Experimental Studies on a Vapour Compression Refrigeration System using Hydrocarbon Mixtures and R-12 Refrigerant

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***Abstract*— this work aims for development of one of the eco-friendly vapour compression refrigeration system. The present vapour compression refrigeration system uses R-134a refrigerant, which has many adverse effects, which is minimized by use of other alternative refrigerant. This work consists of using eco-friendly hydrocarbon gas mixture as refrigerant, which does not deplete ozone layer and it can be used in the commonly used system without any significant change in the system. In this analysis, the performance of vapour compression refrigeration system is assessed experimentally with two different refrigerants. Various parameters are measured, like compressor discharge temperature and pressure. The results obtained are compared and the optimum performance in terms of higher refrigeration effect, better heat transfer rate and COP are studied.**

***Keywords:* Vapour Compression Refrigeration system, R-12, Hydrocarbon refrigerants, Coefficient of Performance.**

I. INTRODUCTION

In nature, heat transfer occurs from the region of higher temperature to lower temperature without requiring any external devices. The reverse process cannot occur by itself. The transfer of heat from lower temperature to higher temperature requires special devices called refrigerators. Refrigerator works under the principle of reversed Carnot cycle. Many types of refrigerants are available for getting refrigerant effect. It is very much important to use a suitable refrigerant, which gives the maximum cooling effect by consuming minimum power. In present situation, most of the vapour compression refrigeration system is equipped with R-134a due to its thermodynamic properties.

1.1 Need for alternative

Chlorofluorocarbon and hydro chlorofluorocarbon refrigerants fulfilled all the primary requirements and heralded an unprecedented revolution in the refrigeration and air-conditioning industry. Today, the litany of the requirements imposed on an ideal refrigerant has increased. The additional primary requirements now include zero ozone depletion potential and low global warming potential. The continuous depletion of the ozone layer, which shields the earth's surface from the biologically damaging ultraviolet sunlight called UV-B radiation has resulted in a series of international treaties demanding a gradual phase out of CFC and HCFC refrigerants.

The CFCs have been phased out in developed countries since 1996 and 2010 in developing countries. Initial alternative to CFCs included some hydro-chlorofluorocarbons, but they will also be phased out internationally by year 2020 and 2030 in developed and developing nations, respectively. Since 2010 to onwards be the fourth generation is being focusing on refrigerants that do not contribute to global warming, ozone layer depletion, efficient, non-flammable and non-toxic with good stability.

1.2 Alternatives

In CFCs and HCFCs present the chlorine content which contribute to the depletion of ozone layer. But the alternative refrigerant of CFCs and HCFCs is Hydrocarbon HCs (R-290, R-600a) as there are no content of chlorine. R-12 is the leading replacement for domestic refrigerators. Although the ODP of R-12 is one, the GWP is relatively high which is shown in the table 1.1

Table 1.1 Refrigerant Information

Refrigerant	Saturated Vapour Pressure [kPa]	Molar Mass [g mol^{-1}]	Molar Vapour Specific Heat [J mol^{-1} K^{-1}]	Safety Designation	GWP [100 years horizon]	ODP
R-600a	199.5	58.122	97.79	A3	20	0
R-134a	374.6	102.03	94.93	A1	1320	0.9
R-290	584.4	44.096	81.88	A3	20	0
R-12	640	120.91	66.63	A1	10600	1
R-410A	995.0	72.585	87.27	A1	2000	1

R-32	1011.5	52.024	69.16	A2	543	1

1.3 Hydrocarbon mixture

Hydrocarbon is an organic compound consisting entirely hydrogen and carbon. The majority of hydrocarbons found on earth naturally occurred in crude oil. Hydrocarbon mixture is an azeotropic mixture of propane (R-290) & isobutene (R-600a). It has property very similar to R-12 & R-134a which is commonly used refrigerant now a day. This blend of hydrocarbons is used in most of the Ac of European cars. It contains 60% propane, +40%isobutane. Moreover it has zero ozone depletion potential and a negligible global warming potential. Although the ODP of HC mixture is Zero, the GWP is relatively very low which is shown in the table 1.2. I have done an experimental investigation with hydrocarbon refrigerant mixture composed of R-290 and R-600a in the ratio of 60%+40% by weight as an alternative to R-12 in a Vapour compression refrigeration system.

Table 1.2 Properties of HC mixtures with R-12 and R-134a

PROPERTIES	**Chemical type**	**Normal Boiling Point**	**Latent Heat**	**ODP**	**GWP**
HYDROCARBON MIXTURE	HC	-31°C	367 kJ/kg	0	3
R-12	CFC	-30°C	145	0.9	10600
R-134a	HFC	-26°C	189	0	1600

2 METHODOLOGY

In this work the experimental work was carried out on vapour compression refrigeration system. The specification of the vapour compression refrigeration system describe in section 2.1. The refrigerant hydrocarbon mixture was used in work, the various parameters like COP, refrigeration effect, compressor work etc. There is no significant change in this system for R-12 system. We used the HCs refrigerant state constraints to specify R-12 system components are evaporator, condenser, and compressor.

2.1 Specification of vapour compression refrigeration system

Capacity	1.5 Ton
Compressor Type	Rotary
Refrigerant	R-12 [Freon]
Charged mass	450g

2.2 Experimental setup

The evaporator and condenser are fabricated as shell and tube type adiabatic (insulated shell) heat exchangers. Compressor used is Sri Ram Model no is JB232 at the range of 5.1 A, 240 V Rotary type. Hand operated valves are provided before and the capillary tube to facilitate easy replacement. The pressure and temperature readings of refrigerant were taken at four strategic points 1, 2, 3 & 4 as indicated in figure 2.1 of the actual experimental set up. All of these pressure gauges were fitted on a wooden panel to ensure that the gauges do not vibrate during testing. The temperature at various points is measured with help of the thermometer and also measured the pressures.

First we have used the hydrocarbon mixture refrigerant and experiment was conducted conventionally by taking all of data manually. The all four points of thermometer were inserting in plugs and these plugs were connected to the refrigerant flow tubes. Four pressure gauges were used and were respectively installed before and after each main component.

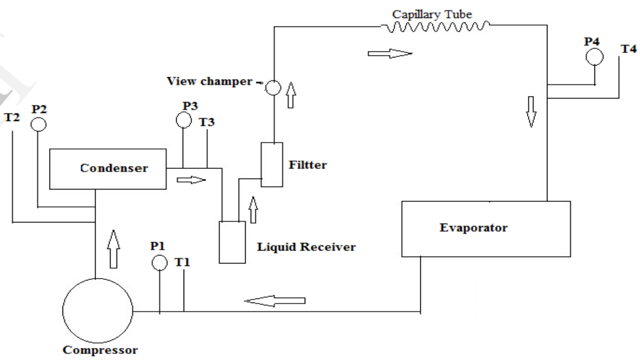

Figure 2.1 Line diagram of Experimental setup

2.3 Experimental procedure

1. Before starting the experiment, the preliminary actions like any leakages in supply line, pressure drop is to be checked.
2. To ensure the effective performance of the system, any vacuum created inside the pipe line was sucked out by using vacuum pump.
3. Initially refrigerant was loaded into compressor suction line and allowed to settle it down for twenty minutes.
4. The corresponding experimental parameters like temperature, pressure and energy consumption was observed for every twenty minutes time interval.

During the experimental condition, the various parameter observed are pressure (P_1,P_2,P_3,P_4) and temperature (T_1,T_2,T_3,T_4). The energy consumed by compressor for different time intervals was measured form the energy meter.

Time [Min]		Temperature [°C]				Pressure (Kg/cm^2)			
		T_1	T_2	T_3	T_4	P_1	P_2	P_3	P_4
HC Mixtures	20	3	68	39	-15	0.7	10	10.3	0.5
	40	2	76	38	-14	0.7	10.1	10.6	0.6
	60	3	79	38	-14	0.8	10.4	10.8	0.6
R-12 Refrigerants	20	26	48	30	7	0.1	7.4	7.8	0.1
	40	26	52	30	8	0.1	7.4	7.8	0.1
	60	27	53	30	8	0.2	7.6	8	0.1

Table 3.2 Experimental Readings

4 RESULTS AND DISCUSSION

R-12 and mixture of two hydrocarbons were used in the experiments. Discussion of the results will be given as turn follows.

Figure 4.1 Time Vs COP

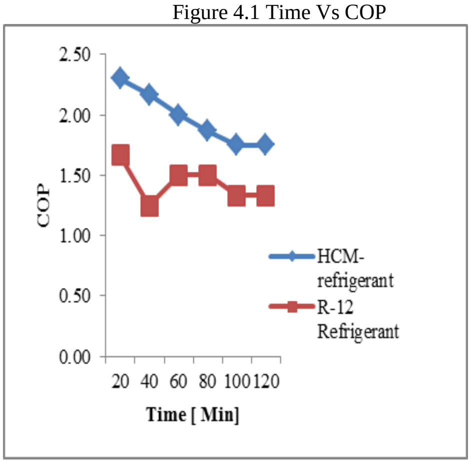

Figure 4.2 Time Vs condenser Heat rejection rate

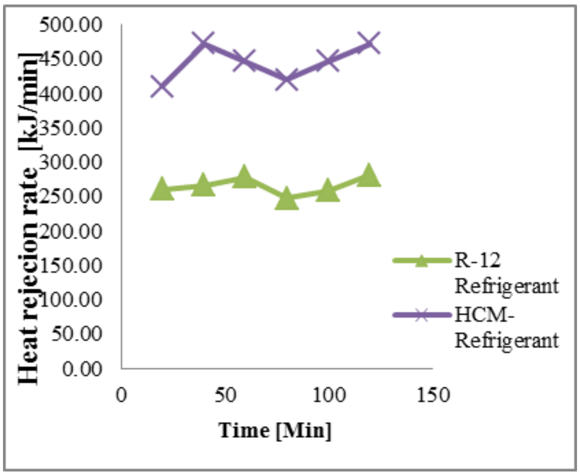

Table: 4.3 Performance comparisons

RESULTS	HC MIXTURES	R-12	Discussion
COP	2	1.3	More than 30% Increased
COMPRESSOR WORK(kW)	0.511	0.4324	15% Increased
THEROTICAL HORSE POWER (hp)	0.66	1.07	38% Decreased
COMPRESSOR TEMPERATURE (°C)	79	54	31% Increased
HEAT REJECTION RATE (kJ/Min)	446	260	50% Increased

Figure 4.3 Time Vs Therotical Horse Power

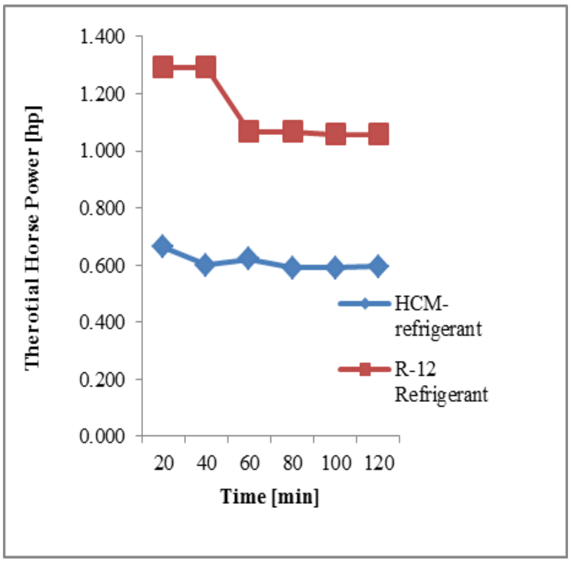

Figure 4.4 Time Vs Compressor work

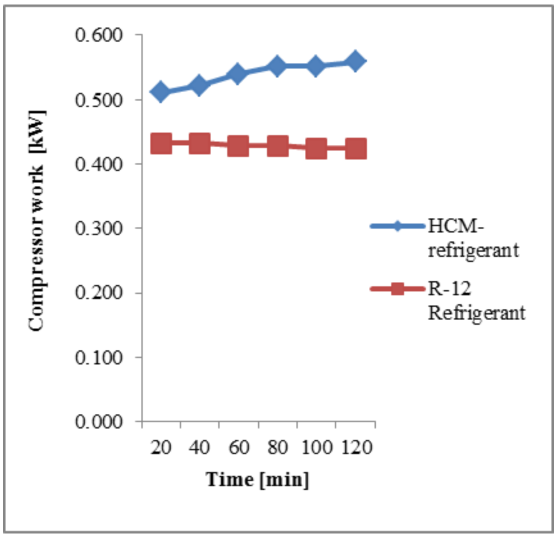

Figure 4.1 represents comparison of COP with time for HC Mixtures and R-12 refrigerant. The COP is high compare the R-12 Refrigerant . The HC mixture higher performance can be obtained.

Figure 4.2 represents comparison of Heat Rejected to the condenser with time for HC Mixtures and R-12 refrigerant. The rate is high compare the R-12 refrigerant .

Figure 4.3 represents comparison of therotical horse power with time for HC Mixtures and R-12 refrigerant. The horse power is low compare the R-12 refrigerant.

Figure 4.4 represents comparison of Compressor with time for HC Mixtures and R-12 refrigerant. The compressor consumed power is slightly high compare the R-12 refrigerant . All the Performances are compared in table 4.3

CONCLUSION

The refrigeration analysis was performed experimentally for different refrigerant mixtures for vapour compression refrigeration system and from the analysis it is concluded that,

- This mixture provides better performance in terms of Heat rejection rate and COP. The heat rejection rate is increased 50% and COP is increased 30% for the vapour compression refrigeration system with hydrocarbon mixture
- Hydrocarbon refrigerant are having less impact on the environment in terms of global warming based on the heat rejection rate.
- Hydrocarbon mixture shows favorable results on theoretical horse power required to drive the compressor. The power required for hydrocarbon mixtures was 38% less than the R-12 refrigerant for same experimental condition.
- In domestic refrigerators and industrial refrigeration systems, the mixture of R-290 & R-600a can be used as alternate refrigerant instead of R-12 and R-134a.

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