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Lecture – 13
Thermal Energy Storage Systems, Part II

Good morning everyone, yesterday we had a lecture on thermal energy storage system in renewable energy engineering solar wind and biomass energy systems.

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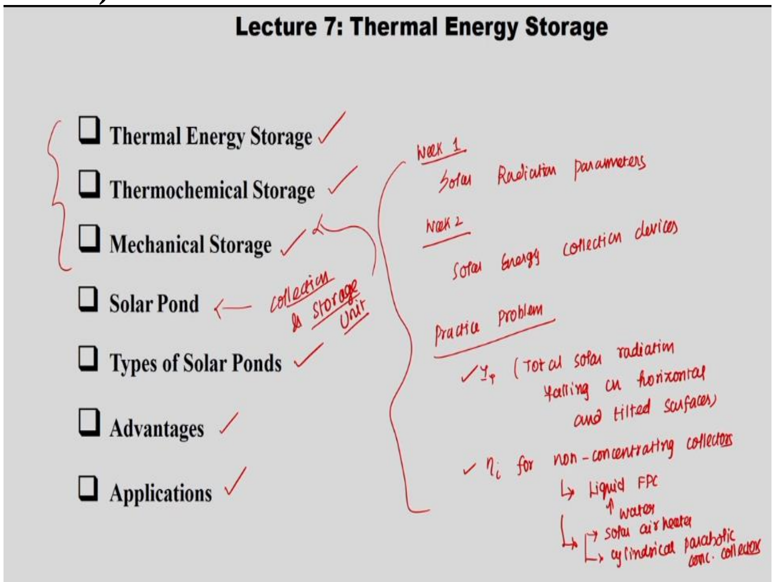

What we could cover is thermal energy storage, thermochemical energy storage and mechanical energy storage. So today we are going to discuss about the collection and storage which is nothing but solar pond and types of solar pond and advantages and applications.

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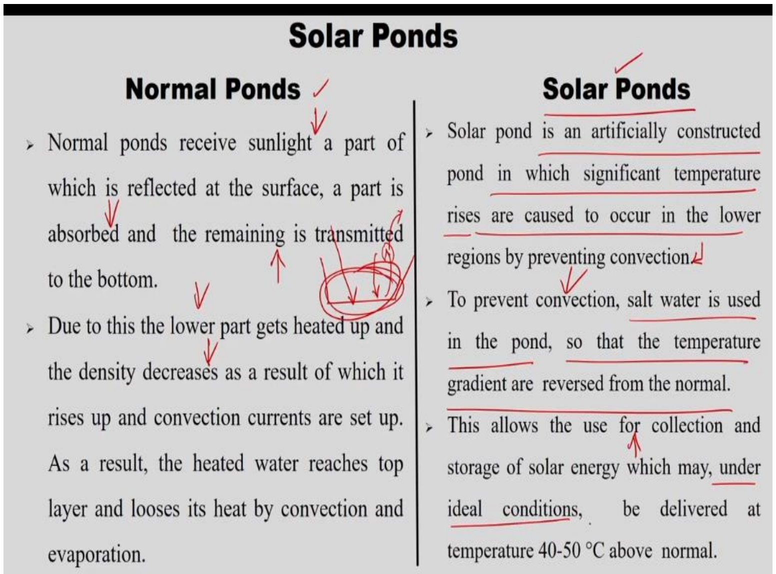

Solar ponds what is the difference between normal and solar ponds, in normal ponds we receive sunlight as a part of which is reflected at the surface and a part is observed and the remaining is transmitted to the bottom. So this is what we have seen in normal non-concentrating collector, so due to this the lower part gets heated up and the density decreases as a result the convection currents sets up in the pond, as a result the heated water reaches the top layer and loses its heat by convection and evaporation with the atmosphere.

In normal ponds when solar energy hits the bottom of the pond with 3 parts one is reflection and another one is by absorption and another one is by transmittance. So based on that whatever the energy collected at the bottom of the pond, it takes the heat and gets heated up because density is low for the heated water it tries to go above and further the cold water which is there in the upper part of the pond comes down. So this water further loses its energy with atmosphere by evaporation or by convection.

So here if you want to store this heat whatever you gained at the bottom of the pond there are certain technology which we need to do to trap the heat in the bottom of the pond. So that is nothing but a solar pond. Solar pond is nothing but an artificially constructed pond in which significant temperature rises or cost to occur in the lower regions by preventing convection. So what am I supposed to do? Because this energy is going waste to the atmosphere in terms of convection and evaporation.

Somehow I need to stop this convection in the bottom of the pond so that it would not reach the surface of the pond and looses its heat with the atmosphere. So to prevent this convection salt water is used in the pond so that temperature gradient or reverse to from the normal. So, if the density is high then the hot water remains in the bottom of the pond only. So that is where we reverse the thermal gradient and make the hot water to stay in the bottom of the pond only.

So this allows the use for collection and storage, so we can collect the solar energy in the bottom of the pond and by adding the salt water or salt into the bottom of the ponds we can stop the convection currents in the water and by and thereby convection and evaporation losses. So solar ponds under ideal conditions be delivered at the temperature of 40 to 50 degrees centigrade above normal.

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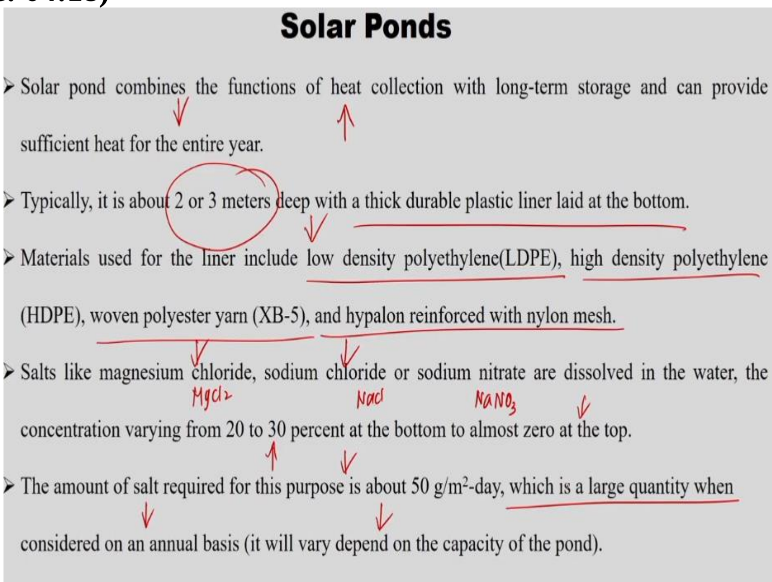

So solar ponds combine the functions of heat collection with the long-term storage and can provide the sufficient heat for the entire year. So typically they are of 2 to 3 meters deep with the thick durable plastic liner laid at the bottom materials used for liner include LDPE low density polyethylene and high density polyethylene HPDE, woven polyester yarn and Hypalon reinforced with nylon mesh and here are some of the material can be black coated as well to trap higher solar radiation.

And salts like magnesium chloride, sodium chloride, MgCl 2 and NaCl and NaNo 3 sodium nitrate are dissolved in the water and the concentration varying from 20 to 30% at the bottom to almost 0 at the top, the concentration at the top is very less concentration at the bottom is 20 to 30% the amount of salt required for this purposes about 50 grams per meter squared per day which is a large quantity when considered on an annual basis. It will vary depend on the capacity of the pond.

And also, since we are using salt, so the salt concentration of the water at the bottom of the solar pond is high we need to also think about when it is being used to for low temperature applications it has to pass through the pipes. So, there may be a corrosion problem as well but still based on the requirement and based on the storage system salt can be used.

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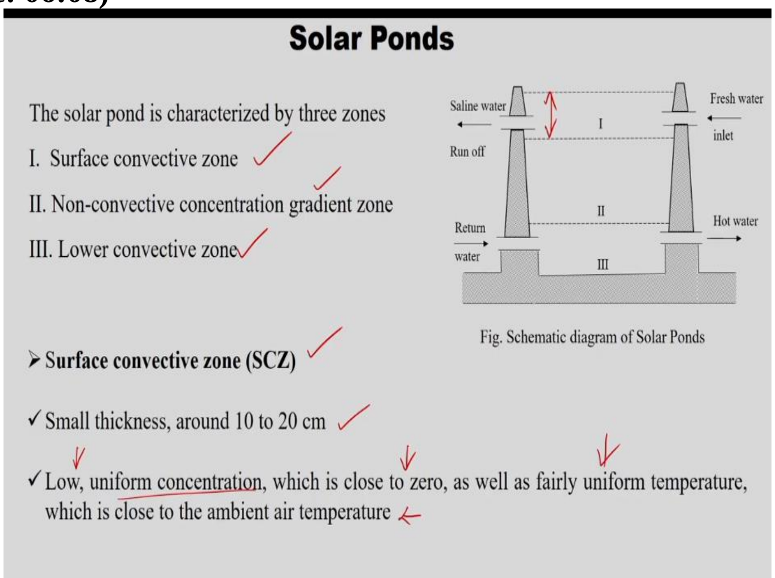

So, the solar pond normally has 3 zones surface convective zone, non-convective concentration gradient zone and lower convective zone. Surface convective zone is nothing but the topmost layer, this is soft small thickness around 10 to 20 centimeter here the concentration is slow and uniform concentration which is close to 0 and as well as fairly uniform temperature which is close to the ambient temperature then only there would not be any convection or evaporation losses. The temperature is almost ambient temperature the concentration is 0 concentrations around 0 concentrations.

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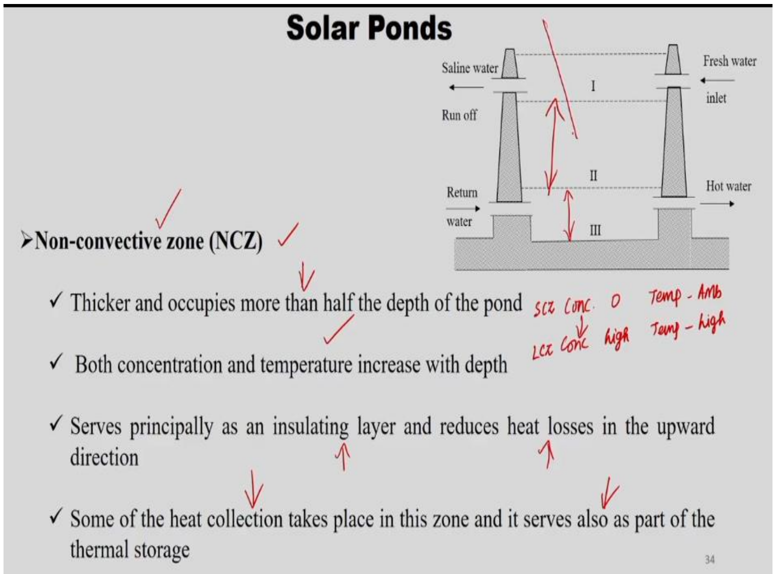

The non-convective zone here it is thicker and occupies more than half of the depth of the pond. So, here both concentration and temperature vary or increases with depth because we set concentration is 0 at the top layer to provide the conviction and concentration is high at the bottom layer this is top which is nothing but surface convective zone SCZ. So, this is last one is lower convective zone.

So, the temporary concentration increases here the temperature is ambient in the upper or SCZ set and the temperature is higher in the bottom lower convective zone. So, in the middle it increases with the depth it serves principally as an insulating layer and reduces the heat losses in the upward direction what we said if we if you did not have put the salt layer in the lower convective zone it starts the convection current starts. So basically, this non-convective zone accessory insulating layer.

Because of high concentration and high temperature in the lower convective zone so, some of the heat collection takes place in this zone as well and basically it serves also a sub part of thermal storage solar radiation enters through this layer, there is some collection also happens.

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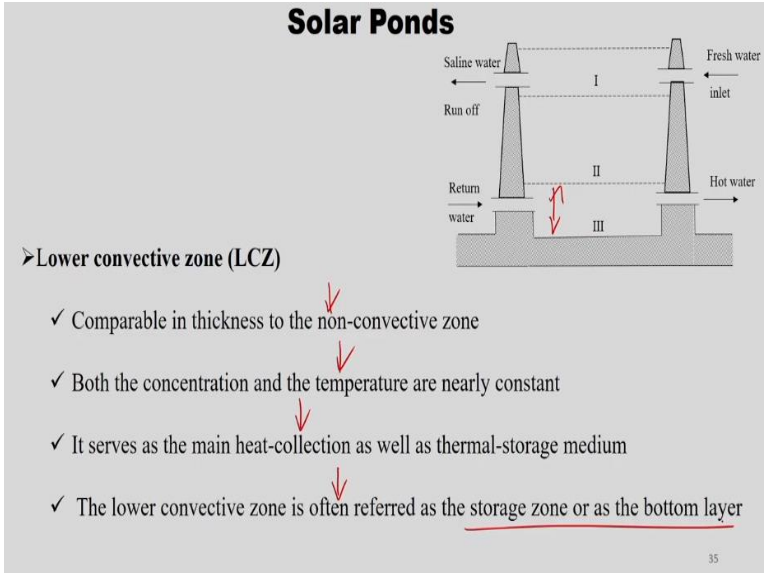

Lower convective zone is nothing but this zone comparable in thickness to the non-convective zone and both the concentration and temperature are nearly constant and high as well itself stuff mainly heat collection as well as the storage or thermal storage medium. The lower convection convective zone is often referred as the storage zone or the bottom layer of the solar pond.

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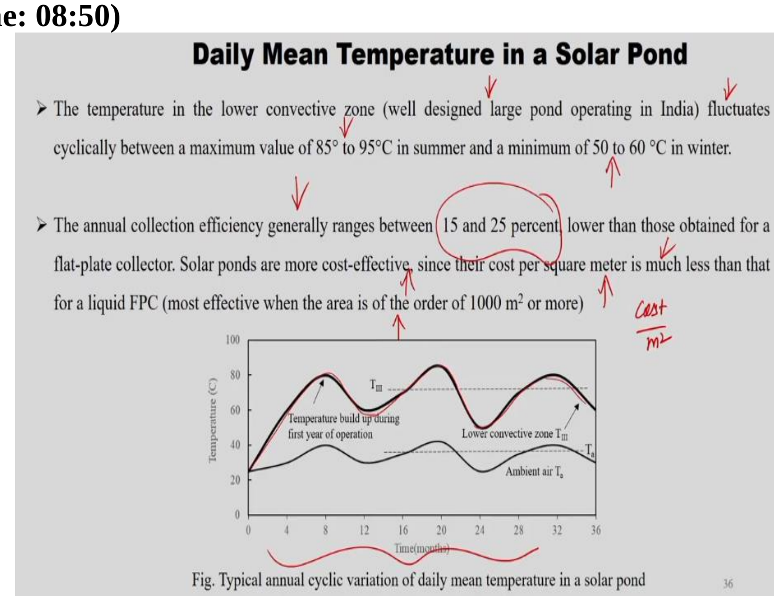

So, this is nothing but daily mean temperature in the solar pond, so if you see this is for almost 3 years it is taken. So here if you see it is almost a cyclic in nature with 1 or 2, months difference. The temperature in the lower convective zone if it is well designed well insulated and a large part operating in India. India in the sense like medium solar radiation happens throughout the year if the temperature in the lower convective zone fluctuates cyclically between a maximum of 85 to 95 degree in summer and a minimum of 50 to 60 degree in the winter.

The annual collection efficiency generally ranges between 15 to 25 percentage which is lower than the FPC. But still solar ponds are more cost effective and they are cost per square meter is much less than that of the liquid FPC collectors. So, this comparison would be more effective, if you have the large area of about 1000 meters squared or more.

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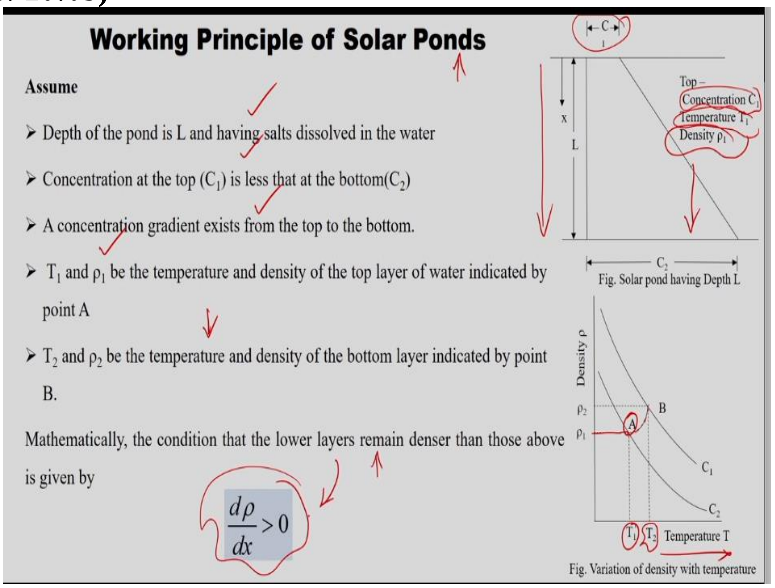

Working principle of solar ponds so, this is if you see this is the concentration this is the depth of the solar pond, which increases in the negative x direction. So, in the top concentration is C 1 temperature is T 1 and density is rho 1. So, this is obviously high in lower zone and if you see that T 1 which is the less temperature the density is rho 1 for higher temperature you have density of rho 2 so this is the curve which connects both. Which is nothing but A B depth of the pond is L and having salts dissolved in the water.

The concentration at top is C 1 which is less than that at the bottom C 2 the concentration gradient exists from top to bottom T 1 rho 1 be the temperature and density of the top layer of the water indicated by A. So, there it is almost at the atmospheric temperature T 2 and rho 2 to be that temperature and density of the bottom layer indicated by point B. So, if you want to write this d dx of rho, rho should be greater than 0 the condition for a lower layer remain denser than those about if that condition is applicable then d dx of rho should be greater than 0.

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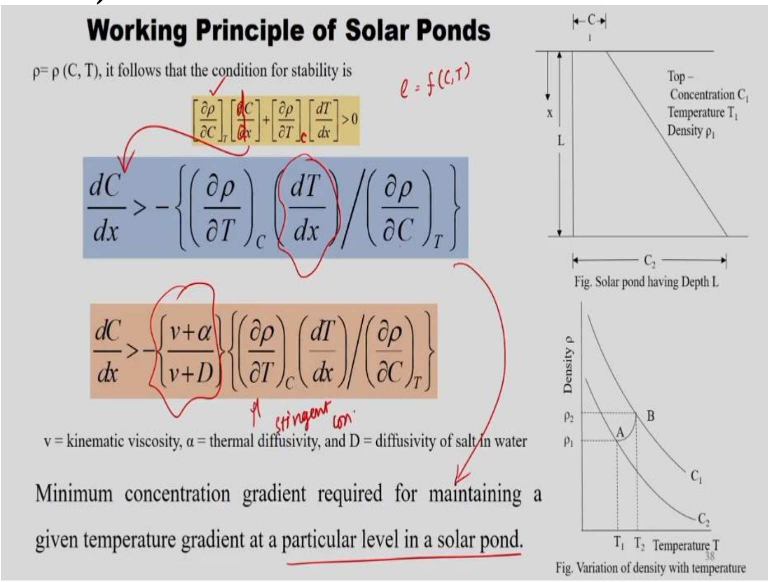

So, in this case, if you write rho as a function of C and T concentration and temperature or how do you write this is dou dou C of rho at a constant T into d dx of C + dou dou T of rho at constant concentration which is multiplied by d dx of T which is greater than 0. So, from this if you calculate dC dx which is greater than of minus of dou dou T rho at C into d dx of T upon dou dou C of rho at constant temperature.

So, this is nothing but minimum concentration required for maintaining a given temperature gradient which is nothing but dT dx at a particular level in a solar pond. So, this is here the kinematic viscosity and thermal diffusivity and diffusivity of salt water is also added to give more stringent condition. Anyway, you can use this particular equation to calculate minimum concentration gradient required for maintaining a given temperature gradient at a particular level in the solar pond.

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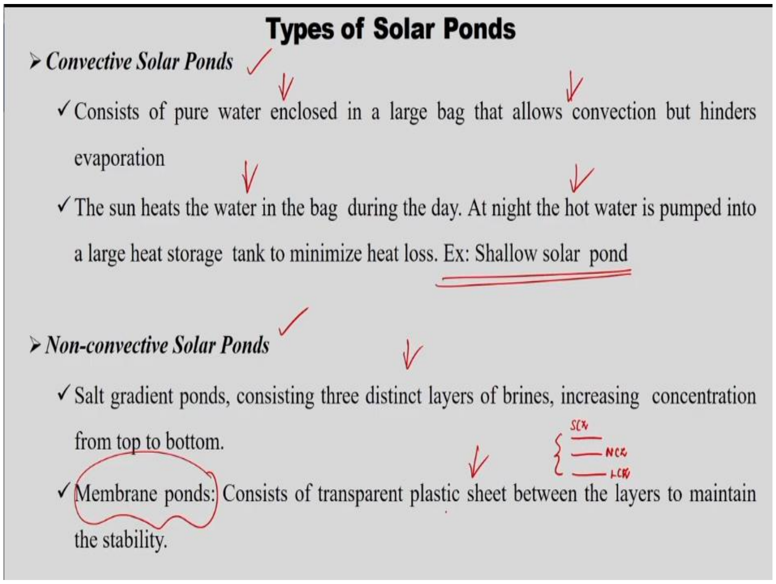

So, types of solar pond convective solar and non-convective solar pond. Convective solar pond we do not make any special effort here the it consists of pure water enclosed in a large back that allows the convection but hinders the evaporation the sun heats the water in the back during a day at night hot water is pumped into large heat storage tanks to minimize the heat loss. So, this example is shallow solar pond so, here we did not stop the convection by adding salt water or anything.

So, normally we keep the large bag with the pure water after taking the heat during the day, it will be shifted to large heat storage tank to minimize the losses in a way it can be used to further energy requirement. Non-conductive solar pond is nothing but whatever we have seen just now, it consists of 3 distinct layers of brines increasing concentration from top to bottom. So, membrane points are also available here in membrane ponds we keep plastic sheet between the layers to maintain the stability.

Otherwise there would be interface layer for example, this is SCZ surface convective zone this is NCZ and then lower convective zone. So, this is based on the thermal stratification their layers become stable but still we cannot expect them to be stable because of the temperature gradient. So, for that purpose transparent plastic sheet between the layers are kept to maintain the stability.

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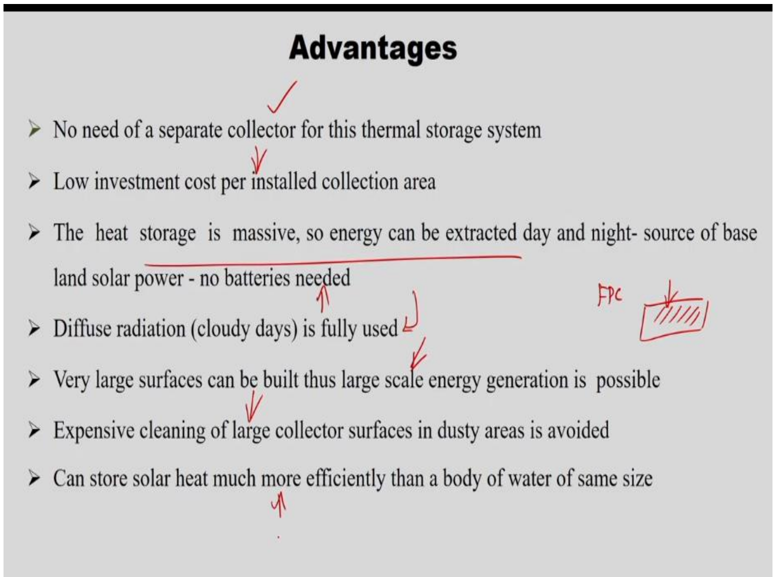

Advantages wise no need of separate collector for thermal storage, it can do both the operation collection as well as storage low investment cost per installed collection area the heat storage is massive. So, energy can be extracted day and night source of base land solar power, no batteries are needed for storage diffusive radiation is also fully used because it is an open area very large surfaces can be built thus large-scale energy generation is possible.

And expensive cleaning of large collector surfaces in dusty areas is avoided because if you are using FPC. So, the top one is glass cover if the gets accumulated, then you cannot expect the solar energy to be transmitted through the glass cover. But here also this dirt problem is there if the dirty materials or gets filled with the upper zone of the solar pond, then there also must be problem but comparatively compared with FPC, this may be lesser because you can clean the time to time but cleaning is easy here in the solar but then compared to FPC. It can store a solar heat much more effectively than a body of water of same size.

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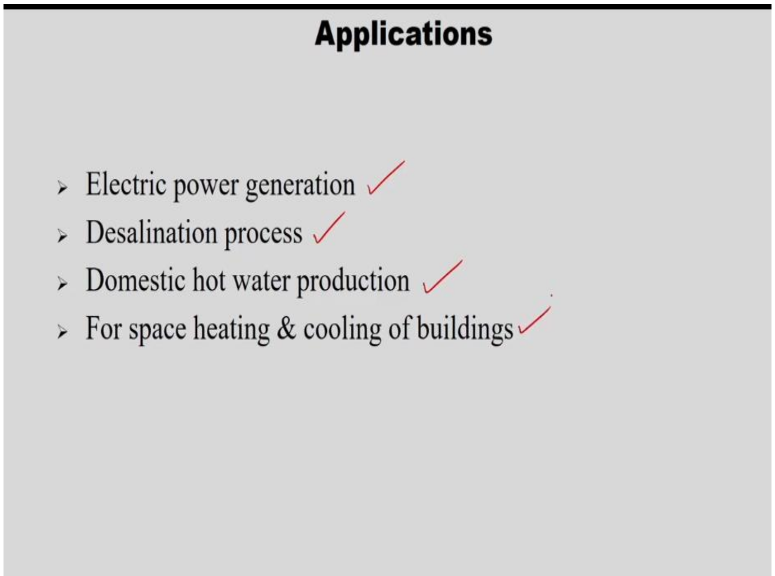

Applications electric power generation desalination process domestic hot water protection and for space heating and cooling of buildings.

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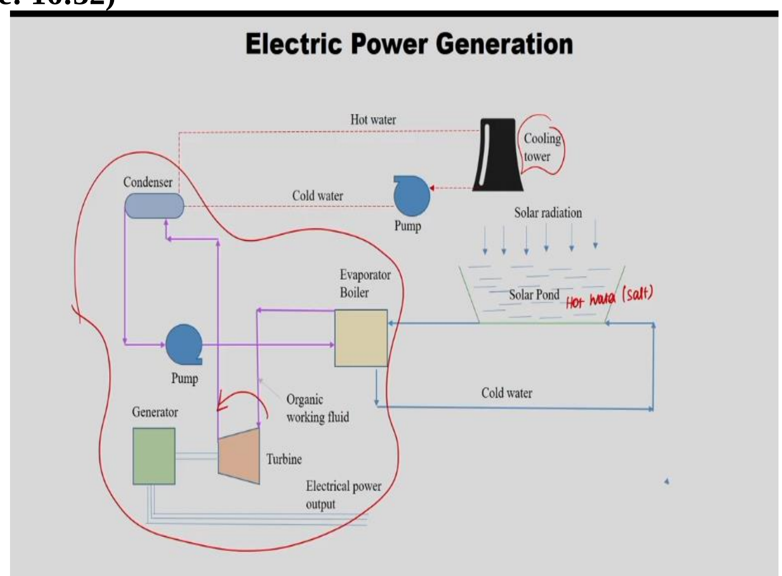

Here we are seeing the electric power generation. In the electric power generation unit this is the one so from the boiler it goes to turbine in the turbine. So, it should be reverse from the boiler it will go to turbine, from the turbine it goes to condenser the working fluid then after that it is pumped back to the evaporator right from the turbine if it is connected to the generator it produces the electricity for the year operator you might require the hot water.

So, the cold water is taken back and gets heated it goes through the solar pond so here already you have a hot water hot saltwater. So, you take a cold water from the evaporator or boiler assembly and use the solar pond as the heat exchanger and takes the heat from the hot water and goes back to the evaporator where you again heat the working fluid. So, this condenser is connected to the cooling tower to provide the cooling water to take away heat from the working fluid.

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The application commercial application the first solar pond in India about 6000 meters square was built at Bhuj which is in Gujarat. The project was sanctioned under the National solar pond program by ministry of non-conventional energy sources in 1987 completed in 1993 with the collaboration with TERI this is the energy and Resources Institute and the Gujarat Energy Development Agency and Gujarat Diary Development Corporation Limited. So, this is the solar pond taken from that source.

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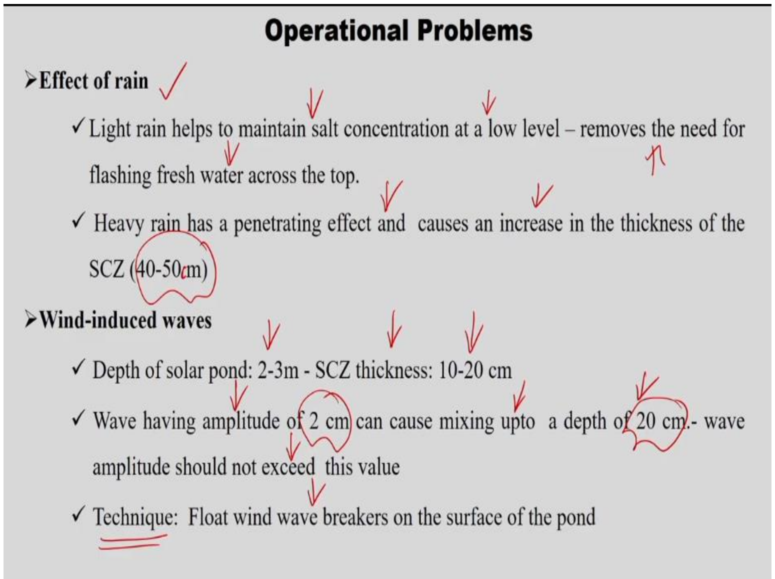

The operational problems the effect of rain when light rain helps to maintain the salt concentration at lower level because it dilutes the surface water and removes the need for flashing freshwater across the top. As I said earlier, there may be concentration change due to stratification, thermal stratification. So, in that case we then under flush the freshwater to dilute the concentration at the top if the light rain happens this helps in that way naturally if heavy rain penetrating.

If heavy rain happens that penetrates the through the solar pond it causes the increase in the thickness of the surface convective zone which is about 40 to 50 meter. Wind induced waves the depth of the solar pond is 2 to3 meter in that the surface so this is centimeter. The surface convective zone thicknesses about 10 to 20 centimeter, they having amplitude of 2 centimeter can cause mixing up to the depth of 20 centimeter total surface convective zone and the wave amplitude should not exceed this level.

So, wave amplitude of 2 centimeter can cause mixing up to a depth of 20 centimeter if the amplitude goes more than this then this thickness would get disturbed. The technique to be used to remove this wind induced wave, this float wind wave breakers on the surface of the pond.

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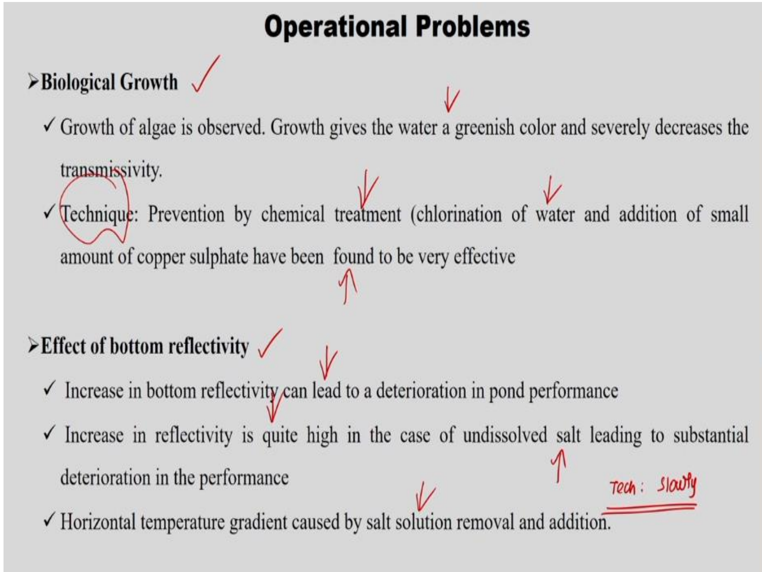

Then biological growth, growth of algae is observed this growth gives the water a greenish color and severely decreases the transmissivity of the solar radiation. The technique to prevent this prevention by chemical treatment chlorination of water and additional small amount of copper sulphate have been found to be very effective and to remove the or to suppress the growth of algae. The effect of bottom reflectivity, increasing bottom reflectivity can lead to your deterioration of the pond performance.

So, increase in reflectivity is quite high in the case of undissolved salt leading to substantial deterioration in the performance, horizontal temperature gradient can cause the disturbance. So, which is created by salt solution removal and addition so what is the technique to be followed do it slowly. So, when you add the salt or remove the salt so that should be done with the slow manner to avoid the horizontal temperature gradient what we require is probably vertical temperature gradient only.

So, in solar pond system we have learned about how the storage and collection happens in the single unit and various zones of the solar pond and what are all its advantages and what are all its operational problem.

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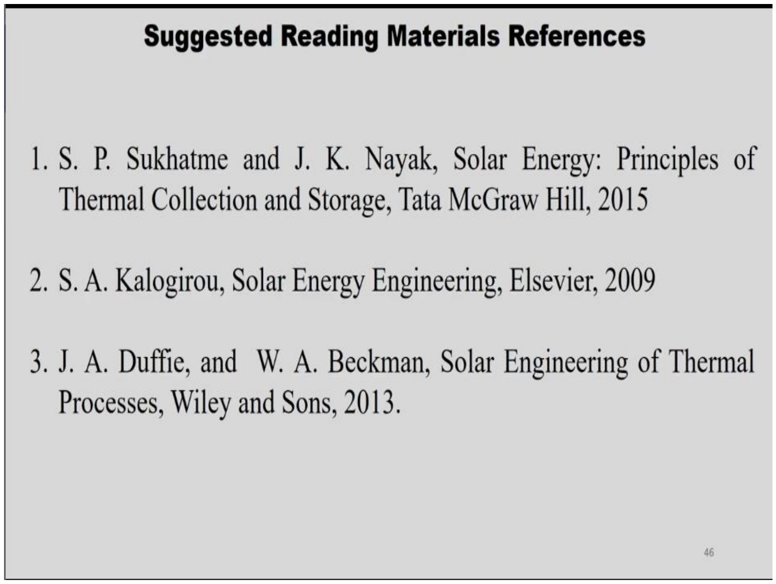

Further you can refer this 3-reference material for in depth understanding. Thank you.