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Study and Fabrication of Vacuum Tube Collector Solar Water Heater

G. C. Nalamwar, N. R. Kannake, S. S. Sontakke

Abstract**-*****The objective is to design, develop and utilize the high-efficient solar energy collectors for the purpose of laying down technical foundation for progressive expansion of the heating range in utilization energy collectors and apply them to solar energy air-conditioning system, solar energy industrial hot water system and solar energy power generation. In general vacuum tube collectors are used in solar process heat systems. Another possibility is to use transparent insulated flat plate collectors. A critical point however, is that most of the common transparent insulating materials cannot withstand high temperatures because they consist of plastics. Thus, temperature resistive collector covers combining a high transitivity with a low U-value are required. One possibility is to use capillaries made of glass instead of plastics. At the same radiation intensity by comparing the heat gain of both the flat plate and vacuum tube solar collector having same capacity tank, mass flow rate and absorber area. It find out that vacuum tube collector is 16.12% more efficient than flat plate solar collector.***

I. INTRODUCTION

The solar thermal energy is collected in a device called solar collector. It consists of a dark surface called absorber, fluid flow passage and suitable provisions for heat loss reduction. When exposed to the Sun, the absorber absorbs the solar radiation and transfer a part of it to the fluid flowing over/under it. The present study is concerned with the flat plate design only. Solar water heater consists of mainly 2 parts. One is the collector and other is the insulated tank. The cold water in the collector get heated up and collected in the tank by Thermo Siphon Principle.

II. REVIEW OF LITERATURE

One of the promising options for energy crisis is to make more extensive use of renewable source of energy derived from the sun. As we know that non conventional energy source are available in amount throughout the world in adequate quantity and of cost. At this moment vacuum tube solar water heater is of the most solar energy applicable for economical point of view as in many countries of the world. In India also it will be competing on equal term with system using other energy sources in near future. In India, the energy problem is serious. The import of crude oil continues to increase and price paid to it constitute a significant part of. Import bill.

On Internet, the website on solar water heater was found. Also the information about vacuum tube solar water heater is found in a site of latest development in solar water heater. Some part of solar energy related to this system is found from the book of S.P. Sukhatme and from Dr. V. S. Bhore. From our project solar water heater firstly we have given information about solar water heater. Than in second step we have compared our project with conventional Flat Plate Collector. The next step is to check economical feasibility of system.

III. DESIGNING

At first we have choose the topic of solar water heater as here is so much scope for increasing its efficiency and solving some difficulties in it. In conventional FPC one side of absorber tube are insulated bu2another side is free to conductive, convective and radioactive losses. It decreases the system efficiency. We select the system of 100 liter per day as we consider the family of 5 person need approximately per day. So we designed the collector of circular cross section having vacuum to minimize these thermal loss.

In conventional setup there are many tedious piping required so we designed the setup having minimum piping requirement. Structure is again is again designed of rigid and lighter than conventional one. So we designed the better system at lower cost and simple construction.

A.Collector Tubes

We have purchased the vacuum tube for 100 LPD systems from fabricator. We choose Borosilicate glass with Aluminum Nitrate coating.

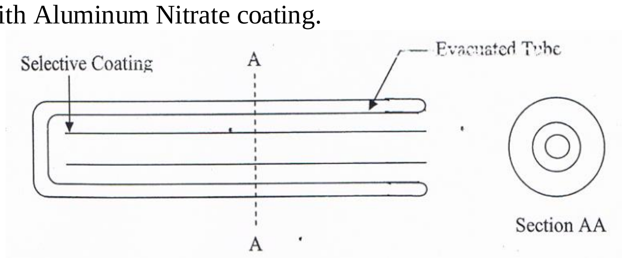

Fig. 1. Evacuated Tube Collector

B.TANK

The tank using will be of Stainless Still with Glass wool insulation of capacity 100 Lit.

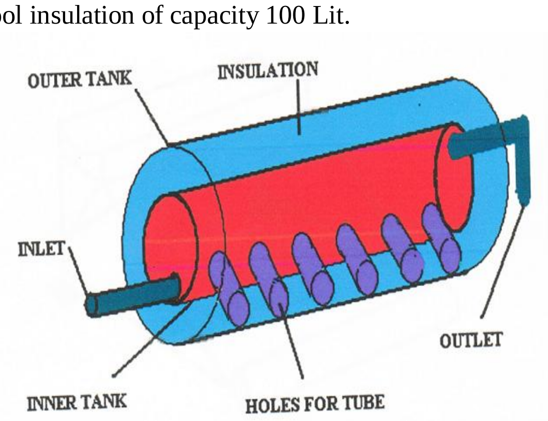

Fig. 2. Insulated Tank

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IV. FABRICATION

A. Collector

We had purchased Vacuum tubes for 100 LPD systems from fabricator.

Dimension - Outer dia - 47 mm
- Inner dia - 42 mm

Material - Borosilicate Glass
Coating - Aluminum Oxide
Pieces - 15 nos.

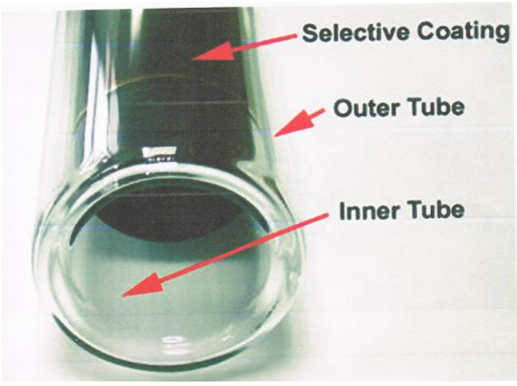

Fig. 3. Collector

B. Tank

We have fabricated the insulated tank of capacity 100 lit having inlet and outlet connection and holes for tubes. Tank is made up two tanks. First inner tank of fabricated than on it glass wool insulation and finally on it tank is fabricated. Tank material is SS light in weight and corrosion resistant.

Capacity - 100 Lit.
Insulation Capacity - 24 Hrs.

Fig. 4. Tank

C. Piping & Flow Meter

Piping is made of GI and flow meter is connected in inlet water line for measuring the discharge then we assembled the structure for system rigidly and assembled the tank on it with nut and bolts. Than we connect the vacuum tube with one end in the tank and another end in the stand. Then we connected the inlet and outlet connection with suitable pipe. In bet inlet connection we connect the flow meter for measuring the discharge of water.

V. WORKING OF VTC SOLAR WATER HEATER

The Vacuum Tube Collector solar water heater is made up of rows of parallel, transparent glass tubes. Each tube consists of a glass outer tube and an inner tube, or absorber, covered with a selective coating that absorbs solar energy well but inhibits radioactive heat loss. The air is withdrawn ("evacuated") from the space between the tubes to form a vacuum, which eliminates conductive and convective heat loss. The Vacuum tube collector absorbs the heat from the solar radiation & heats up the water stored in the system through the Thermosiphonic effect.

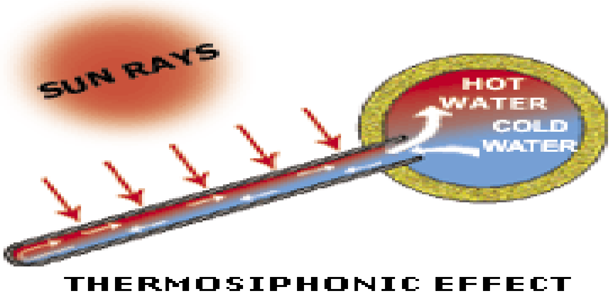

Fig.5. Thermosiphonic Effect

A thermo siphon system relies on warm water rising, a phenomenon known as natural convection, to circulate water through the collectors and to the tank. In this type of installation, the tank must be above the collector. As water in the collector heats, it becomes lighter and rises naturally into the tank above. Meanwhile, cooler water in the tank flows down pipes to the bottom of the collector, causing circulation throughout the system. This is called Thermosiphonic Effect. This process continues steadily for a number of hours till the water stored in the tank is heated up. Very high Temperatures up to 80-85 deg C can be had from such a system. The water heated in this manner is stored overnight in the insulated storage tank and is available for use the next

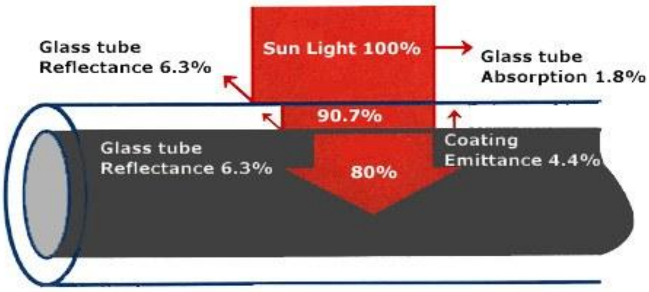

Fig.6. Glass Tube Structure

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VI. TESTING

A. Date Reduction

The date collected is converted in to the quarter hourly average of the parameter measured, which is obtained as follows.

Solar Radiation:

$$\text{Radiation} = \frac{mv \times 1000}{13.27} \times \frac{w}{m^2}$$

mv = mile volt.

13.27 = Solution constant valve.

Example: Output of multi meter = 8.8 mv

$$\text{Radiation} = \frac{8.8 \times 1000}{13.27}$$

= 663.33 w/m^2

Mass flow Rate:

Water from exit in 1 min period

Mo = mass flow = lit/Min

Useful heat gain:

Useful heat gain = m0 × (Tf0-Tfi) kcal

mo = mass flow rate = lit/min.

Tfo= Exit Temperature = oC

Tf1= Inlet Temperature = oC

Efficiency:

$$\text{Efficiency} = \frac{m^o C_p (\Delta T)}{L_T A_P}$$

mo = mass flow rate = lit/min

CP = specific heat

ΔT = temperature difference = oC

IT = Solar radiation = w/m2

Ap = Aperture area

Table 1. Testing of VTC

Time	Tf_1	Tf_0	Radiation
8.00			
9.00			
10.00	29	54	648
11.00	30	68	776
12.00	32	75	874
1.00	33	73	829
2.00	33	71	678

Table 2. Testing of FPC

Time	Tf_1	Tf_0	Radiation
8.00			
9.00			
10.00	29	50	648
11.00	30	62	776
12.00	32	68	874
1.00	33	65	829
2.00	33	60	678

VII. ESTIMATION OF PAY BACK PERIOD

A. Vacuum Tube collector

1. System details: 100 LPD; collector area-1.10 m2; rise in temp from 32oc.

Heat gained by water = mCp ΔT
= 100 × 4.12 × (75-32)
= 100 × 4.12 × 43
= 17716 kJ per day

2. Electricity required

(1 kW = 3600 kJ, assuming efficiency of heating coil=80 %)

Number of electricity unit required = 17716/3600 = 4.92 unit per day.

The electricity consumed = 4.92/0.8 = 6.15 unit per day.

3. Cost of electricity = 6.15 unit × Rs. 5.30 per day.

(@ Rs. 5.30 above 300 unit consumption by monthly)

4. Cost of electricity = Rs. 32.60 per day.

5. Cost of electricity = Rs. 32.60 ×275 day

(We consider 275 effective days per year after deducting summer and rainy season)

= Rs. 8,965.64 per year.

6. Saving per year = Rs. 8966.

7. Cost of 100 LPD solar water heater systems is Rs. 14000.00

8. Payback period =

= Cost of thy system + plumbing + installation / saving per year

= 14000/8966

<u>9. Payback period = 1.56 year.</u>

B. Flat Plate collector

1. System detail: 100 LPD; collector area = 1.76m2; rise in temperature from 32o C to 68o C

Heat Gained by water = mCpΔT
= 100 × 4.12 × (68-32)
= 100 × 4.12 × 38
= 15,656 kJ per day

2 Electricity required

1KW = 3600 KJ, Assuming efficiency of Heating coil = 80 %

Number of electricity units required = 15656/3600
= 4.35 units per day

The electricity consumed = 4.35/0.8
= 5.44units per day

3. Cost of electricity = 5.44 units × Rs. 5.30 per day
= 28.84 Units

(@ Rs. 5.30 above 300 Units consumption bi-monthly)

4. Cost of electricity = Rs. 28.84 per day.

5. Cost of electricity = Rs. 28.84 × 275 days

(We consider 275 effective days per year after deduction summer and rainy season)

= Rs. 7930 per year

6. Saving per year = Rs. 7930

7. Cost of 100 LPD solar water heater systems is Rs. 22000

8. Payback period =

= Cost of thy system + plumbing + installation / saving per year

= 22000/7930

<u>9. Pay pack period = 2.77 year.</u>

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C. Hourly Variation in Solar Radiation

A typical hourly variation of solar radiation on the collector surface is shown in fig. The data reported here are the actually measured values on 09 April 2009. As expected. The maximum variation in parabolic nature is occurring at noon hour. Also reported in this fig. Is the variation in the ambient temperature over the period of experimentation?

It can be seen from the figure that the radiation monotonically increases from zero in the morning, attains its peak value (874W/m2) at around 12:00 hrs, remains constant at the peak value up 13:00hrs, decreases thereafter and reduces to zero in the evening hours. The area under the curve represents total energy received by the collector over the entire day length. It is found to be, in this case, 4.8049KWh/day.

His ambient temperature can be seen to be constant over the Period of experimentation at 32 °C with of 1°C.

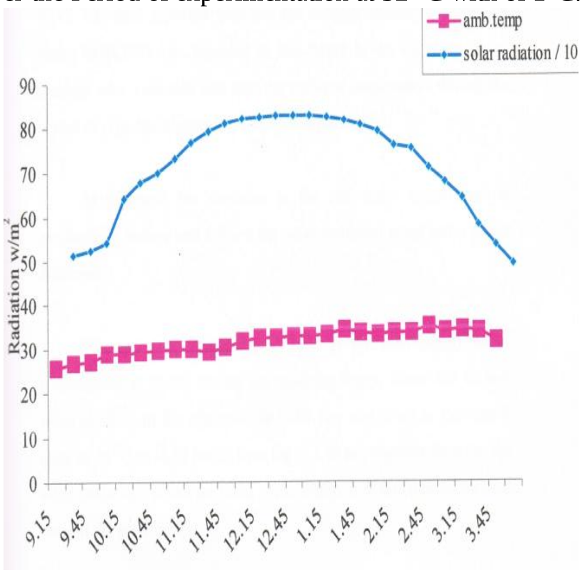

Fig.7. Solar radiation with Ambient Temperature.

D. Hourly Variation in the Exit Water Temperature of VTC

A typical hourly variation in the exit water temperature from the VTC. The data reported here are the actually measured values on (date) 09.04.2009.Also reported in this figure is the variation in the incident solar radiation and also the ambient temperature during the period of experimentation for relative comparison. As expected, the variation in the exit water temperature is parabolic in nature and follows the solar radiation trend but a phase difference.

The exit temp, typically, is same as the inlet supply water temperature at 29o C during the morning hours, attain the highest value of 33 °C in the afternoon at 13.00 Hrs and drops to the supply temp of 28 °C at 16.30 hrs. A time lag of 1.00 hrs was seen between the solar radiations peaks a temp peak, which is a function of thermal mass of the system.

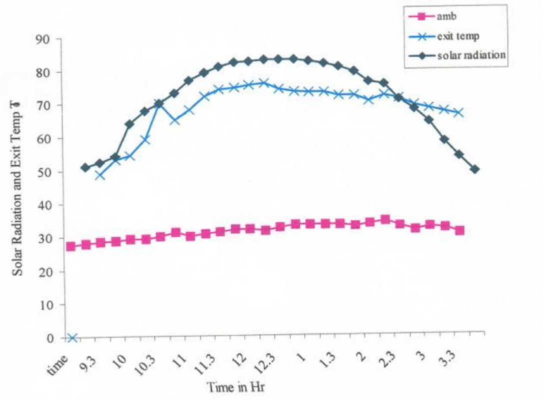

Fig.8.Exit Temperature with Solar Radiation and AMB Temp

VIII. FEATURES OF VACUUM TUBE COLLECTOR (VTC)

- Heating from infrared rays of solar radiation
- Greater absorption area per day
- Greater absorption time per day
- Minimum heat loss from the system due to the vacuum tubes & PUF insulated storage tank
- Better performance in winter & on cloudy days. Up to 10oC higher temperature
- Maintenance free, easy to clean
- Compact size - low height & lesser space required for installation.
- Inner tank and outer tank body are made from SS304 superior grade stainless steel to withstand corrosions and to last a life time
- Allows minimum heat loss from the system as it features vacuum tubes and puff insulated storage tank.
- Provides better performance in winter and cloudy days.
- Its superior construction ensures that ETC tubes are not corroded by hard water scaling.
- Innovative design makes it maintenance free & easy to clean.
- Its compact size & low height makes it easy to install and transport.
- For better durability inner and outer tank body are made of SS 304 grade stainless steel.
- Comes with thermostat electrical backup for non sunny days.
- Light and therefore easier to install (hence reducing install costs).
- If one of the tubes breaks or fails, tube replacement is simple and cheap (the whole panel does not need replacing).
- More efficient than flat-plate collectors by around 20%.
- Faster response times.
- Smaller collector area required to match energy output of flat-plate collectors.

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- Stay clean given the cylindrical shape of the tubes. Hence efficiency of panel is maintained.

IX. CONCLUSION

Comparison of output temperature of VTC & FPC

VTC output = 17716 kJ per day

FPC output = 15656 kJ per day

% Increase in heat gain = (VTC o/p – FPC o/p) VTC o/p

= (17716-15656)/17716

= 0.1162 = 11.62 %

VTC is 11.62 % more efficient than FPC Pay back period of VTC is 2.56 years. and Pay back period of FPC is 2.77 years.

Basically, the main contribution of this work is to present the thermal analysis on conversion efficiency of the tube-type solar thermal collector for engineering design. Furthermore, the solar thermal performance of a real low-cost tube-type collector is evaluated experimentally. The model of the conversion efficiency yields good agreement with experimental results. The results indicate the conversion efficiency is proportional to the ratio of the temperature difference between the mean temperature of the working fluid and the ambient temperature, to the solar radiation. It can be confirmed that material parameters of the solar thermal collectors are coefficient factors of the conversion efficiency. Therefore, in the optimal design on those parameters of the solar thermal collector, a transparent pipe might be selected with high radiation transmission and a black-coated metal pipe can be chosen with high radiation absorption and heat conduction as well as a gap should provide high thermal resistance. It should be noted that other types of solar thermal collectors can be analyzed for parametric characteristics on conversion efficiency by generalizing the concepts of this proposed experimental study for those related works.

X. FUTURE SCOPE

The following developmental work may be taken as extension of the present work.

- In future we can implement some new thing and develop existing ones.
- We can track the collector up to little extend in future which may increases the efficiency.
- In future we can make structure flexible by introducing hinges and rubber pipe which will be advantageous in heavy wind, stocks and favorable in tracking of favorable.
- By using better insulation we can reduce the tank and its weight, which will be favorable.
- We can also clean the vacuum tubes by spraying water automatically after certain period.
- By using better selective coating we can reduce the tube size.

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