EXPERIMENTAL INVESTIGATION OF PERFORMANCE OF VCRS BY USING ALTERNATE REFRIGERANTS

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Abstract: Vapour compression refrigeration has been used in almost everywhere in the world. In that VCRS, refrigerant has ozone layer depleting potential and green house gases. The classical refrigerants such as chloroflurocarbons, hydrochloroflurocarbons and hydroflurocarbons have created the environmental problem. So to avoid the environmental issue has to move alternate refrigerant. In this research, the alternate refrigerant has taken R410a and LPG. The experimental has been conducted by using R410a and blendes of LPG and R410a (60%&40% by weight %) with various condensing temperature like 32°C,35°C and 40°C versus various evaporating temperature. It is found that refrigerating capacity and COP increases with increases in evaporating temperatures and decreases with the increase in condensing temperatures.

Key words: VCRS, Performance, Alternate Refrigerant, R410a, LPG

I. INTRODUCTION

Atmosphere is made up of different layers. The layer closest to the surface is called the troposphere, which extends from the Earth's surface up to about 1 kilometer. The ozone layer is located in the stratosphere. Stratospheric ozone is earth's natural for all life forms, shielding our planet from harmful ultraviolet-B radiation. UV-B radiation is harmful to the earth. The ozone layer has been destroyed by industrial chemicals including ozone depleting refrigerants.

The terms, global warming and climatic change are often used interchangeably. Green house gases such as CO_2, CH_4 and refrigerants create a greenhouse effect by trapping heat in the lower atmosphere. This makes the earth warmer. Most of refrigerants are having the global warming potential and addition to the ozone layer depletion. Non- ozone depleting alternative refrigerants has global warming potential. Montreal protocol and Kyoto protocol are the international treaties on ozone layer depletion and climatic change to stop the use of ozone depleting and global warming refrigerants in refrigeration and air-conditioning equipments to protect the global environment.

II. LITERATURE SURVEY

Dr. Kruse summarizes the results of energy consumption measured in a German Research Center's calorimeter tests of substitutes for R-2 and R-502 under refrigeration conditions varying from -10˚C to -40°C. The substitute refrigerants are tested include R-404a, R-407a, R-407b, R-407c, R-507, R-410a, and R-290. Only R-410a and R-290 have energy efficiencies comparable to R-22, whereas the other fluids show 5% to 15% higher energy consumption. R-410a is advantageous at low evaporation temperatures while R-290 has a small advantage (about 4%) over R-410a in the higher temperature range (-10°C).

Joshua P. Meyer presents a comparative analysis of the performance and environmental effects of R-134a, R-290, R-404a, R-407c, R-410a, and R-22 in a vapor compression experimental setup. He concludes that not one of the refrigerants outperformed all of the other refrigerants on all the criteria considered. The COP was highest in the experimental system for R-134a, although the differences in cooling COP between R-134a, R-290, and R-22 are on average less than 2%. It is followed by R-404a and R-410a which have cooling COPs approximately 12% lower than that of R-134a for this high condensing temperature condition. The cooling COP of R-407c is the lowest, on average 17% below that of R-134a. The paper further concludes that R-290 is marginally better than the alternatives due to its low global warming potential (GWP) and zero ozone depletion potential (ODP).

Chen et al. investigates the feasibility of hydrocarbon refrigerant mixtures as replacements for R-22 in residential air-conditioning and heat pump systems using computer modelling methods. The COP and the seasonal performance factor (SPF) were calculated for R-290 and mixtures of R-290/R600, R-290/R-600a, and R-290/isopentane. The simulation results were compared to results for R-22, R-410a, and R-407c. The simulations were run using a steady state UA model called HPCYCLE and refrigerant properties from the NIST software REFPROP version 4.0. For the simulation the authors assumed that all heat exchangers are counter flow and that part-load performance is identical to steady-state performance. The paper says that the mixture of R-290 and R-600 (25%/75%) are the best performance, with "a higher COP than either one of the currently proposed HFC replacement refrigerants" at 4.27, compared to the COP of 3.66 achieved with R-22, 3.44 with R-410a and 3.86 with R-407c. The paper points out "the disadvantage of R-290/R-600 is the low volumetric capacity which results in a larger, more expensive compressor."

David and Dona1d (1990) have reported that refrigerant mixtures provide solution to the problem of alternatives to CFCs. It has also been reported that the zeotropes, near-azeotropes and zeotropes are the three categories of mixture which can be use as working fluids. The mixing of two or more refrigerants provides an opportunity to adjust or tune those properties that are most desirable.

Venkataratnam et al (1996) have reported that the pinch point would occur only in the condensation or evaporation region of the heat exchangers for zeotropic mixtures. It has also been found that the perfect glide matching might not be possible when two phase enthalpy varies non-linearly with temperature, and if the variation was significant temperature pinches occur somewhere within the ends of the condenser and evaporator depending on the nature of the enthalpy curve. Equations to find the pinch conditions of 300 zoetrope's have also been reported.

Hoist and Florian (1997) have reported that the concentration shift in non-azeotropic. mixtures was due to the factors such as leakage of refrigerant mixture, thermodynamic behaviour of refrigerant mixtures in two- phase regions, and differential solubility of the components of refrigerant mixtures in lubricant oil. It has been reported that the overall average concentration in the heat exchangers with two-phase regions was different from that of the concentration at charging.

III. RESEARCH OBJECTIVE

The objectives of the present project work are:

1. To identify environmental-friendly non-azeotropic refrigerant mixtures (NARMS) as drop in substitute for HFC-22.
2. To regression models using design of experiments to study the performance parameters such as refrigeration capacity, compressor power and coefficient of performance of the selected refrigerants and their performance comparison.

IV. REFRIGERANT SELECTION

Published literature indicates HC refrigerant blend as the promising drop-in substitute for HCFC in refrigeration and air conditioning equipments. Further, it was understood that the addition of HCs to HFCs makes it compatible with mineral oil and thereby avoiding the usage of hygroscopic POE oil.

4.1REFRIGERANTS

4.1.1R-410a

R-410a is a blend of two refrigerants, HFC-32 and HCF-125 (50/50 wt%), that performs very much like a single component refrigerant. R-410a is the leading candidate for replacing R-22 in large commercial and industrial use. R-410a has the leading non-ozone depleting replacement for HCFC-22 in unitized air conditioning systems for residential and light commercial units. R-410a has a significantly higher vapor pressure than R-22. It condensing pressure has 336PSI at standard conditions.

4.1.2 LPG

The typical LPG charge of a German refrigerator is only 25 g (D'hlingero1993). In February 1995, Email released the first of its R-600a refrigerators with a 16% energy saving over the previous R-134a models. They are the Westinghouse Environ RA142M and Kelvinator Daintree M142C, both 140 L bar refrigerators. The measurements indicated reduced compressor work but this could not be determined accurately. The superheats measured were satisfactory with typically an 8% increase in condenser pressure.

V. VAPOUR COMPRESSION REFRIGERATIONS SYSTEM

Mathematical modeling is one of the most widely accepted practices to study the performance of vapour compression refrigeration system with environmentally friendly refrigerants. This chapter deals with the theoretical modeling and prediction of performance of the vapour compression refrigeration system with CFC-12, HFC-134a and the proposed alternative refrigerant mixture.

The theoretical model used to compare the performance of the refrigerants is based on a one stage simple vapour compression cycle consisting of compressor, condenser, expansion valve and evaporator. The vapour compression refrigeration cycle's schematic diagram is shown in below figure. The pressure- Enthalpy (P-H) and Temperature-Entropy (T-S) diagrams for pure and zeotropic refrigerant mixture is shown in figure.

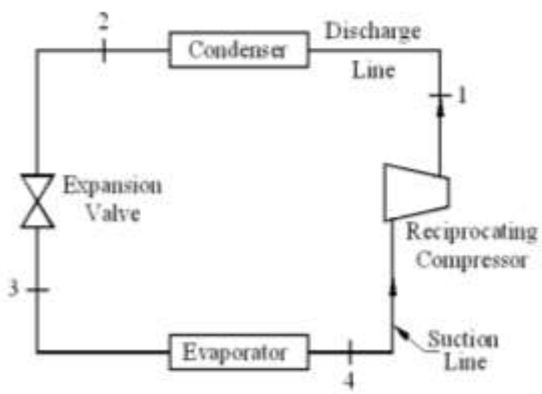

Figure 1 Schematic diagram of vapour compression refrigeration cycle

It is also assumed that steady state and uniform flow conditions throughout the elements of this simple vapour refrigeration cycle and ranges in kinetic potential energies and heat loss from the compressor are neglected. Therefore, specific compressor power, CP can be written as

CP = $\frac{1}{k} X \frac{N}{t} X 3600$ (5.1)

where, K = energy meter constant rev/kW/hr,

N = no of revolution,
T = time taken for N revolution in energy meter.

and

Refrigerating capacity, RC can be written as

RC = $m_b\, C_{p,b}\, \Delta T$ (5.2)

where, m_b = mass flow rate of brine solution kg/s,

C_{pb} = specific heat capacity of brine solution kJ/kgk.

The COP of the theoretical refrigeration cycle is then calculated by

COP_{th} = Refrigerating capacity, (RC) /Compressor power (CP) (5.3)

5.1 SYSTEM PERFORMANCE STUDY – EXPERIMENTAL SET – UP

An experimental set-up was developed to facilitate the study on the performance of vapour compression refrigeration system with the selected refrigerants. The experimental set-up used for this performance study shown in figure 5.1.

Figure 2 Experimental set-up used to test the performance of refrigerants

5.2. Experimental procedure

To regulate the mass flow rate of refrigerant and to set pressure difference by using expansion device. The refrigerant has charged after the system had been vacuum. The experiment has started with R-12 and R-134a to set up the base reference for further comparisons with the other selected alternative refrigerants. The desired evaporating and condensing temperatures were obtained by adjusting all the other parameters in the system such as cooling water flow rate and its temperature, refrigerant flow rate and brine solution flow rate and its temperature. The readings were measured after the system attained steady state conditions. During experimentation, it was observed that to reach steady state, the system taken 1.5 to 2 hours. The experiment was conducted with all selected alternative refrigerants.

VI. RESULTS AND DISCUSSION

The experimental results obtained from the performance analysis of R-410a and LPG/R-410a (60/40 by wt %) are discussed with respect to the parameters such as refrigerating capacity, compressor power and coefficient of performance. The coefficient of performance has calculated from the measured data.

COP = Refrigerating capacity/ Compressor power

$RC = m_b C_{p\,b}\,\Delta t$

Where m_b and Δt represent the coolant brine mass flow rate and the difference of coolant temperatures across the evaporator coil. C_{pb} is the specific heat of the coolant brine.

6.1 Refrigerating capacity

The variation of refrigerating capacity with condensing temperature 32°C, 35°C, 40°C is plotted in figure. It shows that the refrigerating capacity increases with increasing evaporator temperature for refrigerant mixtures. Reason is their higher latent heat of evaporation.

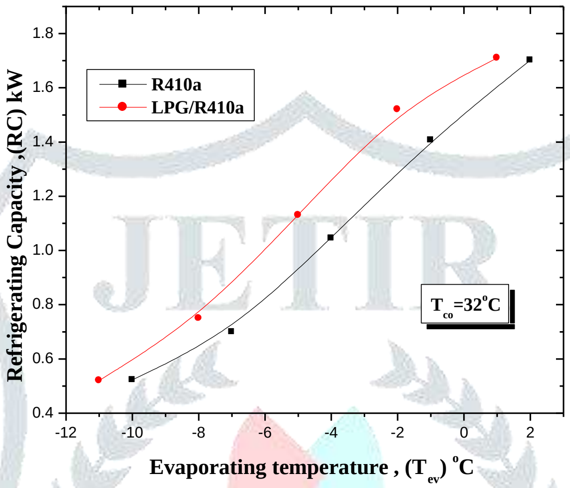

Figure 3 Variation of refrigerating capacity for different evaporating temperature at T_{co} = 32 °C

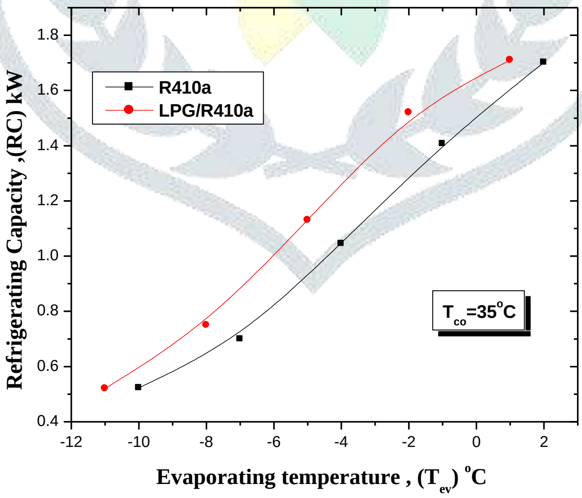

Figure 4 Variation of refrigerating capacity for different evaporating temperature at T_{co} = 35 °C

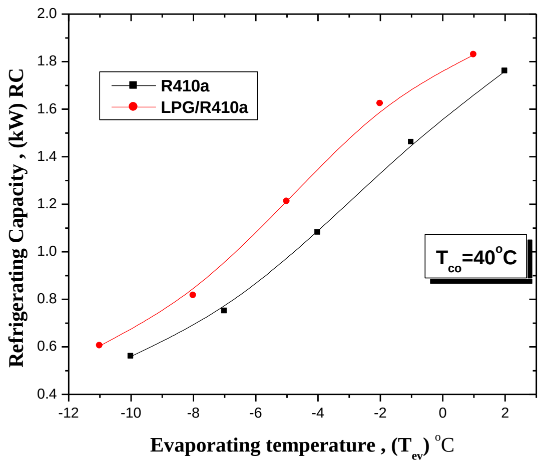

Figure.5 Variation of refrigerating capacity for different evaporating temperature at T_{co} = 40 ˚C

6.2 Compressor power

The variation of compressor power with condensing temperatures 32°C, 35°C, 40°C were plotted in figure. From the figure it is figure found that the compressor power increases with the increase in both evaporating and condensing temperature for all the refrigerants.

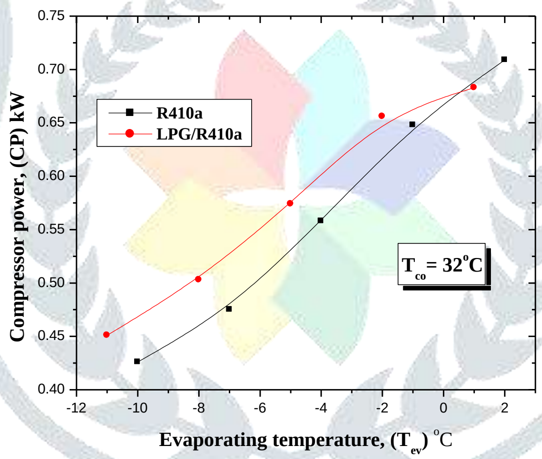

Figure 6 Variation of Compressor Power for different evaporating temperature at T_{co} = 32 ˚C

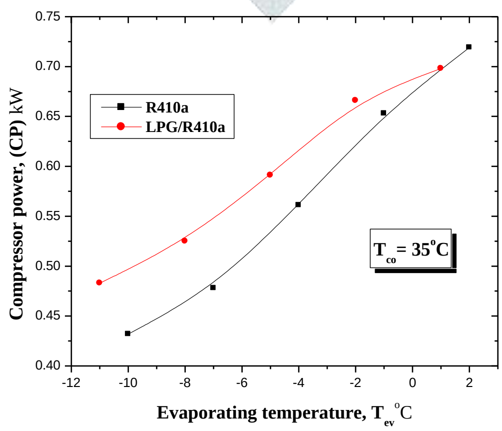

Figure 7 Variation of Compressor Power for different evaporating temperature at T_{co} = 35 ˚C

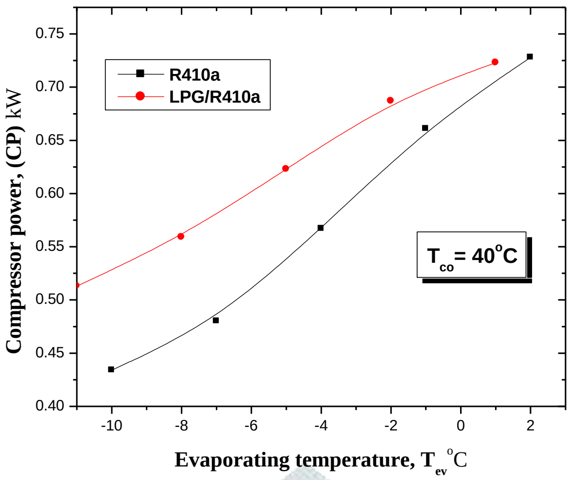

Figure 8 Variation of Compressor Power for different evaporating temperature at T_{co} = 40 °C

6.3 Coefficient of performance

The variations of coefficient of performance with evaporating temperatures at different condensing temperature are plotted in figures. Similar to refrigerating capacity the COP also increases with increases in evaporating temperatures and decreases with the increase in condensing temperatures. Reason is the higher rate of heat transfer as an effect of large temperature difference between the primary and secondary refrigerants. COP is also higher for various condensing temperatures.

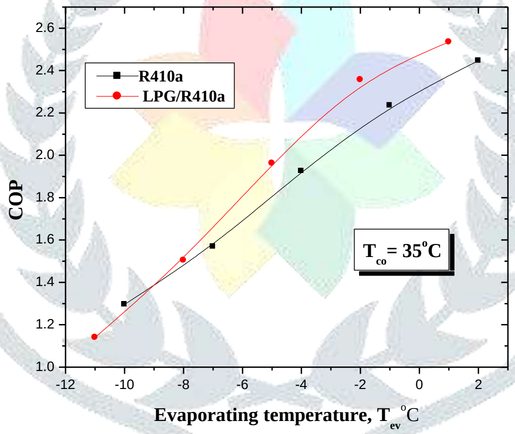

Figure 9 Variation of COP for different evaporating temperature at T_{co} = 35 °C

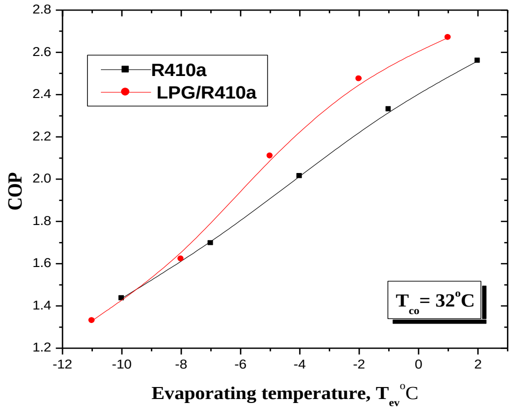

Figure 10 Variation of COP for different evaporating temperature at T_{co} = 32 °C

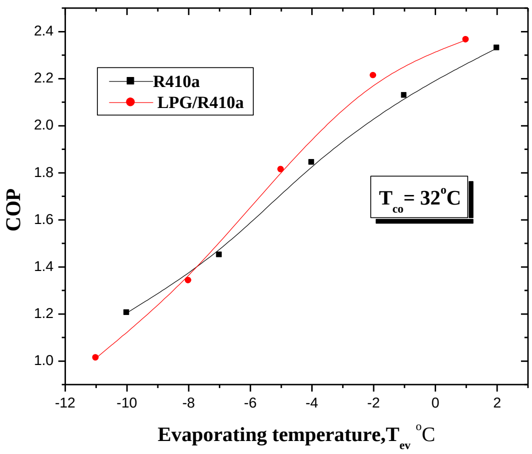

Figure 11 Variation of COP for different evaporating temperature at T_{co} = 40 °C

VII. CONCLUSION

The models developed for the performance parameters of a vapour compression refrigeration system were simple quadratic equation of first and second order correlating the performance parameters of the system. These developed models can be readily used for predicting the system performance for any given set of system variables.

1. From the study it can be observed that the refrigerating capacity and COP of the selected refrigerant mixtures increases with increasing evaporating temperature and decrease with increasing condensing temperature.

2. The refrigerating capacity and COP of LPG/R-410a mixture is higher than that of R-410a. But the values of R-410a are closer to LPG/R-410a mixture. So the mixture LPG/R-410a mixture is also alternative to refrigerant R-22.

3. The COP of the refrigerant LPG/R-410a mixture was lower at the lower T_{ev} and it was slightly higher at higher T_{ev}.

VII. REFERENCE

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