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EXPERIMENTS ON SODIUM CARBONATE SOLUTION FOR A SOLAR POND AT NATURAL ENVIRONMENT

Mehmet ÖZKAYMAK
Department of Mechanical Education, Zonguldak Karaelmas University, 78050 Karabük, Turkey

ABSTRACT

In this study, varying concentrations of sodium carbonate solution in the solar pond in terms of heat storage performance has been examined. Five conditions with different density levels have been carried out and the changes in the temperature and density have been presented graphically within the solar pond. The hourly variation of solar radiation, ambient temperature and wind velocity were also recorded during the outdoor measurements. The experiments show that the maximum temperature difference between the bottom and top level of solar pond is 21°C and the highest temperature in Lower Convective Zone (LCZ) has been measured as 49°C. Experimental apparatus has been located at Karabük Technical Education Faculty of Zonguldak Karaelmas University, Turkey.

Key Words: Solar pond, Sodium carbonate, Heat storage

SODALI SUYUN BİR GÜNEŞ HAVUZUNDA DOĞAL ORTAMDA DENEYSEL İNCELENMESİ

ÖZET

Alternatif enerji kaynaklarından birisi olan güneş enerjisini, ekonomik yönden ucuz ve verimli bir şekilde toplama ve depolama sistemlerinden birisi de güneş havuzlarıdır. Yapılan bu çalışmada, güneş havuzunda, farklı konsantrasyonlara sahip Na_2CO_3 – H_2O (sodyum karbonat-su) çözeltisinin doğal ortamda ısı depolama performansı deneysel olarak incelenmiştir. Deney tesisatı, Z.K.Ü. Karabük Teknik Eğitim Fakültesi'nde kurularak farklı yoğunluklara sahip 5 ayrı deney yapılıp güneş havuzundaki sıcaklık ve yoğunluk değişimleri grafikler halinde sunulmuştur. Yapılan deneylerde güneş havuzunun tabanı ile yüzey arasındaki sıcaklık farkı maksimum 21°C ve alt taşınım bölgesinde (ATB) en yüksek sıcaklık 49°C olarak elde edilmiştir.

Anahtar Kelimeler : Güneş havuzu, sodyum karbonat

1. INTRODUCTION

The solar energy, one of the alternative energy sources, can be economically and efficiently collected by using solar ponds. The solar ponds have ability to collect 20-30 % of solar radiation even at low temperatures and store them for long terms providing 15 % useful heat [7, 5]. Fig. 1 shows the configuration of the salt gradient solar pond.

Mehta et al. [8] constructed a solar pond having a surface area of 1600 m^2 and a depth of 2.3 m in order to analyze the performance of solar pond in India conditions. Salt density gradient of the pond was formed by using seawater. 8-10 % difference was observed when experiment results were compared with model results. Akoshile [1] made a study by using a hyperbolic clay pitcher having a depth of 28 cm as an experiment pond in natural conditions. NaCl solution was used in the experiment. Temperature difference between pond base and surface

was measured as 20°C. Fagbenle [3] studied the applications of solar pond in the areas of agriculture, industry, house heating and commerce in tropical regions, such as Nigeria, from technical and economical point of view. Optimum temperature was about 86°C in a stable solar pond in Nigeria conditions. Subhakar and Murthy [10, 11, 12] constructed a circular solar pond having a diameter of 1 m and a depth of 0.7 m, which is made up of stainless steel, by using $MgCl_2$ salt. By comparing test results with model results, they proved that both results were consistent. They also measured the storage temperature as 55°C. Pawar and Chapgaon [9] studied the temperature and density profiles of $NH_2CONH_2 - H_2O$ solution in a solar pond having 1x1x1.25 m dimensions, which is made up of sheet iron metal. Temperature difference between UCZ and LCZ was obtained as 23°C. Haimour [4] investigated the generation of convective layers on sidewalls of a solar pond with fertilizer salts, such as potassium nitrate (KNO_3), mono ammonium phosphate (MAP) and mono potassium phosphate (MKP). Kurt and coworkers [6] tested the NaCl solution with different concentrations in a solar pond under natural conditions. Numerical and analytical solutions of mathematical model were compared with experimental results. Kurt [5] compared theoretical results with experimental results in a solar pond consisting of Na_2CO_3 solution under laboratory conditions. Temperature difference between pond base and surface was obtained as 18°C and the maximum temperature in the LCZ was obtained as 44°C at the end of the experiment. Chibani [2] compared the natural brine with the artificial brine experimentally by using in a solar pond having 2x2x1 m dimensions. While temperature at LCZ was measured 47° when natural brine used, it was measured 55°C when artificial brine was used for otherwise identical conditions. However, the solar energy has been widely investigated from many aspects point of view (10, 1, 9, 4, 5, 2) , solar ponds containing Na_2CO_3 solutions seem to be scarce. Therefore the aim of this study was to investigate Na_2CO_3 as salt solution in solar pond. This study also aims to explore possible usage of Lake Van water, which contains Na_2CO_3 as natural solution, in Turkey for solar ponds.

2. EXPERIMENTAL WORK

A solar pond constructed in a glass tank was used in the experiments. Schematic diagram of experimental system is shown in Figure 2. The dimensions of the pond were 450 x 200 x 250 mm. The glass tank was sealed with silicon sealant such that there was no gap through the lower surface and the side surfaces. The pond base was painted in black color while the outer surface was surrounded by 0.1 m thick styrofoam for thermal insulation. The Cr-Al thermocouples were placed with 5 cm spacing on one side of the pond in order to measure the temperature. Also, the temperatures of the ambient atmosphere were measured by using thermocouples and the solar radiation intensity coming to the pond surface was measured with a solar meter. Sampling set up where the solution densities were measured is placed on the opposite side of the pond. The solution density was measured by taking five samples using a 10 ml pycnometer having a sensitivity of 10 ml ±0.2 ml. Samples were weighted by Sartorius BP-310 sensitive digital pair of scales, which can weight between 0 and 310 gr. The sensitivity of scales was 1 gr ±0.03 or 50 gr ±0,1 mgr. Table 1 shows solution densities as a function of depth of layers for each condition investigated, while Table 2 gives external parameters for each condition carried out in Table 1. Experiments were performed by using 5 solutions with different densities between July-August 2001 at Karabük Technical Education Faculty. The experimental apparatus was placed on the rooftop of laboratory building.

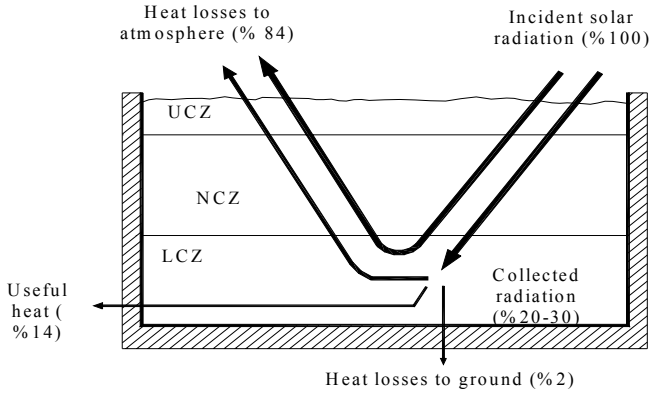

Fig. 1. The salt gradient solar pond configuration

Table 1 Densities and salt concentration of solutions versus depth used in the experiment (at the beginning)

Layer	Depth (cm)	Condition A		Condition B		Condition C		Condition D		Condition E	
		Density (kg/m^3)	Salt Concentration (%)	Density (kg/m^3)	Salt Concentr. (%)	Density (kg/m^3)	Salt Concentr. (%)	Density (kg/m^3)	Salt Concentr. (%)	Density (kg/m^3)	Salt Concentr. (%)
UCZ	0-5	1000	0	1000	0	1000	0	1000	0	1000	0
NCZ	5-10	1050	6.5	1033	5	1025	3.5	1017	3.2	1000	0
	10-15	1100	13.5	1066	9.5	1050	6.5	1034	5.5	1000	0
	15-20	1150	18	1100	13.5	1075	10	1050	6.5	1150	18
LCZ	20-25	1150	18	1100	13.5	1075	10	1050	6.5	1150	18

Table 2. Climatic Data for Karabük

	Condition A		Condition B		Condition C		Condition D		Condition E	
	7^{th} day	Weekly Mean	7^{th} day	Weekly Mean	7^{th} day	Weekly Mean	7^{th} day	Weekly Mean	7^{th} day	Weekly Mean
Mean atmosphere temperature (°C)	31.8	31.2	31.7	31.2	29.8	30.6	31.1	30.7	31.4	30.6
Mean solar radiation ($W.m^{-2}$)	557.7	524.5	606	562.7	533.57	503.3	583.7	580.1	546.7	504
Mean wind velocity	1.9	1.6	3.55	2.03	2.3	2.38	1.7	1.57	3.07	1.87

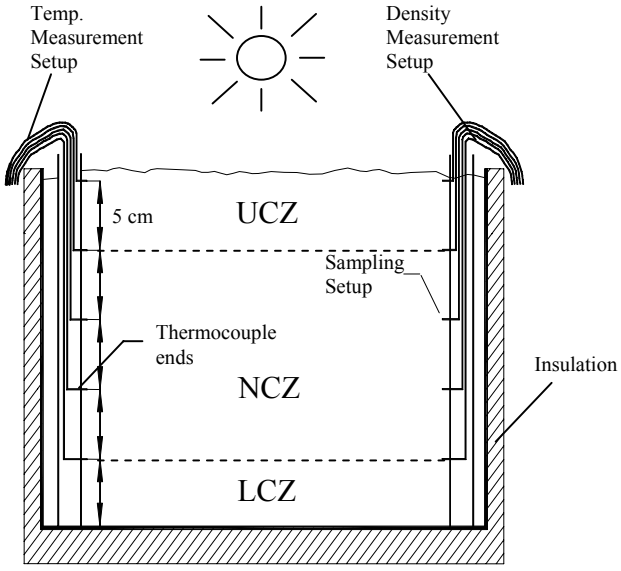

Fig. 2. Experiment setup

Solar pond was carefully filled in such a way that linear salt density gradient were reached from LCZ to UCZ. Linear salt gradient from pond base to its surface was observed to be completed with in one day so that experiments were conducted one day later. Total time span for the each experiment was 7 days. Density measurement was made at every 12 hours and temperature measurement was made starting from $10.^{00}$ till $16.^{00}$ o'clock for every hour. All experiments were completed within 2 months.

4. RESULTS AND DISCUSSION

Fig. 3 shows solution density versus depth of the solar pond. Evidently, linear solution density was reached one day after the filling of the pond as shown in Fig. 3. This was attributed to the difusion rate of the Na_2CO_3 in

water. Experimental results showed that the solution temperature increased as the density of the solution increased (Fig. 4). The maximum solution temperature of 49°C was obtained with condition A in which it contained 18 % Na_2CO_3. Taking into account for the condition D seem to disturb the sequence of the solution temperature as a function of depth. This was probably due to mean solar radiation measured at the experiments. Mean solar radiation for condition C was 533,57 W/m^2, while it was 583,7 W/m^2 for condition D which is higher than the condition C. Temperature at LCZ as a function of salt concentration of various works and present work is depicted in Fig. 5. Evidently, solution temperature increased with increasing salt concentration in accord with works of Subhakar and Murthy [10], Akoshile [1], Pawar and Chapgaon [9], Haimour [4], Chibani at al. [2], Kurt [5]. The significance of Fig. 5, however, is that the solution temperature obtained from various works as a function of salt concentration seems to be scattering. This is attributed to the type of the salts used. For example, Akoshile [1] used 17% NaCl solution and obtained 41°C at LCZ, however, present work showed that 49°C at LCZ was reached by using 18 % Na_2CO_3. Although, the concentration of natural brine, used by Chibani at al., is higher than the present work obtained temperature at LCZ is lower than the present work (Fig. 5). This indicates that salt type has an influence on solution temperature. For example, Chibani at al. [2] reported that 47°C solution temperature was obtained at LCZ by using natural brine whereas it was 55°C as artificial brine was used for otherwise identical conditions. The temperature at LCZ reported by Kurt is lower than the present work although Na_2CO_3 as salt and similar experimental setup were used. This could be explained as, Kurt [5] used 1000 w halogen lamp instead of sun as the source of heat in the experiments.

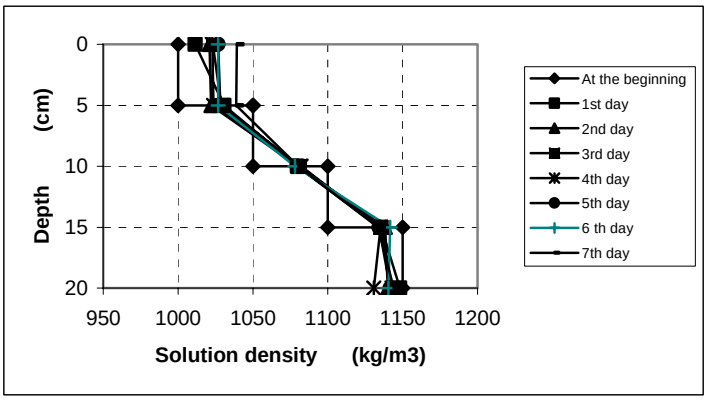

Fig. 3. Variation of solution density with respect to depth of pond (condition A)

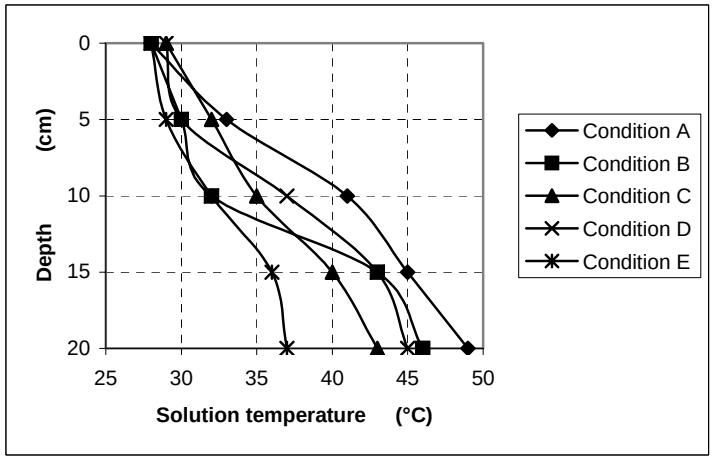

Fig 4. Variation of solution temperature with respect to depth of pond at the end of 1-week period of each condition (7th day, at 16 ^{00}).

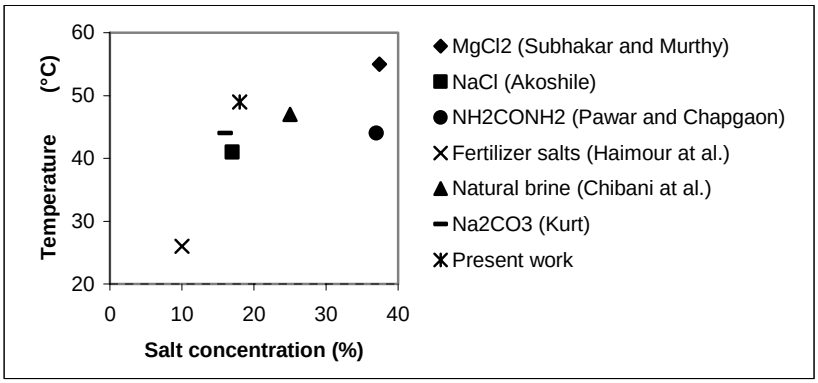

Fig. 5. Temperature at LCZ as a function of salt concentration of various works and present work.

5. CONCLUSION

The results of this study have highlighted the concentration of salt in solar ponds have an important role for obtaining solution temperature at LCZ. Solution temperature increases as the salt concentration increases. Results also showed that Na_2CO_3 could successfully be used in solar ponds.

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