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Evacuated Tube Solar Collectors: A Review

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Abstract: ***In the present review paper, the existing evacuated tube solar collectors are studied with their applications. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollution.one of most promising renewable energy source is Solar energy, the solar radiation incident on the surface of the earth can be conveniently utilized for the benefit of human society. Solar energy collectors act as heat exchangers that convert the solar radiation energy into internal energy of the transport medium. The evacuated tube solar collectors are common and can achieve higher temperature than flat plate collector ranging from 50-130 ℃. Heat extraction from long thin absorber is the main problem with evacuated tube solar Collector, different methods are used to extract heat from evacuated tubes. Some unique advantages of evacuated tube solar collector over other types of collector are listed. The available literature is reviewed to understand the construction, arrangement and application of evacuated tube solar collector.***

Keywords: Renewable energy, Non-renewable energy, Evacuated U-tube collector, Heat pipe evacuated tubes collectors, Water in glass evacuated tube collector

1. Introduction

There are two types of energy renewable and non-renewable the difference is that some renew at faster rate than others making them more sustainable than those that do not renew very fast (berlin energy transition dialogue, March, 2017). Renewable energy obtained from sources that are essentially inexhaustible.

Examples like solar power, wind power, geothermal energy, tidal power and hydroelectric power. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollution (Maxi brochure 05). We are blessed with Solar Energy in abundance at no cost. The solar radiation incident on the surface of the earth can be conveniently utilized for the benefit of human society. Solar collectors are devices that are used to harness the energy from the sun, convert the income solar radiation into useful heat energy, being the key element in solar energy utilization Systems. Solar energy collectors act as heat exchangers that convert the solar radiation energy into internal energy of the transport medium.

The evacuated tube solar collectors are common and can achieve higher temperature than flat plate collector ranging from 50-130 ℃. They are made up of vacuum glass tubes. The absence of air highly reduces convection and conduction thermal losses. They also have barium getter component in common, the main role of getter is to maintain the vacuum inside the tube and to give a visual indicator of the vacuum status. The silver colour of the barium will turn while in case of presence of air indicating the bad functioning conditions of the evacuated tubes can be identified Soteris A. Kalogirou, [9]. Evacuated–tube collector can get very hot, exceeding the boiling point of water and can cause significant issues in an existing domestic solar water systems. You need to use your use your hot water every day to ensure the temperature does not overheated in the tank or end usage. Mixer are easily installed just after the last hot water tank and mix your regular(cool) water supply with the hot water, to ensure the temperature never exceed a set limit.

Heat extraction from long thin absorber is the main problem with evacuated tube solar collector. Following methods are used to extract heat from evacuated tubes M.A. Sabiha [5].

- Heat pipe
- Flow through absorber
- All glass tube
- Storage tubes

Advantage of evacuated tube solar collector over other types of collector

- It can be used in any climate, from extremely hot to extremely cold weather.
- Its high level of vacuum ensures the operation under cold weathered conditions. Evacuated tube solar collectors require lesser space and it is very easy to install.
- It can absorb the solar radiation from multiple angles, due its tubular design.
- Wind and low temperature have less of effect on the function of evacuated tubes.
- In case of damage the tube does not stop working or getting leaked but continue to work at lower efficiency.
- Since no water is flowing through the collector tubes and the tubes are hermetically sealed it does not suffer from corrosion problems as in the case with other solar collector types.

Limitation of evacuated tube solar collector

- Initial cost is high as compared to other collector
- Construction of evacuated U-tube collector is little bite complicated as compare to other collectors and thus proper handling required
- Some-times due to improper handling and maintenance temperature become very high due to lack of water in the tube and hence it causes a thermal shock so tube may crack and resulting vacuum to loose.

Two main categories of evacuated tubes can be identified.

1. **Direct flow evacuated tube collector**: has two pipes the run down and back inside the tube.one pipe is for inlet fluid and other for outlet fluid. Since the fluid flows into and out of each other tube, the tubes are not easily replaced. Also, should the tube break, it's possible that all of the fluid could be pumped out of the system. If a close loop is used or your water will flow out as in a broke pipe, it's an open loop is used. Direct flow principle different arrangements are possible; the working fluid passing through the collector tubes.

1.1 Evacuated U-tube collector (figure 1.1)
1.2 Water in glass evacuated tube collector (figure 1.2)
1.1 Evacuated tube solar collector with U-tube
Evacuated tube collector receiver consists of a copper U-tube inside a glass vacuumed tube.

The copper tube is surrounded by a cylindrical aluminium fin pressed on it. The fin enhances the heat transfer area between the inner glass absorber surface and the U-tube. The working fluid enters the collector inlet pipe, then it is evenly distribution to the U-tubes, absorbs heat and at the end, it is returned to the outer manifold pipe. The outer cylindrical glass transmits the rays to the inner glass tube, which conducts the energy to the absorber fin. The energy transformed into heat is conducted by the fin to the copper U-tube and finally absorbed by the working fluid which is water in this case.

1.1.1 Applications of U-pipe evacuated tube solar collector are as listed below Dilip Mishra and N.k.Saikhedkar [4]

- In industrial field e.g. power plant, steam power plant, in school and hospital
- In laundries, in space heating. Generally used in northern country for heating purpose of water like swimming pool as per the season
- It is used for domestic purpose e.g. electricity, water heating and in kitchen stuff.

Figure 1.1 shows a detailed schematic diagram of the evacuated tube.

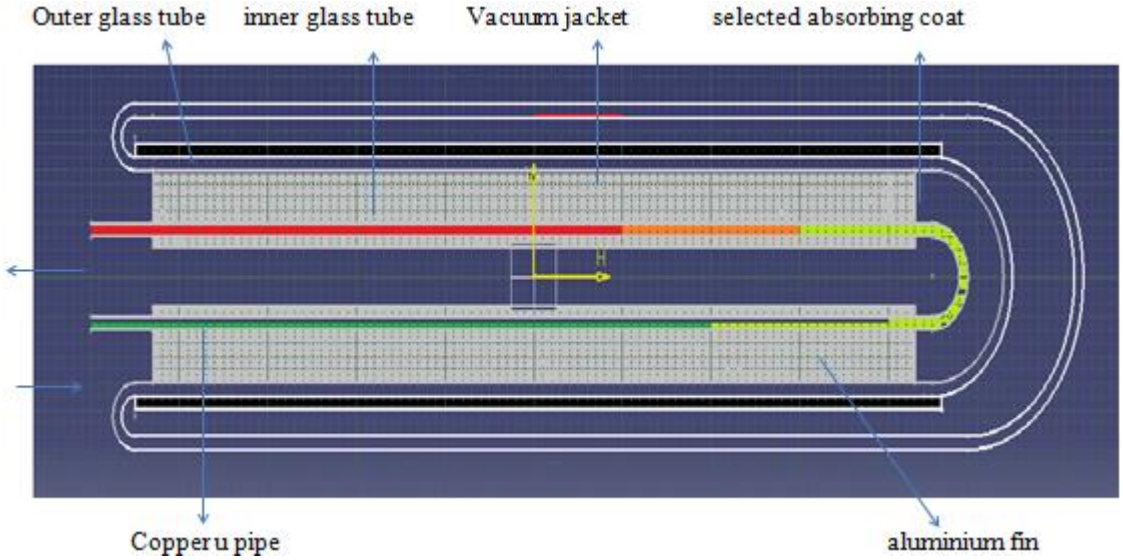

Figure 1.1: Evacuated tube with U-type heat extraction (Catia V5 R19)

1.2 Water in glass evacuated tube collector: evacuated tubes (figure 1.2) are the absorber of the solar water heater and they absorb solar energy converting it into heater and they absorb solar energy converting it into heat for use in heating water. Evacuated tube consists of two glass tubes made from extremely strong borosilicate glass. The outer glass is transparent to allowing light rays to pass through with minimal reflection and the inner tube is coated with a special selection coating (Al-Nickel/Al) which feature excellent solar radiation absorption and minimum reflection characteristics. The free end of tubes are fused together with each other and the air contained in the space between the two layers of glass is pumped out to expose the tube to high temperatures. This vacuum play an important role in the performance of the direct flow evacuated tubes.

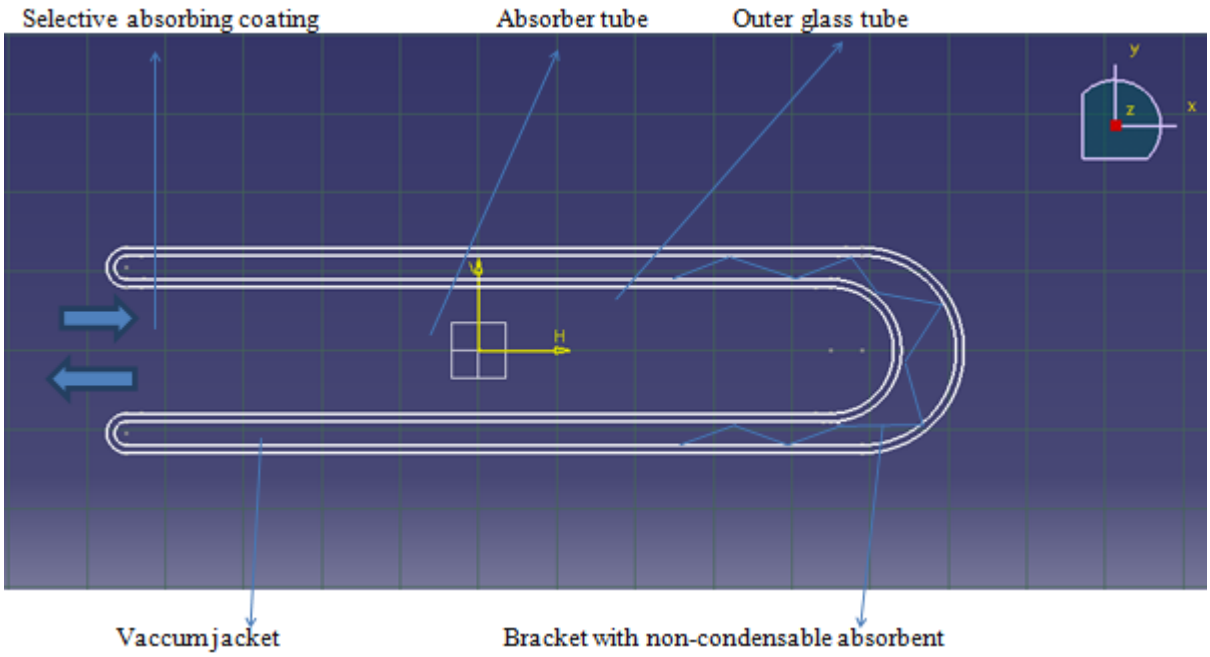

Figure 1.2: Water in glass evacuated tube collector

2. Heat pipe evacuated tubes collectors: contain a copper heat pipe, which is attached to a absorber plate, inside a vacuum sealed tube. The heat pipe is hollow and the space inside is also evacuated. Inside the heat pipe is a small quantity of liquid, such as alcohol or purified water plus specials additives. The vacuum enables the liquid to boil at lower temperatures than it would at normal atmospheric pressure, the liquid in the heat tube quickly turns to hot vapour and rises to the top of the pipe. Water or glycol, flows through a manifold and picks up the heat. The fluid in the heat pipe condenses and flow back down the tube. This process continues as long as the sun shines. Figure1.3 shows evacuated tube solar collector with heat pipe.

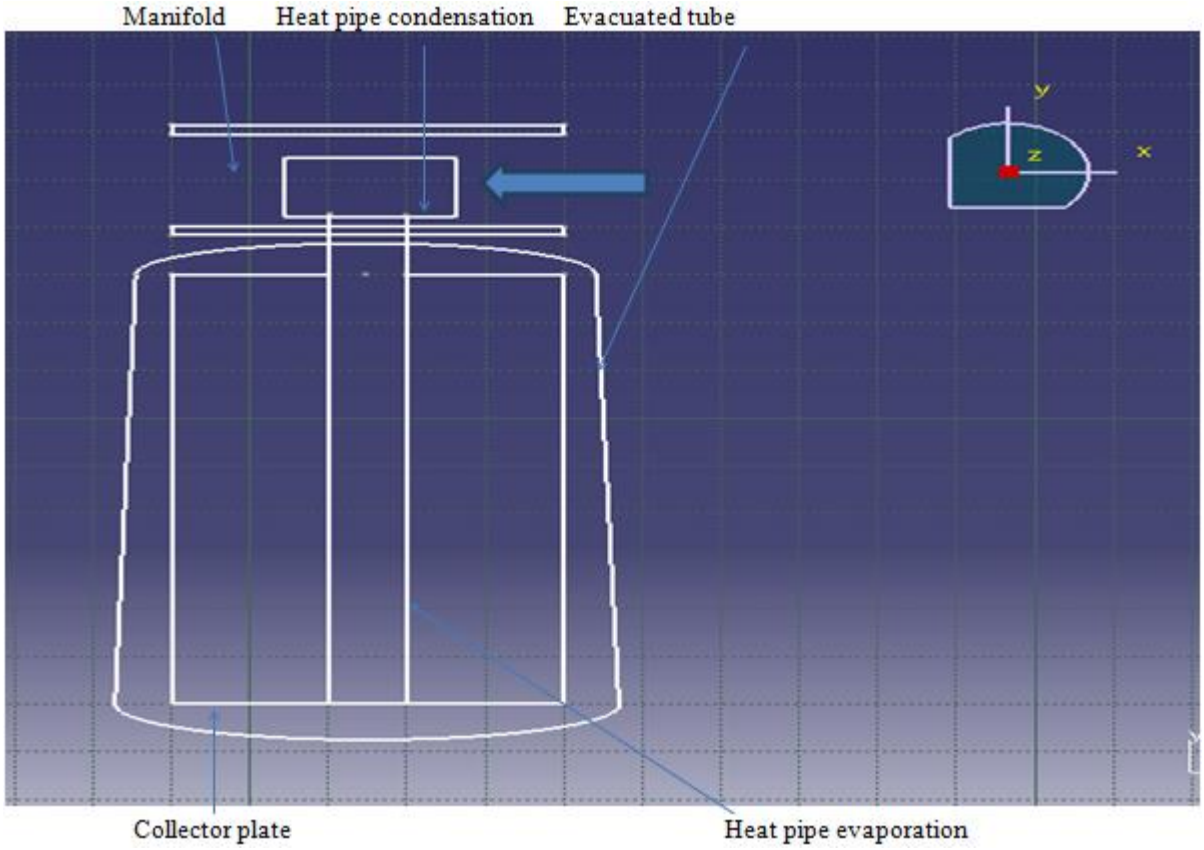

Figure 1.3: Evacuated tube solar collector with heat pipe

2. Literature Review

Soteris and Kalogirou [9] described various types of solar collector such as flat plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish, and Heliostat field collector with their application. This is followed by optical, thermal, and thermodynamic analysis of the collector and the description of the methods used to evaluate their performance these include solar water heater, space heating and cooling, heat pump and refrigeration, industrial process heating, steam generation, desalination, thermal power system and chemical application. Siva et al.[8] Investigated on the performance of the evacuated tube solar collector with heat pipe heat extraction method numerically and experimentally analysis. And see the duration of time required by the collector to gain the heat is less compared to other collector.

Aman and Pathak [2] explained the working model of evacuated tube solar collector, hybrid model and their application (solar water heater, solar cooker, solar dryer, solar desalination, air conditioning, heat engines, steam generation) and the authors reach on the conclusions that an evacuated tube collector is very efficient to be used at higher operation temperature and give some suggestion to overcome obstacles. Budihardjo, et al.[3] have studied the thermal performance of water-in glass evacuated tube solar water heaters and is evaluated using experimental measurements off optical and heat loss characteristics and a simulation model of the thermosiphon circulation in single-ended tubes. The performance of water-in-glass evacuated tube solar collector system are compared with flat plate solar collector shows that an evacuated tube system with 30 tubes has slightly lower energy saving than a two panel flat plate system. Xinyu et al.[10] have worked on experimental investigation of the higher coefficient of thermal performance for water-in glass evacuated tube solar water heater in china. In this test, the performance of more than 1000 water-in-glass evacuated tube SWHs according to Chinese standards and found that the heat loss from the storage tank and capacity of the solar collector affected their thermal performance. In this study, they found that a shorter evacuated tube exhibited better thermal performance than longer tube. A shorter tube is also less likely to be damaged during transportation. The experimental results showed that the distance between the centres of the tubes will have an effect on the thermal performance of a water-in-glass evacuated solar water heater without diffuse reflectors. Zambolin et al [11] carried out thermal performance comparisons in two types of the flat plate and vacuum tubes solar collectors. They concluded that, in the steady-state conditions, the slope of the linear regression instantaneous efficiency with increasing heat losses in flat plate collector is greater than the water-in-glass ETCs.

Adel et al.[1] conducted an experimental study to compare the performance of both FPC and a heat pipe ETC for domestic water heating system application. The collector efficiencies were found to be 46.1% and 60.7% and the system efficiencies were found to be 37.9% and 50.3% for FPC and heat pipe ETC, respectively.

3. Conclusion

Evacuated tube solar collectors are more efficient than flat plate collector in the temperature range of 50-200 ℃ in the application of high temperature used domestic and industrial application. Because advantage of vacuum created between tube is type of collector very common and effective in cooled climate. Since it can harvest both beam and diffuse radiations more efficient than concentric types of solar collector. Since the tube is independent in case of damage only system efficiency is decrease but the other types of collector totally system damage.

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