



# “Thermal performance of long evaporative section acetone fluid thermosyphon used in solar water heating system”

#1Mr.Harendra Kumar Jha <sup>a</sup>, #2Mr.Mahesh.G.Bhong <sup>b</sup>

#1hkjha.on@gmail.com

#2mahesh.bhong@indiraicem.ac.in

#1<sup>2</sup> Department of Mechanical Engineering, Pune University.  
Indira College of Engineering & Management, Pune, India

## ABSTRACT

In this study, the aim is to investigate the application of acetone fluid thermosyphon as a heat transfer tool in a solar water heater (SWH). For this purpose, a long evaporative section thermosyphon (LEST) is designed, constructed and tested at temperatures of 50,60&70°C In this work the LEST is made of copper tube of 1000mm length of internal diameter 24.4 mm and 1mm thickness. The working fluid employed is acetone with filling ratio (FR) 40%. The lengths of evaporator, adiabatic & condenser sections are 600, 200 and 200 mm respectively. The LEST placed centrally in 2 inch UPVC pipe. The 2 inch UPVC pipe water jackets are provided in both evaporative & condenser section of prescribed length for hot water circulation. Heat source at 50°, 60° &70°C temperature of hot water taken during experimentation. Two Immersion water heaters of 3.5 KW were used for water heating process. The results show that efficiency of thermosyphon mode is in range of 53 % to 71%. Experimentally found that the vertical position is the best performance of thermosyphons for maximum mass flow rate of fluid. It was also found that there is no more differences in thermal performance of thermosyphons at an angle of 45°, 60° & 90° as compare with vertical position (90°). The overall thermal resistance also calculated in the range of 0.045°C/W to 0.127°C/W. experimentally found that overall thermal resistance decrease from horizontal position to vertical position. Less overall thermal resistance causes better performance of thermosyphons. After performance test it was found that long evaporative section acetone fluid thermosyphon can be used in solar water heating system, because it will gives better performance in low temperature range .

**Keywords—** Ethanol fluid, Thermosyphon, Solar water heater, Heat pipe, long evaporative section.

## ARTICLE INFO

### Article History

Received :18<sup>th</sup> November 2015

Received in revised form :

19<sup>th</sup> November 2015

Accepted : 21<sup>st</sup> November , 2015

Published online :

22<sup>nd</sup> November 2015

## I. INTRODUCTION

Heat pipes and two phase thermosyphons are heat transfer devices whose operating principles are based on the evaporation/condensation of a working fluid using the capillary pumping forces (in case of heat pipe) and gravity forces (in case of two phase thermosiphons) to ensure the working fluid circulation. Two-phase (thermosyphon) heat transfer involves the liquid-vapor phase change (boiling and condensation) of a working fluid. Thermosyphons & Heat pipes offer high effective thermal conductivities,

energy-efficiency, light weight, low cost and the flexibility of many different size and shape options. As passive heat transfer systems, Thermosyphons & heat pipes offer simple and reliable operation, with high effective thermal conductivity, no moving parts, ability to transport heat over long distances and quiet vibration-free operation. Thermosyphons & Heat pipes transfer heat more efficiently and evenly than solid conductors such as aluminum or copper because of their lower total thermal resistance. It transfers heat many times faster than pure copper. The

Thermosyphon & heat pipe is filled with a small quantity of working fluid (Acetone). Heat is absorbed by vaporizing the working fluid. The vapor transports heat to the condenser region where the condensed vapor releases heat to a cooling medium like water. The condensed working fluid is returned to the evaporator by gravity, or by the heat pipe's wick structure, creating capillary action. Solar water heater is one of the devices that have been used in different shape and types since very old times. The use of Thermosyphon & heat pipes offers several advantages regarding flexibility in operation and application, as they are very proficient in transporting heat even under a small temperature difference<sup>[1]</sup>. Thermosyphon & Heat pipes are currently utilized in many energy systems according to their needs, in industrial areas and aerospace applications, including the solar system considered in the present analysis. The first area that appears most appropriate for

## II. EXPERIMENTAL SETUP

The experimental setup is designed and constructed at ICEM, Pune Workshop. The long evaporative section thermosyphon (LEST) is designed and constructed by Siddharth Solar Technologies, Pune as per our requirement. It is made of copper (Cu) tube of 1000 mm length of internal diameter 24.4 mm and 1 mm thickness. The working fluid employed is acetone with filling ratio (FR) 40%. The lengths of evaporator, adiabatic & condenser sections are 600, 200 and 200 mm respectively. The maximum heat transfer capacity of thermosyphon is 500 W. The pipe was initially evacuated using vacuum pumps (rotary and diffusion pumps) after a series of cleaning processes to remove possible contaminants, which can affect the performance and life of thermosyphon. The pipe is first pumped down at the ambient temperature: and then, the pumping is continued while the pipe is heated [3, 4]. Since high vacuums were required, this was a time-consuming process. Following evacuation, the working fluid was sucked into the pipe through a special valving arrangement and the filling tube attached at the upper end was flattened by crimping to a thickness of 0.1 to 0.2 mm. This process required up to an hour for pipe. UPVC pipes and their fittings like elbow, reducer, ball valves, caps etc are used in manufacturing of test setup. 2 inch and 0.5 inch UPVC pipes and their fittings are used. 2 inch UPVC pipe fitting water jackets prepared in workshop and are provided in both evaporative and condensing section of specified length for hot water circulation. Water circulation was done by using 0.5 hp centrifugal pump. Ball valves are used for controlling the mass flow rate of circulating hot water. The LEST placed centrally in 2 inch UPVC pipe. One cylindrical water tank of diameter 0.6 m & height 1 m was used for storing hot water. Two immersion water heaters of 3.5 KW were used for water heating process. The role of the adiabatic section is to connect the condenser and evaporator sections together. The length of adiabatic section in this setup is constant which is 200 mm. The wall temperature distribution along the pipe was measured using ten calibrated thermocouples (type K). The thermocouples are inserted in (2) mm grooves, machined in the outer surface of the water circulation jacket pipe wall. An

heat pipe application is domestic hot water heating systems. The amount of energy required to heat domestic water is significant, even in comparison with the space heating requirement. Moreover, the environmental issues linked to the use of fossil fuels give great incentives to tie together alternative energies where possible. In the current study we are using thermosyphon for water heating application. We were used thermosyphon in three orientations namely horizontal, vertical and inclined. The size of thermosyphon was selected according to the size of casing of test rig. The selected thermosyphon is of length 1000 mm and diameter 25.4 mm. The working fluid employed is acetone with filling ratio (FR) 40%. The boiling point temperature of acetone is 56°C. Vapour pressures are 30.6 KPa at 25°C & 374 KPa at 100°C. The main aim of this experiment was to find out the performance of thermosyphon which is used in water heating application.

accurate wattmeter is connected to water heater to record the exact power supplied. The temperature was read directly from a digital display. Mass flow rate of the hot and cold water was determined by measuring the amount of the water over an interval of time. Water inlet and outlet temperatures were measured using two thermocouples. The actual experimental facilities' are shown in Fig.01 & 02.



Fig.1 Actual test setup image

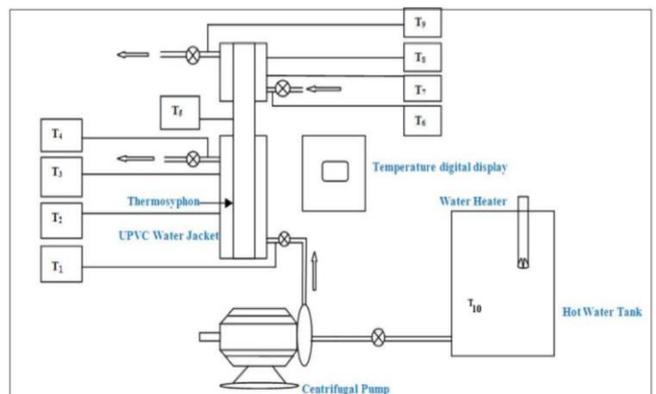
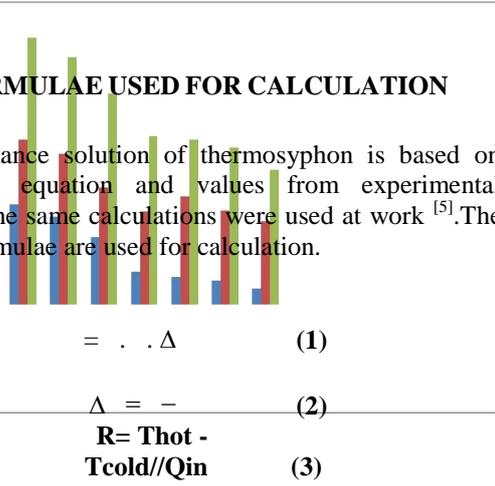


Fig.2 Experimental setup block diagram with thermocouple arrangement

**III. FORMULAE USED FOR CALCULATION**

Heat performance solution of thermosyphon is based on calorimetric equation and values from experimental measuring. The same calculations were used at work [5]. The following formulae are used for calculation.



$$Q = m \cdot c \cdot \Delta T \quad (1)$$

$$\Delta T = \dots \quad (2)$$

$$R = \frac{T_{hot} - T_{cold}}{Q_{in}} \quad (3)$$

Where  $\Delta T$  is the temperature difference between output and input temperature,  $m$  is the mass flow rate of water,  $c$  is the specific heat capacity of liquid,  $R$  is the overall thermal resistant,  $T_{hot}$  &  $T_{cold}$  are the average temperature at evaporative section and condensing section,  $Q_{in}$  is the total heat input in evaporative section.

**IV. RESULT AND DISCUSSION**

The table no-(01) is the performance sheet of acetone thermosyphon. The maximum thermosyphon efficiency found 70.96% at 70°C heat source temperature in vertical position. During experimentation 63.27% efficiency at 50°C also found in 45° angle of orientation. Figure (3) illustrates the variation of thermosyphon efficiency with mass flow rate at different orientation (0°, 15°, 30°, 45°, 60°, 75°, 90°) angle for different heat source (50°C, 60°C, 70°C). Fig No-04 illustrates Heat performance with different orientation angle for different heat source. Best heat performance 353.69 W was found at vertical position for 0.0385 Kg/Sec mass flow rate of water. Fig No-05 illustrates Variation of overall thermal resistance with heat input for different heat source. Thermal resistance decrease with total heat input. Maximum thermal resistance 0.1279°C/W was found at horizontal position for maximum mass flow rate 0.0356 Kg/Sec. Fig No-06 illustrates Variation of overall thermal resistance with tilt angle for different heat source. It was observed that Maximum thermal resistance 0.1279°C/W occurs at horizontal position.

Fig.3 Variation of themosyphon efficiency with mass flow rate at different orientation angle for different heat source.

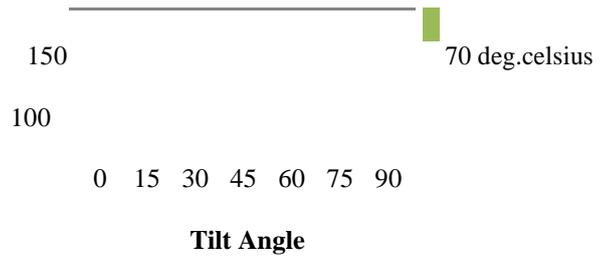
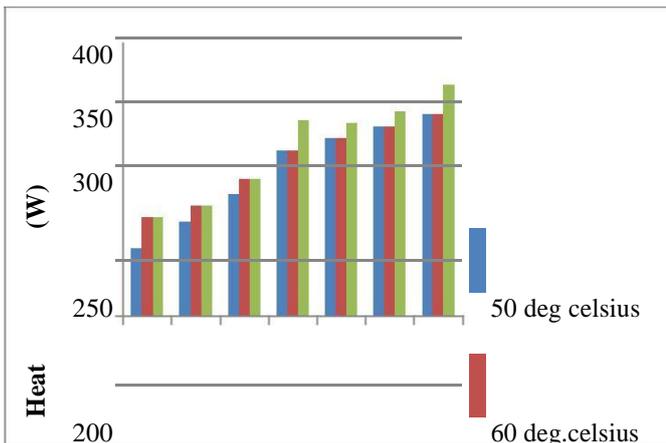


Fig.4 Heat performance with different orientation angle for different heat source.

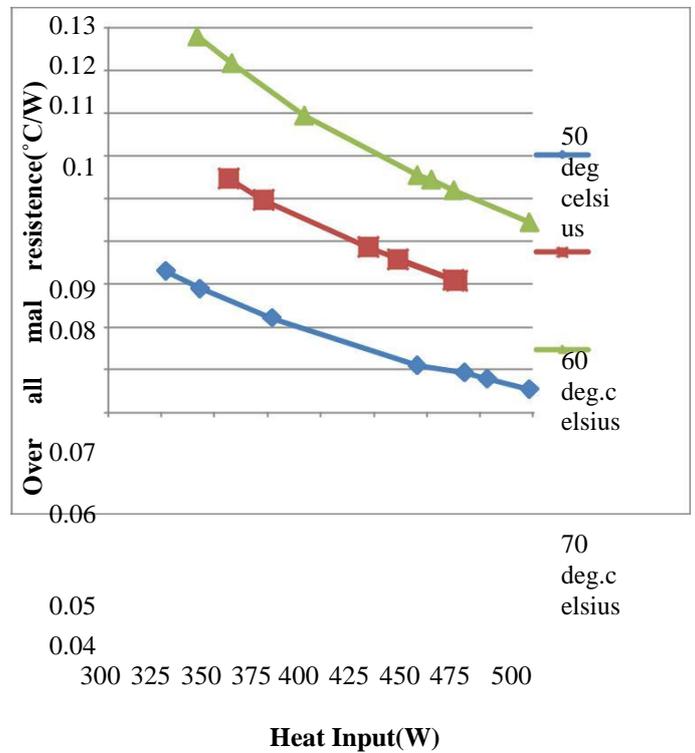
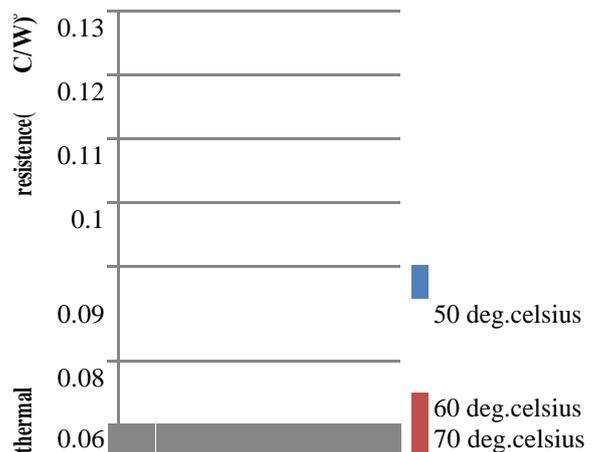


Fig No-05 Variation of overall thermal resistance with heat input for different heat source.



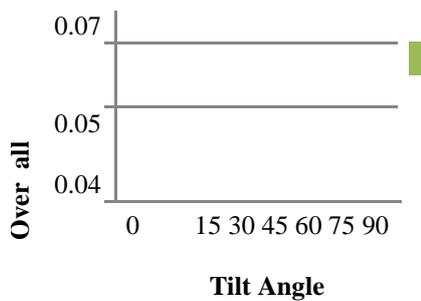


Fig No-06 Variation of overall thermal resistance with tilt angle for different heat source.

### Mass Flow Rate (Kg/S)

### V.CONCLUSION

Ideal working position of thermosyphon is vertical position. Thermosyphon operate on maximum performance and maximum mass flow transfer in this position. From experimental measuring performance of thermosyphon is creating graphic dependences average values of thermal performance from working position of thermosyphon. The maximum thermosyphon efficiency found 70.96% at 70°C heat source temperature in vertical position. During experimentation 63.27% efficiency at 50°C also found in 45° angle of orientation. This experiment has testified that the acetone fluid thermosyphon is able to operate at any other position as vertical and even at the horizontal position. From results measured performances of thermosyphon at various working position discover that the thermosyphon is able to operate at inclined position 45° and total heat performance transfer is not very different as at vertical position. Due to long evaporative section of thermosyphon the heat absorption capacity at evaporative section also found which is maximum 498.38 W at 70°C heat source. Long evaporative section acetone fluid thermosyphon can be used in solar water heating system.

### ACKNOWLEDGMENT

The author would like to thank Prof.S.B.Ingole & Dr.V.M.Kale for his support and discussions. The authors gratefully acknowledge the financial support ICEM, Pune. The authors are also grateful to the anonymous referees who provided detailed and constructive comments.

### REFERENCES

- [1] A. A bhat, Performance investigation of a long, slender heat pipe for thermal energy storage applications, J.Energy 6 (6) (1982).
- [2] Wongee Chuna, \*, Yong Heack Kangb, Hee Youl Kwakb, Young Soo Leeb .305-343, Korea Received 8 August 1996; accepted 31 July 1998.
- [3] S.W. Chi, Heat Pipe Theory and Practice. McGraw-Hill, New York, 1976.
- [4] P. Dunn, D.A. Reay, Heat Pipes. Pergamon Press, New York, 1978.

[5] Nemeč, P., Čaja, A. Lenhard, R.: Influence working position of heat pipe on their thermal performance, Experimental fluid mechanics 2010, TU Liberec 2010.

[6] Thanaphol Sukchana\*, Chaiyun Jaiboonma, Effect of Filling Ratios and Adiabatic Length on Thermal Efficiency of Long Heat Pipe Filled with R-134a, Energy Procedia 34 (2013) 298 – 306

[7] R.Manimaran 1 , K.Palaniradja 2 , N.Alagumurthi 2 , J.Hussain 2,

FACTORS AFFECTING THE THERMAL PERFORMANCE OF HEAT PIPE –A REVIEW, JERS/Vol. III/ Issue II/April-June, 2012/20-24.

[8] Dr. Hussain H. Ahmad Anwar A. Yousif, Comparison between a Heat Pipe and a Thermosyphon Performance with Variable Evaporator Length, Al-Rafidain Engineering Vol.21 No. 2 April 2013.

[9] Ajit M. Kate 1 and Ratnakar R. Kulkarni, Effect of Pipe Cross Section Geometries and Inclination Angle on Heat Transfer Characteristics of Wickless Heat Pipe, International Journal of Engineering Research and Technology. ISSN 0974-3154 Volume 3, Number 3 (2010), pp. 699--710