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Analysis of Ecofriendly Refrigerants and Mixture of Refrigerants (Butane & Isobutane) for Replacing CFC's and HCFC's in Vapour Compression System of Refrigeration

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Abstract:
The objective of this work is to develop an eco-friendly refrigerant and mixture of refrigerants (Blend) with negligible Ozone depletion potential (ODP) and Global warming potential (GWP) values. The present work highlights the comparison of performance of Vapour compression refrigeration system with Hydrocarbon refrigerants and mixture of refrigerants in various proportions which can be considered alternative refrigerant to R-22 and R-134a etc. Viewing the properties of pure refrigerant and the mixture of refrigerants with various proportions in the form of blends and comparing the performance of vapour compression refrigeration system working between the same temperature limits of condenser and evaporator. These refrigerants are found more friendly to the environment, relatively inexpensive, and easily available. From several studies, it was also found that the use of hydrocarbon as refrigerant improves the system performance.
At the advent of the Montreal protocol, R-134a has been suggested as an alternate eco-friendly refrigerant to R-22. R-134a has a high global warming potential and needs to be controlled as per the Kyoto protocol. On the recommendation of Kyoto protocol, fluorinated refrigerants (HFCs) to be phased out, in this view due to favourable thermo physical properties and other compatibility conditions, hydrocarbon refrigerants were given the first priority.

Keywords: *Ref Eff: Refrigeration Effect (KJ/Kg), W/D: Compressor Workdone (KJ/Kg), COP: Coefficient of Performance, MFR: Mass Flow Rate (kg/s), Power (KW), BT: Butane, IB: Isobutane.*

1. Some Important Properties of Pure Refrigerant

	R-22	**R-134a**	**R-600**	**R-600a**
Molar Mass	86.46	102.03	58.12	58.12
Triple point Temparature in ^{0}c	-157.05	-103.30	-138.28	-159.59
Boiling point in ^{0}c	-40.81	-26.07	-0.55	-11.67
Critical Temparature in ^{0}c	96.14	101.06	151.98	134.67
Critical Pressure MPa	4.99	4.059	3.79	3.64
Critical Density Kg/m^3	523.84	511.9	227.84	224.35
GWP (100yrs)	1810	1200	0	0

Table 1

Viewing the above properties some of the refrigerants have zero Global Warming Potential and are eco-friendly to the environment and can be a good substitute for CFC's, HCFC's and HFC's. With the help of above properties Refrigerating effect, Compressor Work done and COP of the system with various refrigerants have been assessed which are tabulated in table (2) below:

2. Refrigerating Effect, Compressor Work done and COP of Pure Refrigerants

	R-22	R-134a	R-600	R-600a
Refrigerating Effect (KJ/Kg)	144.84	128.72	261.16	231.76
Compressor work done (KJ/Kg)	40.09	36.48	70.26	64.55
COP	3.61	3.53	3.72	3.59
Mass Flow Rate (Kg/S)	0.0241	0.0272	0.0134	0.0152
Power (KW)	0.966	0.992	0.941	0.974

Table 2

Comparing the performance of above refrigerants, butane gives the better coefficient of performance. The mass flow rate and power is nearly equal to the existing refrigerant R-22 and R-134a. By observing the above results, the blend of butane and Isobutane in various proportions, have also been tried and the various performance parameters obtained are tabulated in table (3) -

3. Refrigerating Effect, Compressor Work done and COP of Blend or Mixture of Butane and Isobutane with Various Proportion in Percentage

	BT100/ IB00	BT90/ IB10	BT80/ IB20	BT70/ IB30	BT60/ IB40	BT50/ IB50	BT40/ IB60	BT30/ IB70	BT20/ IB80	BT10/ IB90	BT00/ IB100
Ref. Effect	261.16	258.41	255.63	252.79	249.92	247.01	244.06	241.06	238.01	234.91	231.76
Comp W/D	70.26	69.91	69.50	69.04	68.58	68.05	67.49	66.83	66.14	65.37	64.55
COP	3.72	3.69	3.68	3.66	3.64	3.63	3.61	3.61	3.59	3.59	3.59
MFR	0.0134	0.0135	0.0137	0.0138	0.0140	0.0141	0.0143	0.0145	0.0147	0.0149	0.0152
Power	0.941	0.0944	0.952	0.952	0.960	0.959	0.965	0.969	0.972	0.974	0.974

Table 3

4. P-H Plot

This diagram shows the relation between pressure and enthalpy of vapour compression system of refrigeration. Process 1-2 shows the compression, 2-3 shows the condensation, 3-4 shows the expansion and 4-1 shows the evaporation. This is the one way to calculate refrigerating effect, Isentropic work done, Mass flow rate and COP of the system which are shown in the above table (2) and (3). For the performance comparison, the P-H diagram can be drawn for all the pure refrigerants R-22, R-134a, R-600, R600a and also for the mixture (blend) of Butane and Isobutane with their various proportions.

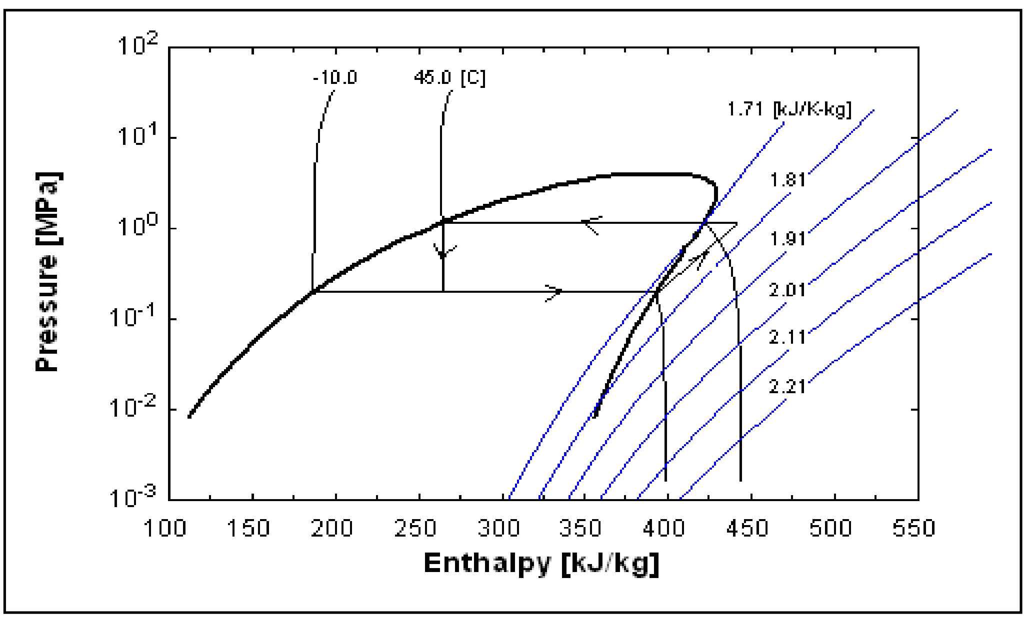

Figure 1

In the above refrigeration cycle the fixed temperature limit taken as 45^0 condensing temperature and -10^0 evaporating temperature for all the refrigerants and blend. Taking the enthalpies at different points from the refrigeration table, The refrigerating effect for unit mass flow rate, compressor work done and the COP of the cycle have been calculated. These values can also be calculated by following formulae.

Refrigeration Effect = $h_1 – h_4$, Isentropic Work Done = $h_2 – h_1$,

Coefficient of Performance = Refrigerating Effect / Work Done
Mass Flow Rate of refrigerant for 1 ton of Refrigeration:
$M (h_1 - h_{4)} = 1 X 3.5$
Power = $m (h_2 - h_1)$

5. Conclusion

Hydrocarbon refrigerants (Butane) and the blend of refrigerants (Butane/Isobutane in various proportions) give better results among all the refrigerants. Butane gives the maximum COP 3.72. Similarly Butane/Isobutane in proportion of 90:10 by mass gives the better coefficient of performance is 3.69 in the vapour compression refrigeration system. The capacity of the refrigerant & blend of refrigerant is nearly equal to existing refrigerants R-22 and R-134a.

6. References

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