# Thermal performance of copper tube closed loop pulsating heat pipe using pure and binary fluids

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*Abstract* — **This paper gives preliminary experimental effects on thermal overall performance of closed loop pulsating heat pipe (PHP) the usage of copper tube having inside and exterior diameter with two mm and 3.6 mm respectively. For all experimentation, filling ratio (FR) used to be 50 %, ten turns and special warmth inputs of 10 to 100W used to be furnished to PHP. The role of the PHP used to be vertical backside warmth mode. The equal size of the section of the evaporator, adiabatic, and condenser was preserved at 50 mm. Working fluids are selected as Methanol, ethanol, acetone, water, and outstanding binary mixtures. So as to test, traits of the thermal resistance and common evaporator temperatures at unique warmness enter for a number of working fluids. Experimental find out about on PHP indicated working fluid is a necessary thing for the overall performance of PHPs. The end result indicates that, the thermal resistance decreases greater unexpectedly with the make bigger of the heating strength from 20W to 60W, whereas slowly decreases above 60W. Pure acetone offers nice thermal overall performance in comparisons with the different working fluid. No measurable distinction has been recorded between the PHP jogging with pure and binary combination working fluids.**

*Keywords* — Pulsating heat pipe, binary mixtures, heat flux, pure natural convection.

## I. INTRODUCTION

In electronic devices, there is a large necessity of miniature equipment for cooling purposes and pulsating heat pipe can be used considerably for cooling purposes. Pulsing heat pipes or oscillating heat pipes (OHPs) are relatively young members of the heat pipe family [1-3].

A typical pulsating heat pipe's basic structure consists of meandering capillary tubes which have no internal wick structure. This can be set out in at least three ways:

a) Open loop system.

b) Closed loop system and

c) Closed loop pulsating heat pipe (CLPHP) with additional flow control check valve.

The pulsing heat pipe is both smaller in scale and more effective for cooling and thermal control than traditional PHP. Pulsing heat pipe is new to the heat pipe family. It is under research all parameters affecting on performance of PHP till not optimize fully. Like working fluid get dry out after certain elevated temperature or heat input and it stop functioning. Previous experiments have demonstrated that a closed loop pulsating heat pipe is thermally more beneficial than an open loop tube because of the fluid movement potential. Although a certain number of check valves have shown performance improvement, the miniaturization of the device makes installing such valves difficult and expensive. Hence, from many realistic perspectives a closed loop system without any test valve(s) is most desirable. Studies (mostly qualitative) have already established specific architecture parameters influencing CLPHP efficiency. This report presents results of a large

experimental matrix which aims to better understand the quantitative parameter dependence of CLPHPs [4-6]

Their function is based on the operating fluid oscillation theory and the dynamics of a phase shift in a capillary drain. The tube diameter must be small enough to allow there to be liquid and vapor plugs. PHP has been regarded as one of the promising technologies for electronic cooling, heat exchanger, cell cryopreservation, spacecraft thermal control system, etc. due to its excellent features, such as good thermal efficiency, rapid response to high heat load, easy architecture and low cost. PHP was deemed one of the promising developments for electronic cooling, heat exchanger, cell cryopreservation, thermal control system for spacecraft, etc. [7-10].

## II. EXPERIMENTAL SETUP

The experimental setup of CLPHP has been developed and tested within the laboratory. PHP set-up photographs are shown in Fig. 1. Both tests are performed under controlled conditions. The configuration involves a closed loop PHP, temperature tracker, power supply panel, and condenser water tank cooling system. All the evaporation and adiabatic portions is thermally well insulated by the appropriate materials. Consisting of 10 twists, the PHP consists of a copper capillary tube with an inner diameter of 2.0 mm; the outer diameter is 3.6 mm. The width of the pitch between the tubes was held 14 mm. For each segment, the PHP consists of evaporation, adiabatics, and condensation sections with a height of 50 mm. A beautifully built power supply unit supplies the heating power. Heating was achieved by oil bath and water tank cooling. The power meter continuously tests the AC voltage, current and the associated output. The loading ratio was 50 per cent retained. The conditioning system was standard power (+900). Ten K-type thermocouples have been fastened to the PHP wall; locations are shown in Fig. 1. Flow meter also reported the cooling water mass flow rate Regarding the tube architecture, PHP's most important condition is the formation of the liquid slug.



Fig. 1. Experimental setup

## III. EXPERIMENTAL PROCEDURE

In the latest transient and steady state experiments, protocol followed is adopted:

- Before the working fluid is filled, air is pumped inside the heat pipe to ensure no fluid is present within the CLPHP.

- CLPHP is loaded with the necessary volume of working fluid using a syringe. The tests are conducted with a 50 percent filling ratio.

- The CLPHP is oil bath heated with the help of a power supply by using heater 500W

- The required amount of working fluid is then filled through a syringe by opening one end of the non-return valve such that the fluid directly enters the evaporator section.

- Now the air is filled through the filling valve provided on the brass tube using another syringe.

- The cooling water is permitted from the constant water bath to the condenser section of PHP and the amount of cooling water is controlled in such a way that the temperature rise of cooling water in the condenser is always between 10 C to 30 C.

- The data logger for temperature is then turned on to monitor the temperature readings.

- The wattage required is set using the power supply unit. The tests have been carried out in the present

research by changing the heat inputs from 10W to 20W in 10 W stages.

- Transient tests are conducted with a filling ratio of 50 percent, the various temperatures are reported using data logger. The studies continue until a stable state is achieved

- Also same time note temperatures at different locations by rotating knob on control panel for every wattage.
- Repeat same procedure for other two configurations.

## IV.    RESULT

From Fig. 2, it is obvious that thermal resistance decreases smoothly with increasing heat input power for pure and binary operating PHP fluids. With increased heat input to the system, the temperature of the evaporator increases resulting in a greater gradient of density in the tubes. The liquid viscosity therefore decreases at the same time reducing the stiffness of the surface. PHP is not adequate for retaining a stable behaviour, initially at low heat inputs up to 20W. Fluid motion is unstable throughout the beginning time, and movement is not started. The PHP 's corresponding neighboring tubes respectively become and stay hot and the reafter cold. The diffusion trajectory for the liquid is arbitrary; staying constant for a single experiment but can change for various experimental runs. The PHP is best suited for all the 30 to 80 W work fluid.

Air, ethanol, methanol, and acetone PHPs dry-out temperatures are at 100W, 80W, 60W, and 70W heat intake respectively. The thermal resistance is as shown in table 1 according to the heat supply.
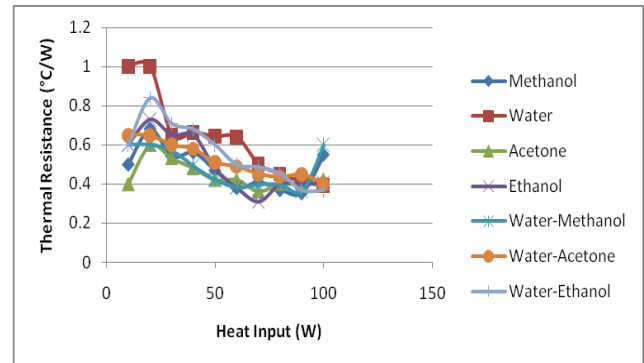


Fig. 2: Thermal resistance of all working fluid PHPs.

## V.    CONCLUSION

It is evident from the above graph that water has more thermal resistance, while pure acetone has less thermal resistance. Thus, pure acetone in this set-up provides the highest thermal efficiency in contrast with the other single and binary operating fluid mixtures. No observable difference between the PHP operating with pure and binary mixture working fluids was reported as to the overall thermal resistance. Working fluid behaviour is strongly dependent on the thermo-physical properties, but vaporization's latent heat is the main property that strongly affects thermal output.

TABLE 1

THERMAL RESISTANCE OF PURE AND BINARY FLUID

| Sr. No. | Heat Input (W) | Thermal Resistance (ºc/W) | | | | | | |
|---------|----------------|-----------|-------|---------|---------|----------------|------------------|-----------------|
| | | Methanol | Water | Acetone | Ethanol | Water-Methanol | Water-Acetone | Water-Ethanol |
| 1 | 10 | 0.5 | 1 | 0.398 | 0.6 | 0.6 | 0.65 | 0.6 |
| 2 | 20 | 0.681 | 1 | 0.6 | 0.73 | 0.6 | 0.65 | 0.842 |
| 3 | 30 | 0.542 | 0.65 | 0.532 | 0.65 | 0.57 | 0.6 | 0.71 |
| 4 | 40 | 0.562 | 0.662 | 0.48 | 0.65 | 0.49 | 0.58 | 0.681 |
| 5 | 50 | 0.47 | 0.642 | 0.42 | 0.48 | 0.421 | 0.51 | 0.6 |
| 6 | 60 | 0.381 | 0.639 | 0.42 | 0.38 | 0.382 | 0.49 | 0.498 |
| 7 | 70 | 0.41 | 0.5 | 0.36 | 0.31 | 0.396 | 0.45 | 0.486 |
| 8 | 80 | 0.371 | 0.451 | 0.4 | 0.4 | 0.396 | 0.436 | 0.452 |
| 9 | 90 | 0.355 | 0.41 | 0.395 | 0.4 | 0.363 | 0.448 | 0.366 |
| 10 | 100 | 0.55 | 0.39 | 0.42 | 0.405 | 0.6 | 0.4 | 0.368 |

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