Solar Energy Engineering and Technology
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Lecture 23
Testing and application of LFPC

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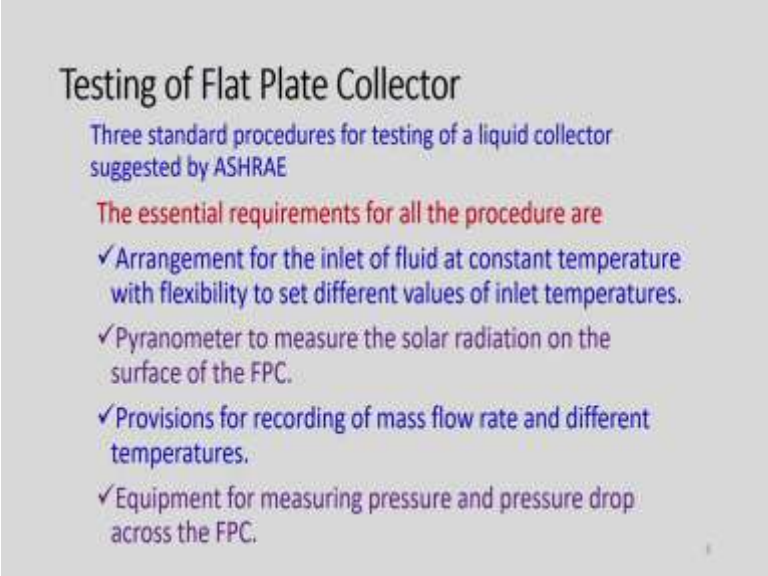

Dear students today we will be discussing about testing of liquid flat plate collector and its application. So this testing of flat plate collector there are three standard procedures for testing which is suggested by ASHRAE. ASHRAE is nothing but American society of heating refrigeration and air conditioning engineers.

The essential requirements for all the procedures are number 1, arrangement for the inlet of fluid at constant temperature with flexibility to set different values of the inlet temperatures, pyranometer to measure the solar radiation on the surface of the flat plate collector then provisions for recording of mass flow rate and different temperatures has to be there. Then equipment for measuring pressure and pressure loss across the FPCs need to be attached.

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Then why this testing is required, because standard testing and rating procedures provide an equitable basis for comparing the efficiency of different types of collectors and an essential basis for their selection for a given applications as well as their design improvement.

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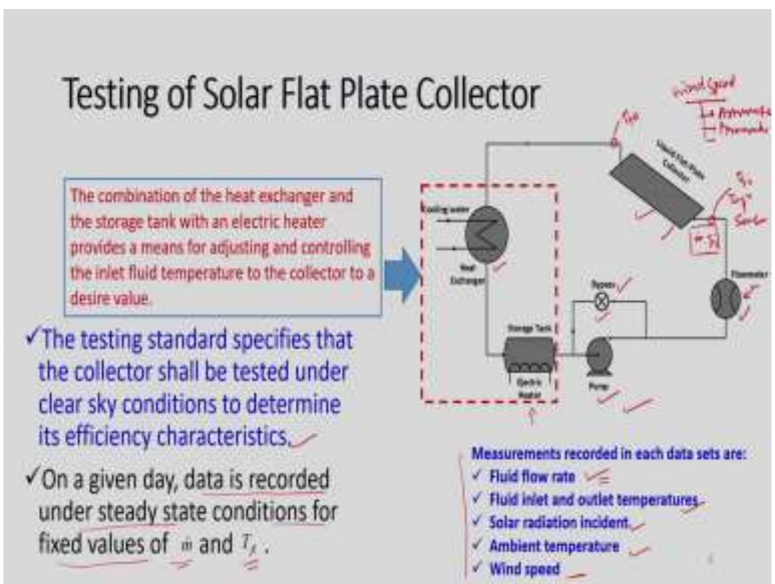

Now let us discuss how this solar flat plate collector can be tested with a standard protocol. So what figure is shown here, is a setup for characterization of a flat plate collector. So it composed of a flat plate collector which need to be characterized, a liquid pump, a heat exchanger with a cooling coil then storage tank of course bypass valve is also required and flow meter.

Of course to know the inlet fluid temperature and outlet fluid temperature we must have some kind of temperature sensor. This is temperature sensor or thermocouple this is for T_{fi}, this is for T_{fo}. Of course we need anemometer for wind speed, one anemometer is required, anemometer and pyranometer, pyranometer for solar radiation, which is global solar radiation and rotameter for flow measurement.

So what happens we need to perform experiments at fixed values of mass flow rate and T_{fi} and we need to do the experiment at different days. So what is the purpose of this heat exchanger? Because we need to provide control amount of fluid through the collector at particular temperature so in order to control this temperature we need to arrange the assembly.

So we have to cool this fluid what is coming out from the collector and then if it is lower than what is required then we need to heat it by using electrical means. So in this storage tank one electrical heater is attached, so that this fluid can be heated to a particular temperature. And this bypass valve is attached to control the amount of flow which need to be flows inside this flat plate collector.

So this measurement recorded in each data set are fluid flow rate, fluid inlet and outlet temperature we need thermocouples. Here we need some kind of rotameters. Solar radiation incident so we need pyranometer which gives global radiation falling on that particular place. Ambient temperature of course we need one thermometer or maybe one temperature sensor and wind speed we need to know.

So for that we need to have a anemometer so once we have those equipment or instruments we can measure all those parameters. So these two assembly the combination of the heat exchanger and the storage tank with an electric heater provides a means for adjusting and controlling the inlet fluid temperature to the collector to a desired value.

So what is required for inlet that has to be controlled by using this arrangement we can control the temperature and we can know fit the temperature to this flat plate collector. The testing standard specifies that the collector shall be tested under clear sky conditions to determine its efficiency characteristics. On a given day data is recorded under steady state condition for fixed values of mass flow rate and fluid inlet temperature. So what is steady state conditions?

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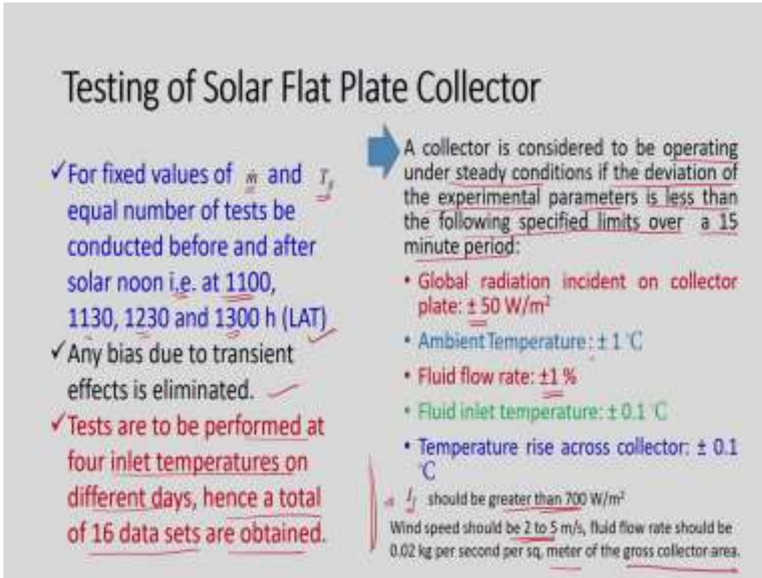

So a collector is considered to be operating under steady state conditions if the deviation of the experimental parameters is less than the following specified limit over a 15 minutes period. So this variation of global radiation incident on the collector should be in this range ±50 W/m^2. And ambient temperature should be in the range of -1 to +1 °C.

And fluid flow rate is ±1 % and fluid inlet temperature variation should be ±0.1 °C and temperature rise across the collector should be in the range of ±0.1 °C. And also this I_T value the total radiation which is falling on the collector should be greater than 700 W/m^{2}and this wind speed should vary from 2 to 5.

And this fluid flow rate should be 0.02 kg per second per square meter of the gross collector area. So this has to be controlled and this arrangement or say this measurement is valid for both indoor and outdoor testing. In indoor of course we need a solar simulator for testing. Now for fixed values of mass flow rate and fluid inlet temperature equal number of tests to be conducted before and after solar noon.

So that is at 11 o'clock, 11:30, 12:30 and 1 or 13:00 hour LAT which is solar time or local apparent time. And also any bias due to transient effect is eliminated during the trace procedure. The tests are to be performed at four inlet temperatures on different days minimum of 4 days is required to characterize a flat plate collector. So hence a total of 16 data sets are obtained if we perform for 4 days during the time mentioned here.

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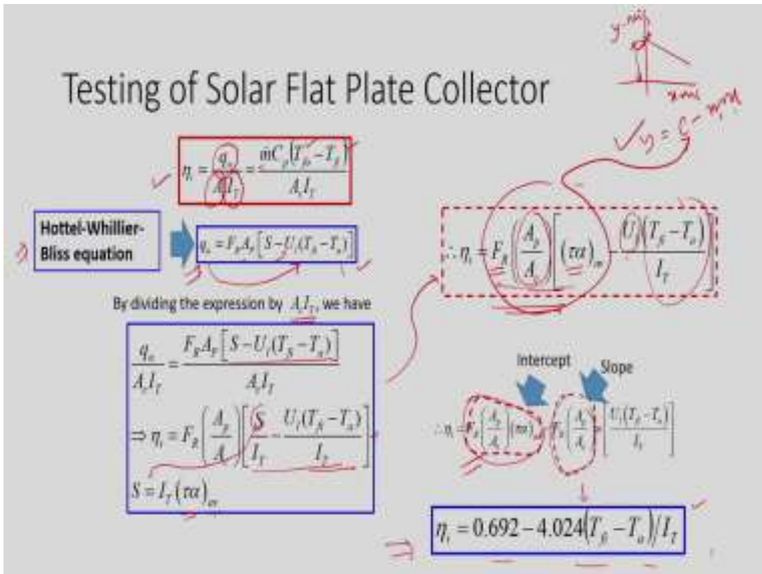

Now if I am interested to know the efficiency of the collector then straight away you can use this expression $\eta_i = \frac{q_u}{A_c I_T}$. So q_u is the useful heat gain A_C is the collector area and I_T is the total solar radiation which is falling on the collector and q_u is nothing but m mass of the fluid which is flowing and C_p is the specific heat of the fluid. Then $(T_{fo} - T_{fi})I_T$.

Also we know the famous equation for measurement of useful heat gain which is given by Hottel Whillier Bliss equation. So this $q_u = F_R A_P \lfloor S - U_l(T_{fi} - T_a) \rfloor$. So this expression q_u is related with T_{fi}. If we know the fluid inlet temperature and ambient is known and if other values are known then straight away you can calculate what will be the useful heat gain.

Now we will relate this to efficiency because of that we need to do something. So we divide this expression by $\frac{q_u}{A_c I_T}$ then what happens here $\frac{q_u}{A_c I_T} = \frac{F_R A_P \lfloor S - U_l(T_{fi} - T_a) \rfloor}{A_c I_T}$. So we can bring this side here then it will be $\frac{A_P}{A_c}$. Of course F_R will be multiplied then this expression will be something like this. Also this S can be expressed something like this here so $I_T(\tau\alpha)_{avg}$.

So it includes both beam and diffuse radiation. So when we talk about average values of transmissivity and absorptivity. So on substitution of this $S = I_T(\tau\alpha)_{avg}$ then what we will have so this expression will be modified to something like $\eta_i = F_R\left(\frac{A_P}{A_c}\right)\left[(\tau\alpha)_{avg}\frac{U_l\left(T_{fi}-T_a\right)}{I_T}\right]$. Now for a particular collector this F_R $(\tau\alpha)_{avg}$ U_l are constant.

So if we see then and this part is constant always for a particular collector so this will be constant here so this will be something like y=mx-c or I can write c -mx. So c is nothing but this constant part here and m will be this multiplied by U_l will be m and x will be this part. So this will be a some kind of straight line with negative slope.

So if we plot it then what will happen so we will get some kind of this kind of plot so if we tell this is y axis and this is x axis. So this intercept is nothing but this value so this intercept will give the value of this part and the slope will give this part. So for a typical case so we will get an expression something like this so we will explain how this can be generated, so this will be the expression. So this is something like a straight line equation with negative slope.

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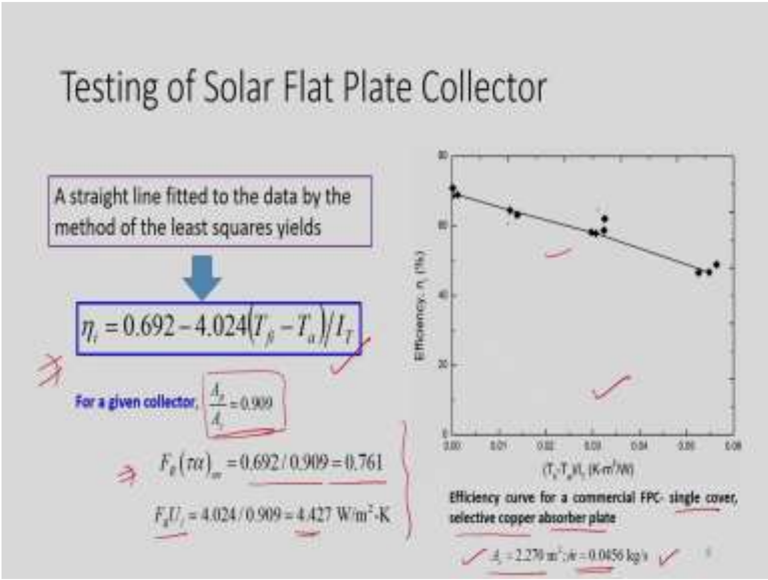

So let us take a commercial FPC say this is the characteristics curve for a commercial FPC having single cover and selective copper absorber plate with area of the collector is 2.27 m^2 and mass product of 0.0456 kg/s. So if we use this then we will have this kind of configuration. And this least square yield will give this straight line fitting equation.

So these expressions you can get from this scatter data so we will get lot of data so if we have a dotted line then we can generate this kind of equation. So if we compare this equation with the earlier what we have described just now so this $\frac{A_p}{A_c}$ for a collector is given as 0.909. And if we use this information for calculation F_R $(\tau\alpha)_{avg}$ then this will be something like this. And also F_R U_l we can calculate so this will about 4.427 W/m^2-K. So this is how we can calculate the value of F_R $(\tau\alpha)_{avg}$ and F_RU_l once you know this intercept and slope.

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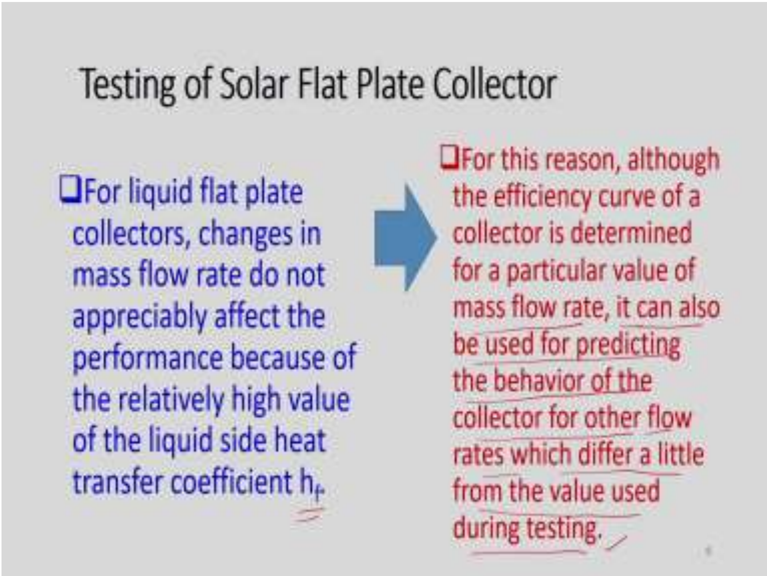

Now for liquid flat plate collectors, changes in mass flow rate do not appreciably affect the performance because of the relatively high value of liquid side heat transfer coefficient. And for this region although the efficiency curve of a collector is determined for a particular value of mass flow rate, it can also be used for predicting the behavior of the collector for other flow rates which differ a little from the value used during testing. We will demonstrate how this can be done in a numerical example.

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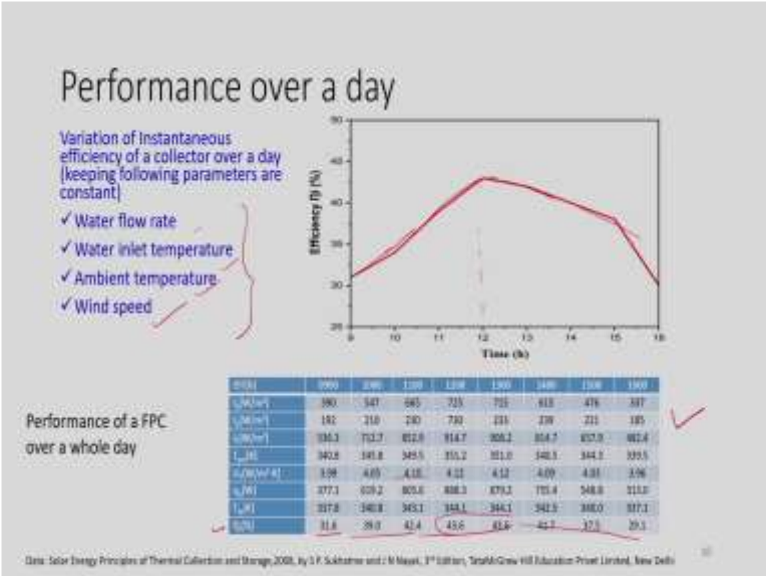

Also sometimes we are interested to know what will be the performance of a flat plate collector over a day. So this data was taken from a book, Solar energy principles of thermal collection and storage by Sukhatme and Nayak. So what it is shown here the variation of efficiency with time. What we can see as the time increases so if efficiency is increasing first, so at noon it is maximum and then it is decreasing. So here also you can see here how these efficiencies are first increasing with time and then reaches a maximum value here and then decreases.

Also you can see here other values so this U_t is also decreasing. So this variation was plotted with an assumption that water flow rate then water inlet temperature, ambient temperature and wind speed are not varying during that time. So what you can conclude here with increase in solar radiation that efficiency can be improved. That is what it is demonstrated in this slide.

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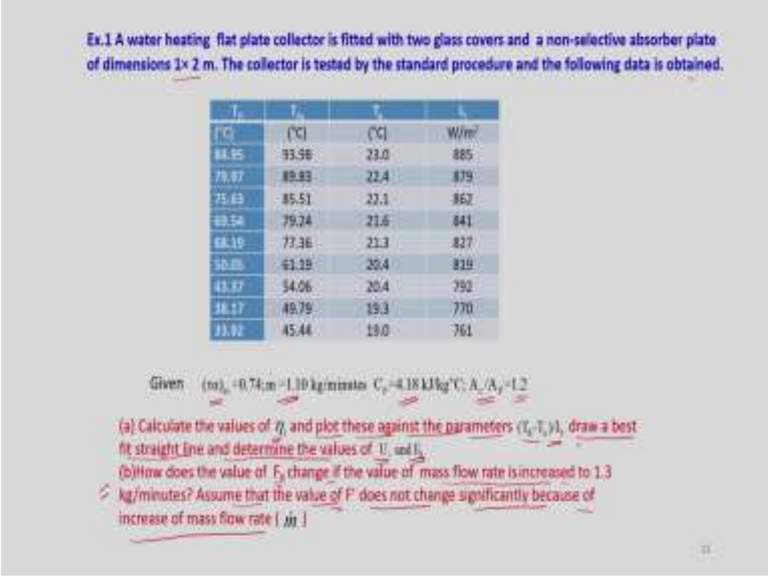

Now let us take a numerical problem. So it goes something like a water heating flat plate collector is fitted with two glass covers and a non-selective absorber plate of dimension 1 by 2 meter the collector is tested by the standard procedure and the following data is obtained. So $(\tau\alpha)_{avg}$ is given, mass flow rate is given, C_p of water is given and $\frac{A_C}{A_P}$ is given.

Now we need to calculate the values of instantaneous efficiency and plot this against the parameter $\frac{(T_{fi} - T_a)}{I_T}$. Then we need to draw a best fit straight line and determine the values of U_l and F_R. Again in the second case how does the values of F_R change if the value of mass product is increased to 1.3 kg per minutes. Assume that the value of $F^{'}$ does not change significantly because of increase of mass flow rate. So let us solve this problem. So given values are here

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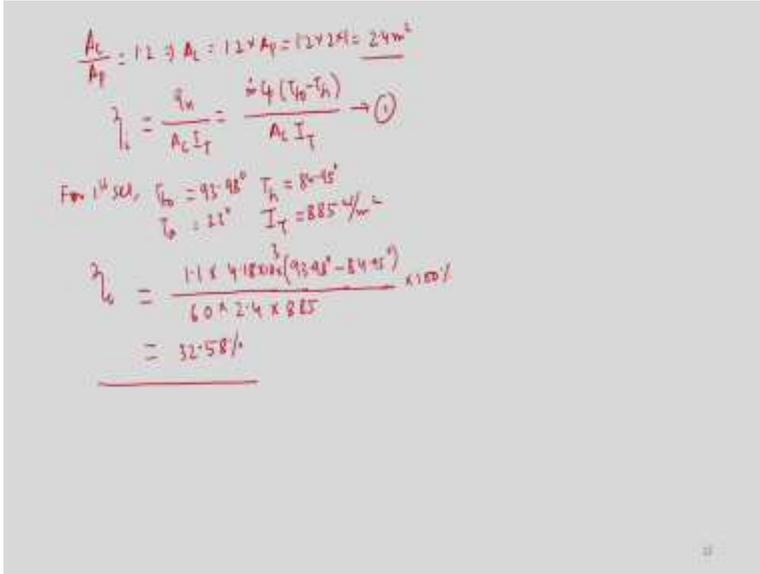

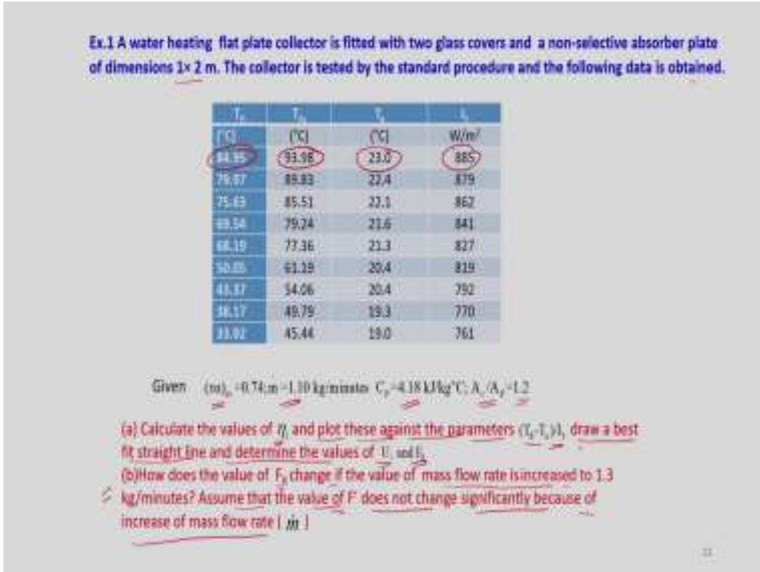

So straight way you can use this expression $\frac{A_C}{A_P}$ is given as 1.2, hence $A_C = 1.2 \times A_P$ which is nothing but $1.2 \times 2 \times 1$. So it will be 2.4 m^2. And under testing conditions this $\eta_i = \frac{q_u}{A_c I_T}$. And also we know this is nothing but mC_p dt is nothing but T_{fo} -T_{fi}.

So first I will show one sample calculation then I will move to this generation of straight line fitting. So this sample calculation by using first set of data which is given in the exercise so for first set what is given in the problem, so T_{fo} is given as 93.98 degree then you have T_{fi} is 84.95 degree and T_a is given as 23 degree.

This can be seen here so this that I am talking about so T_{fo} is 93 then T_{fi} is 84 then T_a is 23 and I is 885. So I_T is equal to 885 W/m^2. So now using this expression means η_i can be calculated so m is how much 1.1 minute, so 1/1 divided by 60, it will be kg/s. Then C_p value is 4.18×10^3 which will be 4.1 kJ, so we have converted to joule

And what is the temperature difference is 93.98 degree T_{fo} then T_{fi} is 84.95 degree and then we will have A_c and I_T, so Ac is already we have calculated which is equal to 2.4 and then I_T is 885 for this first set of data. So it will be so if we multiply it by 100, it will be in percentage so it will be 32.58 %. So now I will show how for all the values η_i can be calculated by using a spreadsheet.

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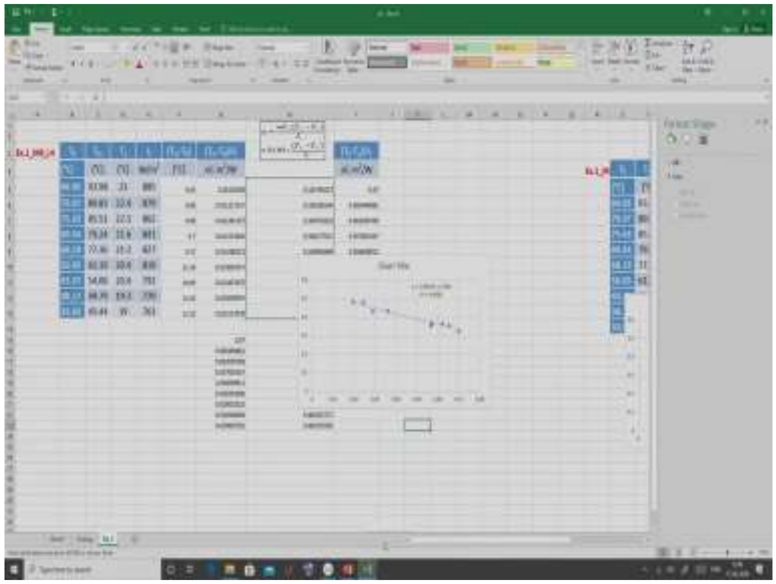

So let us click here and let us learn how this can be generated. So here so what we need to do $f_0 - f_i$, so what is f_0 here so I will use this so this is $f_0 - f_i$. So this will be something like this. So if we drag it then we will have something like this. And then what we can do this divided by I_T so this divided by, divided by I_T is here.

So I can take this value and we can expand it for all the calculations and for calculation of η_i, so this part if we substitute m and then multiply it C_p and divided by A_c then this will be something like this for this case. So for all the calculations this will be fixed mC_p divided by A_c so here what happens what we have learned so this $\frac{mC_p}{A_c}$, so this part is constant for all the values.

So here what happens we can straight away calculate this value, so this 31.93 we have star or multiply by this part. So we can give enter and it will be the efficiency values not in the percentage in the fraction. And here also we can calculate so this value we can calculate so once we know T_{fi}, what is T_{fi} here this is the T_{fi}. Then we have to deduct minus T_a then divided by so this will come outside divided by we will have I_T.

So this is d and then we have this value, so this is T_{fi}, then we have T_a then I_T. So I can use this so this will be I can drag it something like this. So now we need to plot this versus this so I will take this data out from this calculation sheet and I will paste it here which number and here I can paste and then we have these values. So now these two because this will be in the x axis and this will be in y axis.

So we can plot it, we can plot it here, so this is the plot. And again we can add that trend line and we can get the equation, display the equation then R square value. So the equation is something like this here. So as you can see this part is nothing but intercept part and this is the, this part is slope part. So what we have done we have generated the trend line or say this you know fitting line and we can use this equation for calculation of F_R and U_l. So this equation is required now.

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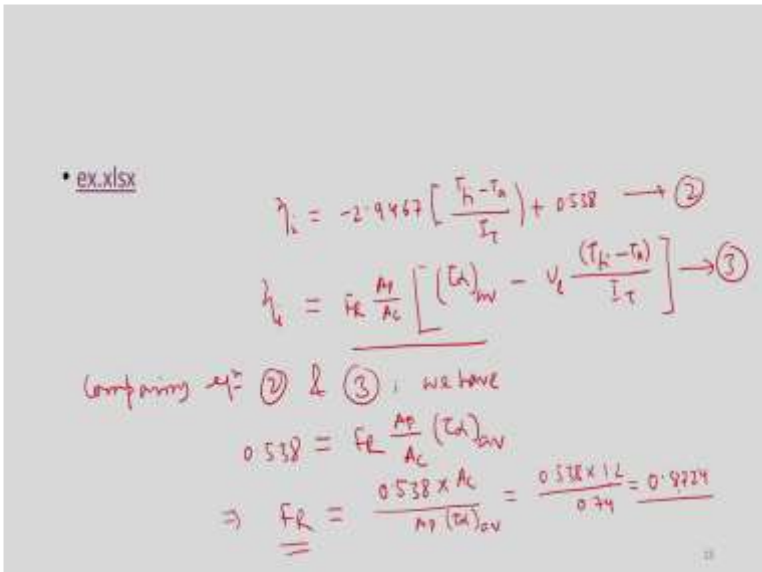

So now we will go back and see how this can be calculated. So here what I can write is the expression what we have got there so this $\eta_i = -2.9467\left(\frac{T_{fi}-T_a}{I_T}\right)+0.538$. So this is known to us now. Now also we know the expression for η_i when we use Hottel Whillier Bliss equation. So this $\eta_i = F_R\left(\frac{A_P}{A_c}\right)\left[(\tau\alpha)_{avg}\frac{U_l\left(T_{fi}-T_a\right)}{I_T}\right]$. So if we this may be equation 2, this may be equation 3.

If we comparing equation 2 and 3 we have this 0.538 so this part is intercept is equal to $F_R\left(\frac{A_P}{A_c}\right)(\tau\alpha)_{avg}$. So if we substitute those values what we have straight away we can calculate what is F_R value or maybe we can simplify F_R which is equal to $0.538A_c$. Then you have $A_P(\tau\alpha)_{avg}$. And if we substitute those values, so $\frac{A_P}{A_c}$ is this is something like it will be 0.538 then we have 1.2 and then $(\tau\alpha)_{avg}$ value is 0.74 which is given in the problem.

So if you substitute then we will get a value of something like 8724. So F_R value is found to be 0.8724. So now our next calculation will be for U_l. So overall loss coefficient how to calculate this overall loss coefficient? So we can use this part. So $F_R A_p U_l$ which is equal to this part. So this part is equivalent to this part, when you multiply this part and this part is actually this part.

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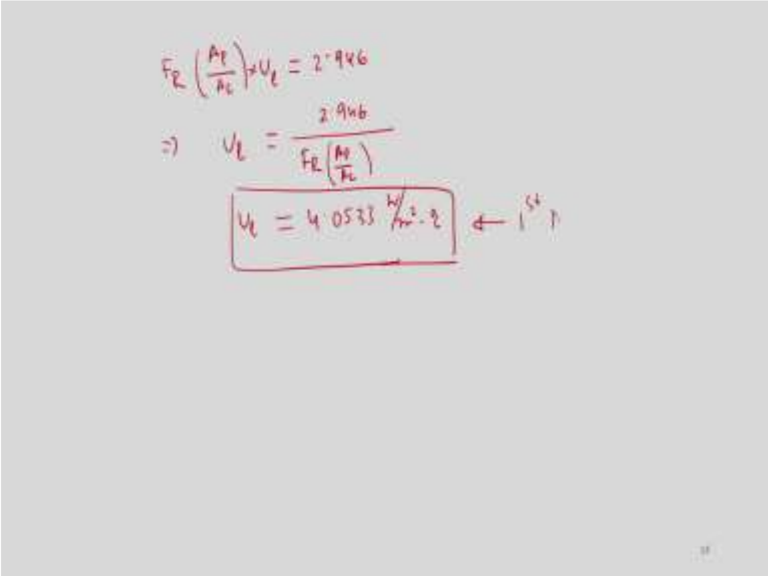

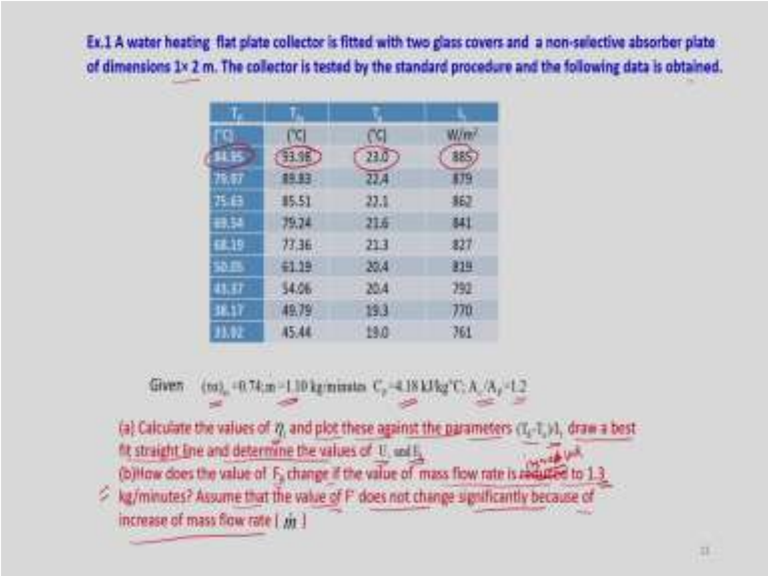

Now if we calculate U_l then we have to use this expression $F_R\left(\frac{A_P}{A_c}\right)U_l$ which is equal to 2.946.

So if you substitute this values of F_R so this $U_l = \frac{2.946}{F_R\left(\frac{A_P}{A_c}\right)}$, so this is the value here. So if we substitute these values then what we will have U_l will be 0.533 W/m^2 if it is in Celsius then Celsius. So U_l value you calculate. So this is the solution for the first part, solution for the first part. So what is the next part? So next part again we need to calculate F_R value if we change our flow rate is increased to 1.3 kg per minutes.

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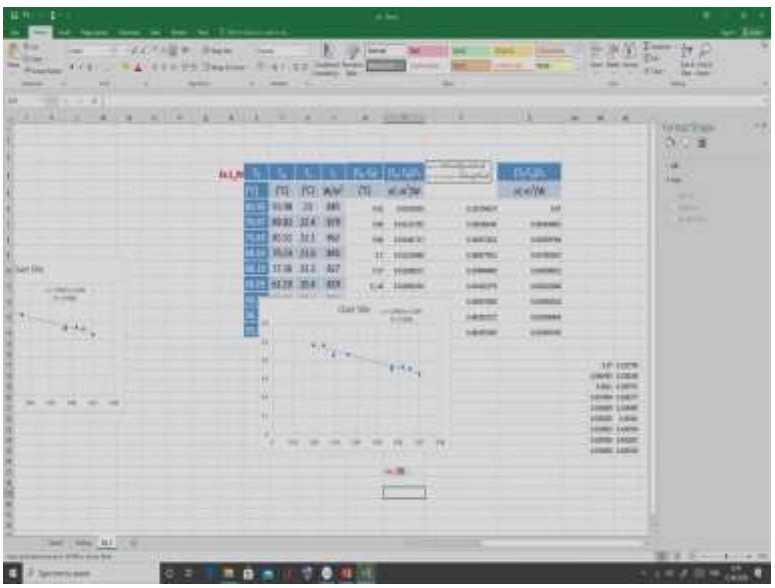

So again we will go back to this spreadsheet and already I have done this calculation for this case. So similarly these equations are known only change will be this part 37.735, this part will be there. So here once we use those calculated value and then use in this calculation then we will get this kind of values.

And for $\frac{T_{fi}-T_a}{I_T}$ will get these values and if we take out these two and then plot it then what we will have this kind of plot and then our equation will be something like this. So similarly if we do the calculation then we will get these values. So in our earlier case it was also about 0.8724 so it is almost constant. So even though this mass flow rate is varying but this F_R is not changing.

That is why in case of liquid flat plate collector only single mass flow rate is enough to characterize the entire flat plate collector. So there is no point of doing the characterization at different mass flow rates. But in case of solar air heater, experiments are need to be performed at different mass flow rates because heat transfer coefficient in the air side is much lower than heat transfer coefficient in the liquid side. So we got a very close value of F_R.

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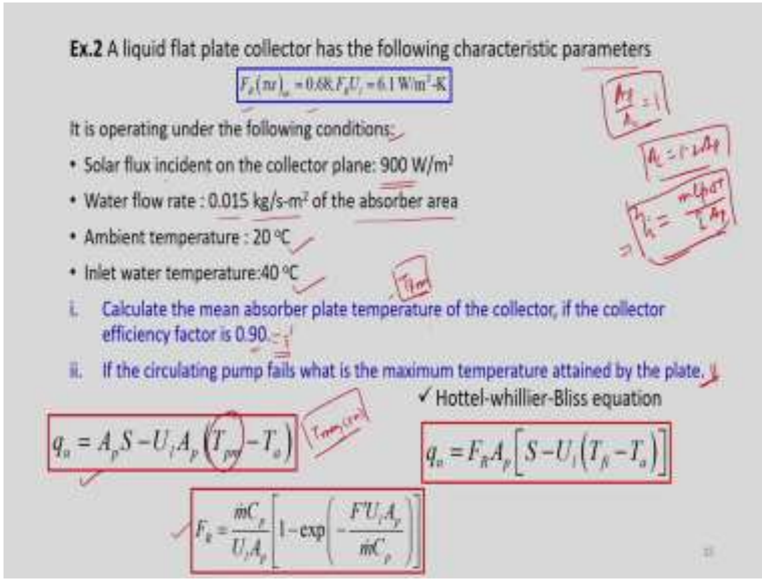

Now let us solve one more problem. So this problem is something like a liquid flat plate collector has the following characteristic parameters $F_R(\tau\alpha)$ is given, F_R U_l is given. So here Ap by, $\left(\frac{A_P}{A_c}\right)$ are same so this is 1. So there is no variations are considered normally A_c is about 1.2 times A_p. Sometimes we can represent this instantaneous efficiency in terms of mCp dt in terms of $i \times A_p$ also. So this can also be represented in terms of plate area.

So it is operating under following conditions like solar flux incident on the collector plane is 900 W/m^2, water flow rate is given as 1.015 kg/s-m^2 of the absorber area, ambient temperature is 20 °C, inlet water temperature is 40 °C. So now we need to calculate the mean absorber plate temperature of the collector if the collector efficiency factor is given. So F’ this is nothing but F’ is given to us and we need to calculate what is T_{PM}, mean temperature of the absorber plate. And second question if the circulating pump fails what is the maximum temperature attained by the plates.

So it may so happen that temperature is very, very high. So under that condition your material may damage, for that condition we need to find out what will be the maximum temperature if that circulation pump is not working. So we can use this expression for calculation of different parameters. So we need to calculate T_{PM} and then maximum temperature, maximum T_{max} or $T_{max(pm)}$ also we need to calculate. So now let us start this solution.

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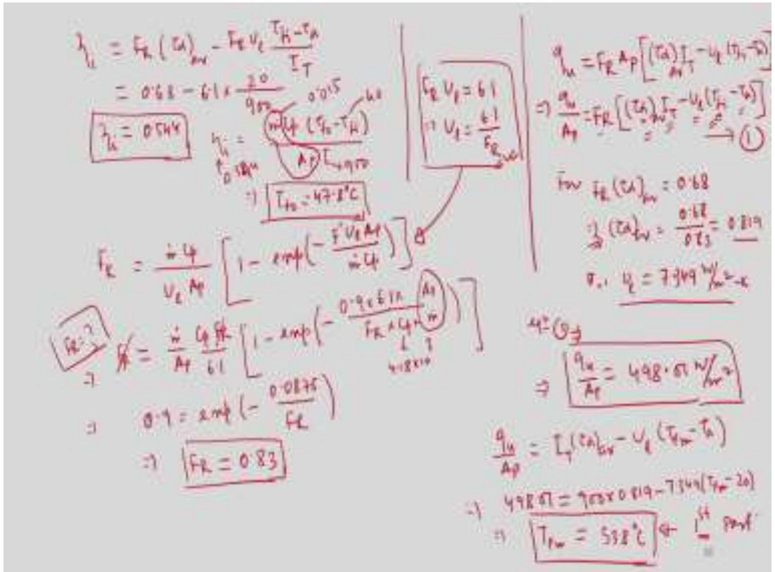

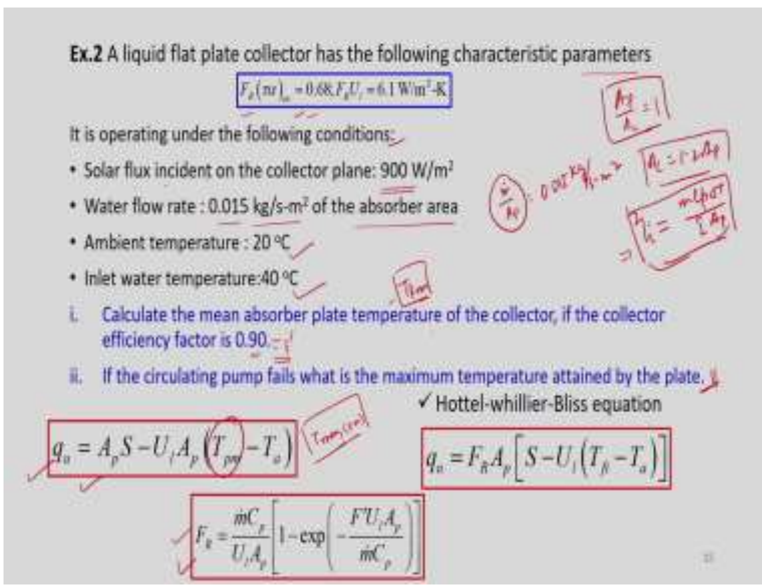

So here we know this expression η_i, first I will write this η_i, so η_i is nothing but F_R. So we assume that A_p and A_c are same so we have $\eta_i = F_R(\tau\alpha)_{avg} - F_R U_l \frac{T_{fi} - T_a}{I_T}$.

And if we substitute those values because $F_R(\tau\alpha)_{avg}$ is given to us, $F_R(\tau\alpha)_{avg}$ is given and then $F_R U_l$ is given so we straight away you can use those values here. So it is 0.68-6.1 into this temperature difference is 20 then I_T is 900 what is given in the problem. So this η_i is found to be 0.544. This is η_i or efficiency of the collector.

We can also find out what will be the T_{fo}. So once you know this instantaneous efficiency we know this $\eta_i = \frac{mC_p\left(T_{fo} - T_{fi}\right)}{A_p I}$. So if you substitute here in all those values so this will be 0.544 and m is given here. So what is the m 0.015 so this is something like m/Ap. So this is m/Ap is given as 0.015 kg/s-m^2.

So we can put a dot here because it is a flow rate. So this value is given so this value is 0.015 and this T_{fi} is given as 40 and I is 900. So on substitution what we can calculate is T_{fo} which is found to be 47.8 °C. So this can also be calculated and also we know the expression for F_R what is given in the last slides. This is the expression for F_R.

So we can write this expression F_R. So this F_R is something like mCp then you have U_l then A_p and then this is $1 - \exp\left(\frac{-F^{'} U_l A_p}{\dot{m} C_p}\right)$. So now we need to find out what is F_R. So U_l we can represent or we can omit this U_l here already we know the value, so what value is known to us $F_R U_l$ is equal to 6.1. Then U_l will be 6.1 divided by F_R.

So we can use this here. So then what will happen $\dot{m} A_p$ is known to us then U_l will be F_R, so this C_p will be there, F_R will be here and then we have 6.1. And then similarly this expression also changes. So $-F^{'}$ value is known to us which is 0.9 and U_l is nothing but 6.1 divided by F_R and C_p value is known. So this is C_p we can write, so C_p is nothing but 4.18×10^3 and multiplied by mC_p.

So this value is also known to us. So this is A_p and then we have m. So these values are also known to us. So if we substitute and this F_R and this F_R goes off then what will have once we simplify it so we will get something $0.9 = \exp\left(-\frac{0.0875}{F_R}\right)$. So we can calculate what will be the F_R by taking ln or log.

It will be 0.83. So once we know F_R, now we can use the other expression, so $q_u = F_R A_P\left[(\tau\alpha)_{avg} I_T - U_l\left(T_{fi} - T_a\right)\right]$ or we can simplify $\frac{q_u}{A_P} = F_R\left[(\tau\alpha)_{avg} I_T - U_l\left(T_{fi} - T_a\right)\right]$.

So this expression I can marked as 1 maybe and for $F_R(\tau\alpha)_{avg}$ is equal to 0.68 and from here we can calculate what is $(\tau\alpha)_{avg}$. So 0.68 to what is F_R value here is 0.83 which will be equal to 0.819. And again we can calculate what will be U_lF_R is known and so if we substitute F_R value here in this expression so we can calculate what will be U_l.

So U_l we can calculate which will be equal to 7.349 W/m^2, what is the unit here, let me see, yeah we can in this kelvin, sometimes it is in Celsius also. So U_l we know now, $(\tau\alpha)_{avg}$ is known to us, so this is known, this is known and T_{fi} is known, so from that we can calculate what is $\frac{q_u}{A_P}$. So now equation 1 implies $\frac{q_u}{A_P}$ on substitution of these values.

So we will get a value of 498.01 W/m^2 because all values are known to us, T_{fi} is known, ti is known I_T is known, these are calculated now, so we can use this, F_R is known. So we can straight away calculate what will be $\frac{q_u}{A_P}$ or heat flux. So once we know this again we can use the equation this equation for useful heat gain. So if we use that equation $\frac{q_u}{A_P} = I_T(\tau\alpha)_{avg} - U_l(T_{pm} - T_a)$.

So if we substitute the value of $\frac{q_u}{A_P}$ 498.01 is equal to I_T is known 900 and the $(\tau\alpha)_{avg}$ is known now 819 and U_l is also known 7.349. Now we need to calculate what is T_{PM} and Ta is also known to us its value is 20. So on calculation we will get T_{PM} value is equal to 53.8 °C. So this is the solution for first part. So now we have calculated what will be the mean temperature of the absorber plate if the characteristics parameters are given for a particular collector.

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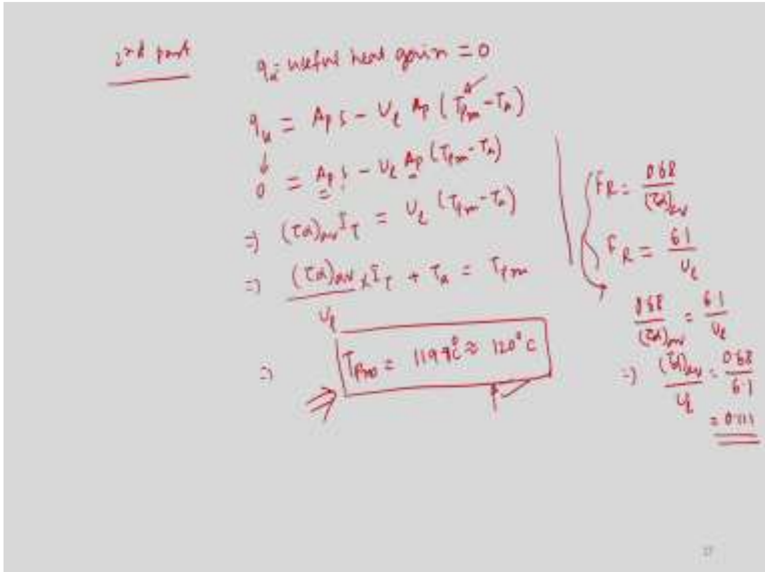

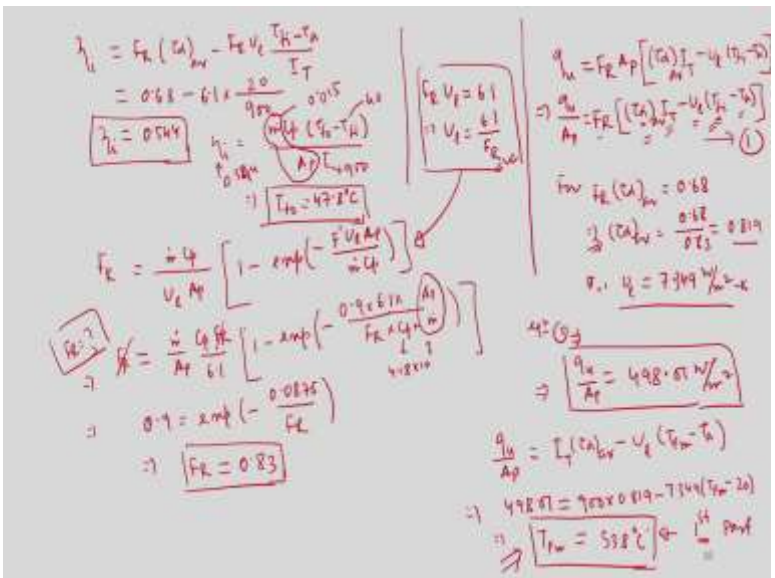

Now our next step is if the circulating pump fails, so pump will circulate there and then if circulating pump fails there is no useful heat gain. So under that condition if there is no useful heat gain so in the second part of the problem is useful heat gain or q_u is nothing but useful heat gain, useful heat gain which is equal to 0. And already we know what is the expression for $q_u = A_p S - U_l (T_{pm} - T_a)$ because we need to find out what will be the mean plate temperature if that circulation pump fails.

That means what will be the maximum temperature will get in the collector if no heat is collected. So this q_u is 0 and here $A_p S - U_l (T_{pm} - T_a)$. So if we simplify we will have this A_p A_p is common for both the expression, so we can take out as this part and S is nothing but $(\tau\alpha)_{avg} I_T$ and this will be something like $U_l (T_{pm} - T_a)$.

So this we can calculate now, what will be these values something like already we know F_R, what is we know F_R is 0.68 by $(\tau\alpha)_{avg}$ and of course we can use what we have calculated but independently also we can solve this 6.1/U_l then by using this, so since both the expression same so 0.68/$(\tau\alpha)_{avg}$ is equal to 6.1/U_l.

So from here we can calculate $(\tau\alpha)_{avg}$/Ul is nothing but 0.68/6.1 which is equal to 0.111. So if we simplify further this will be $\frac{(\tau\alpha)_{avg}}{U_l} I_T + T_a = T_{pm}$. So if you substitute these values so what we will get T_{PM} will be about 119.9 degree so which is equal to 120 °C. So this is T_{PM}.

So this maximum temperature what we will get is 120 if no heat is collected from the collector on the particular day. In earlier case what we got T_{PM} was 53.8 °C. Now you can see the rise in temperature. So this is the maximum temperature which can be seen if no heat is collected from the collector. So I hope that you understand the way we have solved these two problems. So this has got a lot of practical applications so that is why this problem has been discussed in this class.

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Also let us discuss something about applications of liquid flat plate collector. There are multiple applications of liquid flat plate collector, so namely indoor swimming pools nowadays it is quite common, so people are using solar energy for heating water in the swimming pool.

So the water heating is a primary concern. Milk pasteurization also this is seen application of flat plate collector and power generation for low temperature. Power generation this kind of systems are used, drying, then solar water heater for biogas, so it is seen that if we maintain certain temperature by using some kind of heat inside the biogas plant then of course we can maximize the biogas production.

So it is nowadays solar collectors are used to circulate fluid inside the biogas plant to get maximum biogas generation. Then slurry drying is also one of the applications of liquid flat plate collector. So here two examples we have shown. In the first example use of solar energy for indoor swimming pool, what you can see this is a collector so number of collectors required will be decided based on the capacity of the water to be heated.

So collectors will be installed normally at the rooftop or maybe you know some kind of structure and then hot water will be pumped through filter and this will be circulated in the swimming pool, again it will pump back, again it will pump back so it will work in a closed loop. So if we consider this inlet, this is the outlet, so after it will go through this and then it will move this way and then after heat loss is taking place then water has to be circulated.

So this is the circulation loop so this will work in a closed loop. And this figure shows the application of liquid flat plate collector for power generation. So we have this liquid flat plate collector, so hot water is generated and this is also working in a closed loop, so pump will be there so water will be circulated it goes and heat exchange will be there. So this is a heat storage tank.

Again we need to have some kind of heat exchanger so that the amount of heat what is generated that has that can be provided to other working fluid. And that working fluid will move in a circuit that is also in a closed loop and this working fluid is different and it will evaporate at low temperature and this, this will expand, vapor will expand in a turbine and then energy will be generated and remaining it will condense in a condenser and it will pump again through this heat exchanger and it will work in a closed loop.

So of course we need some other devices like cooling tower because this has to be cooled. So this is an assembly so here ORC is used. So ORC is nothing but organic Rankine cycle because organic fluid is used because of that it is known as organic Rankine cycle. So here hot water at temperature at around 100 °C is stored in the thermal storage tank so here about 100 °C the water temperature which is stored in this tank.

And then low boiling point working fluid vaporizes at vapor generator at around 90 °C and leaves the condenser at 35 degree, so here it is at 35 °C. So this will be maybe 90, 95 some losses will be there, so maybe 90 °C. So that way even though carnot efficiency is very, very low, still sometimes this configuration can be applied for generation of small amount of power.

This expansion will be there from 90 to 35 here. So this working fluid normally used R11, R13, R114 then methyl chloride etc. so having low boiling point. So this is also working in close loop and this is also working in close loop we need to have a heat exchanger to exchange the heat what is generated via this flat plate collector and then it is expanding the turbine and electricity is generated and then rest is now condensed and then it is circulated again and again.

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So in this presentation we have learnt details about testing of liquid flat plate collector what is the need of liquid plate collector testing and then how this can be tested and we have solved very interesting problems to strengthen the understanding how this liquid flat plate collector can be tested. And we have also learned the applications of liquid flat plate collector. So thank you very much for watching this video.