

Fabrication and Performance Evaluation of a Flat Plate Solar Collector Water Heater

J. Ramesh¹, J. Kanna Kumar², Dr. E.V Subbareddy³

Assistant Professor, Department of Mechanical Engineering, Dr. KVSRRIT, Kurnool, Andhra Pradesh, India¹

Associate Professor, Department of Mechanical Engineering, Dr. KVSRRIT, Kurnool, Andhra Pradesh, India²

Principal, Dr. KVSRECW, Kurnool, Andhra Pradesh, India³

ABSTRACT: Energy is one of the building blocks of modern society. The growth of the modern society has been fuelled by cheap, abundant energy resources. Solar energy is a form of renewable energy which is available abundantly and collected unreservedly. In this thesis the application of solar energy using flat plate collector is analyzed. The Flat plate solar collector for hot water generation technology is very useful as it is used for approximately all solar energy applications such as steam and power generation, water heating, air heating etc. An experimental setup has been developed to investigate the performance of the solar flat plate collector. Measurements of total direct radiation on the plane of the collector, ambient temperature, wind speed, water flow rate, and inlet and outlet temperatures of the water inside the absorber tube are collected and employed in studying the performance of the flat plate collector. The values of useful heat gain, overall thermal efficiency, instantaneous efficiency and hourly thermal efficiency are calculated and their variation with time and solar intensity are tabulated.

KEYWORDS: Renewable energy, solar energy applications, flat plate collector, water heating.

I. INTRODUCTION

Humans have always used the rays of the sun to gather their energy needs. In the energy needs of today with increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such possibility is solar energy, which has become increasingly popular in recent years.

Now-a-days solar energy has been strongly promoted as available energy source. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat. Hence way that the domestic sector can lessen its impact on the environment is by the installation of solar parabolic trough collectors for heating water. Although it should be said that some of these collectors have been in service for the last 40-50 years without any real significant changes in their design and operational principles.

The use of solar energy is centred at present on photovoltaic and thermal solar energy conversion systems. In the first-named, solar energy is converted into electricity directly by a photoelectric cell. The obtainable outputs are, however still limited. Higher outputs can be achieved by solar thermal conversion. In this process solar energy is received and transferred by a collector system to a working fluid.

Today with increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such possibility is solar energy, which has become increasingly popular in recent years. Solar energy is the radiation produced by nuclear fusion reactions in the core of the sun. This radiation travels to Earth through space in the form of energy called photons. Even though only 30% of the solar power actually reaches The Earth, every 20 minutes the sun produces enough power to supply the Earth with its needs for an entire year.

Due to the nature of solar energy, two components are required in order to have a functional solar energy generator. These two components are a collector and a storage unit. The collector collects the radiation that falls on it and converts it to other forms of energy (electricity, heat). Whilst the storage unit is required because of the non-constant nature of solar energy, as during cloudy days the amount of energy produced by the collector will be quite small. The storage

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unit can hold the energy produced during the periods of maximum radiation and release it when it is needed or the productivity drops [1].

II. OBJECTIVE

The proposed work has the following objectives and contributions in the field of Flat plate solar collector water heating system:

1. To propose a methodology by which the design and selection of flat plate solar collector water heating system can be made comprehensive and easy.
2. The above model is to be used in modelling and analysis for in depth study of the whole system.
3. Optimization of flat plate solar collector with respect to the performance i.e. thermal efficiency, collector efficiency, quality, reliability, durability and most importantly the cost of different materials constituting the system.
4. Complete analysis, evaluation, and comparison of the different flat plate solar collector water heating system available in the global market, and also the ranking and optimum selection of the flat plate solar collector.
5. To design and fabricate the Prototype flat plate solar collector for hot water generation and its feasibility in other applications.
6. To fabricate a cost efficient flat plate solar collector with the use of different alternative materials.
7. To calculate the performance of the flat plate solar collector for the hot water production in terms of useful heat gain, temperature of water in the storage tank, instantaneous efficiency and overall thermal efficiency.
8. Experimental analysis, performance evaluation and comparison of glass cover tubes of a copper pipe diameter in terms of efficiency and selecting the best result for improved efficiency of the fabricated flat plate solar collector water heating system.

To calculate the values of performance parameters of the optimum design thus obtained from the experimental analysis [1].

III. COMPONENTS

The main Components of the above fabricated system are explained as follows:

1. Casing
 2. Layer of Insulation
 3. Absorber plate
 4. Flow tube
 5. Glazing cover
 6. Water Supply Tank
 7. Hot water collecting Tank
 8. Piping Network
- 1) **Casing:** A wooden casing of dimensions (0.59m x 0.435m x 0.08m) is made for outer frame work of the collector. It surrounds and protects the foregoing components employed in the system. Casing keeps the components free from dust and moisture.
 - 2) **Layer of Insulation:** A thin layer of thermocol of 4mm thickness is placed at the bottom of the casing. The insulation helps to minimize the conduction losses from bottom and sides of the casing. The collector can be insulated by different types of insulating materials.
 - 3) **Absorber Plate:** A thin sheet of Galvanized Iron of size 0.54m x 0.39m is coated with a highly selective material that is extremely efficient at absorbing, reflecting the sunlight and converting it into usable heat. The

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main function of absorber plate is to absorb the incident solar radiation to gain heat and then allowing efficient transfer of heat to the working fluid.

- 4) **Flow tubes:** The flow tubes are the tubes used to facilitate the circulation of working fluid. Water is most commonly used working fluid in the solar flat plate collectors. Water enters the collector at inlet of the tube and leaves at outlet.

The copper tube of 6 mm diameter was used in this work as flow tube. The tube was arranged in serpentine configuration with 50 mm minimum space between adjacent tubes and length of each tube is 250mm. The inner and outer diameters of the tube are 6mm and 8 mm respectively.

- 5) **Glazing Cover:** Glazing cover is a transparent cover which limits the radiation and convection heat losses. glass plate of 3mm thickness is used. The transparent cover is placed at top of the collector to minimize the losses due to convection.
- 6) **Water supply tank:** The water tank of 20 litre capacity is used to supply the water to the solar collector. The tank is placed at 1 m height from the collector inlet for creating necessary pressure head for east circulation of water in the system.
- 7) **Hot Water collecting tank:** A storage bucket of 10 litre capacity is place at the exit of the solar flat plate collector to collect the generated hot water. It should be insulated to store the water for a long time.
- 8) **Piping Network:** The Hose pipes of 1m length and 8 mm inner diameter are used to convey the cool water from the supply tank and hot water to the storage tank.
- 9) **Support Structure:** Support structure is made up of wood. The support structure is fabricated in such a way that it could with stand wind loads, stress loads etc. It is also designed so that it could minimize the alignment errors. The provision of manual tracking is also there in the support structure.
- 10) **Measuring devices:**
- The digital Thermometer with range 0-300°C is used to measure the inlet temperature of cold water and outlet temperature of hot water and thus to find the temperature difference.
 - By using measuring tank the time taken to collect 500 ml of water is noted down. This helps in the calculation of mass flow rate of water flowing through the copper tubes.

IV. MATERIALS AND METHODS

The Following Materials are used for the fabrication of Solar Flat Plate Collector.

S.NO	COMPONENTS	MATERIAL	DIMENSIONS
1.	Casing	Wood	0.59m x 0.435m x 0.08m
2.	Insulation	Thermocol	0.54m x 0.39m x 0.004m
3.	Absorber plate	Galvanized Iron	0.54m x 0.39m x 0.002m
4.	Flow tube	Copper	2.25 m length 8 mm dia
5.	Glazing cover	Glass	3 mm thick
6	Water Supply Tank	Plastic	20 litre
7	Hot water collecting Tank	Plastic	10 litre
8	Pipes	Plastic hose	1 m each

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Vol. 6, Issue 4, April 2017

Table III.I: Material used for the fabrication of Flat Plate Solar Collector

S.NO	INSTRUMENTS	Limit
1.	Thermometer	300°C
2.	Measuring Tank	500 ml
3.	Stop Watch	----

Table III.II: Devices used for taking the measurements

V. EXPERIMENTAL SETUP



Fig V.I: Fabricated Flat Plate Solar Collector Water Heater

The Flat plate solar Collector Water heater consists of inlet and outlet water tanks, collector casing, flow tubes, absorber plate, insulating material and supporting structure which are explained above briefly.

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Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

VI. EXPERIMENTAL PROCEDURE

The stepwise experimental procedure which is followed during the experiment is as follows:

- Step 1:** All the components of the Flat Plate Solar Collector are gathered and assembled together.
- Step 2:** The arrangement is placed at the open place on the clean sky days in the local cell of 78.03°E, 15.82°N Kurnool
- Step 3:** Cleaning of the absorber plate, flow tube and glazing cover is done to remove the dust particles and moisture content.
- Step 4:** The cold water supply tank is filled with fresh and clean water and is placed at the height of one meter from the collector to create necessary pressure head caused for the flow of working fluid through copper tube.
- Step 5:** The collector is exposed to the sun, using tracking support, 60 min before start of the experiment.
- Step 6:** The water supply is started from 10:00 am.
- Step 7:** While the water is passing through the collector the ambient temperature, Inlet temperature and outlet temperature of water are noted down
- Step 8:** Mass flow rate of water is measured by observing the time taken for the collection of 500ml of water using measuring jar and stop watch.
- Step 9:** Each experiment is conducted for 1 hour duration by maintaining constant flow rate of water.
- Step 10:** The readings are taken after every hour and are tabulated.
- Step 11:** The experimental procedure is repeated for the next day.

VII. EXPERIMENTAL RESULTS

$$M_w = 0.0051 \text{ kg/sec, } C_p = 4187 \text{ kJ/kgK \& Collector area} = 0.54 * 0.39 = 0.211 \text{ m}^2.$$

VII.I. Experimental readings taken on 01.March.2017

S. NO	Time (hrs)	Ambient Temp T_a (°C)	Temperatures of water			Mass flow rate of water (kg/sec) (0.5/98)	Heat gain Q_u (w)	Solar Intensity (W/m ²)	Thermal efficiency η
			Inlet temp T_i (°C)	Outlet Temp T_o (°C)	Temp Difference ΔT (°C)				
1	10.00	28	29	31	2	0.0051	42.70	1139	17.77 %
2	11.00	30	31	34	3	0.0051	64.06	1142	26.59 %
3	12.00	30	31	35	4	0.0051	85.41	1145	35.35 %
4	01.00	31	32	37	5	0.0051	106.76	1150	44 %
5	02.30	31	32	36	4	0.0051	85.41	1146	35.32%
6	03.00	30	31	34	3	0.0051	64.06	1143	26.56%
7	04:00	29	30	32	2	0.0051	42.70	1140	17.75%

International Journal of Innovative Research in Science, Engineering and Technology

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Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

VII.II. Experimental readings taken on 02.March.2017

S. NO	Time (hrs)	Ambient Temp $T_a(^{\circ}C)$	Temperatures of water			Mass flow rate of water (kg/sec) (0.5/98)	Heat gain Q_u (w)	Solar Intensity (W/m^2)	Thermal efficiency η
			Inlet temp $T_i(^{\circ}C)$	Outlet Temp $T_o(^{\circ}C)$	Temp Difference $\Delta T(^{\circ}C)$				
1	10.00	28	28	31	3	0.0051	64.06	1138	26.67%
2	11.00	30	32	36	4	0.0051	85.41	1140	35.50%
3	12.00	30	33	38	5	0.0051	106.76	1143	44.27%
4	01.00	31	33	38	5	0.0051	106.76	1145	44.20%
5	02.30	31	32	36	4	0.0051	85.41	1146	35.32%
6	03.00	30	31	34	3	0.0051	64.06	1144	26.53%
7	04:00	29	30	32	2	0.0051	42.70	1140	17.755

VIII. CONCLUSION

The following conclusions are drawn with the experimental analysis of the fabricated solar flat plate system for hot water generation on 1st and 2nd of March month

- We observed the high temperature at 38°C on 02.03.2017 at 12:00pm and high thermal efficiency at 44.27% due to high solar intensity. By this a Solar Flat plate collector gains heat more effectively and gives medium performance.
- The lowest temperature was observed as 31°C on 01.03.2017 at 10:00pm on a sunny day. This was the least temperature observed on a sunny day. In the morning, we observe 17.78% of thermal efficiency.
- In this the performance is greatly high even in the mid noon. The highest heat gain was observed as 106.76W on a sunny day, and the lowest heat gain was observed in rainy day 42.70W..
- The performance of Flat plate solar collector will have high during the sunny day and the minimum outlet temperature during the rainy day.
- The solar intensity is approximately constant throughout the day and was varied by the type of the day just as sunny day or rainy day.
- The highest temperature during the day is 38°C and the lowest temperature is 31°C.

The heat gain was increased depending on time and solar intensity.

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Vol. 6, Issue 4, April 2017

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BIOGRAPHY



J. Ramesh received the B.Tech degree in Mechanical Engineering and M.Tech. degree in Thermal Engineering from JNTU Anantapur, AP in 2012 and 2015 respectively. During 2012-2013, he worked as a trainee in a sponge iron plant at Bellary, Karnataka. Now he has been working as assistant professor in the department of Mechanical Engineering at Dr. KVSRT Kurnool, AP, India since 2015. His areas of interest are Solar Energy Application, Thermal Engineering, IC Engines, Thermal Power Plants, Heat Transfer, Refrigeration and Air Conditioning.



J. Kanna kumar graduated (Mechanical Engineering) from Sri Krishna Devaraya niversity, Anantapur in 2000 and the M.Tech (Thermal Sciences and Energy Systems) same university in 2006. Curently he is working as Assoc professor in Dept. of Mechanical Engineering, Dr.KVSubbareddy Institute of Technology, and Kurnool. His area of interest includes Alternative Fuels, Solar Energy, Heat Transfer and Refrigeration and Airconditioning.



Dr. E.V Subba Reddy, graduated (Mechanical Engineering) from SSIT, Bangalore university, M.Tech (R&AC) and Ph.D (Composite materials) from JNTU Anantapuramu . His areas of intrest are Composite materials, Refrigeration and Air Conditioning.