Experimental Analysis of Heating and Cooling Effect in Household Refrigeration System

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ABSTRACT

Refrigerator has become an essential commodity rather than luxury item. The heat absorbed in the refrigerated space and the compressor work added to refrigerant is too rejected to ambient through a condenser. Most of the time the heat from the condenser side is dissipated to room air. Our aim is to recover the waste heat from condenser unit of a refrigerator to improve the performance of the system and use this heat for water heating purpose. The hot water there by produced can be used for several residential and commercial uses. The hot water can also be stored in an insulated tank for later use. In our project, we had design, fabricated and experimentally analyzed waste heat recovery system for domestic refrigerator. From the experimentation it was found that after recovering heat from the condenser of the conventional refrigerator, its performance gets improved than conventional refrigerator and hot water of moderate temperature can be obtained from it. This modification made the household refrigerator to be work as both refrigerator and water heater. Considerable amount of hot water at a significant temperature can be collected from the heat recovery system in an effort to more effectively utilized waste heat, the temperature of water may be increased to a limited range, by raising the condensing pressure in the system or increasing compressor capacity. The temperature of water tank contains 50 liter water then it gets heated to 45^{0}c in just 5-6 hours. After that performance of the system get decreased. So it needs regular use of hot water.

Keywords*: Compressor, Heat recovery unit, Expansion device, Evaporator, Condenser.*

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1. INTRODUCTION

Refrigerator is a common household item used for preserving food. It works on the simple physics principle “The evaporation cause cooling”. In fact, the refrigerator does not actually cool things it removes heat from them. The important part of the refrigerator are Compressor, heat exchanger coil inside the refrigerator(Evaporator), heat exchanger coil outside the refrigerator(Condenser), Expansion device, Refrigerant. The refrigerant is a liquid such as Freon, Ammonia or CFC will vaporize at low temperature. The refrigerant in the heat exchanger coil inside the refrigerator absorbs the heat which causes it to vaporize. The compressor compresses this vapour. This raises the temperature and pressure of the refrigerant. The heat exchanger coil outside the refrigerator allows the refrigerator to dissipate the heat of pressurization. As it cools the refrigerant condenses back into liquid flows through expansion valve. The liquid refrigerant is allowed to move from high pressure zone to low pressure zone, so it expands and evaporates. In evaporation it absorbs heat from the heat exchanger coil inside the refrigerator making it cold. The process basically removes heat from one place that is inside the refrigerator and dissipates it to another place that is outside the refrigerator.

The place from where the heat is removed becomes cold and such place known as refrigerator is used for food preserving. The place where the heat is dissipated is however not used by the refrigerator. The heat dissipated by the refrigerator is the waste heat of the refrigerator.

The compressor of refrigerator works round the clock, round the year with intermediate stoppage when the temperature inside the refrigerator is below the set point. The compressor uses electrical energy which is converted to mechanical energy to compress the refrigerant. Since all the electrical energy can’t be converted to mechanical energy due to limited conversion efficiency, Some energy will be converted to heat energy. This is the also the waste heat generated by the refrigerator. There are many a times to make use of waste heat generated by the refrigerator is used for domestic water heating. The modified system result in energy saving due to non usage of electricity for heating the water and cost saving by combing the both

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utilities(refrigeration and water heating) in one system. The hot water which is obtained from water cooled condenser can be utilized for household applications like cleaning, dish washing, bathing, laundry etc.

2. LITERATURE REVIEW

S.C. Kaushik represents an investigation of the feasibility of heat recovery from the condenser of a vapour compression refrigeration (VCR) system through a Canopus heat exchanger (CHE) between the compressor and condenser components. The presence of the CHE makes it possible to recover the superheat of the discharged vapour and utilize it for increasing the temperature of the external fluid (water) removing heat from the condenser. The effects of the operating temperatures in the condenser and evaporator for different inlet water temperatures and mass flow rates on the heat recovery output and its distribution over the condenser and CHE (the fraction of the condenser heat available through the CHE), available outlet water temperature and heat recovery factor have all been studied and optimum operating parameters for feasible heat recovery have been ascertained. The parametric results obtained for different working fluids, such as R-22, R-12, R-717 and R-500, have been presented. It is found that, in general, a heat recovery factor of the order of 2.0 and 40% of condenser heat can be recovered through the Canopus heat exchanger for a typical set of operating conditions.

Dr.M.S.Tandale presented a case study on Super Heat Recovery Water Heater at Worli, Dairy. They used R717 Kirloskar Reciprocating Compressor having refrigeration system capacity of 270 TR (950KW). The Inlet & Outlet temperature of Refrigerant are 115 & 60°C.The Inlet & Outlet temperatures of Water are 25 & 70°C. They installed super heat recovery water heater in counter current mode. The hot water flow rate is 70000 L/day. In this system fuel saving is about 390 lFO/day. The annual saving is near about Rs.23 Lac/year. Also the reduction in CO_2 emissions is 330 ton/year.

3. THEORY

A typical vapour compression system consist of four major components viz. compressor, condenser, expansion device and an evaporator are depicted schematically in Figure 1.Figure 2 is a thermodynamic diagram of the process where the numbered points correspond to the numbered points in Figure 1.The operation cycle consist of compressing low pressure vapour refrigerant to a high temperature vapour (process 1-2); condensing high pressure vapour to high pressure liquid (process 2-3); expanding high pressure liquid to low pressured super cooled liquid (process 3-4); and evaporating low pressure liquid to low pressure vapour (process 4-1). The heat absorbed from evaporator in process 4-1 is rejected to outside ambient during condensation process 2-3 and is generally a waste heat. The condensation process can be divided in 3 stages viz. de-superheating 2-2a, condensation and sub cooling.

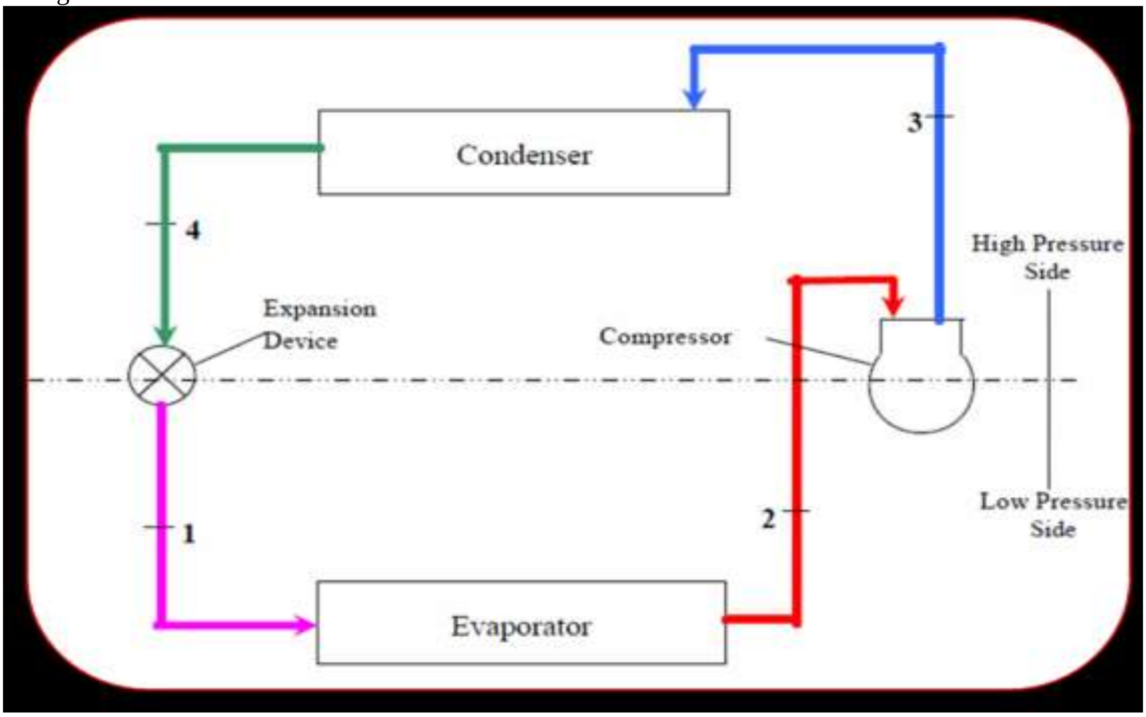

Figure 1: Vapour compression system

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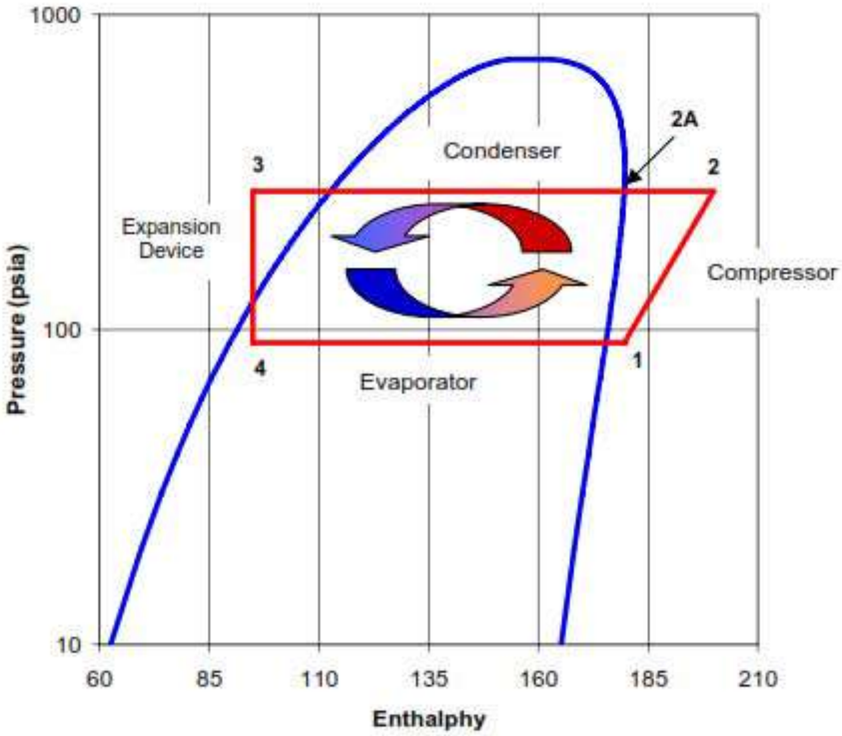

Figure 2: P-H diagram

The saturation temperature by design is anywhere from ten to thirty degree above the heat sink fluid temperature, this ensure the heat sink fluid can extract heat from the refrigerant. The superheat can be as much as 100 F or more higher the saturation temperature. This so-called superheat is a part of waste heat that can be recovered for useful purposes through the use of a heat recovery unit. A heat recovery unit special purpose heat exchanger specifically designed to:

☐ Remove heat represented by process 2-3 in figure 2.

☐ Improve overall system efficiency by using water cooled condenser.

4. EXPERIMENTATION

4.1 Experimental Setup

Experimental setup consists of 165 L capacity, refrigerator system. The system was retrofitted with a water tank having capacity of 20 L. The refrigerator is having a vertical cabinet. A tank made-up of MS is fitted at the beginning of the condenser line. A partial portion of the condenser line is immersed in the tank for de-superheating of refrigerating gas. The volume of water used for testing is 10L.A water in tank was kept stationery till water get temperature more than 40^0 C. An instrument panel made-up of MS is used for mounting gauges. Pressure gauges indicating suction pressure of compressor and pressure after condensation. Also an ammeter and voltmeter has been used to measure the energy consumption. A temperature sensor set has been used to monitor various temperatures encountered in the system. Symbols used for indicating temperatures are listed below:

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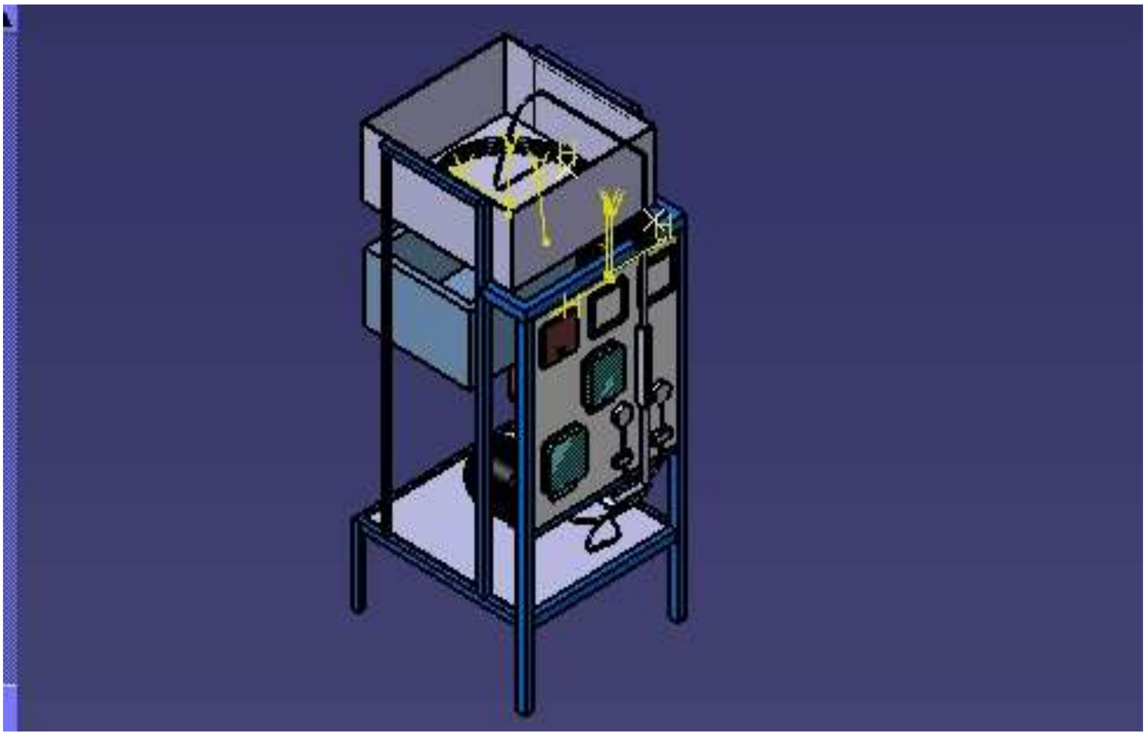


Figure 3: Experimental Setup

4.2 Experimental Procedure

Fig.4 shows the schematic diagram of experimental setup. After the installation of the components on refrigerator test setup started. Test was conducted in two phases which are as follows at each load conditions temperature and pressure at salient points were noted down at every sixty minutes interval. The initial and final temperature of the water also measured. The tests were conducted until steady state is reached. To find out energy consumption energy meter reading were noted. For finding out the coefficient of performance compressor suction and discharge pressure were used. Once equilibrium temperature were reached between water and condensing temperature it was found that, there is no more change in temperature of water. The water temperature was up to satisfactory level or preheated state. Once water got preheated state the water tank is filled fresh water.

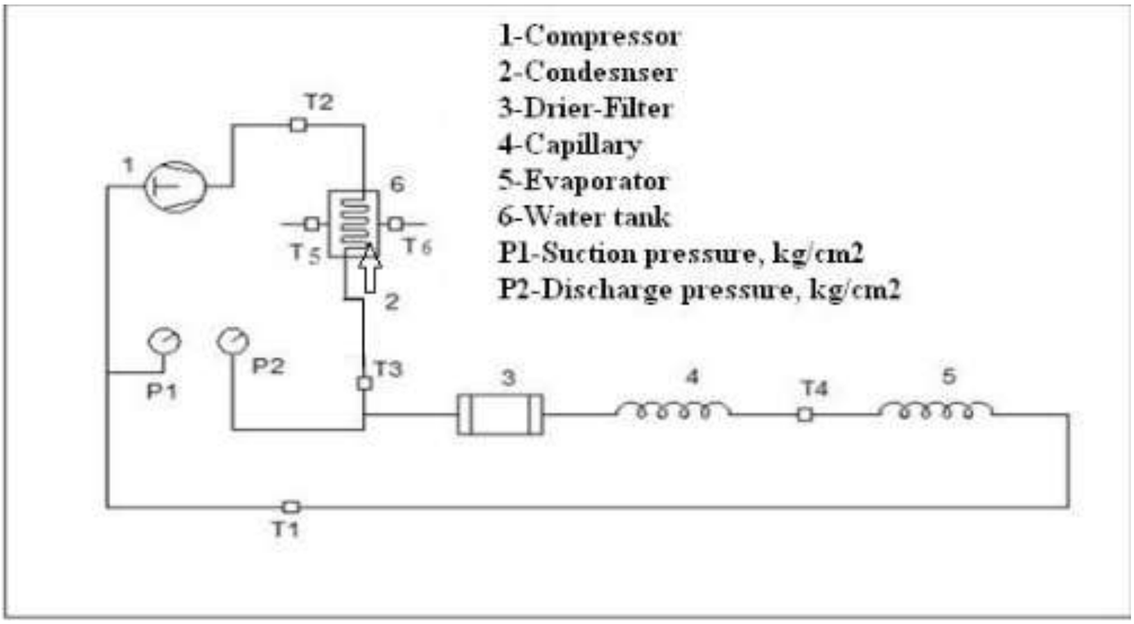


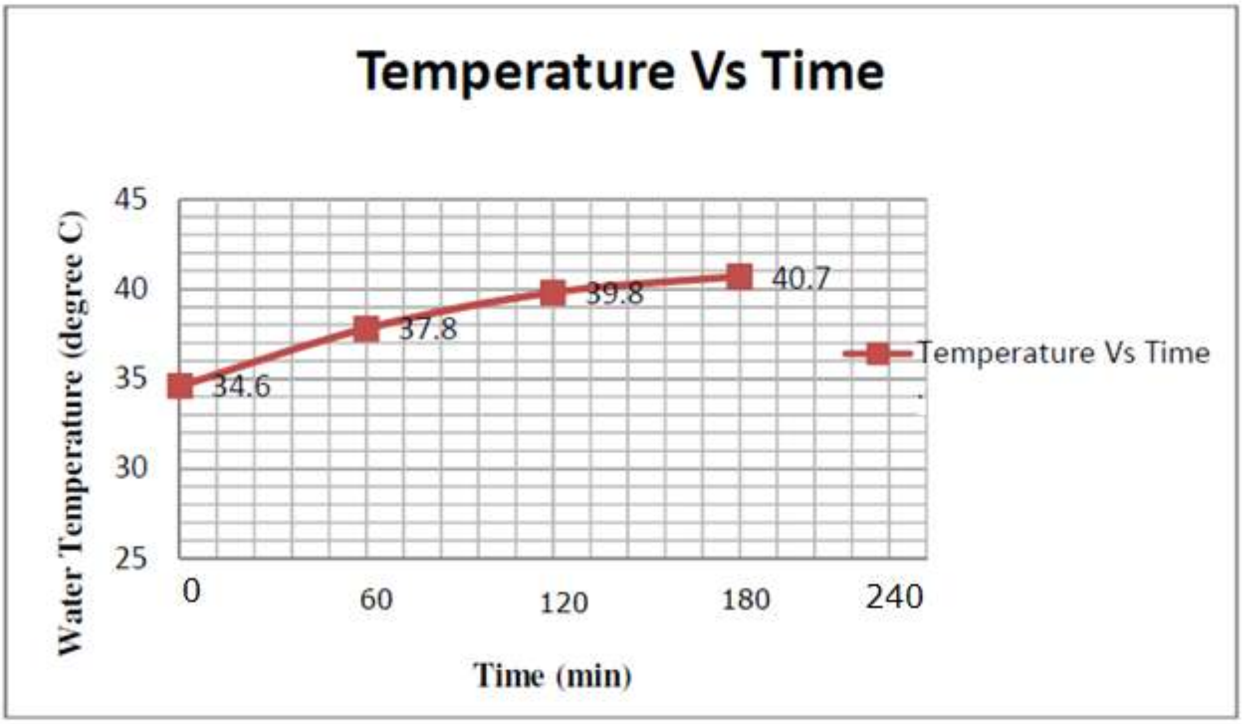
Figure 4: Schematic diagram

Symbol	Component	Symbol	Component
T1	Temperature after evaporation, ^{0}C	T4	Temperature after throttling, ^{0}C
T2	Temperature after compression, ^{0}C	T5	Water inlet temperature, ^{0}C
T3	Temperature after condensation, ^{0}C	T6	Water outlet temperature, ^{0}C

Table-1: Symbols and Components

5. RESULTS AND GRAPHS

The graphs plotted below indicate an increase in the outlet temperature of water with time. The temperature rise varies according to type of load applied. The power consumption decreases with an increase in outlet temperature. The graphs also indicate an increase in the Coefficient of Performance. The COP decreases with an increase in time. Thus as time increases, the COP decreases and remains constant after a certain interval of time.
The overall temperature difference encountered at the end of 60-120 minutes exceeds 10 ^{0}C. Thus, with an increase in the time interval the outlet water temperature can be increased considerably.



Graph-1: Temperature Vs Time

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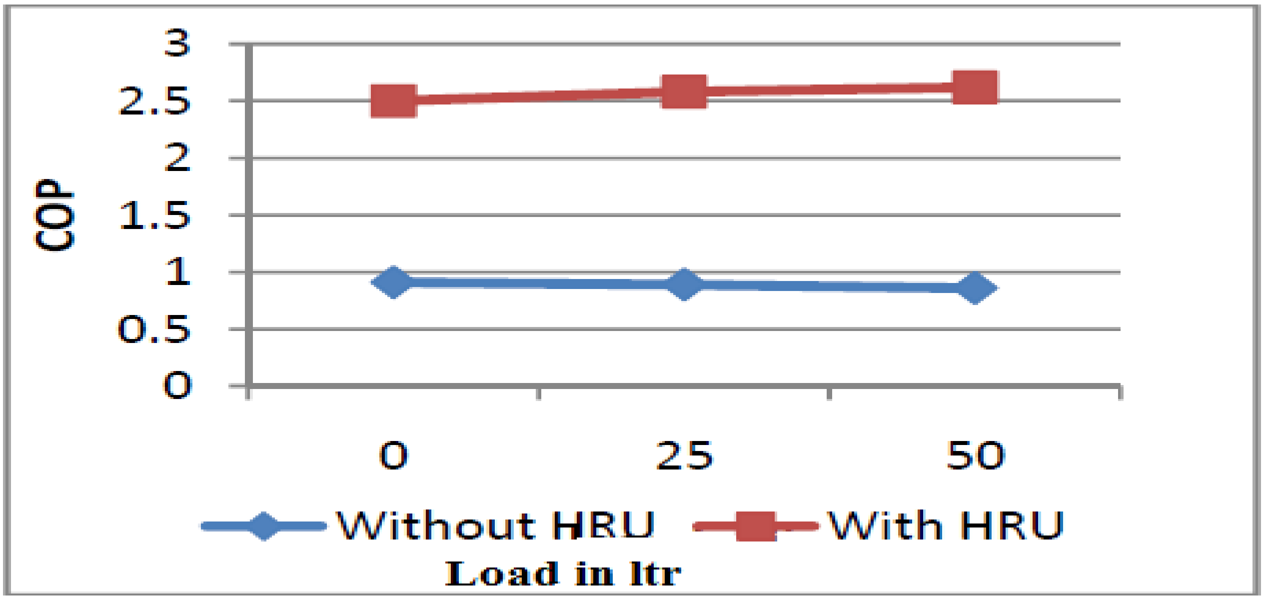

Graph-2: Actual COP Vs Load

Also, the results are the pure comparison between the vapour compression system with heat recovery unit and with air cooled condenser to check Actual COP, Theoretical COP, and rise in temperature of water with different load conditions. There are two different categories in which results are represented

- Performance of the system
- Rise in temperature of water in tank

6. CONCLUSION

Looking towards the results it can be concluded that :

☐ The maximum temperature achieved in the water storage tank at average load is 40°C.

☐ Theoretical COP of the systems when run with HRU is more than the system run with air cooled condenser.

☐ Actual overall COP of the systems when run with HRU are more than the system run with air cooled condenser

☐ The electric consumption is less as compare to conventional and it increases as the temperature in water tank goes above 38^{0}C but it is less than the cost of energy required to heat 100 lit water up to 42 ^{0}C.

☐ Recovery of heat from the condenser reduces the heat load to surrounding and it makes surrounding comfortable.

☐ Power Consumption is reduced by using water cooled (HRU) condenser instead of air cooled.

7. FUTURE SCOPE

In this project we can measure the heating effect along with the desired cooling effect. Also we can have sub cooling effect which increases the COP of the cycle up to certain limit. We can measure the above effects by changing the refrigerant and observing the output with the same.
In future we can add solenoid – float system arrangement for the removing of the heated water. Also when we remove heat from condenser by forced convection instead of natural convection, we will get warm air which can be used to warm the foodstuffs in food warmer.

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