International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Design and Performance Analysis of Solar Still

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Accepted 01 Oct 2016, Available online 05 Oct 2016, **Special Issue-6 (Oct 2016)**

Abstract

Different designs of solar stills have been investigated throughout world by different researchers. Solar stills of different designs have been investigated by many researchers. A new radiation model has been developed to improve the prediction of the performance of a single-slope solar still. An improved (new) Tubular Solar Still (TSS) was, therefore, designed in this paper to overcome those issues and to provide potable water for a few families or a small society in arid, remote and coastal areas. It can be installed near to a house for the purpose of reducing time and labor involved in carrying drinking water. An old TSS was designed using a vinyl chloride sheet as a cover material which was a little bit heavy, expensive and cannot be formed into a desirable size easily. In order to overcome these drawbacks, the new TSS was fabricated using cheap, durable and locally acquisitioned lightweight materials for practical use. Consequently, the weight and cost of the new TSS were noticeably reduced. These improvements also can help to assemble the new TSS easily in those areas. This paper describes the details of the design, fabrication, cost and water production analysis of the New Tubular Solar Still. The new TSS was made of cheap, durable, lightweight and locally available materials.

Keywords: *Distillation,Solar Energy, Solar Stills.*

1. Introduction

This project is environment based i.e. related to energy conservation. In normal water purification units electrical energy is used which is generated from conventional energy sources mostly. This water desalination unit is a perfect option for conventional units even if it doesn't use conventional energy source. a detail comparison of the design, fabrication, cost and water production analysis between an old Tubular Solar Still (TSS) and improved (new) one is presented. Since the cover material, a vinyl chloride sheet, of the old TSS was a little bit heavy, expensive and cannot be formed into a desirable size easily; a highly durable polythene film was adopted as the cover of the new TSS. The new TSS is made of cheap and locally acquisitioned Light weight materials. Consequently, the weight and cost of the new TSS were noticeably reduced and the durability was distinctly increased. It also decreased the cost of desalinated water generation.

2. Structure of old TSS and New TSS

2.1 Old TSS

The old TSS was designed by Islam *et al.* and a series of field water production experiments were carried out in Hamuraniyah agricultural firm, Ras Al Khaimah (UAE) and in Fukui (Japan). The old TSS is comprised with a tubular cover, a transparent polyvinyl chloride lid at both ends of the cover and with a semicircular black trough inside it as shown in Fig. 1.. The attached lid at the end of the tubular cover can be opened and the trough can be promptly taken out and easily inserted back after flushing accumulated salt. The inclination of the support under the old TSS is required to collect the produced water from the lower edge of the still.

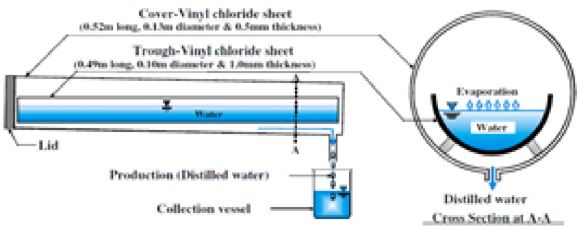

Fig.1 Schematic diagram of old TSS
(R. Dev *et al,* 2010)

2.2 New TSS

In this report, the new TSS was designed to improve the limitations of the old one. The new TSS is consisted of a frame, a tubular cover and a rectangular trough shown in Fig. 2. The frame was assembled with two Stainless Steel (SS) pipes and a SS wire arranged in the

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longitudinal and transverse (in spiral shape) directions, respectively. These two SS pipes also provide support to the trough. The SS pipe is 1m in length and 8 mm in diameter. The SS wire is 1.2 mm in diameter. The frame can restrain the deformation of the tubular cover. The new TSS was designed in such a way that the inclination of the support is not required to collect the produced water.

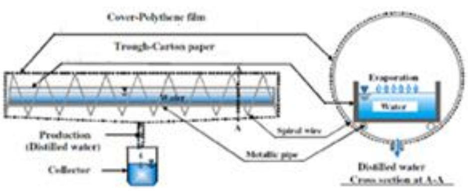

Fig.2 Schematic diagram of new TSS (V.G. Gude *et al,* 2010)

3. Overview of old and new TSS

3.1 Cover and Trough material

In the old TSS, the tubular cover was made of a curled transparent vinyl chloride sheet of 0.5 mm in thickness and a polyvinyl chloride lid at both ends. The transmissibility of the vinyl chloride sheet was about 80%. The vinyl chloride sheet was replaced with a highly durable polythene film (called Diastar) as a cheap material for the cover of the new TSS. The thickness and transmissibility of the Diastar were 0.15 mm and 89%, respectively. The trough was made of a vinyl chloride with 1.0 mm in thickness and of a carton paper with 3.0 mm in thickness for the old TSS and the new one, respectively. The carton paper was then wrapped by a black polythene film of 0.05 mm in thickness to make it waterproof for the new TSS. Fig.1.2 shows the photographs of parts of the old TSS.

3.2 Weight and Durability

The weight calculation was performed for the same specifications of both the TSSs. The weight of the new TSS was reduced by 61% of the old one. Consequently, the new TSS is very convenient for carrying and assembling due to light weight. The overall life of both the cover and trough of the old TSS is about 2 years from field experiences. Whereas, the cover (Diastar) of the new TSS is guaranteed for 5 years and the life of the frame is also about 5 years, while the life of trough is about 1 year. To increase the durability and lifespan of the trough of new TSS, the carton paper could be replaced with Perspex (Plexiglas).

3.3 Waterproduction cost (commercial production)

The most important factor is the cost of fresh water production for commercialization of the new TSS. The cost of fresh water production using the new TSS is about Rs.600, which is about 5 of that of the old TSS. The reverse osmosis is the most popular and the cheapest technique among the desalination technologies. In fact, it is not relevant to compare the cost of solar water distillation with the conventional desalination technologies due to the difference in application purpose. The conventional desalination technologies are suitable to produce massive pure water daily in a city and the cost of initial installment, operation and maintenance is very high. A small rural community might not be able to install these techniques due to the limitations of resources and energy. The solar water distillation is, therefore, more appropriate in such cases. The cost of fresh water production using the new TSS is affordable and about one-third cheaper than the basin-type solar still. The new TSS was made manually one at a time. Therefore, the fabrication cost (consequently, the cost of water production) can be easily reduced by making a large number of TSSs together. The payback period may depend on the fabrication cost, maintenance cost, operating cost, cost of minerals and cost of feed water. Since the purpose is to compare the water production cost and payback period with some previous designs, therefore, the maintenance cost ($0.1/day), the mineral water cost ($0.2/kg) and the cost of minerals ($0.03/5 kg of produced water) are supposed to the same as Velmurugan et al. Thus the cost of produced water per day is $1. The estimated fabrication cost of the new TSS is about Rs.523 (=2×523Rs.=$8.72) with the water production capacity of 5 kg/day. The cost of feed water is neglected. Net earning per day=Cost of water produced?maintenance cost (including cost of minerals)=(1-0.13)=$0.87 Payback time=Fabrication cost/Net earning per day=(872/87)= 0.03 year.

4. Working of TSS

The principle of pure water production from saline water using different designs of a solar water distillation technique is the same. The mechanism of the new TSS is illustrated in Fig.1.4. The solar radiant heat after transmitting through the cover is mostly absorbed by the saline water in the trough. The rest is absorbed by the cover and the trough. Thus, the saline water is heated up and evaporates. The water vapor density of the humid air increases due to evaporation from the water surface. The water vapor is condensed then on the inner surface of the cover, releasing its latent heat due to evaporation. Finally, the condensed water naturally trickles down toward the bottom of the cover due to gravity and is stored in a collector.

There are mainly three processes

1) Evaporation
2) Condensation
3) Production

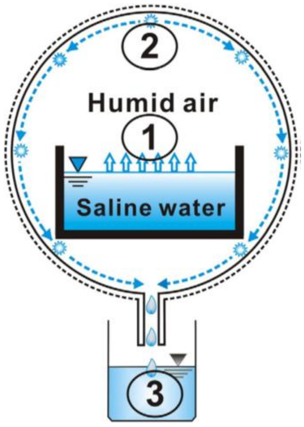

Fig.3 Potable water production principle in a TSS. (1=evaporation, 2=condensation and 3=production) (F.F. Tabrizi *et al,* 2010)

5. Graphical Representation

5.1 Graph of time of the day v/s outer covering & trough water temperature

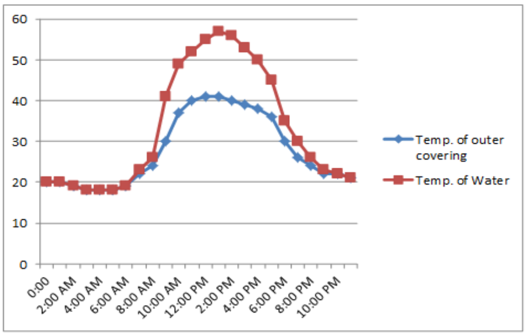

Fig.4 Relation between time of the day and outer cover and water temperature

5.2 Graph of time of the day Vs water flux produced

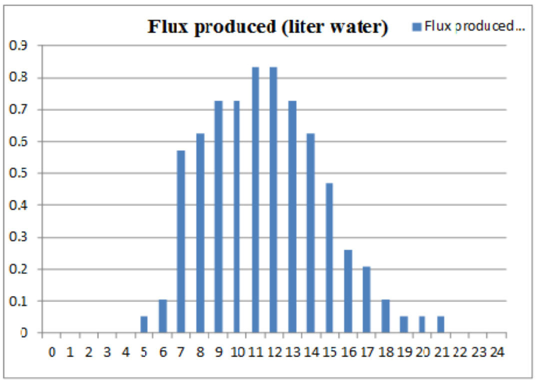

Fig.5 Relation between time of the day and water flux produced

5.3 Graph of time of the day Vs condensation heat transfer coefficient h_{cdha}

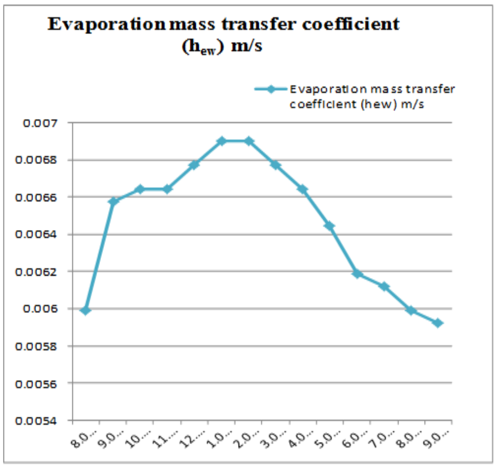

Fig.6 Relation between time of the day and evaporation heat transfer coefficient

5.4 Graph of time of the day Vs Evaporation heat

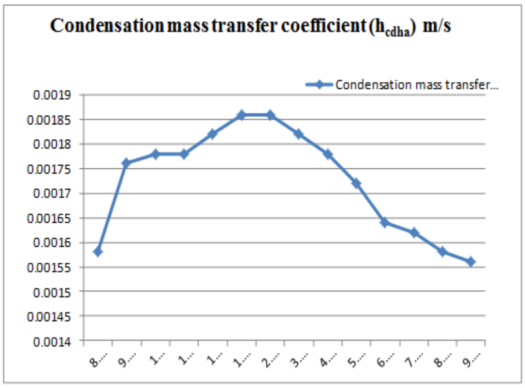

Fig.7 Relation between time of the day Vs Evaporation heat

5.5 Graph of comparison between evaporation and condensation mass transfer coefficient

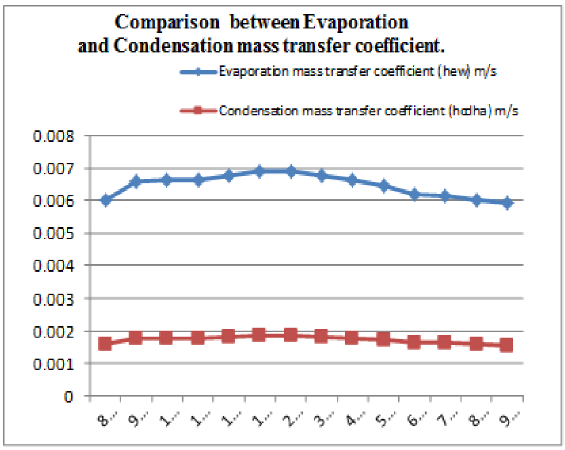

Fig.8 Relation between time of the day and Evaporation heat transfer coefficient h_{ew}(m/s) & condensation heat transfer coefficient h_{cdha}(m/s)

6. Advantages and Future Scope

1) Affordable fabrication cost and less weight compared to old TSS. Weight is nearly one third of the old TSS.
2) Fabrication materials of the new TSS (polythene, carton paper) are easily available in underdeveloped and developing countries.
3) Can be assembled easily on-site without using any special tools.
4) Easy maintenance and repair and Utilization of renewable energy.
5) Electric power is not required at all and environmentally and ecologically favorable approach, i.e. zero CO2 emissions.
6) Satisfactory daily fresh water production (5 $kg/m^2 day$).

Conclusions

1) In Graph1 temperature of water and outer covering observed constant in morning and it increases in evening after 10am and decreases after 12pm
2) In graph2 it is observed that flux was not changed during first 4 days but increases after that and it is at its peak value in day11 and day12 after that it goes decreasing as days gone
3) graph3 is h_{cdha} vs Time of Day, as in above graph condensation heat transfer coefficient has highest value at 12pm
4) From graph4 it is observed that convective heat transfer coefficient also maximum between time of 12pm to 2pm

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