THERMAL PERFORMANCE OF A WATER COOLED HEAT PIPE CHARGED WITH R32 AS WORKING FLUID

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ABSTRACT

This Project presents an experimental investigation on the thermal performance of a thermosyphon charged with R-32 as a working fluid. This experimental study was carried out to scrutinise the optimised fill ratio and angle of inclination for better heat transfer enhancement. The variation of heat transport capability of the thermosyphon was studied for the input heat transfer rate ranging from 0 to 250 W for various filling ratios and orientations. The various fill ratio of the refrigerant used in the analysis are 70%, 60%, 50%,and 40% and angle of inclination for carrying out orientation analysis were taken as 0°, 45° and 90°. Experimental investigations and calculations depicted that the thermal resistance of 50% fill ratio was found to be lower than that of other fill ratios thereby leading to a better thermal performance for thermosyphon charged with R-32. Further, upon further investigation for orientation analysis it was found that the horizontal inclination provided better heat transfer. Experimental results showed that the 50% fill ratio and 0° orientation analysis showed lower thermal resistance on thermosyphon. Hence this present investigation indicates that the thermal performance of a thermo syphon can be enhanced using R-32 at an optimal fill ratio of 50% and at an angle of inclination of 45 °.

INTRODUCTION

Natural convection refers to the process wherein heat, transferred to a fluid, raises its temperature and reduces its density, giving rise to buoyant forces that lift the fluid (due to density difference) and transport the absorbed heat to some other location where it can be removed. Natural convection occurs in a similar manner in two-phase systems. Here, the application of the liquid phase produces a low-density vapor that is free to rise through the liquid and condense at some other location. In either case, continuous circulation of the heat transfer fluid is maintained (Silverstein 1992).

The Perkins tube, a two-phase flow device, is attributed to Ludlow Patton Perkins in the mid nineteenth century. As shown in Figure 1-2, the Perkins tube, which was actually a single-phase,closed-loopthermosyphon, was used to transfer heat from the furnace to the evaporator of a steam boiler.

. In contrast to a heat pipe, which utilizes capillary forces for liquid return, the thermosyphon relies on gravitational or centrifugal force to return the condensed liquid to the evaporator. Heat transfer performance of the thermosyphon is a function of many factors, including properties of the working fluid, geometry and orientation of the thermosyphon, gravity field, and operating temperature or pressure. Fundamental heat transfer theory dictates that any mode of heat transfer is driven by a temperature difference and the larger the temperature difference (T_{hot} - T_{cold}), the higher the heat transfer rate. However, in many applications, it is desirable to transport large amounts of heat over a long distance, but at a relatively small temperature difference (T_{in} – T_{out}). Inside an operating thermosyphon, the vapour (at constant saturation temperature) carries a large amount of latent heat from the evaporator to the condenser.

METHODOLOGY

The wattmeter as shown in Figure 3.6 is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic watt meters are used for measurement of utility frequency and audio frequency power; other types are required for radio frequency measurements. A high frequency range and improved precision make this power meter an excellent tool.

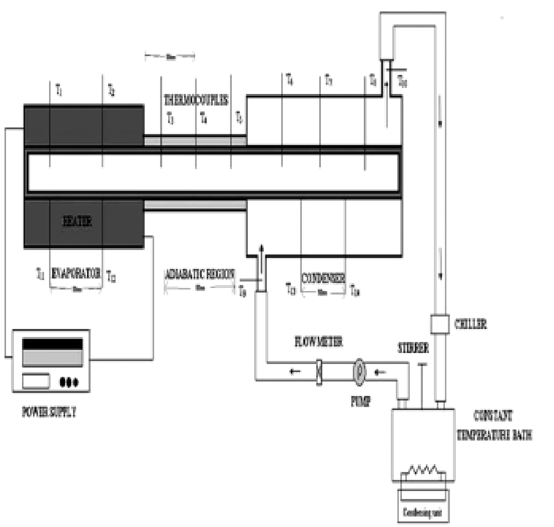
- Maximum input with assured accuracy: 26 A
- Basic accuracy: 0.1%
- DC measurement: 0.5 Hz to 100 kHz frequency range
- Compact design (half-rack size)
- 5 mA range for very low current measurements (model WT210 only)
- User calibration capability
- Large-current measurement capability using external sensor input
- Basic Characteristics
- Comparison with Former Models

CHILLING UNIT

A chiller is a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. This liquid can then be circulated through a heat exchanger (Thermosyphon) to cool air or equipment as required. As a necessary by product, refrigeration creates waste heat that must be exhausted to ambient or, for greater efficiency, recovered for heating purposes. This Chilling unit as shown in Figure 3.7 consists of water and a stirrer in an aluminum drum which is maintained at a refrigeration temperature. This water is allowed from an overhead tank. The water in the overhead tank varies from time to time because of the solar radiation. This liquid is then circulated to the thermosyphon to remove the heat from the condenser.

EXPERIMENTAL DETAILS

The setup as shown in Figure consists of a test rig upon which a two phase closed loop thermosyphon is mounted. It is a Copper coated thermosyphon. The measurements of the thermosyphon were measured to be 350 mm long, 19 mm O/D and 16 mm I/D. The variation of heat transport capability of the thermosyphon was studied for the input heat transfer rate ranging from 0 to 250W for various filling ratios and with operating temperature from 30°C to 150°C. The condenser is connected to tube which allows water from chilling unit to flow through the thermosyphon. Temperature distribution along the external surface of the thermosyphon in the evaporator, condenser and adiabatic sections were measured using software. All the thermocouples were connected to a data logger connected to a computer. The 300 mm long condenser section consisted of a insulated jacket surrounding the pipe. Coolant water and bath temperature were measured using thermocouple



FABRICATION OF THERMOSYPHON

Copper tube length and outer diameter of 350mm and 19mm respectively are taken and both the ends of the copper tube are closed with end caps of brazing. One end cap carries the filling tube. One end of the filling tube is brazed with the end cap and the other end is connected with the closing valve which is used to control the charging of the working fluid. Before brazing, proper cleaning method is followed to clean the copper enclosure. After the brazing of all articles the enclosure is leak tested with a notable amount of pressure. Then the non-condensable in the enclosure is removed by evacuating by using a diffusion pump and subsequently the thermosyphon is charged with required amount of working fluid.

After all the process is completed the heat is vacuumed to ensure all unnecessary particles are removed. Unnecessary gasses and oxides are removed in this process at a very low temperature. Later accordingly the working fluid is filled within the heat pipe for experimentation. The Keysight 34972A Data Acquisition / Data Logger Switch Unit consists of a 3-slot mainframe with a built-in 6 ½ digit DMM and 8 different switch & control modules. This product features built-in LAN and USB interfaces so you can easily connect to a PC or laptop without needing to purchase additional IO cards or converter interfaces. The intuitive graphical Web interface offers easy remote control over the network with per channel measurement configuration, data logging and data monitoring. With the 34972A, there is no computer required for field applications. Use a USB flash drive to upload data logging configurations from Bench Link Data Logger into the 34972A and to transfer large data sets back to the computer. Simply connect the USB stick to your PC when you return and easily import into a spreadsheet or other applications for data analysis.

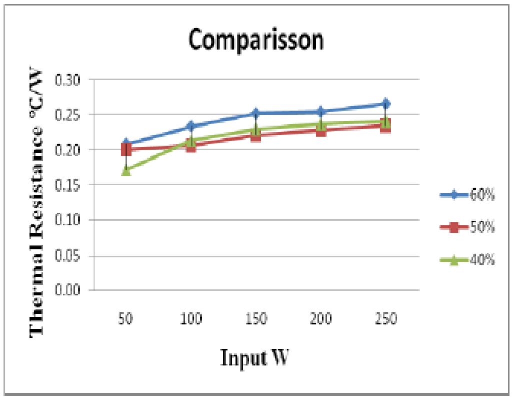
The 34972A can accept any of the 34970A plug-in modules. With a simple address change the 34972A is easily integrated into an existing test with no wiring or hardware changes.

RESULTS AND DISCUSSION

This was calculated with help of general formula $R_{thermal}$=(Te-Tc / Q) °C / w. Fig. 4.1 to 4.6 shows the effect of heat input on thermal resistance of two phase closed thermosyphon at various fill ratio namely (70% to 40%) for R-32. It is clear from the figures that the thermal resistance of two phase closed thermosyphon deteriorates when the fill ratio decreases and heat input increases. The steady state of each experimental reading was taken to be 20 minutes. This is a typical characteristic of the thermosyphon in which evaporation takes place on the surface of a liquid pool in low heat flux and nucleate boiling in a higher heat flux. Therefore thermal resistance reduces drastically with higher heat input. At lower fill ratio of thermosyphon and higher heat input, the thermal resistance is low thereby depicting the fact that there is a higher heat transfer

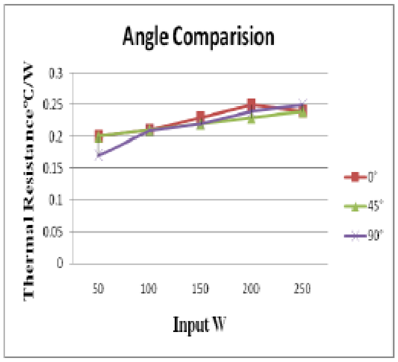
Effect of Filling Ratio on the Thermosyphon (Secondary Analysis)

From the below inference of the graph and tabulation we find that at various heat input the fill ratio of 50% gives the lowest of all thermal resistance. Therefore this shows that lower the thermal resistance, better the heat transfer transportability. In addition to this important inference, it was also found that thermal efficiency varied with that that of the heat input.



Effect of Angle of Inclination on the Thermosyphon

Considering the concept of orientation analysis, it is clear that the thermal resistance of thermosyphon reduces for increasing values of angle of inclination and higher heat input. At low heat input, the thermal resistance of the thermosyphon is high because of the relatively solid liquid film that resides in the evaporator section. When the heat load increases, these thermal resistances condense quickly to their minimum value.



The procedure is carried out in a similar fashion than that of fill ratio. The thermal resistance of heat pipe is filled with R-32 at various inclinations. The thermal resistance of the thermosyphon is depicted by (R) and Te and Tc are average values of temperatures at the evaporator and condenser sections respectively and Q is the heat supplied to the heat pipe

MICROSTRUCTURE

From microstructure analysis, it is found that in unmodified form silicon appears as course flakes as shown in Figure 1 although modification does not actually refines the grain size significantly. Modification breaks up this needle like structure within the grains and enables the fine fibre of silicon to segregate out of the aluminum.

In unmodified LM6 alloy silicon dendrites are present unevenly and it contains larger grains compared to modified alloy. When the stirring action of the molten metal increases the grains are getting finer and equiaxed. Silicon particle are uniformly distributed over the metal. In modified LM6 casting dendrites of silicon particles are broken up into small particles as shown in Figure 5.5. When the stirring time increases fine grains

CONCLUSIONS

Therefore in order to go for a new type of configuration, a Copper based 2-Phase closed thermosyphon was experimentally investigated with R-32 as working fluid. The copper material for the thermosyphon was chosen due to its high thermal conductivity. The working fluid was chosen due to lower global warming potential when compared to Ammonia and R-22 which are flammable and toxic respectively. When filling ratios and angle of inclination was taken into consideration for proving its thermal performance. It was found that at 50% filling ratio and 45° inclined orientation the thermal resistance was lowest and therefore thermal efficiency in those measured parameters were tabulated and shown as optimized .

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