Designing of Portable Solar Pond for Improved Efficiency

Jobanputra Deepak P.
Department of Mechanical Engineering
Parul Institute of Engineering and Technology

Asst. Prof. Vishal Jain
Assistant Professor
Department of Mechanical Engineering
Parul Institute of Engineering and Technology

Asst. Prof. Rankit Patel
Assistant Professor
Department of Mechanical Engineering
Parul Institute of Engineering and Technology

Abstract

Solar pond is one of the most economical and easily constructed device for harvesting solar radiation to meet the present crisis of energy hungry world solar energy is the only means to satisfy the present need. Numbers of method are available to harness the solar energy; solar pond is one of such method. However at present the limited use of solar pond is due to low temperature availability of stored energy, much more efforts and experimentation are needed to find out various alternate solutions for making solar pond more efficient and usable. Since large pond requires much more expenses and up keeping. A portable solar pond can be easily made and can be rigged up to conduct various experiments to find out the best answer for some of the performance parameter for solar pond.This paper deals with design, construction and application of a portable laboratory model of solar pond. The model can be used for various experiments in the laboratory and conduct research work.
Keywords: Solar Pond, Salt Gradient, UCZ, NCZ, LCZ

I. INTRODUCTION

A solar pond is a large reservoir of saline water, with the difference that a specific salinity (or density) profile is artificially created and maintained in the pond. A salinity-gradient solar pond (SGSP) is a body of water that collects and stores solar energy. A typical salinity-gradient solar pond has three regions: surface zone, main gradient zone, and bottom zone (figure 1). The surface zone, also called the upper convective zone (UCZ) is a homogeneous layer of low-salinity brine or fresh water. The bottom zone, also called the lower convective zone (LCZ) or storage zone, is a homogeneous layer of concentrated salt solution. Between the surface and bottom zones is the main gradient zone, which contains positive salinity and density gradients with depth and serves as a transparent insulating layer. Since there is no convection in the main gradient zone, the gradient zone is also called the non-convective zone (NCZ). Solar energy is collected and accumulated in the LCZ causing the temperature to increase. The insulating properties of the gradient zone, combined with the high heat capacity and large volume of water make the solar pond both a solar thermal collector and a long-term thermal storage device. There are many solar ponds thermal energy storage schemes are already operating very successfully and several new systems are being constructed. The aim of the current report shows the design and operation of laboratory model of solar pond to be constructed and used for various experimental setups.

A. Principle of Solar Pond:

In a clear natural pond about 30% solar radiations reaches a depth of 2 metres. This solar radiation is absorbed at the bottom of the pond. The hotter water at the bottom becomes lighter and hence rises to the surface. Here it loses heat to the ambient air and, hence, a natural pond does not attain temperatures much above the ambient. If some mechanism can be devised to prevent the mixing between the upper and lower layers of a pond, then the temperatures of the lower layers will be higher than of the upper layers. This can be achieved in several ways. The simplest method is to make the lower layer denser than the upper layer by adding salt in the lower layers. The salt used is generally sodium chloride or magnesium chloride because of their low cost. Ponds using salts to stabilize the lower layers are called 'salinity gradient ponds'. Typical temperature and density profiles in a large salinity gradient solar pond are shown in figure 1. We find that there are three distinct zones in a solar pond. The lower mixed zone has the highest temperature and density and is the region where solar radiation is absorbed and stored. The upper mixed zone has the lowest temperature and density. This zone is mixed by surface winds, evaporation and nocturnal cooling. The intermediate zone is called the non convective zone (or the gradient zone) because no convection occurs here. Temperature and density decrease from the bottom to the top in this layer, and it acts as a transparent insulator. It permits solar radiation to pass through but reduces the heat loss from the hot lower convective zone to the cold upper convective zone. Heat transfer through this zone is by conduction only.

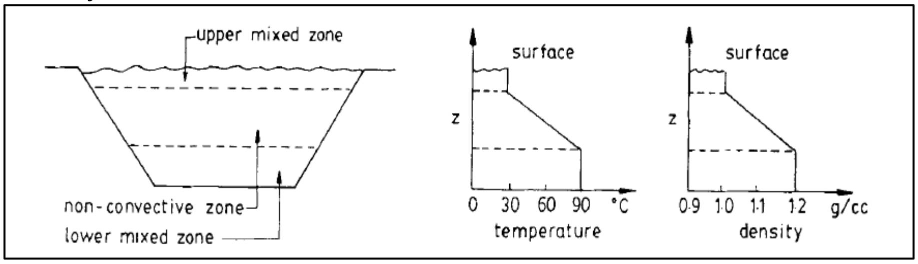

Fig. 1: Principle of Solar Pond (Three Zones of Solar Pond and Salt Gradient)

II. DESIGNING PORTABLE EXPERIMENTAL SET UP OF SOLAR POND

The portable mini solar pond to be designed and constructed is having following main parts.

1) Main body
2) Solar pond stand
3) Reflectors
4) Absorbing surface
5) Insulating material

Design and construction of each are discussed as under:

A. Main Body: Main Solar Pond Body Material

The main body can be constructed from any of the following materials.
M.S. Sheet 1.6 mm thick (16 S.W.G.), Non corrosive stainless steel, Aluminium sheet of 2 mm thick, Plastic sheet etc.
The above material must be coated with anti corrosive paint preferably black to achieve the absorption of sun radiation.
Size and shape: Size of the pond should be about 1 m length and breadth or 1 m diameter having depth of 50 to 60 cm, so that it can be handled and positioned easily at desired location. Shape may be Square, Rectangular

Cylindrical, Conical, Truncated inverted cone /pyramid, though cylindrical shape is better but inverted square pyramid with enlarged heat storage can be easy to fabricate, hence, in this paper the figure shows such design to be used for the experimental model.

B. Solar Pond Stand:

The solar pond stand can be constructed from M.S.Angle of 35 mm size as shown in the figure. The size and shape depends upon the size and shape of main solar pond body. However the size should be such that it should sustain the weight of the solar body and weight of the water / brine. In this design we have selected inverted square pyramid with enlarge heat storage area which will carry about 250 kg maximum. The body should be appropriately strengthened to avoid distortion. The height of the stand should be such that when main body of solar pond is installed on the stand at least 20 cm clearance at bottom of solar pond and ground level should be maintained. In this design as mentioned earlier inverted square pyramid design is discussed hence four legged stand is appropriate and easy to fabricate. Four robust casters should be fixed at the end of each leg to facilitate moving and orientation of solar pond.

C. Reflectors:

Any of the following materials can be used for reflecting surface. Mirror, Stainless steel sheet, Bright aluminium sheet, Plastic sheet with any reflecting foil.

1) Size of the reflectors: The height of the reflector should not be more than 1/3 length or diameter in height otherwise the main concept of catching reflection in morning and evening will not be achieved.
2) As previously mentioned in the shape of solar pond though the conical and cylindrical shape is better but arranging the reflectors on such solar pond is difficult and costly. For this design we have therefore selected rectangular reflector on square inverted pyramid solar pond body.
3) In conical shape solar pond body circular reflector should be designed. In case of present device (square inverted pyramid) we have used 2 reflectors opposite to each other to absorb the morning and evening sun rays, if solar pond is kept in constant position throughout the experiment. However the reflector may be kept side by side but in that case positioning of solar pond is needed during morning and evening.

D. Absorbing Surface:

Material used for absorbing can be Plastic transparent black, Gel, Film coated glass sheet etc. The main purpose of absorbing surface is to absorb the incident solar radiation but it also prevents heat loss due to evaporation, ambient air disturbance and atmospheric contamination.

E. Insulating Material:

The solar pond stores the solar energy in the LCZ water solution while solar incidence is available and can be used simultaneously or later. Heat loss through side walls and bottom is one of the main concern fortunately there are many insulating materials such as Glass wool, Foam, Wooden material Wooden flour, Chemical compounds etc.

III. SET UP PROCEDURE

Prior to setup procedure two important procedure must be carried out, first covering the inside and outside of solar body with anti corrosive paint. Also the application of insulation to the solar pond sides and bottom depends upon types of insulating material. In case of glass wool type insulation the glass wool may be glued to the metallic surface and properly tied with surface to prevent peeling up the insulation. For this purpose metallic or plastic mesh may be used which should be wound round with the help of steel wire. The reflectors may be kept at any angle; however vertical position is more efficient.

A. Preparation Of Brine:

The preparation of brine solution is carried out in three stages. For this purpose as far as possible uncontaminated filter water of about 300 litres are needed. In first phase about 10 litres of concentrated brine solution having a salinity of 20 % is prepared. This solution is for bottom most part i.e. LCZ. In second phase gradient zone brine solution is prepared taking about 100 to 150 litres of water. This is for NCZ zone. In third phase almost pure water is kept aside. Due to ambient temperature dissolving salt in water may create some difficulty. For this purpose warm water may be used for dissolving salt.

B. Filling Up of Pond:

Filling the pond is ticklish method though concentrated brine solution can be poured without any difficulty but low concentrated brine solution on the top of LCZ requires time and patience. For this purpose funnel or plastic tube may be used in such a way that the end of funnel tube should be on the top of LCZ surface, and very gradually solution should be poured in funnel so that minimum disturbance occurs. When the pond is filled up to the surface of NCZ level the remaining portion of solar pond which is UCZ is again carefully filled up by pure water. This way solar pond is filled u in three zones.

C. Maturation of Solar Pond:

Once the solar pond is fully filled up it has two phases, First maturation period and second matured period. Time of maturation depends upon the quantity of total capacity of solar pond. However it may lose about 10 days to create three independent zones i.e. UCZ, NCZ and LCZ. During the maturation period care should be taken so that no disturbance occurs. While filling up, solar pond should be located at desired place and appropriate position.

During the maturation period due to ambient temperature and atmospheric condition may disturb the three zones. Evaporation and contamination is the major issue when solar pond is exposed. Therefore the top of solar pond should be covered by transparent plastic or glass. After about 10 days the solar pond brine solution is matured and ready for conducting experiment.

D. Instrumentation:

Observation data usually requires automatic digital temperature recorder for the measurement of various temperature. Probes may be needed and should be procured. Sextant, ordinary thermometer and specific gravity instrument is also needed depending upon types of experiment.

E. Location and Positioning:

The location and positioning is very important depending upon geographical situation of place where the experimentation is to be carried out. As far as possible the location should be selected so that maximum sun exposure is available. In laboratory it should be on the terrace.

IV. CARE AND MAINTENANCE

Salt solution is highly corrosive for any metallic material. Therefore prior to use all the metallic components should be properly coloured with anti corrosive black paint. Contamination should be prevented and evaporation loss can be substantial frequently. During long term use there is a possibility of salt precipitation due to ambient temperature. Never try to remove the solidify salt from the bottom zone when experimentation is carried out. If the solar pond is not to be used for long period of time it must be emptied to prevent the corrosive effect on solar pond body at bottom.

V. APPLICATION OF EXPERIMENTAL SOLAR POND MODEL

The laboratory model of solar pond can be used for study and evaluation of various performance parameters of solar pond. Some of which are listed below.

1) To study the effectiveness of various heat absorbing transparent surfaces.
2) To study the size and material effectiveness of reflectors.
3) Effectiveness of insulating material for walls and bottom.
4) Effectiveness of fixed and adjustable reflector.
5) Day to day heat absorption.
6) Heat gained as per climate.
7) Various heat losses of stored energy.
8) Performance effectiveness of solar pond throughout the year.
9) Capacity of heat extraction.

VI. PROTOTYPE DESIGN

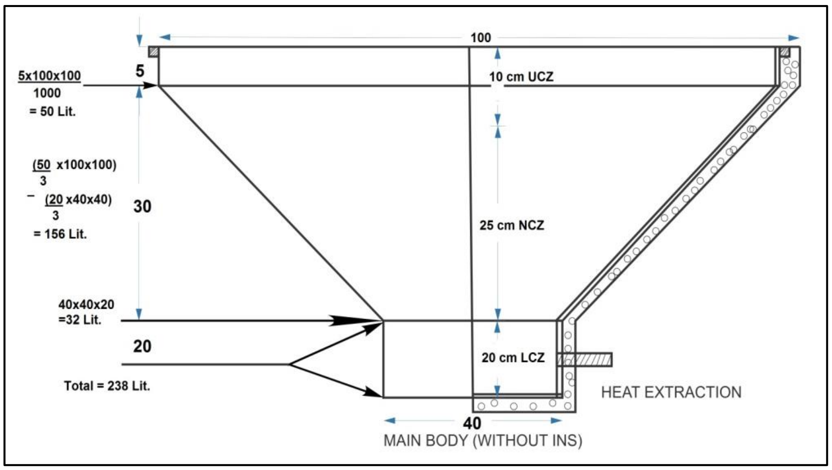

Fig. 2: Elevation View of Solar Pond

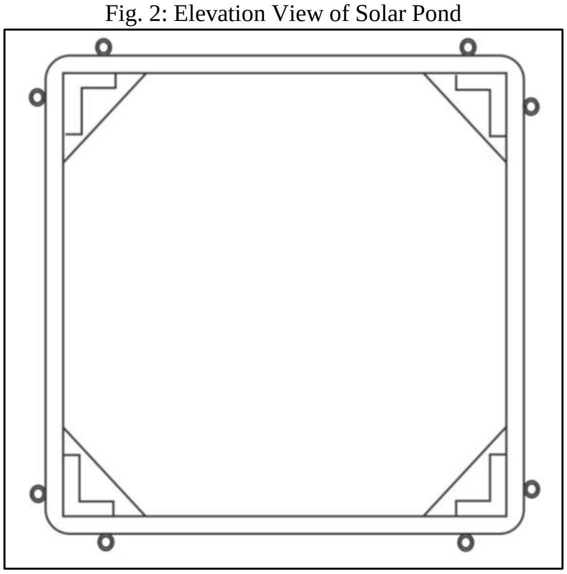

Figure: 3 Plan View of Solar Pond

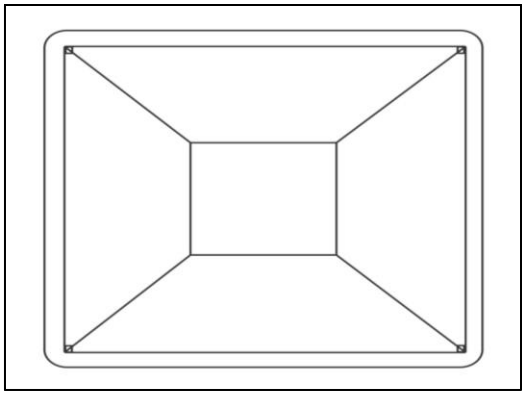

Fig. 4: Stand of Solar Pond

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