Performance Comparison of Fluids in a Closed Loop Pulsating Heat Pipe

A THESIS SUBMITTED TO THE DEPARTMENT OF "MECHANICAL ENGINEERING" IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

Submitted By

Lt. Md. Yakub	Student No: 201418063
Fahim Murshed	Student No: 201418123
Samin Shadman Zahir	Student No: 201318046

Supervised By

Lt. Colonel Golam Saklayen, EME

Associate Professor

Faculty of Mechanical Engineering

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY (MIST)

DEPARTMENT OF MECHANICAL ENGINEERING

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY (MIST)

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Faculty of Mechanical Engineering

Military Institute of Science & Technology (MIST)

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STUDENT DECLARATION

This is to certify that the thesis entitled," **Performance Comparison of Fluids in a Closed Loop Pulsating Heat Pipe"** is an outcome of the investigation carried out by the author under the supervision of **Lt. Colonel Golam Saklayen**, EME, Faculty of Mechanical Engineering, Military Institute of Science and Technology (MIST). This thesis or any part of it has not been submitted to elsewhere for the award of any other degree or diploma or other similar title or prize.

SUBMITTED BY

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Lt. Md. Yakub

Student no: 201418063

____

Fahim Murshed

Student no: 201418123

____

Samin Shadman Zahir

Student no: 201318046

SUPERVISOR CERTIFICATION

This is to certify that **Lt. Md. Yakub**, Student no: 201418063; **Fahim Murshed**, Student no: 201418123; **Samin Shadman Zahir**, Student no: 201318046 have completed their undergraduate thesis report on **“Performance Comparison of Fluids in a Closed Loop Pulsating Heat Pipe”** under my supervision. To the best of my knowledge, the report is their original work and was not submitted elsewhere for other purpose. I wish their ever success in life.

APPROVED BY

Lt. Colonel Golam Saklayen, EME

Associate Professor

Faculty of Mechanical Engineering

Military Institute of Science and Technology

Mirpur Cantonment, Dhaka-1216

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The Authors

Department of Mechanical Engineering

Military Institute of Science and Technology

Mirpur Cantonment, Dhaka-1216

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Abstract

The pulsating heat pipe is the advent of avid progression for the rise of heat transfer technology, which in a plethora of modern techniques has risen automatically to the forefront of microelectronics cooling. Recent advances in electronics design and manufacturing resulted in significant increases in heat flux density through miniaturization of components and a simultaneous increase in power requirements associated with increased product functionality. As a result, production of microelectronics cooling devices will be of optimal importance in the face of scientific development. A PHP or pulsating heat pipe is essentially a non-equilibrium heat transfer device whose performance success depends on continuous maintenance of non-equilibrium conditions within the system. A pulsating heat pipe also promises alternatives for the removal of high localized heat fluxes to provide necessary level of temperature uniformity across the components that need to be cooled. The heat is thus transferred not only by latent heat transfer like in other types of heat pipe, but also by the sweeping of the hot walls by colder moving fluid and vice versa. This phenomenon is the reason of high efficiency of PHPs in comparison with other heat pipes. The aim of this research paper is to better understand the operation of PHP through experimental investigation and obtain comparative results with better for different parameters. A series of experiments are conducted on a closed loop PHP with 8 loops of copper capillary tube of 2mm internal diameter. Initially only ethanol was taking as working fluid, later a blend of ethanol and methanol are used as working fluid and the corresponding effects on the process parameters are measured. The operating conditions are the heat input, filling ratio. For both the working fluid, the filling ratios were taken separately, measure of them being 50%,60%,70%,80%. This paper, shall primarily demonstrate the effect of different parameters on the closed looped system and from where the effects of this parameters on the basic heat transfer properties changes in tis value of the content which is the required or specific target of the experiment. Important insights of the operational of CLPHP are obtained and optimum performance and its variation with different working fluid is identified and studied. To conclude, PHP or CLPHP will remain one of the foremost technology for heat transfer at low weight and cost.

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NOMENCLATURE

Rth= Thermal resistance (°C/W)

ΔT= Temperature difference (°C)

Q= Heat input (W)

ρ= Density (Kg/m)

V= Specific Volume (m /kg)

CP= Specific Heat (kJ/kg-K)

S= Specific Entropy (kJ/kg-K)

e= Specific Enthalpy (kJ/kg)

μ= Dynamic Viscosity (cP)

FR= Filling Ratio (%)

D0= Outer Diameter (mm)

Di= Inner Diameter (mm)

L= Length (mm)

Teva= Evaporator Temperature (°C)

TCond= Condensation Section Temperature (°C)

Chapter 1

INTRODUCTION

1.1 Background

With the headway of current society, the requirement for scaling down and minimization has expanded. Whole human progress now decides on brilliant and helpful gadgets that are anything but difficult to convey and easy to understand. Regular most recent renditions of existing gadgets are being propelled and new plans are being manufactured. This has conveyed the present society eye to eye with issues of high power dispersal and heat thickness (control per unit zone). Market interest for effective microelectronics has represented the test of heating system of expanded power levels combined with high heat motions. These demands pose a simultaneous challenge of managing increased power level and fluxes [1, 2] To moderate and take care of this issue of energy hardware, the utilization of fluid vapor stage change cooling gadgets, for example, the heat channels, have been presented. In spite of the fact that the customary heat channels (e.g. smaller than usual or miniaturized scale) are one of the demonstrated innovations, the assembling of the complex, scaled down wick structure/geometry of these warmth channels could turn into the most cost serious factor. Another basic confinement is as far as possible, which happens when the wick structure can't restore a satisfactory measure of fluid back to the evaporator. The transport mechanism of this simple device also poses an excellent opportunity to understand its complex internal two-phase thermo hydrodynamics.

With a view to defeat these challenges scientists have thought of throbbing heat channels (PHPs) which take a shot at the standard of wavering of the working liquid and stage change wonder in a thin tube. PHP is a wandering container of narrow measurements with many turns filled somewhat with an appropriate working liquid with no wick structure. PHPs are latent two-stage heat control gadgets initially presented by Akachi et al [1-4]. In this application, lessened measurement channels are utilized, which are specifically affected by the chosen working liquid. The vapor plugs created by the dissipation of the working liquid push the fluid slugs toward heat pipe is a heat transfer mechanism that can transport large quantities of heat with a very small difference in temperature [5]. PHPs/OHPs were first presented in 1971 by Smyrnov in a Russian Patent, and in 2004 in a US patent [3]. Next was by Akachi. H. suggested a new variant of the PHPs construction in 1990 [4]. d the buildup area and this movement causes stream motions that guide the gadget operation. Execution of a PHP relies on many components like the geometrical parameters of stream channel, the working liquid, the filling proportion, and number of turns, PHP design and the slant edge [5]. The reasons for this examination are to contemplate the heat exchange attributes of a CLPHP and assess a few issues identified with its execution. In parallel, heat pipes in various configurations and design, have played a decisive role in many applications. In line with these developments is the introduction of pulsating heat pipes in the early nineties [4, 7-9], as a very promising heat transfer technology, especially suited for thermal management of electronics.

There are many designing viable circumstances where heat is being exchanged under states of throbbing and responding stream, for example, the operation of present day control creating offices and mechanical hardware utilized as a part of metallurgy, flight, concoction and nourishment innovation. Cavitation's in water driven pipelines, weight surges and stream of blood are additionally some of recognizable occasion of such streams. The execution of this hardware in warm building applications is influenced by the throbbing stream parameters. Amid the previous couple of decades, various examinations have been given to this throbbing stream and its related heat exchange issues. A survey of these examinations with accentuations on the beginning of turbulence, speed dispersion and pipe stream and the heat exchange qualities including hub heat exchange upgrade and convective heat move are introduced in the accompanying areas.

1.2 Objectives:

The aim of this thesis is –

1.To understand the mechanism of CLPHP

2.Importance of the working fluid inside the PHP.

3.Properties of the working fluid.

4.To compare the temperature distributions of the Evaporator, Adiabatic and Condenser
sections in different orientations.

5.To compare the properties of methanol, ethanol and water

6.To compare Heat transfer coefficient of the system varying
filling ratio.

7. To find out best feature from the comparison between normal stage with different working fluid and blend of ethanol and methanol.

Chapter 2

LITERATURE REVIEW

2.1 Heat pipe

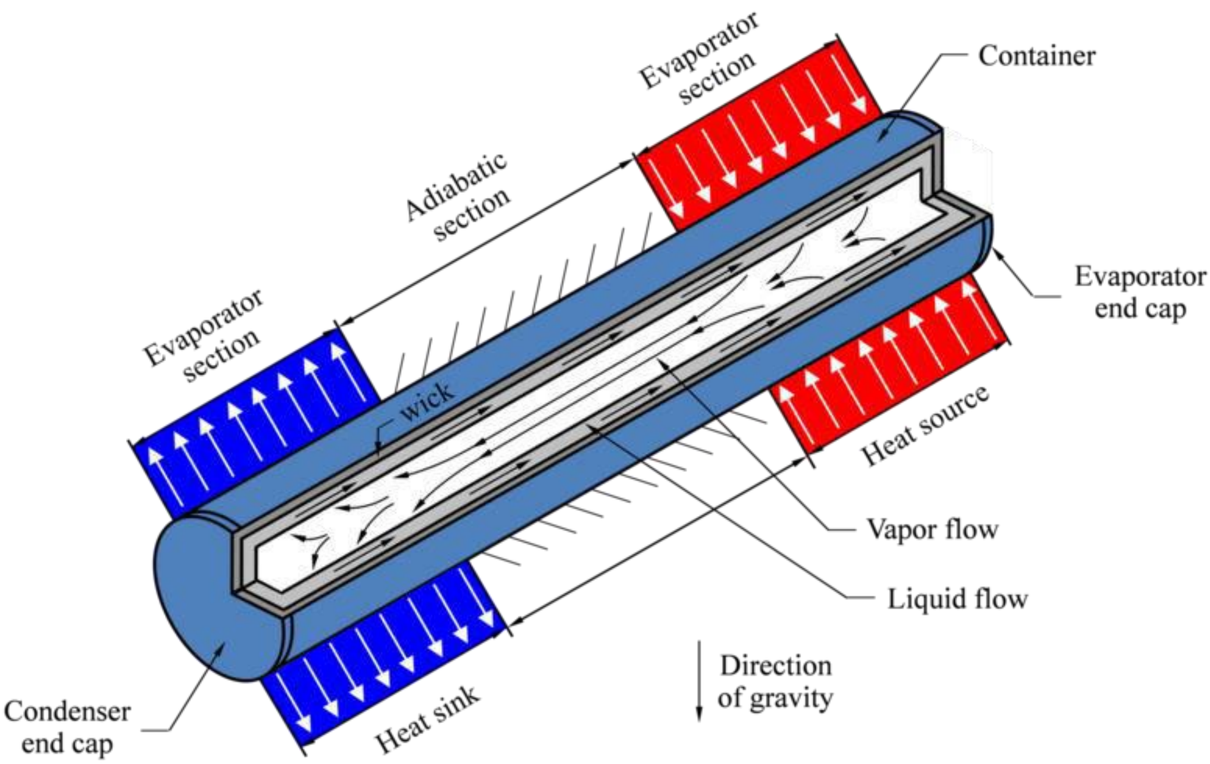


Figure 2.1: Heat pipe

The operation of a heat pipe [9] [10] is easily understood by using a cylindrical geometry, as shown in Fig. 1. However, heat pipes can be of any size or shape. The components of a heat pipe are a sealed container (pipe wall and end caps), a wick structure, and a small amount of working fluid which is in equilibrium with its own vapor. Different types of working fluids such as water, acetone, methanol, ammonia or sodium can be used in heat pipes based on the required operating temperature. The length of a heat pipe is divided into three parts: the evaporator section, adiabatic (transport) section and condenser section. A heat pipe may have multiple heat sources or sinks with or without adiabatic sections depending on specific applications and design. Heat applied externally to the evaporator section is conducted through the pipe wall and wick structure, where it vaporizes the working fluid. The resulting vapor pressure drives the vapor through the adiabatic section to the condenser, where the vapor condenses, releasing its latent heat of vaporization to the provided heat sink. The capillary pressure created by the menisci in the wick pumps the condensed fluid back to the evaporator section. Therefore, the heat pipe can continuously transport the latent heat of vaporization from the evaporator to the condenser section. This process will continue as long as there is a sufficient capillary pressure to drive the condensate back to the evaporator.

The menisci at the liquid-vapor interface are highly curved in the evaporator section due to the fact that the liquid recedes into the pores of the wick. On the other hand, during the condensation process, the menisci in the condenser section are nearly flat. A capillary pressure exists at the liquid-vapor interface due to the surface tension of the working fluid and the curved structure of the interface. The difference in the curvature of the menisci along the liquid-vapor interface causes the capillary pressure to change along the pipe. This capillary pressure gradient circulates the fluid against the liquid and vapor pressure losses, and adverse body forces such as gravity or acceleration. This narrow weight angle flows the liquid against the fluid and vapor weight misfortunes, and antagonistic body powers, for example, gravity or speeding up. Gi et al. [13]

The vapor pressure changes along the heat pipe are due to friction, inertia and blowing (evaporation) and suction (condensation) effects, while the liquid pressure changes mainly as a result of friction [10]. The liquid-vapor interface is flat near the condenser end cap corresponding to a zero local pressure gradient at very low vapor flow rates. A typical axial variation of the shape of the liquid-vapor interface and the liquid and vapor pressures for low vapor flow rates are shown in Figs. 2(a) and 2(b), respectively. Recently, PHPs with a sintered metal wick have been prototyped by Zuo et al. [13,14] and analyzed by Holley and Faghri [15]

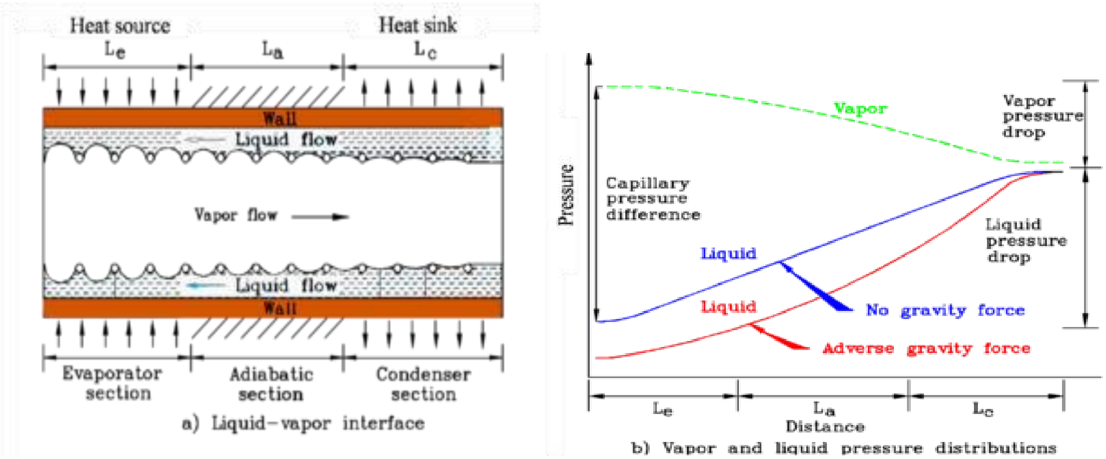


Figure 2.2: Axial variation of liquid vapor interface and the vapor and liquid pressures and liquid pressures heat pipe along low vapor flow rates

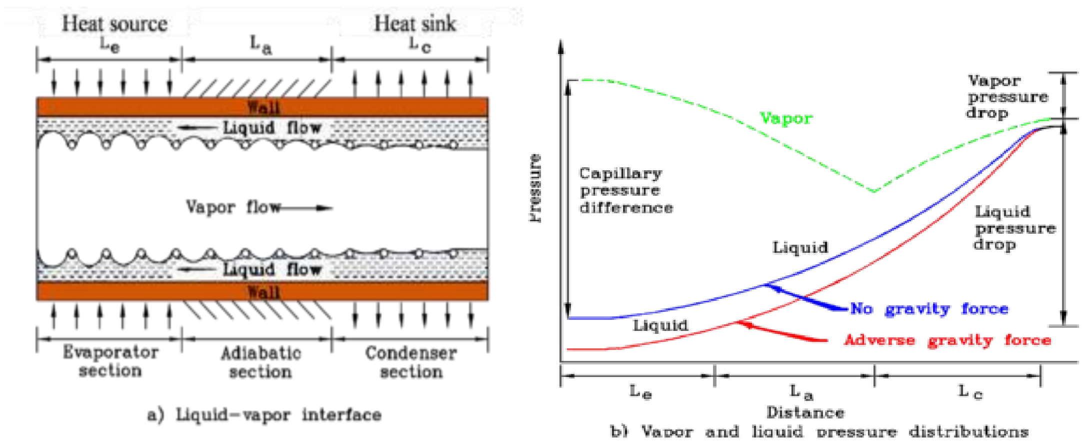


Figure 2.3: Axial variation of vapor liquid interface and the vapor and liquid pressures along the heat pipe at moderate vapor flow rates.

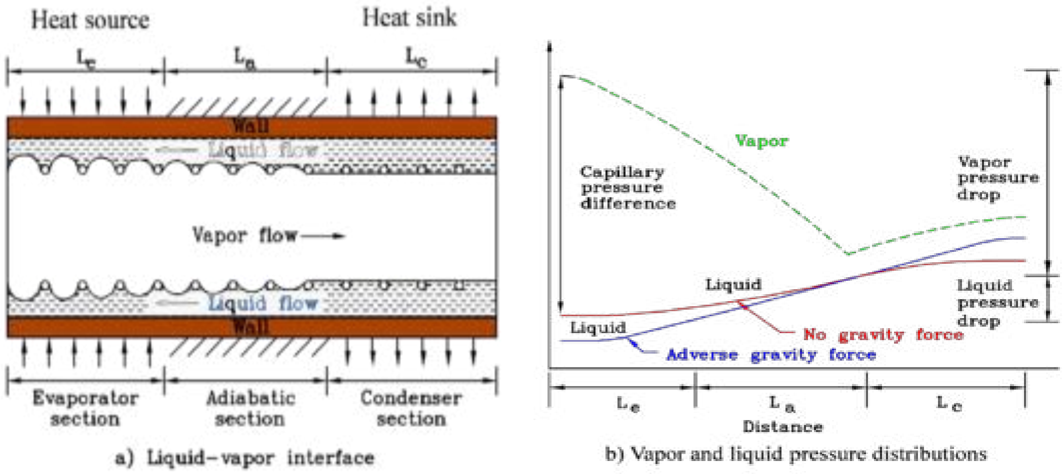


Figure 2.4: Axial variation of liquid vapor interface and the vapor and liquid pressures along the heat pipe at high flowrates

The maximum local pressure difference occurs near the evaporator end cap. This maximum local capillary pressure should be equal to the sum of the pressure drops in the vapor and the liquid across the heat pipe in the absence of body forces. When body forces are present, such as an adverse gravitational force, the liquid pressure drop is greater, indicating that the capillary pressure must be higher in order to return the liquid to the evaporator for a given heat input. At moderate vapor flow rates, dynamic effects cause the vapor pressure drop and recovery along the condenser section, as shown in Fig.2 3(b).

The local liquid-vapor pressure difference is small, but this pressure gradient approaches zero at the condenser end cap similar to the low vapor flow rate case. Again, the capillary pressure difference at the evaporator end cap should be balanced by the sum of the total pressure drop in the vapor and liquid across the heat pipe.

The general trend at high vapor flow rates with low liquid pressure drops is different from the other two cases. The vapor pressure drop can exceed the liquid pressure drop in the condenser section. In such a case, the liquid pressure would be higher than the vapor pressure in the condenser section if the pressure in the liquid and vapor are equal at the condenser end cap. In reality, the wet point is not situated at the condenser end cap as shown in Fig 2.4(b), and the menisci at the liquid-vapor interface in the condenser are curved.

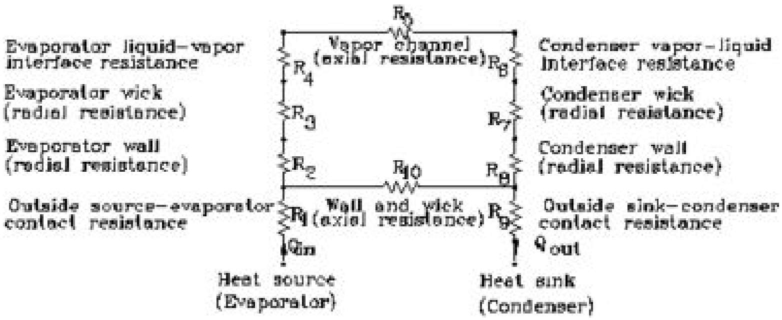


Figure 2.5: Temperature vs resistance modeling

Traditionally, heat pipe theory consists of fundamental analyses related to hydrodynamic and heat transfer processes. Fluid mechanics theory is generally used to describe the axial liquid pressure drop in the wick structure, the maximum capillary pumping head and the vapor flow in the vapor channel. Heat transfer theory is used to model the transfer of heat into and out of the heat pipe. Phenomena such as conjugate heat conduction in the wall and wick, evaporation and condensation at the liquid-vapor interface, and forced convection in the vapor channel and wick structure are described. The various thermal resistances or elements in a conventional heat pipe are shown in Fig. 5. The thermal processes such as solidification and liquefaction, and those related to rarefied gases can play important roles in modeling transient heat pipe operation during startup from the frozen state.

Fundamentally, one expects to analyze the internal thermal processes of a heat pipe as a thermodynamic cycle subject to the first and second laws of thermodynamics [9][10]. Zuo and Faghri predicted the transient heat pipe performance by using a simple thermal resistance model similar to that of Fig 5. However, classical heat pipe theory does not consider a thermodynamic approach. The idealized cycle is shown in Fig. 6(a). A quantity of heat, Qin, is applied to the heat pipe system at an average evaporator temperature, Te. Under steady operation, the same quantity of heat is rejected at a lower average condenser temperature Tc. Work is produced inside the heat pipe, but is then completely used in overcoming the hydrodynamic losses of the system. The thermal energy is converted to mechanical energy due to phase change at the liquid-vapor interface by producing a pressure head.

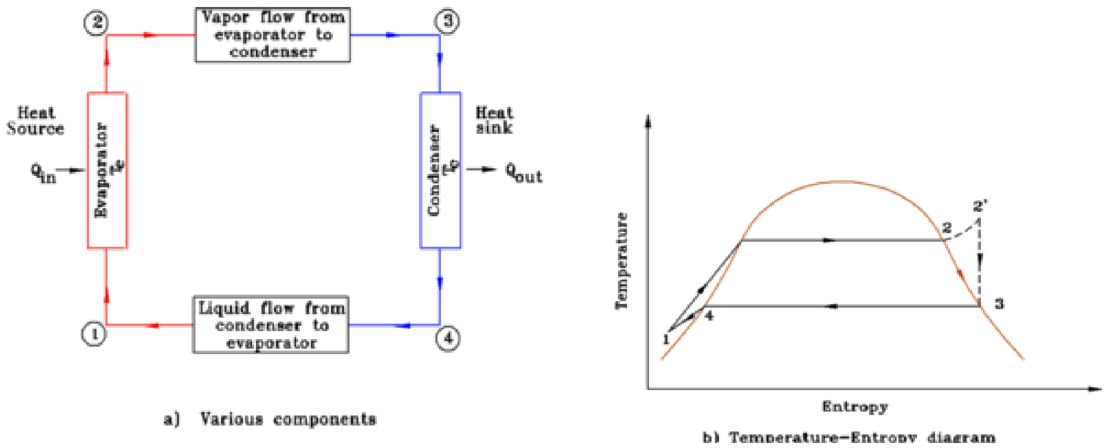


Figure 2.6: Temp vs entropy diagram

The thermodynamic cycle of the heat pipe is shown in Fig. 6(b) [2]. The fluid enters the evaporator as a compressed liquid at temperature T1 and leaves at temperature T2 or T2′ as saturated or superheated vapor, respectively. The vapor flows through the vapor channel from the evaporator to condenser due to the vapor pressure differential in the evaporator and condenser sections (2-3, or 2-2′-3). The vapor enters the condenser section as a saturated vapor or mixture. The condensate enters the adiabatic section as a saturated liquid (4). Finally, the liquid leaves the adiabatic section to enter the evaporator as a compressed liquid to complete the cycle. The work done on the working fluid during its circulation through the heat pipe is the area enclosed by the temperature versus entropy diagram shown in Fig. 6(b). As expected from the second law of thermodynamics, the conversion of thermal energy to kinetic energy is associated with heat rejection at a temperature below the high temperature reservoir in the system with efficiency less than 100%. It should be noted that in most heat pipes, the end-to-end temperature difference is small compared to other conductive systems. Nevertheless, the most ideal heat pipe can never be completely isothermal because this would violate the second law of thermodynamics. The capability of the simple thermodynamic analysis is very limited. In most cases, the heat transfers and fluid mechanics methodologies are needed to solve a heat pipe problem, especially when a quantitative solution is required.

2.1.1 Key components of a heat pipe

The key components of a heat pipe are:

1. Heat pipe working fluid, which transfers heat by evaporation and condensation
2. Heat pipe envelope which provides a leak-tight pressure vessel to contain the working fluid
3. Heat pipe wick, to return liquid from the condenser to the evaporator using capillary forces.

2.2 Closed loop pulsating heat pipe

2.2.1 Pulsating heat pipe

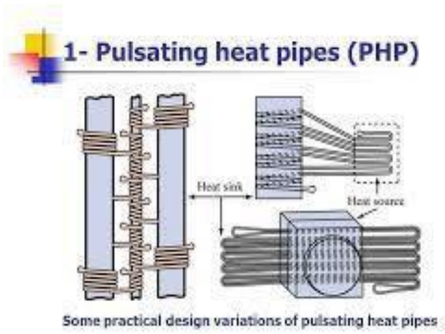


Figure 2.7: Pulsating heat pipe

Heat exchangers are expected to saddle or transport vitality from different process industry operations. [4] The accessible warm vitality may regularly be poor quality and dispersed. Moreover, high warmth transition evacuation at controlled temperature is required for control hardware heat administration and transport necessities. The scope of Pulsating Heat Pipe (PHP) two-stage frameworks presented in the later piece of the most recent century are very appealing from numerous perspectives [Akachi, 1996; Akachi et al., 1996]. Detached operation, high heat transition taking care of, simplicity of produce and intriguing thermo-fluidic two-stage transport from a scholarly perspective, are a portion of the striking highlights of this class of heat channels. PHPs can be applied in a wide range of practical problems, including electronics cooling, GI et al,[12]

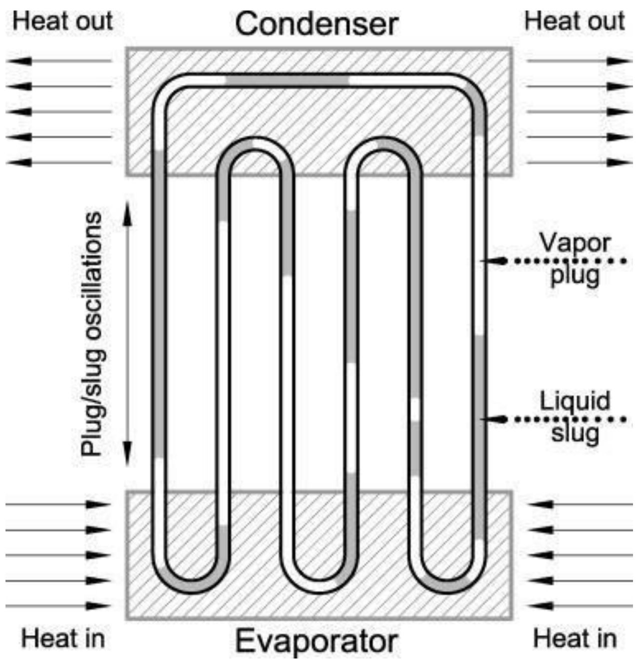


Figure 2.8: Schematic diagram of Pulsating Heat Pipe

Conventional wicked heat pipe heat exchangers have been routinely used for gas-gas heat exchangers for waste heat recovery and air preheating/economizer applications. A PHP heat exchanger has several advantages over conventional heat pipe systems with potentially many applications. Two principal PHP operating modes are possible (i) heat flux controlled and (ii) temperature controlled. Under heat flux controlled mode such structures are inherently capable of handling high heat fluxes ranging from 1 W/cm2 to over 60 W/cm2. Under temperature controlled mode, not many experimental studies are available. Before we explore the experimental study of two types of PHP based heat exchangers and their global modeling approach, we briefly review the fundamental two-phase transport processes inside a pulsating heat pipe and its thermal transport behavior. Recently, PHPs with sintered metal wick have been prototype by Zuo et al.[11,12] and analyzed by Holley and Faghri.[13]

2.2.2 Operational features

The basic structure of a typical pulsating heat pipe consists of meandering capillary tubes having no internal wick structure, as shown in Figure 1-a. The inside diameter of the tube is sufficiently small (critical Bo ~ 1.85) such that surface tension dominates and capillary slug flow is maintained. It can be designed in at least three ways (i) open loop system, (ii) closed loop system and (iii) closed loop with additional flow control check valve(s) as shown in Figure 1-b. The closed loop system allows flow circulation while there is no such possibility in the open loop configuration.

The 21st International Symposium on Transport Phenomena 2-5 November, 2010, Kaohsiung City, Taiwan The entire essence of its thermo-mechanical physics lies in the closed (constant volume), two-phase, bubble-liquid slug system, spontaneously formed inside the tube bundle, at the time of filling the device, due to the dominance of surface tension. This tube bundle receives heat at one end and it is cooled at the other end. Temperature gradients give rise to temporal and spatial pressure disturbances due to resulting phase-change phenomena, i.e. generation and growth of bubbles in the evaporator and simultaneous collapse of bubbles in the condenser. The bubbles act as pumping elements, transporting the entrapped liquid slugs in a complex oscillating-translating-vibratory fashion, resulting in self-sustained thermally driven flow oscillations and ensuing highly efficient heat transfer thereof. In addition to the latent heat, considerable amount of sensible heat transfer also occurs in a PHP. While sweeping the evaporator section, a liquid slug accumulates heat, which is eventually transferred to the condenser. The fundamental transport processes that occur inside the PHP can be understood by looking at Figure 1-c which suggests the various forces, including heat and mass transfer processes acting on a typical liquid-slug vapor-bubble (unit cell) system, as formed inside the PHP. The primary unit-cell processes are:

• The flow pattern in the PHP tubes may be broadly categorized as capillary slug flow. This type of flow is characterized by: (a) the flow pattern is 'generally' axisymmetric, at least in vertical flows (in horizontal flows, there will be some asymmetry depending on the Bo, (b) the velocity of large vapor bubbles relative to the liquid slug is somewhat faster.

- Due to the capillary dimensions of the PHP tube, a train of liquid slugs and vapor bubbles having menisci on its edges are formed due to surface tension forces. Usually a liquid thin film exists surrounding the vapor bubbles. The angle of contact of the menisci, the liquid thin film stability and its thickness depend on the fluid-solid combination and the selected operating parameters.
- Liquid slugs and vapor bubbles move against the gravity vector, in its direction or at an angle to it, depending on the global PHP orientation and the location of slugs/ bubbles in the up-header or down-header tubes.
- The liquid slugs and vapor bubbles are subjected to pressure force 1FGand 2FG from the adjoining slugs/bubbles. These are not only caused due to phase-change mass transfer but also due to capillary forces.
- The liquid slugs and vapor bubbles experience internal viscous dissipation as well as wall shear stress as they move in the PHP tube. Their relative magnitude decides the predominant force to be considered.
- The liquid slugs and vapor bubbles may receive heat, reject heat, or move without any external heat transfer, depending on their location in the evaporator, condenser or the adiabatic section, respectively. Most thermal transport occurs through the thin film and its dynamics plays a crucial role in the overall thermal transport.
- In the evaporator, the liquid slug receives heat which is simultaneously followed by evaporation mass transfer to the adjoining vapor bubbles or breaking up of the liquid slug itself with creation of new bubbles in between as a result of nucleate boiling in the slug flow regime; Psat and Tsat thus increase locally. Probability of events frequently places vapor bubbles in direct contact with the internal tube surface of the evaporator. In this case, saturated vapor bubbles receive heat via the liquid thin film surrounding them, which is simultaneously followed up by evaporation mass transfer from the film as well as the adjoining liquid slugs. Heat transfer under such conditions is strongly dependent on local film geometry.
- The above processes in the evaporator are repeated in a reverse direction in the condenser.
- In the adiabatic section, while passing from the evaporator to the condenser, the train of vapor bubbles and liquid slugs is subjected to a series of complex heat and mass

transfer processes. Essentially non-equilibrium conditions exist whereby the high pressure, high temperature saturated liquid slug's/vapor bubbles are brought down to low pressure, low temperature saturated conditions existing in the condenser. If ideal adiabatic conditions are maintained, with no axial conduction of heat through the tube wall/ fluid itself, then an inherently irreversible isenthalpic process can accomplish this task. Internal enthalpy balancing in the form of latent heat takes place by evaporation mass transfer from the liquid slugs to the vapor bubbles whereby saturation conditions are always imposed on the system during the bulk transit in the adiabatic section. In real systems, this transit is certainly much more complex with non-equilibrium metastable conditions existing throughout. It is to be noted that there occurs no 'classical steady state' in PHP operation as far as the internal hydrodynamics is concerned. Instead, pressure waves and pulsations are generated in each of the individual tubes, which interact with each other possibly generating secondary and ternary reflections with perturbations. The self-exited thermally driven oscillations are dependent on many operating variables. There are several important and unresolved issues with the present understanding of PHPs.

(i) At present there is no comprehensive mathematical model to predict the thermal performance of pulsating heat pipe under a given boundary condition.

(ii) The understanding of heat transfers and pressure drop under self-excited thermally driven oscillating two-phase flow inside capillary tubes is quite unsatisfactory.

(iii) The complete transport phenomena in the unit-cell, remains unresolved.

(iv) Multiple unit-cells, also interact with each other mutually; merger and coalescence of liquid slugs, breakage of Taylor bubbles under the impact of inertia and surface tension, nucleation inside liquid slugs, confined bubble formation, condensation on liquid films, instabilities, surface waves, etc. are additional complexities which makes transport prediction difficult. In this background, we now explore the global behavior of two types of heat exchangers

(a) Temperature controlled (liquid-liquid) module and

(b) heat flux controlled air-cooled module.

2.2.3 Closed loop pulsating heat pipe

One end of the PHP tube bundle receives heat, transferring it to the other by a pulsating action of the working fluid, generating, in general, a capillary slug flow. While in operation, there exists a temperature gradient between the heated and cooled end. Small temperature differences also exist amongst the individual ’U’ bends of the evaporator and condenser due to local non-uniform heat transfer rates which are always present in real systems. Since each tube section between the evaporator and the condenser has a different volumetric distribution of the working fluid, the pressure drop associated with each sub-section is different. This causes pressure imbalances leading to thermally driven two-phase flow instabilities eventually responsible for the thermofluidic transport. Bubble generation processes in the heater tubes sections and condensation processes at the other end create a sustained ‘non-equilibrium’ state as the internal pressure tries to equalize within the closed system. Thus, a self-sustained thermally driven oscillating flow is obtained. There occurs no 'classical steady state' in PHP operation as far as the internal hydrodynamics is concerned. Instead, pressure waves and fluid pulsations are generated in each of the individual tube sections, which interact with each other generating secondary/ ternary reflections with perturbations [8, 9]. It will be appreciated that PHPs are complex heat transfer systems with a very strong thermo-hydrodynamic coupling governing the thermal performance. The cooling philosophy draws inspiration from conventional heat pipes on one hand and single-phase forced flow liquid cooling on the other. Thus, the net heat transfer is a combination of the sensible heat of the liquid plugs and the latent heat of the vapor bubbles. The construction of PHPs is such that on a macro level, heat transfer can be compared to an extended surface ‘fin’ system. Simultaneously, the internal fluid flow may be compared to flow boiling in narrow channels. PHPs may never be as good as an equivalent heat pipe or thermosiphon system which are based on pure latent heat transfer. If the behavior is well understood, the performance may be optimized towards classical heat pipes/thermosiphon’s, as a limiting case. At the least, the manufacturing complexities of heat pipes will be avoided. As compared to an equivalent metallic finned array, at the least there will be a weight advantage. Finally, there is always a reliability advantage because of the absence of an external mechanical pump [10]. The available experimental results and trends indicate that any attempt to analyze PHPs must address two strongly interdependent vital aspects simultaneously, viz. system 'thermo' and 'hydrodynamics'. Figure 2 shows the genealogy of two-phase passive devices. Although the representation is not exhaustive, all the systems with relevance to the present interest are depicted. Although all the systems shown in Figure 2 have 'similar' working principles, there are decisive differences that significantly alter the course of mathematical analyses.

2.2.4 Evaluation of PHP

A PHP can be evaluated by various processes that it runs on. Sometimes this involves the evaporative and condensing sections of the pipe and on other hand the bubble formation because of which heat is transferred continually from one section to the other. The advantages with PHP is that there is a duality with the condenser and evaporative section with one section providing the energy for the other section. Due to this fact, the evaluation of PHP is the evolution of a normal heat pipe from its natural state. Furthermore, the generating and collapsing bubbles act as pumping elements transporting the entrapped liquid slugs in a complex oscillating–translating– vibratory fashion; a direct consequence of thermo-hydrodynamic coupling of pressure/temperature fluctuations with the void fraction (mal-) distribution. This causes heat transfer, essentially as a combination of sensible and latent heat portions. The relative magnitude of these portions is also of profound interest and decisive to the overall thermal performance of the structure. It has been indicated earlier that the sensible heat transfer is the major contributor in the overall heat exchange. Further studies have indicated that after a certain input heat flux, the bubble–liquid slug flow may break down into annular flow regime, It has been shown by previous studies that a closed loop pulsating heat pipe is thermally more advantageous than an open loop device because of the possibility of fluid circulation. Although a certain number of check valves have shown to improve the performance, miniaturization ofthe device makes it difficult and expensive to install such valve(s) [3,10]. Therefore, a closed loop device without any check valve(s) is most favorable from many practical aspects. Studies (mostly qualitative) have already identified various design parameters affecting the performance of CLPHPs

2.2.5 Evolution of PHPs

Genuine advancement of ordinary heat pipes started in the 1960s, since then different geometries, working fluids, and wick structures have been proposed [16]. In the last 20 years, new sorts of warmth pipes, such as capillary pumped loops and loop heat pipes, were introduced, seeking to isolate the fluid and vapor streams to defeat certain confinements inalienable in regular heat pipe

In the 1990s, akachi et al [8] invented new heat pipe also called pulsating heat pipe. PHPs or pulsating heat pipe can generate large heat dissipation mechanism used for cooling electronics components. Heating air or pumping water are the other applications of heat pump.

This article will present an overview of the development of PHP technology over the decades of its existence

The wave equation of pressure oscillation in a PHP based on self-excited oscillation was derived by miyazaki and akachi [17], in which reciprocal excitations between pressure oscillation and void fraction is assumed. An experimental investigation on the oscillatory flow in PHP was measured by Miyazaki and Arikawa [18]and the measurement of wave velocity agreed reasonably with prediction of Akachi et al [8]. Lee et al [19] found out that The departure of small bubbles is considered to be the representative flow pattern the evaporator and adiabatic sections. He also reported that the oscillations of bubbles are caused by nucleate boiling and vapor oscillation. Khandekar [20] also performed various experiments regarding different php configurations. Various parameters such as heat input, filling ratio, number of turns and orientation were measured and studied. There was a distinguish between four regimes related to a

PHP operating curve. At low temperature the thermal resistance slightly decreases with the increase in heat input while at higher temperature, there is decrease in thermal resistance and there is slug flow pattern. Khandekar et al [21]. Furthering their experiment with different fluids, Khandekar et al [22], for ethanol and water the critical diameter was greater than the tube diameter. Depending on the filling ratio and PHP orientation, the bubbles formation is heavily reliable on the two phase oscillating flow. The work on effect of CLPHP thermal performance depends on various parameters like internal diameter of the tube, working fluid, no of turns and inclination angle of the device. The results indicate that gravity had an effect on the performance of CLPHP, the performance can be increased by increasing id or mean number of turns, the buoyancy force affects bubble shape [23]. Hosoda et al [24] investigated and carried out an experiment to observe only two vapor plugs that exist separately in adjacent turns and one of them starts to shrink while the other grows. A simplified numerical solution was also performed dismissing the fluid film that may occur between the vapor plug and tube wall. Also, Riehl [25] studied an open loop PHP in different orientations and then thermal performance using water, ethanol, methanol, propanol and acetone. The use of water as the working fluid led to worst performance where as the result of using methanol and acetone led to the best results The oscillations are more regular as this leads to more uniform nucleation and boiling which aids in vapor slugs formation. The orientation is used for vertical and horizontal, with water the result is independent, with methanol the horizontal orientation is preferred and the vertical with ethanol. Xu et al [26]Modeled the oscillating flow in a closed loop PHP with a high speed camera. For methanol and water various properties were observed. Furthermore vapor slug formation and coalescence were highlighted with water as working fluid. Henceforth, capillary pressure is not uniform in bends resulting in local accumulation of liquid. Methanol as the working fluid, it was found that the coalesce or break up is limited and in this case liquid plugs are longer than with water. Honghhai yang et al[27] presents a paper on experimental study on operational limitation of closed loop pulsating heat pipes(CLPHPs)Three operational orientations were investigated through vertical bottom heated, horizontal heated and vertical top heated orientations. The effects of inner orientation, diameter, filling ratio, and heat flux on thermal properties were studied. The CLPHPS were operated till the performance concerned was not affected by dry out condition. rather high heat loads could be accommodated. The effects of internal diameter, filling ratio, operational orientation and heat load on the performance on two CLPHPs were involved. Best performance occurs on incase of vertical bottom heat mode with 50 percent filling ratio. As inner diameter decreases, performance differences due to different heat modes has very little effect. Also, P.Meena et al[28] based that when the inner diameter changed from 1.77 to 2.03 mm the critical temperature increased and when the inclination angle increased from 0 to 90,the critical temperature increases. Zhang and Faghri[29] studied the oscillatory properties and heat transfer in a U shaped miniature channel. The condenser section was located in the middle whereas the heating section located on the sealed ends of the U shaped channel. The performance of PHP on various non dimensional parameters were investigated and correlations of amplitude and frequency were found out. Sha.i et al.[30] and Zhang and Faghri[31]found that in PHP over 90 percent of heat transfer was due to sensible heat. Kang et al[32] showed that there was a temperature decrease of 0.56 to 0.65 compared to DI water at input power of 30 to 50 watts at the same charge volume using Nano fluid temperature difference. Qu et al [33] performed an experimental investigation with base water and Al2O3 particles 56nm in diameter. It was shown that the thermal resistance decreased by 0.14 degree per watt with pore input 58.8w at 70 percent filling ratio and 0.9 mass fraction

2.2.6 Parameters affecting the performance of CLPHPs

Looking into the available literature, it can be seen that six major thermo-mechanical parameters have emerged as the primary design parameters affecting the PHP system dynamics. These include:

- Internal diameter of the PHP tube,
- Input heat flux to the device,
- Volumetric filling ratio of the working fluid,
- Total number of turns,
- Device orientation with respect to gravity, and

• Working fluid thermo-physical properties.

• Use of flow direction control check valves,

• Tube cross sectional shape,

• Tube material and fluid combination, and

• Rigidity of the tube material, etc.

2.2.6.1 Design/Geometric Parameters: Diameter and material of tube

The diameter of heat pipe plays vital role in the selection of the heat pipe, because it affects theperformance of pulsating heat pipe. The internal diameter directly affects the PHP. A largehydraulic diameter results in a lower wall thermal resistance and increases the effective thermalconductivity. The capillary tube inside diameter must be small enough such that:

$D_{max} = 2[\sigma/g\ (\rho_{liq} - \rho_{vap})]^{1/2}$

Where:

σ = working fluid surface tension (N/m);

g = gravitational acceleration (m/s^2);

ρ_{liq} = liquid density (Kg/m^3);

ρ_{vap} = vapor density(Kg/m^3)

If D < Dmax, surface tension forces dominate and stable liquid plugs are formed. However, if D > Dmax, the surface tension is reduced and the working fluid will stratify by gravity and oscillations will cease6. Also the selection of tube material is important; the different type materials have their own coefficient of heat transfer.

2.2.6.2 Number of turns

As the quantity of turn of PHP expands it gives adaptability to the PHP to working at any introduction (i.e. at different edge of slant with even). Analysts have demonstrated that if the quantity of turns is less then it works in vertical position just, not in even position. Mamelli [24] also concluded that nine turns CLPHP has many advantages with respect to the one with three turns:

i. It is able to work also in the horizontal heat mode.
ii. Its thermal resistance is lower
iii. There are less evident differences between different fluids in terms of overall efficiency

2.2.6.3 Design of evaporator and condenser section

Design of evaporator and condenser plays important role, which affects the performance of heat pipe. It is thumb rule that the condenser should have the larger area than the evaporator in order to avoid the dry out condition. The evaporator section lengths affected on critical heat flux in this range. When the evaporator section lengths increased the critical heat transfer flux decreased. The heat pipe is assumed to be operating at an adiabatic temperature of T1 with heat input of Q1, very close to the dry out power Qdry-1 corresponding to the operating temperature. If, under such operating conditions the condenser capacity is increased, by either lowering the coolant temperature or increasing the coolant mass flow, there is a risk of a dry out to occur. This will happen since the operating temperature drops to T2 for which the heat input Q1 is too high. Thus, increasing the condenser capacity need not necessarily improve the heat transfer for conventional heat pipes. Although there is no well-defined adiabatic operating temperature for

pulsating heat pipes, a similar trend regarding the effect of condenser capacity may be observed. Increasing the condenser capacity affects not only the thermo-physical properties of the working fluid but as a side effect alters the slug-annular flow pattern transitions, thereby altering the final performance. This aspect has to be addressed while practical designing.

2.2.6.4 Bend Effect

In PHP geometry their quantities of U-terns are available. Mamelli [34] clarified the impact of twist on the execution of PHP. Due to the 180° and 90° twisted weight misfortune happens in pipe. Mamelli [26] also have developed the numerical model to account for the local pressure loss taking place in the PHP.

2.2.6.5 Operating Parameters: Filling ratio:

The filling ratio is defined as the fraction by volume of the heat pipe, which is initially filled with the liquid. The optimal filling ratio is determined experimentally when the maximum heat transfer rate is achieved at a given temperature.

2.2.6.6 Heat Flux temperature

PHPs are thermally determined non balance gadgets, and in spite of the fact that they might be exceptionally compelling heat spreaders, a temperature contrast must exist between the evaporator and condenser to keep up their operation. Much of the time, there was seen to be some base heat motion or differential temperature important to start moving stream. Like the ideal charge proportion, the beginning heat transition was diverse for each investigation. Consequently, parametric examination is required to completely comprehend this work. At the point when the quantity of turns is little a basic heat transition in the vicinity of 5.2 and 6.5 W/cm2 is expected to light a steady smooth movement and come to a satisfactory pseudo unfaltering state.

2.2.6.7 Dry out condition

This factor restricts the operation of heat pipe. At the point when the entire working liquid vaporized and there is no any fluid in the evaporator area then we can state dry out condition is happened. This condition happens when there is low filling proportion and high heat input is given to the pipe. At the point when dry out condition achieves the warmth exchange happen totally because of conduction.

2.2.6.8 Properties of working fluid

The choice of working liquid is likewise essential parameter which influences the execution of PHP. Choice of working liquid is straightforwardly connected to the properties of the liquid. The properties will influence both the capacity to exchange heat and the equivalence with the tube material. The working liquid ought to be chosen to such an extent that it bolsters the PHP working temperature run. While choosing a working liquid, the following working liquid attributes ought to be inspected: I. Similarity with the OHP material(s), ii. heat security, iii. Wettability, iv. Sensible vapor weight, v. High inert heat and heat conductivity, vi. Low fluid and vapor viscosities, vii. Satisfactory solidifying point.

For most applications, the thermodynamic attributes of water settle on it a decent decision for PHP applications, as it has high dormant heat, which spreads more warmth with less liquid stream, and high heat conductivity which limits data Be that as it may, water has high surface pressure and may effect sly affect the PHP as it might cause extra grating and farthest point the two stage stream motions of the PHP. Methanol is a decent substitution for water, particularly for below zero applications, as it has roughly 33% the surface strains.

Chapter 3

Experimental setup

3.1 Experimental Set up

A trial office has been outlined, manufactured and introduced to gathered information for this examination. The point by point portrayal of test device and exploratory system are exhibited in this part.

Consequently, mechanical assembly utilized as a part of this analysis are-

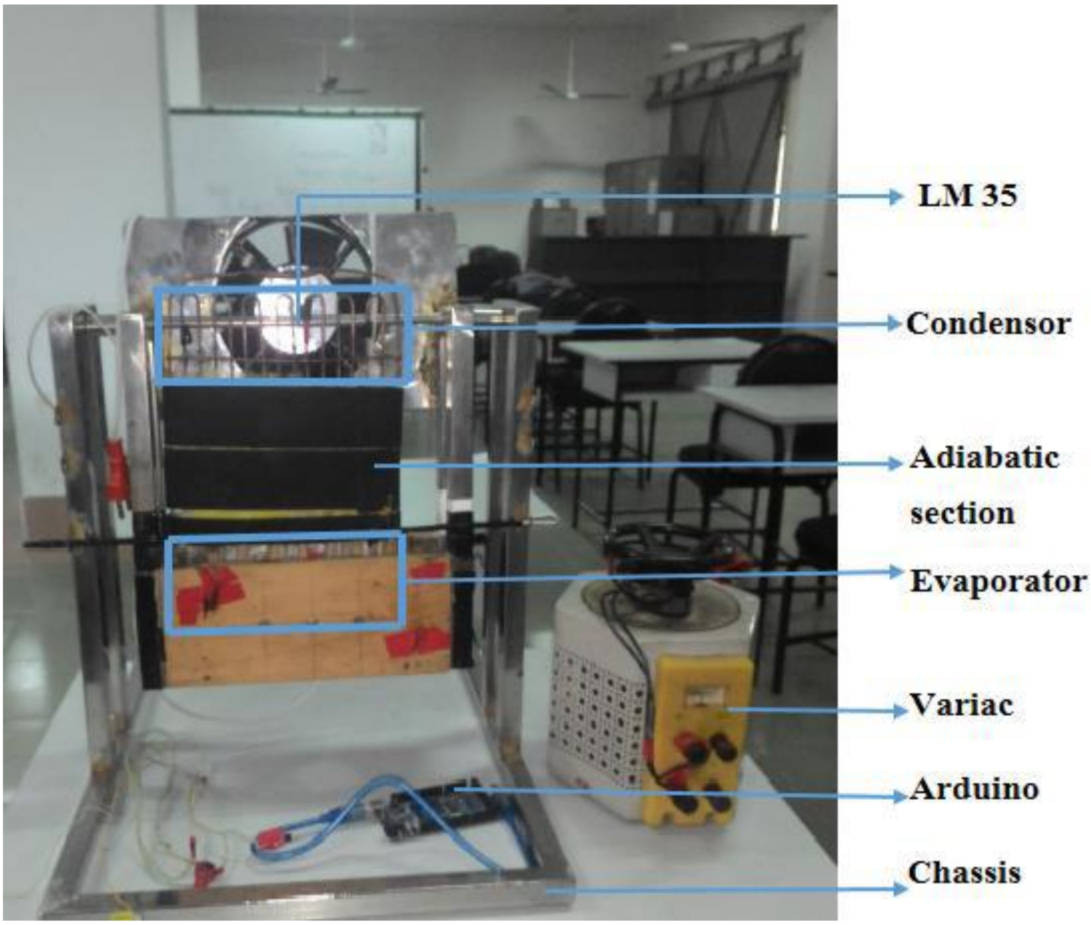
3.1.1 Apparatus

1. Pulsating heat pipe
2.Working fluid(Methanol,ethanol and blend)
3.Test stand

- Heating apparatus 1.Power supply unit
  2.Nichrome wire
  3.Variac

- Cooling apparatus 1.Fan
  2.Adapter Circuit
- Insulating apparatus 1.Mica tape
  2.Aluminium foil
- Measuring Apparatus 1.Temperature sensor
  2.Multimeter
  3.Micro controller(arduino mega)
- Other equipment 1.Filler metal
  2.Glue gun
  3.Electric wire

3.2 View of experimental set up



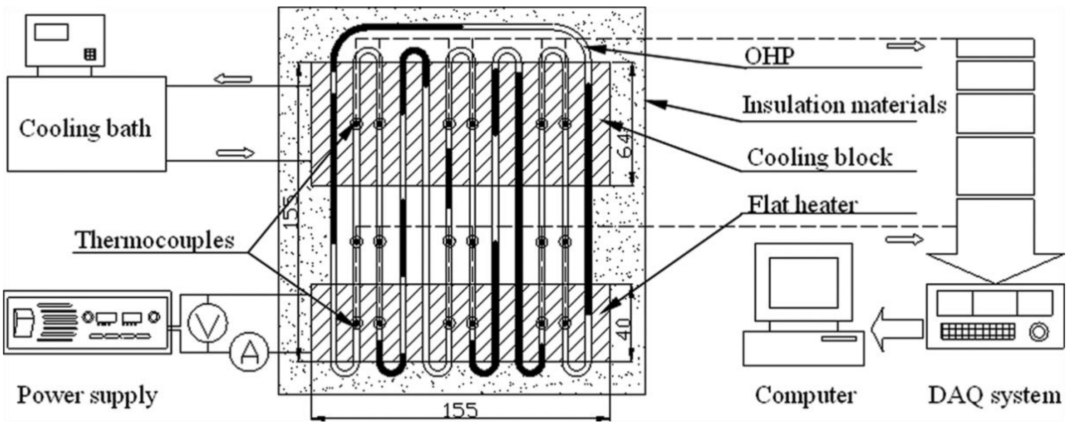


Fig 3.1:Experimental Set up.

3.3 Description of different types of apparatus

3.3.1 Pulsating heat pipe

Pulsating h A closed loop pulsating heat pipe or oscillating heat pipe comprises of a metallic container of fine measurements twisted in a serpentine way and joined end to end. It comprises of 3 segments. They are:

1. Evaporator area

2.Adiabatic area

3. Condenser are:

Evaporator:

In the evaporator segment of the heat pipe the working liquid retains heat from the heat source. It is situated on the base area of the warmth pipe. Warmth is provided to the warmth pipe utilizing Nichrome wire associated with a variable power supply. The Nichrome wire is twisted around the funnels in the evaporator segment over a layer of mica tape. The mica sheet avoids coordinate contact of copper tube with Nichrome wire to keep any plausibility of short out association. The evaporator segment is additionally wrapped by asbestos sheet to decrease warm misfortune to the earth

Adiabatic Section

It is situated between the evaporator segment and condenser segment. In here the fluid and vapor periods of the liquid stream in inverse ways and no critical heat exchange happens between the liquid and encompassing medium. The piece of the tube in adiabatic segment is twisted with aluminum thwart, glass fleece lastly secured with warm protecting tape to forestall heat exchange to the encompassing condition.

Condenser Section

It is the area of the heat pipe where warm is rejected from the working liquid to the encompassing. In this area, the working liquid gathers and rejects a similar measure of heat which is assimilated from the evaporator segment. In this trial, this area is situated on upper segment of the warmth pipe and a DC fan help scattering of heat ceaselessly.

Parameters	Condition
Inner diameter	2.0mm
Outer diameter	2.5mm
Total length	250.0mm
Length of evaporator section	50mm
Length of adiabatic section	120mm
Length of condensor section	80mm
Material	Copper

3.3.2 Working fluid:

3.3.2.1 Methanol

Methanol, otherwise called methyl liquor among others, is a synthetic with the formula CH3OH (frequently contracted MeOH). Methanol obtained the name wood liquor since it was once created predominantly as a side-effect of the dangerous refining of wood. Today, mechanical methanol is created in a synergist procedure straightforwardly from carbon monoxide, carbon dioxide, and hydrogen.

Methanol is the least difficult liquor, being just a methyl aggregate connected to a hydroxyl gathering. It is a light, unstable, boring, combustible fluid with a particular smell fundamentally the same as that of ethanol (drinking alcohol).However, not at all like ethanol, methanol is exceptionally harmful and unfit for utilization. At room temperature, it is a polar fluid. It is utilized as a radiator fluid, dissolvable, fuel, and as a denaturant for ethanol. It is additionally utilized for creating biodiesel by transesterification response.

Methanol is delivered normally in the anaerobic digestion of numerous assortments of microscopic organisms and is ordinarily present in little sums in the earth. Thus, the climate contains a little measure of methanol vapor. Be that as it may, in just a couple of days, air methanol is oxidized by daylight to deliver carbon dioxide and water.

Methanol is likewise found in copious amounts in star-framing districts of room and is utilized as a part of stargazing as a marker for such areas. It is distinguished through its ghastly emanation lines.

Methanol when flushed is used first to formaldehyde and afterward to formic corrosive or formate salts.These are toxic to the focal sensory system and may bring about visual deficiency, extreme lethargies, and demise. On account of these dangerous properties, methanol is every now and again utilized as a denaturant added substance for ethanol made for mechanical employments. This expansion of methanol exempts mechanical ethanol (generally known as "denatured liquor" or "methylated soul") from alcohol extract tax collection in the US and some different nations.

3.3.2.2 Ethanol

Ethanol, also called alcohol, ethyl alcohol, and drinking alcohol, is a chemical compound, a simple alcohol with the chemical formula . Its formula can be written also as CH3CH2OH or C2H5OH (an ethyl group linked to a hydroxyl group), and is often abbreviated as EtOH. Ethanol is a volatile, flammable, colorless liquid with a slight characteristic odor. It is a psychoactive substance and is the principal type of alcohol found in alcoholic drinks.

Ethanol is naturally produced by the fermentation of sugars by yeasts or via petrochemical processes, and is most commonly consumed as a popular recreational drug. It also has medical applications as an antiseptic and disinfectant. The compound is widely used as a chemical solvent, either for scientific chemical testing or in synthesis of other organic compounds, and is a vital substance utilized across many different kinds of manufacturing industries. Ethanol is also used as a clean-burning fuel .

3.3.3 Chassis

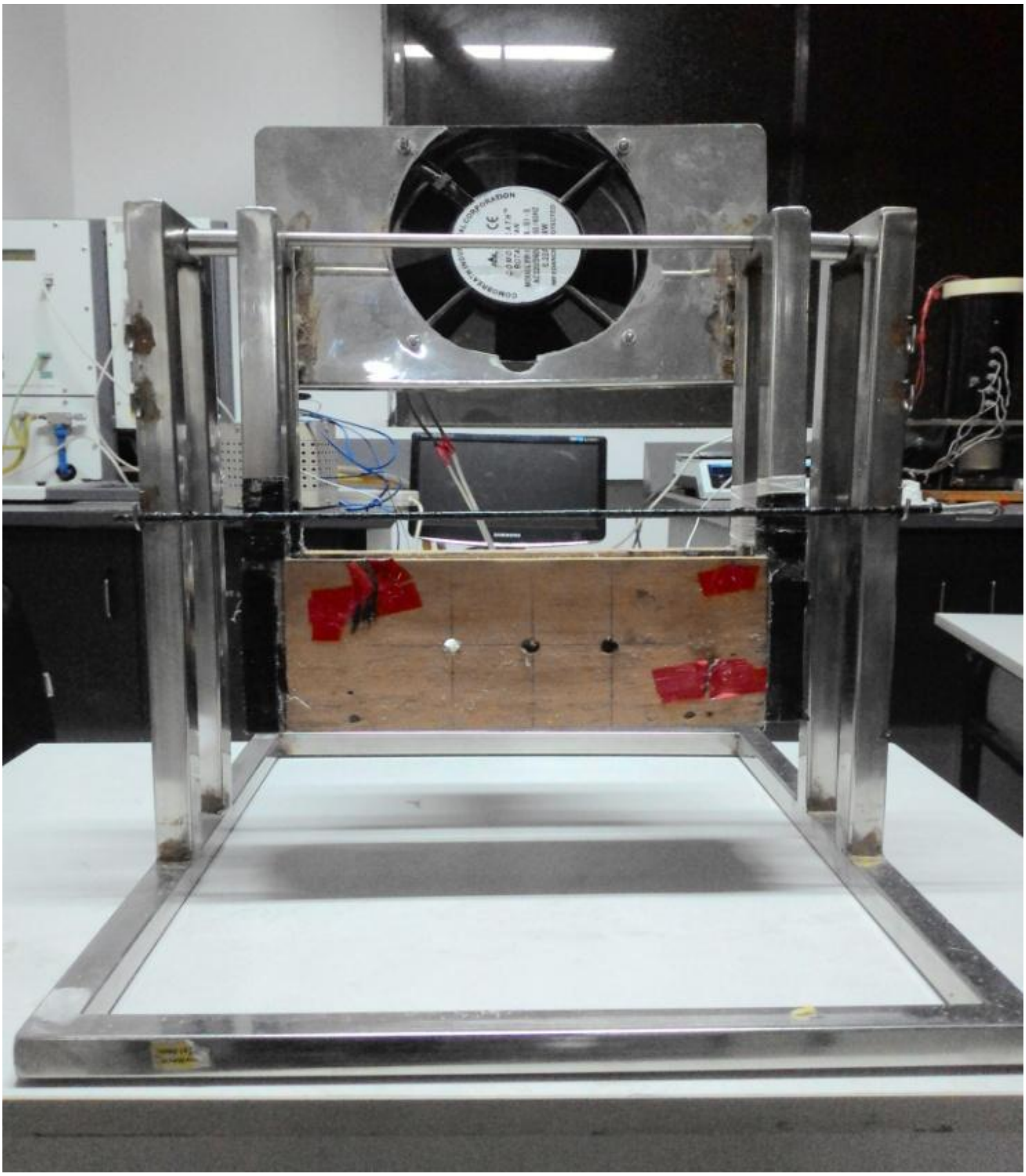


Figure 3.2: Chasis

The test stand is a steel structure with a wooden box that holds the heat pipe. The wooden box contains the evaporator segment of the heat pipe. This is made with lamp fuel wood and it takes out any odds of short out association. The test stand can be turned and can be kept on any unique introduction between level and vertical position. Courses of action have been made to settle the coveted edge. The entire structure is upheld by two sections which is arranged in a vast steel base.

3.4 Heating Apparatus

3.4.1 Power Supply Unit

The power supply unit has the following specification:

Type : A.C

Voltage : Up to 220 volt

Frequency : 50 Hz

3.4.2 Nicrome wire

Figure 3.3:Nichrome wire

Nichrome wire is a compound normally made of 80 percent nickel and 20 percent chrome. In view of Nichrome wire's high inward protection, it warms up quickly while applying power and furthermore chills quickly when closed or expelled from a warmth source. It keeps up its quality as the temperature rises and has a higher dissolving point than other wire. It doesn't oxidize or erode, and is non-attractive and very adaptableWe had used Nichrome wire in our experiment for heating up the test section whose internal resistance was about 18m. Resistivity: 1.0 x 10-6 to 1.5 x 10-6 Ωm,Specific Heat: 450JKg-1K-1.

3.4.3 Variable power supply

Figure 3.4:Variac

Variable power supply gives variable voltage to run diverse sorts of operations or the operation that requires distinctive voltage in times. We utilized voltages ranges from 20-60 volts by this power source. It is associated with the power supply unit to give variable power (warm contribution) by differing voltage yield.

Variable power supply specification

Phase	3ϕ
Rated capacity	300 volt
Rated Frequency	60 Hz
Input voltage	200 volt

3.4 Power Supply Unit

The power supply unit has the following specification:

Type : A.C

Voltage : Up to 220 volt

Frequency : 50 Hz

3.5 Cooling apparatus

3.5.1 Fan

For the cooling procedure, we utilized hub dc fan. A pivotal fan by and large, regardless of whether DC hub fans or something else, is the most normally utilized assortment of cooling fan, and also the most savvy. Likewise called 'box fan' every so often, they move air on a straight hub through the fan. This sort of fan works best under a low weight or low framework impedance condition. With decreased fan speed the clamor delivered by a pivotal fan can be kept at the very least. Due to this low level of capable of being heard commotion, and additionally their practical value exten

Figure 3.5:Fan

3.5.2 Adapter circuit

As the fan is a D.C fan and the power supply is A.C. So for running the fan, a converter circuit is required to convert the A.C current to D.C current. It consists of a transformer, full wave rectifier circuit to convert the A.C to D.C current

3.6 Insulating materials

Figure 3.6:Mica tape

3.6.1 Mica tape

The expression "mica" is utilized for a gathering of minerals that show culminate cleavage. Mineralogically, they are sheets of silicate. The name originates from the Latin word micare, which means to sparkle, in reference to the splendid appearance of this material.

Von Roll's responsibility regarding mica begins with mining, trailed by the extremely specific field of delivering paper from a mineral and completing with the creation of unique mica tapes and also mica auxiliary parts.

Von Roll utilizes two sorts of mica, phlogopite and muscovite, for an assortment of uses and relying upon the required warm and electrical trademark, basically in:

1. Electrical and warm protection of electrical machines
2. Thermal protection of hardware that is liable to a great degree high temperatures, for example, acceptance stoves
3. Insulation of link for imperviousness to fire.

3.6.2 Aluminum foil

Figure 3.7:Aluminium Foil

For the protection of throbbing warmth pipe, aluminum thwart tape is utilized. It opposes fire, dampness, temperature extremes, UV introduction and most chemicals with a sponsorship that

withstands brutal situations. We utilized metal-upheld thwart tapes with the similarity to wrap firmly around for all intents and purposes any shape or form. With the utilized of this aluminum thwart tape, we figured out how to oppose warm misfortune amid temperature estimation in various voltage was in run.

3.7 Measuring apparatus

3.7.1 Temperature sensor(lm35)

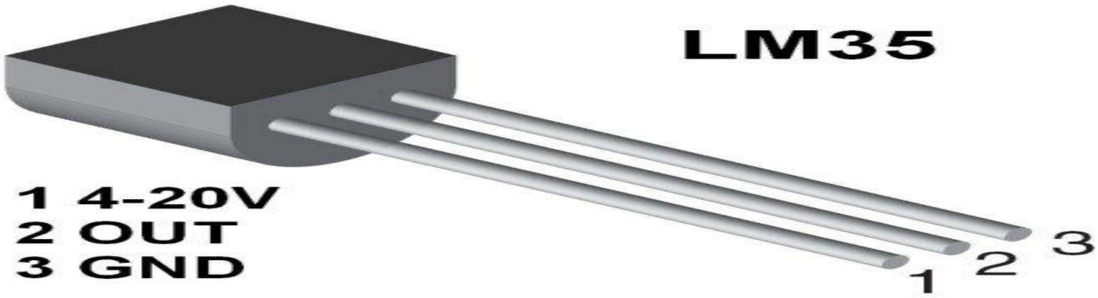


Figure 3.8: Temperature sensor(lm35)

The LM35 is a coordinated circuit sensor that can be utilized to gauge temperature with an electrical yield relative to the temperature (in oC).

An aggregate number of 8 thermocouples are stuck to the mass of throbbing warmth pipe; 4 for evaporator area and the rest 4 for condenser segment. They are aligned and associated with various segments of warmth pipe for measuring temperature. These thermocouples are Type K (Chromel/Alumel). It is 'Universally useful' thermocouple. It is minimal effort and, inferable from its prominence, accessible in a wide of tests.
We utilized lm35 as our favored temperature sensor as-
1. It can quantify temperature more precisely than an utilizing a thermistor.
2. The sensor hardware is fixed and not subject to oxidation, and so forth.
3. The LM35 produces a higher yield voltage than thermocouples and may not require that the yield voltage be opened up.

From general viewpoint, we contemplated lm 35 as it is shabby in cost and successful.
4.It has a yield voltage that is corresponding to the Celsius temperature.
5.The scale factor is .01V/oC

6.The LM35 does not require any outside alignment or trimming and keeps up an exactness of +/ - 0.4 oC at room temperature and +/ - 0.8 oC over a scope of 0 oC to +100 oC.

7.Another critical normal for the LM35DZ is that it draws just 60 smaller scale amps from its supply and has a low self-warming ability. The sensor self-warming causes under 0.1 oC temperature ascend in still air.

3.7.2 Multi meter

Figure 3.9:Multimeter

Used for measuring electric current in a circuit. Instruments used to measure smaller currents, in the milli ampere or microampere range, are designated as milli-ammeters or micro ammeters.

3.7.3 Arduino mega

Fig 3.10: Arduino mega

The Arduino Mega is a microcontroller board in light of the ATmega2560 (datasheet). It has 54 advanced information/yield pins (of which 15 can be utilized as PWM yields), 16 simple sources of info, 4 UARTs (equipment serial ports), a 16 MHz precious stone oscillator, a USB association, a power jack, an ICSP header, and a reset catch. It contains everything expected to help the microcontroller; just interface it to a PC with a USB link or power it with an AC-to-DC connector or battery to begin. The Mega is good with most shields intended for the Arduino Duemilanove or Diecimila.

3.7.4 Arduino 1.5.2 compiler

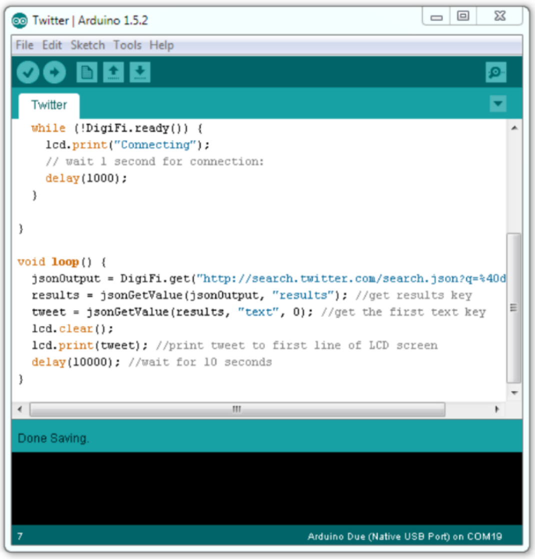


Figure 3.11: Arduino Compiler window

3.8 Other equipments:

3.8.1 Filler metal:

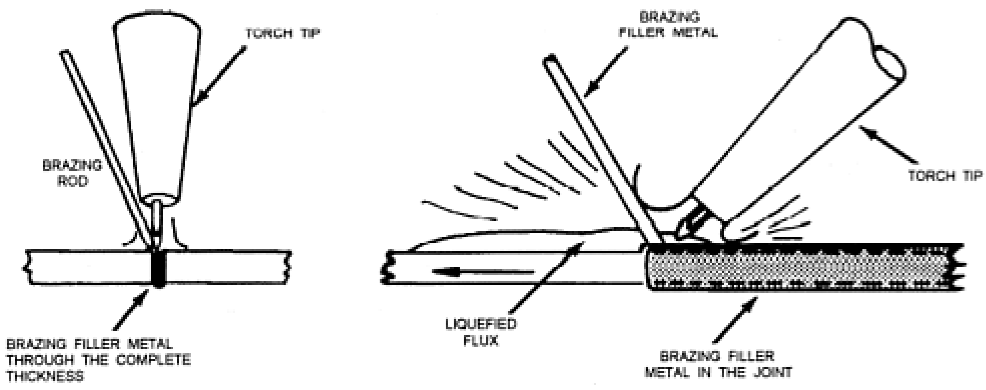


Figure 3.12: Filler Metal

Filler metals are for the most part made by Lead. It is utilized as a part of binding. Fastening is a procedure in which at least two metal things are combined by softening and streaming a filler metal (patch) into the joint, the filler metal having a lower liquefying point than the bordering metal. Fastening varies from welding in that binding does not include dissolving the work pieces. In brazing, the filler metal melts at a higher temperature, yet the work piece metal does not dissolve. Before, about all welds contained lead, however natural concerns have progressively managed utilization of without lead mistake for gadgets and pipes purposes.

3.8.2 Electric wire

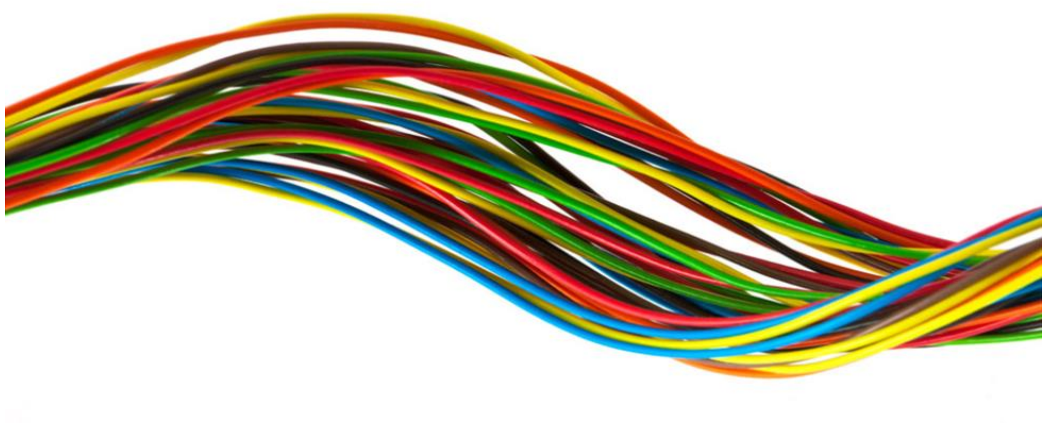


Figure 3.13: Electric Wire

3.8.3 Project board

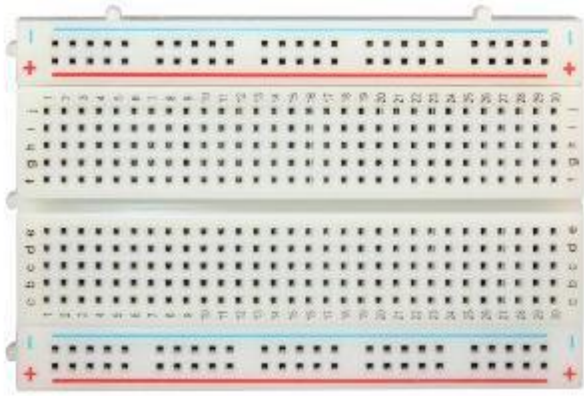


Figure 3.14:Bread board

A venture board (or breadboard) is a development base for prototyping of gadgets. Initially it was actually a bread board, a finished bit of wood utilized for cutting bread. In the 1970s the solderless breadboard (AKA plugboard, a terminal cluster board) wound up noticeably accessible and these days the expression "breadboard" is regularly used to allude to these. "Breadboard" is likewise an equivalent word for "model". An assortment of electronic frameworks might be prototyped by utilizing breadboards, from little simple and computerized circuits to finish focal preparing units (CPUs).

To direct the stream of power, we utilized electric wire of insignificant width. heat detecting component that joins LM35 required electric wire to get and supply information through power.

3.9 Selection of working Fluid:

The determination of the working liquid should likewise be founded on thermodynamic contemplations which is worried about the different impediments to warm stream happening inside the warmth pipe like thick, sonic, narrow, entrainment and nucleate bubbling levels. In warm pipe outline, a high estimation of surface strain is attractive keeping in mind the end goal to empower the warmth pipe to work against gravity and to create a high slender main thrust. The vapor weight over

the working temperature run must be adequately awesome to evade high vapor speeds, which keep an eye on setup huge temperature inclination and cause stream hazards. A high dormant.

Heat of vaporization is attractive keeping in mind the end goal to exchange a lot of warmth with least liquid stream, and henceforth to keep up low weight drops inside the warmth pipe. The warm conductivity of the working liquid ought to ideally be high with a specific end goal to limit the divider surface. The protection from liquid stream will be limited by picking liquids with low esteems and fluid viscosities.

No	Parameter	symbol	Unit	Methanol
1	Freezing Temperature	tfreeze	°C	-97.6
2	Boiling Temperature	tboil	°C	64.7
3	Density (at 20°C)	P	Kg/m	791.8
4	Specific Heat (at 20°C)	Cp	KJ/kg-k	2.54
5	Standard Molar entropy	S° liquid	KJ/mole-K	.127
6	Specific enthalpy of vaporization	E	KJ/kg	1104
7	Dynamic Viscosity(at 27°C)	μ	m 2 /s	.56

Chapter 4

Experimental procedure:

General Aspect

The heat exchange process through throbbing heat pipe with embed has just been appeared in figure before. There are mostly two conditions under which the entire changeability comes about i.e. how quick the heat is bringing up in condenser and how adequately it is raising the temperature. Our expectation was to demonstrate the distinction of heat exchange rate between ordinary throbbing heat channels versus throbbing heat pipe with embed. Our parameters were variable working liquids. Keeping every one of the parameters and working liquids the same, we demonstrated how the warmth pipe changes its productivity when an embedded wire is taken through.

4.1 Experimental Procedure

After the development of the entire setup the trials were completed. The construction included –

1.Steel base and casing

2. Table for putting the entire setup

3. Rotating component of stage to increase distinctive points

4. Evaporator, adiabatic and buildup area with nichrome wire winding

5. Installation of heat pipe

6.Setting the thermocouple associations at wanted areas on the warmth pipe

7. Electrical association by means of variable power supply

8. Electrical association with the cooling fan

9.Electrical association with the arduino mega to run the program to take wanted information readings.

The investigation was completed for ethanol,methanol and blend of both as working liquids, three distinctive filling ratio from 10 to 60 watt of the Heat pipe.

Normal Structure

a) First the inward volume of the heat pipe was checked and afterward vacuum was made utilizing a vacuum pump.

b) Next it was filled 40% of the volume with working liquid methanol (infusing by syringe) and the heat pipe were sealed to make a closed loop

c) The set-up was kept at vertical (00) position.

d) Different heat inputs were given to the framework and temperature perusing of various areas was measured through PC program with the assistance of arduino.

e) The above steps ere carried out systemetically for filling ratios 30,40 and 50 percent with methanol,ethanol and blend of methanol and ethanol

4.2 Precaution amid the investigation:

1. Wooden body is best to set the structure in light of the fact that there is a plausibility of flame amid the investigation.

2 At 60W the information ought to be taken precisely as the temperature get high rapidly also, the nichrome wire get super hot in shading with the goal that fire doesn't get set.

3 Inclination edge ought to be set legitimately

4 During the examination if any of the LM35 get harmed it quits taking temperature information.

5 Temperature information ought to be taken when it get relentless.

6 Circuit association for arduino programming ought to be checked precisely before taking information generally the temperature will indicate high or low even negative which is an blunder.

7 Coding in the arduino ought to be done appropriately

4.3 Program used to Measure Temperature against Time

```
int Q = 60;
int eva1, eva2, eva3, eva4, con1, con2, con3, con4;
float eva[100], con[100];
float t_arry[100];
int i = 0, x;
void setup()
{
Serial.begin(9600);
//analogReference(INTERNAL2V56);
}
void loop()
{
Serial.println("Evaporator Temperature:");
Serial.println();
while (i < 101)
{
eva1 = analogRead(0) * 0.48828125;
eva2 = analogRead(1) * 0.48828125;
eva3 = analogRead(2) * 0.48828125;
eva4 = analogRead(3) * 0.48828125;
con1 = analogRead(10) * 0.48828125;
con2 = analogRead(11) * 0.48828125;
con3 = analogRead(12) * 0.48828125;
con4 = analogRead(13) * 0.48828125;
/*

Serial.println("Evaporator Temperature 1: ");
Serial.println(eva1);
Serial.println("Evaporator Temperature 2: ");
```

```
Serial.println(eva2);
Serial.println("Evaporator Temperature 3: ");
Serial.println(eva3);
Serial.println("Evaporator Temperature 4: ");
Serial.println(eva4);
Serial.println("Condenser Temperature 1: ");
Serial.println(con1);
Serial.println("Condenser Temperature 2: ");
Serial.println(con2);
Serial.println("Condenser Temperature 3: ");
Serial.println(con3);
Serial.println("Condenser Temperature 4: ");
Serial.println(con4);
*/
//Serial.println();
delay(500);
eva[i] = (float)(eva1 + eva2 + eva3 + eva4) / 4.0;
con[i] = (float)(con1 + con2 + con3 + con4) / 4.0;
delay(500);
t_arry[i] = millis() / 1000.0;
Serial.println(eva[i]);
delay(5000);
if (i == 100)
{
Serial.println();
Serial.println();
Serial.println("Time in seconds:");
for (x = 0; x < 101; x++)
{
Serial.println(t_arry[x]);
}
```

```
Serial.println();
Serial.println();
Serial.println("condensation temperature:");
for (x = 0; x < 101; x++)
{
Serial.println(con[x]);
}
Serial.println();


Serial.println();
Serial.println("Thermal Resistance:");
for (x = 0; x < 101; x++)
{
Serial.println((eva[x] - con[x]) / Q);
}
Serial.println();
Serial.println();
Serial.println("Heat Tranasfer Co-efficient :");
for (x = 0; x < 101; x++)
{
Serial.println(Q/(.00196*(eva[x] - con[x])));
}
}
i++;
}
Serial.println("End of the program.");
delay(2000);
}
```

4.4 Program used to measure thermal resistance against heat input

```
char in=11;
int eva1,eva2,eva3,ad1,ad2,con1,con2,con3;
float eva,con;
float t_arry[100];
int i=0,x,m;
float TH[8],TC[8];
void setup()
{
Serial.begin(9600);
analogReference(INTERNAL1V1);
}
void loop()
{
eva1 = analogRead(0)/ 9.31;
eva2 = analogRead(1)/ 9.31;
eva3 = analogRead(2)/ 9.31;
con1 = analogRead(3)/ 9.31;
con2 = analogRead(4)/ 9.31;
con3 = analogRead(5)/ 9.31;
eva=(float)(eva1+eva2+eva3)/3.0;
con=(float)(con1+con2+con3)/3.0;
delay(50);
if (Serial.available() > 0)
{
in = Serial.read();
if (in == '1')
{
Serial.print("Thermal Resistance: ");
Serial.println((eva-con)/10);
```

```
TH[i]=(eva-con)/10;
i++;
}
if (in == '2')
{
Serial.print("Thermal Resistance: ");
Serial.println((eva-con)/20);
TH[i]=(eva-con)/20;
i++;
}
if (in == '3')
{
Serial.print("Thermal Resistance: ");
Serial.println((eva-con)/30);
TH[i]=(eva-con)/30;
i++;
}
if (in == '4')
{
Serial.print("Thermal Resistance: ");
Serial.println((eva-con)/40);
TH[i]=(eva-con)/40;
i++;
}
if (in == '5')
{
Serial.print("Thermal Resistance: ");
Serial.println((eva-con)/50);
TH[i]=(eva-con)/50;
i++;
}
```

```
if (in == '6')
{
Serial.print("Thermal Resistance: ");
Serial.println((eva-con)/60);
TH[i]=(eva-con)/60;
i++;
}
if (in == '7')
{
Serial.print("Thermal Resistance: ");
Serial.println((eva-con)/70);
TH[i]=(eva-con)/70;
i++;
}
if (in == '8')
{
Serial.print("Thermal Resistance: ");
Serial.println((eva-con)/80);
TH[i]=(eva-con)/80;
i++;
}
if(in== '0')
int m;
for(m=0;m<i;m++)
{
Serial.println(TH[m]);
}
Serial.println();
Serial.println();
i++;
} } }
```

4.5 Program used for watt calculation

```
#include<stdio.h>
#include<math.h>
#include <conio.h>
int v=10,x,y,z;
float i[60],w[60];
int main(void)
{
for(x=0;x<=60;x++)
{
i[x]=0.032*v-0.077;
w[x]=i[x]*v;
printf("volt= %d\tCurrent= %.2f\tWatt= %.2f\n \n",v,i[x],(0.75*w[x]));
v++;
}
getch();
}
```

Chapter 5

Graphical Analysis

5.1 Normal Structure

Working Fluids : Ethanol, Methanol, Ethanol-Methanol Blend

Filling Ratio : 30%

Position : 0°(Vertical)

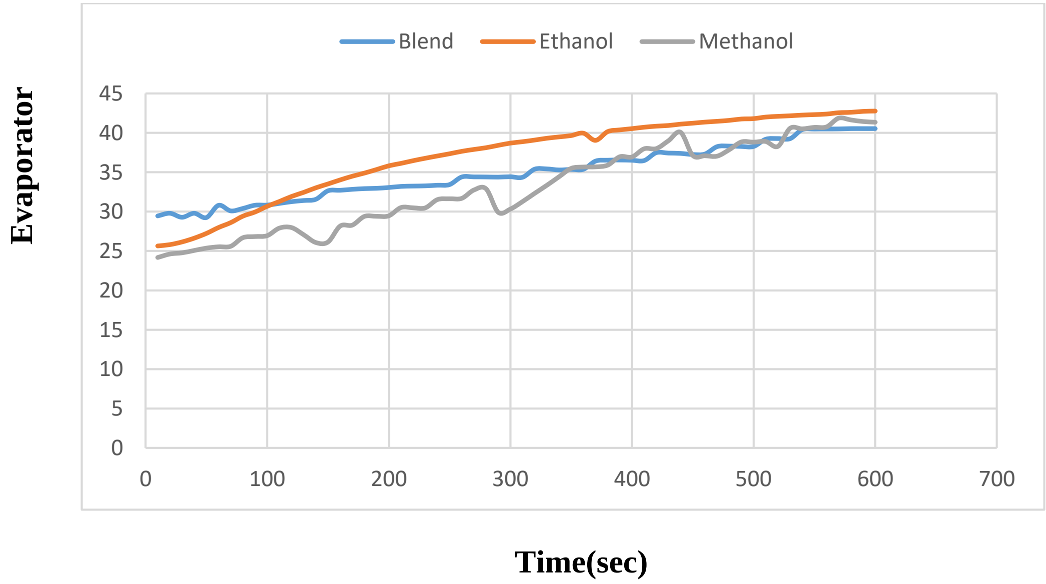


Figure 5.1: Variation of Temperature with Time for 10W heat input

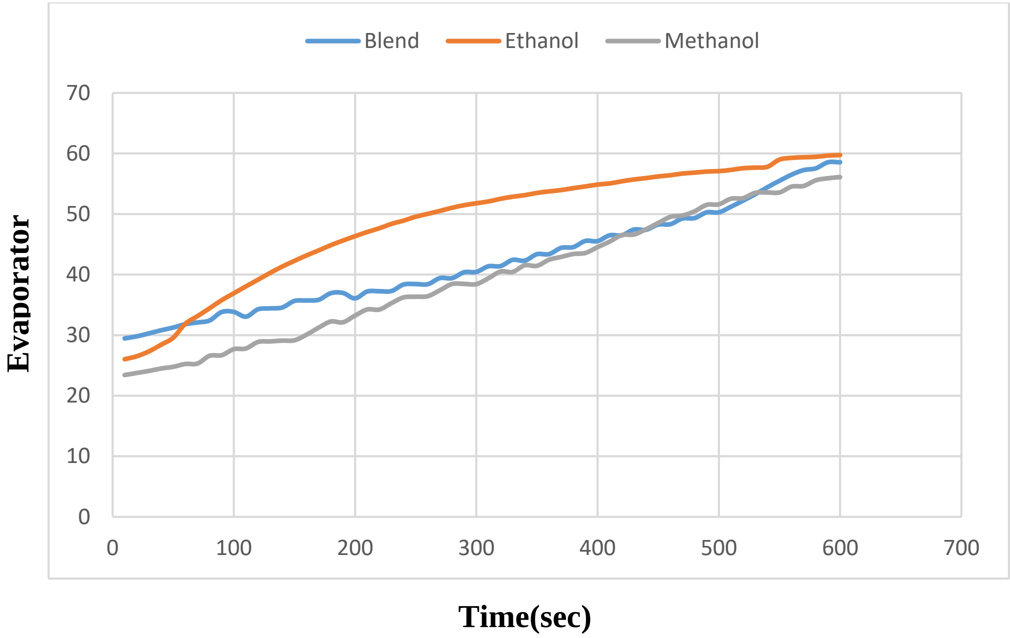


Figure 5.2: Variation of Temperature with Time for 20W heat input

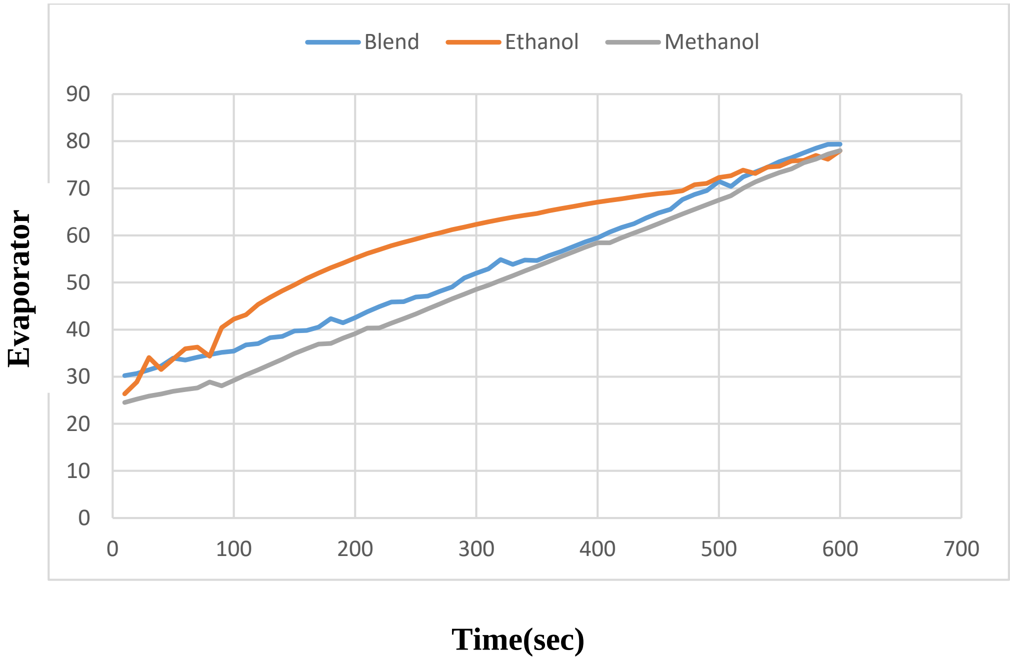


Figure 5.3: Variation of Temperature with Time for 30W heat input

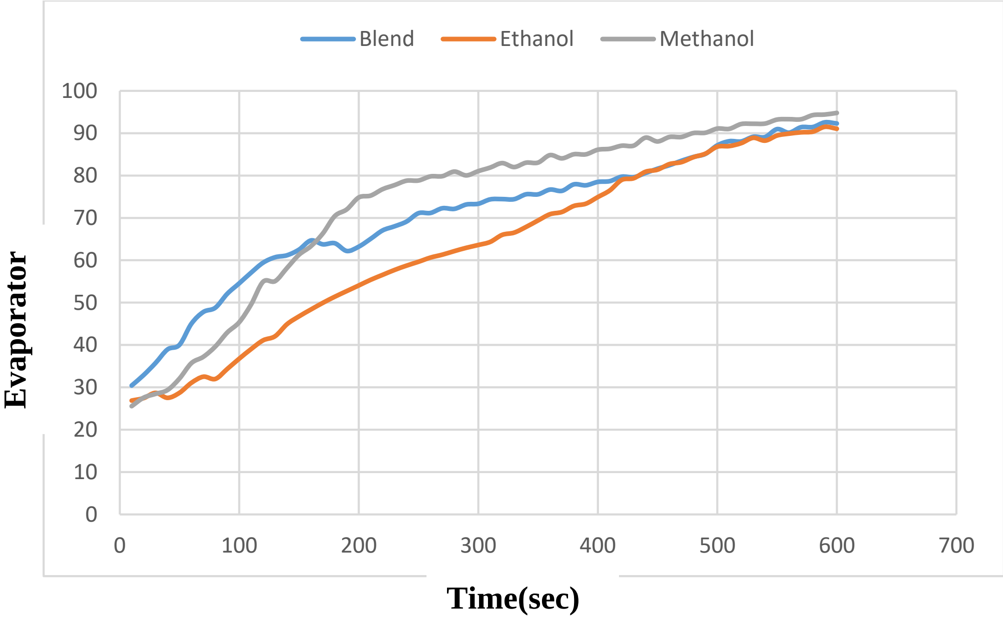


Figure 5.4: Variation of Temperature with Time for 40W heat input

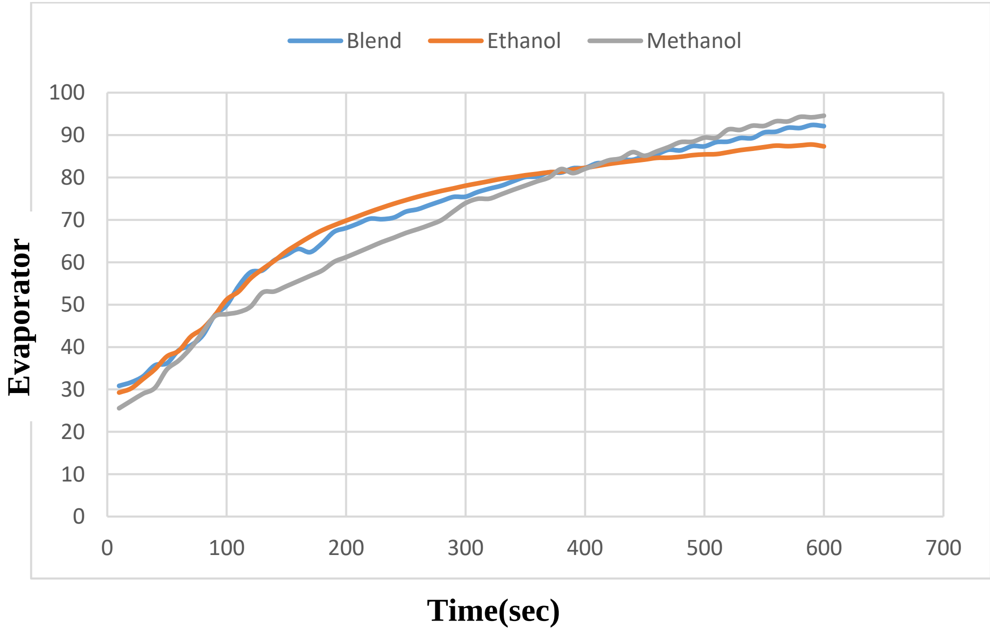


Figure 5.5: Variation of Temperature with Time for 50W heat input

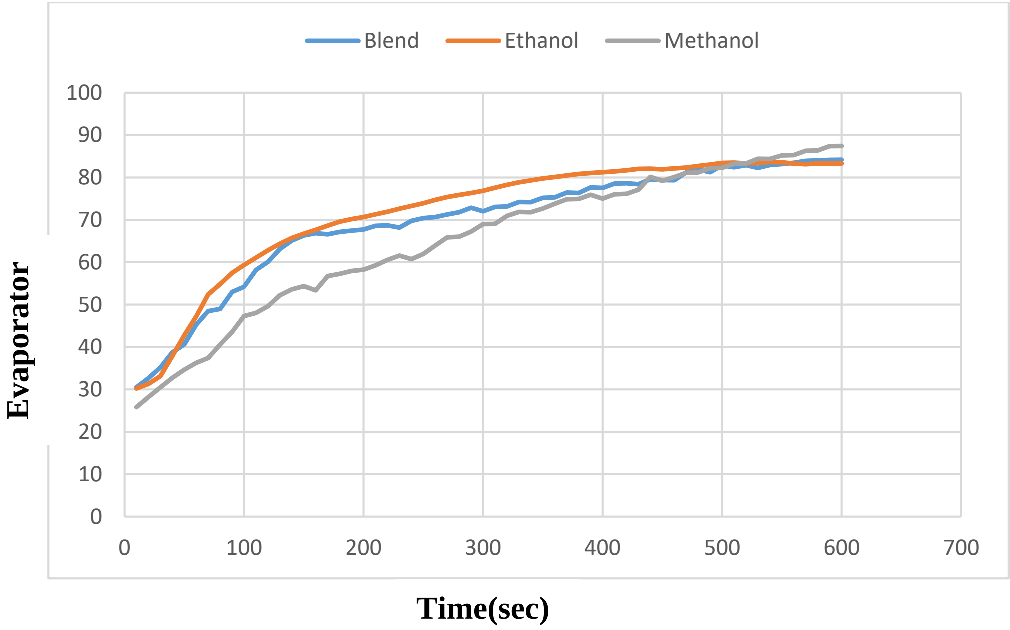


Figure 5.6: Variation of Temperature with Time for 60W heat input

Working Fluids: Ethanol,Methanol,Ethanol-Methanol Blend

Filling Ratio: 40%

Position: 0° (Vertical)

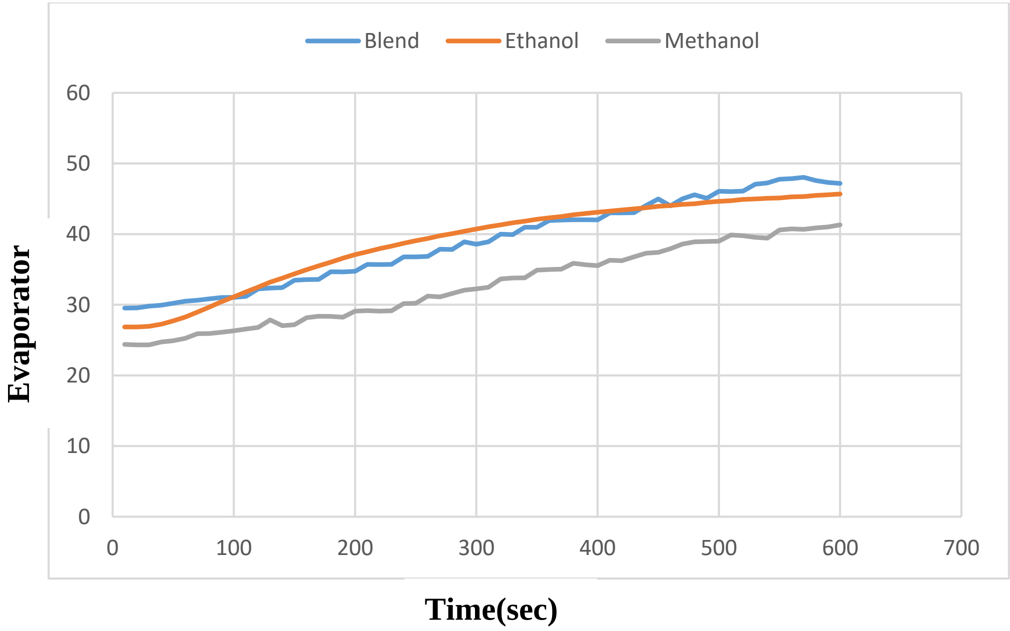


Figure 5.7: Variation of Temperature with Time for 10W heat input

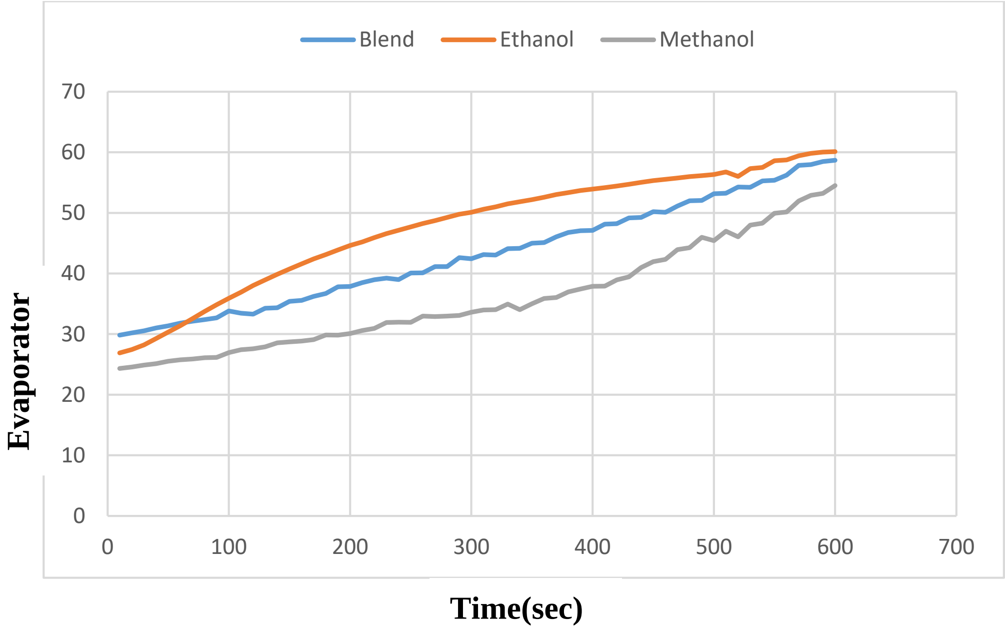


Figure 5.8: Variation of Temperature with Time for 20W heat input

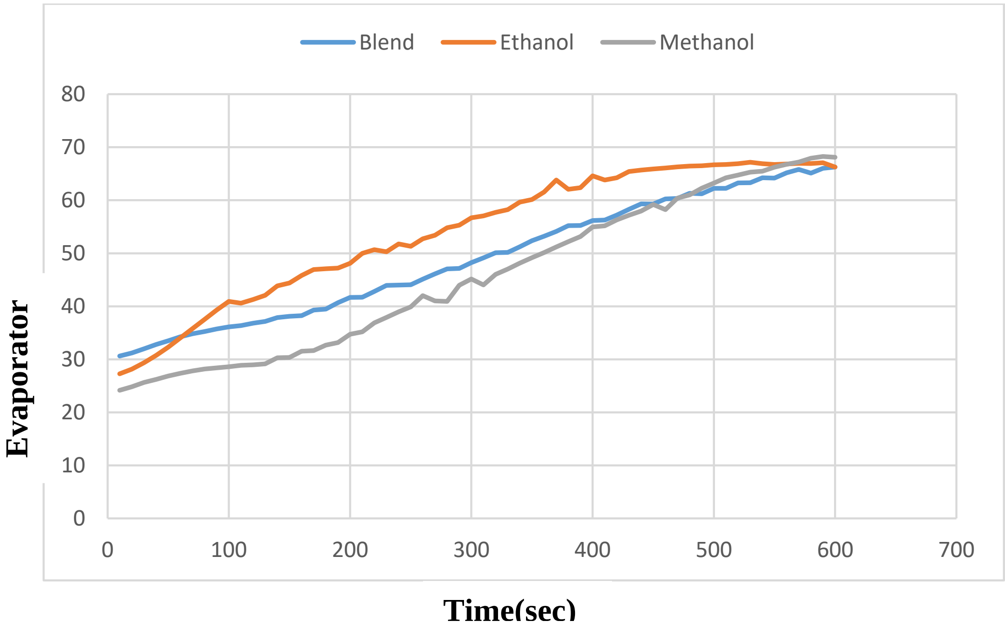


Figure 5.9: Variation of Temperature with Time for 30W heat input

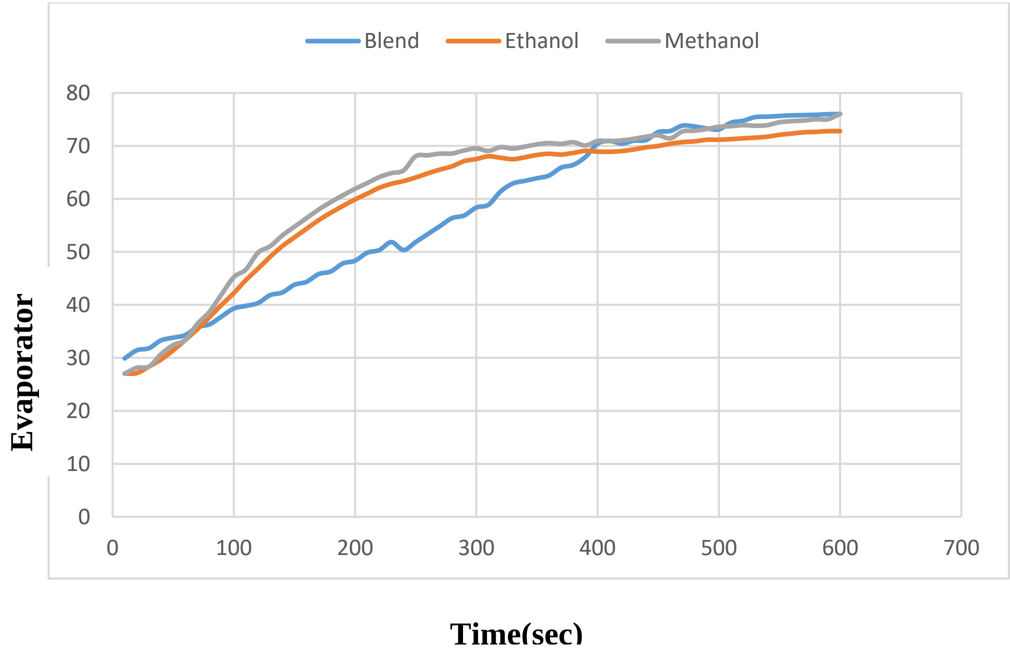


Figure 5.10: Variation of Temperature with Time for 40W heat input

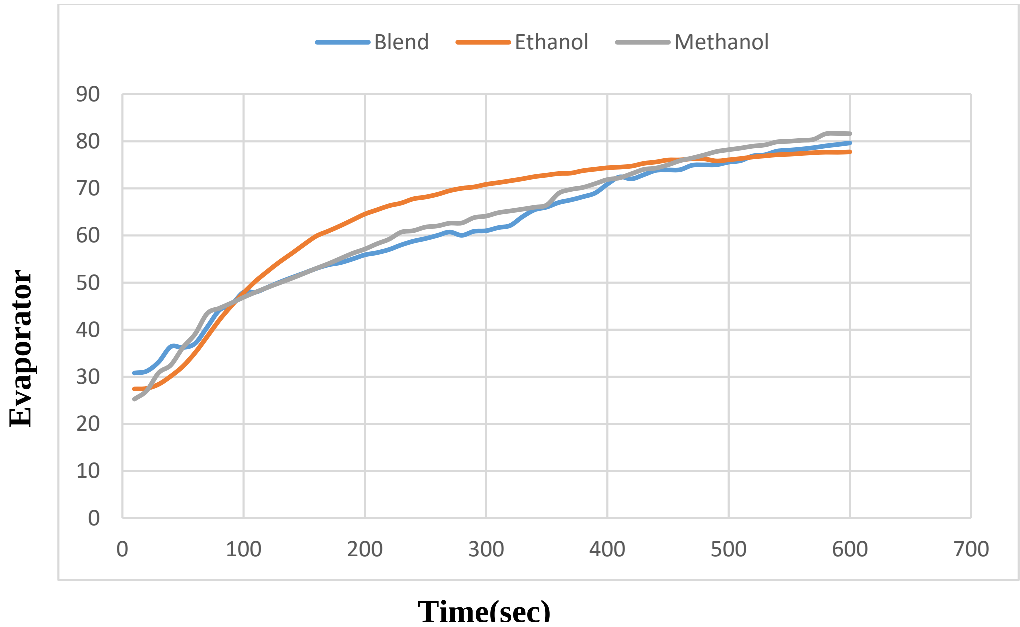


Figure 5.11: Variation of Temperature with Time for 50W heat input

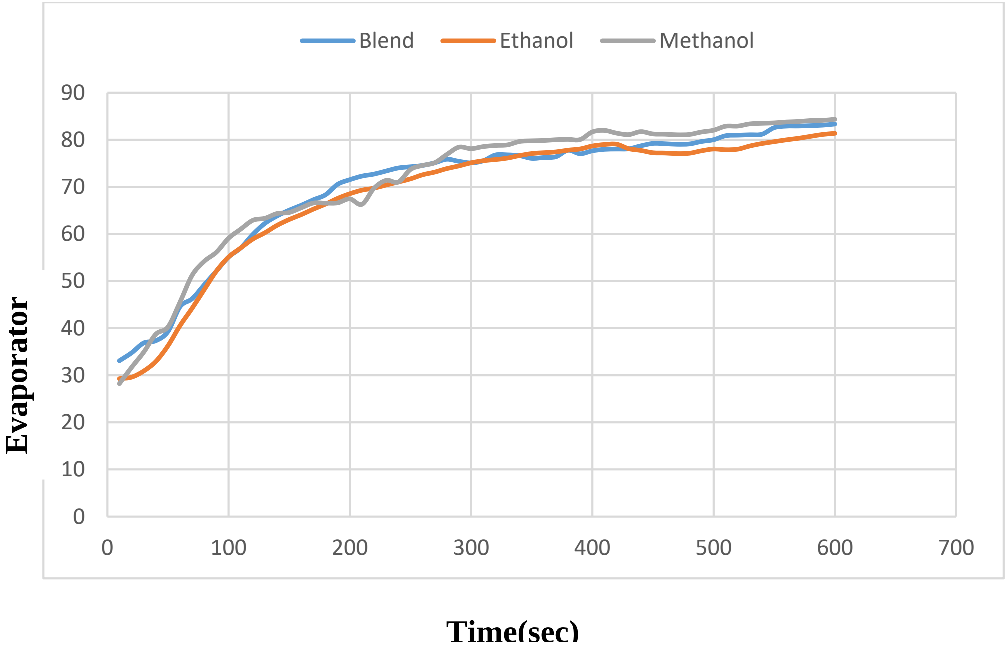


Figure 5.12: Variation of Temperature with Time for 60W heat input

Working Fluids: Ethanol, Methanol, Ethanol-Methanol Blend

Filling Ratio: 50%

Position: 0° (Vertical)

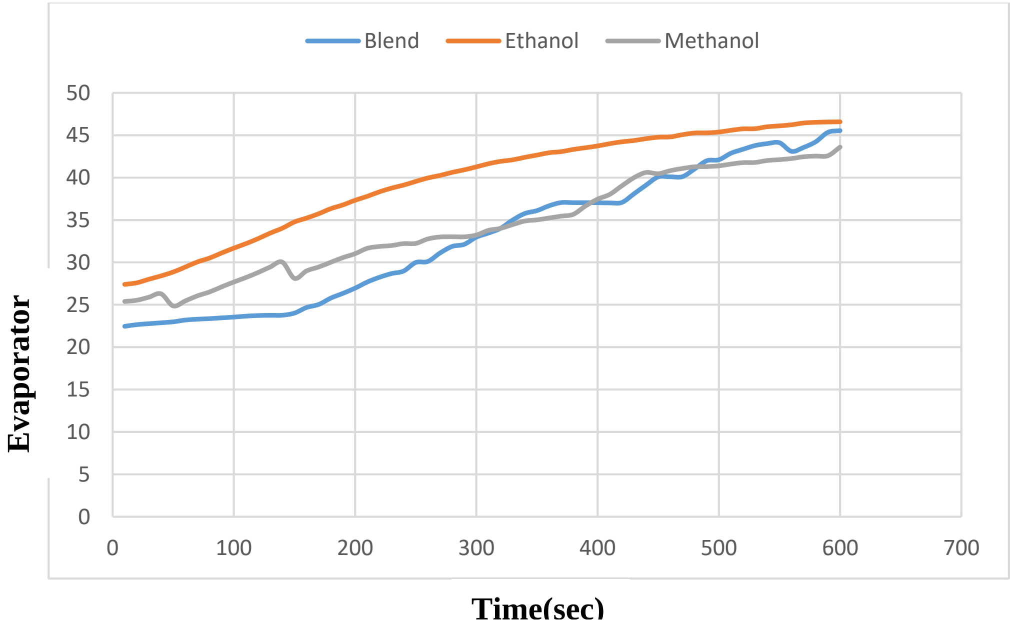


Figure 5.13: Variation of Temperature with Time for 10W heat input

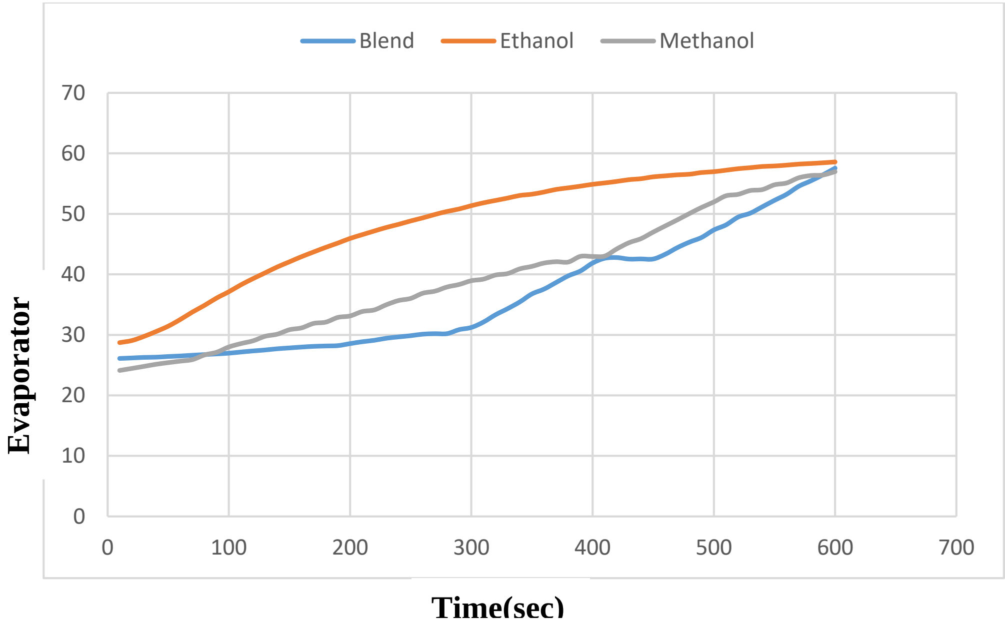


Figure 5.14: Variation of Temperature with Time for 20W heat input

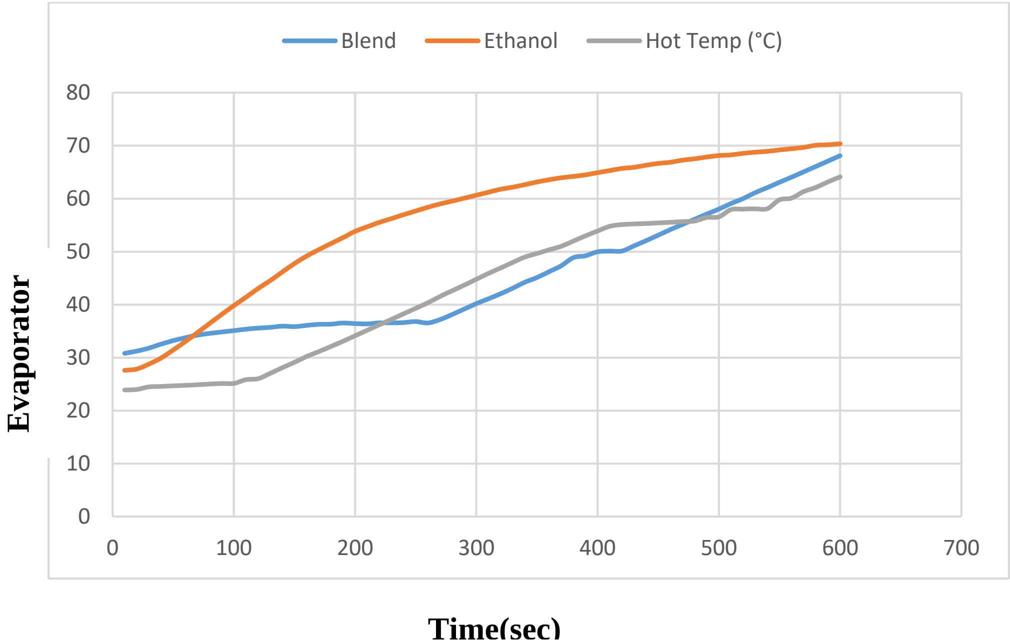


Figure 5.15: Variation of Temperature with Time for 30W heat input

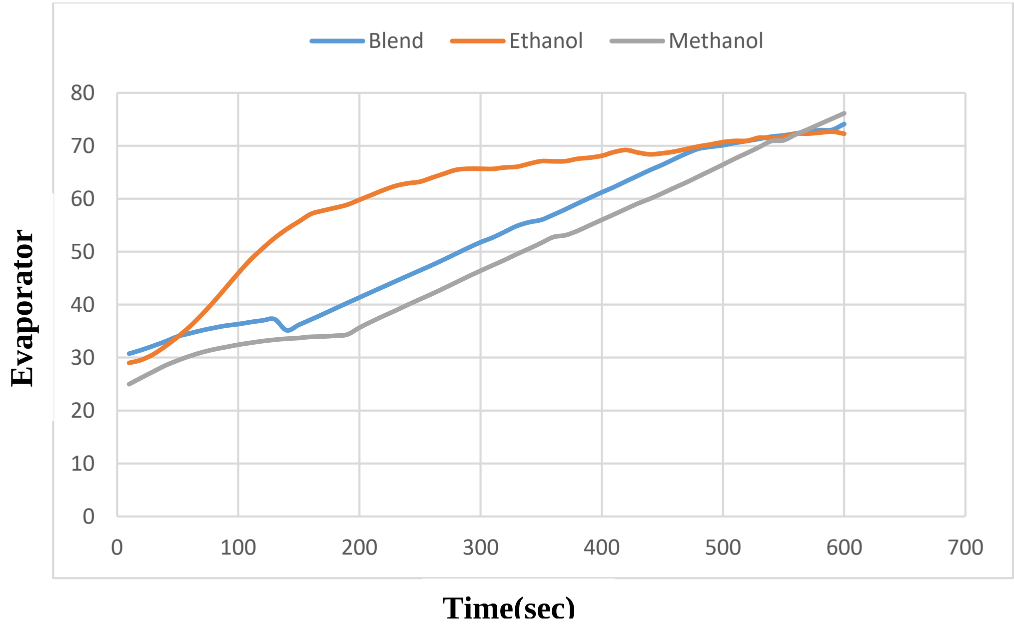


Figure 5.16: Variation of Temperature with Time for 40W heat input

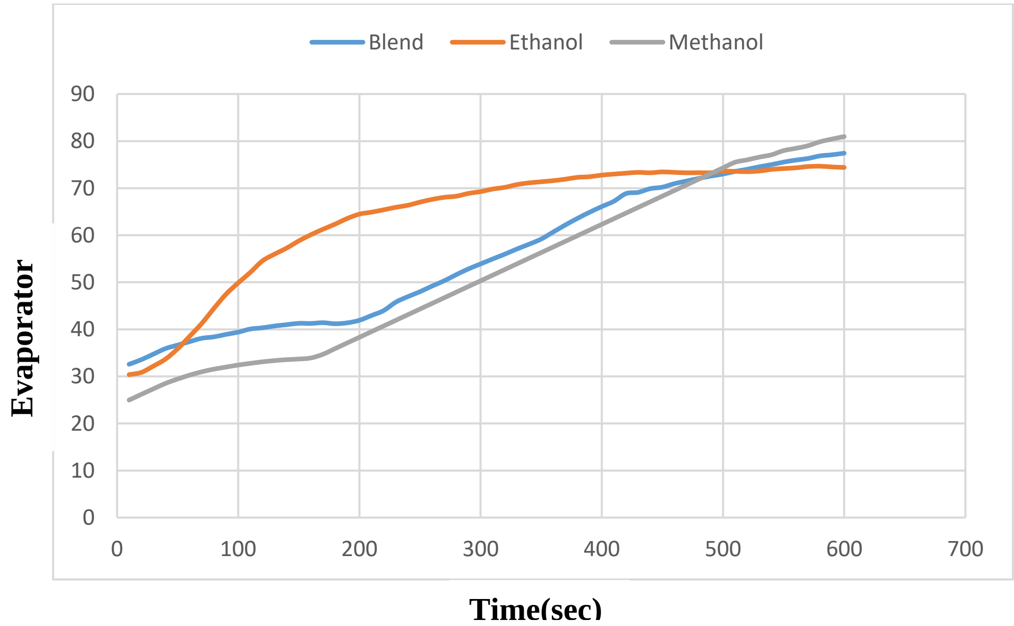


Figure 5.17: Variation of Temperature with Time for 50W heat input

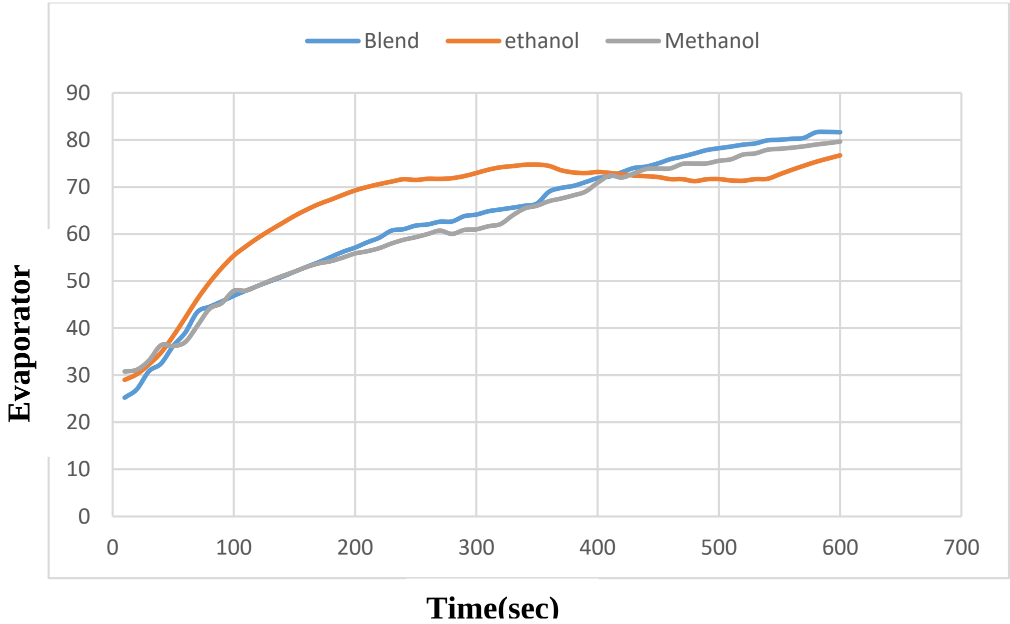


Figure 5.18: Variation of Temperature with Time for 60W heat input

Working Fluids: Ethanol, Methanol, Ethanol-Methanol Blend

Filling Ratio: 30%

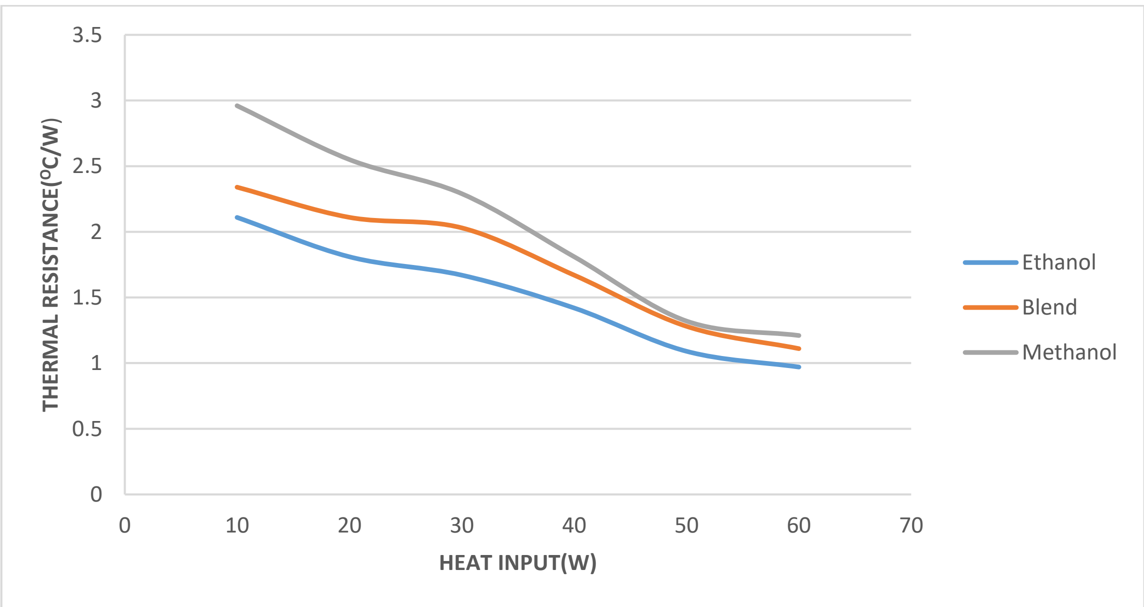


Figure 5.19: Variation of Thermal Resistance with heat input

Working Fluids : Ethanol, Methanol, Ethanol-Methanol Blend

Filling Ratio : 40%

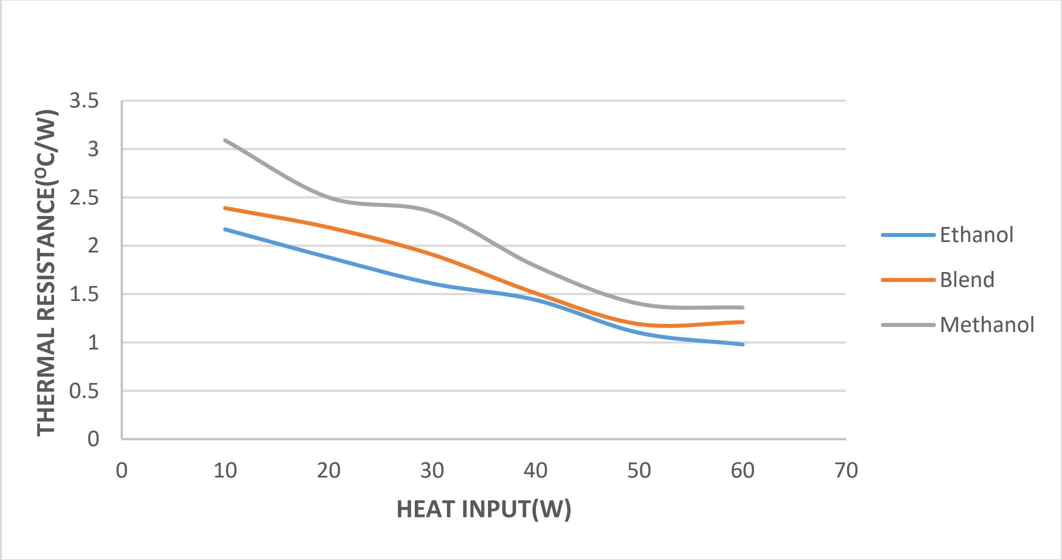


Figure 5.20 : Variation of Thermal Resistance with heat input

Working Fluids: Ethanol, Methanol, Ethanol-Methanol Blend

Filling Ratio: 50%

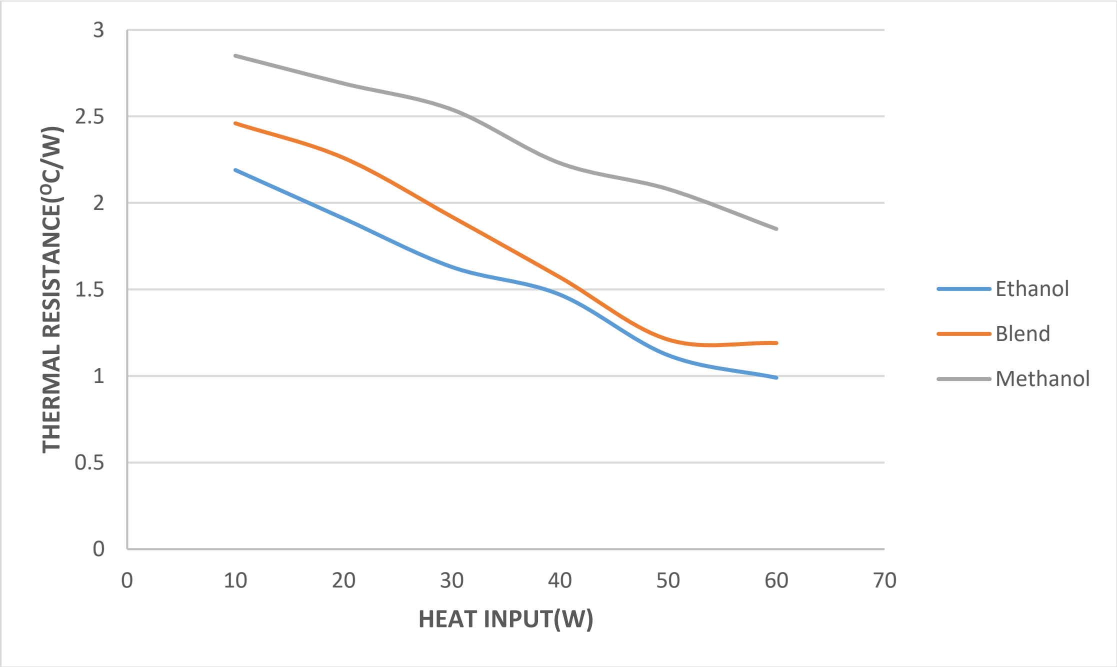


Figure 5.21: Variation of Thermal Resistance with heat input

Chapter 6

Result & Discussions

6.1 Studies from the Experiment

- The working principle in heat pipe is influenced by bubble movement, buoyancy, pressure etc. Moreover, these affect the performance of heat pipe in different manners regarding that they are in vertical position or inclined.
- Three different filling ratio of working fluid and three different working fluid is used. Filling ratios are 30%,40% and 50% of the total volume of CLPHP. Working fluids are ethanol, methanol and Ethanol-Methanol Blend.
- An adiabatic section was considered to be present in between the evaporator and the condenser, where temperature was expected to be constant throughout. But in the assumed adiabatic section, temperature did not remain the same; rather it increases by a small fraction with increased heat input. This can be attributed to the fact that design and construction cannot be made without little faults in the working process.
- The wall temperatures of different portions of CLPHP are measured by using LM35 thermocouples. Thermal resistance is considered in this paper as the indicator of heat pipe effectiveness.
- At first from the measured data, evaporator temperature curve against time were plotted with respect to the fluids used.
- Next the heat input VS thermal resistance for ethanol, methanol and ethanol methanol blend for all filling ratio have been done in the graph.
- The temperature distribution curves show almost similar pattern in all cases. The condenser temperature remains nearly same for all filling ratios.
- The evaporator section is wrapped up by heat insulating materials to stop heat loss to environment while giving heat input to the CLPHP and it is crucial as heat losses result in variation in the performance of the CLPHP.

6.2 Characteristics of temperature distribution

The temperature distribution curves show the evaporator wall temperature and condenser wall temperature plotted against time. The temperature distribution curves are used to find out the startup time for the CLPHP. These curves show almost similar pattern in all cases. The curves are somewhat exponential in nature. These curves are governed by the saturation temperature of the working fluid used as well as its surface tension, buoyancy and gravity. For all the experimental cases, the curves at first increase rapidly with time and then the rate of increase become slow to some extent. This is same for all the evaporator temperature data. But the rate of increase is different for different regions. After reaching the boiling point, the temperature increase in evaporator slows down due to the heat required in phase transfer. Two phase transfer involved and they are boiling and condensation. Then it starts acting on pulsating effect. The pulsating effect is when the liquid starts to boil in the evaporator section it takes the latent heat from the evaporator wall then bubble formation begins. These bubbles with liquid slugs inside due to buoyancy and low surface tension of fluid starts to go up. The liquid slugs inside want to come down due to gravitational force. When the bubble reaches the condenser section the force convection takes away the heat, so the bubble collapses and the relatively less hot liquid goes down again and gets heat from the evaporator wall. As this is a continuous process so at every instance the temperature fluctuates due to this bubble formation and collapsing. The heat transfer is carried out by this fluctuation of temperature, this is the pulsating effect. The saturation temperature of ethanol is 78ºC and the saturation temperature of methanol is 64.7º. Depending on the pressure inside the CLPHP and the heat transfer from the heating arrangement to the liquids inside the CLPHP via the evaporator wall the saturation temperature may vary to a slight extent. Again a thumb rule of heat transfer, about 8-25ºC temperature difference is required for good amount of heat transfer between bodies. In most cases this pulsating effect occurs when the evaporator wall temperature reaches this temperature the ethanol, methanol or ethanol-methanol blend inside the CLPHP starts to boil hence reaches it boiling temperature and starts the pulsating effect. Figure 5.1, 5.2, 5.7, 5.8, 5.9, 5.13, 5.14, 5.15 show that ethanol has reached a maximum evaporation temperature than methanol and ethanol-methanol blend. Figure 5.3, 5.4, 5.10 show ethanol-methanol blend has reached a maximum hot side temperature whereas Figure 5.5, 5.6, 5.11, 5.12, 5.16, 5.17, 5.18 show maximum evaporation temperature is achieved by methanol. It shows ethanol is a good choice in low heat input where methanol shows better performance in high heat input.

From these figures the finding is that the evaporator temperature distribution decreases with filling ratio. At 30%FR there is less amount of fluid inside the CLPHP. As the heat input is increased the pulsating starts and liquid vaporizes and liquefies consistently. Now if high heat input is given then the amount of liquid vaporizing increases and there remains little amount of liquid to take the huge amount of heat. This situation is called DRY UP. When DRY UP occurs the evaporator wall gets heated up as it cannot pass the heat to liquid due to lack of sufficient amount of liquid present inside. As filling ratio increases the amount of liquid available increases so temperature of evaporator walls decreases. It is because at 50%FR the CLPHP has very little unoccupied space or free space than as before like 40%FR or 30%FR. So when the heat input is given the liquid expands, hence the free space reduces to almost zero. This results in very little space for bubble to collapse and also the warm liquid in this case avails in the condenser section also. As a result, condenser temperature increases. Due to force convection by fan the condenser section is constantly cooled so when the liquid cooled goes down the temperature goes down and in an instance warm liquid takes up the condenser section again. As the condenser temperature increases the difference between evaporator temperature and condenser temperature decreases resulting in low thermal resistance but low cooling range which renders it ineffective.

6.3 Effect of thermal resistance

Thermal resistance is a heat property and a measurement of a temperature difference by which an object or material resists a heat flow. Thermal resistance is the reciprocal of thermal conductance. The average temperature of evaporator section is (T_e) and the average temperature of condenser section is (T_c) and the equation for thermal resistance is

$R_{th} = (T_e - T_c) / Q$

Thermal Resistance value indicates the efficiency. The equation indicates how much resistance does heat experiences in the system. Thermal resistance has an inverse relationship with heat input i.e. thermal resistance decreases with increasing heat input. These curves follow an exponential pattern. Thermal resistance decreases with increasing power. At low heat inputs the thermal resistance is high. This is because at low heat inputs the liquid slug movement is very low and there is little bubble formation resulting in low heat transfer. As heat input is increased liquids inside the CLPHP gets exposed to adequate amount of heat and slowly pulsating action starts. At first the decrease rate of thermal resistance is high this is because there is a vast amount of liquid present to pulsating action. As heat input increases more i.e. to high heat input range the decrease rate of thermal resistance becomes low. This results in slowly flattening out of the thermal resistance curve. This is due to high amount of pulsating movement occurring inside the PHP, so amount of ethanol, methanol and blend of both available in liquid form for pulsating movement decreases. The thermal resistance curve decreases up to an optimum value after which the thermal resistance starts to increase. At this point dry out occurs inside the PHP. Dry out means almost all the liquid available is in pulsating action i.e. in bubble form and there is very little liquid available which does not have the ability to compensate the high amount of heat input. In the experiment we carried out up to 60W heat input is applied in the PHP. In our experiment dry out did not occur. This implies that ethanol, methanol and blend of both works well up to 60W heat input. The curves also have not flattened out as much so more heat input can be applied to find out the optimum value of thermal resistance. Thermal resistance is closely governed by filling ratio, inclination of the PHP and structural differences also.

6.4 Effect of Filling Ratio

A PHP is partially charged with a working fluid. The proportion of the working fluid volume to the whole volume of the PHP is called charging ratio. Investigations done in this field have shown that in lower charging ratios, although the working fluid can circulate easily, application of high heat loads to the system leads into dry out of PHP, which deteriorates thermal performance.

Most of the time in between 20% to 50% fill charge the PHP operates as a true pulsating device. The exact range differs for different working fluids and operating parameters. The more bubbles (lower fill charges), the higher is the degree of freedom but simultaneously there is less liquid mass for sensible heat transfer. Less bubbles (higher fill charges) cause less perturbations and the bubble pumping action is reduced thereby lowering the performance. Thus, an optimum fill charge exists.

In addition, as the charging ratio decreases, sensible heat transfer decreases too. On the other hand, in higher charging ratios, due to lack of enough empty space in pipe, the degree of freedom of working fluid for performing oscillation motion is decreased and as a result pumping efficiency of working fluid will be decreased. Furthermore, in this case the number of generated bubbles is too small to form oscillating motion. However, as the charging ratio increases sensible heat transfer increases, and probability of dry-out decreases. Thus, the middle charging ratios are reported to be optimal in a PHP's operation. From the figures it can be seen that the time to reach the steady state increases with decrease in fill ratio. The amplitude of displacement is inversely proportional to the fill ratio.

In figures we can see that at 30% filling ratio fluids shows low pulsating characteristics. With the increasing filling ratio and heat pulsating characteristics improves. In case of 40% filling ratio the curves start pulsating at 70sec in 30 watts and 40sec. This is called the startup time.

From experiment we could realize that at 30%,40% and 50% filling ratio all the fluids startup time is very nearest. At 40% filling ratio at low heat input ethanol shows low startup time and at high heat input methanol shows low startup time. Blend of ethanol and methanol did not show any fixed characteristics in all cases. Sometimes it shows better pulsating characteristics than methanol and sometimes than ethanol at different filling ratios.

6.5 Heat pipe Applications

Heat pipes are extremely reliable since they have no moving parts. This is the main reason they are used extensively in space applications where maintenance is not available. The main cause of heat pipe failures is gas generation in the heat pipe. This problem is totally eliminated by proper cleaning and assembly procedures. For successful transfer of heat, there is no alternative of a heat pipe. It has popularity for its light weight with high conductance. Heat pipes allow transportation of high fluxes with small temperature difference with no change in operating temperature. It can ensure longer life with a minimum maintenance. Also they can be built in different geometries and sizes.

Heat pipes are used in-

- Space & Electronics cooling
- Heat exchangers & production tools
- medicine and human body temperature control
- engines and automotive industry
- Low humidity level necessary o Humidity control require
- Air reheated after cooling in traditional HVAC system
- Large quantities of ventilation air needed
- Laptop heat solution o Solar thermal
- Pipeline over permafrost
- Cooking
- Nuclear power conversion

6.6 LIMITATIONS OF HEAT PIPES

When heated above a certain temperature, all of the working fluid in the heat pipe will vaporized and the condensation process will cease to occur. This is the dry out condition. In such cases, the heat pipes thermal conductivity is effectively reduced to heat conduction properties of its solid metal casing alone.

- If the heat source temperature drops below a certain level, depending on the specific fluid and gas combination in the heat pipe, a complete shut up can occur. So the control feature is particularly useful for last warm up application in addition to its value as a temperature leveler for variable load conditions.
- The rate of heat transfer through the heat pipe is solely dependent on the rate of evaporation and condensation. If non-condensable gases are present in the gas mixture, the heat transfer will be affected. To ensure an effective heat transfer, a mechanism has to be established in the heat pipe then.
- Most manufacturers do not produce heat pipes smaller than two mm diameter for material limitations. This unavailability is a limitation. Heat pipes are excellent heat transfer devices but their sphere of application is mainly confined to transferring relatively small heat loads over relatively short distances when the evaporator and condenser are at the same horizontal level.

As a result of these limitations, different solutions involving structural modifications to the conventional heat pipe have been proposed. Our approach is also to overcome these limitations and increase its efficiency with vast sector of use.

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Chapter 7
CONCLUSION and RECOMMENDATION

7.1 Conclusion

Due to simple design, cost effectiveness excellent thermal performance pulsating heat pipe is gaining more and more popularity. A great deal of experimental studies indicated that the visualization technique combining the scrutiny investigated images of the flow patterns and the experimental data of heat transfer performance, contributed a lot to further understanding of the thermo hydrodynamic mechanism within the PHPs. The characteristics of the start-up procedure and dry-out phenomena are presently the main research topics. Form this experimental study some information related to the fundamental characteristics and operational regimes of a CLPHP are generated. The three important factors-bubble formation, phase transfer, pressure are considered to design heat pipe. It can be emphasized the desired thermo-mechanically boundary conditions resulting convective flow boiling condition in the evaporator design. Different heat inputs to these devices give to different flow pattern inside the tube. This in turn is responsible for various heat transfer characteristics.

The following conclusions can be drawn from this experiment:

- At low heat input ethanol is better working fluid than methanol and at high heat input methanol is better than ethanol. Blend of ethanol and methanol did not show any fixed characteristics. At some filling ratios it shows better result than ethanol and at some ratios better than methanol.
- In most of the cases methanol has slightly higher R_{th} than ethanol that indicates better efficiency of performance of heat transfer, this is due to the effect of their thermos physical properties.
- At 30% filling ratio fluids reaches to the boiling point in very rare cases. 40% and 50% filling ratio shows better pulsating characteristics for all fluids (ethanol, methanol and blend of both).

7.2 Recommendations

The following general recommendations are made for future research directions:

- Even though, a microcontroller based temperature display was used for efficient measurement of temperature, a microcontroller based heater controller could have been implemented for automatic heating of the tube.
- Overall environment can be made more isolated to ensure the least possible heat loss.
- Introducing newer fluids future researchers may discover the more efficient fluid than ethanol and methanol in every aspect.
- Effect of cooling air velocity can be considered t get more accuracy in the experiment.
- Further analysis can be done with modified geometry of heat pipe, fin and insert to investigate its relation with heat transfer enhancement.
- Filling ratios can be varied to other extents to find out different performances. ▯ Nano particles can be mixed with working fluid and can be used to measure performance.

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Appendix-Data collection

Table A-1: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 30%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	25.64	25.46
20	25.81	25.33
30	26.15	25.42
40	26.63	25.34
50	27.23	25.41
60	27.98	25.37
70	28.6	25.35
80	29.42	25.39
90	29.95	25.39
100	30.67	25.42
110	31.28	25.42
120	31.92	25.41
130	32.44	25.35
140	33.02	25.37
150	33.51	25.44
160	34.02	25.37
170	34.49	25.54
180	34.89	25.44
190	35.34	25.49
200	35.81	25.55
210	36.12	25.54
220	36.46	25.55
230	36.77	25.57
240	37.06	25.58
250	37.34	25.63
260	37.65	25.7
270	37.89	25.73
280	38.11	25.68
290	38.41	25.74
300	38.69	25.77
310	38.87	25.79
320	39.08	25.78
330	39.31	25.82
340	39.48	25.83

Table A-2: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 30%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	26.02	24.86
20	26.51	24.86
30	27.31	24.91
40	28.41	24.91
50	29.56	24.87
60	31.87	25.86
70	33.13	25.87
80	34.43	25.87
90	35.77	25.9
100	36.91	25.91
110	38.05	25.98
120	39.16	26.01
130	40.28	26.05
140	41.33	26.08
150	42.26	26.1
160	43.17	26.16
170	43.99	26.21
180	44.86	26.28
190	45.62	26.45
200	46.34	26.42
210	47.03	26.48
220	47.65	26.54
230	48.37	26.58
240	48.91	26.69
250	49.56	26.7
260	50.03	26.69
270	50.52	26.75
280	51.04	26.79
290	51.46	26.83
300	51.78	26.89
310	52.08	26.89
320	52.52	26.92
330	52.86	26.99
340	53.12	27.03
350	53.49	27.05
360	53.74	27.01
370	53.96	27.07

Table A-3: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 30%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	26.37	24.59
20	28.86	26.62
30	34.06	26.44
40	31.52	26.73
50	33.73	26.18
60	35.94	26.72
70	36.27	26.99
80	34.33	25.07
90	40.41	26.22
100	42.23	26.18
110	43.13	26.71
120	45.36	26.76
130	46.86	26.78
140	48.24	26.79
150	49.51	26.88
160	50.86	26.92
170	52.02	27.03
180	53.14	27.05
190	54.13	27.1
200	55.17	27.2
210	56.14	27.22
220	56.98	27.29
230	57.81	27.36
240	58.52	27.4
250	59.23	27.44
260	59.93	27.51
270	60.54	27.6
280	61.21	27.63
290	61.77	27.67
300	62.35	27.77
310	62.89	27.75
320	63.38	27.78
330	63.86	27.96
340	64.29	28
350	64.66	28.02
360	65.24	28.05
370	65.69	28.08

Table A-4: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 30%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	26.85	27.53
20	27.43	27.53
30	28.67	27.5
40	27.5	27.59
50	28.68	27.63
60	31.05	27.61
70	32.49	27.7
80	31.96	27.72
90	34.33	27.73
100	36.75	27.7
110	39.03	27.71
120	41.08	27.78
130	42.05	27.76
140	44.9	27.86
150	46.74	27.91
160	48.37	27.96
170	49.94	28.04
180	51.39	28.16
190	52.72	28.32
200	54.04	28.35
210	55.38	28.42
220	56.55	28.51
230	57.71	28.59
240	58.73	28.72
250	59.64	28.78
260	60.63	28.9
270	61.32	28.96
280	62.16	29.04
290	62.94	29.13
300	63.6	29.2
310	64.33	29.26
320	65.99	29.32
330	66.52	29.41
340	67.87	30.11
350	69.39	30.46
360	70.87	30.57
370	71.4	30.57

Table A-5: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 30%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	29.26	26.88
20	30.23	27.91
30	32.45	27.92
40	34.76	27.95
50	37.78	27.96
60	39.12	27.99
70	42.45	27.99
80	44.35	28.18
90	47.42	28.3
100	51.18	28.47
110	53.08	28.52
120	56.18	28.58
130	58.38	28.67
140	60.35	28.83
150	62.57	28.97
160	64.36	29.13
170	66.05	29.31
180	67.55	29.51
190	68.73	29.71
200	69.82	29.98
210	70.86	30.26
220	71.91	30.57
230	72.88	30.8
240	73.81	30.98
250	74.65	31.23
260	75.45	31.44
270	76.16	31.68
280	76.84	31.87
290	77.43	32.08
300	78.06	32.19
310	78.6	32.39
320	79.13	32.55
330	79.69	32.73
340	80.07	32.93
350	80.52	33.14
360	80.86	33.25
370	81.23	33.38

Table A-6: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 30%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.23	28.12
20	31.29	27.90
30	33.12	27.49
40	37.84	27.51
50	42.76	27.5
60	47.25	27.52
70	52.38	27.5
80	54.83	27.55
90	57.49	27.76
100	59.32	28.21
110	61.08	28.79
120	62.8	29.5
130	64.35	30.43
140	65.73	31.19
150	66.73	31.99
160	67.66	32.8
170	68.63	33.61
180	69.58	34.79
190	70.18	36.49
200	70.68	37.11
210	71.29	37.32
220	71.91	37.3
230	72.61	37.07
240	73.28	36.89
250	73.92	37.19
260	74.7	37.39
270	75.39	37.53
280	75.88	37.88
290	76.32	39.69
300	76.87	40.25
310	77.57	39.62
320	78.26	39.34
330	78.84	39.52
340	79.3	39.67
350	79.77	39.88
360	80.1	40.08
370	80.47	40.1

Table A-7: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 40%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	26.85	25.82
20	26.85	25.76
30	26.96	25.8
40	27.25	25.84
50	27.73	25.89
60	28.27	25.74
70	28.96	25.76
80	29.68	25.77
90	30.43	25.75
100	31.11	25.77
110	31.83	25.78
120	32.5	25.71
130	33.2	25.79
140	33.76	25.85
150	34.37	25.88
160	34.97	25.9
170	35.51	25.94
180	36.03	25.92
190	36.59	26.01
200	37.1	25.98
210	37.51	26.01
220	37.93	25.97
230	38.3	25.98
240	38.7	26.06
250	39.07	26.09
260	39.39	26.2
270	39.76	26.23
280	40.06	26.26
290	40.41	26.28
300	40.71	26.26
310	41.04	26.28
320	41.32	26.3
330	41.61	26.33
340	41.82	26.36
350	42.1	26.45
360	42.31	26.44
370	42.48	26.48

Table A-8: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 40%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	26.89	25.97
20	27.45	25.93
30	28.21	25.95
40	29.26	25.95
50	30.32	26.05
60	31.38	25.95
70	32.55	25.95
80	33.74	26.03
90	34.85	26.01
100	35.91	26.05
110	36.9	26.09
120	38.01	26.13
130	38.94	26.21
140	39.86	26.22
150	40.73	26.26
160	41.6	26.32
170	42.41	26.41
180	43.13	26.51
190	43.9	26.52
200	44.64	26.63
210	45.22	26.6
220	45.91	26.63
230	46.57	26.73
240	47.13	26.79
250	47.68	26.88
260	48.26	26.91
270	48.73	26.9
280	49.25	26.93
290	49.77	26.87
300	50.11	26.93
310	50.6	26.95
320	50.99	27.08
330	51.49	27.01
340	51.83	27.14
350	52.19	27.15
360	52.57	27.26

Table A-9: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 40%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	27.26	25.9
20	28.14	25.97
30	29.36	25.9
40	30.75	25.94
50	32.3	25.87
60	34.03	25.79
70	35.79	25.81
80	37.55	25.86
90	39.29	25.89
100	40.93	26.03
110	40.58	25.98
120	41.28	26.08
130	42.07	26.15
140	43.85	26.19
150	44.4	26.31
160	45.82	26.42
170	46.95	26.43
180	47.1	26.53
190	47.2	26.62
200	48.11	26.68
210	49.99	26.74
220	50.67	26.85
230	50.29	26.87
240	51.77	26.95
250	51.32	27.02
260	52.74	27.11
270	53.41	27.23
280	54.82	27.29
290	55.29	27.38
300	56.7	27.5
310	57.05	27.6
320	57.73	27.65
330	58.23	27.81
340	59.64	27.87
350	60.13	27.83
360	61.55	27.97
370	63.83	28.05

Table A-10: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 40%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	27.02	25.14
20	27.12	25.62
30	28.34	25.78
40	29.68	25.87
50	31.41	25.83
60	33.36	25.81
70	35.41	25.74
80	37.69	25.77
90	40.02	25.79
100	42.21	25.88
110	44.68	25.96
120	46.84	25.99
130	49.06	26.05
140	51.08	26.12
150	52.74	26.16
160	54.36	26.33
170	55.98	26.35
180	57.38	26.5
190	58.67	26.63
200	59.89	26.91
210	60.98	27.22
220	62.1	27.41
230	62.85	27.62
240	63.36	27.76
250	64.04	27.9
260	64.82	28.06
270	65.53	28.19
280	66.15	28.28
290	67.13	28.43
300	67.52	28.5
310	68.04	28.64
320	67.76	28.72
330	67.49	28.75
340	67.85	28.86
350	68.29	29.05
360	68.52	29.28
370	68.37	29.47
380	68.68	29.78

Table A-11: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 40%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	27.42	26.02
20	27.52	26.08
30	28.41	26.11
40	30.12	26.11
50	32.22	26.15
60	35.08	26.17
70	38.52	26.14
80	42.03	26.12
90	45.07	26.2
100	47.81	26.25
110	50.31	26.32
120	52.42	26.43
130	54.43	26.72
140	56.22	27.11
150	58.11	27.65
160	59.86	28.14
170	60.94	28.53
180	62.07	28.79
190	63.30	29.17
200	64.53	29.42
210	65.42	29.75
220	66.30	30.02
230	66.87	30.49
240	67.76	30.87
250	68.15	31.27
260	68.72	31.6
270	69.49	31.9
280	70.01	32.21
290	70.29	32.70
300	70.84	33.11
310	71.20	33.54
320	71.60	33.91
330	72.01	34.30
340	72.48	34.49
350	72.8	34.87
360	73.14	35.69
370	73.23	35.91
380	73.75	35.86

Table A-12: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 40%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	29.29	26.38
20	29.60	26.40
30	30.90	26.36
40	32.93	26.34
50	36.25	26.37
60	40.55	26.37
70	44.25	26.35
80	48.21	26.43
90	52.13	26.40
100	55.09	26.60
110	57.02	26.95
120	58.9	27.35
130	60.25	28.02
140	61.82	28.7
150	63.06	29.35
160	64.10	30.13
170	65.27	30.89
180	66.33	31.49
190	67.55	31.92
200	68.53	32.31
210	69.29	32.79
220	69.72	33.66
230	70.38	34.12
240	71.02	35.04
250	71.68	35.64
260	72.55	35.82
270	73.12	35.85
280	73.87	36.15
290	74.43	36.82
300	75.1	38.53
310	75.54	40.33
320	75.78	39.77
330	76.1	39.88
340	76.63	39.86
350	77.06	39.52
360	77.24	40.04
370	77.41	40.86
380	77.78	41.34

Table A-13: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 50%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	27.40	26.120
20	27.59	26.21
30	28.010	26.10
40	28.40	26.13
50	28.86	26.11
60	29.45	26.11
70	30.05	26.1
80	30.51	26.18
90	31.11	26.13
100	31.68	26.14
110	32.21	26.24
120	32.80	26.23
130	33.45	26.16
140	34.03	26.19
150	34.77	26.26
160	35.23	26.31
170	35.74	26.22
180	36.34	26.28
190	36.78	26.33
200	37.33	26.3
210	37.79	26.39
220	38.32	26.42
230	38.76	26.45
240	39.12	26.44
250	39.55	26.47
260	39.96	26.45
270	40.26	26.53
280	40.62	26.54
290	40.92	26.51
300	41.27	26.64
310	41.64	26.67
320	41.92	26.65
330	42.1	26.64
340	42.4	26.67
350	42.66	26.69
360	42.94	26.7
370	43.07	26.79
380	43.33	26.81

Table A-14: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 50%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	28.73	26.29
20	29.07	26.25
30	29.75	26.30
40	30.56	26.31
50	31.44	26.34
60	32.55	26.41
70	33.78	26.46
80	34.89	26.46
90	36.1	26.53
100	37.13	26.56
110	38.28	26.52
120	39.3	26.57
130	40.26	26.57
140	41.23	26.51
150	42.08	26.64
160	42.93	26.66
170	43.71	26.65
180	44.47	26.71
190	45.18	26.79
200	45.94	26.79
210	46.56	26.81
220	47.17	26.82
230	47.76	26.85
240	48.27	26.89
250	48.83	27
260	49.34	27.03
270	49.9	27.06
280	50.4	27.18
290	50.81	27.15
300	51.35	27.28
310	51.82	27.24
320	52.22	27.26
330	52.61	27.25
340	53.04	27.26
350	53.25	27.35
360	53.61	27.42
370	54.04	27.48
380	54.3	27.5

Table A-15: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 50%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	27.61	26.39
20	27.85	26.29
30	28.79	26.29
40	29.93	26.29
50	31.44	26.31
60	33.04	26.28
70	34.73	26.32
80	36.45	26.36
90	38.16	26.38
100	39.82	26.38
110	41.4	26.41
120	43.05	26.45
130	44.54	26.59
140	46.17	26.62
150	47.77	26.72
160	49.17	26.76
170	50.38	26.81
180	51.53	26.88
190	52.65	26.97
200	53.84	27.06
210	54.71	27.1
220	55.54	27.16
230	56.26	27.2
240	56.99	27.34
250	57.69	27.39
260	58.39	27.52
270	59.02	27.51
280	59.55	27.61
290	60.11	27.61
300	60.67	27.7
310	61.23	27.78
320	61.80	27.86
330	62.18	27.89
340	62.66	27.94
350	63.17	27.96
360	63.59	28.11
370	63.96	28.05
380	64.22	28.12

Table A-16: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 50%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	28.99	26.3
20	29.56	26.51
30	30.62	26.60
40	32.15	26.49
50	33.89	26.49
60	35.84	26.52
70	38.11	26.59
80	40.59	26.64
90	43.25	26.57
100	45.93	26.68
110	48.45	26.69
120	50.59	26.79
130	52.57	26.83
140	54.25	26.9
150	55.68	27
160	57.13	27.02
170	57.76	27.28
180	58.29	27.52
190	58.87	27.81
200	59.8	28.06
210	60.72	28.35
220	61.65	28.55
230	62.44	28.79
240	62.92	28.95
250	63.22	29.23
260	63.99	29.61
270	64.75	29.95
280	65.47	30.25
290	65.67	30.52
300	65.66	30.78
310	65.64	31.02
320	65.91	31.12
330	66.05	31.33
340	66.61	31.47
350	67.1	31.71
360	67.07	32.02
370	67.1	32.02

Table A-17: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 50%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.39	26.69
20	30.86	26.79
30	32.2	26.79
40	33.69	26.75
50	35.87	26.82
60	38.54	26.78
70	41.28	26.91
80	44.46	26.96
90	47.48	26.97
100	49.88	27.03
110	52.1	27.12
120	54.54	27.32
130	55.98	27.63
140	57.27	27.85
150	58.79	28.08
160	60.11	28.37
170	61.28	28.61
180	62.36	28.94
190	63.56	29.17
200	64.48	29.51
210	64.9	30.43
220	65.4	30.97
230	65.93	31.3
240	66.36	31.6
250	67.03	31.71
260	67.61	31.85
270	68.05	32.53
280	68.29	33.02
290	68.88	33.18
300	69.27	33.46
310	69.81	33.7
320	70.17	33.81
330	70.75	33.62
340	71.12	33.74
350	71.36	33.9
360	71.59	34.11
370	71.91	34.02
380	72.29	34.09

Table A-18: Structure: Normal; Working Fluid: Ethanol; Filling Ratio: 50%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	29.01	26.60
20	30.21	26.51
30	32.28	26.50
40	34.80	26.52
50	38.31	26.56
60	42.21	26.61
70	46.2	26.6
80	49.72	26.78
90	52.78	26.92
100	55.41	27.07
110	57.38	27.49
120	59.18	27.99
130	60.81	28.53
140	62.32	29.55
150	63.84	30.04
160	65.16	31.29
170	66.35	32.45
180	67.3	33.28
190	68.31	33.8
200	69.26	34.63
210	69.99	35.22
220	70.6	35.61
230	71.13	36.07
240	71.64	36.38
250	71.48	36.8
260	71.73	36.74
270	71.71	37.85
280	71.86	38.45
290	72.3	38.77
300	72.96	38.51
310	73.67	37.81
320	74.18	38.07
330	74.43	38.94
340	74.71	38.75
350	74.75	39
360	74.47	39.51
370	73.54	42
380	73.08	42.51

Table A-19: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 30%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.18	23.6
20	24.62	23.64
30	24.77	23.68
40	25.07	23.71
50	25.37	23.76
60	25.54	23.9
70	25.6	23.92
80	26.69	23.9
90	26.84	23.91
100	26.95	23.93
110	27.91	23.94
120	27.98	24
130	27.07	24.02
140	26.08	24.02
150	26.14	24.08
160	28.17	24.19
170	28.29	24.23
180	29.4	24.33
190	29.41	24.32
200	29.47	24.38
210	30.52	24.38
220	30.49	24.41
230	30.48	24.51
240	31.53	24.47
250	31.64	24.54
260	31.69	24.56
270	32.75	24.68
280	32.9	24.7
290	29.92	24.76
300	30.33	24.83
310	31.28	24.86
320	32.33	24.91
330	33.35	24.91
340	34.43	24.98
350	35.5	25.03
360	35.67	25.06
370	35.69	25.11
380	35.91	25.13

Table A-20: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 30%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	23.4	23.41
20	23.75	23.52
30	24.08	23.49
40	24.48	23.46
50	24.76	23.6
60	25.23	23.57
70	25.3	23.57
80	26.58	23.55
90	26.68	23.61
100	27.68	23.6
110	27.79	23.55
120	28.87	23.57
130	28.96	23.67
140	29.09	23.7
150	29.14	23.67
160	30.07	23.66
170	31.23	23.73
180	32.25	23.66
190	32.12	23.66
200	33.22	23.62
210	34.24	23.7
220	34.22	23.67
230	35.27	23.68
240	36.23	23.62
250	36.34	23.66
260	36.43	23.71
270	37.41	23.69
280	38.44	23.78
290	38.46	23.76
300	38.42	23.71
310	39.39	23.73
320	40.5	23.81
330	40.44	23.71
340	41.53	23.73
350	41.44	23.8
360	42.45	23.72
370	42.92	23.68
380	43.4	23.75

Table A-21: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 30%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.53	23.67
20	25.25	23.71
30	25.87	23.64
40	26.34	23.67
50	26.89	23.72
60	27.26	23.76
70	27.61	23.84
80	28.86	23.86
90	28.05	23.87
100	29.22	23.87
110	30.4	23.83
120	31.47	23.95
130	32.58	24.04
140	33.69	24.04
150	34.92	24.06
160	35.95	24.07
170	36.94	24.13
180	37.06	24.19
190	38.18	24.23
200	39.14	24.27
210	40.32	24.29
220	40.35	24.26
230	41.36	24.29
240	42.34	24.31
250	43.32	24.26
260	44.4	24.28
270	45.47	24.4
280	46.53	24.34
290	47.51	24.46
300	48.54	24.35
310	49.44	24.38
320	50.44	24.3
330	51.45	24.27
340	52.45	24.37
350	53.44	24.38
360	54.45	24.36
370	55.5	24.48
380	56.49	24.47

Table A-22: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 30%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	25.56	23.84
20	27.57	23.78
30	28.46	23.83
40	29.37	23.81
50	32.08	23.85
60	35.73	23.91
70	37.22	24.02
80	39.64	24.16
90	42.96	24.28
100	45.38	24.35
110	49.61	24.39
120	54.95	24.35
130	55.08	24.4
140	58.2	24.5
150	61.31	24.54
160	63.34	24.46
170	66.36	24.5
180	70.46	24.42
190	72.03	24.46
200	74.84	24.49
210	75.28	24.49
220	76.8	24.53
230	77.76	24.45
240	78.8	24.44
250	78.84	24.46
260	79.81	24.46
270	79.87	24.55
280	80.95	24.56
290	80.05	24.56
300	81.06	24.56
310	81.9	24.55
320	82.95	24.59
330	82.02	24.54
340	83.05	24.55
350	83.07	24.63
360	84.84	24.57
370	84.07	24.55
380	85.05	24.58

Table A-23: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 30%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	25.58	23.83
20	27.31	24.13
30	29.01	24.19
40	30.4	24.24
50	34.73	24.29
60	36.85	24.47
70	39.79	24.5
80	43.48	24.52
90	47.25	24.58
100	47.77	24.68
110	48.25	24.83
120	49.52	25.04
130	52.86	25
140	53.13	25.17
150	54.36	25.18
160	55.58	25.24
170	56.81	25.31
180	58.07	25.28
190	60.11	25.41
200	61.21	25.37
210	62.38	25.47
220	63.58	25.55
230	64.78	25.49
240	65.8	25.35
250	66.92	25.38
260	67.82	25.44
270	68.81	25.43
280	69.98	25.51
290	72.02	25.64
300	73.96	25.55
310	74.97	25.55
320	75.01	25.56
330	76.05	25.45
340	77.1	25.53
350	78.09	25.55
360	79.1	25.55
370	80.03	25.61
380	81.99	25.68

Table A-24: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 30%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	25.83	24.04
20	28.18	24.22
30	30.49	24.4
40	32.71	24.54
50	34.66	24.72
60	36.26	24.8
70	37.39	25.04
80	40.59	25.12
90	43.54	25.24
100	47.3	25.42
110	48.06	25.51
120	49.64	25.59
130	52.2	25.71
140	53.59	25.78
150	54.34	25.91
160	53.38	25.91
170	56.75	26.11
180	57.26	26.21
190	57.93	26.2
200	58.25	26.27
210	59.25	26.28
220	60.55	26.35
230	61.55	26.36
240	60.75	26.48
250	61.93	26.63
260	63.96	26.61
270	65.87	26.55
280	66.01	26.53
290	67.21	26.49
300	68.99	26.5
310	69.03	26.49
320	70.93	26.51
330	71.87	26.56
340	71.81	26.49
350	72.68	26.51
360	73.79	26.46
370	74.85	26.43
380	74.94	26.45

Table A-25: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 40%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.4	23.61
20	24.31	23.62
30	24.31	23.59
40	24.73	23.57
50	24.91	23.52
60	25.24	23.51
70	25.91	23.54
80	25.94	23.51
90	26.1	23.48
100	26.31	23.49
110	26.57	23.53
120	26.8	23.54
130	27.86	23.58
140	27.03	23.62
150	27.17	23.62
160	28.18	23.62
170	28.37	23.63
180	28.36	23.61
190	28.25	23.65
200	29.1	23.62
210	29.16	23.63
220	29.09	23.63
230	29.14	23.61
240	30.16	23.65
250	30.2	23.64
260	31.24	23.65
270	31.11	23.68
280	31.59	23.68
290	32.07	23.65
300	32.24	23.68
310	32.47	23.7
320	33.66	23.72
330	33.78	23.73
340	33.81	23.74
350	34.91	23.74
360	34.99	23.73
370	35.04	23.78
380	35.87	23.78

Table A-26: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 40%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.32	23.89
20	24.56	23.9
30	24.89	23.88
40	25.13	23.88
50	25.53	23.92
60	25.76	23.94
70	25.89	23.91
80	26.1	23.91
90	26.15	23.9
100	26.95	23.88
110	27.41	23.91
120	27.58	23.92
130	27.89	23.92
140	28.57	23.91
150	28.71	23.94
160	28.85	23.92
170	29.09	23.93
180	29.86	23.94
190	29.82	23.95
200	30.09	23.93
210	30.59	23.96
220	30.93	23.96
230	31.91	23.98
240	31.98	23.97
250	31.94	23.98
260	32.97	24.01
270	32.89	24.05
280	32.97	24.06
290	33.09	24.06
300	33.61	24.03
310	33.98	23.97
320	34.02	23.99
330	34.96	23.98
340	34.03	23.95
350	35.01	23.97
360	35.89	23.99
370	36.03	24.04
380	36.97	24.02

Table A-27: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 40%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.15	23.76
20	24.84	23.8
30	25.64	23.86
40	26.22	23.87
50	26.86	23.89
60	27.37	23.94
70	27.81	23.93
80	28.17	23.96
90	28.39	23.96
100	28.59	24.04
110	28.86	24.08
120	28.97	24.09
130	29.15	24.12
140	30.29	24.13
150	30.37	24.14
160	31.53	24.16
170	31.65	24.18
180	32.67	24.22
190	33.17	24.21
200	34.73	24.26
210	35.18	24.25
220	36.89	24.3
230	37.9	24.29
240	38.96	24.29
250	39.91	24.33
260	42.02	24.35
270	41.02	24.32
280	40.93	24.3
290	43.98	24.34
300	45.14	24.34
310	44.04	24.36
320	46.02	24.39
330	47.02	24.4
340	48.15	24.4
350	49.18	24.37
360	50.15	24.37
370	51.2	24.36
380	52.18	24.37

Table A-28: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 40%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	27.02	24.04
20	28.12	24.03
30	28.34	24.09
40	30.68	24.18
50	32.41	24.25
60	33.36	24.33
70	36.41	24.41
80	38.69	24.53
90	42.02	24.58
100	45.21	24.6
110	46.68	24.59
120	49.84	24.6
130	51.06	24.74
140	53.08	24.82
150	54.74	24.78
160	56.36	24.83
170	57.98	24.92
180	59.38	24.9
190	60.67	24.88
200	61.89	24.89
210	62.98	24.94
220	64.1	25.03
230	64.85	24.9
240	65.36	24.99
250	68.04	25.03
260	68.22	25.08
270	68.53	25.08
280	68.55	25.09
290	69.13	25.11
300	69.52	25.12
310	69.04	25.09
320	69.76	25.08
330	69.49	25.11
340	69.85	25.1
350	70.29	25.07
360	70.52	25.1
370	70.37	25.11
380	70.68	25.04

Table A-29: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 40%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	25.25	24.11
20	27.01	24.25
30	30.84	24.3
40	32.48	24.35
50	36.21	30.86
60	39.07	30.92
70	43.43	31.01
80	44.55	31.21
90	45.67	31.11
100	46.88	31.11
110	47.97	31.34
120	48.99	31.29
130	49.97	31.3
140	50.93	31.31
150	51.97	31.38
160	53.02	31.44
170	54.01	31.51
180	55.12	31.49
190	56.22	31.61
200	57.11	31.64
210	58.23	31.69
220	59.21	31.65
230	60.71	31.62
240	61.02	31.78
250	61.78	31.72
260	62.03	31.64
270	62.61	31.71
280	62.66	31.76
290	63.78	31.61
300	64.12	31.77
310	64.83	31.71
320	65.21	31.75
330	65.59	31.69
340	66	31.72
350	66.47	31.69
360	68.98	31.63
370	69.78	31.76
380	70.21	31.65

Table A-30: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 40%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	28.24	24.39
20	31.68	24.5
30	34.9	24.59
40	38.73	24.66
50	40.25	24.79
60	45.55	24.88
70	51.25	25.11
80	54.21	25.22
90	56.13	25.28
100	59.09	25.39
110	61.02	25.58
120	62.9	25.77
130	63.33	25.88
140	64.34	25.91
150	64.56	25.96
160	65.56	25.99
170	66.57	26.1
180	66.54	26.15
190	66.61	26.21
200	67.45	26.2
210	66.29	26.25
220	69.72	26.28
230	71.38	26.32
240	71.02	26.32
250	73.68	26.25
260	74.55	26.25
270	75.12	26.24
280	76.87	26.23
290	78.43	26.24
300	78.1	26.22
310	78.54	26.29
320	78.78	26.4
330	78.91	26.45
340	79.63	26.36
350	79.77	26.35
360	79.84	26.35
370	80.01	26.34
380	80.08	26.35

Table A-31: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 50%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	25.39	24.53
20	25.53	24.53
30	25.89	24.57
40	26.29	24.57
50	24.86	24.62
60	25.45	24.63
70	26.05	24.67
80	26.51	24.71
90	27.11	24.77
100	27.68	24.83
110	28.21	24.94
120	28.8	24.98
130	29.45	25.01
140	30.03	25.1
150	28.11	25.18
160	28.99	25.3
170	29.45	25.4
180	30.01	25.49
190	30.56	25.59
200	31.02	25.7
210	31.65	25.84
220	31.87	25.92
230	31.98	26.02
240	32.21	26.11
250	32.23	26.22
260	32.76	26.32
270	32.99	26.47
280	33.02	26.55
290	33.01	26.59
300	33.22	26.68
310	33.77	26.85
320	34.01	26.94
330	34.45	27
340	34.87	27.04
350	35.01	27.04
360	35.23	27.06
370	35.45	27.09
380	35.66	27.14

Table A-32: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 50%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.11	23.87
20	24.44	23.9
30	24.78	23.9
40	25.13	23.9
50	25.4	23.89
60	25.65	23.92
70	25.9	23.94
80	26.67	23.97
90	27.12	23.98
100	27.99	23.98
110	28.55	23.97
120	29.01	23.99
130	29.76	24.01
140	30.11	24.03
150	30.84	24.05
160	31.15	24.05
170	31.89	24.05
180	32.1	24.06
190	32.88	24.09
200	33.12	24.1
210	33.85	24.08
220	34.12	24.09
230	34.98	24.12
240	35.67	24.1
250	36.02	24.11
260	36.88	24.12
270	37.22	24.13
280	37.91	24.14
290	38.33	24.15
300	38.95	24.13
310	39.21	24.15
320	39.89	24.18
330	40.13	24.21
340	40.91	24.24
350	41.32	24.26
360	41.87	24.26
370	42.09	24.27
380	42.04	24.26

Table A-33: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 50%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	23.88	23.98
20	23.98	23.99
30	24.47	24.03
40	24.56	24.02
50	24.67	24.05
60	24.76	24.08
70	24.87	24.19
80	25.01	24.26
90	25.11	24.24
100	25.12	24.29
110	25.83	24.36
120	26.01	24.4
130	27.02	24.43
140	28.09	24.48
150	29.1	24.5
160	30.21	24.53
170	31.12	24.53
180	32.09	24.56
190	33.07	24.56
200	34.11	24.59
210	35.16	24.56
220	36.19	24.57
230	37.21	24.53
240	38.26	24.53
250	39.29	24.54
260	40.34	24.54
270	41.53	24.51
280	42.61	24.54
290	43.67	24.51
300	44.78	24.53
310	45.89	24.59
320	46.91	24.67
330	47.96	24.66
340	48.98	24.62
350	49.65	24.59
360	50.34	24.59
370	51.01	24.58
380	51.99	24.59

Table A-34: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 50%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.98	24.03
20	26.19	24.07
30	27.36	24.17
40	28.52	24.28
50	29.45	24.36
60	30.28	24.41
70	30.99	24.48
80	31.55	24.53
90	31.99	24.58
100	32.43	24.59
110	32.78	24.64
120	33.11	24.66
130	33.37	24.7
140	33.57	24.78
150	33.7	24.8
160	33.93	24.85
170	33.99	24.87
180	34.13	24.91
190	34.23	24.93
200	34.32	24.92
210	34.39	24.95
220	34.45	24.94
230	34.51	24.95
240	34.56	24.94
250	34.66	24.95
260	34.79	24.95
270	34.86	24.94
280	34.91	24.97
290	34.92	24.98
300	34.95	25.02
310	34.94	25.08
320	34.83	25.06
330	34.89	25.14
340	34.98	25.16
350	35.02	25.23
360	35.01	25.15
370	35.01	25.09
380	35.05	25.12

Table A-35: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 50%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.98	24.03
20	26.19	24.07
30	27.36	24.17
40	28.52	24.28
50	29.45	24.36
60	30.28	24.41
70	30.99	24.48
80	31.55	24.53
90	31.99	24.58
100	32.43	24.59
110	32.78	24.64
120	33.11	24.66
130	33.37	24.7
140	33.57	24.78
150	33.7	24.8
160	33.93	24.85
170	34.72	24.87
180	35.92	24.91
190	37.12	24.93
200	38.32	24.92
210	39.52	24.95
220	40.72	24.94
230	41.92	24.95
240	43.12	24.94
250	44.32	24.95
260	45.52	24.95
270	46.72	24.94
280	47.92	24.97
290	49.12	24.98
300	50.32	25.02
310	51.52	25.08
320	52.72	25.06
330	53.92	25.14
340	55.12	25.16
350	56.32	25.23
360	57.52	25.15
370	58.72	25.09
380	59.92	25.12

Table A-36: Structure: Normal; Working Fluid: Methanol; Filling Ratio: 50%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.8	24.03
20	31.18	24.07
30	33.14	24.17
40	36.39	24.28
50	36.21	24.36
60	37.07	24.41
70	40.52	24.48
80	44.12	24.53
90	45.32	24.58
100	47.95	24.59
110	47.97	24.64
120	49.02	24.66
130	50.11	24.7
140	51.09	24.78
150	52.02	24.8
160	52.99	24.85
170	53.76	24.87
180	54.23	24.91
190	55.01	24.93
200	55.88	24.92
210	56.34	24.95
220	57.01	24.94
230	57.99	24.95
240	58.78	24.94
250	59.34	24.95
260	60.01	24.95
270	60.73	24.94
280	60.03	24.97
290	60.87	24.98
300	61	25.02
310	61.66	25.08
320	62.12	25.06
330	63.97	25.14
340	65.44	25.16
350	66.02	25.23
360	66.99	25.15
370	67.55	25.09
380	68.22	25.12

Table A-37: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 30%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	29.45	29.69
20	29.79	29.75
30	29.28	29.65
40	29.79	29.78
50	29.24	29.77
60	30.8	29.74
70	30.09	29.72
80	30.4	29.88
90	30.81	29.86
100	30.83	29.87
110	31.04	29.96
120	31.26	29.89
130	31.41	30.09
140	31.56	30.06
150	32.64	30.09
160	32.71	30.01
170	32.83	30.01
180	32.92	30.04
190	32.96	30.04
200	33.06	30.16
210	33.2	30.19
220	33.24	30.21
230	33.27	30.21
240	33.35	30.11
250	33.43	30.12
260	34.4	30.14
270	34.41	30.15
280	34.4	30.14
290	34.38	30.19
300	34.43	30.12
310	34.36	30.06
320	35.39	30.05
330	35.42	30.12
340	35.29	30.08
350	35.36	30.17
360	35.37	30.11
370	36.41	30.16
380	36.53	30.2

Table A-38: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 30%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	29.45	29.69
20	29.79	29.75
30	30.28	29.65
40	30.79	29.78
50	31.24	29.77
60	31.8	29.74
70	32.09	29.72
80	32.4	29.88
90	33.81	29.86
100	33.83	29.87
110	33.04	29.96
120	34.26	29.89
130	34.41	30.09
140	34.56	30.06
150	35.64	30.09
160	35.71	30.01
170	35.83	30.01
180	36.92	30.04
190	36.96	30.04
200	36.06	30.16
210	37.2	30.19
220	37.24	30.21
230	37.27	30.21
240	38.35	30.11
250	38.43	30.12
260	38.4	30.14
270	39.41	30.15
280	39.4	30.14
290	40.38	30.19
300	40.43	30.12
310	41.36	30.06
320	41.39	30.05
330	42.42	30.12
340	42.29	30.08
350	43.36	30.17
360	43.37	30.11
370	44.41	30.16
380	44.53	30.2

Table A-39: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 30%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.24	30.01
20	30.69	30.1
30	31.45	29.94
40	32.28	30
50	33.94	29.95
60	33.53	30.05
70	34.15	30.01
80	34.69	30.03
90	35.15	30.12
100	35.43	30.18
110	36.75	30.26
120	37.01	30.23
130	38.28	30.31
140	38.56	30.37
150	39.7	30.34
160	39.8	30.38
170	40.54	30.41
180	42.32	30.42
190	41.45	30.39
200	42.54	30.44
210	43.79	30.49
220	44.88	30.55
230	45.85	30.56
240	45.94	30.64
250	46.92	30.62
260	47.13	30.5
270	48.15	30.61
280	49.04	30.54
290	50.95	30.54
300	51.98	30.61
310	52.9	30.64
320	54.87	30.65
330	53.83	30.5
340	54.77	30.59
350	54.66	30.64
360	55.72	30.6
370	56.61	30.56
380	57.63	30.63

Table A-40: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 30%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.42	29.95
20	32.89	30.03
30	35.75	30.1
40	38.95	30.05
50	40.03	30.12
60	45.03	30.14
70	47.8	30.14
80	48.8	30.33
90	52.1	30.27
100	54.56	30.53
110	57.1	30.53
120	59.44	30.5
130	60.72	30.69
140	61.19	30.61
150	62.52	30.71
160	64.69	30.67
170	63.77	30.72
180	64.02	30.8
190	62.2	30.76
200	63.22	30.84
210	65.08	30.8
220	67.06	30.81
230	68.03	30.76
240	69.15	30.79
250	71.13	30.77
260	71.18	30.83
270	72.3	30.95
280	72.15	30.88
290	73.18	30.93
300	73.35	30.88
310	74.39	30.96
320	74.46	30.95
330	74.43	30.94
340	75.59	30.82
350	75.58	30.85
360	76.7	30.94
370	76.4	30.9
380	77.94	30.96

Table A-41: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 30%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.86	30.15
20	31.69	30.12
30	33.09	30.18
40	35.71	30.14
50	36.18	30.25
60	39.26	30.4
70	40.41	30.3
80	42.77	30.53
90	47.47	30.57
100	49.87	30.59
110	54.37	30.72
120	57.65	30.81
130	58.09	30.84
140	60.49	30.87
150	61.74	30.9
160	63.15	30.98
170	62.4	31.01
180	64.49	31.09
190	67.2	31.05
200	68.08	31.16
210	69.14	31.26
220	70.29	31.14
230	70.17	31.21
240	70.56	31.27
250	71.94	31.24
260	72.52	31.36
270	73.52	31.37
280	74.48	31.34
290	75.43	31.26
300	75.47	31.35
310	76.56	31.32
320	77.37	31.32
330	78.07	31.3
340	79.13	31.34
350	80.12	31.35
360	80.25	31.33
370	81.24	31.27
380	81.16	31.31

Table A-42: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 30%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.48	30.07
20	32.66	29.97
30	35.19	30.12
40	38.73	30.07
50	40.6	30.26
60	45.28	30.36
70	48.46	30.31
80	49.01	30.46
90	52.98	30.62
100	54.19	30.8
110	58.16	30.9
120	60.1	30.98
130	63.1	31.01
140	65.1	31.07
150	66.32	31.21
160	66.84	31.4
170	66.59	31.36
180	67.17	31.37
190	67.44	31.41
200	67.73	31.46
210	68.57	31.49
220	68.69	31.52
230	68.18	31.51
240	69.75	31.59
250	70.41	31.53
260	70.67	31.64
270	71.25	31.72
280	71.79	31.68
290	72.84	31.71
300	72.03	31.8
310	73.04	31.65
320	73.14	31.64
330	74.21	31.71
340	74.19	31.7
350	75.18	31.75
360	75.31	31.8
370	76.45	31.69
380	76.33	31.8

Table A-43: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 40%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	29.52	29.26
20	29.56	29.34
30	29.8	29.44
40	29.94	29.42
50	30.22	29.45
60	30.5	29.47
70	30.64	29.47
80	30.85	29.38
90	31.03	29.61
100	31.04	29.68
110	31.18	29.66
120	32.25	29.6
130	32.36	29.62
140	32.42	29.62
150	33.48	29.7
160	33.57	29.65
170	33.59	29.66
180	34.67	29.71
190	34.64	29.69
200	34.75	29.79
210	35.71	29.74
220	35.7	29.71
230	35.72	29.84
240	36.79	29.73
250	36.78	29.78
260	36.85	29.85
270	37.86	29.84
280	37.83	29.87
290	38.91	29.74
300	38.56	29.8
310	38.9	29.8
320	39.99	29.95
330	39.92	30.06
340	40.96	29.92
350	40.96	29.92
360	41.92	29.95
370	41.98	29.99
380	42.03	29.97

Table A-44: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 40%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	29.83	29.83
20	30.21	29.73
30	30.54	29.7
40	31.02	29.73
50	31.37	29.64
60	31.8	29.95
70	32.12	29.81
80	32.38	29.74
90	32.68	29.87
100	33.81	29.84
110	33.45	29.86
120	33.28	29.93
130	34.26	30.05
140	34.35	29.91
150	35.41	29.91
160	35.56	29.69
170	36.21	29.99
180	36.71	29.84
190	37.82	30.04
200	37.87	29.98
210	38.49	30.07
220	38.98	30.05
230	39.24	30.01
240	39.01	29.93
250	40.09	30.12
260	40.11	29.91
270	41.15	30.04
280	41.13	30.15
290	42.61	30.06
300	42.43	30.16
310	43.12	30
320	43.04	29.99
330	44.11	30.02
340	44.14	30.02
350	45.01	30.23
360	45.11	30.17
370	46.06	29.9
380	46.78	30.11

Table A-45: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 40%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.64	30
20	31.19	30.15
30	31.99	30.1
40	32.81	30.13
50	33.51	30.23
60	34.25	30.13
70	34.82	30.39
80	35.24	30.36
90	35.72	30.4
100	36.12	30.5
110	36.37	30.32
120	36.83	30.54
130	37.14	30.42
140	37.88	30.47
150	38.11	30.69
160	38.23	30.72
170	39.3	30.53
180	39.49	30.61
190	40.67	30.6
200	41.68	30.69
210	41.72	30.62
220	42.81	30.67
230	43.94	30.79
240	44	30.67
250	44.08	30.71
260	45.13	30.73
270	46.12	30.64
280	47.07	30.85
290	47.16	30.74
300	48.22	30.74
310	49.13	30.86
320	50.12	30.76
330	50.17	30.85
340	51.23	30.87
350	52.36	30.87
360	53.21	30.92
370	54.13	30.83
380	55.2	30.63

Table A-46: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 40%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	29.89	30.13
20	31.42	30.18
30	31.81	30.15
40	33.3	30.16
50	33.8	30.27
60	34.3	30.25
70	35.81	30.31
80	36.32	30.4
90	37.82	30.46
100	39.31	30.52
110	39.8	30.52
120	40.34	30.62
130	41.83	30.51
140	42.33	30.62
150	43.79	30.6
160	44.35	30.73
170	45.81	30.6
180	46.3	30.77
190	47.82	30.79
200	48.33	30.72
210	49.83	30.7
220	50.34	30.74
230	51.84	30.88
240	50.35	30.88
250	51.85	31.02
260	53.36	30.93
270	54.86	30.93
280	56.37	31.08
290	56.87	31.09
300	58.38	31.07
310	58.89	31.05
320	61.39	30.98
330	62.89	30.99
340	63.4	31.09
350	63.9	31.1
360	64.41	31.09
370	65.91	31.02
380	66.42	31.08

Table A-47: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 40%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.8	30.7
20	31.18	30.82
30	33.14	30.79
40	36.39	30.82
50	36.21	30.86
60	37.07	30.92
70	40.52	31.01
80	44.12	31.21
90	45.32	31.11
100	47.95	31.11
110	47.97	31.34
120	49.02	31.29
130	50.11	31.3
140	51.09	31.31
150	52.02	31.38
160	52.99	31.44
170	53.76	31.51
180	54.23	31.49
190	55.01	31.61
200	55.88	31.64
210	56.34	31.69
220	57.01	31.65
230	57.99	31.62
240	58.78	31.78
250	59.34	31.72
260	60.01	31.64
270	60.73	31.71
280	60.03	31.76
290	60.87	31.61
300	61	31.77
310	61.66	31.71
320	62.12	31.75
330	63.97	31.69
340	65.44	31.72
350	66.02	31.69
360	66.99	31.63
370	67.55	31.76
380	68.22	31.65

Table A-48: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 40%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	33.07	29.99
20	34.74	30.1
30	36.84	29.96
40	37.32	30.18
50	39.25	30.19
60	44.55	30.22
70	46.25	30.23
80	49.21	30.37
90	52.13	30.43
100	55.09	30.38
110	57.02	30.55
120	59.9	30.67
130	62.25	30.59
140	63.82	30.82
150	65.06	30.68
160	66.10	30.77
170	67.27	30.73
180	68.33	30.76
190	70.55	30.84
200	71.53	30.98
210	72.29	31.11
220	72.72	30.99
230	73.38	31.04
240	74.02	31.08
250	74.28	31.04
260	74.55	31.05
270	75.12	31.04
280	75.87	31.17
290	75.43	31.1
300	75.1	31.21
310	75.54	31.25
320	76.78	31.23
330	76.81	31.19
340	76.63	31.13
350	76.06	31.18
360	76.24	31.15
370	76.41	31.06
380	77.78	31.2

Table A-49: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 50%; Heat Input: 10W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	22.45	29.73
20	22.65	29.77
30	22.76	29.78
40	22.87	29.62
50	22.98	29.68
60	23.19	29.81
70	23.29	29.69
80	23.36	29.84
90	23.45	29.83
100	23.54	29.94
110	23.65	29.78
120	23.72	29.77
130	23.75	29.82
140	23.76	29.83
150	24.01	29.84
160	24.67	29.85
170	25.03	29.93
180	25.78	29.9
190	26.34	29.86
200	26.95	29.83
210	27.67	29.82
220	28.23	29.78
230	28.67	29.93
240	28.97	29.87
250	29.98	29.89
260	30.1	30.01
270	31.09	29.9
280	31.87	29.98
290	32.12	29.91
300	32.97	29.93
310	33.45	29.92
320	34.01	30
330	34.99	29.99
340	35.76	30.05
350	36.1	30.12
360	36.67	30.05
370	37.05	29.99
380	37.04	30.09

Table A-50: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 50%; Heat Input: 20W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	26.11	29.97
20	26.19	29.92
30	26.28	29.93
40	26.32	29.93
50	26.43	30.04
60	26.52	30
70	26.64	30.16
80	26.75	30.07
90	26.86	30.03
100	26.98	30.17
110	27.17	30.12
120	27.35	30.24
130	27.51	30.24
140	27.71	30.18
150	27.85	30.26
160	27.99	30.27
170	28.11	30.24
180	28.17	30.25
190	28.23	30.12
200	28.56	30.24
210	28.87	30.19
220	29.11	30.21
230	29.45	30.21
240	29.67	30.28
250	29.87	30.19
260	30.12	30.24
270	30.2	30.28
280	30.21	30.28
290	30.87	30.35
300	31.23	30.34
310	32.12	30.29
320	33.33	30.35
330	34.34	30.27
340	35.45	30.3
350	36.77	30.33
360	37.57	30.23
370	38.67	30.32
380	39.76	30.35

Table A-51: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 50%; Heat Input: 30W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.8	30.97
20	31.23	31.04
30	31.79	30.82
40	32.54	31.01
50	33.2	31.03
60	33.75	31.04
70	34.24	31.11
80	34.56	31.05
90	34.84	31.1
100	35.09	31.14
110	35.37	31.25
120	35.57	31.28
130	35.71	31.29
140	35.94	31.3
150	35.85	31.23
160	36.08	31.3
170	36.28	31.31
180	36.31	31.33
190	36.53	31.46
200	36.42	31.34
210	36.36	31.36
220	36.56	31.39
230	36.56	31.41
240	36.61	31.46
250	36.81	31.45
260	36.54	31.36
270	37.17	31.49
280	38.13	31.45
290	39.16	31.38
300	40.19	31.32
310	41.1	31.49
320	42.05	31.49
330	43.1	31.49
340	44.23	31.55
350	45.12	31.5
360	46.22	31.55
370	47.34	31.5
380	48.87	31.56

Table A-52: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 50%; Heat Input: 40W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.98	24.03
20	26.19	24.07
30	27.36	24.17
40	28.52	24.28
50	29.45	24.36
60	30.28	24.41
70	30.99	24.48
80	31.55	24.53
90	31.99	24.58
100	32.43	24.59
110	32.78	24.64
120	33.11	24.66
130	33.37	24.7
140	33.57	24.78
150	33.7	24.8
160	33.93	24.85
170	33.99	24.87
180	34.13	24.91
190	34.23	24.93
200	34.32	24.92
210	34.39	24.95
220	34.45	24.94
230	34.51	24.95
240	34.56	24.94
250	34.66	24.95
260	34.79	24.95
270	34.86	24.94
280	34.91	24.97
290	34.92	24.98
300	34.95	25.02
310	34.94	25.08
320	34.83	25.06
330	34.89	25.14
340	34.98	25.16
350	35.02	25.23
360	35.01	25.15
370	35.01	25.09

Table A-53: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 50%; Heat Input: 50W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	24.98	24.03
20	26.19	24.07
30	27.36	24.17
40	28.52	24.28
50	29.45	24.36
60	30.28	24.41
70	30.99	24.48
80	31.55	24.53
90	31.99	24.58
100	32.43	24.59
110	32.78	24.64
120	33.11	24.66
130	33.37	24.7
140	33.57	24.78
150	33.7	24.8
160	33.93	24.85
170	34.72	24.87
180	35.92	24.91
190	37.12	24.93
200	38.32	24.92
210	39.52	24.95
220	40.72	24.94
230	41.92	24.95
240	43.12	24.94
250	44.32	24.95
260	45.52	24.95
270	46.72	24.94
280	47.92	24.97
290	49.12	24.98
300	50.32	25.02
310	51.52	25.08
320	52.72	25.06
330	53.92	25.14
340	55.12	25.16
350	56.32	25.23
360	57.52	25.15
370	58.72	25.09
380	59.92	25.12

Table A-54: Structure: Normal; Working Fluid: Ethanol-Methanol Blend; Filling Ratio: 50%; Heat Input: 60W

Time(Sec)	$T_{evaporator}$(°C)	$T_{condenser}$(°C)
10	30.8	24.03
20	31.18	24.07
30	33.14	24.17
40	36.39	24.28
50	36.21	24.36
60	37.07	24.41
70	40.52	24.48
80	44.12	24.53
90	45.32	24.58
100	47.95	24.59
110	47.97	24.64
120	49.02	24.66
130	50.11	24.7
140	51.09	24.78
150	52.02	24.8
160	52.99	24.85
170	53.76	24.87
180	54.23	24.91
190	55.01	24.93
200	55.88	24.92
210	56.34	24.95
220	57.01	24.94
230	57.99	24.95
240	58.78	24.94
250	59.34	24.95
260	60.01	24.95
270	60.73	24.94
280	60.03	24.97
290	60.87	24.98
300	61	25.02
310	61.66	25.08
320	62.12	25.06
330	63.97	25.14
340	65.44	25.16
350	66.02	25.23
360	66.99	25.15
370	67.55	25.09
380	68.22	25.12