“PERFORMANCE ANALYSIS OF CLOSED LOOP TWO PHASE THERMOSYPHON COOLING USING METHANOL”

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Abstract- Now a day’s there is requirement of various cooling system as heat generation from various systems increased and there is limit on heat transfer rate in air cooling active system the interest for using liquid cooling for high flux application has risen. In this project ‘two phase thermosyphon cooling’ is another liquid cooling technique in which heat transferred as heat of vaporization from evaporator to condenser in closed loop with relatively small temperature difference by natural convection method using methanol as refrigerant or working fluid. It may be conclude that , the closed loop two phase thermosyphon cooling using methanol arises an innovative solution due to their ability of withstanding high heat fluxes with low working fluid charges controlling system temperature automatically and working with minimum energy consumption as well as less noise and high heat transfer rate with high reliability and safety.

Keywords - Closed loop two phase thermosyphon, natural circulation, methanol, two phase flow.

I. INTRODUCTION

As heat generation from various systems increased and there is limit on heat transfer rate in air cooling system the interest for using liquid cooling for high heat flux applications has risen. Thermosyphon cooling is an alternative liquid cooling technique in which heat is transferred as heat of vaporization from evaporator to condenser with a relatively small temperature difference. The thermosyphon has been proved as a promising heat transfer device with very high thermal conductance.

High capacity passive cooling system studied in this project is a thermo loop device that utilizes the thermo loop heat transfer concept. This device is an assemblage of Evaporator, Condenser, Cooling liquid, Non-return valve and Reservoir charged with a liquid for removing heat from any source upon which the evaporator is attached.

Thermal management of electronic systems is one of the major focal points of the design system and is primarily concerned in keeping the temperature of the various components within a maximum allowable limit. It is argued that in the thermal management of electronic systems, the primary and secondary critical factors that the cooling solution must meet are the device’s junction and solder temperatures. The choice of the cooling technique is thus determined not only by the power dissipation but also by the junction temperature. A failure to maintain this temperature below the allowable limit results in the failure of the whole system. Therefore it is extremely important for effective thermal management of electronics system to precisely control the operating temperature of the critical components.

Energy consumption is a major operating cost in the telecommunication field where 33% of electricity is used for cooling. Consequently, a large variety of cooling systems have been studied to maintain an applicable temperature for telecommunication equipment and many more systems. Active cooling systems need complex air filtration designs and high cost maintenance. They do not match the...
demand from the systems with a high thermal dissipation. Air cooling systems are disadvantaged by acoustic noise generation, electrical power consumption, weight addition and periodic maintenance requirements. Passive cooling systems arose as an innovative solution due to their ability of withstanding high heat fluxes with low working fluid charge, controlling system temperature automatically and working with minimum energy consumption and a less noise.

**Fig. Two-phase loop thermosyphon**

**Objectives**

- a) To increase heat transfer rate of the electronic components having high heat generation rate.
- b) To find heat transfer rates by varying the heat load. Heat load is maintained by heating element called heater.
- c) The systems having small heat generation rate may be used to carry heat at relatively small temperature difference in system.
- d) Reduce moving mechanical devices and Noise generation as conventional system has moving components which affects environment.
- e) To overcome continuous power consumption in conventional system and reduce power consumption
- f) To verify heat dissipation rate and effectiveness of thermosyphonic cooling system to compare result with conventional cooling system.

**II. LITERATURE REVIEW**

Jiwon et al [1] had studied a loop thermosyphon type cooling system for high heat flux. With rapid development of the semiconductor technology more efficient cooling systems for electronic devices are needed. In this situation, in the present study a loop thermosyphon type cooling system which is composed mainly of a heating block an evaporator and an air-cooled condenser is investigated experimentally in order to evaluate the cooling performance. At first, it is examined that the optimum volume filling rate of this cooling system is approximately 40%. Next, four kinds of working fluids, R1234ze(E), R1234ze(Z), R134a and ethanol, are tested using a blasted heat transfer surface of the evaporator. In cases of R1234ze(E), R1234ze(Z), R134a and ethanol, the effective heat flux at which the heating block surface temperature reaches 70°C is 116 W/cm², 106 W/cm², 104 W/cm² and 60 W/cm², respectively. This result indicates that R1234ze(E) is the most suitable for the present cooling system. The minimum boiling thermal resistance of R1234ze(E) is 0.05 (cm²-K)/W around the effective heat flux of 100 W/cm². Finally, four kinds of heat transfer surfaces of the evaporator, smooth, blasted,
copper-plated and finned surfaces, are tested using R1234ze(E) as working fluid. The loop thermosyphon type cooling system for high heat flux was investigated experimentally in order to evaluate the cooling performance. The main findings are as follows. With the change in the volume filling rate, the thermal resistance of condenser is more greatly influenced than the boiling thermal resistance, and these indicate that the optimum volume filling rate is approximately 40%. With the combination of R1234ze(E) and the blasted heat transfer surface of the evaporator, the boiling thermal resistance is the smallest up to 116 W/cm² of the effective heat flux, and the minimum boiling thermal resistance is 0.05 (cm²·K)/W around 100 W/cm² of the effective heat flux. With R1234ze(E), the boiling thermal resistance of the blasted surface drastically increases after the appearance of the dry-patch at 116 W/cm², while it of plated and finned surfaces is maintained as 0.1 (cm²·K)/W up to approximately 150 W/cm².

Alessandro et al[2] have given review on closed loop two-phase thermosyphon of small dimensions and experimental results on the heat and mass transfer with channels having a hydraulic diameter of the order of some millimeters and input power below 1 kW is proposed. The available experimental works in the literature are critically analysed in order to highlight the main results and the correlation between mass flow rate and heat input in natural circulation loops. A comparison of different experimental apparatuses and results is made. It is observed that the results are very different among them and in many cases the experimental data disagree with the conventional theory developed for an imposed flow rate. The paper analyses the main differences among the experimental devices and try to understand these disagreements. The paper presents a critical evaluation of existing experimental works in the field of heat transfer of two phase flow (boiling) in Closed Loop Two Phase Thermosyphons of small dimensions. The literature survey provides many works in this field. First of all the aims of the experimental investigation are different among them. Many experimental devices are constructed to investigate the operating mode of cooling system for electronic equipment so that they operate at constant values of the heat input and no general remarks can be obtained. For example heat transfer performance are influenced by measurement instrumentation and dramatically degraded by the presence of a small amount of air. The lack of general results causes difficulties for the practical application of CLTPT in devices operating at variable heat input conditions, like occurs in all the systems different from cooling devices, as for example solar collectors or heat transformers in which the heat input can vary.

Ali et al [3] had studied experimental investigations and modeling of a loop thermosyphon for cooling with zero electrical consumption with analytical model for a thermosyphon loop developed for cooling air inside a telecommunication cabinet. The proposed model is based on the combination of thermal and hydraulic management of two-phase flow in the loop. Experimental tests on a closed thermosyphon loop are conducted with different working fluids that could be used for electronic cooling. Correlations for condensation and evaporation heat transfer in the thermosyphon loop are proposed. They are used in the model to calculate condenser and evaporator thermal resistances in order to predict the cabinet operating temperature, the loop's mass flow rate and pressure drops. The comparative studies show that the present model predicts the experimental data. The model is used to define an optimal liquid and vapour lines diameters and the effect of the ambient temperature on the fluid's mass flow rate and pressure drop. In this paper, a physical model to characterize heat and mass transfer in the thermosyphon loop located in an Orange cabinet is developed. It gave the good approximation of the air operating temperature and system thermal resistance that used as an index for cooling performance. The developed model gave estimations of various parameters characterizing the thermosyphon loop thermal performances without need more than three simple iterations. A first comparison of the predictions with experimental data shows that the developed model gives the good predictions of the operating temperature and system thermal resistance. Moreover the present theoretical
model determines complementary physical parameters influencing the cooling loop performance. Depending on the model, it is shown that increasing the liquid and vapor lines section diameters to 0.012 m and 0.014 m could be one of the vital keys to improve the system thermal efficiency. Moreover, the increase of the external ambient temperature increases the mass flow rate in the loop decreases the evaporator pressure drop and reduces the cooling performance.

Noie et al [4] had verified heat transfer characteristics of a two-phase closed thermosyphon applications are increasing in heat recovery systems in many industrial practices because of their high effectiveness. Various parameters affect the heat transfer performance of thermosyphons. In this paper, the effect of three parameters: input heat transfer rates (100 < Q < 900W) the working fluid filling ratios (30% - 90%) and the evaporator lengths (aspect ratios) were investigated experimentally. The aspect ratios for these experiments were 7.45, 9.8, and 11.8. A series of experiments were carried out to find the influence of the above parameters on steady-state heat transfer characteristics of a vertical two-phase closed thermosyphon. A smooth copper tube of total length of 980 mm with inside and outside diameters of 25 and 32 mm was employed with distilled water as working fluid. The temperature distribution along the thermosyphon was monitored input heat of evaporator section and output heat from condenser was measured. The experimental boiling heat transfer coefficients were compared with existing correlations. Conclusions have been drawn for the optimum-filling ratio at which the thermosyphon operates at its best for a certain aspect ratio The effects of the aspect ratio and filling ratio on the heat transfer characteristics of a closed two-phase thermosyphon under normal operating conditions was investigated in this paper in the range of input heat 100 < Q< 900W. The experimental results were compared with the correlations of Rohsenow and Imura.

It has been concluded that:
1. The temperature distribution along the thermosyphon wall in the evaporator section was almost isothermal. The measured temperature along the condenser showed lower values. This drop of temperature is expected because of the internal resistances due to boiling and condensation.
2. The outside temperature of evaporator section are lower when filling ratio is 90% for aspect ratio of 7.45, while the temperature for aspect ratio of 11.8 is lower when filling ratio is 60%.
3. Maximum heat transfer rates for each aspect ratio take place at different filling ratios. For aspect ratio of 11.8 maximum heat transfer rate occurs when filling ratio is 60%, while for aspect ratios of 7.45 and 9.8 the corresponding filling ratios for maximum rate of heat transfer are 90% and 30% respectively.
4. The boiling heat transfer coefficients for aspect ratio of 9.8 and filling ratios 30%, 60% and 90% were found to be in reasonable agreement with empirical correlations.

Rahmatollah et al [5] had investigated thermal performance of a closed advanced two-phase thermosyphon loop for cooling of radio base stations at different operating conditions. The thermosyphon investigated is designed for the cooling of three parallel high heat flux electronic components. The tested evaporators were made from small blocks of copper in which five vertical channels with a diameter of 1.5 mm and length of 14.6 mm were drilled. The riser and down-comer connected the evaporators to the condenser, which is an air-cooled roll-bond type with a total surface area of 1.5 m² on the airside. Tests were done with Iso-butane (R600a) at heat loads in the range of 10–90 W/cm² to each of the components with forced convection condenser cooling and with natural convection with heat loads of 10–70 W. An experimental study of a closed advanced two-phase thermosyphon designed for cooling of three high heat flux components of a Radio Base Station has been reported. It was found that the thermal resistance between the heat source and the evaporator was the highest thermal resistance for both forced and free convection. Natural convection gave a higher thermal resistance than forced convection due to the low heat transfer coefficient in free convection. The heat transfer coefficient in the evaporator channels which increases with heat flux, was higher for natural convection at heat fluxes larger than 100 kW/m² due to higher system pressure at these ranges. Finally,
overall system performance expressed as overall heat transfer coefficient for forced and free convection was presented. As a conclusion of this study it was stated that the thermal resistances between the heat source/evaporator and the condenser/air are dominating in the thermosyphon system compared to the resistances between the evaporator walls and the condenser walls.

Alessandro et al [6] designed and realized experimental analysis of closed loop two phase thermosyphon for energy systems and of small dimensions where heat flow rate up to 1.7 kW can be furnished. The experimental test rig consists of an evaporator and a water cooled horizontal condenser placed about 1 m over the evaporator. The main characteristic of this apparatus is different ways of measuring the mass flow rate are continuous mode, an integral mode and an indirect mode. The purpose of this analysis is to investigate the correlation between mass flow rate and heat flow rate. The results of an experimental analysis by using water and ethanol as tested fluids at different operating conditions are shown discussed and analysed. The influence of several parameters on the performances was studied experimentally in particular heat load, operating pressure and fluid filling. From this work, understanding and useful information are provided for designing and building a two phase thermosyphon for systems like solar heating. The study proposed in this paper presents experimental results about the heat and mass transfer performances of a small dimension CLTPT operating at atmospheric and sub-atmospheric conditions with the perspective of defining design criteria of systems based on this principle as solar collectors. The experimental apparatus has been designed to overcome the limit of other experimental devices available in the technical literature. The experimental apparatus has been set up and tested for different operating conditions. In this device particular attention is dedicated to the connection between heat and mass flow rate and different measurement methods are implemented. Water and ethanol are used as working fluid representing two typical ranges of thermophysical properties. The tests have been carried out varying the heat input (in the range 0–1700 W) the operating pressure (in the range 0.1 bar–1 bar), the level of the liquid in the evaporator zone (variable between 0.2 and 0.32 m). Using ethanol as working fluid, the systems could reach critical conditions in the evaporation zone, causing the presence of a second type of instability. From the results they concluded that the quantitative prediction of the performance of CLTPT appears to be quite difficult. It is possible to recommend using water in thermosyphons for use at heat flow rate higher than 1000 W, while for heat flow rate below 1000W the use of ethanol could be advantageous. After this first results, that authors in the future analysis will concentrate their attention on further experimental analysis of water with different diameters of the pipes and on experimental analysis of different operating fluids like the refrigerant FC72.

Concluding Remarks

Performance evaluation approach for a two-phase compact thermosyphon for cooling is presented. This study identifies the working fluid, the orientation and the system fan as important factors affecting the performance of the loop thermosyphon. Water is identified as the better working fluid with respect to dielectric liquid; however, optimum charging and proper degassing may improve the qualities of dielectric liquid as a working fluid. The thermal performance of the thermosyphon is also found to be unaffected for large inclination angles. Natural convection case is found to be inefficient however a change in design may make the condenser efficient. The presented experimental and numerical results represent a preliminary study on the performance of the loop thermosyphon. Further detailed experimental studies are needed to accurately predict the behavior of the thermosyphon.

Problem Formulation

From above literature review we realized that various parameters that affect the heat transfer rate are cooling fluid properties, angle of vapour line, filling ratio etc. The experiments were carried out on
various refrigerants except methanol. We realised the heat transfer rate by using above methods is less we can increase heat transfer rate by two phase cooling method by using methanol.

III. METHODOLOGY

The setup analysed in this present work are natural circulation flow loops, where the spontaneous movement of liquid in a closed system is a result of the natural upward movement of vapour and downward movement of colder liquid caused by gravity. Two basic processes take place in flow loops: the heat storage and the movement of the working fluid. Each process can be affected in a variety of ways. The differences in structures and in operative principles concerns the number of phases of the working fluid in the device; the manner of setting the heat transfer agent in motion, the manner of liquid heat transfer agent return to the zone (in our case gravitation) and the type of ordering of hot and cold heat transfer agent movement. According to the schematic vision proposed in Fig 1.2 it is possible to identify three major kinds:

![Fig. schematic of major natural convection loop](image)

(a) simple thermosyphon
(b) thermosyphon with a bubble lift.
(c) two-phase thermosyphon–gravitational channel heat pipe

1. Self-acting liquid circulation loop (simple thermosyphon).
2. Two-phase loop with a liquid heat transfer agent and circulation accelerated with vapour bubbles (thermosyphon with a bubble lift).
3. Two-phase circulation loop, with vapour heat transfer agent and condensate return caused by gravitation (two-phase thermosyphon–gravitational channel heat pipe).

The specific interest of the present investigation is dedicated to Two-phase circulation loop, with vapour heat transfer agent and condensate return caused by gravitation (two-phase thermosyphon–gravitational channel heat pipe) here referred only as Closed Loop Two Phase Thermosyphon.

Construction
A Closed Loop Two Phase Thermosyphon consists of an evaporator and a condenser connected by two tubes, the riser and the down-comer, reservoir, working fluid, flow meter, electric heater, temperature measuring devices and DC controlling unit to control electric supply to heater.

![Constructional diagram of a system.](image)

**Fig.** Constructional diagram of a system.

## IV. WORKING

In the evaporator, where the circulating fluid is heated, the liquid boils and in the condenser, where the heat is rejected to environment, the vapour completely comes back to liquid phase. The system relies on gravity for the liquid return to the evaporator. In these applications the loop thermosyphons usually operate at low pressure and temperatures comprise into the range 20–120 °C. The operating principle of those devices with respect to the well-known single tube thermosyphons, deals with the separation of the pathways of the replenishment liquid from that of the vapour escaping from the evaporation zone. In such a way a meaningful increase of heat transport with respect to the conventional two phases closed thermosyphons is obtained and the classical operative limitations like flooding or entrainment limitations are overcome. These effects are more remarkable as the size of the devices decreases. Several key parameters influences the performances of the close loop two phase thermosyphon systems like:

- Heat input.
- Internal tube diameter.
- Distance between evaporator and condenser.
- Thermo-physical properties of the working fluid.
- Operating pressure.
- Sub-cooling of the fluid.
- Volumetric filling ratio (fill charge ratio).
- Pressure drops and thermal resistances at different part of the thermosyphon.

These loops of small dimension (with pipes diameters of the order of bubble departure diameter) show additional problems connected to the boiling which occurs in confined spaces, to the weakness of the buoyancy forces, to the effect of the operative pressure and the low liquid head and lastly to the high influence of the pressure drops and the fittings. It would be highly desirable to develop mechanistic and analytical models for flow boiling in small to micro-channels that are well validated by experiments. These models expect the preliminary knowledge of the flow pattern, nucleate boiling, forced convective...
boiling, film flow boiling and annular two phase flow boiling. Experiment also determines in small diameter tubes heat transfer coefficients were more or less independent of vapour quality and mass flux, but strongly dependent on heat flux and saturation pressure. Conventionally, this is interpreted as evidence that nucleate boiling is the dominant heat transfer mechanism.

V. EXPERIMENTAL SETUP

A Closed Loop Two Phase Thermosyphon consists of an evaporator condenser capillary tube non return valve pressure gauges and PT100 sensor. An evaporator is the heat exchanger device in which liquid fluid enters from condenser temp $T_1$ is measure at inlet of evaporator this liquid absorbs its latent heat of vapourisation from heating source and gets vapourised. The vapourised fluid is discharged through the outlet of evaporator which is further transfers to the condenser through the vertical riser tubes. Evaporator is constructed using copper tubes as copper is having high thermal conductivity riser and down-comer tubes. Riser tube is connected between evaporator outlet and condenser inlet which carries vapourised fluid and downcomer tube is connected between the condenser through reservoir to inlet of evaporator which carry fluid in liquid state. Condenser is a heat exchanging device which is used to condense fluid from vapour state to liquid state. It is connected between outlet of riser and inlet of reservoir. The condenser used in this experiment is air cooled natural flow type temp $T_2$ is measure at inlet of condenser and temp $T_3$ is measure at outlet of condenser Working fluid is the medium of heat transfers which absorbs heat from heat source and reject heat at condenser. Higher rate of heat transfer is achieved due to phase change of working fluid. Fluids having higher latent heat are preferred for high heat transfer rate. Pressure gauge are use to measure the pressure at inlet and outlet of evaporator non return valve is connected between outlet of condenser and inlet of evaporator it avoid backflow of cooling agent.

Water is heated inside the container and act as heating source. Temperature of water is kept above 70°C. Methanol act as the cooling agent whose boiling temperature is 63°C. Methanol absorbs heat from water and covert into vapour phase. Temp $T_1$ pressure $P_1$ is measure at outlet of evaporator now that vapour start to flow through air cool condenser where pressure remain constant but temp decreases rapidly and vapour transform into liquid temp $T_2$ is measure at outlet of condenser pressure remain almost constant in condenser capillary tube is use to reduce the pressure to atmospheric temp. pressure $P_3$ is measure at outlet of capillary tube by using pressure gauge now again liquid methanol start to flow through evaporator.
From the literature review, it is found that various researches have been done on various working fluid solutions like water, distilled water, butanol, ethanol. Refrigerant like R-12, R-22, R-134a, FC-72, FC-77, FC-84, and nanoparticles such as Al2O3, Ag2O3 and Fe2O3, etc. In many investigation of thermosyphon it is seen that water as a working fluid has a better performance than other solutions. But because of its high boiling point it cannot be used for cold temperature regions. By using other solutions as a working fluid does not get better thermal performance than water. So it is need of time to use binary mixture of various solutions to get better thermodynamic property for using working fluid in thermosyphon heat pipe.

The selection of refrigerant played important role for thermosyphonic cooling effect as it depends on density difference. As the experiment was to be conducted at atmospheric temperature the refrigerant selected must have its boiling point above atmospheric temperature to achieve the phase change. Refrigerant selected are as follows.

| Sr.No. | Refrigerant No. | Refrigerant Name                  | Boiling point at atm. Pressure (°C) | Freezing point atm. pressure (°C) |
|--------|-----------------|-----------------------------------|-------------------------------------|----------------------------------|
| 1      | R-30            | Methylene Chloride                | 40.66                               | -                                |
| 2      | R-113           | Trichlorotrifluoroethane          | 47.77                               | 0.55                             |
| 3      | CH3OH           | Methanol                          | 63.5                                | -                                |
| 4      | R-611           | Methyl Formate                    | 31.66                               | -63.33                           |

Table. Refrigerant and its properties

The refrigerant suitable was R-30, R113 and R-611. These are CFC’s phase out as they increases global warming and green house effect so the suitable and available refrigerant was CH3OH (Methanol) with highest specific heat of vaporization.

Table .Properties Of Methonal

| Property                                      | Value         |
|-----------------------------------------------|---------------|
| Saturation Temperature($T_{sat}$)             | 64.4 (°C)     |
| Density of liquid($\rho_L$)                    | 748.4 (kg/m³) |
| Density of vapour($\rho_V$)                    | 1.22 (kg/m³)  |
| Enthalpy of vapourisation($h_LV$)              | 1101.23 (kJ/kg)|
| Surface tension($\sigma$)                     | 0.018949 (N/m) |
| Viscosity of liquid phase($\mu_L$)             | 0.000544 (pa s)|
| Molecular weight                              | 32.04         |
| Water                                          | 0.25 (%)      |

**VI. EXPERIMENTAL OUTCOMES**

**Expected Out Come**

With this experiment we are expecting

- High heat transfer rate as compared to conventional methods of heat transfer.
- To get the effect of fill ratio and pressure gradient on heat transfer rate.
- To analysis the heat transfer rate at different temperature gradient.
Observations

a) Indoor Reading

| Sr. No. | Time   | Condenser inlet (°C) | Condenser outlet (°C) | Evaporator inlet (°C) | Water temperature (°C) | ΔT (°C) |
|--------|--------|----------------------|-----------------------|-----------------------|------------------------|---------|
| 1      | 4:10   | 66                   | 43                    | 41                    | 83                     | 23      |
| 2      | 4:15   | 64                   | 41                    | 40                    | 81                     | 23      |
| 3      | 4:20   | 62                   | 41                    | 40                    | 79                     | 21      |
| 4      | 4:25   | 60                   | 39                    | 39                    | 78                     | 21      |
| 5      | 4:30   | 58                   | 39                    | 39                    | 77                     | 19      |

b) Outdoor Reading

| Sr. No. | Time   | Condenser inlet (°C) | Condenser outlet (°C) | Evaporator inlet (°C) | Water temperature (°C) | ΔT (°C) |
|---------|--------|----------------------|-----------------------|-----------------------|------------------------|---------|
| 1       | 4:35   | 66                   | 40                    | 39                    | 85                     | 26      |
| 2       | 4:40   | 66                   | 38                    | 37                    | 83                     | 28      |
| 3       | 4:45   | 63                   | 37                    | 36                    | 80                     | 26      |
| 4       | 4:50   | 60                   | 36                    | 36                    | 78                     | 24      |
| 5       | 4:55   | 59                   | 36                    | 36                    | 75                     | 23      |

Calculation

Density of methanol = 748 Kg/m³
Mass Flow Rate (m),
Time required to fill 600 ml in measuring cylinder = 374 seconds.

Hence,

\[
\text{Discharge (Q')} = \frac{(600 \times 10^{-3})}{(374)} \text{ (lit/sec)}
\]

\[
\text{Q} = \frac{(0.001604 \times 10^{-3})}{(m^3/sec)}
\]

Mass Flow Rate (m) = Discharge x Density of Methanol

\[
\text{m} = \frac{(0.001604 \times 10^{-3}) \times (748)}{0.0012} \text{ (Kg/sec)}
\]

Heat rejection at condenser

Known Quantities

\[
\text{m} = 0.0012 \text{ kg/sec}
\]

\[
\text{C_P} = 1.7 \text{ kj/kg°C}
\]
\[ \Delta T = \text{Temperature difference in } ^\circ\text{C} \]
\[ q = \text{Heat rejected in } \text{kJ/sec} \]

**a. For Heat Rejected in Room**

We know that

\[ Q = \dot{m} C_p \Delta T \]

From Observation Table

For Reading 1

\[ \Delta T = (66 - 43) \]
\[ \Delta T = 23 ^\circ\text{C} \]
\[ Q_1 = 0.0012 \times 1.7 \times 23 \text{kJ/sec} \]
\[ Q_1 = 0.047 \text{kJ/sec} \]

In the same way we calculated Q for reaming readings

For Reading 2

\[ \Delta T = 23 ^\circ\text{C} \]
\[ Q_2 = 0.047 \text{kJ/sec} \]

For Reading 3

\[ \Delta T = 21 ^\circ\text{C} \]
\[ Q_3 = 0.043 \text{kJ/sec} \]

For Reading 4

\[ \Delta T = 21 ^\circ\text{C} \]
\[ Q_4 = 0.043 \text{kJ/sec} \]

For Reading 5

\[ \Delta T = 19 ^\circ\text{C} \]
\[ Q_5 = 0.039 \text{kJ/sec} \]

**b. For Heat Rejected Outside the room**

\[ Q = \dot{m} C_p \Delta T \]

For Reading 1

\[ \Delta T = (66 - 40) \]
\[ \Delta T = 26 ^\circ\text{C} \]
\[ Q_1 = 0.0012 \times 1.7 \times 26 \text{kJ/sec} \]
\[ Q_1 = 0.053 \text{kJ/sec} \]

In the same way we calculated Q for reaming readings

For Reading 2

\[ \Delta T = 28 ^\circ\text{C} \]
\[ Q_2 = 0.057 \text{kJ/sec} \]

For Reading 3

\[ \Delta T = 26 ^\circ\text{C} \]
\[ Q_3 = 0.053 \text{kJ/sec} \]

For Reading 4

\[ \Delta T = 24 ^\circ\text{C} \]
\[ Q_4 = 0.049 \text{kJ/sec} \]

For Reading 5

\[ \Delta T = 23 ^\circ\text{C} \]
\[ Q_5 = 0.047 \text{kJ/sec} \]

**VII. RESULT AND DISCUSSION**

**Table. Indoor and outdoor Readings**

| Time(min) | Water temp(\(^\circ\text{C}\)) | Heat transfer(Kw) | Water temp(\(^\circ\text{C}\)) | Heat transfer(Kw) |
|-----------|-------------------------------|-------------------|-------------------------------|-------------------|
| 0         | 83                            | 0.047             | 85                            | 0.053             |
| 5         | 81                            | 0.047             | 83                            | 0.057             |
| 10        | 79                            | 0.043             | 80                            | 0.053             |
| 15        | 78                            | 0.043             | 78                            | 0.049             |
| 20        | 77                            | 0.039             | 75                            | 0.047             |
From above results and paper studied we can conclude that,
- With change in temperature of heat source, heat dissipation rate changes substantially, higher the temperature of water high will be the heat dissipation rate and vice versa.
- Heat dissipation rate also depends on the surrounding conditions of evaporator.
- With high velocity air in open atmosphere, system gives high rate of heat dissipation.
- Heat dissipation rate depends on the cooling fluid used and its properties of vaporisation temperature and specific heat of vaporisation.
- Filling ratio affects the vaporisation temperature of the cooling liquid and so heat dissipation rate.

**VIII. FUTURE SCOPE**

In nuclear reactor controlled temperature is required with high security requirement so cooling by using electric component is avoided in nuclear reactor so for cooling purpose thermosyphon closed loop cooling is used in nuclear reactor. When there is heat dissipated from the source is large then thermosyphon cooling can be used. In chemical or pharmaceutical industry, control air movement as well as control temperature is required which cannot be controlled by conventional cooling systems. So thermosyphon cooling has scope in that industry. When temperature gradient is very small conventional system does not work effectively, this limitation can be overcome by thermosyphon cooling system. Thermosyphon can be used in cooling of high performance electronics modules as conventional system requires lot of electrical energy.
IX. CONCLUSION

From the above experimental study we conclude that, the cooling effect can be achieved without any external source to system. The cooling effect achieved in outdoor is greater than indoor system about 60%. Air stream velocity affect largely to the heat transfer rate. If condenser is kept in open atmosphere than the system gives better result. This system can be used effectively in correlation with conventional system.

REFERENCES

[1] Jiwon Yeo, Seiya Yamashita, Mizuki Hayashida, Shigeru Koyama [A Loop Thermosyphon Type Cooling System for High Heat Flux] (2014)
[2] Alessandro Franco, SauroFilippeschi [Closed Loop Two-Phase Thermosyphon of Small Dimensions Review of the Experimental Results] (2011).
[3] Ali Chehade, HasnaLouahlia-Gualous, Stephane Le Masson b Eric Lepinasse[ Experimental investigations and modeling of a loop thermosyphon for cooling with zero electrical consumption] (2015).
[4] S.H. Noie [heat transfer characteristics of a two-phase closed thermosyphon] (2015).
[5] RahmatollahKhodabandeh [Thermal performance of a closed advanced two-phase thermosyphon loop for cooling of radio base stations at different operating conditions] (2004).
[6] Alessandro Franco ,SauroFilippeschi [Experimental analysis of Closed Loop Two Phase Thermosyphon (CLTPT) for energy systems] (2013).
[7] RahmatollahKhodabandeh [Heat transfer in the evaporator of an advanced two-phase thermosyphon loop] (2005).
[8] M. Maiani , W. J. M. de kruijf , W. Ambosini [An analytical model for the determination of stability boundaries in a natural circulation single-phase thermosyphon loop] (2003).
[9] Gilles Desrayaud , Alberto Ficher , Manuel Marcoux [Numerical investigation of natural circulation in a 2D – annular closed-loop thermosyphon](2006).
[10] Patrick T. Garrity, James F. klausner, Renweimei [Instability phenomena in a two-phase microchannel thermosyphon] (2009).
[11] Hamidrezashabgard, Bin Xiao, Amir Faghri, Ramesh Gupta, walterWeissman [Thermal characteristics of a closed thermosyphon under various filling conditions](2014).
[12] ShanmugaSundaram , R.V. Seeniraj , R. Velraj [An experimental investigation on a passive cooling system comprising phase change material and two-phase closed thermosyphon for telecom shelters in tropical and desert regions] (2010).
[13] S. Filippeschi [Comparison between miniature periodic two-phase thermosyphons and miniature LHP applied to electronic equipment](2011)
[14] F. Devia , M. Misale [Analysis of the effect of heat sink temperature on single-phase natural circulation loops behaviour]. Augusto J.P. Zimmermann , Claudio Melo [Two-phase loop thermosyphon using carbon dioxide applied to the cold end of the stirling cooler](2014).
[15] Augusto J.P. Zimmermann , Claudio Melo [Two-phase loop thermosyphon using carbon dioxide applied to the cold end of the stirling cooler](2014).
[16] Robert W. macGregor , Peter A. Kew , David A. Reay [Investigation of low global warming potential working fluids for a closed loop two-phase thermosyphon](2013).