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Solar Still –A Review

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Abstract —Solar distillation” is a technology for producing potable water from brackish and underground water of low-quality at low cost. It can reduce water scarcity problems together with other water purification technologies. Solar distillation is analogous to natural hydrological cycle. It uses an apparatus called a solar still in which water is evaporated using solar energy, a form of renewable energy, and collected as distillate after condensation of the vapor. It effectively produces distilled water after removal of impurities. The major advantage of this is the use of solar energy instead of electrical energy generated from conventional fuels. This helps in producing potable water without degrading our environment. Over time, researchers have studied several designs of solar stills to evaluate its performance for different climatic, operational, and design parameters.

Keywords— Solar still,single and double slope solar still,active and passive solar stills.

I. INTRODUCTION

Water is one of the most essential resources and can be either consumed directly or used in applications such as irrigation, industry and power generation. Increases in population, urbanisation, industrialisation and modern agriculture have put a lot of amount of stress on bodies of freshwater, threatening the health of mankind. The quality of water is vastly deteriorating due to improper waste disposal, water management and environmental views. The World Health Organisation reported that all of the water on earth available, can be classified as 97.5% salt water and 2.5% freshwater, 70% of which is frozen in the polar icecaps.The remaining 30% of freshwater is mostly present as soil moisture. In the end, less than 1% of the world’s freshwater (about 0.007% of all water on earth) is readily accessible for direct human use [1]. Globally, 3.575 million people die each year from water-related diseases and 98% of the deaths occur in developing countries. Therefore, the importance of supplying drinkable water to remote areas can hardly be overstressed. The World Health Organisation (WHO) reported that more than 1.1 billion people across the globe draw water from unsafe sources [2].

LITERATURE REVIEW

Solar still basic principle- A solar still is a device used in which impure/saline water is fed to obtain distilled water by solar distillation. It is a box type structure that can be made of materials such as fiber reinforced plastic (FRP), wood, concrete, or galvanized iron (GI) sheet covered with some insulation. The box is covered with a glass cover. The solar radiation passes through the glass cover. A major portion of this solar radiation is absorbed by the black painted surface of the basin, generally known as the basin liner. However, a small amount of reflection loss takes place at the glass cover, the water, and the basin liner surfaces. A small amount of solar radiation is also absorbed by the glass cover and water because of their absorptivity.

A large portion of heat absorbed by the basin liner is transferred to the saline water by convection effect as top heat loss. The remaining amount of absorbed heat is lost by conduction as bottom heat loss. Heat transfer from the water surface to the glass cover takes place by three

mechanisms: evaporation, convection, and radiation. An evaporative heat transfer is a dominant effect, which is responsible for the production of the distillate. This evaporated water with some volatile material undergoes film type condensation at the inner surface of the glass cover. A film type condensation occurs because of inclination of the glass cover, cohesion between condensed water molecules, and gravity effect. The condensed water trickles down to a trough, which goes into a container. The yield form a single slope passive solar still may vary from 0.5 to 1.2 l/m2/day (in winter) and 1.0 to 2.5 l/m2/day (in summer). There are The advantages of solar stills are
such as: (a) an easy, small-scale, and cost effective technique for providing safe water in homes or in small communities; (b) producing distilled water, (c) simplicity in design; having no moving parts (pumps, motors, etc.) are required to run the unit in passive mode of operation; (e) no conventional sources of energy are required which helps in reducing the environmental pollution as it requires only solar energy (low grade energy), which is renewable and non-polluting. However, a solar still has some drawbacks, which sometimes limit the use of this technique for large-scale production: (a) large solar radiation collection area requirements, (b) vulnerability to weather-related damage, (c) low yield, (d) low efficiency, (e) less market demand of technology, and (f) low interest of the manufacturers, etc.

The solar distillation technology has major application for producing potable water in marshy, coastal, rural, and remote areas, etc. (i.e., for on site production of the water where the electricity has not been reached due to which the implementation of other technologies is not possible and solar distillation can be the only option there for producing water). The distilled water produced by solar stills has many applications such as cleaning utensils, mechanical parts, and apparatus in chemical laboratories, educational institutes, automobile garage/workshops, hospitals, and industries. This distilled water can also be used in various chemical reactions.

Classification of Solar Stills.

The solar distillation systems are mainly classified as passive solar still and active solar still. The numerous parameters are affecting the performance of the still such as water depth in the basin, material of the basin, wind velocity, solar radiation, ambient temperature and inclination angle. The productivity of any type of solar still will be a dependent factor by the temperature difference between the water in the basin and inner surface glass cover.

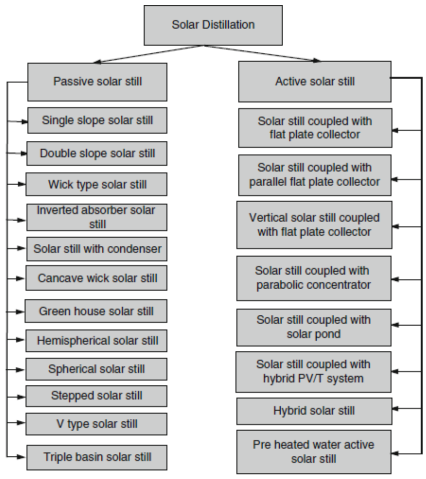

Fig1-Classification of solar distillation system.

In a passive solar still, the solar radiation is received directly by the basin water which is the only source of energy for raising the water temperature and consequently the evaporation leading to a lower productivity. This is the main drawback of a passive solar still. The conventional passive solar still is the most economical solar still to provide drinking water for domestic applications at decentralised level. This is due to its simple design and fabrication, easy to handling and
low cost of water per kg. Further, due to low operation and maintenance cost, it is most suitable for the rural areas of remote region. Later, in order to overcome the problem of lower yield, many active solar stills have been developed. In active solar still, additional thermal energy is fed into the basin water using solar collectors or any other heat source to increase the basin water temperature and in turn improve its productivity.

Passive Solar Stills

1)Single Slope Solar Still- The simplest structure of a solar still is single slope solar still and it is shown in Fig. 2. It contains a basin having a certain depth of saline water and a cover transparent to solar radiation, yet blocks the long wavelengths radiation emitted by the interior surface of the solar still. A sloped cover, which provides a cool surface for condensation of water vapour,due to which there is easy flow of the water droplets into condensate trough. The base of the still is blackened on the interior surface to maximise absorption of solar radiation and insulated on the exterior surface to minimise heat losses. is reduced by a film of cooling water continuously flowing over the glass. Toure and Meukam [3] studied the single basin solar still theoretically and
experimentally. The results gives that the maximum yield was 5 l/m2-day for a sunny day in

Abidjan and. Kalidasa Murugavel et al. [4] reviewed the progress of solar still effectiveness of the single basin passive solar still. They suggested that the orientation of the glass cover depends on the latitude and surface heating of water mass. Velmurugan et al. [5] conducted the experiments on fin type passive solar still and found the yield was increased by 52%. Tiwari et al. [6] presented the performance of various designs of solar stills and inferred that the single slope solar still gives better yield than double slope solar still in winter. Madani and Zaki [7] conducted the experiments in single slope solar still with porous basin and found that the daily yield is in the range of 2.5–5 kg/m3. Lowering the cover temperature helps in increasing the productivity. The cooler inner glass surface increases the rate of condensation.

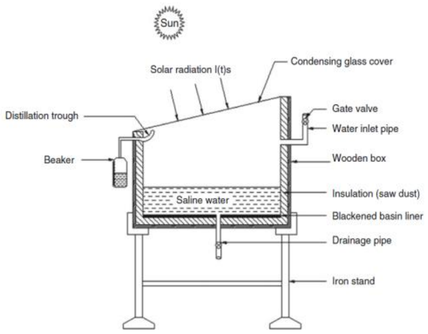

Fig.2-Single Slope Solar Still

2) Double Slope Solar Still

The cross-sectional view of a double slope passive solar still is shown in Fig. 3. and it is placed normally in east west direction to receive the maximum solar radiation. The material normally used for construction of single and double slope solar still are galvanised iron sheet, fibre-reinforced plastic (FRP), glass-reinforced plastic (GRP) and concrete. The material required for making double slope solar still per square metre is less than two single slope solar stills due to absence of the two vertical walls. The principle of solar still operation remains same as single slope solar still and distillates yield collected in both ends of double slope solar still. Dwivedi and Tiwari [8] found that the annual yield of single slope passive solar still is higher than double slope passive solar still. Kalidasa Murugavel and Srithar [9] experimentally studied the basin type double slope solar still with different wick materials like black cotton cloth, light jute cloth, waste cotton pieces, coir mate, aluminium fins and sponge sheet. The study revealed that the aluminium fins covered with cotton cloth gave the maximum yield of 3.58 kg/day.

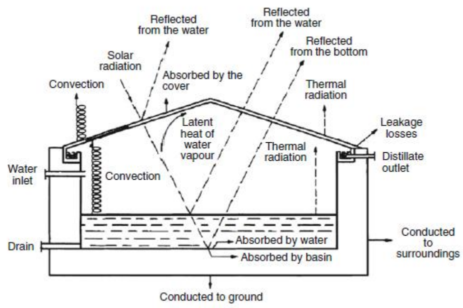

Fig.3-Double Slope Solar Still

3) Wick Type Solar Still

A conventional basin type solar still has some disadvantages: (1) the horizontal surface of water intercepts lesser solar radiation than a tilted surface, and (2) the output of basin type solar has limitation of the large thermal capacity of the water in the basin. A multi wick solar still (Fig.4) is the best alternative for avoiding the above mentioned points. In which blackened wet jute cloth forms, the liquid surface which can be oriented to intercept maximum solar radiation and a smaller mass of water will be heated to higher temperature and will evaporate rapidly.

The wet surface is made by a series of jute cloth pieces of increasing length separated by thin polythene sheets; these pieces are arranged along an incline and the upper edges are dipped in a saline water tank. Suction by the capillary action of the cloth fibre provides a surface of the liquid, and the arrangement ensures that all the surface irradiated by the sun is wet at all times; the portion of a piece of cloth, covered by the polythene sheet does not suffer evaporation and hence the exposed portion of the piece retains wetness [10,11] Sodha et al. [10, 11] observed that, overall efficiency of multiple wick solar still is 4% higher than the basin type still. Their results also show that the its costs is less than half of the cost of a basin type still of same area and provide a higher yield of distillate.

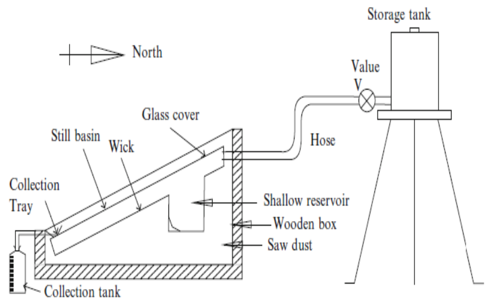

Fig.4- Wick Type Solar Still

4) Inverted Absorber Solar Still-The schematic diagram of inverted absorber solar still is shown in Fig.5. The solar radiation, after

transmission through the glass cover g_1, is reflected back to the inverted absorber of a solar still. The absorbed solar radiation is partially convected to the water mass above the inverted absorber; while the rest of the radiation is lost to the atmosphere through the glass covers g_1 and g_2. Now, the water gets heated. There are radiative, convective and evaporative heat losses from the water mass to the condensing cover. The evaporated water is condensed on the inner surface of the condensing cover, releasing its latent heat. The condensed water trickles down the condensing surface under gravity and is finally collected through drainage provided at the lower end [12]. Sunej et al. [13] also observed that an inverted absorber solar still gives a higher output than the conventional double effect solar still. The overall daily yield in the case of the inverted triple effect absorber solar still is 30% higher than the conventional triple effect solar still [14-16]. Suneja and Tiwari [17] optimised the number of effect on the multi basin solar still. They found that the yield from inverted absorber solar stills increases as the number of basins increased and reaches an optimum value when the number of basin is seven

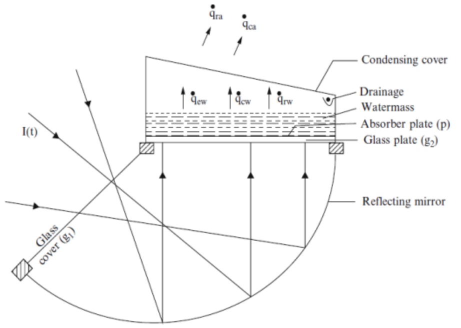

Fig.5- Inverted Absorber Solar Still-

5) Stepped Solar Still-The stepped still has the same construction of conventional still; in addition, the absorber plate is made of number of steps as shown in Fig.6 The glass temperature and basinwater temperature of stepped solar still are higher than that of conventional still. This may be referred to two reasons:(1)a smaller air volume trapped inside the still chamber than in the conventional still and therefore heating up the trapped air will be much faster,and(2)the step-wise basin provides higher heat and mass transfer surface area than the flat basin [4], thus consequently leads to increase the basin water temperature of stepped solar still.Also, the high water temperature leads to increase the evaporation and condensation rate,thus consequently leads to increase the glass temperature of stepped solar still. So that the stepped still gave higher thermal performance than conventional stills [18]

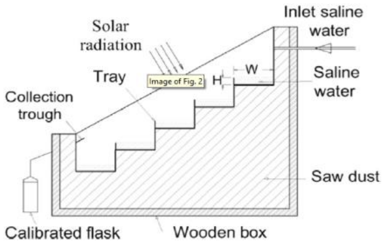

Fig.6- Stepped Solar Still

Active Solar Stills-

Later, in order to overcome the lower yield, many active solar stills have been developed. In active solar still, additional thermal energy is fed into the basin water using solar collectors or any other heat source to increase the basin water temperature and in turn improve its productivity. The temperature difference between water in the basin and condensing glass cover also has a direct effect in the performance of the still. The increased temperature of the water in basin can increase the temperature difference between the evaporating and condensing surfaces. To achieve better evaporation and condensation rate, the temperature of water in the basin could be raised by feeding thermal energy from some external sources. The detailed review of active solar distillation system was presented by Sampathkumar et al. [19].

1) Solar Still Coupled with Flat Plate Collector

The solar still coupled with flat plate collector is working as high temperature distillation method as shown in fig.7. The solar still coupled with flat plate collector (FPC) works either in forced circulation mode or natural circulation mode. In forced circulation mode, a pump is used for supplying water. In natural circulation mode, water flows due to the difference in the density of water. The flat plate collector gives an additional thermal energy to the basin of the solar still. A pump is used to circulate the water from the basin via flat plate collector to the basin.

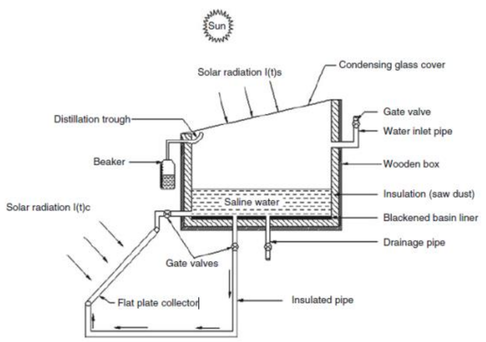

Fig.7- Solar Still Coupled with Flat Plate Collector

2) *Solar Still Coupled with Parabolic Concentrator.*

The schematic diagram of the solar still coupled with parabolic concentrator is shown in Fig.8. The parabolic-shaped concentrator or solar collector concentrates the incident solar radiation on large surface and it focuses on to a small absorber or receiver area. The performance of concentrators is much affected by the sun tracking mechanism. The tracking mechanism should move the collectors throughout the day to keep them focused on the sunrays to achieve the higher efficiency. These types of solar collectors reach higher temperature compared to flat plate collectors owing to reduced heat loss area [20].

The various types of concentrators were used over the years based on the applications. To achieve higher yield, the contractor is coupled with solar still by means of increasing water temperature in the basin. The water or oil will be supplied to trough receiver pipe by natural circulation mode or forced circulation mode.

They found that the fresh water productivity was increased by an average of 18%. Singh et al. [21] found an analytical expression for water temperature of an active solar still with flat plate collectors and parabolic concentrator through natural circulation mode. The results show that the efficiency of the system with concentrator is higher than parabolic collector as the evaporative heat transfer coefficient is higher in concentrator.

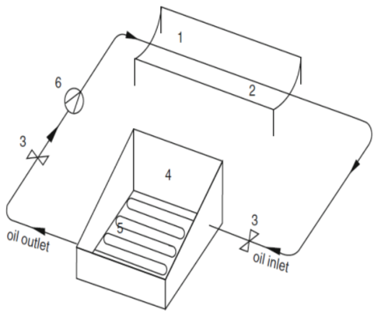

Fig.8- Solar Still Coupled with Parabolic Concentrator

3) Solar Still Coupled with Solar Pond

Solar pond is an artificially constructed pond in which significant temperature rises are caused to occur in the lower regions by preventing convection. Solar ponds are used for collection and storage of solar energy, and it is used for various thermal applications, and this detailed review of solar pond has been done by Velmurugan and Srithar [22]. Velmurgan and Srithar [23] theoretically and experimentally analysed the mini solar pond assisted solar still with sponge cube. The results show that average increase in productivity when a pond is integrated with a still is 27.6% and when pond and sponge are integrated with a still, is 57.8%. Velmurugan et al. [24-26] 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. A mini solar pond connected to the stills to enhance the productivity and tested individually. The schematic diagram of experimental setup is shown in Fig. 9. The results show that maximum productivity of 100% was obtained when the fin type solar still was integrated with pebble and sponge. The productivity increases with increase in solar intensity and water-glass temperature difference, and decreases with increase in wind velocity. Velmurugan et al. [24-26] experimentally investigated the possibility of enhancing the productivity of the solar stills by connecting a mini solar pond, stepped solar still and a single basin solar still in series. Pebbles, baffle plates, fins and sponges are used in the stepped solar still for productivity augmentation. Their finding shows that maximum productivity of 78% occurred when fins and sponges were used in the stepped solar still and also found that the productivity during night also improved when pebbles were used in the solar stills. El-Sebaii et al. [27] experimentally studied to improve the productivity of the single effect solar stills, a single slope single basin solar still integrated with a shallow solar pond (SSP). They found that the annual average values of daily productivity and efficiency of the still with SSP were higher than those obtained without the SSP by 52.36 and 43.80%, respectively.

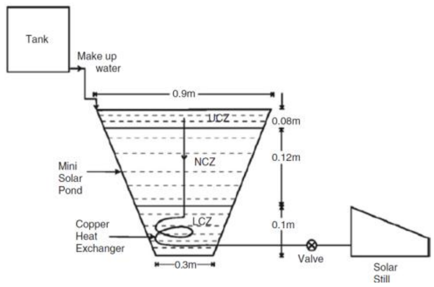

Fig.9-Solar Still Coupled with Solar Pond

Conclusion

In finale, solar stills are cost-effective when compared to all other available desalinations systems in use today. The main advantage of the solar still is easy to construct and operate even in remote areas. The only disadvantage of the solar still is very low yield and it may be improved by increasing the basin area. Passive solar stills are more suitable for freshwater supply in rural areas as compared to active solar stills.

Although solar distillation at present cannot compete with oil-fired desalination in large central plants, it has potential to become a viable technology in near future, when oil supplies stops. However, producing freshwater from saline water with solar stills is much useful for remote areas where no other economically viable method for obtaining freshwater supply is available

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