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DESIGN AND PERFORMANCE ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM USING R12&R134A

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Abstract

The design and performance analysis of refrigeration system using R12 & R134a refrigerants are presented in this report. The design calculations of the suitable and necessary refrigerator equipment and their results are also reported here .CFC -12 is the most widely used refrigerant. It serves both in residential and commercial applications, from small window units to large water chillers, and everything in between. Its particular combination of efficiency, capacity and pressure has made it a popular choice for equipment designers. Nevertheless, it does have some ODP, so international law set forth in the Montreal protocol has put CFC-12 on a phase out schedule .HFC-134a has been established as a drop –in alternative for CFC-12 in the industry due to

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their Zero Ozone Depletion Potential (ODP) and similarities in thermodynamic properties and performance. However, when a system is charged with a HFC-134a compressor oil has to be changed. The purpose of this project is to investigate behavior of R134a refrigerant. This includes performance and efficiency variations when it replaces R12 in an existing system as well as changes involved in maintain the system charged with R134a.

1. Introduction

Mechanical refrigeration is accomplished by continuously circulating, evaporating and condensing a fixed supply of refrigerant in closed system. Evaporation occurs at a low temperature and low pressure while condensation occurs at high temperature and pressure. Thus it is possible to transfer heat from an area of low temperature (i.e. refrigerator cabinet) to an area of high temperature (i.e. Kitchen).

The R-134a is considered as most preferred substitute for R-12.Its boiling point is -26.15degree Celsius which is quite close to the boiling point of R-12 which is -29degree Celsius at atmospheric pressure .since the refrigerant R-134a has no chlorine atom, therefore this refrigerant has zero ozone depleting potential (ODP) and has 74% less global warming potential (GWP) as compared to R-12 .It has lower suction pressure and large suction vapour volume.it is not soluble in mineral oil. Hence for use in domestic refrigerators with hermite units, suitable synthetic (polyester based) used. care should be taken to prevent moisture from getting into the refrigeration system .For use in existing R-12 reciprocating compressors, it would require either an average increase in compressor speed of 5 to 8% or an equivalent increase in cylinder volume .since the molecules of R-134a are smaller than R-12 therefore a very sensitive leak detector is used to detect leaks.

It is extremely important to analyze completely every system and understand the intended function of the each component before attempting or determine the cause of malfunction or failure.

2. Literature review

S.Venkataiah et al., has presented in his paper the simulation results of a 1.5Ton (5.276kW/18000BTU/Hr.) Capacity room air conditioner with some selected refrigerants that have been assessed for their suitability as alternative refrigerants to R-22 for air-conditioning applications. The Performance of the selected refrigerants viz., R-22, R407C, R410A, R404A, R507A, R290, and R600a is considered in the analysis. A.Baskaran et al., has performed analysis on a vapour compression refrigeration system with various eco-friendly refrigerants of HFC152a, HFC32, HC290, HC1270, HC600a, RE170 were done and their results were compared with R134a as possible alternative replacements. The results showed that the alternative refrigerants investigated in the analysis RE170, R152a and R600a have a slightly higher performance coefficient (COP) than R134a for the condensation temperature of 50^0C and evaporating temperatures ranging between -30C and 10C. M.Mohanraj et al., in his studies reported about new refrigerant mixtures in domestic refrigerators, commercial refrigeration systems, air conditioners, heat pumps, chillers and in automobile air conditioners. In addition, the technical difficulties faced with new refrigerant mixtures, further research needs in this field and future refrigerant options for new upcoming systems have been discussed in detail. This paper concludes that HC based refrigerant mixtures are identified as a long-term alternative to phase out the existing halogenated refrigerants in the vapour compression-based systems also in the same year. Haile Wang et al., has introduced in his study a novel thermally activated cooling concept – a combined cycle couples an ORC (organic Rankine cycle) and a VCC (vapour compression cycle).A systematic design study was conducted to investigate effects of various cycle configurations on overall cycle COP. With both sub cooling and cooling recuperation in the vapourcompression cycle, the overall cycle COP reaches 0.66 at extreme military conditions with outdoor temperature of 48.9 °C. M.I. Karamangil et al., has presented a literature review, especially in recent years, on the absorption refrigeration systems (*ARS*s), the currently used refrigerant–absorbent pairs and their alternatives. It was concluded that performances of the cycles improve with increasing generator and evaporator temperatures, but reduce with increasing condenser and absorber temperatures. Zaghdoudi et al., has simulated the performance of ten alternate refrigerants such as [R134a, R290, R600, R404A, R407A, R407C, R407D, R410A, R410B and R417A] to replace R22 in Air conditioner of 9000BTU/hr. (0.75TR) capacity by using NIST Cycle-D.

3. Materials and methods

3.1. Design of Evaporator

(a) Refrigerant side heat transfer coefficient

Thermodynamic properties of R-134a at -5 are

Psat = 243.5 Kpa

Pf = 1311 Kg/M3

Pg = 12.07 Kg/M3

hFg = 202.4 kj/kg

Cg =873.8 j/kgk

Cf = 1330 j/kg.k

Kf = 0.0989 W/M.K.

Kg = 0.01161 W/M.K.

μg = 2.947 x 10 -4 Kg/M.s

μg = 6.707 x 10 -6 Kg/M.s

(Pr)f = 4.051, (Pr)g = 0.505

σ (Surface tension) = 0.01229 N/m

β = 0.00249

Let the temperature drop across the outside refrigerant film be

Δ To = 50c

Water inlet Temp = 300 c

Water outlet Temp = 100 c

From Rohsenow correlation {Ref: C.P. Arora (9.1)}

$$h_i \, \Delta T = \mu \, fhrg \left| \frac{g(\rho_f - \rho_g)}{\sigma} \right|^{1/2} \left| \frac{4 \, \Delta T}{0.013 hfg \, pr_f^{1.7}} \right|^{3}$$

h_i = 660.15 $W/m^{2\,0}K$

(b) Water side heat transfer co efficient

Inlet Temp of the evaporation coil Tc1 = -5^0c

Outlet Temp of the evaporation coil Tc2 = 4.44^0c

Temp diff h/w inlet and outlet of the evaporation = 5- (-5) = 10^0c

Refrigerating capacity =

Load taken by evaporator f=

0.5 x 210 Kj/min = UA $(\Delta T)_M$ -------------(1)

U_o = overall heat transfer co efficient

Using correlations [*Ref: C.P. Arora (Page. 59)*]

Free convention correlations

Free convention takes place as tube cum placed horizontally in water

$Nu = C\,(4rpr)^n$

$$G_r = \frac{gBp^2 \Delta T L^3}{\mu^2} \text{ ------(2)}$$

B is the coefficient of thermal expansion = 1/T

L refers to diameter of horizontal Tube

$\Delta T = Ts - T_\infty$

$= 30 - (-5) = 35^0c$

Mean Temperature (Tf) $= (-5+30)/2$

$= 12.5^0C$

$G_r = 196453.9074$

$P_r = 8.91$

For given case

(Gr.pr) = 196453.9074 x 8.91 = 1750404.31 S

$10^4 <$ Gr.pr $< 10^9$ =>laminar flow

Hence,

$Nu = 0.37\ [1750414.315]^{0.25}$ (n = 1 / 4, c = 0.37)

$\frac{hl}{k} = 13.42$

Heat transfer coefficient on water side

$h_o = 817.47\ W/m^2\ K$

$Q = U.A.\ \Delta T_m$

(*Q= capacity in tons* for given system = 0.5T)

Therefore,

$\Delta Tm = LMTD = 29.7\ ^oC$

Outer diameter of coil = 6.2 mm

Inner diameter of coil = 4.8mm

Scaling factors,R_{fo} = $0.0002 m^2\ K/W$

3.2 Steps for converting R134a to R12 Refrigerator

- Replace the compressor.
- Flush the entire system clean with alcohol and let it be free for few hours.
- Then rinse it with alcohol again and then blew it clean with DRY AIR (if you don't have a good air dryer for your compressor (or have no compressor), get a good compressed air).
- Replace all seals on the spring clamp and screw together.
- Put the required amount of lubricating oil in the compressor.
- Charge with the new R134A refrigerant

3.3. Experimental Setup using R134a

The following figure 3.1 shows the schematic arrangement of components used to carry out the experiment using the refrigerant R134a.

Fig.1 Photographic view of the experimental setup using R134a

The bench consists of 0.25 kW compressor, an air cooled condenser, capillary and a thermostatic expansion valve. Hot vapors from evaporator are compressed by compressor and sent to air cooled condenser. Liquid R134a emerging out from condenser coil is sent through bypass connection through a rotometer during refrigerant flow measurement .alternative arrangement of passing the liquid refrigerant either through a capillary or a thermostatic expansion valve is provided where liquid refrigerant is throttled to low pressure and temperature and is sent to evaporator where it evaporates dryer is provided in this way to throttle device .pressure gauges and thermometers are provided to measure pressure and temperature .voltmeter and ammeter are provided to measure the power supply to the compressor .solenoid valve is provided to stop the liquid refrigerant flooding the evaporator under the circumstances of failing the thermostatic expansion valve HP/LP cut outs are provided for condenser and compressor to keep the pressure within specified ranges.

3.4 Methodology

- Fill the chiller tank with a measured quantity of water and keep the same quantity of water in freezer
- Ensure that thermostat is on
- Switch on the main supply
- Bring on capillary tube mode as an expansion device.
- Run the system for specific duration as required and note down the following

P1 = pressure of refrigerant at suction and

P2 = pressure of refrigerant after completion

T1 = temperature of refrigerant inlet to evaporator

T2 = temperature of refrigerant from outlet of the evaporator

3.5 Observations for R134a

Compressor exit pressure =10kg/cm^2

Expansion pressure = 45 cm of Hg

Evaporator exit pressure = 50 cm of Hg

Energy meter reading for 10 revolutions = 60 (seconds)

Mass flow rate of refrigerant m_r= 0.06 kg/s

Actual refrigerating effect = 0.06×1.25× (25.7-10)

= 1.175 KW

Where,

C_p specific heat of refrigerant = 1.25Kj/Kg k

Power input to the compressor = $\{\frac{3600 \times Nr}{Ne \times T}\}$

Where, N_e = energy meter constant.

N_r =no of revolutions of energy meter.

Work input to the compressor $=\frac{3600\times 10}{1200\times 60}$ =. 0.5KW

Actual cop = 2.35

Theoretical cop = $(h_1 - h_4)/(h_2 - h_1) = \frac{405.55-267.03}{446.29-405.55}$ = 3.4

Relative cop= 2.35/3.4= 0.68

3.6 Observations for R12

Compressor exit pressure = 10kg/cm^2

Expansion pressure = 45 cm of Hg

Evaporator exit pressure = 50 cm of Hg

Energy meter reading = 75(seconds)

Actual refrigerating effect = 0.06×1.27× (12.2+3.5)

= 1.19634 KW

Mass flow rate of refrigerant= 0.06kg/s

Where C_p specific heat of refrigerant = 1.27Kj/Kg k

Power input to the compressor = $\{\frac{3600\times Nr}{Ne\times T}\} = \frac{3600\times 10}{1200\times 75}$ = 0.4KW

Actual cop =1.19634 /0.4= 2.99

Theoretical cop = $(h_1 - h_4)/(h_2 - h_1) = \frac{415.55-290.03}{445.29-415.55}$ = 4.01

Relative cop= 2.99/4.01 = 0.73

4. Resilts and discussion

The following table 4.1 shows the variation of coefficient performance of the system using R-134a and R12 with respect to the evaporator temperature while the condenser temperature is at 25^oC

4.1 Variation of COP with evaporator temperature at constant condenser temperature 25^0 C

Table.1 Variation of cop with respect to the evaporator temperature difference

Evaporator temperature difference (ΔT)	cop R134a	Cop R12
10	1.5	1.905
15	2.25	2.85
20	3.1	3.81
25	3.95	4.21
30	4.5	4.7

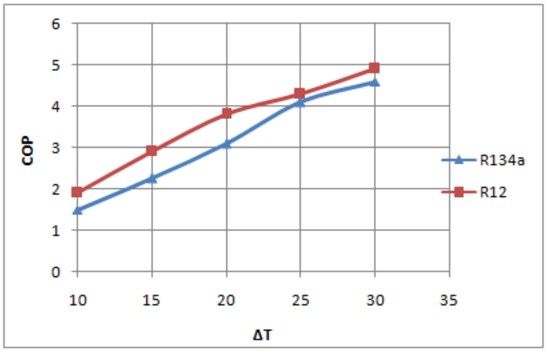

Fig.2 Comparison of R134a and R12

From the figure it is observed that the coefficient of performance of the refrigeration system is increasing almost linearly as the evaporator temperature is increased when the refrigerant used was R12.the space of the graph is almost similar when the results were plotted using R134a as the refrigerant however it is observed that the values of coefficient of performance are slightly higher in case of refrigerants R12. But refrigerant are R134a may be preferred because of the zero value of the ozone depletion potential.

4.2 Coefficient of performance at different mass flow rate of refrigerant

(At evaporator temperature difference 15.7^{o}C)

Table.2 Variation of cop with respect to massflow rate

Mass flow rate (m_r) in kg/s	R-134a	R12
0.04	1.57	1.99
0.05	2.1	2.49
0.06	2.35	2.99
0.07	2.74	3.48

Results	R134 a	R12
Actual COP	2.35	2.99
Theoretical COP	2.909	3.046
Relative COP	0.69	0.73

4.3 Coefficient of performance at different mass flow rate of refrigerant

(At evaporator temperature difference 20^{o}C)

The following table 4.5 shows the variation cop at different mass flow rates while the evaporator temperature difference 20^{o}C

Table.3 Variation of cop with respect to massflow rate

Mass flow rate (m_r) in kg/s	R-134a	R12
0.04	2.1	3.17
0.05	2.5	3.175
0.06	3.2	3.81
0.07	3.5	4.12

Results	R134a	R12
Actual COP	2.01	2.49
Theoretical COP	2.909	3.046
Relative COP	0.67	0.81

5. Conclusions

In order to know working of VCR system practically and also for knowing the pressure and temperatures at various points of the cycle. These results will help for modifications and for new designs. It has been seen from the results and graphs that COP of R12 is little greater than COP of R134a. Even though COP of R12 is greater than R134a it must be replaced withR134a because of following reasons.

- R134a refrigerant is non-toxic and does not flare up within the whole range of operational temperatures.

- Ozone depletion potential ODP=0, global warming potential GWP=0.25 and Estimated Atmospheric life EAL=16
- In Middle temperature refrigeration facilities and air conditioning systems, refrigerating factor of R134a is equal to the factor for R12 or higher than that.
- In high temperature refrigeration facilities, specific cold-productivity when operating on R134a is also a bit higher than that of R12.
- Increasing of dehumidifying ability of filter dehydrators due to high hygroscopic property of R134a system-synthetic oil.

Improvement of widely used all over the world as a main substitute of R12 for refrigeration equipment operating within middle-temperature range. It is used in automobile air-conditioners, domestic refrigerators, commercial refrigeration middle-temperature equipment, industrial facilities, air-conditioning systems in building and industrial areas, as well as on refrigeration.

References

[1] S.B. Riffat (2007), "Comparison of R134a and R12 refrigerants in a vapour compression system", proceedings of the International Journal of Energy Research, University of Nottingham, Nottingham, U.K, vol .17, pages 439-442.

[2] N.J.Shanland (1989), "Thermo physical properties of 1,1,1,2 – tetra fluoro ethane (R134a)", proceedings of the International Journal of Thermo physics, Netherlands, vol .10, No.3, PP 591-603.

[3] C.Aprea (2001), Department of Mechanical Engineering, University of Salerno, Italy.

[4] M.J.Molinaand Rowland's (1974), "Stratospheric sink for chlorofluoromethanes, chlorine atom catalyzed destruction of ozone", vol.249, PP 808-812.

[5] A.S.Parmer (1995), "Performance of hydrocarbon refrigerants in motor car air-conditioning", B.E.thesis, School of Mechanical and Manufacturing Engineering, The University of New South Wales, Sydney.

[6] K.Mani and V. Selladura (2008)," Experimental analysis of a new refrigerant mixture as drop-in replacement". Proceedings of the International Journal of Thermal Sciences, vol.47, pages 1490-1495.

[7] M.Mohanraj, S.Jayraj&C.Muraleetharan (2008),"Environmental friendly alternatives to halogenated refrigerants". The review of the International Journal of Greenhouse Gas Control.

[8] A.Anderson and I.Potts (2003), "A comparison of the operating performance of alternative refrigerants". The review of Applied Thermal Engineering, vol .23, pages 1441-1451.

[9] M.Fatouh, M.EI Kafaty (2006),"Assessment of propane/commercial butane mixture as possible alternatives to R134a in domestic refrigerators". The review of the energy conversion and management, vol .47, pages 2644-2658.

[10] Gallagher, J. Huber (1993), "Thermodynamic properties of refrigerants and refrigerants mixtures Database (ref prop)", version 4.0 user's guide, NIST standard reference database 23, NIST, Gaithersburg MD.

[11] S.C. Arora and S.Domakundwar, a course in Refrigeration and Air Conditioning, DhanpatRai and sons.