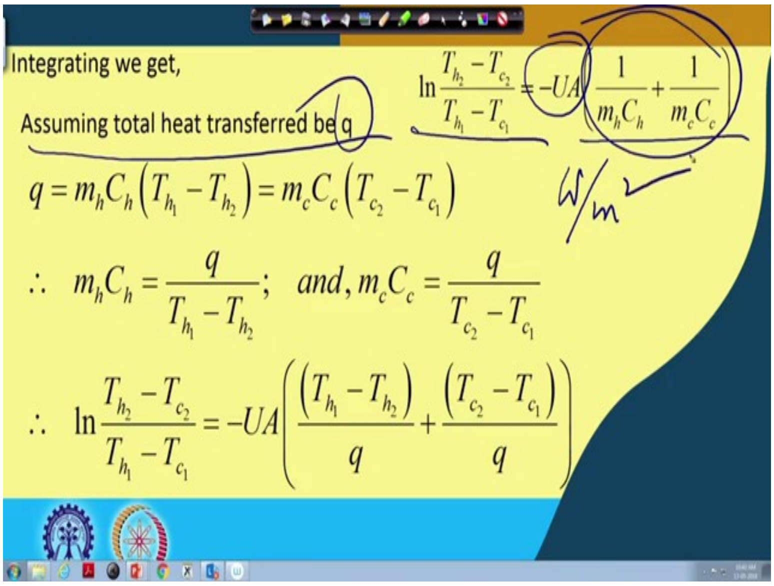

Integrating we get, $\ln\frac{T_{h_2}-T_{c_2}}{T_{h_1}-T_{c_1}} = -UA\left(\frac{1}{m_hC_h}+\frac{1}{m_cC_c}\right)$

Assuming total heat transferred be q

$$q = m_hC_h\left(T_{h_1}-T_{h_2}\right) = m_cC_c\left(T_{c_2}-T_{c_1}\right)$$

$$\therefore \ m_hC_h = \frac{q}{T_{h_1}-T_{h_2}}; \quad and, m_cC_c = \frac{q}{T_{c_2}-T_{c_1}}$$

$$\therefore \ \ln\frac{T_{h_2}-T_{c_2}}{T_{h_1}-T_{c_1}} = -UA\left(\frac{\left(T_{h_1}-T_{h_2}\right)}{q}+\frac{\left(T_{c_2}-T_{c_1}\right)}{q}\right)$$

W/m^2

So, if this is true then, let us see integrating it we get ln ((T_{h2} - T_{c2})/(T_{h1} - T_{c1})) is -UA (1/ m_hC_h + 1/ m_cC_c).

Again assuming total heat to be transferred or total heat transferred to be q then of course, this q is W/m^2, 'right' that is what we are writing here no a. So, q = m_hC_h × (T_{h1} – T_{h2}) that is equal to $m_c C_c$ (T_{c2} - T_{c1}). So, we can write $m_h C_h$ = q/ (T_{h1} – T_{h2}) and $m_c C_c$ = q/ (T_{c2} - T_{c1}), 'right'. So, taking the log, we can write ln (T_{h2} - T_{c2}) this time or this one that we can write, this is equal to ln {(T_{h2} - T_{c2}) /(T_{h1} - T_{c1})} this is equal to -UA which we got.

Now, substituting these with this m_c m_h C_h and m_c C_c in this equation we get and rearranging (T_{h1} – T_{h2}) / q + (T_{c2} - T_{c1}) /q, 'right'. So, ln of that is this.

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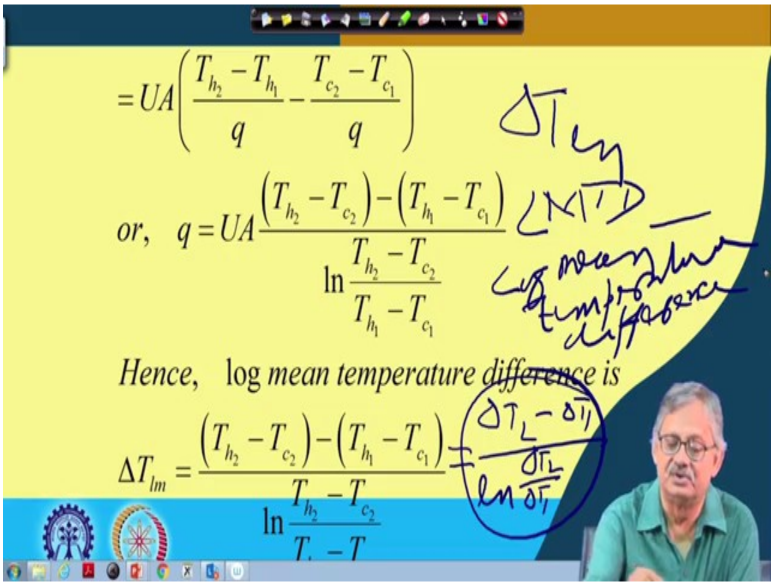

$$= UA\left(\frac{T_{h_2}-T_{h_1}}{q}-\frac{T_{c_2}-T_{c_1}}{q}\right)$$

$$or,\quad q = UA\frac{\left(T_{h_2}-T_{c_2}\right)-\left(T_{h_1}-T_{c_1}\right)}{\ln\frac{T_{h_2}-T_{c_2}}{T_{h_1}-T_{c_1}}}$$

Hence, log mean temperature difference is

$$\Delta T_{lm} = \frac{\left(T_{h_2}-T_{c_2}\right)-\left(T_{h_1}-T_{c_1}\right)}{\ln\frac{T_{h_2}-T_{c_2}}{T - T}} = \boxed{\frac{\Delta T_L - \Delta T_1}{\ln\frac{\Delta T_L}{\Delta T_1}}}$$

ΔT_{lm}

LMTD — log mean temperature difference

So, this we can write is equal to UA ($T_{h1} – T_{h2}$) / q minus because that minus which we had earlier that we have taken into inside and this is what we would like to this minus, ‘right’ that we have taken inside. So, that is why this has become minus. So, (T_{h2} - T_{h1})/q – (T_{c2} -T_{c1})/q, ‘right’ that minus which was here has been taken inside.

So, we can write, q u q is equal to UA × [(T_{h2} – T_{c2}) - (T_{h1} -T_{c1})] / ln ((T_{h2} – Tc_2)/(T_{h1} - T_{c1})), ‘right’. So, the log mean temperature difference that we can write, ΔT_{lm} = [(T_{h2} – Tc_2) – (T_{h1} -T_{c1})] / ln ((T_{h2} – Tc_2)/(T_{h1} -T_{c1})), ‘right’.

So, this is called log mean temperature difference which is nothing, but can be written as we can write this is (ΔT_2 - ΔT_1) / ln ($\Delta T_2/\Delta T_1$) normally in this for $\ln_{lmtd}$ or ΔT_{lm} a is written. So, this can also be told LMTD or log mean log mean temperature difference, ‘right’ LMTD.

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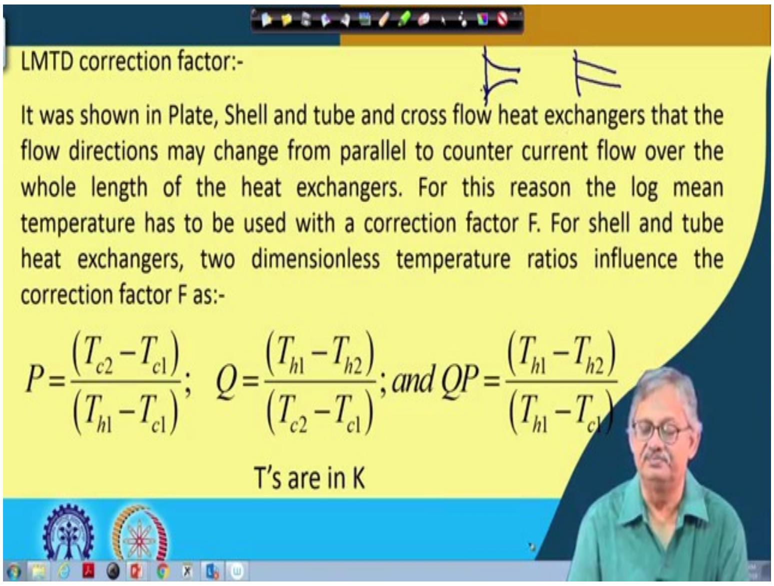

LMTD correction factor:-

It was shown in Plate, Shell and tube and cross flow heat exchangers that the flow directions may change from parallel to counter current flow over the whole length of the heat exchangers. For this reason the log mean temperature has to be used with a correction factor F. For shell and tube heat exchangers, two dimensionless temperature ratios influence the correction factor F as:-

$$P=\frac{(T_{c2}-T_{c1})}{(T_{h1}-T_{c1})};\quad Q=\frac{(T_{h1}-T_{h2})}{(T_{c2}-T_{c1})};\ and\ QP=\frac{(T_{h1}-T_{h2})}{(T_{h1}-T_{c1})}$$

T's are in K

So, once we have this log mean temperature difference then we can write one more thing, this LMTD was what we had shown you was with respect to if this is this was the temperature with respect to this was for co-current and this was for counter current, ‘right’.

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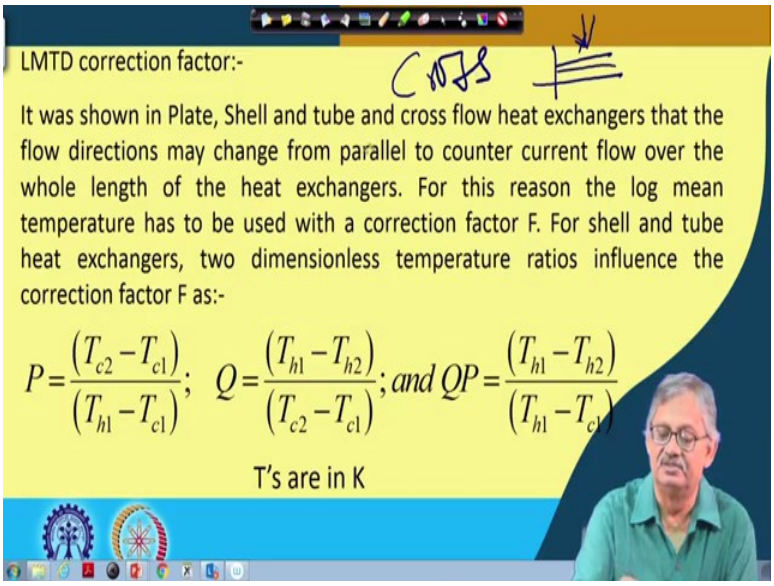

LMTD correction factor:-

Cross

It was shown in Plate, Shell and tube and cross flow heat exchangers that the flow directions may change from parallel to counter current flow over the whole length of the heat exchangers. For this reason the log mean temperature has to be used with a correction factor F. For shell and tube heat exchangers, two dimensionless temperature ratios influence the correction factor F as:-

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T's are in K

So, if this is true then the third one which one was perpendicular to the flow, ‘right’. So, this was perpendicular to the flow or this was told cross flow, ‘right’. So, for cross flow that LMTD is not so simple. For that, it is it is seen that both plate shell and tube, plate shell and tube and cross flow heat exchangers that the flow directions may change from parallel to counter current flow over the whole length of the heat exchangers, 'right'.

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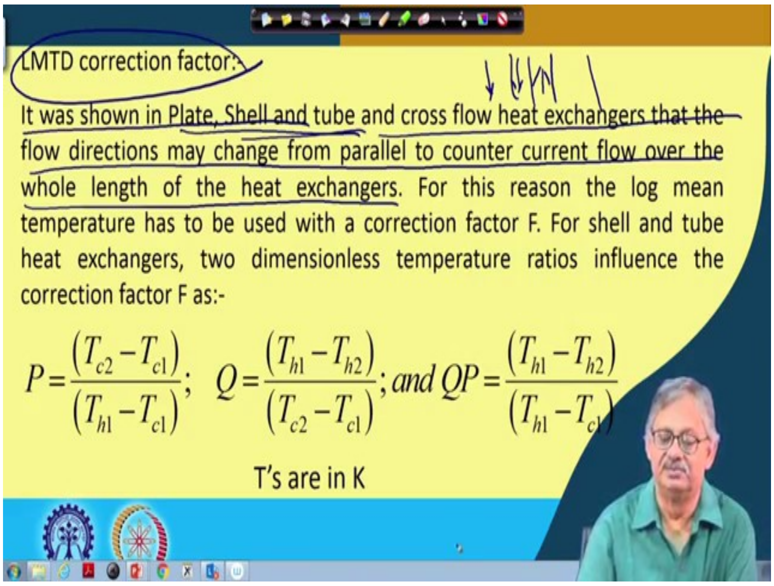

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T's are in K

In the plate we have already said so many plates are there depending on whether this is co-current or counter current that will detect how much co currency counter currency is there in plate heat exchanger. Similarly in shell and tube will also depending on how the weapons have been put. So, it can be, 'right'. So, it may change from parallel to counter current flow over the whole length of the heat exchanger. For this reason the log mean temperature has to be used with a correction factor.

For a shell and tube heat exchangers, two dimensionless parameters or temperature ratios influence the correction factor F as, this one is P that is (T_{c2} - T_{c1}) / (T_{h1} - T_{c1}). Another is Q, 'right' of course; this Q is not that heat transfer. So, you can also write R in many cases may be this is written as R, 'right'. So, if you are not comfortable with Q you may write with R, 'right'.

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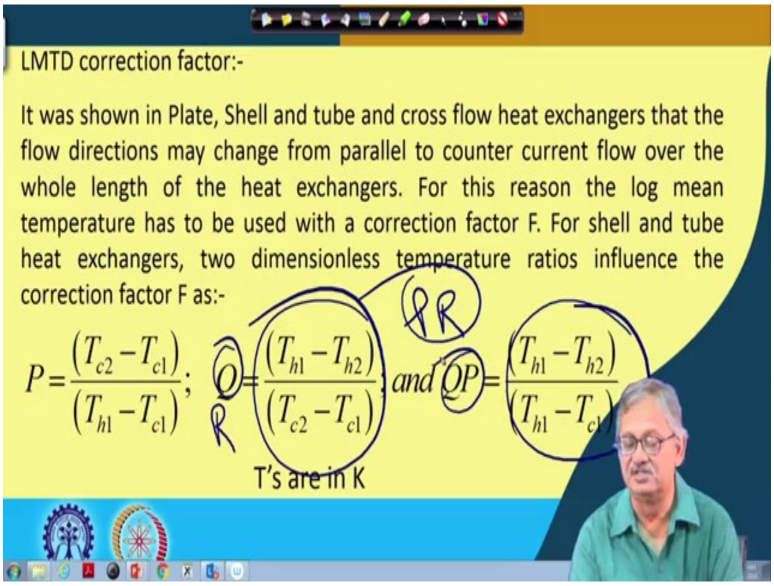

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$$P=\frac{(T_{c2}-T_{c1})}{(T_{h1}-T_{c1})};\quad Q=\frac{(T_{h1}-T_{h2})}{(T_{c2}-T_{c1})}\ and\ QP=\frac{(T_{h1}-T_{h2})}{(T_{h1}-T_{c1})}$$

R

PR

T's are in K

Similarly, if it is not then you can write P and R, 'right' ok. So, if R = $(T_{h1} - T_{h2})/(T_{c2} - T_{c1})$ and product of PR is $(T_{h1} - T_{h2})/(T_{h1} - T_{c1})$.

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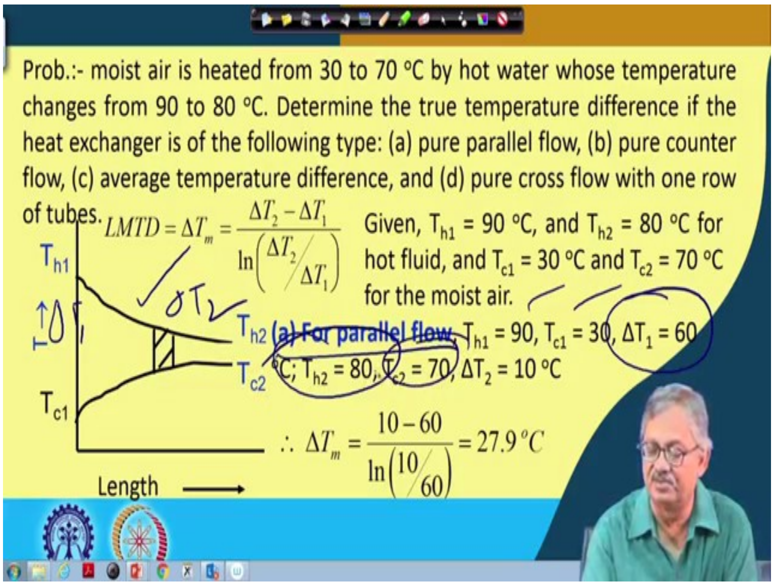

Prob.:- moist air is heated from 30 to 70 °C by hot water whose temperature changes from 90 to 80 °C. Determine the true temperature difference if the heat exchanger is of the following type: (a) pure parallel flow, (b) pure counter flow, (c) average temperature difference, and (d) pure cross flow with one row of tubes.

$$LMTD=\Delta T_m=\frac{\Delta T_2-\Delta T_1}{\ln\left(\Delta T_2/\Delta T_1\right)}$$

Given, T_{h1} = 90 °C, and T_{h2} = 80 °C for hot fluid, and T_{c1} = 30 °C and T_{c2} = 70 °C for the moist air.

(a) For parallel flow, $T_{h1} = 90$, $T_{c1} = 30$, $\Delta T_1 = 60$ °C; $T_{h2} = 80$, $T_{c2} = 70$, $\Delta T_2 = 10$ °C

$$\therefore\ \Delta T_m=\frac{10-60}{\ln\left(10/60\right)}=27.9\,^{\circ}C$$

So, with this correction factors for the output of the heat exchanger, we can now try with a problem whether this is coming or not. Very quickly, moist air is heated from 30 to 70 °C by hot water which temperature changes from 90 to 80 °C. Determine the true temperature difference, if the heat exchanger is the following type one is pure parallel flow another is pure counter flow third is average temperature difference and fourth is pure cross flow, ‘right’.

So, from the LMTD definition we know $(\Delta T_2 - \Delta T_1) / \ln(\Delta T_2 / \Delta T1)$ and we have been given T_{h1} 90, T_{h2} 80, T_{c1} 30 and T_{c2} 70, ‘right’. So, in that case we can find out for parallel flow; obviously, parallel flow that ΔT_1 and ΔT_2 will not be identical with the counter current, ‘right’.

So, for parallel flow we find out T_{h1} is 90 T_{c1} is 30. So, ΔT_1 is 60 and T_{h2} is 80 T_{c2} is 70. So, ΔT_2 is 10°. So, by putting in the formula we get $\Delta T_m = (10 - 60) / \ln(10/60)$ that is 27.9 °C, ‘right’.

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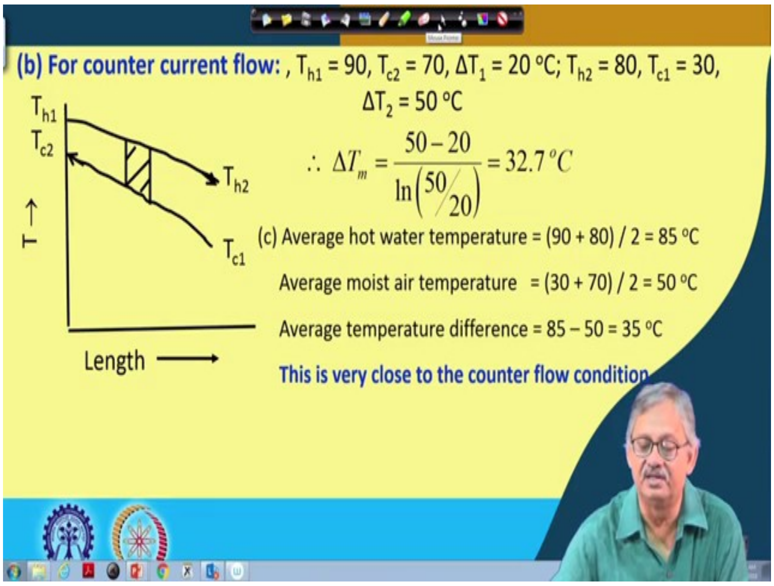

(b) For counter current flow: , $T_{h1} = 90$, $T_{c2} = 70$, $\Delta T_1 = 20$ °C; $T_{h2} = 80$, $T_{c1} = 30$, $\Delta T_2 = 50$ °C

$$\therefore \Delta T_m = \frac{50-20}{\ln\left(50/20\right)} = 32.7\,^{\circ}C$$

(c) Average hot water temperature = (90 + 80) / 2 = 85 °C

Average moist air temperature = (30 + 70) / 2 = 50 °C

Average temperature difference = 85 – 50 = 35 °C

This is very close to the counter flow condition

So, if it is 27.9 °C then, for counter flow again that T_{h1} is 90, T_{c2} is 70. So, ΔT_1 is 20 and T_{h2} is 80 like this, ‘right’ and T_{c1} is 30. So, $\Delta T_2$is 50 °C. So, ΔT_{mean} from that we get $(50 - 20)/ \ln(50/20)$ is 32.7 °C for counter flow, ‘right’.

An average hot temperature is (90 + 80) / 2 that is 85 °C. An average moist air temperature or cold temperature is (30 + 70)/2 that is 50 °C. So, average difference is (85 – 50) that is 35 °C, ‘right’. So, this is very close to the counter flow because 35 °C and this was 32.7 °C, ‘right’.

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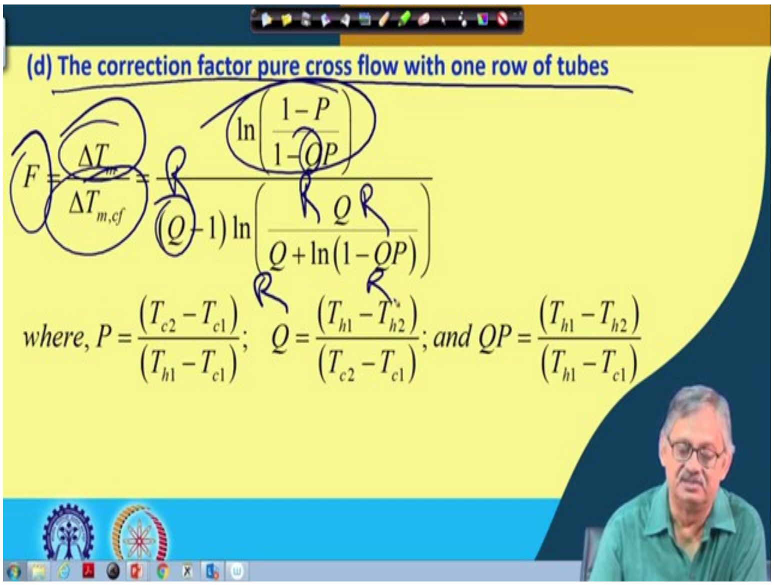

(d) The correction factor pure cross flow with one row of tubes

$$F=\frac{\Delta T_m}{\Delta T_{m,cf}}=\frac{\ln\left(\frac{1-P}{1-\overset{R}{Q}P}\right)}{(\overset{R}{Q}-1)\ln\left(\frac{\overset{R}{Q}}{Q+\ln(1-QP)}\right)}$$

$$where,\ P=\frac{(T_{c2}-T_{c1})}{(T_{h1}-T_{c1})};\quad \overset{R}{Q}=\frac{(T_{h1}-T_{h2})}{(T_{c2}-T_{c1})};\ and\ QP=\frac{(T_{h1}-T_{h2})}{(T_{h1}-T_{c1})}$$

So, if we look at the third one this is the third of course, the forth one that is cross flow then we need the correction factor. Correction factor for pure cross flow F = $\Delta T_{mean}/ \Delta T_{mean,cf}$ that is counter flow. So, we get ln ((1- P) / (1 – QP)) or Q is replaced by R, ‘right’ and this Q is replaced by R that is (R – 1) ln of ln (R/ R + ln (RP)), ‘right’.

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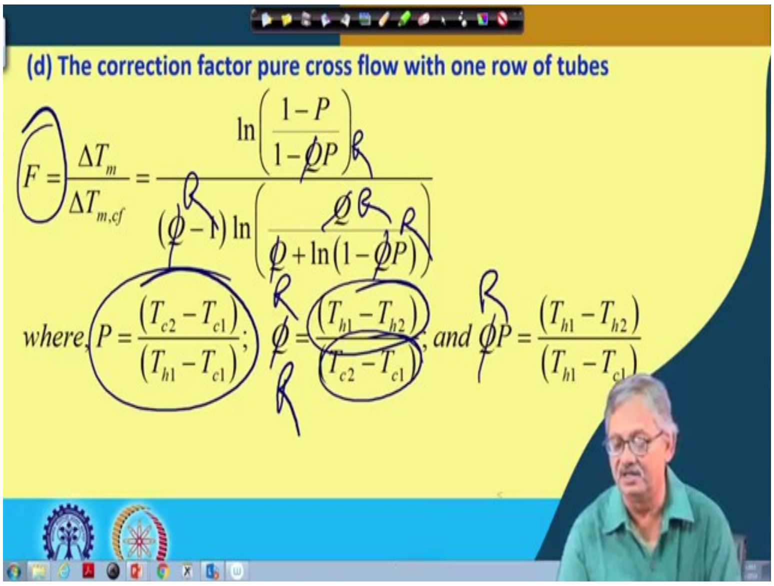

(d) The correction factor pure cross flow with one row of tubes

$$F=\frac{\Delta T_m}{\Delta T_{m,cf}}=\frac{\ln\left(\frac{1-P}{1-\overset{R}{\cancel{Q}}P}\right)}{(\overset{R}{\cancel{Q}}-1)\ln\left(\frac{\overset{R}{\cancel{Q}}}{\cancel{Q}+\ln(1-\overset{R}{\cancel{Q}}P)}\right)}$$

$$where,\ P=\frac{(T_{c2}-T_{c1})}{(T_{h1}-T_{c1})};\quad \overset{R}{\cancel{Q}}=\frac{(T_{h1}-T_{h2})}{(T_{c2}-T_{c1})};\ and\ \overset{R}{\cancel{Q}}P=\frac{(T_{h1}-T_{h2})}{(T_{h1}-T_{c1})}$$

So, we can rewrite in place of Q, we are writing R, here also R, here also R, and here R and here also R, ‘right’. So, this is the correction factor, where this P= c_2 (T_{c2} - T_{c1}) / (T_{h1}

- T_{c1}), 'right' and this Q is replaced by R so that is (T_{h1} - T_{h2}) / (T_{c2} - T_{c1}) and RP or PR is (T_{h1} - T_{h2}) / (T_{h1} - T_{c1}).

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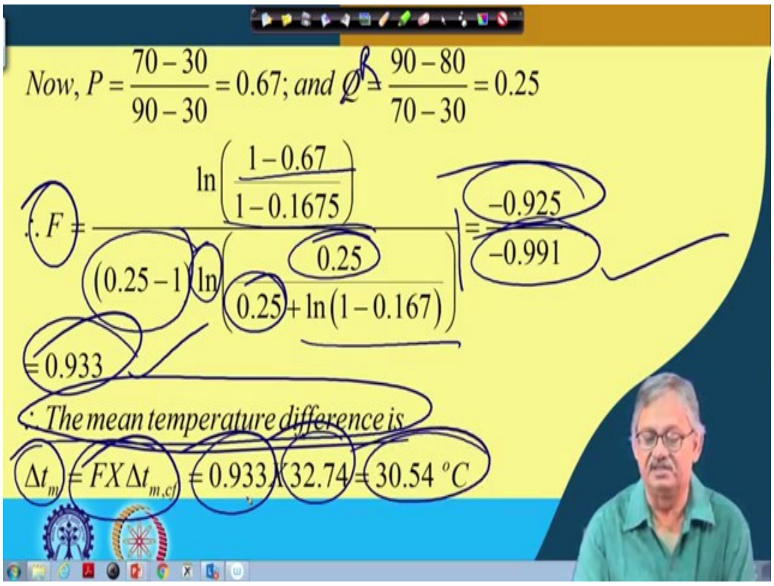

$$Now,\ P = \frac{70-30}{90-30} = 0.67;\ and\ \overset{R}{\cancel{Q}} = \frac{90-80}{70-30} = 0.25$$

$$\therefore F = \frac{\ln\left(\frac{1-0.67}{1-0.1675}\right)}{(0.25-1)\ln\left(\frac{0.25}{0.25+\ln(1-0.167)}\right)} = \frac{-0.925}{-0.991}$$

$$= 0.933$$

$\therefore$ The mean temperature difference is

$$\Delta t_m = F X \Delta t_{m,cf} = 0.933 X 32.74 = 30.54\ ^{\circ}C$$

So, if this is known then let us put the values and if we put the values we get, P is equal to we get P = (70 – 30) / (90 – 30) that is 0.67 and Q = (90 – 80) / (70 – 30) is 0.25. So, for the Q or R sorry this is r, 'right' so instead of Q this was R.

So, we can write F = ln {(1 - 0.67) / (1 - 0.1675)}, 'right' that is P × R = 0.1675 and this divided by (0.25 – 1) ln (0.25/(0.25 + ln(1- 0.167)). So, this comes equal to -0.925/ -0.991. So, that is 0.933, 'right'. So, the mean temperature difference is Δt_{mean} is F × $\Delta t_{m,cf}$, 'right'. So, that is 0.933 this one times 32.74 is 30.7 or 30.54.

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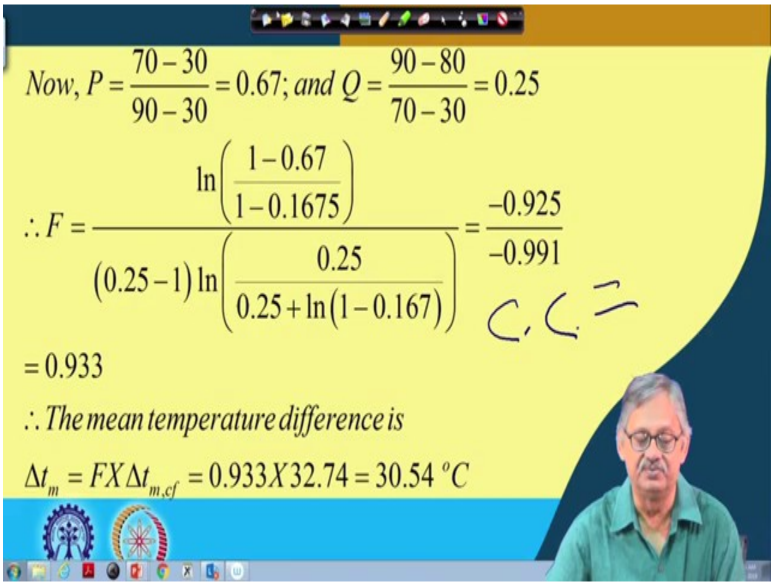

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C.C =

$$= 0.933$$

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$$\Delta t_m = F X \Delta t_{m,cf} = 0.933 X 32.74 = 30.54\ ^{\circ}C$$

So, we see that counter current is the most realistic and it is coming almost closer to the normal average, ‘right’.

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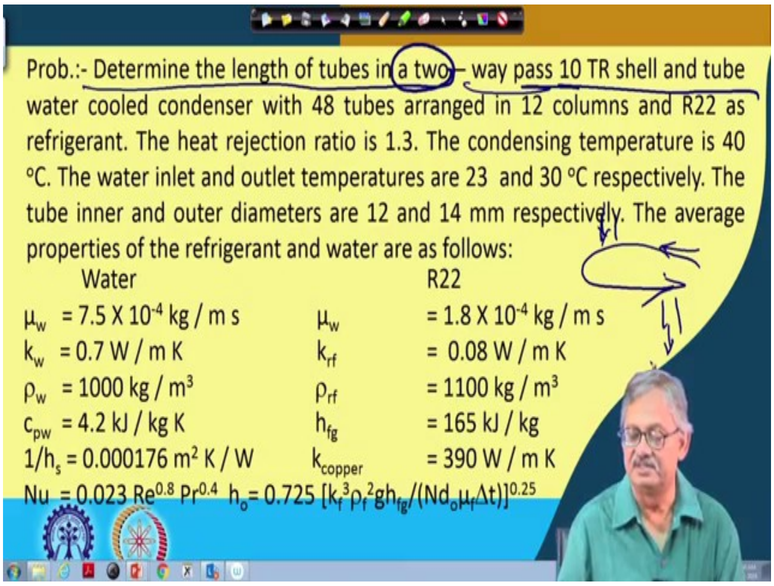

Prob.:- Determine the length of tubes in a two – way pass 10 TR shell and tube water cooled condenser with 48 tubes arranged in 12 columns and R22 as refrigerant. The heat rejection ratio is 1.3. The condensing temperature is 40 °C. The water inlet and outlet temperatures are 23 and 30 °C respectively. The tube inner and outer diameters are 12 and 14 mm respectively. The average properties of the refrigerant and water are as follows:

	Water		R22
μ_w	$= 7.5 X 10^{-4}$ kg / m s	μ_w	$= 1.8 X 10^{-4}$ kg / m s
k_w	= 0.7 W / m K	k_{rf}	= 0.08 W / m K
ρ_w	= 1000 kg / m^3	ρ_{rf}	= 1100 kg / m^3
c_{pw}	= 4.2 kJ / kg K	h_{fg}	= 165 kJ / kg
$1/h_s$	= 0.000176 m^2 K / W	k_{copper}	= 390 W / m K

$Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$ $h_o = 0.725\ [k_f^3 \rho_f^2 g h_{fg} / (N d_o \mu_f \Delta t)]^{0.25}$

So, like this if you do problems with other temperature sources or other temperature distributions that will be very good for you. Now I give you a problem, but this problem cannot be solved very easily, ‘right’. This can only be solved if there are trial and error methods involved, ‘right’. So, it is like this determines the length of tubes of a two-way pass 10 tons of refrigeration, ‘right’.

So, single pass is like that and this is the inlet and this is the outlet and another fluid flowing like that. So, in that case this would have been a single pass, 'right'. So, two way-pass means it will have two pass. So, two way-pass 10 ton of refrigeration TR means tunnels of refrigeration shell and tube water cooled condenser.

Now, these condensers are used in different cold stores and many other cold units, 'right'. So, there the other day we had said that you are vapour which is getting that the there are some the some heat exchangers which we said as vapour is coming out, 'right' and evaporative condenser that which said and this is another condenser.

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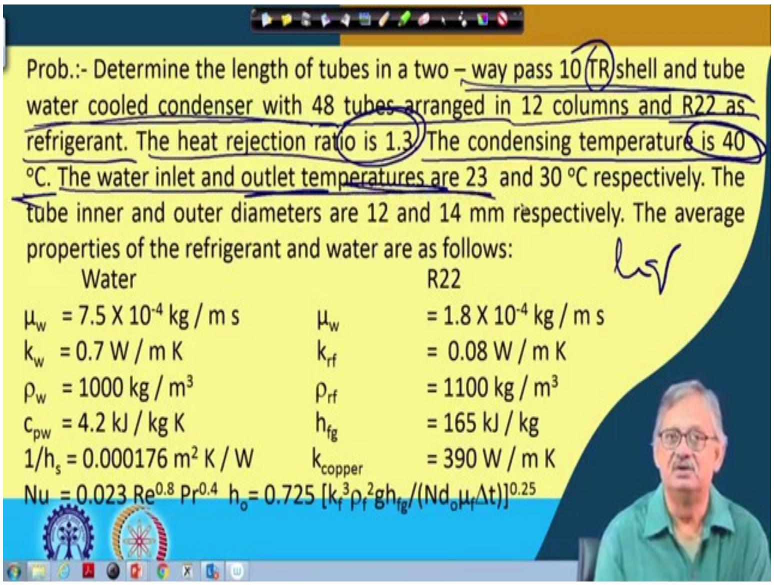

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ls√

Water	R22
$\mu_w = 7.5 \times 10^{-4}$ kg / m s	$\mu_w = 1.8 \times 10^{-4}$ kg / m s
$k_w = 0.7$ W / m K	$k_{rf} = 0.08$ W / m K
$\rho_w = 1000$ kg / m^3	$\rho_{rf} = 1100$ kg / m^3
$c_{pw} = 4.2$ kJ / kg K	$h_{fg} = 165$ kJ / kg
$1/h_s = 0.000176$ m^2 K / W	$k_{copper} = 390$ W / m K

$Nu = 0.023\, Re^{0.8}\, Pr^{0.4}$ $h_o = 0.725\,[k_f^3 \rho_f^2 g h_{fg}/(N d_o \mu_f \Delta t)]^{0.25}$

So, where it is with respect to the water or cooling medium or and heating medium both are liquid medium, 'right'. So, by two-way partial and their 10 TR shell and tube water cooled condenser with 48 tubes arranged in 12 columns and R22 as refrigerant. The heat rejection ratio which I will tell afterwards after this that heat rejection ratio is 1.3, 'right'. The condensing temperature is 40 °C. The water inlet and outlet temperatures are 23 and 30 °C respectively.

The tube inner and outer diameters are 12 and 14 mm respectively. The average properties of the refrigerant and water which are taken for this problem are. For water, mu w is 7.5 μ at the wall is 7.5 × 10^{-4} kg/m.s, kw that is thermal conductivity is 0.7 W/m.K or °C, ρ_w density of water is 1000 kg/m^3, c_{pw} or specific heat of water is 4.2 Kh/kg. °C or Kelvin, $1/h_s$ is 0.000176 m^2.K/W or m^2. °C/W.

And Knudsen number = 0.023 $Re^{0.8}$ $Pr^{0.4}$, h_o outside heat transfer coefficient is 0.725 [k_f^3 ρ_f^2 g h_f g / (N d_o μ_f Δt)] this t can be written as this ΔT capital.

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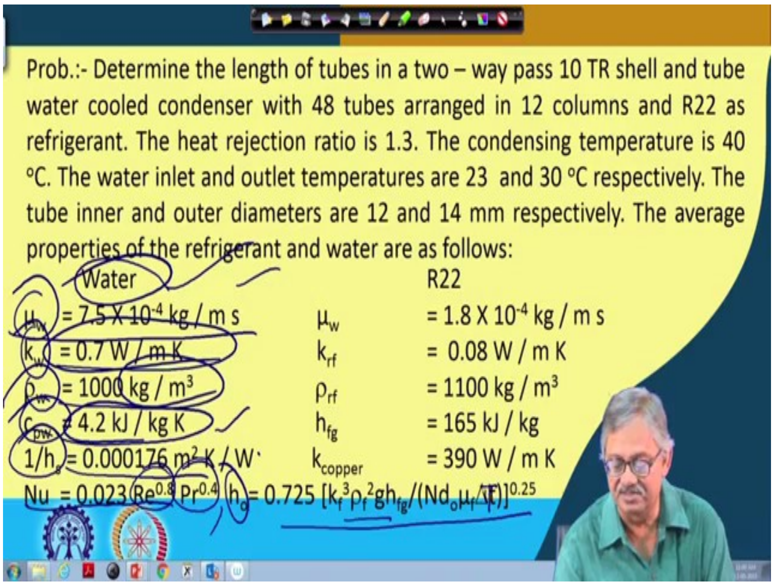

Prob.:- Determine the length of tubes in a two – way pass 10 TR shell and tube water cooled condenser with 48 tubes arranged in 12 columns and R22 as refrigerant. The heat rejection ratio is 1.3. The condensing temperature is 40 °C. The water inlet and outlet temperatures are 23 and 30 °C respectively. The tube inner and outer diameters are 12 and 14 mm respectively. The average properties of the refrigerant and water are as follows:

Water		R22	
μ_w	$= 7.5 \times 10^{-4}$ kg / m s	μ_w	$= 1.8 \times 10^{-4}$ kg / m s
k_w	= 0.7 W / m K	k_{rf}	= 0.08 W / m K
ρ_w	= 1000 kg / m^3	ρ_{rf}	= 1100 kg / m^3
c_{pw}	= 4.2 kJ / kg K	h_{fg}	= 165 kJ / kg
$1/h_s$	= 0.000176 m^2 K / W	k_{copper}	= 390 W / m K

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So, that temperature is probably set to the power point 0.25. So, other properties values for R22, these are the relations μ_w or viscosity of the of the refrigerant at the wall is 1.8 $\times 10^{-4}$ kg/ms, k_{rf} refrigeration refrigerant thermal conductivity is 0.08 W/m.°C or Kelvin ρ_{rf} that is the density of the refrigerant is 1100 kg/m^3 and h_f g is 165 kJ/kg that is this is heat of this is latent heat of either condensation or vaporization, 'right'.

So, h_f g and k of copper is 390 W/m.K because, the this is made of copper, 'right' this is made of copper I do did we write anywhere, outer average refrigerant condensing temperature no it is not written but normally the coils are made of copper if it is inside and we have taken R22.

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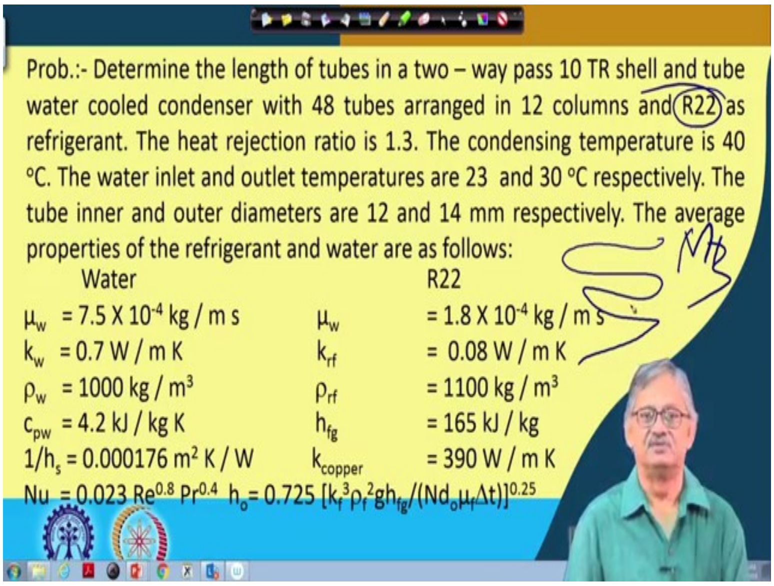

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NH_3

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So, it can be easily copper, if it is if it would have been not R22 say ammonia then you cannot use copper because ammonia is very corrosive. So, there you cannot use copper, there you have to use mild steel or some other, but since R22 or refrigerant 22 that is chlorofluorocarbon is used.

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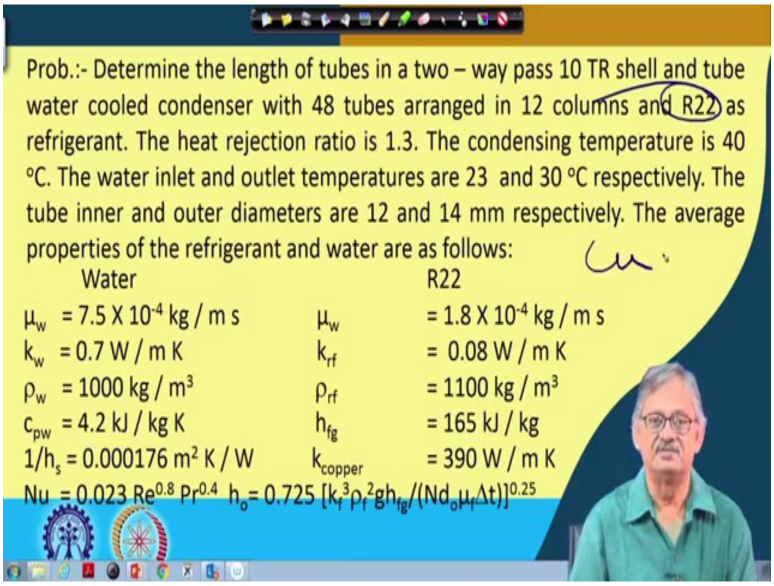

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Cu

So, you can use copper as the as the element or metal for the evaporators or condensers to be build up, ‘right’. So, that is why the conductivity of copper is given as so high 390 W/m.K. So, this problem I wish you do and to do this, you will see some things some delta t may be may be refrigerant temperature and the difference of TPO, ‘right’ these are not given.

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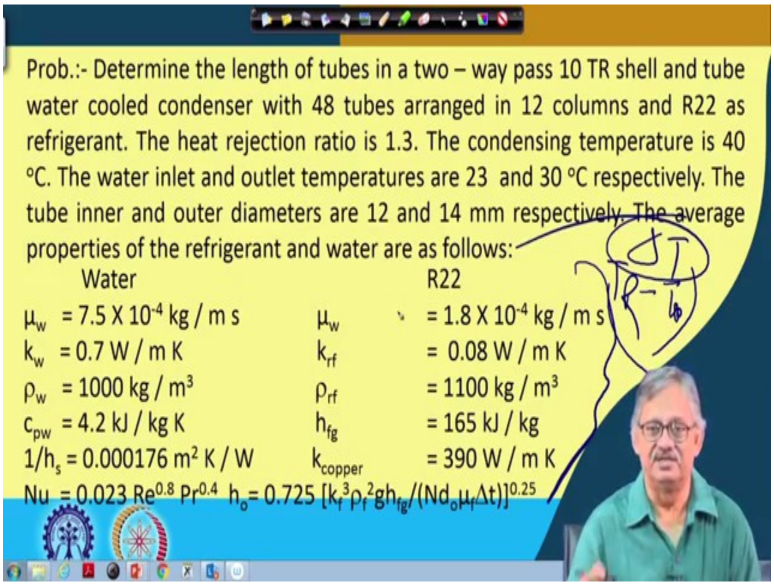

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So, maybe you have to use it has trial and; that means, you have to assume and then do the calculation. So, that type of thing it may require, but as I said I have to say one thing that is the heat rejection ratio of 1.3, what is that?

So, if we say that heat rejection ratio then you try yourself to solve because some of the relations we have already said and Knudsen number you may need. Outside heat transferred coefficient some inside it surface heat transferred coefficient has already been told. So, we can use this and we can now go to see what is the heat rejection ratio? ‘right’.

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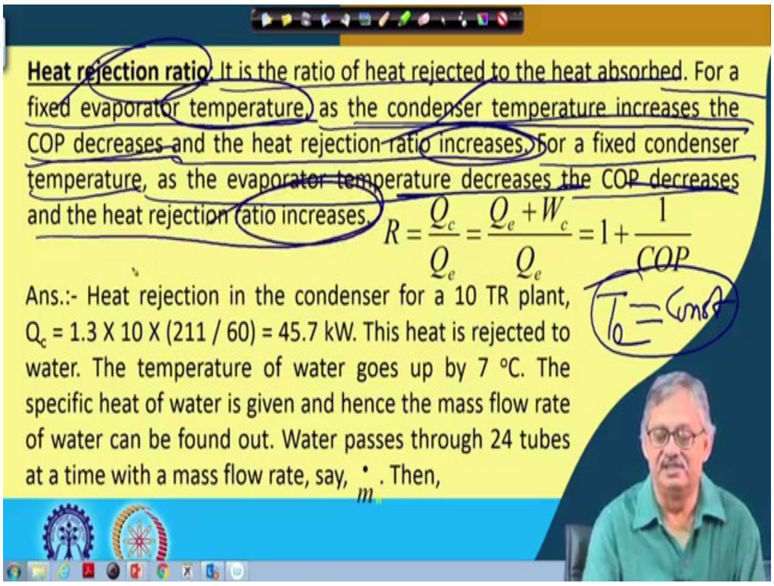

Heat rejection ratio: It is the ratio of heat rejected to the heat absorbed. For a fixed evaporator temperature, as the condenser temperature increases the COP decreases and the heat rejection ratio increases. For a fixed condenser temperature, as the evaporator temperature decreases the COP decreases and the heat rejection ratio increases.

$$R = \frac{Q_c}{Q_e} = \frac{Q_e + W_c}{Q_e} = 1 + \frac{1}{COP}$$

T_0 = Const

Ans.:- Heat rejection in the condenser for a 10 TR plant, Q_c = 1.3 X 10 X (211 / 60) = 45.7 kW. This heat is rejected to water. The temperature of water goes up by 7 °C. The specific heat of water is given and hence the mass flow rate of water can be found out. Water passes through 24 tubes at a time with a mass flow rate, say, $\dot{m}$. Then,

So, heat rejection ratio is like that that heat rejection ratio is like that it is the ratio of heat rejected to that of heat absorbed, ‘right’. It is the ratio of heat rejected to the heat absorbed, ‘right’ how much it has given how much it has absorbed.

So, this ratio is the heat rejection ratio, ‘right’ very useful in condenser, evaporators there because that unless you know the heat rejection ratio, you will not be able to find out many parameters. So, the heat rejection ratio is nothing, but ratio of heat rejected to the heat absorbed for a fixed evaporator temperature, ‘right’.

That is t evaporator is fixed, ‘right’ is equal to constant, ‘right’ if that be true as the condenser temperature increases the COP decreases, ‘right’. This we can see more if we are looking at some other course that is more related to your cooling technology for food materials. So, there it is said in detail, ‘right’ so; however, that the COP decreases keeping the evaporator temperature condense constant if the condenser temperature increases, the COP decreases and the heat rejection ratio increases whereas, for a fixed condenser temperature as the evaporator temperature decreases the cop decreases, ‘right’.

And the heat rejection ratio increases, ‘right’. So, in that case we can say that heat rejection ratio are can be said as Q_c / Q_e where Q_c is the quantity of heat rejected by the condenser and Q_e is the quantity of heat absorbed by the evaporator because in the cold store what is happening evaporator is absorbing heat and condenser is rejecting heat, 'right' this is how the this works evaporator is rejecting absorbing heat and condenser is rejecting heat.

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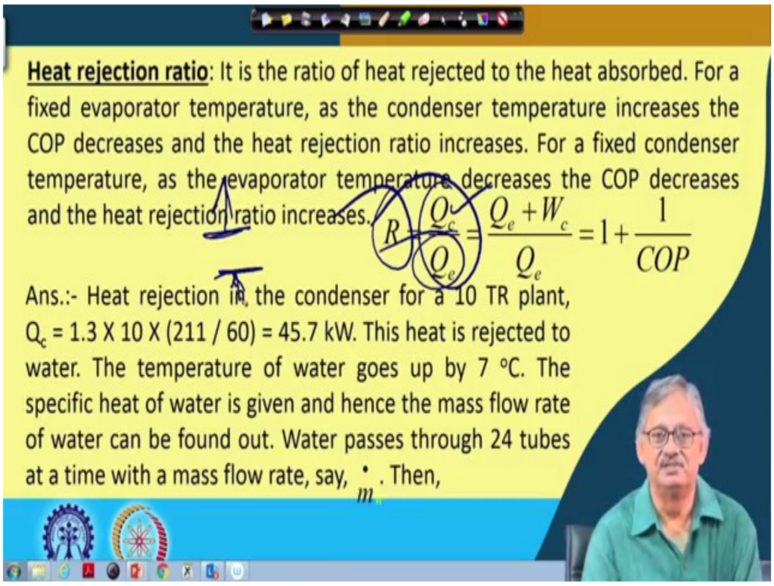

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So, that is why this ratio came Q_c over Q_e and we know from the first law that Q_e is $Q_c = Q_e + W_c$ how much work the compressor has done that is W_c.

So, $Q_e + W_c$. So, Q_c is replaced by $Q_e + W_c$ and denominator is Q_c Q_e so, 'right'. So, it comes to that Q_e Q_e is $1 + W_c / Q_e$. Now, W_c / Q_e is nothing, but inverse of COP. COP is nothing but Q_e / W_c. So, it is inverse of COP that is W_c / Q_e, 'right'.

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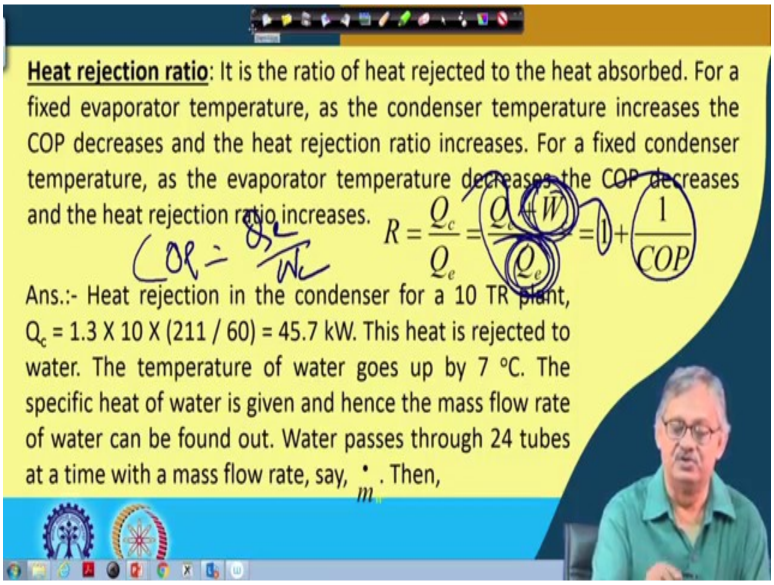

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$COP = \frac{Q_e}{W_c}$

So, rejection ratio R is 1 +1 + 1 / COP. So, this if you keep in mind and progress accordingly and may be if you are not able to, in some other class I will try and solve it, but may be this solution itself will take one whole class, ok.

Thank you.