Performance Comparison of Hydrocarbon Refrigerant as Isobutane R600a and Propane R290 in Domestic Refrigerator as Alternative Refrigerants to R134a

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ABSTRACT: This study focuses on an experimental study of hydrocarbon blend of isobutene (R-600a) and propane (R-290) as an environment friendly refrigerators with zero ozone depletion potential (ODP) and very low global warming potential (GWP), to replace conventional refrigerators tetrafluoroethane R-134a in a domestic refrigerators. The performance is observed for a domestic refrigerator by using blend of hydrocarbon R-600a and R-290 and its performance is compared with R-134a without change in original system. Due to the higher value of latent heat of hydrocarbons the amount of refrigerant charge required found to be reduced as compared with hydrofluorocarbon R-134a. Comparative performance study shows refrigerating effect is improved by using hydrocarbon blends, reduction of 35-40% in the refrigerant charge, the energy consumption per day reduced by 5-10%.

Keywords: CFC, Hydrocarbon, isobutane R600a, propane R290, Refrigeration system

1. Introduction

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures. Refrigeration systems are also used extensively for providing thermal comfort to human beings by means of air conditioning. The Hydrocarbon (HC) and Hydro Fluro Carbon (HFC) mixtures (such as R404a, R407, and R410A) are not currently manufactured indigenously and hence have to be imported at a higher cost. This is likely to affect the growth in refrigeration and air conditioning sector in India. Domestic refrigerators manufactured in India range in capacities from 65 to 580lit. Most of the refrigerators uses R134a as refrigerant. The choice of alternative to R134a is narrowed down to R12 and hydrocarbon refrigerants. Refrigerators manufactured before 2000 were still running on R12. To full fill the objectives of the Montreal Protocol, R12 has to be replaced by either hydrocarbon mixtures or R134a/hydrocarbon mixtures without modification in the existing system. The most commonly used commercial refrigerant R134a and the proven alternative mixture of zeot ropic propane R290 and isobutane R600a mixture with R290 and R600a and was prepared and the corresponding performance was investigated.

R.S.Agarwal et. al. has discussed the salient features of R600a and mixtures of 50%R290/50%R600a for domestic and small capacity commercial refrigeration working with R12. The performance of the refrigerator with the alternative refrigerants R600a and mixtures of R290/R600a was compared with R12. Hydrocarbons have a zero ODP and negligible GWP, compatible with most of the materials and commonly used lubricating oils. HC refrigerants in comparison with R12 have high latent heat of vaporization and low value of density which makes the refrigerant attractive inspite of their flammability because of low charge and circulation rate. The charge levels are approximately 40% that of R12. Compressor discharge temperature in case of HC refrigerants is lower than R12.

R.S.Agarwal has conducted experiments to evaluate the substitute for R12 with the HC mixture of R290/R600a (50%/50%) and R134a/R600a. Thermodynamic properties of these mixtures needed for the analysis have been computed using REFPROP. The HC blend consumes 12% less energy than R134a/R600a. Pull down time for R134a/R600a (88%/12%) is 11 hours 50 minutes and it is 13 hours 15 minutes for HC blend. COP of the R134a/R600a is 1.7938 and it is 1.9445 for the R12. Up to a certain extent energy consumption decreases with the increase in capillary length.

Y.S.Lee et. al. has conducted performance tests of a domestic VCR system with R600a as the refrigerant. The tests were carried out by varying the input power of the compressor between 230 and 300 W, while the amount of the charged refrigerant was about 150g. The refrigeration temperatures were set at about 4 and −100C. The COP of the system lies between 0.8 and 3.5 in the freezing application, which is comparable with those of the system with R12 and R22 as the refrigerant and the refrigeration capacity increases with the refrigeration loads.

S.Joseph Sekhar et. al. has developed drop in substitutes for R12 with R134a and HC blends. HC refrigerants have inherent problems in respect of flammability. R134a is neither flammable nor toxic. But HFCs are not compatible with mineral oil and the oil change is a major issue while retrofitting. The experimental analysis has been carried out in a 165 liter R12 domestic refrigerator...
retrofitted with the ternary mixture of 91% R134a/4.032% R290/4.968% R600a without changing the mineral oil. Its COP as well as energy consumption is compared with the conventional one. It has been found that the new mixture could reduce the energy consumption by 4 to 11% and improve the actual COP by 3 to 8% of R12.

Man-Hoe Kim has assessed the performance of a hydrocarbon refrigerant, R600a, as an alternative to R12 in a 215 liters domestic refrigerator. A theoretical analysis was performed with REFPROP and tests were conducted with R600a. All the tests were performed in a temperature controlled room at 30±1°C. The test results showed that the energy efficiencies and the cooling speeds with R600a were improved by 1 to 11% and 3 to 10%, respectively, when compared to R12.

M.S. Kim et al. has experimentally investigated the performance of a heat pump with two azeotropic refrigerant mixtures of R290/R134a and R134a/R600a with the mass fractions of 45%/55% and 80%/20%. The performance parameters of the azeotropes were compared with pure R12, R134a, R290 and R22 at the both heating and cooling conditions with suction-liquid heat exchanger. The COP of R134a/R290 was lower than that of R22 and R290, and R600a/R134a shows higher COP than R12 and R134a. The capacity for R134a/R290 was higher than that for R290 and R22, and R600a/R134a exhibits higher system capacity than R12 and R134a. Experimental results show that the compressor discharge temperatures of the considered azeotropic mixtures are lesser than those of the pure refrigerants i.e., R22 and R12.

M.A. Sattar et al. investigated and compared the performance of the refrigerator using R600a, R600 and a ternary mixture of mixture of R290/R600a/R600 as refrigerants with the R134a. The effects of evaporator and condenser temperatures on COP, refrigerating effect, compressor power and heat rejection ratio were investigated. The results show that the compressor consumed 3% and 2% less energy than that of R134a at 28°C ambient temperature when R600a and R600 was used as refrigerants respectively. The compressor power and COP of hydrocarbons and their blends shows that hydrocarbons can be used as refrigerants in the domestic refrigerator. The COP and other results obtained from the experiments show a positive indication of using HC as refrigerants in a domestic refrigerator.

The isentropic work input to compressor -
\[ W_c = m \cdot (h_2 - h_1) \quad \text{kJ/s} \]

- where \( h_2 \) is the enthalpy of refrigerant at the outlet of compressor (kJ/kg)

The heat rejected by the condenser to the atmosphere -
\[ Q_{\text{cond}} = m \cdot (h_2 - h_3) \quad \text{kJ/s} \]
- \( h_3 \) is the enthalpy of refrigerant at the outlet of condenser (kJ/kg)

\[ \text{COP} = \frac{Q_{\text{evap}}}{W_c} \]

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**Table 1** Properties of Hydrocarbon Refrigerants

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>ODP</th>
<th>Boiling Point</th>
<th>Latent heat kJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>R134a</td>
<td>0</td>
<td>-26.10</td>
<td>216.87</td>
</tr>
<tr>
<td>R600a</td>
<td>0</td>
<td>-11.73</td>
<td>364.25</td>
</tr>
<tr>
<td>R290</td>
<td>0</td>
<td>-42.04</td>
<td>423.33</td>
</tr>
</tbody>
</table>
2. Results

![COP Vs Evaporator Temperature](image1)

Fig. 2 COP Vs Evaporator Temperature

![Power input in Kw Vs Evaporator Temperature](image2)

Fig. 3 Power input in Kw Vs Evaporator Temperature

![Pressure Ratio Vs Discharge Temperature](image3)

Fig. 4 Pressure Ratio Vs Discharge Temperature

3. Conclusion

Based on the experimental work and literature review, it was observed that the R290/R600a (30/70), R290/R600 (40/60), R290/R600a (50/50), R290/R600 (60/40) and R290/R600 (70/30) refrigerant blend could be a viable alternative HFC134.

From the experimental study it has been observed that the refrigerating capacity and COP of the selected refrigerant mixtures increases with increasing evaporator temperature and decreases with constant condensing temperature.

The compressor power consumption was higher with the refrigerants R290/R600a (30/70), R290/R600 (40/60), R290/R600a (50/50), R290/R600 (60/40) and R290/R600 (70/30) for the range of operating conditions.

The COP of the refrigerant R290/R600 (40/60), was slightly higher at higher Tev than that of R12 and R134a. All the alternative refrigerant mixtures showed a reduction in charge due to their low liquid densities.

REFERENCES


