Experimental Investigation of Waste Heat Recovery System for Domestic Refrigerator

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Abstract: The heat is a type of energy, so energy saving is the main aim to everyone at this condition and to protect global warming and environment and save the life which is stay on earth. Waste heat is release from different sources which affect on environment leads to increase the global warming and ozone layer deflection. So it is essential to recover this waste heat in any form. Air cooled condenser used for commercial purposes. In this system, heat is removed by the condenser. This heat is generally exhausted to the atmosphere. This exhausted heat can be utilized for different applications such as heating of water, snack drying, drying of cotton in minimum constructional and running cost. We modified the refrigerator with capacity 165 litre. A insulated box is fitted on a top of refrigerator. The coil is surrounded inside the box to recover the waste heat. The temperature in the box is varied with time. Our modified system is safer than regular system.

IndexTerms **- Eco friendly, cost effective, global warming, waste heat recovery.**

I. INTRODUCTION

Refrigeration is a procedure of expelling heat starting with one area then onto the next. The heat transfer is determined by mechanical work, but can likewise be driven by heat, power, laser, or different means. Refrigeration has numerous applications, including, yet not constrained to domestic refrigerators, mechanical coolers, cryogenics, and air conditioning .Heat pumps may utilize as heat output7 of the refrigeration process, and furthermore might be intended to be reversible, however are generally like refrigeration units. Refrigeration has largely affected industry, way of life, agriculture and settlement designs. Preserving food stuffs goes back to the ancient Roman and Chinese. In any case, refrigeration innovation has quickly developed in the most recent century, from ice harvesting to temperature-controlled rail autos. The introduction of refrigerated rail autos added toward the westward expansion of the US, permitting settlement in zones that were not on principle transport channels such as streams, harbors, or valley trails. In most developed nations, urban areas are largely reliant upon refrigeration in general stores, in order to obtain their food stuff for every day utilization. The increment in nourishment sources has prompted a bigger centralization of agricultural sales originating from a littler level of existing farms. Homesteads today have a substantially bigger output for each individual in comparison with the late 1800s. This has brought about new sustenance sources accessible to whole populations, which has largely affected the nourishment of society.

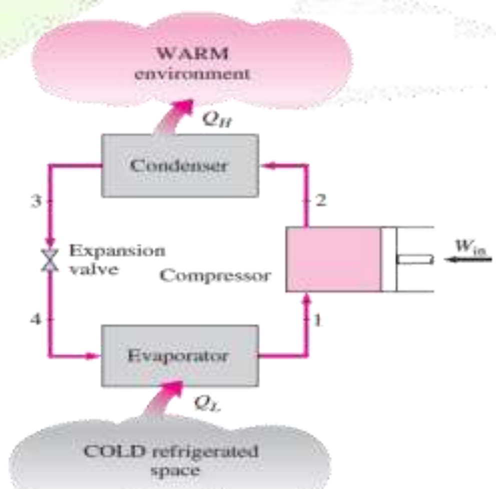

Fig.1 Schematic Diagram for ideal vapour compression refrigeration cycle

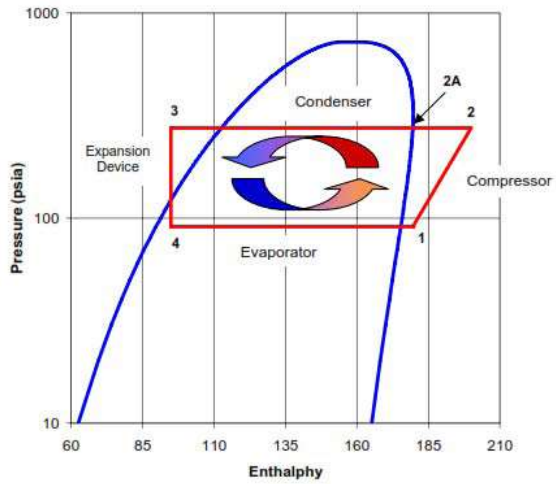

Fig 2 Pressure Enthalpy Curve

II. LITERATURE REVIEW

LAKSHYA SONI: He developed system which rejects less heat to environment. So it is safer in environmental aspects and runs at normal conditions. They fixed the insulated cabin on the top of refrigerator which contains copper coils and hot water sink. The temperature of the refrigerant is increased. The cooling of this refrigerant is done by water sprinkles on containers. These water drops are collected in hot water sink.

G.G. MOMIN: He modified the domestic refrigerator to increase the COP. He utilized waste heat of condenser to the water in the water storage tank. There is increase in water temperature up to 60°C. It can see framework while working under full load condition gives a superior COP when contrasted with no load condition. In this way more ideal and productive framework can be worked to give better outcomes.

TANAJI SHINDE: Domestic refrigerator runs continuously to the preservation of food. The warmth is rejected from condenser is of low quality .He investigate that the raising the consolidating strain to accomplish the higher nature of waste warmth. While the framework is working on full load condition it gives higher cop when contrasted with when no load condition. The temp difference between the water inlet and outlet is 10 centigrade obtained.

S.C.WALWADE: An attempt is to made to recover the waste heat from the 165 liters domestic refrigerator. This heat can be used for number of domestic and industrial purposes in minimum running cost. This recovered heat can be utilized for food and snacks warmer, grain dryer and water heater. An endeavor has been made to use squander warm from condenser of icebox. In least constructional, support and running expense, explored a WHRS and tested to recuperate buildup warm from domestic cooler.

P.ELUMALI: In this system, hot box is placed in between the components of vapor compression refrigeration system. By using this setup, waste heat is recovered. The temperature is increased inside the hot box. The temperature of box varies with time. He recognizes that the maximum waste heat which is emitted to the atmosphere is utilized. In this system utilized the maximum heat by using oven and heating water. By using this system power consumption in house for heating food items is reduced.

N.B.CHAUDHARI: In this system study on thermos siphon heat recovery system. Utilization of heat for heating the water for residential and commercial use. This system eliminates the need of pump. The quantity of heat recovered by the condenser was theoretically calculated. It is in the range 375 watt to 407 watt. This is totally depending on a rate of water circulation.

PATIL AND DONGE: Modify the domestic refrigerator to recover the waste heat from condenser. It can introduce the water tank containing the condenser coil of the residential refrigerator. It expands the temperature up to 40 centigrade. But the main drawback is that it has no mobility.

ROMDHANE B. SHARMA: Develop a system in which the air cooled condenser is replaced by heat exchanger to heat the water. This system increases the temperature up to 60 centigrade. This paper also analyzed the economic important of power saving.

III. SYSTEM DESIGN AND DESCRIPTION

In the proposed framework we can utilize the heat from the condenser of the domestic refrigerator which is running at normal condition. In that the insulated cabin is fitted at the top of the refrigerator.

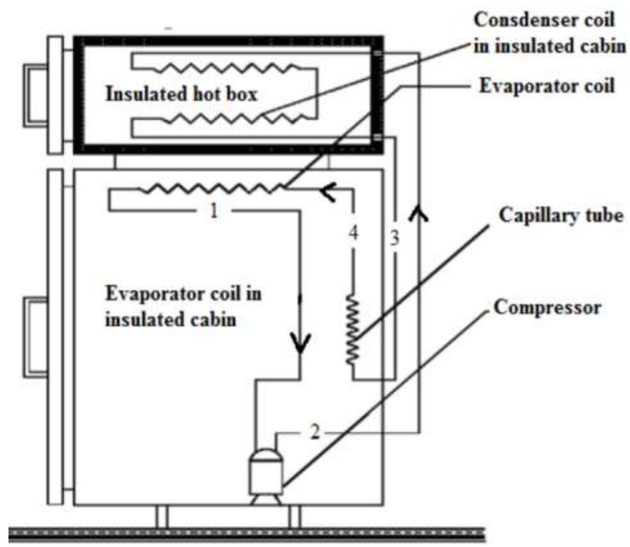

Fig 3 Proposed Setup

The copper coils are wounded in the insulated box. The design and construction of the insulated box is simple and with fair cost. After completing the process the temperature and pressure of the refrigerator (R134a) increases. This high temperature refrigerant is passed to the condenser coil which is mounted on the insulated box. Due to the refrigerant released the heat in the insulated box, the temperature inside the box will high and the space get warmed.

Various parameters of domestic refrigeration system used for experiment are as follows:

Capacity in Liter: 165

Power Rating: Single phase 220-240 volt, 50 Hz , A.C. supply . 220 W

Refrigerant type: 134 A (CF3CH2F)

Condenser: External, Finned Air cooled

Type of compressor: Reciprocating type

Capacity of compressor: 1/8HP

Atmospheric temperature during experiment: 33 °C

Pressure parameters were estimated utilizing pressure gauge and Temperature parameters were estimated utilizing computerized or digital thermometer. Temperature variation as for time in the proposed system is additionally estimated and classified.

IV. FABRICATION AND ASSEMBLY WORK

Since the idea gives brief thought regarding using waste heat at household level, thus we have chosen to utilize a "Godrej" second hand working household refrigerator of limit 165 litres. Parts of domestic fridge are Compressor, Air cooled Condenser, Capillary Tube, Plate write Evaporator and Insulated cabin. The protected insulated cabin is a fridge part which is used for utilizing the waste heat from domestic refrigerator. This insulated cabin is created by utilizing galvanized iron sheets.

Firstly remove the refrigerant from the system and cut the condenser coil. Then take thermocole box whose outside dimension are 53×40×41 centimeter and thickness of 3 centimeters. This box is fixed at the top of the refrigerator by using special glues. Condenser coil placed in the insulated cabin. The inlet port of the condenser coil is welded to the compressor outlet port and another port is welded to the expansion valve by using gas welding. At last the gas charging is done with refrigerant R134a.

V. EQUIPMENTS WITH SPECIFICATION

Table 1: Equipment's with Specifications

Sr. No	Equipment	Type/Material	Specification/Capacity	Manufacturer
1	<u>Refrigerator</u> ➢ Compressor ➢ Condenser ➢ Evaporator	Domestic type Hermetically sealed Copper, air cooled Plate type	165 liters 1/8th HP No of Tubes -18	Godrej Kirloskar Kirloskar Roll bond
2	<u>Refrigerant</u>	R134A	450g	Godrej Smart care
3	<u>Insulated Cabin</u> ➢ Outer box ➢ Inner box ➢ Insulation	Galvanized Iron Galvanized Iron Galvanized Iron Thermocole	 53×40×41 cm 47×34×35 cm Thickness 3 cm	

VI. ACTUAL SETUP

Fig 4 Actual Proposed System

Fig 5 Insulated Box with condensor coils

VII. COEFFICIENT OF PERFORMANCE OF REFRIGERATOR

Actual COP of the system is based on theoretical data

For refrigerator of 165 liters capacity, given data from kirloskar Ltd manual follows:

Refrigerator cooling capacity (amount of refrigeration produced or heat extracted in refrigerator)

= 76 Kcal/ hr.

$$= \frac{76 \times 4.187 \times 1000}{3600}$$

= 88.392 watt

Power required running the compressor (work done on refrigerant)

= 1/8 HP

= 1/8×746

= 93.25 W

The coefficient of performance (COP) is the ratio of heat extracted in the refrigerator to the work done on refrigerant,

$$COP_{actual} = \frac{\text{Heat extracted in refrigerator}}{\text{Work done by compressor}}$$

$$= \frac{88.392}{93.25}$$

= 0.948

The main point is to expand the COP of system by using energy. At the point when the condenser heat is used, COP of system will boost up.

Examinations are directed by taking readings as follows.

A stainless steel plate is loaded with known amount of water is put inside the cabin and temperatures are noted after particular interval of time.

VIII. OBSERVATION TABLE

Table 2: Observation readings

Time (mins)	Temp of water (℃)
0	26.03
15	31.01
25	35.6
35	39.0
45	41.3
55	42.8
65	43.7
75	44.2

IX. TIME TEMPERATURE GRAPH

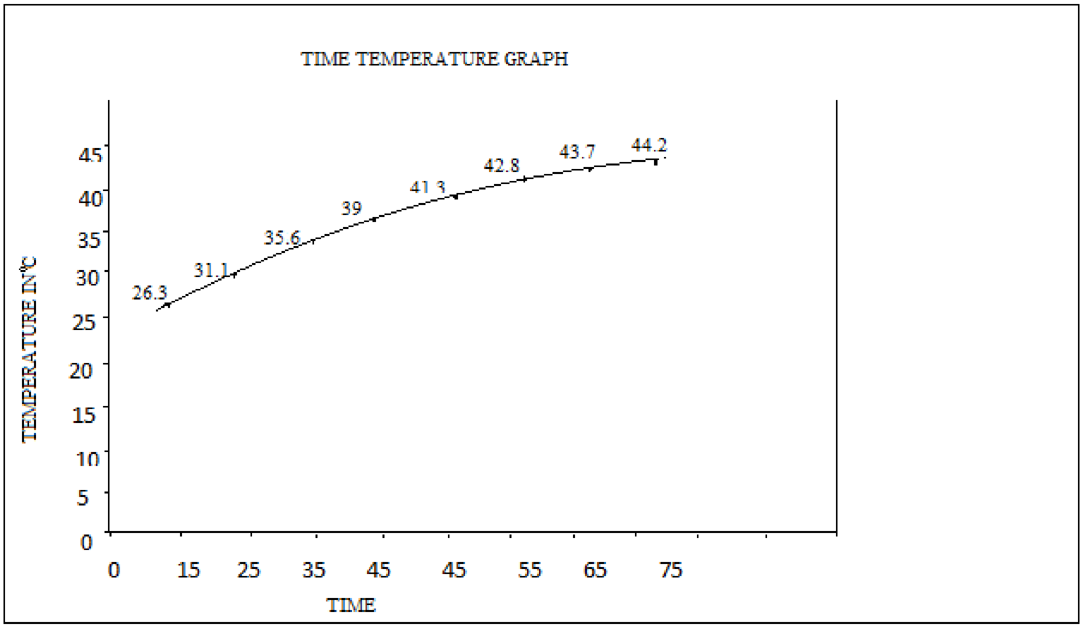

Fig 6 Time Temperature Graph

X. CALCULATIONS FOR INCREASED RATE OF WASTE HEAT

Heat recovery achieved, Q = Heat absorbed by water

Given data-

Mass of water in plate, m = 500 gm. = 0.500 kg

Specific heat of water, C_p = 4.187 KJ/KG K

Initial temperature of water = 26.3 ℃

Final temperature of water = 44.2 ℃

$$Q = \frac{m \times Cp \times \Delta T}{\Delta t}$$

$$= \frac{0.500 \times 4.187 \times 17.9}{75 \times 60}$$

= 8.32 J/S

Heat recovery achieved, Q = Heat absorbed by water

=8.32 W

Improvement in COP

Condenser heat is utilized, which is the part of compressor work. The denominator will reduce in value. Hence Cop of the system will improve.

$$\text{COP}_{\text{improved}} = \frac{\text{Heat extraced in refrigeration}}{\text{Work done by compressor} - \text{Heat recovery achieved}}$$

$$= \frac{88.392}{93.25 - 8.32}$$

$$= 1.0346$$

$$\text{Improvement in COP} = \frac{\text{COP}_{\text{Improved}} - \text{COP}_{\text{Actual}}}{\text{COP}_{\text{Improved}}} \times 100$$

$$= \frac{1.0346 - 0.948}{0.948}$$

$$= 9.135\ \%$$

XI. RESULTS AND DISCUSSION

The coefficient of performance (COP) is the proportion of heat extracted in fridge to the work done on refrigerant. Readings of temperatures of evaporator, condenser, and protected hot box are taken for time interval of 10 minute. COP for every perusing are as follows.

COP actual = Heat extracted in fridge/Work done by compressor.

COP of waste heat recovery = Heat extracted in fridge (Work done by compressor - Waste heat recovery accomplished)

It is watched that COP of domestic fridge was 0.948 without waste heat recovery and 9.135 after waste heat recovery through hot protected box. So from counts COP enhanced by 8.187 %.

XII. CONCLUSION

"Waste heat recovery system" is an amazing device to save accessible energy. An attempt is made to recover the waste heat from 165 L fridge utilized for conventional reason. As listed in this paper, recovered heat can be used as food and snacks hotter, water heater, grain dryer. So one can save part of time and energy too.

The study gives following conclusions:

1. Suitable heat waste recovery system can be designed and produced for each family unit fridge.

2. The experimentation has demonstrated that such a system is practically feasible.

3. Technical investigation has demonstrated that it is economically suitable.

4. If this can be begun from singular level then it can sum up and enormous effect can be acquired. In this way with little addition in cost in system, if we recover and reuse the waste heat, we can advance towards energy conservation and simultaneously accomplish our day today work.

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