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EXPERIMENTAL INVESTIGATION OF DOMESTIC REFRIGERATOR WITH MICROCHANNEL CONDENSER USING 134A AND HYDROCARBON REFRIGERANT

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ABSTRACT

This paper present an experimental study of hydrocarbon an environment friendly refrigerants with zero ozone depletion potential (ODP) and very low global warming potential (GWP) to replace with R134a in domestic refrigerator. The performance of refrigerator designed to work with micro channel condenser for evaluation and comparison of hydrocarbon and R-134a. The effect of condenser temperature and evaporator temperature on COP, refrigerant effect, compression work done, mass flow rate and pressure ratio are investigate.

The average COP using hydrocarbon was 19% higher than R134a. The Refrigerant effect increases and mass flow rate decreases when hydrocarbons refrigerant are used.

Keywords- R134a, hydrocarbon, micro-channel condenser and refrigerator.

I. INTRODUCTION

Refrigerants mean the cooling or removal of heat from a system. The equipment employed to maintain the system at a low temperature is termed as refrigerating system and the system which is kept at lower temperature is called refrigerated system.

Natural refrigerants such as hydrocarbons, ammonia, and carbon dioxide have good thermodynamic fluids for a vapor compression system because they have large latent heats of vaporization which yield lower refrigerant flow rates and have low pressure drops because of their properties. Hydrocarbon refrigerants, such as propane, have some advantages over other natural refrigerants like ammonia or CO₂. Therefore in order to make flammable or toxic Refrigerants useful for systems larger than a refrigerator, it is necessary to reduce their charge below the levels necessary to warrant a toxic or flammable situation in the case of a system leak. Another constraint introduced with the reduction of charge in a system, is the maintaining of a base line thermal performance of the system including capacity, compressor power, and COP. As tubes and components are made smaller, the capacity and COP can suffer due to a higher pressure drop even though the charge is reduced.

The refrigerants chlorofluorocarbons (CFCs) and hydro fluorocarbon (HFCs) both have high ozone depleting potential (ODP) and global warming potential (GWP) and contributes to ozone layer depletion and global warming. Therefore refrigerants are required to be replaced with environmentally friendly refrigerants to protect the environment. The hydrocarbon refrigerants with zero ozone depletion potential have been recommended as alternatives.

Refrigerants	GWP	ODP
CFCs	1300	0
HCs	<3	0

Extruded aluminum multi-port micro channel tubing is a technology that has become widely used as the condenser in automotive air conditioning. Many industries are actively investigating the use of micro channel tubes for many other heat transfer applications in refrigerators, condensing units and house hold air conditioning. A micro channel condenser consists of headers, fins, and aluminum micro channel tubes. The logic behind the micro channel condenser brings to the overall performance, due to increases in compactness, improvement of the heat transfer and the reduction of the refrigerant charges. Micro channel condenser will permit smaller system to be designed that requires less charge, less compressor power and therefore less energy consumption.

The previous work by **K. Mani, V. selladurai**, [1] investigated the experimental performance and study on a VCRS with new refrigerant mixture R290/R600 as drop in replacement was compared with CFCs 12 and HFCs 134a. In the lower evaporating temp COP of R290/R600a mixture was higher in the range 3.9-23.1% and 11.8-17.6% higher in the higher evaporating temp than R12. In the lower operating temperature refrigerating capacity of R290/R600a was higher in the range 19.9-50.1% and 21.2-28.5% in the higher evaporating temperature. The refrigeration efficiency of the system increases with the increases evaporating and condensing temperature from the two major environmental impact (ozone layer depletion and global warming potential) point of view thus R290/R600a mixture can be used as drop in replacement refrigerant for CFC 12 and HFCs 134a.

Mohan M. Tayde, and et al. [2] design and investigated with classical refrigeration using vapour compression has been widely applied over the last decades to large scale industrial systems. Now, the mini-scale (miniature) refrigerator using VCR seems to be an alternative solution for the electronic cooling problem. Fabrication of very small devices is now possible due to advances in technology. In this investigation a mini-scale refrigerator of 300W cooling capacity using R-134a as refrigerant is designed, built and tested. This test indicates that the actual COP of the developed system is 1.6 and second law efficiency is 19%. **Somchar Wongwiises and et al.** [3] conducted an experimental study on the application of hydrocarbon mixtures to replace HFC- 134a in a domestic refrigerator. The hydrocarbons investigated are propane (R290), butane (R600) and isobutene (R600a). The consumed energy, compressor power and refrigerant temperature and pressure at the inlet and outlet of the compressor are recorded and analyzed as well as the distributions of temperature at various positions in the refrigerator. The experiments are conducted with the refrigerants under the same no load condition at a surrounding temperature of 25 °C. The results show that propane/butane 60% - 40% is the most appropriate alternative refrigerant to HFC-134a.

M. A. Sattar, and et al. [4] studied the domestic refrigerator designed to work with R-134a was used as a test unit to assess the possibility of using hydrocarbons and their blends as refrigerants. Pure butane, isobutene and mixture of propane, butane and isobutene were used as refrigerants. The performance of the refrigerator using hydrocarbons as refrigerants was investigated and compared with the performance of refrigerator when R-134a was used as refrigerant. The effect of condenser temperature and evaporator temperature on COP, refrigerating effect, condenser duty, work of compression and heat rejection ratio were investigated. The energy consumption of the refrigerator during experiment with hydrocarbons and R-134a was measured. The results show that the compressor consumed 3% and 2% less energy than that of HFC-134a at 28 °C ambient temperature when iso-butane and butane was used as refrigerants respectively. The energy consumption and COP of hydrocarbons and their blends shows that hydrocarbon can be used as refrigerant in the domestic refrigerator. The COP and other result obtained in this experiment show a positive indication of using HC as refrigerants in domestic refrigerator. **A.Baskaran1, and et al.** [5] determined the performance analysis on a vapour compression refrigeration system with various eco-friendly refrigerants of HFC152a, HFC32, HC290, HC1270, HC600a and RE170 were done and their results were compared with R134a as possible alternative replacement. The results showed that the alternative refrigerants investigated in the analysis RE170, R152a and R600a have a slightly higher performance coefficient (COP) than R134a for the condensation temperature of 50 °C and evaporating temperatures ranging between -30 °C and 10 °C. Refrigerant RE170 instead of R134a was found to be a replacement refrigerant among other alternatives. The effects of the main parameters of performance analysis such as refrigerant type, degree of sub cooling and super heating on the refrigerating effect, coefficient of performance and volumetric refrigeration capacity were also investigated for various evaporating temperatures. **Mohd. Aasim, and et al.** [6] investigated experimental study of isobutene (R-600a), an environment friendly refrigerants with zero ozone depletion potential (ODP) and very low global warming potential (GWP), to replace R-134a in domestic refrigerators. A refrigerator designed to work with R-134a was tested, and its performance using R-600a was evaluated and compared its performance with R-134a. The average COP using R-600a was 27% higher than R-134a respectively. The power consumption by compressor reduced by 3.7% with R600a refrigerant. The compressor ON time ratio was lowered by 6.98% with R-600a compared with R-134a. The experimental results showed that R-600a can be used as replacement for R-134a in domestic refrigerator.

II. EXPERIMENTAL SETUP & METHODOLOGY

Vapour compression refrigeration cycle is a very widely used cycle of refrigeration in ground, air, space and marine application. It uses a variety of refrigeration such as ammonia (NH₃), Freon group (R12, R-22 etc), sulphur dioxide (SO₂) and carbon dioxide (CO₂). The vapour compression refrigeration systems have fundamentally four basic components and basic process:-

1. Evaporator
2. Compressor
3. Condenser (Micro Channel Air Cooled)
4. Expansion Device

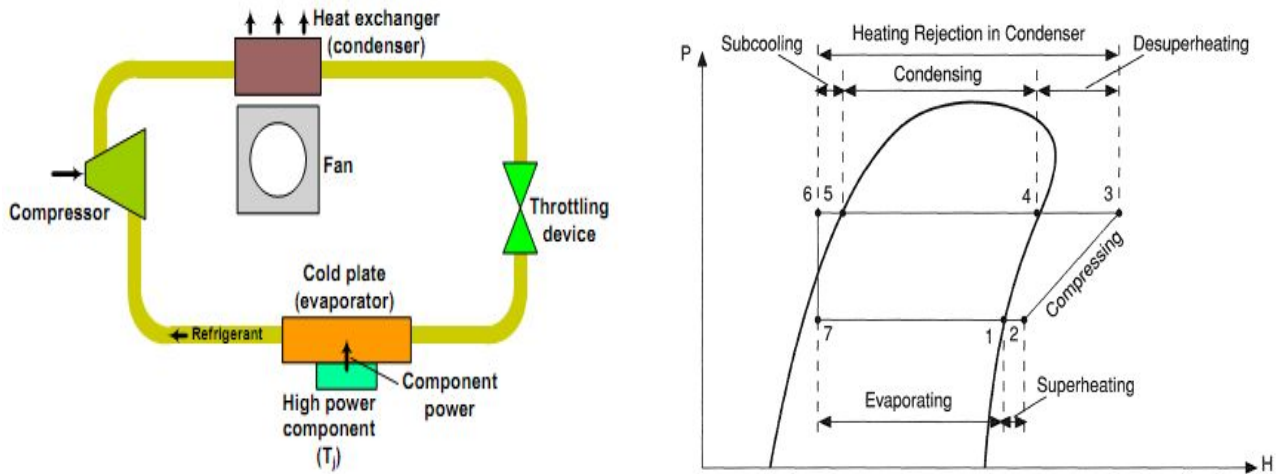


Fig:- 2.1 Refrigeration cycle with P-H diagram

The present work has been designed to demonstrate refrigeration process and used two refrigerant with micro channel condenser for investigate the performance of refrigerator. The experimental setup is shown in Fig 2.2. The specifications of the set-up are given in Table no. 1. In domestic refrigerator the simple condenser replace by micro channel condenser. The micro channel condenser fitted back side in domestic refrigerator. A small fan is used for circulating of air in the micro channel condenser. And investigate the performance of two different refrigerants in summer session. In this setup low and high pressure gauge was used for measuring pressure in the cycle and digital temperature meter and thermocouple was used for measuring the positive and negative temperature on various points in the cycle which measuring range is -50° to 200°C .

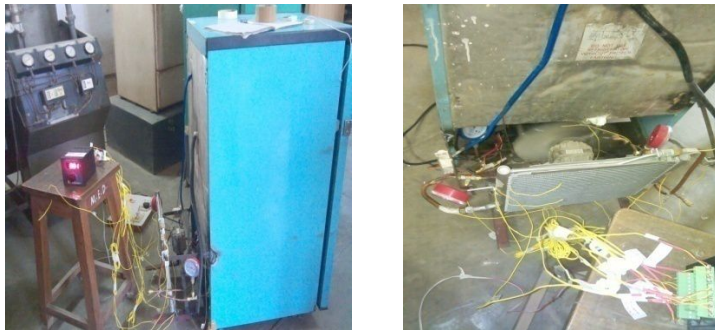


Fig: - 2.2 Domestic Refrigerator with Micro-Channel Condenser (Actual Experimental Setup)

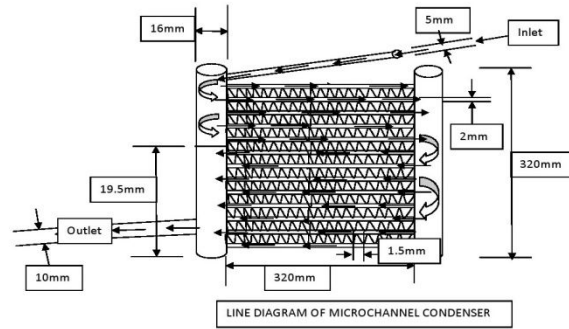


Fig: - 2.3 Line diagram of micro-channel condenser

Table 1: Specification of refrigerator

1	Refrigerator capacity	210 liter
2	Current rating	1.0 amp
3	voltage	220 volt
4	frequency	50 Hz
5	No. of door	01
6	refrigerant	R134a 60g, and hydrocarbon 40g
7	Defrost system	Auto defrost

III. FORMULA USED FOR DATA CALCULATION

- 1 Refrigerating Effect (R_e) In kJ/kg = $h_2 - h_7$
 - 2 Compression Work done (W_c) In kJ/kg = $h_3 - h_2$
 - 3 Coefficient of Performance(COP) = Refrigerating Effect/ Compression work done
= $h_2 - h_7 / h_3 - h_2$
 - 4 Specific volume at suction to compressor in m^3/kg = $V_g / T_g = V_{g(sup)} / T_{g(sup)}$
 - 5 Suction volume in m^3/min $V = m \times v_{(sup)}$
- Where: - h_3 , & h_2 , h_7 Enthalpy at high and low temperature.

IV. OBSERVATION & RESULT

The experiment was conducted during summer days in the month of April 2014, various parameters are measured with the help of respective measuring device and data was collected and tabulated as shown below.

Table: 2 observation table for different parameters for refrigerant R134a

T_c (°C)	T_E (°C)	P_L (bar)	P_H (bar)	Sub Cooling (°C)	Super Heating (°C)	R_e (kJ/kg)	W_c (kw)	C.O. P	V_g Sup (m^3/min)	M_{fr} (kg/mi n)	V (m^3/mi n)	P_r
50	1	3.7	13.9	6	5	143.7 0	25.38	5.25	.9420	1.5	1.32	3.7 5
58	-8	2.9	13.8	6	8	126.3 4	36.10	5.92	.9246	1.6	1.49	4.7 5
57	-10	2.7	13.1	7	6	123.4 7	36.76	3.35	.5979	1.8	1.12	4.7 6
57	-12	2.3	13.0	7	6	112.2	47.95	2.34	.0537	1.9	0.11	5.6

						1						9
56	-15	2.0	12.5 2	8	5	110.1 1	50.31	2.18	.0480	1.9	0.07	6.2 6
54	-18	1.8	11.9 0	8	6	102.0 9	52.12	2.00	.0450	2.2	0.10	6.6 1

Table: 3 observation table for different parameters for hydrocarbon refrigerant

T _C (°C)	T _E (°C)	P _L (bar)	P _H (bar)	Sub Cooling (°C)	Super Heating (°C)	R _e (kJ/kg)	W _c ((kw))	C.O.P	V _g Sup (m ³ /min)	M _{fr} (kg/mn i)	V (m ³ /mi n)	P _r
45	01	5.4	13.0 9	7	4	279.5 8	48.58	5.65	.0145	.83	0.026	2.4 1
45	-8	4.15	13.0 7	7	4	269.7 3	58.48	4.61	.032	.86	0.05	3.1 3
45	-10	3.9	13.0 3	7	4	258.7 5	69.46	3.72	.0616	.901	0.046	3.3 4
43	-12	3.8	12.7 3	6	5	257.6 8	71.25	3.60	.0582	.905	0.0525	3.3 5
43	-15	3.9	12.4	7	4	250.7 8	72.75	3.45	.0411	.931	0.038	3.1 7
42	-18	2.9	11.8 5	8	4	243.4 3	74.01	3.28	.0378	.958	0.036	4.0 8

Graphical Representation

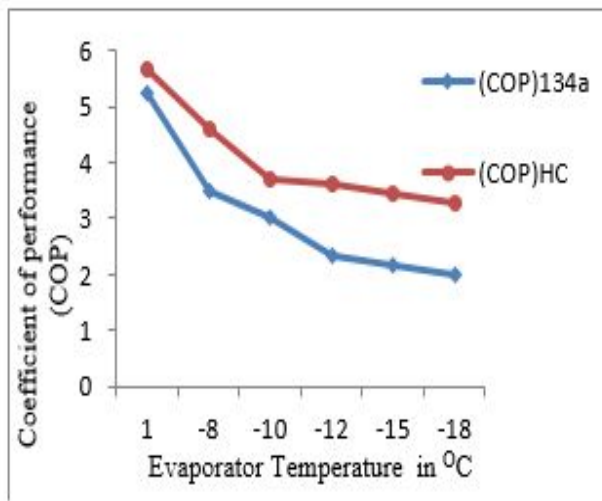


Fig: 4.1 Variation in COP with respect to Evaporator Temperature for R-134a and Hydrocarbon Refrigerants

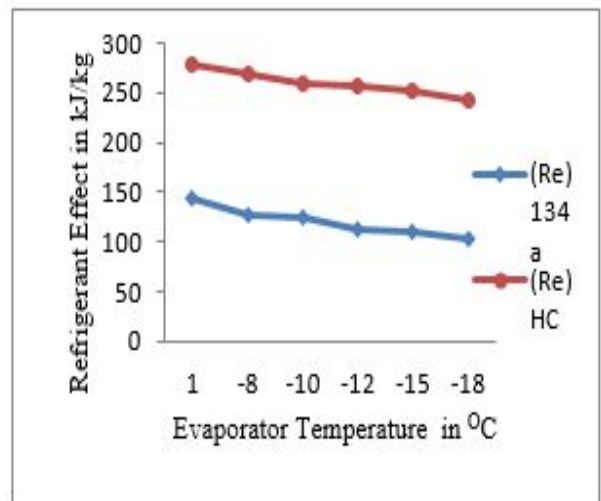


Fig: 4.2 Variation in Refrigerating Effect in kJ/kg with respect to Evaporator Temperature for R-134a and Hydrocarbon Refrigerants

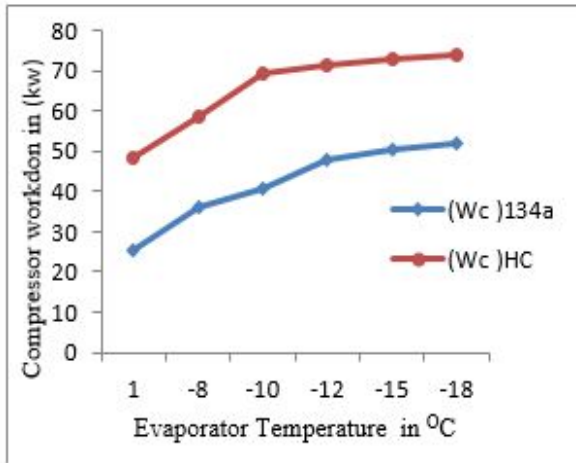


Fig: - 4.3 Variation in compressor work done with respect to Evaporator Temperature for R-134a and Hydrocarbon Refrigerants

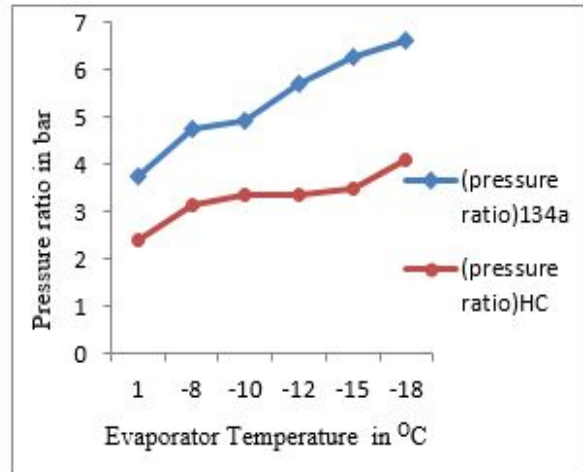


Fig: - 4.4 Pressure Ratio in bar V/S Evaporator Temperature in °C

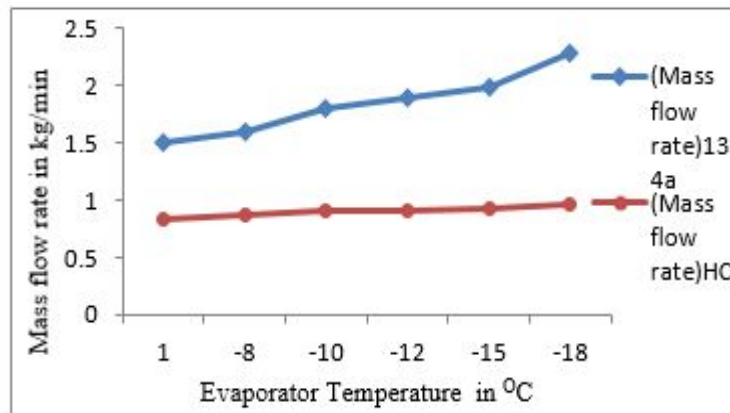


Fig: - 4.5 Mass Flow Rate in kg/min V/S Evaporator Temperature in °C

V. CONCLUSION

This work invested an ozone friendly, energy efficient, and user friendly, safe and cost- effective alternative refrigerant for HFC 134a in domestic refrigeration system. After the successful investigation on the performance of the refrigerant HC and R134a

The following conclusions can be drawn based on the results obtained.

1. The COP of the system has been improved with the hydrocarbon refrigerants. The average COP of HC 19% higher than that of R134a.
2. The domestic refrigerator was charged with 60g in 134a and 40g of HC. This is indication of better performance of HC as refrigerants.
3. Refrigeration efficiency of the system increases with the increases in condensing and evaporating temperature.
4. Mass flow rate is reduced when we are using hydrocarbon as refrigerant.

Nomenclature

CFC	–	Chlorofluorocarbon	P_h	–	High Pressure in bar
COP	–	Coefficient of Performance	T_c	–	Condenser Temperature °C
HCFC	–	Hydro chlorofluorocarbon	T_E	–	Evaporator Temperature °C
HFC	–	Hydro fluorocarbon	V	–	Volume In m ³ /min
HC	–	Hydrocarbon	h	–	Enthalpy
ODP	–	Ozone Depletion Potential	C_p	–	Specific Heat
GWP	–	Global Warming Potential	Subscripts		
P	–	Pressure In bar	Cond	–	Condenser
R_e	–	Refrigerating Effect in kJ/kg	Evap	–	Evaporator
W_c	–	Compression Work Done in kw	Com	–	Compressor
T	–	Temperature in °C	Sub	–	Sub Cooling
P_r	–	Pressure Ratio	Sup	–	Superheating
M_{fr}	–	Mass Flow Rate In kg/min	Dis	–	Discharge
P_L	–	Low Pressure in bar	Ref	–	Refrigerant

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