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Effect of Mixture of Ethanol-Methanol as a Working Fluid on Heat Transfer Characteristics of Thermosyphon

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ABSTRACT

Thermosyphon are a great prospect towards cooling of high heat dissipating electronics. The implementation of a compact Thermosyphon for cooling of control panels is being presented in this paper. The Thermosyphon involves three components in a loop: an evaporator with a boiling enhancement structure, adiabatic section at the centre and condenser. Experiments will be done to assess the effects of working fluids and of system inclination on the performance of the Thermosyphon. The Thermosyphon selected for application is a one inch (25.4) mm diameter and 500 mm length designed to dissipate 65 to 80 watt from the application. The working fluid will be various ethanol – methanol mixture in 60-40%, 70 -30 % by volume. The method of testing being that the heat load be applied to the Thermosyphon by two band heater of 60 watt capacity and the condenser section being cooled by water jacket with coolant pump and flow control arrangement. The testing of the Thermosyphon in either case will be done orientation of the Thermosyphon at inclination of 0^0, 30^0, 45^0 respective to study the effect on heat transfer ability of the system. Expected outcome from the study is to and Effect of Mixture of Ethanol-Methanol as a Working Fluid on Heat Transfer so also the effect of angle of inclination of Thermosyphon on heat transfer ability (watt) in either cases of Thermosyphon

***Keywords*— Angle of Inclination, Surface Treatment, Thermosyphon, Working Fluids.**

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I. INTRODUCTION

Effective thermal management has become one of the most vital challenges in many technologies because of constant demands for faster speeds and continuous reduction of device dimensions. Recent technological advances in manufacturing have led to the miniaturization of many devices with various applications. Thermal performance of equipments can be improved in many ways such as using two-phase close Thermosyphon (TPCT) which are high efficient heat conductors and can be used to enhance heat transfer because of phase changes of working fluid inside them. It have simple structure, small thermal resistance, high efficiency and low fabrication cost. They are used in many applications such as anti-freezing, baking ovens, heat exchangers in waste heat recovery applications, water heaters and solar energy systems and are showing some promise in high-performance electronics thermal management for situations which are orientation specific. The Thermosyphon consists of an evacuated sealed tube that contains a small amount of liquid. They are proven to be very effective, low cost and reliable heat transfer devices for applications in many thermal management and heat recovery systems. A typical Thermosyphon consist an evacuated-close tube filled with a certain amount of working fluid, and hermetically sealed. When the Thermosyphon is heated at one end, the working fluid evaporates (phase change) and rise through the hollow core to the other end of the Thermosyphon at near sonic speed, where its thermal energy is being removed by a heat sink or other means. Then the vapor condenses and falls back to its origin. In contrast to the Conventional heat pipes which capillary force returns the liquid to evaporator section, a Thermosyphon uses gravitation to return the condensate. Since, the latent heat of evaporation is much larger than sensible heat, therefore working fluid transport very large

Amount of heat and make it 100s to 1000s times better than a solid copper rod. Key factors affecting on thermal performance are: filling ratio (FR), aspect ratio (AR), inclination angle, operational temperature and pressure and working fluid. Many researchers have studied these factors. Most commonly used working fluids are water; methanol; ethylene glycol (EG) and their mixtures [1].

Two-phase closed Thermosyphon is considered as one of the most potential solutions in the field of electronic cooling. It usually does not have capillary structures, and the driving head is mainly from outer fields of force, such as gravity or centrifugal force. This often results in less operating limitations and better heat transfer characteristics for a TPCT than other capillary-structured devices. Factors that influence the performance of Thermosyphon were of great interests in the past researches. Investigations widely studied the effects and confinements of the different boiling-enhanced structures to the evaporators, and the influences of entrainment and flooding phenomena to the cooling sections of it. Researchers also endeavored to scale the size and weight down and discussed the size effects of the Thermosyphon for more and more compact electronic equipments are designed and presented. Besides the traditional vertical, studies about the closed-loop Two Phase Thermosyphon also flourished lately. These researches offered notable contributions for the understandings of the effects of dimensions, system pressure, heating power, properties and fill ratio of working fluids in two-phase Thermosyphon [2].

It is difficult to apply the traditional cooling techniques, e.g. heat sink, fan, water-cooling etc., to the high heat flux electronic devices. In this regard, two-phase closed thermosyphon is considered as one of the most potential solutions in the field of electronic cooling. It usually does not have capillary structures, and the driving head is mainly from gravity or centrifugal force [3].

A number of experimental investigations pertaining to the thermal– hydraulic mechanism and the improvement of thermosyphon design and performance have been reported in recent years. The heat transfer capacity of a thermosyphon is subject to a number of heat transfer limits which are critical to thermosyphon design and operation. Many mathematical models have been developed to analyze the flooding and dry out heat transfer limits in a thermosyphon [4].

In order to increase the oil production, keeping the oil sustainable mobility in the wellbore is vital. At present, the widely used method in China and abroad is to install electric heating equipment in the sucker rod. However, this method has some limitations, such as high energy consumption, high production cost, complicated well construction and operation demands. The thermosyphon is an innovative way applied in wellbores to improve the fluid temperature distribution and reduce fluid viscosity, which heats the oil by geothermal energy without additional energy consumption. During the working process of thermosyphon, the heat absorption and release depend on the temperature difference between the production fluid in the wellbore and the working medium of the thermosyphon, and the related heat transfer also has a close relationship with the oil production and the working medium state. So oil production is a non-steady state process [5].

II. LITERATURE REVIEW

In this literature review the study of various categories research papers on the thermosyphon is done. After going through these research papers it is observed that a lot of work has been done on the heat transfer performance of the thermosyphon system. Some research work has been done on different input conditions of thermosyphon system i.e. filling ratio, aspect ratio and combination of various working fluids. The proposed work that has been done mainly on the basis of the literature review is explained below. The conventional techniques of thermosyphon heat pipe have been studied from the view point of optimization and some novel strategies including inclination of thermosyphon on account of heat transfer, use of nanofluids, type of fluid used in evaporator, cooling process of condenser, etc. present great potential for extensive research. The purpose of this literature review is to go through the main topics of interest i.e. effect of angle of inclination of thermosyphon and mass flow rate of water for cooling process of condenser with ethanol-methanol mixture and surface treatments.

S.H. Noie, et al. [1], made a two-phase closed thermosyphon (TPCT) is a device for heat transmission. It consists of an evacuated close tube filled with a certain amount of working fluid. Fluids with nanoparticles (particles smaller than 100 nm) suspended in them are called nanofluids that they have a great potential in heat transfer enhancement. In the present study, we combined two mentioned techniques for heat transfer enhancement. Nanofluids of aqueous Al_2O_3 nanoparticles suspensions were prepared in various volume concentration of 1–3% and used in a TPCT as working media. Experimental results showed that for different input powers, the efficiency of the TPCT increases up to 14.7% when Al_2O_3/water nanofluids was used instead of pure water. Temperature distributions on TPCT confirm these results too.

Te-En Tsai, et al. [2], by this article experimentally investigates a two-phase closed thermosyphon vapor-chamber system for electronic cooling. A thermal resistance net work is developed in order to study the effects of heating power, fill ratio of working fluid, and evaporator surface structure on the thermal performance of the system. The results indicate that either a growing heating power or a decreasing fill ratio decreases the total thermal resistance, and the surface structure also influences the evaporator function prominently. A reasonable agreement with Rohesnow's empirical correlation is found for the evaporator. An optimum overall performance exists at 140W heating power and 20% fill ratio with sintered surface, and the corresponding total thermal resistance is 0.495 °CW−1.

Hao Peng, et al. [3], made numerical investigation of a novel fin-plate thermosyphon (FPT), used to cool the high heat dissipation electronic devices, was performed. Three dimensional model of fin-plate thermosyphon is established using the fluent software. The effects of fin pinch, fin thickness and fin type at the air side on thermal characteristics are presented with the air flow velocity various from 1.0 m/s to 4.0 m/s. The heat transfer efficiency and pressure drops of FPT for plain fins were reduced by increasing the fin space. It also can be indicated that the cooling performance of FPT with serrated fins was better than plain fins for the same structural parameters.

Hamidreza Shabgard, et al. [4], developed two-dimensional numerical model to simulate the transient operation of a thermosyphon with various working fluid filling ratios. Conservation equations for mass, momentum, and thermal energy are solved using finite volume scheme to determine the hydrodynamic and thermal behavior of the thermosyphon. The heat transfer due to the liquid pool and liquid film are accounted for. The numerical model is validated through comparison with experimental data available in the literature. The model is capable of predicting the optimal filling ratio which corresponds to a condensate film extending from the condenser end cap to the evaporator end cap at steady-state for a given heat input. Overfilled and under filled conditions for which the working fluid inventories are respectively greater than and less than the optimal case are also investigated. Simulation results show that the evaporator temperature of the under filled thermosyphon rises dramatically due to dry out. The optimally-filled thermosyphon has the shortest response time and the lowest thermal resistance, however, a slight increase in the input power will cause breakdown of the condensate film. The overfilled thermosyphon poses a slightly slower thermal response and greater thermal resistance compared to the optimal condition. To ensure optimal and stable steady-state operation, an optimally-filled thermosyphon is recommended with a small amount of additional working fluid to prevent breakdown of the liquid film.

Runze Jia, et al. [5], an experimental rig was established to test the self-balancing heat transfer performance of the thermosyphon with three diameters in an unsteady temperature field, which exists in the actual oil production process. The experimental rig was also able to demonstrate certain factors can impact on the heat transfer performance of thermosyphon include the diameter of the pipe, angle, with or without working medium and so on. Based on experimental results, a long thermosyphon made of several hollow sucker rods was designed and manufactured, which has been used in the Su 28 Well situated in the Huabei oil field in China. Experimental results further indicated that the thermosyphon can effectively transfer the required heat of the fluid from wellbore bottom to wellbore top, causing the temperature of wellhead fluid to increase from 22 ^{0}C to 39 ^{0}C. In addition, a mathematical model is established to simulate the heat transfer process of this thermosyphon. The positive correlation between the simulated results and the experimental data demonstrated the effectiveness of the model. With this model, the heat transfer process of thermosyphon during oil production is simulated, with results indicating that the fluid temperature at the wellhead would increase when the production of oil increases, given a linear tendency pump setting.

A.A. Chehade, et al. [6], presents the experimental investigation of a two-phase closed loop. The experimental setup consists of an evaporator and a condenser connected by two insulated tubes. Using water as a working fluid, the experiments were conducted to evaluate the performance of a thermosyphon: the effects of fill charge ratio, the condenser jacket coolant inlet temperature and the mass flow rate. Finally, the results show that the optimal fill charge ratio is between 7% and 10%, the cooling system has the optimal performance when controlling the condenser jacket water temperature and flow rate at 5^{0}C and at 0.7 l/min respectively. System, loop, evaporator, vapor line, condenser, and liquid line thermal resistances analysis is directed additionally to the pressure and temperature evolutions for the better understand of the main parameters affecting the cooling system performance.

M.M. Sarafraz, et al. [7], this paper focuses on fouling formation of nanofluids in a gravity-assisted thermosyphon equipped with a mesh screen wick. A transient study has been established on the fouling resistance of water-based TiO2 nanofluids at different operating conditions comprising the applied heat flux, mass concentration and inclination of thermosyphon. Nanofluids were prepared using prolonged sanitation, stirring, and pH control. Triton X-100 was utilized as a dispersant. The thermosyphon is a copper made tube, which is dimensionally 10.7 mm and 12 mm for inner and outer pipe diameters respectively and total length of 280 mm. Transient results over the extended time reveal a considerable deterioration of heat transfer coefficient and thermal performance as a result of fouling formation inside the wick at evaporator section. According to the results, rate of fouling can be enhanced by increasing the nanofluids mass concentration. Intensification of fouling on wick structure and internal wall of evaporator causes instabilities in thermal performance of thermosyphon over the time, which eventually causes the thermosyphon failure. This point has been ignored by most of previous researchers, which has a considerably negative impact on thermal performance of thermosyphon at longer operating time and higher heat loads. Therefore, a new fouling resistance model has been re-developed combining the micro fluidic typical models. This model can predict the fouling resistance of nanofluids inside the thermosyphon with approximate deviation of 30%

III.PROPOSED EXPERIMENTAL DETAILS

A. Principle of Operation of Thermosyphon

The thermosyphon has been proved as a promising heat transfer device with very high thermal conductance. In practice, the effective thermal conductivity of thermosyphon exceeds that of copper 200 to 500 times. A two-phase closed thermosyphon is a high performance heat transfer device which is used to transfer a large amount of heat at a high rate with minimum temperature difference. Thermosyphon make use of the highly efficient heat transfer process of evaporation and condensation to maximize the thermal conductance between a heat source and a heat sink. They are often referred to as thermal superconductors because they can transfer large amounts of heat over relatively large distances with minimum temperature differences between the heat source and heat sink.

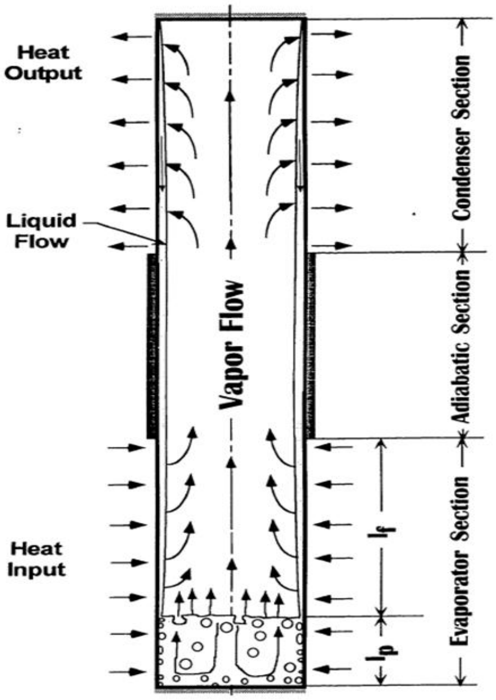

Fig. 1 Two-phase closed thermosyphon working principle [8]

The amount of heat that can be transported by these devices is usually several orders of magnitude greater than pure conduction through a solid metal. They are proven to be very effective, low cost and reliable heat transfer devices for applications in many thermal management and heat recovery systems. Due to the more heat transfer effectiveness the thermosyphon has its own importance in the low temperature difference heat transfer. The thermosyphon consists of an evacuated sealed tube that contains a small amount of liquid. The heat applied at the evaporator section is conducted across the pipe wall causing the liquid in the thermosyphon to boil in the liquid pool region and evaporate and/or boil in the film region. In this way the working fluid absorbs the applied heat load converting it to latent heat. The vapour in the evaporator zone is at a higher pressure than in the condenser section causing the vapour to flow upward. In the cooler condenser region, the vapour condenses thus releasing the latent heat that was absorbed in the evaporator section. The heat then conducts across the thin liquid film and exits the thermosyphon through the tube wall and into the external environment. Within the tube, the flow circuit is completed by the liquid being forced by gravity back to the evaporator section in the form of a thin liquid film. As the thermosyphon relies on gravity to pump the liquid back to the evaporator section, it cannot operate at inclinations close to the horizontal position.

B. Proposed Experimental Setup

Experimental setup of two phase closed thermosyphon is illustrated in Fig. 2. It consists of an enclosed evacuated copper tube having evaporator section at lower side and condenser section at the upper side. 6 thermocouples are attached on the copper tube at similar distances, and the positions of thermocouples are selected such that entire temperature distribution of thermosyphon tube should be covered.

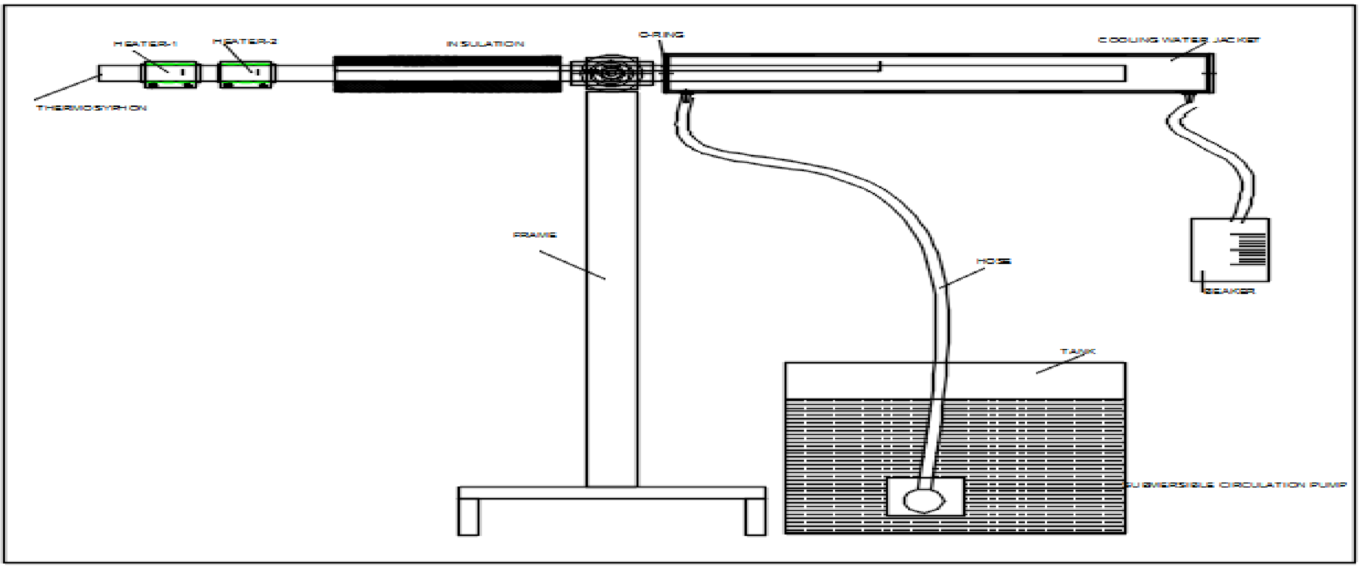

Fig. 2 Proposed Experimental setup of two phase closed thermosyphon

Temperature indicator displays the temperature of the thermocouples attached to the copper tube. Coil heaters or band heaters are attached to the evaporator section for heat supply and it is controlled by controlling the voltage and current. Condenser section is surrounded by concentric cylinder through which coolant flows. The coolant flow is varied by a controlled valve. For initial evacuation of tube arrangement is made to attach vacuumed pump at the top and also pressure gauge is attached to measure the pressure inside the tube. Evacuation is necessary to eliminate the effect of non condensable gases. Following table shows the general configuration of experimental setup which may vary according to researchers requirement. The liquid is being forced by gravity back to the evaporator section in the form of a thin liquid film. As the thermosyphon relies on gravity to pump the liquid back to the evaporator section, it cannot operate at the horizontal position [9].

C. Factors for Experimental Analysis

1) Filling Ratio

It is one of the important parameter. Filling ratio considered for this experimentation 10% to 70%.Filling ratio has two opposite effects on the rate of evaporation. First, at higher fill ratio it is possible to have more heat transfer from the evaporator wall to the working fluid, as more evaporator's wall surface is in contact with the working fluid. This can increase the evaporation rate and consequent thermosyphon performance. From experimentation it is proved that 10% to 60% filling ratio, increases thermosyphon performance. However higher height of working fluid has a negative effect of large bubbles or film formation in the lower parts of the evaporator. This has direct effect on heat transfer rate to the evaporator and can decrease the thermosyphon performance. From experimentation, onwards 70% filling ratio decreases thermal performance of thermosyphon [12].

2) Inclination Angle

It is also important factor which affect thermal performance of thermosyphon to great extent. The lower end of the thermosyphon tube was heated causing the liquid to vaporize and the vapour to move to the cold end of the tube where it is condensed. The condensate is returned to the hot end by gravity. This is why thermosyphon is kept vertical i.e., 90^o with horizontal. Experimentation also includes study at various inclination angles to evaluate thermal performance. At various inclination angles and at various heat loads thermal performance is varying [10, 12]. So after experimentation we got best configuration factor of inclination angle and heat load which is responsible for higher thermal performance.

3) Heat Load

Heat load is given to the evaporator section of the thermosyphon. After applying heat, working fluid get vaporize in the evaporator. But heat load is dependent on working fluid. It defines boiling limit of the working fluid. If the boiling point of the working fluid is higher near about 100 oC, then heat load can be applied from 100 ^oC to the point where maximum fluid will evaporate. In this experimental model, we have used binary mixture of ethanol-methanol as a working fluid. Thermodynamic properties of ethanol and methanol are shown in Table 3.3 Ethanol and methanol has lower boiling points than water and under vacuum mixture gain low boiling point. So for experimentation we have selected heat load range of 25 W to 200 W.

D. Proposed Experimental Setup Description

TABLE I
PROPPSED EXPERIMENTAL SETUP DESCRIPTION

Working Fluid	**Ethanol-Methanol Mixture**
Tube material	Copper
Internal diameter (mm)	25.4
External diameter (mm)	26
Total length (mm)	500
Evaporator length (mm)	200
Condenser length (mm)	200
Adiabatic length (mm)	100
Aspect ratio (L/D ratio of evaporator section)	8.33

E. Proposed Experimentation Parameters

Experimentation was carried on the thermosyphon heat pipe. Working fluid is important parameter in the experimentation. Ethanol-Methanol binary mixture was used as a working fluid. Other parameters and its description as follows

TABLE III
PROPPSED EXPERIMENTAL SETUP PARAMETERS

Parameter	**Description**
Filling ratio	50%
Inclination angle with horizontal axis	0^o, 30^0, 45^0(Horizontal),
Heat load (W)	60 to 85W
Coolant flow rate (Kg/hr)	varying
Aspect ratio	8.33

F. Heat Transfer Rate

The following calculations were carried out to determine the input and output heat transfer rate of the thermosyphon [10]. The actual heat input to the evaporator section was obtained from Eq. (1)

$$Q = VI - Q_{loss} \quad (1)$$

Where, Q_{loss} is the sum of heat losses from the evaporator section by radiation and free convection.

$$Q_{loss} = Q_{rad} + Q_{conv} \quad (2)$$

The radiation heat transfer rate was evaluated from Eq. (3)

$$Q = \varepsilon\ \sigma\ A_e\ (T_{ins}^4 - T_{air}^4) \quad (3)$$

And free convection heat transfer was calculated from Eq. (4)

$$Q = h_{conv} A_e (T_{ins} - T_{air}) \quad (4)$$

Free convection heat transfer coefficient on a vertical and inclined cylinder was evaluated from Churchill and Chu Eq. (5)

$$Nu = h_{conv}. L_e / k_{air} = \{0.825 + 0.387 Ra^{1/6} / [1 + (0.492 / Pr)^{9/16}]^{8/27}\}^2 \quad (5)$$

Where, Ra (Rayleigh number) was evaluated from Eq. (6)

$$Ra = g.\beta. (T_{ins} - T_{air}). L_e^3 / \alpha.\upsilon \quad (6)$$

Incropera and De Witt recommended that for 30◦≤ Φ <90◦, g can be replaced by g.sinΦ and Eq. (6) is used to compute average Nusselt Number. Hence, the sum of heat loss was about 2.34%, 2.67% and 2.93% of input power to the evaporator section for aspect ratios of 15, 20 and 30 respectively. The heat transmitted from the condenser section is equal to the rejected heat to coolant water in the jacket, and was calculated from Eq. (7)

$$Q_{out} = m.Cp, w (T_{o, w} - T_{i, w}) \quad (7)$$

G. Heat Transfer Limitations

There are various parameters that put limitations and constraint on the steady and transient operation of a two-phase closed thermosyphon. Physical phenomena that might limit heat transport in two-phase closed Thermosyphon are due to dry-out, flooding (or entrainment), and boiling. The dry-out limit is the easiest to avoid by providing a sufficient amount of working fluid into the thermosyphon at startup (F.R≥20%). Since, in this work the filling ratios are higher than 20%, only the boiling and flooding limits are examined. Because the input heat is rather low, the boiling limit is evaluated based on a correlation proposed by Gorbis and Savchenkov [10].

$$Q_{C, 90} = Ku \{h_{fg}. P_v^{0.5} [\sigma. g. (\rho_1 - \rho_v)]^{0.25} \quad (8)$$

Where,

$$Ku = 0.0093 (A.R)^{-1.1} (D_i / L_c)^{-0.88} (F.R)^{-0.74} (1 + 0.03Bo)^2 \quad \cdots\cdots \quad 2< Bo< 60 \quad (9)$$

The flooding limit is evaluated based on a correlation proposed by Faghri.

$$Q_{C, 90} = K.h_{fg}.A_{cross}. [g.\sigma. (\rho_1 - \rho_v)^{0.25}] \text{ x } [\rho_v^{-0.25} + \rho_1^{-0.25}]^{-2} \quad (10)$$

Where,

$$K = (\rho_1 / \rho_v)^{0.14} \tanh^2 (Bo)^{0.25} \quad (11)$$

The above correlations are used for the vertical situation of a Thermosyphon. For the inclined Thermosyphon the following correlation is used for the calculation of the both boiling limit and the flooding limit, presented by Shiraishi et al.

$$Q_{c,i} / Q_{C, 90} = 1+ 0.13 \{[(\rho_1 / \rho_v)^{½} + 0.005 / (\rho_1 / \rho_v) + 0.05] – 1\} \quad (12)$$

Also Consider Other Various Parameters that Put Limitations

There are various parameters that put limitations and constraints on the steady and transient operations of Thermosyphon. In other words, the rate of heat transport though a Thermosyphon is subjected to a number of operating limits. The physical phenomena for each limitation are briefly presented below [11].

1) Sonic Limit

The rate at which vapours travels from evaporator to condenser is known as sonic limit; The evaporator and condenser sections of a Thermosyphon represent a vapour flow channel with mass addition and extraction due to the evaporation and condensation, respectively. The vapour velocity increases along the evaporator and reaches a maximum at the end of the evaporator section. The limitation of such a flow system is similar to that of a converging-diverging nozzle with a constant mass flow rate, where the evaporator exit corresponds to the throat of the nozzle. Therefore, one expects that the vapour velocity at that point cannot exceed the local speed of sound. This choked flow condition is called the sonic limitation. The sonic limit usually occurs either during heat pipe starts up or during steady state operation when the heat transfer coefficient at the condenser is high. The sonic limit is usually associated with liquid-metal heat pipes due to high vapour velocities and low densities. When the sonic limit is exceeded, it does not represent a serious failure. The sonic limitation corresponds to a given evaporator end cap temperature. Increasing the evaporator end cap temperature will increase this limit to a new higher sonic limit. The rate of heat transfer will not increase by decreasing the condenser temperature under the choked condition. Therefore, when the sonic limit is reached, further increases in the heat transfer rate can be realized only when the evaporator temperature increases. Operation of heat pipes with a heat rate close to or at the sonic limit results in a significant axial temperature drop along the heat pipe.

2) Boiling Limit

The rate at which the working fluid vaporizes from the added heat; If the radial heat flux in the evaporator section becomes too high, the liquid in the evaporator section boils and the wall temperature becomes excessively high. The vapour bubbles that form near the pipe wall prevent the liquid from wetting the pipe wall, which causes hot spots, resulting in the rapid increase in evaporator wall temperature, which is defined as the boiling limit. However, under a low or moderate radial heat flux, low intensity stable boiling is possible without causing dry out. It should be noted that the boiling limitation is a radial heat flux limitation as compared to an axial heat flux limitation for the other heat pipe limits. However, since they are related though the evaporator surface area, the maximum radial heat flux limitation also specifies the maximum axial heat transport. The boiling limit is often associated with heat pipes of non-metallic working fluids. For liquid-metal heat pipes, the boiling limit is rarely seen.

3) Entrainment Limit

This limit occurs due to the friction between working fluid and vapour which travel in opposite directions. A shear force exists at the liquid-vapour interface since the vapour and liquid move in opposite directions. At high relative velocities, droplets of liquid entrained into the vapour flowing toward the condenser section. If the entrainment becomes too great, the evaporator will dry out. The heat transfer rate at which this occurs is called the entrainment limit. Entrainment can be detected by the sounds made by droplets striking the condenser end of the heat pipe. The entrainment limit is often associated with low or moderate temperature heat pipes with small diameters, or high temperature heat pipes when the heat input at the evaporator is high.

4) Vapour Pressure Limit

Properties	**Methanol (CH3OH)**	**Ethanol (C2H5OH)**
Molecular Weight	32	46
Boiling point (^oC)	65	78
Melting point (^oC)	-98	-144
Useful temperature range (^oC)	10 to 130	0 to 130
Thermal Conductivity at 300K (W/m-K)	0.202	0.171
Latent heat of vaporization (kJ/kg)	1100	846

At low operating temperatures, viscous forces may be dominant for the vapour moving flow down the heat pipe. For a long liquid-metal heat pipe, the vapour pressure at the condenser end may reduce to zero. The heat transport of the heat pipe may be limited under this condition. The vapour pressure limit (viscous limit) is encountered when a heat pipe operates at temperatures below its normal operating range, such as during start up from the frozen state. In this case, the vapour pressure is very small, with the condenser end cap pressure nearly zero.

5) Flooding Limit

The flooding limit is the most common concern for long Thermosyphon with large liquid fill ratios, large axial heat fluxes, and small radial heat fluxes. This limit occurs due to the instability of the liquid film generated by a high value of interfacial shear, which is a result of the large vapour velocities induced by high axial heat fluxes. The vapour shear hold-up prevents the condensate from returning to the evaporator and leads to a flooding condition in the condenser section. This causes a partial dry out of the evaporator, which results in wall temperature excursions or in limiting the operation of the system.

H. Condensation Heat Transfer Coefficient

Experimental condensation heat transfer coefficient is evaluated from the following equation

$$h_c = Q_{out} / A_c (T_v - T_{c,m}) \qquad (13)$$

The condenser temperature, $T_{c,m}$ is calculated by the arithmetic mean of the surface temperatures of the condenser section. T_v is vapor temperature that, in this research, was considered to be equal to adiabatic temperature as discussed [10].

I. Effect of Working Fluid on Thermosyphon

1) Binary Mixture

From the literature review, it is found that various researches has been done on various working fluid solutions like water, distilled water, butanol, ethanol, etc., refrigerant like R-12, R-22, R-134a, FC-72, FC-77, FC-84, etc. and nanoparticles such as Al_2O_3, TiO_2 and Fe_2O_3, 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 [11].

2) Ethanol-Methanol Mixture

As far as selection of working fluid for Thermosyphon is concerned, first go through various thermodynamic properties of ethanol and methanol.

TABLE IIIII
PROPERTIES OF ETHANOL AND METHANOL

In this experiment we used ethanol and methanol ratio 60:40 (by volume) because at this ratio these two solutions are completely soluble with each other.

TABLE IVV
PROPERTIES OF ETHANOL AND METHANOL MIXTURE

Properties	**Ethanol-Methanol Mixture**
Boiling point (^oC)	72.8
Melting point (^oC)	-125.6
Useful temperature range (^oC)	0 to 100
Thermal conductivity at 300 K (W/m-K)	0.1834
Latent heat of vaporization (kJ/kg)	947.6

These thermodynamic properties are useful for the Thermosyphon as a working fluid in 0 ^oC to 100 ^oC temperature applications. Hence ethanol-methanol mixture was selected for the experimental assessment of the Thermosyphon as a working fluid.

J. Thermosyphon Reliability

Thermosyphon have no moving parts. However, care must be given when designing and manufacturing the Thermosyphon heat pipe. Two manufacturing factors can reduce the reliability of the Thermosyphon: the seal of the pipe and the cleanness of pipe internal chamber. Any leakage in the Thermosyphon pipe will eventually fail the pipe. If the internal chamber is not thoroughly clean, when the Thermosyphon subjected to heat, the residual may generate non-condensable gas and degrade the pipe performance. Improper bending and flattening of the pipe may also cause the leakage on the pipe seal. There are some external factors that may also shorten the life of a Thermosyphon such as shock, vibration, force impact, thermal shock and corrosive environment.

K. Common Industrial Thermosyphon Applications Include

1) Gas Turbine Blade Cooling
2) Electrical Machine Rotor Cooling
3) Transformer Cooling
4) Nuclear Reactor Cooling
5) Steam Tubes for Baker's Oven
6) Cooling for Internal Combustion Engines
7) Electronics Cooling

IV. OBJECTIVES OF PROPOSED STUDY

The proposed work has *main objective is performance improvement of Thermosyphon system* by adopting the various Ethanol-Methanol mixture.

- In this design, copper tubes are used with fixed length and diameter (i.e. aspect ratio 8.33)
- Working fluid flows in through an inner of Thermosyphon and it is ethanol-methanol mixture of 60-40%, 70-30% like by volume.
- Performance of Thermosyphon is analyzed by angle of inclination 0^0, 30^0, 45^0 and change in mass flow rate of water through condenser.

V. METHODOLOGY OF PROPOSED STUDY

To achieve the above mentioned objectives the following methodology is preferable for the proposed work -

- To develop a *mathematical model* and *integration of all the parameters* that defines the whole system and also relationships between different parameters affecting the Thermosyphon system.
- *Testing of Thermosyphon* with ethanol and methanol as working fluid by various volume
- *Experimental investigation* of the effect of angle of orientation on heat dissipation ability of Thermosyphon with ethanol and methanol as working fluid thereby it will be possible to decide the most effective angle of orientation of the Thermosyphon.
- *Graphs of heat dissipation* ability of Thermosyphon Vs angle of orientation can be plotted.
- *To design and fabricate* the Thermosyphon system for low temperature gradient difference.
- *Thermal analysis and performance calculation* of the Thermosyphon system for the heat transfer rate by various working fluid, mass flow rate of water from the storage tank, overall heat transfer coefficient.

Experimental validation, performance evaluation and selecting the best result for improved the heat transfer performance of Thermosyphon system.

VI. CONCLUSION

It is found that various researches has been done on various working fluid solutions like water, distilled water, butanol, ethanol, etc., Refrigerant like R-12, R-22, R-134a, FC-72, FC-77, FC-84, etc. and nanoparticles such as Al_2O_3, TiO_2 and Fe_2O_3, 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.

In this paper, here scope of use Binary fluid like Ethanol-Methanol mixture and check the performance of Thermosyphon by changing the Ethanol-Methanol mixture ratio by volume.

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