Evacuated Tube Solar Collector

Shubham Shah[1], Guruprasad Rane[2], Yogesh Pawar[3], Siddhesh Sawant[4], Prof. V. D. Patel[5]
[1, 2, 3, 4, 5] Department of Mechanical Engineering
[1, 2, 3, 4, 5] Vidyavardhini's College of Engineering and Technology, Vasai, Maharashtra, India.

Abstract- *Now a days Flat plate collectors are used for domestic applications and are effective. But these flat plate collectors are not that effective. So we came up with the idea of increasing the efficiency of the flat plate collectors by using Evacuated Tube solar collectors. We did a little modification in the Evacuated tube solar collector which would increase the efficiency of the Evacuated tube solar collectors. The aim of this paper is to increase the usage of solar energy by making the existing system more efficient. The purpose of this report was to measure the efficiency of evacuated tube solar collectors under various operating conditions like fluid flow rate, and compare with other solar collectors. The operating conditions and configurations were chosen to represent realistic or probable installation scenarios and environmental conditions. The scope of applications of this project is been very vast but for our convenience we limited our scope to domestic applications. When the efficiency of a collector is considered within a system it is proposed that effectiveness may be a better measure of overall performance. It was genuinely a challenging task of finding an Evacuated tube which are not manufactured in India and this are to be imported from China. The results show a considerable increase in efficiency of the system as well as it guarantees longer life also the initial investment is lower. All the design of the Evacuated tube solar collector and the assembly of the same was completed using computer design software called Solid works.*

MOTIVATION

India along with the world is facing 'Energy Crisis'. There is a significant gap in the demand and supply for electricity. Day by day as our country progresses towards development, this gap is increasing and tackling this situation is very important to continue our country's ascending path. In order to meet this situation a number of options are being considered with a large focus on renewable energy research & development. The options considered are solar energy, biogas, wind energy, geothermal energy to name a few. To support this background, it is essential that we acquire indigenous capability to design, develop and install solar thermal plants.

Above Crisis arises due to very low usage of renewable resources. This also increases the consumption of non-renewable resources. All these limitations motivated us to take a project on solar energy applications.

PROBLEM DEFINITION

Solar Energy is being collected by various ways. This collected energy is utilized for domestic and industrial applications. One of the domestic application is by flat plate collector. But various limitations are introduced in flat plate collector. This collector has very less exposed area which makes the system less efficient. Also the solar ray's incident on the flat plate is less which produces less heat thus requires more time to heat water. There are very high corrosion problems. Flat plat collectors are heavier, take up more room, and can be cumbersome to install on certain roofs.

All the above drawbacks of flat plate collectors can be overcome by evacuated tube collectors. Hence we decide to take project on evacuated tube solar collector.

I. INTRODUCTION

Solar water heaters are more and more used worldwide, and the evacuated-tube designs are the most popular due to their simplicity and better overall performance over their flat-plate counterparts, especially in adverse weather conditions. Many evacuated-tube designs have been developed and are being used among which the water-in-glass design is very popular because of its low cost and simple manufacturing and installation procedures. In this case the working fluid undergoes a phase change operation while it is transported up and down [1]

Evaluation of the overall performance of solar collectors is usually carried out experimentally using proven procedures according to international standards and many correlations have been developed for the purpose of predicting the overall efficiency under various climatic conditions. Various studies have been conducted to evaluate the thermal performance of evacuated-tube solar collectors and to compare them to their flat plate counterparts [5]

Evacuated-tube collectors are generally manufactured in standard sizes and are mounted inclined at an angle, which is to be estimated using the latitude of the location under consideration. Various parameters may affect the overall

performance of collectors among which the tilt angle, the weather conditions, the collector dimensions, etc. It is well admitted that the best performance is achieved when the sun rays hit the collector elements at right angle in order to maximize the energy absorption mechanism [5]

II. METHODOLOGY

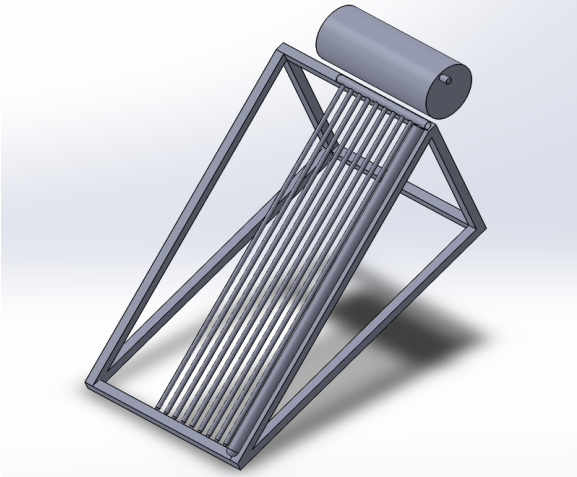

Figure 1.

Working:

The evacuated tube solar collector converts sunlight into heat. It is more efficient than the solar flat plate collectors. The whole assembly is mounted on the frame which is made of aluminum or steel. Evacuated solar tubes are connected to manifold through copper pipe. The storage tank and manifold copper pipe is insulated by using polyurethane foam material. Because of these the heat losses get reduces.

Solar rays incidents on borosilicate glass tube which contains copper pipe and heat transfer fins. As it incident the solar heat gets absorbs by glass tube and transfer heat with the help of fins. The entry and exit of water in the system is carried out by circulation system, which moves liquid through the manifold pipe. This carries heat back to the storage tank. Gradually throughout the day the intensity of sun rays goes on increasing, the temperature inside the copper tube increases, the heat transfer fin and coating helps to increase it. This water gets heated up in the tubes and then flows to storage tank.

Then circulation system moves the heated liquid out of storage tank for the further use of it. When hot water is used, solar pre-heated water is fed into a traditional water heater which boosts the temperature if not already hot enough.

Components:

Evacuated Tube:

Evacuated tube is made of Borosilicate Glass. There is a vacuum between two layers of the glass tube. It absorbs solar energy and converts it to usable heat. A vacuum between the two glass layers insulates against heat loss. The heat is transfer to the water inside the copper tube [6]

Copper Tube:

The copper tube contains of the water that to be heated. The copper tube gains the heat from the Evacuated tube and transfer to the water in it. The water inside tube is heated and flow to the manifold by decrease in the density of hot water [6]

Tank:

The solar water tank is of capacity 50 liters for approximate 5 person of family. The tank is insulated by the polyurethane foam to insulate from the surrounding atmosphere.[6]

Frame:

Mounting frames are used to safely secure the solar collector in place. Mounting location may be a wall, pitched roof, flat roof or ground level and so a range of mounting equipment is required. The frame design may need to consider wind loading, snow loading the environmental conditions ensure a strong and durable installation. The angle of inclination of frame is between 27 to 29 degree [6]

III. THEORETICAL EVALUATION

In our project we are aiming to heat 50 litres of water upto $60^0 - 65^0$Celsius temperature, for this we required glass tube of diameter 58 mm and length 1800 mm .The tubes are 10 in number which are sufficient to achieve that much temperature.

Tubes:-

Exposed area = $\pi * D * L$

$= \pi * 0.058 * 1.69$

$= 0.3095\ m^2$

Gross area = $\pi * D * L$

$= \pi * 0.058 * 1.8$

$= 0.3280\ m^2$

As our project is mainly based on solar energy, solar incident or intensity of the solar rays also takes place in consideration. The input for this model is cold water having the temperature about 〖32〗^0 Celsius.

Along this, we have tank and manifold. Tank is made of aluminium having cylindrical shape of diameter 300 mm and length of 720 mm for the capacity of 50 litre.

Tank:-

Volume = area * lenghth

$0.05 = \frac{\pi}{4} * d^2 * 0.720$

d = 0.3 m

d = 300mm

The temperature of water inside of tube, manifold depends on the heat transfer rate, thickness of coating material. It also plays very vital role in it, hence the gross are of the tube and the exposed area of the collector. The design of the frame is done by taking on standard inclination angle i.e, 27^0, with the help of this we can find frame dimension.

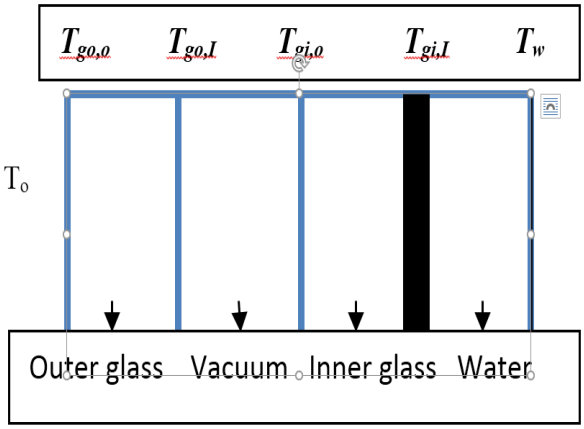

Figure 2.

Heat Transfer[8]

$$Q = m * c_p * (T_{out} - T_{in})$$
$$= 0.05 * 4.187 * (338 - 305)$$
$$= 6.90 \text{ KW}$$

Heat Losses[8]

By Conduction (Inner Glass)

$$Q_{cond} = \frac{\ln(D_{gi}/d_{gi})}{2 * \pi * L * k}$$
$$= \frac{\ln(0.047/0.045)}{2 * \pi * 1.8 * 1.14}$$
$$= 3.37 \times 10^{-3} \text{ W}$$

By Conduction (Outer Glass)

$$Q_{cond} = \frac{\ln(D_{go}/d_{go})}{2 * \pi * L * k}$$
$$= \frac{\ln(0.058/0.056)}{2 * \pi * 1.8 * 1.14}$$
$$= 2.17 \times 10^{-3} \text{ W}$$

By Convection (Outer Glass)

$$Q_{conv} = \frac{1}{h * A_c}$$
$$= \frac{\ln(0.058/0.056)}{1.14 * \frac{31.20}{0.058} * 0.058 * 1.8 * \pi}$$
$$= 4.97 \times 10^{-3} \text{ W}$$

Input

$$Q = m * c_p * (T_{cold\ water} - T_{room})$$
$$= 0.05 * 4.187 * (305 - 293)$$
$$= 2.51 \text{ KW}$$

Output

$$Q = m * c_p * (T_{hot\ water} - T_{room})$$
$$= 0.05 * 4.187 * (338 - 293)$$
$$= 9.42 \text{ KW}$$

Efficiency

$$\eta = \frac{Input}{Output}$$
$$\eta = \frac{2.51}{9.42}$$
$$\eta = 26.66\ \%$$

IV. RESULT TABLE

Table 1. RESULT TABLE

Heat transfer	6.90 KW
Heat loss by conduction inner tube	3.37×10^{-3} W
Heat loss by conduction outer tube	2.17×10^{-3} W
Heat loss by convection outer tube	4.97×10^{-3} W
Input	2.51 KW
Output	9.42 KW
Efficiency	26.64 %

The present study of evacuated tube solar water heating system report that the trend of using power efficient device will be rapidly growing in coming decades. This analysis of energy consumption by mean of water heating is estimated also Evacuated tube water heater. Comparison of analysis data and experimentally reported that Evacuated U-tube water heating system is much efficient around 10% to 15% than the water-in- glass evacuated tube collector for above mentioned climatic condition.

The evacuated tube solar collector was successfully designed and all the other performances were calculated and the calculations were performed. The results Evacuated tube solar collector is 20% more efficient than flat plate collector. The temperature of water, which was at atmospheric temperature (assumed) of about 40-45 degrees is expected to be achieved.

V. CONCLUSION

The evacuated tube solar collector was successfully designed. The evacuated solar water heating device is one of the efficient way for house hold purpose not because of it is efficient as compare to other mean of water heating devices but also it is eco-friendly and non-polluting device. It's requited only one time investment the after certain time period it is does not required any charges for outcome (except maintains which is almost negligible). It returns your money in 567 sunny days, and next 20 years it will be free. This is a step towards reducing pollution free environment.

The evacuated tube solar collectors provide a substantial difference in the temperature of the working fluid. The amount of heat transferred to the working fluid depends on the incident flux of solar radiation and on the aperture of the tubes. The heat transfer coefficient of the air gap in the tubes plays a major role in facilitating the heat transfer.

Various concepts of Heat Transfer, Thermodynamics, Solar Energy were used in the process of designing. Design of the evacuated tube solar collector was completed using a computer design software called Solid works and the corresponding results were calculated.

REFERENCES

[1] Michel Hayeka, Johnny Assaf (2011) "Experimental Investigation of the Performance of Evacuated Tube Solar Collectors under Eastern Mediterranean Climatic Conditions"

[2] Amir Yadollah Faraji, Abhijit Date, Randeep Singh (2013) "Base-load thermoelectric power generation using evacuated tube solar collector and water storage tank"

[3] Marco Riccia, Enrico Bocci (2015) "Experimental Tests of Solar Collectors Prototypes Systems"

[4] Roonak Daghigh (2016) "An experimental study of heat pipe evacuated tube solar dryer with heat recovery system

[5] Ignacio R. Martin-Domínguez (2016) "Economic feasibility of flat plate vs evacuated tube solar collectors"

[6] http://www.apricus.com/html/solar_collector.htm#.WAjX0uh97IU

[7] Zhen Lu, Jili Zhang, Ruobing Liang (2010) "Thermal performance analysis of the glass evacuated tube solar collector with U-tube"

[8] M.B. Shafli,M.M. Lotfi (2016) "A modified solar desalination system using evacuated tube collector"