EXPERIMENTAL STUDY ON A FLAT PLATE COLLECTOR ASSISTED FOR SOLAR WATER HEATING UNIT

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Summary: The aim of the study was to develop Flat Plate Collector (FPC) from the locally available material in the market for the purpose of solar water heating. The efficiency of the collector was tested with the normal flow of water under ambient temperatures of 25^{o}C for the consequently months of the year. The efficiency was noted 36.97% and 37.29% with the highest amount of absorbing solar irradiance from 4580 kJ.m^{-2}.hr^{-1} and 4365 kJ.m^{-2}.hr^{-1} for the month of June and July respectively. Results showed that the efficiency was increased significantly with the increasing of zenith and azimuth angle of the sun. From the results it was clearly showed that the collector gives maximum heated water from 16930 to 16277 l/month respectively due to the greater sun rays falling on the collector. It was observed from the experimental results, that water heated at a very fast rate with the highest amount of solar irradiance absorption with the highest efficiency of the collector and proves that FPC was the best technique to be used for the purposes of water heating.

NOMENCLATURE

Symbol	Meaning	Unit
FPC	Flat Plate Collector	-
SHW	Solar Water heating	-
P.V.C	Polyvinyl chloride	-
I_s	Solar Irradiance	kJ.m^{-2}.hr^{-1}
C_v	Chart Value	Cal.cm^{-2}.min^{-1}
η	Efficiency	%
π	Content term	3.14
R_{ab}	Radius of the absorber pipe and water tank	Meter
L_{ab}	Length of absorber pipe and water tank	Meter
V	Volume of the absorber pipe and water tank	Cubic meter
Q	Daily output of heated water	Liter
E	Overall Efficiency	%
G	Daily solar radiation	kJ.m^{-2}.hr^{-1}
A	Aperture area of the collector	Meter

Introduction

Hydroelectric and thermal solar energy has huge potential sources of renewable energy. Pakistan is the thriving renewable energy sources i. e. solar energy, biomass and wind energy etc, but for the development of country the utilization of solar energy is most important [15, 16, 17]. In Pakistan solar energy has very huge in amount and earth received a greater amount of energy from the sun

throughout the year of about 7000 $MJ.m^{-2}$ and 34°N latitude and 71°E longitude of Peshawar (Pakistan) received a 20 $MJ.m^{-2}.day^{-1}$ energy from the sun [4, 13]. For the using of this huge amount of energy for the different purposes of i.e. drying and water heating etc, the best choice is solar collectors [3, 7]. A solar collector is a device which converts sun energy into thermal energy which is used for drying of different types of fruits & vegetable and also for heating of water [5, 10]. Water is the most important thing for human life to survive in the earth [18, 19]. There is necessity of clean, drinkable and pure water for the surviving of human being in many countries, but there is brackish, harmful and containing impurities i. e. Ca, Mg, NaCl and Zn in the water resources [20, 21]. [24] Studied that solar energy is one of the promising techniques for getting the pure and clean water from potable water resources. For getting pure and clean water from the potable water resources, there are so many techniques which are used for heated water to produce clean and pure water i. e. solar collector, solar photovoltaic etc [25, 26].

Renewable energy donates clean, nontoxic energy source and the primary sources of energy are the sun, wind, biomass, waves and geothermal energy [18, 27]. Sun energy can be utilized in the form of thermal energy with the using of solar collectors for different purposes of i.e. water heating, drying, distillation and producing electricity etc [3, 22]. Solar collectors are the best techniques for the production of heated water from the potable water [15]. A FPC is the best choice for heating of water with convective heat flow having an efficiency of 35% to 45% which is the least expensive and time saving technique [6, 7]. Several years of research shown that FPC is the best technique for the using of heating of farm shops, dairy buildings and water heating [1]. For the using of FPC for heating of water, the key important parameter is its efficiency [5, 6]. The efficiency of the collector depends on the optimum combination of temperature and flow rate [10].

The shortage of pure, clean and drinking water in many countries is the serious problems. Human being has to depend for rivers, sea water and underground water reservoirs for its fresh water needs, but these resources are more saline and cannot be drinkable [20]. To resolve this problem, different techniques of solar heating have been used in different countries. To use a FPC efficiently for heating of water, the optimization of the collector area, fluid flow rate and ambient temperature of the collector will give a result in greater efficiency [14]. In the present research study, we accentuate on the performance of FPC and its efficiency and developed for the production of heated water for the commercial use. The specific objective of this study was, to study the performance and efficiency of the FPC with the study of heating of water.

Methods and Materials

Solar Radiation

The Mechanical Pyranometer is in an instrument which give sun rays reading in chart, which falling directly on the instrument. The data which are recorded in the chart from the incoming sun rays multiplied with the constant 0.88 ($cal.cm^{-2}.min^{-1}$) which give reading per minute. Further converting this data in to a standard unit, multiply with constant 418 ($kJ.m^{-2}.min^{-1}$), calculating solar radiation the following Eq. 1 is used.

$$I_s = 0.88 \times 418 \times Cv \quad (1)$$

Assembling of Solar Water Heating Unit

For the experiment of SWH purposes we used FPC with water tank, which is used for both purposes (cooled and hot water) during the experimental work showed in Fig. 1.

Flat Plate Collector

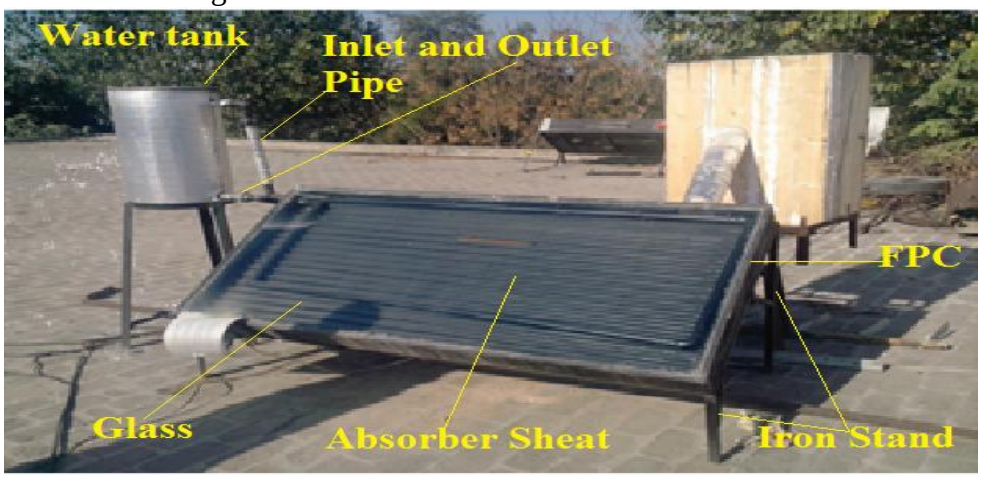
The FPC consists of a glass, heating transfer fins (absorbing sheet, made from aluminum material) and heating pipes. The heating pipes which were used in the collector having the length and diameter of 1.52m and 0.076m which are made of reflective mirror and steeliness steel respectively. These tubes were inter-connected with each other; from this the cold water passed within heating

pipes and heated the water with the absorbing of sun irradiance with the help of glass because they are good radiated heat, cheap, easily available in the local market, having a high melting point and have low weight shown in Fig. 1.

Hot Water Tank

The hot water tank, having length and diameter is 1.212m and 0.106m respectively, made from steel sheet, used for storage of water (cold and hot water) and inlet and outlet pipe (Diameter= 0.762m) was made up of P.V.C fixed with the storage tank showed in Fig. 1. Inlet was fixed at the bottom of the tank for the cold water providences to the collector, while the outlet was fixed at the top of the storage tank due to the low density of the hot water. These pipes were connected with the FPC from the one side of the heating pipes. This water passed from the pipes and heated with the help of sunlight and in these heated water stored in the storage tank. The outlet was provided at the top of FPC because hot water goes up to due to the low density. Both the inlet and outlet duct have a cross sectional area of 0.912m^2.

Fig. 1. Isometric view of FPC assisted for SWH



Collector Tilt Angle

The collector was fixed with the tilt angle of 35^o facing North-South axis, with the horizontal plane surface of the experimental site. The collector received maximum solar irradiance due to the azimuth and zenith angles of the sun which falls on the collector surface. As the experimental site is suited at the latitude of 34^o received maximum solar radiation from the collector which was tilted to 35^o so that the incident solar irradiance was normal to the collector surface.

Recorded the Data

The solar radiation data were recorded daily, weekly and monthly basis with the help of Mechanical Pyranometer in the form of a graph or chart [4]. The ambient and collector temperature was recorded with the help of digital thermometer by the method of [2]. The Efficiency of FPC was calculated from the Eq. 2, which is the ratio of the output of water to the input of solar energy in the collector which is recorded in percentage (%) and volume of the heating pipe and water tank was calculated by using the equation 3, by the method of [4, 5].

$$\eta\,(\%) = \frac{Mass\ of\ water\ (Kg)}{Solar\ energy\ (kJ)} \times 100 \quad (2)$$

$$V = \pi {R_{ab}}^2 L_{ab} \quad (3)$$

Performance of Flat Plate Collector

The performance of FPC is the total amount of heating water in liters daily basis. The energy required to evaporate the water is 2.3 MJ per kilogram. The efficiency and performance of FPC can

be expressed as the fraction of total solar radiation falls on the collector and that actually heated up the water to the vaporization stage. There is so many techniques to be used for the production of heated water and can be calculated with the using of following Eq. 4.

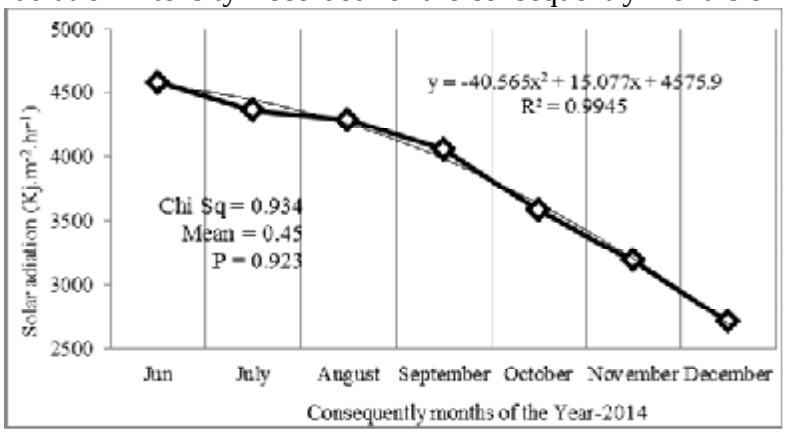
$$Q = \frac{E \times G \times A}{2.3} \quad (4)$$

Results and Discussions

Solar Radiation Intensity

The average total solar radiation intensity were recorded for each month of the year-2014 in the range of 4580 kJ.m^{-2}.hr^{-1} to 2708 kJ.m^{-2}.hr^{-1} as shown in Fig. 2. The average maximum solar radiation intensity was recorded at 4580 kJ.m^{-2}.hr^{-1} for the month of June, followed by 4365 kJ.m^{-2}.hr^{-1}, 4288 kJ.m^{-2}.hr^{-1} for the month of July and August respectively, while the average minimum solar radiation intensity was noted in 3192 kJ.m^{-2}.hr^{-1} and 2708 kJ.m^{-2}.hr^{-1} in the month of November and December respectively, due to the low sunshine and rainy days. Similarly in the month of October the average sun radiation intensity was recorded 3587 kJ.m^{-2}.hr^{-1} due to low sunshine. In Fig. 2, the solar radiation intensity of each month of the year showed the difference due to the azimuth and zenith angles, which changed in the months of the year of the sun rays incident on the solar collector. The results of solar radiation intensity are related to the findings of [9], who noted 3567 kJ.m^{-2}.hr^{-1} solar radiation intensity in the months of October to December. The average total solar radiation intensity is high at 12:00Noon observed [6, 7]. The collector is used for collecting solar energy in the form of heat for heating of water from 9:00 AM to 4:00 PM. The graph showed that the distribution is normal with chi square value of 0.934 and P = 0.923. The analysis of the data showed that a linear model equation is fitted for the data and their interrelationship between the months of the year-2014.

Fig. 2. Solar Radiation Intensity Recorded for the consequently months of the Year-2014

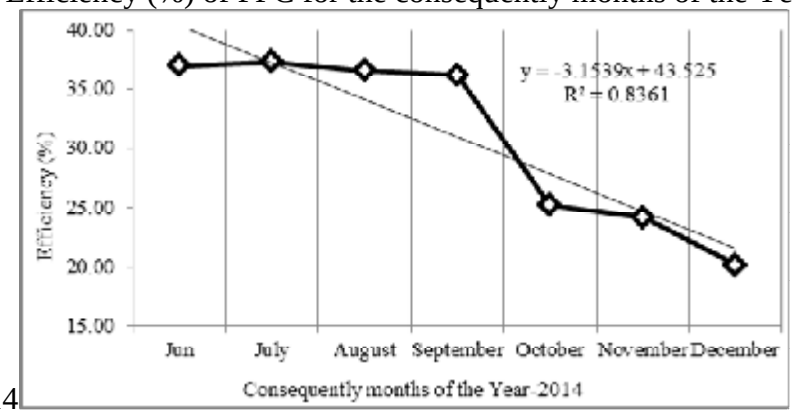


Efficiency of the Flat Plate Collector

Efficiency is the ratio of heat input and output of the collector. Efficiency of the FPC was evaluated for the consequently months of the year i.e. June to December with the ambient temperature level of 25^{o}C was shown in Fig 3. Maximum efficiency was noted 37.29% in the month of July, followed by 36.97%, 36.54% and 36.20% for the month of June, August and September respectively due to high intensity of the sun and highly sunny days. The results are nearly closer with the finding of [12], while for the month of October the efficiency was noted of 25.14% which closer to the finding of [20, 21]. Data were analyzed and found the efficiency of FPC with the significant interval difference ($P < 0.8361$) and the data were fitted with a linear model equation. From the figure, R^2 value showed that there is inter relationship between the months of the year. Figure 3, showed that the lowest efficiency of the collector were recorded in the months of December of 20.11% due to the

low sun shine and also with the rainy days in this month of the year due to angle of the sun incident (which rays don't strike on the collector) which are similar results with the finding of [5, 12].

Fig. 3. Efficiency (%) of FPC for the consequently months of the Year-2014

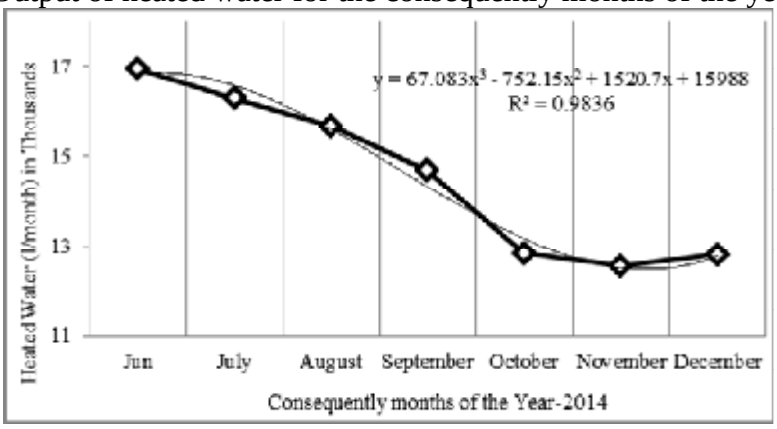


Performance of Solar Water Heating Unit

Output of Heated Water

In the Fig. 4, shows the average values of the output heated water for the consequently months of the year-2014, and the data were recorded in liter per month. The highest value of heated water were noted in the month of June and July of 16930 l/month and 16277 l/month respectively which is similar with the finding of [1, 16], followed by the highest of 15670 l/month and 14679 l/month for the months of August and September. Similarly the lowest output heated water were noted for November of 12565 l/month, followed by the least output of 12850 l/month and 12813 l/month were noted for the month of October and December respectively which is closer with the finding of [7, 11] due to the cloudy days in these months of the year. Data were analyzed and found that the linear model equation is fitted with data of heated water for the months of the year with the significant interval difference ($P < 0.9836$). From the figure, R^2 value showed that there is inter relationship between the months of the year. The collector was fixed with the angles of 34^o with the latitude of the location for the whole experiments. So that's why the output of heated water graph was lower and higher due to the sun tracking angles and sun rays which falling on the collector daily.

Fig. 4. Output of heated water for the consequently months of the year-2014



Conclusions

FPC has been fabricated with the locally available market materials and experimentally tested with the normal flow rate of water. The results of the experiment, it was concluded that efficiency of the FPC increased significantly with the increasing of solar absorbing irradiance. Further it was concluded that the efficiency of the collector was increased with the angle of the collector focus on the sun azimuth angle. Furthermore, from the experiment it was also concluded that output of heated water increased with the increased absorbance of sun radiation.

Recommendation

From the experiment, we have done the following recommendation and suggestion, that FPC is a cheap source of making SHW as compared to electrical heated plant. The collector should be focused on the zenith and azimuth angle of the location and also placed in open space for absorbing maximum solar radiation to get maximum heated water. Further from the experimental results, it was recommended that FPC works efficiently for 7 hours from 09:00AM to 04:00PM for the consequently months of the year-2014 i.e. June to December. Furthermore, suggested from the results that for increasing the collector efficiency, sensor revolving system should be developed with reference to direct reflection of sun rays.

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