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EXPERIMENTAL ANALYSIS ON THERMOSYPHON HEATPIPE TO FIND HEAT TRANSFER COEFFICENT

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Abstract – : *To extract heat from various devices one of the method is using heat pipe. In this present paper experimental investigations are carried out to estimate the thermal performance of thermosyphon heat pipe to get maximum heat transfer coefficient at different inclinations. This experimental set up is carried with a thermosyphon heat pipe of 16 mm OD, 570 mm long with De-ionized water as working fluid. Different flow rates are given in the experimentation like 10 ml/sec, 15 ml/sec, and 20 ml/sec for different heat inputs of 155 W, 200 W, 250 W and 300Wwith different inclination as 30, 45 and 90 degrees are studied. Obtained readings are calculated and results are analyzed and compared. Graphs are drawn for 20 ml/sec for input power of 155 W, 200W, 250 W and 300 W for 30 and 45 degrees and conclusions are given based on comparisons in this paper.*

Key Words: Thermosyphon, heat pipe, heat transfer coefficient, heat flux, thermal efficiency

1. INTRODUCTION

A heat pipe is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two interfaces.

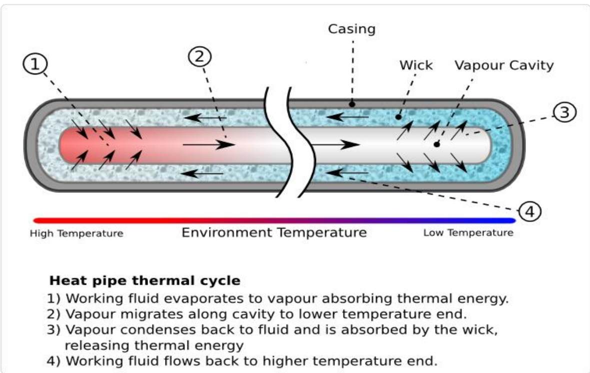

Figure 1: Heat pipe thermal cycle

A typical heat pipe consists of a sealed pipe or tube made of a material that is compatible with the working fluid such as copper for water heat pipes, or aluminium for ammonia heat pipes. Typically, a vacuum pump is used to remove the air from the empty heat pipe. The heat pipe is partially filled with a *working fluid* and then sealed. The working fluid mass is chosen so that the heat pipe contains both vapor and liquid over the operating temperature range. Below the operating temperature, the liquid is too cold and cannot vaporize into a gas. Above the operating temperature, all the liquid has turned to gas, and the environmental temperature is too high for any of the gas to condense.

At the hot interface of a heat pipe, a liquid in contact with a thermally conductive solid surface turns into a vapor by absorbing heat from that surface. The vapor then travels along the heat pipe to the cold interface and condenses back into a liquid - releasing the latent heat. The liquid then returns to the hot interface through either capillary action, centrifugal force, or gravity, and the cycle repeats. Due to the very high heat transfer coefficients for boiling and condensation, heat pipes are highly effective thermal conductors.

2. WORKING FLUID AND ITS CYCLE

Copper/water heat pipes have a copper envelope, use water as the working fluid and typically operate in the temperature range of 20 to 150 °C. Water heat pipes are sometimes filled by partially filling with water, heating until the water boils and displaces the air, and then sealed while hot. Purpose of heat pipe is to transfer heat, it must contain saturated liquid and its vapor. The saturated liquid vaporizes and travels to the condenser, where it is cooled and turned back to a saturated liquid. In a standard heat pipe, the condensed liquid is returned to the evaporator using a wick structure exerting a capillary action on the liquid phase of the working fluid. Wick structures used in heat pipes include sintered metal powder, screen, and grooved wicks, which have a series of grooves parallel to the pipe axis. When the condenser is located above the evaporator in a gravitational field, gravity can return the liquid. In this paper, the heat pipe is a thermosyphon. Finally, rotating heat pipes use centrifugal forces to return liquid from the condenser to the evaporator.

Fig -2: Heat pipes

3. THERMOSYPHON HEAT PIPE

Thermosyphon is a physical effect and refers to a method of passive heat exchange based on natural convection, which circulates a fluid without the necessity of a mechanical pump. Thermo siphoning is used for circulation of liquids and volatile gases in heating and cooling applications, such as heat pumps, water heaters, boilers and furnaces. Thermo siphoning also occurs across air temperature gradients such as those utilized in a wood fire chimney, or solar chimney. This circulation can be open loop, as when the substance in a holding tank is passed in one direction via a heated transfer tube mounted at the bottom of the tank to a distribution point-even one mounted above the originating tank or it can be vertical closed loop circuit with return to the original container. Its purpose is to simplify the transfer of liquid or gas while avoiding the cost and complexity of a conventional pump.

Convective movement of the liquid starts when liquid in the loop is heated, causing it to expand and become less dense, and thus more buoyant than the cooler liquid in the bottom of the loop. Convection moves the heated liquid upwards in the system as it is simultaneously replaced by cooler liquid returning by gravity. Ideally, the liquid flows easily because a good thermosyphon should have very little hydraulic resistance.

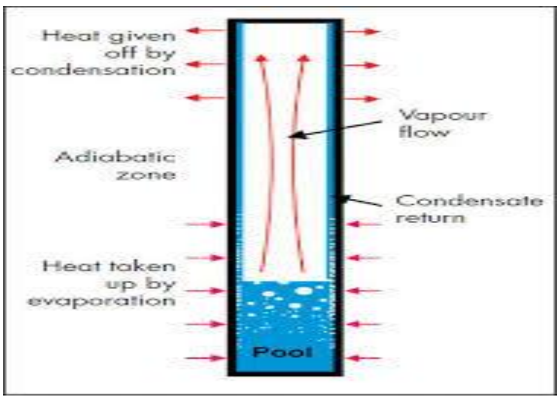

Fig-3: Thermosyphon heat pipe

4. EXPERIMENTAL ANALYSIS

The experiment is carried out to evaluate thermal performance of thermosyphon heat pipe of 5/8" OD and approximately 570 mm long using De-Ionized water as working fluid. The equipment uses a tube heater as the heat input source with a facility to apply controlled wattage through a variac. Cooling water jacket is supplied with a fractional HP water pump with a facility to circulate controlled water supply through the jacket by manipulating two valves. Inclination angle of the thermo syphon can be set by providing angle to the water jacket.

The temperatures of evaporator and condenser are sensed through J-Type thermocouples clamped at each extreme end of the heat pipe and are directly displayed on respective temperature indicators.

The main objective of this experimental study is to evaluate the efficiency, heat transfer coefficient of evaporator and condenser also the thermal resistance by varying the parameters like tilt angle (angle of inclination), flow rate of inlet water and heat inputs to the equipment.

4.1 specifications of equipment

Table -1: Specifications

Manufacturer	Capri cables private ltd.
Types of heat pipe	Thermosyphon
Material of heat pipe	Copper
Diameter	5/8" outer diameter
Length	570mm
Working fluid	De-ionized water
Water supply	HP water pump
Thermocouple	J-Type

4.2 EXPERIMENTAL PROCEDURE

- Switch 'on' the incoming power breaker to power up the temperature indicators. The temperature being sensed by the thermo couples will be displayed. If the display does not show digits check for breakages or wrong connection of thermocouples.
- Insert heat pipe condenser end(cone-shaped sealing end) into the water jacket and observes the flow control valve position .Valve 1,which is the by-pass valve to the water tank ,is normally kept in full open position and valve 2 that is connected to the water jacket normally in close position
- Measure the flow at the drain pipe of the water jacket by slowly opening valve 2 and by using water flow measurement jar. Set it to require flow rate as per the planned experiment.
- Slide the tubular heater element on to the evaporator end of the heat pipe .Position the heater such that there is about 15 mm gap available at heat pipe end for clamping the thermocouple .Support this position of heater by support bracket
- Clamp thermocouples on both ends of heat pipe

- Switch 'ON' heater supply fixed on right side of the control panel
- Heater can be now fixed to the required level of watts by varying the dial on the variac. Voltage and Amps are displayed in the voltmeter and ammeter fixed on the control panel.
- The experiment has now started and behavior of the heat pipe is noted by recording temp readings displayed in temperature indicators at desired intervals. Run the machine continuously for half an hour till the stabilization of temperature at evaporator and condenser end and record final temperature readings.
- Switch off pump and mains after the experiment is completed.
- Repeat the procedure for different parameters.

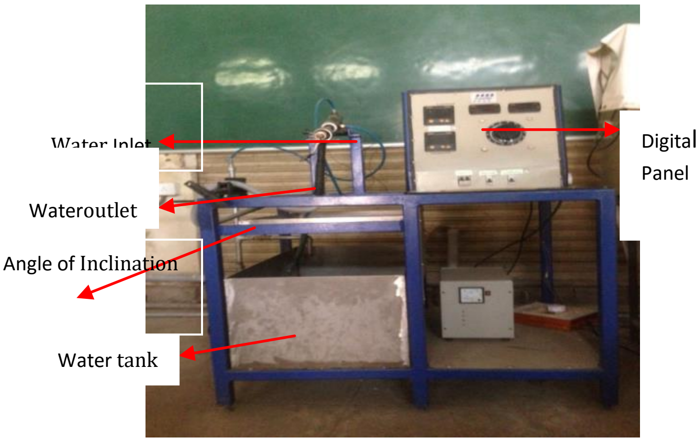

Fig- 4: Experimental set up & Layout

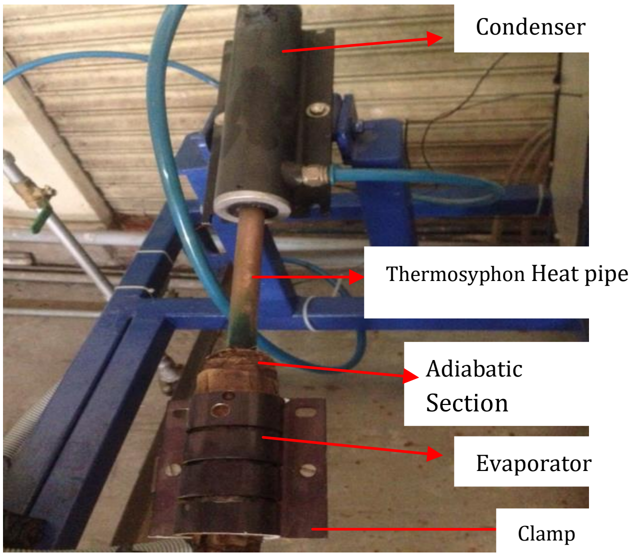

Fig-5: Thermosyphon heat pipe

5.0 PERFORMANCE PARAMETERS AND CALCULATIONS

a) Thermal efficiency (%):

Thermal efficiency of a heat pipe is the ratio of output power (Qo) to the input power (Qi). It is denoted by η_{th}

η_{th} = Qo/Qi

b) 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 (heat per time unit or thermal resistance). Thermal resistance is the reciprocal of thermal conductance. It is denoted by R_{th}.

R_{th} = (Te-Tc)/Qi K/W

c) Heat flux

Heat flux is defined as the amount of heat transferred per unit area.

It is denoted by q .

q = Q/(πdL)

here Q is heat transferred

πdL is surface area KW/m²

d) Heat transfer co-efficient:

Heat transfer coefficient is a quantitative characteristic of convective heat transfer between a fluid medium (a fluid) and the surface (wall) flowed over by the fluid.

It is denoted by **h.**

$$h = \frac{q}{\Delta T} \quad KW/m^2K$$

5.1 Experimental Readings and results

Specific heat of water = 4.186 KJ/Kg K(from data book, at 60⁰C)

Table-2: Table of readings for flow rate of 20ml/sec

Power	Inclination	Te	Tc	Tw(in)	Tw(out)
155W	30⁰C	46	28	22	23
	45⁰C	50	41	35.2	36.6
200W	30⁰C	46	29	23	24
	45⁰C	47	34	26	28
250W	30⁰C	52	33	24.5	26.5
	45⁰C	52	39	30.5	33
300W	30⁰C	54	37	31.5	33.5
	45⁰C	57	42	32	34.8

Te = evaporator temperature Tc = condenser temperature Evaporator and condenser temperatures are measured by conducting experiments at different heat inputs and at different flow rates with water as working fluid.

Table-3: Table of results at flow rate of 20 ml/sec

Power	Inclination (degrees)	Thermal efficiency (%)	Thermal Resistance (°C /W)	Heat flux-q (kw/m²)	Heat transfer coefficient-h(kw/m²k)
155W	30⁰C	53.08	0.1141	20.92	0.09125
	45⁰C	77.14	0.0592	20.16	1.061
200W	30⁰C	42.4	0.086	26.19	0.844
	45⁰C	83.6	0.0649	26.56	1.021
250W	30⁰C	66.0	0.075	33.43	1.238
	45⁰C	83.89	0.056	33.12	1.577
300W	30⁰C	57.5	0.058	38.64	1.68
	45⁰C	77.5	0.049	40.12	2.22

5.3 comparisons of results

Following graphs show the comparison of heat pipe inclination for thermal efficiency,

Heat flux, thermal resistance and heat transfer coefficient for the angles of 30^0 and 45^0

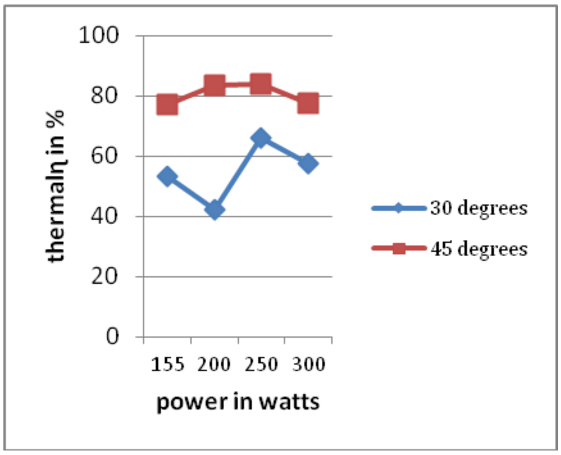

Chart-1: thermal efficiency Vs Power

Chart-1 shows thermal efficiency is higher for 45 degrees inclination for the same power as compared with 30 degrees inclination.

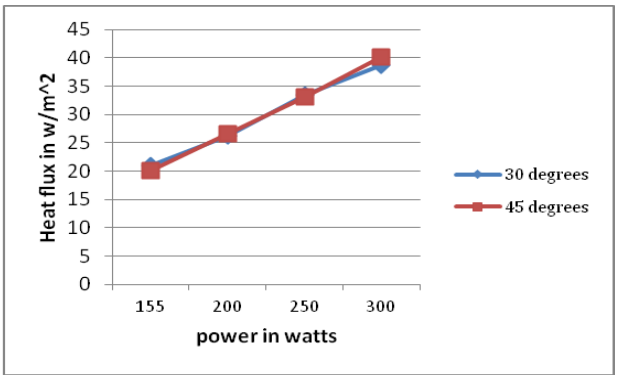

Chart-2: Heat flux Vs Power

Chart-2 shows heat flux is slightly lower at 155 W power then 30 degree inclination and it is higher for 45 degrees inclination for the same power of 300 watt as compared with 30 degrees inclination

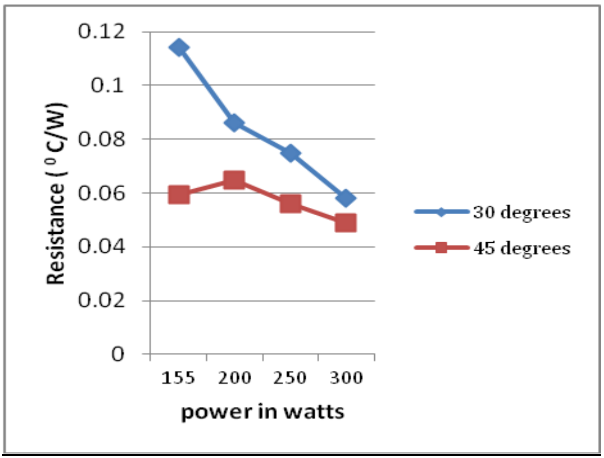

Chart-3: thermal resistance Vs Power

Chart-3 shows thermal resistance is lower for 45 degrees inclination for the same power as compared with 30 degrees inclination. It shows 45^0 inclination is more efficient

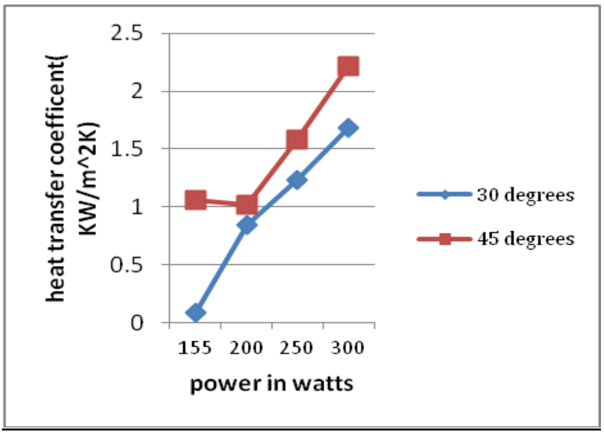

Chart-4: heat transfer coefficient Vs Power

Chart-4 shows heat transfer coefficient is higher for 45 degrees inclination for the same power as compared with 30 degrees inclination. It shows 45^0 inclination is more efficient. Because of higher heat transfer coefficient 45^0 inclination is further conducted for different flow rate and those comparisons are given as follows

Following graphs shows the experimental results for different flow rates at the inclination of 45^0 angle (water):

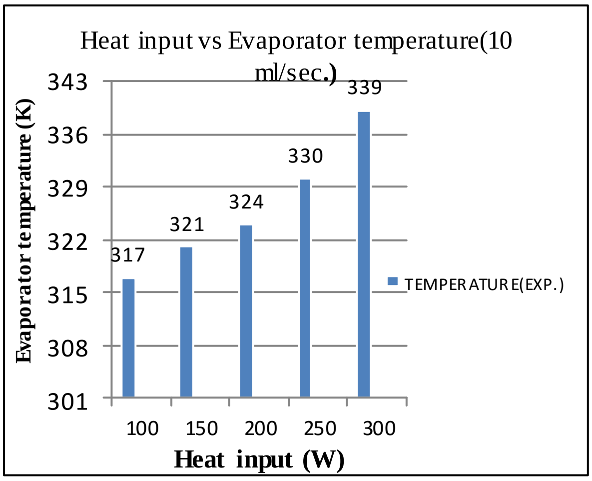

Chart- 5: evaporator temperature with heat input for a water flow rate of 10 ml/sec.

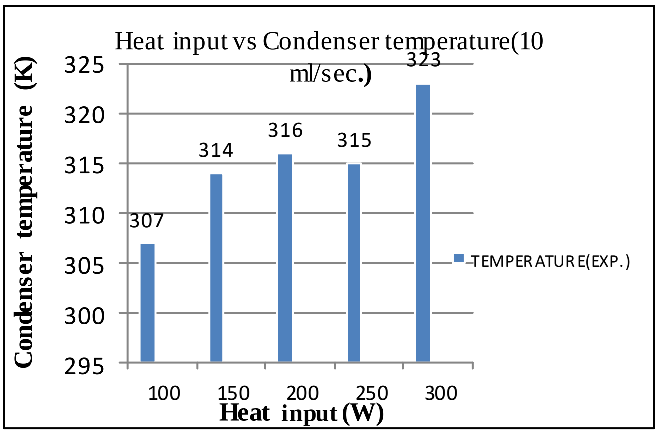

Chart- 6: condenser temperature with heat input for a water flow rate of 10 ml/sec.

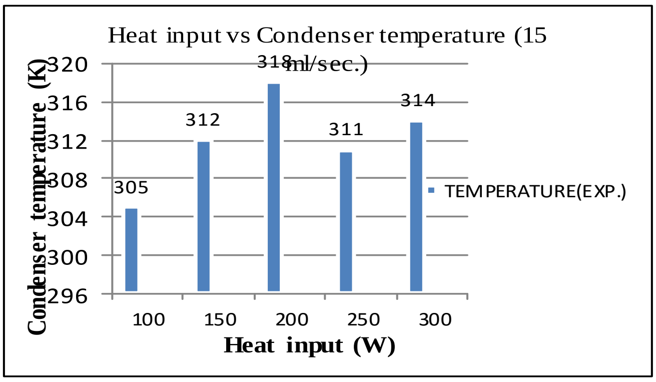

Chart- 7: condenser temperature with heat input for a water flow rate of 15 ml/sec.

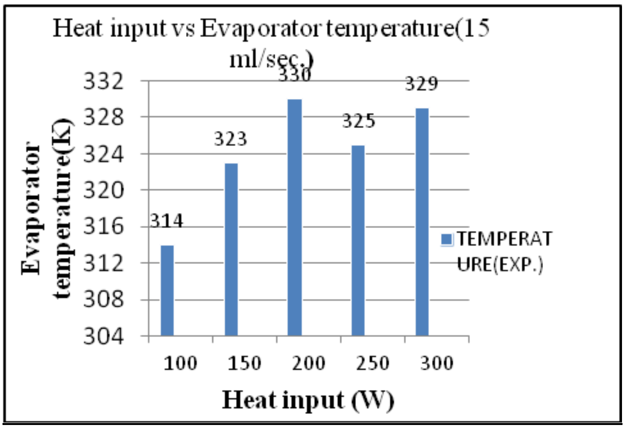

Chart -8: evaporator temperature with heat input for a water flow rate of 15 ml/sec.

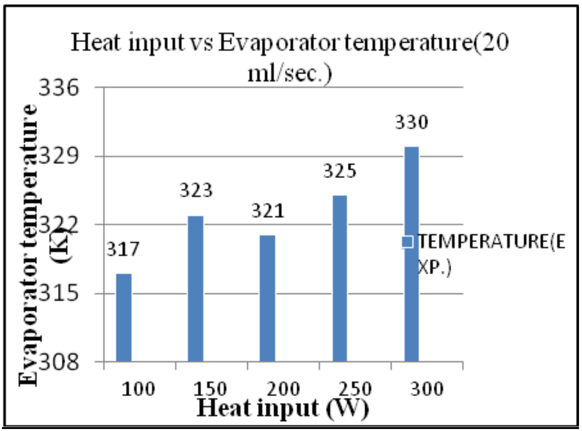

Chart- 9: evaporator temperature with heat input for a water flow rate of 20 ml/sec

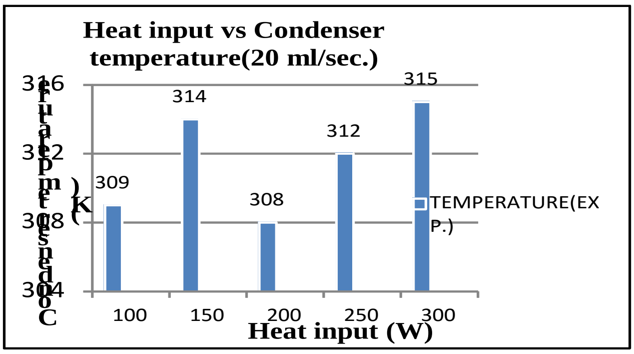

Chart-10: variation of condenser temperature with heat input for a water flow rate of 20 ml/sec

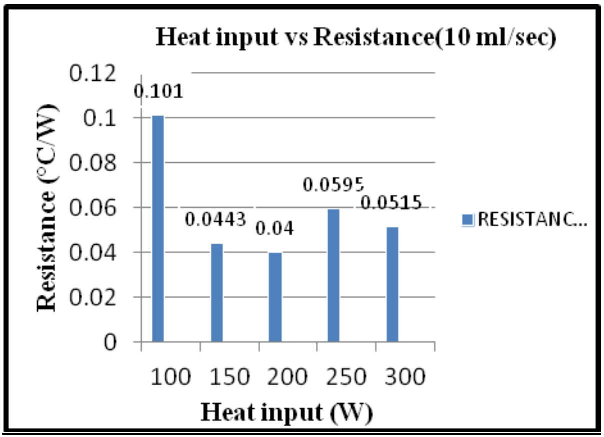

Chart- 11: variation of resistance with heat input for a water flow rate of 10 ml/sec.

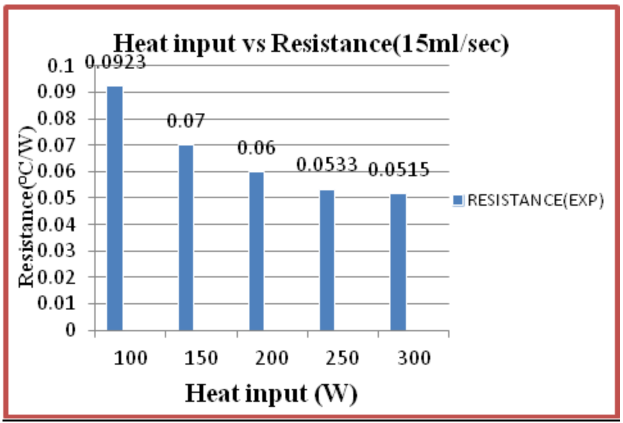

Chart-12: variation of resistance with heat input for a water flow rate of 15 ml/sec.

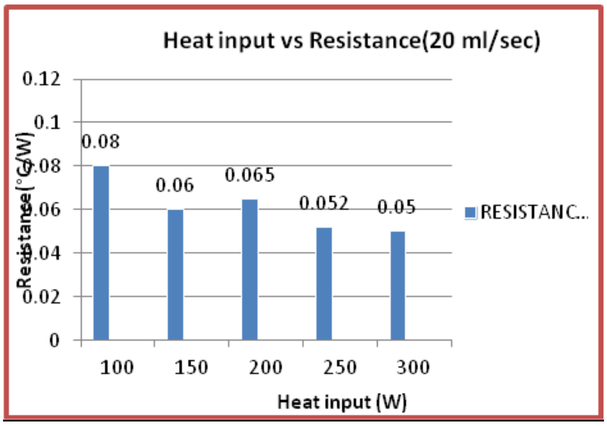

Chart-13: variation of resistance with heat input at 20 ml/sec water flow rate.

6.0 CONCLUSION:

- Experimental investigations are carried out using thermosyphon heat pipe of 16 mm OD and 570 mm long with De-ionized water as working fluid. Flow rates of cooling water over condenser section is varied as 10 ml/sec, 15 ml/sec and 20 ml/sec with different heat inputs of 150 W,200 W,250 W and 300 W at evaporator section. The maximum resistance of heat pipe is observed to be at 155 W of heat input as 0.114°C /W. thermal resistance observed with de-ionized water is decreasing with the increase of power input. Thermal efficiencies are compared for different power in put for different inclinations of heat pipe and observed thermal efficiency is more at all power inputs for inclined angle of 45^0 as compared with the inclination of 30^0. Heat transfer coefficient also compared for different power in put for different inclinations of heat pipe and observed heat transfer coefficient is increasing for all inclinations with the increase of power input but it is more for 45^0as compared with the inclination of 30^0 with increase of power input. Based on high thermal efficiency, lower thermal resistance and higher heat transfer coefficient, it is concluded as 45^0 is more efficient then other Inclinations.

7.0 FUTURE SCOPE

In the present study experimental is conducted with water and it can be studied with methanol and ethanol as working fluids at different heat inputs and different flow rates.
This investigation can be extended in the following areas:

- acetone,R134a could be used as heat pipe working fluids in place of water, methanol and ethanol.
- The same analysis can also be carried out with different inclinations like 30°,60° etc.

- Experimental and numerical investigations can also be extended to grooved heat pipe and mesh wick heat pipe for improved performance of heat pipe.

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