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Special type V-through solar water heater

Thiruvasagam.C[1], Thangapandiyan.R[2],Keerthivasan.K[2],Thirunavukarasu.K[2],Velu.VM[2]

[1]*Associate professor, Dept. of Mechanical Engineering, Gnanamani College of Technology, Namakkal, Tamil Nadu, India*

[2]*UG Students, Dept. of Mechanical Engineering, Gnanamani College of Technology, Namakkal, Tamil Nadu, India*

Abstract :

There are various types of solar water heater system available in the commercial market to fulfil different customers' demand, such as flat plate collector, concentrating collector, evacuated tube collector and integrated collector storage. A cost effective cum easy fabricated v-trough solar water heater system using forced circulation system is proposed. Integrating the solar absorber with the easily fabricated v-trough reflector can improve the performance of solar water heater system. In this paper, optical analysis, experimental study and cost analysis of the stationary v-trough are presented in details. The experimental result has shown very promising results in both optical efficiency of v-trough reflector and the overall thermal performance of the solar water heater.To increase the thermal performance of solar water heater. A cost effective and easy fabricated v - trough solar water heater was modified by parallel flow thermosyphon water heater. Integrating the solar absorber with the easily fabricated v-trough reflector can improve the performance of solar water heater system. The performance of v - trough solar water heater is compared with flat plate solar water heater at same operating condition

Keywords: **Thermal insulating, Thermosyphon, Solar , Glazing**

I.INTRODUCTION

Renewable energy sources can play a vital role in developing countries like India, since there is an enormous demand for energy which is mainly obtained from conventional sources of energy like crude oil, coal etc. Energy from these conventional sources pollutes the environment, causes global warming and acid rain, limited reach and very costly production cost. Moreover they consume huge amount of foreign exchange which directly affects the economy of the nation. Hence there is an urgency to improve the share of renewable energy in the power sector and it can be promoted through R&D, demonstration projects, dissemination projects/programmes supported by Government and fiscal incentives. Among all renewable energy technologies, solar thermal technologies have a natural advantage in India due to fact that average solar radiation available is 4.5 - 6 kW hr/m^2 per day with 280 clear days over the year. The technical potential has been estimated as 140 million square meter of collector area. India was the first country in the world to set up a ministry of non-conventional energy resources, in early 1980s. India's cumulative Grid interactive (excluding Large Hydro) has reached 26.9GW, of which 68.9% comes from wind, while solar PV contributed nearly 4.59% of the Renewable Energy installed capacity [1]. Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy. The Government of India upgraded the Department of Non-Conventional Energy Sources to Ministry of Non-conventional Energy Sources (MNES) in 1992 due to the increasing importance of renewable energy sources. The National Solar Mission is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. Based on the mission document the country would be capable of generating 1,000 mw of solar power every year by 2013. A complete package has been proposed to propel the power sector into `solar reforms' that could lead to annual production of 20,000 mw of grid-based solar power, 2,000 mw of off-grid solar power by 2020 and cover 20 million sq metres with collectors. The ever increasing demand for thermal energy is met to a greater extent by the use of solar energy among other renewable.

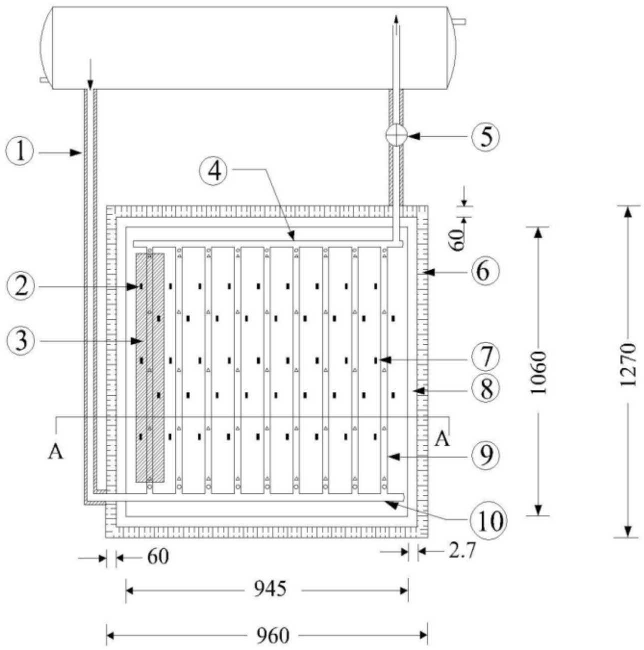
II.EXPERIMENTAL SETUP

EXPERIMENTAL SETUP AND DATA COLLECTION

This chapter presents the constructional details of the experimental setup of solar water heating system used in the present research.The experimental setup consists of a flat plate thermosyphon solar collector and a storage tank for natural circulation system with necessary instrumentation. Four collectors (Plain tube, full length V troughed tape, V troughed tape with rod, V troughed tape with spacer) are kept in open atmospheric condition and experimentation has been carried out.

Description of the experimental setup (Flat plate)

The experimental setup consists of a flat plate collector of 1 m^2 aperture area connected to a well insulated storage tank of 100 litres capacity and named as plain tube collector as shown in Fig.3.1. Basically it is a commercial solar water heating system for domestic applications which is available in the market with some minor design modifications. The cold water from the storage tank enters the collector from the lower header and is evenly distributed in the nine parallel riser tubes. The riser tubes are brazed to the bottom of a black absorber plate and the absorbed solar radiation is conducted to the riser tubes. The heat is then transferred by convection from the riser tube wall to the fluid. Finally the hot water is collected from the upper header and storedin the insulated storage tank. The temperature difference in storage tank between the water at the lower part and upper part accelerates the driving force/potential and the cycle is repeated until the temperature difference between the inlet and outlet water is zero. A digital ultra flow meter connected between the collector outlet and the storage tank measures the flow rate. A single transparent glass cover of 3 mm thickness transmits the solar energy to the absorber plate. The collector and the pipe connections are well insulated to minimize the heat losses. Absorber plate, riser tubes and headers are made up of copper. Out of the eighteen RTD's having ± 0.1°C accuracy, nine are placed at the inlet and nine are placed at the exit of the each riser tube to measure the inlet and outlet temperature of the water. T-type thermocouple wires having an accuracy of ± 0.5°C are welded by JM-60 thermocouple wire welding machine at six locations of absorber plate equally distributed over 1000 mm length. There are 54 measurable points of temperature corresponding to 9 absorber plates. Similarly thermocouple wires are brazed at 4 locations around the outer periphery of the riser tube that measures the wall temperature for distances of 0, 250, 500, 750 and 1000 mm over the entire length of riser tube totalling to 20 measurable points in each riser tube and hence 180 measurable points for 9 riser tubes for each collector. The cross sectional details for the same shown in Fig.3.2.The smart/Hart STX 2100 series differential pressure transducers having an accuracy of ± 0.1% are used to measure differential pressure of water in each riser tube .The global solar radiation is measured by Kipp and Zonen pyranometer having an accuracy of ±3%.The mass flow rate of collector loop is measured by ultra low flow meters having an accuracy of ± 1.0 % and is connected between the collector outlet and storage tank.



1.Water inlet to collector	7.Riser tube temperature
2.Absorber plate temperature	8.Wooden sides
3.Absorber plate	9.Riser tube
4.Upper header	10.Lower header
5.Flow meter	Δ- Taps for measuring pressure drop
6.Glass wool supported by aluminium frame	O- Taps for measuring water inlet& outlet Temperature

Note: All Dimensions are in mm

Optical Analysis of Stationary V-Trough Collector

Stationary V-trough collector was designed with the initiative to increase the solar concentration ratio (C) of the absorber plate up to two suns. Fig. 1shows the schematic diagram to describe how a flat reflector to be inclined at a certain angle $\angle ABE = \theta = 60^\circ$, can map all the vertical rays from the inclined reflector to the absorber plate. To verify the sunlight fallen on the proposed V-trough reflector can be uniformly mapped onto the absorber plate, a 2-D ray-tracing method was used in our preliminary analysis.

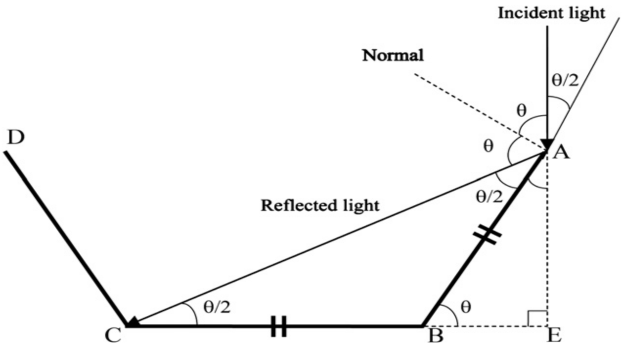


Fig -1: The schematic diagram to describe how a flat reflector to be inclined at a certain angle $\angle ABE = \theta = 60^\circ$ can fully map all the vertical rays from the inclined reflector to the absorber plate purely based on geometrical optics.

Technical Specification of Flat plate solar water heater and Storage tank

No.	Design materials/parameters	Specifications
Collector		
1	Tilt angle	11.4° (South facing)
2	Aperture area, A_c	1 m^2
3	Collector glazing	Single transparent glass of 3 mm thickness
4	Lower header	ID 25.5 mm
5	Upper header	ID 25.5 mm
6	Riser tubes	OD 12.5 mm, ID 11 mm, length 1000 mm
7	Absorber plate	Width 122 mm, length 1000 mm
8	Bottom insulation	100 mm glass wool
9	Side insulation	60 mm glass wool covered by aluminium frame
10	Absorber plate coating absorptivity	0.92
11	Transmittance of glazing	0.91
12	Number of riser tubes	9
Storage tank and piping		
13	Tank type	Horizontal
14	Tank volume	100 litres
15	Tank wall thickness	4 mm

Construction of V-Trough Solar Water Heater

The proposed V-trough SWH with high thermal efficiency can be easily constructed and installed in the rural area without the requirement of sophisticated equipment. It can help to reduce the dependency on the fossil fuel especially in the developing country. The prototype of V-trough SWH system was constructed in the University Tunku Abdul Rahman campus this located at Kuala Lumpur with latitude 11.4°c. In this system, the stationary V-trough collector was designed to concentrate the sunlight onto the absorber in order to effectively convert solar energy into thermal energy. The following describe the details of each component of the prototype V-trough SWH system and how these components were constructed.

V-Trough Collector

The solar collector is made from two major parts: a flat absorber Plate and V-trough reflector. The V-trough reflector was constructed using two rectangular facet mirrors with a dimension of 14cm (width) ×100 cm (length) ×0.5 cm (thickness) each and inclined at the angle of 60◦ relative to the absorber plate. To optimize the optical performance, the V-trough reflector was aligned horizontally along south direction. Ideally the V-trough reflector should be south facing and inclined at the angle of 11.4◦the local latitude. However, in order to simplify the mechanical structure of the prototype with a very minimum effect to the overall performance, we decided to place the V-trough reflector in horizontal since the local latitude is only 3.2◦ N. The absorber plate was fabricated by joining a brass sheet with a dimension of 14 cm (width) ×100 cm (length) × 0.5mm (thickness) to two equally distant copper pipes with outer diameter of 12.5 cm each. Although the width of the constructed absorber is 0.5 cm different from that of width applied in the optical analysis, the small discrepancy in the collector width does not incur any influence to the final result as it can be explained in the following two reasons. First, the ratio of V-trough aperture size per absorberarea still remains the same in both cases. Second, the average solar concentration throughout the whole area of absorber is taken in account. It is inevitable to consider the absorber dimension of14 cm × 100 cm in the optical analysis owing to the convenience to represent it by the equivalent 141×1001 reflective pointscompared to the dimension of 14 cm ×100 cm.The copper pipes were brazed to the bottom surface of the copper sheet for maximizing the exposure area of the copper pipes to the solar radiation. The copper sheet was selected as a supporting base because of its good thermal conductivity and high tensile strength. The top surface of the absorber plate was painted in black color as to maximize the absorptivity to solar irradiance. Five absorber plates were built and then screwed onto three hollow aluminium beams with the length of 150 cm to provide physical support to the V-trough collector .Last but not the least, float glass was used as main glazing material to insulate the space above the absorber plate for prohibiting cool air from flowing into this space that could cause the convective loss. Five rectangular float glasses with the dimension of 28 cm (width) × 100 cm (length) × 0.5 cm (thickness) each were fixed on top of the each V-trough reflector with silicone adhesive. Trapezium-shaped float glasses were used to cover both ends of the V-trough reflector and the remaining gaps were filled with extruded polystyrene extruded Polystyrene was also employed to insulate the external surface of V-trough reflector from heat loss through both conductive and convective processes. Extruded polystyrene is chosen as main insulating material of the prototype SWH due to its low cost and weather proof characteristic that is in line with our design concept. Storage tank of prototype SWH was simply a standard with a dimension of 42 ×28.5 × 26 cm3 capable of storing at least 100 L of hot water for domestic usage. Two holes were drilled where one hole was at the bottom of the tank for the connection to the absorber inlet and the other hole was at the top part of the water tank's side wall for the connection to the absorber outlet. Fibre glass and aluminium foil were utilized to enhance the heat insulation of the water tank from convective and radiation losses respectively due to their easy availability, cost effectiveness and light weight. Aluminium foil was fixed at the external layer to embrace the fibre glass at the internal layer and they were bonded to water tank with the use of silicone adhesive. Shows the picture of the storage tank that was constructed for the experimental test.

Fig -2: Special Type V-Trough Solar Water Heater

III.MATERIAL USED IN V-TROUGH

The selection of suitable materials determines the effective use of solar energy.

Reflecting Surfaces in v-trough

The reflector should have high reflectivity and good specular reflectance. Low concentration ratio the reflector need not be highly specular. Aluminium is used of this purpose other material like metalized plastic film and thin metal sheets are also useful. Aluminium has a total reflectivity of about 80% to 85%.it is very good reflecting surface for solar energy application. The reflector should be lightweight so that they can be oriented easily. They should be able to withstand wind and other weather extremes as dust stand and other contamination strongly affect the performance, although the effect varies with the material used collector configuration, exposure time and site. Highly polished aluminium sheets are used as the reflectivity will be increased. Aluminium sheet of 1m length and 0.70m width is used

Receiver Cover or Absorber

A simple flat receiver can be used in v trough concentrator. Glass and transparent plastic films are generally used as cover materials for the receiver. Glass should have low iron content to reduce absorption. The etching can be done but the cost is increased generally plastics are not suitable as cover materials because of low service temperature limit and ultraviolet degration. So glass tube of size 3 cm diameter and 1m length is used. It also produced green house effect so the heat energy transferred from the absorber to the fluid is increased. The absorbed tube is copper, as it is a good conductor of heat. The copper tube will be placed on the focal line of the concentrator. The copper tube gets heated up and heat is transferred to the fluid passing through it. Generally black paints are used for coating on the copper tube.

Working Fluid

It is the working fluid that takes away the heat from the receiver for further use. Therefore for effective heat transfer, the fluid should be stable at high temperature be non-corrosive and safe, besides it also needs to be cost effective. The water, which is easily available, can be used as the working fluid.

Insulation

Insulation is required to reduce heat losses from the un-irradiated portions of receiver and the pipes carrying working fluid. Besides being cost effective, the insulation should be strong enough to withstand high temperature fluctuations. Glass wool can be used as insulator.

IV.WORKING FOR PLAIN TUBE COLLECTOR

This chapter discusses the working for plain tube collector in natural circulation mode. The experimental Nusselt number and friction factor are compared with the fundamental equations and the deviations are found to fall within the acceptable limits.

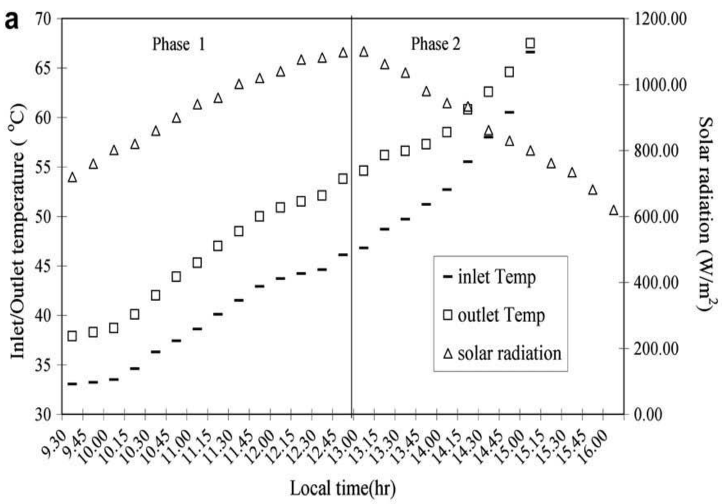
Thermosyphon solar water heating system

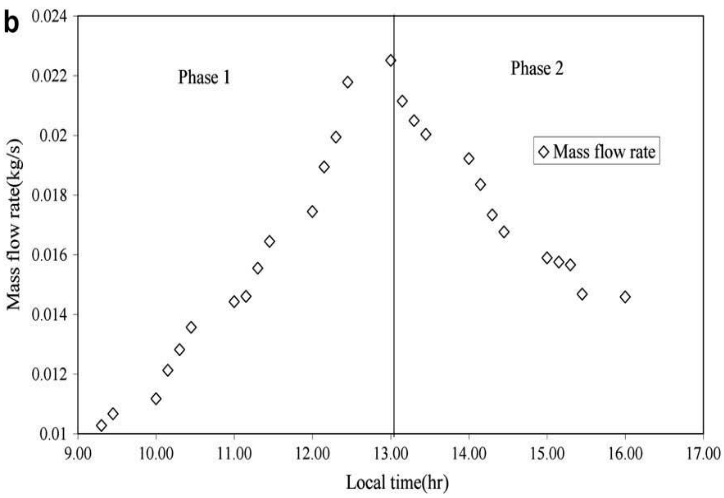
Thermosyphon system operateson the temperature difference between the hot and cold water in the storage tank that accelerates the driving force. Convective movement of the liquid starts when liquid in the loop is heated in the riser tube, causing it to expand and become less dense, and thus more buoyant than the cooler water in the bottom of the loop. Convection moves heated liquid upwards in the system as it is simultaneously replaced by cooler liquid returning by gravity. Ideally, the liquid flows easily because a good thermosyphon should have very little hydraulic resistance. The characteristics of this thermosyphon solar water heating system are as demonstrated below.

Characteristics of thermosyphon system

The characteristics of thermosyphon solar water heating system with plain tube, for typical sunny days are depicted in Fig.2. The solar radiation is found to increase gradually and reach a maximum at 1.00 p.m. and later decrease gradually till 4.00 p.m. Mass flow rate also exhibits a similar trend. Inlet and outlet temperature of water increases gradually until both the temperatures are equal. Since the consecutive days in which the trials are conducted, showed similar trend, the observation of this characteristic of the solar water heating system is divided into two phases, 9.00 a.m. to 1.00 p.m. is considered as Phase 1 and 1.00 p.m. to 4.00 p.m. is considered as Phase 2. The heat transfer increases and friction factor decreases in Phase 1 due to the increase in mass flow rate and solar radiation. In Phase 2, the decrease in solar radiation and mass flow rate reduces the heat transfer effect and increases the friction factor. Due to the above characteristics the instantaneous efficiency increases from 29% to 64.7% in Phase 1 and later decreases from 64.7% to 31.4 % in Phase 2. Convective movement of the liquid starts when liquid in the loop is heated in the riser tube, causing it to expand and become less dense, and thus more buoyant than the cooler water in the bottom of the loop. Convection moves heated liquid upwards in the system as it is simultaneously replaced by cooler liquid returning by gravity.

Graph No- :1 Thermal performance data for V trough





CONCLUSION:

It may be seen that man has changed everything which is available in nature, according to his need .Solar is naturally available, Inexhaustible source of energy. By proper recognition this energy could supply all the present and future be utilised in many ways. It can also be used for power generation. We throughout the project work have projected on utilisation of solar energy with the help of parabolic trough as a solution to energy crisis. The novel stationary V-trough solar water heater with the maximum solar concentration ratio of 1.8 suns has been proposed to improve the thermal efficiency of the whole system. The advantages of the new proposal are that easy to be fabricated, cost effective and high thermal efficiency. The collected data has shown that the prototype has achieved the optical efficiency of 70.54% or1.41 suns and the temperature of 85.9 _C. The prototype can be easily constructed through DIY using off-the-shelf materials with total cost of RM 1489.40 and total payback period of 12.2 year for discounted form or 8.9 years for undiscounted form.

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REFERENCE

1. Gao W, Lin, W, Liu, T, Xia C.Analytical and experimental studies on the thermal performance of cross-corrugated and flat-plate solar air heaters. Applied energy 2007; 84:425-41

2. Sivashanmugam P, Suresh S. Experimental studies on heat transfer and friction factor characteristics of laminar flow through a circular tube fitted with v-trough. Applied Thermal Engineering 2006; 26(16):1990–7.

3. Kumar A, Prasad BN. Investigation of v trough inserted solar water heatersd heat transfer, friction factor and thermal performance results. Renewable Energy 2000; 19(3):379–98.

4. Jaisankar S, Radhkrishnan TK, Sheeba KN. Experimental studies on heattransfer and friction factor characteristics of thermosyphon solar water heater system fitted with spacer at the trailing edge of v trough. Applied Thermal Engineering 2009; 29(5–6):1224–31.

BIOGRAPHIES:

V.M.Velu, Doing B.E mechanical engineeering in Gnanamani College Technology, Namakkal. And also completed Diploma mechanical engineering.

K.Thirunavukarasu, Doing B.E mechanical engineeering in Gnanamani College Technology.And also completed Diploma in automobile engineering.

R.Thangapandiyan, Doing B.E mechanical engineeering in gnanamani college technology.

K.Keerthivasan, Doing B.E mechanical engineeering in Gnanamani College Technology, Namakkal.And also completed Diploma in mechanical engineering.