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A Descriptive Study of the Constructional Features of Evacuated Tube Solar Water Heating System

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ABSTRACT : *Renewable sources of energy are anticipated to play a significant role in energy generation in India in the future. The word itself —Solar, describes that we are dealing with some renewable energy source for a hot water system. The solar hot water system has been a popular throughout the world as it is cost effective and easy to maintain. The system is always successful when its efficiency level increases. Solar water heating (SWH) systems are gaining popularity in India with increasing number of affluent population in society and environmental concerns from seemingly unchanged reliance on fossil-based fuels. The penetration of these systems and technologies into Indian markets is a welcome development; however there is a need for the method of assessment of their thermal performances. Evacuated tube collector system is one of the effective methods of solar water heating systems. The usage of evacuated tube collectors is increasing day by day. This paper describes the evacuated tube solar water heating system with respect to its constructional features.*

Keywords – *Evacuated glass tubes, Solar collectors, Solar Irradiance, Storage tank, Thermal performance*

I. INTRODUCTION

Solar energy, being abundant and widespread in its availability, makes it one of the most attractive sources of energies. Tapping this energy will not only help in bridging the gap between demand and supply of electricity but shall also save money in the long run. A Solar Water Heating System (SWHS) is a device that makes available the thermal energy of the incident solar radiation for use in various applications by heating the water[5]. The SWHS consists of solar thermal collectors, water tanks, interconnecting pipelines, and the water, which gets circulated in the system. Solar radiation incident on the collector heats up the tubes, thereby transferring the heat energy to water flowing through it. The performance of the SWHS largely depends on the collector's efficiency at capturing the incident solar radiation and transferring it to the water. With today's SWHS, water can be heated up to temperatures of 60 °C to 80 °C. Heated water is collected in a tank insulated to prevent heat loss. Circulation of water from the tank through the collectors and back to the tank continues automatically due to the thermosiphon principle [6]. The hot water generated finds many end-use applications in domestic, commercial, and industrial sectors. The world market for solar water heaters has expanded significantly in the last decade. As a result, there have been large-scale developments of new-technology and improved-quality products. The evacuated tube solar collectors perform better in comparison to flat plate solar collectors, in particular for high temperature operations. However, it provided no real competition for flat plate solar collectors, because of difficulties in manufacturing and maintenance of the metal-to-glass vacuum seal. One of the most significant developments is the use of double-glass evacuated tubular solar water heaters. The mechanism of this type of solar water heater is driven by natural circulation of the fluid in the collector and the storage tank. It consists of all-glass vacuum tubes, inserted directly into a storage tank, with water in direct contact with the absorber surface. Morrison et al has mentioned that evacuated tube solar collectors perform better than flat plate collectors during high temperature operations [3]. Evacuated tube solar collector system is better option for domestic utilization because of its simplicity and low cost. Many solar water heaters manufacturers in India are importing evacuated tubes from China. The space required for mounting a 100LPD system is $30m^2$. Thus, it is important to study the features of evacuated tube solar water heater system, as the usage of evacuated tube collectors is increasing day by day in India as compared to conventional flat plate collector systems.

II. CONSTRUCTIONAL FEATURES

Main components of evacuated tube solar water heater **(**open Circuit, non-pressure system)

- Evacuated glass tubes and Barium Getter
- Storage tank
- Mounting frame

• External water supply source

Fig.1 shows constructional features of Evacuated Glass Tube solar water heating system.

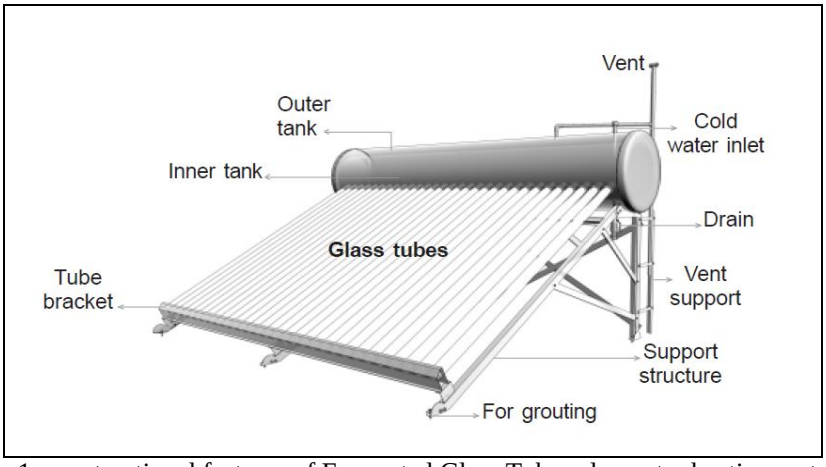

Fig.1: constructional features of Evacuated Glass Tube solar water heating system

2.1 Evacuated Glass Tubes

Figure 2 shows the Structure of evacuated glass tube is similar to a Dewar flask which has a double wall with a vacuum between the walls. Each evacuated tube consists of two glass tubes made from extremely strong borosilicate glass with high chemical and thermal shock resistance. The outer tube is transparent allowing light rays to pass through with minimal reflection. The outer side of the inner tube is coated with a sputtered solar selective coating (Al-N/Al or AlN/AlN-SS/Cu) which features excellent solar radiation absorption and minimal reflection properties [1]. The top of the two tubes are fused together and the air contained in the annular space between the two layers of glass is evacuated to eliminate conductive and convective heat loss. This is why the tubes are able to absorb the energy from infrared rays which can pass through clouds. Wind and low temperatures also have less of effect on the function of evacuated tubes when compared to flat plate solar collectors due to the insulating properties of the vacuum. The top end of these parallel tubes is fitted in to the inner storage tank. In the process of pulling the vacuum, a Barium Getter is inserted into the base of the outer glass tube. The inner glass tube is then inserted into the outside tube with the Getter centering the inner glass tube. A barium layer actively absorbs any CO, CO_2, N_2, O_2, H_2O, H_2 out gassed from the tube during storage and operation, thus helping to maintaining the vacuum [2]. The barium layer also provides a clear visual indicator of the vacuum status. The silver colour barium layer will turn white if even the vacuum is lost.

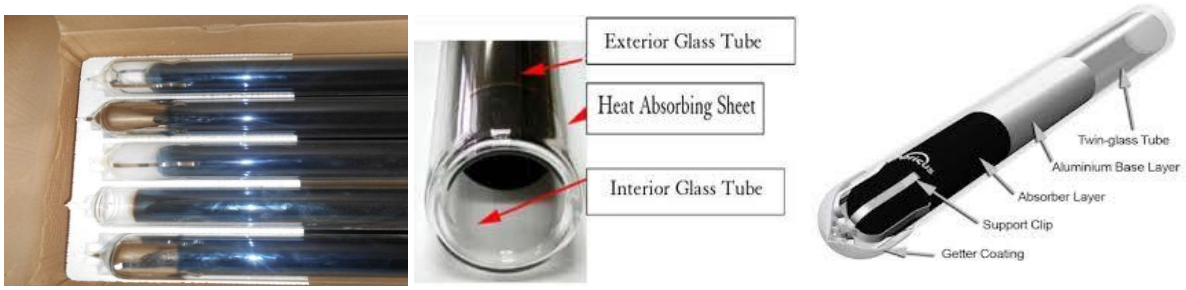

Fig.2: Details of Evacuated Glass Tube

2.2 Storage Tank

It is a tank which stores the water and come from external water source like water tank. It is mainly consist of two tank i.e. inner tank and outer tank. The inner tank is placed inside the outer tank. The gap is maintained between two tanks. This gap is filled by high tech insulating material (Rock Wool or mineral wool) in order to

reduce the heat losses from the heated water exist inside the inner tank heated by the evacuated tube solar water heater. Rock wool is a man made fiber and has many excellent characters like non-combustible, non-toxic, low thermal conductivity, long service life and so on. Storage tank is placed at the top of frame and tubes. The top open end of the tubes is connected to the storage tank. The bottom end of tubes is placed in a holder provided at bottom of the frame. Figure 3 shows storage tank of 500LPD capacity.

Fig.3: Storage Tank

2.3 Insulation

Thermal insulation is the reduction of the effects of the various processes of heat transfer between objects in thermal contact or in range of radiative influence [4]. Heat is the transfer of thermal energy between objects of differing temperature. The means to stem heat flow may be especially engineered methods or processes, as well as suitable static objects and materials. Heat flow is an inevitable consequence of contact of objects of differing temperature. Thermal insulation provides a means to maintain a gradient of temperature, by providing a region of insulation in which heat flow is reduced or thermal radiation is reflected rather than absorbed. A wide range of insulation materials is available; selection of insulation material should be based on initial cost, effectiveness, durability, the adaptation of its form/shape to that of the collector and tank and the installation methods available. From an economic point of view, it may be better to choose an insulating material with a lower thermal conductivity rather than increase the thickness of the insulation in the hold walls [4]. By reducing the thermal conductivity, less insulation will be required. One of the best commercially available choices of insulation material is polyurethane foam (Figure 4). It has good thermal insulating properties, low moisture-vapour permeability, and high resistance to water absorption, relatively high mechanical strength and low density. In addition, it is relatively easy and economical to install.

Fig.4 PUF Insulation

2.4 Manifold

Manifold is square frame structure made of G.I. sheet which comprises holes to insert or mount evacuated tubes with silicon seals or fittings.

Fig.5: Manifolds

2.5 Mounting Frame

It is structure made of no. of metallic angle or plate, on which no. of units like storage tank (in case of open circuit), manifold box, tubes etc. are mounted.

Figure 6 shows a frame assembly for evacuated glass tube solar water heating system.

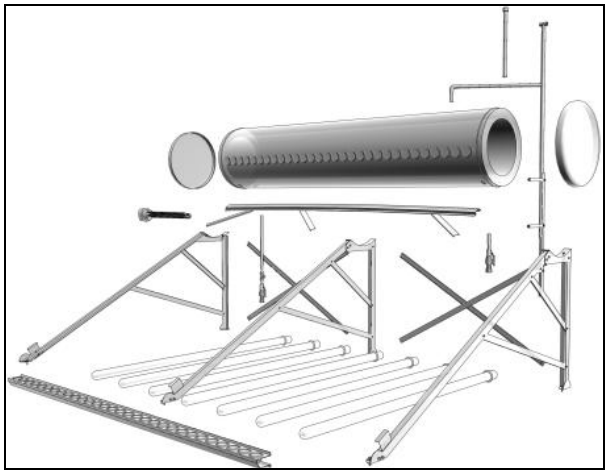

Fig. 6 Frame Assembly

Following Fig. 7 and Fig. 8 shows frame structure for Evacuated Tube Solar Water Heating System upto 300 LPD And above 300LPD Capacity respectively.

It consists of following parts –

1-Front track, 2-Bottom track, 3-Side supports, 4-Back stands upper bar, 5- Back stands lower bar

6- X back supports, 7- Feet.

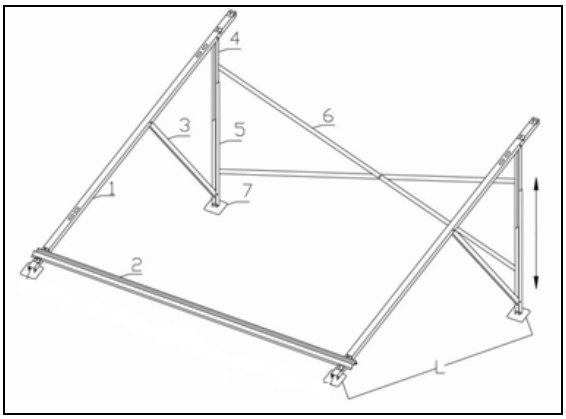

Fig.7 Frame for Capacity upto 300LPD

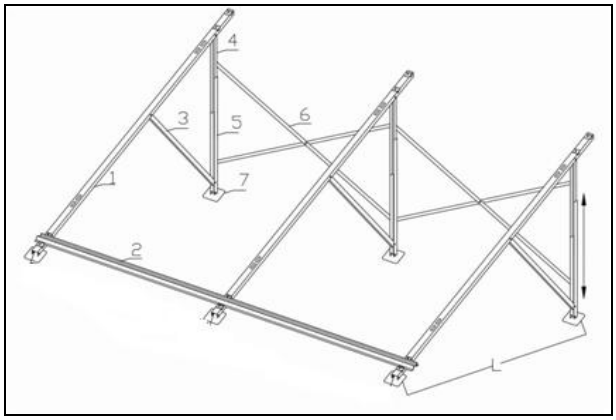

Fig.8 Frame for Capacity above 300LPD

III. WORKING PRINCIPLE

A solar water heating system consists of a vacuum glass tube collector, an insulated storage tank and connecting stand parts. The evacuated glass tubes are filled with water and exposed to sun, thus heating up the water in the glass tubes. As the specific gravity of cold water is heavier than hot water, the hot water in the glass tubes starts rising in the insulated water tank, and the cold water in the insulated water tank sinks into the glass tubes. As this cycle is repeated, water in the solar water heater gets heated. This process is known as thermo siphon and is based on natural convection. The storage tank is insulated so the water stays hot and can be used later in the day or even the following day. There are two tricks to the high efficiency of this solar heater. First, a vacuum

prevents any conductive or convective heat loss to the environment from the absorber. Second, heat pipes ensure one-way heat transfer from the absorber to the water: the water can not heat the absorber [3]. The selective coating in the inner cover of the evacuated tubes ensures high energy absorption and low heat radiance losses. The liquid in the inner glass heat pipes changes into vapor which then rises up the heat pipe. When heat is exchanged between the condenser end of the heat pipe and the cold water in the tank, it turns into liquid again, and comes down to the base of the heat pipe. This cycle continuously repeats as long as the sun shines. Hot water can be obtained by injecting cold water into the bottom of the tank, with the hot water being forced out the top. The evacuated tubular collector with heat pipes are quasi-tracking in four seasons, which is to say that as the sun tracks across the sky, about the same absorber area is facing the sun all the time, since the absorber surfaces are cylindrical. The collector will be in operation as long as sun shines. The solar water heater can be in service all year round even in cold climate areas since heat pipes transfer heat in one direction only within the collector and the vacuum prevents convective heat losses. Figure 9 shows the working principle of ETC system.

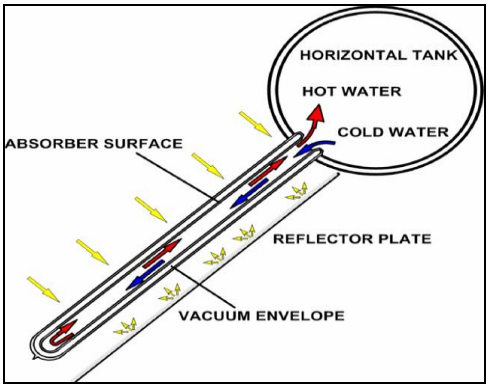

Fig.9 working principle of ETC system

IV. TYPICAL SPECIFICATIONS OF EVACUATED TUBE COLLECTOR (ETC) BASED SOLAR SYSTEM

Following Table 1 describes typical specifications of Evacuated Tube Collector (ETC) based solar system**.**

Table 1: typical specifications of Evacuated Tube Collector (ETC) based solar system

	Capacity			
Specifications	150 LPD	200 LPD	250 LPD	300 LPD
Storage Tank	Inner tank thickness – 2.5mm (material- G.I.)			
	Cladding thickness – 0.5mm (material- G.I.)			
Insulation Details	PUF Insulation (50mm thickness)			
Mounting Structure	M.S. with Epoxy/Anti-rust coating			
No. of Tubes	15	20	25	30
Heat Collecting Surface Area	2.46 Sq. mts.	3.28 Sq. mts.	4.10 Sq. mts.	4.92 Sq. mts.
Size of Tubes	58 mm (diameter of outer tube) 48 mm (diameter of inner tube) 1800 mm (length of tube)			
Glass Thickness	1.6mm to 2.0mm			
Glass Material	Borosilicate Glass with selective coating (Al-N/Al or AlN/AlN-SS/Cu)			

V. CONCLUSIONS

From the descriptive study, it may seen that there is little difference between flat plate and evacuated tubes, in fact flat plate may actually be higher, but this is during minimal heat loss conditions. When averaged over a year evacuated tube collector have a clear advantage.
The key points are:

1. Due to the cylindrical shape of the evacuated tube, the solar tubes are able to passively track the sun throughout the day. Flat plate collector only provides peak energy output at midday when the sun is perpendicular to the collector's surface.
2. Air is evacuated from the solar tube to form a vacuum. This greatly reduces conductive and convective heat loss from the interior of the tube. As a result wind and cold temperatures have less effect on the efficiency of the evacuated tube collector.
3. Evacuated tubes are strong, long lasting, and should one be broken, inexpensive and easy to replace. If a flat plate collector panel is damaged the whole panel must be replaced.
4. Due to the high efficiency absorption of solar radiation even during overcast conditions, combined with excellent insulative properties of the solar tube, solar tube collectors can heat water all year round (backup from gas and electricity is still required).
5. Due to the various advantages of evacuated tube collector over flat plate collectors, a smaller collector can be used to provide the same heating performance. For example, a standard household of 4-5 people would usually require a 250-300L water storage tank.

Depending on your location, only 25 evacuated tubes would be required to provide all summer hot water needs and a large percentage in other seasons. Flat plate solar collectors can produce similar heat output to evacuated tube collectors, but generally only during hot, sunny conditions. When averaged over an entire year, evacuated tube collector heat output per net m^2 of absorber area is between 25% to 40% greater than a flat plate collector.
Also, future study related to evacuated tube collectors includes that, to carry out different tests at different inclination angles and at vertical position of tubes, because it is current requirement of manufacturers due to space limitations in countries like India.

Acknowledgement

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