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ANALYSIS OF EVACUATED TUBE HEATPIPE COLLECTORS USING OIL AND FOAMED METALS: - A REVIEW

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Abstract

The Evacuated tube collector includes a number of rows of parallel transparent glass tubes connected to a header pipe and that are used in region of the blackened warmness absorbing plate we saw in the previous flat plate collector. Different types of glass materials of heat pipe have been used with different profile. Inside the fluid flow (octadecane) nano fluid on heat pipe. We found that they gives better temperature distribution and mass transformation in capillary tube of heat pipe. Heat pipe evacuated tube collectors, a sealed heat pipe, usually made of copper to increase the collectors efficiency in cold temperatures, is attached to a heat absorbing reflector plate within the vacuum sealed tube. The hollow copper heat pipe within the tube is evacuated of air but contains a small quantity of a low pressure alcohol/water liquid plus some additional additives to prevent corrosion or oxidation.

Keywords- *Heat Pipe, Evacuated Tube, CFD*

I INTRODUCTION

Evacuated tube solar collectors are extensively and widely used because it's good thermal insulation characteristics and insensitivity to the direction of sun light. Sabiha et al. made a comprehensive review on the progress and latest developments of evacuated tube solar collectors and why evacuated tubes are mostly preferred. There are three common types of evacuated tube solar collectors, which are (a) Water-in glass evacuated tube solar collector, (b) U-type evacuated tube solar collector and (c) evacuated tube heat pipe solar collector.

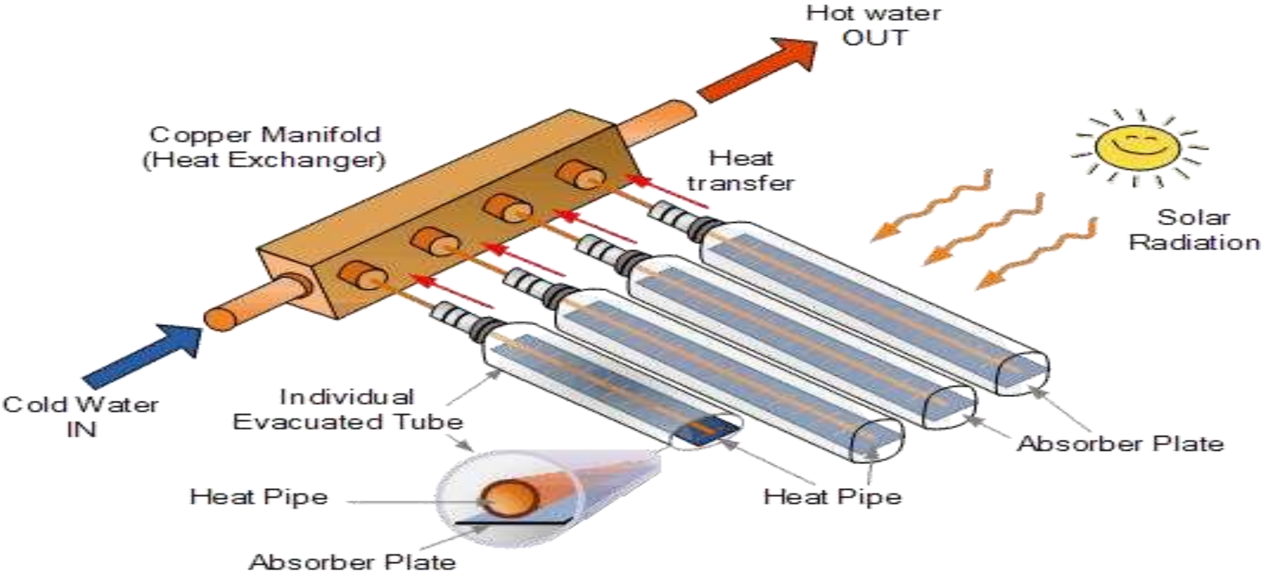

Figure 1.1 Evacuated tube collectors

The **Evacuated tube collector** consists of a number of rows of parallel transparent glass tubes connected to a header pipe and which are used in place of the blackened heat absorbing plate we saw in the previous flat plate collector. These glass tubes are cylindrical in shape. Therefore, the angle of the sunlight is always perpendicular to the heat absorbing tubes which enables these collectors to perform well even when sunlight is low such as when it is early in the morning or late in the afternoon, or when shaded by clouds. Evacuated tube collectors are particularly useful in areas with cold, cloudy wintry weathers.

Evacuated tube collectors are made up of a single or multiple rows of parallel, transparent glass tubes supported on a frame. Each individual tube varies in diameter from between 1" (25mm) to 3" (75mm) and between 5′ (1500mm) to 8′ (2400mm) in length depending upon the manufacturer. Each tube consists of a thick glass outer tube and a thinner glass inner tube, (called a "twin-glass tube") or a "thermos-flask tube" which is covered with a special coating that absorbs solar energy but inhibits heat loss. The tubes are made of borosilicate or soda lime glass, which is strong, resistant to high temperatures and has a high transmittance for solar irradiation. Unlike flat panel collectors, evacuated tube collectors do not heat the water directly within the tubes. Instead, air is removed or evacuated from the space between the two tubes, forming a vacuum (hence the name evacuated tubes). This vacuum acts as an insulator reducing any heat loss significantly to the surrounding atmosphere either through convection or radiation making the collector much more efficient than the internal insulating that flat plate collectors have to offer. With the assistance of these vacuum, evacuated tube collectors generally produce higher fluid temperatures than they're flat plate counterparts so may become very hot in summer.

Inside the each glass tube, a flat or curved aluminum or copper fin is attached to a metal heat pipe running through the inner tube. The fin is covered with a selective coating that transfers heat to the fluid that is circulating through the pipe. This sealed copper heat pipe transfers the solar heat via convection of its internal heat transfer fluid to a "hot bulb" that indirectly heats a copper manifold within the header tank. These copper pipes are all connected to a common manifold which is then connected to a storage tank, thus heating the hot water during the day. The hot water can then be used at night or the next day due to the insulating properties of the tank.

The insulation properties of the vacuum are so good that while the inner tube may be as high as 150oC, the outer tube is cooler to touch. This means that evacuated tube water heaters can perform well and can heat water to fairly high temperatures even in cold weather when flat plate collectors perform poorly due to heat loss.

However, the downside is that they can be a lot more expensive compared to standard flat plate collectors or solar batch collectors. Evacuated tube solar collectors are well suited to commercial and industrial hot water heating applications and can be an effective alternative to flat plate collectors for domestic space heating, especially in areas where it is often cloudy.

Evacuated tube collectors are overall more modern and more efficient compared to the standard flat plate collectors as they can extract the heat out of the air on a humid, dull overcast days and do not need direct sunlight to operate. Due to the vacuum inside the glass tube, the total efficiency in all areas is higher and there is a better performance even when the sun is not at an optimum angle. For these types of solar hot water panels, the configuration of the vacuum tube is what's really important. There are a few different vacuum tube configurations, single wall tube, double wall tube, direct flow or heat pipe, and these differences can determine how the fluid is circulated around the solar hot water panel.

Evacuated Tube Collectors are a very efficient way of heating much of your hot water use just using the power of the sun. They can achieve high very temperatures but are more fragile than other types of solar collectors and are much more expensive to install. They can be used in either an active open-loop (without heat exchanger) or an active closed-loop (with heat exchanger) solar hot water system but a pump is required to circulate the heat transfer fluid from collector to storage in order to stop it from overheating

II Heat Pipe Evacuated Tube Collectors

Heat pipe evacuated tube collectors, a sealed heat pipe, usually made of copper to increase the collectors efficiency in cold temperatures, is attached to a heat absorbing reflector plate within the vacuum sealed tube. The hollow copper heat pipe within the tube is evacuated of air but contains a small quantity of a low pressure alcohol/water liquid plus some additional additives to prevent corrosion or oxidation.

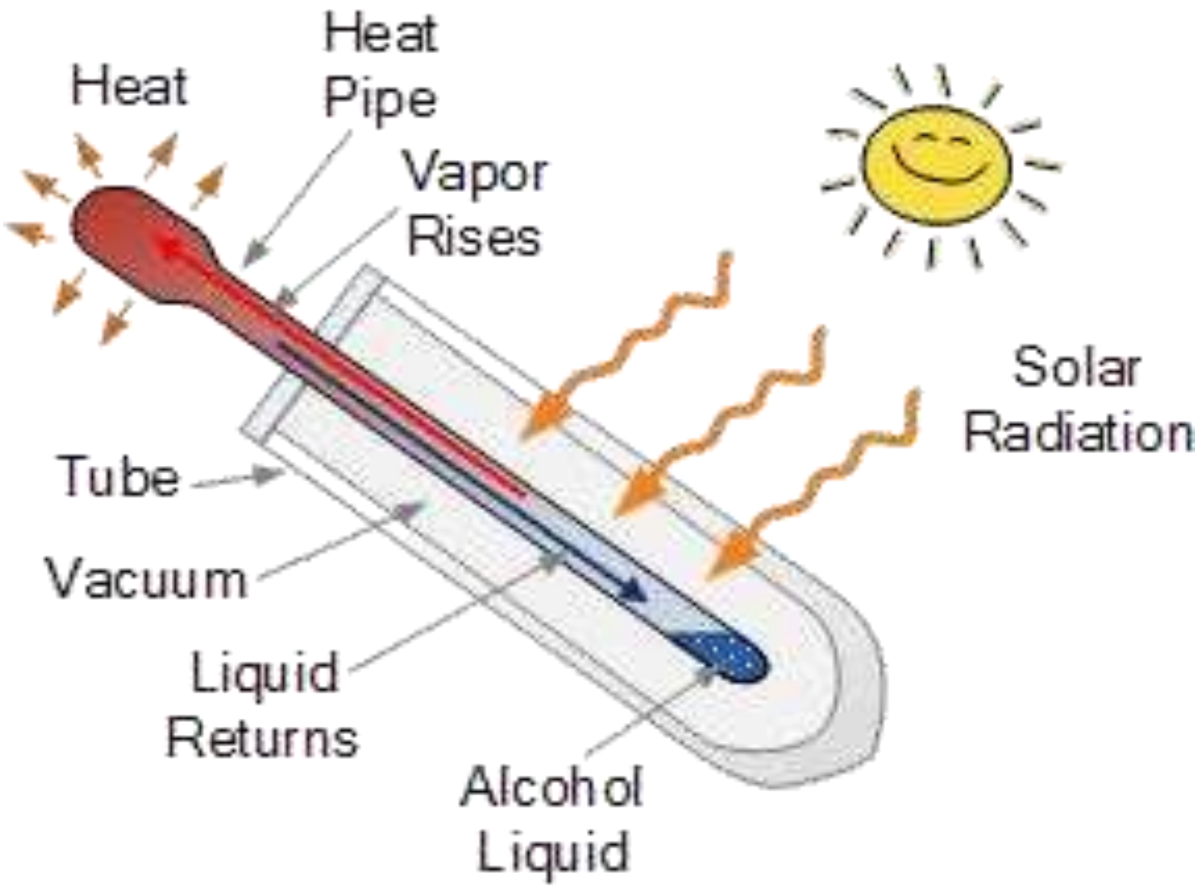

Figure 2.1 Heat Pipe Evacuated Tube Collector

This vacuum enables the liquid to vapourise at very lower temperatures than it would normally at atmospheric pressure. When sunlight in the form of solar radiation hits the surface of the absorber plate inside the tube, the liquid in the heat pipe quickly turns into a hot vapour type gas due to presence of the vacuum. As this gas vapour is now lighter, it rises up to the top portion of the pipe heating it up to a very high temperature. The top part of the heat pipe, and therefore the evacuated tube is connected to a copper heat exchanger called the "manifold". When the hot vapours still inside the sealed heat tube enters the manifold, the heat energy of the vapour is transferred to the water or glycol fluid flowing through the connecting manifold. As the hot vapour looses energy and cools, it condenses back from a gas to a liquid flowing back down the heat pipe to be reheated.

The heat pipe and therefore the evacuated tube collectors must be mounted in such a way as to have a minimum tilt angle (around 30o) in order for the internal liquid of the heat pipe to return back down to the hot absorber plate at the bottom of the tube. This process of converting a liquid into a gas and back into a liquid again continues inside the sealed heat pipe as long as the sun shines. The main advantage of Heat Pipe Evacuated Tube Collectors is that there is a "dry" connection between the absorber plate and the manifold making installation much easier than with direct flow collectors. Also, in the event an evacuated tube cracking or breaking and the vacuum becoming lost the individual tube can be exchanged without emptying or dismantling the entire system. This flexibility makes heat pipe evacuated tube solar hot water collectors ideal for closed loop solar designs as the modular assembly allows for easy installation and ability to easily expand by adding as many tubes as you want.

III Direct Flow Evacuated Tube Collector

Direct flow evacuated tube collectors also known as "U" pipe collectors, are different from the previous ones in that they have two heat pipes running through the centre of the tube. One pipe acts as the flow pipe while the other acts as the return pipe. Both pipes are connected together at the bottom of the tube with a "U-bend", hence the name. The heat absorbing reflective plate acts like a dividing strip which separates the flow and the return pipes through the solar collector tubes. The absorber plate and the heat transfer tube are also vacuum sealed inside a glass tube providing exceptional insulation properties.

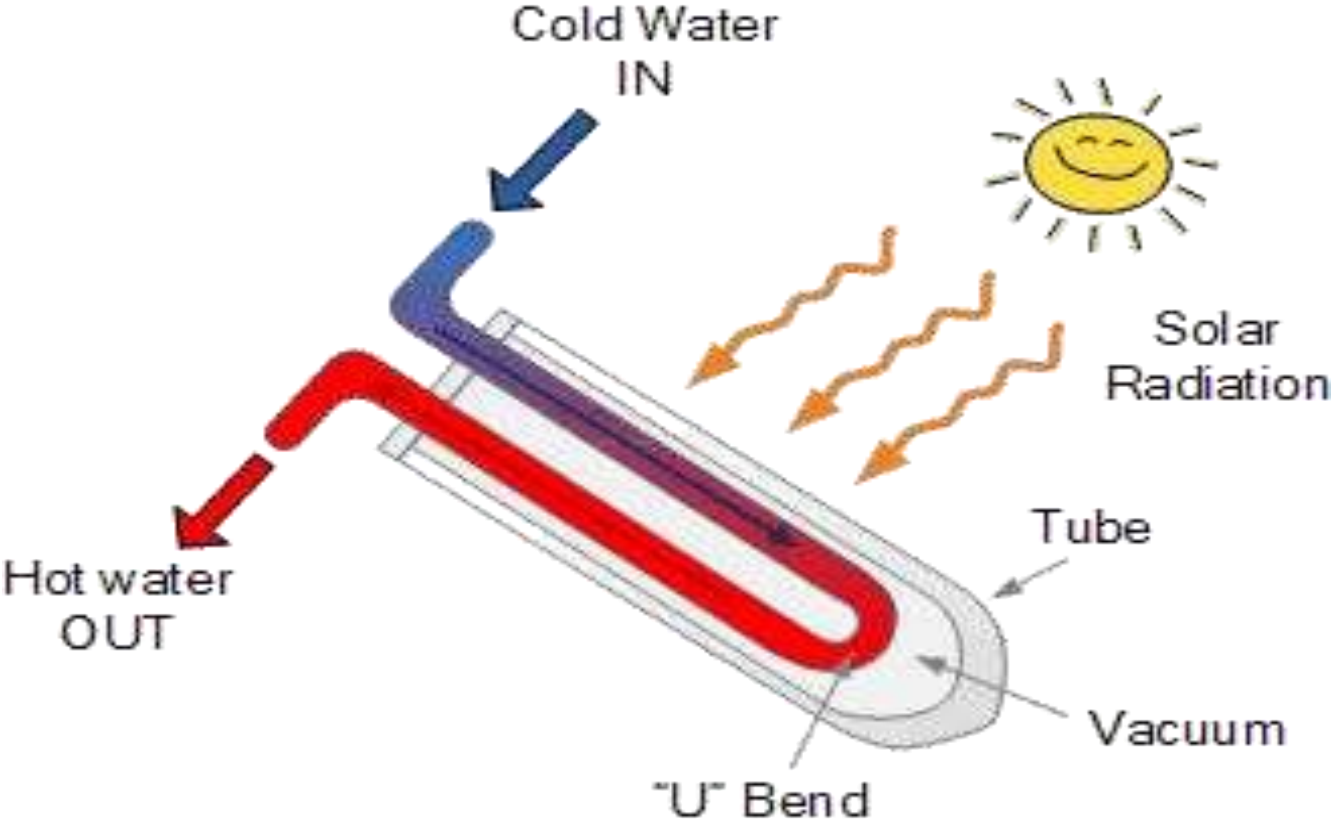

Figure 3.1 Direct Flow Evacuated Tube Collector

The hollow heat pipes and the flat or curved reflector plate are made out of copper with a selective coating to increase the collectors overall efficiency. This particular evacuated tube configuration is similar in operation to the flat plate collectors, with the exception of the vacuum provided by the outer tube.

Since the heat transfer fluid flows into and out of each tube, direct flow evacuated tube collectors are not as flexible as the heat pipe types. If a tube cracks or breaks it cannot be easily replaced. The system will require draining as there is a "wet" connection between the tube and manifold. Many solar industry professionals believe that direct flow evacuated tube designs are more energy efficient than heat pipe designs, because with direct flow, there isn't a heat exchange between fluids. Also, in an all-glass direct flow construction the two heat tubes are placed one inside the other so the fluid being heated passes down the middle of the inner tube and then back up through the outer absorber tube.

Direct flow evacuated tubes can collect both direct and diffuse radiation and do not require solar tracking. However, various reflector shapes placed behind the tubes are sometimes used to usefully collect some of the solar energy, which may otherwise be lost, thus providing a small amount of solar concentration.

IV Literature review

M.S. Abd-Elhady et.al [1] - the investigation improves the heating capability of evacuated tubes that comprises heat pipes. Thermal oil is inserted in the evacuated tube in order to improve the rate of heat transfer, such that the mode of heat transfer from the inner surface of the evacuated tube to the heat pipe becomes convection via the oil, as well as conduction through the installed fin. The finned surface has been replaced by a foamed-copper. An experimental setup has been developed to study the influence of oil and foamed metals on the performance of evacuated tubes with heat pipes. It has been found that the bulb temperature as well as the heating efficiency of the evacuated tube heat pipe has increased in case of inserting oil in the evacuated tube and replacing the finned surface with foamed copper. Also, the thermal oil acts as a heat storage.

Sarvenaz Sobhansarbandi et.al [2]-this investigation to Solar water heaters (SWHs) are a well-established renewable energy technology that have been widely adopted around the world. In this study we have significantly improved the Evacuated Tube solar Collectors (ETCs) by utilizing the ‘‘dry-drawable” Carbon Nanotube (CNT) sheet coatings to increase the solar energy absorption and Phase Change Materials (PCMs) to increase the heat accumulation for application in solar water heaters. The proposed solar collector utilizes a phase change material namely Octadecane paraffin, with melting temperatures of 28 C which is categorized as non-toxic with longterm chemical stability PCM. As PCMs particularly in powder form may not be effective by itself due to the poor heat transfer rate, low thermal diffusivity and thermal conductivity, by combining CNT layers with the high thermal diffusivity and thermal conductivity compare to phase change materials, we are able to overcome the shortcomings of PCMs and design an innovative and efficient solar water heater. With the current technology, we can provide a near ideal black body surface, absorbing a maximum of 98%, between 600 and 1100 nm, of solar light striking the surface, and providing additional spectral absorption which improves the performance of the solar heater. Applying CNT sheets in conjunction with PCM enables heat storage directly on the collector for a more constant output, even on a cloudy day and prolonged output of heat at night.

S. SivaKumar et.al. [3] - the investigation the Renewable source of energy is the future energy source that meets out our demand for energy. In this solar energy is one of the prime sources. The harnessing of the solar energy can be done in both ways Solar (PV), Solar Thermal. Solar thermal finds more suitable for domestic needs such as Space Heating, Cooling, Hot water systems, drying. Hence the need for producing thermal energy from the collectors is important. Out of all the thermal collectors the evacuated tube solar collector (ETSC) is found to have the best efficiency with low solar insolation. In this paper the evacuated tube is modelled with heat pipe for the enhancement of the heat generated from the collector. The objective of this research is to design and investigate the heat transfer analysis of Heat Pipe Evacuated Tube solar collector is made of Borosilicate glass with length 1.8m and 0.058m and 0.049m diameter of outside and inside tubes for the Coimbatore location.

A.E. Kabeel et.al [4] - the investigation Modified coaxial heat pipes have been designed and manufactured to improve the thermal performance of the glass vacated solar collectors. Heat pipes were made up of two concentric copper tubes so that the annulus volume space between the concentric tubes was charged with refrigerant. In addition, the air as the working fluid at four different mass flow rates 0.0051, 0.0062, 0.007 and 0.009 kg/s flows through the inner tube of the heat pipe to the flow through the annulus between the heat pipe and glass evacuated solar tubes. The effect of the tilt angle of the evacuated tube on thermal performance of the evacuated solar tube collector was examined to obtain the optimum tilt angle during the experiments period. The influence of filling ratio for the two types of refrigerant R22 and R 134a on the thermal efficiency of the coaxial heat pipe solar collector at filing ratio range from 30% to 60% was conducted experimentally. Results show that the maximum increased in the thermal efficiency reached 67% corresponding to without heat pipes at mass flow rate 0.009 kg/s. The experiment results showed similarity between the two refrigerants.

Piotr Felinski and Robert Sekret [5] - this investigation a novel concept of using a phase change material (PCM) to store thermal energy directly within a heat pipe evacuated tube collector equipped with a compound parabolic concentrator (CPC). The excellent insulating properties of evacuated tubes and the use of latent heat are significant advantages of a PCM integrated evacuated tube collector/storage (ETC/S) over traditional solar water heaters. However, during the charge cycle of the ETC/S, direct solar radiation only reaches the exposed area of the evacuated tubes, which results in uneven heating of the PCM due to a lower energy input in the shaded area. This can be prevented by using a CPC to concentrate the solar radiation on the shaded area of the evacuated tubes, thereby raising the temperature of the PCM and quantity of stored heat. Therefore, a polished, thin aluminum sheet was used as low cost CPC with a concentration ratio of 1.2x. Technical grade paraffin with an onset melting temperature of 51.24 C was used as the PCM. The results from this study showed that the application of the CPC caused the temperature of paraffin on the shaded side of the evacuated tubes to increase more rapidly, especially during and after melting of the paraffin. Furthermore, the use of a CPC in a PCM integrated ETC/S improved the average gross charging efficiency from 31% to 36% and the maximum charging efficiency from 40% to 49%.

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