Experimental Validation of Heat Pipe Solar Collector For Water Heating- a Review

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February 24, 2021

Experimental Validation of Heat Pipe Solar Collector For Water Heating- A REVIEW

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Abstract-
Nowadays 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 water heating is the prime application of solar energy. The problem faced by the existing solar water heating system is periodic inspections, maintenance, time to time component may need repair or replacement and also sufficient quantity of hot water is not available during cloudy/rainy days. Hence to overcome the above problem by the use of heat pipe concept which utilizes the low boiling temperature fluid to increase the heating efficiency, the objective of present work is to increase the heating efficiency solar water heater using low boiling temperature fluid.

Keywords— Solar water heater, concept of heat pipe, low boiling temperature fluid (working fluid), thermosiphon.

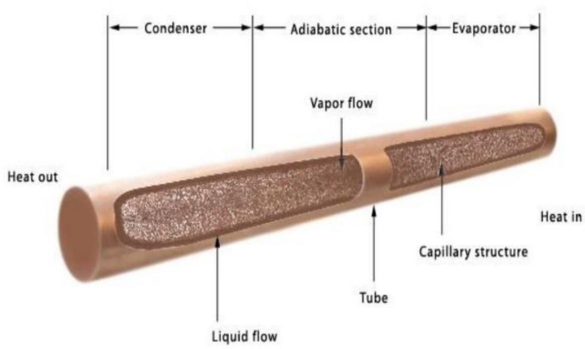
I. INTRODUCTION

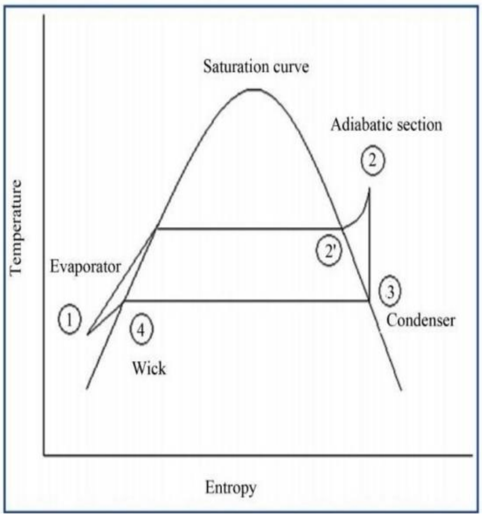
The demand for energy is increasing at a substantial rate as the economy of the populous developing countries in growing Currently, this high energy demand mainly depends on fossils fuel resources. And from the difficulty of meeting the high energy demand, the issue of environment and sustainability has led to a critical concern on power generation and its utilization. Fossil fuels are sources of emissions and are unsustainable due to their dwindling reserves, price rise and resource not evenly distributed in the world Geopolitical instability in resource area is also a major concern. Following this, today's agenda is power production from renewable resources which are environmentally benign and sustainable. Renewable energy sources such as solar energy are the long-term options to substitute conventional energy systems.

Solar water heaters are the most developed renewable energy technologies used in the world. For the past several years, conventional flat plate collectors have been well studied and developed. Their relatively low cost, lower maintenance and easy of construction have made these systems very competitive and are widely used all over the world specially for low temperature thermal systems. Conventional flat plate solar collectors use water pipes attached to the collecting where water circulates either naturally or forced inside the pipes and so transfers the best collected by the plate to the storage tank.

A. Working Principle of Heat Pipe*:*

A heat pipe heat exchanger is a simple device which is made use of to transfer heat from one location to another, using an evaporation-condensation cycle. The heat input region of the heat pipe is called evaporator, the cooling region is called condenser. In between the evaporator and condenser regions, there is another region known as adiabatic region. Components of Heat Pipe are Container, Working Fluid and Wick or Capillary Structure. In a solar collector, the condensation zone is arranged to be at a higher level than the evaporation zone so that the heat transport medium condensed in the condensation zone returns to the evaporation zone under the influence of the gravity. In that case there is no need for a capillary wick structure. In a solar collector, the condensation zone is arranged to be at a higher level than the evaporation zone so that the heat transport medium condensed in the condensation zone returns to the evaporation zone under the influence of the gravity. In that case there is no need for a capillary wick structure.





This cycle is drawn between temperature and entropy. Otherwise known as T-S diagram. In this T-S diagram, we can know about Phase Changing process occurred in Evaporator and Condenser Section. The following process are discussed below processes,

Process (1-2) - Heat applied to evaporator (1) through external sources vaporizes working fluid to a saturated (2'). Process (2-3) - Vapor pressure drives vapor through adiabatic section (3) to Condenser.
Process (3-4) - Vapor condenses, releasing heat to a heat sink. Process 4-1 Capillary pressure created by menisci in wick (4) pumps condensed fluid into evaporator section.

B. CONTAINER:

The function of the container is to isolate the working fluid from the outside environment. The most common material available for the container copper, aluminum, and stainless steel. Copper is eminently satisfactory for heat pipes. The Container material mainly depends on compatibility, thermal conductivity and porosity. Aluminum and stainless steel which are readily available and can be obtained in a wide variety of diameters and wall thicknesses in tubular form. Pure copper tube is suitable, the oxygen-free high conductivity type is preferable.

C. WORKING FLUID:

In a thermodynamics system, the working fluid is a liquid or gas that absorbs or transmits energy. Prime requirements of working fluids are good thermal stability, high latent heat, low liquid, vapor viscosities, high surface tension and acceptable freezing or pour point. Water is most commonly used working fluid for copper envelope, which is mostly used for electronic cooling applications, since it is occurring in low to moderate temperatures, hence it will provide highest liquid transport factor. In aluminum envelope, ammonia is the most commonly used working fluid for spacecraft thermal control.

D. EVAPORATOR SECTION:

The heat passes from the external source is first enters this section. The heat pipe is a closed evaporator system consisting of a sealed, hollow tube whose inside walls are lined with a wick.

E. ADIABATIC SECTION:

The vapor flow through between evaporation section to condensation section, no heat transfer [Q=0].

F. CONDENSER SECTION:

The saturated liquid vaporizes and travels to the condenser, where it is cooled and turned back to a saturated liquid. In this section, it condenses a fluid from gaseous state to liquid.

G. WICK:

The wick function is to generate capillary pressure to transport the working fluid from the condenser to the evaporator. The maximum capillary head generated by a wick increases with decrease in pore size. Therefore, wick permeability is inversely proportional to pore size. The purpose of a wick in the heat pipe is to provide the necessary flow passages for the return of the condensed liquid and to maintain surface forces at the liquid-vapour interface for development of the required capillary pumping pressure.

II. LITERATURE REVIEW

Pradeep Kumar K V (1), Srinath T(2) , Venkatesh Reddy(3) [1] stated that, from literature, This research has its own special features. The collector cannot be easily tilted and oriented, as per the position of the sun with tracking mechanism and external power will be needed. The maintenance cost is minimum and hence economical. Running cost is nil. The labor cost is minimized on account of its simple design. Although the research has its own limitations, that is, intermittent supply of solar energy and converted energy cannot be stored; it is satisfactory considering the market survey report. The use of solar troughs is limited only to clear sunny days. The Solar trough tilting angle is limited to a maximum of 120°. The steam can produce scaling inside the metal absorber pipe and hence, non-corrosive coating should be applied in it.

Roshan D.Bhagat(1) , K.M.Watt(2) [2]comments that**,** The thermal resistance of closed loop pulsating heat pipe decreases with increase in the heat input for both methanol and acetone hence the thermal performance of closed loop pulsating heat pipe increases with increase in the heat input. Also, it was found from the experimental result that the thermal resistance offered by closed loop pulsating heat pipe with acetone as working fluid is comparatively less for the same heat input as compared to closed loop pulsating heat pipe with methanol as working fluid. Hence for the filling ratio of 60 % closed loop pulsating heat pipe with acetone as working fluid provides best thermal performance.

P.Ramkumar,M.Sivasubramanian(1),P.Raveendiran(2),R.Suraj(3),M.Mohamed Arabi(4) , M.Jothi Basu(5) [3] stated that ,Influence of heat pipe induced in the shell and heat exchanger have been experimentally investigated. To increase the heat transfer performance of the heat pipe, experimental investigations were carried out by considering the heat pipe in horizontal axis. Water is used as heat transfer fluid in the heat exchanger and methanol is used as working fluid in the heat pipe. The mass flow rate for the both hot water and cold water were considered, and temperatures of the hot water inlet were maintained constant throughout the investigation. Hot water mass flow rate as 50 lph to 90 lph, cold water mass flow rate as 25 lph to 45 lph and temperature of hot water at inlet varying from 40ºC to 60ºC are considered for the investigation. For varying mass flow rate and inlet temperature the overall heat transfer coefficient, heat transfer rate and effectiveness of the heat exchanger was investigated. The investigations result states more effectiveness is obtained with the hot water mass flow rate 90 lph and temperature of hot water inlet 60ºC.

A.A.Walunj(1),F.Z.Pathan(2),A.A.Shaikh(3),Ahmed Kadhim Hussein (4) [4] :This paper describes the research results of heat transfer characteristics of various types of heat pipes using nanofluids as working fluids. Results of the limited number of available references have shown that nanofluids have great application prospects in various heat pipes. Adding nanoparticles to the working liquid can significantly enhance the heat transfer, reduce the total heat resistance, and increase the maximum heat removal capacity. At the same time, there are still some problems and challenges on the mechanisms of the heat transfer enhancement and the actual applications. The present research of nanofluids in heat pipes is still at its initial stage and needs further development.

B.Naga Murali(1) , Kudumala Govardhan reddy(2) ,P.Kranthi Kumar(3) [5], This paper states that, All in all it is necessary to understand all the basic theories of heat and mass transfer to understand the working principle of a heat pipe. On a first look a heat pipe seems to be a very easy tool to transport energy, but if one looks closer, it is a very complex heat and mass transfer process which takes place in a heat pipe. First of all, one has convective heat transfer in the adiabatic transport range and other has convection through porous materials (cotton) also. The second major point is mass transfer due to vaporization, condensation & also through porous media. Furthermore, there are capillary effects like pressure effects and heat conduction effects have been involved which create a complex structure of heat transfer, where a lot of knowledge is involved. And all these points can be treated as an own problem. In this project heat pipe has been fabricated by using copper material as a container and Aluminum for fins. In the place of copper, sintered powder has been used with cotton as a wick material in order to produce cooling effect in a cheapest way. Here the two working fluids are Acetone and Methanol. The rate of heat transfer for methanol as a working fluid = 33.86 W. The rate of Heat transfer for Acetone as a working fluid = 33.149 W. By comparing both working fluids the rate of heat transfer is nearer but methanol is costlier than acetone so acetone can be used as a working fluid in heat pipes in order to decrease the cost.

Devendra Yadav (1), Simbal Pal (2), Saddam Quraishi(3),Mohammad Farhan(4) [6], In this work, heat pipe and thermosiphon have been made at very low cost. A new manual operated vacuum pump is developed for the perfect evacuation of the heat pipe. The fabricated heat pipe performance is analyzed for the different coolants, evaporator temperature and the angular positions. Water heat pipe (thermosiphon) has a better performance at 60°. For acetone heat pipe, its heat transfer capability is maximum at horizontal position. Due to the smaller cavity space for vapour transport in acetone heat pipe, it has lower heat transportation capability compared to the water thermosiphon.

E.AZXD(1),F.BXHAR(2),F.MOZTARZADEH(3)[7], This paper presents a theoretical and experimental study of a solar water heater using gravity-assisted heat pipes with methanol as the working fluid. The heat pipe solar water heater has been designed, constructed and tested at the Materials and Energy Research Centre (MERC). In this study the experimental results are compared against the predictions described in this paper.

Sethuraman Ramasamy(1), Pakkirisamy Balashanmugam (2)[8] the paper states that, The radiation, heat gain and efficiency of the solar water heater are more when fin is used. In the morning, it is nearly same but in the afternoon the graph goes high. In general view, during 11am to 2pm, at this place, the solar intensity is high. Also, the solar water heater performed well in this condition and received almost all heat. This is the reason behind the increase in the efficiency. Solar water heaters with fins have better efficiency than that of without fins.

III. SHORT COMING OF LITERATURE REVIEW

Heat pipes must be tuned to particular cooling conditions. The choice of pipe material, size and coolant all have an effect on the optimal temperatures at which heat pipes work. When heated above a certain temperature, all of the working fluid in the heat pipe vaporizes and the condensation process ceases in such conditions. The heat pipe's thermal conductivity is effectively reduced to the heat conduction properties of its solid metal casing alone. As most heat pipes are constructed of copper (a metal with high heat conductivity) an overheated heat pipe will generally continue to conduct heat at around 1/80 of the original flux via conduction only rather than evaporation. In addition, below a certain temperature, the working fluid will not undergo phase change and the thermal conductivity is reduced to that of the solid metal casing. One of the key criteria for selecting a working fluid is the desired operational temperature range of the application Most manufacturers cannot make a traditional heat pipe smaller than 3 mm in diameter due to material limitations (though 1.85 mm thin sheets with embedded, flattened heat pipes can be fabricated, as well 1.0 mm thin vapor chambers.

Metal	Density (ṕ) kg/m³	Specific heat J/kgk	Thermal conductivity (K) W/mk
Copper	8954	383	386.0
Aluminum	2707	896	204.2

Table 1. Property values of metals

Working fluid	Compatible materials
Water	Stainless steel, copper, nickel
Methanol	Stainless steel, iron, nickel, copper
Acetone	Aluminum, Stainless steel, Copper, nickel
Freon-11	Aluminum
Freon-21	Aluminum, iron

Table 2. Suitable materials as to working fluids.

IV. CONCLUSION

In this paper, we discussed briefly about the heat pipes construction, various types of solar heat collector, working fluids used in heat pipes, different types of wick materials, heat pipe working and its application. Heat transfer characteristics of heat pipes seems to be growing continuously. It is also believed that many these new applications will be in the field of crystal growth. Heat pipes capable of operating in oxidizing atmospheres at temperatures in the range of 1100-1500 K. For Energy storage applications heat pipes where used transfer energy into underground storage are perhaps the most promising. Nano heat pipes are more advanced pipes used in aerospace. The several heat pipe concepts studied in this paper should provide seeds for thought on improving heat pipe performance capability.

ACKNOWLEDGMENT

I would like to express my sincere thanks to **DR.U.C. Kapale, Head of Department of Mechanical Engineering, Sanjay Ghodawat University,Atigre, Kolhapur.**

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