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Some Methods to Improve the Performance of Solar Pond - A Review

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***Abstract* - Solar pond is one of the most simple and economic systems for the storage and reuse of solar energy. Energy efficiency of a simple solar pond is very low. Therefore, many researchers are working on ways to improve the performance of a solar pond. In this paper some of the simple and effective techniques to improve the efficiency of a solar pond have been discussed.**

Keywords - Coal cinder, PCM, Nanoparticles.

I. INTRODUCTION

A solar pond is a pool of water with a large area to capture solar radiations falling on it and store it as heat. A fraction of the insolation entering the pond surface is absorbed in different layers of water as it passes through the mass of water and the remaining amount of insolation reaching the bottom of the solar pond is absorbed by the bottom. In a simply designed pond, sun rays warm up the water and the warm water rises from the bottom of the pond. The warm water rises, reaches the top surface and loses the heat to the environment. The net outcome of the process of natural convection is that the pond water gets cooled and attains a temperature nearly the same as that of the atmosphere. In a solar pond, the process of natural convection is retarded significantly by dissolving the salt in the water thereby altering the density of different layers of water such that it stops the automatic process of natural convection [1-5].

II. DESIGN OF SOLAR POND

In the salt-gradient solar ponds, layers of water with different densities are created by dissolving the salt in the water (more the concentration of salt dissolved in a layer, denser it is). Typically, a solar pond has the three zones having different density.

1) Surface convective zone, with 0.3-0.5m depth and salinity < 5%.
2) Non-convective zone, with 1-1.5m depth. The salinity and the density of this layer increase with depth.
3) Storage zone, with 1.5-2m depth and salinity > 15%.

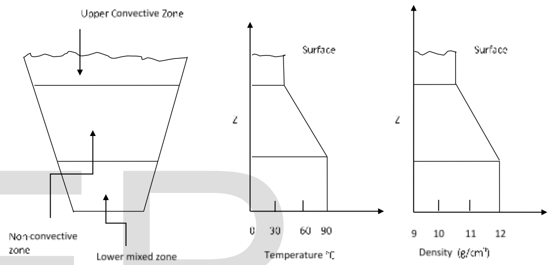

Fig.1. Diagram of a solar pond

The upper zone having a very small salt concentration (nearly equal to zero) is also known as the surface zone or Upper Convective Zone (UCZ). It has the same temperature as the ambient temperature. The bottom zone has the highest concentration of salt and it is the heaviest. It is called Lower Convective Zone (LCZ) and acts as a heat storage zone. The function of this zone is to trap and store solar energy in the form of heat. A significant gradient zone, which is also known as Non–Convective Zone (NCZ), separates these two zones. This zone has salinity and density gradient due to varying salt concentration. The salt concentration in water gradually increases as the depth increase. The non-convective zone above the lower convective zone acts as an insulating layer and reduces the heat loss from the LCZ. High-saline water at the base of the pond having high density does not mix up easily with the low-saline water just above it. When the water in the bottom layer gets heated by radiation, convection takes place in the bottom and top layers separately, with a little mixing between both the layers. Thus solar energy is trapped in the LCZ which is withdrawn in the form of hot brine through a heat exchanger [5-11].

A. Applications of Solar Pond

Due to a large amount of heat stored and negligible daily variation in water-temperature, the solar pond is very useful for many applications like space heating or cooling, industrial process heat, agricultural crop drying, process heating in dairy plants, power production and desalination. When a solar pond is operated along with a heat pump, the warm water which is stored in the bottom zone of the solar pond can be used as a heat energy source for a gas engine driven heat pump used for heating of a greenhouse [12-13]. Multi-flash desalination plants in conjunction with a solar pond is an effective and economical way for producing distilled water because operating range of this plants is below 100 ^{0}C which can be easily obtained by a solar pond [14-15]. Solar ponds can be utilized for power production at low temperature that is obtained from the solar ponds. For the power production solar pond can be used as a heat source for low boiling point organic working fluid operated power plants. Halocarbons i.e. freon or hydrocarbons i.e. propane were very useful as low boiling point organic working fluids [16-17]. The solar pond can be used for supplying heat to industries, hence saving natural gas, oil, coal and electricity. A Solar pond can also be used for agriculture applications, i.e. agriculture crop drying [18].

III. Methods For Improving Performance Of LCZ

There are various methods by which performance of LCZ can be increased. Some of the methods that have been experimented by various researchers are discussed below:

A. Effect of Coal Cinder placed at the bottom

Coal cinder has a good insulating property, absorptivity, and low thermal diffusivity. Many researchers have studied experimentally as well as theoretically, the effect of placing coal cinder at the bottom of SGSP.

Wang, Zou, Cortina, and Kizito [19] used three identical plastic tanks for the experiment, each having a base area of 0.4 m × 0.25 m and a height of 0.3 m. First of these three tanks was left untreated (without any treatment on the bottom), the second tank was painted black on the inside bottom and in the third tank a thin layer of coal cinder was spread on the bottom.

It was found that the highest temperature of 65.5 ^{0}C was achieved in the third tank which had a layer of coal cinder at the bottom at about 13:00 hrs. It was 14 ^{0}C and 12 ^{0}C higher than that of the untreated tank and the tank containing black plastic cover at the bottom respectively. The experimental results showed a significant increase in temperature of LCZ of SGSP when coal cinder was added in the bottom of the salt gradient solar pond. The black plastic covered bottom also showed better performance than the traditional untreated bottom [19].

B. Effect of Porous Materials placed at the bottom

Wang, Zou, Cortina, and Kizito [19] studied the effect of porous material spread at the bottom of the tanks. They conducted experiments in three small plastic tanks simultaneously. The three sets included a) a tank without any treatment on the bottom, b) a tank with the pebble-covered bottom and c) a tank with coal cinder in the bottom. The tanks were compared for 20 days. The porosity of the zone made by the mixture of salt water and coal cinder was 50% and that of zone made by the mixture of pebble and salt water was 32%.

It was observed that every morning the temperature of the LCZ was near to the atmospheric temperature for all the cases. In the afternoon the temperature was found to be maximum for the tank with coal cinder covered bottom [19].

C. Effect of Polyethene Film placed between NCZ and LCZ

A polyethene film having a thickness of 100 µm was placed between LCZ and NCZ. The film being impervious would prevent diffusion between LCZ and NCZ and thus maintain a salinity gradient for a longer duration. It was observed that the temperature of the LCZ i.e. heat storage zone was considerably higher for the solar pond with polyethene film just above LCZ as compared with the case having no separating polyethene film. The efficiency of the solar pond with polyethene film above LCZ was found to be 69% while that for the conventional solar pond was about 52% [21].

The rate of rising of the temperature of LCZ, i.e. heat storage zone, was also considerably higher for the solar pond with separating polyethene film as compared with the solar pond without any polyethene film.

D. Effect of Covering the Top Surface of the Pond

Evaporation is one of the significant challenges in efficient working of solar ponds. A large part of the heat is lost to the environment through evaporation.

Ruskowitz, Suarez, Tyler and Childress [22], experimented with floating hemispheres, floating discs, and a continuous cover over a solar pond. It was found that when a floating disc covers the solar pond with 88% surface, the evaporation rate decreased from 4.8 to 2.5 mm/day whereas the temperature increased by 7 ^{0}C, i.e. from 34 ^{0}C to 43 ^{0}C. The heat content also increased by 41MJ, i.e. from 179 MJ to 220 MJ. Suppression of evaporation also resulted in a reduction in the heat lost to the surroundings and increase in the heat content of the LCZ, which improved the efficiency of the solar pond. This also resulted in a reduction in heat loss from LCZ to NCZ and hence, a higher temperature was obtained in LCZ and NCZ. Further, by suppressing the evaporation in the solar pond, it can be operated in locations where the availability of water is less.

E. Effect of Encapsulated PCM and Nanoparticles placed at the Bottom

Phase change material (PCM) can be used as LCZ in a solar pond instead of the salt solution that is normally used in solar ponds. It was preferred over salt because of its higher storage capacity. However, PCM has poor thermal conductivity hence time for charging and discharging of PCM is more. To overcome this problem, Al_2O_3 nanoparticles were added to PCM. Since the thermal conductivity of Al_2O_3 nanoparticles is good, energy storing period and energy extraction period of the solar pond could be restrained considerably, at the same time the rate of heat transfer could also be increased.

It was observed that normal solar pond can deliver water at an elevated temperature only till the availability of sun, while the solar pond with PCM containing nanoparticles was capable of delivering high-temperature water for one and a half hours extra after the sunshine hours [23].

F. Effect of Reflective Covers

Folding cover having a reflective surface on one side is an effective way to reduce heat loss from solar pond surface during night time and capture a greater amount of solar radiations during the daytime and thereby the efficiency of the solar pond was improved [24].

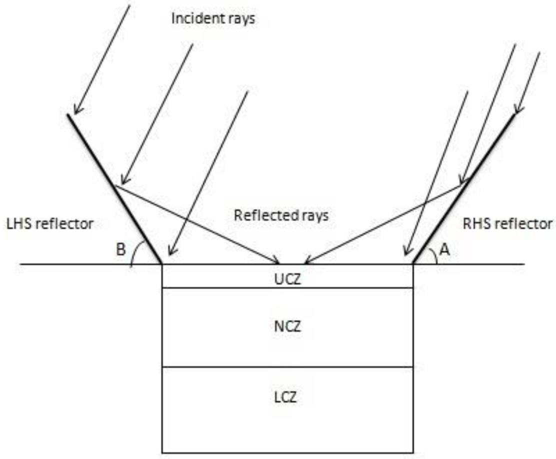

Fig. 2. Reflectors over a solar pond

It was found that solar pond performance could be increased by about 25% by using reflective covers.

The effect of the position of reflectors was observed by carrying out the simulation in two different ways.

Firstly, the simulation was done for temperature variation in LCZ when RHS reflector was placed at a constant angle of 89^0 whereas LHS reflector position was gradually altered from 30^0 to 80^0 with 10^0 intervals (angle is measured from the horizontal axis). The minimum and maximum solar pond temperature were found when the combination of angles was 80^0–89^0 and 30^0–89^0, respectively.

In the second simulation, LHS reflector was fixed at an angle of 30^0 and RHS reflector angle was altered from 20^0 to 80^0 with 10^0 intervals (angle is measured from the horizontal axis). The minimum and the maximum solar pond temperature was found when the combination of angles was 30^0–20^0 and 30^0–80^0, respectively [24].

The average deviation in temperature of LCZ between the solar pond with a cover during the night time only and the normal solar pond without any cover was found to be 1 ^{0}C whereas the average deviation in temperature between the solar pond with a cover & reflector and the normal solar pond without any cover & reflector was found to be about 10 ^{0}C. Thus the reflectors were found to play an important role in the thermal performance of the solar pond.

G. *Effect of Different Salts*

Performance of salt gradient solar ponds also depends on the type of salt used. To study the effect of type of the salt on the performance of solar ponds, three different salts, namely NaCl, Na_2CO_3 and $CaCl_2$ were used in three different solar ponds, each having a size of 1 m^3.

The results showed that solar pond with $CaCl_2$ salt reacts thermally more rapidly than the other two ponds. The highest temperatures recorded in the three ponds after experimentation for 28 days were 75.09 ^{0}C, 72.00 ^{0}C and 65.64 ^{0}C for the $CaCl_2$, NaCl and Na_2CO_3 respectively. This was due to the difference in thermal capacity of the salts. $CaCl_2$ offers a better alternative in the regions with low solar radiations, as it can provide higher temperatures due to its low thermal capacity. However, temperature decreases more rapidly in the $CaCl_2$ pond during the night period [25].

IV. Conclusions

There are some simple and promising ways in which the performance of an SG Solar Pond can be enhanced. Some of the common, prominent and easy to implement methods have been highlighted in this paper. The methods discussed in this paper are, 1) Adding coal cinder in the bottom of the solar pond to improve the absorptivity of solar radiations in LCZ, 2) Use of porous material at the bottom of the solar pond, 3) Use of polyethene film between NCZ and LCZ to prevent diffusion of salt from one layer to another and thus maintaining the salt gradient in the pond and preventing natural convection between NCZ and LCZ due to presence of a physical barrier, 4) Covering the top surface of the pond, partially or fully, to prevent the loss of water and energy through evaporation, 5) Use of PCMs with nano-particles to improve the storage capacity of the LCZ and provide heat after the sunset, 6) Use of covers and reflective surfaces to prevent evaporation during night and to capture more solar radiations during the day, and 7) Use of different Salts improving the temperature and storage of LCZ. All the methods discussed above are simple and cost effective and have positive impact on the performance of the solar ponds.

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