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Variation of Performance of Refrigeration System at different Temperature

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Abstract

In this paper, the performances of four ozone-friendly Hydrofluorocarbon (HFC) refrigerants (R125, R134a, R143a and R152a) selected to replace R12 in a vapour compression refrigeration system were investigated experimentally and compared. The performance in term of coefficient of performance (COP), refrigerating capacity (RC), and compressor work (We) were evaluated for the investigated refrigerants at various evaporating and condensing temperatures. The system performance increases as the evaporating temperature increases, but reduces as the condensing temperature increases. The results obtained showed that the investigated refrigerants confirmed that R152a and R134a have approximately the same thermodynamic performances similar to R12 while deviation of R125 and R143a were very large. But the best performance was obtained from the used of R152a in the system. As a result, R152a could be used as a drop-in replacement for R134a in vapour compression refrigeration system. The COP of R152a obtained was higher than those of R12, R125, R134a, R143a. Also, R152a offers the best desirable environmental requirements; zero Ozone Depleting Potential (ODP) and very low Global Warming Potential (GWP).

Keywords: Hydro-Fluoro-Carbon, refrigerants, ozone-friendly, performance characteristics, refrigeration system.

Introduction

A class of chemical compounds called Chlorofluorocarbon (CFC) refrigerants has been in widespread use since the 1930s in such diverse applications as refrigerants for refrigerating and air-conditioning systems, blowing agents for plastic foams solvents for microelectronic circuitry and dry cleaning sterilants for medical instruments (Bolaji BO, 2005). The linkage of the CFC refrigerants to the destruction of the ozone layer, which has been established recently; is attributable to their exceptional stability because of which they can survive in the atmosphere for decades and ultimately diffusing to the rarefied heights where the stratospheric ozone layer resides (McMullan JT,2002). The inventors of these refrigerants could not have visualized the ravaging effects of the refrigerants on the ozone layer. They intentionally pursued refrigerants with the exceptional stability that was imposed as one of the necessary requirements of the ideal refrigerant they were called upon to invent (Cavallini A, 1996). The primary requirements of the ideal refrigerant before the discovery of CFC refrigerants were as follow: it should have normal boiling point in the range of -40°C to 0°C; it should be non-toxic; it should be non-flammable; and it should be stable. None of the refrigerants available at that time, including sulphur dioxide, carbon dioxide, ammonia, methyl chloride, and ethyl chloride; could meet any of the requirements. The CFC refrigerants fulfilled all the primary requirements and heralded an unprecedented revolution in then refrigeration and air-conditioning industry (Bhatti, M.S.1999). Today, the litany of the requirements imposed on an ideal refrigerant has increased. The additional primary requirements now include zero Ozone Depletion Potential (ODP) and zero Global Warming Potential (GWP) (Kumar KS, Rajagopal K, 2007 and Park K, Shim Y, Jung D 2009). According to Calm et al. (Calm JM, Wuebbles DJ, Jain AK 1999), the environmental concerns relating to ozone depletion and global warming were not dreamt of when Midgley and associates invented the CFC refrigerants. A single-fluid Hydrofluorocarbon (HFC) refrigerant, R134a

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and R152a are the leading replacement for domestic refrigerators. Although the ODP of these are zero,

(Table 1).

Refrigerants	Chemical formula	Molecular mass	Boiling point(ºC)	Ozone depletion potential(ODP)	Global warming potential (GWP)
R12	CF_2Cl_2	121	-29.8	1	8100
R125	C_2HF_S	120	-48.1	0	2800
R134a	C2H2F2	102	-26.1	0	1300

Experimental

Technical detail of experimental system

The ‘UNICOOL’ make, vapour compression refrigeration system manufactured by NEELAM ENGG., AGRA helps in understanding basics of a refrigerator. A small heater provided in evaporator simulates heat load. Various measurements like evaporating and condensing pressure and temperature, input to compressor and heater enable the students to calculate power consumption and theoretical and actual COP of the refrigeration system.

The machine consists of following components:

- Hermitically sealed KIRLOSKAR compressor of capacity 1/3 tons which runs on R12 operating between 0 and 55 C
- Air cooled condenser (Free Convection)
- Evaporator with proper insulation and a variable input heater installed inside
- Capillary expansion valve
- Measuring gauges for temperature and pressure at allcontrol points.

Objective

The vapour compression refrigeration system is an important refrigeration unit of the thermal lab of the department of mechanical engineering of University institute of technology, the constituent college of the Rajiv Gandhi technical university, which controls engineering education in the state of Madhya Pradesh. The vapour compression refrigeration system operates on refrigerant R12 which is most important CFC refrigerant identified for phase out in the country by HFC refrigerant. The system is frequently used for experimentation by graduate and post graduate students of the department. The institute has been one of the few institutes selected for funding for research work under World Bank project TEQIP. A research work was undertaken for finding the most suitable ozone-friendly. Hydro-fluorocarbon refrigerant for replacing ozone depleting refrigerant R12. In the paper, the performance evaluation of alternative ozone-friendly Hydro-fluorocarbon refrigerants in the vapour compression refrigeration system has been done. Then most suitable refrigerant has been selected for replacing harmful refrigerant

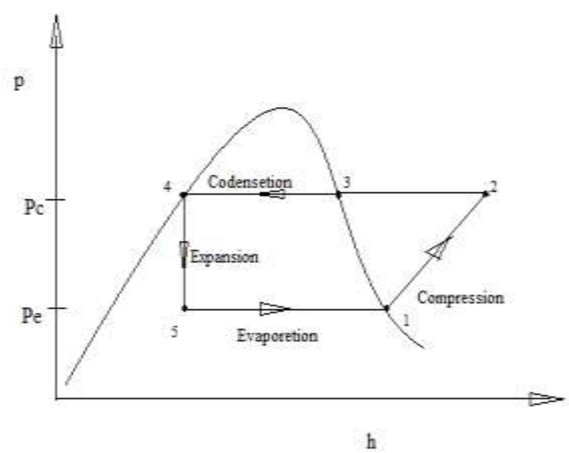

Fig 1: Vapour compression refrigeration cycle on p-h diagram. The p-h diagram is frequently used in the analysis of vapour compression refrigeration cycle and usually consists of the four processes.

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Refrigerants	Pe(bar)	Te	Pe	T_2(ºC)	RC (KJ/Kg)	We(KJ/Kg)	C.O.P
R12	9.5882	-20	1.5070	60	104.44	31.4	3.3261
R125	20.0790	-20	3.3755	58	68.09	20.76	3.2798
R134a	10.1660	-20	1.3273	60	130.14	40.08	3.2470

Process 1-2 is the compression.
Process 2-4 is the Condensation.
Process 4-5 is the expansion.
Process 5-1 is the evaporation.
Cp = Specific heat capacity at constant pressure.
Cv = Specific heat capacity at constant volume.

Methodology

$pv^k = c$
Where
V = Volume

$P_1V_1^K = P_2V_2^K$ (a)

$T_2 = T_1(P_2/P_1)^{K-1/K}$ (b)

The polytrophic index (k) is evaluated at T_1
T1 and T2 are the suction and discharge temperatures.
P1 and P2 are the evaporating and condensing pressures.

Results and discussions

Results

The selected Hydro-fluorocarbon (HFC) refrigerants were evaluated at different condensing and evaporating temperature and the results are as shown below:

Table 4.1: Thermodynamic properties of refrigerants at condensing temperature 40º

Refrigerants	Pe(bar)	Te	Pe	T_2(ºC)	RC (KJ/Kg)	We(KJ/Kg)	C.O.P
R12	7.4365	-20	1.5070	48	114.61	27.97	4.0976
R125	15.6800	-20	3.3755	46	82.84	24.03	3.4474
R134a	10.1660	-20	1.3273	60	130.14	40.08	3.2470

Table 4.3 and 4.4: Thermodynamic properties of refrigerants at condensing temperature 30ºC

Discussion

From above analysis the refrigerating capacity of the selected HFC refrigerants and that of R12. The RC increases as the evaporating temperature increases and also increases as the condensing temperature reduces. R134a, R152a and R143a have a higher refrigerating capacity than that of R12 for the three condensing temperatures considered, while that of R125 is much lower and the cooling effect of a vapour compression refrigeration system is evaluated by its refrigerating capacity.

Figure 4.1 to 4.6 show the effect of evaporating temperatures on the compressor loads for the three condensing temperatures (40, 30 and 20°C) for R12 and its potential alternative HFC refrigerants in a vapour compression refrigeration system. As shown in these figures, the compressor work increases as the evaporating temperature reduces and increases as condensing temperature increases.

Above data show the variation of coefficient of performance (COP) with varying evaporating temperature for three condensing temperatures (40, and 30°C) for R12and its four HFC refrigerants in a vapour compression refrigeration system. As shown in these figures, COP increases as the evaporating temperature increases and it reduces as the condensing temperature increase. Similar trends and variations were obtained for COP of the potential alternative HFC refrigerants for all the cases studied.R134a andR152a shows a slightly lower and .higher COP with average value of 3.9% an 13.2% and that of R12.

An average value of 34% lower and 35.2% higher were obtained for R125 and R143a. At a lower evaporating and condensing temperature, the COP

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ofR143a reduces. Based on these results, R152a and R134a are better R12alternatives than R125 and R143a because they have higher refrigerating capacity (RC) and coefficient of performance (COP) which are required in a vapour compression refrigeration system, but R134a which is the current leading alternative for R12 in all domestic applications has a relatively high global warming potential (GWP) and has hindered its general acceptance as the ideal alternative refrigerant (Table 1.1). Therefore R152a with

Lower GWP is recommended for comprehensive evaluation.

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