International Journal of scientific research and management (IJSRM)
\||*Volume*||*3*||*Issue*||*3*||*Pages*|| *2409-2414*||*2015*||
Website: www.ijsrm.in ISSN (e): 2321-3418

A Review On Recovering Waste Heat From Condenser Of Domestic Refrigerator

Tanmay Patil, Nitesh Medhane, Yogesh Mahapure, Kalpesh Nagmoti, Prof. Anil Dube

Department of Mechanical Engineering,
Sandip Institute of Technology and research Centre,Nasik

Abstract: To review the energy savings associated with improved utilization of waste heat from a domestic refrigerator. Domestic refrigerators may be operating continuously to maintain proper food storage condition. The continuous operation of this equipment accounts more electrical energy consumption. So it is that a significant and concrete effort should be made for conserving energy through waste heat recovery. A significant amount of waste heat is rejected by the condensers of refrigerator. So an attempt has been made to utilize waste heat from the condenser of a refrigerator. Practical uses of waste heat from the domestic refrigerators are typically to space heating and water heating in minimum constructional maintenance and running cost. A cabin was installed on a domestic refrigerator with condenser coils of refrigerator serving as heating coils inside the cabin. Known quantity of water was heated by the condenser coils (due to convection currents) thereby increasing the overall COP of the refrigerator. Besides, the refrigerator may be used as conventional refrigerator by keeping the cabin door open in case of absence of heat sink.

Keywords: Domestic refrigerator, air cooled condenser, heat recovery unit, experimental analysis.

1. Introduction

Refrigerator has become an essential commodity rather than luxury item. A household refrigerator is a common household appliance that consists of a thermally Insulated compartment and which when works, transfer 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 room. Heat rejection may occur directly to the air in the case of a conventional household refrigerator having air-cooled condenser or to water in the case of a water-cooled condenser. Tetrafluoroethane (HFC134a) refrigerant was now widely used in most of the domestic refrigerators. Waste heat which is rejected from a process at temperature enough high above the ambient temperature permits the recovery of energy for some useful purpose in economic manner Heat can be recovered by using the water-cooled condenser and the system can work as a waste heat recovery unit. The heat recovery from the condenser can be used for bathing, cleaning, laundry, dish washing etc. Low temperature waste heat may be useful in a supplementary way for preheating purposes Keeping this in mind, a technique or condensing heat of the refrigeration system is proposed in this paper. The proposed system employs a combined air and water-cooling (desuperheating) technique for condensing heat of refrigerator. This new system provides not only the refrigeration effect, but also hot water.

2. Theory

A typical vapor compression system consist of four major components i.e. 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 operating low pressure liquid to low pressure vapor (processes4-1). 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. condensation process can be divided in 3 stages viz. desuperheating2-2a, condensation and sub cooling. 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 process 2-3 in figure 2.
- Improved overall system efficiency by using water cooled condenser.
- Use of thermo syphon system to circulate water to minimize pumping cost.
- Protection against contamination of portable water via

double wall construction.

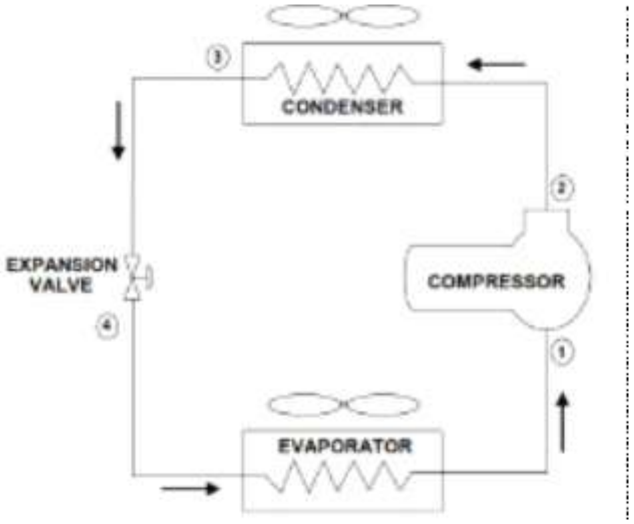

Figure 1: Vapor compression system

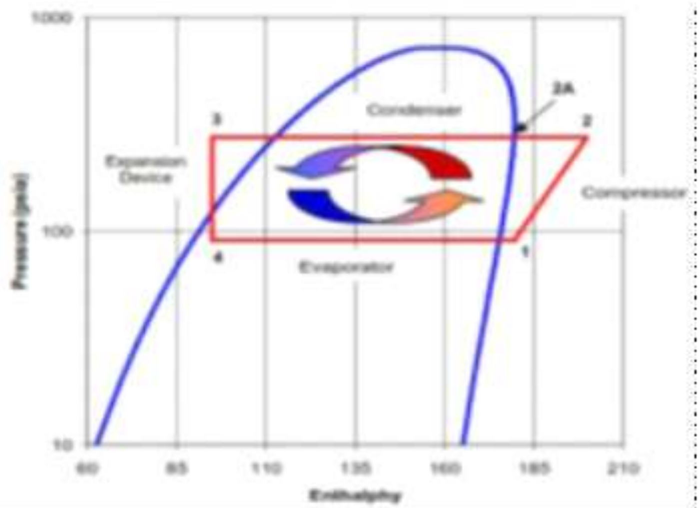

Figure 2: P-H diagram

3.Litrature Reviews

Romdhane ben slama**[1]** 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.

Sheng shan Bi et al **[2]** experimentally investigated the performance of a domestic refrigerator using TiO2-R600a nano-refrigerants. The test results shows that refrigerator performance was better than the pure R600a system, with 9.6% less energy used with 0.5 g/L TiO2-R600a nano- refrigerant. S.S. Hu, B.J. Huang et al**[3]** conducted an experimental investigation on a split air conditioner having water cooled condensers. They developed a simple water-cooled air conditioner utilizing a cooling tower with cellulose pad filling material to cool the water for condensing operations. The experimental investigation verified that the water-cooled condenser and cooling tower results in decreasing the power consumption of the compressor.

H.I. Abu-Mulaweh **[4]** designed and developed a thermosyphon heat recovery system which can recover heat from a window air conditioner. They design two types of heat exchangers, concentric type heat exchanger & coiled heat exchanger and then it is retrofitted in to the air conditioning system. They analyzed the performance of the system with these two types of heat exchangers. The circulation of water through the heat exchanger is done with the therom syphon effect which completely eliminates the need of pump. For having that, the heat exchangers are connected to a water storage tank and when the water in the heat exchanger get heated up by the superheated refrigerant the hot water flow upward through the connecting pipe into the top of the storage tank and at the same time the cold water from the bottom of the tank will flow into the heat exchanger. The test result show that the concentric heat exchanger produce hot water at a temperature of 45ºC and the coil type produced hot water having 40ºC.Sheng-shan Bi et al **[5]** experimentally investigated the performance of a domestic refrigerator with SUNISO 3GS mineral oil and TiO2 nanoparticles in the working fluid. The result indicated that the energy consumption of the HFC134a refrigerant using SUNISO 3GS mineral oil and 0.06% mass fraction of TiO2 nanoparticle mixture as lubricant reduced the energy consumption by 21.2% when compared to that of HFC134a and POE oil system.

S.C. Kaushik **[6]** et al presents an investigation of the feasibility of heat recovery from the condenser of a vapor compression refrigeration (VCR) system through a Canopus heat exchanger(CHE) between the compressor and condenser component. The presence of the CHE makes it possible to recover the superheat of the discharged vapor and utilize it for increasing the temperature of the external fluid (water) removing heat from the condenser. The effects of operating temperatures in the condenser and evaporator for different inlet water temperatures and mass flow rates on the heat recovery output and its distribution over the condenser and CHE (the fraction of the condenser heat available through the CHE),the available outlet water temperature and heat recovery factor have all been studied and optimum operating parameters for feasible heat recovery have been ascertained. The parametric results obtaine for different working fluids, such asR-22, R-12, R-717 & R-500, have been presented. It is found that in general, a heat recovery factor of the order 2.0 and 40% of condenser heat can be recovered through the Canopus heat exchanger for a typical set of operating conditions.

Dr. M.S.Tandale**[7]** presented a case study on Super Heat Recovery Water Heater At Worli, Dairy. They used R717 Kirloskar Reciprocating Compressor having refrigeration system capacity of270 TR (950KW). The Inlet & Outlet temperature of Refrigerant are 115 & 60°C.The Inlet & Outlet temperatures of Water are 25 & 70°C. They installed super heat recovery water heater in countercurrent mode. The hot water flow rate is 70000 Lit/day. In this system fuel saving is about 390 lFO/day. The annual saving is near about Rs.23 Lakhs/year. Also the reduction of CO2 emissions is 330ton/year.

Mukuna and Kilfoil **[8]**investigated the technical feasibility of combined refrigerator/heat exchanger and geyser system. It was concluded that 0.8 % of the total input energy in the geyser was saved in cycling mode of the refrigerator and continuous mode of the geyser. However, the refrigerator's effectiveness was reduced because the refrigerant was not cool enough. Patil and Dange **[9]** 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.

Sreejith **[10]** investigated the effect of different types of compressor oil in a domestic refrigerator with water cooled condenser. The experiments were done using HFC134a as the refrigerant, Polyester oil (POE) oil and SUNISO 3GS mineral oil. It was concluded that the HFC134a/SUNISO 3GS mineral oil system worked normally and efficiently in the household refrigerator with water-cooled condenser and the energy consumption of the HFC134a refrigerator using SUNISO 3GS mineral oil as the lubricant reduced the energy consumption of the household refrigerator between 8% and 11% for different loads.

Momin et al. **[11]** recovered waste heat from condenser unit of a household refrigerator to improve the performance of the system by using a thermo siphon. It was found that after recovering heat from the condenser of the conventional refrigerator, its performance was improved than conventional refrigerator. It was concluded that the theoretical COP of the system was more than the system running with air cooled condenser. M. M. Rahman et al. **[12]** developed a heat recovery system which can recover heat from a split air conditioning system. In this case, 60 litre heating tank is designed in a way that the copper tube conveying refrigerant is not submerged in water. The heating recovery tank consists of two cylindrical chambers, the inner chamber, is filled with water, is coiled with the hot refrigerant carring tube at the outer surfaces. It was found that this heat recovery system improved the compressor efficiency and at the same time continuously supplied warm water for domestic purpose.This system rejected less heat to the environment so it is safer in environmental aspects.Turgul Ogulta **[13]** discussed the utilization of waste heat recovery n textile drying process.Sathiamurthiet al **[14]**discussed in studies on waste heat recovery from an air conditioner unit that the energy can be recovered and utilized without sacrificing comfort level

P. Sathiamurthi and PSS. Shrinivasan **[15]** discussed in studies on WHR from an air conditioning unit that the energy can be recovered and utilized without sacrificing comfort level. They have also shown that such a system is economically viable. Energy consumption in the system and environmental pollution can still further be reduced by designing and employing energy saving equipments. F.N.Yu, K.T.Chan **[16]** discussed the improved condenser design for air cooled chillers.O'Brien et al. **[17]** designed a prototype refrigeration-cum-hot water heating system for domestic use. The system used heat energy rejected from the compressor and condenser of a vapour-compression refrigerator by storing it in a heat sink. It was concluded that the system performed better as the prototype than it did as a hot water heater but needs to be improved further to fully explore its expected potential.

R.A Clark *et al.***[18]** described the design, construction, and testing of an integrated heat recovery system which was designed both to enhance the performance of a residential refrigerator and simultaneously to provide preheated water for an electric hot water heater. The particular opportunity investigated in that study was to preheat the supply water for a hot water system using refrigerator condenser waste heat. An economic analysis revealed that a savings of 18.3 % on the water heater operating cost was possible. The refrig. R- 12 used in that project was not friendly to the ozone layer. The time to increase the temperature of water of 30 ºC in the no use test was fivedays. Thus the apparatus developed in this experimental study did not heat water quickly enough.Sanmati Mirji **[19]** presented a multipurpose warming apparatus utilizing the waste heat of domestic refrigerator. The multipurpose apparatus was constructed as an additional part of the refrigerator. It uses the waste heat generated by the refrigerator and has several possible household uses like food warming, domestic fermentation purpose such as curd making, fermentation for Indian food. The maximum temperature of the chamber got as high as 50ºC and the average temperature was around 40 ºC. The main advantage of the invention was to keep cooked food warm for a sufficiently long duration before consumption as well as warming the food removed from the refrigerator before consumption. It makes use of the waste heat generated by the domestic refrigerator and does not need any additional power supply.

Crown et al. **[20]** discussed the findings of 'An experimental study designed to show the effect of changing refrigerants on the performance of a refrigeration system'. It was concluded that COP and cooling capacity of R-134a proved to exceed that of R12 for the majority of test conditions. The values of COP and capacity of R134a were maximum of 5.4% and 6.8% higher than that of R-12, respectively.

Sr.no.	Author	Description
1	Romdhane Ben Slama	Water-heater coupled with the refrigerator to develop the heat of the condenser
2	Sheng-shan Bi, Lin Shi , Li-li Zhang	experimentally investigated the performance of a domestic refrigerator using TiO2-R600a nano-refrigerant.
3	S.S. Hu, B.J. Huang et al	developed a simple water-cooled air conditioner utilizing a cooling tower with cellulose pad filling material to cool the water for condensing operation.
4	H.I. Abu-Mulaweh	designed and developed a thermosyphon heat recovery system which can recover heat from a window air conditioner
5	Shengshan Bi, Kai Guo, Zhigang Liu, Jiangtao Wu	experimentally investigated the performance of a domestic refrigerator with SUNISO 3GS mineral oil and TiO2 nanoparticles in the working fluid
6	S.C.Kaushik, M.Singh	presents an investigation of the feasibility of HR from the condenser of VCR system through a Canopus heat exchanger(CHE) between the compressor and condenser components
7	Dr. M.S.Tandale	study on Super Heat Recovery Water Heater At Worli, Dairy
8	Mukuna, J.G., Kilfoil, M	Technical Feasibility Of Combined Refrigerator/Heat Exchanger And Geyser System
9	Patil Y.A., Dange H.M.	Improving the Performance of Household Refrigerator by Recovering Heat from the Condenser
10	Sreejith.K	investigated the effect of different types of compressor oil in a domestic refrigerator with water cooled condenser
11	Momin,G.G Deshmukh, M.T	recovered waste heat from condenser unit of a household refrigerator to improve the performance of the system by using a thermo siphon.
12	.M. M. Rahman, Chin Wai Meng	developed a heat recovery system which can recover heat from a split air conditioning system
13	R. Turgul Ogulata,	discussed the utilization of waste heat recovery n textile drying process.
14	P. Sathiamurthi, R.Sudhakaran	energy can be recovered and utilized without sacrificing comfort level
15	PSS.Srinivasan	studies on WHR from an air conditioning unit that the energy can be recovered and utilized without sacrificing comfort level
16	F.N.Yu, K.T.Chan	discussed the improved condenser design for air cooled chillers
17	O'Brien. M.J, Bansal P. K.	a prototype refrigeration-cum-hot water heating system for domestic use.

18	Robert A. Clark, Richard, N. Smith and Michael K. Jensen	the design, construction, and testing of an integrated heat recovery system which was designed both to enhance the performance of a residential refrigerator
19	Sanmati Mirji	presented a multipurpose warming apparatus utilizing the waste heat of domestic refrigerator

4.CONCLUSION

This paper undertook a review based study into COP Enhancement of a Domestic Air Cooled Refrigerator by recovering heat from Condenser in terms of its background, originality, current status, and researches. This all work has great significant for developing new technologies relates to heat recovery from a domestic refrigerator, in order to get cooling at low energy cost, no harmful effect to environment and also having low initial cost. So more attention is required in this area and lot of work has to be done.

5. REFERENCES

1. Sheng-shan Bi, Lin Shi , Li-li Zhang. Application of nanoparticles in domestic refrigerators. Applied Thermal Engineering 28 (2008) : 1834–1843.

2. Romdhane Ben Slama. Water-heater coupled with the refrigerator to develop the heat of the condenser. International Renewable Energy Congress November 5-7, 2009; Sousse Tunisia.

3. S.C.Kaushik, M.Singh., Feasibility and Design studies for heat recovery from a refrigeration system with a canopus heat exchanger, *Heat Recovery Systems & CHP*, *Vol.15*(1995)665673 4.P.Sathiamurthi, PSS.Srinivasan, Studies on waste heat recovery and utilization. Globally competitive eco-friendly technologies engineering *National conference*, (2005)39.

4. Douglas T.Reindl, Todd B. Jekel, “Heat Recovery In Industrial Refrigeration”, ASHRAE Journal, August 2007.

5. S.S. Hu, B.J. Huang. Study of a high efficiency residential split water-cooled air conditioner. Applied Thermal Engineering 25 (2005) : 1599–1613.

6. H.I. Abu-Mulaweh. Design and performance of a thermosiphon heat recovery system. Applied Thermal Engineering 26 (2006) : 471–477.

7. Shengshan Bi, Kai Guo, Zhigang Liu, Jiangtao Wu. Performance of a domestic refrigerator using TiO2- R600a nano-refrigerant as working fluid. Energy Conversion and Management 52 (2011) : 733–737.

8. Mukuna, J.G., Kilfoil, M., Testing of combined refrigerator/heat exchanger and geyser. International domestic use of energy conference, cape town, South Africa (2011)

9. Patil Y.A., Dange H.M., Improving the Performance of Household Refrigerator by Recovering Heat from the Condenser. International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064 Volume 2 Issue 6 (2013)

10. Sreejith.K., Experimental Investigation of A Domestic Refrigerator Having Water-Cooled Condenser Using Various Compressor Oils”. Research Inventy: International Journal Of Engineering And Science Issn: 2278-4721, Vol. 2, Issue 5 (February 2013), pp 27-31 (2013)

11. Momin, G.G., Deshmukh, S.R., Deshmukh, M.T., Chavan, P.T.,Choudhari P.P., Cop Enhancement of Domestic Refrigerator by Recovering Heat from the Condenser. International Journal of Research in Advent Technology, Vol.2, No.5, May 2014 E-ISSN: 2321-9637 (2014)

12. M. M. Rahman, Chin Wai Meng, Adrian Ng, “Air Conditioning and Water Heating- An Environmental Friendly and Cost Effective Way of Waste Heat Recovery”, AEESEAP, Journal of Engineering Education 2007, Vol. 31, No. 2

13. R. Turgul Ogulata, “Utilization of waste heat recovery in textile drying”, Applied energy (in press) (2004)

14. P. Sathiamurthi, R. Sudhakaran “ Effective utilization of waste heat in air conditioner” Energy and environmental technologies for sustainable development –Int. Conf. Proc.(2003).

15. P.Sathiamurthi, PSS.Srinivasan, Studies on waste heat recovery and utilization. Globally competitive eco-friendly technologies engineering *National conference*, (2005)39.

16. P.Sathiamurthi, PSS.Srinivasan “Design and Development of Waste Heat Recovery System for air Conditioning Unit, *European Journal of Scientific Research,Vol.54 No.1* (2011), pp.102-110

17. F.N.Yu, K.T.Chan, “Improved condenser design and condenser-fan operation for air-cooled chillers”, *Applied Energy*, *Vol.83* (2006) 628-648.

18. O'Brien. M.J, Bansal P. K. and Raine R. R., An integrated domestic refrigerator and hot water system” International Journal of Energy Research, Volume 22, Issue 8, pages 761–776 (1998)

19. Robert A. Clark, Richard, N. Smith and Michael K. Jensen: ”An experimental study of waste heat recovery from a residential refrigerator, *Energy Conversion Engineering Conference vol 3,* pp 1887-1892. 1996.

20. Sanmati Mirji: A multipurpose warming apparatus utilizing the waste heat of domestic refrigerator, Unites States patent, August, 2006.