Hot and Cold Storage using Waste Heat Recovery System

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Abstract -*In the present era, the world is grappling with a significant energy crisis, necessitating the adoption of energy-efficient practices in all areas of life. Given that heat is a form of energy, it becomes crucial to prioritize energy conservation, especially concerning the use of refrigerants, to safeguard the global environment. The dissipation of waste heat contributes to adverse environmental conditions, such as global warming and ozone layer depletion. Therefore, it becomes imperative to make substantial and tangible efforts toward conserving energy through waste heat recovery. In this regard, an endeavor has been undertaken to harness the waste heat emitted from refrigerator condensers. This captured heat holds potential for various domestic and industrial applications. With low construction, maintenance, and operational costs, this system proves highly beneficial for domestic purposes. It serves as a valuable alternative approach to enhance overall efficiency and repurpose waste heat. The feasibility study indicates the technical and economic viability of this system, wherein a simple refrigerator is equipped with a compartment, positioned beneath the freezer, designed to capture heat emitted by the condenser coils. This compartment can be utilized for hot storage, while the refrigerator continues to function conventionally. Moreover, there is room for further improvement in the coefficient of performance (COP). Preliminary calculations indicate that a hot box temperature of approximately 35°C-40°C can be generated without consuming additional electric power by harnessing the recovered heat from a domestic refrigerator.*

Key Words: Waste heat, Overall efficiency, Refrigerator, Energy conservation, Condenser

1.INTRODUCTION

Energy efficiency and sustainability have emerged as crucial considerations in today's society, given the increasing demand for cooling and heating systems. In order to maximize energy utilization and minimize waste, it has become essential to explore innovative approaches. One promising avenue is the utilization of waste heat generated by domestic refrigerators, which typically goes unused and dissipates into the environment. This research paper focuses on the concept of utilizing waste heat for hot and cold storage, presenting a unique method to harness and utilize this energy for sustainable applications. By harnessing the waste heat produced by refrigeration systems, our objective is to contribute to the development of more energy-efficient and environmentally friendly cooling and heating solutions. This paper examines the underlying principles, challenges, and potential benefits associated with this innovative approach, shedding light on its viability and broader implications for a greener future.

1.1 Principle of VCC in household refrigerator

The Vapor Compression Cycle (VCC) is commonly used in household refrigerators to transfer heat from a low temperature to a high temperature environment. The primary purpose of a refrigerator is to remove heat from a low-temperature medium. During the operation of a household refrigerator, heat is rejected to the surrounding environment from the condenser. Unfortunately, in warm climates, this heat is typically wasted. This paper explores the feasibility of a new system that utilizes the rejected heat from the refrigerator's condenser to create hot storage. The objective is to investigate the utilization of waste heat from the condenser within the same system where the refrigeration process takes place.

The thermodynamic cycle of the refrigeration system involves controlling heating and cooling in storage. The cycle begins with the compressor, which receives vaporized refrigerant and compresses it. The compressed vapor exits the compressor as superheated vapor, which then passes through the condenser. In the condenser, the superheated vapor cools down and releases heat, causing it to condense into a liquid. Additional heat, pressure, and temperature are removed from the liquid refrigerant by a fan blowing across the condenser coil.

The warm air in the hot room passes through the condenser coil, becoming heated in the process. This heat is absorbed by the products stored in the hot room.

The liquid refrigerant then flows through the expansion valve, where a sudden pressure drop leads to flash evaporation. The resulting cold liquid-vapor mixture travels through the evaporation coil, where it is vaporized by the warm air cooled by a fan across the evaporation coil. The refrigerant vapor returns to the condenser inlet, thus completing the cycle. The temperature of the hot room is maintained with the help of exhaust fans and fresh air fans.

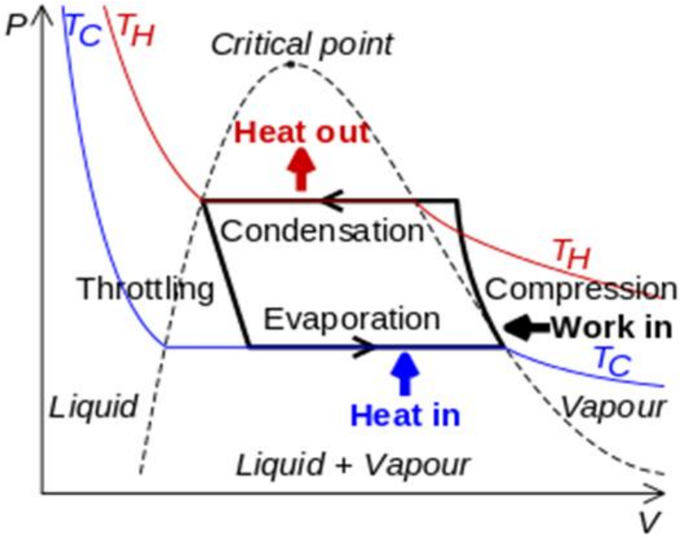


Figure 1 Graphical representation of VCC using P-V graph

2. CONSTRUCTIN OF HOT STORAGE

In this paper we have constructed a HOT & COLD STORAGE in a same household refrigerator of 2 doors and having capacity of 230 litre. We had to remove the lower door insulation from side condenser coil so that heat which is transferred to the surrounding from radiation and conduction can be transferred to the lower hot box with the help of holes created on the inner side of the Hot storage. Insulation between the two compartments is the most important element and for that the PUF spray is used. Polyurethane is a type of sealant used for various purposes like sealing and isolation. For temperature control exhaust fan is attached to the back of the hot storage compartment which is controlled by an Arduino circuit with the help of a motor driver and exhaust fan. The temperature sensors sense the temperature in each of the compartments and send the data to the Arduino uno. This is then displayed on the LCD display. Now for temperature regulation, when the value in the hot storage reaches a certain upper threshold, the fan turns on which helps to regulate or remove the heat from the lower compartment. the fan is mounted on the back side of the lower compartment above the compressor. After it has been running for some time, the fan turns off when the temperature reading from the LM35 reads a certain pre-set lower temperature value.

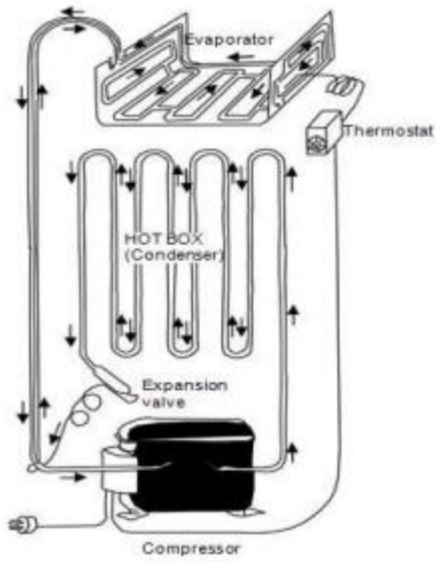


Figure 2 Construction of Refrigerator

3. METHODOLOGY

Method for controlling heating and cooling in a room comprises the steps of circulating refrigerant in the compressor

(**1**) As the said vapor is compressed and then exists the compressor superheated vapor that passes through the condenser

(**2**) which first cools and removes the superheat, the vapor is condensed into a liquid by removing additional heat pressure and temperature by using a fan.

(**3**) Across the condenser coil, the warm air in hot room passes through the condenser coil and gets heated up, this heat is absorbed by the products kept in hot room, the said liquid refrigerant goes through the expansion valve.

(**4**) When pressure suddenly drops down, flash evaporations take place, the cold liquid vapor mixture then travels through the evaporation coil

(**5**) and is vaporized by the cooling of the warm air by a fan

(**6**) Across the evaporation coil, the refrigerant vapor returns to the condenser inlet to repeat the cycle. In one specific example of system in accordance with the invention a constant volume thermodynamic machine has hot and cold level working rooms with hot and cold displacers cycling working fluid.

4. APPLICATIONS

4.1 Advantages of System

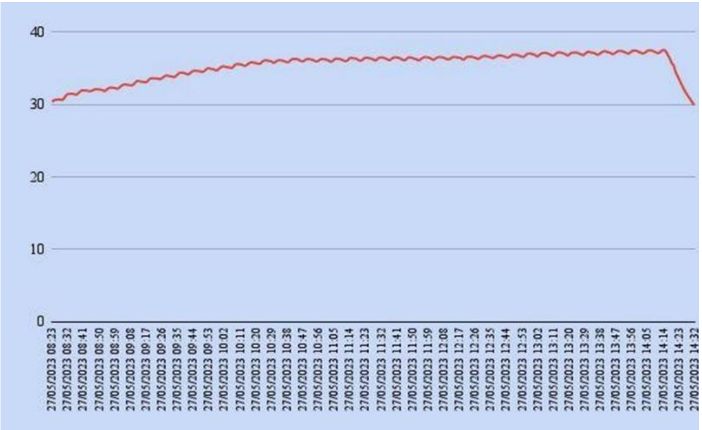
- ✓ Effective utilization of waste heat recovery due to which global warming can be reduced.
- ✓ Increase in overall effectiveness of domestic refrigerator and saving in energy.
- ✓ Increase in Coefficient of performance of domestic refrigerator.
- ✓ Efficient and economical combination of refrigerator and food / water warmer.
- ✓ Simulated for medium to large system or multiple domestic refrigerators.
- ✓ Heat load in kitchen due to heat rejected in room is also reduced which indirectly reduces energy required to cool the room.

4.2 Applications of System

- ➢ To dry grains and dry-fruits etc.
- ➢ Maintaining temperature of substances up to 35°C-40°C.
- ➢ Keep snacks and food warm.
- ➢ Grocery stores for storing cold and warm items simultaneously.
- ➢ Used in health care centres, schools, etc.
- ➢ Any other application requiring warm air.
- ➢ Serving both cooling and heating purpose i.e., Machine is multipurpose.

5. CALCULATIONS

The observations for the following graph were recorded using Data Loggers.



5.1 COP CALCULATIONS

- Time required for reading, Δt = 100 min
- Initial temperature of water T_1 = 30 ^{0}C
- Final temperature of water T_2 = 35 ^{0}C
- Temperature difference ΔT = 5 ^{0}C
- Mass of water in the box, m = 1300 gm
- Specific heat of water, Cp = 4.184 KJ/Kg K
- Heat Absorbed By Water, Q = m x Cp x $\Delta T/\Delta t$ = 4.53 J/s
- Heat recovery achieved, Q = Heat Absorbed by Water = 4.53 W
- Refrigerator cooling capacity = 160.00 W
- Power required for running the compressor = Work done on refrigerant = 130 W

➢ COP actual = $\dfrac{\text{Heat extracted}}{\text{Work done by compressor}}$

$$= \frac{160.00}{130.00}$$

= 1.23

➢ Waste heat of condenser is utilized to heating hot box which is the part of System work. Hence COP of system will improve.

COP improved = $\dfrac{\textit{Heat extracted in refrigeration}}{\text{Work done by compressor - Heat recovery achieved}}$

$$= \frac{160}{130-4.53}$$

= 1.28

Improvement (%) in COP =

$$\frac{(\text{COP improved} - \text{COP actual})\times 100}{\text{COP actual}}$$

$$= \frac{(1.28 - 1.23)\times 100}{1.23}$$

= 4.1 %

6. CONCLUSIONS

- This innovative approach has the potential to improve the overall efficiency of domestic refrigeration systems and contribute to energy conservation by harnessing otherwise wasted heat energy.
- The experimental analysis conducted in this study revealed that the proposed system could generate temperatures of around 35°C-40°C in the hot box.
- The graph illustrating temperature variations over time provided valuable insights into the system's performance.
- Calculations to determine the coefficient of performance (COP) of the system indicated an approximate 4.1% increase in efficiency. This improvement in COP implies reduced energy consumption and enhanced energy utilization.
- The findings of this research support the notion that utilizing waste heat from domestic refrigerators for hot and cold storage is a promising approach with potential benefits for energy efficiency and conservation.

DRAWBACK OF THE SYSTEM:

• The temperature inside the hot box is dependent on the operation of the refrigerator, which can limit the control and stability of the hot storage environment.

7. RESULTS

- Thus, we have experimentally proved that the COP or the efficiency of the domestic refrigerator is increased by incorporating a waste heat recovery system.
- An increase of 4.1% is obtained in the COP of the refrigerator corresponding to a 5^{o} rise in the temperature of water.

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