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Experimental Investigation of Effect of Different Tube Geometries on Heat Transfer in Solar Pond

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Abstract — *Solar Ponds are used for storing solar thermal energy without the expense of storage devices. Solar Ponds can store low grade thermal heat of 70-80°C at ambient temperature of 20°C. They are ponds with saline water that can store sensible heat. These ponds have made a tremendous growth in past thirty years. In this paper we have presented the effects of using different tube geometries in solar pond using experimental setup in college campus. Tubes are made of copper. Also the effect of changing salinity has been discussed.*

Keywords- *Solar Pond, Upper Convective Zone, Non Convective Zone, Lower Convective Zone, Brine Solution, Heat Exchanger, Heat Transfer Rate, Green House Effect.*

I. INTRODUCTION

Energy production and consumption are directly related to a country's social and economic growth. The standard of living of citizens can be related to per capita energy consumption of a nation. Industrialization and modernization has led to an increase in demand for energy across all sectors. Traditionally this energy is met by fossil fuels and other conventional sources of energy. As these sources are perishable; there should be an alternative that can meet this ever increasing demand. The alternate source of energy should be renewable and friendly to environment. Sun is the primary source of energy to our planet earth. Energy received from sun in form of solar radiation is renewable and available in abundance. [1]

Solar Ponds are used to harvest this energy. They are used for storing solar thermal energy without the expense of storage devices. Solar Ponds can store low grade thermal heat of 70-80°C at ambient temperature of 20°C. They are ponds with saline water that can store sensible heat. Tropical countries receive sunlight for long time throughout the day, throughout the year. India being a tropical country has a good opportunity to harvest solar energy on a large scale to meet the demand of its population of over 1.3 Billion. [3]

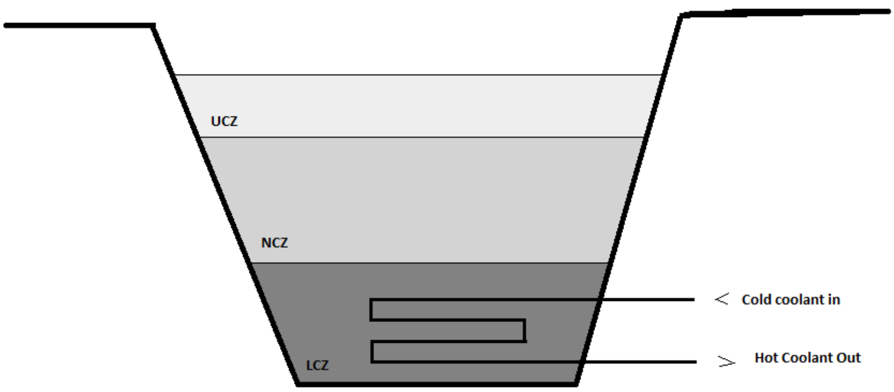

Figure 1. Solar Pond Schematic Diagram

Thus solar ponds will prove to be a boon in country like India. Solar pond is basically a pond of saline water with salinity gradient. The lowest part being the densest and the top most being the least dense. The lowest zone is called Lower Convective Zone and it is responsible for storing the sensible heat energy. The upper most zone is called Upper Convective Zone. The middle zone is called Non Convective Zone and its function is to trap the heat inside to LCZ. LCZ can store low grade thermal heat of 70-80°C at ambient temperature of 20°C. This heat is then extracted by primary coolant usually water, for different purposes like salt production, preheating water to feed boilers, desalination, and much more. [6]

The amount of heat stored by solar pond depends upon the salinity of brine used. Usually the salinity of LCZ is 20-30% by weight for optimum results. The heat collected at the LCZ is extracted by using heat exchangers. The paper includes effect of different tube geometries (without fins and with fins) on heat extraction in solar pond. [2]

II. EXPERIMENTAL SETUP

A. The Tank for Solar Pond

Mild Steel Sheet (1.5 mm thickness, Strength: 370 MPa) is used to fabricate the tank. A tank of surface area 1.2 m X 1.2 m and depth 1 m has been fabricated. Bottom surface of the tank is 0.9 m X 0.9 m. The walls are inclined at an angle of 98.53° from bottom surface to ensure sunlight reaches bottom surface. UCZ makes up 0.1 m thick layer, which consists of fresh water. The NCZ is about 0.3 m thick and functions as insulation to trap heat in storage zone i.e. LCZ. NCZ has gradually increasing brine concentration towards the bottom. The LCZ is about 0.5 m thick layer of high-density brine. It stores the solar thermal energy in form of sensible heat. The side walls and bottom surface is double layered and filled with glass wool for insulation. The gap between these layers is 8 cm. The inside of the tank is painted black to increase the absorptivity of heat. Thermostat is used to measure the temperature of water in pond at different depths. Also to measure the temperature of coolant at inlet and outlet. [3]

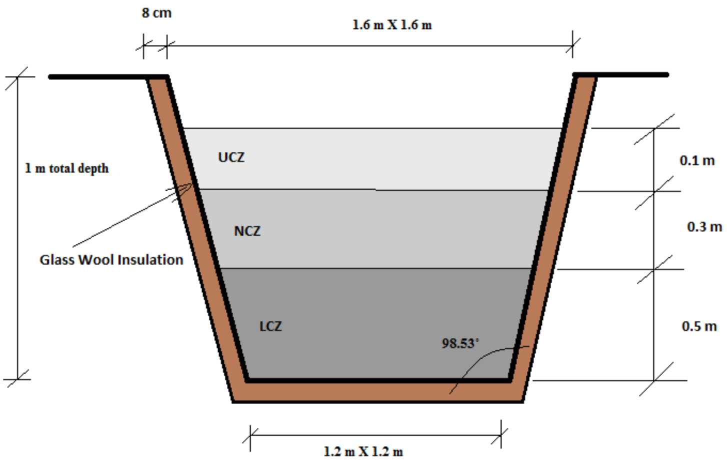

Figure 2. Tank Design for the Experimental Setup

B. The Glass Glazing

The tank is covered with a glass glazing. The thickness of glazing is 4 mm. The purpose of this is to trap the heat inside the tank and also save the water from evaporation. The glazing also prevents foreign material to enter the tank and contaminate it. The glazing is 10° inclined to the horizontal.

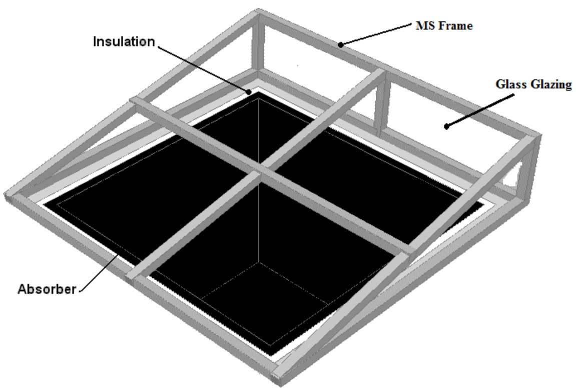

Figure 3. Tank Glass Glazing

C. Heat Exchanger (Heat Extraction Tubes)

Two heat extraction tubes of copper are used in the solar pond, having different geometries. One is without fin circular tube and the other is finned circular tube. The total length of each heat exchanger is 8 ft (2.4384m). The tubes are of diameter 5/8 inch. There are 16 equally spaced fins on finned heat exchanger, with height of 1 inch (2.54 cm) each and

1.5 mm thick. A pump of 0.22 kg/s discharge (as measured) is used to maintain flow of coolant. 10 kg of pure water as coolant is circulated.

D. Brine Water Solution

95 kg of common salt i.e. NaCl is first added to water in the tank at level 0.5 m. Later fresh water is added up to height of 0.9 m (992 litre). The solution is allowed to settle for 2-3 days. A salinity gradient will be obtained with LCZ having highest density at the bottom (20% by weight), NCZ with salinity gradient above it and fresh water at the top most layer i.e. UCZ.

E. Experimental Setup

Figure 4. Experimental Setup

F. Properties Table

Table 1. List of Material and Properties

Sr. No.	Title	Value
1	Material of Tank Walls	Mild Steel
2	Thickness of MS Sheets	1.5 mm
3	Tube Material	Copper
4	Tube Diameter	5/8 inch(1.5875 cm)
5	Tube Length	8 ft (2.4384 m)
6	Conductivity of Copper	385 W/mK
7	Fin Material	Copper
8	Fin Height	1 inch (2.54 cm)
9	Fin Thickness	1.5 mm
10	Glass Wool Thermal Conductivity	0.030 W/mK
11	NaCl Molar Mass	58.443 g/mol
12	NaCl Density	2.165 g/cm^3
13	NaCl Melting Point	801°C
14	NaCl Boiling Point	1413°C
15	NaCl Solubility in Water	356 g/L

III. OBSERVATIONS

A. Ambient Temperature and Tank Temperature Profile

The ambient temperature is measured at Bhusawal (MS), latitude of 21.0418° N. The temperatures readings for different solar pond zones are taken at depths 0.05 m (UCZ), 0.25 m (NCZ) and 1 m (LCZ).

Table 2. Ambient Temperature and Tank Temperature Profile

Date	Ambient Temperature (T_{amb} °C)	R W/m^2 [4]	ucz °C	ncz °C	lcz °C
15-April-2020	40	1057.4	36.2	43.1	53.2
20-April-2020	40	1058.9	35.8	43.2	51.6
25-April-2020	38	1060.0	34.1	42.8	52.7
30-April-2020	41	1060.9	35.4	44.2	54.4
05-May-2020	42	1061.6	36.3	45.0	56.8
10-May-2020	44	1062.0	37.8	45.7	58.0
14-May-2020	45	1062.2	38.1	46.3	58.5

B. Coolant Inlet and Outlet Temperatures from Heat Exchangers

Table 3. Coolant Inlet and Outlet Temperatures from Heat Exchangers

Date	M kg	t min	lcz °C	T_1 °C	T_{2a} °C	T_{2b} °C
15-April-2020	10	5	53.2	28.4	41.6	46.7
20-April-2020	10	5	51.6	27.2	41.3	46.8
25-April-2020	10	5	52.7	27.6	43.1	47.8
30-April-2020	10	5	54.4	29.3	43.7	48.6
05-May-2020	10	5	56.8	28.5	44.9	49.4
10-May-2020	10	5	58.0	28.1	48.0	54.0
14-May-2020	10	5	58.5	27.2	47.9	53.3

M: Total mass of coolant in kg
t: Time for flow of coolant in min
T_1: Coolant inlet temperature in °C
T_{2a}: Coolant outlet temperature in °C, for tube without fins
T_{2b}: Coolant outlet temperature in °C, for tube with fins
ucz: Temperature of UCZ at 0.05 m depth in °C
ncz: Temperature of NCZ at 0.25 m depth in °C
lcz: Temperature of LCZ at 1 m depth in °C
R: Total Solar Radiation in W/m^2

IV. CALCULATIONS

Heat gained by coolant to raise temperature from T_1°C to T_2°C is given as,

$$Q = M \times C_p \times (T_2 - T_1) \quad \ldots. (1)$$

Heat extraction rate in solar pond is given as,

$$\dot{q} = U \times A \times \theta_m \quad \ldots.. (2)$$

$$Q = \dot{q} \times t$$

C_p: Specific Heat of water in J/kgK = 4.183 kJ/kgK
U: Overall heat transfer coefficient in kW/m^{2}K
A: Heat transfer surface area in m^2 = πxDxL (Tube diameter=5/8 inch=0.015875 m, Tube length=2.4348 m) = 0.12161 m^2
θ_m: Logarithmic Mean Temperature Difference in K = $[\theta_1 - \theta_2] \div [\ln(\theta_1/\theta_2)]$
θ_1 = (lcz-T_1) K
θ_2 = (lcz-T_2) K

Table 4. Heat Transfer

Date	LMTD (θ_m K)		Heat Gained by Coolant (Q kJ)		Heat Extraction Rate in Solar Pond ($\dot{q}$ kW)	
	θ_{ma}	θ_{mb}	Q_a	Q_b	$\dot{q}_a$	$\dot{q}_b$
15-April-2020	17.4	13.7	552.2	765.5	1.84	2.55
20-April-2020	16.3	12.1	589.8	819.9	1.97	2.73
25-April-2020	16.1	12.4	648.4	845.0	2.16	2.82
30-April-2020	16.9	13.2	602.4	807.4	2.01	2.69
05-May-2020	18.9	15.6	686.0	874.2	2.29	2.91
10-May-2020	18.2	12.9	832.4	1083.4	2.77	3.61
14-May-2020	19.1	14.5	865.9	1091.8	2.89	3.64

θ_{ma} and θ_{mb} are LMTD for without fin and with fin heat extraction tubes
Q_a and Q_b are Heat Gained by Coolant for without fin and with fin heat extraction tubes
$\dot{q}_a$ and $\dot{q}_b$ are Heat Extraction Rate in Solar Pond for without fin and with fin heat extraction tubes

V. CONCLUSION

In the Table 2 shown; temperature variations for different zones are shown. The temperatures observed for UCZ was between 34.1°C and 38.1°C, for NCZ was between 42.8°C and 46.3°C and for LCZ was between 51.6°C and 58.5°C. The ambient temperature was recorded to be between 38°C and 45°C. The above data was collected between 15th April 2020 to 14th May 2020.

In the Table 4, heat extraction from solar pond by using different tube by experimental verification is shown. It is found for tube without fins, the rate of heat extraction from SGSP was between 1.84 kW to 2.89 kW and for tube with fins it was between 2.55 kW to 3.64 kW.

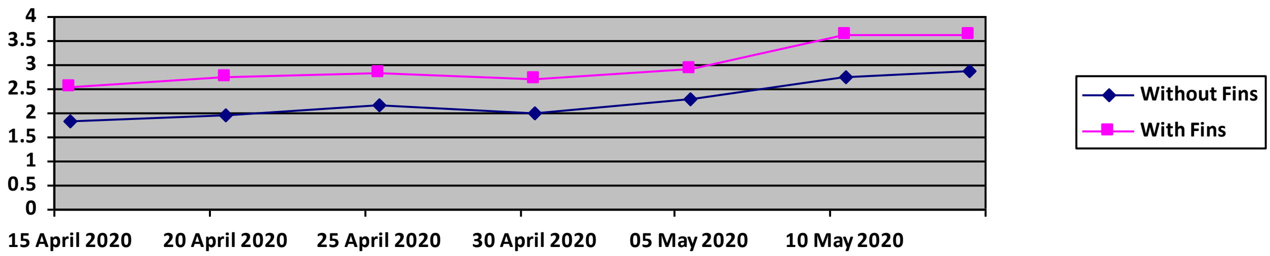

Figure 5. Variation of heat extraction rate for different tubes (kW)

It's being observed that the heat extraction from SGSP improves by 31.6 % at an average, by using fin type heat exchanger.

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REFERENCES

[1] Rudhrala Sivaprasad, B. Srinivasarao, Experimental Investigation of Solar Pond Integrated With PCM Storage, International Journal of Innovative Research in Technology Volume 5 Issue 1, pg. 208-212, June 2018.
[2] J Srinivasan, Solar Pond Technology, *Sādhanā* Volume 18 Part 1, pg. 39-55, March 1993.
[3] Abhishek Saxena, Varun Goel, A Technical Note on Fabrication and Thermal Performance Studies of a Solar Pond Model, Hindawi Publishing Corporation Journal of Renewable Energy Volume 2013, Article ID 475282.
[4] PV-Education.org, Solar Radiation Data, Calculation of Solar Insolation, viewed 20 April 2020, <https://www.pveducation.org/pvcdrom/properties-of-sunlight/calculation-of-solar-insolation>
[5] Er. R. K. Rajput, Heat and Mass Transfer, Sixth Edition 2015, S. Chand Publication, New Delhi.
[6] G. D. Rai, Non-conventional Energy Sources, Sixth Edition, Khanna Publication, Delhi.

