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TECHNIQUES USED TO REDUCE BACK WALL LOSSES OF SOLAR STILLS - A REVIEW

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ABSTRACT. Access to clean water is being limited throughout the globe day by day. Several illnesses are caused by water supplies that are contaminated or not distilled. Immediately people's necessity is to purify water without impacting the environment. Solar distillation is an extremely clean distillation in a water treatment procedure. Solar still is among the methods for water purification that produce potable water. Several atmospheric and operational factors require the still lay-out to be augmented. As is commonly known, the vertical sides of the SS become hotter as solar radiation hits them, and the high temperature area resulted in considerable energy losses to the surroundings. To increase the profitability of solar stills, researchers have investigated a variety of models. Throughout its experiments, the solar still with rotating components has been regarded as a reliable and efficient system. Throughout this comprehensive review, we presented, clarified, and analyzed the status of various techniques used to reduce losses of back wall of solar stills solar distillers, for instance rotating wick, vertical wick, drum, trays, discs... etc. Diverse outcomes (highest daily output & improvement) demonstrated the significance of rotating parts, including vertical wick distiller (7.2 L/m²/d & 154%), moving wick solar still (9.17 L/m²/d & 315%), drum distiller (9.22 L/m²/d & 350%), and vertical disc distiller (16.5 L/m²/d & 617.4%).

KEYWORDS: Solar still; Review; Rotating parts; Wick; Solar desalination, Nanoparticles.

1. INTRODUCTION

God gave us water, which is essential for the growth of a society's economy. The planet always has a limited supply of pure water. In addition to the quickening technological revolution, overpopulation is another factor contributing to the rapid rise in clean water needs. The availability of drinkable water is one of the greatest issues that both industrialized and developing nations must deal with. Unfortunately, the majority of health issues are brought on by lack of access to potable water. In recent years, only sporadic rainfall has been recorded in several parts of the world, and the salt of the water has risen. Water supplies are growing more and more polluted as a result of several factors like population growth, industrial development, etc. All of these methods have a detrimental effect on the quality of water in rural and agricultural areas. Each day, individuals spend 200 million hours, primarily by collecting water from contaminated remote streams. 3,575 million people each year die from polluted water. The majority of rural residents are still ignorant of the consequences of polluted water supplies. There are no known health facilities in any of the settlements in industrialized or developing nations.

It is fortunate that distillers offer many benefits for rural areas and islands, where transportation costs for purified water are currently needed due to a water shortage. Although it is more cost-effective to build it with readily available materials, with a little need for operation and maintenance, as well as environmentally sustainable infrastructure. Solar panels are therefore a useful way to actively use solar energy. There are two main advantages of using solar stills. The first is free, secure electricity. Environmental friendliness will be the second advantage. Wherever sunlight (renewable energy) is used more frequently, less fossil fuel and toxic materials are used, which reduces global warming emissions. The main disadvantage, however, is that it produces less cleaned water than other desalination systems. The basic form's daily capacity ranges only from 2 to 5 L/m^2. In comparison to other conventional desalination applications, the distiller's efficiency in solar desalination applications is quite low [1]. The primary desalination processes, including vapor distillation, reverse osmosis, and electrolysis, all need electrical energy as an energy input. Due to a heavy reliance on conventional energy sources, most countries around the world have experienced this big energy issue in recent decades. (carbon, fossil fuels, etc.). Therefore, their environmental and economic development has a tremendous impact on these areas. These systems are not appropriate for small, far-off villages. Fresh water may be effectively supplied to these locations using solar stills.

There has been numerous research conducted to improve the thermal productivity and efficiency of solar still (SS) systems. A variety of SS system geometries, including CSS, half barrel SS [2, 3], stepped SS [4-7], trays SS [8, 9], tubular SS [10-13], and pyramid SS [14-17], have been tested under varied design and operational conditions. Additionally, fins [18], reflectors [19, 20], phase change material [21], nanoparticles [22, 23], wick material [24], and rotating components [25-27] have been applied to improve the functionality of SS systems..

2. THE BASIC SOLAR STILL'S MECHANISM

As shown in Fig. 1, a basic solar distiller consists of a tank with shallow contaminated water in the basin (typically painted black to have high absorptivity), an inclined crystal cover made mostly of glass, a trough for collecting purified water, insulation on all sides except glass, an intake for unclean water, and a drain valve for cleaning the still basin.

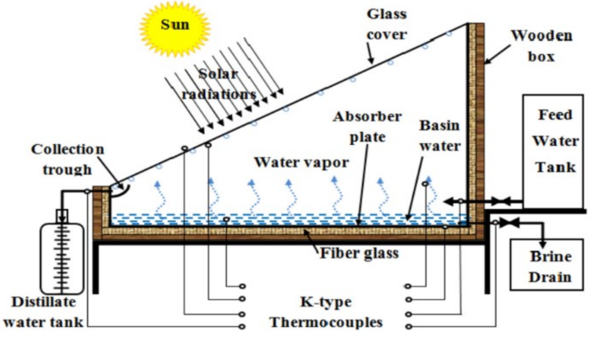

Fig. 1. A simple distiller's graph.

Sunlight that penetrates through the clear glass lid of the tank fills it, Convection from the tank's basin heats the water in the tank, which then turns into vapor. In the empty region, the vapors ascend to the top. When the glass cover absorbs the heat, the vapors are transformed into liquid water. Condensate drips from the tilting lid onto the distillation channel on the still's lower wall. As a result, the pool's salts and other pollutants are left behind, where they may be later removed through the drainage system, whereas the incident solar light merely causes water to evaporate. Saline water can be converted into drinkable water using a traditional solar still, but it has a weak capacity for distillation and is inefficient.

3. TECHNIQUES USED TO REDUCE LOSSES OF BACK WALL OF SOLAR STILLS

3.1. VERTICAL WICK SOLAR STILL

The solar energy that strikes the vertical sides of the SS causes a high temperature area, and the significant energy losses to ambient that resulted from this high temperature area. Younes et al., [2] introduced a wick material to the corrugated SS (CWSS) and half-barrel SS (BWSS) vertical sides, Fig. 2. The wick material maximizes the area where water evaporates and prevents direct sun radiation from falling on the SS vertical sides. Consequently, the rate of evaporation and condensation rose while the heat losses were decreased. Under the absorbers, nanoparticles (CuO) combined with phase change material (PCM) was used to further enhance the performance of CWSS and BWSS. The findings showed that compared to traditional SS, BWSS and CWSS had daily production that was respectively 154% and 139% higher.

Fig. 2. Vertical wick solar still [2].

Park et al., [28] experimented with an alternative solar still using a multi-effect diffusion (MED) unit, the system's heat sources included both waste energy and solar intensity, as shown in Fig. 3 and Fig. 4. Steel plates that made up the partitions were covered with cotton flannel wicks on one side of each plate. The eleven partitions of the multi-effect diffusion unit (total thickness: 6.2 cm) were separated from one another by 5 mm. The authors looked at the effects of changing the flow rate of sea water to the wicks, the heat input to the hybrid still, and the depth of the water in the basin. According to the results, increasing the input heat (22.37 MJ per day) causes the output freshwater (18.02 l/m²) to increase. The best distillation of freshwater was also produced at the lowest water height. The study's final finding was that the multi-effect diffusion unit contributed significantly to system performance, contributing more than the basin alone.

3.2. TRAYS SOLAR STILL

Tray SS, a brand-new SS design, is used to increase efficiency and decrease solar still wall losses. Both theoretical and experimental research on the performance TSS has been done by [8, 29], Figs. 5, 6 and 7. The traditional SS was modified to include internal trays as well as exterior and internal reflectors at the bottom and top, which led to the creation of the trays solar still design. Trays and reflectors can be used on TSS vertical walls to lower their temperature and lessen heat leakage to the environment. Their outcome indicated that the Trays SS using internal and external reflectors indicated 95% increase in the fresh water productivity than that of CSS. Abdullah et al., [29] investigated experimentally trays type SS to study a few performance enhancing measures. They tested three such techniques: basin walls and trays coated with mixture of nanoparticles and black paint, paraffin wax mixed with CuO nanoparticles, internal mirrors. A theoretical model was presented in addition to the experiment. A 108 % improvement in daily productivity was obtained when all of these tactics were combined.

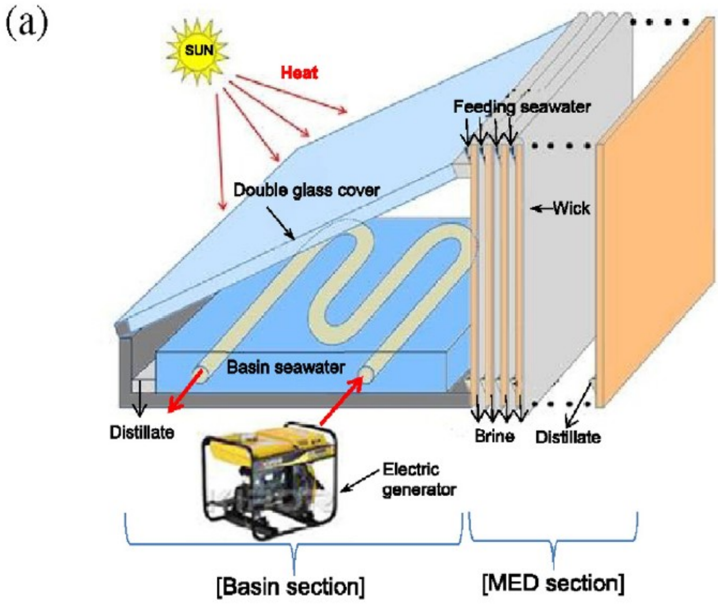

Fig. 3. Hybrid multi-effect diffusion still's schematic [28].

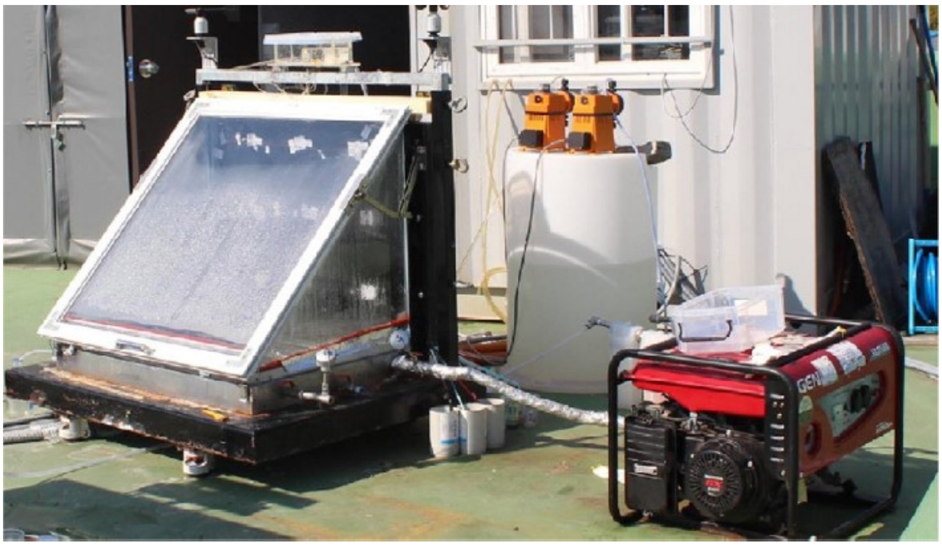

Fig. 4. Test setup for hybrid multi-effect diffusion still experiments [28].

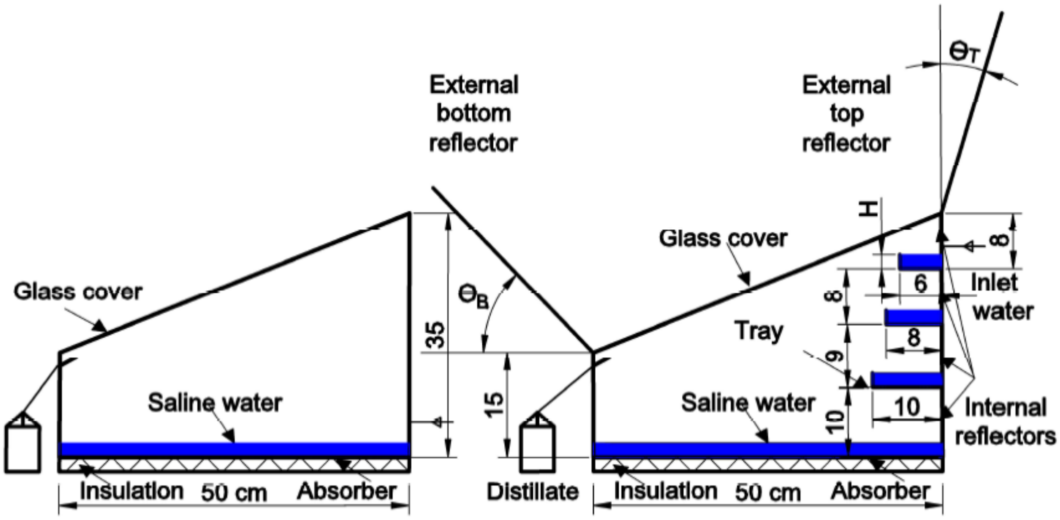

Fig. 5. Cross-sectional picture of the experiment's configuration [8].

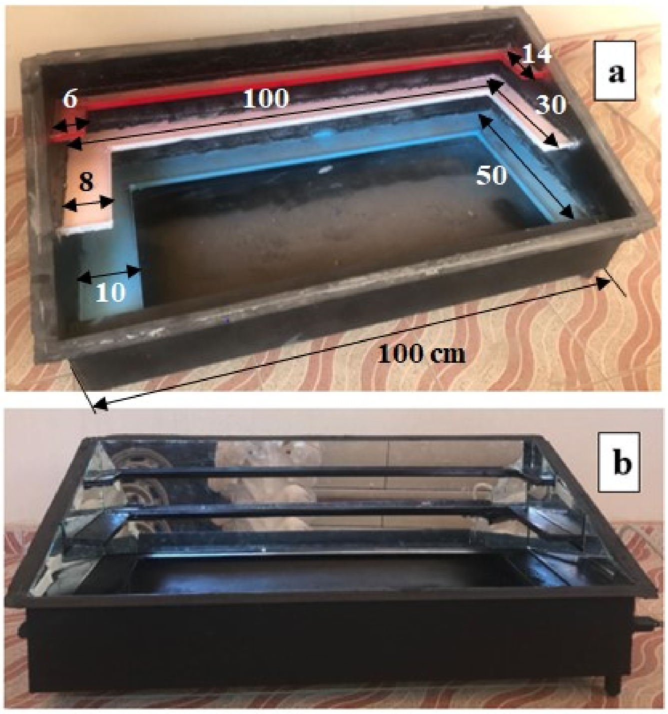

Fig. 6. Trays solar still, (a) Trays before applying black paint (b) inside mirrors [8].

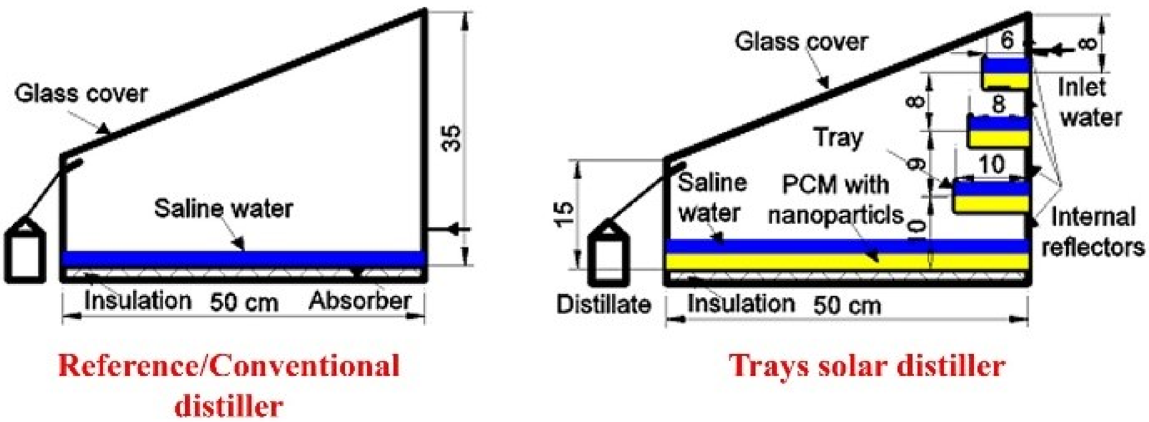

Fig. 7. Cross-sectional view of trays with PCM [29].

3.3. VERTICAL MIRRORS SOLAR STILL

Omara et al., [30] experimented with placing wick material (double-layered) over the solar still's corrugated absorber that was integrated with mirrors that covered the interior of the SS four walls, , Fig. 8. The authors also investigated how the still performed in varied water height (1, 2, and 3 cm). The experiments demonstrated that the amount of distillate and total thermal efficiency could both be raised. As shown in Fig. 9, utilizing wicks (double-layered) and wicks with reflectors, respectively, at 1 cm water depth, increased the production of freshwater by 90% and 145.5% above that of the conventional solar still. Additionally, by utilizing wick material and wicks with mirrors, the thermal efficiency was raised from 49.3% to 59%, respectively.

Fig. 8. Corrugated absorber solar still with mirrors and wick [30].

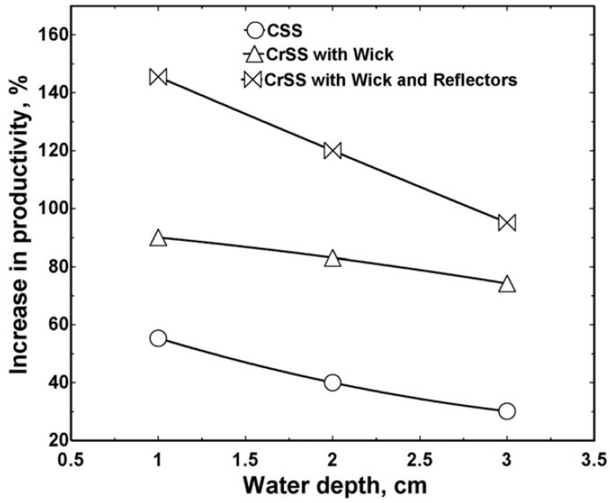

Fig. 9. Productivity increases for conventional still (CSS) and corrugated still (CrSS) [30].

In a separate experimental study, Omara et al., [31] tested the effects of integrating external condenser on the performance of V-corrugated basin liner solar still. A vacuum pump fixed into the still's back has been used to extract steam from the solar still to the external condenser, as shown in Fig. 10 and Fig. 11. The scientists further investigated the still's performance using different nanoparticles in water of 1, 2, and 3 cm depths while integrating vertical mirrors over the interiors of the four vertical walls, as seen in Fig. 11. The results of the experiment showed that all of the evaluated parameters had a substantial impact on the output freshwater distillate. As a result, the corrugated-wick still with mirrors achieved a productivity that was 180% higher than that of the conventional type when providing vacuum inside the modified basin at 1 cm basin water. Additionally, in the same conditions, adding cuprous and aluminum oxides increased the output distillate by 285.10% and 254.88%, respectively.

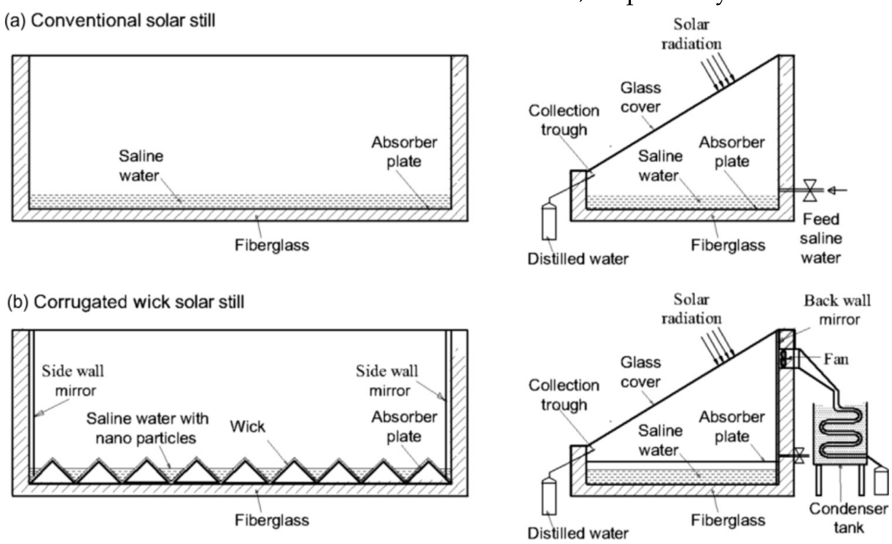

Fig. 10. Schematic of solar stills [31].

Fig. 11. Image of the corrugated wick still with the vacuum and mirrors [31].

3.4. ROTATING PARTS SOLAR STILL

3.4.1. SOLAR STILL WITH ROTATING SOLID OR HOLLOW DRUM

The impact of employing a moving solid drum at different speeds with SS has been tested by Abdullah et al., [32]. They investigated how the performance of the distiller differed from the conventional one when equipped with a solar water heater and an outside condenser. Additionally, as depicted in Fig. 12, they tried adding water-copper oxide mixture (nanofluid).

Their customized solar still's productivity was experimentally increased by 350% when compared to a traditional distiller under the same metrological conditions while the drum rotating speed was 0.1 rpm. Additionally, by including a solar water heater, an outside condenser, and nanofluids, they reported an efficiency of 85.5%. In addition, they found that the modified solar still cost 22% less to produce distilled water than the traditional still did.

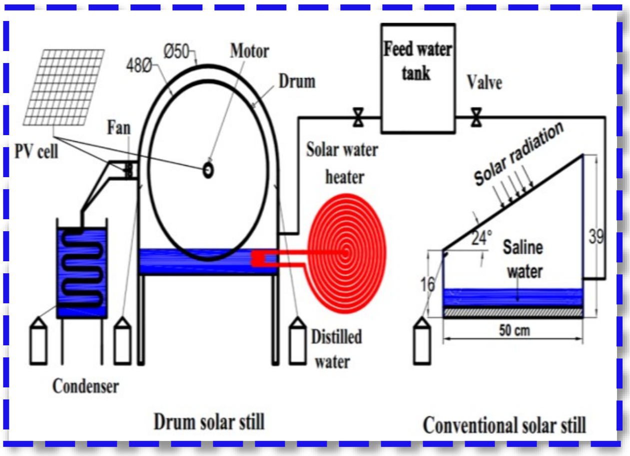

Fig. 12. A graph of conventional and modified solar stills [32].

In a different study, Malaeb et al. [33, 34] examined the effects of adding a rotational cylinder to a simple distiller and suggested increasing the evaporation surface area. The solar still output increased by 250% as a result. In the basin cavity, a hollow drum was used. Additionally, they highlighted how the cover geometry affected their design [35], as seen in Figs. 13, 14, and 15.

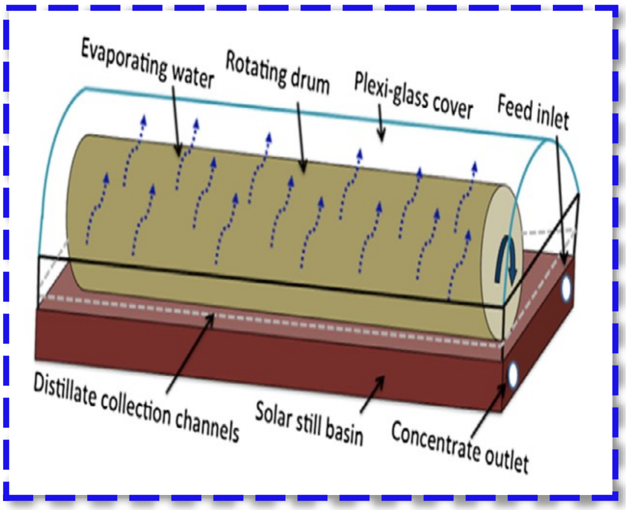

Fig. 13. A graph of a rotary drum inside an adjusted distiller [33].

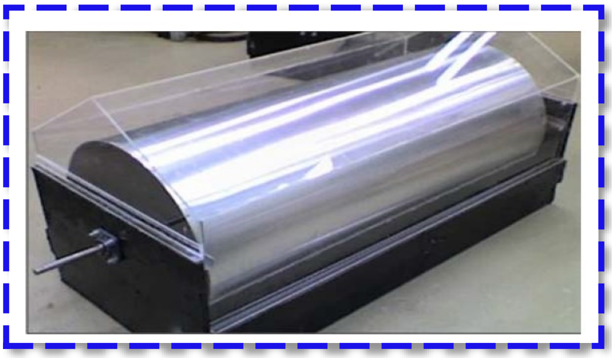

Fig. 14. Modified triangular double-sloped solar still [34].

Fig. 15. A cover geometry diagram for a modified distiller [35].

Abdullah et al., [36] investigated a new design of revolving drum inside the traditional distiller as another modification to the solar still, Fig. 16. At various rotating speed (0.02, 0.05, 0.1, 0.2, 0.5, 1.0, 2.0, 3.0, and 4.0 rpm) the drum performance was investigated. Additionally, they made several useful adjustments including employing a PV cell to power the DC motor, internal high-wall reflectors on the rear of the drum to reduce still heat loss, and the effect of combining nanoparticles and wick on drum performance. The results showed that the modified drum solar still with nanofluid and reflectors at 0.1 rpm was 296% more productive than the conventional distiller. While the maximum distillate output for the modified drum SS with wick was 280% at 0.05 rpm.

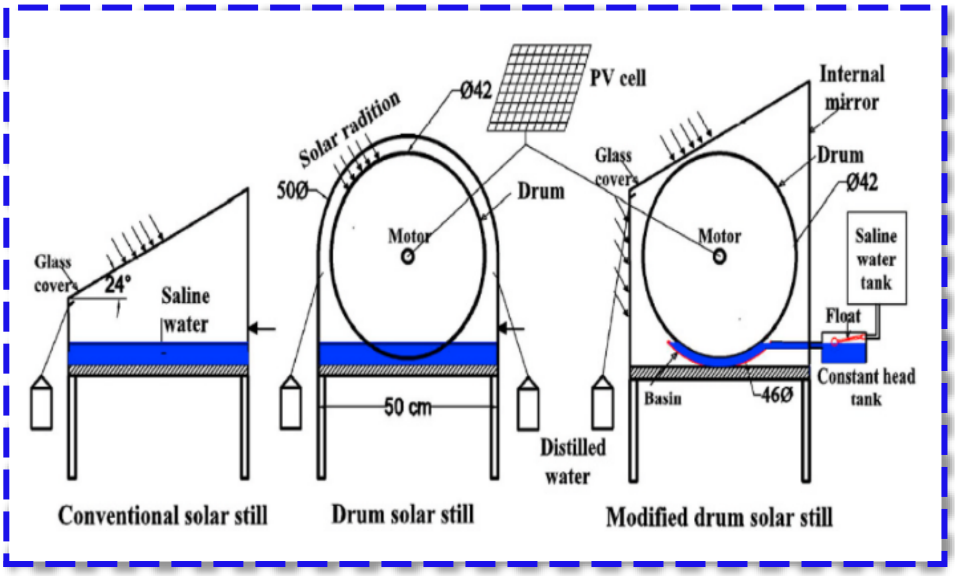

Fig. 16. A lay-out of modified drum distiller [36].

Also, Essa et al., [37] improved the performance of a tubular distiller by including a revolving drum inside the basin, as depicted in Fig. 17. They exhibited a modified method for lowering the water depth inside the tubular SS using a spinning drum in both practical and theoretical ways. The moving drum in the tubular SS displaces the least water into the basin and creates a thin, quickly evaporating water layer. As a result, the effect of using closed ends drum as opposed to open ends drum on a tubular distiller's productivity was investigated. Additionally, the tubular solar still's exposure and evaporation surface areas were improved by the employment of a revolving drum. Additionally, it was examined how the performance of the distiller was affected by various rotational speeds. The mechanism was also examined both with and without the wick. The findings showed that at 0.1 rpm and without wicks, the tubular drum yield increased by 121%, while closed and open-end drums improved by 136%. Tubular drum output rose by 175% and 140% on the open and closed ends, respectively, at 0.05 rpm and with wick. Additionally, the thermal and energy efficiency of the drum was maintained at 56.4% and 3.45% for the closed ends with wick and at 61 and 3.6% for the open ends.

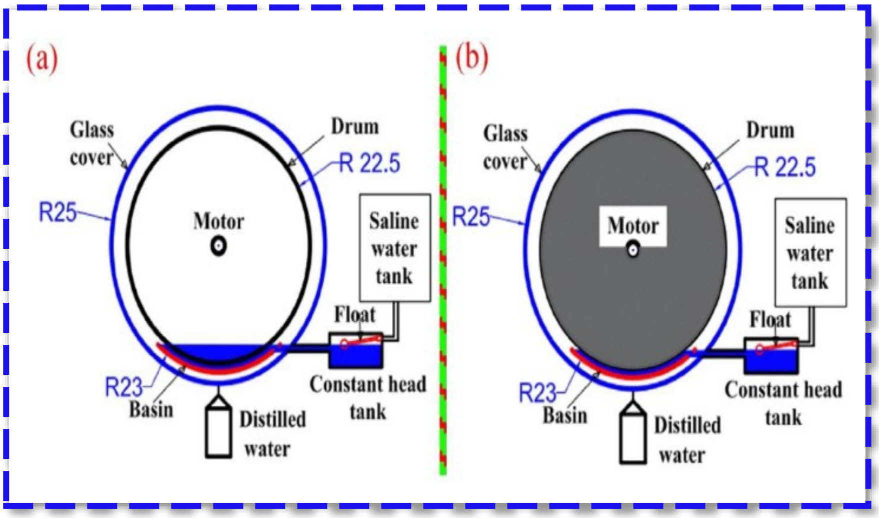

Fig. 17. An illustration of the tubular SSs that were investigated shows (a) open-ended drum and (b) closed-ended drum. [37].

3.4.2. SOLAR STILLS WITH THIN ROTATING DISC

Essa et al., [38] created a revolutionary distillation method by combining rotational discs with the conventional solar still. The goal of the designers was to minimize the amount of saltwater while maximizing the area of the basin's evaporative surface and the area exposed to solar radiation. Due to this, two different rotating disc types, flat and corrugated discs with and without wick material were put within the distiller to be examined. Analysis of the output of the modified solar still with rotating discs at various rotational speeds.

According to the investigation, the produced freshwater distillate by the disc SS was more than the conventional one. Additionally, when the flat and corrugated discs were mixed with and without wick, the modified distiller performed best at 0.05 rpm and 0.1 rpm. Additionally, the corrugated disc solar still with wick produced 124% more freshwater distillate than the benchmark distiller. Corrugated and flat disc solar stills with wick had maximum thermal efficiencies of 54.5% and 50%, respectively, at 0.05 rpm.

In a recent study, Essa et al., [39] examined experimentally integrating rotating flat discs with the vertical SS, Fig. 19. The researchers used revolving discs inside the distiller basin to reduce the water film and improve the area of evaporation. Additionally, the rotary discs aided in the evaporation process by reducing the tension on the water's surface. They also changed the glass cover's shape to better absorb solar rays. They consequently employed a single-stage vertical distiller with two flat discs. The stages were then doubled, as seen in Fig. 19. .Finally, they experimented with various disc speed ranges (0.125, 0.25, 0.31, 0.5, 0.75, 1.0, 1.25, 1.5, 2.0 and 2.5 rpm). The investigates revealed that using discs inside the distiller significantly increased the productivity of the distilled water as compared to a traditional distiller. In addition, 1.5 rpm was the ideal speed for the rotating discs. Its highest thermal efficiency was 77.2% at 1.5 rpm and 5 cm saltwater depth, and the freshwater distillate of the four revolving discs-two stages vertical SS was improved by 617.4% over the reference still.

3.4.3. WICK BELT IN MOTION WITHIN THE SOLAR STILL BASIN

Researchers put in a lot of work to increase distiller productivity. Consequently, research is done on a different moving-wick concept. The primary goal of utilizing a black clothing belt that rotates between twin rollers at different speeds is to maximize distillate production. The belt may be vertical, horizontal, or angled.

Haddad et al., [40] increased the daily production of the standard distiller by including a rotary vertical wick (RVW). The major goal of this idea is to increase the evaporation rate in comparison to the back of a conventional SS (Fig. 20) by using a black spinning jute belt. This design has many advantages, necessitating little effort, expense, and space. By including the RVW, any single slope distiller can be altered. As a result, compared to the conventional distiller, daily productivity increased by around 14.72% in the summer and by nearly 51% in the winter. As a result, the cost of distilling water increased from 0.009 to 0.011 $/kg by raising the average thermal efficiency from 46% to 65%.

Abdullah et al., [41] investigated the performance of the spinning wick distiller under various operating and design situations. A belt (black jute cloth) that rotates both horizontally and vertically inside the solar still, as shown in Fig. 21. A small photovoltaic (PV) device turns the belt with a DC motor. Under a 30 minute OFF period, the spinning wick distiller's production is 84% and 82%, respectively with and without nanofluids. The accumulated productivity was higher than that of the conventional distiller, at 315% and 300% with and without nanofluids, respectively. Each litre of distillation costs 0.05 and 0.027 $/L in conventional and rotating wick, respectively.

Abdullah et al., [42] examined the effects of utilizing various wick materials on the effectiveness of all different kinds of distillers. They concluded that the profitability of the solar still purification was strongly impacted by the employment of wick materials of various types throughout the distiller basin, whether they were stationary or rotating. In comparison to the other materials, black cotton fabric increased the distiller's efficiency. Additionally, Abdullah et al., [43] searched into a belt (black jute) that was rotated both horizontally and vertically inside the distiller's basin, as shown in Fig. 22. At various belt sliding speeds, the impact of wick belt moving direction (counterclockwise and clockwise) on still performance has been examined. Mirrors were also employed inside and outside the still to help focus more sun energy onto the component. It was noted that the modified still produced more freshwater distillate than the conventional distiller did. The modified distiller's highest performance was attained at 0.05 min-1 and in an up-down sliding motion. Furthermore, compared to a conventional still, 300% higher distillate yield with reflectors against 260% without reflectors.

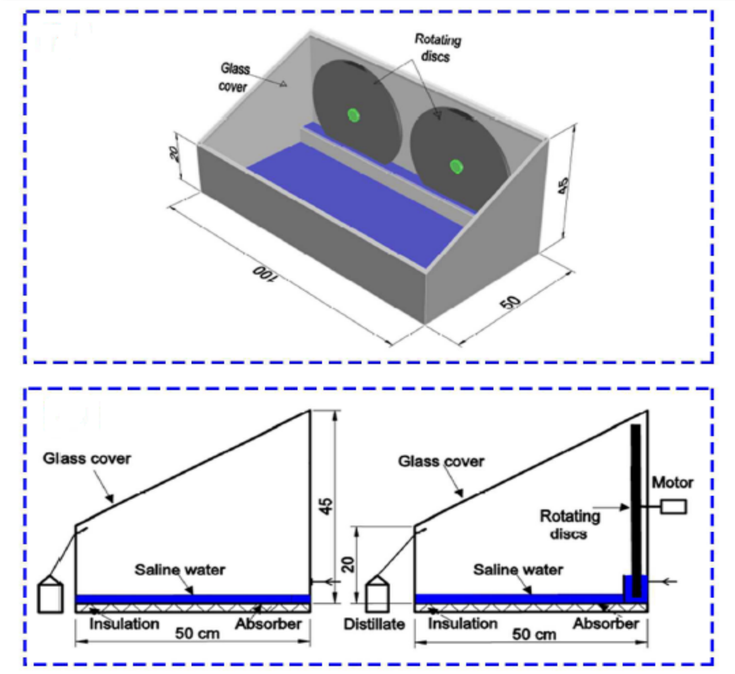

Fig. 18. Schematic illustration of the rotating disc solar still [38].

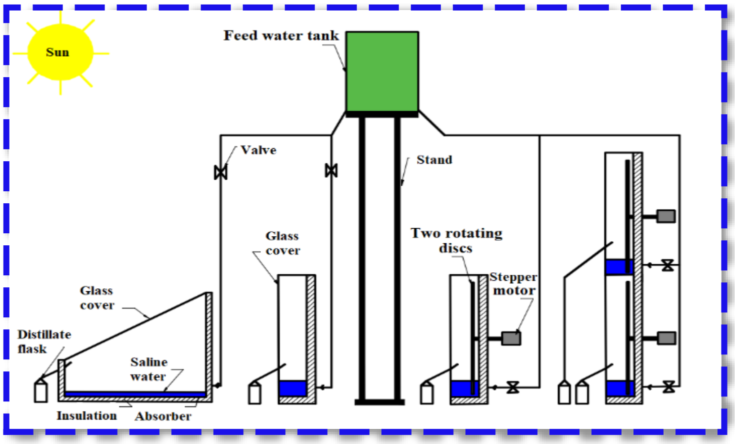

Fig. 19. Diagrammatic representation of the rotating discs addition to the vertical solar still [39].

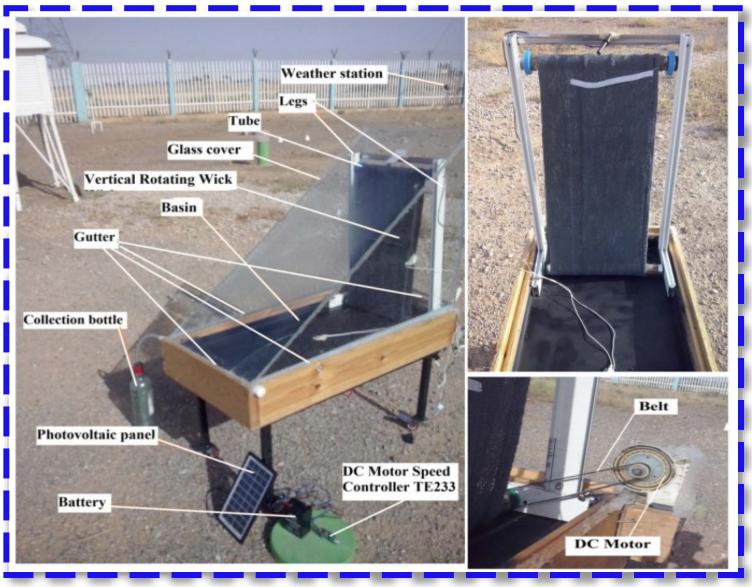

Fig. 20. A picture of the test rig for experiments [40].

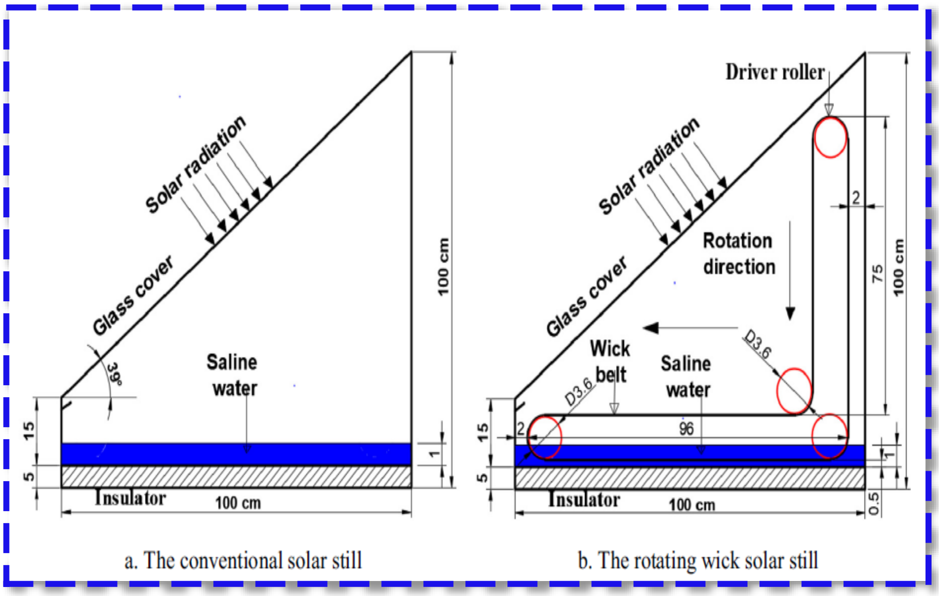

Fig. 21. The spinning wick distiller and conventional distiller designs [41]

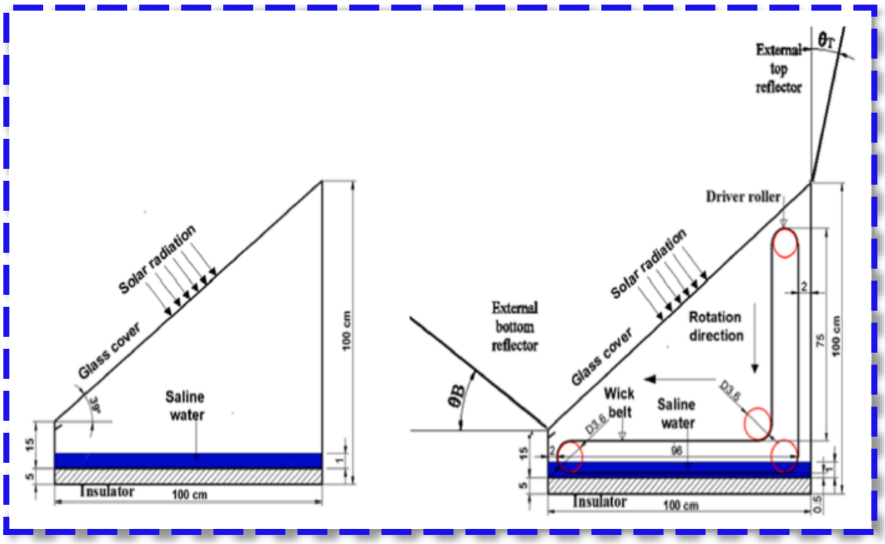

Fig. 22. The configuration of the spinning and traditional wick distillers [43].

A vertical SS with a spinning wick was the subject of an experimental investigation by Omara et al., [44] for a different kind of solar still, as shown in Fig. 23. Assessment was carried out under different operational states. Different wick belt materials (including cotton and jute cloth) were examined with various rotational speeds and orientations (counterclockwise and clockwise). The findings revealed that using a wick distiller increased the freshwater yield from 4350 mL/m² per day to 7250 mL/m² per day (jute wick-CCW- 0.1 rpm).

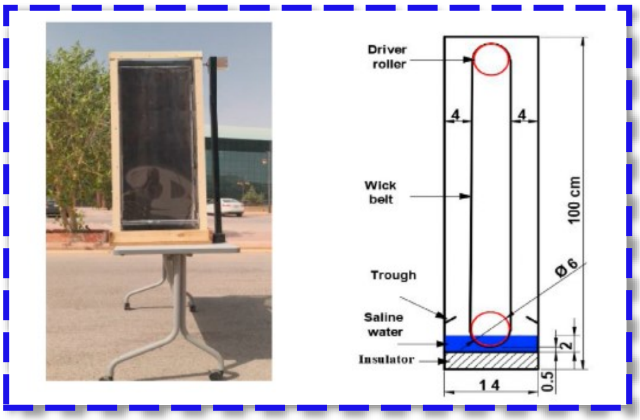

Fig. 23. A vertical distiller's design and graph with a rotating wick belt [44].

4. CONCLUSION

There have been various research projects to lower the warmth of the SS's back side wall. Additionally, the space along the back wall can be used to expand the SS's internal evaporation area. Based on the review presented above, which was done in various sections, the following conclusions can be drawn: Half barrel wick SS and corrugated wick SS both saw their daily production increased by 154% and 139%, respectively, when wick material was added to the vertical sides. Also, employing trays on the back side wall of the SS enhanced the productivity of the single slope SS up to 108% higher than that for conventional SS. Besides, integrating reflectors on all side walls of wick SS enhanced its productivity by about 55% over that for conventional SS. Furthermore, using rotating discs on the back side wall of the SS enhanced its yield up to 124% higher than conventional SS.

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