“EFFECT OF ALCOHOLS ON THERMAL RESISTANCE OF CLOSED LOOP PULSATING HEAT PIPE (CLPHP)’’

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ABSTRACT

The emergence of pulsed heat pipe heat transfer technology has led to exciting advances, leading the way in automated microelectronic cooling in many modern technologies. Recent advances in electronic product design and manufacturing have resulted in significant increases in heat flux densities through component miniaturization and concurrent increases in power requirements associated with increased product performance. Therefore, before the development of science, microelectronics will be more and more important for cooling devices, heat exchanges, cell cold storage, spacecraft. The PHP or pulsed heat pipe is essentially an unbalanced heat transfer device whose success depends on the constant maintenance of unbalanced conditions in the system. A pulsed heat pipe promises highly localized heat rejection options to provide the required degree of temperature uniformity for the components that need to be cooled. Thus, heat is transferred not only by latent heat transfer as in other types of heat pipes, but also through the hot wall by the cold moving liquid and vice versa. This phenomenon is the reason for the high efficiency of PHP compared to other heat pipes. The goal of this research paper is to better understand the performance of PHP through experimental investigation and get better comparison results for different parameters. A series of tests were performed on a PHP closed loop with 4 rings of copper capillary tubes with an inner diameter of 2 mm. Initially, propanol, ethanol, butanol, water was taken as the active fluids and the respective effects of the process parameters were measured. The operating conditions are heat input, fill rate. For both working fluids, the fill rates are taken separately, their measurements are (10%, 30%, 50%). This paper will initially demonstrate the influence of different parameters on a closed-loop system and hence the influence of these parameters on the basic heat transfer characteristics that alter the TIS value of the object, which is required or specific objective of the experiment. Important insights into the operational aspects of CLPHP are identified and studied for its optimal performance and variability with different working fluids. In conclusion, PHP or CLPHP will remain one of the leading technologies for heat transfer with low weight and cost.

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DECLARATION & AUTHORSHIP

This is to certify that the thesis entitled, **“EFFECT OF ALCOHOLS ON THERMAL RESISTANCE OF CLOSED LOOP PULSATING HEAT PIPE (CLPHP)”**is an outcome of the investigation carried out by the author under the supervision of **Md Sojib Kaisar**, Assistant Professor **,**Department of Mechanical Engineering, Sonargaon University (SU).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.

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Chapter 1

INTRODUCTION

1.1 Background

With the headway of modern-day society, the requirement for cutting down and minimization has improved. Whole human development now comes to a decision on excellent and beneficial devices which can be some thing however tough to bring and clean to apprehend. Regular maximum current renditions of current devices are being propelled and new plans are being manufactured. This has conveyed the prevailing society eye to eye with troubles of excessive strength dispersal and warmth thickness (manage in keeping with unit zone). Market hobby for powerful microelectronics has represented the check of heating device of improved strength stages blended with excessive warmness motions. These needs pose a simultaneous mission of coping with multiplied strength degree and fluxes [1, 2] To mild and contend with this difficulty of strength hardware, the usage of fluid vapor level extrude cooling devices, for example, the warmth channels, were supplied. In spite of the reality that the normal warmness channels (e.g. smaller than regular or miniaturized scale) are one of the proven innovations, the assembling of the complicated, scaled down wick shape/geometry of those warm temperature channels should develop into the maximum fee extreme factor. Another fundamental confinement is as a ways as possible, which occurs whilst the wick shape cannot repair a first-rate degree of fluid again to the evaporator. The shipping mechanism of this easy tool additionally poses an exceptional possibility to apprehend its complicated inner two-section thermo hydrodynamics. With a view to defeat those demanding situations scientists have notion of throbbing warmness channels (PHPs) which take a shot at the same old of wavering of the running liquid and level extrude surprise in a skinny tube. PHP is a wandering field of slender measurements with many turns crammed rather with the perfect running liquid without a wick shape. PHPs are latent two-level warmness manage devices to begin with supplied via way of means of Akachi et al [1-4]. In this application, lessened dimension channels are utilized, which can be especially laid low with the selected running liquid. The vapor plugs Fluid mass pressure into the heat pipe caused by the dissipation of the working fluid is a heat transfer mechanism that can transport large amounts of heat with very small temperature differences [5]. PHPs/OHPs were first presented by his Smyrnov in a Russian patent in 1971 and in a US patent in 2004 [3]. Akachi is next. H., in 1990 he proposed a new variant of the PHP structure [4]. d build area and this movement causes the current movement to guide the gadget operation. PHP performance depends on many components, including flow channel geometric parameters, working fluid, filling factor and number of turns, PHP design, and chamfered edges [5]. The purpose of this study is to examine the heat exchange attributes of CLPHP and evaluate some of the problems found in its implementation. In parallel, heat pipes of various configurations and designs have played an important role in many applications. Consistent with these developments is the introduction of pulsatile heat pipes in the early 1990s [4, 7-9] as a highly promising heat transfer technology, particularly suitable for thermal management in electronic devices. For example, many practical applications where heat is exchanged under conditions of pulsating reactive currents, such as the operation of today's control units that manufacture office and machine hardware used as part of metallurgy, flight, preparation, and food innovation. I have a situation. Water-driven pipeline cavitation, weight effects, and blood flow are also some of the identifiable causes of such flows. The performance of this hardware in warm construction applications is subject to pulsating current parameters. This throbbing flow and the associated heat exchange problems have been the subject of much research over the past decades. An overview of these studies, with an emphasis on turbulence initiation, velocity propagation, tube flow, and heat exchange quality including hub heat exchange upgrades and convective thermal motions, is provided in the sections below.

1.2 Block Diagram

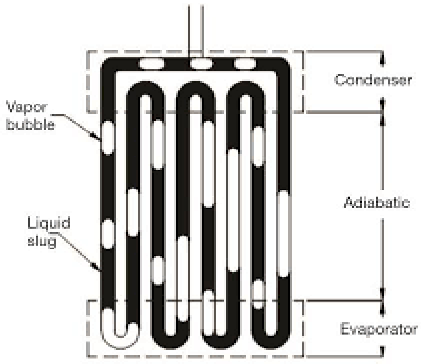


Fig 1.1: Block diagram of CLPHP

1.3 Objectives

Helps to formulate and understand the process of CLPHP, Effect of alcohol on thermal resistance, To determine the importance of working fluid inside PHP, To determine working fluid properties, To compare evaporator, adiabatic and condenser temperature distributions in different orientation sections, Propanol, Ethanol , to compare the properties of butanol and water, to compare the heat transfer coefficient of the system, to vary the fill ratio, to find the best properties from normal phase comparisons with different working fluids, ethanol, propanol and butanol using 50% fill ratio.

Chapter 2

LITERATURE REVIEW

2.1 Heat pipe.

Heat pipes are hollow metal pipes filled with a liquid coolant that moves heat by evaporating and condensing in an endless cycle. It combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two solid interfaces.

As the lower end of the Heat pipe is exposed to heat, the coolant within it starts to evaporate, absorbing heat. As the coolant turns into vapor, it, and its heat load, convection within the heat pipe. The reduced molecular density forces the vaporized coolant upwards, where it is exposed to the cold end of the Heat pipe. The coolant then condenses back into a liquid state, releasing the latent heat. Since the rate of condensation increases with increased delta temperatures between the vapor and Heat pipe surface, the gaseous coolant automatically streams towards the coldest spot within the Heat pipe. As the coolant condenses, and its molecular density increases once more, gravitational forces pull the coolant towards the lower end of the Heat pipe. To aid this coolant cycle, improve its performance, and make it less dependent on the orientation of the Heat pipe towards earth gravitational center, modern Heat pipes feature inner walls with a fine, capillary structure. The capillary surfaces within the Heat pipe break the coolants surface tension, distributing it evenly throughout the structure. As soon as coolant evaporates on one end, the coolants surface tension automatically pulls in fresh coolant from the surrounding area. As a result of the self-organizing streams of the coolant in both phases, heat is actively convection through Heat pipes throughout the entire coolant cycle, at a rate unmatched by solid Heat spreaders and Heat sinks. Heat pipes enable passive cooling solutions for high heat load and high temperature equipment, lacking moving parts and boasting extraordinary lifetimes as a result. The idea of heat pipe was given by Gaugler [6] from General Motors. However, the technology of that period presented no clear need for such a device and it lay dormant for two decades. Then it was in 1963 when a Los Alamos National Research Laboratory engineer named George Grover [6] demonstrated the first heat pipe. Heat pipe technology was borrowed from simple heat conducting pipes used by English bakers 100 years ago. Since 1963, heat pipes progressed and modern applications of this technology range from miniature heat pipes for cooling processors inside laptop computers, to groups of half inch diameter and five feet long pipes that will be used in NASA spacecraft, to pipes of two inch diameters (or more) which are used to cool injection molds used in plastic forming. The lengths of the pipes can vary from inches to 24 feet or more. Starting in the 1980s Sony began incorporating heat pipes into the cooling schemes for some of its commercial electronic products in place of both forced convection and passive finned heat sinks. Initially they were used in tuners and amplifiers, soon spreading to other high heat flux electronics applications.

2.2 Closed Loop Pulsating Heat Pipe:

Closed pulsating is a new addition to the heat pipe family. The principle difference is that CLPHP has no wick structure. This enable the working fluid to transfer heat by formation and collapse of vapor bubbles. The vapor formed at the evaporator is pushed towards the condenser in the form of discrete vapor bubbles among packets of fluid at the condenser. At the condenser the vapor gets condensed and releases the latent heat of vaporization and returns to the evaporator to complete the cycle. The entire essence of thermo-mechanical physics lies in the closed (constant volume), two- phase, and bubble–liquid slug system formed inside the tube-bundle due to the dominance of surface tension forces. These can be divided into 3 groups at least: (a) closed loop PHP (CLPHP); (b) CLPHP with check valves; (c) open loop PHP (OLPHP), also called closed end PHP (CEPHP). It is simple in structure with a coil of capillary tubes filled with certain working fluid in it and extended from the heat source to sink. Unlike a conventional heat pipe, PHP having no wick structure prevents the condensate from returning to the evaporator section. PHP works on the principle of fluid pressure oscillations created by means of differential pressure across vapor plugs from evaporator to condenser and back [7].

2.3 Operation features

A PHP is a complex heat transfer device with a strong thermo-hydraulic coupling governing its performance. It is essentially a non-equilibrium heat transfer device. The performance success of the device primarily depends on the continuous maintenance or sustenance of these non-equilibrium conditions within the system. The liquid and vapor slug transport results because of the pressure pulsations caused in the system. Since these pressure pulsations are fully thermally driven, because of the inherent constructions of the device, there is no external mechanical power source required for the fluid transport.

Consider a case when a PHP is kept isothermal throughout, say at room temperature. In this case, the liquid and vapor phases inside the device must exist in equilibrium at the saturated pressure corresponding to the fixed isothermal temperature. Referring to the pressure- enthalpy diagram, the thermodynamic state of all the liquid plugs, irrespective of their size and position, can be represented by point A. Similarly point B represents the thermodynamic state of all the vapor bubbles present in the PHP. Suppose the temperature of the entire PHP structure is now quasi-statically increased to a new constant value. Then the system will again come to a new equilibrium temperature and corresponding saturation pressure, point A“ and point B“. In doing so, there will be some evaporation mass transfer from the liquid until equilibrium is reached again. A similar phenomenon will be observed if the system is quasi-statically cooled to a new equilibrium condition A” and B” (exaggerated representation for clarity).

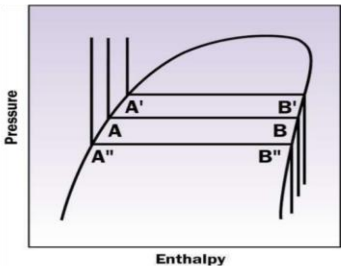


Fig 2.1: Pressure Vs Enthalpy Graph

In an actual working PHP, there exists a temperature gradient between the evaporator and the condenser section. Further, inherent perturbations are always present in real systems as a result of:

- Pressure fluctuations within the evaporator and condenser sections due to the local non uniform heat transfer always expected in real systems.
- Unsymmetrical liquid-vapor distributions causing uneven void fraction in the tubes.
- The presence of an approximately triangular or saw-tooth alternating component of pressure drop superimposed on the average pressure gradient in a capillary slug flow due to the presence of vapor bubbles.

The net effect of all these temperature gradients within the system is to cause non-equilibrium pressure condition which, as stated earlier, is the primary driving force for thermo-fluidic transport. As shown in upper figure, heating at the evaporator continuously tries to push point

2.4 Evolution of PHP

Pulsating Heat Pipes (PHPs) has been the subject of research in an increasing number of laboratories in the recent times. PHPs were presented in 1971 by Smyrnov in a Russian Patent and in 2003 in a U.S. patent. PHP in the form as they are investigated today have been first proposed by Akachi [1-4] in the 1990.

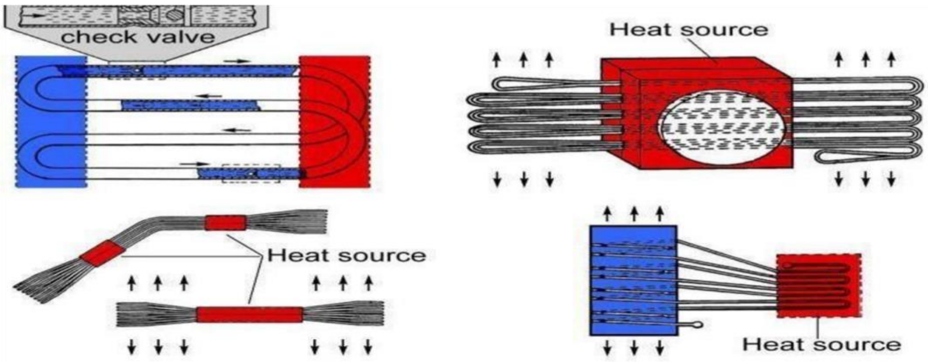


Fig 2.2: Earlier versions presented of heat pipe by Akachi

P. Charoensawan et.al [8]; has a work on effect to CLPHP thermal performance depends on various parameter like internal diameter of tube, number of turns, working fluid and inclination angle of the device and experimentally studied. The conclusion of P. Charoensawan's experimentation were, gravity has a great influence on the performance on the CLPHP, internal diameter must be specified with critical Bond number within the limit, the performance can be increased by increasing the ID and/or no. of meandering turns, the buoyancy forces effect bubble shape. Different fluids are beneficial under different operating conditions and the relative share of latent heat and sensible heat, flow behavior.

Honghai Yang et.al. [9] Presented a paper on experimental study on the operational limitation of closed loop pulsating heat pipes (CLPHPs). Investigated, viz. vertical bottom

Flux on thermal performance and performance limitation were investigated. The CLPHPs were operated till a performance limit characterized by serious evaporator overheating (dry- out) occurred. Rather high heat loads could be accommodated. An experimental study was performed on two closed loop pulsating heat pipes (CLPHPs) to investigate the effects of inner diameter, filling ratio, operational orientation and heat load on thermal performance and occurrence of performance limitation in the form of evaporator dry-out. In general, the CLPHPs obtain the best thermal performance and maximum performance limitation when they operate in the vertical bottom heat mode with 50% filling ratio. As the inner diameter decreases, performance differences due to the different heat modes (i.e. the effect of gravity) become relatively small and even insignificant. The effect of inner diameter and inclination angles on operation limit of a closed loop oscillating heat pipes with check valves (CLOHP/CV) were studied in this paper.

Copper tubes of ID 1.77 and 2.03 mm with 4 turn, with R123 was used as the working fluid. The inclination angles were 0°.

P. Meena et al. [10] were concluded that when the inner diameter changed from 1.77-2.03 mm the critical temperature increased. And when increase the inclination angles from 0 until to 90° the critical temperature increased.

S. Rittidech et.al. [11] a visualization study of the internal flow patterns of a closed–loop oscillating heat-pipe with check valves (CLOHP/CV) at normal operating condition for several evaporator lengths (Le), and ratio of check valves to number of turns (Rcv) has been conducted. This article describes the effects of varying Le, and Rcv on flow patterns. It was found that the internal flow patterns could be classified according to the Le and Rcv as follows: At the high heat source when the Le decreases the main flow changes from the bubble flow with slug flow to disperse bubble flow. The Rcv decreases the main flow changes from the disperse bubble flow with bubble flow to disperse bubble When the velocity of slug increases, the length of vapor bubbles rapidly decreases and the heat flux rapidly increases. The ratio of check valves to number of turns decreases the main flow changes from the dispersed bubble flow with bubble flow to disperse bubble flow for the high heat source.

P. Meena, et.al. [12] Has aims to study the effect of evaporator section lengths and working fluids on operational limit of closed loop oscillating heat pipes with check valves (CLOHP/CV). It is experimentally concluded when the evaporator lengths increased the critical heat transfer flux decreased. There was working fluids change from R123 to Ethanol and water the critical heat flux decreased. The latent heat of vaporization affects the critical heat flux. The working fluid with the lower latent heat of vaporization exhibits a higher critical heat flux.

Stéphane Lips Ahlem Bensalem et al. [13] various experiments were conducted on two fullsize pulsating heat pipes (PHP) which differed from their diameter, number of turns, and working fluid. The analysis of the experimental results for low heat fluxes the PHP performance is sensitive to the orientation and for high heat fluxes, it is independent from the orientation. The experiments were conducted at the scale of a single branch of a PHP. The test section was either adiabatic or heated. The adiabatic experiments brought to therefore the importance of dynamic contact angles in the flow and the dissymmetry between the

N. Panyoya et al. [14] the purpose of this research was to determine the effects of aspect r ratios (ratio of evaporator length to the inner diameter of tube) and number of meandering turns on performance limit of an inclined closed-loop oscillating heat pipe. The geometrical sizes, which were the variable parameters were the internal diameter, the evaporator section length of, the adiabatic and condenser section length of each set was equaled to the evaporator length and the numbers of meandering turn and also variable inclination angles adjusted by 10°.The result indicated that the aspect ratio, the ratio of evaporator length by internal diameter and number of meandering turns significantly affect the maximum heat flux and inclination angle. The effects of aspect ratios and number of meandering turns on maximum heat flux of an inclined CLOHP have been thoroughly investigated in this study. In the case of aspect ratio, it can be seen that, the highest maximum heat flux occurs at inclination angle about 70-90° and lower value of aspect ratio. In the case of number of meandering turns, it can be seen that, when number of meandering turns increases, number of meandering turns does not affect to the maximum heat flux. In the case of inclination angle, it can be seen that, when the inclination angle increases from 0-90°, the maximum heat flux increases with respect to increasing numbers of tubes. Moreover, the highest maximum heat flux occurs at vertical position to about 70°. P. Sakulchangsatjatai et al. [15] this research studies the effect of length ratios on heat transfer characteristic of Closed Loop Oscillating Heat Pipe with Non-Uniform Diameter (CLOHP/NUD) i.e. inner diameter of capillary tube were alternated connection and bent into several numbers of turns and both ends were connected to form of loop. It was found that, the CLOHP/NUD transferred higher heat than the conventional Closed Loop Oscillating Heat Pipe (CLOHP) with the same heat transfer area because the working fluid flowed in only one direction. Working fluid moved to condenser section in larger inner diameter and returned to evaporator section in smaller inner diameter. The heat transfer performance of CLOHP/NUD can be improved if one directional circulation of working fluid can be induced. The effects of length ratios and working fluids on the heat performance of CLOHP/NUD have been experimentally investigated and conclude heat flux increased when the length ratio decreased.

2.5 Heat Pipe Materials and Working Fluids

Heat pipes have an envelope, a wick, and a working fluid. Heat pipes are designed for very long-term operation with no maintenance, so the heat pipe wall and wick must be compatible with the working fluid. Some material/working fluids pairs that appear to be compatible are not. For example, water in an aluminum envelope will develop large amounts of non- condensable gas over a few hours or days, preventing normal operation of the heat pipe.

Since heat pipes were rediscovered by George Grover in 1963, extensive life tests have been conducted to determine compatible envelope/pairs, some going on for decades. In a heat pipe life test, heat pipes are operated for long periods of time, and monitored for problems such as non-condensable gas generation, material transport, and corrosion. The most commonly used envelope (and wick)/fluid pairs include:

- Copper envelope/Water working fluid for electronics cooling. This is by far the most common type of heat pipe.
- Copper or Steel envelope/Refrigerant R134a working fluid for energy recovery in HVAC systems
- Aluminum envelope/Ammonia working fluid for Spacecraft Thermal Control
- Super alloy envelope/Alkali Metal (Cesium, Potassium, Sodium) working fluid for high temperature heat pipes, most commonly used for calibrating primary temperature measurement devices

Other pairs include stainless steel envelopes with nitrogen, oxygen, neon, hydrogen, or helium working fluids at temperatures below 100 K, copper/methanol heat pipes for electronics cooling when the heat pipe must operate below the water range, aluminum/ethane heat pipes for spacecraft thermal control in environments when ammonia can freeze, and refractory metal envelope/lithium working fluid for high temperature (above 1050 °C) applications.

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 (Propanol, ethanol, Butanol and Water)

3. Chassis

4. Heating apparatus
    1. Power supply unit
    1. Nichrome wire
    2. Variac

5 Cooling apparatus

    1. Fan
    2.Adapter Circuit

6. Insulating apparatus

    1. Mica tape
    2.Aluminium foil
    3. Glass wool
    4. Foam tape

7.Measuring Apparatus

    1. Temperature Controller (RKC-900)
    2. Multimeter
    3. Watt meter

8. Other equipment

    1.Filler metal
    2. Electrical wire
    3.Silicon Tube

3.2 View of experimental set up

Fig 3.1 Normal Structure

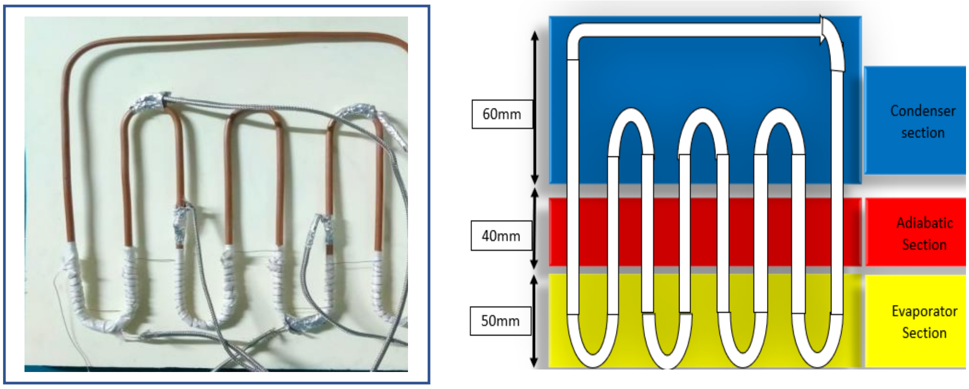


Fig 3.2: Experiment Design

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

3.3.2

Evaporator Section:

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

3.3.3 Condenser Section

It is the section of heat pipe where heat is rejected from the working fluid. In this section, the working fluid condenses & rejects little bit of less amount of heat which is absorbed from the evaporator section. In this experiment, this section is located on upper section of the heat pipe.

3.3.4 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.

Parameter	Condition
Inner diameter	2.0mm
Outer diameter	4.0mm
Total length	1480.0mm
Length of evaporator section	50mm
Length of adiabatic section	40mm
Length of condenser section	60mm
Materials	Copper

Table 3.1: Experimental Component Parameter and Dimension

3.4 Working fluid:

3.4.1 Propanol

Propanol is one of the most common types of alcohol. Propanol has the formula $CH_3CH_2CH_2OH$. Propan-1-ol, n-propyl alcohol, 1-propyl alcohol, or n-propanol are all names for this colorless oil.Some general properties of propanol are given below. Molecular Formula C_3H_8O, Molecular Weight 60.0952 g/mol , Density 6.5 lb / gal ,Boiling Point 207 °F at760 mm Hg Melting Point -195.2 °F Appearance Colorless liquid, Odor Similar to ethanol Solubility Miscible.

Figure 3.4.1 Propanol

3.4.2 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 CH_3CH_2OH or C_2H_5OH (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 viapetrochemical 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 .

Figure 3.4.2 Ethanol

3.4.3 Butanol

B2 1-Butanol is a colorless, flammable, volatile liquid with a sweet to rancid odor detectable at a threshold of about 0.8 ppm (2.5 mg/m 3) .Russian investigators have reported an odor threshold of 1.2mg/m3. Synonyms: 1-butyl alcohol, n-butanol, butyl alcohol Formula: CH3CH2CH2CH2OH CAS number:71-36-3 Molecular weight:74.1 Boiling point: 118°C,Melting point: -89°C,Specific gravity: 0.81,Vapor pressure: 6.5 mmHg at 20°C,Lower explosive limit (air): 1.4% (vol/vol),Solubility: Water solubility about 7%, miscible with organic solvents, Conversion factors: 1 ppm = 3.08 mg/m3,1 mg/m3 = 0.325 ppm .OCCURRENCE AND USE 1-Butanol is used in cosmetics, flavorings, brake fluids, degreasers, repellants, and as a solvent for many processes; it is used as an extractant in the manufacture of antibiotics, hormones, hop, vegetable oils, and vitamins (WHO, 1987; Lington and Bevan, 1994). This alcohol occurs naturally as a product of carbohydrate fermentation; therefore, it is present in alcoholic beverages, fruits, cheeses, and a variety of other foods (Brandt, 1987). Air inside mobile homes has been reported to contain 1-butanol in samples at a frequency of about 50% and at concentrations up to 0.08 mg/m3 (Connor et al., 1985). 1-Butanol has been found in about one third of the samples of air from recent space-shuttle flights at concentrations ranging from 0.01 to 1 mg/m3 (James et al., 1994). The primary source of this compound for spacecraft atmospheres is off-gassing from flight hardware; however, a small contribution (about 1 mg/d per human) might come from human metabolism.

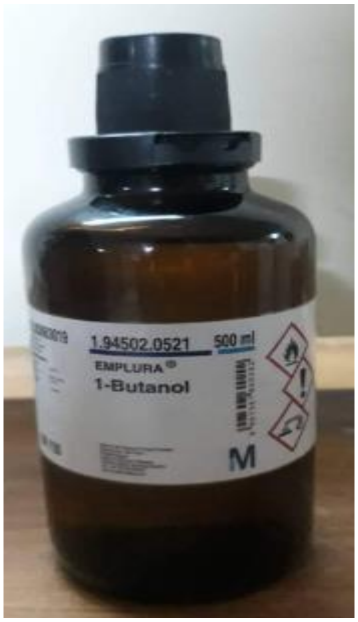


Figure 3.4.3 Butanol

3.4.4 Distilled Water

Distilled water is steam from boiling water that's been cooled and returned to its liquid state. Some people claim distilled water is the purest water you can drink. All water -- no matter if it comes from a natural spring, artesian well, or regular tap -- may have trace but safe amounts of minerals, bacteria, pesticides, and other contaminants. Distilling rids water of all those impurities. It also removes more than 99.9% of the minerals dissolved in water.

Figure 3.4.4 Distilled Water

3.5 Chassis

The test stand is a wooden structure with a PVC board that holds the heat pipe. The PVC board 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.

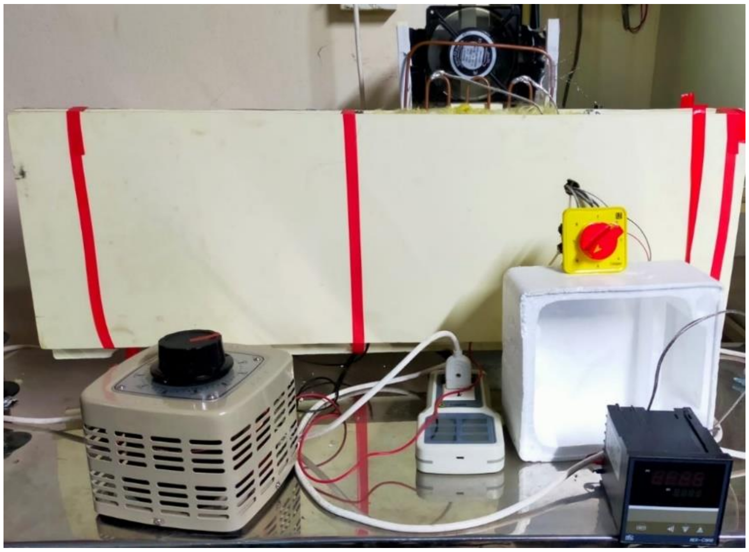


Figure3.5: Chassis

3.6 Heating Apparatus

3.6.1 Power Supply Unit

The power supply unit has the following specification:

Type: A.C

Voltage: Up to 220 volt

Frequency: 50 Hz

3.6.2 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 adaptable We 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 Ω m, Specific Heat: 450JKg-1K-1

Figure 3.6.2: Nichrome wire

3.6.3 Variable power supply

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 from20-60 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	Single
Rated capacity	1000 volt
Rated frequency	50 Hz
Input voltage	220 volt
Out put voltage	220 volt

Figure3.6.3:Variac

3.7 Cooling apparatus

3.7.1 Fan

For the cooling procedure, we utilized hub ac fan. A pivotal fan by and large, regardless of whether AC 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 extend.

Figure 3.7.1:Fan

3.8 Insulating apparatus

3.8.1 Mica Tape

The term "mica" is used for a group of minerals that show perfect cleavage. Mineralogically speaking, they are sheets of silicate. The name comes from the Latin word micare, meaning to shine, in reference to the brilliant appearance of this material.

Von Roll's commitment to mica starts with mining, followed by the very specialized field of producing paper from a mineral and finishing with the production of special mica tapes as well as mica ancillary parts. Von Roll uses two types of mica, phlogopite and muscovite, for a variety of applications and depending on the needed thermal and electrical characteristic, mainly in:

Electrical and thermal insulation of electrical machines

Thermal insulation of equipment that is subject to extremely high temperatures, such as induction ovens

Insulation of cable for fire resistance

Fig 3.8.1: Mica Tape

3.8.2 Aluminum 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.

Figure 3.8.2:Aluminium Foil

3.8.3. Glass Wool (thermal Insulation)

Glass wool is an insulating material made from fiber of glass arranged using a binder into a texture similar to wool. This was used surrounding the adiabatic section so that the heat can be kept trapped in desired section. The process traps many small pockets of air between the glass, and these small air pockets result in high thermal insulation properties. Glass wool is produced in rolls

Fig 3.8.3: Glass wool

3.8.4 Asbestos tape:

It is usually used for thermal insulation. Sticky gray tape that everyone has come to know and love got its name from its very practical function; Duct tape was intended to be used for taping various kinds of ducts, especially those used for heating. The tape keeps excess heat from escaping, making it a money-saving and useful product. Duct tape has gone on to become a trendy home product with thousands of uses. It comes in all colors, sizes, and different levels of quality. In our experiment, we used Asbestos tape of 2” width and .25” in thickness.

Fig 3.8.4: Asbestos tape:

3.9 Measuring Apparatus

3.9.1 Thermocouple controller(RKC-900)

Temperature controllers are used in any process requiring a set temperature to be maintained stable. The processes where an object is required to be heated, cooled or both and to remain at the target temperature, which is also known as the set-point, regardless of the changing environment around it. The fundamental types of temperature control are open loop and closed loop.

Fig 3.9.1: RKC-900 Thermocouple controllers

A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple produces a temperature-dependent voltage as a result of the See beck effect, and this voltage can be interpreted to measure temperature. Thermocouples are widely used as temperature sensors. Type K (chromel–alumel) is the most common general-purpose thermocouple with a sensitivity of approximately 41 µV/°C. It is inexpensive, and a wide variety of probes are available in its −200 °C to +1350 °C (−330 °F to +2460 °F) range.

3.9.2 Wattmeter

Wattmeter's measure how much electricity is being used by an electrical circuit. A typical wattmeter can measure voltage, current resistance. The wattmeter is used in various like:

- Laboratories
- Industries
- Measurements of power in distribution and transmission power.

Fig 3.9.2: Wattmeter

3.10 Other Equipment

3.10.1 Electric wire

To conduct the flow of electricity. we used electric wire of negligible diameter this wire used to connected electric equipment

Figure 3.10.1: Electric Wire

3.10.2 PVC board

PVC Polyvinyl chloride is especially used for electrical and sanitary fittings. PVC is employed because the insulation on electrical cables.

Figure 3.10.2: PVC board

3.10.3 Silicone Tube

Fig 3.10.3: Silicone Tube

3.11 Experiment procedure

To build the entire setup, the entire setup table is set up by framing the wooden base with another PVC board. Evaporator, Adiabatic and Condensing Section with nichrome wire winding • Heat pipe is installed at 90-degree angle and thermocouple is connected at desired point of heat pipe. Electrical connection is provided by variable power supply. Electrical connection with cooling fan is provided. Temperature controller is connected to take desired data reading. The experiment was carried out as working fluid ethanol, propanol, butanol, water , Three different filling ratios(10%,30%,50%) and four Turns angular orientations of the heat pipe, to determine the thermal resistance and efficiency. Several comparative graphs were plotted for all the experimental data sets in the graphical analysis chapter.

3.12 Mathematical Equations and Calculations

3.12.1 Calculation of filling Ratio

Let, V = Internal volume of the heat pipe
= 100% Fill Ratio
Length (L) = 1480mm, Diameter=2mm

,

$$\text{Now, } V = \left(\frac{\pi}{4} * D^2\right) * L$$

$$V = \left(\frac{\pi}{4} * 2^2\right) * 1480$$

$$V = 4649.56\text{mm}^3$$

$$V = 4.650\text{ml}$$

As there is no additional container for working fluid in the test setup, the total internal volume of the pipe is considered to be the maximum capacity of the system. For example, to study the heat transfer characteristics **0.465ml, 1.39ml and 2.32ml** of working fluids were used which yielded **10%, 30% and 50%** filling ratio respectively

3.12.2 Calculation of Thermal Resistance

Let, R_{th} = Thermal resistance

Q = Heat input(watt)

$\Delta t = Te - Tc$

T_e= Evaporator Temp Avg.─ ℃

T_c= Condenser Temp Avg ─

We know that,

$$R_{th}=\frac{\Delta t}{Q}$$

$$R_{th}=\frac{Te-Tc}{Q}$$

3.13 Safety measurement

The following this were considered while performing the experiment:

- During the entire experiment, all other source that can effect heat transfer process, kept off.
- The sensor (K- type thermocouple sensors) used in the experiment must be checked properly before taking temperature measurement.
- The injection of fluid has to be precise as the fill ratio has an impact on performance of heat pipe.
- Temperature readings must be taken only when that particular temperature is reached at steady state or a constant value

Chapter 4

RESULT & DISSCUSSION

4.1 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.

4.2 Effect of Filling Ratio on thermal Resistance of closed loop pulsating.

4.2.1 Working fluid Propanol & Filling ratio10%- Its seems that 15 watt point we get good performance . after its making dry out condition.

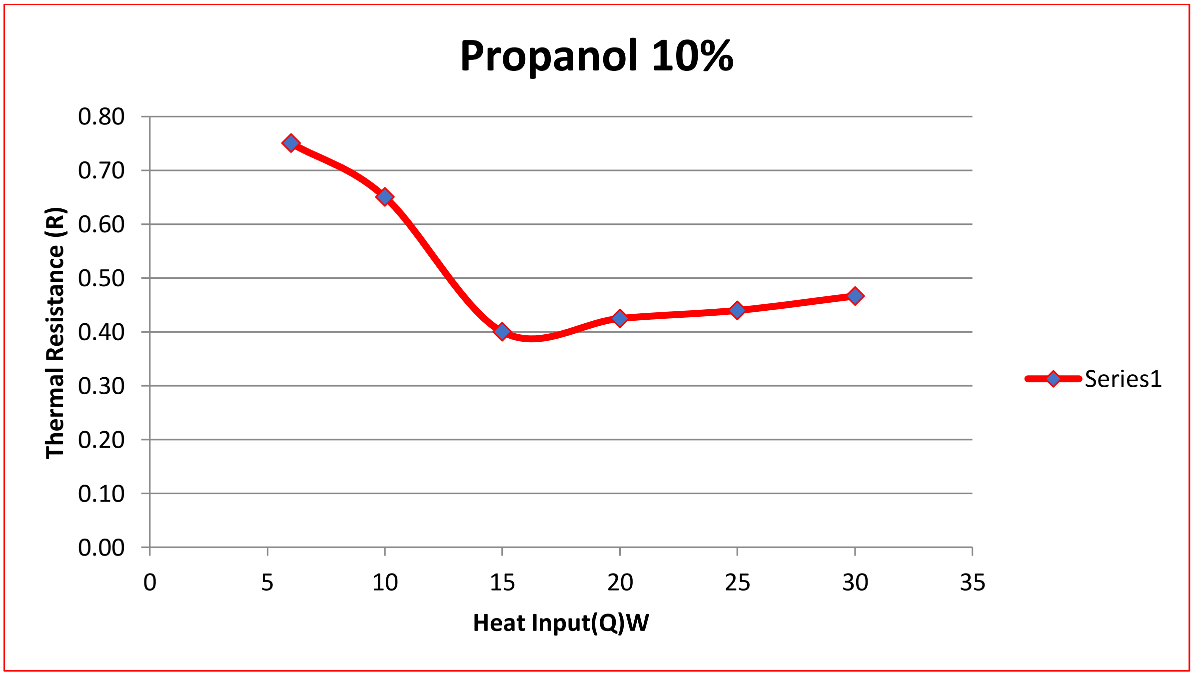


Fig 4.2.1: Effect of filling ratio Propanol 10%

4.2.2 Working fluid Propanol & Filling ratio 30%- Its seems that 15 watt point we get good performance . after its making dry out condition may be cause bubble formation.

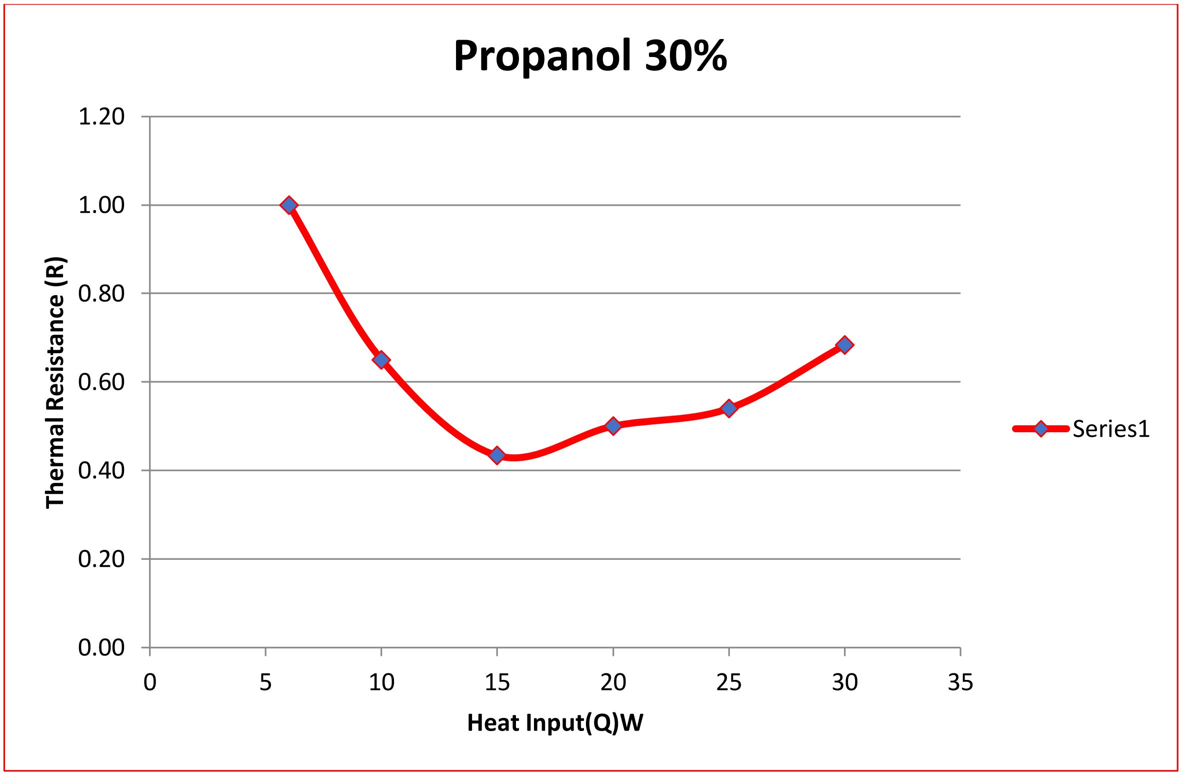


Fig 4.2.2: Effect of filling ratio Propanol 30%

4.2.3 Working fluid Propanol & Filling ratio 50%- Its seems that 15 watt point we get good performance . after its making dry out condition with steady condition.

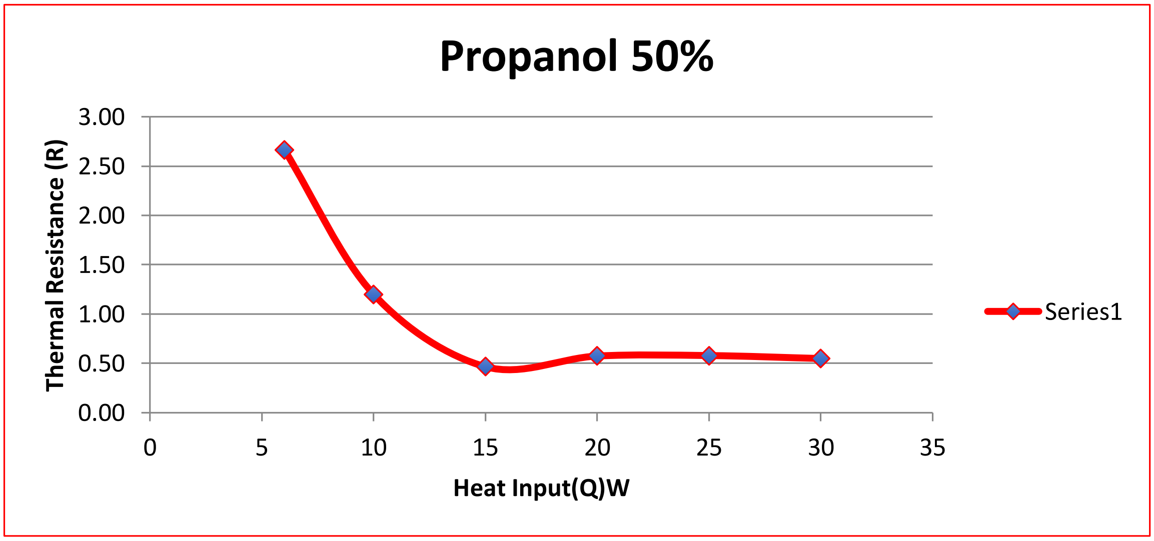


Fig 4.2.3: Effect of filling ratio Propanol50%

4.2.4 Working fluid Ethanol & Filling ratio 10%:- Its seems that 15 watt point we get good performance . after its making dry out condition

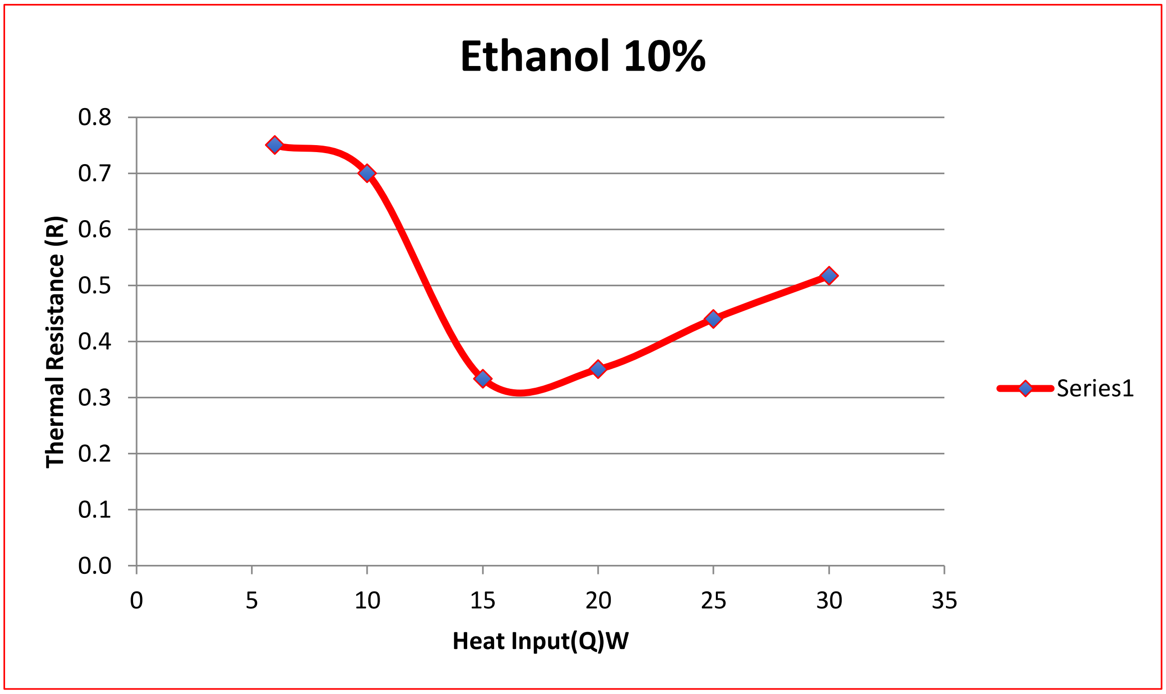


Fig 4.2.4: Effect of filling ratio Ethanol 10%

4.2.5 Working fluid Ethanol & Filling ratio 30%- Its seems that till 25 watt point we get good performance . after its making steady condition

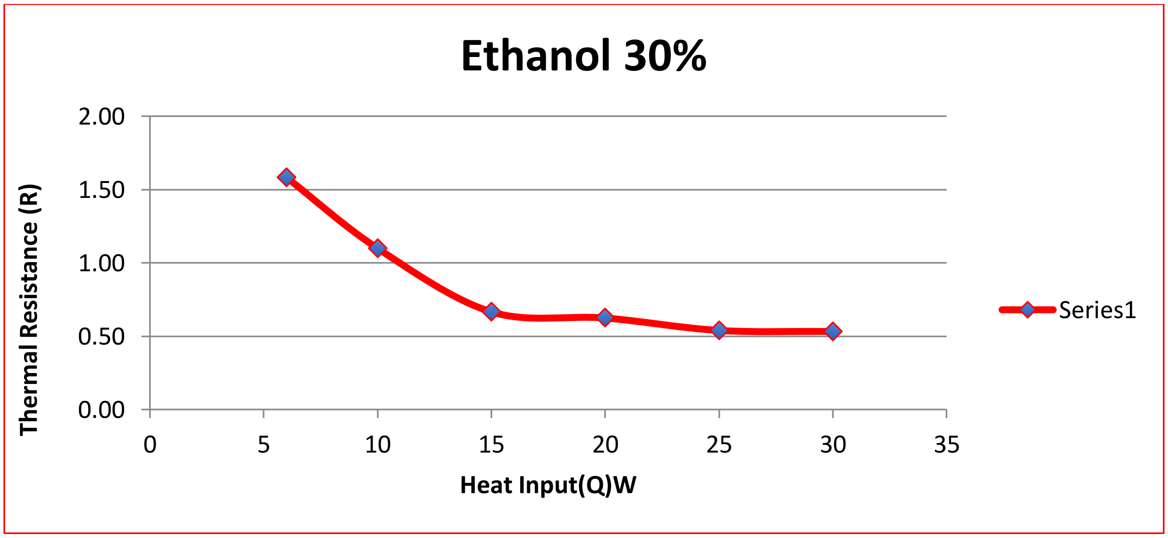


Fig 4.2.5: Effect of filling ratio Ethanol 30%

4.2.6 Working fluid Ethanol & Filling ratio 50%- Its seems that till 20 watt point we get good performance . after its making steady condition

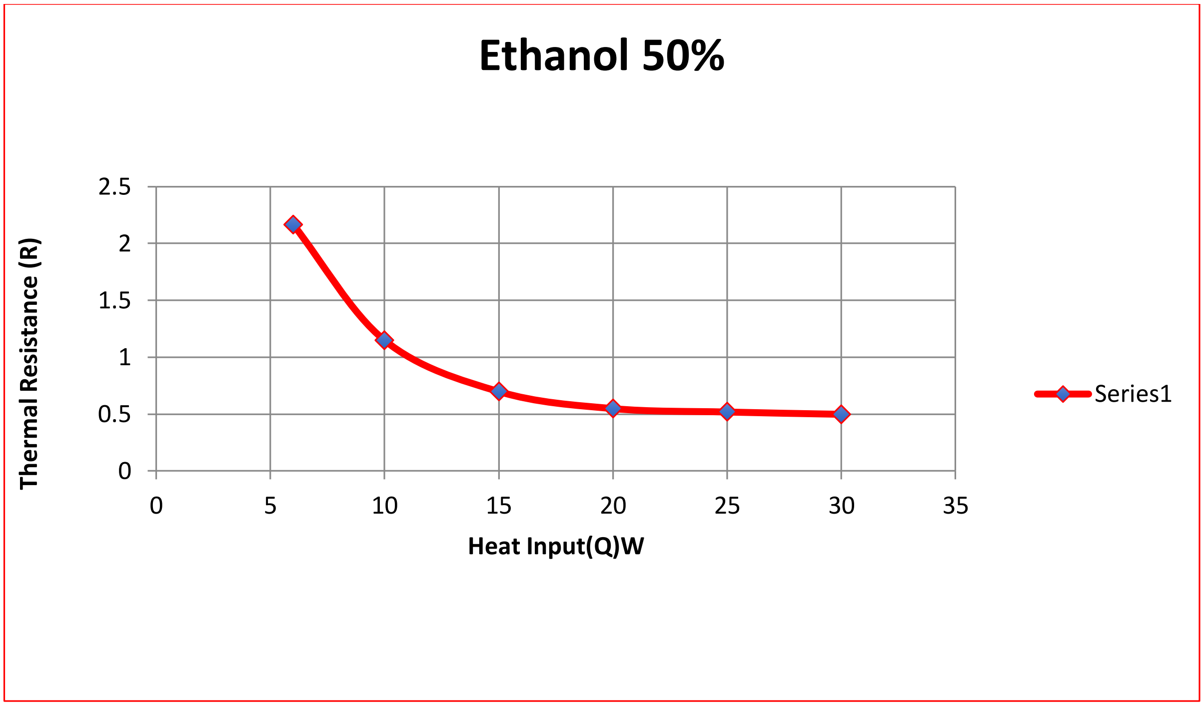


Fig 4.2.6: Effect of filling ratio Ethanol 50%

4.2.7 Working fluid Butanol & Filling ratio 10%- Its seems that 15 watt point we get good performance . Due to Bubble formation after its making dry out condition with steady condition.

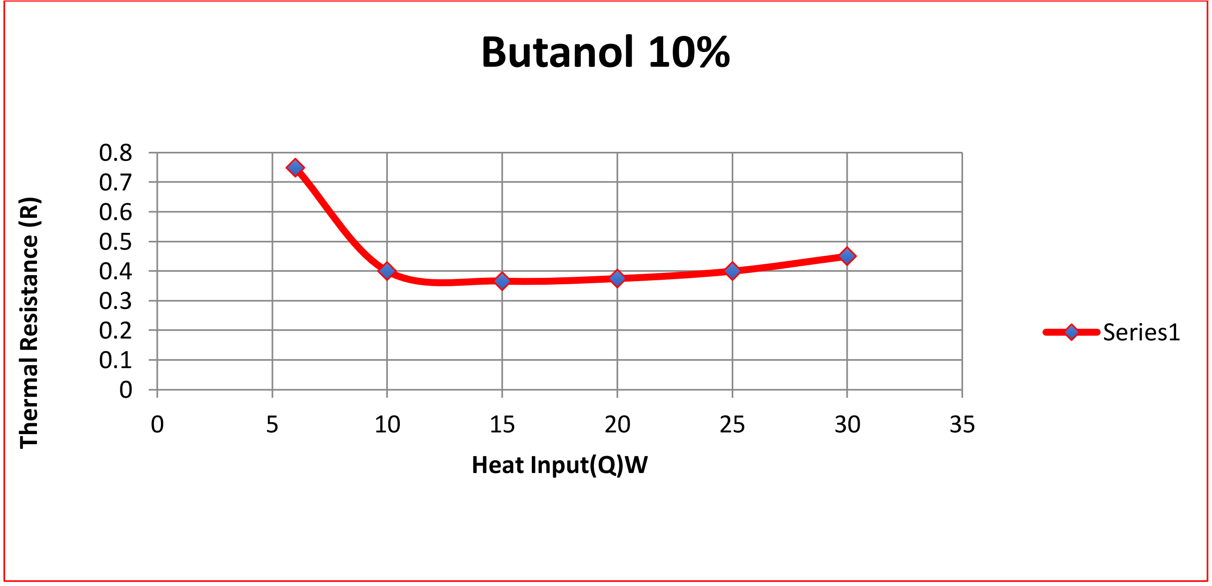


Fig 4.2.7: Effect of filling ratio Butanol 10%

4.2.8 Working fluid Butanol & Filling ratio 30%- Its seems that 15 watt point we get good performance . Due to Bubble formation after its making dry out condition .

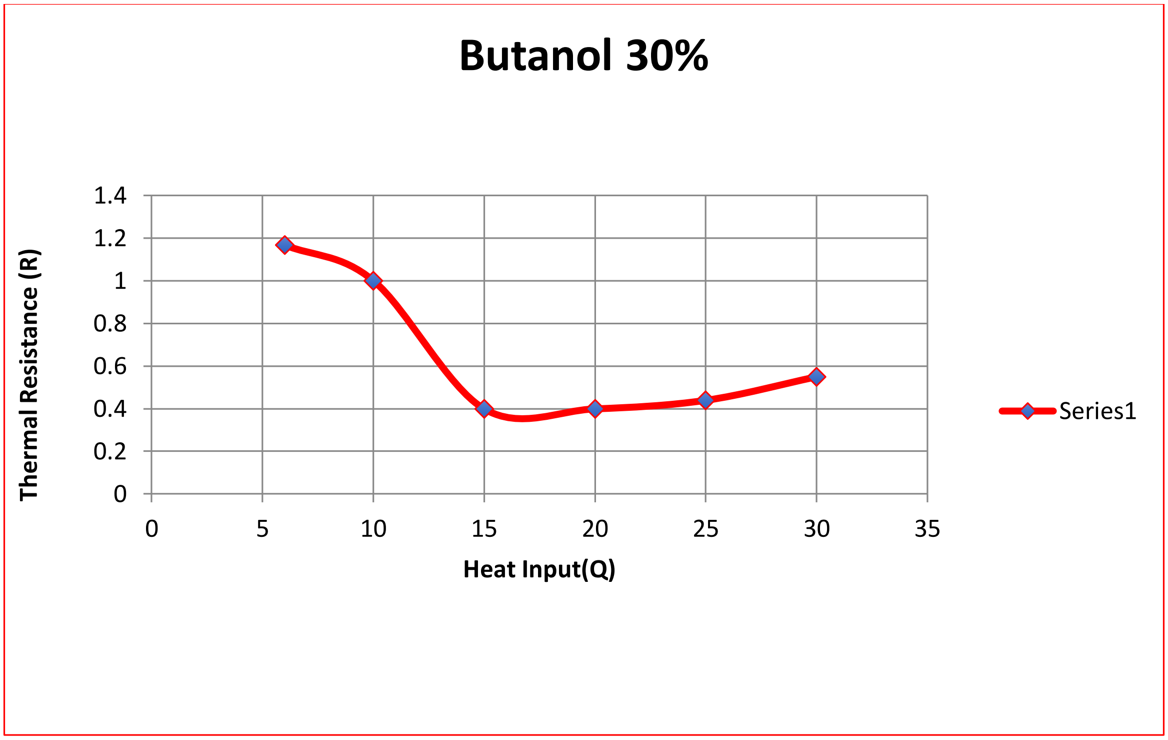


Fig 4.2.9: Effect of filling ratio Butanol 30%

4.2.9 Working fluid Butanol & Filling ratio 50%- Its seems that 15 watt point we get good performance . Due to Bubble formation after its making dry out condition.

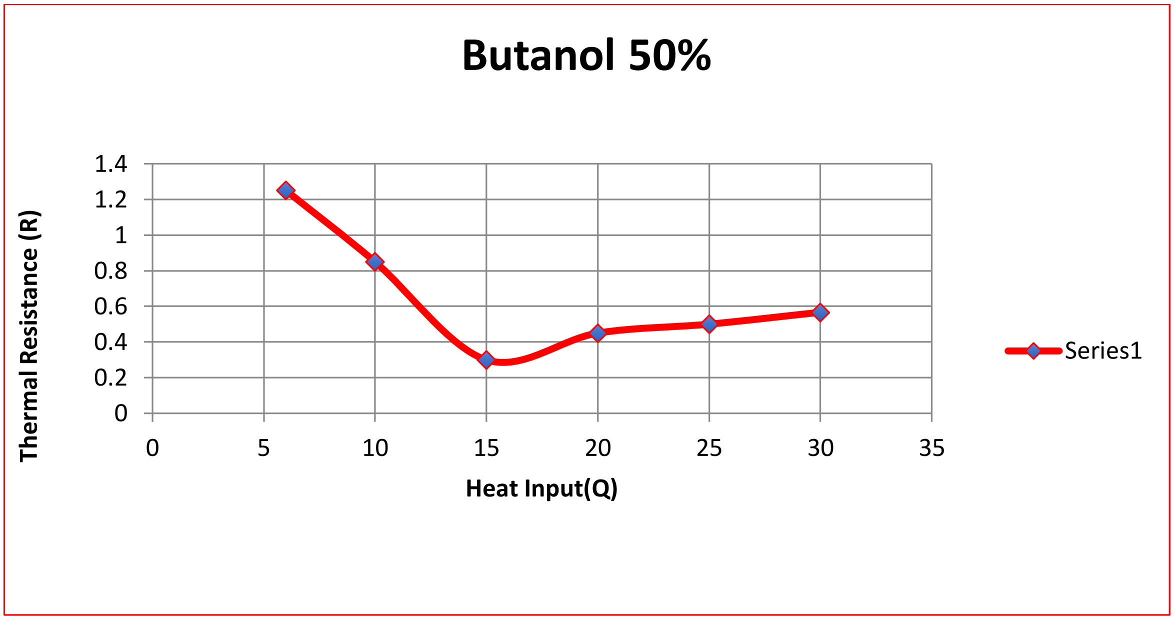


Fig 4.2.8: Effect of filling ratio Butanol 50%

4.2.10 Working fluid DI Water & Filling ratio 10% - Its seems that 15 watt point we get good performance . Due to Bubble formation after its making dry out condition.

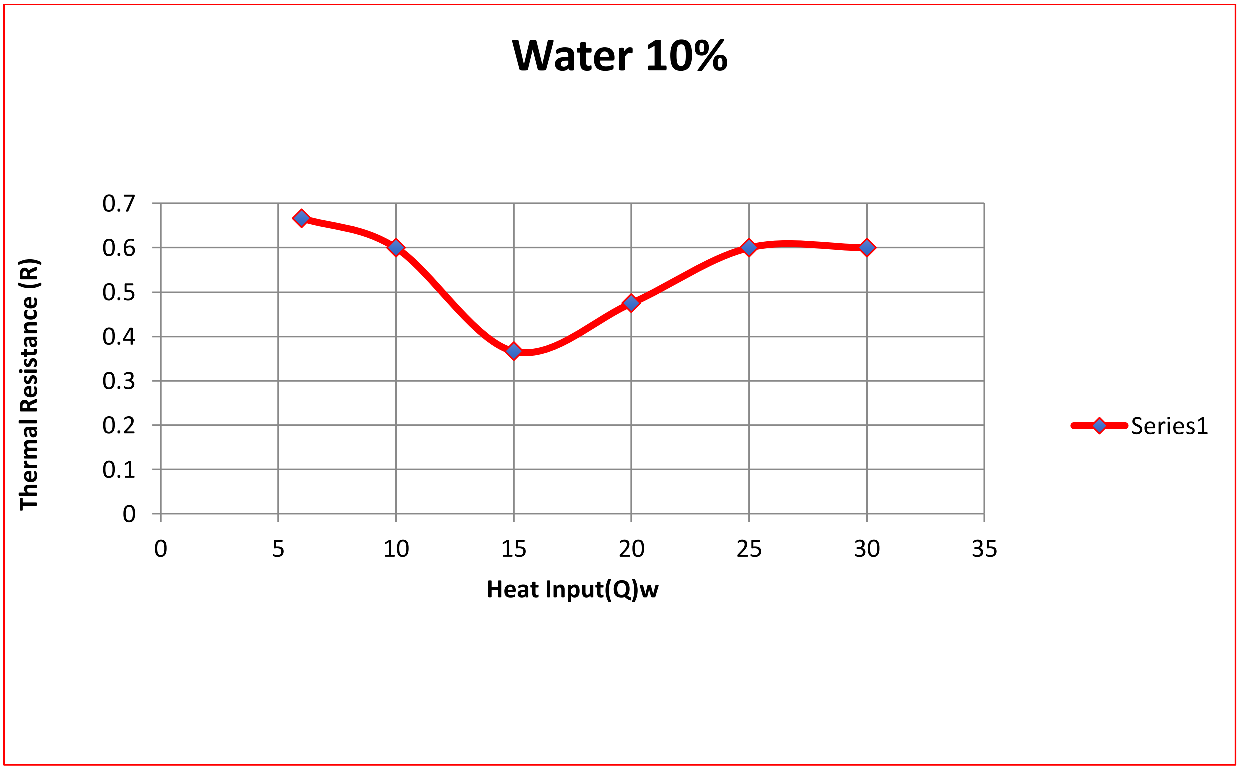


Fig 4.2.10: Effect of filling ratio Water 10%

4.2.11 Working fluid DI Water & Filling ratio 30%: - Its seems that 15 watt point we get good performance . Due to Bubble formation after its making dry out condition.

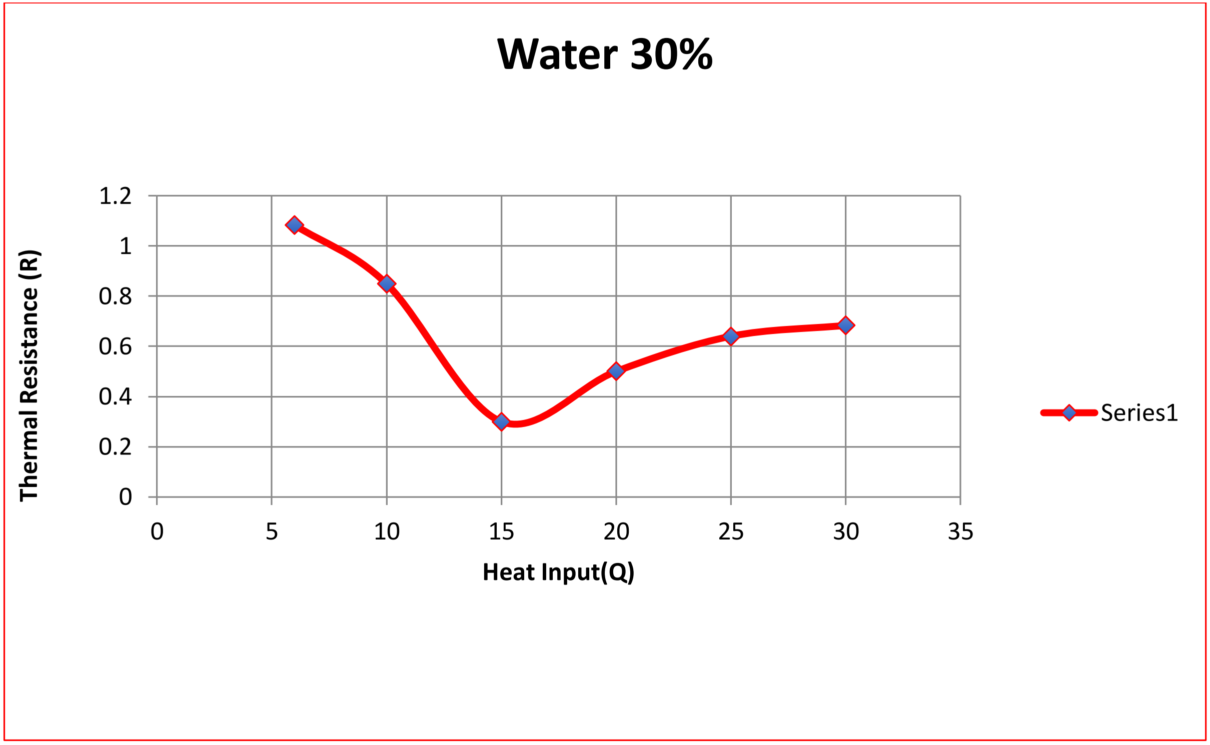


Fig 4.2.11: Effect of filling ratio Water 30%

4.2.12 Working fluid DI Water & Filling ratio 30%: - Its seems that 15 watt point we get good performance. Due to Bubble formation after its making dry out condition

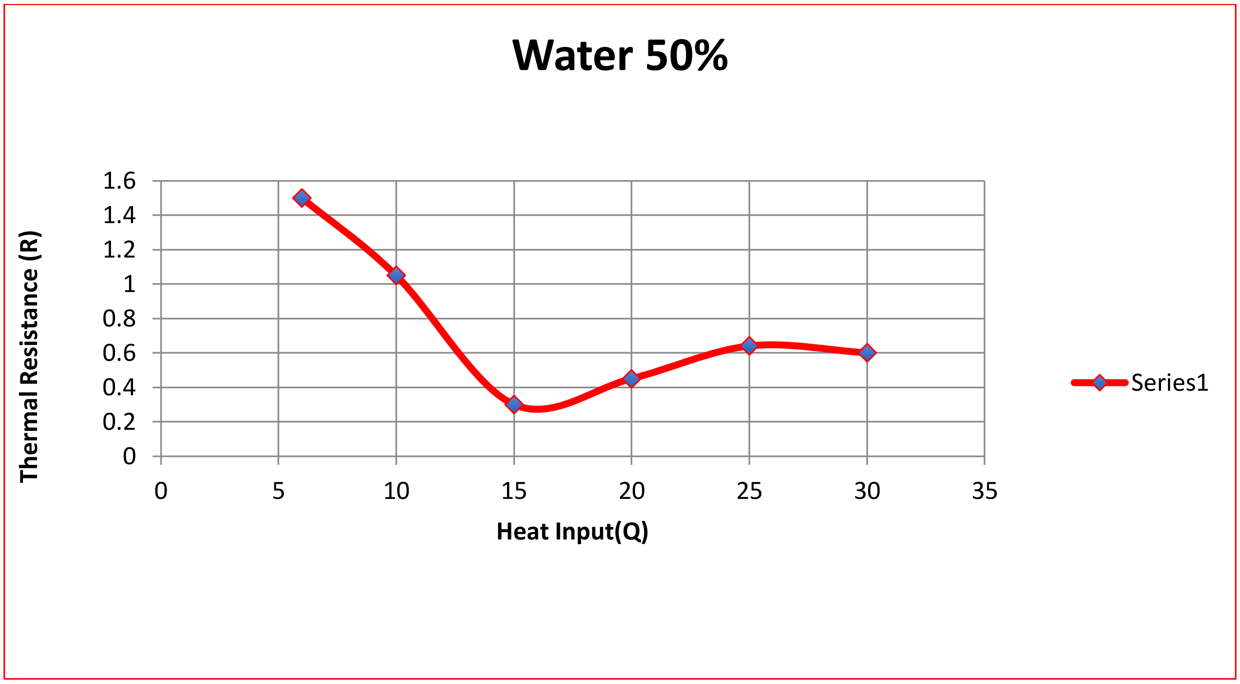
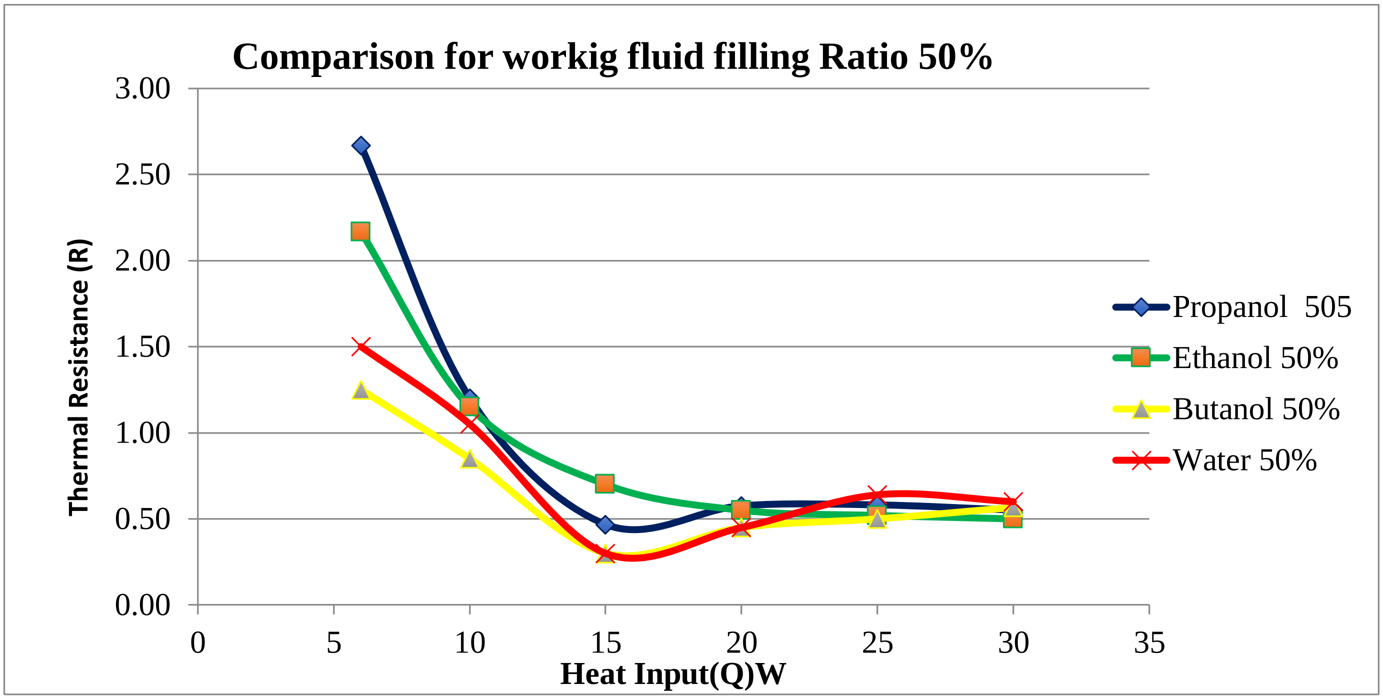


Fig 4.2.12: Effect of filling ratio Water 50%



4.2.13 Effect of 50% Filling ratio (Water, Ethanol , Butanol , Propanol) on thermal Resistance of closed loop pulsating.

During Experiment time we found that Till 15 watt with 50 % filling ration all working fluids performance very good. After 15 watt bubble formation creating or dry out condition or steady condition that time thermal resistance increasing . on 15 watt we get most efficient Thermal resistance. In this Comparison we get Q=15 watt and thermal resistance (0.3)from Butanol and water.Fig 4.2.13: Comparison for Effect of fluid filling ratio 50% (Propanol ,ethanol, water, butanol)

4.3 General findings and outcomes

Heat transfer characteristics of CLPHP are studied for ethanol, Butanol, propanol , water as working fluid using normal type of CLPHP structures. The structures used are normal CLPHP on the condenser section. Among these structures normal structures show the best performance on butanol and water. Three different filling ratio of working fluid is used for each type of structures. Filling ratios are 10%,30%,50% of the total volume of the CLPHP. The optimum filling ratio is accounted based on the heat transfer characteristics and start up characteristics. Filling ratio good performance of 50% FR for Butanol And water. Optimum filling ratio good performance at most of the cases. 50%FR and 70%FR also show close performances. The experiment is carried out for vertical angles taking vertical orientation as 0º inclination of the CLPHP. The best performance is observed at vertical condition for all cases.

The minimum starts up power required for pulsating effect to activate is about 6W. This may vary depending on the working fluid used in the CLPHP. For normal structures the minimum starts up time is observed for 50%FR. Six different parameters are considered in this work for evaluating the performance of CLPHP using for ethanol, Butanol, propanol , water as working fluid. These parameters are thermal resistance, heat transfer coefficient and minimum start up condition i.e. time and power. The performance of CLPHP is affected by the working fluid used, saturation temperature of the working fluid, wall temperature, bubble formation, buoyancy, surface tension, inside geometry, vapor pressure and transient conditions. The Thermal resistance distribution curves show almost similar pattern in all cases. The adiabatic section considered is assumed to be completely adiabatic. But in practical there is always a very little heat loss from the section which cannot be stopped. The evaporator section must be wrapped up by heat insulating materials to stop heat loss to environment while giving heat input to the CLPHP. This is very important as heat losses result in variation in the performance of the CLPHP.

4.4 Minimum Start up Conditions

Mainly three parameters are used to evaluate the performance of PHP, start-up time and power, thermal resistance and heat transfer coefficient. The startup power is the minimum power needed by the PHP to get started. When the PHP reaches the required startup condition, the oscillating motion in the PHP starts. The time required for this is minimum start up time. When the required superheat or input power meets the required condition, the stable oscillating motion can be self-sustained. The startup condition is very important for the stable oscillating motion or pulsating motion occurring in a PHP. The startup depends on many factors like the filling ratio, tube geometry, wall temperature variation, heat flux level, physical properties of working fluid, heating and cooling modes, transient heat transfer process, initial temperature, and so on.

The minimum starts up condition refers to both the minimum start up power and minimum start up time. The startup condition for normal and wire insert structures are shown for all filling ratios. As the finned normal structure and finned wire insert structure are the same as normal and wire insert structure respectively, no change in heating media, only fin is used at the condenser section so the startup curves will be more or less same. Show start up curve for normal structure and wire insert structure respectively for different filling ratio at different heat inputs. From Figs. it can be seen that at different heat inputs the temperature of evaporator increases and then becomes constant after which the device starts working in pulsating mode. This is the startup condition when the device starts working. Before the start up condition has reached, the pressure in the vapor bubble is not sufficient to drive the train of liquid plug and vapor bubble above it. After the achievement of startup condition, nucleate boiling starts in the heating section and the size of vapor bubbles grow, increasing its instant pressure and thus the pressure difference between the evaporator and the condenser section, which is the driving force for the oscillatory motion inside [16]. It is seen that for higher filling ratio the startup time is less than lower filling ratios. Again, at higher filling ratios start up power required is higher than lower filling ratios. The minimum starts up power required is about 6 W for both normal and wire insert structure. Based on the startup condition the optimum filling ratio is 50% for normal structures.

4.5 Limitations of CLPHP

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.

Chapter 5

CONCLUSION and RECOMMENDATION

5.1 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 propanol and butanol, water and at high heat input propanol is better than ethanol. Blend of ethanol and propanol did not show any fixed characteristics. At some filling ratios it shows better result than ethanol and at some ratios better than propanol. In most of the cases ethanol has slightly higher R_{th} than propanol & butanol that indicates better efficiency of performance of heat transfer, this is due to the effect of their thermos physical properties. At 10% & 30% filling ratio fluids reaches to the boiling point in very rare cases. 50% filling ratio shows better pulsating characteristics for all fluids (propanol, ethanol, butanol and water of both). All of fluid shown better R_{th} in 50% filling ratio. All of fluid perform better till 15W power supply, after 15W R_{th} perform steady , Bubble formation.

5.2Recommendations: -

The following general recommendations are made for future research directions: 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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LIST OF TABLE

Table -01: Effect of Propanol 10% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	**Propanol**			**Filling Ratio:**		**10%**		**Time**		**5 Min**
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	34	32	32	32	28	29	33	28.5	0.75
2	10	35	37	34	36	29	30	36	29.5	0.65
3	15	44	42	36	40	36	38	43	37	0.40
4	20	49	50	38	48	40	42	49.5	41	0.43
5	25	55	61	40	57	46	48	58	47	0.44
6	30	63	70	42	64	51	54	66.5	52.5	0.47

Table -02: Effect of Propanol 30% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	**Propanol**			**Filling Ratio:**		**30%**		**Time**	**5 Min**	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	34	35	33	33	28	29	34.5	28.5	1.00
2	10	35	37	32	35	29	30	36	29.5	0.65
3	15	42	45	37	41	36	38	43.5	37	0.43
4	20	51	52	38	47	41	42	51.5	41.5	0.50
5	25	58	59	40	54	43	47	58.5	45	0.54
6	30	68	78	46	45	50	55	73	52.5	0.68

Table -03: Effect of Propanol 50% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	**Propanol**			**Filling Ratio:**		**50%**		**Time**	**5 Min**	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	44	45	36	42	28	29	44.5	28.5	2.67
2	10	41	42	34	39	29	30	41.5	29.5	1.20
3	15	45	47	37	43	38	40	46	39	0.47
4	20	54	55	39	49	42	44	54.5	43	0.58
5	25	60	62	40	54	45	48	61	46.5	0.58
6	30	67	69	42	61	48	55	68	51.5	0.55

Table -04: Effect of Ethanol 10% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Ethanol			Filling Ratio:		10%		**Time**	**5 Min**	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	33	33	32	32	28	29	33	28.5	0.8
2	10	36	37	34	35	29	30	36.5	29.5	0.7
3	15	41	42	34	40	36	37	41.5	36.5	0.3
4	20	48	47	36	44	40	41	47.5	40.5	0.4
5	25	54	55	38	51	41	46	54.5	43.5	0.4
6	30	65	65	46	59	48	51	65	49.5	0.5

Table -05: Effect of Ethanol 30% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Ethanol			Filling Ratio:		30%		**Time**	**5 Min**	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	38	38	35	36	28	29	38	28.5	1.58
2	10	40	41	35	36	29	30	40.5	29.5	1.10
3	15	41	42	35	37	31	32	41.5	31.5	0.67
4	20	48	49	36	45	35	37	48.5	36	0.63
5	25	58	60	37	54	43	48	59	45.5	0.54
6	30	65	64	40	58	47	50	64.5	48.5	0.53

Table -06: Effect of Ethanol 50% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Ethanol			Filling Ratio:		50%		**Time**	**5 Min**	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	42	41	33	34	28	29	41.5	28.5	2.166666667
2	10	42	40	30	32	29	30	41	29.5	1.15
3	15	45	46	32	38	34	36	45.5	35	0.7
4	20	52	51	34	46	40	41	51.5	40.5	0.55
5	25	58	57	36	50	43	46	57.5	44.5	0.52
6	30	68	67	38	62	51	54	67.5	52.5	0.5

Table -07: Effect of Butanol 10% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Butanol			Filling Ratio:		10%		**Time**	**5 Min**	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	33	33	32	33	28	29	33	28.5	0.75
2	10	40	41	41	38	37	36	40.5	36.5	0.4
3	15	44	46	39	42	39	40	45	39.5	0.366666667
4	20	50	52	48	49	42	45	51	43.5	0.375
5	25	60	62	45	58	51	51	61	51	0.4
6	30	71	74	45	68	58	60	72.5	59	0.45

Table -08: Effect of Butanol 30% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Butanol			Filling Ratio:		30%		**Time**	**5 Min**	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	35	36	37	37	28	29	35.5	28.5	1.166666667
2	10	39	40	36	37	29	30	39.5	29.5	1
3	15	45	45	45	45	38	40	45	39	0.4
4	20	50	52	52	50	42	44	51	43	0.4
5	25	57	59	57	56	46	48	58	47	0.44
6	30	70	73	72	68	52	58	71.5	55	0.55

Table -09: Effect of Butanol 50% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Butanol			Filling Ratio:		50%		**Time**	**5 Min**	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	35	37	35	35	28	29	36	28.5	1.25
2	10	38	38	38	38	29	30	38	29.5	0.85
3	15	40	46	44	43	38	39	43	38.5	0.3
4	20	49	54	53	51	42	43	51.5	42.5	0.45
5	25	57	63	62	60	46	49	60	47.5	0.5
6	30	68	74	74	69	52	56	71	54	0.566666667

Table -10: Effect of Water 10% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Water			Filling Ratio:		10%		Time	5 Min	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	33	33	33	33	29	29	33	29	0.666666667
2	10	35	37	37	37	30	30	36	30	0.6
3	15	45	47	41	45	40	41	46	40.5	0.366666667
4	20	53	56	56	53	45	45	54.5	45	0.475
5	25	67	70	71	66	52	55	68.5	53.5	0.6
6	30	75	79	79	73	56	62	77	59	0.6

Table -11: Effect of Water 30% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Water			Filling Ratio:		30%		Time	5 Min	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	36	36	36	36	29	30	36	29.5	1.083333333
2	10	38	40	39	38	30	31	39	30.5	0.85
3	15	43	45	45	43	39	40	44	39.5	0.3
4	20	54	56	56	51	45	45	55	45	0.5
5	25	72	72	75	67	55	57	72	56	0.64
6	30	79	78	80	71	57	59	78.5	58	0.683333333

Table -12: Effect of Water 50% Filling Ratio on thermal Resistance of closed loop pulsating

Liquid:	Water			Filling Ratio:		50%		Time	5 Min	
		Eva		Adi		con				
S/N	Q(W)	T1	T4	T3	T5	T2	T6	T Eva(avg)	T Con(avg)	R
1	6	38	39	38	38	29	30	38.5	29.5	1.5
2	10	42	40	40	39	30	31	41	30.5	1.05
3	15	49	47	53	47	43	44	48	43.5	0.3
4	20	55	56	57	53	46	47	55.5	46.5	0.45
5	25	70	70	72	65	54	54	70	54	0.64
6	30	76	78	79	72	59	59	77	59	0.6