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Design of the Evacuated Tube for Solar Water Heating System

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ABSTRACT
The main 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 applications for residential and industrial, solar energy industrial hot water system and solar energy power generation. In general vacuum tube collectors are used in solar process heat systems. Plastic materials, cannot withstand high temperatures so we can use temperature resistive collector covers which combine a high transitivity with a low U-value are used. Another possibility is to use capillaries made of glass. This paper work focuses on designing and fabricating the Solar evacuated tube collector system for water heating system, the capacity of system is 100LPD. The conversion of solar energy to heat energy the important parameters are area aperture, inlet and outlet temperature and insulation materials, and calculating the cost of the project and compare to the electricity cost and payback period. The design calculation was done based on the amount of heat gained by the water, which absorbed from the sun by Evacuated tube collector system.

***Index terms*: Solar panel, water heater, Evacuated tube collector, piping, insulation material**.

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. 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.

Solar energy can be used for other things besides heating. Solar energy is used to cool things by phase changing a liquid to gas through heat, and then forcing the gas into a lower pressure chamber. The temperature of a gas is related to the pressure containing it, and all other things being held equal, the same gas under a lower pressure will have a lower temperature. This cool gas will be used to absorb heat from the area of interest and then be forced into a

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region of higher pressure where the excess heat will be lost to the outside world. The net effect is that of a pump moving heat from one area into another, and the first is accordingly cooled. Besides being used for heating and cooling, solar energy can be directly converted to electricity. Most of our tools are designed to be driven by electricity, so if you can create electricity through solar power, you can run almost anything with solar power. The solar collectors that convert radiation into electricity can be either flat-plane collectors or focusing collectors, and the silicon components of these collectors are photovoltaic cells.

Photovoltaic cells, by their very nature, convert radiation to electricity. This phenomenon has been known for well over half a century, but until recently the amounts of electricity generated were good for little more than measuring radiation intensity. Most of the photovoltaic cells on the market today operate at an efficiency of less than 15%2 ; that is, of all the radiation that falls upon them, less than 15% of it is converted to electricity. The maximum theoretical efficiency for a photovoltaic cell is only 32.3%3, but at this efficiency, solar electricity is very economical. Most of our other forms of electricity generation are at a lower efficiency than this. Unfortunately, reality still lags behind theory and a15% efficiency is not usually considered economical by most power companies, even if it is fine for toys and pocket calculators. Hope for bulk solar electricity should not be abandoned, however, for recent scientific advances have created a solar cell with an efficiency of 28.2% efficiency in the laboratory. This type of cell has yet to be field tested. If it maintains its efficiency in the uncontrolled environment of the outside world, and if it does not have a tendency to break down, it will be economical for power companies to build solar power facilities after all.

Of the main types of energy usage, the least suited to solar power is transportation. While large, relatively slow vehicles like ships could power themselves with large onboard solar panels, small constantly turning vehicles like cars could not. The only possible way a car could be completely solar powered would be through the use of battery that was charged by solar power at some stationary point and then later loaded into the car. Electric cars that are partially powered by solar energy are available now, but it is unlikely that solar power will provide the world's transportation costs in the near future. Solar power has two big advantages over fossil fuels. The first is in the fact that it is renewable; it is never going to run out. The second is its effect on the environment.

As the primary element of construction of solar panels, silicon, is the second most common element on the planet, there is very little environmental disturbance caused by the creation of solar panels. In fact, solar energy only causes environmental disruption if it is centralized and produced on a gigantic scale. Solar power certainly can be produced on a gigantic scale, too. 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.

Of all the energy sources available, solar has perhaps the most promise. Numerically, it is capable of producing the raw power required to satisfy the entire planet's energy needs. Environmentally, it is one of the least destructive of all the sources of energy. Practically, it can be adjusted to power nearly everything except transportation with very little adjustment, and even transportation with some modest modifications to the current general system of travel. Clearly, solar energy is a resource of the future.

II. RELATED WORK:

The idea behind the proposed system is to design and develop the Vacuum tube (Evacuated tube) collectors which are used to absorb the solar radiation maximum from sun and to utilize for heating of water for industrial and home purpose and calculate the efficiency of the collector. The calculated value are compare to reference values and selects the best parameter for to get better efficiency of system. Conduct test and compare the results of insulation materials of Rockwool and PUF (Poly uterine

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foam).Calculate the cost for Vacuum tube collecting system and payback period for this system. They designed and fabricated vacuum tube collectors and simulate the cost analysis and calculated the payback period and capital budget for solar water heating system.

In this proposed model the design parameters are taken for the 5 ltr, storage water tank is insulated with rock wool for better heat reduction from the heat up water.

1. 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.

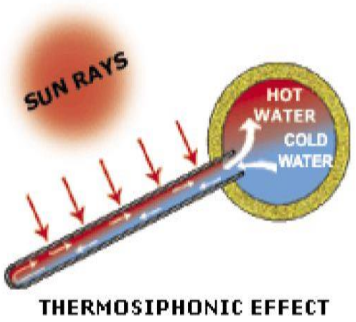

Fig 1. Image of Thermosiphonic Effect

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.

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

2. Numerical Calculation &Testing VTC Solar Water Heater:

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

Solar Radiation:

$$\text{Radiation} = \frac{Mv\ X\ 1000}{13.27}\ {}^{w}/_{m2}$$

Mv = Multi meter reading

13.27 = Solution constant valve.

Example: Output of multi meter = 8.8 mv

$$\text{Radiation} = \frac{8.8\ X\ 1000}{13.27} = 663.33\ w/m2$$

Mass flow Rate:

Water from exit in 1 min period

M_o = mass flow = lit/Min

Useful heat gain:

Useful heat gain = $M_0 \times (T_{f0}-T_{fi})$ kcal

M_o = mass flow rate = lit/min.

T_{fo}= Exit Temperature = ^oC

T_{f1}= Inlet Temperature = ^oC

Efficiency:

$$\text{Efficiency} = \frac{MoCp(\triangle T)}{LtAp}$$

Mo = mass flow rate = lit/min

CP = specific heat

$\triangle T$ = temperature difference = ^oC

L_T = Solar radiation = w/m^2

Ap = Aperture area

3. Benefits of Solar Water Heating System

Benefits of vacuum tube collectors are more they are categorized by following

(i)Technical benefits:

•Fuel saving

The wood savings due to installation of SWHS in a typical unit having 1000 LPD hot water generation capacity is estimated at 60 tons per annum. The wood savings is estimated

based on the present Chulhas efficiency of 6.25 %.

•Electricity saving

Project implementation will not save electricity consumption directly and indirectly.

•Improvement in product quality

Product quality achieved would be same as the present quality. It does not have any impact in improving the quality of the product.

•Increase in production

The proposed equipment does not contribute to any increase in production.

•Reduction in raw material consumption

Raw material consumption is same even after the implementation of proposed technology.

(ii)Monetary benefits

Annual monetary savings due to implementation of SWHS in place of the conventional

Challah is 1.50 lakh per annum. Energy & monetary benefit analysis of energy efficient

(iii)Social benefits

•Improvement in working environment in the plant

The replacement of inefficient chulhas with SWHS will reduce the wood consumption and will improve the work condition and environment.

•Improvement in skill set of workers

The technology implemented will create awareness among the workforce towards clean and renewable energy systems.

•Impact on wages/emoluments

No significant impact on wages and emoluments of the workers.

(iv)Environmental benefits

•Reduction in effluent generation

There is no major impact in effluent generation due to implementation of the project

•Reduction in GHG emission such as CO_2, NO_x

Implementation of this project will lead to reduction in CO_2 emissions due to reduction in overall fuel consumption. Implementation of this project will result in saving of 60 tonnes of Wood per year thereby; reducing 84 tonnes of CO_2 emissions per year from one unit. Similarly, there are many similar type of unit in Solapur, and if all units will implement this project then significant amount of CO_2 emission reduction possible per year. This will also help in getting the carbon credit benefit through Clean Development Mechanism (CDM) project. Taking CO_2 emission factor as 1.4 tCO_2 per tonnes of wood consumption

•Reduction in other emissions like SO_x

As wood doesn't contain sulphur and hence there is no impact on SO_x emissions.

III. FABRICATION OF PROPOSED MODEL

In this paper we have presented a design of Evacuated vacuum Tube collectors for Solar Water Heating System.

Initially need to prepare the analysis related to solar water heater and ways of increasing its efficiency and solving some difficulties in it. In conventional FPC one side of absorber tube are insulated but to another side is free to conductive, convective and radioactive losses. It decreases the system efficiency. We select the system of 2 liter per hour. 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 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

The vacuum tube for 2 LPD systems from fabricator we choose Borosilicate glass with Aluminum Nitrate coating.

b.Tank

There are two tanks used in the proposed model.

First inner tank of fabricated than on it Rock wool insulation and PUF finally on it tank is fabricated and the tank using will be of GI with Rockwool wool insulation of capacity 100 Lit.

Vacuum tube from fabricator

Dimension –

outer dia – 47mm

Material - Borosilicate Glass Coating - Aluminum Oxide Pieces - 14 nos

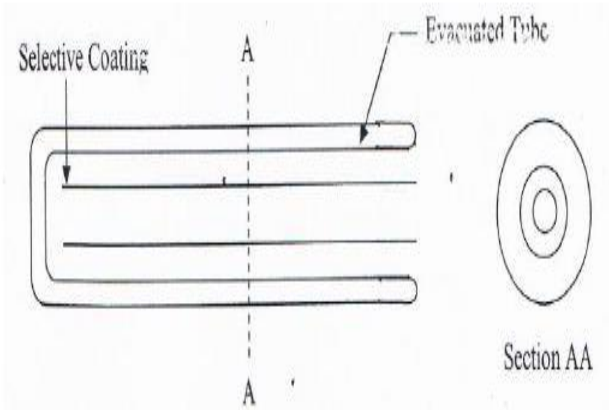

Fig 2. Sectional view of Evacuated tube

Another second tank is insulated tank of capacity 5 lit having inlet and outlet connection and holes for tubes. Tank material is GI light in weight. Capacity - 100 Lit.

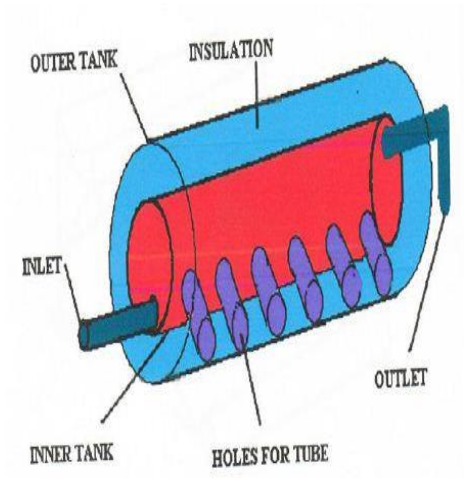

Fig 3.Image of Storage tank

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c. Piping

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

d. Insulation:

We used Rockwool and PUF (Poly uterine foam) as insulator with thickness of 45mm

Fig 4. Image of Rock wool

Summary Of designing and fabrication of the Vacuum tube collector system.

Solar Irradiation	4.81kwh/m^2
Diameter of Evacuated Tube	0.047mtrs
Area of solar energy collected	1.10m^2
Water tank capacity	100ltr

The performance of the vacuum tube collector is depends up on following parameters.

- Temperature of water inlet and out let
- Area of solar energy collected
- The amount of water which converted

To evaluate the effect that these parameters have, a set of experiments was conducted spanning all the parameters.

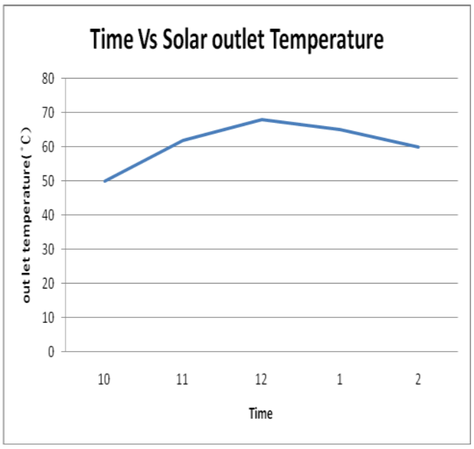

Fig 5. Graph of Time Vs Outlet temperature

The Graph gives the results of the performance evaluation of the collector which depend on the variation of the water outlet temperature from the storage tanks for different time beings.

IV.CONCLUSION

The existed model of "**Design of the Evacuated Tube for Solar Water Heating System**" was designed such that evacuated tube for solar water heating system, at temperature of water inlet is 33°C the evacuated collectors gives the highest output value. The paper also provides the uses of this technology in residential buildings where the demand for hot water has a large impact on energy bills. In future the developmental work can be extended for tracking the collector up to little extent which can increase the efficiency. We can also make use of 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 Also by using better selective coating we can reduce the tube size.

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