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PERFORMANCE & ANALYSIS AND OPTIMIZATION OF STEPPED TYPE SOLAR STILL (A REVIEW)

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ABSTRACT
The availability of drinking water is reducing day by day; where as the requirement of drinking water is increasing rapidly. To overcome this problem there is a need for some sustainable source for the water distillation (purification). Solar still is a useful device that can be used for the distilling of brackish water for the drinking purposes Solar still is a simple way of distilling water using the heat of the sun. The performance of stepped type solar still with internal and external reflectors have been investigated in the current study. The reflectors are used to enhance energy input to the stepped still. The influence of internal and external (top and bottom) reflectors on the performance of the stepped solar still is investigated.A comparison between modified stepped solar still and solar still is carried out to evaluate the developed desalination system performance under the same climate conditions. The results indicated that, during experimentation the productivity of the modified stepped solar still with internal and external (top and bottom) reflectors is higher than that for conventional still approximately by 125%. In this case the estimated cost of distillate for stepped still with reflectors and conventional solar stillsis approximately 0.031$ and 0.049$, respectively.

I. INTRODUCTION
the viable options to deal with the water problem is the conversion of saline water to potable water through water desalination by solar energy. Solar stills represent a most attractive and simple technique among other distillation processes. Given all their merits, solar stills face the problem of low productivity compared to their costs.The various factors affecting the productivity of solar still [1] are solar intensity, wind velocity, ambient temperature, water–glass temperature difference, free surface area of water, absorber plate area, temperature of inlet water, glass angle and depth of water.The solar intensity, wind velocity, ambient temperature cannot be controlled as they are metrological parameters. Whereas the remaining parameters can be varied to enhance the productivity of the solar One stills. Many modifications have been done to increase the productivity of distillate of a basin type still, reviewed by [1,2]. Depth of water in the solar still inversely affects the productivity of the solar still. Investigations indicated that a reduction of the brine depth in the still improves the productivity, mainly due to the higher basin temperature. For maintaining minimum depth,wicks, plastic water purifier and stepped solar still were used. So that stepped solar stills can increase the distillate productivity about conventional solar stills, many reports studied the performance of stepped solar still [3–7].Velmurugan [3,4] studied the augmentation of saline streams in solar stills integrated with a mini solar pond. Industrial effluent was used as feed for fin type single basin solar still and stepped solar still, maximum increase in productivity of 100% was obtained when the fin type solar still was integrated with pebble and sponge. An attempt was made to enhance the productivity of the solar stills by connecting a mini solar pond, stepped solar still and a single basin solar still in series. The results showed that, when fins and sponges are used in both the solar stills a maximum increase in productivity of 80% is obtained. In addition, Velmurugan [5] used a stepped still and a settling tank to desalinate the textile effluent.A maximum increase in productivity of 98% is reported in stepped solar still when fin, sponge and pebbles are used in this basin.A weir-type cascade solar still, integrated with latent heat thermal energy storage system, was designed with the view of enhancing productivity [6]. A heat storage system with 18 kg mass (2 cm thickness) of paraffin wax beneath the absorber plate was used, to keep the operating temperature of the still high enough to produce distillated water during the lack of sunshine, particularly at night.Kabeel [7] conducted experiments on two solar stills simultaneously; a conventional single sloped solar

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still and a modified stepped solar still. The influence of depth and width of trays on the performance of the stepped solar still were investigated. Feed water temperature to the stepped still was varied using a vacuum tube solar collector. For further augmentation of the yield, a wick on the vertical sides was added to the stepped still It is found that maximum productivity of stepped still was achieved at a tray depth of 5 mm and tray width of 120 mm, which is about 57.3% higher than that of the conventional still.

II. LITERATURE REVIEW

Productivity Enhancement of Conventional Solar Stills Using Water Sprinklers and Cooling Fan. Husham M. Ahmed and Khalid 08/05/12

The aim of the present research is to experimentally evaluate the effect of reducing the volumetric space, the wind velocity and using a sprinkler to cool down the glass cover of the conventional, single base, single slope solar still under the climate of the city of Kuwait during the month of August 2011.

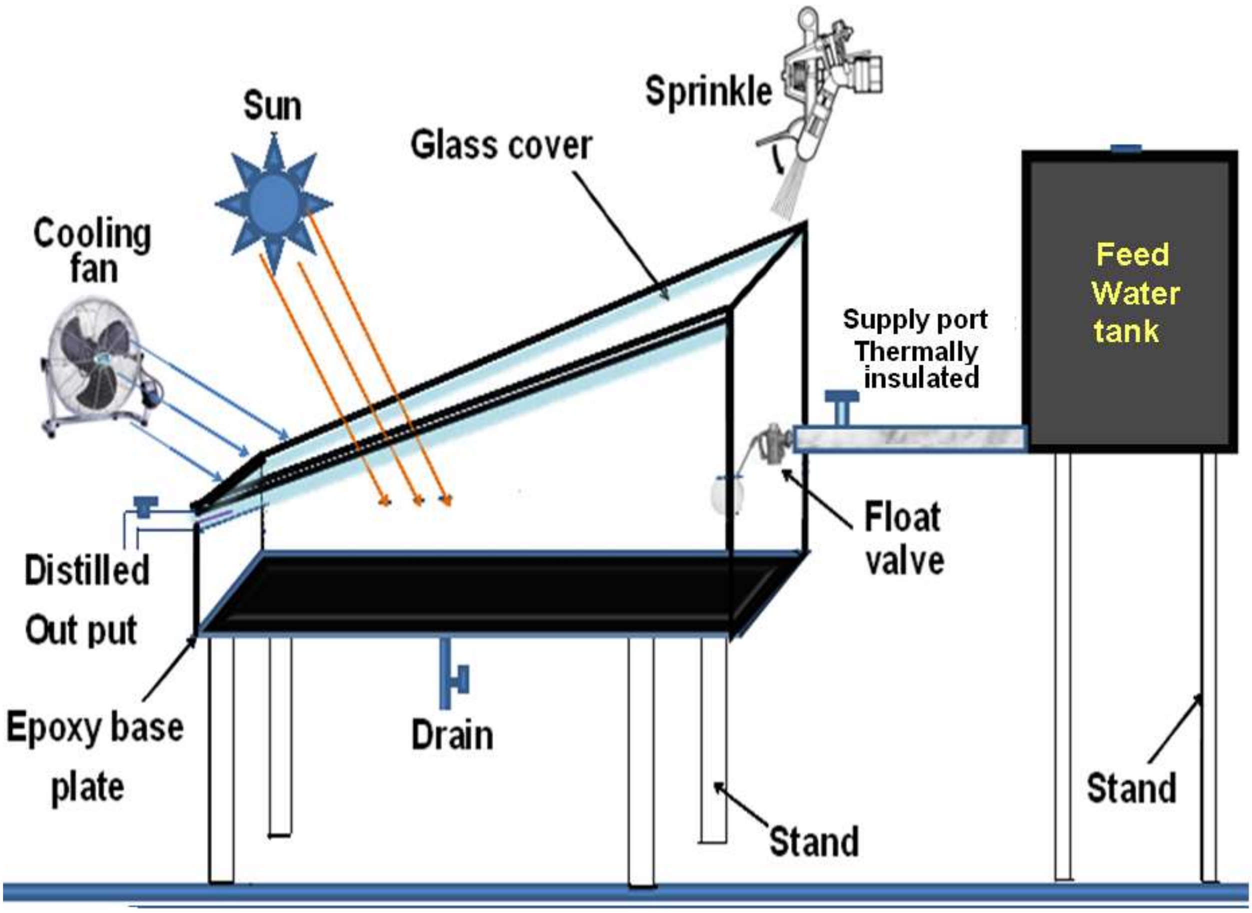

fig. 1 Solar still schematics diagram setup

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Working of a solar still
A solar still is a very simple way for distilling water, which is powered by the heat of the sun. Impure water is inserted into the container, where it is evaporated by the sun through clear plastic/ glass. The pure water vapour condenses on top and drips down to side, where it is collected and removed [4]. A schematic diagram of simple solar still is shown in Fig. 2. It consists of an insulated black painted aluminum pan where impure water stands at shallow depth. A sloping cover of glass, supported by an appropriate frame, covers the pan and is sealed tightly to minimize vapour leakage.A distillate through runs along the lower edge of the glass to collect the

distillate and carried out of the enclosure through a plastic well insulating tube. The aluminum pan containing water is placed on an insulating base, while the wood frame is enclosed in the system [5]. The experimental part of the study consists of running the experiment with different sets of system and operating parameters. The analytical/numerical part includes the development of a mathematical model for solar still and then solving those mathematical models for the prediction of the solar still performance using computer simulation. In general a maximum efficiency of solar still is around 50% as compared to full insulation. A less insulation can cause a reduction of 14.5% in the efficiency. The increase of wind velocity from 0 to 3.6 mph yielded a slight reduction (2%) in the still performance.

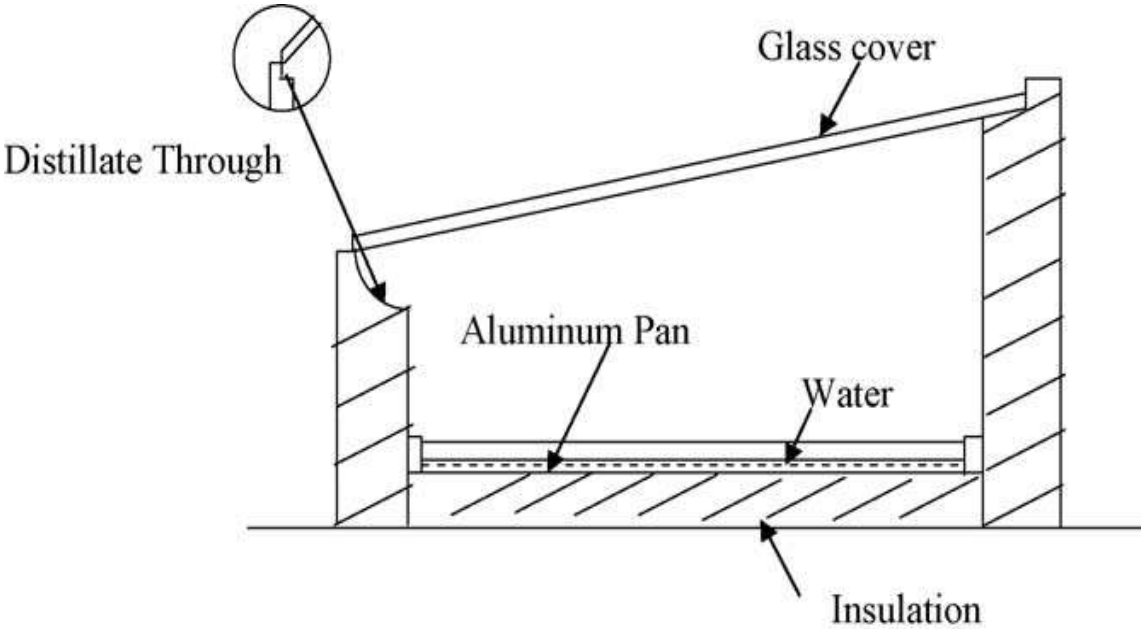

Fig. 2. A schematic diagram of a simple solar still.

Stepped Type Solar Still

In stepped type solar still, a still similar to greenhouse type is considered. The insulated box and glass roof are the same as traditionally constructed. However, the stepped type basin replaces the basin (normally the same size as the glass cover). The distillate collection trough is provided at the bottom of the glass cover as shown in Fig.3 A sufficient depth to each step is provided to remain the water stagnant and continuously exposed to the incoming isolation. The number of steps is depending on the area of solar still.

Redesigning the water basin into a stepped type structure gives higher thermal performance than single basin type solar still. This is due to two reasons:

(i) A smaller air volume is trapped inside the still chamber than in the single basin solar still and therefore heating up the trapped air in the still is much faster and

(ii) The stepwise basin provides higher heat and mass transfer surface area than the single basin for the same overall dimensions.

The advance stepped type solar still over the other conventional solar still is the reduced distance of the glass from the basin which would result the reduction in irradiative and convective losses. Also the same distance is maintained for the entire basin area from the glass cover, which is not possible in single basin, or double solar still in which glass is at varying distance from the basin. The glass slope is adjusted as per the design of step.

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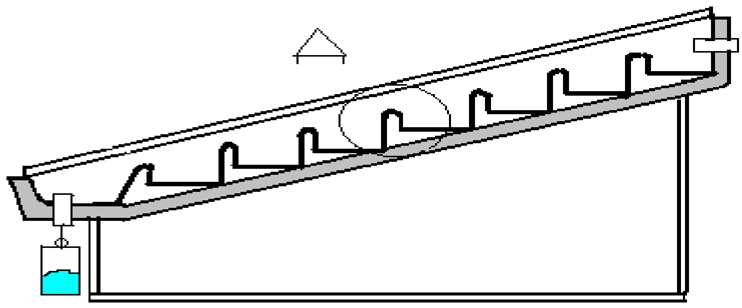

Fig.3: Schematic diagram of stepped type solar still

In operation, solar radiation is transmitted through the cover and gets absorbed by the saline water in the basin. The solution is heated, the water evaporates and vaporizes to the cover by convection where it is condensed on the underside of the cover. The condensate flows by gravity into the collection through at the lower edge of the cover; the cover must be at sufficient slope that surface tension of water will cause it to the lower end of the glass and into the trough without dropping back into the basin. The trough is constructed with enough pitch along its length so that condense will flow to the lower end of the still where its drains into a product collection system.

The operation of the still may be continuous or batch. If seawater with approximately 3.5% salt is used as a feed, the concentration is usually allowed to double before the brine is removed, so about half of water in the feed is distilled off.

Salient Features of Stepped Type Solar Still

- Its working is completely a natural process.
- It uses renewable sources of energy and hence helps in reducing shortage of power in the country.
- As it do not require any fuel for its operation hence its operation & maintenance cost is very low.
- The distilled water obtained as the end product is very pure, an ultra-pure product.
- It eliminates chemicals from raw water such as chloride, nitrate, cyanide, arsenic, Phenolic compounds, Mineral oil, Pesticides, etc.
- It eliminates salts such as Sulphate, Nitrate, Chlorides, etc.
- It eliminates sediments such as sand, dust, mud

Enhancing the stepped solar still performance using internal and external reflectors Z.M. Omara A.E. Kabeel , M.M. Younes a Mechanical Engineering Department, Faculty of Engineering, Kafrelsheikh University, Kafrelsheikh,

III. EXPERIMENTAL SETUP

The experimental setup of the present study was located at the Faculty of Engineering, Kafrelsheikh University, Egypt (Latitude 31.07_N and longitude 30.57_E). The experiments were carried out during June to September 2012. Fig. shows a schematic diagram of the experimental setup. It consists of a saline water tank, a conventional still (single basin solar still) and a stepped solar still. The description of experimental setup is same Ref. [7] with some modification for stepped still. Basin area of the conventional still is 1 m2 (0.5 m _ 2.0 m). High side wall depth is 450 mm and the low-side wall height is 160 mm. The still is made of Galvanized steel sheets. The whole basin surfaces are coated with black paint from inside to increase the absorptivity. Also, the still is insulated from the bottom to the side walls with sawdust of 4 cm thick to reduce the heat loss from the still to ambient. The insulation layer is supported by a wooden frame. The basin is covered with a clear glass sheet 3 mm thick inclined at nearly 30_ horizontally, which is the latitude of Kafrelsheikh, Egypt to maximize the amount of incident solar radiation. The whole experimental setup is kept in the south direction to receive maximum solar radiation throughout the year. The stepped still has the same dimension and construction of conventional still; in addition the absorber plate is made of five steps (each of size 0.1 m _ 2 m) with tray depth 5 mm and width 120 mm, so that the absorber and water area are equal to 1.16 m2. The mirrors added on the

vertical sides of the steps as internal reflectors of stepped still. The top external reflector inclined backward. A photo of the stepped solar still with an internal and external reflectors is shown in Fig. 4. The angle of the glass cover was set at 30_ from horizontal. The width and length of the external (top and bottom) reflector are 60 cm _ 200 cm nearly the same area of glass cover. Ref. [18] indicated that the top reflector is able to be inclined forwards or backwards according to the seasons. In winter, the altitude angle of the sun decreases so a considerable amount of the reflected radiation from the vertical reflector would escape to the ground without hitting the still. Therefore, the top reflector should be inclined slightly forward. On the other hand, the altitude angle of the sun increases in summer and the vertical reflector cannot effectively reflect sunrays to the still. Therefore, the top reflector should be inclined slightly toward the back and the inclination angle of the reflector would be less than 25_ throughout the year. Ref. [13] indicated that, a flat plate bottom reflector extending from the lower edge of the still and inclined upwards from horizontal (through the year) would also be able to increase the solar radiation absorbed on the still as well as the distillate productivity. Table 1 shows the optimum inclination of top and bottom external reflectors. So, in the present study (the experiments in summer season) the angles of the top and bottom external reflectors (hT and hB) were set at 15_ and 50_ which was predicted as an optimum reflector angle in the summer season when glass cover angle is 30_ [11,13,17]. Calibrated copper constantan type thermocouples (±1 _C) in combination with a modular PLC was used to measure the base, water, and outside glass temperatures of the studied stills. Also, a thermocouple is used to measure the ambient temperature. The solar radiation intensity is measured instantaneously by solarimeter with an accuracy of ±1 W/m2. A flask of 2 l capacity and an accuracy of 5 ml was used to measure the hourly yield. Vane type digital anemometer was used to measure the wind velocity with an accuracy of ±0.1 m/s. The solar radiation, ambient temperature, and the temperature of basin plate, saline water, outside glass cover and distilled water are measured every 1 h. The accumulated productivity during the day is also measured.The depth of the saline water in the solar stills is H = 5 mm, where Kabeel et al. [7] Found that the maximum productivity of stepped solar still is achieved at a depth H = 5 mm. The error analysis is same Ref. [7]. In addition, the depth of the saline water in the solar still is kept approximately constant during the experiment by manual make up every half hour with an amount of water equal to
the distillate.

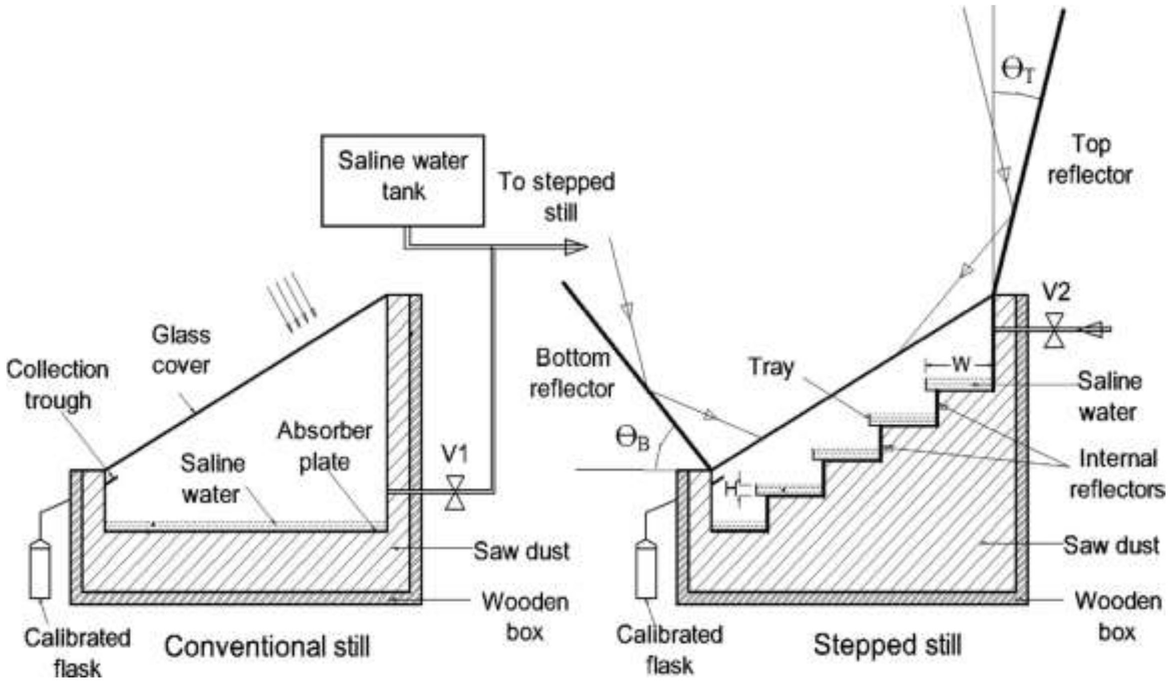

Fig. 4. Schematic diagram of the experimental setup

IV. CONCLUSION

We performed outdoor experiments of a stepped solar still with internal and external (top and bottom) reflectors. The results show that the thermal performance of a modified stepped solar still can be considerably improved through the new modification. A very simple modification using internal and external (top and bottom) reflectors can increase the daily productivity of a stepped solar still by about 125% over conventional still. In

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this case the estimated cost of 1 l of distillate for stepped still with reflectors and conventional solar stills is approximately 0.031$ and 0.049$, respectively.

V. SCOPE FOR FUTURE WORK

In the present work, an attempt has been made to analyze various configurations of stepped type solar stills with different modes of operations. These results reveal that the stepped type solar still provided with convex surface area of the basin produces higher distillate yield. These analyses suggest that the various configurations of stepped type solar stills to produce pure distilled water. At a time when attention is firmly focused worldwide on control and prevention of pollution, efficient use of energy and more reliance on renewable energy sources, these different types of distillation systems are warmly welcome to fight against environmental pollution and they are packed with energy saving and environmental friendly features.

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