A Review: Advancement and Performance of Heat Pipe - Solar Collectors

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Abstract— *With the advancement of our human race, we have utilized a huge amount of fossil fuel to generate power and this has not only caused scarcity of fossil fuels but has harmed our environment and climate. Thus, we need to develop and implement new green renewable energy conversion methods. In this paper, we have discussed the advancement and performance of solar collectors, namely flat plate and evacuated tube solar collectors. A study of different types of fluids used in heat pipes and its performance has been compiled from different research papers, journals and books. We have also summarized housing and industrial applications of solar collectors. Established from the accessible literatures, we can review and conclude the need of solar collectors and that the efficiency of evacuated tubes is higher than any other collector. Nevertheless, the cost of manufacturing and maintenance is high for evacuated collectors, thus sometimes it is better to use flat plate collectors using heat pipes for efficient results.*

Keywords— Energy, Heat pipes, Operational fluids, Performance, Solar collector.

I. INTRODUCTION

In our household, energy required to heat water amounts to a large percentage of total energy consumption. Hence, it is sensible to use solar energy for heating of water. Solar energy can be harnessed with help of solar collectors, which collects heat by absorbing sunlight. Solar collectors are mainly of three types: flat plate, focused and evacuated tube solar collectors. The absorbed sunlight then heats up the heat pipes inside the solar collector and this heat is transferred to the required container of liquid which need heating via condenser of the heat pipe. Heated liquid is then collected in an insulated chamber to preclude heat loss.

Heat pipe is a heat-transfer apparatus that combines the principles of phase transition and thermal conductivity mutually to transfer heat from one place to another. It has three main sections: evaporation section, adiabatic section, condensation section. It is a concealed tube, which contains a working fluid surrounded by wick. The fluid is evaporated inside the evaporation section and the vapours travel through the adiabatic section, without any heat transfer to environment, to the condenser where they condense and the heat is transferred to the environment. Heat tubes have small thermal resistance for heat exchange than any other metals. Many of the limitations or problems of solar collectors can be solved by using a compacted heat pipe solar collector structure.

II. EVACUATED TUBE SOLAR COLLECTOR

This solar collector is a vacuum-sealed tube, which contains heat pipe inside it. The space required by evacuated tube solar collectors is comparatively lower than other solar collector and thus can be fitted on smaller roofs and in areas where there is space restriction. Evacuated tubes are largely more productive than most flat plate collectors are, however because of this expanded effectiveness and their intricate structure they are additionally expensive. The absorber is attached in an evacuated and pressure-resilient glass tube hence, conductive and convective damages are lessened thus productivity is increased. These glass tubes are then coated with reflective material from the inside to prevent heat loss from radiation.

In the present scenario, evacuated tubes are used in two ways: one by using heat pipes inside them and the other method is direct fluid method. In the direct fluid method, the fluid is directly filled inside the tube and heated. Even though this method is more efficient, we cannot accommodate a large amount of fluid inside the evacuated tube thus we use heat pipes to transport the heat from the solar collector to a reservoir.

2.1 Flat Plate Solar Collector

Flat plate collectors are the most widely recognized sunlight based equipment. They comprise of a walled in area containing a dim shaded plate with liquid flow paths, and a see-through shield to permit transmission of sunlight into the arena. These usually take up more space than evacuated tube collector takes, but are cheap to manufacture. The most common configuration found in the flat plate solar collector is when a direct piping system is used under the collector to heat up water.

In the present scenario, heat pipes are being incorporated inside flat plate solar collectors. This has caused the reduction in the size of solar collector and has increased the efficiency of the overall system. The copper heat pipes are attached to aluminium fins for efficient absorption of heat. A dark covering is connected to the sun-confronting side of the fins to gather and retain sun's heat. A typical fin is covered with flat black enamel paint.

2.2 Operational Fluid inside Heat Pipe

Operational fluid is the most important element in a heat pipe. Heat pipes efficiency is calculated based on the properties of this fluid. The fluid needs to be inert in nature so that it does not react with environment chemically and should have specific thermal characteristics as per the application.

In the present scenario, we are using nanotechnology to develop Nano-fluids that have a colloidal disturbance of Nano sized solid elements in place of common operational fluids. The fluids that we have been using earlier have particle size in mm or µm and this can choke the microscopic channels of new miniaturized technologies. Hence, we have developed Nano-fluids, which have particle size between 1-100 nm.

2.3 Applications

Solar collector and heat pipes have a wide range of application over industrial and household application. It is used to heat water for bathing, food preparation, swimming pool heating, and air-conditioning in the household. In industry, it is used to generate electricity by producing steam.

III. LITERATURE REVIEW

Kamal A.R. Ismail et al. [1] performed an evaluation study between speculative estimates and practical results of a flat-plate solar collector consisting heat pipes. He used methanol as the operational fluid inside the heat pipe. The evaporators of the heat pipe were implanted under pressure in the flat plate and the heat was transferred to the required reservoir through the condenser. The condensers were kept wickless and inclined at 15 degree more than the inclination wick at the evaporators to aid the coming back of the condensate to the evaporators. He discovered that the immediate efficiencies of the heat pipe are lower than the traditional collector in the first part of the day and greater when the heat pipes achieve their working temperatures.

Wenbo Fang et al. [2] used microencapsulated phase-change material (PCM) as a heat-transport medium in an evacuated heat pipe solar collector. He then compared the results of the efficiency of the heat pipe using PCM to that of a heat pipe using H2O as the operational fluid. The results were clear with an average efficiency of solar collector being higher in case of PCM.

Lee et al. [3] used Nano fluids with oxide particles. Using hot wire method, he measured thermal conductivities of Al2O3 and CuO nanoparticles dispersed equally in de-ionized water and ethylene glycol. The heat transfer effect of CuO nanoparticles were greater than Al2O3 particles.

International Journal of Engineering Research & Science (IJOER)
ISBN: [978-93-5321-411-1] ISSN: [2395-6992] [Vol-5, Issue-3, March- 2019]

Jorge Facão et al. [4] compared the mathematical model, which is based on energy equilibrium equalities assuming a quasi-steady state condition to the experimental model. A solar collector, with an opening space of about 0.1m^2, was practically checked. Results demonstrated a solar collector effectiveness of 64% and a general loss of 5.5 W/(m^2K), for a non-selective surface covering. There was a decent understanding among mathematical and trial outcomes.

M.A. El-Nasr et al. [5] used a wickless heat pipe solar collector. He used acetone, R-11, and water as operational fluid at changed charging pressures. He discovered that the best liquid fill in the wickless heat pipe with solar applications occurred when there was temperature flattening in the collector and it was 0.7. The appropriate operational fluid for more extensive temperature leveling is R-11 compared with acetone or water.

K. Sivakumar [6] uses elliptical heat pipe in a flat plat solar collector. He checked the solar collector with a slope angle of 11°. In addition, he performed experimental investigation of the influence of condenser size / evaporator size (Lc/Le) proportion, of the heat pipe. Copper tube were used as the tube material with methanol as operational fluid inside the heat pipe. These heat pipes were attached to the absorber plate of the solar collector and the execution of elliptical heat pipe has been calculated, and outcomes were compared. He demonstrated that elliptical heat pipe solar collector whose Lc/Le ratio is 0.1764 attained higher immediate efficiency.

P.Selvakumar et al. [7] formed a relation between the thermal performance of a solar water warmer and its structural inclination. He carried out the study at angles, 0°, 15°, 30°, 45°, 60° and 90°, to find out the temperature characteristics.

Bin Du et al. [8] in the Southeast University, China, planned an experimental way for checking solar collectors. He has described the way in which he planned for the testing and has recorded the results in the paper. He used H2O as the operational fluid. The examination is concentrated on the immediate effectiveness and its associations with the receiver and absorber spaces, the operative heat capacity, and the pressure drop.

Gambo Buhari Abubakar et al. [9] calculated the thermal performance of solar flat plate collector. He used the direct heating of water method and not the heat pipes. H2O was allowed to flow from end to end through the fixed copper pipes in the collector and he kept a measure of temperatures at the entry and exit in an interval of 5 minutes. He found out that the exit temperature of water were contingent upon the external climate like intensity of solar radiation and cloud shield.

IV. CONCLUSION

Humanity is at a stage where our existence is in a threat due to adverse climate conditions and due to global warming. Hence, we need to implement green technologies wherever possible and using solar collectors is one option of many. Selecting the most ideal and proficient solar collector can be contingent on the requisite temperatures of the warm water in the structure and the environment where the system is fitted. The suitability of a solar collector to a required system relies upon the evaluated effectiveness of appropriateness to the application. The evacuated tube collectors have a vacuum seal, which lessens the losses through conduction, and convection that allows the collectors to function at greater temperatures than flat plate collectors. Thus, evacuated tube solar collectors are more efficient than flat plate solar collectors are. Further, flat plate collectors face a huge problem of corrosion, which is not seen in evacuated tube collectors. In addition, the development of Nano-fluids has resulted in high performance of solar collectors as they have high thermal conductivities and heat transfer co-efficient as compared to previous operational fluids. Moreover, it has been demonstrated tentatively that, for a given concentration level, the thermal conductivity of the Nano-liquids increments with a decline in molecule diameter. Since flat plate collectors are cheap and easy to manufacture, we can use them by increasing their efficiency by using heat pipes inside them.

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ISBN: [978-93-5321-411-1] ISSN: [2395-6992] [Vol-5, Issue-3, March- 2019]

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