3.3 Solar Ponds:

3.3.1 SOLAR POND

A solar pond is a solar energy collector, generally fairly large in size, that looks likea pond. This type of solar energy collector uses a large, salty lake as a kind of a flat plate collector that absorbs and stores energy from the Sun in the warm,lower layers of the pond. These ponds can be natural or man-made, but generally speaking the solar ponds that are in operation today are artificial.

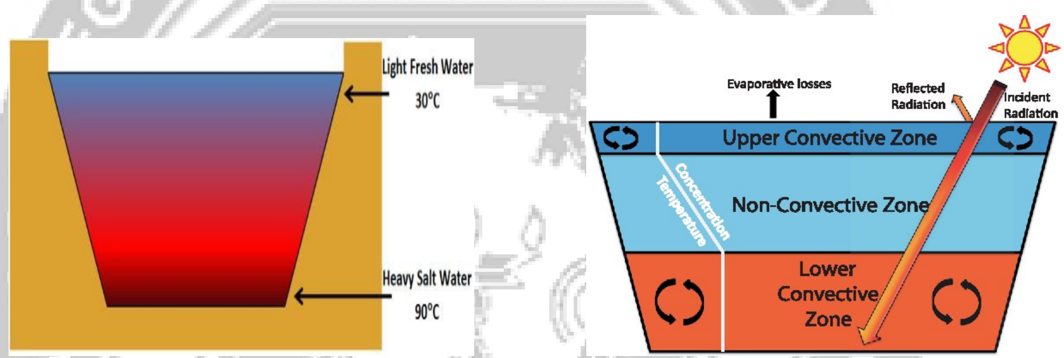

Figure: 3.3.1

[Source: "Solar Photovoltaics: Fundamentals,Technologies andApplications" by ChetanSingh Solanki, Page: 211]

SOLAR POND POWER PLANTS

- Solar ponds are power plants that utilize the effect of water stratification as abasis for the collector.
- A basin filled with brine (i.e. a water/salt mixture) functions as collector and heat storage.
- The water at the bottom of the solar pond serves as primary heat storage from which heat is withdrawn.
- The deeper water layers and the bottom of the solar pond itself serve as absorber for the impinging direct and diffuse solar radiation.
- Due to the distribution of the salt concentration within the basin, which increases towards the bottom of the basin, natural convection and theensuing heat loss at the surface due to evaporation, convection and radiationis minimized.
- This is why heat of an approximate temperature between 80 and 90 °C (approximate

stagnation temperature 100 °C) can be extracted from the bottom.

- Heat can then be used for power generation.

System components:

- Pond collector Heat
- Exchangers Thermal
- Engine

Pond collector:

- Pond collectors are either natural or artificial lakes, ponds or basins that act as a flat plate collector because of the different salt contents of water layers due to stratification.
- The upper water layers of relatively low salt content are often provided with plastic covers to inhibit waves.
- This upper mixing zone of such pond collectors usually is approximately 0.5 m thick.
- The adjacent transition zone has a thickness of 1 to 2 m, and the lower storage zone is of 1.5 to 5 m thickness.

Mechanism:

- If deeper layers of a common pond or lake are heated by the sun, the heated water rises up to the surface since warm water has a lower density than cold water.
- The heat supplied by the sun is returned to the atmosphere at the watersurface.
- This is why, in most cases, the mean water temperature approximately equals ambient temperature.
- In a solar pond, heat transmission to the atmosphere is prevented by the salt dissolved in deeper layers, since, due to the salt, water density at the bottom of the pond is that high, that the water cannot rise to the surface, even if the sun heats up the water to temperatures that are close to the boiling point.
- The salt concentration of the different layers must thus increase with increasing depth.

- In a first phase, this ensures stable water stratification.
- The upper, almost salt-less layer only acts as transparent, heat-insulating cover for the cooling, heat-storing deeper layers at the pond bottom

Heat exchangers:

- Basically, there are two methods to withdraw heat from a solar pond: The working fluid of the thermal engine flows through tube bundle heat exchangers installed within the storage zone of the solar pond, and isthereby heated up.
- The hot brine can also be pumped from the storage zone by means of an intake diffuser, subsequently be transmitted to the working fluid of the thermal engine and eventually be re-supplied to greater depths of the pond by another diffuser, once the brine has cooled down.
- The technical approach allows adjusting the position of the intake diffuser to the depth of the highest temperature.
- Secondly, heat losses by the pond bottom are reduced, since the cooled water is recycled to the pond near the bottom.

Thermal Engine:

- To convert solar thermal energy into mechanical and afterwards in electricalenergy, usually Organic Rankine Cycles (ORC) processes are applied.
- These are basically steam cycles which utilize a low-boiling, generallyorganic, cycle fluid.
- Such processes permit to provide electrical energy also at low usefultemperature differences

Plant Concepts:

- Plant diagram of a solar pond power plant
- The water absorbs the incident direct and diffuse radiation, similar to the absorber of a conventional solar collector, and is heated up.
- The technically adjusted salt concentration prevents natural convection and the resulting heat loss at the surface due to evaporation, convection and radiation.
- Water can thus be withdrawn from the storage zone at the bottom at an approximate temperature of 80 – 90°C.

- This heat can subsequently be used for power generation by an ORC process

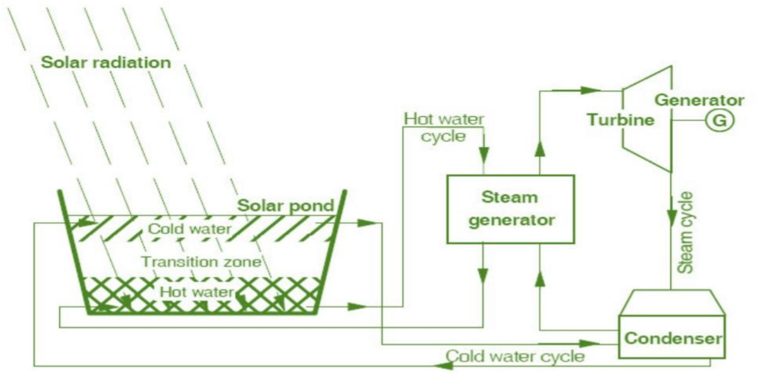

Figure: 3.3.2

[Source: "Solar Photovoltaics: Fundamentals,Technologies andApplications" by ChetanSingh Solanki, Page: 212]

WORKING OF SOLAR POND:

- The key characteristic of solar ponds that allow them to function effectively asa solar energy collector is a salt-concentration gradient of the water.
- This gradient results in water that is heavily salinated collecting at the bottomof the pond, with concentration decreasing towards the surface resulting in cool, fresh water on top of the pond.
- This collection of salty water at the bottom of the lake is known as the "storagezone", while the freshwater top layer is known as the "surface zone".
- The overall pond is several meters deep, with the "storage zone" being one or two meters thick.
- These ponds must be clear for them to operate properly, as sunlight cannot penetrate to the bottom of the pond if the water is murky.
- When sunlight is incident on these ponds, most of the incoming sunlightreaches the bottom and thus the "storage zone" heats up. However, this newly heated water cannot rise and thus heat loss upwards is prevented.
- The salty water cannot rise because it is heavier than the fresh water that is ontop of the pond, and thus the upper layer prevents convection currents from forming.
- Because of this, the top layer of the pond acts as a type of insulating blanket, and the

main heat loss process from the storage zone is stopped.

- Without a loss of heat, the bottom of the pond is warmed to extremely high temperatures - it can reach about 90°C.

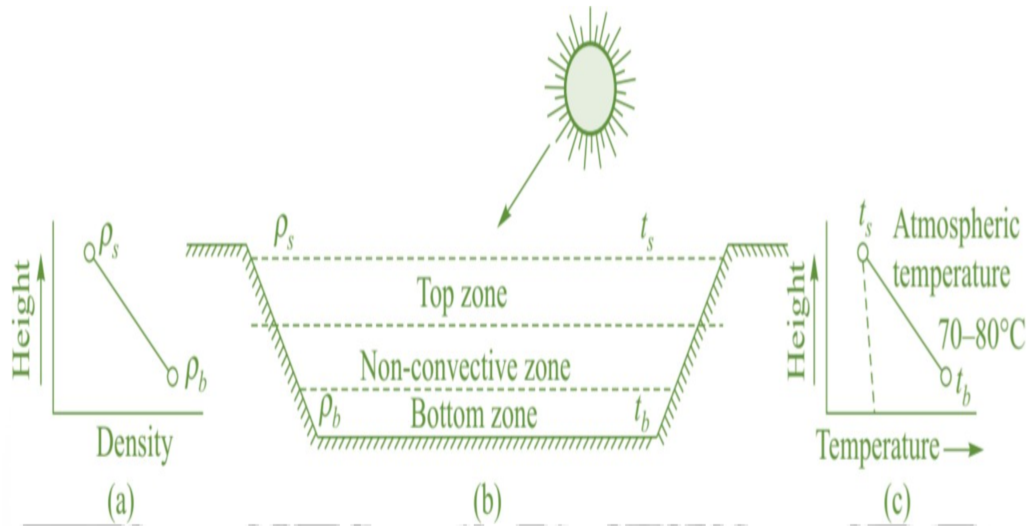

Figure 3.3.3: The Concept of Solar pond (a) Variation of density (b) Three zones in pond (c) Variation of temperature

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- If the pond is being used to generate electricity this temperature is highenough to initiate and run an organic Rankine cycle engine.
- It is vital that the salt concentrations and cool temperature of the top layer aremaintained in order for these ponds to work.
- The surface zone is mixed and kept cool by winds and heat loss byevaporation.
- This top zone must also be flushed continuously with fresh water to ensure that there is no accumulation of salt in the top layer, since the salt from the bottom layer diffuses through the saline gradient over time.
- Additionally, a solid salt or brine mixture must be added to the pond frequentlyto make up for any upwards salt loses.

APPLICATIONS:

- The heat from solar ponds can be used in a variety of different ways.
- They are ideal for use in heating and cooling buildings as they can maintain a

fairly stable temperature.

- These ponds can also be used to generate electricity either by driving athermo-electric device or some organic Rankine engine cycle - simply a turbine powered by evaporating a fluid (in this case a fluid with a lower boiling point).
- Finally, solar ponds can be used for desalination purposes as the low cost ofthis thermal energy can be used to remove the salt from water for drinking or irrigation purposes.