Improving the Performance of Household Refrigerator by Recovering Heat from the Condenser

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Abstract: ***Refrigerator has become an essential commodity rather than luxury item. The heat absorbed in refrigerated space and the compressor work added to refrigerant is too rejected to ambient through a condenser. Our aim is to recover waste heat from condenser unit of a household refrigerator to improve the performance of the system. The heat recovery from the household refrigerator is by thermo siphon. From the experimentation it was found that after recovering heat from the condenser of the conventional refrigerator its performance get improved than conventional refrigerator. The maximum temperature achieved in water tank with 100 liter of water is 45ºC at the full load condition. If the water tank contains 50 liter water then it gets heated to 45 ºC in just 5 to 6 hrs. After that performance of the system gets decreased. So it needs regular use of that hot water.***

Key words: Heat recovery unit, compressor, expansion device, evaporator

1. Introduction

Waste heat which is rejected from a process at a temperature enough high above the ambient temperature permits the recovery of energy for some useful purpose in an economic manner. The strategy of how to recover this heat depend not only on the temperature of the waste heat sources but also on the economics involves behind the technology incorporated. Abu-Mulaweh [1] made a case study of a thermosyphon heat recovery system that recovers heat from which is rejected from an air conditioner .Sathiamurthiet al [2]discussed in studies on waste heat recovery from an air conditioner unit that the energy can be recovered and utilized without sacrificing comfort level. Kaushikmand Singh [3] has found that in general, 40% of condenser heat can be recovered through the Canopus heat exchanger for a typical set of operating conditions. Turgul Ogulta [4] discussed the utilization of waste heat recovery n textile drying process.

In this paper authors have investigated a Waste Heat Recovery System with Thermo Syphon (HRS) and experimented to recover condenser heat from the household refrigerator of 200 litters. By HRS rejected heat of the system is utilized to generate hot water and this can be utilized in kitchen. There by saves significant amount of energy.

2. Theory

A typical vapor 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 vapor refrigerant to a high temperature vapor(process 1-2); condensing high pressure vapor 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 vapor (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. desuperheating2-2a, condensation and sub cooling.

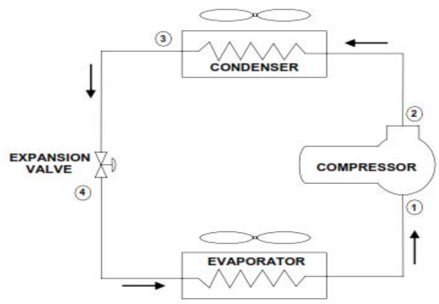

Figure 1: Vapor compression system

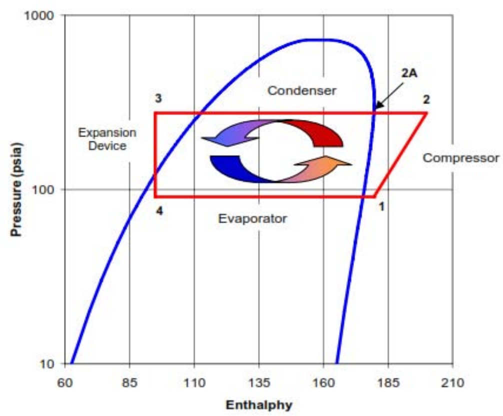

Figure 2: P-H diagram

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 above 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 is special purpose heat exchanger specifically designed to:

- Remove heat represented by 2-3 in figure 2.
- Improve overall system efficiency by using water cooled condenser.
- Use thermo syphon system to circulate water to minimize pumping cost.
- Protect against contamination of portable water via double wall construction.

3. System Description

Figure 3 shows household refrigerator with heat recovery unit. It consist of vertical copper tube of diameter 4.8cm through which water is flowing and refrigerant tube of 0.7cm is brazed helically on it for effective heat transfer. The Water tank is placed at the top of vertical tube on stand and with the help of flexible pipe it is again connected to bottom of vertical pipe to make close circuit. The heat recovery unit extracts heat from the hot refrigerant and heats the water which is inside the vertical pipe .Due to temperature difference hot water in pipe moves upward and cold water comes in from the bottom. As the circulation is by themosyphon there is no need of pump.

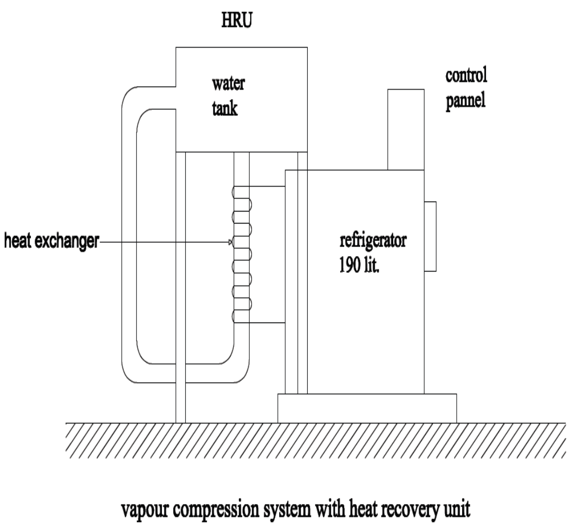

Figure3 Refrigerator with Heat Recovery Unit

The heat recovery unit in figure 3 is heating potable water for institutional uses such as food preparation, dishwashing, laundry, showers, etc. The amount of heat recovered is dependent upon discharge temperature of compressor, load in refrigerator, and water quantity in tank.

4. Experimentation and Measurement

A Panasonic refrigerator of 190L capacity, the Compressor Model: THK 1340 YCF was selected for the development of system. The refrigerator has a reciprocating compressor with the following technical specifications. The air cooled condenser is replaced by water cooled condenser as shown in figure 3.

The Heat Recovery Unit is installed on household refrigerator therefore there may be change in the applied load of the refrigerator. Therefore tests are carried out at different load conditions to measure COP and performance of Heat Recovery Unit i.e. temperature in water tank for 8 hours. From this data economy of the system will be decided.

Refrigerant	R-134a
Cooling capacity	365Btu/ hr
Power input -Rated	100Watts
Refrigerant Control	CAPILLARY
Compressor Cooling	STATIC
Evaporating Temp Range	-34TO-12°C
Displacement /revolution	4.00CC
No. of Cylinders	One
Evaporating Temperature	-23.3°C
Condensing Temperature	54°C
Liquid Sub Cooling Temp	32°C
Return Gas Temperature	32°C
ambient pressure –suction temperature	32°C
Pressure -Suction	0.32Kg/Cm2
Pressure -Discharge	12.9Kg/ Cm

Table 1: Specifications of the system

5. Results and Discussions

Results are the pure comparison between the vapor 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

5.1 For average load condition

5.1.1 Temperature variation in water tank

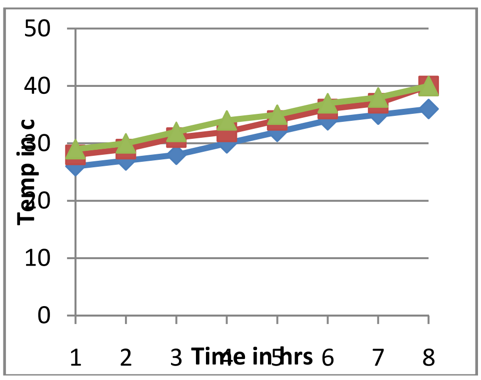

Figure 4 Temperature variations in tank with time

100 lit of water in water tank gets heated up to 40°C within eight hours at average load condition.

5.1.2 Theoretical COP measured for two different cases

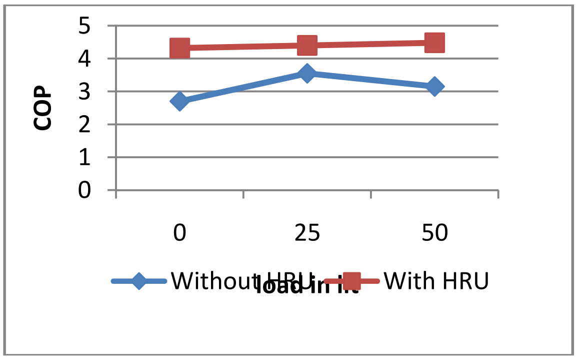

Figure 5: Theoretical COP Vs load

Theoretical COP of the system with heat recovery unit is more than system without heat recovery system.

5.1.3 Actual COP measured for two different cases

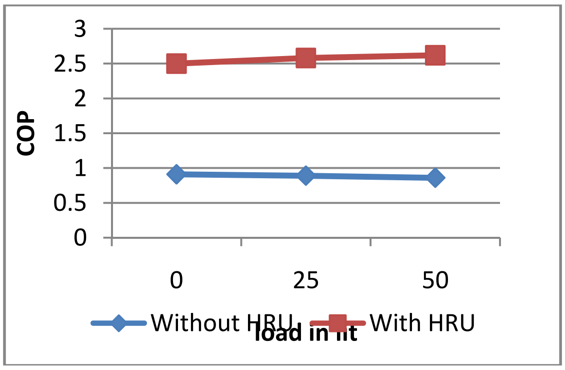

Figure 6: Actual overall COP Vs load

Actual overall COP of the system heat recovery unit is more than system without heat recovery system

6. Conclusion

Looking towards the results it is 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.

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