Solar Energy Engineering and Technology
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Lecture - 30
Solar Pond

Dear students, today we will be discussing about Solar Pond. Basically, we will study Salt Gradient Solar Pond.

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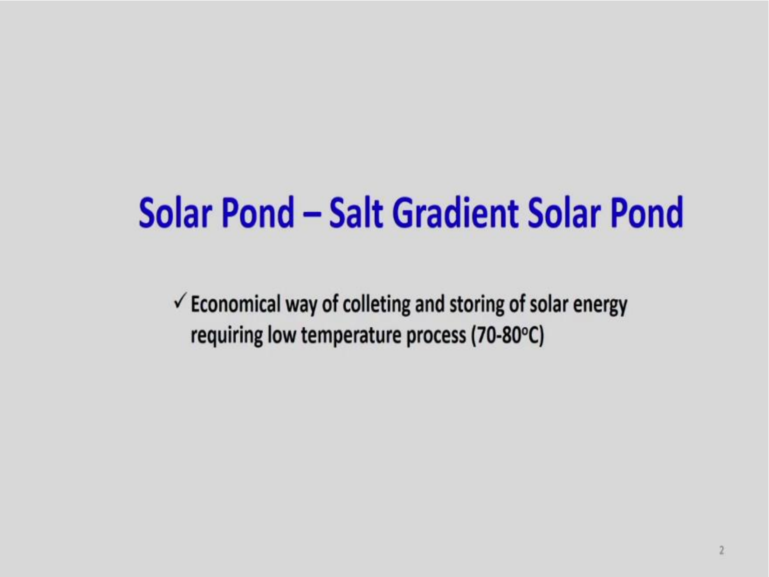

This Salt Gradient solar pond is an economical way of collecting and storing of solar energy requiring low-temperature process, and it can provide process heat at a temperature of 70 to 80 ^{o}C in an average. So, first let us learn what is solar pond?

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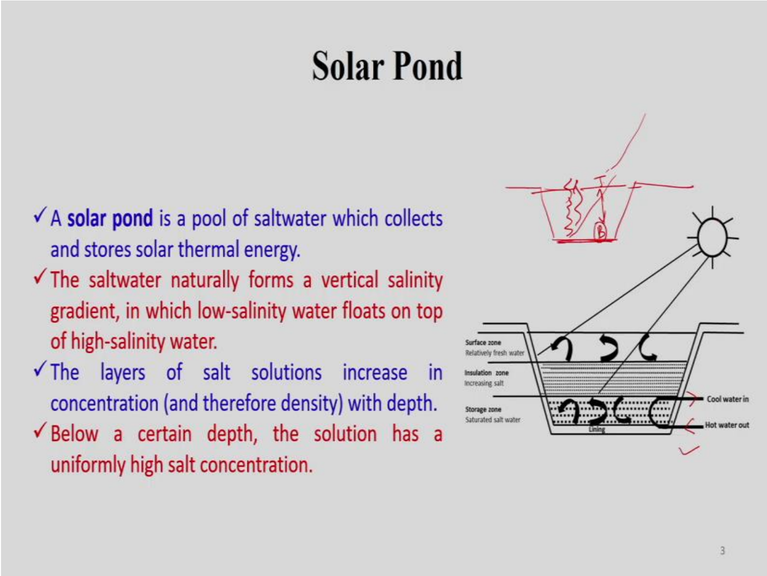

A solar pond is a pool of saltwater which collects and stores solar thermal energy. The saltwater naturally forms a vertical salinity gradient, in which low salinity water floats on top of high salinity water. The layers of salt solutions increases in concentration with depth. Below a certain depth, the solution has a uniformly high salt concentration. So pictorially, it can be represented something like this. Here, solar radiation is receiving and it transmits through these layers and receives at the bottom and it is retained, because this salt gradient is maintained.

So, what is the difference between these solar pond and normal pond? In case of normal pond what happens, this solar radiation received from the sun, and then, as soon as it receives at the bottom, so what happens, a convection or convective current is generated. Because of that, this temperature difference between this top layer and this bottom layer is very, very less.

Here in this case, what happens, salt is applied to reduce this convective current, so that the amount of heat which is retained at the bottom or received at the bottom can be retained for other applications. So, this is nothing but solar energy collection and storage. Once we can heat or we can have high temperature here, we can collect it for applications required for a particular process.

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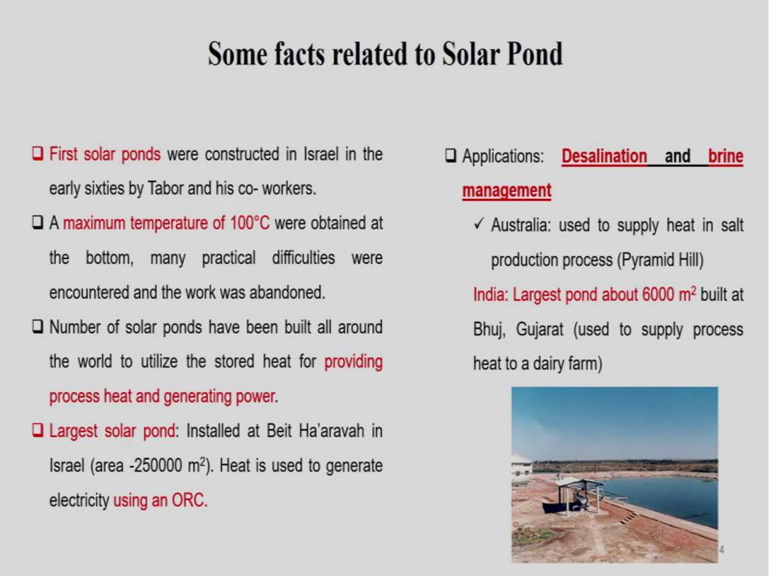

So, let us discuss some of the facts related to solar pond. The first solar ponds were constructed in Israel in the early 60s by Tabor and his co-workers. A maximum temperature of 100 ^oC were obtained at the bottom. Many practical difficulties were encountered and the work was abandoned. The number of solar ponds have been built all around the world to utilize the stored heat for providing process heat and generating power.

The largest solar pond was installed at Israel and its covers an area of about 250000 m^2. That heat, what is generated there, is used to generate electricity by using an Organic Rankine Cycle. Mostly what you can see in this applications, these applications are restricted to desalinations and brine management. In Australia, they use this kind of system to supply heat in salt production process in a place called Pyramid Hill.

In India, we have a solar pond at Bhuj, Gujrat. And its covers an area of 6000 m^2. And this is used to supply process heat to a dairy farm. So, this a photograph of the plant which is installed at Gujrat.

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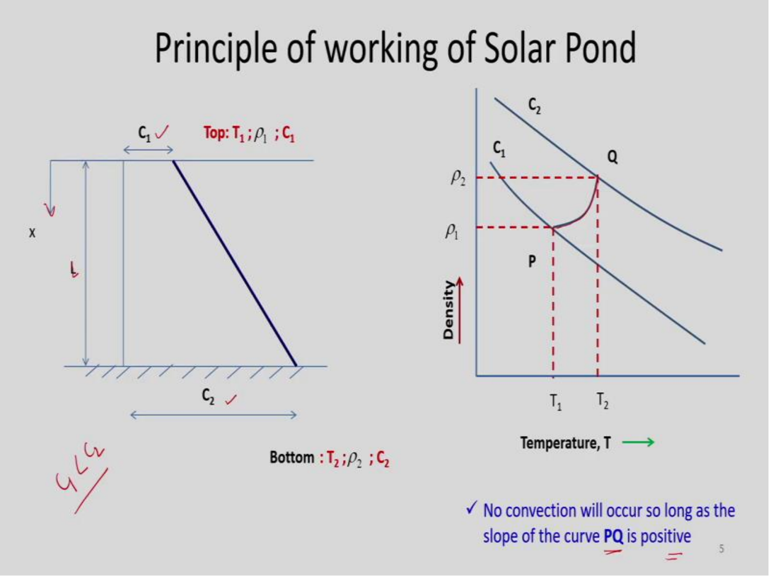

Now, let us learn the working principle of solar pond. How does a solar pond works? So here, what is shown, let us consider a pond of depth L, so it is going towards x direction and this the depth of the pond L. And let us consider, the concentration of the top layer is C_1 and concentration on the bottom layer is C_2. So, there is a concentration gradient. So, $C_1 < C_2$, concentration of brine.

Now, if I am interested to see the variation of density and temperature at this concentrations, how it will look like? So, it will be something like this. So, this vertical axis shows the density and then horizontal axis shows the temperature variation. So, if we consider this C_1 is the concentration for the top layer and C_2 is the concentration for the bottom layer. So, here ρ_1 and T_1 is the density and temperature at point P where this C_1 meets. And then ρ_2 and T_2 are the density and temperature at the bottom layer.

And there will be something like this kind of profile of variation of density with respect to temperature. So, we can have multiple points in between this top layer and bottom layer, and then we can find out, what will be the exact values of this density at particular temperature. So, what we can understood here, no convection will occur so long as the slope of the curve PQ is positive. So, if this curve is positive, so convection will not occur. So, there will be a concentration gradient, so which is required for a solar pond.

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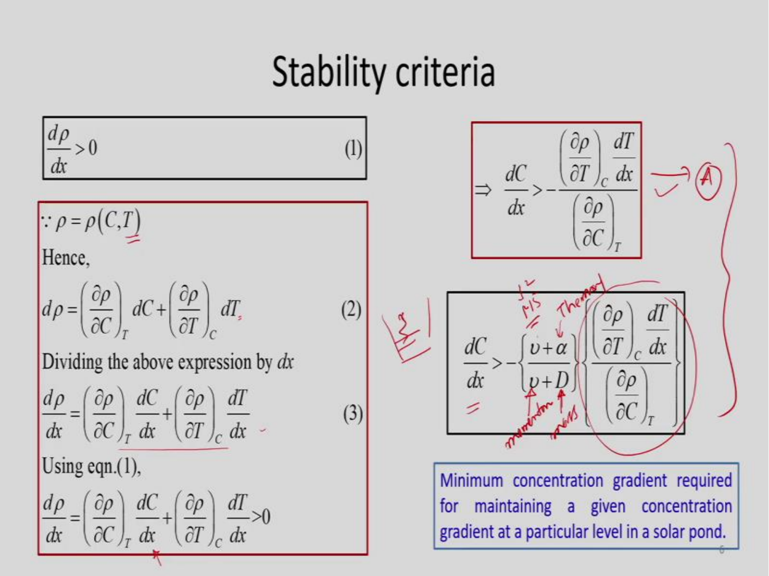

Now, mathematically, we can represent this $\frac{d\rho}{dx} > 0$; that means what, density at the bottom layer is always more than the just above layer. So, this ρ, density of the brine solution is a function of concentration and temperature. So, we can apply the total differentiation $d\rho = \left(\frac{\partial\rho}{\partial C}\right)_T dC + \left(\frac{\partial\rho}{\partial T}\right)_C dT$. Then if we divide the above expression by dx, so it will be something like this.

Now, if we apply the equation one, then $\frac{d\rho}{dx}$ is equal to this portion, which is greater than 0. Now, if I am interested to develop the expression in terms of $\frac{dC}{dx}$, the concentration gradient along the depth, then we can develop it, $\frac{d\rho}{dx}$ will be something like this. So, this equation may be A, I can write here.

Or in a very involved way, if we consider the momentum diffusivity, then thermal diffusivity, and mass diffusivity, this is the mass diffusivity. Mass diffusion will be there, because if salt is there at the bottom, so salt is here and then mass diffusion will takes place. Because of that we need to consider this mass diffusivity D and this υ is momentum diffusivity and this α is thermal diffusivity. So, this is thermal, mass, and this is momentum, momentum diffusivity.

So, this value as per the experimental observation, it is found to be 1.15. So, $\frac{dC}{dx}$ > 1.15 times this expression, to be precise. Normally, this is also considered as 2. So, if we have to make a design, so some kind of margin we have to maintain. So, this expression, need to be multiplied by 2. Then what we can get, the $\frac{dC}{dx}$ stability criteria.

So, calculation of minimum concentration gradient required for maintaining a given concentration gradient at a particular level in a solar pond can be calculated by using either of this equations. So, this is very, very important. So, once this stability criteria is established, then it is found that things will work perfectly as designed.

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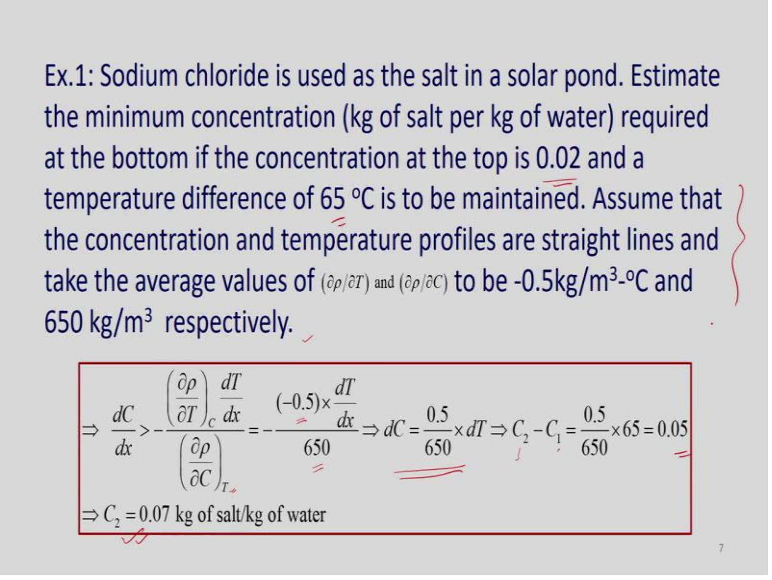

So, let us take an small example about this concentration to understand in more deeper sense. Like sodium chloride is used as a salt in a solar pond. Estimate the minimum concentration, that is, kg of salt per kg of water required at the bottom, if the concentration at the top is given as 0.02 and the temperature difference of 65 is given and that has to be maintained.

Assuming the concentration and temperature profiles are straight line and take the average value of $\left(\frac{\partial\rho}{\partial T}\right)_C$, and $\left(\frac{\partial\rho}{\partial C}\right)_T$ to be - 0.5 kg/m^3 ^{o}C , and 650 kg/m^3 respectively. Then we can calculate the minimum concentration. We know the stability criteria, something like this

$$\frac{dC}{dx} > -\frac{\left(\frac{\partial \rho}{\partial T}\right)_C \frac{dT}{dx}}{\left(\frac{\partial \rho}{\partial C}\right)_T}.$$

So, we can substitute the values given in the problem. So, this is $\frac{dC}{dx} = -\frac{(-0.5)\frac{dT}{dx}}{650}$ and then dC is something like this with simplification. And then (C_2 - C_1) is the concentration at the bottom part minus top. And then, we can have this expression, and finally, what we will get C_2 = 0.02 kg of salt per kg of water. So, this is how we can calculate the concentration gradient required for this kind of analysis.

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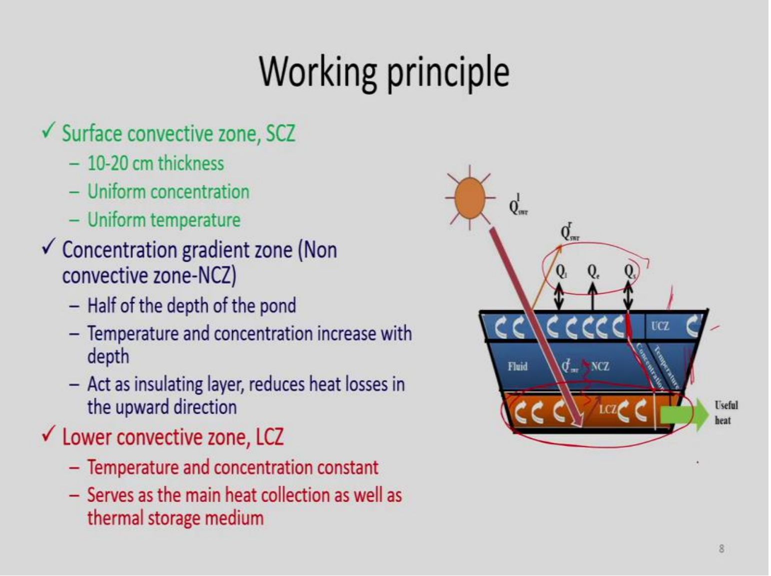

Now, let us learn the working principle. So here, as we understand now, in case of solar pond, there are three layers; upper layer is called upper convective zone or sometimes it is called surface convective zone, and middle layer is a non-convective zone. The bottom layer is called lower convective zone, where this part is the storage anode connection and middle part is something like insulation, so that no convection current is generated, and most of the heat what is fallen here is lost to the environment.

These are the heat. Some kind of evaporation losses will be there and then heat interaction from the ambient is there. So, it is shown that the energy is falling from the sun and is received at the bottom. And then this convection current is resisted by this salt gradient.

So, let us learn one by one. This surface convective zone or upper convective zone is very, very less thick. So, each about 10 to 20 cm and concentration is uniform and temperature is also uniform. Because of that, we can have just a line here, so concentration and temperature is something like constant. And in the non-convective zone, half of the depth of the pond normally considered as this non-convective zone.

So if it is, total depth is 1 m, 0.5 m is for non-convective zone. And temperature and concentration increases with depth. So, this variation will be something like this. So, temperature and concentration will vary in this zone. And this zone act as insulating layer and reduces heat losses in the upward direction. Role of this zone is very, very crucial for successful operation of a salt gradient solar pond.

And the third zone is lower convective zone. This part is the lower convective zone, where temperature and concentration is constant. And this part is, serve as main heat collection as well as thermal storage medium. So, heat will be stored here and then from the here, heat has to be collected. By installing some kind of heat exchanger or maybe Organic Rankine Cycle, if electricity generation is the prime activity.

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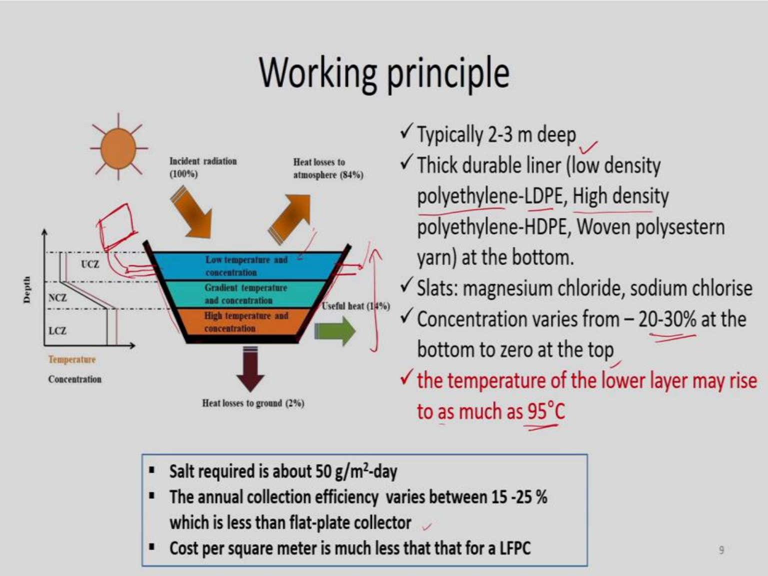

So, this is the pond. So, this the upper temperature and concentration. And what happens here, sometimes we need to provide fresh water here to maintain the salinity gradient. So, when we provide fresh water, along with this salt is also moves. Salt is also moves, and then in order to use this salt again, then we need to have a separate plant to evaporate the water present, and then we can separate salt and water, and then that salt can be used here again to maintain the salinity gradient.

So, this depth is typically 2 to 3 m and here, this black coloured things, what is shown, this is nothing but a thick durable liner, normally composed of low-density polyethylene or LDPE or high-density polyethylene HDPE or woven polyester yarn, which are attached at the bottom in order to reduce the heat losses. And the, the kind of salt used for this kind of arrangement is magnesium chloride or maybe sodium chloride. And this concentration varies from 20 to 30 % at the bottom to the 0, at the top. This concentration is to be maintained.

The temperature of the lower layer may rise to as high as 95 ^{o}C in summer. For winter, it is about 60 ^{o}C. And this salt requirement is about 50 g/m^2-day, which is really a significant amount if we consider for a yearly operation. So, that is why this evaporation of this water when freshwater is added and then reuse of the salt is very, very important.

The annual collection efficiency varies from 15 to 25 %, which is less than the flat plate collector. And cost per square meter is much less than the flat plate collector. So, this is a very, very economical way of collection and storage of thermal energy.

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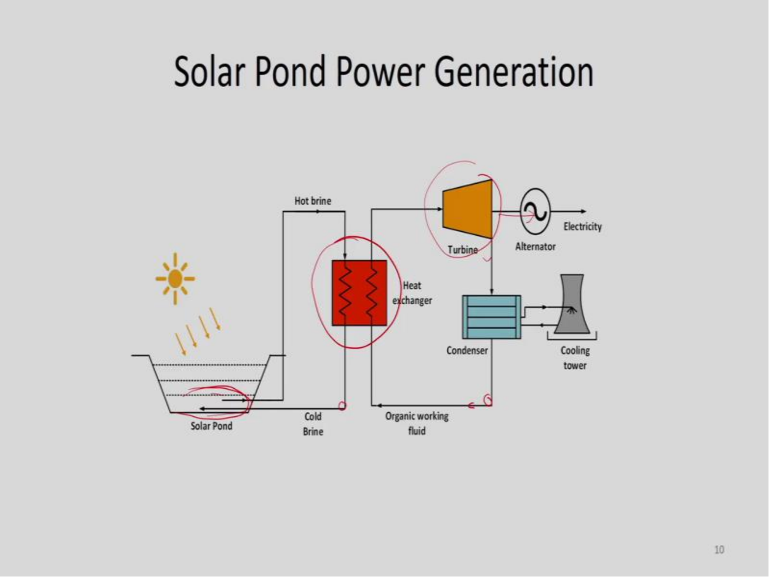

And this arrangement, what is shown here is use of solar pond for power generation. So, here what happens, collection and storage will be there and then we can circulate cold brine and then hot brine will move out and there will be heat exchanger. Heat will exchange from this hot brine to the organic fluid used in the secondary cycle. So, this may be ammonia.

So, this organic fluid takes the heat from the brine and it is evaporated and then it is expanded in the turbine and electricity can be generated. And this eject of this turbine is cooled by using a condenser, cooling tower assembly. And, of course, here we need a pump to circulate the fluid again and again in the closed-loop. So, this pumps, here also we need a pump. So, this figure shows the working of a solar pond for power generation application.

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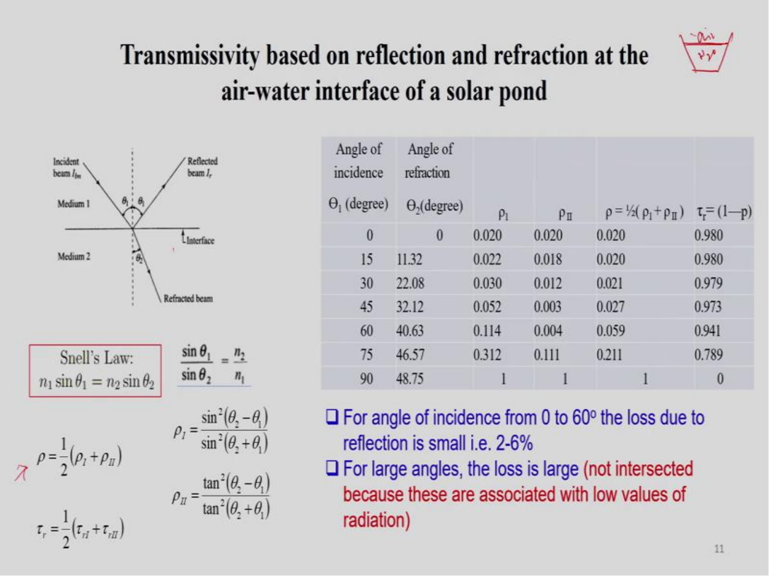

Now, let us analyze the performance of a salt gradient solar pond. So for that, we need to understand the transmissivity based on reflection and refraction at the air-water interface. Because we have air and water, this is the pond and we have air here and we have water here. So, this is the air-water interface. So, we need to know the transmissivity based on the reflect on reflection, and also transmissivity based on refraction.

Already, we have studied cases when there is air and glass in case of flat plate collector. So, what happens, the incident beam falls on this transparent cover, and then it is reflected, and it is refracted. So, we know the relationship between θ_1 and θ_2 by using the Snell's law. Same principle can be applied here. So, if we know the reflective indices of water with respect to air, which is nothing but 1.33.

So, if we know this 1.33, and θ_1 is known, then θ_2 can be calculated. So, same principle what we have followed for design of a flat plate collector can be applied here. And also, we know these two components of polarization. So, if we know this two components of polarization for reflection, so this is ρ can be calculated. And then, if we know ρ, then again, we can use the same methodology for calculation of τ_r. So, this is transmissivity based on reflection and refraction and this τ_{rI} and τ_{rII} are the two-component of polarization.

Now, here people have done lot of research and they have found these kind of observations. So, by varying these angles of incidence from 0 to 70, and then this θ_2 can be calculated because n_2/n_1 is known that is 1.33. So, if we do this this, so kind of data can be generated and we can get the values of τ_r at different incidence angle. So, as you can see, when incident angle is increases, so this τ_r is reduces. So, it is more significant if we go beyond 75, and at 90, it is almost 0. So, at higher angles, it is not encouraged.

For angles of incidence from 0 to 60, the loss due to reflection is small, that is 2 to 6%. For large angles, the loss is large. So, which is not interested because these are associated with low values of radiation.

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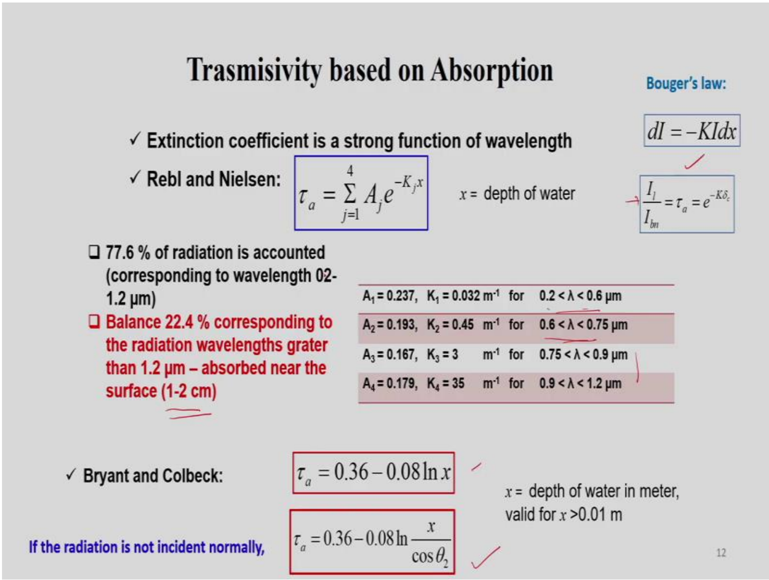

Now, let us analyze on transmissivity based on absorption. As we know, this expression Bouger's law, $dI \infty I\, dx$, and this K is the constant. This is known as extinction coefficient and we can have a solution of something like this. So, we can get the value of transmissivity based on the absorption by using this expression. But this cannot be used directly here because this K, extinction coefficient is a strong function of wavelength.

So, this wavelength has been considered by authors like Nielsen and Rebl, and they found this kind of correlations. $\tau_a = e^{-K_j x}$, x is nothing but the depth of the water. And this A_j values at different conditions were calculated, these are the fitting coefficients. And this A_1 is valid for this range of wavelength, and A_2 is valid for this range of wavelength. So, similarly, A_3 and A_4 are valid for a range of wavelength.

So, if we combine this A_1, A_2, A_3, A_4, and if we analyze critically, it is found that about 77.6 % of radiation is accounted corresponding to wavelength of 0.2 to 1.2. This is 0.2 to 1.2 μm. And this balance 22.4 % corresponds to the radiation wavelength greater than 1.2 μm, which is absorbed near the surface 1 to 2 cm from the surface.

Also, we can use this kind of correlation which is very, very simple, developed by Bryant and Colbeck. So, this is the expression where x is the depth of the water, which is in meter and this is valid for x has to be greater than 0.01 meter. And this expression is valid when solar radiation is falling normal to the horizontal surface.

So, if it is inclined, then we need to express the correlation something like this. It will be $x/\cos\theta_2$. So, we must know what is θ_2. So, these expressions need to be applied for calculation of transmissivity based on absorption.

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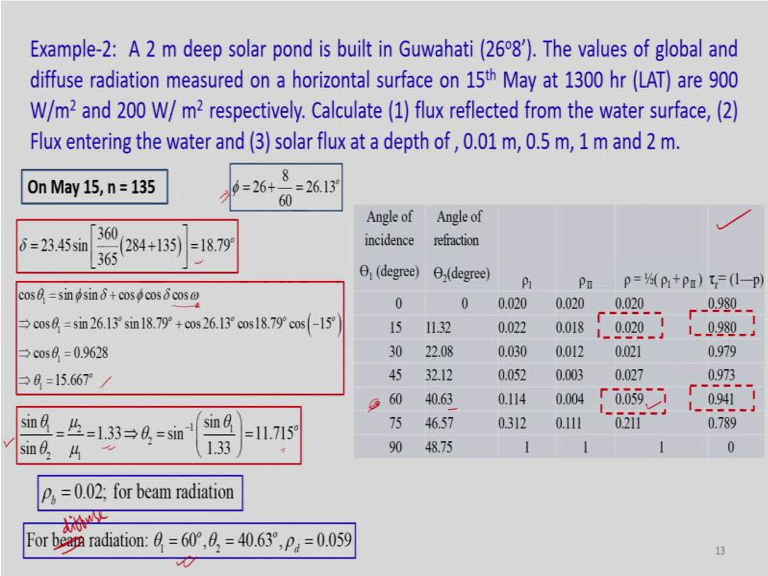

Now, let us take an example, it goes something like; a 2 m deep solar pond is built in Guwahati. Its latitude is given 26° 8′. The values of global and diffuse radiation measured on a horizontal surface on 15th May at 13:00 local apparent time or solar time are 900 W/m^2 and 200 W/m^2 respectively. Calculate number 1, flux reflected from the water surface; number 2, flux entering the water, and number 3, solar flux at a depth of 0.01, 0.5, 1, and 2 m.

So, on May 15th, n = 135, we can calculate it. And $\phi = (26 + 8/60)$, it will be degree now 26.13°. So, if we know n, then straightaway we can calculate, what will be the declination? So, δ can be calculated by using this expression. And now, next step, we need to calculate what is θ_1. So, this θ_1 is related with this expression and ϕ is already known, δ is known here. And ω, here it is 13:00 local apparent time, means -15.

So, we can substitute those values here and we can find out what is θ_1. So, θ_1 will be about 15.667°. So, once we know θ_1, then we can calculate what is θ_2, by using the equations. So,

$\frac{\sin\theta_1}{\sin\theta_2}=\frac{\mu_2}{\mu_1}$, so this is 1.33. So, θ_2 is about 11.715. So, we can use the chart to know this ρ_b for beam radiation and for diffuse radiation. This is for diffuse radiation, θ_1 = 60 we have considered, and θ_2 = 40.62, and ρ_d = 0.059. From where we got this? We got this from this table.

So, as you can see, this is 15. So, θ_1 is about 15.67, it is close to 15. And then θ_2 is about 11.71. So, it is very close by, so we can take a value of 0.020 for ρ. And for diffuse radiation, since we can consider, so when solar radiation is falling at an angle of 60^o, so that can be considered as diffuse radiation. That is why, this θ_1 is considered as 60. So, under that condition, θ_2 will be 40.63, and then we can get a value of ρ = 0.059. So, with these values, we can calculate the flux reflected from the water surface.

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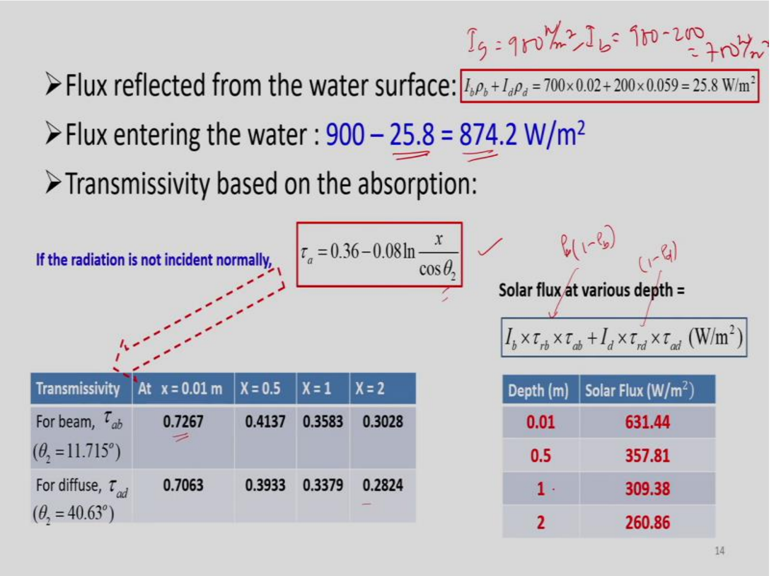

So, this is flux reflected from the water surface. So, how we can calculate? We know this ρ_b know and ρ_d, and I_b is known because I_g is given. I_g is given as 900 W/m^2, so what will be I_b? So, I_b = (900 – 200) because I_d is given as 200 W/m^2. So, it will be 700 W/m^2. So that way, we can get what is I_b. $I_b\rho_b + I_d\rho_d = 700\times0.2+200\times0.059 = 25.8 W/m^2$.

Now, this flux entered the water, that means this is reflected back. So, 900 is the amount of solar radiation, that is global radiation falling on the solar pond. So, (900-25.8), it will be 874.2 W/m^2, which is entering in the water. Now, we need to calculate the transmissivity based on the absorptions. So, we can use these equation, so which is known to us now. So, once we substitute the value of θ_2 and x for a particular case, so we can calculate what will be the reflectivity based on the absorption.

So we can, we can develop this chart and equations are known, so if we consider for beam radiation, it will be τ_{ab}. So, $\theta_2 = 11.715^o$ and if we do that calculation, it is found to be 0.7262. Then at x = 0.5, it is 0.4135; x = 1, it will be 0.3583; x = 2, it will be 0.3028.

Similarly, for diffuse radiation, this is τ_{ad} and $\theta_2 = 40.63$, because θ_2 is required here. And different values of x we can calculate what is τ_{ad}. So, these are the values we got for diffuse radiation. What is the next step? So, next step is to calculate the solar flux at various depth. So, what will be the solar flux at x = 0.01, x = 0.5, x = 1, and x = 2 m.

So, this the expression we can use and these values are known to us. So, τ_{rd}, how to calculate? Because ρ_b is known, then $\rho_b(1- \rho_b) = \tau_{rb}$. So similarly, $(1- \rho_d) = \tau_{rd}$. So that way, we can consider and we can calculate and it is found to be something like this. So at various depth, the solar flux received will be something like this. So, we can plot it, how this solar flux is varies at different depth.

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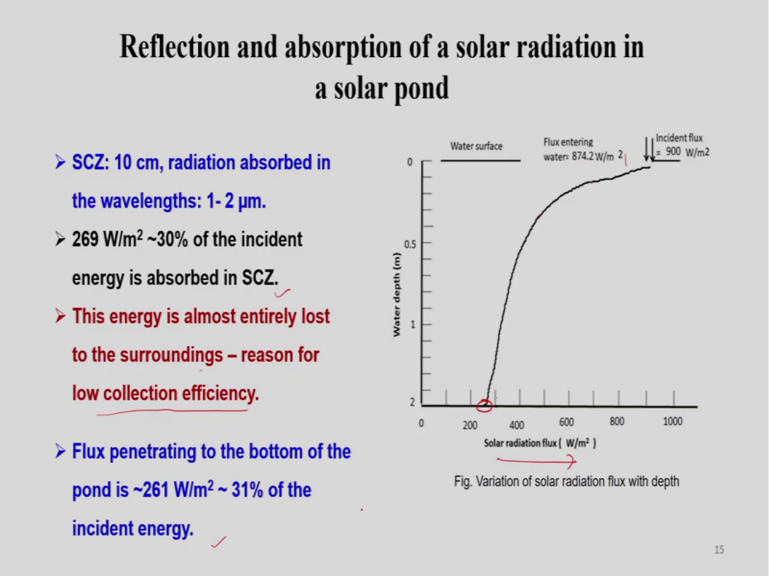

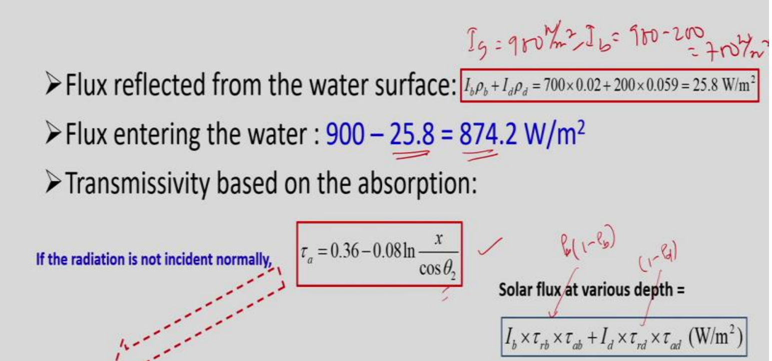

Transmissivity	At x = 0.01 m	X = 0.5	X = 1	X = 2
For beam, τ_{ab} ($\theta_2 = 11.715^{\circ}$)	0.7267	0.4137	0.3583	0.3028
For diffuse, τ_{ad} ($\theta_2 = 40.63^{\circ}$)	0.7063	0.3933	0.3379	0.2824

Depth (m)	Solar Flux (W/m2)
0.01	631.44
0.5	357.81
1	309.38
2	260.86

So if we plot it, so what kind of conclusion we can draw? So, we can develop this kind of plot. So, this is water depth is here, and then solar flux is in the horizontal axis. So, if we say 900 is, W/m^2 is the incident flux, and then after considering the reflection, it will be 874 W/m^2 is entering into the water. And then what happens? It reduces, and then finally, the amount of solar flux received is about 200 something. So, which is calculated in the last slide, so it is when it reaches about 260.86.

Now, if we see for this case, it is considered that the surface convective zone or upper convective zone is about 10 cm, and radiation absorbed in the wavelength is about 1 to 2 µm. And about 269 W/m^2 is 30 % of the incident energies absorbed in the solar convective zone. Since we have considered 10 cm, so that much of energy we can deduct from the amount of energy what is available. So, that much of energy is absorbed in the solar surface convective zone, and this energy is almost entirely lost to the surroundings and this is the reason for low collection efficiency.

So, this energy is almost entirely lost to the surroundings and this is the reason for low collection efficiency. And this flux, which is penetrating to the bottom of the pond is about 261 W/m^2, which is about 31 % of the incident energy. So that much of energy is utilized for generation of hot water or may be generation of electricity.

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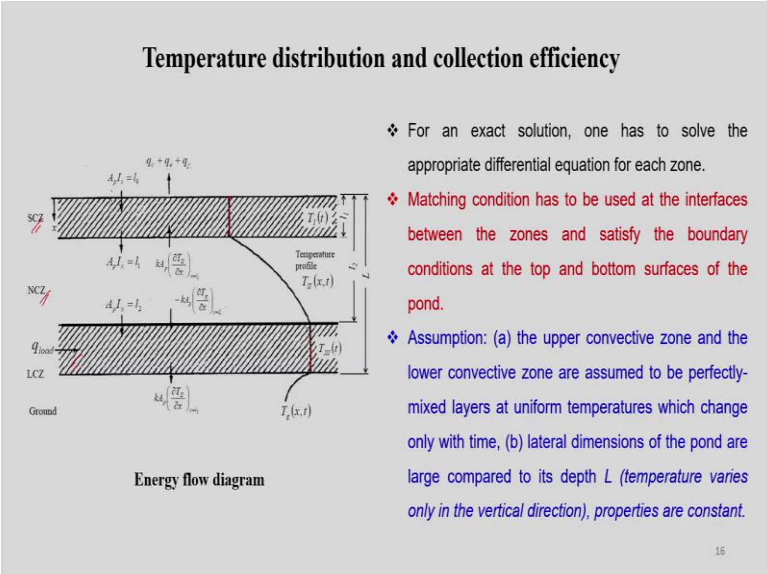

Now, we are interested about temperature distribution and collection efficiency. So, if we consider these layers, this is surface convective zone, non-convective zone, lower convective zone. As you know, this temperature and concentration is constant in this zone and then there is a variation of temperature and concentration in the non-convective zone. Again, it is constant in the lower convective zone or where collection and storage taking place.

So, this the profile and we if we represent this l_1 is the thickness of the surface convective zone and l_2 is the depth from the surface to the end of the non-convective zone, and L is the depth of the pond. So now, how to proceed for investigation of temperature distribution and collection efficiency?

So, for an exact solution, one has to solve the appropriate differential equation for each zone, and then matching condition has to be used at the interfaces between the zones and satisfy the boundary conditions at the top and bottom surface of the pond. And assumptions are something like, the upper convective zone and the lower convective zone are assumed to be perfectly mixed layer at uniform temperatures, which changes only with time. And second assumption is the lateral dimensions of the pond are large compared to the length. And this temperature varies only in the vertical direction and properties are constant.

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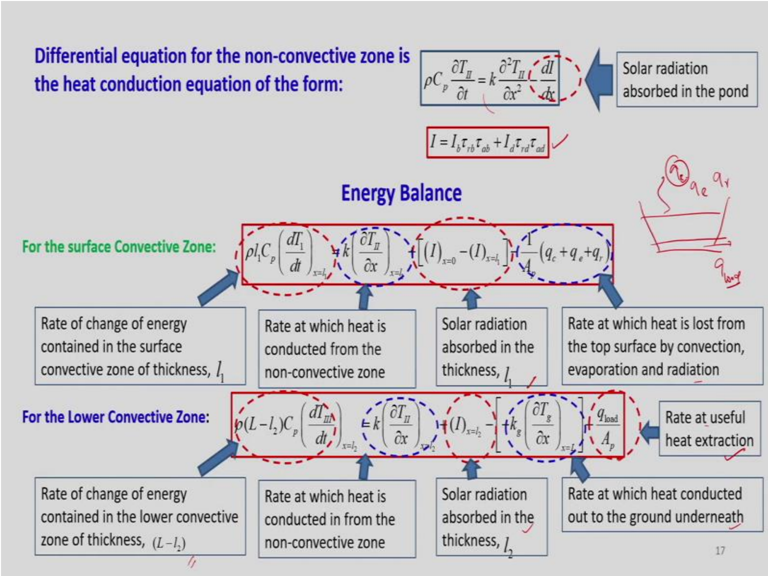

So, if we develop the differential equation for non-convective zone, it is represented something like this. So, this dI/dt is the solar radiation, which is absorbed in the pond. And this is the amount of energy which is stored, and this is the conductive heat transfer in the non-convective zone. And this I can be represented by using this expression, already this is done in the problem, what we have discussed.

Now, we are interested about energy balance for upper convective zone and lower convective zone. So, this is the expression for upper convective zone. So, this $\rho l_1 C_p \left(\frac{dT_1}{dt}\right)_{x=l_1}$, this represent the rate of change of energy contained in the surface convective zone of thickness l1. And this $K\left(\frac{\partial T}{\partial x}\right)$, is the rate at which heat is conducted from the non-convective zone. And this $[(I)_{x=0} - (I)_{x=l})]$, this is the solar radiation absorbed in the thickness l_1 and this part is the rate at which heat is lost from the top surface by convection, evaporation, and radiation.

So, from the top, if we draw this something like this, so from the top, we will have conduction losses, evaporation losses, and then radiation losses or conductive losses, this is convective losses, not conduction losses. Now, if I am interested for lower convective zone, so equation will be something like this. So, this part shows about rate of change of energy content in the lower convective zone of thickness ($L - l_2$) and this is the rate at which heat is conducted in from the non-convective zone.

So, this is the conduction part and this is the solar radiation absorbed in the thickness l_2 and this $K_g\left(\frac{\partial T_g}{\partial x}\right)$ is something like that at which heat conducted out of the ground underneath.

And q_{load}, so where, this in the lower convective zone, this load is like our utility. This q_{load}, this rate of useful heat extraction is represented by q_{load}/A_p. So, these are need to be studied critically to investigate the performance of a salt gradient solar pond.

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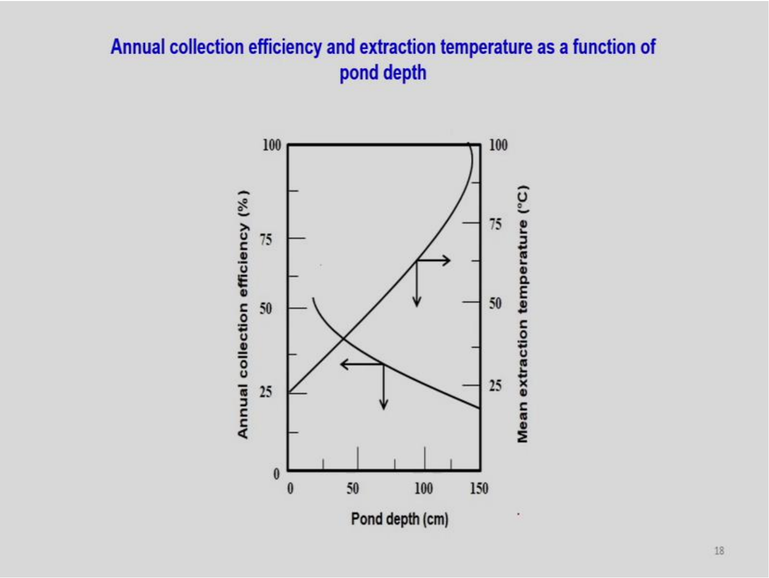

And also, we can develop the annual collection efficiency and extraction temperature, which is function of pond depth. So, this figure shows about the variation of annual collection efficiency with pond depth. So, this is something like this. So, as pond depth increases, annual collection efficiency actually increases and this mean extraction temperature is decreases with increase in pond depth.

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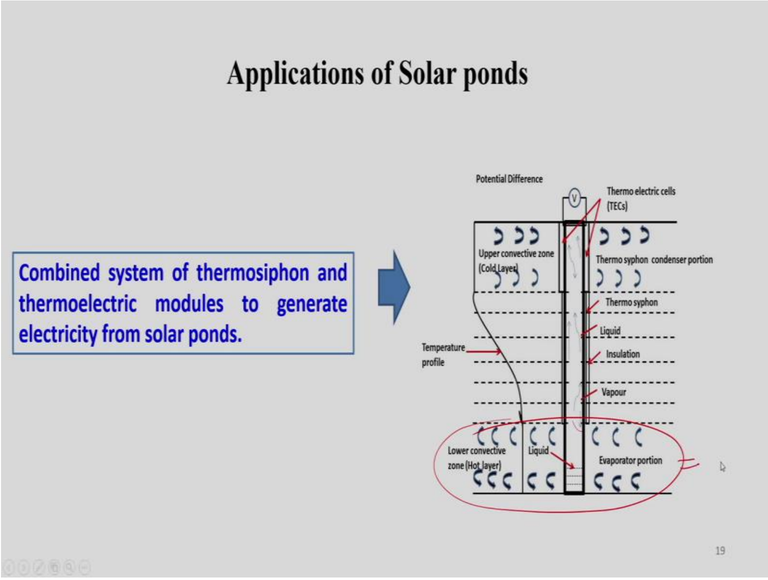

So, there are applications of solar ponds, like we can have combine system of thermosiphon and thermoelectric modules to generate electricity from solar ponds. So here, what happens, this is the thermoelectric part. This temperature difference is utilized to generate electricity and this is the collection and storage part, from useful heat gain can be extracted and applied as per the application.

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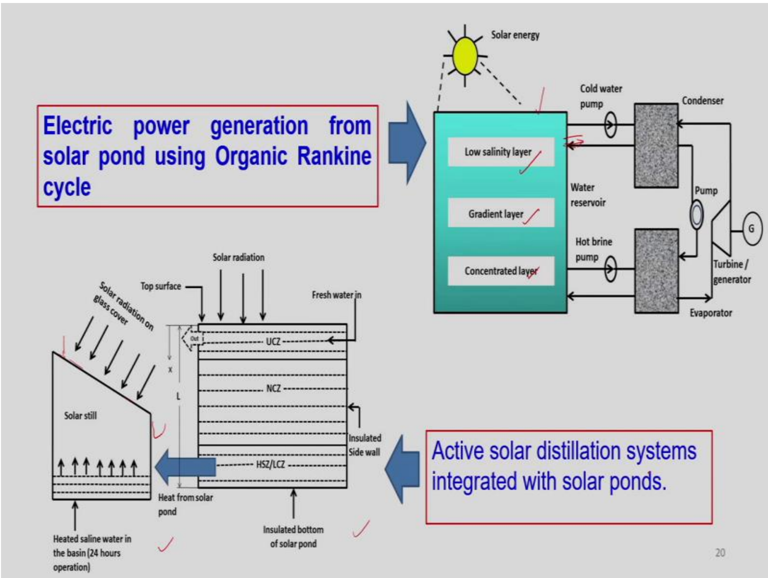

And here, what we can see is the electric power generation from solar pond using Organic Rankine Cycle. So, here is the low salinity layer, then gradient layer, then concentrated layer. What happens here, so sometimes, we have to apply freshwater and then when we have to take this saline water out and it contains saline or, say, salt and that has to be separated and that can be again applied in the other layers to maintain the salinity gradient. And the amount of heat what is collected from this lower convective zone, that is used for generation of electricity by using Organic Rankine Cycle.

And this one of the applications which is used for generation of distilled water. So, this is the solar pond and hot water is supplied to this solar still and here, what happens, evaporation and condensation takes place. First evaporation, because of this temperature difference, again condensation will be there and that can be collected. So, distillate can be collected by using this system and this is nothing but a active solar system integrated with a solar pond.

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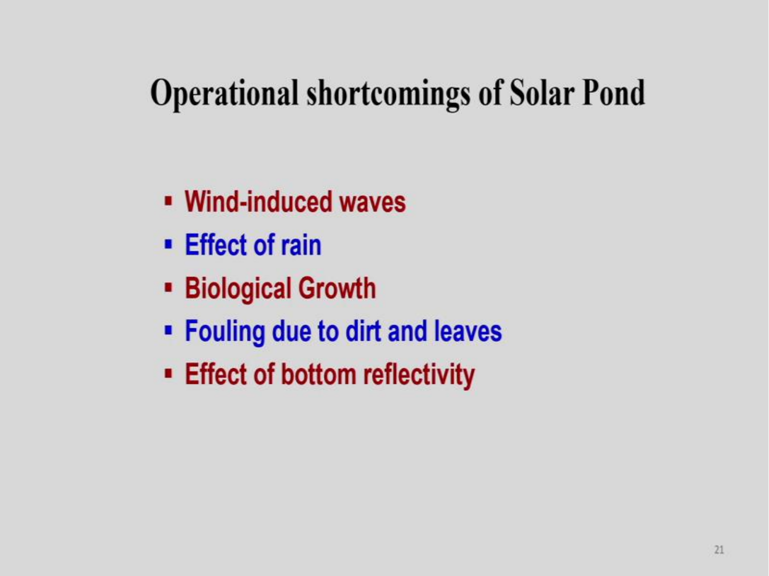

And there are some operational shortcoming of solar ponds like wind-induced waves. If wind is there, means there will be waves. So what will happen, there will be mixing of layers. So, if wind is very, very high, it is not good for the solar pond. And effect of rain is important. If mild rain is advantageous. If it is heavy rain, then it is not advantageous. So, dilution will takes place, because salt will, salt will be diffused from the bottom and then it will be diluted.

So, the concentration gradient will not exist. And then biological growth will be there. Sometimes, if it is a stagnant water, then biological growth, algae, will be developed. So, this needs to be cleaned periodically to increase the transmissivity. And fouling due to dirt and leaves, because leaves falls and it accumulates at the bottom and that reduces the efficiency of the solar pond. And effect of bottom reflectivity is also important and it reduce the reflectivity to increase the collection temperature.

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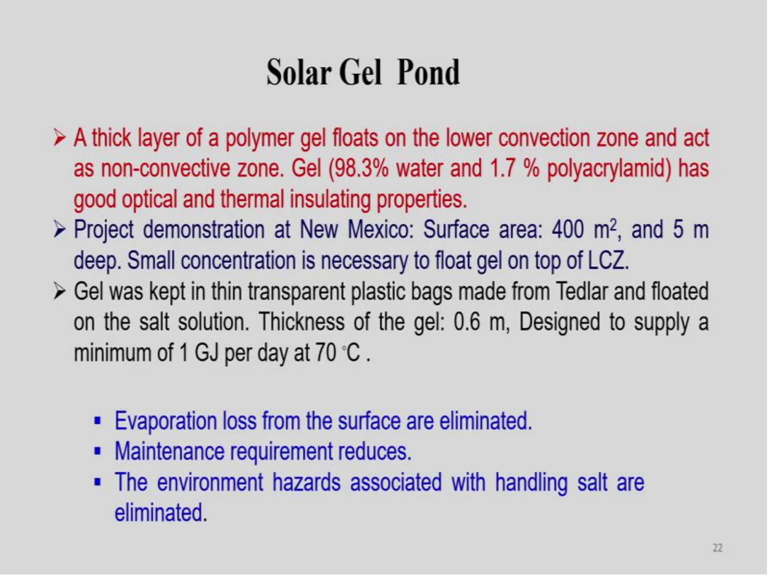

And there are another kind of solar pond called solar gel pond. And these gel pond, what happens, a thick layer of polymer gel floats on the lower convective zone and act as non-convective zone. This gel is nothing but 98.3% water and 1.7% polyacrylamide, has a very good optical and thermal insulating properties.

And this project demonstrated at New Mexico, where surface area considered about 400 m^2 and depth considered was 5 m and a small concentration is necessary to float the gel on the top of lower convective zone has been observed. The gel was kept in thin transparent plastic bags made from Tedlar and floated on the salt solution. The thickness of the gel is about 0.6 m and is designed to supply a minimum of 1 GJ heat per day at 70 ^oC.

So, if we compare this solar gel pond and salt gradient solar pond, so it is advantageous, because evaporation loss from the surface are eliminated, then maintenance requirement reduces and the environment hazards associated with handling salt are eliminated. So, these are the advantages of solar gel pond.

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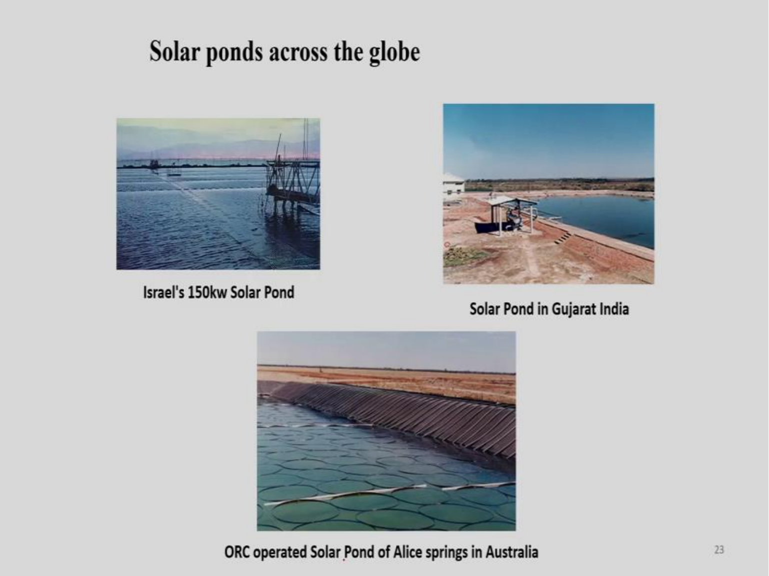

So, solar ponds across the globes, so these are some of the installations. Like solar pond installed at Israel, its capacity is 150 kW as shown here. And second figure is for solar pond in Gujrat in India, and third photograph is for ORC operated solar pond on Alice Springs in Australia.

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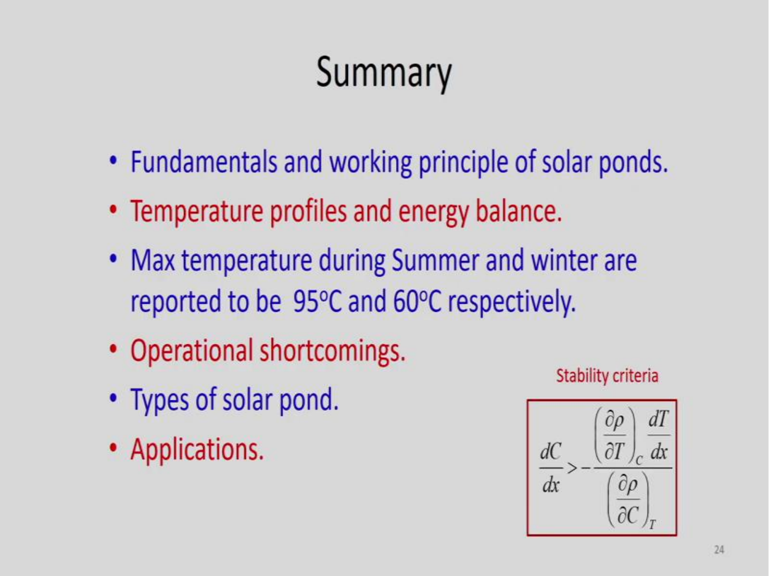

So now, we can summarize what we have discussed today. We have discussed fundamentals and working principles of solar ponds, which is very, very important, and economical way of collecting and storing solar thermal energy. And also, we have studied the temperature profiles and energy balance at different layers, because it composed of three layers, surface convective zone, then non-convective zone, and lower convective zone.

And maximum temperature during summer and winter are reported to be about 95 ^{o}C and 60 ^{o}C respectively in India. And we have also discussed some of the operational shortcomings and type of solar ponds and applications. On the top of it, we have studied the stability criteria, how to calculate the minimum concentration to operate a salt gradient solar pond. So, thank you very much for watching this video. Hope you have enjoyed this video.