Solar Energy Technology
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Lecture - 34
Exercise - Two (Contd.)

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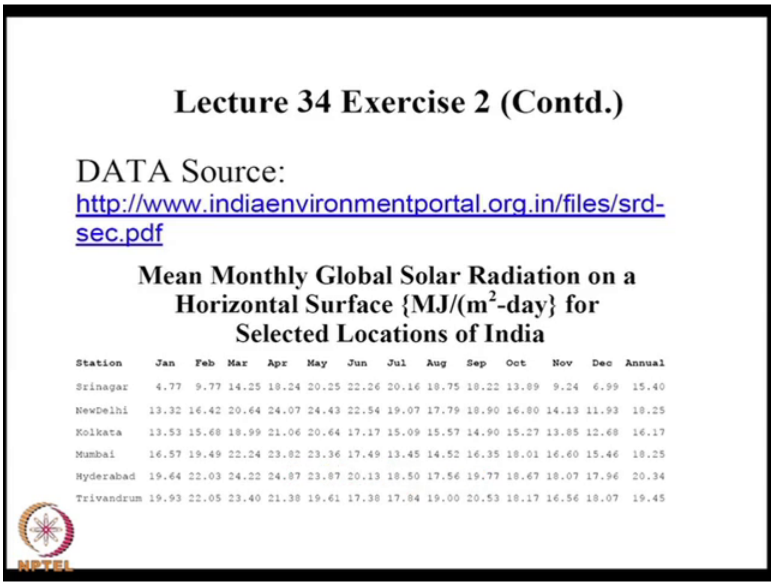

Lecture 34 Exercise 2 (Contd.)

DATA Source:
http://www.indiaenvironmentportal.org.in/files/srd-sec.pdf

Mean Monthly Global Solar Radiation on a Horizontal Surface {MJ/(m^2-day} for Selected Locations of India

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Srinagar	4.77	9.77	14.25	18.24	20.25	22.26	20.16	18.75	18.22	13.89	9.24	6.99	15.40
NewDelhi	13.32	16.42	20.64	24.07	24.43	22.54	19.07	17.79	18.90	16.80	14.13	11.93	18.25
Kolkata	13.53	15.68	18.99	21.06	20.64	17.17	15.09	15.57	14.90	15.27	13.85	12.68	16.17
Mumbai	16.57	19.49	22.24	23.82	23.36	17.49	13.45	14.52	16.35	18.01	16.60	15.46	18.25
Hyderabad	19.64	22.03	24.22	24.87	23.87	20.13	18.50	17.56	19.77	18.67	18.07	17.96	20.34
Trivandrum	19.93	22.05	23.40	21.38	19.61	17.38	17.84	19.00	20.53	18.17	16.56	18.07	19.45

We shall continue with the problems involved in the phi bar f chart method, which we will call it exercise 2 continued I have already described about the data source taken from the particular website, and for six important locations I have given the data that is Srinagar, new Delhi, Kolkata, Mumbai, Hyderabad and Trivandrum.

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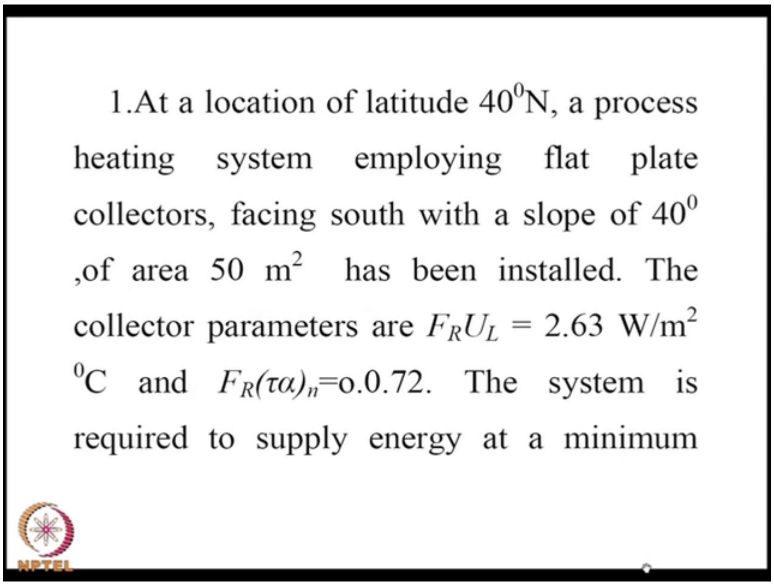

1.At a location of latitude 40^0N, a process heating system employing flat plate collectors, facing south with a slope of 40^0 ,of area 50 m^2 has been installed. The collector parameters are F_RU_L = 2.63 W/m^2 ^{0}C and $F_R(\tau\alpha)_n$=o.0.72. The system is required to supply energy at a minimum

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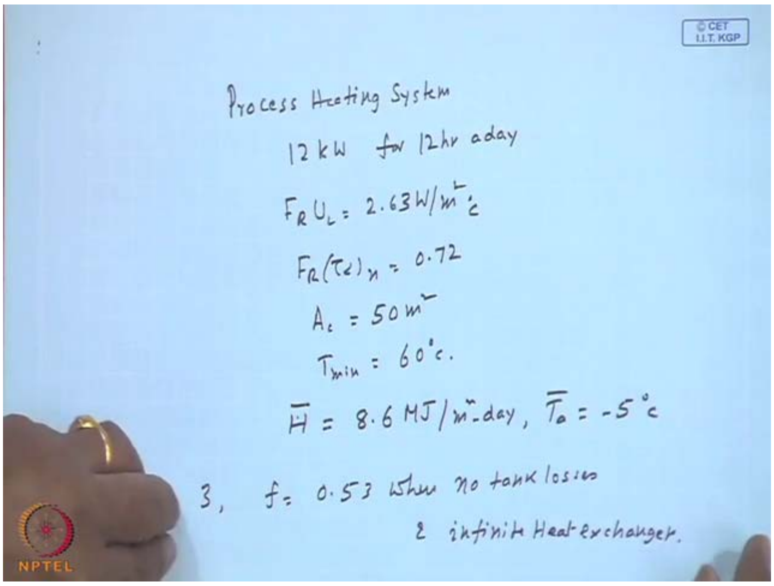

Process Heating System

12 kW for 12hr aday

$F_R U_L = 2.63 W/m^2 {}^\circ c$

$F_R(\tau\alpha)_n = 0.72$

$A_c = 50 m^2$

$T_{min} = 60^\circ c.$

$\bar{H} = 8.6 MJ/m^2\text{-day}, \bar{T_a} = -5^\circ c$

3, $f = 0.53$ when no tank losses

& infinite Heat exchanger.

And we were trying to find out the phi bar f chart calculation for a process heating system, supplying 12 kilo watts of energy for 12 hours a day, the collector parameters are given F R U L 2.63 watts per meta square degree c, F R tau alpha normal is 0.72, area of the system is 50 square meters, and T minimum required to supply at 60 degrees c and the data for Srinagar for the month of January is sorry, H bar for the location under consideration is 8.6 mega joules per meta squared day and the ambient temperature is minus 5 degrees c.

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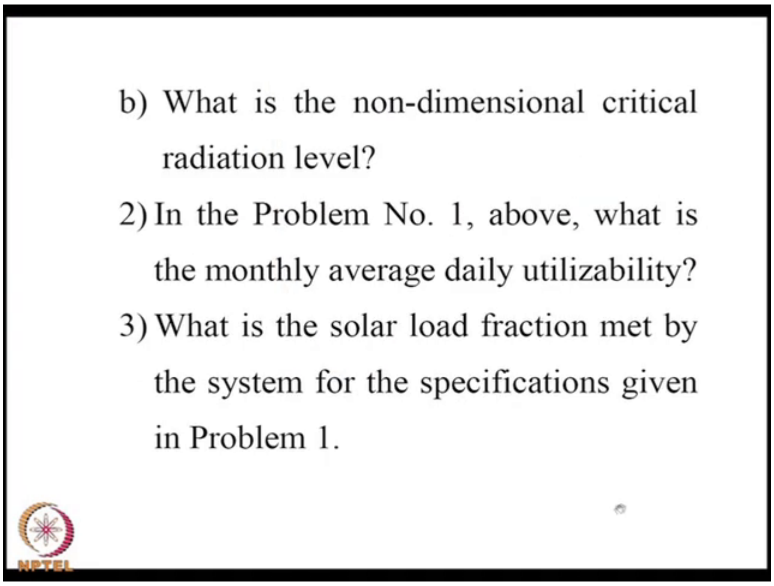

b) What is the non-dimensional critical radiation level?

2) In the Problem No. 1, above, what is the monthly average daily utilizability?

3) What is the solar load fraction met by the system for the specifications given in Problem 1.

So, we calculate the dimensional critical radiation level, and then we calculated the non-dimension critical level and the monthly average daily utilizability, and the solar load fraction 3 f equal to 0.53 when no tank losses and infinite heat exchanger. Basically this is a way of technical way of calling a infinite heat exchanger, which essentially means there is no temperature loss across the load heat exchanger.

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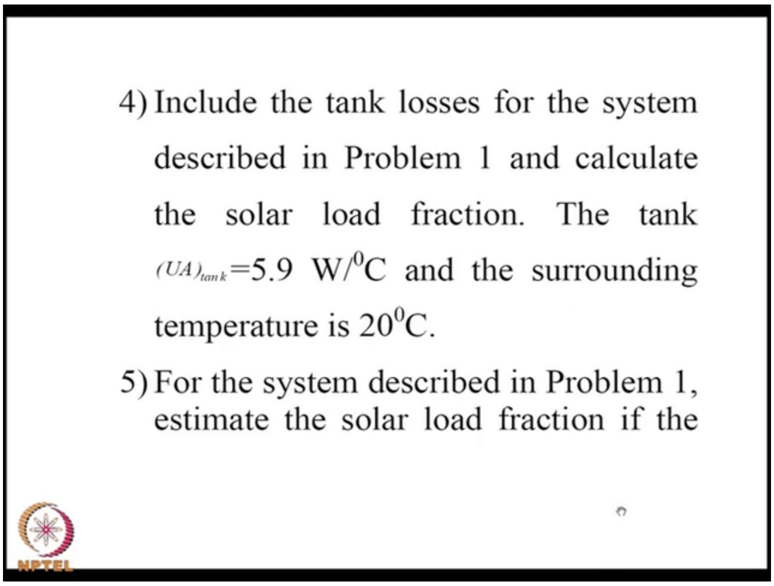

4) Include the tank losses for the system described in Problem 1 and calculate the solar load fraction. The tank $(UA)_{tank}$=5.9 W/^{0}C and the surrounding temperature is 20^{0}C.

5) For the system described in Problem 1, estimate the solar load fraction if the

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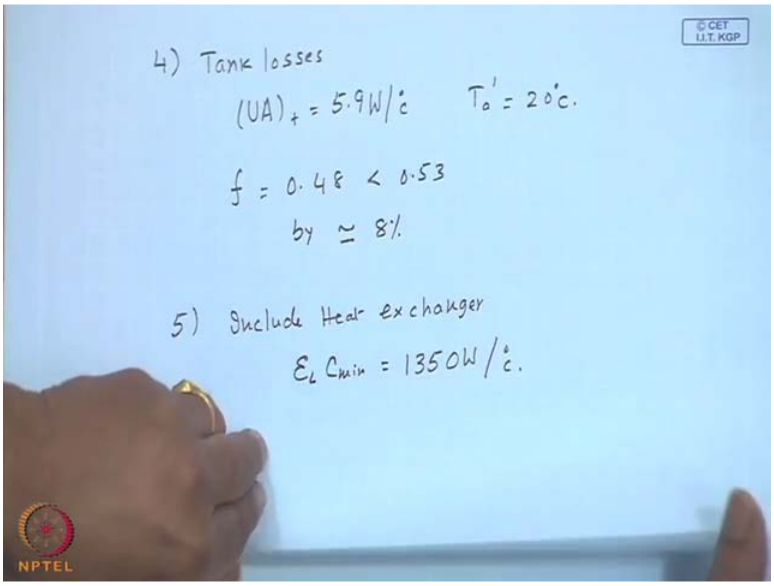

4) Tank losses

$(UA)_t = 5.9 W/^\circ c$ $T_a' = 20^\circ c.$

$f = 0.48 < 0.53$

by $\simeq 8\%$

5) Include Heat exchanger

$\varepsilon_L C_{min} = 1350 W/^\circ c.$

Then subsequently we included the tank losses in problem 4 which has got a tank with UA t of 5.9 watts per degree c losing to environment at 20 degrees c, then f we got it to be 0.49 which is less than 0.53 by approximately 8 percent; that is the effect of including the tank losses. Now, we shall go ahead and include a heat exchanger which has got epsilon L C minimum equal to 1350 watts per degree c.

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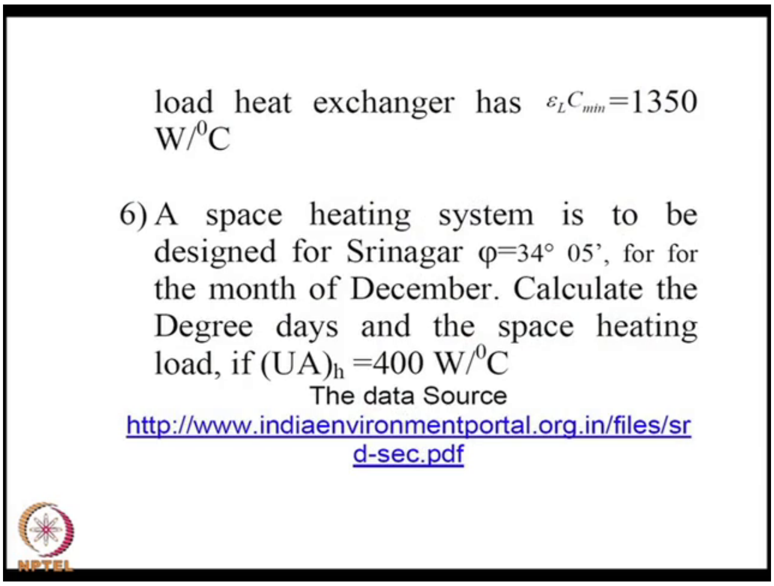

load heat exchanger has $\varepsilon_L C_{min} = 1350$ W/^{0}C

6) A space heating system is to be designed for Srinagar φ=34° 05’, for for the month of December. Calculate the Degree days and the space heating load, if $(UA)_h = 400$ W/^{0}C

The data Source

http://www.indiaenvironmentportal.org.in/files/srd-sec.pdf

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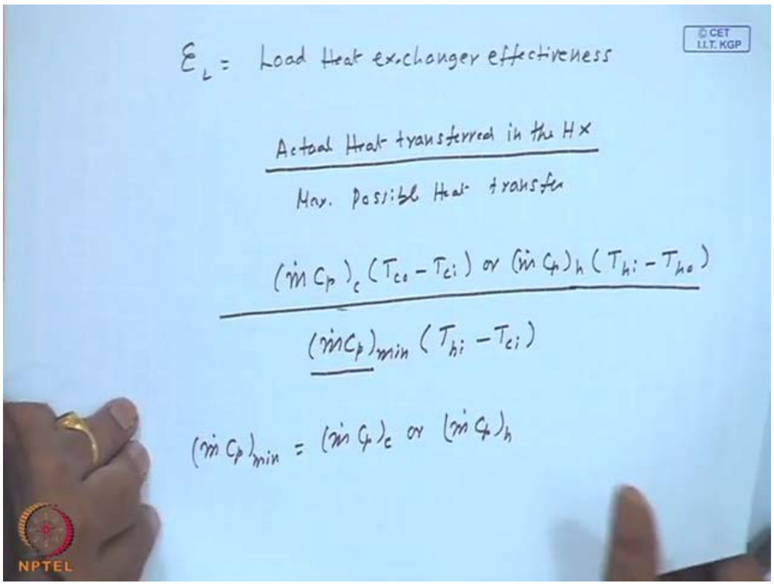

ε_L = Load Heat exchanger effectiveness

$$= \frac{\text{Actual Heat transferred in the Hx}}{\text{Max. Possible Heat transfer}}$$

$$= \frac{(\dot{m} C_p)_c (T_{co} - T_{ci}) \text{ or } (\dot{m} C_p)_h (T_{hi} - T_{ho})}{\underline{(\dot{m} C_p)}_{min} (T_{hi} - T_{ci})}$$

$(\dot{m} C_p)_{min} = (\dot{m} C_p)_c$ or $(\dot{m} C_p)_h$

Epsilon L is the load heat exchanger effectiveness for those of you who are not very familiar with heat transfer or heat exchangers, this may be defined as actual heat transferred in the heat exchanger, I am using the short form H x for heat exchanger by max and possible heat transfer. This first I should write the denominator first, if m dot c p lower of the cold or the hot fluids multiplied by T h i minus T c i. So, when I write this temperature difference as T h i minus T c i, the possibility is that the cold fluid can get heated up to the inlet temperature of the hot fluid or the hot fluid can get cooled to the cold fluid inlet temperature. So, consequently this is the maximum possible temperature change that can occur to either of the fluids depending upon the purpose.

Now, that chance is there for the fluid with the lower heat capacitance m dot C p minimum, this m dot C p minimum may be equal to m dot C p cold or m dot C p h depending upon which one is lower of the 2. So, in the numerator I can write actual heat gained as m dot C p cold into T c o minus T c i or m dot C p hot into T h i minus T h o. If m dot C p minimum is m dot C p h you can cancel that and use this or if cold one is the minimum you can cancel that and use this. Of course, inherent in this formula is that if you write like this that the heat gained by the cold fluid is equal to the heat lost by the hot fluid. If not another practical way of writing the denominator is depending upon the objective whatever is the change or the acquired heat transfer by the cold or the hot fluid upon m dot C p minimum times T h i minus T c i. So, this indicates how good the effectiveness or the heat exchanger is.

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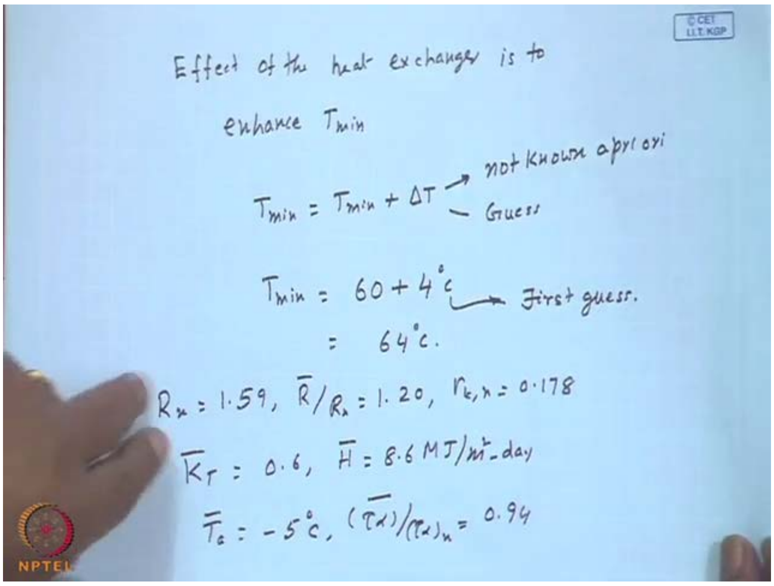

Effect of the heat exchanger is to

enhance T_{min}

$T_{min} = T_{min} + \Delta T$ → not known apriori

— Guess

$T_{min} = 60 + 4^\circ c$ → First guess.

$= 64^\circ c.$

$R_n = 1.59$, $\bar{R}/R_n = 1.20$, $r_{t,n} = 0.178$

$\bar{K}_T = 0.6$, $\bar{H} = 8.6\ MJ/m^2\text{-}day$

$\bar{T}_a = -5^\circ c$, $(\overline{\tau\alpha})/(\tau\alpha)_n = 0.94$

Now, so to include this the effect of the heat exchanger not the effectiveness effect of the heat exchanger is to enhance T minimum, since there is a temperature drop across the load heat exchanger, the collector will be required to supply energy not at T minimum, but at a temperature higher than T minimum. And let that be now T minimum will be the original T minimum which is our 60 plus a delta T not known a prior. So, we will make a guess. So, T min is the 60 original temperature at which it is required to supply energy plus 4 degrees c, this is my first guess.

So, effectively this is equal to 64 degrees c. So, from this I shall repeat the parameters which we already have calculated R n is 1.59 R bar by R n is 1.20 and r t n is 0.178, K T bar is 0.6, H bar equal to 8.6 mega joules per meter square day, and T a bar is minus 5 degree c. And we calculated tau alpha bar by tau alpha n equal to 0.94. The first step will be to calculate the non-dimensional critical level corresponding to T minimum is 60 plus 4, 64.

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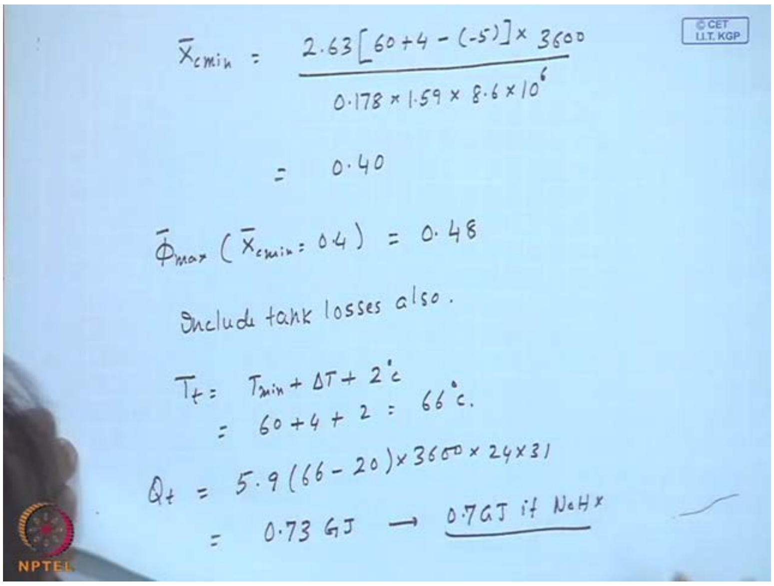

$$\bar{X}_{c\,min} = \frac{2.63[60+4-(-5)] \times 3600}{0.178 \times 1.59 \times 8.6 \times 10^6}$$

$$= 0.40$$

$$\bar{\Phi}_{max}(\bar{X}_{c\,min} = 0.4) = 0.48$$

Include tank losses also.

$$T_t = T_{min} + \Delta T + 2^\circ c$$
$$= 60 + 4 + 2 = 66^\circ c.$$

$$Q_t = 5.9(66-20) \times 3600 \times 24 \times 31$$
$$= 0.73\ GJ \longrightarrow \underline{0.7\,GJ \text{ if No } H x}$$

So, x c bar minimum will be FRUL, that is 2.63 times 60 plus guest 4 temperature minus T a bar which is minus 5 times 3600 to make it time unit proper by R t n times r n times 8.6 h bar into h t bar sorry 10.6, that is the this is H bar R t n yes. So, that is to make it joules which will be equal to 0.40, and phi bar max corresponding to X c bar minimum equal to 0.4, we have written that relation number of times which you can use and come out with answer of0.48 . So, now the system has a utilizability of 0.48, if we include the heat exchanger to be responsible for a temperature increased in the required minimum energy delivery by 4 degrees.

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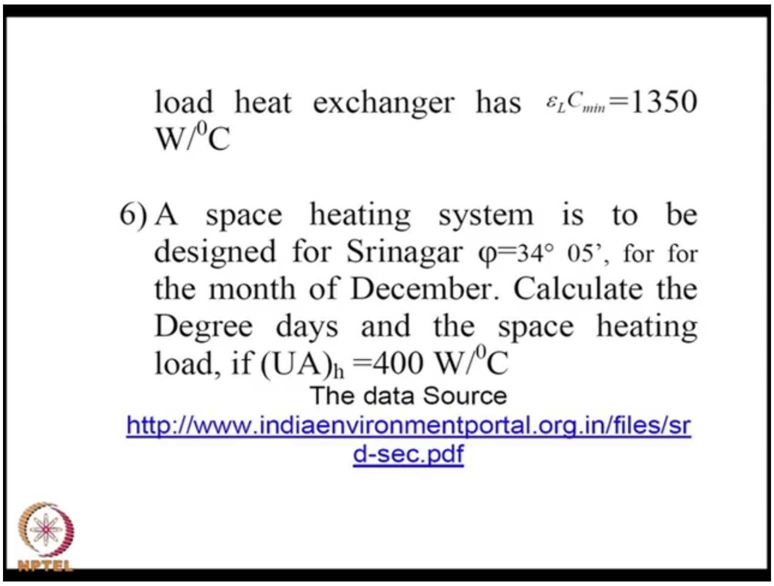

load heat exchanger has $\varepsilon_L C_{min}$=1350 W/^{0}C

6) A space heating system is to be designed for Srinagar φ=34° 05’, for for the month of December. Calculate the Degree days and the space heating load, if $(UA)_h$ =400 W/^{0}C

The data Source

http://www.indiaenvironmentportal.org.in/files/srd-sec.pdf

Now, we want to include the tank losses also, what should be T t, originally what we did was it will be T minimum plus 2 degrees or whatever it is. Now, that T minimum has become T minimum plus delta T plus; let us say 2 degrees c, that will be equal to 60 plus 4 plus 2 equal to 66 degrees c. So, Q tank loss from the tank now will be slight different from the previous calculation 5.9 times 66 minus 20 times 3600 into 24 into 31; that is it will be in joules large number that this is equal to 0.73 giga joules. We got earlier this was 0.7 giga joules, if no heat exchanger.

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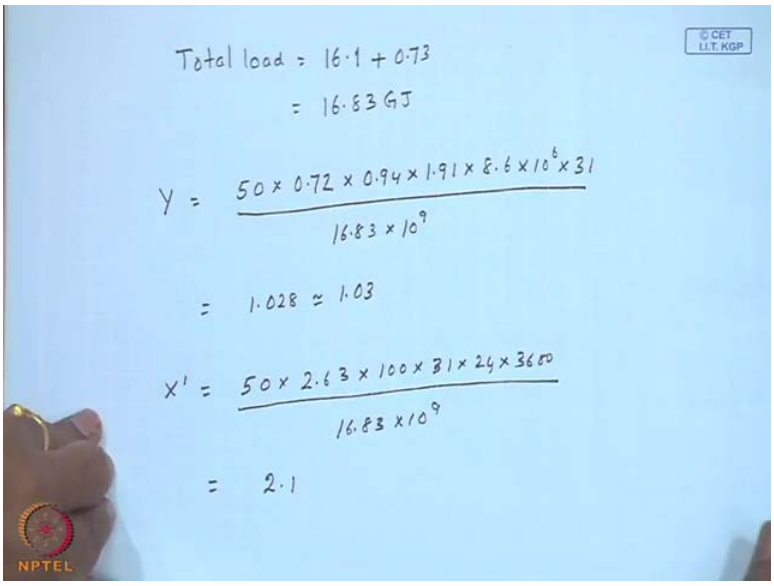

$$\text{Total load} = 16{\cdot}1 + 0{\cdot}73$$

$$= 16{\cdot}83\ \text{GJ}$$

$$Y = \frac{50 \times 0{\cdot}72 \times 0{\cdot}94 \times 1{\cdot}91 \times 8{\cdot}6 \times 10^6 \times 31}{16{\cdot}83 \times 10^9}$$

$$= 1{\cdot}028 \simeq 1{\cdot}03$$

$$X' = \frac{50 \times 2{\cdot}63 \times 100 \times 31 \times 24 \times 3600}{16{\cdot}83 \times 10^9}$$

$$= 2{\cdot}1$$

Then, now the total load 16.1 that is the original process heating load plus the tank loss 0.73 which will be 16.83 giga joules instead of 16.8, if you had not included the heat exchanger, the modified Y will be area 50 meter square into tau alpha normal F r 0.72 multiplied by tau alpha bar by tau alpha n 0.94 times r bar 1.91 into H 8.6 into 10 to the power 6 to make it joules multiplied by 31, the number of days by 16.83 into 10 to the power 9 to make it joules this is 1.028, which is approximately 1.03. And the variable X dashed will be area 50 times FRUL 2.63 into 100, that is a formula number in the formula times number of seconds in the month 31 into 24 into 3600 by 16.83 into 10 to the power 9 which is 2.1.

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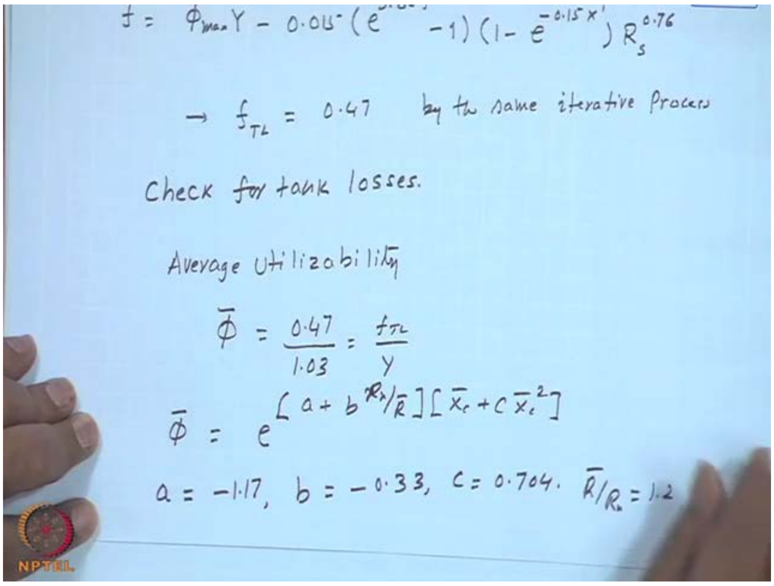

$f = \phi_{max} Y - 0.015 (e - 1)(1 - e^{-0.15 X'}) R_s^{0.76}$

$\rightarrow f_{TL} = 0.47$ by the same iterative Process

Check for tank losses.

Average utilizability

$\bar{\phi} = \frac{0.47}{1.03} = \frac{f_{TL}}{Y}$

$\bar{\phi} = e^{[a + b R_n/\bar{R}][\bar{X}_c + c \bar{X}_c^2]}$

$a = -1.17$, $b = -0.33$, $c = 0.704$. $\bar{R}/R_n = 1.2$

So, now we have got a method of calculating the solar load fraction f will be the same relation phi bar max y minus 0.015 e to the power 3.85 f minus 1 times 1 minus exponential to the power minus 0.15 x dashed times their ratio of standard storage to the actual storage s to the power 0.76. So, this will come out to be now we should call it f T l, because it included the tank losses 0.47, it is by the same iterative process which I have described in the last class put all the numbers on the right hand side, and this half should be less than phi bar max y that will be your first guess. And then keep on iterating evaluating right hand side, and see where it is equal to the left hand side by by let us say 0.01 or 005.

Now, we should go with check for the tank losses first, because we guessed that the tank temperature is 2 degrees above. So, this is in effect is operating at a average utilizability of phi bar equal to 0.47 by 1.03; that is f T L upon the y that is actually f T L by y. And this is how much? Whatever is the number that should be equal to e to the power a plus b R n by R bar times x c bar plus c x c bar square. So, with a this is almost 0.45 or so the constants a we have already calculated minus 1.17, and b minus 0.33, and c 0.704. and R n by R bar R bar by R n is 1.2. So, from this number whatever this number I have put it down here.

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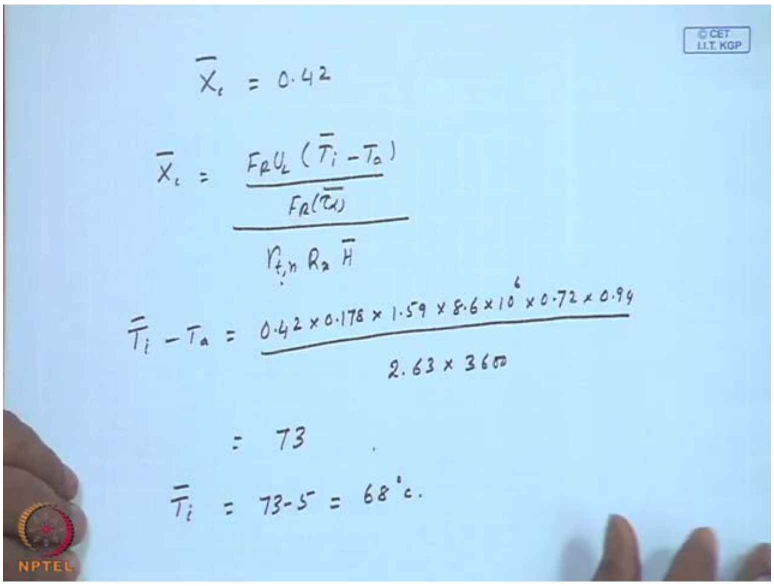

$$\bar{X}_c = 0.42$$

$$\bar{X}_c = \frac{\dfrac{F_R U_L(\bar{T}_i - T_a)}{F_R(\overline{\tau\alpha})}}{r_{t,n} R_n \bar{H}}$$

$$\bar{T}_i - T_a = \frac{0.42 \times 0.178 \times 1.59 \times 8.6 \times 10^6 \times 0.72 \times 0.94}{2.63 \times 3600}$$

$$= 73$$

$$\bar{T}_i = 73 - 5 = 68^\circ c.$$

You can back calculate x c bar turns out to be 0.42. So, from which x c bar equal to FRUL into T i bar average in the temperature minus T a by F R tau alpha bar by r t n R n H bar and so T i bar minus T a, I will take this T i bar minus T a is 0.42 times 0.178 that is r t n, R n is 1.59 multiplied by h point 8.6 into10 to the power 6, this F R tau alpha bar is 0.72 into 0.94 by 2.63 and the time factor 3600. This comes to73, so T i bar will be 73 minus 5 or remember this T a is a minus 5. So, this becomes plus when you transfer on to this side it will be minus 5, 68 degrees c.

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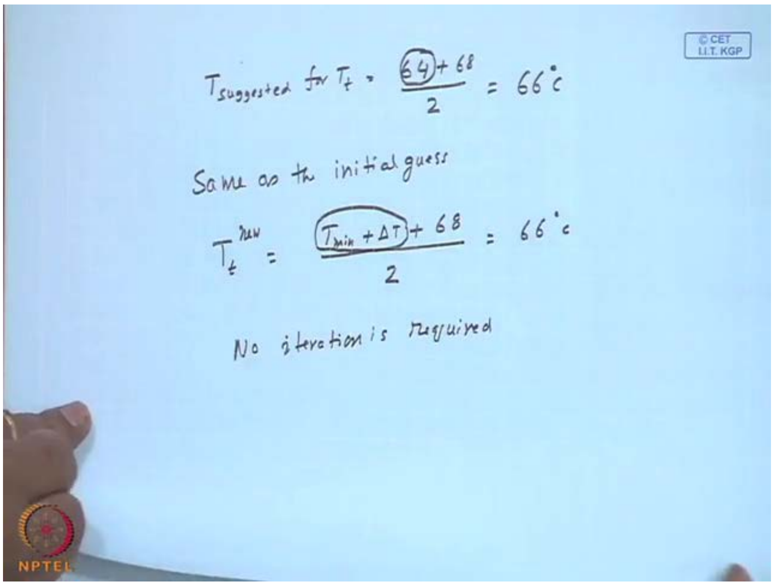

$$T_{suggested} \text{ for } T_t = \frac{\boxed{64} + 68}{2} = 66^\circ c$$

Same as the initial guess

$$T_t^{new} = \frac{\boxed{T_{min} + \Delta T} + 68}{2} = 66^\circ c$$

No iteration is required

So, as per the suggestion T suggested for T t theta is 64 plus 68 by 2, this 68 is this much and this is the T minimum which is 64, that is coming from 60 plus 4 not 2 that additional thing equal to 66 degree c is same as initial guess. So, let me once again clarify this T t, after this calculation mu is actual your T min plus delta T which we included, because of the heat exchanger plus 68 which is the T i bar based upon the average utilizability by 2 which is 66 degrees. So, what I want to say is this 64 comprising of T minimum plus delta t. So, no iteration is required, otherwise with this number you we start and we calculate.

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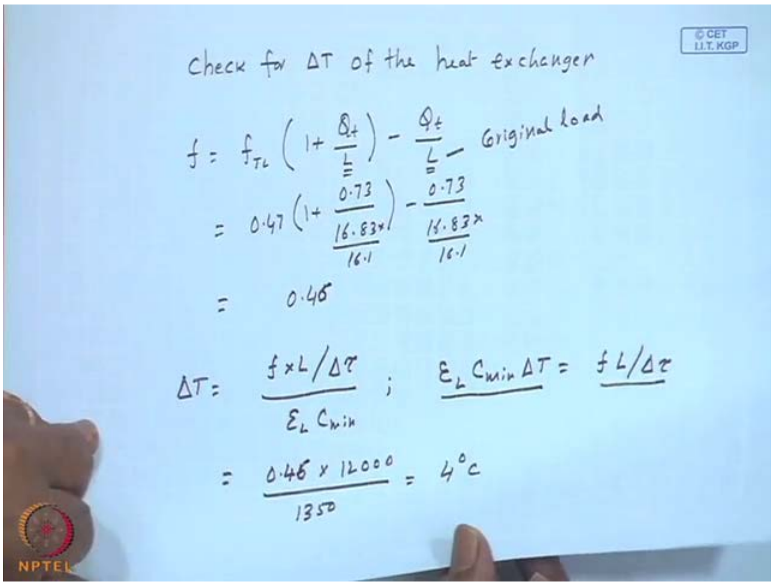

Check for ΔT of the heat exchanger

$$f = f_{TL}\left(1 + \frac{Q_t}{\underline{\underline{L}}}\right) - \frac{Q_t}{\underline{\underline{L}}} \text{ — Original load}$$

$$= 0.47\left(1 + \frac{0.73}{\frac{16.83 \times}{16.1}}\right) - \frac{0.73}{\frac{16.83 \times}{16.1}}$$

$$= 0.46$$

$$\Delta T = \frac{f \times L/\Delta\tau}{\varepsilon_L C_{min}} \; ; \quad \underline{\varepsilon_L C_{min} \Delta T} = \underline{f L/\Delta\tau}$$

$$= \frac{0.46 \times 12000}{1350} = 4^\circ c$$

And check for delta T of the heat exchanger. Now, we got f will be f T L times 1 plus Q t by l minus Q t by l, that is equal to 0.47 we got times 1 plus 0.73 by 16.83 minus 0.73 by 16.83, that will be equal to0.45. So, this is a matter of fact it should be only not 16.1, it should be 16.1, because this is a original L in calculating f T L. So, this number does not change, because both places we are underestimating minus and plus except for this factor, it may be little higher may be 0.46. And alright the so this should be the original load only this is fine. So, delta T across the heat exchanger should be f into L is the amount of energy transferred in the time delta tau by epsilon c minimum right, and I said for your convenience epsilon L C minimum times delta t should be equal to heat transfer which in this case is f L by delta tau. So, if you interpret like that, this is the perfect heat exchanger heat gain equation, and this is the energy transferred.

So, you have this delta should be equal to 0.45 into 12000 0.46 into 12000 by 1350, I do not have to calculate from 16.1 giga joules by 24 by 31, 36; all that because the rate is already known to us which is 4 degree c.

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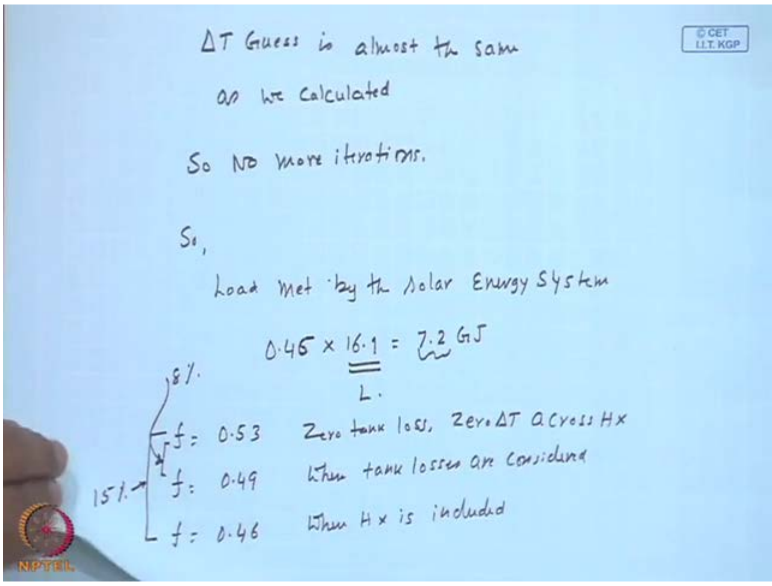

ΔT Guess is almost th same as we calculated

So No more iterations.

So,

Load met by th solar Energy System

$0.46 \times \underline{\underline{16.1}} = \underset{\sim}{7.2}$ GJ

L.

8%

15%

f = 0.53 Zero tank loss, Zero ΔT across Hx

f = 0.49 When tank losses are considerd

f = 0.46 When Hx is includd

So, delta T guess is almost at least the same as we calculated. So, no more iterations, some of you may be wondering in an examination or when you have to solve the problem or you may not be able to guess the value. So, correctly the answer for that is yes, you may have to iterate more than once or may be twice, but the direction in which it is going to change is indicated by the calculated number. So, if 4 has become 3, you start with 3 sometime then maybe you end up with 3.2 and it should stop. And typically the examples if you go through some more you will find that the effect of the tank temperature loss is to make the tank temperature 2 to 3 degrees more than the T minimum, and the heat exchange it is about 4 degrees and depending upon actual epsilon l c minimum one can make a guess about it.

But that is a very complicated theory nevertheless, this 2 4 3 and or else if you put it in the calculator many numbers will not change, and the changed numbers can be calculated on a pure basis. So, for example, the load if it becomes 16.8 instead of 16.1 you multiply by y and x according to that ratio. So, you do not have to recalculate all of them all the time.

So, finally this load met by the solar energy system 0.45 times 16.1 equal to 7.2 giga joules; once again this is the original L, because this is the amount of energy that the user is going to feel that it has supplied. Not what it lost across the heat exchanger and what it lost to the tank. So, if you again have a little bit of summary f is equal to 0.530 tank loss and 0 delta T across the heat exchanger. Then this became 0.49 when tank losses are considered and that became 0.46, this is 46 when heat exchanger is included. So, if you look at from this to this, this is about 15 percent, this is about 8 percent. So, this gives as a field for the numbers.

Basically we designed whether we have calculated the solar load fraction met for one month by a process heating system employing flat plate characters of certain specifications at a location of latitude 40 degrees with slope of let 40 degrees facing south having a tank of u a t 5.9 watts per degree c, and the heat exchanger of epsilon l c minimum of 1350 watts per degree c. So, the solar load fraction for that 16.1 giga joules which is 12 kilo watts per 12 hours for 30, 24, 31 days in the month came to 61 16.1 giga joules, and the load fractions are respectively most ideal case 0.43 when tank losses are included to joules 2.49 and when the heat exchanger effect also is added it became 0.46. So, now we shall go to little bit with Indian data for Indian locations, and see if you can design a space heating system and make use of f chart.

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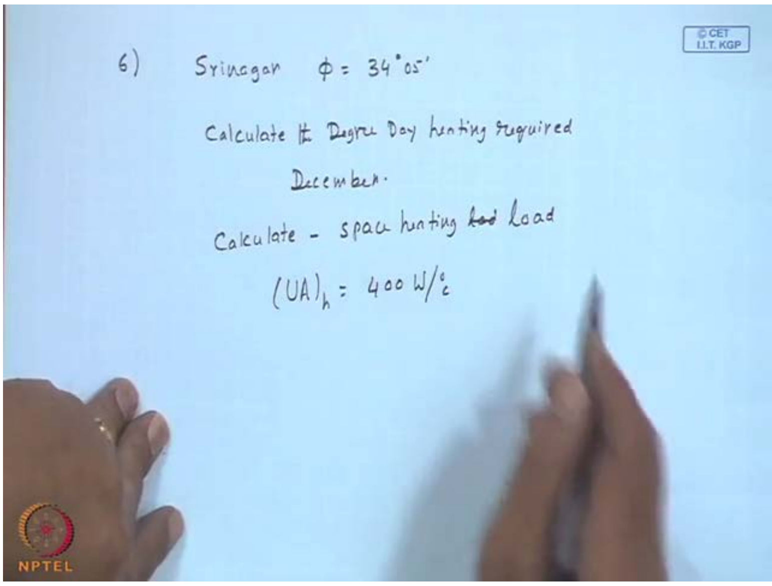

6) Srinagar $\phi = 34^\circ 05'$

Calculate the Degree Day heating required

December.

Calculate - space heating ~~load~~ load

$(UA)_h = 400\ W/^\circ c$

So, that is the problem number 6 to have reasonable space heating requirement, the location I have chosen is Srinagar and latitude east 34 degrees 5 minutes, and we first have to calculate the data already I have given once again or you can pick up from the portal which I already told last time. First step is degree day information is not available calculate, if you can heating required naturally December, January will be the coldest. So, I choose December, and then calculate your space heating load with building heat transfer heat lost co efficient of 400 watts per degree c, something like 200 to 600 depending upon the dwelling size is the reasonable number, and if it is it may be medium or a small one with lots of leakages. So, this is what we shall do?

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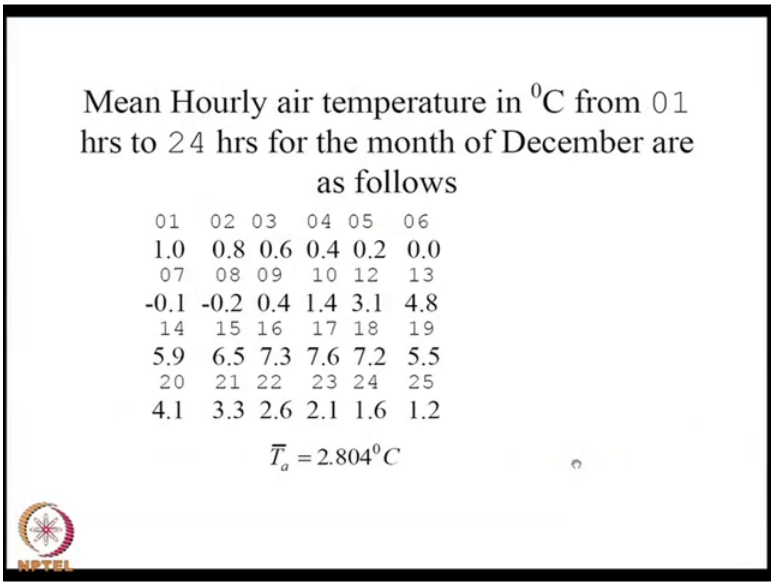

Mean Hourly air temperature in ^{0}C from 01 hrs to 24 hrs for the month of December are as follows

01	02	03	04	05	06
1.0	0.8	0.6	0.4	0.2	0.0
07	08	09	10	12	13
-0.1	-0.2	0.4	1.4	3.1	4.8
14	15	16	17	18	19
5.9	6.5	7.3	7.6	7.2	5.5
20	21	22	23	24	25
4.1	3.3	2.6	2.1	1.6	1.2

$$\overline{T}_a = 2.804^0 C$$

Now, the data you can pick up you have got monthly average hourly ambient temperature, which I shall show you, so this I have written I do not know if you can see the cursor; first 01 hour means ending at one am and 24 means ending at 12 midnight. So, the 23, 24 somewhere one number is missing 12, 13 yeah. So, that should be 24 and they have got at one am one degree, 2 am 0.8 degrees like that. So, this table will give you the 24 hour data and first calculated the average for the day turns out to be 2.804, just some of those numbers and divided by 24.

Now this so called mean hourly a temperature. So, for example, for a hour let us say ending at 1 AM, this is T a for 12 to 1 AM for all the days by. So, you pick up a particular hour and take the data for all the 30 or 31 days in that month and divide it that becomes a monthly average hourly temperature. So, you have got 24 values for the 24 hours, if I average all those things this should be the monthly average daily temperature. So, this should be the monthly average, that is how you can compile from the data that is available in the website monthly average daily ambient, there is a purpose I really do not need it.

Now, if you look at how do I compute DD? First I shall write the formula it will be more easier to understand that should be summation 20 minus T i into 31 by 24 and this is 1 to 24. So, 20 degree c I assumed the base temperature or the comfort condition. It could be 18.7 many people use 19 18.7 assuming that there will be internal heat generation due to lighting cooking etcetera, etcetera. So however, I just used a 20, so a round number and this T i changes 1 to 24 hours an each day, since I already have a monthly average value, if I multiply by 31, if I multiply by 31, since I have got already T i bar sort of... So, that will give me the total days, but this is done for 24 hours I should derive by 24.

Technically it should have been 1 to 24 summation 1 to 31 of each being T i of each day. So, this is nothing but the average day temperature for a particular hour that multiplied by 31, I will get degree hours and that makes a day by dividing by 24. Because I am go going to add 24 times.

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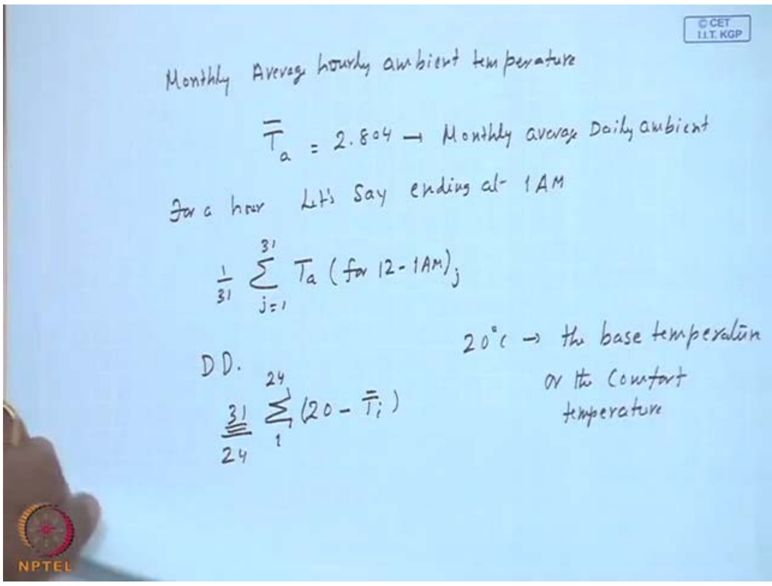

Monthly Averag hourly ambient temperature

$\bar{\bar{T}}_a = 2.804$ → Monthly average Daily ambient

For a hour Let's Say ending at 1 AM

$$\frac{1}{31}\sum_{j=1}^{31} T_a\,(\text{for } 12\text{-}1\text{AM})_j$$

20°c → the base temperature or the Comfort temperature

D.D.

$$\frac{31}{24}\sum_{1}^{24}(20-\bar{T}_i)$$

So, this let me write it down degree days is 31 summation 20 minus T i bar, where i is equal to 1 to 24 by 24. In other words this is the average day multiplied by the number of days. And in fact to be precise I can put a plus that is if 20 minus T i bar is less than 0; that means, T i bar is more no heating is required. So, 20 minus T i bar will be considered as 0 and, 20 minus T i bar is greater than 0 20 minus T i bar equal to 20 minus T i bar.

This is how we will get this. So, I have done this for 24 calculations came out with 533 D D degrees. So, this total turns out to be 31 by 24 into 412.7 which is about 533. Basically each term is suppose the first hour temperature is 1, this will be 19, the second hour temperature is 0.8, 19.2; third hour temperature is 0.6. So, this will be 19.4 then 0.4, 19.6 so on and so forth. You can do this very simple arithmetic and that the total turns out to be 412.7 multiplied by 31 by 24 is 533, this is degree days degree c day.

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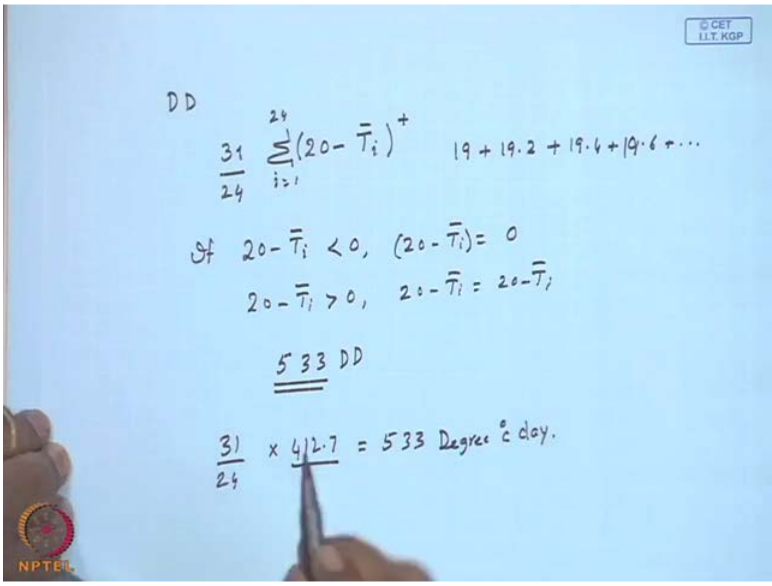

DD

$$\frac{31}{24}\sum_{i=1}^{24}(20-\bar{T}_i)^+ \qquad 19 + 19.2 + 19.4 + 19.6 + \cdots$$

If $20-\bar{T}_i < 0$, $(20-\bar{T}_i) = 0$

$20-\bar{T}_i > 0$, $20-\bar{T}_i = 20-\bar{T}_i$

$\underline{\underline{533}}$ DD

$$\frac{31}{24} \times \underline{412.7} = 533 \text{ Degree °c day.}$$

Now, I was suggesting a simpler method that is simply degree days or approximately, now 20 is the comfort condition minus 2.8, the monthly average temperature which is multiplied by 31 equal to 533. So, this is the T a bar. Now, both are identical, this came somewhat as surprise even to me because after making number of calculations I am aware, if your if T a bar is less than 15 degrees c or so right. Then this approximate 20 minus T a bar into 31 works satisfactorily, but still if it is 10, 11 it will definitely work. Now, if you look at it these 20 minus T i bars for our data, nowhere 20 minus T i bar is less than 0, all temperatures are less than 20. So, the contribution is there for every hour.

So, whether you averaged out in substitute or multiplied by 31 or take the summation of each day you will get identical result.

So, and this is correct still there is an approximation, because this is based upon T i bars and not T i of each day, but nevertheless considering the highest temperature to be 7.6 averaged the chances are it may not exceed 20 at any time in the 31 days for that particular month. So, this is how you can generate the data only you should remember that if 20 minus T a bar plus should be taken care of.

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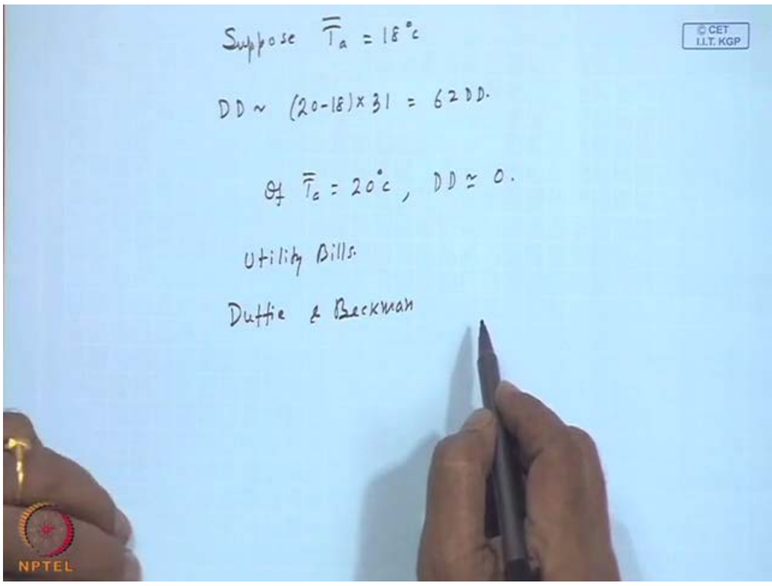

Suppose $\bar{T}_a = 18^\circ c$

$DD \sim (20-18) \times 31 = 62\,DD.$

If $\bar{T}_a = 20^\circ c$, $DD \simeq 0.$

Utility Bills.

Duffie & Beckman

Just to illustrate that point and make home the point, suppose T a bar is 18 pretty close to 20. So, D D approximate according to the formula I was suggesting 20 minus 18 times 31, which is 62 DD. Now, this may be right, but there may be exactly how many days are less than 18 and how many days are more than 20 that more than 20 does not contribute in this though it contributes in the average to become higher. So, there will be an error the when it is T a bar 18 degrees pretty close to 20 degrees, chances are there will be certain days above 20 degree centigrade which do not contribute in the degree days or though un necessarily they have raised rather they have raised not un necessarily the ambient temperature.

Similarly, if you go hour to hour there will be even much more swing or even more variation. So, as this T a bar goes closer to 18 degrees the error will be much larger, and the case and point could be if T a bar equal to 20 degree c, my D D approximate is 0, which definitely is incorrect because 20 degree c, there will be days with less than 20 c which require some heating. And there will be hours even much lesser than that days average temperature which requires some of heating. Of course, if you average it out what it means is at the cold when the temperature is less than 20 is to be compensated by heat, when the temperature is more than 20 as a energy consideration it is right, but not for the human comfort.

So, degree days calculation the best thing is if you have the hour or data file one can compile it or depend upon the utility bills. So, if heating required, so much of kilo watt hours of energy and you paid, so much that much is the space heating load. So, what I wanted to demonstrate was basically you can calculate with the monthly average hourly data available reasonably well, and and it works if the ambient temperature even the daily average is less than 15 to 12 degrees and that you can see the data given in perhaps the text book by Duffie and Beckman, because that has got a large data base 240 locations or so and the latitudes are much higher than the latitudes in India in the northern America, and there the ambient temperatures are much lower. So, you will have I mean good number of degree days of heating requirement, and hence you can check the formula and approximate formulae; that is about the degree days.

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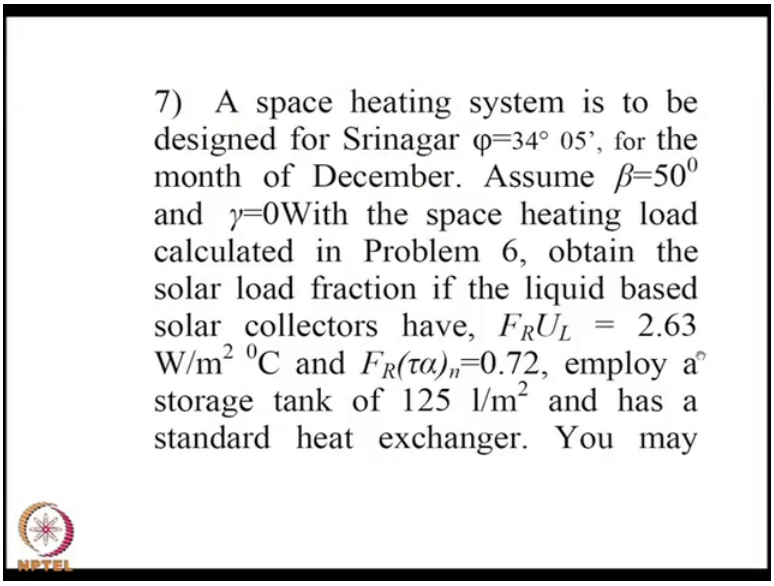

7) A space heating system is to be designed for Srinagar φ=34° 05', for the month of December. Assume $\beta=50^0$ and $\gamma=0$With the space heating load calculated in Problem 6, obtain the solar load fraction if the liquid based solar collectors have, $F_R U_L = 2.63$ W/m^2 ^{0}C and $F_R(\tau\alpha)_n=0.72$, employ a storage tank of 125 l/m^2 and has a standard heat exchanger. You may

So, this is a good data I could pickup. So, this demonstrate that and you can just calculate and find the difference for each month of an of the six locations or so the data for which it is given right, and you search for yourself that this calculations are good and where the calculations failed.

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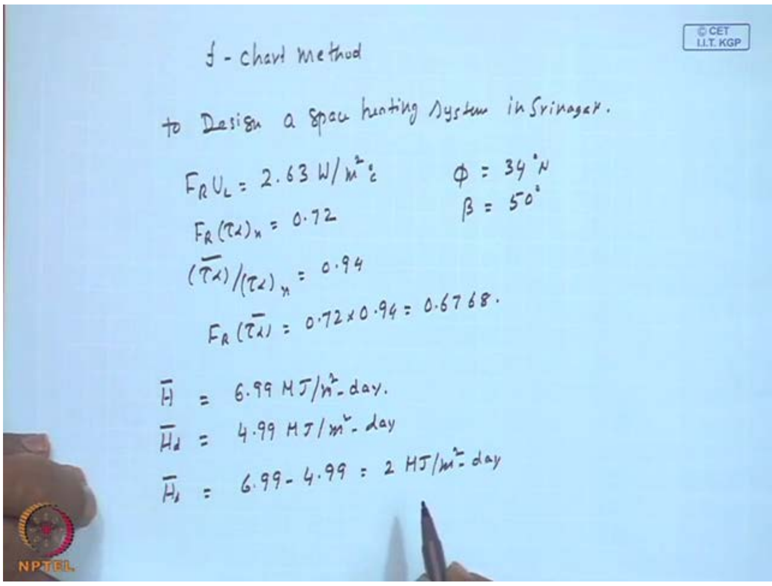

f - chart method

to Design a space heating system in Srinagar.

$F_R U_L = 2.63\ W/m^2\,{}^\circ C$ $\phi = 34^\circ N$

$F_R(\tau\alpha)_n = 0.72$ $\beta = 50^\circ$

$(\overline{\tau\alpha})/(\tau\alpha)_n = 0.94$

$F_R(\overline{\tau\alpha}) = 0.72 \times 0.94 = 0.6768.$

$\bar{H} = 6.99\ MJ/m^2\text{-day.}$

$\bar{H}_d = 4.99\ MJ/m^2\text{-day}$

$\bar{H}_b = 6.99 - 4.99 = 2\ MJ/m^2\text{-day}$

Now, let us use f chart method to design a space heating system in Srinagar, which may use the same collector parameters, F R U L is equal to 2.63 watts per meter square degree c, and then F R tau alpha normal is 0.72 and you have got tau alpha bar by tau alpha normal 0.94, which we have calculated I makes small difference because the latitude phi is 34 beta we will chose for winter something like 50 degrees. So, F R tau alpha bar will be 0.72 into 0.94 equal to 0.6768, H bar from the data file is 6.99 mega joules per meter square day, and then fortunately H d bar also is available in the data file 4.99 mega joules per meter square day.

So, this means your H b direct radiation is 6.99 minus 4.99, which is equal to 2 mega joules per meter square day; that means, the diffused fraction is almost 5 by 7 or it is about 0.7. So, it is a pretty low clearness index, that is what you have to check it up I think that is the data that is how it is.

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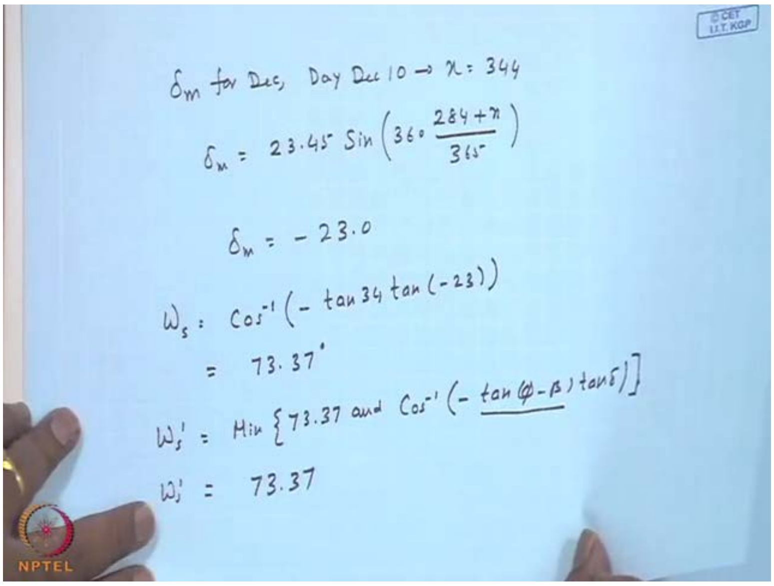

δ_m for Dec, Day Dec 10 → $n = 344$

$$\delta_m = 23.45 \sin\left(360 \cdot \frac{284+n}{365}\right)$$

$$\delta_m = -23.0$$

$$\omega_s = \cos^{-1}(-\tan 34 \tan(-23))$$

$$= 73.37^\circ$$

$$\omega_s' = \text{Min}\left\{73.37 \text{ and } \cos^{-1}(-\underline{\tan(\phi-\beta)}\tan\delta)\right]$$

$$\omega_s' = 73.37$$

And first thing we shall calculate the delta mean for December recommended day is December tenth, which corresponds to n is equal to 344. So, delta m is 23.45 sin 360 into 284 plus n by 365 this formula now you should have gotten by heart. So, this is a recommended value for December which will be equal to this 23 degrees. So, delta h bar is known, now we will calculate sunset hour angle omega s is cosine inverse minus tan 34 tan minus 23, which is equal to 73.37 degrees, omega s dashed is minimum of 73.37 and cos inverse minus tan 5 minus beta tan delta which is I do not even calculate we argued Indian northern hemisphere in winter months, omega s dashed will be limited to omega s 73.7. So, you can make out tan phi minus beta will be a smaller number with a negative thing and this being negative, it will become a larger number. So, omega s dashed will always be omega s in winter or delta negative months in the northern hemisphere.

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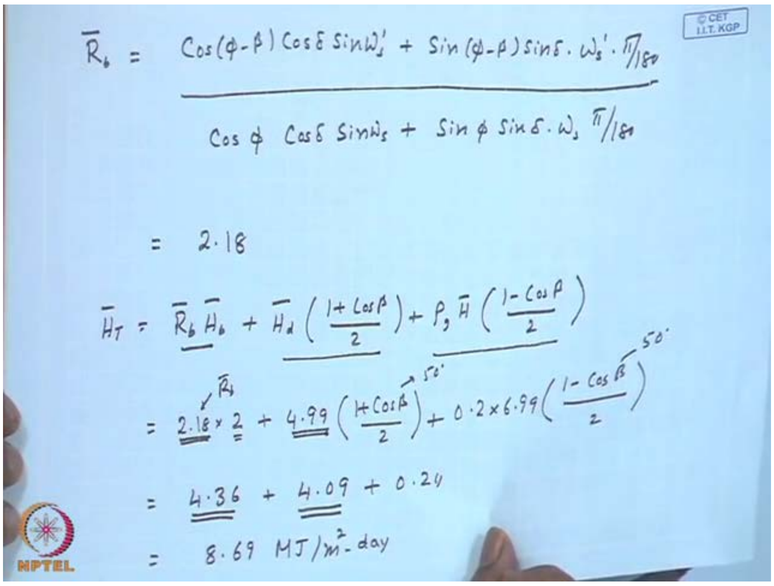

$$\bar{R}_b = \frac{\cos(\phi-\beta)\cos\delta\sin\omega_s' + \sin(\phi-\beta)\sin\delta\cdot\omega_s'\cdot\pi/180}{\cos\phi\cos\delta\sin\omega_s + \sin\phi\sin\delta\cdot\omega_s\,\pi/180}$$

$$= 2.18$$

$$\bar{H}_T = \underline{\bar{R}_b\bar{H}_b} + \underline{\bar{H}_d\left(\frac{1+\cos\beta}{2}\right)} + \underline{\rho_g\bar{H}\left(\frac{1-\cos\beta}{2}\right)}$$

$$= \overset{\bar{R}_b}{\underline{2.18}}\times\underline{2} + \underline{4.99}\left(\frac{1+\cos\overset{50^\circ}{\beta}}{2}\right) + 0.2\times6.99\left(\frac{1-\cos\overset{50^\circ}{\beta}}{2}\right)$$

$$= \underline{4.36} + \underline{4.09} + 0.24$$

$$= 8.69\ \mathrm{MJ/m^2\text{-}day}$$

So, first step is to calculate the solar radiation on the collector surface we need R b bar which is again cos phi minus beta cos delta sine omega s dashed plus sine phi minus beta sine delta into omega s dashed into the conversion factor pi by 180 upon cosine beta z which is cos phi cos delta sine omega s plus sine phi sine delta omega s pi by 180. At some places it is written as 2 pi by 360 and at other places it written as pi by 180 by me as well as in books. So, do not worry pi by 180 is exactly the same as 2 pi by 360.

This will be 2.18, if you want the numbers that you can easily calculate. So, this R b bar is a good value that is a winter, and we have optimized sort of the winter orientation and now we will calculate H t bar should be equal to R b bar H b bar plus H d bar into 1 plus cos beta by 2 plus rho g h bar into1 minus cos beta by 2, this is a formula which we are familiar the total radiation on the tilted collector surface consists of the beam component, consists of the sky diffuse component, and the ground reflected component. So, this will be R b bar is 2.18 into H b bar is 2 plus 4.99 into 1 plus cos beta by 2 plus rho g I shall use 0.2 times H bar is 6.99 into 1 minus cos beta which is 50 of course by 2.

So, this is 50 degrees this is 50 degrees. So, these components are 4.36, I am doing this just to bring out something interesting 409 plus 0.24 which is 8.69 mega joules per meter square day. If you see the diffused components contribution is as much as the direct radiation contribution, though actually diffuse direct radiation is rather low diffuse radiation is rather high, but you have got a a large R b bar in winter months.

This also shows the efficacy or rather expected utility of a flat plate collector that it accepts the diffuse radiation, and if you look at it, it is almost a 50 50 percent contribution in this H d bar for flat plate collectors. This is a winter month the diffused fraction is high, diffuse radiation relative to the global radiation is almost 70 percent, 65 percent, but still the solar radiation on the collector is 8.69 mega joules per meter square day. So, we shall stop here from where we have to calculate the f chart a variables, then find out what is the solar load fraction met by the a system. And various variants with standard storage, non standard storage, air system; these are the things we shall consider in the next class.

Thank you.