Evaluation of Vapour Compression Refrigeration System Using R407C and R507

Rahul V. Ikhar[1] H.S. Farkade[2]

Post graduate scholar (Thermal Engineering)[1], Asst. Professor [2]

Department of Mechanical Engineering

Govt. College of Engineering

Amravati, Maharashtra

India

ABSTRACT

The existing refrigerant requirements are, system performance should not be compromised, refrigerant and lubrication interaction should be as required, it should be energy efficient, environment friendly etc. After Montreal protocol, use of refrigerants like CFC and HCFC banned because of high ozone depleting potential (ODP). So there is need to find out a refrigerant which is environment friendly, such as HFC refrigerants as working fluids in refrigeration and air conditioning systems and which can be used long term substitute for existing refrigerants. The most important qualification for refrigerants is low ozone depleting potential (ODP). HFC refrigerants have suitable specifications such as non-flammability, stability, and similar vapour pressure to the refrigerant CFCs and HCFCs and zero ozone depleting potential (ODP) . They are used in many applications with safety of the leakage from the system also with these refrigerants it was found that, there was no need to change in the design of the refrigeration system. So we can look forward to HFC refrigerants. R407C and R507 are HFC refrigerants which are under study.

KEY WORDS: *Refrigeration system, VCR, Refrigerant, Environment.*

1. INTRODUCTION

Vapour compression refrigeration system is a system which is used to transfer heat from low temperature reservoir to high temperature reservoir with the help of working fluid, called refrigerant. There are different types of refrigerant, which were used as the working medium in vapour compression refrigeration system in the last few decades, but they cause of ozone layer depletion and green house effect. Refrigeration System: Working Principle and Construction Refrigeration system is based upon the Clausius statement of second law of thermodynamics. This statement shows, “It is impossible to construct a device which, operating in a cycle, will produce no affect other than the transfer of heat from a cooler to a hotter body. This system consists of four basic components, i.e. a compressor, an evaporator, a condenser and capillary tubes. Here the compressor delivery head, discharge line, condenser and liquid line form the high pressure side of the system. The expansion line, evaporator, suction line and compressor suction head form the low pressure side of the system. In plants with a large amount of refrigerant charge, a receiver is installed in the liquid line. A drier is also installed in the liquid line. The drier contains silica gel and absorb traces of moisture presented in the liquid refrigerants so that it does not enter the narrow cross section of the expansion device causing moisture chocking by freezing. Refrigerant: The working fluid used to transfer the heat from low temperature reservoir to high temperature reservoir is called refrigerant. There are different types of refrigerant which are described as followings. CFC: They are molecules composed of carbon, chlorine and fluorine. They are stable, allowing them to reach the stratosphere without too many problems. It contributes to the destruction of the ozone layer. These are R11, R12, R113, R500, R502 etc. HCFC: They are molecules composed of carbon, chlorine, fluorine and hydrogen. They are less stable than CFCs, destroy ozone and to a lesser extent. These are R22, R123, R124, R401a etc. HFC: They are molecules composed of carbon, fluorine and hydrogen. They do not contain chlorine and therefore do not participate in the destruction of the ozone layer. This is known as substitution substance. Restrictions on this family of gas are currently limited. Within the European Union, the HFC will be banned from air conditioners for cars from 2011.These are R134a.

Mixture of refrigerants: They can be classified according to the type of fluorinated components they contain. They are also distinguished by the fact that some mixtures are:

Zeotropic: in a state change (condensation, evaporation), the temperature varies. These are R404a, R407a and R410a *etc*.

Azeotropes: they behave like pure, with no change in temperature during the change of state. These are R500, R502 and R507a etc.

Ammonia (NH3) or R717: Fluid inorganic thermodynamically is an excellent refrigerant for evaporation temperatures between -350C to 20C. But it is a fluid dangerous toxic and flammable, so it is generally used in industrial refrigeration.

Hydrocarbons (HC) as R290, R600a: This is primarily propane (R290), butane (R600) and isobutene (R600a). These fluids have good thermodynamic properties, but are dangerous because of their flammability. The world of the cold has always been wary of these fluids, even if they have reappeared recently in refrigerators and insulating foams. Their future use in air conditioning seems unlikely, given the cost of setting both mechanical and electrical safety.

Carbon dioxide (CO2) or R744: This is inorganic, non-toxic, non flammable, but inefficient in thermodynamics. Its use would involve high pressure and special compressors. Currently, specialists in air conditioning and refrigeration are interested again by: Its low environmental impact (ODP = 0, GWP =1); The low specific volume resulting in facilities with low volume (small leak); It has the distinction of having a low critical temperature at 310C at a pressure of 73.6 bars.

Some refrigerants are expelled due to their environmental impact, are expected to be replaced. Replacing them is a difficult task considering that the only solution currently available are so-called “natural” refrigerants, such as ammonia, hydrocarbons and CO2. The disadvantages of these refrigerants are mainly toxicity (NH3), flammability

(HC) and high pressures (CO_2) Some refrigerants are banned due to their high ozone depletion potential (ODP), these are following.

• Production of R11 was halted by the clean air act on January 1, 1996.

• Production of R12 was halted by the clean air act on January 1, 1996.

• Production of R113 was halted by the clean air act on January 1, 1996.

• Production of R500 was halted by the clean air act on January 1, 1996.

• Production of R134a is commercially available hydro fluorocarbon (HFC) refrigerant.

So to find the performance of refrigerants R407C and R507 we will conduct the experiment on vapour compression refrigeration system.

1.1 Standard Vapour Compression Refrigeration System (VCRS)

Figure.1 shows the schematic of a standard, saturated, single stage (SSS) vapour compression refrigeration system and the operating cycle on a T s diagram. As shown in the figure the standard single stage, saturated vapour compression refrigeration system consists of the following four processes:

Process 1-2: Isentropic compression of saturated vapour in compressor

Process 2-3: Isobaric heat rejection in condenser

Process 3-4: Isenthalpic expansion of saturated liquid in expansion device

Process 4-1: Isobaric heat extraction in the evaporator

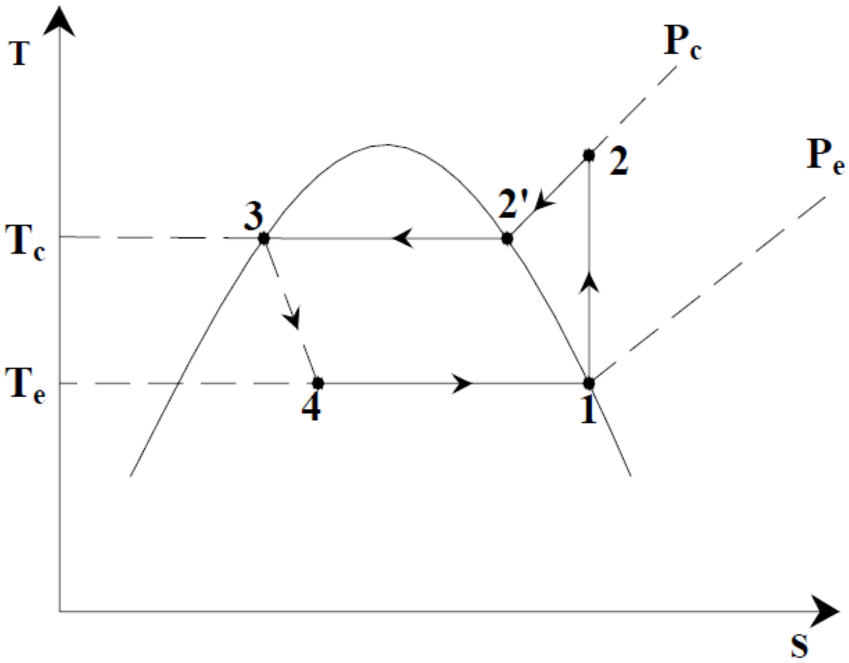

Figure1. T-S diagram of vapour compression refrigeration system

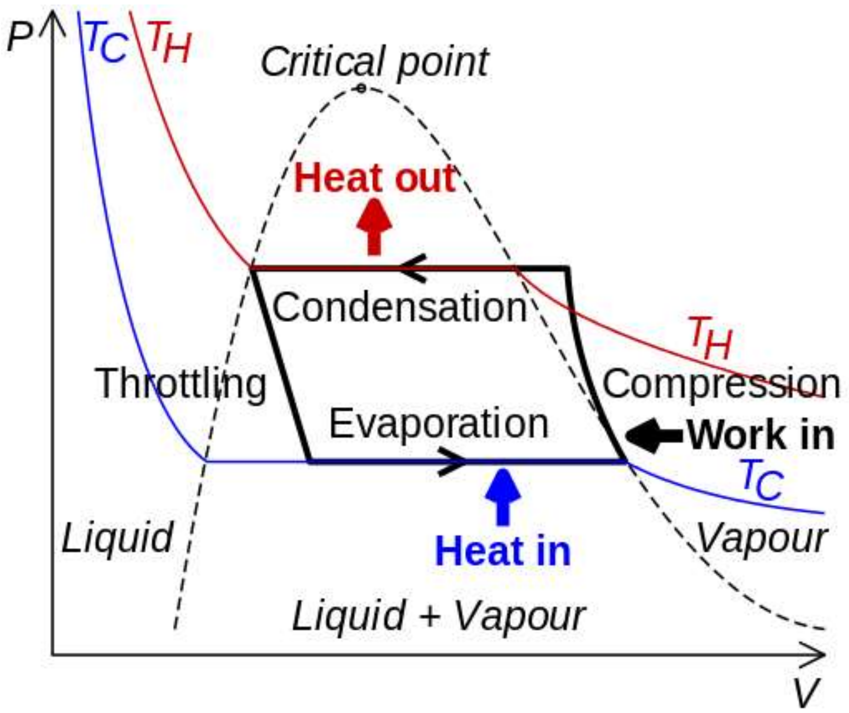

Figure2. P-V diagram of vapour compression refrigeration system

2. LITERATURE REVIEW

All over the world researchers have been performing research and experimentation on VCR using different refrigerant and mixture of different refrigerant.

S. J. Sekhar, D. M. Lal [1] have used the mixture of HFC-134a and HC blend (55.2% HC 600a and 44.8% HC290) a retrofit for CFC 12. CFC 12 requires mineral oil as lubricant but it is not compatible with HCF-134a. For HFC-134a, POE is required as lubricant and POE is highly hygroscopic. Use of HC blend in HFC-134a allows using mineral oil as lubricant. Best results obtained using 9% of HC blend with HFC-134a where the actual COP of the system was improved by 5-17% in low temperature system; also energy consumption was less by 4.1 to 7.6 % as compared to CFC 12.

B. O. Balaji, M. A. Akintunde [2] compared the performance of R134a and other two low GWP HFC refrigerants i.e. R 32 and R152a, in vapour compression refrigeration system. Results show that for R152a, discharge temperature is lower, vapour pressure is lower, condenser heat load is lowest, pressure ratio is lowest, compressor input power is lowest and volumetric cooling capacity is highest hence R152a shows the best performance among three refrigerants in the system.

Yongmei Xuan, Guangming Chen [3] has used a ternary mixture of HFC-161, HFC-125 and HFC-143a as a promising alternative refrigerant to R-502. This mixture is retrofitted to the compressor originally designed for R404A.ODP of the proposed mixture is zero and GWP is smaller than those of R502, R404a. COP of the mixture is almost equal to that of R 404A under lower evaporation temperature and its discharge temperature is higher than that of R404A, but its COP is greater than that of R404A under higher evaporative temperature and discharge temperature is lower than that of R404A.

Ciro Aprea, Angelo Maiorino, Rita Mastrullo [4] compared R22 and R422D. R422D has zero ODP so can be used as retrofit for R22. The result obtained as COP of R422D is on average 20% lower than that of R22, this occurs mainly due to the high vapour density of R422Dwhich led both to a reduction of cooling capacity and to an increase of the electrical power absorbed. The energy performance of the plant retrofitted with R422D was improved by the improvement of the heat exchange at the condenser by augmenting the fan speed. In particular increasing the fan speed by 20% researchers obtained an improving of the COP included in the range 14.5-23.5%.

Buloka Olalekan Balaji [5] investigated the performance of R22 and its ozone friendly alternative refrigerants (R404A and R507) in a window air conditioner. R22 is HCFC therefore lubricant required for this is mineral oil and R507 as well as R404A are HFCs therefore they require Polyol ester oil (POE) as lubricant.

During retrofitting, R22 was first recovered then the compressor was removed from the system and the mineral oil was drained through the suction line of the compressor. The compressor was charged with fresh polyol ester lubricant. The result showed that R507 has the highest COP than those of R22 and R404A at any ambient air temperature.

Chennuchetty Chinnaraj, Palanisamy Govindarajan and Raghavan Vijayan [6] investigated the performance of R22 and its eco-friendly alternatives R407C and R290 using electronic expansion valve in the window air conditioner. It is obtained that mass flow rate and cooling capacity of refrigerants R407C and R290 are always less than that of R22. For all the refrigerants, mass flow rate and COP are decreasing with increase in degree of superheat, hence for better performance the EEV should be operated at lower degree of superheat. R407C and R290 can be used as drop in substitutes to R22 also R290 is a better choice in terms of energy efficiency.

K. Mani, V. Selladurai [7] comparison of CFC 12 with HFC-134a and new R290/R600a refrigerant mixture as drop in replacement was done. ODP of HFC-134a and new mixture of R290/R600a is zero, so they are environment friendly.

The experimental apparatus was consisted of two loops, a main loop and secondary loop. The main loop was composed of compressor, condenser, a filter-drier, refrigerant flow meter, sight glass, expansion valve and evaporator, The secondary loop was composed of a pump, a flow meter and an electrically heated unit within the insulated tank. Refrigeration capacity of R290/R600a was higher than R12 and R134a. Similarly COP of R290/R600a mixture was higher than R12 and R134a.

Y. Chen, J. Gu. [8] Found that more heat transfer corresponds to lower quality at the capillary outlet. The increase of inner diameter di, cooling pressure Pk and outside heat transfer coefficient will lead to longer capillary length, while increasing evaporating temperature T0 and cooling capacity Q0, lead to shorter length. The heat transfer rates change with different kinds of capillary tubes under different conditions.

2.1 Literature Gap

Till now different types of refrigerant have been compared in VCRS such as hydrocarbons (R290, R600, R600a), HFCs, also mixtures of hydrocarbon refrigerants were used in different proportions to compare with conventional refrigerants. But for comparison of R507 and R407C with R134a refrigerant in pure form there was nobody performed experiments. So I decided to work on this gap which was remained. At different capillary tube diameter performance of VCR system varies so I decided to evaluate the VCR system at three different capillary tube diameters which are 0.036inch, 0.040inch and 0.050inch.

3. PROPOSED SYSTEM DEVELOPMENT

3.1 Experimental Model

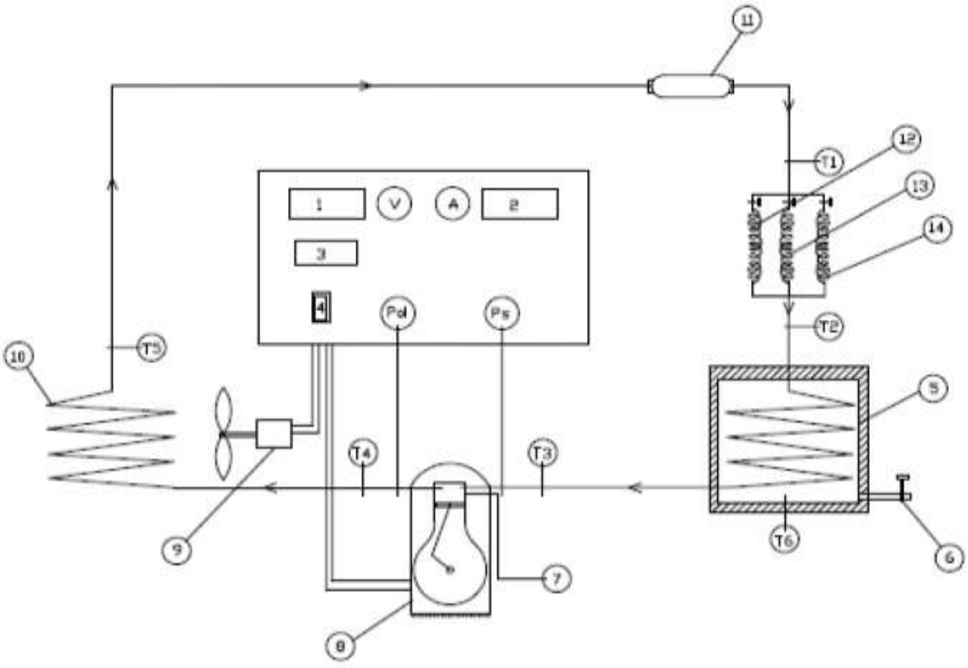

Figure3. Block Diagram of Experimental Model

V. Voltmeter	6. Water drainage valve
A. Ampere meter	7. Gas charging line
Pd. Discharge pressure (psi)	8. Compressor
Ps. Suction pressure (psi)	9. Condenser fan motor
Tx. Thermocouple	10. Condenser
1. Energy meter	11. Filter-drier
2. Temperature sensor	12. Capillary tube of ID 0.036 inch
3. Digital thermostat	13. Capillary tube of ID 0.040 inch
4. Electrical switch	14. Capillary tube of ID 0.050 inch
5. Evaporator tank	

The system under study will be composed of five components, i.e., a compressor, an evaporator, a condenser, capillary tubes and a liquid line filter-drier, as shown in the figure. A three-phase 220V, reciprocating compressor originally designed for R134a system will be used. Capillary tubes of different internal diameters will be used to find the optimum operating points of the system.

4. CONCLUTION

Use of capillary tube as expansion valve with different diameter results in variation of VCR system performance parameters such as coefficient of performance (COP), suction and discharge pressure, discharge temperature, power input etc. which gives optimum capillary tube diameter for better performance.

REFERENCES

[1] S.J. Sekhar, D.M. Lal, HFC134a/HC600a/HC290 mixture a retrofit for CFC12 systems, International Journal of Refrigeration, Vol. 28, 2005, pp. 735–743.

[2] B. O. Balaji, M. A. Akintunde and T. O. Falade. Comparative analysis of performance of Three ozone friendly HFC refrigeration in a vopour compression refrigerator. Journal of sustainable energy and Environment. Vol. 2, 2011, pp. 61-64

[3] Yongmei Xuan, Guangming Chen. Experimental study on HFC-161 mixture as an alternative refrigerant to R502. International Journal of Refrigeration.

[4] Ciro Aprea, Angelo Maiorino, Rita Mastrullo. Change in energy performance as a result of a R422D retrofit: an experimental analysis for a vapour compression refrigeration plant for a walk in cooler. Applied Energy 88(2011) 4742-4748.

[5] Bukola Olalekan Balaji. Performance investigation of ozone-friendly alternative refrigerants R404A and R507 refrigerants as alternatives to R22 in a window air-conditioner.

[6] Chennuchetty Chinnaraj. Influence of Electronic expansion valve on the performance of small window air conditioner retrofitted with R407C and R290.

[7] [3] K. Mani, V. Selladurai, "Experimental analysis of a new refrigerant mixture as dropin replacement for CFC12 and HFC134a", International Journal of Thermal Sciences, Vol. 47, 2008, pp. 1490–1495.

[8] Y. Chen, J. Gu. Non-adiabatic capillary tube flow of carbon dioxide in a novel refrigeration cycle. Applied Thermal Engineering 25 (2005) 1670-1683.

[9] Y.S. Lee, C.C. Su. Experimental studies of isobutane (R600a) as the refrigerant in domestic refrigeration system. Applied Thermal Engineering 22 (2002) 507–519.

[10] Ki-Jung Park, Taebeom Seo, Dongsoo Jung. Performance of alternative refrigerants for residential air-conditioning applications. Applied Energy 84 (2007) 985–991.

[11] Ki-Jung Park, Dongsoo Jung. Thermodynamic performance of HCFC22 alternative refrigerants for residential air-conditioning applications. Energy and Buildings 39 (2007) 675–680.

[12] Masoud Zareh , Hossien Shokouhmand , Mohammad Reza Salimpour , Mohammad Taeibi. Numerical simulation and experimental analysis of refrigerants flow through adiabatic helical capillary tube. International journal of refrigeration on 38 (2014) 299e309

[13] Subodh D. Deodhar, Hardik B. Kothadia, K.N. Iyer, S.V. Prabhu. Experimental and numerical studies of choked flow through adiabatic and diabatic capillary tubes. Applied Thermal Engineering 90 (2015) 879e894.

[14] Adriana Greco, Giuseppe Peter Vanoli. Evaporation of refrigerants in a smooth horizontal tube: prediction of R22 and R507 heat transfer coefficients and pressure drop. Applied Thermal Engineering 24 (2004) 2189–2206.

[15] Dongsoo Jung, Youngmok Cho, Kiho Park. Flow condensation heat transfer coefficients of R22, R134a, R407C, and R410A inside plain and microfin tubes. International Journal of Refrigeration 27 (2004) 25–32.

[16] ZhixingWang, MingshanWei, Fazhan Peng, Haibiao Liu, Chong Guo,Guohong Tian. Experimental evaluation of an integrated electric vehicle AC/HP system operating with R134a and R407C. Applied Thermal Engineering 100 (2016) 1179-1188.