Experimental Investigation of Performance of VCR System using Refrigerants R134A, R600A, and R290

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Abstract - *Vapor compression refrigeration system is used in all refrigeration industries that requires refrigeration, heating, cooling, ventilation and air conditioning. Due to the usage of present refrigerants ozone layer depletion and global warming potential are increasing day by day and more over the increasing energy demand lead to the need to develop an energy efficient refrigeration system.*

Thus an alternative with lower ozone layer depletion and global warming potential and higher heat transfer co-efficient is needed to overcome the above defined problem. The hydrocarbons have zero ozone depletion potential and very less global warming potential.

This paper studies the Performance of commonly used refrigerant R134a in a VCR system and extends to the performance analysis of VCR system using hydrocarbon refrigerants R600a and R290.

Key Words: **COP, Eco-friendly refrigerants, Hydrocarbons, R134a, R290, R600a, VCR**

1. INTRODUCTION

Vapor compression refrigeration system is used in all refrigeration industries that requires refrigeration, heating, cooling, ventilation and air conditioning. Due to the usage of present refrigerants ozone layer depletion and global warming potential are increasing day by day and more over the increasing energy demand lead to the need to develop an energy efficient refrigeration system.

Thus an alternative with lower ozone layer depletion and global warming potential and higher heat transfer co-efficient is needed to overcome the above defined problem. The hydrocarbons have zero ozone depletion potential and very less global warming potential.

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2. COMMONLY USED REFRIGERANTS

Air

1. It is a refrigerant commonly used from ancient times.
2. It is used in air craft where efficiency is not of much importance.

Ammonia

1. It is a oldest refrigerant whose COP is of order 4
2. Its highly toxic inflammable, cheap and has low specific volume

Carbon dioxide

1. It has low boiling point which makes it suitable for low temperature refrigeration.
2. It is stable and immiscible with lubricant oil.

Halocarbon refrigerants

These refrigerants are obtained by replacing one or more hydrogen atoms of hydrocarbons with halogens like chlorine, fluorine.

1. They are non flammable
2. They are non toxic
3. They are stable

R12

- It is not generally used because of its high global warming potential.

R13

- They have high specific volume and are suitable for centrifugal compressors.

R22

- They are more soluble in water.
- They are used in packed air conditioning and liquid chillers.
- They are not used because of polluting environment

Hydroflurocarbons

R134a

- It is not miscible with traditional mineral oils so it is used with synthetic polyester and poly alkylen glycol.
- It is the commonly used refrigerant.

R152a

- It has low global warming potential.
- It is flammable and has low energy consumption.

R404a

- It has low efficiency at high condensation temperatures

Hydrocarbons

It consists of hydrogen and carbon atoms and it is a colorless gas and it is most suitable for low temperature applications

R600a

- It is an organic compound with large volumetric flow.
- It provides a safe, quiet and highly efficient system.

R290

- They are compactable with the components and lubricants used in conventional refrigeration system
- It is highly flammable.

3. ENVIRONMENTAL ISSUES

In addition to being toxic or explosive and thereby dangerous to people's health, there are other problems associated with refrigerants. Environmental aspects are increasingly being taken into consideration. Refrigerants can thus also be ranked according to their impact on the stratospheric ozone layer (the Ozone Depletion Potential, ODP) or as greenhouse gases (the Global Warming Potential, GWP).

Ozone Depletion Potential, ODP

The ODP is the ratio of the impact on ozone of a chemical compared with the impact of a similar mass of CFC-11 (R11). Thus, the ODP of CFC-11 is 1.0 by definition.

Global Warming potential, GWP

The GWP is the ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide. Thus, the GWP of CO2 is 1.0 by definition

Table -1: GWP and ODP of various refrigerants

REFRIGERANT	GWP	ODP
R134a	1430	Low
R600a	3	0
R290	3	0
R22	1810	High

4. EXPERIMENTAL ANALYSIS

Experimental analysis of refrigerants such as R134a, R600a, R290 are carried out.

EXPERIMENTAL PROCEDURE

- Evacuation is done using a rotary vacuum pump by creating vacuum in the experimental setup.
- Using charging line, charging valve and digital weighing machine optimum amount of the refrigerant is charged.
- Load the evaporator with desired liters of water and switch on the setup and note down the readings.
- Note the initial and final energy meter reading and initial and final water temperature.
- Note the pressure at suction and discharge side of compressor and condenser discharge pressure. Similarly temperature at various location of setup.
- Then experiment is carried out till the water reaches the maximum negative temperature.
- Using the formulas discussed below actual and relative COP of the system is calculated.

FORMULAS

The actual and relative COP of the refrigerating system is calculated using the below discussed formulas.

ACTUAL COP

$$COP = \frac{REFRIGERATING\ EFFECT}{COMPRESSOR\ WORK}$$

RE $=[\, mc_{p\ water}(\Delta T_{UPTO\ 0^{\circ}}) + mh_{fg} + mc_{p\ ice}(\Delta T_{AFTER\ 0\ C})] \div$ TIME TAKEN IN MINUTES

m = mass of water (Kg)

C_{Pwater} =specific heat of water(KJ/Kg K)

h_{fg} =latent heat of fusion of ice(KJ/Kg)

$C_{p\ ice}$ =specific heat of ice(KJ/Kg K)

W_C =[ΔE ×60]/ Time taken in minutes

ΔE = difference in energy meter reading(KWh)

IDEAL COP

$$IDEAL\ COP = \frac{h1 - h3}{h2 - h1}$$

h1=enthalpy at evaporator outlet (KJ/Kg)

h2=enthalpy at compressor outlet (KJ/Kg)

h3=enthalpy at condenser outlet (KJ/Kg)

RELATIVE COP

$$\text{RELATIVE COP} = \frac{ACTUAL\ COP}{IDEAL\ COP}$$

5. DATA COLLECTION

Table -2: Data collection of R134a.

LOAD (kg)	TIME(min)	INITIAL READING ^0C	FINAL READING ^0C	ENERGY METER READING kW-hr
1	115	26	-2	0.34

Table -3: Data collection of R600a.

LOAD (kg)	TIME(min)	INITIAL READING ^0C	FINAL READING ^0C	ENERGY METER READING kW-hr
1	165	23	0	0.4

Table -4: Data collection of R290.

LOAD (kg)	TIME(min)	INITIAL READING ^0C	FINAL READING ^0C	ENERGY METER READING kW-hr
1	134	23	0	0.55

6. RESULTS AND DISCUSSION

The following are the results obtained for refrigerant R134a,

1. LOAD = 1 kg
2. REFRIGERATION EFFECT = 0.0648 kW
3. COMPRESSOR WORK = 0.177 kW
4. ACTUAL COP = 0.365
5. IDEAL COP = 0.3864
6. RELATIVE COP = 0.944

The following are the results obtained for refrigerant R600a,

1. LOAD = 1 kg
2. REFRIGERATION EFFECT = 0.043 kW
3. COMPRESSOR WORK = 0.1454
4. ACTUAL COP = 0.299
5. IDEAL COP = 1.272
6. RELATIVE COP = 0.2349

The following are the results obtained for refrigerant R290,

1. LOAD = 1 kg
2. REFRIGERATION EFFECT = 0.062 kW
3. COMPRESSOR WORK = 0.243
4. ACTUAL COP = 0.255
5. IDEAL COP = 1.25
6. RELATIVE COP = 0.204

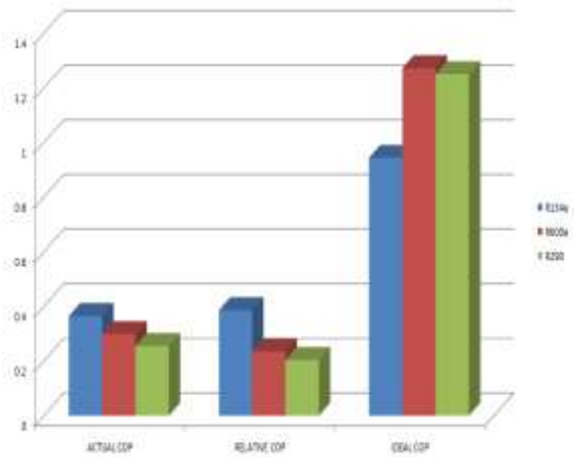

Chart -1: Graphical representation of COP (coefficient of performance) of refrigerants R134a, R600a, and R290.

From the above graph it is inferred that Coefficient of performance of R134a is higher than R600a and R290 in a relative measure even though hydrocarbons like R600a and R 290 can be used owing to their low global warming effects.

7. NOMENCLATURE

VCR **-** Vapor compression refrigeration.

COP **-** Coefficient of performance.

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