International Journal of Students Research in Technology & Management
Vol 1(2), April 2013, pg 156-162

NON CONVENTIONAL ENERGY SOURCES: SOLAR POND

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Abstract

The sun is the largest source of renewable energy and this energy is abundantly available in all parts of the earth. It is in fact one of the best alternatives to the non-renewable sources of energy. One way to tap solar energy is through the use of solar ponds. Solar ponds are large-scale energy collectors with integral heat storage for supplying thermal energy. It can be use for various applications, such as process heating, water desalination, refrigeration, drying and power generation. The solar pond works on a very simple principle. It is well-known that water or air is heated they become lighter and rise upward e.g. a hot air balloon. Similarly, in an ordinary pond, the sun's rays heat the water and the heated water from within the pond rises and reaches the top but loses the heat into the atmosphere. The net result is that the pond water remains at the atmospheric temperature. The solar pond restricts this tendency by dissolving salt in the bottom layer of the pond making it too heavy to rise. Though solar ponds can be constructed anywhere, it is economical to construct them at places where there is low cost salt and bittern, good supply of sea water or water for filling and flushing, high solar radiation, and availability of land at low cost.

Keywords- Solar thermal energy, Convecting Solar Ponds, Nonconvecting Solar Ponds, Salinity gradient**,** Desalination

I. INTRODUCTION

A solar pond is simply a pool of saltwater which collects and stores solar thermal energy. The saltwater naturally forms a vertical salinity gradient also known as a "halocline", in which low-salinity water floats on top of high-salinity water. The layers of salt solutions increase in concentration (and therefore density) with depth. Below a certain depth, the solution has a uniformly high salt concentration. There are 3 distinct layers of water in the pond:

- The top layer, which has a low salt content.
- An intermediate insulating layer with a salt gradient, which establishes a density gradient that prevents heat exchange by natural convection.
- The bottom layer, which has a high salt content.

If the water is relatively translucent, and the pond's bottom has high optical absorption, then nearly all of the incident solar radiation (sunlight) will go into heating the bottom layer.

When solar energy is absorbed in the water, its temperature increases causing thermal expansion and reduced density. If the water were fresh, the low-density warm water would float to the surface, causing convection current. The temperature gradient alone causes a density gradient that *decreases* with depth. However the salinity gradient forms a density gradient that *increases* with depth, and this counteracts the temperature gradient, thus preventing heat in the lower layers from moving upwards by convection and leaving the pond. This means that the temperature at the bottom of the pond will rise to over 90°C while the temperature at the top of the pond is usually around 30 °C. A natural example of these effects in a saline water body is Solar Lake in the Sinai Peninsula of Egypt.

The heat trapped in the salty bottom layer can be used for many different purposes, such as the heating of buildings or industrial hot water or to drive an organic Rankine cycle turbine or Stirling engine for generating electricity.

II. TYPES OF SOLAR PONDS

There are two main categories of solar ponds:

- nonconvecting ponds, which reduce heat loss by preventing convection from occurring within the pond; and
- convecting ponds, which reduce heat loss by hindering evaporation with a cover over the surface of the pond.

A. Convectıng Solar Ponds:

A well-researched example of a convecting pond is the shallow solar pond. This pond consists of pure water enclosed in a large bag that allows convection but hinders evaporation. The bag has a blackened bottom, has foam insulation below, and two types of glazing (sheets of plastic or glass) on top. The sun heats the water in the bag during the day. At night the hot water is pumped into a large heat storage tank to minimize heat loss. Excessive heat loss when pumping the hot water to the storage tank has limited the development of shallow solar ponds.

Another type of convecting pond is the deep, saltless pond. This convecting pond differs from shallow solar ponds only in that the water need not be pumped in and out of storage. Double-glazing covers deep saltless ponds. At night, or when solar energy is not available, placing insulation on top of the glazing reduces heat loss.

B. Nonconvectıng Solar Ponds:

There are two main types of nonconvecting ponds: salt gradient ponds and membrane ponds. A salt gradient pond has three distinct layers of brine (a mixture of salt and water) of varying concentrations.

Because the density of the brine increases with salt concentration, the most concentrated layer forms at the bottom. The least concentrated layer is at the surface. The salts commonly used are sodium chloride and magnesium chloride. A dark-colored material usually butyl rubber lines the pond. The dark lining enhances absorption of the sun's radiation and prevents the salt from contaminating the surrounding soil and groundwater. As sunlight enters the pond, the water and the lining absorb the solar radiation. As a result, the water near the bottom of the pond becomes warm up to 93.3°C. Although all of the layers store some heat, the bottom layer stores the most. Even when it becomes warm, the bottom layer remains denser than the upper layers, thus inhibiting convection. Pumping the brine through an external heat exchanger or an evaporator removes the heat from this bottom layer. Another method of heat removal is to extract heat with a heat transfer fluid as it is pumped through a heat exchanger placed on the bottom of the pond.

Another type of nonconvecting pond, the membrane pond, inhibits convection by physically separating the layers with thin transparent membranes. As with salt gradient ponds, heat is removed from the bottom layer. In figure 2 you can see an example of salt gradient solar pond.

Fig. 1 Salt Gradient Solar Pond.

III. ADVANTAGES AND DISADVANTAGES

- The approach is particularly attractive for rural areas in developing countries. Very large area collectors can be set up for just the cost of the clay or plastic pond liner.
- The evaporated surface water needs to be constantly replenished.
- The accumulating salt crystals have to be removed and can be both a valuable by-product and a maintenance expense.
- No need of a separate collector for this thermal storage system.

IV. APPLICATIONS

- Salt production (for enhanced evaporation or purification of salt, that is production of ‘vacuum quality’ salt)

- Aquaculture, using saline or fresh water (to grow, for example, fish or brine shrimp)
- Dairy industry (for example, to preheat feed water to boilers)
- Fruit and vegetable canning industry
- Fruit and vegetable drying (for example, vine fruit drying)
- Grain industry (for grain drying) Water supply (for desalination)
- **Process heat**

Studies have indicated that there is excellent scope for process heat applications (i.e. water heated to 80 to 90° C.), when a large quantity of hot water is required, such as textile processing and dairy industries. Hot air for industrial uses such as drying agricultural produce, timber, fish and chemicals and space heating are other possible applications.

- **Desalination**

Drinking water is a chronic problem for many villages in India. In remote coastal villages where seawater is available, solar ponds can provide a cost-effective solution to the potable drinking water problem. Desalination costs in these places work out to be 7.5paise per litre, which compares favourably with the current costs incurred in the reverse osmosis or electrodialysis/desalination process.

- **Refrigeration**

Refrigeration applications have a tremendous scope in a tropical country like India. Perishable products like agricultural produce and life saving drugs like vaccines can be preserved for long stretches of time in cold storage using solar pond technology in conjunction with ammonia based absorption refrigeration system.

V. EXAMPLES OF SOLAR PONDS

- Bhuj Solar Pond
- El paso Solar Pond
- Pyramid Hill Solar Pond

A. Bhuj Solar Pond

The 6000-square-metre solar pond in Bhuj, the first large-scale pond in industrial environment to cater to actual user demand, supplied totally about 15 million litres of hot water to the dairy at an average temperature of 75°C between September 1993 and April 1995. In figure 3 you can see the Bhuj solar pond.

Fig. 2 The Bhuj Solar Pond.

It was the first experiment in India, which successfully demonstrated the use of a solar pond to supply heat to an actual industrial user. But, sadly, the Bhuj solar pond, constructed by the Tata Energy Research Institute (TERI), today lies in disuse for want of financial support and government policy to help this eco-friendly technology grow.

The Bhuj solar pond was conceived as a research and development project of TERI, which took over nine years to establish, to demonstrate the feasibility of using a salt gradient pond for industrial heating.

The solar pond is 100 m long and 60 m wide and has a depth of 3.5 m. The pond was then filled with water and 4000 tonnes of common salt was dissolved in it to make dense brine.

B. El Paso Solar Pond:

The El Paso Solar Pond project is a research, development, and demonstration project initiated by the University of Texas at El Paso in 1983. It has operated since May 1986 and has successfully shown that process heat, electricity, and fresh water can be produced in the southwestern United States using solar pond technology.

Fig. 4 El Paso Solar Pond.

The El Paso Solar Pond project began when the University of Texas at El Paso discovered an existing pond which has a 3350 square meter area and 3 meter depth located at Bruce Foods, a canning plant in northeast El Paso, Texas. In figure 5 you can see another view of El Paso Solar Pond.

Fig. 5 Closer View of El Paso Solar Pond.

Over 90 graduate and undergraduate students have been involved in the project, performing tasks ranging from construction to applied research. In addition, numerous students have done projects related to the pond, gaining valuable experience in equipment design and construction, lab techniques, problem solving, instrumentation, and documentation.

The solar pond provides a unique opportunity to do research in such areas as double diffusive convection, wind/wave interaction, flow in stratified fluids, and computer modeling. In addition, the state of the art equipment on site provides an excellent opportunity for energy efficiency studies, cost analysis, system studies, heat exchanger.

C. Pyramid Hill Solar Pond:

A consortium of RMIT University, Geo-Eng Australia Pty Ltd and Pyramid Salt Pty Ltd has completed a project using a 3000 square metre solar pond located at the Pyramid Hill salt works in northern Victoria to capture and store solar energy using pond water which can reach up to 80°C. In Figure 6 you can see the picture of this solar pond.

Fig. 6 The Pyramid Hill Solar Pond.

Pyramid Salt will use the pond's heat not only in its commercial salt production but also for aquaculture, specifically producing brine shrimps for stock feed. It is planned in a subsequent stage of the project to generate electricity using the heat stored in the solar pond, thus making this local industry more energy self-sufficient.

At the local level this will be a significant boost in an area with high unemployment and a depressed economy.

VI. COST OF SOLAR PONDS

As technology develops, the energy needs of communities increases. This energy need is provided from different energy sources known as traditional energy sources, such as coal, fuel oils, geothermal energy, hydraulic energy, and nuclear energy. These energy sources have some disadvantages. The first three of these energy sources have limited life times. Hydraulic energy is an insufficient energy source, and nuclear energy has some unsolved environmental and safety problems. Therefore, the researchers have condensed their studies on new alternative energy sources known as renewable energy sources.

These are biomass, biogas, wind energy, wave energy, hydrogen energy, and solar energy.

Solar energy among these energy sources is the most abundant and considerable research is being carried out in this area. In figure 7 you can see a table which is comparing initial costs of different water heating systems.

Table 1. The initial costs of different water heating systems (1991 prices).

System	Price (TL)	Additional expenses (TL)	Total (TL)
Flat-plate collectors(*)	1 388 280	874 566	2 262 846
Solar ponds (insulated)	832 000	400 000	1 232 000
Electric geyser	280 000	125 000	405 000
LPG geyser	830 000	250 000	1 080 000
Electric thermosiphon	800 000	150 000	950 000
Kerosene geyser	500 000	75 000	575 000
Thermosiphon (**)	365 000	75 000	440 000

(*) naturally circulated systems (**) the systems using coal, lignite, or wood

Fig. 7 The Initial Costs of Several Water Heating Systems (1991 prices).

Salinity gradient solar ponds, although not dramatically cheaper than other disposal methods, may still be a viable option especially in circumstances where the unit cost of power is very high or where access to a power grid is limited. Moreover, the actual cost of utilizing SGSPs may be lower than reported when other factors are taken into account, such as savings incurred by bypassing the waste disposal permitting process, the environmental savings associated with using a renewable fuel, or tax breaks that may be developed for facilities that use renewable fuels.

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