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Study and Performance Analysis of Concentric Tube Solar Water Heater

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ABSTRACT

Using the sun's energy to heat water is not a new idea. More than one hundred years ago, black painted water tanks were used as simple solar water heaters in a number of countries. Solar water heating (SWH) technology has greatly improved during the past century. Today there are more than 30 million m2 of solar collectors installed around the globe. In addition to the energy cost savings on water heating, there are several other benefits derived from using the sun's energy to heat water. Most solar water heaters come with an additional water tank, which feeds the conventional hot water tank. In the present work a concentric tubular type solar water heater have been designed to get maximum effectiveness. It is found that temperature has increased so much as compared to uncoated pipe.

Keywords: - *Solar energy, solar water heater.*

I. INTRODUCTION

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy.

Solar energy is quite simply the energy produced directly by the sun and collected elsewhere, normally the Earth. The sun creates its energy through a thermonuclear process that converts about 650,000,000 tons of hydrogen to helium every second. The process creates heat and electromagnetic radiation. The heat remains in the sun and is instrumental in maintaining the thermonuclear reaction. The electromagnetic radiation (including visible light, infra-red light, and ultra-violet radiation) streams out into space in all directions.

Only a very small fraction of the total radiation produced reaches the Earth. The radiation that does reach the Earth is the indirect source of nearly every type of energy used today. The exceptions are geothermal energy, and nuclear fission and fusion. Even fossil fuels owe their origins to the sun; they were once living plants and animals whose life was dependent upon the sun.

Much of the world's required energy can be supplied directly by solar power. More still can be provided indirectly. The practicality of doing so will be examined, as well as the benefits and drawbacks. In addition, the uses solar energy is currently applied to will be noted.

Due to the nature of solar energy, two components are required to have a functional solar energy generator. These two components are a collector and a storage unit. The collector simply collects the radiation that falls on it and converts a fraction of it to other forms of energy (either electricity and heat or heat alone). The storage unit is required because of the non-constant nature of solar energy; at certain times only a very small amount of radiation will be received. At night or during heavy cloud cover, for example, the amount of energy produced by the collector will be quite small. The storage unit can hold the excess energy produced during the periods of maximum productivity, and release it when the productivity drops. In practice, a backup power supply is usually added, too, for the situations when the amount of energy required is greater than both what is being produced and what is stored in the container. Among the renewable resources, only in solar power do we find the potential for an energy source capable of supplying more energy than is used. Suppose that of the 4.5×10^{17} kWh per annum that is used by the earth to evaporate water from the oceans we were to acquire just 0.1% or 4.5x10 kWh per annum. Dividing by the hours in the year gives a continuous yield of 2.90×10^{10} kW. This would supply 2.4 kW to 12.1 billion people.

II. METHODS OF COLLECTING AND STORING SOLAR ENERGY

Methods of collecting and storing solar energy depending on the uses planned for the solar generator. In general, there are three types of collectors and many forms of storage units. The three types of collectors are flat-plate collectors, focusing collectors, and passive collectors.

Flat-plate collectors are the more commonly used type of collector today. They are arrays of solar panels arranged in a simple plane. They can be of nearly any size, and have an output that is directly related to a few variables including size, facing, and cleanliness. These variables all affect the amount of radiation that falls on the collector. Often these collector panels have automated machinery that keeps them facing the sun. The additional energy they take in due to the correction of facing more than compensates for the energy needed to drive the extra machinery. Focusing collectors are essentially flat-plane collectors with optical devices arranged to maximize the radiation falling on the focus of the collector.

These are currently used only in a few scattered areas. Solar furnaces are examples of this type of collector. Although they can produce far greater amounts of energy at a single point than the flat-plane collectors can, they lose some of the radiation that the flat-plane panels do not. Radiation reflected off the ground will be used by flat-plane panels but usually will be ignored by focusing collectors (in snow covered regions, this reflected radiation can be significant). One other problem with focusing collectors in general is due to temperature. The fragile silicon components that absorb the incoming radiation lose efficiency at high temperatures, and if they get too hot they can even be permanently damaged. The focusing collectors by their very nature can create much higher temperatures and need more safeguards to protect their silicon components.

III. SOLAR ENERGY SCENARIO

Developing countries, in particular, face situations of limited energy resources, especially the provision of electricity in rural areas, and there is an urgent need to address this constraint to social and economic development. India faces a significant gap between electricity demand and supply. Demand is increasing at a very rapid rate compared to the supply. According to the World Bank, roughly 40 percent of residences in India are without electricity. In addition, blackouts are a common occurrence throughout the country's main cities. The World Bank also reports that one-third of Indian businesses believe that unreliable electricity is one of their primary impediments to doing business. In addition, coal shortages are further straining power generation capabilities. Available solar energy is one such option. India is endowed with rich solar energy resource. The average intensity of solar radiation received on India is 200 MW/km square (megawatt per kilometer square). With a geographical area of 3.287 million km square, this amounts to 657.4 million MW. However, 87.5% of the land is used for agriculture, forests, fallow lands, etc., 6.7% for housing, industry, etc., and 5.8% is either barren, snow bound, or generally inhabitable. Thus, only 12.5% of the land area amounting to 0.413 million km square can, in theory, be used for solar energy installations. Even if 10% of this area can be used, the available solar energy would be 8 million MW.

IV. WHY SOLAR ENERGY?

It is clear that India has high solar incidence throughout the year. It can be seen from Fig that Rajasthan, Gujarat, west Madhya Pradesh and north Maharashtra receive more than 3000 to 3200 hours of bright sunshine in a year. Over 2600 to 2800 hours of bright sunshine are available over the rest of the country, except Kerala, the north-eastern states, and Jammu and Kashmir where they are appreciably lower.

During monsoon (June – August), a significant decrease in sunshine occurs over the whole country except Jammu and Kashmir where the maximum duration of sunshine occurs in June and July, and minimum in January due to its location. The north-eastern states and south-east peninsula also receive relatively less sunshine during October and November due to the north-east monsoons. As far as the availability of global solar radiation is concerned, more than 2000 kWh/m2-year are received over Rajasthan and Gujarat, while east Bihar, North West Bengal and the north-eastern states receive less than 1700 kWh/m^2-year. The availability of diffuse solar radiation varies widely in the country. The annual pattern shows a minimum of 740 kWh/m^2-year over Rajasthan increasing eastwards to 840 kWh/m2-year

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in the north-eastern states, and south wards to 920 kWh/m^2-year. - A huge market for solar energy; given the high solar incidence in India (there are about 300 clear sunny days in a year in most parts of India and the daily average solar energy incident over India varies from 4-7 kWh/m2.

V. TYPES OF SOLAR CONCENTRATOR

The solar concentrators are mainly classified as:

1. Focusing Type
2. Line Focus Type
3. Point Focus Type
4. Non-Focusing Type

Line Focus Type
Cylindrical Parabolic Concentrator
Fixed Mirrors Solar Concentrator

1. Mirror

2.Copper tube

3. Blackboard Paint

4. Acrylic Fiber Glass

VI. FABRICATION OF SEMI-CIRCULAR CONCENTRATOR

For construction of a Semi circular type concentrator we use a ply wood of for the base. After it we took 7 pipes of PVC for making the cylindrical trough by cutting the pipes into two halves. Mirrors used as a reflecting medium are pasted on the pipes. Now we use copper pipe for heat absorption in it we placed this in center of curvature in the PVC pipe for concentration of solar radiation.

We put both side open and give inlet and outlet for supply of water. Now for adjusting the focuses we made a stand which can rotate 30-180 with base.
Frame of iron is made to fix the complete structure so that there will not be any buckling in the plywood.

VII. SYSTEM DESIGN REQUIREMENTS

The type, complexity and size of a solar water heating system are mostly determined by:

- The temperature and amount of the water required from the system.
- Changes in ambient temperature and solar radiation between summer and winter.
- The changes in ambient temperature during the day-night cycle.
- The possibility of the potable water or collector fluid overheating.
- The possibility of the potable water or collector fluid freezing.

The minimum requirements of the system are typically determined by the amount or temperature of hot water required during winter, when a system's output and incoming water temperature are typically at their lowest. The maximum output of the system is determined by the need to prevent the water in the system from becoming too hot.

VIII. SPECIFICATIONS

Components	Quantity	Dimensions
Ply Wood	1	4 x 6 ft.
PVC	7	Φ 6.5 inch
Mirror	4000 pieces	2 x 0.5 inch & 2 mm thick
Copper Tube	37.5 ft.	Φ 0.5 inch
Stand	1	4 x 6 ft.
Frame	1	4 x 6 ft.
Castor Wheel	4	Φ 40 mm
Blackboard Paint	1	-
Fiber Glass	1	4 x 6 ft.
Silicon Adhesive Tube	1	250 ml

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Hose Pipe	6	Φ 12.7 mm, 2 m length
Glass Wool	1.5 kg	-
Insulating Tank	1	20 litres

IX. WORKING PROCEDURE

A parabolic trough is a type of solar thermal energy collector. It is constructed as a long semi circular cylindrical mirror with a copper tube running its length at the focal point. Sunlight is reflected by the mirror and concentrated on the copper tube. The trough is usually aligned on a north-south axis, and rotated to track the sun as it moves across the sky each day. A trough consists of a linear semi circular reflector that concentrates light onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned directly above the middle of the semi circular mirror and filled with a working fluid. The reflector follows the sun during the daylight hours by tracking along a single axis. A working fluid is heated as it flows through the receiver and is then used as a heat source for a power generation system.

X. MECHANICS

Heat transfer fluid (usually oil) runs through the tube to absorb the concentrated sunlight. This increases the temperature of the fluid to some 400°C.The heat transfer fluid is then used to heat steam in a standard turbine generator. The process is economical and, for heating the pipe, thermal efficiency ranges from 60-80%. The overall efficiency from collector to grid, i.e. (Electrical Output Power)/(Total Impinging Solar Power) is about 15%, similar to PV (Photovoltaic Cells) but less than sterling dish concentrators.

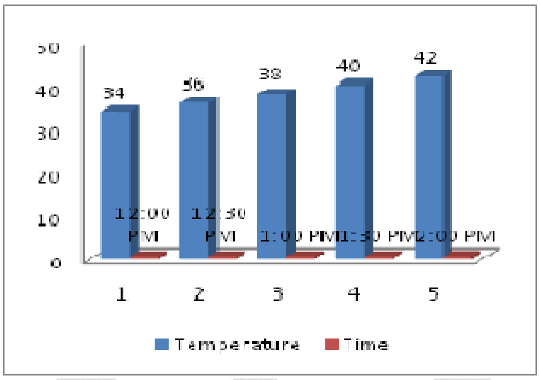
XI. ENERGY STORAGE

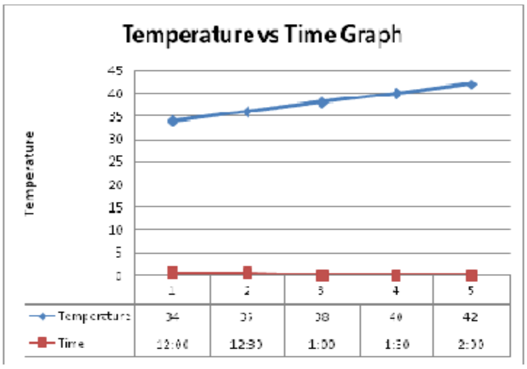
As this renewable source of energy is inconsistent by nature, methods for energy storage have been studied, for instance the single-tank storage technology for large-scale solar thermal power plants. The thermo cline tank approach uses a mixture of silica sand and quartzite rock to displace a significant portion of the volume in the tank. Then it is filled with the heat transfer fluid, typically a molten nitrate salt.

XII. PERFORMANCE STUDY

S. No.	Time	Temperature
1.	12:00 p.m.	34°C
2.	12:30 p.m.	36°C
3.	1:00 p.m.	38°C
4.	1:30 p.m.	40°C
5.	2:00 p.m.	42°C

Observation Table – 1:- Date: 8th October, 2012 (Without black paint coating of copper tubes)





Graph: 1

S. No.	Time	Temperature
1.	1:33 p.m.	36°C
2.	1:43 p.m.	39°C
3.	1:53 p.m.	42°C
4.	2:03 p.m.	45°C

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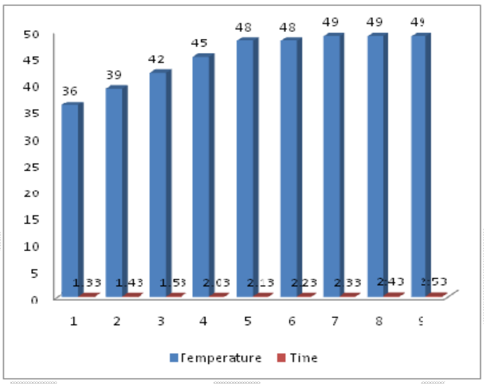
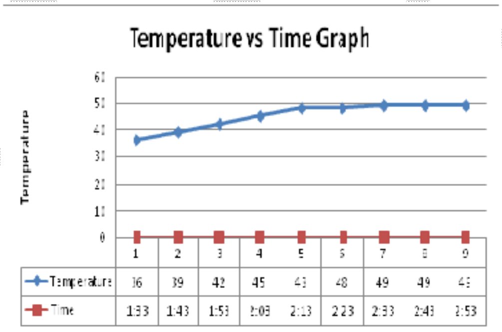
5.	2:13 p.m.	48°C
6.	2:23 p.m.	48°C
7.	2:33 p.m.	49°C
8.	2:43 p.m.	49°C
9.	2:53 p.m.	49°C

Observation Table – 2:- Date: 12th October, 2012 (After black paint coating of copper tubes). Normal temperature of water = 36°C

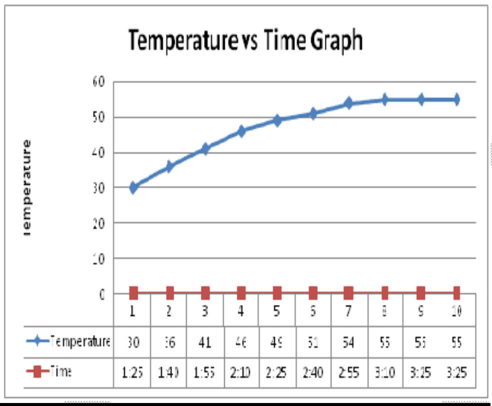




Graph: 2

S. No.	Time	Temperature
1.	1:25 p.m.	30°C
2.	1:40 p.m.	36°C
3.	1:55 p.m.	41°C
4.	2:10 p.m.	46°C
5.	2:25 p.m.	49°C
6.	2:40 p.m.	51°C
7.	2:55 p.m.	54°C
8.	3:10 p.m.	55°C
9.	3:25 p.m.	55°C

Observation Table – 3:- Date: 5th November, 2012 (After glass covering of the whole assembly)
Time Setup: 1:00 p.m., Quantity of Water = 20 liters
Inlet Water Temperature at the beginning of experiment (Normal Water Temperature) = 30°C



Graph: 3

S. No.	Time	Temperature
1.	9:30 a.m.	27°C
2.	10:30 a.m.	44°C
3.	11:30 a.m.	58°C
4.	12:30 p.m.	67°C

Observation Table – 4:- Date: 7th November, 2012 (With glass covering of the whole assembly)
Quantity of Water = 20 litres
Normal Temperature of Water = 27°C

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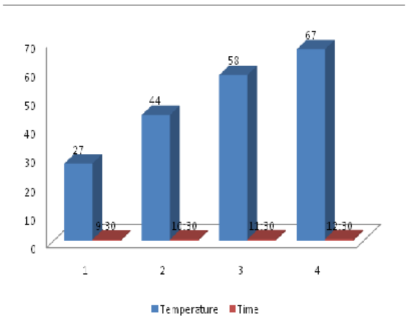
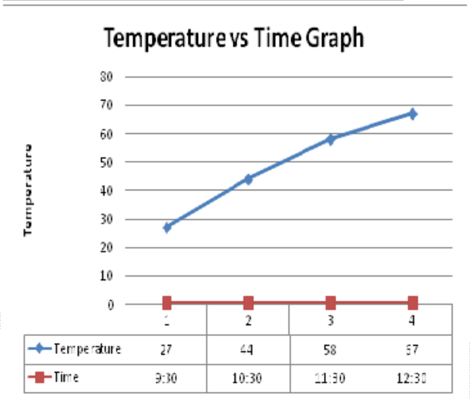




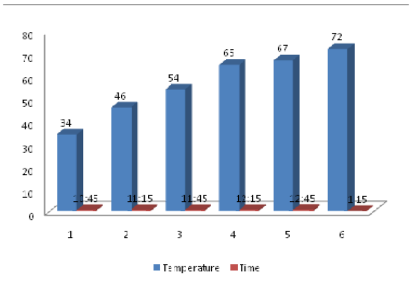
Graph: 4

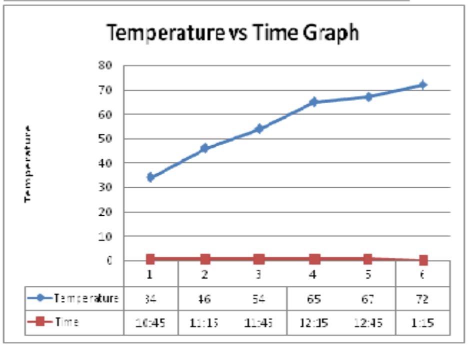
S. No.	Time	Temperature
1.	10:45 a.m.	34°C
2.	11:15 a.m.	46°C
3.	11:45 a.m.	54°C
4.	12:15 p.m.	65°C
5.	12:45 p.m.	67°C
6.	1:15 p.m.	72°C

Observation Table – 5:- Date: 8th November, 2012 (With glass covering of the whole assembly)

Quantity of Water = 20 litres

Inlet Water Temperature at the beginning of experiment (Normal Water Temperature) = 34°C





Graph: 5

XIII. COST REPORT

Component	Qty.	Dim	Cost (in Rs.)
Ply Wood	2	Thickness: 18 mm 6 x 4 ft.	2600
Stand	1	6 x 4 ft.	1500
Frame	1	6 x 4 ft.	. 1500
Mirror	4000 pieces	2 x 0.5 inch & 2 mm thick	2500
Copper Tube	1	Φ 0.5 inch 37.5 ft.	2660
Acrylic Fiber Glass Sheet	1	Thickness: 5 mm 5 x 4 ft.	1400
PVC Sanitary Pipe	7	Φ 6.5 inch	2800
PVC Pipe	1	Φ 0.5 inch 30 ft.	300
Castor Wheel	4	Φ 40mm	250
Thermometer	1	(-10 to 100°C)	80

Hose pipe	1	Φ 0.75inch 6.6ft	300
Silicon Paste	1	200ml	156
Fevicol Marine	1	500ml	110
Insulating pipe	3	Φ 0.75inch 18ft.	200
Insulating Sheet	1	3 x 6 ft.	50
Black board Paint	1	200 ml	60
Varnish	1	500 ml	200
Paint	1	200 ml	50
Wall Putty	1	3kg	250
Regulating Valve	2	Φ 0.5 inch	50
Glass Wool	1	2kg	65
Clamp	10	Φ 0.5 inch	50
Nail	250 gm	0.5, 1 inch	30
Electric Wire & Socket	1	Φ 0.5 mm	. 100
Submersible Electric Motor	1	40 Watt 3400 litre/hr	. 200
Rs. 17461			

XIV. CONCLUSION

Water heating through solar-concentrator is economical as compare to other sources of energy as it is non-renewable, non-polluting and easily available source of energy. It can be effectively used by the solar concentrator for the various purposes such as water heating, solar energy in the form of electricity etc. As the capital cost of manufacturing and installing is higher than other non-conventional sources of energy. But the maintenance and operating cost is negligible.

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