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A Comparative Study and Analysis for Retrofitting Of R-12 Vapour Compression Refrigeration System with Eco- Friendly Refrigerants R-507, R-407c, R404a

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Abstract: *The Montreal Protocol has sealed the use of Halogenated Hydrocarbons; Keeping in view they affect the environment in the form of Ozone layer depletion and Global warming. Thus one of the major thrust areas is to identify substitute of Halogenated Hydrocarbons, especially CFCs. The substitute refrigerant should be eco-friendly, chemically stable and C-134a a is currently the leading alternative to CFC-12. Other promising substitutes are R-507as a binary mixture of R-143a &R-125.R-407c is a ternary mixture of R-134a, R-32 andR-125.R404a is a binary mixture of R143a &R-125a. In this paper, performance evaluation of eco-friendly alternate refrigerant R-507, R-407c for replacing CFC12 has been done and a suitable alternative refrigerant for retrofitting has been identified.*

Keywords:*Ozone depletion; Montreal protocol; eco-friendly refrigerant; hydrocarbon refrigerant; retrofitting.*

I. Introduction

Recent studies have established that CFCs are depleting the Ozone layer and also contributed towards global warming. As due to favourable thermo dynamical and transport properties CFCs are used in the refrigeration system so there must be some alternative refrigerant, which is eco-friendly and having properties which are suited for refrigeration purpose In1987, several countries across the world signed an international treaty, the Montreal protocol, to control substances that deplete the ozone layer. According to this protocol, countries would phase out CFCs and other ODS as per a given schedule, with a complete halt by 2010. 190 countries are signatories to the Montreal protocol. Under this agreement, the use of CFCs as refrigerants in all commercial and industrial refrigeration and air-conditioning equipments has been banned in 1999 in all developed countries. Countries like India which have ODS consumption below the threshold annual value of 0.3 kg per capita are required to freeze the consumption of CFC by 1999, then reduce the use by 50% by 2005 and complete phase out by 2010 (Agrawal, 2001). It is believed that if the international agreement is adhered to the ozone layer is expected to recover by 2050.

1.1 India's commitment to the Montreal protocol

India became party to the Montreal protocol on Sept 17, 1992. India mainly produced and used seven of the 20 substances controlled under the Montreal protocol. These are CFC-11, CFC12, CFC113, Halon1211, Halon-1301, CTC, methyl chloroform and methyl bromide. India had prepared a detailed country programme (CP) in 1993 to phase out ODS in accordance with its national industrial development strategy (INFRAS, 2000). The objectives of the CP were to phase out ODS without undue economic burden to both consumers and industry manufacturing equipments using ODSs and provided India with an opportunity to access the protocol's financial mechanism. The other objectives of the CP also include minimization of economic dislocation as a result of conversion to non-ODS technology, maximization of indigenous production, preference to one time replacement, emphasis is on decentralized management and minimization of obsolescence. In 1991, the total ODS consumption in the refrigeration and air-conditioning sector in India was 1,990 MT. This constituted about 39% of India's total consumption of CFCs. About two-thirds of this consumption was estimated to be used in servicing of existing equipment. The growth rate in this sector was forecast at 10-20% annually until 2010. The refrigeration and air-conditioning sector was therefore identified as a priority sector in India for initiating phase-out activities (Kapil, 2008).

1.2 Retrofitting

Imminent CFC shortages would threaten the useful life of the appliance of CFC equipment. As the CFC shortages increase, the cost of CFCs will rise, along with the operating costs of the equipment. "Retrofitting" is the only long term and the most effective solution for discontinuing and reducing the CFC emissions from existing appliances. Retrofitting is the process by which the equipment currently using an ODS refrigerant is made to operate on a non ODS refrigerant, without major effects on the performance of the equipment and without significant modifications or changes for the equipment, ensuring that existing equipment operates until the end of it's economic life. It has been proved by various case studied that retrofitting is economically viable in small scale refrigeration equipment (Othmar& Adrian, 1998) than in large capacity systems.

II. Vapour Compression Refrigeration Systems

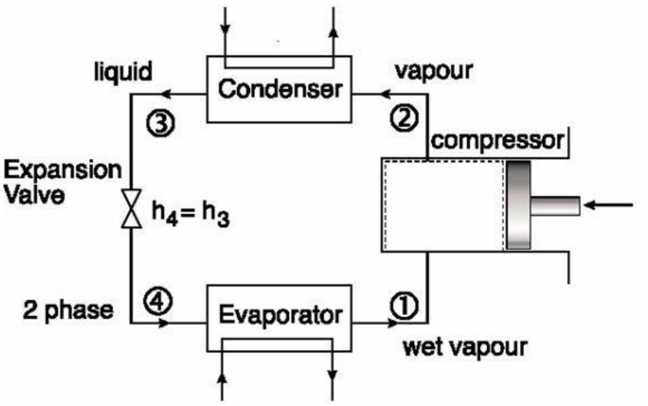


Figure 1

The simple Vapour Compression Refrigeration cycle is shown in Fig.3. It consists of following four essential parts1.Compressor, 2.Condenser, 3.Expansion Valve, and 4.Evaporator.

Compressor compresses the vapour refrigerant to the condenser with high pressure and temperature , in the condenser condensation takes place by rejecting heat with cooling medium either water or air as a cooling medium the phase transfer takes place from vapour refrigerant to liquid refrigerant and enters into the Expansion Valve , the function of the expansion valve is to reduce the pressure from high condenser pressure to low evaporator pressure by throttling process, finally the liquid refrigerant enters in the Evaporator where cooling effect is produced by absorbing heat from the cooling space and only pure vapour enters into the compressor

III. Eco-Friendly Refrigerants R-507,R-407c&404a

Recent studies have established that CFCs are depleting the Ozone layer and also contributed towards global warming. As due to favourable thermo dynamical and transport properties CFCs are used in the refrigeration system so there must be some alternative refrigerant, which is eco-friendly and having properties which are suited for refrigeration purpose.

R-507 a is a blend of HFC - 134a & R-125 that has been developed as a zero ODP replacement for CFC-12 in existing refrigeration system.

The composition or R-507 is as follows (by weight %)

	HFC- 134a	HFC-125
R- 507	52%	48%

R-407c a is a blend of HFC-134a, HFC-32 & HFC-125 that has been developed as a zero ODP replacement for CFC-12 in existing refrigeration system.

The composition or R-407c is as follows (by weight %)

	HFC - 134a	HFC-32	HFC-134a
R-407c	32%	23%	3%

R404a is a blend of HFC - 134a,HFC-143a & R-125 has a boiling temp of -43.56C at 1 bar which is having zero ODP. It near-isotropic mixture & behaves like a single fluid system. This mixture is compatible with existing lubrication oil & non- toxic. Its other thermodynamic properties are nearly

	HFC-125	HFC-143A	HFC-134a
R-404A	44%	52%	4%

They are compatible to the existing lubricants. Analysis of vapour compression refrigeration system can be carried out using thermodynamic properties of the working fluid.

The composition or R-404a is as follows (by weight %)

Prediction of the performance of compression refrigeration system at design and off design conditions needs repeated calculations. This necessitates the development of correlation for various properties such as vapor pressure, specific volume, saturated vapour and saturated vapour enthalpy as a function of temperature and pressure.

3.1 Correlation for vapour pressure :

Correlation for Vapour pressure correlation for CFC-12, HFC-134a,R-507, R-407c & R-404A

$P_v = A+B*T+C*T^2+D*T^3$

3.1.1Coefficients for vapor pressure correlation

Refrigerant	A	B	C	D
R-12	308.6	10.144	0.125753	0.0006640294
R-134a	293.4	10.642	0.146852	0.0008955292
R-407c	452	14.72	2.90	-1.64
R-507	50	0.6433	0.625	-0.3375
R-404A	601.3	19.4	-.1917	.1167

Table 3.1.1 Coefficients for vapor pressure correlation

3.2 Correlation for saturated vapour specificvolume

Correlation for vapour enthalpy for R-12,R-134a R-507 ,R-407c&404a as a function of temperature are given below.

$V_g=(A+B*T)/(1+C*T+D*T^2)$

The constants A, B, C, and D are given in table 3.1a

3.2.1 Coefficients for vapor specific Volume correlation

Refrigerant	A	B	C	D
R-12	0.055386671	-0.0003223	0.0255523	0.0001983527
R-134a	0.069321776	-0.0004813	0.0280071	0.0002395776
R-507	.89	-0.0077	0.0025	-0.0071
R-407c	.0528	.0013	-0.0008	0.0005
R-404a	.0334	.0011	-4e-05	5e-05

Table3.2.1 Coefficients for vapor specific Volume correlation

3.3 Correlation for saturated liquid enthalpy and Saturated Vapour Enthalpy

Correlation for liquid and vapour enthalpy for CFC-12, HFC-134a binary blend R507,R-407c and ternary blends R-404a as a function of temperature are given below.

$H_f = A+B.T+C.T^2+D.T^3$

The constants A, B, C,&Dare given in table 3.2a

3.3.1 Coefficients for saturated liquid of enthalpy correlation

Refrigerant	A	B	C	D
R-12	200.0	0.9247	0.00070954	4.24163 e-006
R-134a	200.0	1.3447	0.00136341	3.83317 e-006
R-407c	200.8	0.07167	0.2	-0.0167
R-507	12.2	.3	2e-10	-5e-11
R-404A	200	1.1483	0.4125	-0.1958

Table 3.3.1 Coefficients for Fluid Specific Enthalpy Correlation

3.3.2 Correlation for saturated vapour enthalpy

Correlation for liquid and vapour enthalpy for CFC-12, HFC134a,R-507, R-407c & R-404A as a function of temperature are given below.

$H_g = A+B.T+C.T^2+D.T^3$

The constants A, B, C,D, are given in table 3.2(b)

3.3.3 Coefficients for specific Enthalpy of Vapour Correlation

Refrigerant	A	B	C	D
R-12	351.4	0.427	-0.00065	-4.161 e-006
R-134a	398.7	0.584	-0.00096	-8.792 e-006
R-507	87.9	0.5367	-0.3333	0.1125
R-407c	413.9	.956	-.625	.3375
R-404A	368.3	.6833	.1	.0167

Table 3.3.3 Coefficients for fluid specific Enthalpy of Vapour Correlation

3.4 Correlation for Saturated Liquid and Saturated Vapor Entropy

Correlation for liquid and vapor entropy for CFC-12, HFC-134a binary blend R-507 and ternary blends R-407c&R404a as a function of temperature are given below:

(Formula: $S_f = A+B.T+C.T^2+D.T^3$)

3.4.1 Coefficients for Fluid Specific Entropy Correlation

Refrigerant	A	B	C	D
R-12	1.00000	0.003393	-4.83 e-006	1.41048 e-008
R-134a	1.00006	0.004890	-4.20 e-006	2.37316 e-008
R-407c	1	-.002	.013	.006
R-507	0.028	0.0002	-0.0002	.0007
R-404A	1	.0035	-.0005	0.0003

Table 3.4.1 Coefficients for Fluid Specific Entropy Correlation

(Formula :$S_g = A+B.T+C.T^2+D.T^3$)

3.4.2Coefficients for Vapor Specific Entropy Correlation

Refrigerant	A	B	C	D
R-12	1.554	-0.0004	-5.080 e-006	-3.755 e-008
R-134a	1.727	-0.0005	6.859 e-006	-6.518 e-008
R-407c	1.792	-.001	-4e-05	3e-05
R-507	.192	-5e-12	2e-12	-9e-13
R-404A	1.6168	.0003	-2e-30	1e-30

Table 3.4.2Coefficients for Vapor Specific Entropy Correlation

IV. Performance Analysis Of Refrigeration System For Refrigeration Unit

The refrigeration system of 1-ton cooling capacity has been chosen for the study. The system consists of the four usual components i.e. the compressor, condenser, evaporator and capillary tube (throttling device), as shown in figure 1.

The operating conditions for the refrigeration unit in Indian conditions are as follows.

S.No	parameters	
1.	Condensing Temperature	45^0C, 50^0C and 55^0C
2	Evaporator Temperature	-10^0C,-5^0C, 0^0C, 5^0C, 10^0C
3.	Superheating	0^oC
4	Sub-cooling	0^oC

Performance characteristics of reciprocating compressor are-

1. Volumetric efficiency of compressor: The ratio of clearance volume v_0 to the swept volume v_p is called the clearance factor(c).

$$c= v_0 /v_p$$

This factor has been taken as 0.03(3%of v_p).

The expression of volume efficiency is given by-

$$\eta=1+c-c^*(v_{suction}/d_{ischarge})$$

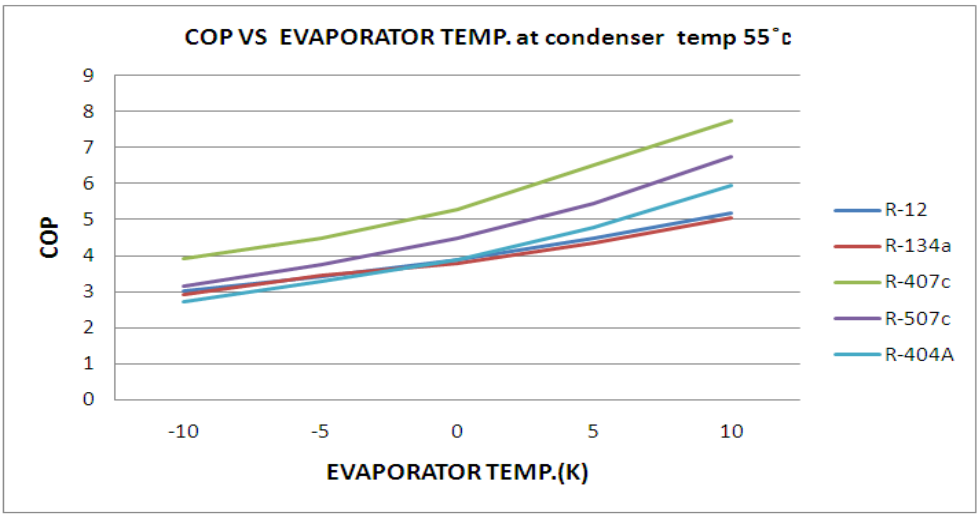
2. COP of vapour compressor refrigeration system:

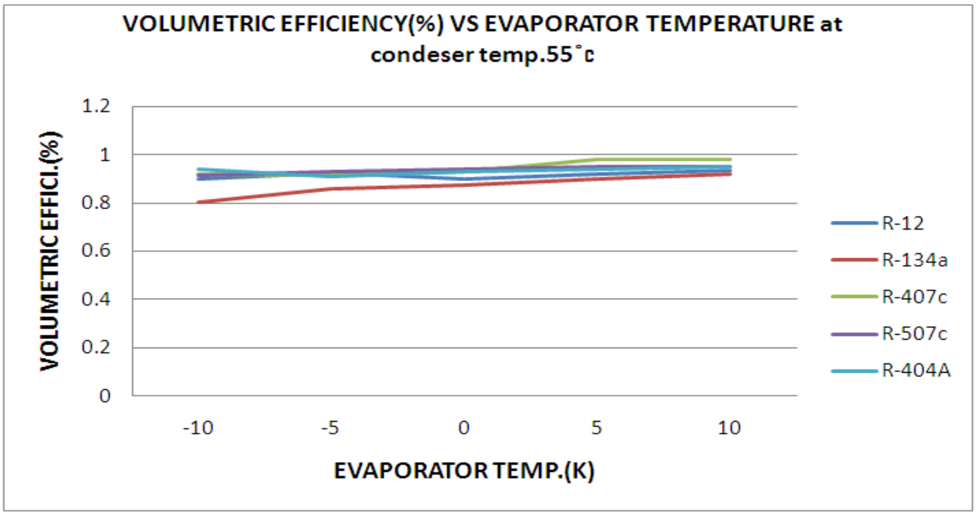
COP= Refrigeration Effect/Work Input

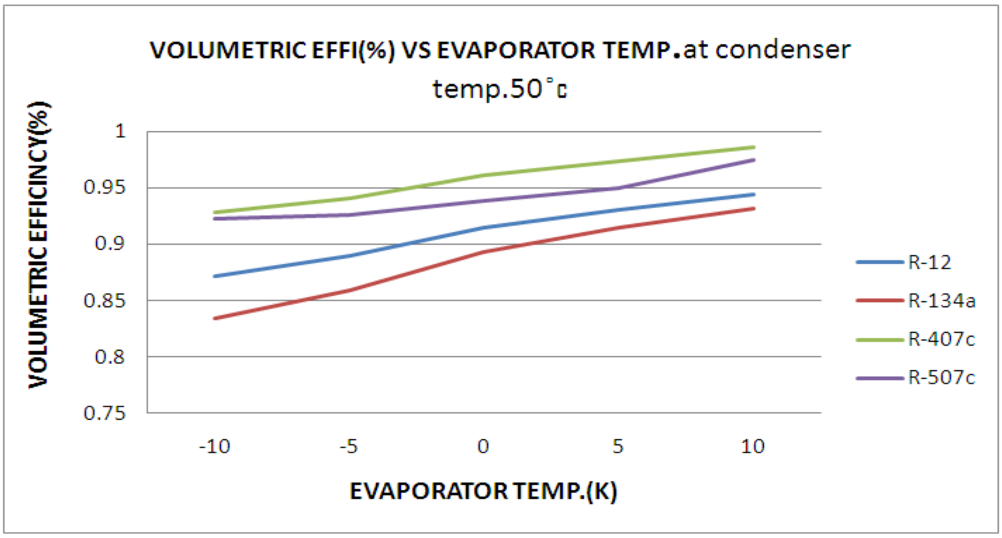
V. Results

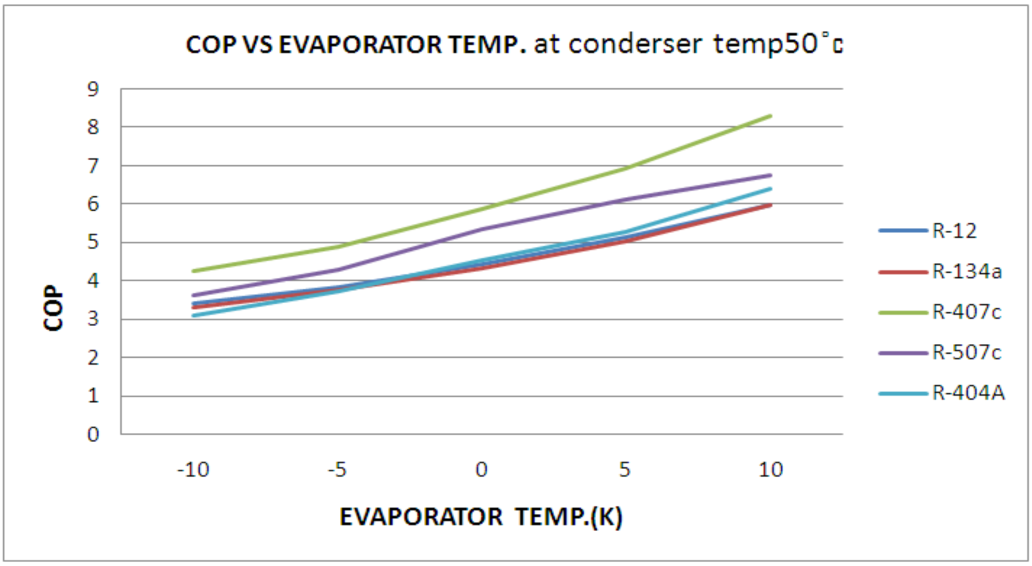
The performance analysis on the basis of volumetric efficiency of compressor and COP of vapour compressor refrigeration system has been carried out by using software & manual calculations for evaporator temperatures -10^{0}c,-5^{0}c, 0^{0}c, 5^{0}c,and 10^{0}c, and condenser temperatures 55^{0}c, 50^{0}c and 45^{0}c. The performance parameters have been calculated without considering sub-cooling & superheating.

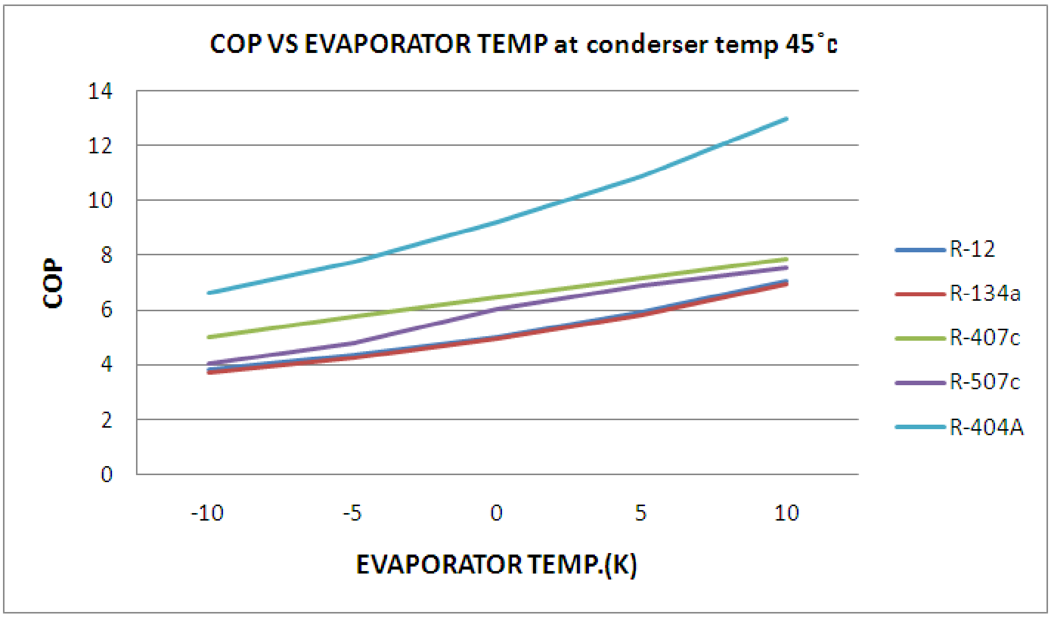
Figure 1

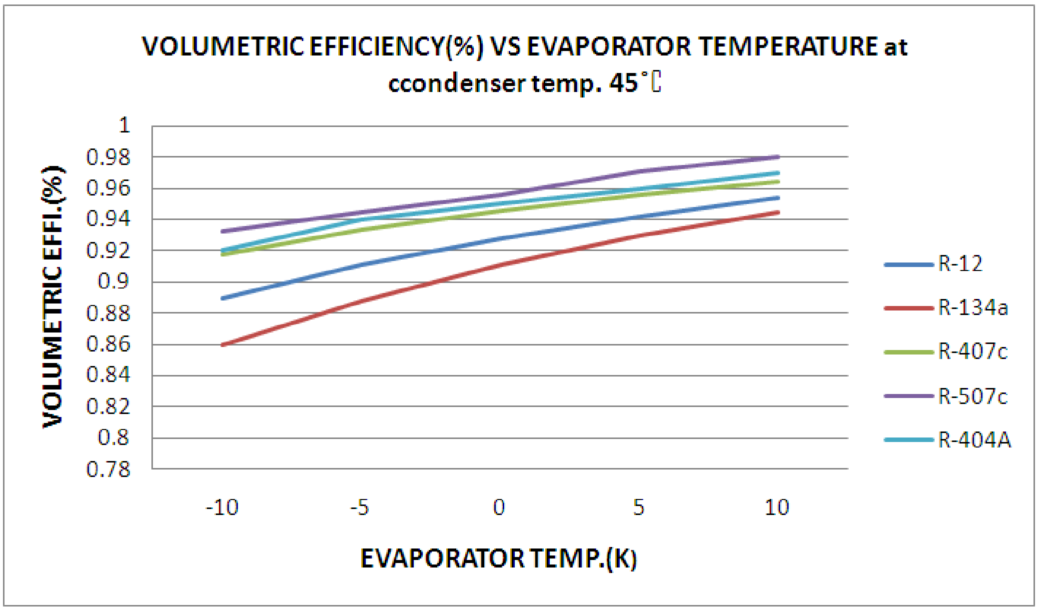







COP VS EVAPORATOR TEMP. at conderser temp50˚c
COP
9
8
7
6
5
4
3
2
1
0
-10
-5
0
5
10
EVAPORATOR TEMP.(K)
R-12
R-134a
R-407c
R-507c
R-404A


COP VS EVAPORATOR TEMP at conderser temp 45˚c
COP
14
12
10
8
6
4
2
0
-10
-5
0
5
10
EVAPORATOR TEMP.(K)
R-12
R-134a
R-407c
R-507c
R-404A


VOLUMETRIC EFFICIENCY(%) VS EVAPORATOR TEMPERATURE at ccondenser temp. 45˚
VOLUMETRIC EFFI.(%)
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0.78
-10
-5
0
5
10
EVAPORATOR TEMP.(K)
R-12
R-134a
R-407c
R-507c
R-404A

VI. Conclusion

COP and Volumetric efficiency of compressor of R-134a, R-507,R404a and R-407c is nearly same to that of R-12. This also indicates the suitability of retrofitting of R-134a, R-507a and R-407c with an existing R-12 system. Volumetric efficiency of compressor usingR404a is high&R-407c is slightly less than that of R-12. This is due to higher specific volume of R-407c. But this does not affect the performance of the system. Making an overall comparison, all three refrigerants R-134a, R-507 and R-407c are attractive alternatives to CFC-12. Research results are favourable, with no major drawback.

References

[1]. "Montreal protocol on substances that deplete the Ozone Layer" UNEP 2006 Report of the refrigeration, air conditioning and heat pumps technical options committee, 2006 Assessment.
[2]. www. refrigerants.dupont.com, USA for thermodynamic tables of R-423a and R- 413a
[3]. "Thermodynamic study of a ternary Isotropic mixture for Vapour Compression systems", Bansal V K, Mechanical Engineering Department, IIT Delhi 1990.
[4]. Analysis of Vapour Compression Refrigeration system for Domestic Refrigerator Using Eco-Friendly Hydrocarbon Mixture", Sameer Vida MechanicalEngineering Department, JEC Jabalpur 2002.
[5]. Arora C.P., "Refrigeration and Air-conditioning", TMH publication.
[6]. Stocker and jones, "Refrigeration and Air-Conditioning", McGraw Hill publication.
[7]. Retrofitting of vapour compression refrigeration trainer by an eco-friendly refrigerant AlkaBaniAgrawal and VipinShrivastavaIndian Journal of Science and Technology Vol. 3 No. 4 (Apr. 2010)
[8]. Suva@DupontTM Corporation, USA for thermodynamic tables of R-404a and R- 407c (www. refrigerants.dupont.com)
[9]. IOSR Journal of Engineering May.2012, Vol. 2(5) pp: 952-955 ISSN: 2250-3021 www.iosrjen.orgI
[10]. International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 4, October 2012 [11] Kadam Sanjay V et al.IOSR Journal of Engineering May. 2012, Vol. 2(5) pp: 952-955 ISSN: 2250-3021 www.iosrjen.org 952 |
[11]. Miguel Padilla et alSchool of Mechanical Engineering, Central University of Venezuela, Caracas 1051, Venezuela
[12]. Mukesh K et alInternational Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 4, October 2012
[13]. Ciro Aprea et alApplied Energy 88 (2011) 4742–4748. Ciro Aprea et al Energy 36 (2011) 1161-1170.