FABRICATION OF MEMBRANE STRATIFIED SOLAR POND MODEL

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ABSTRACT

Extracting energy from the sun has revolutionized the global energy industry. Different literatures have been reviewed to give an appropriate theory and mathematical model for the design of solar pond. In this research paper we have observed the heating effect of solar energy under different conditions. For this we have used different sheets to transmit and retain an appreciable amount of energy. Salinity of the water plays an important role in heat carrying capacity of the water therefore we observed the behavior of solar pond under various salinities and collected the data to show comparison between different sheets.

The paper "Fabrication of Membrane Stratified Solar Pond Model" deals with comparative study of different sheets under different salinities in order to show the variation of temperature in different heat storage zones.

Keywords: Design, Fibre and Glass Sheet, Salinity, Solar Pond, Temperature Variation

I. INTRODUCTION

Global warming could be one of the world's most important issues in the 21st century. Every year, billions of tones of carbon dioxide have been emitted into the global atmosphere[1].Global warming mainly occurs due to human activities such as transportation, producing electricity and in industries which involves burning fossil fuels, which could lead to a significant decrease in world fossil fuels reserves. However, renewable energy technologies have been developed and introduced as an alternative source for energy production; renewable energy technology can produce energy with zero carbon dioxide emissions, unlimited sources and benefits the economy. Solar energy is one of the essential world renewable energy sources. The conversion of the energy can be operated by several techniques such as photovoltaic systems for producing electricity and solar hot water for heating water with solar energy. Solar ponds have been suggested to be simple and economical in terms of collecting and storing energy on a large scale.

A solar pond is a large-area collector of solar energy resembling a pond that stores heat, which is then available to use for practical purposes. Researched designs include saltwater ponds, gel ponds, and others such as shallow ponds with covers, deep ponds with glass or plastic containment devices. Their common features are to store the energy in the incoming solar radiation in the heated depths of the pond, and to suppress the convection currents that would otherwise lead to heat loss to the surroundings.

There are two general types of solar ponds to be mentioned-

- Convecting solar ponds
- Non- Convecting solar ponds.

1.1 Membrane Stratified Solar Ponds

Membrane Stratified solar ponds belong to the group of partitioned solar ponds, where the HSZ is separated physically from the upper layer or layers.

In previous works and descriptions of such ponds, the HSZ of a partitioned solar pond was covered by a transparent membrane, but a salt-gradient zone combined with a fresh water layer was installed on top of it too. This system could be seen as a salt-gradient solar pond with an additional physical separation of the HSZ.

The big advantage of a physical separation of the HSZ from the rest of the system lies in the increased stability of the several layers when heat is extracted from the HSZ. A membrane does not allow any disruptions and interactions between the HSZ and the upper layer, no matter if it is a NCZ and a UCZ or only one fresh water layer.

Furthermore, the heat extraction in a salt-gradient solar pond is a complicated and technically difficult process, The disadvantage of adding a physical layer to a system where solar radiation is the only input is obviously the diminished total transmission of sun light to the bottom of the pond. Since this is an optical boundary layer, there will be of course optical effects like reflection, transmission and absorption which counteract the performance of the pond.

There have been studies with even two membranes separating each of the three layers from each other. There have been some interesting results showing that a membrane salt-gradient pond has a higher efficiency than standard salt- gradient ponds.

The objective of this work is to show the provide behaviour of pond under various conditions. For this observations are made under three conditions-

- No Layer
- Fibre Layer
- Glass Layer

1.2. About the Construction of Solar Pond Model

1.2.1. Objective of Solar Pond

The intention of the structure of the solar pond primarily lies in the applicability in sea water and an easy and not complicated construction. The main goal is a low- tech solution for hot water supply and maybe generation of electrical energy with an organic ranking cycle.

1.2.2 Idea of the Pond Structure

This led to the idea of using a 4% salt water solution to simulate the use of sea water in the HSZ and to study potential problems connected with or caused by the salt content.

The future prospect could be a self- maintaining system where a room beyond a membrane, which is fixed in separate housing, is filled by valves with sea water and the room above the membrane is filled with fresh water by precipitation.

Based on these considerations, the main structure of this experimental membrane stratified solar pond was set to a 4% salt-water layer as HSZ, a transparent membrane, a fresh water layer on top of it and insulation of the side walls.

1.2.3. Location of the Pond

The pond was placed in the M.J.P. Rohilkhand University, Bareilly, Uttar Pradesh, in India. This region is northern plain of the country. The solar pond model was setup on the roof of Mechanical Engineering Department.

Figure 2 Location of M.J.P. Rohilkhand University, Bareilly, Uttar Pradesh

Figure 1 Location of Mechanical Engineering Department

1.2.4 Orientation of the Pond Model

Due to the change of the solar altitude and the azimuth, and due to the shadowing effect of the side walls of the pond, the whole surface area of the HSZ, which is equivalent to the area of the membrane, will never be hit by the direct radiation from the sun.

This will limit the performance of the pond of course, although it was attempted in this experimental study to orientate the pond in a way where it can work as effective as possible. We tried to do this by orientating the pond with one sidewall directly facing the south to always have a large area exposed to sunlight.

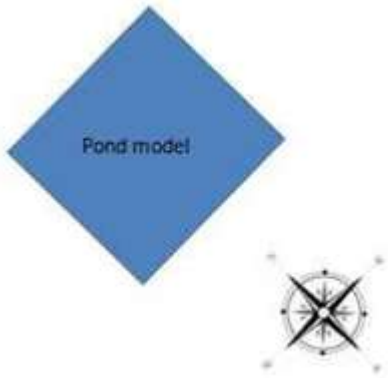

Figure 3 Orientation of the Pond Model

II. DESIGN

2.1 Dimensions of the Solar Pond Model

Depth of the zones

1. HSZ : From bottom up to 13cm
2. NCZ : From bottom up to 22cm
3. UCZ : From bottom up to 27cm

Volume of the solar pond

= area of cross section (trapezium) * depth of cross section

= [1/2 * (60+30) * 30] * 90=121500 cm^3

Volume of the HSZ

= area of cross section (trapezium) * depth of cross section

= [1/2 * (41+30) * 13] * 90= 41535 cm^3 Volume of the NCZ

= area of cross section (trapezium) * depth of cross section

= [1/2 * (41+50) * 9] * 90 = 36855 cm^3

Volume of the UCZ = area of cross section (trapezium) * depth of cross section

= [1/2 * (58+50) * 5] * 90 = 24300 cm^3

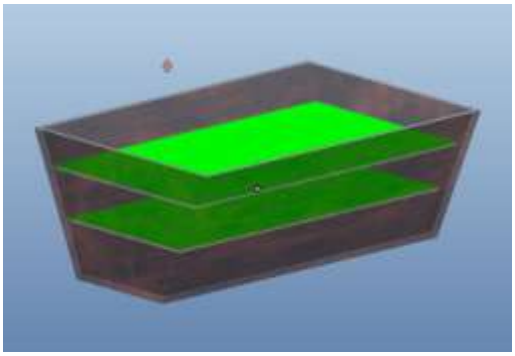

Figure 4 Solar Pond Model on PRO E

2.2 Glass Layer Size

1. Length 87.5 cm and Breadth 41cm
2. Length 87.5 cm and Breadth 50 cm
3. Thickness = 4mm

2.3 Digital Thermometers Position

ST-1A, with simple and small and better appearance adopts micro-computer high performance chip and high precision sensors can switch between ^{o} C and ^{o} F, measure and display the temperature clearly under the circumstances such as refrigerated cabinet, air condition outlet, cold storage, also suitable for aquarium market and household and present action.

Technical Parameters:

Temperature measuring range: -^{o}C~+80^{o}C

Accuracy: $\pm$0.5^{o}C

Resolution: 0.1^{o}C

Size: 55.5x42.5x16 mm^3

Sensors: NTC Sensors 1m long

Power: one button Battery (LR44, 1.5V)

Position of Thermometers-

1. One at the bottom or in HSZ
2. One in the NCZ
3. One in the UCZ
4. One in the atmosphere

2.4 Views of Solar Pond Model

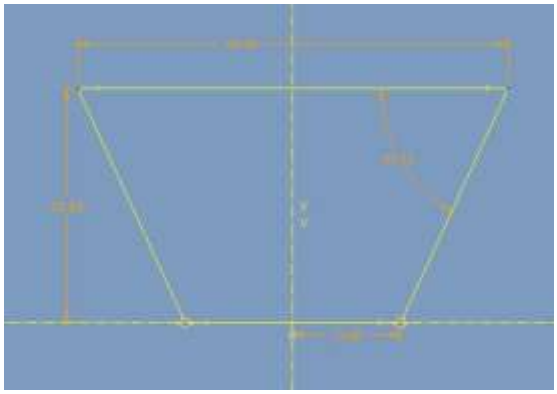

Figure 5 Side View of Solar Pond

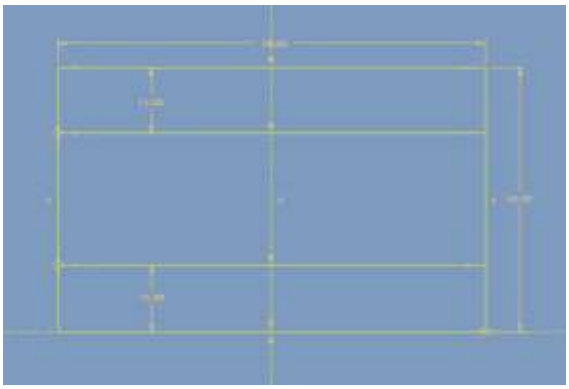

Figure 6 Top View of Solar Pond

III. OBSERVATIONS

The temperatures of the atmosphere and the various zone are calculated in various salinities in the following days with

-no layer

-with fiber layer

-and glass layer

Salt Used- 99.9% NaCl, Sodium Chloride or Simple Salt

Density of salt- 2.17 kg/cm^3

Amount and volume of salt calculated for different salinities

Table 1 Amount and Volume of Salt Calculated

Salinity %	Volume (cm3)	Weight (gms.)
2	**830.7**	**1802.49**
4	**1661.4**	**3605.2**
6	**2492.1**	**5407.85**
8	**3322.8**	**7210.47**
10	**4153.5**	**8974.02**

Day1—11th May 2014, Sunday

The pond was filled at 11:30 am. We took the readings with salinity=2% at HSZ which decreasing towards NCZ and fresh water in UCZ, and used Fiber Layer to separate the zones.

The readings are-

Table 2 Readings of Day 1

Time	Atm.	HSZ	NCZ	UCZ
12:00	**41.8**	**31.4**	**31.3**	**32**
12:20	**42.3**	**31.6**	**31.4**	**31.9**
12:40	**42.9**	**32.3**	**31.8**	**31.9**
1:00	**43.5**	**33**	**32.2**	**31.5**
1:20	**43.1**	**33.7**	**32.6**	**31.1**
1:40	**43.4**	**34**	**32.8**	**31**

2:00	**44.5**	**34.7**	**33.5**	**30.8**
2:20	**43.2**	**35.3**	**34.1**	**30.9**
2:40	**42.9**	**36.2**	**34.9**	**29.8**
3:00	**42.7**	**37.3**	**35.8**	**29.9**
3:20	**42.8**	**38**	**36.7**	**30.2**
3:40	**43.1**	**38.8**	**37.2**	**30.3**
4:00	**42.6**	**39.5**	**37.8**	**29.8**

Maximum temperature of HSZ=39.5

Maximum temperature of UCZ=32

Maximum Atmospheric Temperature=44.5

It is observed from the graph that the temperature of water in UCZ slightly stable which is approx. 5^{o}C less than the normal atmospheric temperature.

The temperature of HSZ is less than that of the atmospheric in this case and no appreciable increase is observed.

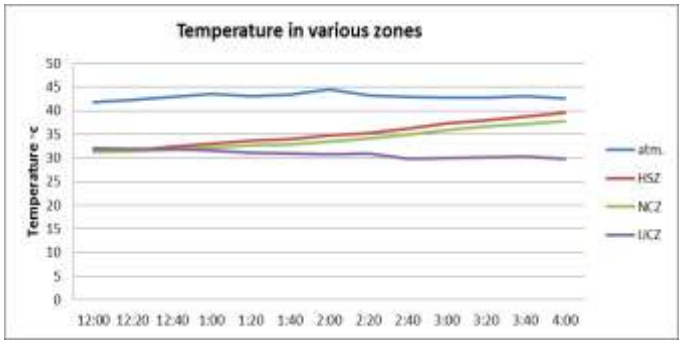

Figure 7. Temperature Variation on 11th May

Day2—12th May 2014, Monday

By examining the previous day's performance of the model, we emptied the pond and again experimented it with an increase of 2% salinity i.e. 4% now. The pond was filled at 11:30 am. The observation of the day were-

Table 3 Readings of Day 2

Time	HSZ	NCZ	UCZ	Atm.
12:00	**33.3**	**31.2**	**31.2**	**31.3**
12:20	**34.1**	**30**	**31.8**	**33.4**
12:40	**34.9**	**30.8**	**32.6**	**33.8**
1:00	**35.7**	**31.2**	**32.4**	**34.8**
1:20	**36.9**	**31.9**	**31.9**	**35.5**
1:40	**37.5**	**32**	**32**	**35**
2:00	**38.1**	**33.9**	**31.7**	**36.1**
2:20	**39**	**34.8**	**32.3**	**37.8**
2:40	**39.7**	**35.1**	**32**	**33.2**
3:00	**40.2**	**35.4**	**31.1**	**35.6**
3:20	**41.1**	**35.9**	**30.6**	**34.8**
3:40	**41.4**	**36.2**	**29.7**	**34.5**
4:00	**41.9**	**36.8**	**29.3**	**34.1**

Maximum temperature of HSZ=41.9

Maximum temperature of UCZ=32.6

Maximum Atmospheric Temperature=37.8

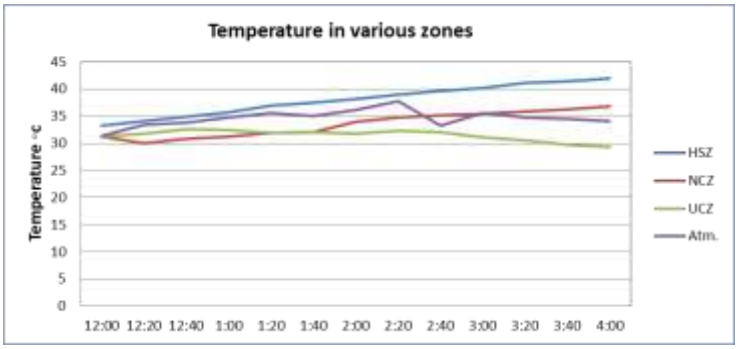

Figure 8. Temperature Variation on 12th May

It is observed from the graph that the temperature of water in UCZ slightly stable which is approx. 5°C less than the normal atmospheric temperature.

We got good results with an appreciable increase in the temperature of HSZ more than that of the atmospheric. The increase of 4.1 °C was observed.

Day3—13th May 2014, Tuesday

The experiment was continued without any changes with the same salinity. The pond absorbed the radiations from early morning. The observation of the day were-

Table 4. Readings of Day 3

Time	HSZ	NCZ	UCZ	Atm.
12:00	33.9	28.2	30.4	34.4
12:20	34.1	29.6	30.1	34.5
12:40	35.2	30.5	29.7	34.7
1:00	35.7	31.1	29.7	32.7
1:20	38.2	32	29.6	33.8
1:40	39.8	32.8	29.8	36.4
2:00	41.4	33.4	29.9	35.7
2:20	41.6	34.1	30	35.3
2:40	42.2	34.6	29.9	35.4
3:00	42.6	34.9	29.7	36.1
3:20	43	35.2	28.9	35.7
3:40	43.8	35.6	29.1	35.3
4:00	44.1	35.8	29	34.6

Maximum temperature of HSZ=44.1

Maximum temperature of UCZ=36.4

Maximum Atmospheric Temperature=37.8

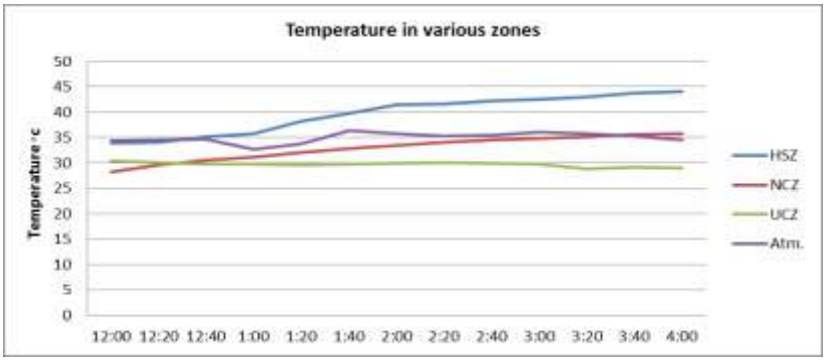

Figure 9. Temperature Variation on 13th May

It is observed from the graph that the temperature of water in UCZ slightly stable which is approx. 5°C less than the normal atmospheric temperature.

We got good results with an appreciable increase in the temperature of HSZ more than that of the atmospheric. The increase of 6.3 °C was observed.

With the fiber layer, we get about 6.3 °C. Now, we proceed with glass layer.

Day4—14th May 2014, Wednesday

On previous day observations were taken with fibre layer. Today, the pond is filled on 11:30 am with 6% saline water in HSZ and salinity decreases towards NCZ upto 2%.

These readings were taken with two glass layers which separated the zones.

Table 5 Readings of Day 4

Time	HSZ	NCZ	UCZ	Atm.
12:20	34.1	29.6	30.1	34.5
12:40	35.2	30.5	29.7	34.7
1:00	35.7	31.1	29.6	32.7
1:20	38.2	32	29.8	33.8
1:40	39.8	32.8	29.9	36.4
2:00	41.4	33.4	30	35.7
2:20	41.6	34.1	29.9	35.3
2:40	42.2	34.6	30	35.4
3:00	42.6	34.9	29.7	36.1
3:20	43	35.2	28.9	35.7
3:40	43.8	35.6	29.1	35.3
4:00	44.1	35.8	29	34.6
4:20	44.8	36	28.2	34.8

Maximum temperature of HSZ=44.8°C

Maximum temperature of UCZ=30.1°C

Maximum Atmospheric Temperature=36.4°C

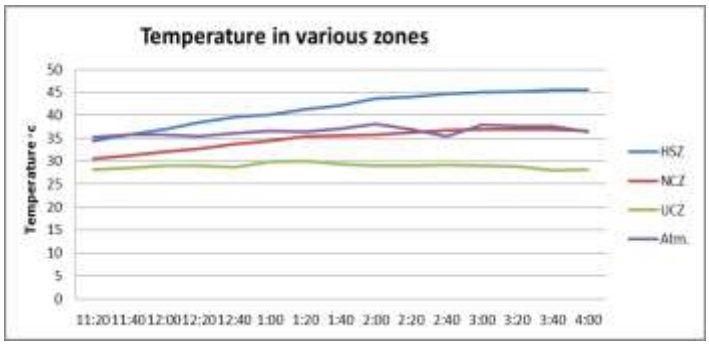

Figure 10. Temperature Variation on 14th May

It is observed from the graph that the temperature of water in UCZ slightly stable which is approx. 5°C less than the normal atmospheric temperature.

We got good results with an appreciable increase in the temperature of HSZ more than that of the atmospheric. The increase of 8.4°C was observed.

With the glass layer, we get about 8.4°C, which is more than that of fibre layer.

Day5—15th May 2014, Thursday

The experiment was continued without any changes with the same salinity. The pond absorbed the radiations from early morning. The observation of the day were-

Table 6. Readings of Day 5

Time	Atm.	UCZ	NCZ	HSZ
11:20	35.3	28.2	30.6	34.5
11:40	35.7	28.5	31.3	35.8
12:00	35.8	29	32	36.9
12:20	35.5	29.1	32.8	38.5
12:40	36.1	28.7	33.8	39.6
1:00	36.7	29.8	34.4	40.1
1:20	36.4	30.1	35.4	41.3
1:40	37.1	29.4	35.6	42.2
2:00	38.1	29	35.8	43.7
2:20	36.9	29.1	36.3	44.1
2:40	35.5	29.2	36.8	44.7
3:00	37.1	29	36.9	45
3:20	37.3	28.9	36.8	45.2
3:40	36.5	29.1	37	45.5
4:00	36.1	28.2	36.6	45.8

Maximum temperature of HSZ=45.8°C

Maximum temperature of UCZ=29.8°C

Maximum Atmospheric Temperature=38.1°C

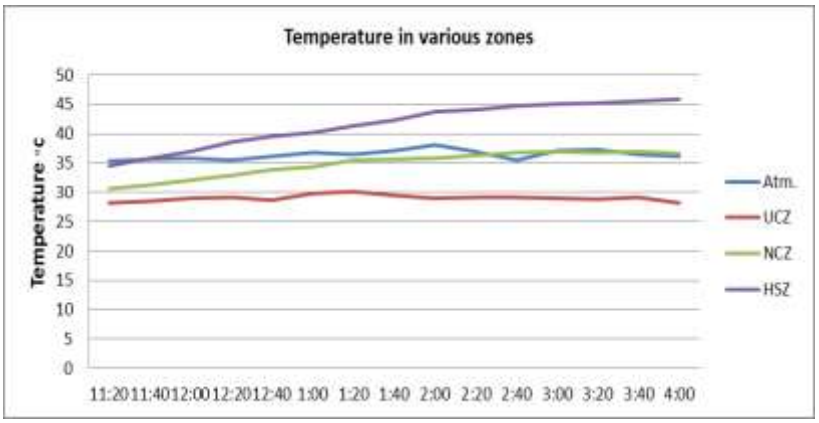

Figure 11 Temperature Variation on 15th May

It is observed from the graph that the temperature of water in UCZ slightly stable which is approx. 5°C less than the normal atmospheric temperature.

We got good results with an appreciable increase in the temperature of HSZ more than that of the atmospheric. The increase of 7.7°C was observed. The maximum temperature of HSZ=45.8°C which is more than previous day.

With the glass layer, we get about 7.7°C, which is more than that of fibre layer.

Day6—16th May 2014, Friday

The experiment was continued without any changes with the same salinity. The pond absorbed the radiations from early morning. The observation of the day were-

Table 7. Readings of Day 6

Time	Atm.	UCZ	NCZ	HSZ
12:00	35.2	29.8	30.6	38.2
12:20	37.4	29.9	31.2	39.9
12:40	38.1	30.2	31.9	40.8
1:00	38.5	29.9	32.8	41.5
1:20	37.9	29.8	33.4	42.4
1:40	39.9	31.2	33.9	43.6
2:00	38.9	31.1	34.7	44.2
2:20	38.5	30.5	35.4	45.1
2:40	37.1	31.2	36.1	45.8
3:00	37	29.9	37.2	47
3:20	37.2	30	37.9	47.9
3:40	36.8	29.8	38.4	48.2
4:00	36.2	29.7	38.2	48.6

Maximum temperature of HSZ=48.6°C

Maximum temperature of UCZ=31.2°C

Maximum Atmospheric Temperature=39.9°C

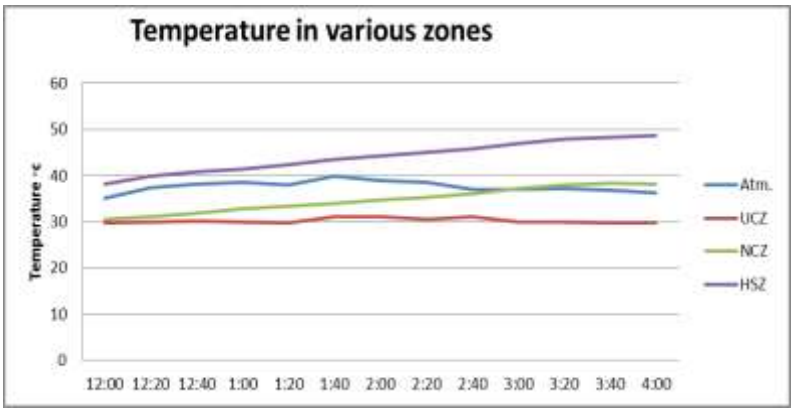

Figure 12. Temperature Variation on 16th May

The graph shows that the maximum atmospheric temperature=39.9^{O}C is increased so there was a maximum temperature of HSZ was about 48.6^{o}C and appreciable increase of 8.7^{O}C. the temperature of UCZ just remains almost same but the temperature in HSZ increases regularly.

Day7—03rd June 2014, Tuesday

After performing the experiment with the glass layer, we decided to do the comparison with no separation layer. The solar pond was filled with 4% saline water at 11:00 am. A glass layer was put on the top of the solar pond to prevent from dust and wind.

Table 8. Readings of Day 7

Time	HSZ	UCZ	Atm.
12:00	34.5	35.2	42.8
12:20	35.1	35.8	42.6
12:40	36.1	36.4	42.9
1:00	37.1	37.5	43.1
1:20	37.9	38.3	42.8
1:40	38.8	39.2	42.5
2:00	39.5	40	42.1
2:20	40.3	41.6	42.3
2:40	40.9	41.9	42.2
3:00	41.5	42.2	41.9
3:20	42	42.5	42.3
3:40	43.1	42.8	42.1
4:00	43.8	43.1	42.2

Maximum temperature of HSZ=43.8^{o}C

Maximum temperature of UCZ=43.1^{O}C

Maximum Atmospheric Temperature=43.1^{O}C

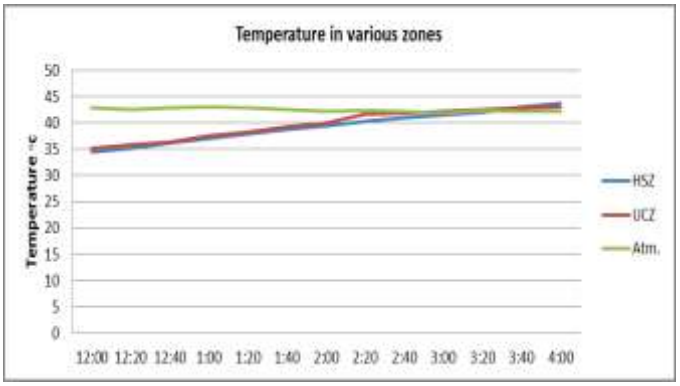

Figure 13. Temperature Variation of 3rd June

The graph shows that in the earlier as pond was started then atmospheric temperature is higher than the UCZ and HSZ but as time spent then temperature pond was increased at last it was equal to the atmospheric temperature.

Without layer the water absorbing the power but there was loss of heat so there is no appreciable rise in comparison with layers.

Day8—04th June 2014, Wednesday

The experiment was continued without any changes with the same salinity. The pond absorbed the radiations from early morning. The observation of the day were-

Table 9. Readings of Day 8

Time	Atm.	HSZ	UCZ
12:00	46.5	47.9	49.8
12:20	46.9	48.1	50.1
12:40	47	48.7	50.3
1:00	47.4	49.3	50.5
1:20	46.9	49.6	50.7
1:40	46.5	50.1	50.8
2:00	46.4	50.5	51
2:20	46.1	51.1	51.3
2:40	46	51.4	51.6
3:00	45.8	52	51.7
3:20	45.6	52.2	52
3:40	45.7	52.3	52.1
4:00	45.4	52.5	52.2

Maximum temperature of HSZ=52.5^{o}C

Maximum temperature of UCZ=52.2^{O}C

Maximum Atmospheric Temperature=47.4^{O}C

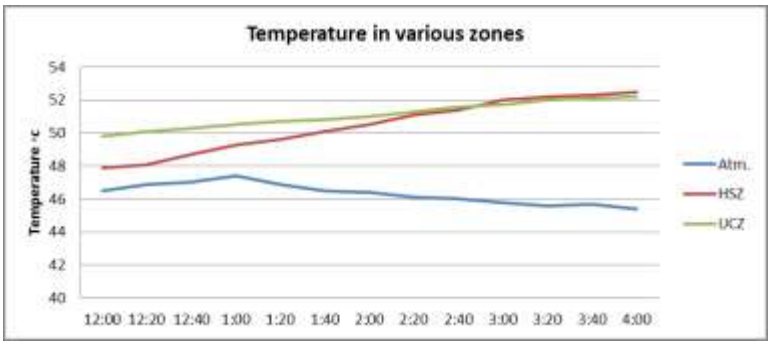

Figure 14. Temperature Variation of 4th June

As on this day process was continued from yesterday so the radiation were absorbed from early morning and so the temperature was more of the HSZ is more than the atmospheric.

But this rise is also low than as in case of glass layers or fiber layers.

IV. CONCLUSION

The results of the experiment show the problems and the possibilities of a membrane stratified solar pond and solar ponds in general.

The pond temperatures have been above the ambient temperature almost all the time but as soon as the irradiation decreases, the losses dominate the pond's performance and therefore limit the temperatures at a level some degrees over ambient temperature. The side walls are coupled with wind effects too, but due to the good insulation this effect is less marked here.

We performed the experiment with three types of pond –

-no layer

-with fiber layer

-with glass layer

We conclude that the performance of membrane stratified solar pond is much better than the other type of solar ponds.

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