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PERFORMANCE OF A VERTICAL HEAT PIPE USING REFRIGERANT R-22 AS WORKING FLUID

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Abstract*- A heat pipe is a device for transferring heat efficiently between two locations by using the evaporation and condensation of a fluid contained therein. To provide better cooling techniques various methods have been applied. Cooling by heat pipe is one of the heavily investigated approaches. So investigation of heat pipe is necessary for further improvement and development of its performance. This paper illustrates an experimental work, which have been studied the performance of refrigerant R-22 as working fluid on a vertical heat pipe at both free and forced convection and also with and without constant power input. During the experiment the air velocities were 2.4 and 3.2 m/s while the power input was 7.84 watt. It has been observed that the heat transfer co-efficient was higher in free convection than the forced convection while the thermal contact resistance was higher in forced convection rather than free convection.*

Keywords: Vertical heat pipe, Refrigerant R-22, Thermal contact resistance, Heat transfer co-efficient.

1. INTRODUCTION

Heat pipe is a closed container in which a continuing cycle of evaporation and condensation of a fluid takes place with the heat being given off at the condenser end and which is more effective in transferring heat than a metallic conductor. [4]. Heat pipes were developed especially for space applications during the early 60´s by NASA. [1]. The idea behind is to create a flow field which transports heat energy from one spot to another by means of convection, because convective heat transfer is much faster than heat transfer due to conduction. Now a day's heat pipe is being used in electronics cooling, aerospace, heat-exchangers, production tools, engines and automotive industries, medicine and human body temperature control. [2].Basically heat pipe consists of three section; evaporator, adiabatic and condenser section. [3].The basic idea of heat pipes is based on an evaporation and condensation process. At the hot side, the working fluid evaporates and at the cool side it condensates again. At the heat source the cold liquid evaporates, the hot vapor flow is afterwards transported to the heat sink where the vapor condensates again and is transported back to the heat source. The problem of this process is the space consumption; hence it was necessary to develop a compacter way to transport the heat energy with the shown process. The idea of a heat pipe is now to include the complete convective transport in one pipe, where the vapor flow is in the center of the pipe and the liquid flow takes place on the outside of the cylinder.

The working fluid is that matter contained within the system boundary (which can be a liquid or gas) which absorbs or transmits these energies. A particular working fluid can only be functional at certain temperature ranges. The choice of working fluid should also incorporate the fluid's interactions with the heat pipe container and wick. [2]. Here performance of R-22 refrigerant as working fluid is evaluated.

Chlorodifluoromethane or difluoromonochloromethane is a hydrochlorofluorocarbon (HCFC) which is a colorless gas is known as R-22. It is commonly used as a propellant and refrigerant. R-22 is often used as an alternative to the highly ozone-depleting CFC-11 and CFC-12.

2. EXPERIMENTAL

Figure-1 shows the experimental setup in this investigation. It consists of a mug full of hot water in which the evaporator section of the heat pipe was dipped in, heater, k-type thermocouple, mercury thermometer, and fan. The heat pipe was constructed using a 25.4mm diameter and 450mm long copper tube. Porous structure made of steel was inserted inside the copper tube which was used as the wick structure. Two layers of porous structure were used. The copper tube was 170mm in condenser section, 140mm in adiabatic section and 140mm in evaporator section. The adiabatic section was insulated using glass wool and tape. Five (15cm×7cm) rectangular fin made of tin was integrated on the condenser section. The water has been heated up to 56˚C using a heater. Mercury thermometer was used to measure the hot water temperature that is evaporator temperature (assuming evaporator temperature = hot water temperature) and k-type thermocouple was used to measure the condenser temperature. Fan was used for forced convection. A digital anemometer was used to measure the fan velocity.

At first the performance was evaluated without power supply for free and forced convection and then the performance was evaluated with 7.84watt constant power input.

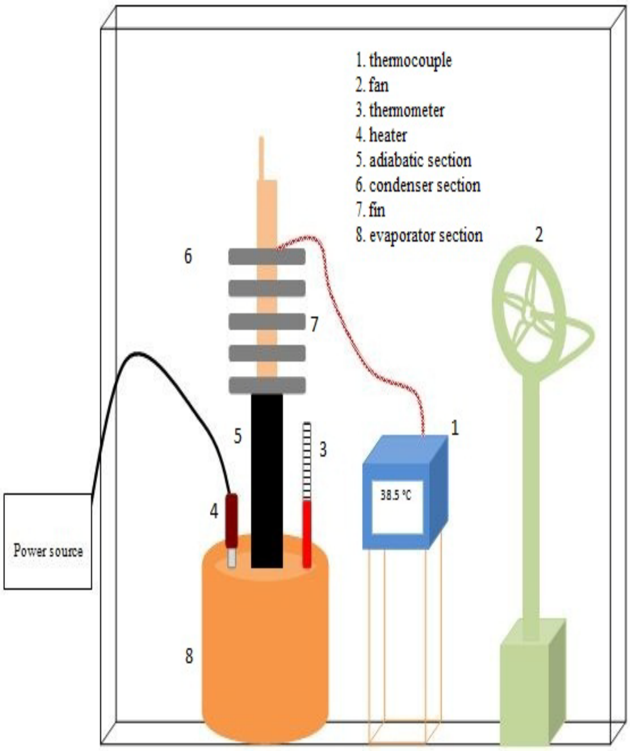

Figure-1: Schematic diagram of experimental setup

3. RESULT

Plotting the temperature of evaporator section in different conditions with respect to time, it was seen that, normal cooling without using heat pipe takes more time than using heat pipe. It was also seen that, using heat pipe with forced convection is more efficient than other conditions.

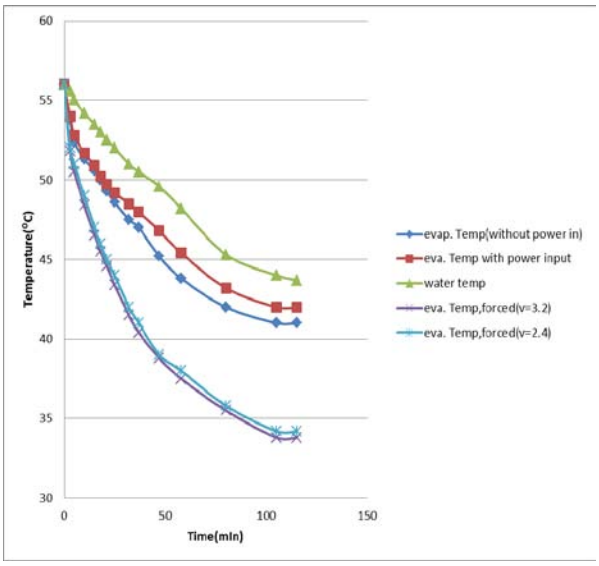

Figure 2: Time vs. Evaporator Temperature.

Plotting the temperature of condenser section in different conditions with respect to time, it was seen that, free convection takes more time to become steady than forced convection. Here it was also seen that, forced convection is more efficient than other conditions.

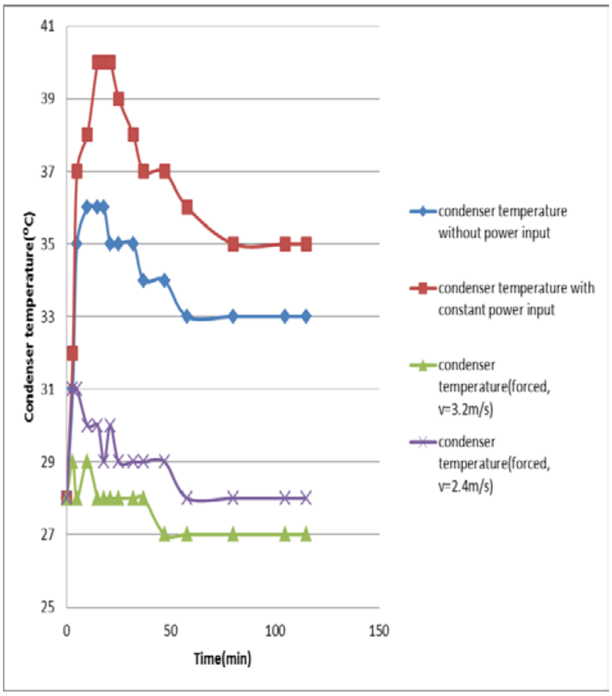

Figure 3: Time vs. Condenser Temperature.

Here, Thermal contact resistance was calculated by the following formula.

Thermal contact resistance, $R = \frac{T_e - T_c}{Q}$ ………... (1) [5]

For different time starting from zero, the temperature of condenser and evaporator temperature was recorded for forced and free convection. The calculated value of R is given in the following table and a graph of thermal contact resistance vs. time is plotted for three different conditions; free convection, forced convection for two different air velocity. Heat supply was 7.84Watt.

Table 1: Thermal contact resistance for free and forced convection at vertical position

Time, (min)	For Free Convection, R, (°CW^{-1})	For Forced Convection(2.4 ms^{-1}), R, (°CW^{-1})	For Forced Convection(3.2 ms^{-1}), R, (°CW^{-1})
0	3.57	3.57	3.57
3	2.81	2.68	2.91
5	2.27	2.55	2.87
15	1.38	2.17	2.36
21	1.43	1.91	2.12
32	1.47	1.66	1.72
47	1.25	1.66	1.76
58	1.2	1.28	1.34
80	0.92	0.99	1.08
105	0.8	0.79	0.86
110	0.8	0.79	0.86

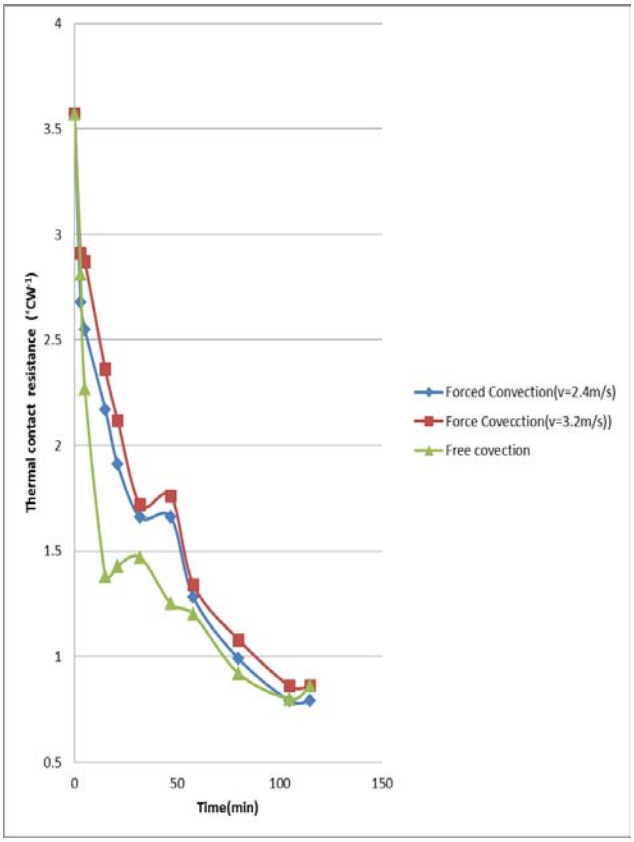

Figure 4: Thermal contact resistance for free and forced convection at vertical position.

Heat transfer coefficient was calculated by the following formula.

Heat transfer coefficient, $h = \frac{Q}{A(Te-Tc)}$............ (2) [6]

Different temperature of evaporator and condenser was recorded against time for free convection and forced convection. Two different air velocity 2.4 ms^{-1} and 3.2 ms^{-1} was used for forced convection with a heat supply of 7.84 watt.

Table 2: Heat transfer co-efficient for free and forced convection at vertical position.

Time, (min)	For Free Convection, h, ($Wm^{-2}{}^{\circ}C^{-1}$)	For Forced Convection(2.4 ms^{-1}), h, ($Wm^{-2}{}^{\circ}C^{-1}$)	For Forced Convection(3.2 ms^{-1}), h, ($Wm^{-2}{}^{\circ}C^{-1}$)
0	27	27	27
3	34.37	36	33.16
5	42.48	37.8	33.61
15	70.01	44.48	40.87
21	67.51	50.41	45.55
32	67.75	58.16	56.01
47	77.12	58.16	54.79
58	80.44	75.62	72.01
80	105.02	96.94	88.96
105	126.03	121.96	111.2
110	126.03	121.96	111.2

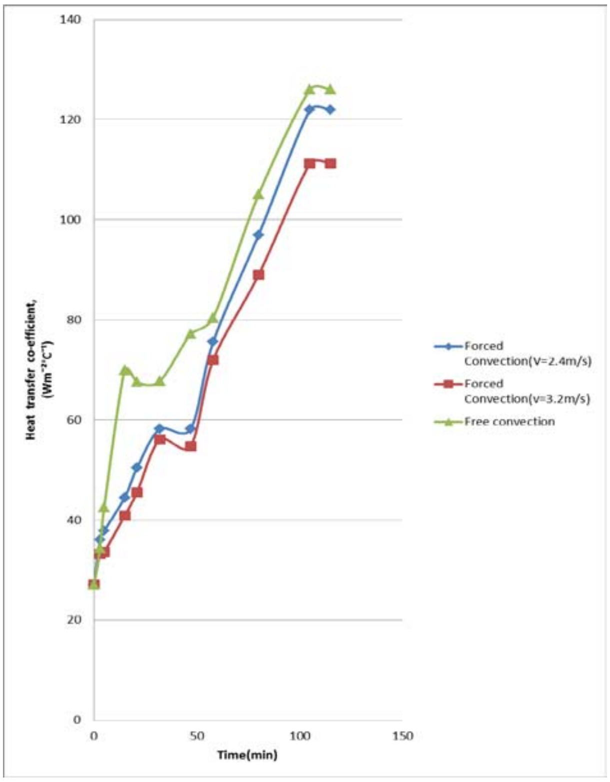

Figure 5: Heat transfer co-efficient for free and forced convection at vertical position.

4. CONCLUSION

Using Refrigerant as a working fluid in heat pipe is very effective. Changing the pressure of the refrigerant it is possible to attain a suitable temperature range.

- ✓ From figure 1 it is clear that the refrigerant cools down the hot water very quickly even with a constant power input. So if we want to keep a constant temperature we just need to keep a certain pressure for that range of temperature. Refrigerant cannot cool below the range depending on the pressure.
- ✓ From figure 4, it is found that the thermal resistance decreases with time. This is because thermal resistance, $R = \frac{Te - Tc}{Q}$, here Q is constant, so the lower the temperature difference the lower the value of R. In the curve it is also seen that, R in forced convection is higher than free convection, this is also due to the fact that temperature difference is greater in forced convection than the free convection as the condenser was kept cooler using air.
- ✓ From figure 5 it is found that the heat transfer co-efficient increases with time. Heat transfer co-efficient, $h = \frac{Q}{A(Te-Tc)}$, here heat input Q and condenser surface Area is fixed. So the lower the temperature difference the higher the heat transfer co-efficient. Since temperature difference in forced convection is higher than the free convection, heat transfer co-efficient is lower in forced convection than free convection.

5. REFERENCES

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6. NOMENCLATURE

Symbol	Meaning	Unit
T_e	Evaporator Temperature	(K)
T_c	Condenser Temperature	(K)
A	Surface Area of Evaporator	(m^2)
Q	Power Input	(W)
h	Heat transfer Co-efficient	(Wm^{-2}°C)
R	Thermal Contact Resistance	(°CW^{-1})