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Design and manufacture a new solar unit for distillation and water heating in Basrah City

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Abstract

In this paper a new solar unit for water heating and distillation has been designed and manufactured. It was operated for a period of 6 month from December 2013 to May 2014 in Basrah city which lies on longitude (47o45) and latitude (30o33). The average daily productivity of distilled water at the operated month was ranged between (8.4 -14.56) liter/m^2 and a hot water at a temperature of 43-70 Co at a normal flow of 65 ml/min.

Keywords: solar collector , solar energy , solar distillation , solar water heating , solar still.

1. Introduction

Water is the basic necessity for human along with food and air. There is almost no water left on Earth that is safe to drink without purification. Only 1% of Earth's water is in a fresh, liquid state, and nearly all of this is polluted by both diseases and toxic chemicals. For this reason, purification of water supplies is extremely important. Moreover, typical purification systems are easily damaged or compromised by disasters, natural or otherwise. This results in a very challenging situation for individuals trying to prepare for such situations, and keep themselves and their families safe from the myriad diseases and toxic chemicals present in untreated water. Everyone wants to find out the solution of above problem with the available sources of energy in order to achieve pure water. Fortunately there is a solution to these problems. It is a technology that is not only capable of removing a very wide variety of contaminants in just one step, but is simple, cost-effective, and environmentally friendly. That is use of solar energy [1].

Desalination is the process of removing high salt content, minerals and organisms from a water source. Desalination systems require energy for the separation of salt and water. Solar desalination systems are systems that utilize the sun energy (solar radiation) for the separation of water and salt. Classification of solar desalination varies depending on techniques and energy supply. The most common type of solar desalination system is the solar still [2].

A solar still is a simple device which can be used to convert saline or brackish water into drinking water. Solar still can be broadly divided into passive and active types. Passstills are further divided into basin and inclined types. Extensive research was made to improve the productivity of these stills [3]. The principles of operation are the same for all solar stills. The basin of the still is filled with brackish or seawater, the incident solar radiation is transmitted through the glass cover and is absorbed as heat by a black surface (basin) which contains the salt (brackish) water. Thus, the water is heated and gives off water vapor. The vapor condenses on the glass cover, which is at a lower temperature because it is in contact with the ambient air, if the glass cover is tilted, the formed condensation drops will start running down the cover by gravitational forces, and may then be collected in a channel to go out the side of the still to a storage tank [4].

The conventional basin-type solar still has three major shortcomings: (1) the latent heat is not reused in distillation condensation processes; (2) the temperature increase of the evaporation surface is limited due to the large thermal mass of the brine; (3) the free convection heat transfer process limits the heat transfer efficiency. The yield can be increased 3 20 times with the same energy input relative to a single-effect solar distillation system.

Dunkle found out that the mass transfer rate depends on the temperature difference between the water surface and the glass cover. In order to increase this temperature difference some researchers studied the effect of coupling the solar still to a flat plate solar collector. Another way to increase the temperature difference is to reduce the temperature of the glass cover. The temperature difference between the saline water surface and the transparent cover could be increased by adding a condenser to the still, thus increasing the heat sink capacity, hence the still performance. Evaporation at a low temperature using vacuum conditions, leads to a good improvement in the system efficiency as the evaporation rate increases with the reduction of pressure. System productivity higher than that from similar solar desalination systems operating under atmospheric pressure has been reported by many researchers [5].

There are various reports on the efforts to enhance the still distilled water productivity and improving the still operations condition by coupling solar still to a flat plate collector. Tiris et al.[6] Voropoulos et al.[7-9] have investigated the performance of solar still coupled with solar collectors and storage tank. There are several types of water heating solar collectors currently available: including flat plate, evacuated tube, and reflector concentrator collectors. Owing to lower cost and complexity, flat plate collectors are by far the most common solar collector in residential applications [10]. Based on the literature review there is no work available related to reduce the latent heat inside the still in order to increase the productivity. In this work a new design of solar unit to produce distilled water and hot water at the same time has been designed and operated. This unit consist of solar still coupled with flat plat collector, and this unit have been manufactured to improve the output of the simple basin solar still through the coupling of a flat plate collector and condensation tank inside the still. The principle concept of this design is to reduce the latent heat by reused it to heat the inlet water which comes from the external tank to the flat plat collector.

2. Experiment

The present solar unit consists of asymmetric solar still coupled with solar collector.

2.1. asymmetric solar still

It has a black painted aluminum basin area of (0.224) m^2 filled with brackish water supplied to it from a collector . The basin linked with small stainless steel cylindrical tank S2 which has a capacity of 1 liter to receive the over flow hot water from the basin and this hot water can be supplied to the home uses. Also small stainless steel cylindrical tank S1 with a capacity of 3.4 liter was installed inside the still to receive the cold water from the external tank. S1 helps to reduce the latent heat inside the still and increases the condensation process, also it is supplying the flat plate collector with warm water. A small floating ball to control the level of water in the basin at the depth of 1 cm was installed in the tank S1, as. The bottoms of, S1, S2 and basin are linked with the collector by copper tube with valves V1,V2,V3 and V4 shown in figure (1).

The basin and the two small tanks S1,S2 are installed inside asymmetric double slope glass box as shown in figures (2) and (3). The cover of the still is tilted at a slight angle (23^o) from one side and at an angle of 55o from the other side to let the fresh water that condenses on its underside trickle down to a collecting trough. A trough running along the bottom side of the glass cover ensures the collection of the distilled water towards the collecting vessel. The glass also holds the heat inside the still. Holes were drilled in the body of still to fix thermometer to measure the temperature of water in the basin, S1 and S2.

2.2 A flat plate collector

Solar collector (woodn box, (1.12) m long, 0.62 m width and 0.15 m high) has been manufactured and used to preheat the water entering the still; the collector is made of a zigzag copper tube diameter of 0.0095 m and length of 7.57 m which was fixed on copper plate length of (1) m , width of (0.5) m and thickness of (0.0005) m . A glass wool thickness of (0.05) m have been used under the absorber plate as insulator. The copper tube was welded to the copper plat from many points in order to increase the heat exchange between the tube and the copper plate . A matt plack paint was used to paint the copper plat and tube to absorb maximum solar radiation. A glass plat thickness of 0.4 cm , length of 1.12 m and width of 0.62 m was used as a cover to the solar collector.

The schematic diagram of the solar unit is shown in Figure (2). The collector is receive water from the tank S1 by opening the valve V1 and closed the other valves. And then each first hour at morning the valve V1 must be closed and V2, V3 must be opened manually to make circulation to the brackish water. At the second hour of each morning the valves V2 and V3 must be closed and the valve V1 must be opened to allow the water interring the collector from S1, where S1 receives the brackish water from the external tank. The external tank was taking from a damage water cooler with a capacity of 20 liter and must be filled with brackish water as soon as it was emptied. Silicon rubber sealant is used to prevent leakage from any gap between the glass covers and the still box.

In this work after many experimental attempts, the valve V4 has been opened to control the flow continuously at speed of 65 ml/min. The inclination angle of the flat plate solar collector was manually changed between 15° at summer and 45 in winter with the horizontal to get better performance.

The experiment was carried out keeping water in the basin at depth of 1 cm. Every hour the temperature of water inside the basin, temperature of hot water out from V4, amount of distill water, temperature inside S1 and S2 were measured. Also the day time ambient temperature and day productivity of distilled and hot water were also measured. This new solar unit has been designed, installed and operated at physics department of education college of Basrah University in Iraq.

3. Results and Discussion

Vapor was raised from basin , S2 and maybe from S1, and then because of temperature difference between water surface and the inner sides of glass walls and cover the condensation processes will appear and then droplet to the bottom of the still and go out to the distill water vessel . The table (1) shows the average of monthly measurements for daily productivity of distill water and atmosphere ,basin water, S1, S2 and tab water temperatures for the new solar unit at the operating months (from December 2013 to May 2014). The aim of our experiment was to get hot water and pure water from the brackish water . figure (4,5) shows that the average daily productivity increase with increasing atmosphere temperature, it mean that the productivity proportional to solar radiation. Also this unit is suitable to heat the water for home usage. During the testing process its found that the main appropriate speed for the flow of hot water from the valve V4 is about 66 ml/min, where the temperatur of hot water in S2 at this flow speed is nearly not affected.

TDS and PH of produce distill water was measured, and found that the TDS level is (1.05) PPM and PH is (6.1) .

4. Conclusion

The purpose of this study has been to evaluate the productivity of a new solar unit for heat and distill water at local climatic conditions of Basrah city longitude (47o45) and latitude (30o33). On the basis of the results of this study the following conclusions are reached for Basrah city.

- The solar still productivity is directly proportional to sun energy.
- The maximum daily productivity of this unit of distill water reach to 14.6 liter/m^2.
- The maximum basin water temperature of asymmetric solar still is 70.2 C^o .
- The maximum water temperature of the tank S1 is 34 C^o, where it is 62.3 C^o for the tank S2 at flow speed of 69 ml/min from the valve V4.
- This new solar unit suitable to produce hot water and fresh water at the same time.

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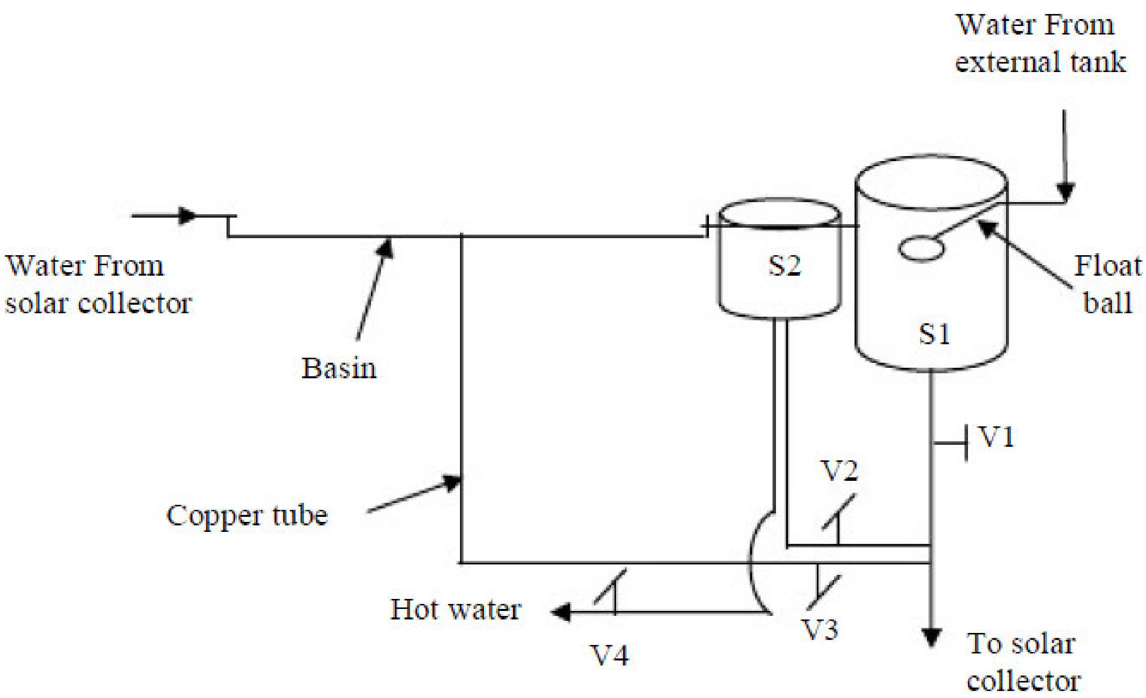
a



b

Figure 1. a) A block diagram to the basin and S1,S2, b)A photograph the basin and S1,S2

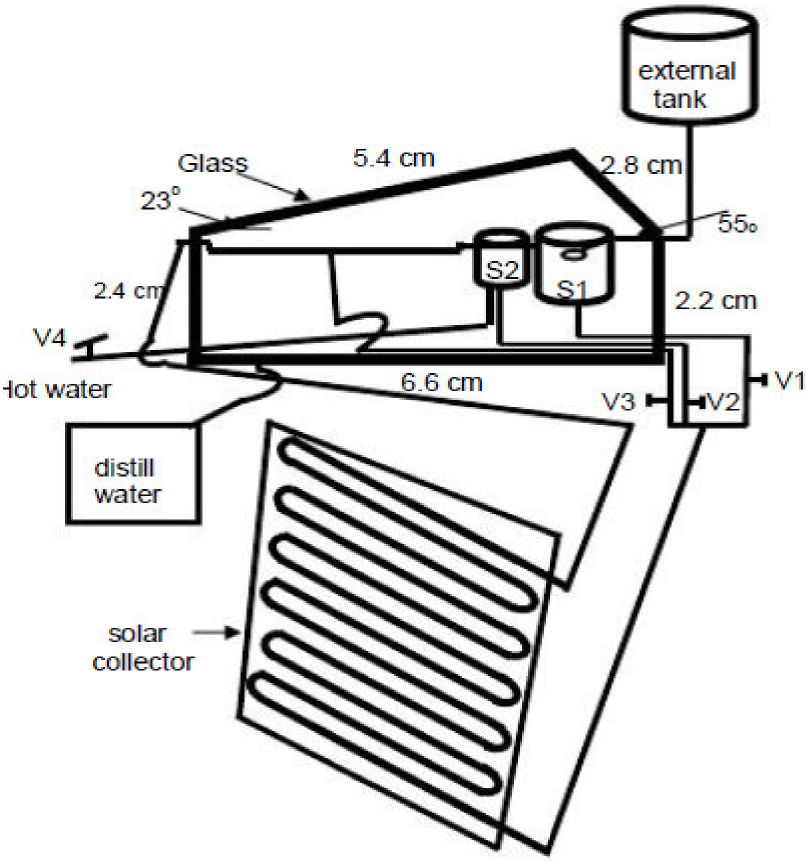


Figure 2. A diagram of the new solar unit.

a

b

Figure 3. a) A photograph of asymmetric solar still with valves, b) A photograph of the new solar unit.

Table 1: Experimental measurements for the new solar unit through 6 month.

Month	Dec.	Jan.	Feb.	Mar.	Apr.	May
Productivity liter/m²	9.26	8.4	9.88	12	13.56	14.56
average of Atmosphere temperature(Ta)C°	19	16	21.5	28	34.8	41
average of basin water temperature (Tb) C°	54.8	53.2	56.1	61.3	66.2	70.2
average of water temperature in S1 (T s1) C°	19.3	18.2	20.6	25.1	27.8	34.5
average of water temperature in S2 (T s2) C°	47.3	45.8	48.2	53.8	58.7	62.3
average temperature of Hot water from V3 C°	47.3	45.8	48.2	53.8	58.7	62.3
Speed hot water flow ml/min	65	64	65	66	67	69
average temperature of tap water T(tap)C°	14.6	13.7	15.9	19.3	22.9	29.8

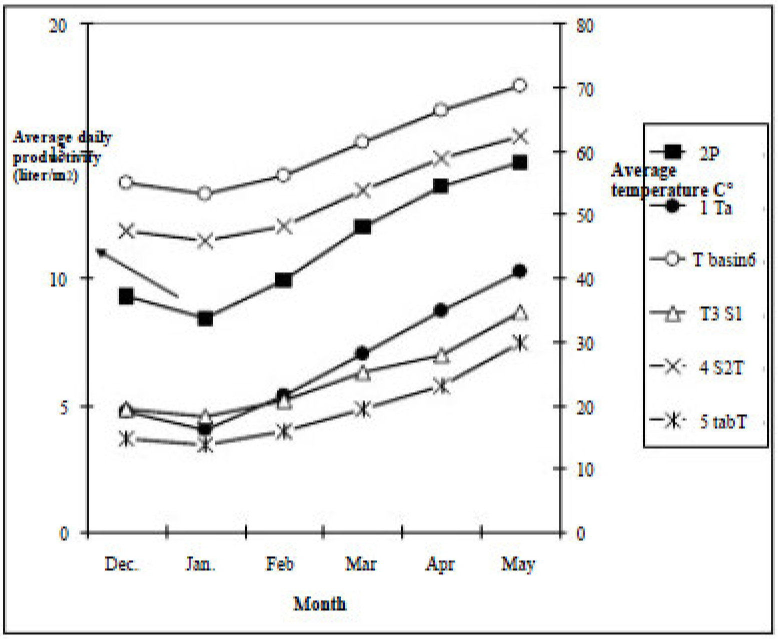


Figure 4. The average of daily productivity for the Month (Dec. 2013 to May 2014)

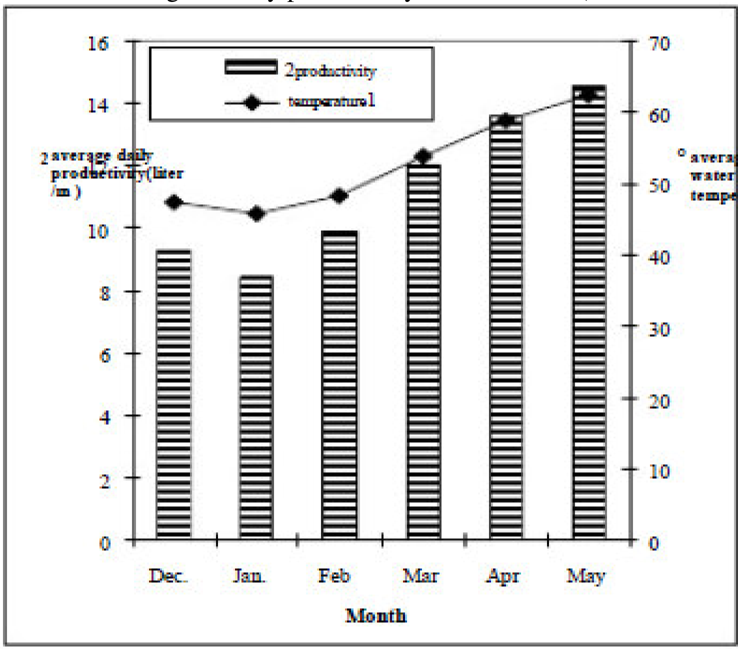


Figure 5. The average of daily productivity and average hot water temperature obtained from a new solar unit for the Month (Dec. - 2013 to May-2014)