Review Study of Waste Heat Recovery using Refrigeration System

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Abstract

Energy crisis all over the world compelled us to take necessary steps to reduce energy consumption. Heat is energy, so energy saving is one of the key matters from view point of use of refrigerants and for the protection of global environment This waste heat will affect the environmental conditions because as heat in the environment will increases it will cause global warming and also not good for our ozone layer too. By saving energy we balance the demand & supply of electricity. So it is necessary that a significant and concrete effort should be made for conserving energy through waste heat recovery system. We have tried to make a cabinet to recover waste heat from condenser from refrigeration system by storing a heat in an insulated cabinet. This heat can be used for number of domestic and industrial purposes. In minimum constructional, maintenance and running cost, this system is more useful for domestic purpose. Basically domestic refrigerator is used to store perishable goods like vegetables, fruits, milk and other beverages etc. All domestic refrigerators use air cooled finned condenser on backside. As domestic refrigerators reject large heat inside room which make us uncomfortable in summer due to temperature rise inside the room. So it is now essential to store this heat inside an insulated cabinet to utilize it for different purposes. Stored heat is used for keeping food hot, heating water which may be used for different purposes.

Keywords- Waste Heat Recovery, Vapour Compression System, Refrigerator, Air Cooled Condenser, Saving Energy

I. INTRODUCTION

Whenever a temperature gradient exists within a system, or whenever two systems at different temperatures are brought into contact, energy is transferred. The process by which the energy transport takes place is known as heat transfer. All heat transfer processes involve the exchange and/or conversion of energy. They must, therefore, obey the first as well as the second law of thermodynamics. Heat transfer is a basic and very important topic that deals with energy and has long been an essential part of mechanical engineering curricula all over the world. Heat transfer processes are encountered in a large number of engineering applicatio0ns such as heat recovery systems. It is essential for mechanical engineers to understand the principles of thermodynamics and heat transfer and be able to use right equation that govern the amount of energy being transferred. By retro fitting a waste heat recovery system this waste heat can be recovered and can be utilised for water heating purpose. The hot water thereby produced can be used for several residential and commercial usages. The hot water can also be stored in a tank for later use. The modified system results in energy saving due to non-usage of electricity for heating the water and cost saving by combining both utilities (refrigeration and heating) in one system.

The aim of this study is to design, construct and evaluate dual refrigeration system by manufacturing an experimental apparatus of heat recovery system from the condenser and evaporator. Although studies have been done before on dual refrigeration systems, more research could be done to further enhance the results obtained by experimenting using different sets of working pair's material and testing them in different conditions and shape and sizes. For example, in experimentation with waste heat recovery system (WHRS) in refrigeration unit, Kaushik and Singh in 2015 have found that 40% of condenser heat can be recovered through the Canopus heat exchanger for typical set of operating conditions in a dual refrigeration system [r1]. To generate ice, the evaporator temperature must be< 0 oc. The above system could generate a COP of about 1.2 to 1.4 and in this study the aim of maintaining the COP more than or equal to 1. The main aim is to increase the COP of system by utilizing energy. When the condenser heat is utilized, COP of system will boost up [r2].

While eating food in colleges/office every buddy need water cold and Tiffin hot, but we are not gating it. In offices we usually use microwave for heating food, for that we are using electricity i.e. heat energy, similarly for cooling water we are using refrigerator of water cooler in that case we are wasting heat energy from condenser. For both microwave and condenser we are paying electricity. We also have to find what temperature can be generating in the condenser and evaporator so that which foods

can be warmed or cooled in the system. This study proves to utilize a combined system rather than a single system, where cooling and heating could be produced continuously in places far away from conventional grid. Most rural and urban area may benefit from this system in years to come.

II. ENERGY CONSERVATION IN REFRIGERATOR

A household refrigerator is a common household appliance that consists of a thermally insulated compartment and which when works, transfers heat from the inside of the compartment to its external environment so that the inside of the thermally insulated compartment is cooled to a temperature below the ambient temperature of the room. In most cases, household refrigerator uses air-cooled condenser. Tetrafluoroethane (HFC134a) refrigerant was now widely used in most of the domestic refrigerators and automobile air- conditioners and are using POE oil as the conventional lubricant. Generally, heat from the condenser side is dissipated to room air. If this heat is not utilised, it simply becomes waste heat [r5]. Refrigerator has become an essential commodity rather than need. Very few of us are aware about the fact that lot of heat is wasted to ambient by the condenser of refrigerator. If this energy can be utilized effectively then it will be an added advantage of commodity our project aims towards the same goal. Refrigerator in simple language is removal of heat from the place where it is objectionable and dissipation of heat to the place where it is not objectionable. The working process of the refrigerator is explained as below. The systematic diagram of the refrigerator and its various parts is as shown below:-

A. Compressor

The compressor is the heart of the refrigerator. The input power that is electricity is used to run the compressor. The compressor compresses the refrigerant(R-12 or R-22) which is in the gaseous form to increase its pressure and temperature. The capacity(tons) of the refrigerator decides the power input to the compressor.

B. Condenser

The main purpose of condenser is to transfer the heat generated in refrigerant during the compression process. The temperature of the refrigerant entering in condenser is about 400-600c depending input power of compressor. The atmospheric temperature is about 250-300c. Due to such large temperature difference heat transfer takes place from condenser to atmosphere. That means this heat is wasted to atmosphere.

C. Expansion Tube /Valve

A capillary tube (small bore copper tube) is used to reduce pressure of refrigerant from condenser to evaporator pressure.

D. Evaporator

This part is placed at the freezer compartment. The working is same as the condenser. The refrigerant boiling in the evaporator tubes takes latent heat from surrounding and in turn cools the space.

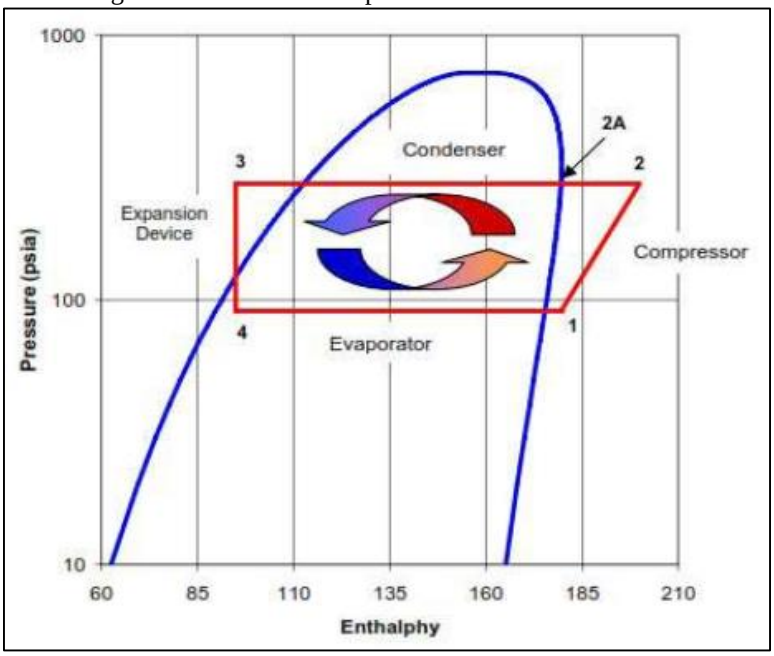

Fig. 1: Representation of Vapour Compression Cycle

III. LITERATURE REVIEW

That waste heat will be used in two applications:

A. Waste Heat Recovery System in the Application of Water Heating

Romdhane ben slama: Developed a system that can recover heat from the condenser of the refrigerator. In this work air-cooled conventional condenser is replaced by another heat exchanger to heat water. The results show that water at a temperature of 60ºC was produced by the system. This paper also analyzed the economic importance of the waste heat recovery system from the energy saving point of view.

Shinde, V. Dhanal: presented a case study on Super Heat Recovery Water and It can be concluded that the system while operating under full load condition gives a better COP as compared to no load condition. Hence if the system continuously operates under full load, the COP can be improved. The heat absorbed by water has been observed to be highest during full load. The heat recovery technique, which can be applied to a refrigeration system, provides a compound air-cooling and water-cooling. The use of heat recovery system illustrates the improvement in COP and also the reduction in power consumption. The temperature difference obtained between the water inlet and outlet exceeds 10 0C. Thus a more optimum and efficient system can be built to give better results. The heat recovery module can thus be used in various refrigeration applications as well as in air conditioning [r6].

Patil and Dange: modified a domestic 190 liter refrigerator to recover the waste heat by installing a water tank containing the condenser coils of refrigerator. Experiment showed that maximum temperature increment was up to 40 degree centigrade. But major drawback with this type of arrangement was that it had no mobility and cannot be used for domestic purposes.

N. B. Chaudhari: discussed Heat Recovery System from the Condenser of a Refrigerator. The quantity of heat to be recovered from the condenser of a domestic refrigerator was theoretically calculated. It is in the range 375 Watt to 407 Watt. The quantity of heat recovered from the condenser of a domestic refrigerator I is found experimentally and found as 202 Watt to 410. This depends on the flow rate of water circulated. In this case the water flow rate range is wide. Therefore, there is a wide variation in the results. In this article, they experimented by utilizing real life applications such as using waste heat from a condenser of a refrigerator to heat water for residential and commercial use. Heat recovery from condenser of a refrigerator by thermo-siphon system is attractive because it eliminates the need of a circulating pump. Heat recovery system in chaudhari experiment was in this manner: An apparatus for recovering waste heat from conventional refrigerating systems in which a heat exchanger is connected between the compressor and condenser to transfer heat to water pumped there through. The heated water is stored n a small holding tank and transferred to a larger water storage tank when hot water is withdrawn from the larger tank. The design, construction, and testing of an integrated heat recovery system which has been designed both to enhance the performance of a residential refrigerator and simultaneously to provide preheated water R an electric hot water heater. A commercial, indirect – heated HT water tank was retrofitted with suitable tubing to permit it to serve as water cooled condenser for a residential refrigerator. This condenser operates in parallel with the air- cooled condenser tubing of the refrigerator so that either one or the other is active when the refrigerator is running. The refrigerator was housed in a controlled environment chamber, and it was instrumented so that its performance could be monitored carefully in conjunction with the water pre-heating system. The system H been tested under a variety of hot after usage protocols and the resulting data set has provided significant insight into issues associated with commercial implementation of the concept. [r7]

B. Waste Heat Recovery System in the Application of Air Heating

S.C. Walawade: et al presents an attempt is made to recover the waste heat from 165 L refrigerator used for domestic purpose. As indicated in this paper, recovered heat can be utilized as food and snacks warmer, water heater, grain dryer. In the proposed system, the basic requirement is to utilize more and more energy (waste heat). 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 two sections of air cooled condenser one at bottom and one at top side of the insulated cabin. This whole assembly is placed on the top of the refrigerator. The main advantage of this design is that we can get maximum heat with minimum losses [r2].

P. Elumalai: recovered waste heat from condenser unit of a household refrigerator to improve the performance of the system by using a thermo siphon. As we can see the schematic diagram in Fig No: 4 it was found that after recovering heat from the condenser of the conventional refrigerator, its performance was improved than conventional refrigerator. The following experimental facility has been created. Highly insulated hot oven box and heater vessel with 5 litre capacity is installed in the compressor outlet. The control of water inlet to the heater vessel is done by float valve attached inside the chamber. The high pressure high temperature vapour refrigerant is made to pass through the copper tube which is coiled inside the hot oven and heater chamber. The copper tube is highly insulated outside the oven and heater with asbestos rope. Oven box is also fully insulated with foam or fiber wool to prevent loss of heat to atmosphere. By this the heat of the refrigerant is emitted only inside the hot oven and heater chamber and the waste heat is recovered and utilised for useful purpose [r1].

Lakshya Soni, Pawan Kumar, Rahul Goyal: The experiment has shown that such a system is technically feasible and economically viable. This system rejected less heat to the environment so it is safer in environmental aspects. This is a system having the refrigerator that is running at normal running condition. And an insulate cabin over it that contains the copper coils and

hot water sink. That cabin is a main part of the setup. Exhaust hot gas (134a) from the compressor is make pass through the quarter inches copper coil, which coil is fitted in the cabin and after being cool the gas is again returned to the compressor. This cooling is done directly by water in the form of water sprinkles from the water container that is at the top of the cabin, and that hot water is dropped and collected in the hot water sink and that sink have an exit nipple so we can get the water outside the cabin as per requirement [r4].

Sreejith K., T.R. Sreesastha: Ram they had designed fabricated and experimentally analysed a waste heat recovery system for domestic refrigerator. They had analysed the system at various load conditions (No load, 40 W load and 100W load). They also carried out the techno-economic analysis by comparing the waste heat recovery system with the conventional geyser. The refrigerator was of 165L capacity, single door, manufactured by Godrej. The system was retrofitted with a Waste Heat Recovery System (WHRS). WHRS is a single tube heat exchanger coiled around and over the air-cooled condenser and compressor and having an inlet for the cooling water and an exit for collecting the hot water. The modified household refrigerator was properly instrumented with digital thermometer, pressure gauges and digital energy meter [r5].

Table 1: Consolidated Tabulated Literature Review

SRNo	*Name of the Authors*	*Title*	*Journal /Vol/Issue*	*Research Methodology*	*Overall Conclusion*
1	*1. P. Sarat Babu, 2.Prof.N.HariBabu*	*Experimental Study of Domestic Refrigerator/Freezer Using Variable Condenser Length*	*International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 12, Dec 2013*	*In this experimental work, it is proposed to optimize condenser length for domestic refrigerator of 165 liters capacity. It may give a chance to find a different length other than existing length will give better performance and concluded that the optimum length of coil is 7.01m*	*Hence experimental investigations are the best in terms of optimization of certain design parameters*
2	*1. S. C. Walawade 2. B.R. Barve, 3. P. R. Kulkarni*	*Design& Development of WHR System for Domestic Refrigerator*	*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684,PP: 28-32,June 2014*	*An attempt has been made to utilize waste heat from condenser of refrigerator. In minimum constructional, maintenance and running cost, investigated a WHRS and experimented to recover condensation heat from domestic refrigerator of 165 liter.*	*This system is much useful for domestic purpose. Recovered heat can be utilized as food and snacks warmer, water heater, grain dryer. Technical analysis has shown that it is economically viable.*
3	*1.Tanaji Shinde, 2. Shailendra. V. Dhanal, 3. Shirish S. Mane*	*Experimental Investigation Of Waste Heat Recovery System For Domestic Refrigerator*	*IAEME, Volume 5, Issue 8, pp. 73-83, August 2014*	*Fabrication, Experimentation and performance evaluation of Waste Heat Recovery System under the following test conditions, 1)Refrigerator 2) Refrigerator-cum-Water Heater*	*It can seen system while operating under full load condition gives a better COP as compared to no load condition. Thus more optimum and efficient system can be built to give better results.*
4	*1. N. B.Chaudhari, 2. P. N. Chaudhar*	*Heat Recovery System from the Condenser of a Refrigerator – an Experimental Analysis*	*IJTARME, ISSN (Print): 2319-3182, Volume -4, Issue-2, April 2015*	*Heat transfer processes by utilizing real life applications such as using waste heat from a condenser of a refrigerator to heat water for residential and commercial use. Heat recovery from condenser of a refrigerator by thermo siphon system because it eliminates the need of a circulating pump*	*Theoretical COP without heat recovery is about 1.88 and with heat recovery system it is 2.53. The actual COP of air cooled condenser system is 1.078 and For water cooled with heat recovery system practically COP is 3.79*

5	*1. A. M. Vibhute , 2. Avinash M. Patil*	*Waste heat recovery in Domestic Refrigerator*	*IERJ, Special Issue Page 131-133, November 2015*	*As domestic refrigerators reject large heat inside room which make us uncomfortable in summer due to temperature rise inside the room. So it is now essential to reject this heat outside the room or utilize it for different purposes. Rejected heat is used for keeping food hot, heating water which may be used for different purposes.*	*Increase in overall effectiveness of domestic refrigerator and saving in energy. Increase in COP of domestic refrigerator. Efficient and economical combination of refrigerator and food / water warmer*
6	*1. P. Elumalai, 2. R. Vijayan, 3. K.K. Ramasam 4. M. Premkumar*	*Experimental Study on Energy Recovery from Condenser Unit of Small Capacity Domestic Refrigerator*	*Middle-East Journal of Scientific Research 23 (3): 417-420, Dec 2015*	*Recovered waste heat from condenser unit of a household refrigerator to improve the performance of the system by using a thermo siphon. The effect of operating temperature in the oven and heater for varying operating time of a refrigeration system have all been studied and feasible heat recovery have been ascertained*	*By this system the power consumption and LPG consumption in a house for heating food items and water can be reduced. Thus the waste energy emitted to the atmosphere is utilized for useful purposes and the demand for power is reduced.*
7	*1.Sreejith K, 2.T.R. Sreesastha Ram*	*Experimental Investigation of Waste Heat Recovery System for Household Refrigerator*	*International Journal of Engineering And Science Vol.6, Issue 4 PP - 19-23, April 2016*	*Analysed the system at various load conditions (No load, 40 W load and 100W load). They carried out the techno economic analysis by comparing the waste heat recovery system with the conventional geyser.*	*They found that the waste heat recovery system performs well along with the household refrigerator. This modification made the household refrigerator to be work as both refrigerator and water heater*
8	*Lakshy Soni, 2. Pawan Kumar 3. Rahul Goyal*	*Study of an adsorption refrigeration system powered by parabolic trough collector and coupled with a heat pipe*	*Imperial Journalof Interdisciplinary Research Vol-2, Issue-8,ISSN: 2454-1362,May 2016*	*To utilize waste heat from condenser of refrigerator. This system is nothing but a cabin that they are going to install over the head of the simple refrigerator this cabin will be an arrangement of coils that will work as a heat exchanger.*	*The results show that water at a temperature of 60ºC was produced by the system. If this system is established all over world, excessive amount of LPG gas gets saved.*

IV. CONCLUSION

We conclude by presenting this review paper that, there are many ways to recover the 40% of heat from the condenser of a refrigerator i.e. by water cooled condenser or by air cooled condenser. We also seen that after reading literature review, the COP of the refrigerator will also increase by heat recovery system and efficiency of the system also improves. This system will also reduce the consumption of electricity by providing same power of electricity to compressor to run evaporator and condenser. Condenser of the refrigerator can be work as an oven by storing the escaping heat from the condenser to the environment and reduce the rise in temperature of environment to stop the effect of global warming. This can be done by forming an insulated cabinet to store the condenser coil. The heat recovery cabinet can thus be used in various refrigeration applications as well as in air conditioning. By this system consumption of LPG for heating food and water can be eliminated and an ECO system made for these applications without removing human comfort.

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