



363 - Thermal Energy Production by a Dual Solar Pond

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Abstract

A Salt Gradient Solar Pond (SGSP) is a salt water basin that collects and stores solar energy. These devices rely on the existence of a non-convective zone (NCZ) that functions as a transparent thermal insulation zone, created by a salt gradient. Salinity and temperature gradients in this zone can give rise to double diffusive problems that can decrease the insulation properties of this zone.

The stability of this zone is thus crucial in a SGSP.

Stability control, analysis of energy extraction, device efficiency and maintenance strategies are determinant for the correct performance of the SGSP. The implementation of these strategies can be expensive and not sufficient to prevent instability problems. This paper intends to give a contribution to the maintenance problem presenting a new concept of a SGSP utilisation: The Dual Solar Pond (DSP)

Keywords: Solar Pond, stability, maintenance.

1. Introduction

A Solar Pond is a salt water basin that collects and stores solar thermal energy. These devices are based on the prevention of free convection, either by increasing the solution's viscosity, or by the establishment of a salinity gradient that opposes the adverse temperature gradient, induced by solar radiation absorption. Most existing Solar Ponds are based on this last type. The working of a Salt Gradient Solar Pond settles in the stability of its non convective zone, where salinity and temperature gradients are established and where physical instabilities may occur as a result of double diffusion phenomena. There are several models that analyse the behaviour of this zone. These models allow the control and prevention of any perturbations capable of triggering an instability process. For the study here presented it will be considered a simplified structure of a SGSP with two zones: the gradient non convective zone (NCZ) and the storage zone (SZ) as it is depicted in Figure 1. It was considered that the Storage Zone is nearly saturation in terms of concentration (25 % in salt) and that the top of the gradient zone has a concentration near of that of sea water (3%).

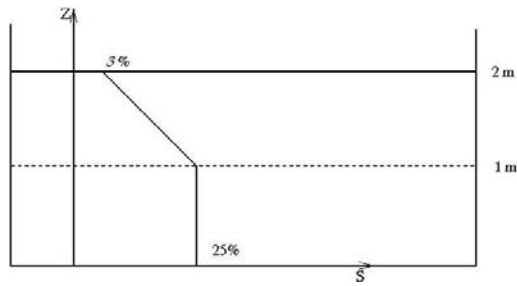


Fig.1. Simplified structure of a Solar Pond

Presently Solar Pond studies focus on stability control of the non convective zone, analysis of energy extraction, device efficiency and maintenance strategies as in the works of [1], [2], [3], [4], [5], [6] and others.

Applications of Solar Ponds are very important especially for Mediterranean countries and go from greenhouse or livestock structures heating, aquaculture heating, salt purification and water desalination processes and even electricity production, using Rankine cycle engines. All these applications are an opportunity to economic development of near coast regions using local resources (seawater, salt and solar energy) and promoting employment. Concerning environment these solar applications could achieve an integrated way to the mitigation of GEE with low environmental impacts.

2. Maintenance and Implementation of Solar Ponds

A SGSP collects and stores solar energy all over the year being the storage zone designed in a way that the summer stored energy can be used during winter [7]. Temperatures in the Storage Zone can range from some degrees above ambient temperature to values reaching 100 °C , depending on the Solar radiation available in the region and on the design of the storage zone and thus are appropriated for a wide range of applications. In this work we will focus in Aquaculture facilities.

In fact, the decrease of natural catches and the increase of fish demand as a food source, led to a growing interest in intensive aquaculture. In Portugal, Aquaculture growth, in the last decade, with an hundred farms providing 5% of the total consumed fish. Portugal is also the European country with largest per capita consumption and one of the highest in the world, with an annual average consumption of 60 kg/person.

In order to build a Solar Pond the basic conditions are the union of three factors: good solar irradiation good access to salt (typically NaCl but other available salts can be used) and existence of water. In the presence of these conditions the initial cost of construction evolves basically: excavation and waterproofing of a basin and the installation of some kind of heat extraction device. In a second phase the pond must be monitored making it possible to measure salinity and temperature gradients and the state of the Pond in terms of transparency to solar radiation. Those measurements will allow to predict the beginning of instabilities in the gradient zone allowing consequently its reposition. It may be referred that the basic destabilizing process in the gradient zone is the diffusion of salt which is a very slow process which in fact is the reason why solar ponds actually work. However the presence of the opposing temperature gradient can give rise to double diffusive instabilities and from time to time maintenance operations are necessary to correct the salinity gradient to values well above the critical values for the start of instabilities [8].

These corrections can be the extraction of a higher quantity of thermal energy from the storage zone, if the temperature achieved by the Solar Pond is higher than a known value, the injection of salt if the initial imposed profile is getting smooth, as a consequence of the diffusion process or of any convective instability, the injection of low concentration water on top of the gradient zone in the case of the existence of great losses by evaporation and the introduction of wind suppressors at surface, in the case of the existence of wind ripple at the surface [9].

If only the salt diffusion process was involved as a destabilizing process in a SGSP the expected lifetime of these devices without maintenance would be around ten years. However the above mentioned double diffusion instabilities and also the gradual decrease of transparency lead to the necessity of maintenance of the pond at least two times a year.

The idea behind this paper is to propose a different concept for the maintenance of a solar pond making maintenance operations simple standardized and with an annual periodicity.

3. Dual Solar Pond Concept (DSP)

3.1. How it works

The concept of a Dual Solar Pond (DSP) settles in the existence of two ponds one near the other that can work alternatively. They will be used as Solar Ponds at different times. In this paper we will consider the use of unused marine salt works for building the ponds, and we will consider a pond with a medium size SZ of 1 m and a NCZ of 1 m making a pond with a total depth of 2 m which is relatively easy to build in old marine salt works.

The single operation consists in create the gradient zone in order to establish the pretended NCZ. With these dimensions a simulation made with the parametric model presented in [7] points to a 21 days start up. For the same conditions but with a deeper SZ (3m), a conventional pond will need about 57 days. During the following months the DSP will work without maintenance until its NCZ degradation. Some time before the second marine salt work must be prepared to run as a Solar Pond. All this is shown in Figure 5.

Then DSP concept consists in recovering traditional marine salt works that will act as two alternating Solar Pond basins. When the first one begins the extraction energy mode the other is at stand by. When the first begins to have instability problems the second needs to be built in. In this way Solar Pond monitoring results to be very simplified. One must only predict when a Pond undergoing instability (not acting more as a Solar Pond) in order to begin, with same advance, to fill the other marine salt work .

The present work shows how to make this prediction concerning the dynamics of the whole process, including energy extraction to Aquaculture applications.

3.2 Performance

For a wide range of Aquaculture facilities operational temperature must be 24°C during winter. This section shows the simulation for a Solar Pond with a 1000 m² area and 2 m depth, considering that variables ambient temperature, energy extraction and solar radiation at surface are sinusoidal like in the work presented in [7].

In order to a better knowledge of the simulation we consider two years of Pond performance even operational DSP will be operated at an annual periodicity basis. Energy extraction will be the important criteria to achieve the temperature level of the SZ.

For an example application in the Portuguese west coast (Lat 38N) which leads to the ambient temperature presented in model we are going to consider three regimes of DSP energy extraction.

Considering an high rate of energy extraction the temperature in the storage zone varies between 20° C and 65°C achieving not the desirable minimal winter temperature for the example application (Figure 2).

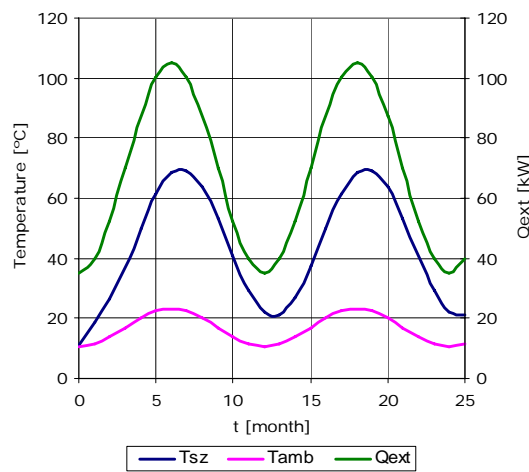


Fig. 2 – 1000m² Solar Pond high level energy extraction.

For the situation of virtually no energy extraction, the temperature raises more than 100°C, which leads to a quickly homogenization of the Pond (Figure 3).

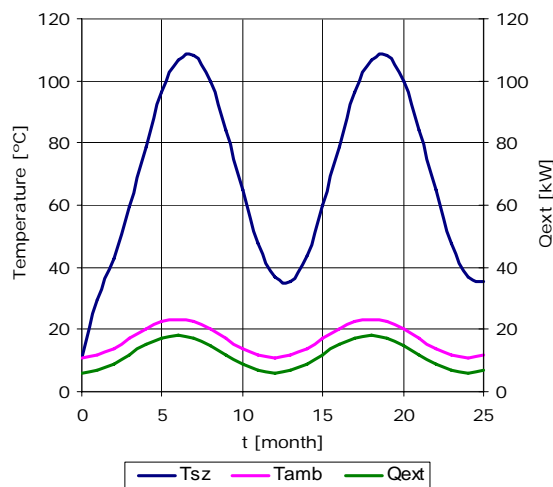


Fig. 3 – 1000m² Solar Pond low level energy extraction

This example is not adequate with the operation of a Solar Pond. If it is going to boil the zones became homogeneous and the Solar Pond destabilized. So neither these situations are in agreement with the expectations for an application.

A third situation seems to be adequate to achieve Aquaculture thermal demand. Here the level of extracted energy is slowly less but the temperature in the storage zone is in a proper range, 25°C to 75°C (Figure 4).

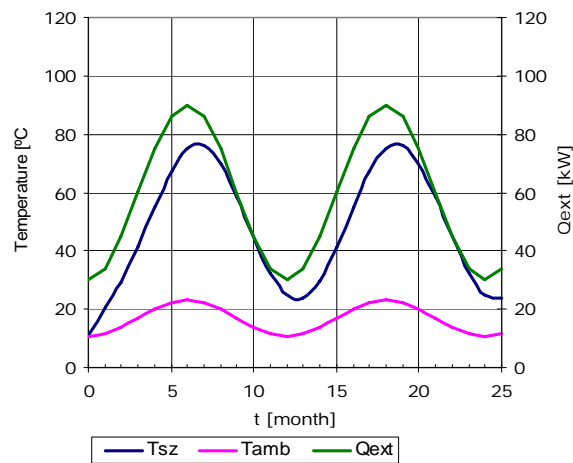


Fig. 4 – 1000 m² Solar Pond adjusted level energy extraction.

3.3 DSP Operation

If the Aquaculture plant is build near marine salt works the DSP could be a good alternative to a conventional Solar Pond. We are going to considered two typical side-by-side salt works with 1000 m² surface and 2m depth represented by L1 and L2 (Figure 5).

The first basin is constructed in order to act as a Solar Pond (Figure 5:1) and will work in a regime adjusted to aquaculture operation with an energy extraction of 30 kW. The only operation to be done is to create the gradient in L1 (Figure 5:2).

This is usually done with a diffuser that fills the pond from 1.5 m to 2 m depth. Here a salinity gradient is created being upper zone with 3% (seawater salinity) and the bottom with 25% of salt concentration. This operation takes about one week. At this time L2 basin is in a stand by mode.

If we only consider losses by salt diffusion L1 can work for a long time (about nine years) (Figure 5:3). After this the NCZ of L1 will be homogenized (Figure 5:4). Nevertheless there are other kinds of instabilities that accelerate this process. On the other hand we need to alternate the operation of L1 and L2 ponds with a periodicity of one year.

When L2 begins to be constructed as a Solar Pond (Figure 5:2a) L1 can aid to raise the initial temperature by energy extraction transfer. After about one week L2 is in conditions to work (Figure 5:2b). In this way L1 and L2 are connected.

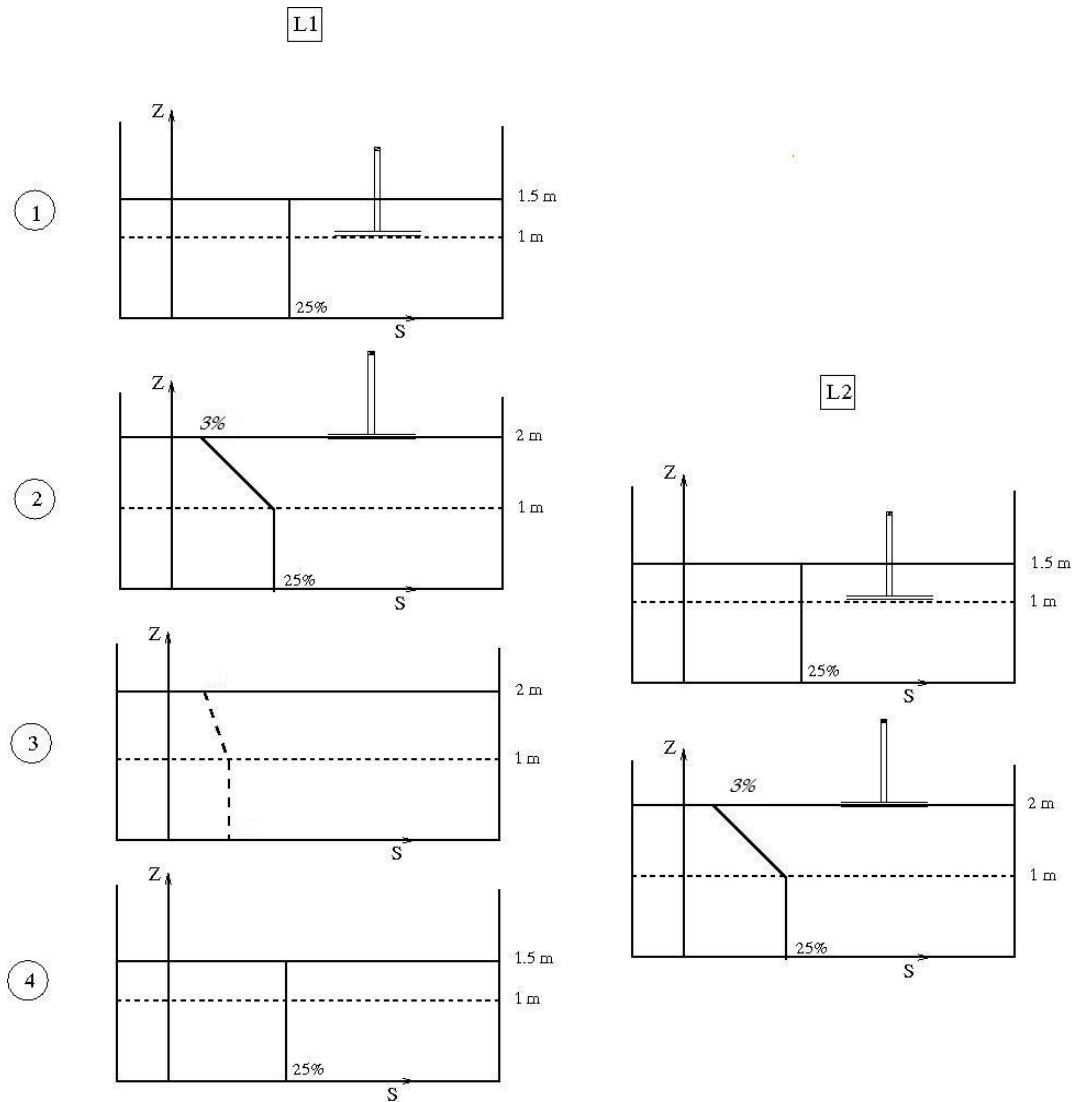


Fig.5 - Diagram with the two Solar Ponds, DSP concept, L1 and L2.

If L1 is not completed homogenized (Figure 5:4) the process must be accelerated. There are several processes to do this. Nevertheless, the simpler one is to stop the heat extraction. This will quickly raise the temperatures at the SZ and will destabilize the pond (Figure 6).

After this stage is reached, one must regain the initial concentration of 25% at the bottom. The remaining water must be evaporated from the pond until this concentration is reached. Basic calculations give the rate of evaporation to reach the original salt concentration of 25%. Results points that we need 51 days for a pond temperature of 40 °C, 29 days for 50 °C, and only 10 days for 80°C.

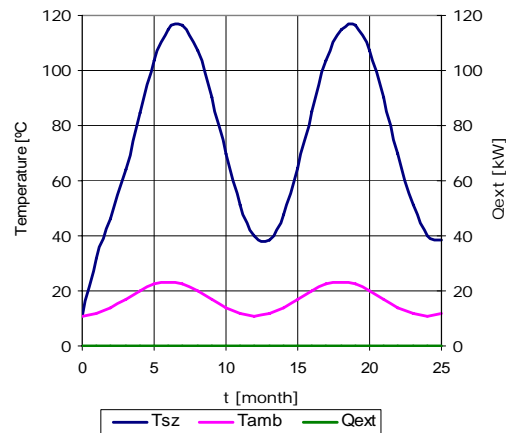


Fig. 6- 1000 m² DSP without heat extraction.

4.-Conclusions

We may conclude that for Aquaculture facilities these kind of solar ponds, are well designed and considerable less expensive than conventional ones. We must emphasize that this concept needs an annual periodicity of construction that is the periodicity of marine salt works recovering. In this way we have always a Pond that is working. The key of the concept of Dual Pond is to standardized maintenance operations with an annual periodicity.

The results here presented are a first approximation and more work must be done to deal the concept with assurance. Nevertheless in a first insight it seems to work giving the thermal energy needed for the application in mind.

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