Performance characteristics of various refrigerant blends in a refrigeration kit

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ABSTRACT

In this project mainly focused on finding alternatives to a prominent refrigerant that exists in the market. The various blends out of the refrigerant and evaluating their performances in a refrigeration test kit to determine the best alternative by comparing the performance of the system in each case. The performance of the cooling equipment when R134a kept as the reference value. The type of refrigeration occurring here is the "Vapour Compression Refrigeration". The roster of refrigerants used in this system is R134a, R290, and R600a.The experimentation is carried out by having r-134a as the base coolant and producing mixtures out of it in various proportions. We have chosen to work with two such blends which are

Blend 1: R134a/ R290 (90%/10%).

Blend 2: R134a/ R290/ R600a (70%/10%/20%).

Also, the environmental impacts of an HFC like R134a having a Global Warming Potential (GWP) of 1430 can be minimized by blending with Hydrocarbons like R290 and R600a has very low values of GWP of 3.3 and three respectively. Also for the Kyoto Protocol, instead of eliminating R134a, we try to investigate its performance and that of its alternatives (blends) in this experimentation.

KEY WORDS: refrigerant, blend, REFPROP, cop.

1. INTRODUCTION

Austin, 2012, deals with a household refrigerator designed to work with R-134a used as a base refrigerant. The cooler using mixed refrigerant was investigated and compared with the performance of refrigerator when R-134a used as a coolant. The energy consumption of the fridge during an experiment with mixed refrigerant and R-134a was measured. The lowest electric power consumption was achieved using a mixed refrigerant with heat level is less that -15^{o} C. This mixture made higher volumetric cooling capacity and lower freezer air temperature compared to R134a. The values of pressure ratio and power consumption, Pull-down time of a mixed refrigerant compared with R134a refrigerator. The C.O.P and other result obtained in this experiment show a positive indication of using mixed refrigerant as refrigerants in the household refrigerator.

Nazeer, 2013, deals the study of different environmental friendly refrigerants of either hydrocarbon or Hydrofluorocarbons (HFC). Due to a higher value of the latent heat of Hydrocarbons (HCs), the amount of coolant supplied also reduced as compared with HFC-134a. When Hydro Chlorofluorocarbons (HCFCs) replaced with HFCs, the system delivered a poor performance with increased energy consumption. When nanoparticles added to the refrigerant, the system gave better performance with reduced power consumption than that of pure coolant.

Sattar, 2007, deals the experimental results on the performance of butane isobutene and their mixture as a refrigerant in a fridge. Pure butane, isobutene, and the 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 used as a coolant. The effect of condenser temperature and evaporator temperature on COP, refrigerating effect, condenser duty, work of compression and heat rejection ratio investigated. The energy consumption 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 and 28^{o} C ambient temperature when isobutane and butane were used as refrigerants respectively. The power consumption and COP of hydrocarbons and their blends show that hydrocarbon can utilize as the refrigerant in the domestic refrigerator. The COP and other result obtained in this experiment show a positive indication of using HC as refrigerants in the domestic refrigerator.

Sergio, 2004, deals the blends formed mixing Hydro Fluorocarbons (HFC) and Hydrocarbons (HC) can be classified as semi-natural refrigerants since, by optimizing the composition, it is in principle possible to adapt basic features such as GWP, TEWI, and flammability to the industrial and environmental requirements. However, the energetic efficiency must be competitive with the traditional refrigerants. To evaluate the efficiency, it is necessary to know the actual thermodynamic properties.

Selection of Blends: In our experiment, the basic requirements of a refrigerant to be satisfied were mainly the thermal properties as well as the environmental friendliness. So, indeed considering a blend would require the satisfying the conditions. The basic approach to the procedure would be to select a refrigerant of a high eminence in the field and to work on producing blends out of it to find out improvements in the characteristics we have chosen. So in this process, we have opted for a refrigerant of a high prominence R134 a and are working on improving its qualities

Properties of R134a:

Table.1.Properties of R134a

Chemical formula	**CH_2FCF_3**
Molar mass	102.03 g/mol
Appearance	Colourless gas
Density	0.00425 g/cm^3, gas
Melting point	−103.3 °C
Boiling point	−26.3 °C
Solubility in water	0.15 wt%

Environmental friendly properties:
ODP = 0.
GWP = 1430.
We now look forward to blending a hydrocarbon to improve our target properties effectively
Blend 1
Name of the Blend: R134 a/ R 290.
Total blend1 weight: 1000 grams
The weight of the solvent: 900 grams. (90%)
The weight of the Solute: 100 grams. (10%)
Weight of the cylinder: 800 grams
Total weight: 1800 grams
Environmental friendly properties:
ODP = 0, GWP = 3.3.
Properties of R290a:

Table.2. Properties of R290a

Chemical formula	**C_3H_8**
Molar mass	44.10 g·mol^{-1}
Appearance	Colorless gas
Odour	Odourless
Density	2.0098 kg/m^3
Melting point	−187.7 °C
Boiling point	−42.25 °C
Vapour pressure	853.16 KPa (at 21.1 °C)

Blend 2:
Name of the Blend: R134 a / R600a/R290 a
Total weight of the blend2: 1000 grams
The weight of the solvent: 700 grams. (70%)
Weight Of the Solute 1: 200 grams. (20%).
The weight of the solute 2: 100 grams. (10%)
Total weight : 1800 grams
Environmental friendly properties:
ODP = 0.
GWP = 4
Properties of R600a:

Table.3. Properties of R600a

Chemical formula	**C_4H_{10}**
Molar mass	58.12 g·mol^{-1}
Appearance	Colourless gas
Odour	Odourless
Density	2.51 mg mL^{-1} (at 288 K, 1 bar)
Melting point	−159.42 °C
Boiling point	−11.7 °C
Vapour pressure	204.8 KPa (at 21 °C)

Improvement of the target properties:
C.O.P: The C.O.P depends on upon the extent to which the refrigerant is miscible with the compressor oil. Hydrocarbons increase the miscibility of the refrigeration blend with the compressor oil making the thermodynamics more efficient. In the system, the amount of the refrigerant through the system becomes more uniform, and mass flow rate of the refrigerant becomes increased

Environmental Properties: The ozone depletion potential for R290 is also zero. But when the other parameter comes into play, i.e. the GWP, it turns out to be very low for R290. The value is astonishingly small which is 3.3. So this blend would undoubtedly prove to be a more eco-friendly one than the pure solvent Similarly, the values of ODP and GWP for R600a are 0 and three respectively. So a combination of a more eco-friendly refrigerant would improve the overall quality of the refrigerant

2. EXPERIMENTAL SETUP AND PROCEDURE

Fig.1.Experimental setup

Experimental setup:

Compressor: The work of a compressor is to increase the pressure, and corresponding saturation temperature (boiling point) of the refrigerant vapor to high enough level so the refrigerant can condense by rejecting its heat through the condenser.

Condenser: The high-temperature refrigerant passes through a condenser coil. As the vapor refrigerant travels through the coil, air from a fan passes over the coil to cool the gas refrigerant. As the gas cools it condenses and becomes a liquid. The flow passage will be maximum to remove maximum heat

Evaporator: The evaporator is the central part of the refrigeration system. The evaporator placed where the cooling effect is to be needed. The evaporator consists of tubes, which absorbs heat from the air blown through a coil by a fan. The tubes are made of metals with high thermal conductivity to maximize heat transfer

Expansion valve: Expansion valve used to control the flow of the liquid refrigerant into the evaporator. Control devices usually are thermostatic, meaning that they are responsive to the temperature of the coolant

Energy meter: The electromechanical induction meter was used to find the energy consumption. Time taken is noted for three revolutions of the disc for calculation purposes

Anti-choke: It is used to remove moisture content from the pipes or tubes to ensure a free flow of the refrigerant gas.

Gauge manifold: Manifold gauges are used to check both the high and low side pressures of the refrigerant inside the system. In this case, we make use of it as an inlet manifold to feed the refrigerant gas inside the compressor.

Vacuum pump: The vacuum motor was used to create the partial vacuum. The difference in the pressure gradients sucks the gas into the system

Water tank: A water tank consists of the water to be cooled. It has a capacity of nearly 7 liters. The coolant is made to pass through the water through the capillary tube, and windings

Experimentation:

- Firstly, fill the tank of 4.5 liters capacity with water, which is the fluid to be cooled.
- Note down the initial temperature of the water with the thermometer.
- Let the system run for about 15 minutes.
- Then note down the values of T1, T2, T3&T4 and subsequently those of P1, P2, P3, and P4.
- Note down the time taken by the disc in the energy meter to complete three revolutions with a stopwatch.
- Repeat the procedure for every 15 minutes till 45 minutes are complete.
- Repeat the same process by varying the pressures by discharging the refrigerant via the discharge pin of the compressor.
- In our case, the pressures achieved are 40 psi, 35 psi, 30 psi and 25 psi respectively.

$$\text{Cop} = \frac{\text{Actual refrigeration effect}}{\text{Compressor workdowne}} = \frac{Q}{W}$$

$Q = m*C_P*\Delta t \div T.$

$w = 1/E_C*n/t*3600.$

m = mass of the water = 4.5 liters.

Cp = specific heat capacity of water = 4.187 KJ/Kg-k.

Δt = difference between initial and final water temperature.

T = time duration.

EC = energy meter reading = 750 kw/hr.

N = number of revolution of energy meter = 3.

T = time taken for three revolutions of the energy meter.

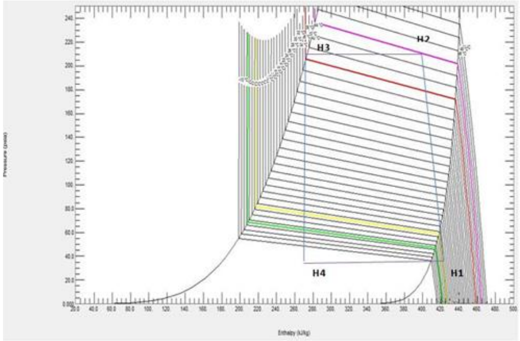

Figure.2. p-h chart for blend1 at 40psi

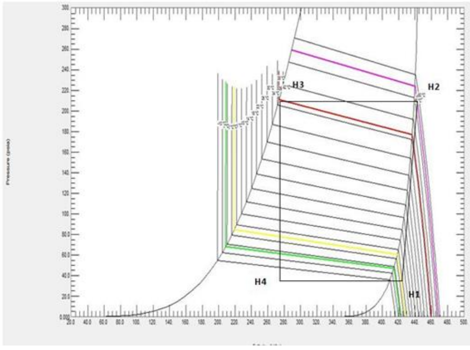

Figure.3. p-h chart for blend1 at 35 psi

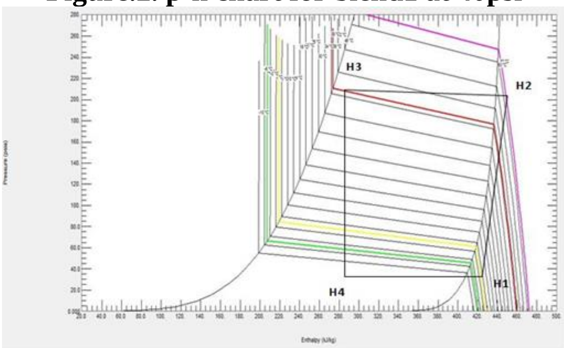

Figure.4. p-h chart for blend1 at 30 psi

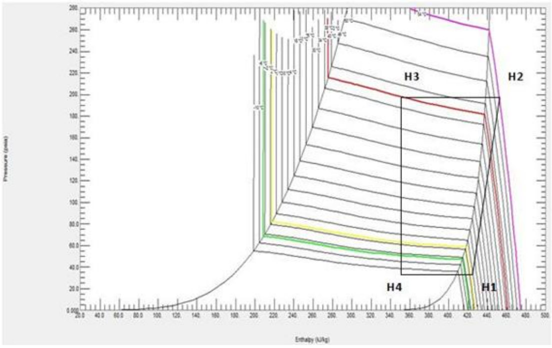

Figure.5. ph chart for blend1 at 25 psi

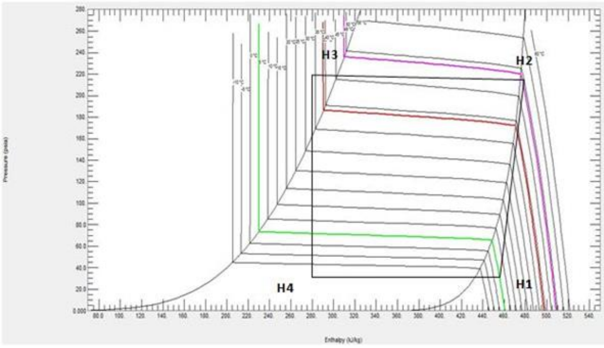

Figure.6. p-h chart for blend2 at 40 psi

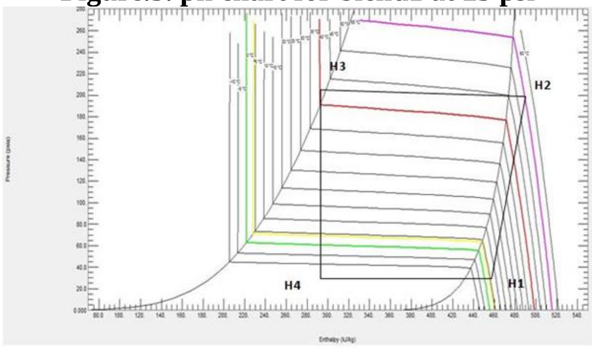

Figure.7. ph chart for blend2 at 35 psi

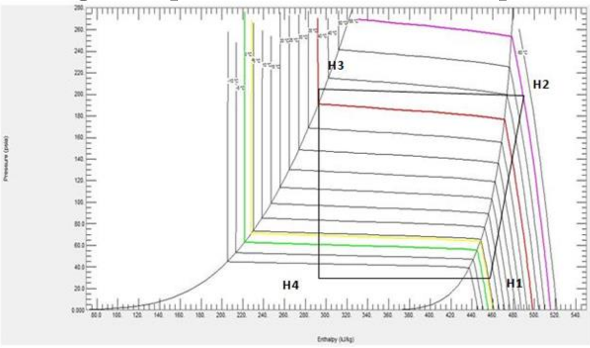

Figure.8. p-h chart for blend2 at 30 psi

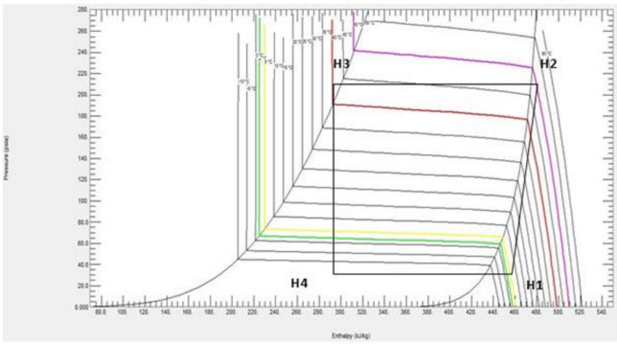

Figure.9. ph chart for blend2 at 35 psi

3. RESULT AND DISCUSSION

Table.4.Result Comparison

Pressure	R-134a		Blend 1		Blend2	
(PSI)	Actual COP	Theoretical COP	Actual COP	Theoretical COP	Actual COP	Theoretical COP
40 PSI	1	0.91	1.12	1.15	1.03	0.9
35 PSI	0.99	0.9	1.06	0.9	1.006	0.84
30 PSI	1.018	0.92	1.074	0.82	1.009	0.91
25 PSI	1.02	0.903	1.04	0.70.	1.08	0.88

Actual &Theoretical COP values: We had conducted the experiment for each refrigerant at various pressures and times to get a more detailed theoretical comprehension. So, for briefing the results we chose to take examples of the values obtained individually at 40 PSI and 15 minutes for each refrigerant. Thus, the particularly selected values of the refrigeration effect of the refrigerants R134a, Blend 1 and Blend 2 are 0.23 KW, 0.356 KW, and 0.293 KW, respectively. We can infer from this that the refrigeration effect has increased by 54.7% in Blend one as compared to R134a, whereas the increase is 27.4% (i.e. half of the earlier increase) in blend two as compared to R134a.

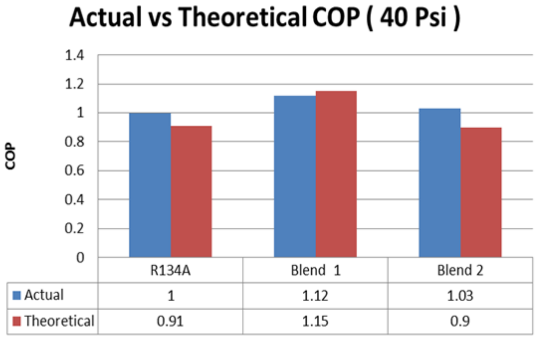

Figure.10. Actual vs. Theoretical cop

The increase in refrigeration effect is a function of the cooling effect caused by the addition of hydrocarbons. The cooling effect is a function of the temperature change value in the given period since other parameters such as mass to be cooled and the specific heat capacity remains the same. The increase in cooling effect caused due to increase in a rate of evaporation due to the presence of hydrocarbons in the blends. In this experiment, the values of various temperatures as pressures recorded though not useful in calculating the actual COP, helps us to plot the p-h charts and deduce the value of COP theoretically by finding the respective values of enthalpies at each stage. Thus, the values of COP obtained for R134a, and Blend 1 and Blend 2 are 0.9, 1.15 and 0.9 respectively.

The selected values of refrigeration effect at 40 PSI and 15 min are:

1. Q_{R134A} = 0.23 KW
2. Q_{BLEND1} = 0.356 KW (54.7% increase)
3. Q_{BLEND2} = 0.293KW (27.4% increase)

Thus, the resulting COPs of R134a, Blend 1and Blend 2 for the same working conditions are found to be 1.27, 1.92 and 1.63 respectively. The respective increases in COP in comparison to that of R134A are 51.2% and 28.3%.

4. CONCLUSION

In this project investigated the performance of three different mixtures in a vapor compression refrigeration kit. The values are compared with R134a, having the C.O.P. values of R134a as the comparing parameter. By conducting the experimental analysis, we have found out that Blend 1 (R134a/R290) of the ration 90% and 10% has the maximum C.O.P, and the Blend 2 (R134a/R600a/R290) has given the least C.O.P when compared to R134a. The Blend 1 has shown a slight increase C.O.P. by 12% when compared to the C.O.P. of R134a in the same system. The Blend 2 is very slightly more than the pure R134a regarding C.O.P. i.e. by 3%. The increase in C.O.P. is due to the presence of HC in the blends which cause the increase in the rate of evaporation of the refrigerant. Also, while comparing the input work data, the system when charged with blends 1&2 operated with low energy consumption than R134a refrigerant. While considering the power consumption parameter, it is understood that both the mixtures can be used as an alternate refrigerant to R134a on a long term run. The results show that hydrocarbon mixtures have lower energy consumption. The overall performance of the hydrocarbon mixtures revealed that this could be the long term alternative to phase out R134a.

REFERENCES

Abuzar Qureshi M, Shikha Bhatt, Comparative analysis of cop using R134a and R600a refrigerant in domestic refrigerator at steady state condition, International Journal of Science And Research, 3(12), 2014.

Austin N, Senthil Kumar P, Kanthavel Kumaran N Thermodynamic optimization of household refrigerator using propane–butane as mixed refrigerant" by / International Journal of Engineering Research and Applications (IJERA), 2(6), 2012, 268-271.

Mohd Aasim Nazeer Ahmed Quaraishi and Wankhede US, Use of hydrocarbons and blend as refrigerant, International Journal of Modern Engineering Research, 3(1), 2013, 255-257.

Neil A.Roberts and Owen R,Chambers, Rhodia Organique, Energy saving refrigerant blends comprising R134a, R125 & R600 or R600a, by Fine Ltd. International Refrigeration And Air Conditioning Conference Paper 632 at Purdue, July 12-15, 2004.

Prabha C, Koshy Mathews P and Arun Kumar SP, Performance assessment of an eco-friendly alternative refrigerant R441a, by International Journal For Research in Emerging Science And Technology, 1(5), 2014.

Sattar MA, Saidur R, and Masjuki HH, Butane, Isobutane and their mixtures as an alterantives to R134a in domestic refrigerator, International Journal of Mechanical and Materials Engineering, 2(2), 2007, 154-160.

Sergio Bobbo, Roberto Camporese, Laura Fedele and Roman Stryjek. HFC and HC blends as refrigerants, International Refrigeration And Air Conditioning Conference at Purdue, July 12-15, 2004.