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Performance Analysis of Evacuated Tube Collector

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Abstract

To counter the energy crisis due to over dependence on conventional fossil fuels researchers are working on solar energy based systems. In domestic and industrial sector dependence of evacuated water heaters is increasing for ensuring uninterrupted supply of low temperature hot water. In this work the performance of ETC was evaluated following standard test procedure in the University. At this location adequate amount of solar radiation are available throughout year.

The result obtained from the test predicts that the maximum efficiency of the system, ηsys, is 51% and overall heat loss coefficient of the system during day time test, Usys,d, found to 1.81 W/m²K.

Keywords: Evacuated Tube, Collectors, Thermal Analysis, Concentric-Tube, Flat Plate

NOMENCLATURE

m= Mass flow rate of the heat transfer fluid, kg/s

I= solar irradiation

t = Time in sec.

A = Aperture area of collector

Ta Ambient air temperature, ºC

Tm Cold water temperature from mains, ºC

Ts Temperature of water in storage tank, ºC

Ts fn= water temperature at the end of night-test, ºC

T_i= Temperature of fluid entering the collector, ºC

T_o=outlet temperature at specified time t, ºC

Tad= Average air temperature during day-test, ºC

Tan= Average air temperature during night-test, ºC

INTRODUCTION

Presently, the energy crisis is predominant as conventional sources of power such as fossil fuels are depleting at a quicker rate. Also, the utilization of these fuels, adversely have an effect on our environment ensuing in global warming, ozone layer depletion, acid rain etc [1]. Hence, there is a necessity to shift the center of attention closer to different non-conventional and renewable electricity sources. Solar power finds its utility over various fields. [2-3]

The world market for solar water heaters has increased substantially in the last decade. As a result, there have been large-scale trends of new-technology and improved-quality products [4]. The evacuated tube solar collectors operate better in comparison to flat plate solar collectors, in unique for high temperature operations. [5]. However, previously, it provided no actual competition for flat plate solar collectors, due to the fact of difficulties in manufacturing and maintenance of the vacuum seal. [6]

The supply of thermal energy required by using most of the water heating processes can range from 70-120°C. [7] which can ideally be produced by using evacuated tube collectors which can without difficulty obtain this range and have the delivered gain of a excessive performance.[8] With the recent advances in vacuum technology, evacuated tube collectors can be reliably mass produced. [9-10]. it was identified that the creation of vacuum between the absorber and the cover of a solar collector would end result in a considerable improvement in collector efficiency due to reduction in heat loss via convection and conduction. [11-12].

Each evacuated tube consists of two glass tubes. The outer tube is made of extremely sturdy transparent borosilicate glass that is in a position to resist impact from hail up to 38 mm in diameter. The internal tube is additionally made of borosilicate glass, but lined with a one-of-a-kind selective coating (ALN/AIN-SS/CU).

SITE DETAILS

The experiment will carried out at Deen Bandu Chhotu Ram University of Science and Technology Murthal, Haryana (longitude=77° 07' E, latitude=29° 03' N), which had Sunny day, partially cloudy and scattered cloud day some times. During the testing time, the collector faced south direction at a tilt angle equal to latitude of Murthal.

Radiation data for the test region

Month	**Radiation (kWhr/m2/Day)**	**Month**	**Radiation (kWhr/m2/Day)**
January	5.46	July	3.71
February	5.94	August	4.08
March	6.39	September	4.83
April	5.93	October	4.54
May	5.35	November	4.65
June	3.87	December	4.99

Specifications of ETC:

The evacuated tube collector containing ten tubes was selected for this study. The collector is of direct flow type with tube length 0f 1800 mm having outer diameter is 57.90 mm and inner is 43.25 mm having three layer coating. The exposed area of single tube is 0.164 m² and gross aperture area is 1.31m. The structure for collector is aluminum powder coated galvanized iron made having1.58 mm thickness having no leakage at 0.2 kg/cm2 pressure as found in static pressure leakage test. The detail specifications of the ETC are follows:

Table 1. Evacuated Test Collector's Specifications

Type of collector	**Evacuated Tube Collector, direst flow**
Tube length	1800 mm
Inner diameter of each tube	43.25 mm
Outer diameter of each tube	57.90 mm
Gap between two tube	22.08 mm
Number of tubes	10
Details of selective coating	Graded AL-N with Copper
Exposed area (gross) of a single tube (Di L), m²	0.164 m²
Gross aperture area of the collector, m²	1.31 m²
Aperture length	1670 mm
Aperture Width	78402 mm
Reflector below the tubes	Not Provided

Testing Procedure for ETC

The testing procedure adapting for the following test is ASHARE standard 93 followed by many countries [1] and has been adopted by an Indian standard IS 12933 (part5) [12]. The standard specifies that the collector shall be tested under clear sky conditions in order to determine efficiency. On any given day data is recorded under steady state conditions for fixed values of mass flow rate 'm' and inlet water temperature 'Ti'. For each set of fixed values, it is specified that an equal number of tests be conducted symmetrically before and after solar noon. For eg. If data of five set is recorded then the time of recording should be 11:00 am, 11:30 am 2 noon, 12:31 pm and 13:00 pm, Theses set of reading at given time and intervals eliminate any biasness because of transient effects.

As per standard test procedure the data was recorded for four inlet temperatures on different days and total sixteen data sets were obtained,. The efficiency of the ETC was calculated using the standard Hottelier equation [13] and the calculated values of the efficiency are shown in Table 2. Further, while testing the collector is considered to be operating under steady state conditions, if the deviations in the experimental parameters is within permissible limits. The experimental parameters recorded during the test are shown in Table 3 and were within permissible limit.

Table 2. Test Results

Date of Test	**Tsid** °C	**Tsfd** °C	**Average Ambient Temp. Tad** °C	**Average Solar Radiation, GT** W/m²	**(1+2)/2**	**ΔT**	**X**	**η**	**% η**
26.07.2017	42.9	66.3	33.6	635	54.60	21.00	0.03	0.47	46.7
27.07.2017	46.5	68.2	34.0	626	57.35	23.35	0.04	0.44	44.0
28.07.2017	53.2	74.4	33.2	646	63.80	30.60	0.05	0.42	41.6
30.07.2017	59.5	80.2	34.6	630	69.85	35.25	0.06	0.42	41.7
01.08.2017	64.2	85.6	35.1	652	74.9	39.8	0.06	0.42	41.6

Table 3. Experimental Parameters.

Sr. No.	**Time**	**Ambient Temp.**	**Average Global Radiation (I)**	**Average Temp. of water in tank**	**Average Wind Speed**
	Hrs.	**°C**	**W/m²**	**°C**	**m/s**
1	8:40	33.1	515	42.9	1.1
2	9:10	34.3	594	43.9	0.9
3	9:40	34.6	630	45.2	0.7
4	10:10	33.2	650	44.7	1.7
5	10:40	32.8	700	46.4	2.2
6	11:10	34.4	710	47.8	1.2
7	11:40	34	680	51.2	0.3
8	12:10	34.2	670	52.5	2.3
9	12:40	33.3	621	53.1	4
10	13:10	34.7	615	54.9	2.4
11	13:40	35.9	620	56.0	4.4
12	14:10	35.2	662	58.1	2.7
13	14:40	34.5	679	58.2	3
14	15:10	34.5	623	59.3	5.4
15	15:40	33.6	592	60.1	4.6

RESULTS AND DISCUSSIONS

Figure 1 show the thermal efficiency of the evacuated tube collector. The efficiency curve shows the negative slope indicating that as the temperature of the inlet water increases the thermal efficiency of the collector decreases. If the thermal efficiency curve is extended towards the left and it touches the vertical axis then the pint of intersection shows the point of maximum efficiency for the given collector. Extending the curve on right side and the point where it touches the horizontal axes then point of coincide at horizontal axes indicates zero thermal performance. The point of zero thermal performance depends on the slope of the curve. Greater the slope of the curve earlier it will coincide the horizontal axes. Therefore, it is concluded from the discussions that for larger range of efficiency the slope of the curve should be gentle.

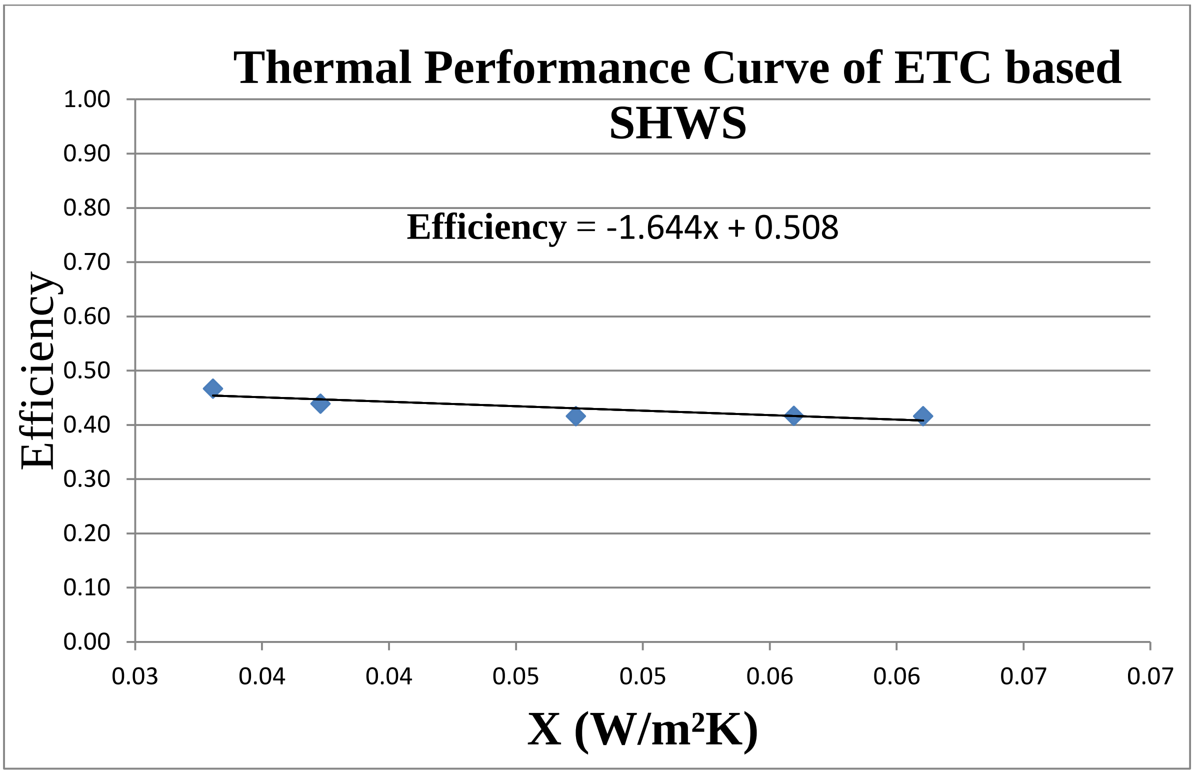

Figure 1. Efficiency curve for a commercial evacuated tube collector

The test results obtained are summerised below:

- Efficiency, ɳc of the collector is found equal to 51%
- Overall heat loss coefficient of the system during day time test, Usys,d, found to 1.81 W/m²K.
- Percentage system efficiency at standard test conditions Ts = 50°C, Tad = 25°C, GT=700 W/m²) is found 0.43 as calculated above.
- Average amount of energy collected (Q) during the period of day time test corresponding to standard test conditions (Kwh) is 2.76.

CONCLUSIONS

Prescribed standards worldwide for testing the solar thermal collectors are unique and very precise in predicting the thermal performance of the solar collectors. The results obtained from the tests can be used for further designing and improvements in the evacuated collectors for any location globally and also for particular applications.

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