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V-GROOVED SOLAR FLAT PLATE WATER HEATER

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ABSTRACT

Solar energy is the cheapest and cleanest source of energy which is readily available in this world. Over the years, many researches and commercial activities have been carried out to utilize the solar energy. The flat plate PVT collector systems inherit the benefits of PV module. It works on noiseless environment; do not produce any unwanted waste such as radioactive materials, highly credibility system with life span expectation is between 20 and 30 years and very low maintenance cost and suitable for the application of building integrated photovoltaic/thermal system (BIPVT).

Key words: PVT,PV,BIPVT,V-GROOVED FLATE PLATE

I. INTRODUCTION:

Technologies toward harvesting solar energy can be divided into three main applications namely; solar thermal, solar photovoltaic and solar photovoltaic/ thermal. For most developing countries, agriculture activities are located in remote villages and rural areas. Due to economic factors, the activities experience difficulties in connecting the drying systems to the national grid. The same problem occurs for rural consumers to get sufficient electricity, hot water for domestic utilities. Therefore the concept of using photovoltaic/thermal solar collector has been introduced. A photovoltaic thermal solar collector is a combination of photovoltaic panel (PV) and solar thermal components or system which is capable of producing both electricity and thermal energy simultaneously in one integrated system. The sun is a sphere of hot intensely hot gaseous matter with a diameter of 1.39m.the solar energy strikes our planet in a mere 8min and 20 sec after leaving the giant furnace, the sun which is 1.5×1011m away. The sun is the world's largest energy resource, and solar energy is a form of renewable energy which is abundant in our environment. On average the annual solar radiation is around 5300MJ/m^2. Solar energy, radiant light and heat from the sun, is harnessed using a range of ever-evolving technologies such as solar heating, solar photovoltaics, solar thermal electricity, solar architecture and artificial photosynthesis. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional

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costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared"

II. MEASURING FLASK

Fig 8 - Measuring Flask

III. V - GROOVED FLAT PLATE COLLECTER

Flat-plate collectors are in wide use for domestic household hot-water heating and for space heating, where the demand temperature is low. Many excellent models of flat-plate collectors are available commercially to the solar designer. A discussion of flat-plate collectors is included here because of their use in industrial systems either to supply low-temperature demands or to preheat the heat transfer fluid before entering a field of higher-temperature concentrating, collectors. Detailed descriptions of flat-plate collector design, performance and system design using these collectors may be found in the following sources: Duffie and Beckman (1980), Lunde (1980), and Kreider and Kreith (1982). The interested reader is referred to these for further information.

Fig 10 - Absorber Plate

Fig 11 - Glass Cover

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IV. EXPERIMENTAL INVESTIGATION

Specifications

Length of Collector	:	1.25m
Width of collector	:	0.75m
Area of collector	:	1.42m X 0.7m
Diameter of the tube	:	0.9375m^2
Tube Centre to Centre dist.	:	0.01m
Length of observer plate	:	1.38m
Width of observer plate	:	0.69m
Material of observer plate	:	MS
Observer plate thickness	:	22 gauge
Glass cover emissivity	:	0.85
Refractive index	:	1.5
Diameter of header pipe	:	0.019m
Insulating material	:	Glass wool
Density of insulating material	:	200kg/m^3
Density of MS	:	2.70gc

Fig 12 - Glass Absorber Plate

The diagram in the figure above shows the experimental arrangement of the solar Flat plate collector. The solar flat plate collector consists of a flat plate observer made up of MS with an area of 0.875m^2 and which is lined with glass wool insulation. There is totally seven number of pipes which are placed over the observer plate in parallel with equal distance. The size of the collector is length 1.25m, width 0.75m and area of 0.9375m^2.The pipes are connected to a header pipe of diameter 0.019m.

A glass flat of thickness 6mm is mounted on the top serves as protective shield for avoiding the loss of radiation. All the joints of the metal box are well sealed. Global solar radiations were measured with Pyranometer. Temperatures at different places were measured. The flat plate collector consists of seven pipes coated with black paint. The pipes are connected with each other in parallel through header pipes which are placed over the observer plate which is coated with black paint. The inlet header is connected to fresh water tank. The total setup was tilted at an angle of 11^0 degree to the horizontal. The thermocouples were located at different locations (i.e.) observer plate, glass plates, tubes, inlet and outlet pipes. The collector side and bottom were properly insulated to reduce heat loss. The solar flat plate collector was kept in open roof top facing south and exposed to solar radiation.

The experiments were conducted from 10:00am to 2:15pm on different days with different flow rates. The instantaneous efficiency of the solar flat plate collector was estimated. Based on the observed data, graphs were drawn.

Observation Table-1

Date : 05.06.2014 Flow rate of water : 300ml/min

Sl. No.	Time of day hr / min	Inlet temp °C	Outlet temp °C	Absorber plate temp °C	Glass plate temp °C	Pyranometer m.v	Atm temp °C
1.	10:00	34	40	45	38	1.2	37
2.	10:15	35	42	47	39	1.8	37
3.	10:30	35	43	47	39	2	38
4.	10:45	35	45	53	43	2.8	38
5.	11:00	36	50	66	49	5.4	39
6.	11:15	37	55	61	50	5.6	39
7.	11:30	37	56	65	51	4.8	39
8.	11:45	36	56	65	51	6.2	39
9.	12:00	37	58	76	56	6.3	39
10.	12:15	36	60	76	57	5.2	40
11.	12:30	36	59	71	53	4.2	40
12.	12:45	36	50	58	48	4	39
13.	1:00	36	52	60	48	4	39
14.	1:15	37	53	61	50	3.2	39
15.	1:30	37	54	70	54	4	39
16.	1:45	37	55	60	50	3.8	39
17.	2:00	36	50	54	45	3	39

PERFORMANCE ANALYSIS

1. Area of the collector (A) = length × breadth

Where, L=Length of collector

B=Breadth of collector

2. Total heat available in (kj/hrm^2) = $\frac{Pyranometer\ reading\ in\ mv}{Pyranometer\ constant \times 1000}$ x 60 x 4.186 x 10^4

Where, Pyranometer constant = 5.56 v/cal.min^{-1}

3. Heat available in the collector in (kj/hr) =Total heat available x area of the collector

4. Heat gained by water in (kj/hr) = m x Cp x Δt

Where, m = mass flow rate of water in Kg/hr

Cp = specific heat of water = 4.186 J/Kg K

$\Delta_t = t_o - t_i$

5. Efficiency = (Heat gained)/(Heat available) x 100

Specimen Calculation -1

READING TIME:10:00AM

Flow rate of water: 300ml/min (18kg/hr)

1. Area of collector (A) = length x breadth = 1.25m x 0.75m = 0.9375m^2

Sl. No.	Time of day hr / min	Inlet temp °C	Outlet temp °C	Absorber plate temp °C	Glass plate temp °C	Pyrano meter m.v	Atm temp °C
1.	10:00	34	39	61	48	3	38
2.	10:15	34	40	64	50	3.8	38
3.	10:30	34	41	65	50	3.8	38
4.	10:45	34	44	67	52	4	38
5.	11:00	35	46	69	52	4.2	39
6.	11:15	35	47	70	53	4.4	39
7.	11:30	35	47	71	53	4.9	39
8.	11:45	35	51	72	54	5	39
9.	12:00	35	51	73	56	5.4	41
10.	12:15	35	51	73	55	5.4	40
11.	12:30	35	52	74	56	5.4	40
12.	12:45	35	52	73	56	5.4	39
13.	1:00	34	51	74	57	5.2	39
14.	1:15	34	50	72	54	5	39
15.	1:30	34	47	71	54	4.8	39
16.	1:45	34	45	69	53	4.4	38
17.	2:00	34	44	69	54	4.3	38

2. Total heat available = $\frac{Pyranometer\ reading\ in\ mv}{Pyranometer\ constant \times 1000}$ x 60 x 4.186 x 10^4 = $\frac{1.2}{5.56 \times 1000}$ x 60 x 4.186 x 10^4 = 542.071 kj/hrm²

3. Heat available in the collector = Total heat available x area of the collector

= 542.07 x0.9375 = 508.19 kj/hr

4. Heat gained by water = m x Cp x Δt

= 18 x 4.186 x (40-34) = 452.088 kj/hr

Observation Table-2

READING TIME:10:00AM DATE:06-06-2014

5. Efficiency = (Heat gained)/(Heat available) x 100

= (565.11)/ (1270.47) x 100 = 88.95%

SPECIMEN CALCULATION -2

Flow rate of water: 450ml/min (27kg/hr)

1. Area of collector(A) = length x breadth

= 1.25m x 0.75m = 0.9375m^2

2. Total heat available = $\frac{Pyranometer\ reading\ in\ mv}{Pyranometer\ constant \times 1000}$ x 60 x 4.18

= $\frac{3}{5.56 \times 1000}$ x 60 x 4.186 x 10^4 =1355.17 kj/hrm²

3. Heat available in the collector = Total heat available x area of the collector

=1355.17 x0.9375 =1270.47 kj/hr

4. Heat gained by water = m x Cp x Δt

=27 x 4.186 x (40-34) = 565.11 kj/hr

5. Efficiency = (Heat gained)/(Heat available) x 100

=(565.11)/ (1270.47) x 100 = 44.48 %

RESULT TABULATION – 1

Date: 05.06.14 flow rate of water: 300ml/min

Sl. No.	Time of day hr/min	Heat available per unit area (w/m^2)	Heat available in v-grooved plate collector (w)	Heat gain by the water (w)	Efficiency of collector (%)
1.	10:00	520.60	520.60	62.79	89.95
2.	10:15	498.91	498.91	83.72	69.19
3.	10:30	477.22	477.22	83.72	71.16
4.	10:45	488.06	488.06	104.65	72.79
5.	11:00	477.22	477.22	83.72	46.12
6.	11:15	455.53	455.53	83.72	57.18
7.	11:30	466.37	466.37	83.72	70.42
8.	11:45	455.53	455.53	146.51	57.39
9.	12:00	542.29	542.29	188.37	59.30
10.	12:15	553.14	553.14	188.37	82.11
11.	12:30	563.99	563.99	230.23	91.34
12.	12:45	553.14	553.14	209.3	58.38
13.	1:00	542.29	542.29	209.3	71.16
14.	1:15	531.45	531.45	209.3	88.96
15.	1:30	520.60	520.60	188.37	70.88
16.	1:45	509.76	509.76	125.58	84.27
17.	2:00	498.91	498.91	83.72	77.84

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RESULT TABULATION –2

Date : 06.06.14 flow rate of water : 450kg/min

Sl. No.	Time of day hr/min	Heat available per unit area (kj/hrm²)	Heat available in v-grooved plate collector (kj/hr)	Heat gain by the water (kj/hr)	Efficiency of collector (%)
1.	10:00	1355.17	1270.47	565.11	44.40
2.	10:15	1716.56	1609.27	678.13	42.1
3.	10:30	1716.56	1609.27	791.15	49.16
4.	10:45	1806.90	1693.96	1130.22	66.72
5.	11:00	1897.25	1778.67	1243.24	69.89
6.	11:15	1987.59	1863.36	1356.26	72.78
7.	11:30	2213.46	2075.11	1808.35	87.14
8.	11:45	2258.63	2398.71	1808.35	75.38
9.	12:00	2439.32	2286.86	1808.35	79.07
10.	12:15	2439.32	2286.86	1808.35	79.07
11.	12:30	2439.32	2286.86	1921.37	84.01
12.	12:45	2439.32	2286.86	1921.37	84.01
13.	1:00	2348.97	2202.15	1921.37	87.24
14.	1:15	2258.63	2117.46	1808.35	85.40
15.	1:30	2168.28	2032.76	1582.30	77.83
16.	1:45	1987.59	1863.36	1469.28	78.85
17.	2:00	1942.42	1821.01	1243.44	68.27

GRAPH 1

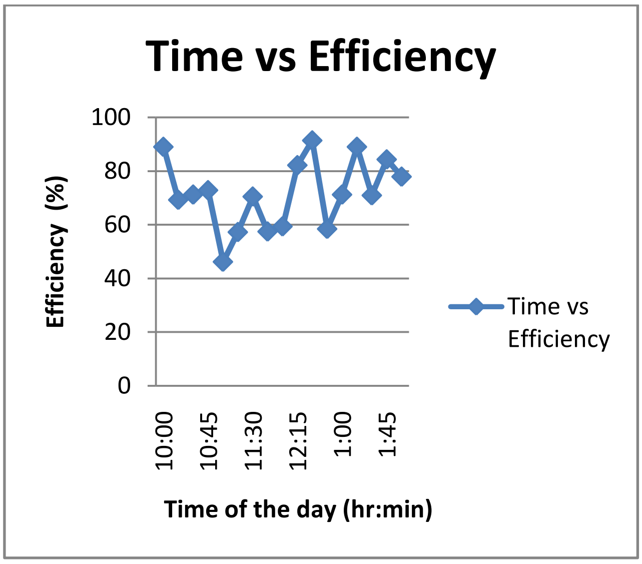

Fig 12 - Time Vs Efficiency Plot (300 Ml/Min)

GRAPH 2

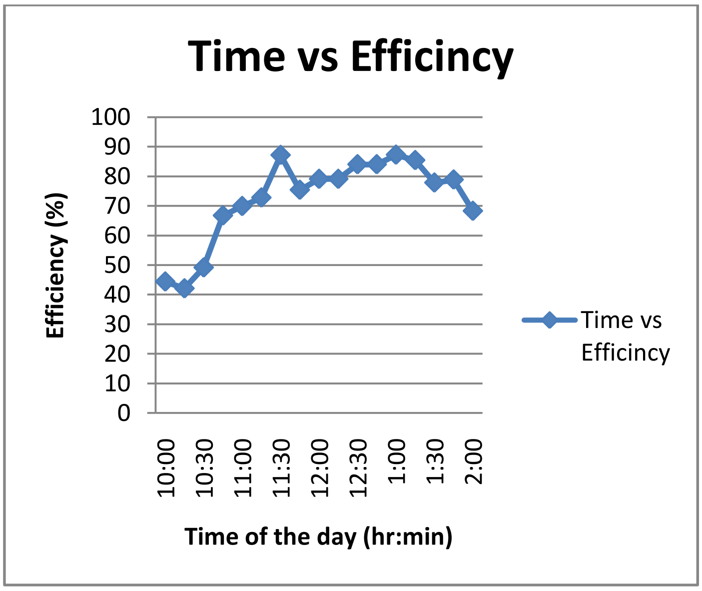

Fig 13 - Time Vs Efficiency Plot (450 ml/min)

V. CONCLUSION

The flat plate PVT collector systems inherit the benefits of PV module. It works on noiseless environment; do not produce any unwanted waste such as radioactive materials, highly credibility system with life span expectation is between 20 and 30 years and very low maintenance cost and suitable for the application of building integrated photovoltaic/thermal system (BIPVT). In conclusion, the PV/T can be improved further based on few suggestions, such as:

- New design of absorber collector to improve efficiency of the PV.
- Replacing the roofing material with new material that will increase the efficiency of the system and at the same time reduces the payback period – attractive in case the available roof surface is limited.
- Payback – proposed system that gain pay back in less than 10 years.
- Production and installation cost – new method to integrate the systems into one product with value added production.
- Sustainable Energy – ensure that the energy produced by the system is sustainable with zero CO_2 emissions.
- Aesthetics – integration rather than ‘‘bolt on roof’’ gives better architectural look.
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