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Relative study of steel solar pond with sodium chloride and pebbles

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ABSTRACT

The salt-gradient solar pond is the pre-eminent solar desalination process for storing thermal energy. Due to the high concentration of salt content present in the lower convective zone heat will be stored for a longer period and will supply thermal energy at whatever time is required to have a temperature varying from 50 °C to 90 °C. This paper proposes an experimental and theoretical analysis of the convective type solar pond with trapezoid cross sections with the surface area of 1.7 m^2 and depth of 0.5 m made-up of 2 mm thickness mild steel sheet-metal lined by 20 mm and 2 mm thickness of thermo styrene, high density polyethylene sheet. The salinity-gradient is having three zones and these zones are separated due to salt concentration, each zone is having a varying thickness of 1.5 m (upper zone), 2 m (middle zone) and 1 m (lower zone). K-type thermocouple and solar power meter is used to measure the variation of temperature and solar radiation of the pond, thermocouples were space equally of 5 cm at six intervals and the readings were taken for eight hours per day and it is recorded during the months of December and January for further analysis. Experiments are conducted to find efficiency with NaCl and Pebbles. The experimental result reveals that efficiency is higher in NaCl (7%) compared with Pebbles (4%).

1. Introduction

Naturally occurring solar ponds is found in numerous locations on the earth. Approximately 2500 years ago solar energy were used by Romanians, were the Roman baths are heated by the sun rays. The discovery of solar ponds dates back from the early years of 1900s. Von Kalecsinky was the first person to discover the natural solar ponds at the high concentration salt regions of Transylvania and Hungary in the year (1989, 1902) where there is a various natural occurring lakes. For avoiding convective heat transfer of the pond, periodically salt will be added into the lowest surface of the pond [1].

Following the natural solar lake's concept, further investigations were conducted in the 1950s and 1960s in Israel in relation to artificial solar ponds. The cumulative research experiences provided some insight into how future solar pond facilities can be designed and operated to extract solar heat. Artificial solar ponds offer the promise of low cost heats.

In Sdom, Israel the first non-natural salinity gradient solar pond was constructed in 1960 having a surface area of 25 m × 25 m with a depth of 0.8 m. The main objective of this pond was to have a detailed study about the physics of the solar pond and its financial feasibility. The pond operated on September 1959 and April 1960 and attained a maximum heat storage zone temperature of 92 °C. The subsequent solar pond at Sdom was operated on the periods June to December on 1962. Additionally, two more experimental solar ponds were built-up at Sdom, Israel.

Sathish. D et al., experimentally investigated the shallow solar pond using CuO nano particles and concluded shallow ponds also having the capability to store to heat while by adding some concentration of nano particles [2]. Rabla and Nielson from Ohio State University introduced the solar pond technology at the United States in 1973 and their experimental was typically related to heat extraction. For the purpose of brine control and heat extraction two secondary ponds were used until 1986 that was constructed at Chattanooga, Tennessee. In Iowa, New Jersey, Ohio and El Paso, Texas, commercial solar ponds are being used for heat extraction for private use; the most famous is El Paso Solar Pond [3].

2. What is salt gradient solar pond?

Salt-gradient solar pond is one of the types of Non-convective solar pond because the convection part is prevented by the presence of salt concentration. Increasing salinity with increasing depth suppresses the normal convection patterns and creates what

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is basically a three-layered pond. Salt gradient solar ponds surface area having a range minor experimental solar ponds (~1 m^2 of surface area) and major (~20 ha) and it has been constructed in various localities all over the place the world. [3].

2.1. UCZ-upper convective zone

An upper convective zone or the surface zone consists of crystal clear pure water which performances as a solar radiation absorber or receiver where it transmits the radiations which are falling on it. The very shallow top layer of fresh or slightly salty water has the same salinity throughout its entire depth and thus convection takes place.

2.2. NCZ – non-convective zone

Middle layers of pond occupy the half depth of pond and having salt concentration much higher than the above layer. The salinity presents in the pond divide the NCZ and UCZ. Central layers ranging from slightly saltier at its upper boundary to very salty at its lower boundary is non-convecting because of its salt gradient. This stable middle layer serves partially as heat storage, but more importantly as insulation for the lower storage layer. The major center of attention to the non-convective zone is to maintain interior stability. It can't function as an inside unchanging salinity gradient and as part of the least necessity or increase moving back to avoid any gravitational overturn. This zone will perform as insulating zone, so that small amount of energy will be lost when the solar rays penetrate from the surface to the gradient zone and stores in heat storage zone. NCZ is the vital zone for the functional of a solar pond [4].

2.3. LCZ – lower convective zone

The highly saline bottom storage layer is also a storage layer due to the relatively strong absorption of solar energy at the bottom of the pond. Lower convective zone has high salt concentration and acts as a storage zone. Heat storage zone is normally where the heat is stored and when it is needed it can be extracted. Temperature stored in the pond can be obtained by extracting the brine solution from the pond or by passing spiral tubes inside the pond. For the operation and maintenance of solar ponds, periodic observations of basic parameters are necessary in order to monitor and predict the pond performance. Data recording for temperature and solar radiation was done.

3. Pond description

In this study, the solar pond was built up near has an area of 1.7 square meters at the surface and its depth is 0.5 m. And it is located in Pachapalayam (Coimbatore) 10.9°N – 76.8°E, as far as possible the location should be selected so that maximum sun exposure is available [5]. The pond was fabricated from 2 mm thickness of mild steel and their base and walls were insulated with 2 mm thickness of high density polyethylene sheet of black colour to absorb more amount of solar radiation, provide further protection against the leakage of water [6] and 20 mm thickness of them styrene.

To monitor the thermal stratification within the pond, temperature is measured along the pond in vertical lines of six points spaced at 5 cm apart, by k-type thermocouple with a temperature range of −55 °C to 125 °C with ±0.1 °C accuracy at 0 °C. In this research salt and Pebbles are used to find the difference in temperature. To keep up the salinity inside the pond a 15 cm diameter pipe is used to replenish the salt periodically. Fresh water is added on the surface or upper convective layer. The charging period of the ponds was started from the 07.11.16 to 18.11.16 and it is experimentally analyzed (see Fig. 1).

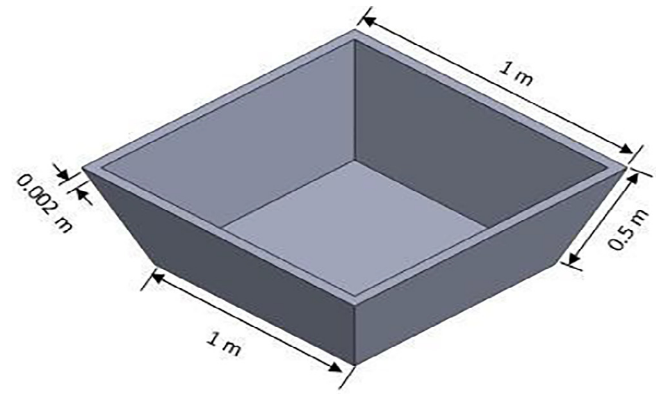

Fig. 1. Description of Solar Pond.

4. Results and discussions

Fig. 2 shows the amount of solar radiation w.r.to time. As indicated in the profile the solar radiation will get increased from the forenoon session but when the time moves on it start to decrease from the second half of the session.

Fig. 3 shows variations on temperature in all zone like UCZ, NCZ and LCZ for the sodium chloride salt. The temperature on day 1 will be equal to ambient temperature but when the days go on the temperature will get increased from all zones, this is due to presence of salt concentration will be high in lower layers the salt has the ability to store the heat of it. Since the middle and upper layers have low salinity the temperature will be lower when compared to storage zone.

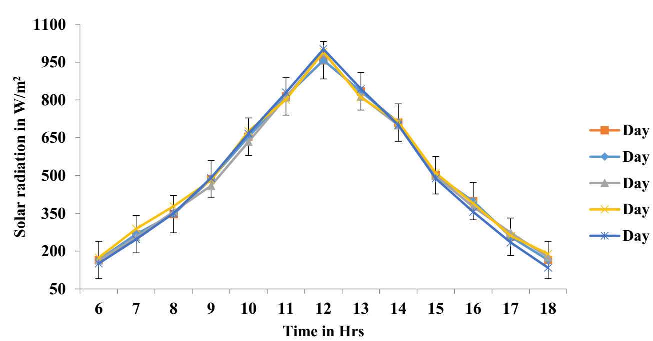

Fig. 2. Solar Radiation Vs Time.

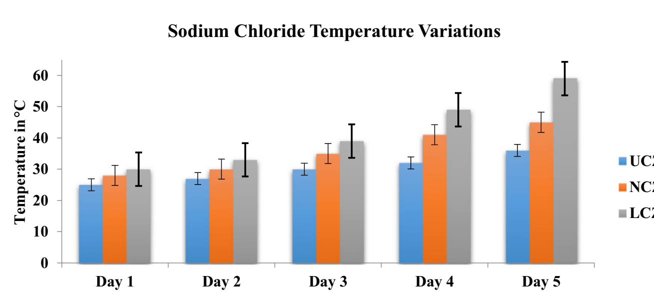

Fig. 3. Temperature distributions of Sodium Chloride salt.