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Design &Analysis of Waste Heat Recovery System for Domestic Refrigerator

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Abstract: *Heat is energy, so energy saving is one of the key matters from view point of fuel consumption and for the protection of global environment. So it is necessary that a significant and concrete effort should be made for conserving energy through waste heat recovery too. The main objective of this paper is to study "Waste Heat recovery system for domestic refrigerator". An attempt has been made to utilize waste heat from condenser of refrigerator. This heat can be used for number of domestic and industrial purposes. In minimum constructional, maintenance and running cost, this system is much useful for domestic purpose. It is valuable alternative approach to improve overall efficiency and reuse the waste heat. The study has shown that such a system is technically feasible and economically viable.*

Keywords: *Waste heat recovery, 165 liter Domestic refrigerator, COP of refrigerator, Refrigerating effect.*

I. Introduction

Waste heat is generally the energy associated with the waste streams of air, gases and liquids that leaves the boundary of the system and enter into environment. 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 purposes in an economic manner. The essential quality of heat is not the amount but its value. Waste heat recovery and utilization is the process of capturing and reusing waste heat for useful purposes. Not all waste heat is practically recoverable. The strategy of how to recover this heat depends on the temperature of the waste heat sources and on the economics involves behind the technology incorporated.

Cooling generates considerable quantities of heat. If not utilized, this energy simply becomes waste heat. The cooling may be for the process cooling, air conditioning or other use. Thus all the heat removed from the process, plus most of the energy added by the compressor and ancillary pumps, is rejected to the local environment. This rejected heat can often be economically recovered and be used instead of heat generated from fossil fuels. While there is a cost in running the refrigeration plant, this heat is effectively close to 'free'.

Stinson et al. [1] conducted research in dairy refrigeration by recovering the heat from condenser. They found out that by using the water cooled condenser COP of the system is enhanced by 10% to 18%. They also found that increase in condenser pressure reduces COP, and inclusion of heat recovery heat exchanger reduces head loss. Rane et al. [2] developed sensible heat recovery unit and carried out experiments. Waste heat recovered is utilized for water heating. Their findings are: (i) chiller cooling capacity enhanced by 30% and COP by 20%.Kulkarni,Barve [3] *discussed in studies on* to heat water by recovering the heat released on the level of the condenser of the cooling systems such as refrigerator, air-conditioner, cold room etc.They have also shown that such a system is economically viable. Energy consumption by the system and environmental pollution can still further be reduced by designing and employing energy saving equipments. F.N.Yu, K.T.Chan [4] discussed the improved condenser design for air cooled chillers.

II. System Description and Design

The present work was with the aim to recover and utilize waste heat from the domestic refrigerator which as such is let off to the surrounding through its surface condenser. To assess the viability of this concept a very common house hold appliance known as hot case was selected and its energisation is replaced from high quality electrical power to low grade waste heat of hot refrigerant vapors keeping in view the likelihood of more effective cooling of high pressure hot refrigerant vapors from the compressor.For that purpose some calculations are made regarding size and length of condenser and then WHRS is designed. But after different discussions and calculations for heat transfer rates we approached to the final design of insulated cabin with compact construction and with reasonable cost. So as to extract more and more heat, we have mounted a hot case on top, left and right side of refrigerator. The main advantage of this design is that we can get maximum heat with minimum losses.

2.1 Fabrication and assembly work:-

2.1.1 Major equipments and parts:-

Since the concept gives brief idea about utilizing waste heat at domestic level, hence we have decided to use a "GODREDE" second hand working domestic refrigerator of capacity 165 liters. Parts of domestic refrigerator are as follows. Compressor, Modified Air cooled Condenser, Capillary Tube, Plate type Evaporator & Insulated Cabin. The insulated cabin is a peripheral component which is used for utilizing the waste heat from refrigerator. This insulated cabin is fabricated by using galvanized iron sheets.

Table 2.1: Equipments with Specifications

SR.NO	Equipment	Type/ Material	Specification/ Capacity	Manufacturer
1	Refrigerator a. Compressor b. Condenser c. Evaporator	Domestic Type 2 Hermetically sealed Water cooled Plate type	165 Liters 1/8th HP No. of Tubes – 18	Godrej Kirloskar Kirloskar \ Roll bond
2	Refrigerant	CCl_2F_2	110 gms	Innotech technology
3	Insulated Cabin 1.on both side of refrigerator 2.on top of the refrigerator 3 Insulation	Galvanized Iron Galvanized Iron Thermocole	(70cmX35cmX2cm)X 2 =9.8 liters =1.2 liters Thickness:- 3.50cm	-----------------
4	Energy Meter	DJ01 A.C.1 Phase 2 wire static kwh meter	Rating:5-30 Amp 240 V. 50Hz	U.G. Jaipur Industries (India)
5	Temperature Indicator	Multipoint Temp. detector	Power: 230 VAC .50 Hz Input:RTD-PT100 x4 NO Range:-25 to 100 ^{0}c	Kristech solution ltd ,pune

1.1.2..Experimental Setup:

Figure shows the assembly and the connection of the hot case, energy meter, temperature detector with the refrigerator.

III. EXPERIMENTAL RESULT AND ANALYSIS

3.1.1Actual COP of System Based On Theoretical Data

For Refrigerator of 165 liters capacity, given data from Kirloskar Ltd manual follows-
Refrigerator cooling capacity:(PROVIDED BY GODREJ)

=76 kcal/hr

= 76×4.187×1000/3600 = 88.392 W

Power required running the compressor

= 1/8 HP

= 1/8×746 = 93.25 W

The coefficient of performance (COP) :

$$= \frac{\text{Refrigeration effect}}{\text{Work supplied}}$$

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

= 0.958

3.1.2 Practical Cop of System

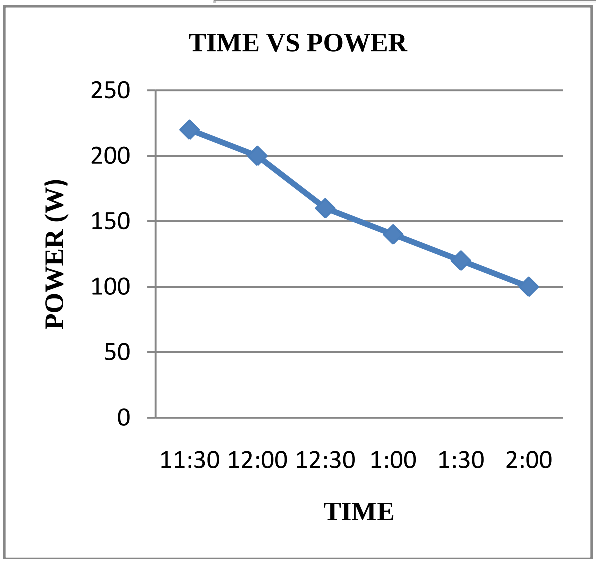
Pot filled with known quantity of water is put inside evaporator and main cabin and outide compartment and temperatures are noted after specific interval of time. By following above procedure, observations are noted and time V_s temperature and COP graphs are plotted.

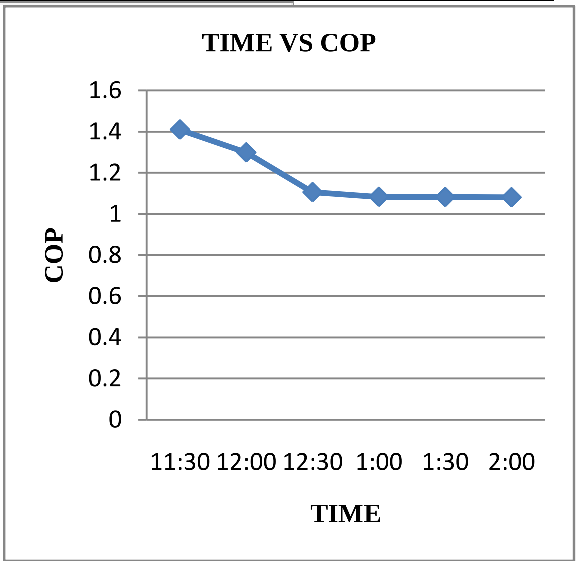
3.1.2.1. Refrigerator with Hot Case

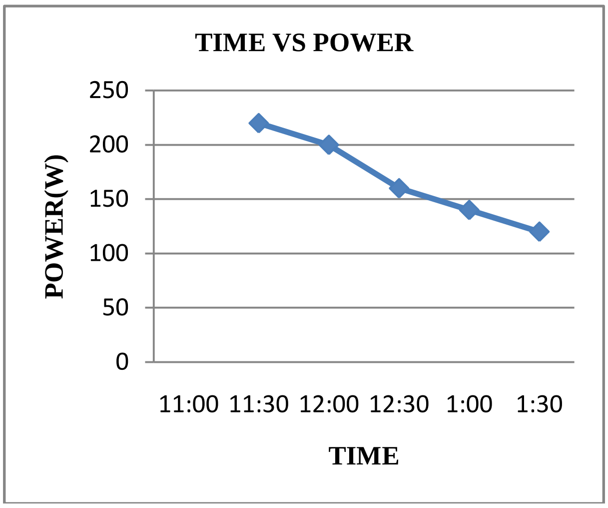
Sr. No	Time	Energy Meter reading K.W.Hr.	Power watts	Temp. of water in evapora-tor ⁰C	Temp . of water in main cabin ⁰C	Temp of water in outside cabin ⁰c	Refrigerating effect in evaporator (watt)	Refrigeratin g effect in main cabin watts	Total refrigeration effect watts	C.O.P
1	11:00	12.50	-------	34	34	34	-----------	-----------	-----------	--------
2	11:30	12.61	220	20	28	36	97.53	309	306.53	1.410
3	12:00	12.70	200	05	24	39	104.5	139.33	243.63	1.299
4	12:30	12.78	160	00	20	40.9	36.83	139.33	176.16	1.106
5	01:00	12.85	140	-5.3	16.7	45.7	36.92	114.05	150.97	1.083
6	01:30	12.91	120	-8.3	13.6	48.6	22.99	107.3	130.2	1.082
7	02:00	12.96	100	-11.0	11.2	50.6	18.81	90.086	108.89	1.081

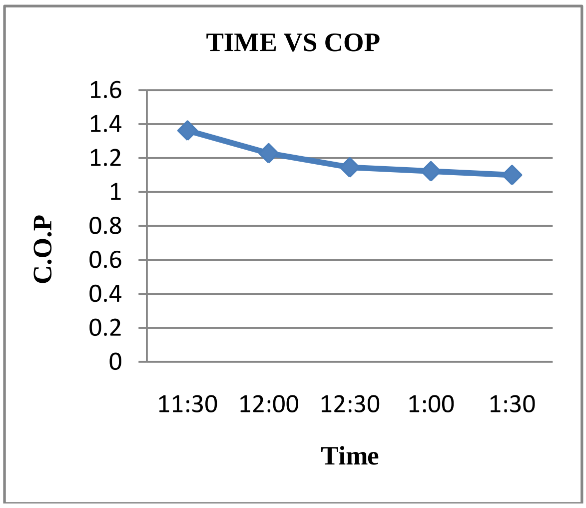
3.1.2.2. Refrigerator without Hot Case

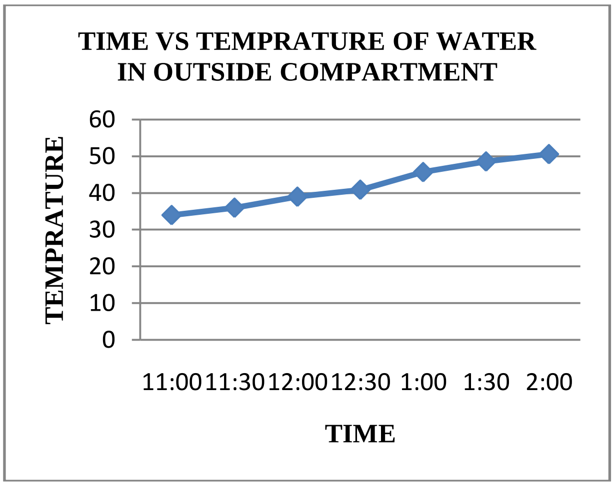
Sr. No	Time	Energy Meter reading K.W.Hr .	Power watts	Temp. of water in evapor a-tor ⁰C	Temp . of water in main cabin ⁰C	Temp of water in outside cabin ⁰c	Refrigeratin g effect in evaporator (watt)	Refrigeratin g effect in main cabin watts	Total refrigeratio n effect watts	C.O.P
1	11:00	17.14	-------	34	34	------------	-------------	-----------	-----------	-------
2	11:30	17.26	220	19	28.5	------------	104.12	209.4	313.16	1.363
3	12:00	17.37	200	09	23.1	------------	69.66	188.1	257.76	1.229
4	12:30	17.46	160	0	17.3	------------	34.83	160.23	195.06	1.146
5	01:00	17.53	140	-4	13.6	------------	28.86	128.88	157.74	1.123
6	01:30	17.59	120	-8.3	10.9	------------	28.56	96.04	124.60	1.101











IV. CONCLUSION

From the results tabulated it can be concluded that with time the energy consumption of the refrigerator decreases for certain time and then it remain constant.The refrigerating effect keeps decreasing as the temperature difference between the refrigerant and article placed Is decreased.The C.O.P. remains almost constant though it decreases a little bit.

With hot case, as if we add up heating effect in desired effect, then the c.o.p. is increased also otherwise it is almost little bit more than the unit with the hot case.

Thus the hot case has not bad effect on the refrigerator. Here with use of hot case, we can keep some food stuff, is hot condition, also temperature of food/milk, etc can be increased without change in taste, so amount of electrical energy used for hot case, as in case of conventional system, can be saved.

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