Experimental Analysis of Waste Heat Recovery From Condenser of Refrigerator

Jagtap Vivek D[1], Ghuge N. C[2]
[1] Dept of Mechanical Engineering
[2]Assistant Professor, Dept of Mechanical Engineering
[1, 2] MCOE, Savitribai Phule University Pune

Abstract- *Energy can be mainly divided into two types of high grade energy and low grade energy. The high grade energy sources are limited and depleting rapidly. So, it is necessary to make use of non conventional sources of energy or to recover the waste heat liberated from many processes. Refrigeration processes liberate large amount of heat to atmosphere. Waste heat liberated from the condenser of refrigerator goes to the atmosphere. This heat can be recovered and utilized for some other purposes. This project aims at extracting the waste heat from the condenser of the refrigerator with help of water cooled heat exchanger. In this paper, experimental setup is provided and readings are taken for different mass flow rates of cooling water. As the mass flow rate of cooling water increases COP of the system increases. Further the results are compared for refrigerants R134a and the mixture R290/R600a. The COP is increased in case of water cooled refrigerator. The COP using R134a is little lesser than the COP using R290/R600a.*

Keywords- Condenser, COP, Heat exchanger, Refrigeration, Refrigerant, R134a, R290/R600a

I. INTRODUCTION

Energy is regarded as the driving force of any nation and it measures the prosperity of the nation. Per capita energy consumption is related to per capita income of the country. The developed countries are rapidly using the conventional sources of energy to fulfill their high industrial and domestic demands. As the conventional sources are limited on earth, they will exhaust after a short period of time. The engineers and scientists are striving hard to make efficient use of non conventional sources of energy and to utilize waste heat. Waste heat is the heat which gets untapped and released to the atmosphere without any use. It is released in the form of hot gases, hot liquid or through radiation to the surrounding. Refrigeration devices liberate large amount of waste heat. The condenser of the domestic refrigerator emits waste heat to the atmosphere. In present work, this waste heat through condenser is trapped and used to heat water with help of water cooled condenser. The hot water can be further used for any domestic use. This technique not only utilizes the waste heat but also improves the performance of the refrigeration system and increases its COP.

II. LITERATURE REVIEW

N. B. Chaudhari et. al. presented an experimental set up for the waste heat recovery through condenser. The experimental setup consisted of a VCC system and a water cooled heat exchanger was used. Instead of using pump for cooling water circulation they used Thermo- siphon system. The experimental results showed that as the mass flow rate of cooling water increases, heat recovered through cooling water and COP of the system increases. Further, they proved that COP of water cooled condenser is greater than that of air cooled condenser.

Sreejith K. et al. experimentally analyzed the effects of water-cooled condenser in a house-hold refrigerator. They used R134a as the refrigerant and Polyester oil as the lubricant. The functionality of air-cooled and water-cooled condenser was examined for many load situations. The solutions display that the refrigerator functionality got elevated when water-cooled condenser was used in place of air-cooled condenser on all load situations.

Vedil et al. have analyzed hypothetical method to use the waste heat liberated from the vapor compression cycle, to operate vapor absorption cycle. The solar heat has been provided as waste is not sufficient to run VAS alone. They examined the effectiveness of combined cooling cycle. Results showed that overall COP of the combine cycle is greater than the individual cycles when operated separately.

Momin et al. retrieved waste heat coming from the condenser of the home refrigerator to enhance the overall performance of the system. Retrieval of heat is done by thermo siphon. From the experimentation, it was observed that after heat retrieving process from the condenser of the refrigerator its overall COP got raised when compared to conventional refrigerator.

Ajoy Bhargav et al. designed a domestic refrigerator to work with R134a was investigated to assess the possibility of using a mixture of propane and iso-butane. The performance of the refrigerator using azeotropic mixture of refrigerant was investigated and compared with the performance of refrigerator when R134a, R12, R22, R290, R600a are used as refrigerant.

D.O. Ariyo et al. determined cooling capacities and other parameter for a refrigeration cycle operating between temperature limits of -25oC (evaporator temperature) and 42oC (condenser temperature). The refrigerants used in the refrigeration cycle analysis were R134a and R290/R600a. Compressor capacity of 125W, degree of sub cooling of 9K and degree of superheating of 15K were maintained for refrigeration cycles using R134a and a binary mixture of R290/R600a. Parameters such as refrigerating capacity, mass flow rate, compression work, condenser capacity and Coefficient of Performance (COP) were computed for each refrigeration cycle. The analysis showed that cooling capacities of the two refrigerants are close enough and are therefore proposed as substitutes in existing R12 refrigeration systems.

III. METHODOLOGY

The setup consists of a vapor compression refrigeration system. The condenser is a water cooled type. For cooling copper coils are used with diameter of 3/8". For measuring the flow of cooling water, flow meter is mounted at the outlet of the exchanger. A flow control valve is mounted at the inlet of heat exchanger to control the flow rate of cooling water. Thermocouple is mounted at the outlet of HE to monitor the difference in cooling water temperature for different mass flow rates.

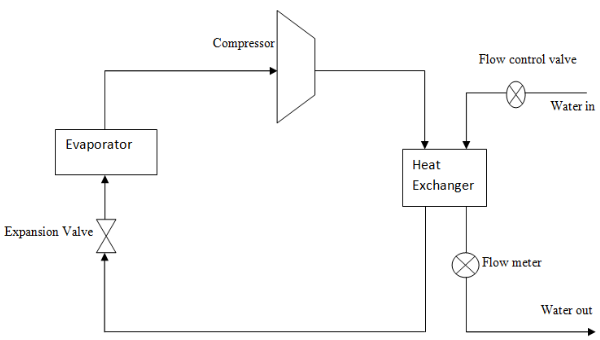

Fig.1 Schematic Diagram of Heat Recovery System

[A] Technical Specification

Capacity of refrigerator- 0.1060 TOR
Compressor Power- 0.5 hp
R134a- 340gm
R290/R600a- 60/40 % by mass

Table 1:- Thermodynamic Property Chart for R290 / R600a

Temperatures	pressure	Enthalpy (liquid)	Enthalpy (vapour)	Entropy (liquid)	Entropy (vapour)
^{0}c	Bar	KJ/kg	KJ/kg	KJ/kg	KJ/kg
-30	1.14	130.6	529.5	0.732	2.404
-25	1.67	153.1	542.3	0.823	2.387
-20	2.01	164.6	548.6	0.868	2.381
-10	2.39	176.6	555.0	0.912	2.375
-5	2.82	188.1	561.3	0.956	2.371
0	3.31	200	567.7	1.00	2.367
5	3.85	212.1	574.0	1.044	2.365
10	4.47	224.4	580.2	1.087	2.362
15	5.15	236.8	586.4	1.130	2.361
20	5.91	249.5	592.6	1.173	2.359
25	6.75	262.3	598.6	1.216	2.359
30	7.67	275.3	604.6	1.259	2.360
35	8.67	288.5	610.5	1.301	2.360

Table 2:- Comparison of R290/R600a with R12 and R134a

Product	R290/R600a	R12	R134a
Chemical type	HC	CFC	HFC
Composition	Azeotropic mixture	Pure	Pure
Ozone depletion potential	0	0.9	0
Global warming potential	3	10600	1600
Normal boiling point	-31^{0}c	-30^{0}c	-26^{0}c
Latent heat	367 kJ/kg	145 kJ/kg	189 kJ/kg

Table 3:-Performance data of R134a and R290/R600a

Refrigerant	Operating temperature (0C)	Corresponding pressure (bar)	Degree of superheating	Degree of sub cooling
R134a	Evaporator		9	15
	-25	1.00		
	Condenser			
	42	10.70		
R290/R600a	Evaporator		9	15
	-25	1.40		
	Condenser			
	42	10.5740		

[B] Experimentation And Calculation

A. *Calculation of Theoretical COP*

Theorotical COP of refrigerant R134a

$$(C.O.P)_{th} = \frac{R.E}{W_c} = \frac{h_1 - h_4}{h_2 - h_1}$$

From P-h diagram,

h_1 = 396 Kj/kg
h_2 = 448 Kj/kg
h_3 = h_4 = 243 Kj/kg

$$(C.O.P)_{th} = \frac{396-243}{448-396} = 2.9423$$

Theorotical COP of refrigerant R290/R600a

$$(C.O.P)_{th} = \frac{R.E}{W_c} = \frac{h_1-h_4}{h_2-h_1}$$

From property table ,

$h_1 = 535.9$ Kj/kg

$h_2 = 625.9$ Kj/kg

$h_3 = h_4 = 141.85$ Kj/kg

$$(C.O.P)_{th} = \frac{535.9-141.85}{625.9-535.9} = 4.37$$

B. Calculation of Actual COP

Actual COP of refrigerant R134a

Cooling capacity of refrigerator=Q_{th} = 373Watts

For mass flow rate 9plh

Take Tci = 27 ^{0}C

Heat recovered = $Q_{rev} = \dot{m}\ Cp_w\ \Delta T$

$= \dot{m}\ Cp_w\ (Tco - Tci)$

$= 9 \times 4.18 \times 1\,000 \times (52-27)$

Q_{rev} = 261.25 Watts

$$(C.O.P)_{Act.} = \frac{Q_{th} + Q_{rev}}{V x I} = \frac{373 + 261.25}{1.2 \times 228} = 2.3181$$

Similarly, readings are taken for different mass flow rates and temperature of outlet cooling water is noted. The heat recovered and the COP in each case is calculated as shown above. The following table shows the same.

Table 4:-Observation Table for Different Mass Flow Rates

Mass flow rate (lph)	Outlet temperature		Heat recovered (Watts)		COP	
	R134a	R290/ R600a	R134a	R290/ R600a		
9	52	48	261.25	219.45	2.31	2.16
13	50.2	46.8	350.19	298.87	2.64	2.45
17	48.3	45.4	420.43	363.19	2.89	2.69
23	45.4	43.7	491.38	445.98	3.15	2.99

IV. RESULTS AND DISCUSSION

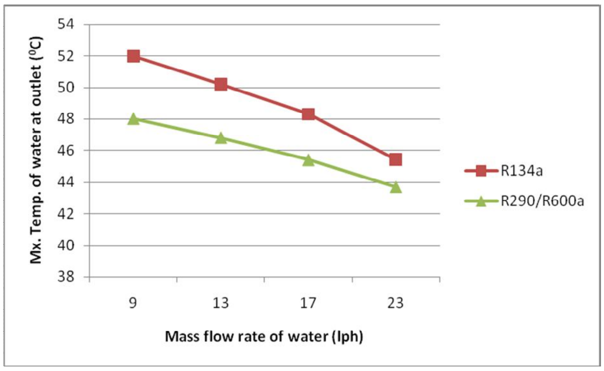

Fig. 2.Maximum Temperature of Hot Water at Outlet Vs Different Mass Flow

The maximum temperature of hot water obtained for various mass flow rates is shown in above graph. It could be easily noted that as the mass flow rate of cooling water increases its outlet temperature decreases. It quantifies the amount of water which can be obtained at particular temperature.

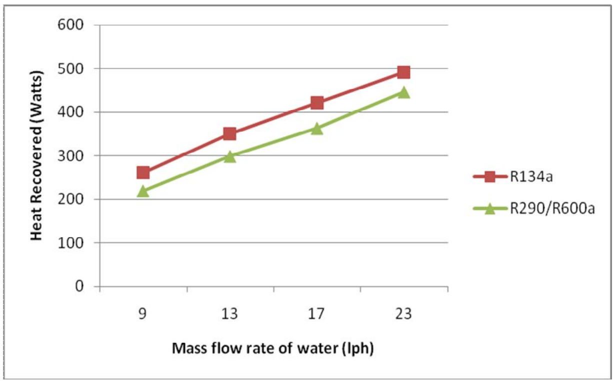

Fig. 3.Heat Recovered Vs Mass Flow Rate of Water

Heat recovered for various mass flow rates is shown in above graph. As the mass flow rate increases quantity of heat recovered increases but reduces the temperature of water available. It can be seen that maximum heat recovered is about 492 Watts.

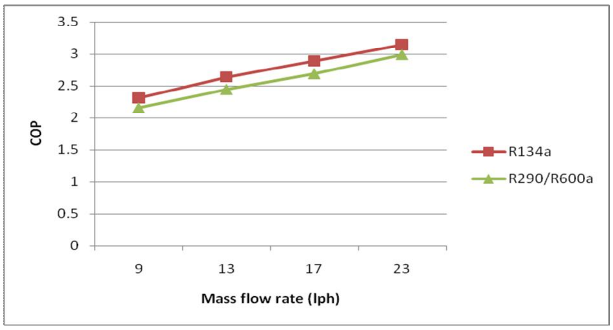

Fig. 4.Heat Recovered Vs Mass Flow Rate of Water

Maximum COP obtained for refrigerant R134a is 3.1592 and for R290/R600a is 2.9933 for mass flow rates of 23 lph. After increasing the mass flow rate further, the COP starts decreasing considerably.

V. CONCLUSION

Theoretical COP of refrigerant R134a and R290/R600a is found to be 2.9423 and 4.37. Actual COP of R134a and R290/R600a is found experimentally for different mass flow rates of water. It is found that maximum COP obtained for R134a is 3.15 and for R290/R600a is 2.99 for mass flow rate of 23 lph. As the mass flow rate increases COP increases till certain point after that COP decreases. COP of R134a is little higher than the COP of R290/R600a. Maximum heat recovery for R134a and R290/R600a is 491.38Watts and 445.98 Watts respectively for mass flow rate of 23 lph. The COP of water cooled condenser system is greater than COP of air cooled condenser. Thus, for R134a, we get 23 lph of water at temperature 45.4 ^{0}C and for R290/600a, we get 23 lph of water at temperature 43.7 ^{0}C.

REFERENCES

[1] N. B. Chaudhari, P. N. Chaudhar, "Heat Recovery System from the Condenser of a Refrigerator – an Experimental Analysis", International Journal on Theoretical and Applied Research in Mechanical Engineering , vol 4 No.-2, PP-204-210.

[2] Sreejith K., S.Sushmitha, Das Vipin, "Experimental Investigation of a Household Refrigerator Using Air-Cooled and Water-Cooled Condenser", International Journal of Engineering And Science, Vol.4, Issue 6, 2014, 13-17.

[3] Vedil S.N., Kumar A. And Mahto D., "Waste Heat Utilization of Vapour Compression Cycle, International Journal of Scientific and Research Publications", Volume 4, Issue 11, 2014, 1-4.

[4] 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, 2014, 402-406.

[5] Ajoy Bhargav1, Nitin Jaiswal2, "Comparative Analysis of R290/R600a with commonly used refrigerant", IJAET International Journal of Application of Engineering and Technology, Vol-2 No.-3,235-238.

[6] D.O. Ariyo, M.A. Azeez and T.O. Woli, "Comparison of Cooling Parameters of R134a and R290/R600a", Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 14, Issue 3 Ver. II (May. - June. 2017), PP 87-90.

[7] Slama Romdhane Ben, "Thermodynamic Heat Water by The Condenser of Refrigerator", Int. Symp. On Convective Heat and Mass Transfer in Sustainable Energy, 6029 Gabes Tunisia, 2009.

[8] Agarwal Tarang, Kumar Manoj, Gautam Praveen Kumar, "Cost-Effective COP Enhancement of a Domestic Air Cooled Refrigertor Using R-134a Refrigerant", International Journal of Emerging Technology and Advanced Engineering, Volume 4, Issue 11, 2014, 300-305.

[9] Stinson G. E., "Design principles of refrigeration waste energy recovery", Aust Refrig Aircond Heat, 1985, 25–30.

[10] Elumalai P., Vijayan R., Ramasamy K.K. And Premkumar M., "Experimental Study on Energy Recovery from Condenser Unit of Small Capacity Domestic Refrigerator", Middle-East Journal of Scientific Research 23 (3), 2015, 417-420.