Theoretical and Experimental Investigation on a Single Basin Double Slope Solar Still

Venkatraman k., Anadhavelu k ,thiruvasamoorthy k
Research Scholar

ABSTRACT

Solar still, which converts available brackish or impure water into potable water, can be used to supply drinking water for the people living in arid and remote areas. But, this still is not popular because of its lower productivity. This research work presents the theoretical and actual performance of the single basin double slope solar still and explores the different method to improve the efficiency.

A single basin double slope still with overall size of 2.5 m x 1.5 m was fabricated and tested under laboratory conditions (still − solar) and in actual solar radiation conditions. The variation of energy losses at cover plates were studied. A new model is proposed for the theoretical analysis by considering the transmittance variations of the cover plates and radiation received at the glass cover as input.

Experiments were conducted using different glass thickness with different inclination and orientation and the variations in transmittance were studied. A regression equation was established to calculate the transmittance of the given thickness of glass plate at any place and at any time for a given radiation condition. The variation of energy loss at cover plates was increasing with the decrease in depth.

Different wick materials like light cotton cloth, jute cloth, and light sponge sheet were used. Aluminium rectangular fins arranged in length and breadth were used to increase the transmittance. The solid materials like quartzite rock of different sizes, naturally washed stones, cement concrete pieces, and brick pieces were used in the basin. The above solid materials were not used so far.

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high. This different operation region was prolonged for more duration for lower depth and higher solar intensity. The experimental results of still–laboratory and still–solar were compared with still–theoretical with proposed model for different depth and different basin materials. The production rate, water temperature, glass temperature and glass–atmospheric temperature difference were similar. The still with 0.5 cm depth was more productive. For still–laboratory and still–solar, from 60°C water temperature point to maximum production rate point, the still operation was different and the water–glass temperature difference is inversely proportional to production rate. From the correlation graph for production rate, it was observed that for higher water temperatures, the production rate was complex function of water, glass, atmospheric, water–glass temperature difference and glass–atmospheric temperature difference. Also, the proposed theoretical model predicted the production rate with higher deviation with actual. Hence, to predict the production rate accurately, a thermal model, which was the refinement of the proposed model, was established and validated.

INTRODUCTION

1.1 THE NEED FOR DESALINATION

Clean potable water is a basic necessity for man along with food and air. Fresh water is also required for agricultural and industrial purposes. The main sources of water are rivers, lakes and underground water reservoirs. However, direct uses of water from such sources are not always advisable, because of the presence of higher amount of salt and harmful organisms. The higher growth rate in the world population and industries resulted in a large escalation of demand for fresh water. The natural source can meet a limited demand and this lead to acute shortage of fresh water. Hence, there is an issue to essentially treat salt and contaminated water into purified water.

EXPERIMENTATION

4.1 EXPERIMENTATION ON WINDOW GLASSES

4.1.1 Experimental setup

The experiment was carried out using a commercially available tracking type Photovoltaic (PV) sun meter (Figure 4.1). The meter had a 0.36 m × 0.17 m size PV panel to sense the sun radiation. The panel was fixed on a stand that can be set at any inclination with horizontal. The panel stand was mounted on a base with leveling screws. A display unit was connected with PV panel. The unit was calibrated at a display to the total radiation, when the panel is exposed to sunlight.

When the beam radiation on the PV panel is shaded, it measures diffused radiation. A black umbrella fixed on the movable black vertical pipe, placed 5’ above the PV panel, is used as a shading device. When glass is placed on the PV panel, the display reads the radiation transmitted through the glass.
4.1.2 Experimental procedure

The experiment was conducted during NOV. 2015 to DEC. 2015 on the terrace of the Mechanical Engineering Department in building, M R K institute of technology, Kattumanarkoil (9°11’N, 77° 52’E). The sunmeter was placed on the table, so that the panel was along the north-south direction. The levelscrews were adjusted to bring the base of the panel in perfect horizontal position. Commercially available window pane glass of different thicknesses 2mm, 3mm, 4mm, 5mm and 6mm were used for transmittance analysis. Total and diffused radiations were measured for horizontal, 10, 20, 30° and 40° degrees inclination towards north and south planes with and without glass on the PV panel. The ratio between the radiation transmitted (radiation reading with glass) and radiation received at the top surface (radiation reading without glass) was the transmittance of the glass. Readings were taken daily from morning 6am to evening 6pm with one-hour interval.

As a single basindouble slope solar still has been fabricated with mild steel plate as shown in Figure 4.2. The outer basins were 2.08m x 0.84m, 0.075m x 2.3m and 1m x 0.25m, respectively. The gap between the inner and outer basin was air tightly packed with rice husk. The outer basin was made up of mild steel sheet. The top was covered with two glasses of thickness 4mm, inclined at 30° on both sides using wooden frame. The outer surfaces were covered with glass wool and thermocool insulation. The condensed water was collected in the V-shaped drainage, provided below the glassed edged on both sides of the still. The condensate collected was continuously drained through flexible hose and stored in a measuring jar. K-type thermocouples were inserted through a hole in the basin sidewall for the measurement of the basin water, still and condensate temperature. Four thermocouples were placed in the basin at different locations. Two thermocouples were placed in both the drainage to measure the condensate temperature. The hole was closed with insulating material to avoid heat and vapour loss. Mercury thermometer was used to measure the atmospheric temperature. Another hole was provided for water inlet. Through this hole, a small tube was inserted, to supply compensation raw water continuously from storage tank using a measuring tube. The control valves arrangement was used to keep the mass of water in the basin always constant. By adjusting the controlval...
ves V1 and V2, required quantity of raw water was stored in the measuring tube. When the set two valves kept closed and V3 is opened, the water stored in the measuring is supplied to the basin. The heating coil of 2000 W was placed below the inner basin to supply necessary heat to the basin. The AC electrical power was supplied to the heater through a control circuit. The input power was varied using a variable voltage transformer. An AC digital watt meter was fitted with the circuit to measure the input power. Figure 4.3 shows the photographic view of the still–laboratory.

**Experimental setup of still–solar**

To convert the still–laboratory into still–solar, the heater, power supply, power measurement system, and mild steel basin were removed. The bottom of the still was leveled with 5 cm thick cement concrete to minimize heat loss through the basin and to read the minimum depth of water uniformly as shown in Figure 4.4. The concrete surface was painted black to improve the radiation absorption capacity. The total and diffused solar radiations at the horizontal, the plane inclined at 30° facing north and south were measured using the calibrated photovoltaic type sun meter.

Thermal temperatures of water and condensate were recorded with the help of a calibrated K-type thermocouples in combination with a digital temperature indicator having a least count of 0.1°C. The ambient temperature was measured using a calibrated mercury thermometer having a least count of 1°C. The raw water input was supplied through a measuring tube with a least count of 10 ml. The distillate output was measured using a measuring jar of least count 10 ml. The AC power was measured using a digital wattmeter with the least count of

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1W. The total and diffused radiation on 30° inclined plane facing south and north were measured using a calibrated Photovoltaic type sunmeter having a least count of 1 W/m². The diffused radiation on inclined surfaces were measured by shading the beam radiation on the photovoltaic surface. The ambient air velocity was measured with an electronic digital anemometer of having a least count of 0.1 m/s with ±2% accuracy on the full-scale range of 0-15 m/s.

4.2.3 Experimental procedure

4.2.3.1 Still-laboratory

The experiment was carried out at the Steam Laboratory, National Engineering College, Kovilpatti (9°11’N, 77°52’E), a city in southern India, during January 2006 to March 2006. The heat input was given to the still using a heating coil. Two types of experiments were carried out. In the first work, the heat input was varied to match with respect to actual solar radiation condition. For various water depths, this experiment was conducted. In the second work, the experiments were conducted for constant depth with different constant power inputs. For a given constant depth of basin water condition, the puttothe heater was varied for every 15 minutes from 0-775 W/m² between 6 am and 12 noon and from 775-0 W/m² between 12 noon and 6 pm. To match with the helio calaverage solar radiation condition (Anna Mani 1980), the heater was switched off during the night.

The experiments were conducted for 2 cm, 1.5 cm, 1 cm, 0.5 cm, and 0.2 cm water depths in the still basin for the same varying heat input condition without freezing. For experiments with depth of water 0.5 cm and 0.2 cm, a light black cotton cloth was used to spread the water through the entire area of the basin. For the given depth, all the observations were taken for 24 hours starting from 6 am. The temperature of the atmosphere, basin water, and the condensate were noted for every 30 min. The watt meter reading and condensate collected on both sides of the still were also noted. Since the thermocouple fixed on the glass cover will not read the correct temperature due to sun radiation effect, the condensate temperature was considered as glass temperature.

The experiments were conducted with a layer of water equivalent to 2 cm. The experiments were conducted with wick materials like light cotton cloth, light jute cloth, and spongesheet of 2 mm thickness and solid materials like washed natural rock of average size 3/8”x1/4” and quartzite rock of average size 3/8”. These wick and solid materials were used to spread the layer of water through the entire area of the basin.

The still was also tested under various constant input conditions with a constant basin depth of 1 cm. The heat is supplied by the heater until the steady state condition was reached. The then...
the power was cutoff and the still was allowed to cool naturally to reach equilibrium state with atmosphere. The basin water temperature, condensate temperature and condensate collected were recorded for every 30 minutes. The experiments were carried out for the constant input powers of 300W, 600W, 900W, 1200W and 1500W.

4.2.3.2 Still–solar

The experiment with still – solar with concrete basin at actual sunshine condition was conducted at open terrace of the main block, Department of Mechanical Engineering, National Engineering College, Kovilpatti. The experiments were conducted during January to April 2007. The experiments were also conducted with mild steel basin during January to April 2008.

Experiments were conducted in still – solar with concrete and mild steel basin for various depths of 8 cm, 5 cm, 2 cm, 1 cm and 0.5 cm. A light black cotton cloth was used in the basin to spread the water when the water depth is 0.5 cm for concrete and mild steel basin.

The experiments were conducted in still – solar with mild steel basin with various basin conditions. The experiments were conducted with a layer of water and different wick and solid materials during August 2008 to October 2008. Different wick materials used in the basin along with 0.5 cm depth of water were light cotton cloth, light jute cloth, spongesheet of 2 mm thickness and coir sheet made up of fiber from coconut shell. The different solid materials used along with 0.5 cm and 0.75 cm depth of water were washed natural rock of average size 3/8” x 1/4” and quartzite rock of average size 3/8. These wick and solid materials were used to spread the layer of water throughout the entire area of the basin. Experiments were also conducted with aluminium rectangular fins in the basin arranged in both length and breadthwise arrangements covered with light cotton cloth and jute cloth.

The observations were taken for 24 hours duration, starting from 6 am to next day 5 am. The total radiation on horizontal plane, atmospheric temperature, basin water temperature, still air temperature, condensate temperature and the condensate collected were noted for every 30 minutes. For every 30 minutes, the compensating raw water equivalent distilled water collected was supplied to the basin from storage tank through measuring tube and the control valve arrangements.

CONCLUSION

Experiments were conducted on different thickness window glasses to study its transmittance behavior for various solar radiation conditions. It was found that, the transmittance was indirectly proportional to thickness of the glass, indirectly proportional to solar incidence angles and diffused radiation fractions. The transmittance mainly...
y depended on diffused radiation fraction at higher incidence angles. The regression equation could be used to estimate transmittance of the glass at any location and at any time for different radiation conditions.