THOMSON REUTERS
ENDNOTE

[Soni* *et al.*, 5(7): July, 2016] **ISSN: 2277-9655**
IC™ Value: 3.00 **Impact Factor: 4.116**

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

WASTE HEAT RECOVERY SYSTEM FROM DOMESTIC REFRIGERATOR FOR WATER AND AIR HEATING

Lakshya Soni*, Pawan Kumar, Rahul Goyal
* PG Student, Mechanical Engineering Department, Vivekananda Global University Jaipur, India
Asst. Professor, Mechanical Engineering Department, Vivekananda Global University Jaipur, India
Associate Professor, Mechanical Engineering Department, Manipal University Jaipur, India

DOI: 10.5281/zenodo.57617

ABSTRACT

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. So it is necessary that a significant and concrete effort should be made for conserving energy through waste heat recovery too. 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 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.

KEYWORDS: Refrigerator, eco friendly, cost effective design, Global warming, Improve overall efficiency, waste heat recovery, condenser.

INTRODUCTION

This system is nothing but a cabin that we 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. These coils are hot coils of condenser of the refrigerator that will be modified and will braze in the cabin. It can serve the purpose of cooking (oven), geysers etc. Besides, the refrigerator may be used as conventional refrigerator by keeping the cabin door open in case of absence of heat sink. Further increase in COP is possible. We can increase the temperature of water and air upto 43^o and 48^{o}respectively. 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.

A typical vapor compression system consist of four major components i.e. compressor, condenser, expansion device and an evaporator. In the following [1] Fig – 1.1 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.

ISSN: 2277-9655
Impact Factor: 4.116

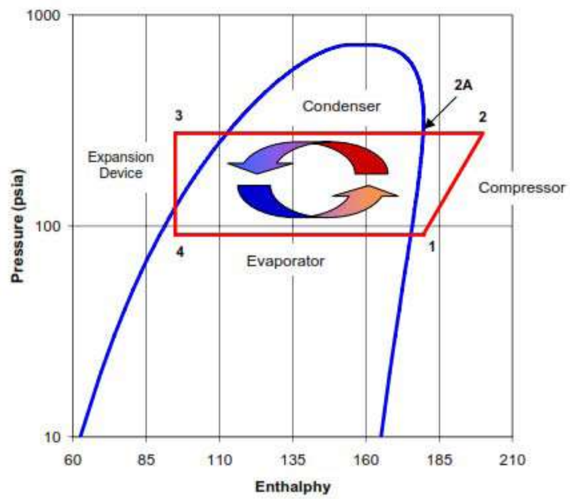

Fig – 1.1 Pressure-Enthalpy curve

A heat recovery unit is special purpose heat exchanger specifically designed to:

- Remove heat represented by process 2-3 in figure.
- Improved overall system efficiency by using water cooled condenser.
- Use of thermo siphon system to circulate water to minimize pumping cost.
- Protection against contamination of portable water via double wall construction.

The present [2] innovation relates to the coupling of a refrigerator to a cumulus to heat water and this, thanks to the heat yielded to the level of the condenser of the refrigerating system even. The heating of water is carried out thus without energy over consumption. The quantity of heat transferred by the water-cooled condenser is sufficient to raise the temperature of this latter with 60 °C at the end of five hours. This can satisfy completely or partially the requirements out of hot water of a family which can distribute its requirements out of hot water all along the day and the week. The quantity of heat recovered by water to heat rises with four multiples the power consumption by the compressor. The system thus makes it possible to save energy and to safeguard the environment.

Table.1: Thermal conductivity of various materials

Materials	Thermal Conductivity(w/mk)
GI sheet Copper tube Thermocole sheet	18 385 0.033

By experimentation with waste heat recovery system (WHRS) in refrigeration unit, Kaushik and Singh [3] have found that 40% of condenser heat can be recovered through the Canopus heat exchanger for typical set of operating conditions. P. Sathiamurthi and PSS. Shrinivasan [4, 5] 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 by the system and environmental pollution can still further be reduced by designing and employing energy saving equipments. F.N.Yu, K.T.Chan [6] discussed the improved condenser design for air cooled chillers.

EXPERIMENTAL WORK

Experimental setup

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.

We can see the full experimental setup as under

Fig. 1.2 Waste heat recovery system from domestic refrigerator

Fabrication of the insulated hot cabin

The insulated cabin is made of 24gaze galvanized iron sheet by the operation of **cutting and riveting**. 6 pieces of 16" GI sheet is folded from the corners by 1" and riveted with each other and shaped in a form of cabin.

The upper ceiling piece is free to open, That mean it is a cap of the cabin that can be removed for proper installation. This cap have two small 1" diameter's holes at the centre so that water bottles of cold water containers can be installed over it for sprinkling of cold water over the hot gas passing copper tube. Two holes of just larger than quarter inch are made at the backward sheet of the cabin so that copper tube can be enter and exit from the cabin. Now that cabin is covered by a half inched thermocole (Expanded polystyrene) for insulation of the cabin because thermocole have thermal conductivity of 0.033 W/mK.

Cabin size – 15"x15"x15"

Polystyrene sheet – 0.5" thick

Fig 1.3 Insulated polystyrene cabin having copper tubes and hot water sink

That cabin is now ready to install over the refrigerator. And as the refrigerator start to do work that gas flows through the copper tubes and water is now sprinkling on the hot coils and dropped in the water container below the tubes and this water sink have a setup to provide hot water at the exit. That hot water can be used in domestic uses like in kitchen, washing of utensils, bathing, washing of clothes etc. and if we add an small exhaust rotor fan at the side of the cabin than the heat of cabin can be used to warm a small area near the cabin. Or this cabin can be used further as a hot oven for keep food warm, So that we can save LPG for making food hat again and again.

Welding of copper tube and Gas recharging in the compressor of the refrigerator

At the exit of the compressor from where the hot 134a sent to condenser coils of the refrigerator, There in this system quarter inched circular copper tube(24 ft) is welded at that end, and that copper tube is fixed in the insulated cabin as like we can see the arrangement as in above figure. This tube's another end is welded at the entrance of the cold gas in the compressor of the refrigerator. This welding is done by acetylene cylinder of 1 liter and a welding gun with a copper rod. For proper welding of copper, make the pipes (That are connected with each other) Red hot and just touch the copper rod now in between the filler line and that copper will be automatically fill the space and will join them properly.

After the welding process gas is to be recharge in the compressor of the refrigerator. For that a cylinder of R134a, that is HCF134a, is connected with the recharging pipe and another end of that pipe is connected with compressor of refrigerator. As the valve of recharging pipe is opened, Gas started to fill and after a few seconds compressor is must to start by supplying power on, So that the gas will be filled properly in the compressor.

Fig 1.4: Welding of copper tubes and gas filling by cylinder.

The addition of a regenerator of heat on the level of the condenser and evaporator will increase more the performances.

CALCULATIONS FOR THE SETUP

Table 2 ***units and standard measures***

C_P	heat mass (J/°K kg)
COP	Coefficient of performance
h	Enthalpy (J)
Pcomp	Compressor power (W)
Qcomp	Heat compressor (J)
Qf	Heat evaporator (J)
m	Mass (kg)
tcomp	Functioning compressor duration (s)
T_2	Heating temperature (°C)
T_1	Cooling temperature (°C)
Wcomp	Compressor consumption , Wth (J)
ΔT	Temperature increase (°C)
Qcabin	Heat Cabin (J)

Operation life of the compressor (min): The cumulated time of daily operation is 450 min, that is to say an operation of the compressor during one the third of time.
By taking a COP of 3 (acceptable minimum for the heat pump) and a power of 120 W consumed by the compressor, the quantity of heat yielded by the condenser is:

$$Q_c = COP \times W_{comp.}$$
$$= COP \times P_{comp.}.\sum T_{comp.} \quad \text{(here COP= 3,P =120w}$$
$$= 3 \times 120 \times 450 \times 60 = 9720 \text{ KJ}$$

Now the initial temperature of water $t_1 = 30.3^oc$

After passing water from hot copper coil $t_2 = 43.2^o c$

$$\Delta T = T_2 - T_1 = 12.9\ ^o c$$

$$Q_c = m_{water} . C_p . \Delta T$$

$$m_{water} = \frac{Qc}{Cpx12.9} = \frac{9720 \times 10^{\wedge}3}{4185 \times 12.9} = 180 \text{ KG}$$

$$= 180 \text{ litre}$$

But here in the experiment we are taking 1.2 Litre at once or if we take around 10 to 20litre water once, it means this system is easy to multiply the use of the water-heater several times per day.

For the COP of the cabin installed over the refrigerator

$$Q_{cabin} = m_{water} x\ C_p x\ \Delta T = 12.9 \times 1.2 \times 4185$$

$$= 64.7 \text{ KJ}$$

$$COP_{cabin} = \frac{Qc}{Wcabin} = \frac{64.7}{29} = 2.2$$

Total Coefficient of performance of the system

Total COP of the system = 3+ 2.2 = 5.2

Now we can see that the whole system is a new step to being in the favor of the environment and human comfort.

CONCLUISON AND FUTURE WORK

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 of full setup up-to 2 and also the reduction in power consumption. The temperature difference obtained between the water inlet and outlet exceeds more than 10^o C. The hot air by this system gives the temperature up-to 46^o C. 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. 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.

At this, is added the applications in the tertiary sector (hotels, hospital, restaurants, deposits of conservations, refrigerators of tradesmen of food...), that is to say practically the double: consumption of 800 Mtoe /year and emission of 2000 Mt CO2.

RREFERENCES

[1] Tanmay Patil, Nitesh Medhane, Yogesh Mahapure, Kalpesh Nagmoti, Prof. Anil Dube., A Review On Recovering Waste Heat From Condenser Of Domestic Refrigerator, International Journal of scientific research and management (IJSRM), Volume3 (2409-2414)(2015).

[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.

[5] 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.

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