

Recovering Rejected Heat from Refrigerator for Water Heating using Heat Pipes

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ABSTRACT: A refrigerator is defined as an electrical appliance that is used to artificially cool, store and preserve the things (food, drinks etc.) kept inside it. The reduction of energy consumption has become a priority for all countries in the world at present due to the limitation of earth's natural resources, global warming and the increasingly high costs of energy consumption. The objective of this research is to utilize the heat dissipated by the refrigerator at compressor outlet by using heat pipes for water heating and saving electricity. Due to various negative effects of the CFC's on environment and the shortage of natural resources the research aims at reducing the wastage of energy and utilizing it as a useful energy source. Design and development of test rig for the waste heat recovery using heat pipes is carried out.

KEYWORDS: Heat pipe, refrigerator, and geyser.

I. INTRODUCTION

With the faster growing economy and incessant developments in the technology, the energy consumption is greatly increasing causing a lot of wastes to be disposed in the environment leading to global warming and pollution. The increase of energy consumption has been realized due to the major developments in sectors such as industrial, transport, residential, and commercial sectors. Based on the World Energy Council (WEC), the world energy demand would increase up to 50–80% in 2020 considering the current situation [1]. If energy in the form of heat is considered, the waste heat is heat which is generated in any process by way of fuel combustion or chemical reaction, and then dumped into the environment even though it could still be reused for some useful and economic purpose [2]. Refrigerators are one of the devices that are widely used domestically. Refrigerator is an electronic device that is used to store or preserve food etc at a temperature below the surroundings in a sealed or closed system. The refrigerator uses refrigerant to take away heat from its inside and transfer it to the surroundings which are at a higher temperature compared to the inside of the refrigerator, thus work is needed to be done on the system. The rejected heat is a waste and can be recovered from the refrigerator system using some specified method. Recovering the heat adds advantages like less heat wastage and improves the working efficiency of the system. Heat pipe is an efficient heat exchange device which is being effectively employed in the heat recovery and cooling systems at low operating costs. Heat pipes are widely used in heat exchangers. The following paper describes how the heat pipes can be used for heat recovery and its advantages on refrigeration, environment and energy consumption.

Heat Pipe

Heat pipe is a passive heat transfer device with high thermal conductivity. It is a closed system usually in form of a tube sealed at both ends and partially filled with a working fluid that transfers heat as latent heat of evaporation. R.S. Gaugler of General Motors first suggested the idea about capillary based heat pipes. The development started and in 1963 George Grover successfully demonstrated a capillary based heat transfer device which was patented and named heat pipe. Since then the heat pipe technology has evolved and found a role in various applications like computer cooling, spacecraft thermal control, heat exchangers, manufacturing etc. Heat pipes are designed and built with cross sectional areas as small as 30 μ m*80 μ m depth and 19.75mm length and as large as about 20.1m in length [3].

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

Working of Heat Pipe

Most of the heat pipes are cylindrical in shape and consists of the components like container, wick structure and working fluid. Fig.-1. The length of the heat pipe can be divided into three segments namely- evaporator section, adiabatic section and condenser section. The outer tube is normally made of heat conducting material like copper. The working principle of heat pipe is based on the continuous cycle of vaporization and condensation process [4]. When the heat pipe is brought in contact with a heat source, the evaporator section absorbs the heat and the working fluid in the section vaporizes and moves to the condenser section via adiabatic section (because of pressure difference, the vapour at evaporator section is at higher pressure than the condenser section). In condenser section the heat is rejected and the working fluid changes from vapour to liquid. This liquid at condenser section is brought back to the evaporator through wick. Wick is a porous structure inside heat pipe that circulates working fluid from the condenser to evaporator section through capillary action. The process is repeated and this cycle is how heat pipe operates. The process can be described thermodynamically as follows [3]- Fig.-2.

- Evaporator to adiabatic region 1-2: heat applied to evaporator through external sources vaporizes the working fluid to saturated (2) or super heated (2) vapour- isothermal expansion.
- Adiabatic to condenser region 2-3: vapour pressure drives vapour through adiabatic section to condenser-adiabatic expansion
- Condenser to sink 3-4: vapour condenses releasing heat to a heat sink-isothermal compression
- Condenser wick to evaporator wick 4-1: capillary pressure created by menisci in the wick pumps condensed fluid into evaporator section-adiabatic compression

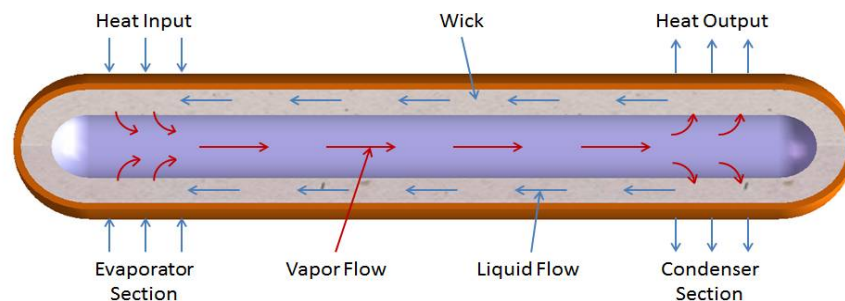


Fig. 1: Heat Pipe

Heat pipes are of different types some of them are as follows –

- Thermal diodes
- Micro heat pipes
- Variable conductance heat pipes
- Loop heat pipes
- Capillary pumped heat pipes
- Pulsating heat pipes
- Rotating heat pipes
- Sorption heat pipes
- Magnetic fluid heat pipe[5]

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

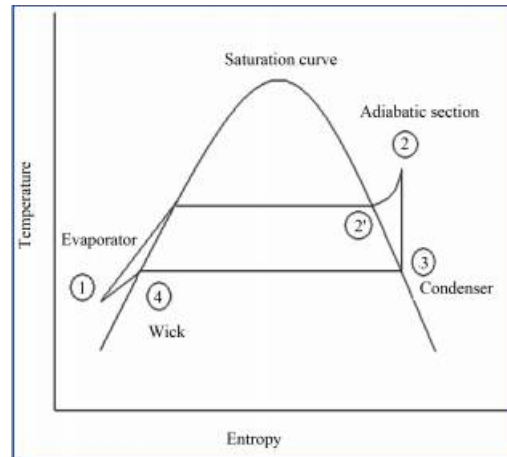


Fig. 2: Thermodynamic operation of a Heat Pipe [5]

Selection of Heat Pipe

Proper heat pipe selection is crucial for the optimum working of the test rig. The heat pipe is selected considering the factors like the temperature change required, the maximum temperature at the compressor outlet tube and the diameter of the compressor outlet tube where the heat pipe is needed to be attached. The Heat Pipe will need to work under the temperature conditions between 0°C and 60°C if extreme temperature conditions are considered for India. Even if temperature conditions of other countries are also considered the water comes out to be the best option for the working fluid in Heat Pipes as water has a working range of 30°C to 200°C as a working fluid and is thus best suited for the present application. For the outer casing of the Heat Pipe a material with high thermal conductivity is required and thus copper is incorporated as the casing material. The parameters like number of heat pipes to be attached and its length depends on the amount of heat to be recovered and the space available in the refrigerator system. For the present application two copper Heat Pipes with water as working fluid are used.

II. RELATED WORK

In the past a lot of developments took place in the Heat Pipe technology. From the day Heat Pipes were invented many scholars have studied and made technological amendments in it and as a result it has found uncountable applications in many electrical, non electrical devices and structures. K.N. Shukla[3] in his work describes about the history of heat pipe, its development and its application in the Satellite and Spacecrafts (i.e. for equalising the temperature between the surface exposed to sun radiation and the opposite surface in the dark in space and for dissipating heat generated by the electrical components in the Satellite). His work also gives information about the working of the Heat Pipe, various types of Heat Pipes and also about the compatibility of material related to the working fluid. Leonard.L.Vasilev[6] explains about different types of Heat Pipes like conventional heat pipes, loop heat pipes, vapour dynamic thermosyphons, spaghetti heat pipes, sorption heat pipes etc. and their application in thermoelectric coolers and heat exchangers for air preheating. Saffa Riffat[7] describes about Novel loop heat pipes and Novel flat heat pipes. He also writes about the various applications of Heat Pipe in Solar collector system and solar cooking system. According to him Heat Pipes can be used in the heat recovery system for e.g.- for heat recovery in air conditioning devices and heat recovery from a process exhaust stream to preheat air for space heating. T.Mallikharjuna Rao[8] worked on the use of heat pipes in steam condensation. A.Shanmuga Sundaram[4] also did studies on the Heat Pipes and concluded that there are various resistances in Heat Pipe namely

1. Evaporative resistance at the inner surface of the evaporator section.
2. Condensing resistance at the inner surface of the condenser side
3. Convective resistance at the evaporator outer surface

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

4. Convective resistance at the condenser outer surface

Chintan D Patel[9] in his work studied the efficiency of Heat Pipe under various filling ratios of 0% (dry test), 40%, 60%, and 80% under gravity and anti gravity. He concluded that heat transfer rate with working fluid filled inside the pulsating heat pipe was higher compared to the dry pulsating heat pipe and heat throughput in gravity supported orientation performs better than pulsating heat pipe in anti gravity. He found out that pulsating heat pipe performed better at 40% volumetric filling ratio than that of 80%. GABOR Timea[10] developed a system using Heat Pipes in the recovery of waste heat from urban wastewaters and concluded that heat recovery increases with the flow rate of the fluid and the efficiency of the heat exchanger depends very much on the preheated cold water flow rate. This paper describes about the method of recovering the waste heat from the refrigerator and using it into water heating using heat pipes.

III. EXPERIMENTAL PROCEDURE AND SETUP

The experimental setup is designed to save the electricity (waste heat recovery from refrigerator) using heat pipes to heat the water.

Specifications of the important part(s) are as follows:-

1) Heat Pipe-

- Diameter = 5 mm
- Length = 300 mm
- Working Fluid = water
- Working Range =30°C to 200°C
- Outer Casing Material = Copper
- Wick Structure = sintered metal

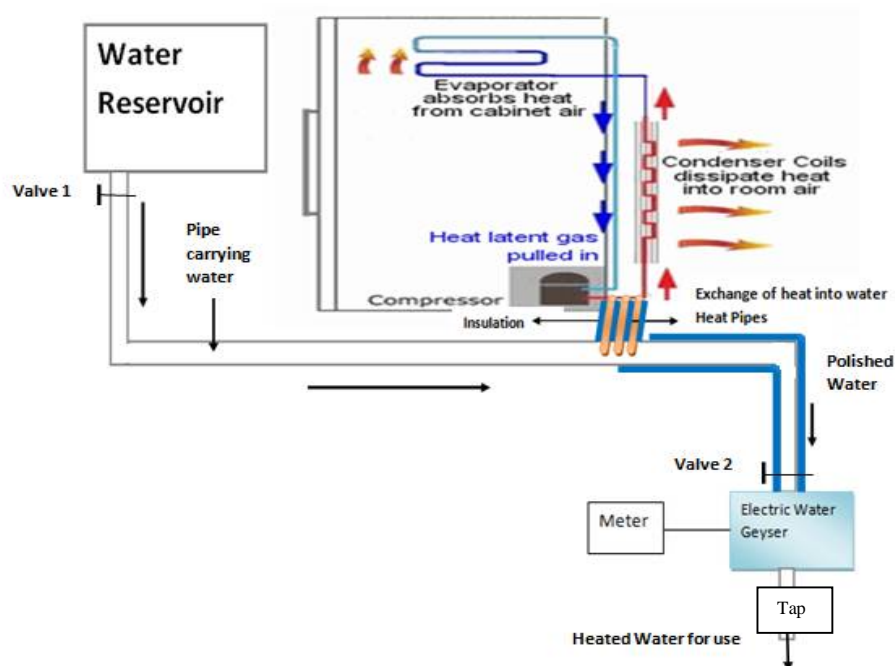


Figure3. Experimental Setup with Heat Pipes

Figure3 shows the schematic diagram of the experimental apparatus. The system comprises of four main components: geyser (for heating the water), cylindrical pipe type heat pipe, a refrigerator, and metre (for measuring parameters). In

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

order to extract or utilise the waste heat from the refrigerator, measure the size and the shape of the compressor outlet. According to the diameter and the available space at the compressor outlet select the diameter as well as the number of the heat pipes required so that the maximum area of the heat pipe comes in contact with the surface. Thus we will be able to extract maximum quantity of heat. It should be noted that the line of contact of the compressor outlet and the heat pipes must be sufficiently insulated so that the convective losses can be avoided and better results can be obtained. The water tank is placed at a certain amount of height and filled with the water to be heated which is further connected with a pipe through valve number 1 which is insulated to avoid convective loss. The heat pipes are placed horizontally and at one end they are inserted in the pipe in such a way that they transfer the heat from the compressor outlet into the water flowing in the pipe. We know that in a typical vapour compression refrigeration system, the low temperature, low pressure at the compressor inlet is compressed to high temperature and pressure at its outlet. This temperature can be utilised to preheat the water of the tank and hence reducing the consumption of the electricity by the geyser. The other end of the pipe is connected to the geyser with valve number 2. A resistance temperature detector (RTD) is equipped before this valve to measure the rise in the temperature of the water due to the heat gained from the heat pipes. The geyser is connected to the electric meter. The procedure is as follows:-

1. Check all the connections for the test rig and check for any leakages.
2. Load the refrigerator with things to be chilled.
3. Fill the water into the water tank up to the specified level.
4. Run the refrigerator for certain period of time.
5. After running the refrigerator for the specified time open the valve number 1 to let water flow from the water tank.
6. Ensure the opening of valve number 1 to be quick to ensure turbulent flow remaining the valve number 2 to be closed.
7. Wait for few seconds to allow complete heat to transfer to water through heat pipes.
8. Open the valve number 2 to let the heated water enter the geyser.
9. Ensure the geyser is full of water.
10. Check the meter connections again and switch on the power supply for the geyser.
11. Count the number of units of electricity consumed to reach the maximum temperature.
12. After getting the desired temperature switch off the supply.
13. Repeat the following steps after removing the heat pipes.
14. Calculate the electricity consumption for the set up with and without heat pipes.

IV. RESULT

The heat from the refrigerator can be successfully recovered using the Heat Pipes and the test rig can be successfully used for the water heating and is able to reduce the energy consumption by reducing the electricity required to heat the water in geyser (high temperature water is fed to the geyser thus less energy is required to further heat water to a specified temperature). The refrigerator system without heat pipes has low working efficiency as compared to the refrigerator with Heat Pipes.

V. CONCLUSION

The waste heat from the refrigerator was recovered and is successful in reducing the energy consumption thus reducing the negative effects on environment. The proposed arrangement reduces the electricity consumption and also improves the working of refrigerator. Heat from the outlet of compressor is extracted thus the temperature of the pressurized refrigerant is reduced which further gets reduced in the condenser coils thus refrigerant is now more cooled and results in the increase in the performance of refrigerator. Heat Pipes are easy to use, require less maintenance, no mechanical failure due to absence of moving parts and have long life without affecting the performance.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 9, September 2016

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