ISSN 2395-1621

Experimental Evaluation of a Vapour Compression Cycle Performance using R134a, R22, R407C, R404A as Working Refrigerants

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ABSTRACT

This Paper present on experimental investigation of performance of R134a, R22, R407C, R404A Refrigerants. The experimental Test is performed on Compressor Calorimeter Test Rig. For different operating conditions. The operating variables Condensing temperature were in range from 38.5^{0}C to 45.5^{0}C and Evaporating temperature were in rang of 2 ^{0}C to 10^{0}C .Degree of sub cooling and Degree of Superheating were kept constant as 3^{0}C and 10^{0}C respectively. The Performance Characteristics followed to be analyze the compressor power consumption, Refrigerating capacity, mass flow rate, pressure ratio, Discharge temperature and Coefficient of Performance with R134a, R22, R407C, R404A Refrigerants.

Keywords: Compressor Calorimeter, Experimental Performance, Refrigerants: R134a, R22, R407C, And R404A.

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

working fluid in vapor compression refrigeration system. it was found that R22 & other chloroflouro carbon (CFC) and Hydrochlro flouro carbon (HFC) refrigerants destroys the stratospheric ozone layer & also contribute significantly to the worlds greenhouse warming problems.

[Devotta et al.2005, Bolaji 2010, Fatouch 2010]. et al .Hydro chloroflouro carbons (HFC) cause less harm to the ozone layer .they contain less chlorine atoms in their chemical structure than CFC's.Therefore, they have less ozone depletion potential than CFC,s .However ,they are considered to be harmful as well , CFC's Have been banned in developed countries since 1996 & from January 1st 2010 production and use of CFC's is prohibited completely all over the worlds HCFC refrigerants will also be phased out by 2020 & 2030 in developed and developing countries .respectively

[Fatouch, 2006].et al .Ozone depletion potential (ODP) of R134a is zero the global warming potential is high (GWP=1300).Due to this reason, some restrictions have been placed on its use in Europe. Therefore, the production & use of R134a will be terminated in the near future.

[Li & Zhao]et.al R404A is zeotropic Refrigerant blend of R125/143a/134a(44,52,4%) which can be suitable alternative for R134a ,R410a & CFC R502 Zeotropic Refrigerants therefore do not boil at constant temperature unlike azeotropic Refrigerants any substitute showed generally posses some ideal properties like non flammability ,non toxic ecofriendly to the natural environment, stable at all operating condition & have similar characteristics of refrigerant for which hydro flouro carbons (HFC's) & its blends of refrigerants such as zeotropes are finding its applications sector as commercial Refrigeration effect .

[S.Devotta,A,S.Padalkar,N.K.Sane.2004].et.al .Experimental performance analysis of a 1.5 TR window air-conditioner, retrofitted ,with R-407C as a substitute that to HCFC-22,experimental results showed that R-407C ,for the operating condition covered in this, study had lower cooling capacity in the Range 2.1-7.9% .with respect to HCFC-22 the coefficient of performance for R-407C was lower in Range 7.9-13.5%.the power consumption of the unit with R-407C was higher in the Range 6-7%. Than HCFC-22.the Discharge pressure for R-407C Were higher in the Range 11-13% than HCFC-22.

[Bolaji.2010b park & Jange 2009] et.al CFC % HCFC are controlled substances by the Montreal Protocol & greenhouse warming gases are controlled by the Kyoto Protocol. Non-ozone depleting hydroflurocarbon (HCFC's) Which have been used as alternative Refrigerants for the past two decades ,are part of greenhouse warming gases ,consequently in the long run Refrigerants with low greenhouse warming potential (GWP) & zero ozone depletion potential (ODP) are to be used in refrigeration & air-conditioning application. At the same time the performance of Refrigeration & Air-conditioning equipment has to be improved to cause by the use of electricity generated mainly by the combustion of fossil fuels.

AIRAH, Air Conditioning and Refrigeration Industry Refrigerant Selection Guide, 7th ed., The Australian Institute of Refrigeration, Air conditioning and Heating (AIRAH), 2003. et.al .R404A and R507 are blends which are absolutely chlorine free (ODP = 0), their basic components belong to the HFC group and are therefore long term alternatives. R404A is a near azeotropic refrigerant mixture of R125, R134a and R143a (44/4/52% by weight). One of the components, R143a, belongs to the flammable category, but due to the combination with a relatively proportion of R125 the flammability is effectively counteracted. A feature of all the three components is the very low isentropic compression exponent, which results in a very low discharge temperature. The efficient application of single stage compressors with evaporating temperatures is therefore guaranteed.

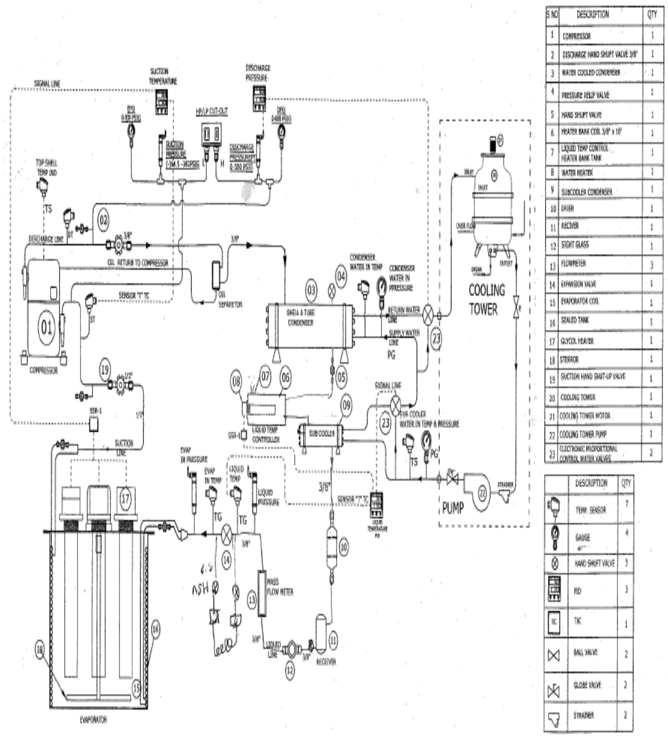

Fig. 1 Schematic diagram of Experimental setup

II. EXPERIMENTAL SET-UP

In Fig.1 shown that the refrigerants (any HFC /HCFC's) are to be charged at the suction port of the rig. The whole set up has the capacity of accommodating nearly 3 kg of the refrigerant feeded.When the mains is turned on subsequently the glycol heaters, cooling tower fan & pump is to be turned and finally the compressor is to be turned on, it takes around 2 minutes to the compressor to actually start functioning, reason being the compressor circuit has two minutes lag time.

Once the compressor starts it pumps up the refrigerant to the higher pressure, following the compressor there is a discharge hand shut valve having the capacity to withstand the pressure of nearly 350 psi. This again limits the study of any refrigerant in the set up to decide the maximum condensing temperature limits. The discharge hand shut valve is been regulated by the pressure switch which is open to calibration and flexible enough to set the tripping range of the pressure (compressor discharge pressure). Oil Separator, available at the outlet of the hand shut valve separates the oil that is probably carried along with refrigerants during the compression stroke. The lubricating oil is drained back to the compressor via return line from the separator. The outlet of the compressor has two thermocouples to measure the compressor top shell (T_S) temperature and discharge temperature of the compressor (T_D).

From the oil separator the refrigerant passes via 3/8" line to the shell and tube condenser, where in the cooling water supplied by the cooling tower at the ambient condition exchanges heat in the shell and tube frame work of the condenser, The refrigerant coming out of the condenser expected to be in the saturated state is made to flow in the sub cooler, liquid temperature controller, where the liquid is further condensed to ensure the liquid state before its expensed in the expansion valve. The cooling in sub cooler is supported by the water supplied in ambient condition by the cooling tower.

The liquid (sub cooled) phase refrigerant passes on to the drier, to get wiped out of any moisture content present within. The receiver following next to the drier is just a storage unit where in it stores the refrigerant. The sight glass, attached next to the receiver facilitates to observe the bubble formation while charging which is again a measure to have a check on the charging of the refrigerant to the system. Bubble formation is at the peak when the system is supplied with the refrigerant well below its capacity. Mass flow meter measures the amount of refrigerant that is been used by the compressor for particular given condition.

Then the refrigerant is passed to the evaporator, where actually the cycle is theoretically believed as the starting point. The evaporator cabin (Sealed tank) incorporates evaporator coil, stirrer and glycol heater; the glycol mixture is used as anti-freezing agent in the cabin to see to that the temperature does fall beyond the set value during the experimentation.

There are 7 temperature sensors fixed in the circuit lines to measure the temperature condition of the refrigerant and the cooling water that runs in the system during cycle operation. The suction pressure and the discharge pressure of the compressor is been regulated by the pressure switch, the magnitudes of the same is measured by the transducer fixed at the inlet and outlet of the compressor. There are two more pressure transducer to sense the pressure in water supply lines to the condenser and sub cooler.

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) used in this system 3 in numbers that is been used to set the discharge pressure of the compressor, desired sub cooling temperature of the refrigerant and the suction temperature of the refrigerant before it enters the compressor. There are pairs of ball valves and globe valves at the cooling tower inlet and outlets to regulate the water flow to the system. This is merely the complete working of the setup.

III. RESULT AND DISCUSSION

At Minimum Condensing Temperature 38.5 ^{0} C & Maximum Evaporator Temperature 10 ^{0}C

Refrigerant	Evaporator Temp.(^{0}C)	Refrigeration Capacity (kw) Qe	Compressor Power (Kw) Wc	COP (Qe/Wc)	Mass Flow Rate (Kg/hr)	Discharge Temp.(^{0}C)	Pressure Ratio
R22	10	3.3	0.99	3.33	60.1	82.4	2.55
R407C	10	2.95	0.96	3.07	66.2	71.2	2.76
R134a	10	2.88	0.99	3.91	41.2	74.2	1.53
R404A	10	2.78	0.99	2.81	99.25	62.3	2.49

R22 and its retrofit refrigerants (R407C, R404A, and R134a) were used in compressor calorimeter test rig. And system performance was evaluated and compared. The result of refrigeration capacity obtained at different evaporating temperatures is

shown in Fig.2 Evaporating temperature was varied between 2 ^{0} C to 10 ^{0} C As a result of its variation of condenser temperature. it was observed that for all the investigated refrigerants, the refrigeration capacity increased with increase in evaporator temperature. All Result at evaporating Temperature at 10 ^{0} C. The refrigeration capacity of R407C is the 10.60% lower than that from the R22 and R134a is lower by 12.72%, while that with R404A is lower by 15.75 % than that with R22.

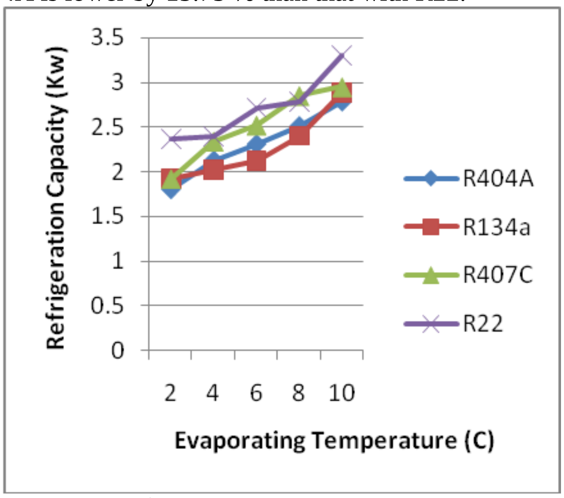

Fig. 2 Variation Refrigeration Capacity with Evaporating Temperature

Fig.3 shows the relationship between the compressors Power and the evaporating temperature of R22 and alternative refrigerants. The change of compressor power with evaporating temperature is similar for the three refrigerants; as the compressor power increases with increases evaporating temperature. The compressor power of R134a and R404A are same as R22.the compressor power of R407C is reduced by 3.03 %Compared with R22.

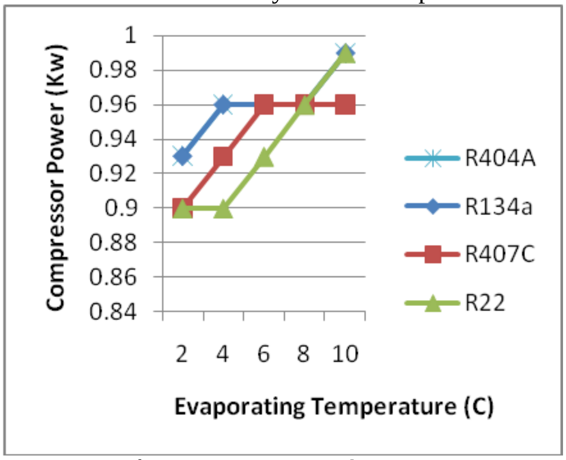

Fig.-3 Variation of Compressors Power with Evaporating Temperature

Fig.4 shows that the relation between evaporating temperature and coefficient of performance (COP).
The COP Increases with increases in evaporating temperature. The COP of R22 is higher, the COP of R407C is reduced by 7.80% and COP of R134a, and R404A are reduced by 12.62% and 15.61% respectively with R22.

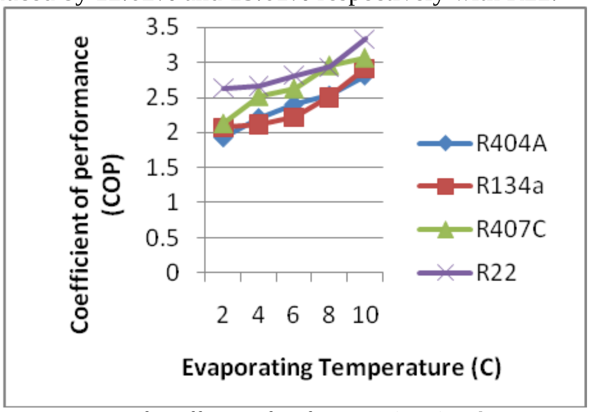

Fig. 4 Variation of Coefficient of performance (COP) with Evaporating Temperature

Fig.5 shows the relationship between the Discharge Temperature and the evaporating temperature of R22 and alternative refrigerants. The changes of Discharge Temperature with evaporating temperature are similar for the three refrigerants, as the Discharge temperature decreases with increases evaporating temperature.

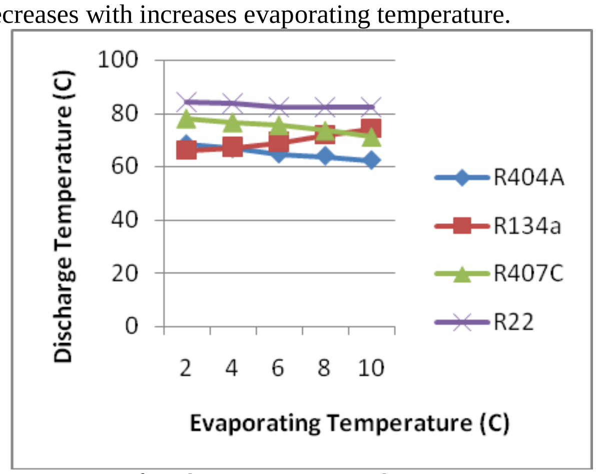

Fig. 5 Variation of Discharge Temperature with Evaporating Temperature

The Discharge Temperature with R22 is higher than R407C, R404A, and R134a.compared with R22 the Discharge temperature with R407C reduced
By 13.59%, that with R134a, reduced by 9.25% and that with R404A is reduced by 24.39%.
Fig.6 shows that the relation between evaporating temperature and Mass flow rate of refrigerant. The Mass flow rate of R407C is higher by 10.15% than R22.The mass flow rate of R134a and R404a are lower by 31.44% and higher by 65.14% with R22 respectively.

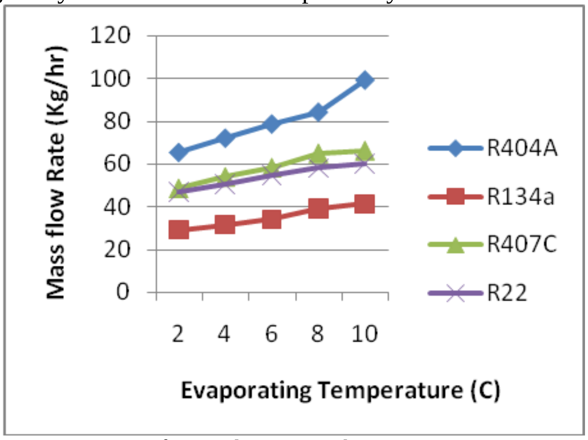

Fig.6. Variation of Mass Flow Rate with Evaporating Temperature

Fig.7 shows that the relation between evaporating temperature and Pressure Ratio .The Pressure Ratio of R407C is higher by 8.23% than R22.The Pressure Ratio of R134a and R404a are lower by 40 % and lower by 2.35% with R22 respectively.

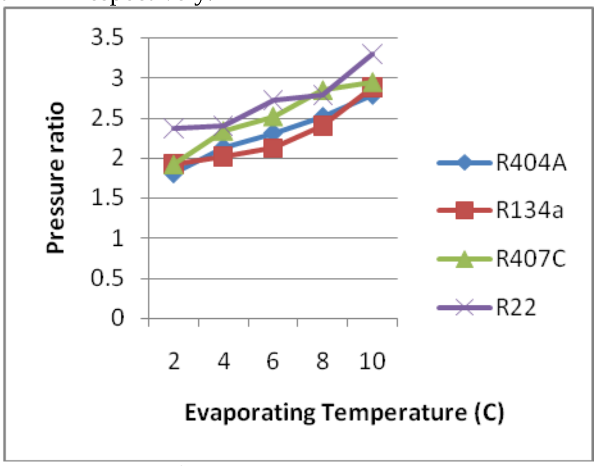

Fig. 7 Variation of Pressure ratio with Evaporating Temperature

IV. CONCLUSION

In this Experiments were carried out Evaluation performance of R22 and its R407C, R134a and R404A in Compressor colorimeter test Rig..Based upon the experimental Results, at Condenser Temperature are 38.5 ^{o} C. The Degree of Sub cooling Temperature is 3 ^{o} C and Degree of Superheating Temperature is 10 ^{o}C and the all result at evaporating Temperature at 10 ^{o}C.Following Conclusion were drawn:

1) For the entire investigated refrigerant, as the evaporating temperature increases, the Refrigeration capacity, compressor power, COP and Mass flow Rate increases, while The Discharge Temperature and Pressure Ratio Decreases.

2) The Refrigeration Capacity of R407C is lower by 10.60%. With R22.The refrigeration capacity of R134a is lower by 12.72 % & R404A is lower by 15.75 % respectively compared with R22.
The compressor Power of R134a and R404A are low same as R22 and The Compressor Power is lower by 3.03 % Compared with R22.

3) The COP of R22 is higher; the COP of R407C is reduced by 7.80% with R22 and COP of R134a, and R404Aare reduced by 12.72% and 15.75% compared with R22 respectively.

4) The Discharge Temperature with R22 is higher than R407C, R404A, and R134a.compared with R22 the Discharge temperature with R407C reduced
By 13.59%, that with R134a, reduced by 9.25% and that with R404A is reduced by 24.39%.

5) The Pressure Ratio of R407C is higher by 8.23% than R22.The Pressure Ratio of R134a and R404a are lower by 40 % and lower by 2.35% with R22 respectively.

Finally, the system charge with R407C Consistently had best performance when compared with when it's containing R22, R134a and R404A, Therefore, R407C would be a better choice for retrofitting existing vapour compression cycle.

ACKNOLEDGEMENT

Thanks to Dr P. A. Patil for his valuable guidance in this experimental work and also thanks to Jayawantrao Sawant College of Engineering for providing Compressor Calorimeter test rig for experimentation.

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