Review on Enhancing the Performance of an Evacuated Tube in Solar Collector using Heat Pipes

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Abstract— Solar energy is a glowing light and heat from the sun that is hardnessed using a variety of ever-developing technologies for instance solar heating, photovoltaics, solar thermal energy, solar architecture and artificial photosynthesis. The heat pipe is a modern device capable of transfer large quantities of heat throughout relatively small cross-sectional areas, and with very little temperature differences. Evacuated tube is the Most vacuum tube collectors in use in middle Europe use heat pipes for their core instead of passing liquid directly through them Direct flow is more widespread in China. Evacuated heat pipe tubes (EHPTs) are composed of various evacuated glass tubes each containing an absorber plate attached to a heat pipe. The heat is transferred to the fluid (water or an antifreeze mix—stereotypically propylene glycol) of a domestic hot water or hydronic space heating system in a heat exchanger called a "manifold". The manifold is wrapped in insulation and enclosed by a protective sheet metal or plastic case. The vacuum in the internal portion of the evacuated tube collectors have been confirmed to preceding more than 25 years, the reflective coating designed for encapsulated in the vacuum inside of the tube, which will not damage until the vacuum is lost.

Key words: Solar Collector, Enhancing the Performance of an Evacuated Tube

I. INTRODUCTION

The most specific Solar Energy definition is liveliness from the sun. There are two kinds of solar energy are thermal energy and electric energy. The sun's diameter is 1.39E9 m which is 120 times larger than earth and the aforementioned thing's distance from earth is 1.495E11 m. The effective blackbody temperature of sun is 5777 K. In 1800s A.M. Perkins and also

J.Perkins established Perkins tube and in 1944, R.S.Gaugler familiarized the usage of a wicking structure. Later in 1964, G.M.Grover issued research and coined the name "Heat Pipe". A heat pipe is a heat-transfer device that syndicates the principles of both thermal conductivity and phase transition to capably bring about the transfer of heat between two solid interfaces. At the hot interface of a heat pipe, a liquid interaction will be with thermally conductive solid surface turns into a vapour by engrossing heat from that surface. The vapour then travels inside the heat pipe to the cold interface. In this cold interface, the heat in the liquid is transferred to the cold surface of the pipe and then the vapour condenses back into a liquid with discharging the latent heat. The liquid then returns to the hot interface through any capillary action, centrifugal force, or gravity, and the sequence repeats. Due to the very high heat transfer factors for boiling and condensation, heat pipes are highly operative thermal conductors. For Copper envelope, the working fluid is Water, which is used in electronics freezing. This is the mutual type of heat pipe. For Copper or Steel envelope, the working fluid is refrigerant R134a, which is used for energy regaining in HVAC structures. In Aluminium envelope, the working fluid is Ammonia that is used for spacecraft thermal controller. Finally for Super alloy envelope the working fluid is Alkali Metal composed of Cesium, Potassium, and Sodium, which is used for high temperature heat pipes, most frequently used for adjusting primary temperature measurement devices. Evacuated Tube Solar Collector reduces conduction and convection losses and allows the collector to operate at high temperature. The conventional fluids, which are used as the heat transfer medium in solar collectors, suffer from poor thermal and heat absorption properties. It has been found that these conventional fluids have a limited capacity to carry heat up, which in turn limits the collector performance he tubes are made from low emissivity borosilicate glass (glass with a very low iron content that has superior durability and heat resistance) with an all-glass seal and they employ AL/N on AL selective coating, which enables the use of the whole solar energy range to generate heat.

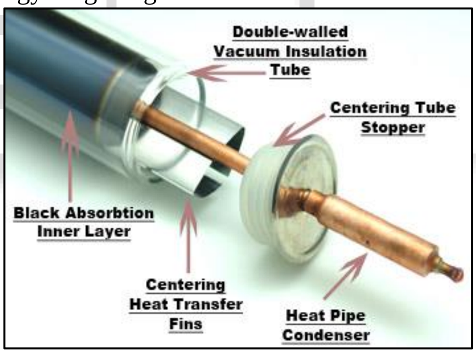

Fig. 1: Evacuated Tube

A. *Construction of Evacuated Heat Pipe*

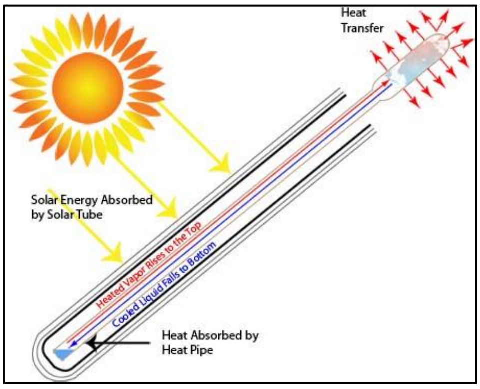

Fig. 2: Construction of Evacuated Heat Pipe

1) *Glass Tube*

Evacuated tube solar collector has two glass tubes they are outer tube and inner tube. Outer tube is made up of enormously strong glass that is transparent and with small reflection. It can transfer sun light through them. Outer tube

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is made by borosilicate glass. Inner tube is also made by borosilicate glass but covered with special selective coating like (Al-N) or Al. On the inner tube surface there is an absorber that collect the solar radiation

2) Heat Pipe

Some evacuated tube system is called a U-Tube, meaning that the glycol solution arrives and exists each tube as opposed to flowing diagonally a manifold. The SPP evacuated tube system uses what is called a heat pipe. A heat pipe allows for rapid heat transfer. The heat pipe itself is a copper tube that maintains a vacuum and contains a small amount of liquid. The low pressure (vacuum) in the copper pipes means that the liquid boils at a low temperature (about 30º C / 86º C), turning to steam and whoosh up to the heat of the heat pipe, carrying heat. It dumps the heat (to the glycol solution running through the header), shrinks and runs back down to repeat the process. The SPP heat pipes are made from Oxygen free copper of a very high purity, which is important to ensure the long-term longevity of the heat pipe. Ordinary water pipe copper (as used for the header) is not suitable for the heat pipe because over time oxygen and other trace element leak out, forming an air pocket in the top of the heat pipe. For Copper envelope, the working fluid is Water, which is used in electronics freezing. This is the most mutual type of heat pipe. For Copper or Steel envelope, the working fluid is refrigerant R134a, which is used for energy regaining in HVAC structures. In aluminium envelope, the working fluid is Ammonia, which is used for spacecraft thermal controller. Finally for Super alloy envelope the working fluid is Alkali Metal composed of Cesium, Potassium, and Sodium, which is used for high temperature heat pipes, most frequently used for adjusting primary temperature measurement devices. Evacuated Tube Solar Collector reduces conduction and convection losses and allows the collector to operate at high temperature. The conventional fluids that are used as the heat transfer medium in solar collectors suffer from poor thermal and heat absorption properties. It has been found that these conventional fluids have a limited capacity to carry heat up, which in turn limits the collector performance he tubes are made from low emissivity borosilicate glass (glass with a very low iron content that has superior durability and heat resistance) with an all-glass seal and they employ AL/N on AL selective coating, which enables the use of the whole solar energy range to generate heat.

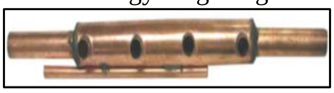

Fig. 3: Solar Collector Part

3) Advantages

a) Increased Life Expectancy

Heat pipes do not rely on thin metal surface for heat transfer and hence can be built out of more robust materials offering increased resistance to erosion. Integral design minimizing the adverse effects of metal expansion, heat pipes are free to expand and contract independently of the casing. No moving parts for virtually maintenance free operation. In operation, the temperature remains constant and which eliminates cold condensation spots thus eliminating low temperature corrosion.

b) Increased Flexibility

Because of their robust and simple construction heat pipe exchangers can be deployed in hitherto “difficult” heat recovery environments unsuitable for conventional exchanger designs. Units can be designed for bespoke applications and are very suitable for retrofit. The ability to remove or add heat pipes to an operational exchanger allows the system to be fine-tuned to ensure optimum heat recovery. This feature is entirely unique to heat pipe recovery units.

c) Increased Reliability

Each individual heat pipe operates independently hence, a single pipe failure will not incapacitate the system. Any failed heat pipes simply get replaced at the next scheduled maintenance event. Zero cross contamination through independent pipe operation. Various coatings and construction materials available to protect units against a variety of exhaust air conditions.

Industry	Heat Source	Typical Applications
Metal Processing	Melting/holding furnace, smelter, sintering machine	Preheat combustion air; hot water For process, heating or sanitary use
Food Processing	Baking ovens, vacuum pumps	Preheat combustion air; hot water for process, absorption chillers, heating or sanitary use
Construction Material	Cement, glass furnaces	Preheat combustion air; hot water For process, heating
Power Generation	Turbines, diesel generators	Pre-heat hot water for process, heating or sanitary use; Pre-heat heavy fuel oil
Waste processing	Incinerators	Pre-heat hot water for process, heating or sanitary use
Commercial Buildings	Heating boilers	Pre-heat combustion air or boiler feed water; warm water for process, heating or sanitary use

Table 1: Typical Applications

B. Process used in Heat Pipes

A heat pipe is a closed evaporator-condenser system consisting of a sealed, hollow tube whose inside walls are lined with a capillary structure or wick. Thermodynamic working fluid, with substantial vapor pressure at the desired operating temperature, saturates the pores of the wick in a state of equilibrium between liquid and vapor. When heat is applied to the heat pipe, the liquid in the wick heats and evaporates. As the evaporating fluid fills the heat pipe hollow center, it diffuses throughout its length. Condensation of the vapor occurs wherever the temperature is even slightly below that of the evaporation area. As it condenses, the vapor gives up the heat it acquired during evaporation. This effective high thermal conductance helps maintain near constant temperatures along the entire length of the pipe. Attaching a heat sink to a portion of the heat pipe makes condensation take place at this point of heat transfer and establishes a vapour flow pattern. Capillary action within the wick returns the condensate to the

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evaporator (heat source) and completes the operating cycle. This system, proven in aerospace applications, transmits thermal energy at rates hundreds of times greater and with a far superior energy-to-weight ratio than can be gained from the most efficient solid conductor.

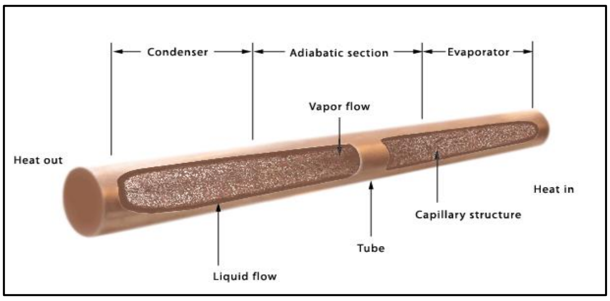

Fig. 5: Section of Heat Pipes

C. *Methodology Used*

Passive thermal management refers to cooling technologies that rely solely on the thermo-dynamics of conduction, convection and radiation to complete the heat transfer process. These technologies are the most commonly used, the least expensive and the easiest to implement. The most frequently employed passive cooling device is the heat sink. Heat is transferred from the component to the heat sink through conduction and then dissipated through the heat sink's surface into the ambient air through natural convection.

D. *Working Fluid Properties*

Medium	Melting Point	Boiling Point
Hydrogen	-227	-261
Nitrogen	-210	-196
Ammonia	-78	-33
Pentane	-130	28
Acetone	-95	57
Ethanol	-112	64
Water	0	100
Potassium	62	774
Sodium	98	892
Silver	960	2212

Table 2: Working Fluid Properties

E. *Working of Glass Evacuated Tube*

Evacuated tube solar collector operates on the basic principle of using the light from the sun to heat liquids. The working fluids remain at saturated conditions as long as the operating temperature is between the triple point & the critical state.

A typical heat pipe consists of three sections

- Evaporator or heat addition section,
- an adiabatic section,
- a condenser or heat rejection section.

When heat is added to the evaporator section of the heat pipe, the heat is transferred through the case and reaches the liquid.

When the liquid in the evaporator section receives sufficient thermal energy and liquid get vaporizes. The vapor carries the thermal energy through the adiabatic section to the condenser section, where the vapor is condensed into the liquid and release the latent heat of vaporization. The condensate is pumped back from the condenser to the evaporator due to gravity. The water, which passes over the manifold tube, gets heat by copper heat pipes .The vapor which present inside the heat pipes is used to heat the water, which passes through the manifold. The hollow copper heat pipes contain some fluids inside it. The hollow centre of the heat pipe is a vacuum so that even at the temperature of 30°c it enough to vaporize the fluid inside the heat pipe

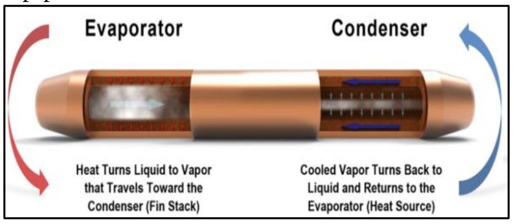

Fig. 6: Evaporator and Condenser

II. TYPES OF HEAT PIPE USED IN SOLAR COLLECTOR

A. *Flat Plate Collector*

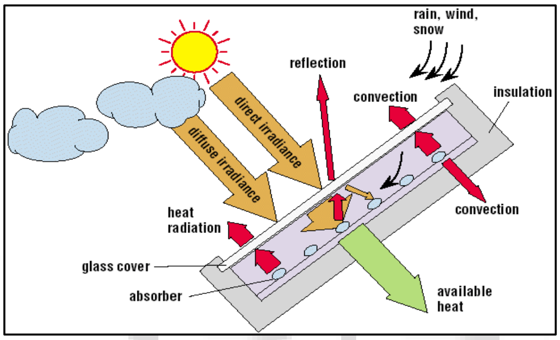

Fig. 7: Flat Plate Collector

Flat plate collectors contains of

- A dark flat-plate absorber,
- A transparent cover,
- A heat-transfer fluid, and
- A heat insulating backing.

A dark flat-plate absorber has a reedy absorber sheet that is assisted by a coil of fluid tubes. A grid or coil of fluid tubing is placed in an insulated casing with a glass or polycarbonate cover. In water heat panels, fluid is passed through tubing to transfer heat from the absorber to a shielded water tank. In flat plate collectors, first sun radiation is absorbed by absorber plate and converts solar energy into heat energy. This heat energy then transferred to the liquid (water) which is circulating through pipes, which attached to the absorber plate. Absorber plates are highlighted with "selective Coatings" which absorb and retain heat better than regular black paint. The absorber plates are made from copper or aluminium because this type of metal is good conductor of heat, which transmits more amount of heat, by calculation. Primarily copper is used for absorber plate and it is more exclusive, but a reduced amount of corrosiveness than aluminium.

B. *Evacuated Tube Collector*

There are different categories of evacuated tube collectors existing such as

- Glass- metal evacuated tube collectors
- Glass- Glass evacuated tube collectors.

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1) Glass –Metal Evacuated Tube Collectors

It is further secreted as concentric fluid inlet and outlet and separated inlet and outlet pipes according to flow of fluid in pipes. There is a single glass tube in concentric fluid inlet and outlet tube.

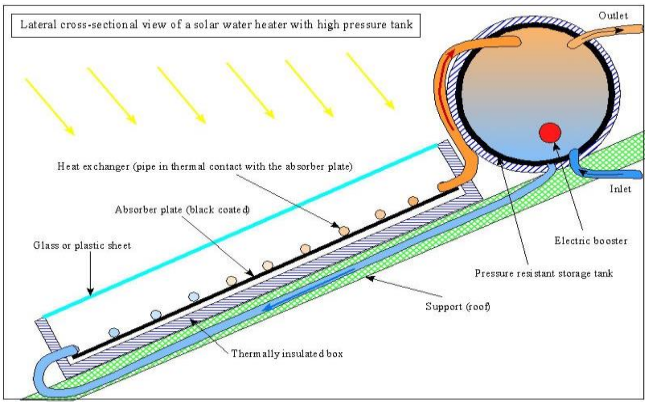

Fig. 8: Glass-Metal Evacuated Tube Collector

There is a copper heat pipe or water flow pipe with attached fin is inside the tube. In this type of construction, each single pipe and absorber fins are free to rotate in any direction (angle) even if the collector is mounted horizontally.

Glass- metal with separated inlet and outlet pipes evacuated tube collectors are of traditional type collector. The shape of absorber in this type of collector is flat or curved.

2) Glass- Glass Evacuated Tube Collectors

In construction of glass-glass evacuated tube collectors two glass tubes fused together at one end. There are coating of integrated cylindrical metal absorber is available in the inner tube. This type of evacuated tube collectors is less efficient than the glass-metal type but cheaper in cost and more reliable than glass-metal type. Glass- Glass collectors are more efficient at high working temperatures.

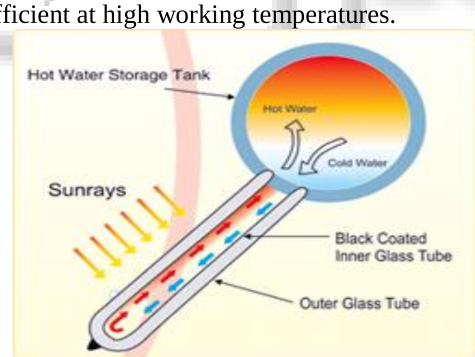

Fig. 9: Glass –Glass Evacuated Tube Collector

III. LITERATURE REVIEW

P.Selvakumar et al [1] (2012) clarified about effect of inclination angle on temperature characteristics of water in-glass evacuated tubes of domestic solar water heater that solar tube water heater that this will work in conditions that are not conventional. and it does not depend on any inclination angle.

Dilip Mishra et al [2] (2015) conduct experimental analysis of thermal performance of evacuated U-tube solar collector and states that effect of copper fin and U-tube in terms of its heat retaining capacity has observed that the thermal efficiency of evacuated u-tube collector has been improved by 10-15% then water-in-glass evacuated tube solar water heater.M.A.Sabiha et al [3] (2015) analysis the progress and latest developments of evacuated tube solar collectors and states that evacuated tube solar collectors can temperatures easily and are able to preserve heat even when the outside weather is cold and states that efficiency can increase by using Nano fluid .Vishal Dabra et al [4] (2013) discussed that there is also a solar air collector and states that their performance can vary by the tilt angle 30°is effective and there is performance decrease at an angle of 45°.Raghurajsinh .B et al [5] (2016) states that solar collector performance is worst without heat pipes and also the hydraulic resistance is low. Hence the tube with heat pipes has good performance than any other for heating water therefore they are used in refrigeration used for horticulture product.Soteris A. Kalogirou [6] (2004) describes the various applications of solar collectors and also discus about various types of collectors like flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field.Zhao-Chun WU et al [7] (2015) relate the heat transfer efficiency between the heat pipe and tube bundles heat exchanger and finally provide an result of heat pipe exchanger is not better than a general heat exchanger. Because it includes complicated manufacturing process.K. N. Shukla et al [8] (2015) specified some of the applications of heart pipes in aerospace and space missions and deliberated different types of heat pipes and fluids used inside them according to the temperature.N.S.Sathawane et al [9] (2014) detailed that thermoelectric materials are able to convert heat to electricity directly by the effort of charge carriers and this process is an eco-friendly in this paper thermoelectric module can be used with flat plate collectors, parabolic collectors and parabolic dish or evacuated tube collectors to produce heat and electricity instantaneously. Vishal G. Shelke et al [10] (2015) represent the solar water heating system like active system and passive system and notified that conventional sources are wasted to produce hot water for domestic and industrial needs to overcome that thermal energy plays an major role. The present solar heating should be studied and increased.Rohit Radhakrishnan et al [11] (2015) proposed that the efficiency of evacuated is better than that of flat plate collectors. Moreover, it can be increased by providing copper as a fin in evacuated tube solar collectors and also state water-in-glass evacuated tube collector had better performance than flat plate collectors, but heat pipe collector had 15 to 20 % higher efficiency than water-in-glass collectors which proved to be a better option. In addition, many methods to improve the efficiency of these tubes.M. Mahendran et al [12] (2012) presented that Nano fluids has more thermal conductivity than the water therefore it can easily transfer heat. In addition, the efficiency of the collector. It is mainly dependent on the geographic location, weather and climate because temperature will change in these above condition and finally said the efficiency can increase by Nano fluids.Zhen –Hua liu et al [13] (2007) implemented to understand the nucleate boiling heat transfer of water–CuO nanoparticles suspension at different operating pressures and different nanoparticle mass concentrations Nanofluid as a new kind of functional fluid, has many unique characteristics. CuO nanoparticles suspension as a working fluid can significantly strengthen the heat transfer performance and the maximum power of the miniature flat

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heat pipe evaporator with micro-grooved surface under low-pressure conditions.

IV. EXPERIMENTAL SETUP

An evacuated heat pipe consist of many parts but in this it is covered but a thin outer glass inside this it consists of manifold and deeper to it consists of evacuated heat tube inside of this tube there will be working fluid the working fluid is decided by the material of heat pipe used for the heat pipe. The schematic diagram of evacuated solar collector is as follows,

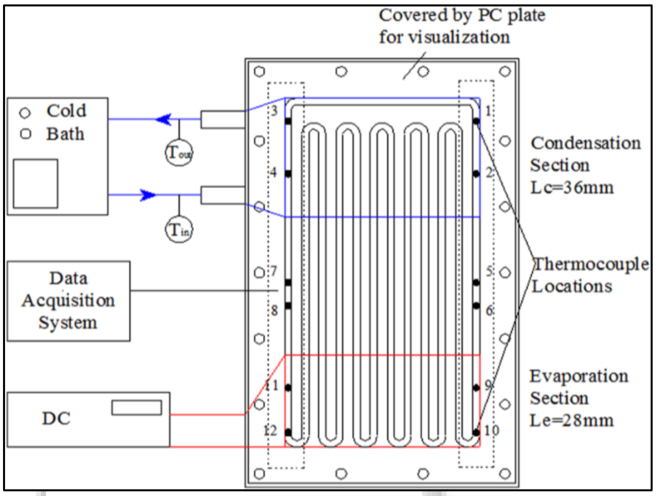

Fig. 10: Experimental Setup(*Ref*)

V. CONCLUSION

From this, we came to know that if white beach sand, which is rich of silicon dioxide, will retain heat more than the zinc metal pallets and it supply heat of 7°C more than the zinc pallets. The sand will store some heat energy within it and in night time, it will supply heat to the manifold so that we can also get heat energy even after the sun set. The sunlight, which falls on the glass tube but only 93%, is reached the manifold and the remaining 7% is get losses.

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REFERENCES

[1] P.Selvakumar, “Effect of Inclination Angle on Temperature Characteristics of Water in-Glass Evacuated Tubes of Domestic Solar Water Heater” International Journal of Engineering and Innovative Technology (IJEIT) Volume 1, Issue 4, April 2012.
[2] Dilip Mishra “Experimental Analysis of Thermal Performance of Evacuated U-Tube Solar Collector” ISSN (Print): 2349-1094, ISSN (Online) 2349-1108, Vol_2, Issue_3, 2015.
[3] M.A. Sabiha “Progress and latest developments of evacuated tube solar collectors” Renewable and Sustainable Energy Reviews 51(2015)1038–1054 12 May 2015
[4] Vishal Dabra “The effect of tilt angle on the performance of evacuated tube solar air collector experimental analysis” International Journal of Engineering, Science and Technology Vol. 5, No. 4, 2013, pp. 100-110
[5] Raghurajsinh .B. Parmar “Performance of an evacuated tube collector with heat pipe technology” International Journal of Engineering Research and General Science Volume 4, Issue 3, May-June, 2016 ISSN 2091-2730
[6] Soteris A. Kalogirou “Solar thermal collectors and applications” Progress in Energy and Combustion Science 30 (2004) 231–295
[7] Zhao-Chun WU “Comparison of heat transfer efficiency between heat pipe and tube bundles heat exchanger” Wu, Z.-C., et al.: comparison of heat transfer efficiency between heat pipe and thermal science, Year 2015, Vol. 19, No. 4, pp. 1397-1402
[8] K. N. Shukla “Heat Pipe for Aerospace Applications an Overview” Journal of Electronics Cooling and Thermal Control, 2015, 5, 1-14
[9] N.S.Sathawaneet “ A Review On Solar Thermoelectric Cogenerator With Evacuated Tube Solar Collector” International Journal of Advance Research In Science And Engineering http://www.ijarse.com IJARSE, Vol. No.3, Issue No.3, March 2014 ISSN-2319-8354(E)
[10] Vishal G. Shelke “Solar Water Heating Systems: A Review” International Journal of Scientific Engineering and Research (IJSER) www.ijser.in ISSN (Online): 2347-3878, Impact Factor (2014): 3.05
[11] Rohit Radhakrishnan “ Review of Evacuated Glass Tube Based Solar Collectors for Various Fluid Heating Applications” IJSRD - International Journal for Scientific Research & Development, Vol. 3, Issue 03, 2015, ISSN (online): 2321-0613
[12] M. Mahendran “Performance of Evacuated Tube Solar Collector Using Water-Based Titanium Oxide Nanofluid” Journal of Mechanical Engineering and Sciences (JMES) ISSN (Print): 2289-4659; e-ISSN: 2231-8380; Volume 3, pp. 301-310, December 2012
[13] Zhen –Hua liu “Boiling heat transfer characteristics of Nano fluids in a flat heat pipe evaporator with micro-grooved heating surface” International Journal of Multiphase Flow 33 (2007) 1284–1295.
[14] G.L. Morrison, I. Budihardjo, M. Behnia (2004), “Water-in-glass evacuated tube solar water heaters”, Solar Energy, Vol.76, pp.135-140.

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