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MODIFIED BASIN-TYPE SOLAR STILL *

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ABSTRACT

A modified basin-type solar still (BTSS) has been developed. The new idea introduced is to re-use the latent heat due to condensation for increasing the temperature of saline water flowing into the device. A new term had been introduced in the balance of equation of conventional BTSS leading to the increase of the efficiency. According to the suggested model, a modified BTSS had been constructed and tested. It is found that the increase in the efficiency is about 14%.

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Theoretical idea

The process of evaporation followed by condensation during a complete cycle is a physically reversible process. This means that if the evaporated water is condensed again to liquid phase of the same initial temperature, assuming no loss, the same quantity of heat will be given. Theoretically speaking, if one could collect all heat liberated during the condensation process and re-use it for evaporation of equal quantity of water, the overall process of evaporation condensation will not need energy during the complete cycle. In practice, one could try to collect the heat liberated during condensation by means of the quantity of water which is going to be evaporated. Such a mechanism will lead to the increase of the temperature of water coming into the cycle and will, in addition, make the condenser cooler and more efficient. If in practice some energy must be lost the overall process may continue if the system will be fed by the amount necessary to compensate such losses only. This idea may improve the current devices used for desalination of water [1,2]. Moreover, if the water flowing in the device passes over the outer surface of the condenser it may clean it continuously from the dust and sand settled on the condenser, specially in the desert area. The heat collected during this process by water will be added to the amount of heat provided by the flat absorber and consequently increase the efficiency of the performance of the still.

Design and construction of the modified still

To realize the above discussed idea and to test the difference in performance between the conventional and the suggested still (hereafter we call it modified still), two identical stills were constructed, one of them employing the recycling process (denoted by 3M-20-cool), while the other is of the conventional form (denoted by 3M-20).

Fig.1 represents the schematic design of the constructed still. It is mounted on the roof of the Physics Department Building, Faculty of Science, Suez Canal University, Ismailia (latitude 30° 36' 21.6" N and longitude 32° 19' 3.6" E). One face of each still's cover faces due East and the other faces due West. Each still contains the following basic parts:

1) Tent-shaped glass cover.
2) Aluminum saline water trough.
3) Distillate water trough.

Fig.1 shows the feeding trough and the dimensions of the still (3M-20-cool). Walls of the feeding trough are covered with a piece of cotton cloth.

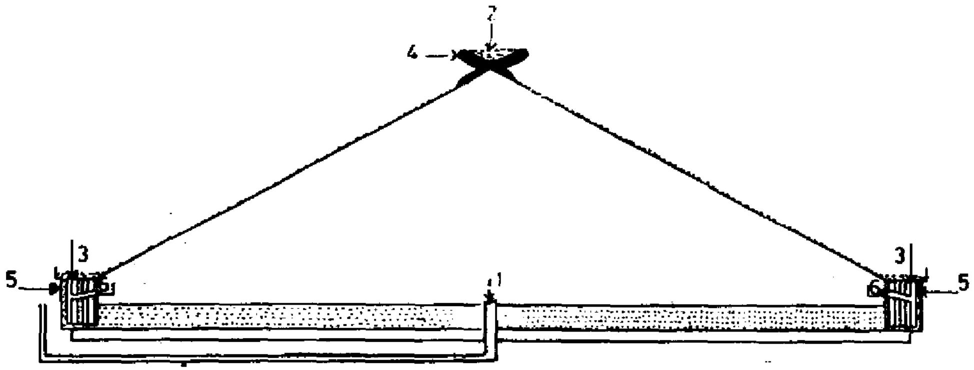

Fig.1

The still's pipes, feeding and collecting troughs.

(1) Overflow line
(2) Feeding trough
(3) Collecting trough
(4) Cloth covers all the feeding trough from inside and outside
(5) The inlet pipe
(6) Outline pipe.

The mechanism of the cooling water cycle can be described as follows:

1. A pipette-attached to ten liters aspirator containing saline water will feed the feeding trough with cool water. The rate of cool water flow from the feeding trough through the cloth is adjusted so that saline water could wet all the outer surface of the cover continuously.

2. The cool water after flow - under gravity - all over the cover will be collected in the collecting trough and will feed inside the still through the inlet pipes. This step will lead to the increase of temperature of inlet water and to the decrease of the temperature of the condenser.

Balance equation of the still 3M-20-cool

For conventional stills the heat balance equation is as follows:

$$\eta\, G_h = Q + (M_{sea} - M_e)\, C_{sw}\, \Delta T + Me\, L \quad , \qquad (1)$$

where $\eta\, G_h$ is the heat transmitted per unit time through the glass cover of transmittance η if the total incident energy per unit time is G_h, Q is the total heat lost by all means from the basin, M_{sea} is the mass per unit time of sea water, M_e is the mass of evaporated water, ΔT is the difference between the temperatures of sea water at the moment of evaporation and just before reaching the basin and L is the latent heat of evaporation.

The total rate of heat lost Q through all sides of the still, may include

$$Q = q_{rb} + q_{cnb} + q_b \quad , \qquad (2)$$

where q_b, q_{cnb} and q_b are the heat lost by radiation, convection and conductions, respectively, from the basin per unit time.

If α is the solar absorptance of the condenser, and we assume, for the first approximation, that the temperature profile through the condenser is linear, the total heat flowing to the external surface of the condenser is

$$\alpha G_h + A \frac{k_g}{x_g} (T_{gi} - T_{g0}) \quad , \qquad (3)$$

where T_{gi}, T_{g0} are the temperatures of the external and internal surface of the cover, A, k_g and x_g are the area, the thermal conductivity coefficient and the thickness of the glass cover, respectively. This will provide an estimation of the heat lost through the condenser.

On the other hand, the balance equation for the modified still may be rewritten as

$$M_{cool}\, C_{sw}\, (T_2 - T_1) + \eta\, G_h = Q + (M_{sw} - M_e)\, \Delta T + M_e\, L \quad , \qquad (4)$$

where T_1 and T_2 are the temperature of the cooling water (M_{cool}), which may be measured at the upper and lower edges of the still's cover, and $\eta\, G_h$ is the heat flux transmitted through the thin layer and cover together into the still.

The calculation of the efficiencies of the used devices had been carried out according to the definition given by Sayigh [3], of the overall efficiency of the still

$$\xi = \frac{q_e}{G_T} \times 100 = \frac{M_e L}{G_T} \times 100\% \quad ,$$

where q_e is the evaporation rate and L is the latent heat of condensation and G_T is the total solar radiation given by

$$G_T = N\, k\, \exp\left\{S_1 - \frac{R}{15} - \frac{1}{T_{max}}\right\} \quad ,$$

where R is the average relative humidity and T_{max} is the maximum ambient temperature,

$$N = 1.7 - 0.458\, \Phi = 1.455$$

(where $\Phi = 1.755$ is the latitude of our positions),

$$S_1 = S/Z, \; Z = \frac{2}{15} \text{ arc cos}(-\tan\phi \tan\delta)$$

$$\delta = (23 + \frac{27}{60})^{\circ} \sin\left\{\frac{360 \times d}{365.25}\right\}$$

(d is the number of days after spring equinox, which is 21 March for our nothern hemisphere) and

$$K = 100\, (\lambda + \psi_{ij} \cos\varphi), \quad \text{gm-cal/cm}^2\text{-day} \quad ,$$

where ψ_{ij} is the relative humidity factor (4) and

$$\lambda = 0.2/(1 + 18\varphi/\pi)$$

The daily sunshine hours (s) are recorded by Campbell-Stocks sunshine recorder model W6060.

Experimental results and discussion

The inclination angle of condenser glass surface used in the tested device is 20°. Initial studies had been carried out on devices with three different angles of inclination of the condenser namely 15°, 20° and 30°. The results showed that the inclination angle 20° of the device 3M-20 is the most efficient. This fact is clear from Table I which summarizes the daily production and the efficiencies of the three devices 3M-15, 3M-20 and 3M-30. For the device 3M-20 the efficiency ranges between 15-32, while for the other devices it is much smaller (2-5 and 7-20 for 3M-15 and 3M-30, respectively). The absorber used in all the three devices was natural sand taken from the Nile bottom settled on aluminium sheet. Actually we had tried to use 6-mm glass covered by black dye as absorber. But it was broken every one or two days, although the efficiency in this case was much higher than in the case of the sand absorber. To examine the change in the efficiency due to the modification

suggested, two identical devices with inclination angle 20°, one of the conventional type and the other with cooling effect (see Fig.1) had been constructed.

The reseutls obtained during ten days in April and May 1980 are given in Figs.2 and 3. Fig. 2 illustrates the hourly productivity of the still 3M-20-cool during six days in the Spring of 1981, while Fig.3 illustrates the daily productivity of the conventional and modified stills during ten days.

Table I summarizes the daily productivity of the two devices in ten different days. The increase in the efficiency is about 10% due to the suggested idea. Actually, more better absorber may lead to better results.

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Table I

day	Productivity kg/day		difference kg/day	percentage
	3M-20-cool	3M-20		
29-4-80	0.900	0.718	0.182	25%
4.5.80	0.750	0.566	0.184	32%
5-5-80	0.900	0.608	0.292	48%
6-5-80	1.200	1.092	0.108	9.8%
7-5-80	0.950	0.923	0.27	2.9%
8-5-80	0.875	0.840	0.035	4.1%
9-5-80	1.100	1.040	0.06	5.7%
10-5-80	1.125	1.054	0.071	6.7%
11-5-80	0.950	0.895	0.055	6.1%
12-5-80	1.100	1.090	0.01	0.9%

Comparison between the daily production rate of the conventional and modified stills.

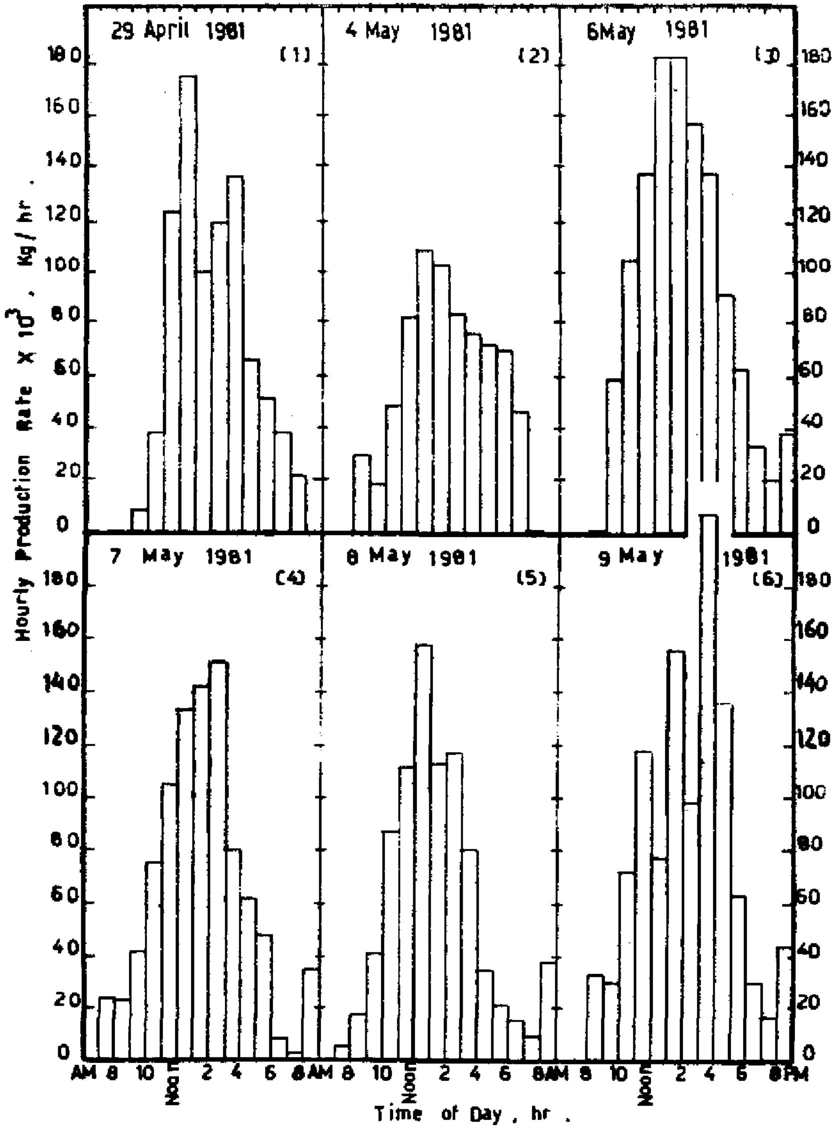

FIG. 2: . Hourly Production Rate in Still

Model 3M - 20 - Cool (Ismailia).

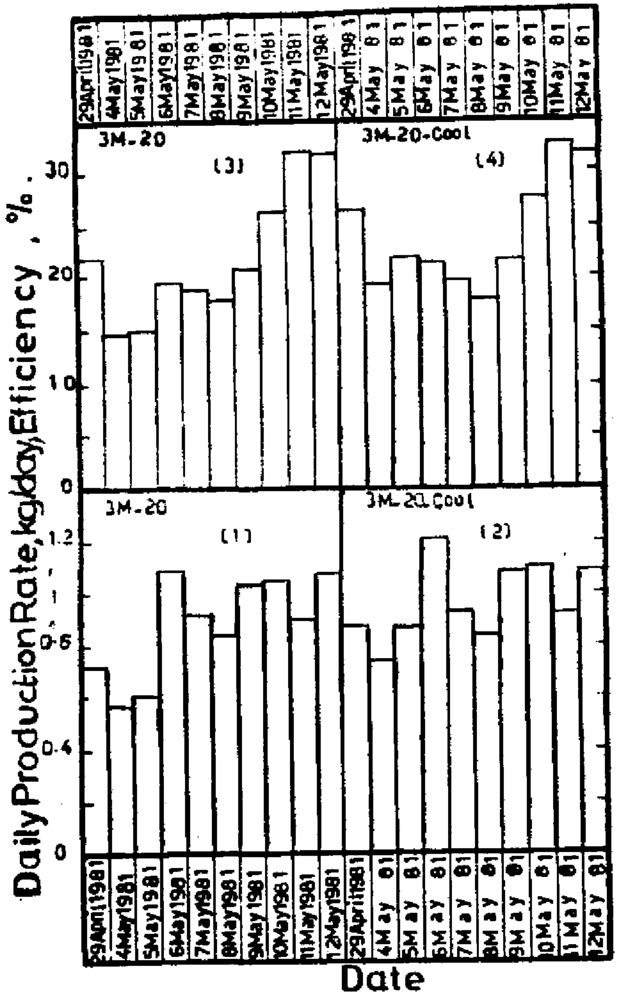

FIG 3: Daily Production Rate & the Efficiency .

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