International Journal of Engineering Research
Volume No.5, Issue No.1, pp : 30-33
ISSN:2319-6890)(online),2347-5013(print)
01 Jan. 2016

Parametric Factors Affecting the Performance Improvement of a Solar Still Coupled With a Flat Plate Collector

Govind S. Menon
Lecturer, Kunjali Marakkar School of Marine Engineering, Cochin University of Science and Technology, Kochi - 682 022, Kerala, India
Corresponding Email: govindsmenongsm@gmail.com

Abstract: The present study discusses the effect of parametric factors on the performance improvement of the combined system consisting of the solar still and flat plate collector. In the present study a flat plate collector (FPC) for heating water was designed and fabricated. The FPC was combined with the solar still for evaluating its performance and efficiency improvement. A 12% increase in efficiency was obtained on combining the solar still with the FPC.

Keywords: **Solar Still, Flat Plate Collector, FPC, Parametric Factors, Solar Radiation**

I. Introduction

Water covers 70% of our planet, and it is easy to think that it will always be plentiful. However, freshwater is incredibly rare. Only 3% of the world's water is fresh water, and two-thirds of that is tucked away in frozen glaciers or otherwise unavailable for our use. As a result, about 1.1 billion people worldwide lack access to water, and a total of 2.7 billion find water scarce for at least one month of the year. (www.worldwildlife.org). Acute drought conditions and dwindling natural water resources are focusing more attention on what continues to be a worldwide problem: a lack of access to fresh, potable water for drinking and sanitation.

Due to increasing urbanization and scarcity of water, solar energy has been used as a source of power generation also. Apart from that it is practically not feasible to find out novel freshwater resources. The solar still creates a new direction to obtain freshwater using solar energy (Mohsen, 2000). A solar still is a device by which distilled or portable water can be produced from saline water, such as seawater or brackish water (Pratap Singh, 2003). The Flat Plate Collectors (FPC) are the most common solar collectors for use in solar water heating systems in homes and in solar space heating (Badran *et al.*, 2005). An FPC basically consists of an insulated metal box with a glass or plastic cover (the glazing) and dark coloured absorber plate. Solar radiation is absorbed by the absorber plate and transferred to a fluid that circulates the collector in tubes.

The present paper describes the designing and fabrication of a single basin solar still. Further, experimentation was done on the solar still. Parametric factors such as water depth, solar radiation etc. were studied. A flat plate collector was used as a heat exchanger. The flat plate collector consisted of a glass cover, absorber plate, insulation and heating pipes. The solar still and flat plate collector are used to produce pure water for drinking purpose utilizing the renewable energy and using no electricity (Panchal *et al.*, 2011). The present study was aimed at assessing the parametric factors upon the improvement of performance of the solar still together with the FPC.

II. Materials and Methodology

The main frame of the solar still is composed of galvanized iron and glass is fixed on the top of the still using cycle tubes. The outside and inside of the complete distiller is coated with black Asta paint to increase absorption of solar radiation. The top cover is made of normal glass of 3mm thickness.

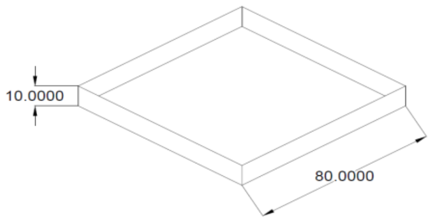
Solar still combined with the Flat Plate Collector

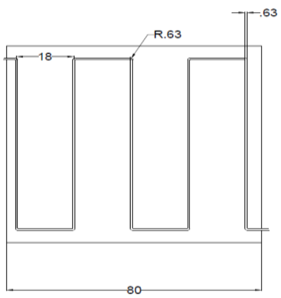
The design specifications of the solar still are as follows: Glass cover thickness - 3mm, Length - 55cm, Breadth - 55cm, Inclination -10^o based on Latitude = 11^o and Longitude 77^o of Thrikkakara, Cochin. Solar Still Basin dimensions: Length = 55cm, Breadth = 55cm, Height = 10cm, Material of Basin: Galvanized iron (GI) sheet - 22 gauge, 3×3 feet.

The Design Specifications of the FPC are as follows: Length and Width of absorber plate - 80cm each, Thermal Conductivity of plate Material - 210W/Mk, Plate thickness - 4mm, Centre to centre distance of tube - 18cm, Insulation Material - Sponge, Insulation material conductivity - 0.11W/Mk, Thickness - 1inch.

Box: Made of Galvanised iron sheet of 22 gauge (78 cm square), 2mm thickness. Absorber plate: Aluminium sheet of 4mm thickness. Heating Pipes: PVC Pipes of 0.625cm dia-0.5inch,78cm length and 78cm breadth. Glass cover: 3mm thick glass. No of heating Pipes = 5. Spacing between tubes = 18cm.

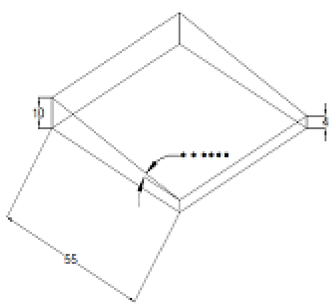
Basic Design Drawings





Flat Plate Collector

Spacing between tubes = 18cm, Area of box = 0.64m^2(80*80), No of heating Pipes = 5



Solar Still

The measuring devices used in this experiment are Measuring Beaker, Digital Thermometer, Anemometer and Radiation Meter.

The flat plate collector and solar still are arranged in such a way that there is natural circulation of water from FPC to still. Height difference was 30cms, Height from the ground was 32cms. Heating time of water in FPC was set as 30 minutes. Velocity of water = $C_v \times \sqrt{2gh}$, C_v=Coefficient of velocity.

The different parameters studied included Water depth, Solar radiation, Inclination of the glass cover, Temperature of water basin, Temperature of the glass and are related with performance of the solar still.

III. Results and Discussions

The Efficiency η of the solar still is obtained from the formula:

Efficiency η = [(Total Distilled amount-Yield ÷ t)× h_{fg}]÷∑I(t)×a

Yield of water is the total distilled amount of a day (adding total yield of each hour) h_{fg} is the Latent heat of vapourisation of water obtained from the steam tables corresponding to average value of temperature of water basin (kJ/kg), m = mass of water = total distilled amount = Volume× Density (kg), a is Basin Linear area = 0.3025m^2 (0.55m-length×0.55m-breadth), ∑I(t) is Total Sum of Radiation intensities (W/m^2), t = Time in seconds for a full day operation (24hrs).

The FPC is a heat exchanger that exchanges heat of fluids (heat and cold) (Bhadran *et. al*., 2003). The FPC and solar still are arranged in such a way that there is natural circulation of water from FPC to still. Height difference was 30cms, Height from ground was 32cms. Heating time of water in FPC was set as 30 minutes. Velocity of water = $C_v \times \sqrt{2gh}$. The FPC is placed based on the latitude of the place and at an angle of 15 degrees. FPC works on the principle of Thermosyphon effect wherein water flows from FPC to still without the use of mechanical pumping (Salah Abdallaha *et al*., 2008).

Efficiency of solar still at various water depths considering various parameters

The highest yield of 720 mL is obtained at a particular day. The yield of water corresponding to the equation are given in the Table 1. As revealed the efficiency percentage varies from a minimum of 42.39% to maximum of 48.11%. Average of efficiencies of 5 days = 44.624%. The studies revealed that a 2 cm water depth is best for good performance (5.2L of input water). High intensity radiation improves the efficiency. The highest yield of 1070mL is obtained at a particular day. The Table 2. shows efficiency values at various water depths.

Table 1. Yield of water at various water depths

Sl No	Water deapth (cm)	Total Radiation (W/m^2)	Total Water Yield (mL)	Temp at water basin (°C)	Enthalpy (kJ/kg)	Efficiency (%)
1	2.0	6151.75	3260	54.35	2373.1	48.11
2	3.0	5300.55	2470	51.82	2378.0	42.39
3	3.0	5667.75	2660	52.04	2378.1	42.70
4	2.0	6451.75	3360	53.68	2374.4	45.34
5	2.5	6368.00	3120	52.12	2378.1	44.58

*Time in Seconds - 3600 x 24 = 86400
**Basin area (M^2) = 0.3025

The efficiency of the flat pate collector

(m×C_p×dt)÷(∑I(t)×a), Cp = 4.187kj/kgk, dt = The temperature of hot output water of FPC - Temperature of glass cover, m = density × a_{pipe}×V, density=1000 kg/m^3 V = $C_v \times \sqrt{2gh}$,h = height difference between solar still and FPC = 30cms,a_{pipe} = (3.14÷4)×d^2, a = area of Collector (absorber plate) 1st day values are: Cv = Coefficient of velocity.

Table 2. Efficiency of still and FPC under various parameters

Sl No	Water depth (cm)	Total Radiation (W/m^2)	Total Water Yield (mL)	Temp at water basin (^oC)	Enthalpy (kJ/kg)	Efficiency of the still combined with FPC (%)
1	2.0	7011.50	4700	59.94	2358.6	60.49
2	3.0	6847.00	4000	57.77	2363.4	52.82
3	2.5	6967.75	4480	59.21	2361.1	58.08
4	3.0	6676.25	3750	57.67	2363.5	50.79
5	2.5	7217.50	4470	59.11	2361.1	55.94
6	3.0	7044.25	4140	58.33	2363.5	53.14
7	2.0	7082.25	4860	60.32	2357.3	61.89
8	2.0	7070.00	4810	59.96	2363.3	61.51

*Time in Seconds - 3600 x 24 = 86400
**Basin area (M^2) = 0.3025

$V = C_v \times \sqrt{2gh}$, $C_V = 0.67$, h = 30cms, $a_{pipe} = 0.311m^2$, $a = 0.60m^2$, $V = 0.67 \times \sqrt{2 \times 9.81 \times 0.30} = 1.625$m/Sec

8.m = 1000×0.311×1.625 = 505.375kg/sec

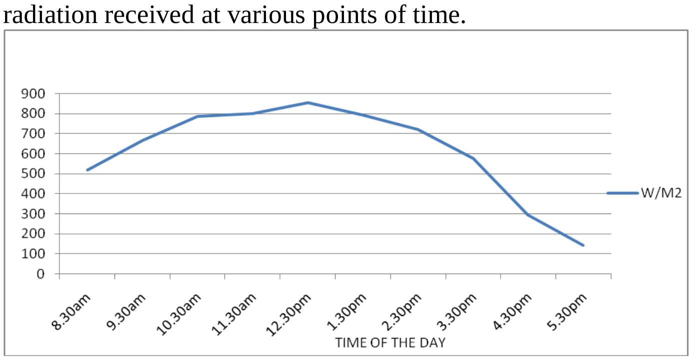
9.Cp = 4187J/kgk

10.dt = (69.47-66.08)=3.39^0C ,m= 0.127 kg/sec

11. $a = 0.60m^2$,$\sum I = 7011.5 W/m^2$

Overall efficiency of Flat plate collector is $(m \times C_p \times dt) \div (\sum I(t) \times a) = (505.375 \times 4187 \times 3.39) \div (7011.5 \times 0.60) = 17.05\%$

The average value of efficiency of nine days was observed to be 56.428%. The graph below depicts the amount of radiation received at various points of time.

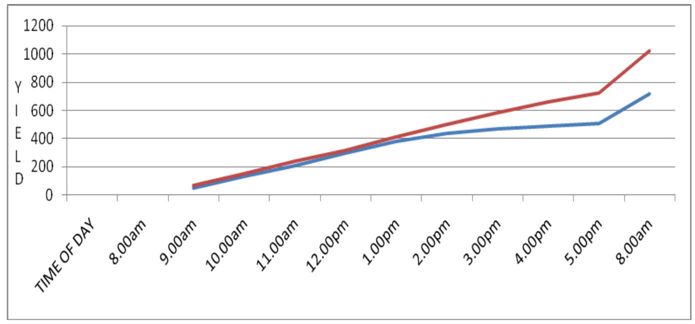


Radiation vs Time of the Day Day 1 (On Y axis – Radiation intensisty W/m^2)

It was observed that the maximum radiation was obtained at 12.30 PM which had a correlation with the yield of water in the solar still. The graph below depicts the amount of radiation received at various points of time.

The graph reveals the water yield comparison of solar still combined with a FPC. Maximum yield of water obtained in a day is 1070mL when the solar still was combined with FPC as compared to 720mL of solar still alone.

The cost analysis of the entire system worked out as follows: Cost of GI Sheet = Rs. 950/-, Cost of aluminium absorbing plate = Rs.186/-, Cost of PVC Pipes, elbows, valves etc.



Amount of radiation at hourly interval

= Rs. 321/-, Cost of T Bend, tape, M seal etc. = Rs. 85/-, Cost of Glass cover = Rs. 305/-, Cost of Sponge (insulator) = Rs. 140/-, Cost of black Asta paint, thinner etc. = Rs. 95/-, Cost of fabrication = Rs. 1300/-,Total cost = Rs. 3282/-, Combined cost of Solar Still + Flat Plate Collector = Rs. 3282/- + Rs. 2270/- = Rs. 5652/-.

Acute drought conditions and dwindling natural water resources are focusing more attention on what continues to be a worldwide problem: a lack of access to fresh, potable water for drinking and sanitation. Distillation is a method where water is removed from the contaminations rather than to remove contaminants from the water (Akash, 1998).The solar distillation involves zero maintenance cost and no energy costs. Among the available purification technologies, solar desalination process proves to be a suitable solution for resolving this existing crisis. This renewable energy technology operates on a basic principle of which the solar radiation enters through the glass surface inside a closed chamber touching the black surface generating heat energy, which gets trapped inside. This gradually raises the temperature of the liquid resulting in evaporation process and further condensation, which is drained out for use (Vinoth Kumar and Kasturi Bai, 2008). In the present study the designing and fabrication of a solar still coupled with a Flat Plat Collector was carried out.

Earlier investigations by Badran and Al-Tahaineh (2005) revealed that coupling of a solar collector with a still has increased the productivity by 36%. Also the increase of water depth has decreased the productivity, while the still productivity is found to be proportional to the solar radiation intensity. In literature it also reported that the climatic conditions may also have an effect on the efficiency of the system (Singh and Tiwari, 2004).

IV. Conclusion

Experimental investigation to study the effect of coupling a FPC on the productivity of solar stills was carried out. Different parameters (i.e. water depth, direction of still, solar radiation etc.) on enhancement of productivity were also studied. It was found that the average efficiency of five days is 44.62% with highest yield of 720 mL. The average efficiency of nine days is 56.42% with highest yield of 1070 mL.

Acknowledgement

Thanks are due to Dr. P.V. Shouri, Associate Professor, Government Model Engineering College, Cochin for his valuable

ISSN:2319-6890)(online),2347-5013(print)
01 Jan. 2016

ideas in carrying out this work as a dissertation for M. Tech. degree.

References

i. *Akash, B.A. (1998) - Experimental evaluation of a single-basin solar still using different absorbing materials, Renewable Energy* ***14(4):*** *307–310.*

ii. *Badran, O.O. and Al-Tahaineh (2005) – The effect of coupling a flat-late collector on the solar still productivity, Desalination,* ***183(1-3):*** *137-142.*

iii. *Badran, A.A., Al-Hallaq, I.A., Eval Salman, I.A. and Odat, M.Z. (2005) - A solar still augmented with a flat-plate collector, Desalination,* ***172(3):*** *227-234.*

iv. *Hitesh N. Panchal, Ajeet Kumar Rai, Vivek Sachar and Nupendra Batla (2011) - Comparative analysis of single slope solar still coupled with a flat plate collector, Applied Energy,* ***2(6):*** *985-998.*

v. *Mohsen, M.S. (2000) - Experimental study of the basin type solar still under local climate conditions, Energy Conv. Manage* ***41(9):*** *883–890.*

vi. *Pratap Singh (2003) - Design, fabrication, testing of a modified single slope solar still, Indian J. Mech. Eng,* ***41(4):*** *8-14.*

vii. *Salah Abdallaha, Omar Badien and Mazen M. Arthur (2008) - Performance evaluation of a modified design of a solar still. Applied Energy,* ***12(2):*** *282-290.*

viii. *Singh, H.N. and Tiwari, G.N. (2004) – Monthly performance of passive and active stills for different Indian climatic conditions, Desalination,* ***168:*** *145-150.*

ix. *Vinoth Kumar, K. And Kasturi Bai, R. (2008) – Performance study on solar with enhanced condensation, Desalination,* ***230(1-3):*** *51-61.*

x. *www.worldwildlife.org*