ABSTRACT

Enhancement forced convection solar still of a closed cycle type is designed and manufactured for which experimental work is conducted. The performance of such still based upon the hourly variation is presented to cover different parameters, such as fluid temperatures along the channel, productivity and efficiency. The effect of air mass flow ranging from (0.0303 to 0.05424) kg/sec and condenser cooling water temperature ranging from (27 to 33) °C for the basic still is investigated.

The optimum air mass flow for the basic still is found to be equal to 0.052 kg/sec, and the reduction in cooling water temperature from 33 °C to 27 °C produce an improvement of 17 % in the productivity. The basic still is modified by introducing a humidifier to enhance its yield. The improvement in yield and efficiency is in the order of 12 % and 7.75 % respectively.

1. INTRODUCTION

The drinking water supplying system in a region with abundant fresh water, such as lakes, rivers, and underground is very different from the one corresponding to place without any such source e.g. deserts, and marshy lands, which may have only brackish water. Economic considerations may render distillation of saline and/or brackish water better choice than supplying water by trucks or by laying long pipe-lines. Most of the conventional water distillation plants are energy-intensive and require scare electric power or fossil fuel for operation. Solar energy is not a monopoly and the technology involved in distillation of saline water using solar energy is relatively simple. A very large component of fabrication, men and materials, of solar stills can be indigenous and maintenance can be carried out by semiskilled or unskilled operators. Since the maximum productivity of the classical solar still (natural convection type) is of order (3.5 to Lit/m² day) [1-20], in order to enhance this productivity, another approach should be applied. Following the design of Grune & Zandi [1] designed and investigated a hallow basin forced convection still with external heat exchanger having a maximum productivity of 5.975 Lit/m². day, under solar insolation of 28.39 MJ/m².day. El-Desouky, [2], has investigated a forced convection solar still, to study its performance, theoretically and experimentally. A mathematical model was developed, to analyze the heat and mass transfer. An experimental test-rig of solar channel was built to scale, with 30
meters length. The maximum productivity up to 6.5 kg/m² day of fresh water was obtained corresponds to a solar radiation of 24.6 MJ/m², with an efficiency of 62 %.

In the present investigation an enhanced scheme for forced convection solar still is presented with a humidifier and condensing heat exchanger.

2.EXPERIMENTAL WORK

A test rig was constructed and located on the roof of the Shoubra Faculty of Engineering. Water and power supply mains were connected to the test rig. Fig. (1) shows the construction of the test rig which is divided into the following main components:

- The solar channel
d- Pumps & Piping system
- The Blower
e- The Heat exchanger
- Over Head water tank

The solar channel length is 14.8 m, with effective length of 13.3 m and it is fabricated from a steel sheet of 1.25 mm, thickness, as U shape. The solar channel is fixed on a steel frame with 60 cm distance from the ground. The clearance for pipe connection of water pipes is to drain the water out of the channel, and to check the water leakage. At the low side of the channel, a V-shape trough is welded to collect the condensate in case the channel is used as solar still. The channel glass cover, is placed on rubber gasket, at both of the channel sides, silicon rubber was applied, to seal this connection properly, and to eliminate the air leakage.

The measuring station layout, the place, and depth, of each sensor as shown in Fig. (2). Each station have four sensors. The humidifier screen location and the inside details of the channel is shown in Fig. (3). These screens are removable, in order to change their positions and for maintenance purposes. They are fitted vertically through a steel U-shape groove passage, fixed inside the solar channel. This screen was constructed of wire mesh fixed to a steel frame. The filter porosity was filled with wood and covered from both sides with clothes. On the top of the humidifier screen there is a d tube drilled with a large number of holes to get a uniform water spray all over the humidifier screen, the feeding water coming to the screen from a water pipe line from the heat exchanger outlet water.

3.EXPERIMENTAL RESULTS AND DISCUSSION

The performance of the existing solar still is presented, through a set of curves. The effect of air mass flow through the system and condenser cooling temperature on the performance of solar still is also presented according to the following experimental conditions.

1. Standard forced convection solar still
2. Modification of the standard solar still by introducing a humidifier.
3.1 TEMPERATURE DISTRIBUTION ALONG THE CHANNEL

The temperature profiles along the channel was recorded every half an hour, for a typical day in June and July as shown in Fig. (4&5), with an average solar intensity ranging from (500 to 540 W/m²), while the average ambient temperature ranging from (27 C to 33 C). The experiments were conducted with three circulating air volume flow rates of (0.0303, 0.0383, and 0.5424 m³/sec).

A systematic variation in all curves is observed during the day (10.30 Am to 6.30 Pm). Both temperatures are increasing to maximum value up to station 4 (last station in the solar channel), as expected due to heat and mass transfer from water bed.

As the humid air passes through the unexposed solar channel, leading to condenser. Both temperatures were dropped as a result of heat lost to the surrounding. This drop in temperature is noticeable during the peak radiation hours, when the temperature difference between circulating air and ambient air is large, while this difference is minimum at 6.30 Pm, since the driving force for heat loss to the surrounding is minimum.

Both dry and wet bulb temperatures were reduced after passing through the primary and secondary condensers, where moisture is removed from the circulating air.

For the return air, as it passes through the circular duct painted black where it acts as a heater, the air temperature is expected to rise. Also during the first hours of the day, the noticeable effect of heat added to the air is due the blower and secondary flow losses in duct bends.

Another way to present the temperature variation is to look for the variation of wet and dry bulb temperatures for each specific station with respect to time according to the variation in maximum parameters maintained before.

The result corresponding to the typical day in June and July are shown from Figs. (6&7). Both temperatures show maximum value at 2.30 PM. (one hour and half lagged from the maximum of solar insolation), this is due to the thermal inertia of the solar still which imposed a time lag, i.e. effect of time constant of the system.

3.2 SOLAR STILL YIELD IMPROVEMENT

The solar still yield can be improved substantially by introducing the following parameters:

1. Increase of air mass flow through the system.
2. Increase the humidity of circulating air by introducing air by introducing a humidifier.
3. Reducing the inlet cooling condenser water temperature.
As noticed from Fig. (8 to 11) which represent the solar intensities, yields and efficiencies for a typical day in June.

It is noticed from these curves that the effect of reducing inlet condenser water temperature has a substantial effect on productivity of 17 % (for June 18). This improvement is due to both cooling temperature and the elevated air mass flow. The effect of increasing air mass flow is reflected on yield enhancement by 10 %.

The reason for introducing lower condenser temperature is to simulate the tape water as the feeding water pipe due to available facility in the faculty extended about 60 m length along the roof subjected to solar insolation, i.e the temperature of supplied water to the condenser is increased by about 5 C.

It is observed that an improvement in efficiency is accompanied with the increase in air mass flow (11.9 %). An increase in air mass flow and reduction in condenser cooling water temperature will enhance the efficiency by 18.6 %. The maximum yield of about 8.7 Liter was attained with lowering the cooling condenser temperature as shown in figure (9), compared to 7.5 Liter in figure (10). The sloped of yield against time is also improved and the area under the curve is enhanced by the reduced cooling water temperature. It is expected that the moisture content in the following air would be reduced and hence the return air would be also colder, and has an ability to carry more moisture.

The inlet water to the humidifier is kept the same as the inlet water to the solar still. Comparing two days with nearly the same solar insulation as 7th of June and 12th of July also with the same air mass flow and nearly the same inlet water temperature. It is noticed from table 1 that there is a substantial increase in yield from 46.6 to 51.5 Lit/day, i.e. an increase by 12% while the improvement in efficiency is of the order of 7.75 %. The enhanced in this case is due to the introducing of water to the still circulating air which depends upon the amount of water introduced and area subjected to evaporation, which is limit by the solar still cross sectional area. The humidification problem of air from the solar still and humidifier has contradicated effect. As shown from experimental results that maximizing the air mass flow will produce higher moisture content from the water basin, which minimizing the amount of water from the humidifier. Optimizing these two effects is beyond the scope of present work.
4. CONCLUSIONS

1. A forced convection solar still of a closed cycle type is designed and manufactured

2. Experimental results for the design still is presented, showing its productivity, air mass flow and efficiency for different values for cooling water temperature.

3. The condenser cooling water temperature has a great effect on productivity, improvement is of the order of 17% by reducing inlet cooling water temperature from 33°C to 27°C.

4. The optimum air mass flow for this system is found to be equal to 0.052 kg/sec.

5. The design still is adapted to accommodate a humidifier, to enhance the moisture content carried by circulating air.

6. By introducing a humidifier, the yield is increased by 12% while the efficiency is increased by 7.75%

REFERENCES