Exposition of Large heat absorption area Acetone fluid Copper Thermosyphon for Solar Water Heating (SWH) Application

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Abstract- *In Present study, the main 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 large heat absorption area thermosyphon (LHAAT) is designed, constructed and tested at temperatures of 30,50&70˚C In this work the LHAAT is made of copper tube of 1000 mm 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 LHAAT 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. Immersion water heater was used for water heating process. The Inclination of the LEST varies between 0˚ to 90˚. Seven different tests were carried out in different orientation angle. The results show that efficiency of thermosyphon mode is in range of 53.21% to 70.96 %.Experimentally found that the vertical position as well as 45˚angle are the best for thermosyphon. Due to large evaporative area for collection of heat, Long evaporative section acetone fluid thermosyphon can be used in solar water heating application.*

Keywords- Acetone fluid, Thermosyphon, Solar water heater

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 [1]. 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 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 main aim of this experiment was to find out the performance of thermosyphon which is use in water heating application.

II. EXPERIMENTAL SETUP

The experimental setup is designed and constructed at Patna Workshop. The large heat absorption area thermosyphon (LHAAT) is designed and constructed by Golden Star Pvt Ltd & siddharth solar Technergies, Pune It is made of copper(Cu) tube of 1000 mm length of internal diameter 24.4 mm and1mm thickness. The working fluid employed is acetone with filling ratio (FR) 45%. 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 0.1to 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 work shop 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 LHAAT placed centrally in 2 inch UPVC pipe. One Cylindrical water tank of diameter 1m was used for storing hot water. Immersion water heater of 2000 Watt capacity was 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 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.

Figure 1. Actual test setup image.

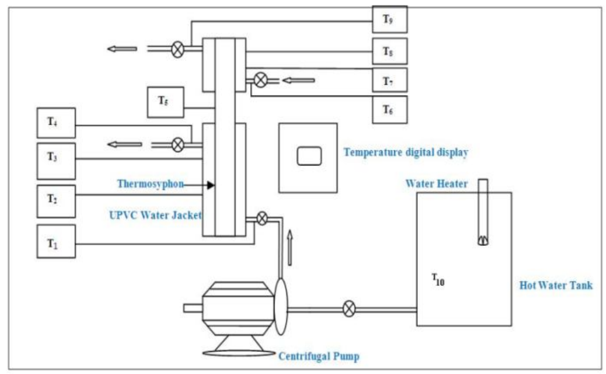

Figure 2. Experimental setup block diagram with thermocouple arrangement.

III. FORMULAE USED FOR CALCULATION

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

$$Q = m.c.\Delta t \quad (1)$$

$$\Delta t = t_2 - t_1 \quad (2)$$

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

Where Δt 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. RESULTS AND DISCUSSIONS

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 60.71% efficiency at 60˚C also found in 45˚angle of orientation. The table no-(02) is the Experimental setup block diagram with thermocouple arrangement. 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 498.38 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 0.095476˚C/W was found at 45˚ position for maximum mass flow rate 0.0417 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 0.095476˚C/W occurs at 45˚ position.

Table 1. Performance of acetone thermosyphon.

Thermosyphon Working Fluid-Acetone				
Working Temperature	**Angle**	**Mass Flow Rate(Kg/ Sec)**	**Thermosyphon efficiency(% ή)**	**Over all Thermal resistance(˚ C/W)**
30˚C	0˚	0.0356	53.2197	0.073031
	15˚	0.0357	59.38494	0.068952
	30˚	0.0361	62.048	0.062093
	45˚	0.0368	63.27313	0.050935
	60˚	0.0373	63.05882	0.049208
	75˚	0.0382	64.31525	0.047793
	90˚	0.0385	64.51613	0.045397
50˚C	0˚	0.0417	58.54167	0.094605
	15˚	0.0407	59.18699	0.089694
	30˚	0.0400	59.35714	0.078634
	45˚	0.0397	60.71552	0.070731
	60˚	0.0392	67.56303	0.075678
	75˚	0.0388	66.53301	0.071001
	90˚	0.0385	66.66667	0.067592
70˚C	0˚	0.0417	61.08696	0.127946
	15˚	0.0407	61.65312	0.121691
	30˚	0.0400	63.92308	0.10947
	45˚	0.0397	70.71702	0.095476
	60˚	0.0392	68.85734	0.094459
	75˚	0.0388	70.03475	0.091912
	90˚	0.0385	70.96774	0.084423

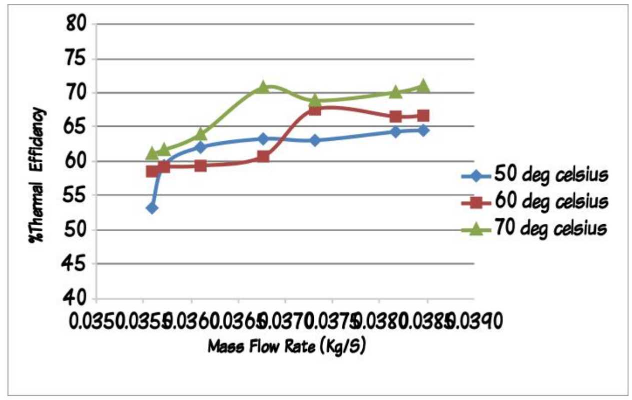

Figure 3. Variation of themosyphon efficiency with mass flow rate at different orientation angle for different heat source.

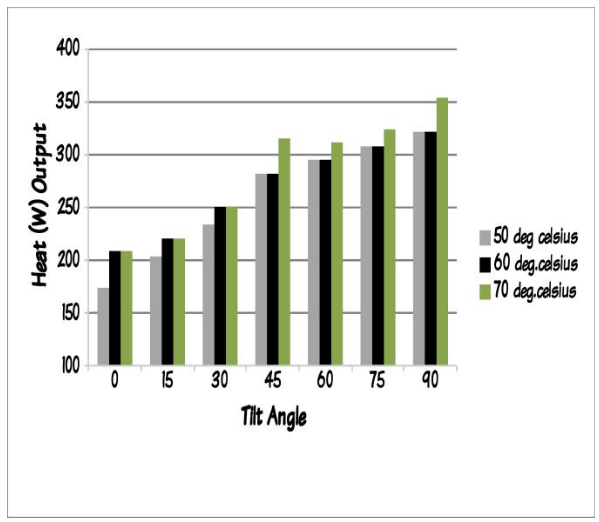

Figure 4. Heat performance with different orientation angle for different heat source.

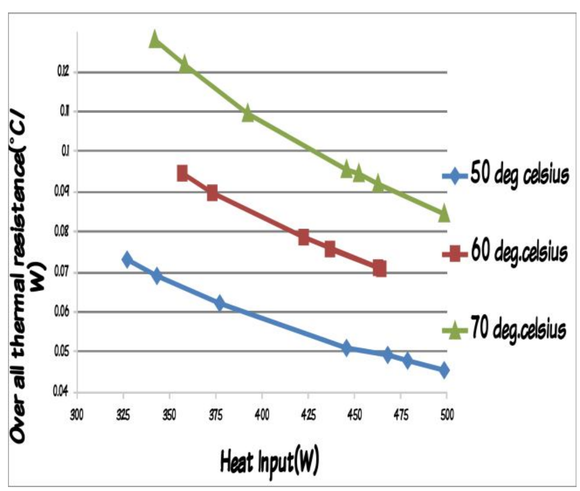

Figure 5. Variation of overall thermal resistance with heat input for different heat source.

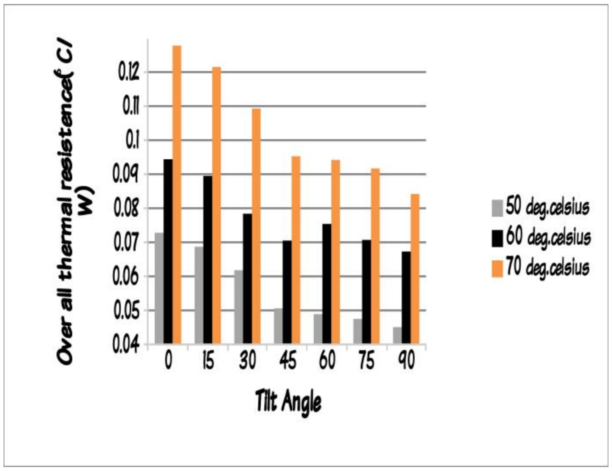

Figure 6. Variation of overall thermal resistance with tilt angle for different heat source.

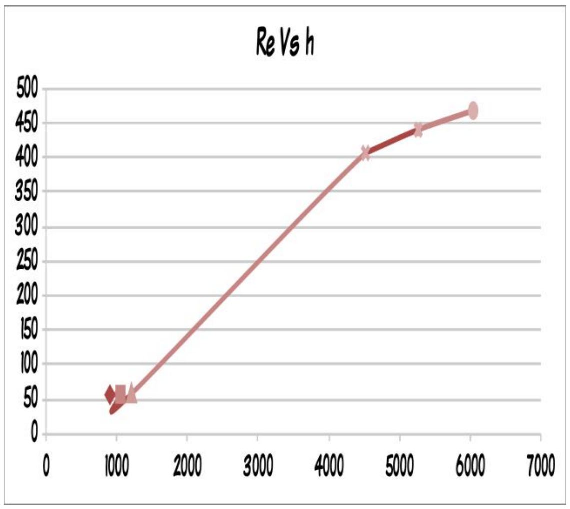

Figure 7. Co-relation MAT Lab Graph of Re Vs.h

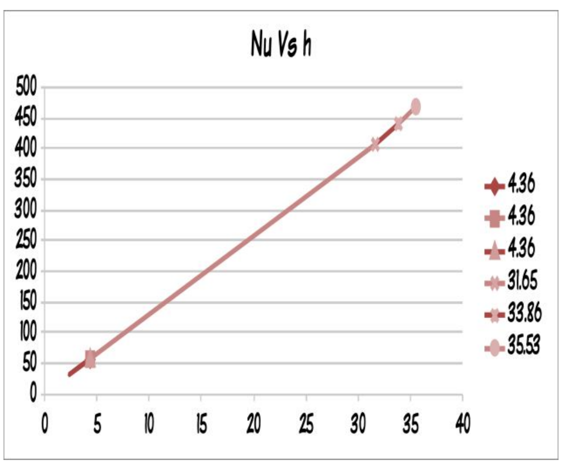

Figure 8. Co-relation MAT Lab Graph of Nu Vs.h

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 60.71% efficiency at 60˚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. Large heat absorption area (LHAAT) acetone fluid thermosyphon can be used in solar water heating system. Every research work always has a definite scope of further activity or extension of previous research work. It is ongoing process of research that the present status of the system can be changed by having certain modification, improvement, innovation, etc. This work can be taken further to study effect of variations in diameter, length, material, fluids and fins in the construction of Thermosyphons for evaluating heat transfer performance in various industrial applications.

VI. ACKNOWLEDGMENT

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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 aDepartment of Nuclear and Energy Engineering, Cheju National University, Cheju, 690-756, Korea bKorea Institute of Energy Research(KIER), Daedeok Science Town, Taejon 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] Nemec, P., Čaja, A. Lenhard, R.: Influence working position of heat pipe on their thermal performance, Experimental fluid mechanics 2010, TU Liberec 2010.

[6] S.W. Chi. Heat Pipe Theory and Practice. McGraw-Hill, New York, 1976.

[7] P. Dunn, D.A. Reay, Heat Pipes. Pergamon Press, New York, 1978.

[8] Mahesh Rathore, Engineering Heat and Mass Transfer, 4th ed. New Delh: University science press, 2006.

[9] J.P. Holman, Experimental methods for engineers, 8, Ed.: McGraw-Hill series in mechanical engineering, 2007.