South Asian J. Food Technol. Environ., 6(2): 990-994(2020)
ISSN 2394-5168 (Print), 2454- 6445(online)
View on line at www.sweft.in
DOI: https://doi.org/10.46370/sajfte.2020.v06i02.07

Optimization and Performance Evaluation of Domestic Solar Water Heater

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Abstract

Solar technologies are been developed to harness the available environmentally friendly and sustainable solar radiation. New ways of utilizing free power for different energy consuming process continued to be created. In this experiment the flat plate solar water heater had been kept for several days. To estimation of better performance of flat plate solar heater, it had been experimented with different cover, inclination angle and oriented direction to get better efficiency of solar water heater. The flow system for water heater has been placed in a spiral manner due to its configuration. It was installed in 125˚ northwest direction where it could be got maximum sunlight with an inclination angle of 45˚. At that position it was absorbed that it had maximum efficiency was 70.18%. Heating efficiency of water has been increased by placing with glass cover which had a suitable air gap to retain the heat, which was generated inside of collector. A glass covering has been provided over the surface of the tubes thereby decreasing the reflectivity of the sunlight and enhancing maximum absorption.

Keywords: Sun, Solar Water Heater, Energy Solar Cells & Solar Panels.

Paper cited: Singh, V., Kumar, S. and Kharya, S. (2020). Optimization and performance evaluation of domestic solar water heater. *South Asian Journal of Food Technology and Environment*, 6(2): 990-994.

Introduction

Sun is an ultimate source of energy. Which is spreads its energy over all time to entire Earth. Solar Energy is radiant light and heat from the sun that is harnessed using a range of all evolving technologies such as solar heating, photovoltaic, solar thermal energy etc. The solar technologies are classified as either passive or active, depending on the way they capture, convert and distribute sunlight. The conversion of solar radiation into heat energy takes place inside the absorber of solar panels and solar collector. The absorption of "short wave" radiation results in an emission of "long wave" heat radiation (infrared radiation). Absorbance 1 (100%) a radiation is entirely absorbed. Actual absorption of solar radiation with the black absorber: 92% to 98%. Actual emission of heat radiation with black bodies: 75% to 85% a "selective" surface coating of absorbers reduces emissions to only 3% to 5% (especially titanium oxinitrid coating on copper or aluminium and ceramic coatings) (Zain *et al.*, 2002). Modelling of the system helps to approximate the performance characteristics of collectors, solar fraction, and comparison between collector types. This makes modelling a very essential tool for the approximation and also prediction purposes. The effective use and supply of energy has an essential role in the economic development as well as the growth of the society.

Materials and Methods

Solar water heating technology would be reviewed. The areas of interest include the understanding of the various types of solar collectors commonly used, solar hot water sizing and usage habits especially in hospitals, principles of economic evaluation while taking purchase decisions of solar water heaters, calculation of annual energy and cost savings as well as the payback period of solar water heaters[IS 12933:1990]. Mathematical equations for sizing and computing the thermal and economic performance of the solar water heating system would also be generated through containing some data analyses.

System Performance Evaluation Design Parameter-To do the determination of working performance of SWH system, some values were constant which had been referred from Solar water heating system code (Table 1) of practices i.e. IS 12976:1990.

Table 1: System Performance Evaluation Design Parameter of practices

S. No.	Design Parameters	Values
1.	Collector flow rate	0.015 l/s
2.	Collector heat exchanger factor	0.9
3.	cover	Glass cover, plastic cover and no cover
4.	Inclination angle	0^0, 15^0, 30^0, 45^0 and 60^0
5.	Oriented direction	Northwest, Northeast, North, West & East
6.	Storage capacity	50 to 100 l/m^2
7.	Load heat exchanger	1
8.	Collector slope	10 due south
9.	Preheat tank storage capacity	1.5 to 2.0 times capacity of conventional water heater

The two dimensionless parameters X and Y are calculated as

$$x = \frac{A.b.(100 - T_a).n.24.C_2.C_3.C_4}{L.1000}$$

$$y = \frac{\text{Absorbed Solar Energy}}{\text{Heating Load}} = \frac{A.a.H.n.C_1.C_2}{L}$$

n = number of days in the month

Ta = average air temperature of the month

σ = Density of water

Cp = specific heat of water

a = No loss coefficient

C_3 = correction term if the storage/collector ratio is other than 75 l/m^2 collector area (between the limits of 37.5 and 300 l/m^2

H = Daily average radiation on the collector kW/h

L= Monthly heating load
= V. σ. Cp.(Tw-Ta).N

Tw = Minimum acceptable temperature of water

C_1 = correction term for glazing, 0.85 single glass

C_2 = correction term for heat exchangers in circuit,
= 0.97 for counter flow heat exchanger
= 0.95 for average heat exchanger,
= 0.90 (lowest value)

C_4 = correction term for the system

Results and discussions

The performance evaluation of the solar water heater was done according to the BIS Test code [**ISO 9806:1995**]. Data were recorded 5 times on each day within the duration of 5 days. Two days were introduced with an indoor analysis of water heater test in Absence of sun light. On other hand three days of water heater analysis had been kept in presence of sun light. To measure the system performance preliminary measurements were taken for particular interest.

a) Water temperature variation throughout the day
b) Solar insulation

The solar insulation is needed for the calculation of the water heater efficiency. A flat plate water heater, which is commercially available with a capacity of 100 liters/day is used to conduct the experiment work. Experiments were conducted for 5 days during which the atmospheric conditions were almost uniform and data was collected. The model is also used for evaluating the effectiveness of an applied collector. Using the experimental setup fabricated the heat exchanger effectiveness is evaluated at difference various temperature. The calculation is show that the solar water is quite good for domestic purpose. The following determination of solar water heater observation has been given below:

Table 2: Determination of solar water heater observation

S. No.	Parameters	Formulae	Values
1.	The gross area (G_a)	$G_a = h. w$	0.94 m^2
2.	Aperature area (A_{pa})	$A_{pa} = h.l$	1.23 m^2
3.	Absorber area (A_{ba})	$A_{ba} = w.l$	1.82 m^2
4.	Flux on collector (RF)	$RF = T_{cov}.A_p.G$	1.70 W
5.	Area of solar collector (A_c)	$A_c = E/I\eta$	4.51 m^2
6.	Collection of solar radiation (Q_i)	$Q_i = G.A$	18.62 W

Collector Efficiency Estimation- The solar water heater kept for 5 days on that day the separate efficiency of collector had been observed. With cover and no cover condition. At initial point of experiment, it had been observed that solar water heater can be efficient whether it have to install in suitable position of it, effective inclination, orientation and covering material had been introduced to observe 5 experimental days of solar water heater. For 5 experimental days the solar water had been installed with glass cover having inclination angle of 45º and oriented direction was northwest where it was getting maximum sunlight through the day and could trapped effective sunlight due to suitable inclination angle.

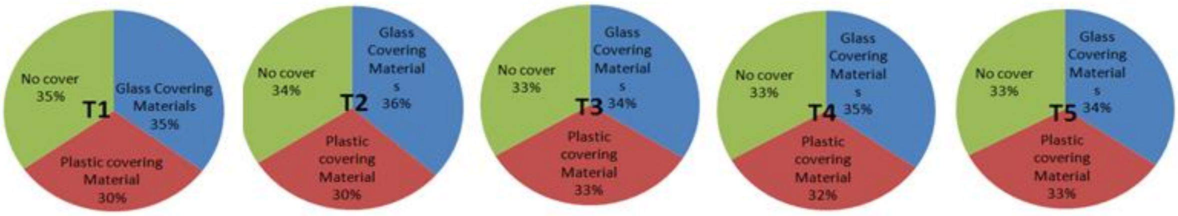

Fig. 1: Pie Chart for Average Efficiency of Solar water heater with different covering material for different days

Grey Relational Analysis: The Grey theory can provide a solution of a system in which the model is unsure or the information is incomplete. Besides, it provides an efficient solution to the uncertainty, multi-input and discrete data problem. GRA have been done to attain most suitable covering material, with respect to the efficiencies of the SWH of different days.

Reference sequence definition: After the grey relational generating procedure all performance values will be scaled into (0, 1) (Table 4).

Table 3: Qualitative measures for Layout Alternatives of SWH

Trials	Control Factors	Response				
		T_1	T_2	T_3	T_4	T_5
1.	Glass Covering Materials	62.5	66	74.438	76.924	77.014
2.	No cover	53.56	53.44	71.902	71.032	73.314
3.	Plastic covering Material	61.82	61.68	73.508	73.512	72.972

Table 4: Calculations and Results of grey relational generating at (0,1)

Control Factors	Grey relational At 0					Grey relational At 1				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
No cover	0	0	0	0	0.09	0	0	0	0	0
Glass Covering Materials	1	1	1	1	1	1	1	1	1	0.96
Plastic covering Material	0.92	0.66	0.63	0.42	0	0.076	0.34	0.37	0.56	1.00

Grey relational coefficient: The grey relational coefficient is calculated to express the relation between the efficiencies to be estimated each day (reference sequence) and sequences to be compared for each covering material. The results for grey relation coefficient of different treatments (days) for different covering material are presented in Table 5.

Table 5: Calculations and Results Gray Relational Coefficients

Control Factors	Gray Relational Coefficient				
	T_1	T_2	T_3	T_4	T_5
No cover	1	1	1	1	1
Glass Covering Materials	3	3	3	3	1
Plastic covering Material	1.152125	1.687898	1.733438	2.158181	1

Grey Relational Grade and Rank calculation- The degree of similarity between them is easily determined using the GRG. The greater GRG between two efficiencies, the closer the relationship between these days are. In other words, the more alike the two efficiencies for the different trials are, the greater of GRG is glass cover. Due to the glass sun light can be retain for a long time because glass is best absorber of sunlight and it can conserve heat also, so that the flow of water can get efficient heat and it can be use at domestic purpose easily. In an experiment grade rank of glass was extreme than the other covers that is one because of maximum heat retain property of it. Hence solar water heater with no cover had grade rank 3 because it was getting heat directly and could not retain heat so that heat got loss and observation of heat was less.

Table 6: Grey relational rank and grade generating

Control factors	GRA Grade	Ranks
No cover	1	3
Glass covering material	2.966155	1
Plastic covering material	1.546328	2

Conclusion

It was shown that there are a number of key points to be observed particularly when heating the water through the collector where significant improvements can be made to the collector's performance. An issue that was observed with the collector design was the high heat losses caused by air spaces. Further the indoor efficiency of solar water heater system is 64.25% and outdoor efficiency of solar water heater system is 76.12%.The measurement of overall efficiency for solar water heater is 70.18%.It has been determined that Flow of water was 5lit./min and it was the constant for all days. Temperature of Hot Water Tank, when the experiment was conducted inside of room and there was high temperature has been noted 34.3 ºC and low was 32.3 ºC. Temperature of flat plate collector inside of room high noted as 34.3 ºC and low was noted as 32.3 ºC. Whether it was kept in outside it has been obtained that the temperature of flat plate collector maximum was 105.5 ºC and low was 70.3 ºC. Efficiency of water heater has been noted for inside the maximum efficiency has been noted as 71.5% and minimum was 56%. For outdoor setup the maximum efficiency about 80.13% and minimum was 70.63%.

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Received : February, 2020
Revised : July, 2020
Published : December, 2020