Experimental Investigation of V-type solar still coupled with solar water heater

Vivekanand Krishnaswamy, Prof Rashed Ali, Prof Meetha Shirish Vedpathak

Abstract— Potable water has become the scarce resource due to ever increasing demand and limited supply. Solar desalination and solar distillation are one of the methods where brackish or saline water is evaporated using solar energy. This can be used as one of alternative to bridge the gap of high demand of fresh potable water. Energy of sun can be used to harness the abundant available solar energy. In this paper option of solar desalination is being experimentally investigated using V-type solar still coupled with flat plate type solar water heater. This paper describes the operation of V-type solar still which is used along with flat plate solar water heater. It involves the construction, testing, and examination of a V-type solar still used with flat plate solar water heater for low scale domestic purpose. V-type solar still is constructed from Fibre Reinforced Plastic material. The paper compares distillate output collected in measuring cylinder when connected and not connected to solar water heater. Water level in the still is kept equal at 80 mm height level in the still. It is concluded that distillate output enhances when still is connected with solar water heater.

Index Terms— V-type solar still, Solar water heater, Flat plate collector, FRP,Solar Desalination,Solar Distillation,Solar energy.

1 INTRODUCTION

Fresh water is one of the primary needs of human being. Scarcity and impurity of the freshwater results in various diseases.The tropical location of India of our country in geographical map has blessed with abundant amount of sunshine. The average daily solar energy varies between 4 and 7 kWh/m² for different locations of the country. There are normally 250–300 clear sunny days in a calendar year approximately, thus country receives approximately 5000 trillion KWH of solar energy annually. Annular solar radiation varies from 220KW/m² to 1600Kw/m². In India Northern Gujrat and Rajasthan receives highest annual global radiation [1].The benefit of solar energy systems are being flexible in nature it can be installed as per capacity requirement. As India's geographical location is such that maximum part of the country has more number of sunny days and this favors harnessing solar related technology. Solar distillation is a normal phenomenon on Earth. Solar Energy heats water in seas and lakes, vaporizing it and then condensing it as clouds to return back to earth as rain water. Solar distillation proves to be both least expensive and environmental friendly technique in rural areas.Solar still operates similar to natural hydrological sequence of evaporation and condensation this process takes place in a small compact chamber or enclosure called as still. The energy from sun reaches water in the basin through inclined transparent cover .The water is heated thus vaporizing it and condenses on inner surface of the transparent cover.This condensed water is stored in cylindrical vessel through a single channel in case of V-type of solar still. The solar distillation systems are mainly classified as passive solar still and active solar still.

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Solar desalination using V-type solar still is experimentally examined. The present report gives investigation work carried out using active and passive V-type solar still. Distillation using solar energy is a encouraging method for the supply of freshwater to rural populations. Worldwide passive solar still is used for solar distillation plants because of its simple construction, working and low cost; though the yield is low. Researchers have put more effort and alterd the design in order to improve its yield and to identify the effect of different constraints on the stills output rates. Various active methods have been developed to overcome this issue. However, these developments increase the system cost.

2 LITERATURE REVIEW

2.1 Review Stage

Passive type Solar still are simple in construction, working and economical the only drawback is low yield to counter this problem active type solar still using hybrid system using different heat absorbing material, such as flat plate, evacuated tube water heater, parabolic collector. Productivity of solar still having single slope is enhanced when connected with evacuated tube solar water heater [2]. It was reported that performance of solar still having minimum water level maintained by spreading and using various materials on basin like charcoal, glass balls and quartzite rock etc. It was seen quartzite rock of size ¾ inch gave maximum increase in the distillate output [3]. It was inferred from numerical analysis made for location Delhi location east west orientation of double slope still gave maximum yield for glass cover inclination at around 55 degrees [4]. Experimental study on single slope basin solar still having varying brine depth was carried out.It showed that distillate output decreased with increase level of brine depth in still [5]. The thermal performance of V-type of solar still with charcoal absorber and mirror to boost solar radiation was carried out. Floating charcoal increases absorption of radiation and mirror concentrated the incident radiation results in increase of vaporization of water and water collec-

tion [6]. The presence of wet wick over the V-type solar still increases distillate yield in early hours later as temperature increase yield rate is reduced since capillary action is insufficient to keep wick wet [7].The experimental results performed at Delhi location during winter season using single slope and double slope FRP solar still.Single slope FRP still gives better yield in comparision to double slope FRP still where as in summer double slope still gives better yield than single slope solar still .The sample of distilled water passes the bacterial test [8]. The paper gives use of solar energy for double slope solar still when connected with flat plate solar water heater. Heated water from solar water heater storage tank can be used for various domestic activities and when not in use can be used in night for desalination thus giving system high thermal efficiency [9]. Performance of double slope (passive mode) solar stills and double slope solar still connected to flat plate collector (active mode) was evaluated in terms internal thermal efficiency and system productivity. The results of investigation revealed that active solar still maximizes both fresh water productivity and internal thermal efficiency compared to passive solar still. Experiment was carried out at The brine depth of one cm and 3 mm glass cover thickness. [10]. Experimental investigation was done on V- type wavy absorber solar still built with phase change material. The system is tested with and without the PCM (Phase Change Material) using different water masses, and wick over the V-type wavy plate using PCM is also investigated. The experimental investigation reveals that the solar still using the PCM beneath the corrugated plate with less basin water mass achieves the best thermal performance. Using the PCM causes a little decrease in the daylight productivity and considerable increase in the overnight productivity of still [11]. Productivity of single slope solar still when connected to flat plate collector is improved.Parameter that was studied were water depth , orientation of still and solar radiation.It was found that coupling of flat plate collector increased the productivity by 36%.Increase in depth reduced the productivity where as increase in solar radiation increased the productivity[12].

3 AIM OF WORK AND OBJECTIVES

The experiment set up aims to increase the temperature of water in the still basin using flat plate type solar water heater. This heater is used for desalination purpose.For this experiment Electra make solar water heater of 125 LPD capacity is used. Current study deviates from earlier research work carried in following aspects type of solar still used, location of experimental set up, season and type of collector used in set up.a)Total yield of the distillate is measured using calibrated measuring cylinder.For simplifying and categorizing total distillate output is clasifid as Day Output (9am-6pm) & Night output(6pm-9am). The total output is obtained by summing up Day and Night output.The level of water in the still is kept at 80 mm level of the still. Hourly temperature and distillate output readings are recorded on hourly basis during (9am-6pm) whereas from (6pm-9am) cumulative distillate output is recorded at the end this is followed for following experimental cases. i) Case A: In Passive mode Solar still kept underneath sunny open sky through out the day(9am-9am), ii) Case B: Active mode Solar still connected to FPC throughout the day (9am-9am) kept in open sky for 24 hours. During start of experiment ie at 9am Hot water from solar water heater is filled into still till 80 mm level.Hourly readings of temperature and distillate output is noted till 6PM .b) To compare the distillate output in caseA and caseB.

4 EXPERIMENTAL SETUP

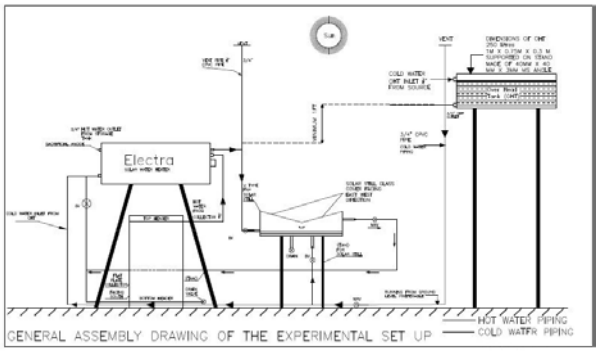

Fig. 1. General Assembly Drawing of the experimental set up.

The above set up was assembled in Pillai College of Engineering, New Panvel Maharashtra in an open ground.The V-type solar still of dimension 1metreX1metreX0.3metre is fabricated using Fiber reinforced Plastic (FRP) sheet of 5 mm thickness. The General assembly drawing of the setup is as shown in above Fig 1.The V-type solar still is mounted on the stand fabricated from MS angles and MS strips .The still base is kept at viewable height from ground level. All the surface of still is insulated from (lateral faces and base) by insulating material Rockwool. The insulating material prevents the loss of heat from the still to the surroundings; the still has various components and parts for proper working of the set up. The glass is inclined at 15^0 to the horizontal on either side to form V shape. The glass surface of the still acts as a condensing surface for evaporated water vapors is facing East West direction. The glass and the top surface of the still are sealed by means of rubber gasket.This is done across all the four edges .The two glass edge intersect at cente to form V shape.This is sealed using silicon adhesive thus making it leak proof at the joint.This ensures to arrest the air and vapor leakage into the still .The glass cover are heldon the edges firmly with help of aluminium 'C' clamp. Inlet of brackish or saline water to the still is either by hot water from solar water heater storage tank.This is operated by side entry ball valve, or coldwater through the base of the still from over head tank (OHT).The flow through the base of ball valve is regulated by ball valve. This is for water inlet directly from overhead tank (OHT) into the still.The still is provided with drain valve (ball valve) for completely draining or cleaning the still. The overflow valve is in form of NRV is provided at the outlet of the still. The inner bottom surface of the solar still is applied with commercially available black paint. The still constructed has a $1m^2$ collection

base area which is 1metre wide, 1meter long and 0.3metre deep.A water condensate collector with the width of 0.05metre and height of 0.15metre is provided to collect the distillate. The condensate collector is slightly inclined at an angle of 2 degree.The condensate collected in a measuring cylinder is measured periodically at an interval of one hour (9am-6pm) and Cumulative output (6pm-9am) at 9am. The saline water level is adjusted to the desired level by means of ball valve. The waterlevel is adjusted so that the still is filled with 80 mm of water level.The scale is fixed on one of the lateral inner side surface of still to check water level. As the water evaporates it will be collected under the glass covers on both the sides. The glass cover transmits the incoming radiation and small percentage is reflected also a part of the incident radiation is reflected by basin water. The water collection segment reflects a part and a small portion leaks at the bottom through conduction. The remaining portion of heat is used to rise the temperature of water which causes evaporation. When still is connected to flat plate solar water heater, collector is used to heat the brackish/saline water coming from the overhead tank (OHT). The Solar water heating systems works on principal of Thermosiphon and black body absorption principle.

5 METHODOLOGY

The principle of solar distillation is used in V-type solar still. The still is in Passive mode when not coupled to Flat plate solar water heater and is in active mode when coupled to flat plate solar water heater. Solar water heater is used for productive improvement of the solar still. It is used to increase the temperature of water using energy of sun. The heated water from solar water heater is stored in hot water tank and is utilized as per the case A and B as mentioned in aim of work and objective. The use of solar water heater is used during the period when hot water for domestic purpose is minimum. For this experimental investigation distillate output readings aretaken for period of one day full 24 hours.Day time of the investigation is taken from 9am to 6pm and night time is taken as 6pm to9am. The solar still coupled flat plate collector works in a natural circulation mode. Here water flows due to change in density of water. In a passive mode , the radiation from sun is the only source of energy for raising water temperature which is received directly where as in active mode solar still thermal energy is supplied to basin through external mode to enhance or improve the productivity. In this investigation Flat plate type solar water heater is used as thermal input.At various conditions as mentioned in fig 2 the investigation of V type solar still is done in passive and active mode. At the intial stage of experiment saline or brackish water is supplied to flat plate solar water heater and solar still and is run for a day or two to achieve steady state condition.The water level in the solar still is kept at 80 mm for active and passive method of operation. During begining of experiment to avoid dust deposition glass cover on still and solar water heater it is cleaned and wiped on regular basis. The quantity of water collected in the measuring cylinder is noted and recorded as mentioned in aims and objective above. The experiment readings are taken at an interval for 1 hour during day time i.e. from 9am to 6pm (day output) and collective readings of distillate output are taken at 9am i.e. night output. The readings are taken for following conditions. **Case A**: Salty or brackish water from OHT is kept at 80 mm level. Still is kept underneath open clear sky for 24 hours from 9am-9am next day. Temperature and distillate output readings are taken at hourly basis from 9am-6pm and cumulative distillate output reading is taken at 9am for period from 6 pm to 9am. **Case B:** Hot Salty or brackish water from solar water heater storage tank is flown in to still and kept at 80 mm level.
Still is kept underneath open clear sky for 24 hours from 9am-9am next day.

	Day Output (9-6) PM	Night output (6pm-9am)
CASE A	Solar still	Solar still
CASE B	Solar heater+Solar still	

Fig. 2. Table showing the timings for Day and Night output for case A & B and also the method Passive (Solar Still), Active (Solar still+Solar water heater) method used for solar distillation in Case A and Case B.

Saline or brackish water from solar water heater storage tank is flown in to still and kept at 80 mm level.
Still is kept underneath open clear sky for twenty four hours from 9am-9am next day. Temperature and distillate output readings are taken at hourly basis from 9am-6pm and only collective distillate output is taken at 9am for period from 6 pm to 9am**.** Thermocouple wire with temperature indicator was used for the measurement of the various temperature of the system such as, temperature of water(T_w) in the still, vapor temperature between glass and waterT_v; inner side of the glass cover of still (T_{gi}), outer side of the glass cover(T_{go}), hot water storage tank temperature, collector inlet temperature and the ambient temperature of the surrounding.(T_a)type thermocouple indicator wire and sensor are used to measure above temperature paramenter.Solar insolation is calculated theoretically by ASHRAE Model its equations and formulae.

6 RESULT AND DISCUSSIONS

The experiment was carried out using above setup shown in Fig.1. For each case A/B the experiments were carried out.The duration of the experiment was for 24 hours. The water level maintained in the still is 80mm. Figure 2 represents method of heating for various cases and readings of distillate output of tests conducted for 2 different days i.e. On 24/01/2018 and 25/01/2018 from 9 am to 6 pm on hourly basis and from 6pm to 9am on cumulative basis (At end of 9am).The test results are analysed and compared for CASE A and CASE B.

a)**Comparision of Distillate output:** Chart shown below in Fig 3. Shows the comparision of Total Distillate output (Night and Day) for case A and case B.It is clearly observed that Total distillate output in case B is more than in case A. Addition of heated water from solar water heater in the still basin caused much difference in temperature of water(T_w) and inner surface of glass(T_{gi}).This resulted in high productivity in caseB.This is

clearly visible in graph shown in fig 6 .It can be concluded that the productivity of the solar still is increased when flat tube collector was connected with the solar still when hot water from solar sill is used in day time.

b) Day Collection v/s Night Collection: Refer fig 3 graph it is clear that night output is more than day output.This is due to large amount of energy from sun is absorbed and stored as sensible energy in hot water due to which there is steady rise in temperature. It is observed that every day significant amount of distillate is seen after 2pm when water temperature of basin is at peak. The same gradually go on increasing till 6pm and after the sunset the surrounding temperature drops .Thus due high difference in basin temperature and surrounding at the initial stage there is rapid rate of condensation. Thus total output collection during night is more compared to day collection

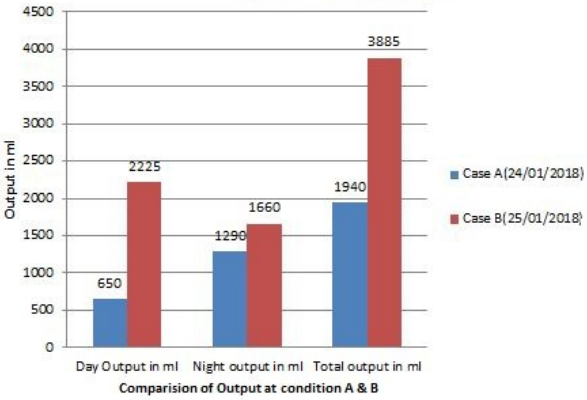

Fig. 3. Graphical comparision of the distillate output results for case A and Case B carried out on 24th& 25thJanuary.Graph shows comparision of Day, Night and total output.

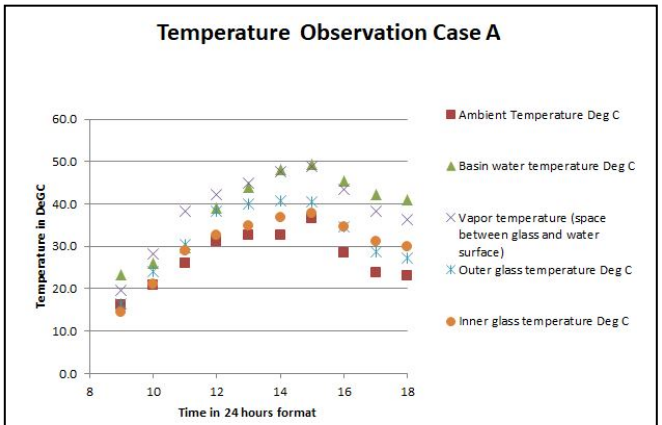

Fig. 4. Graphical observation of the temperature at still for caseA

c) dT v/s Output: The performance of the solar still was based on the temperature difference between the water T_w and the inner glass cover T_{gi}.(dT) For both the caseA and B it is shown in fig 6. The temperature observations at various sections of still is shown in case A and case B .It is observed that incase of case B temperature difference of Temperature of water (T_w) and Inner glass temperature (T_{gi}) is more.The performance of the solar still was based on the temperature difference between the basin water and the inner glass cover. Refer Fig 6 graph of comparision of dT V/s Output collection in an hour for case A and Case B is shown .Narrow temperature difference of inner glass temperature of (T_{gi})and basin water temperature(T_w) is observed in case A thus results in low output . It is seen that distillate collection output is maximum when the dT>10 Deg C ,In case of Case A it is maxm After 1700 hrs due to decrease in surrounding temperature (results in dT>10)thus we have more output during that period.In case A between 11am-13 hours dT is low hence result in low output during that period.

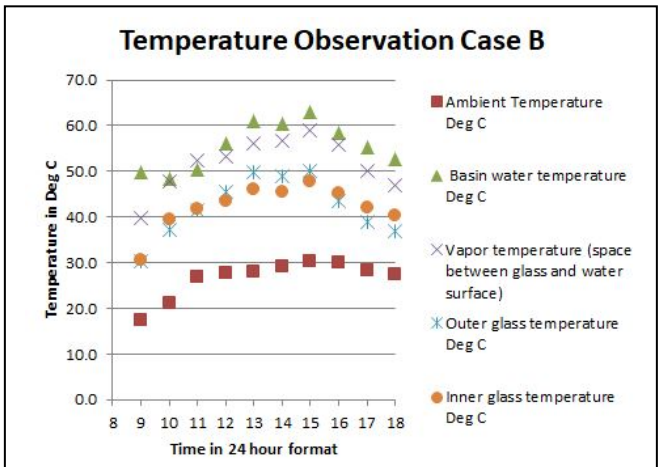

Fig. 5. Graphical observation of the temperature at still for caseB

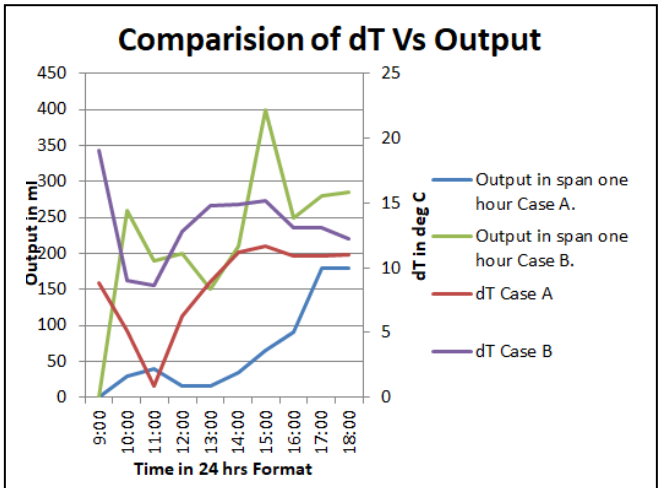

Fig. 6. Graph showing difference in temperature (dT) (T_w and T_{gi}) Vs Output for Case A and Case B.

In case of Case B, the dT value varies from 8.6 Deg C to 19 Deg C due to coupling of solar water heater, hence we have high distillate output incase B.

7 Conclusion

From the above experimental study it is concluded that for 80 mm of water level the Total output from case A (with solar still) is 1.94 LPD/m^2 whereas in case B (by connecting the solar

still with Solar water heater) the total output is 3.885LPD/m^2 thus output is almost increased by 200% by connecting with the Flat plate collector and V-type solar still.

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