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Complete Evaluation of Vapour Compression Refrigeration System Using R407C and R507

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Abstract: *For the existence of refrigerant current requirements are, system performance should not be compromised, refrigerant and lubrication interaction should be as required, it should be energy efficient, environment friendly etc. CFC and HCFC have high ozone depleting potential (ODP) therefore after Montreal protocol their use has been banned. So it is a need of time 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).CFF and HCFC refrigerants can be replaced by hydrofluorocarbon (HFC) as they have similar vapour pressure also HFC is nonflammable and stable compound more over HFC has zero ODP. After use of HFC refrigerants in many applications, it is found that we don't need to change the design of refrigeration system. So we can look forward to HFC refrigerants. R407C and R507 are HFC refrigerants which are studied in this paper. Thus, the aim of the present work is to compare refrigerants R407C and R507 with R134a refrigerant using different parameters such as COP Vs Ambient Air Temperature, Refrigeration Capacity Vs Ambient Air Temperature, and Compressor Discharge Temperature Vs Ambient Air Temperature etc.*

KEYWORDS: Refrigeration system, VCR, Refrigerant, Environment.

1. INTRODUCTION

Refrigerants are classified as CFC: CFC is a molecule having carbon, fluorine and chlorine atoms. CFC is stable compound hence it reaches stratosphere and contribute to the destruction of ozone layer. E.g. R11, R113, R12, R500, R502 etc. HCFC: HCFC is a molecule having Hydrogen, Carbon, Fluorine and chlorine atoms. HCFC affect Ozone layer by lesser extent as they are less stable. E.g. R22, R123, R124, R401a etc. HFC: It is a molecule having hydrogen, fluorine and carbon. As HFC does not contain Chlorine, it does not affect ozone layer.

1.1Standard Vapour Compression Refrigeration System (VCRS)

T-S and P-V diagrams of standard, saturated, single stage (SSS) vapour compression refrigeration system are shown in fig.1 and fig.2 respectively. Standard VCRS consist of following four processes:
Process 1-2: Compressor Work (Isentropic compression of saturated vapour)
Process 2-3: Condensation (Isobaric heat rejection)
Process 3-4: Throttling (Isenthalpic expansion of saturated liquid)
Process 4-1: Evaporation (Isobaric heat extraction)

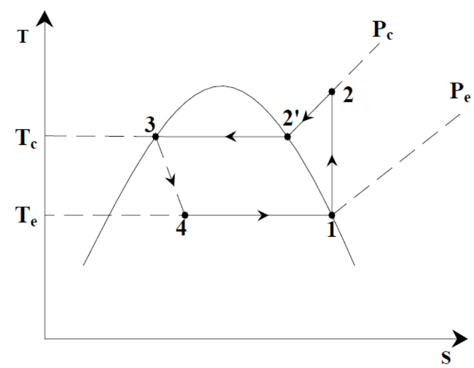


Figure-1: T-S diagram of VCRS.

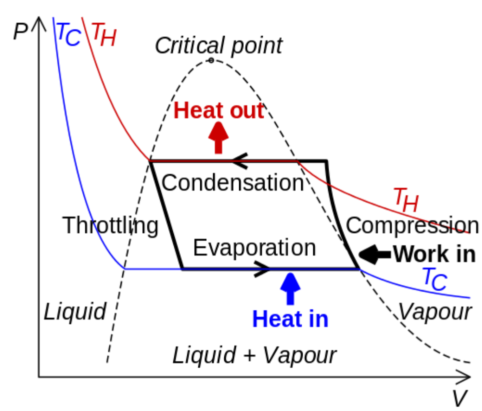
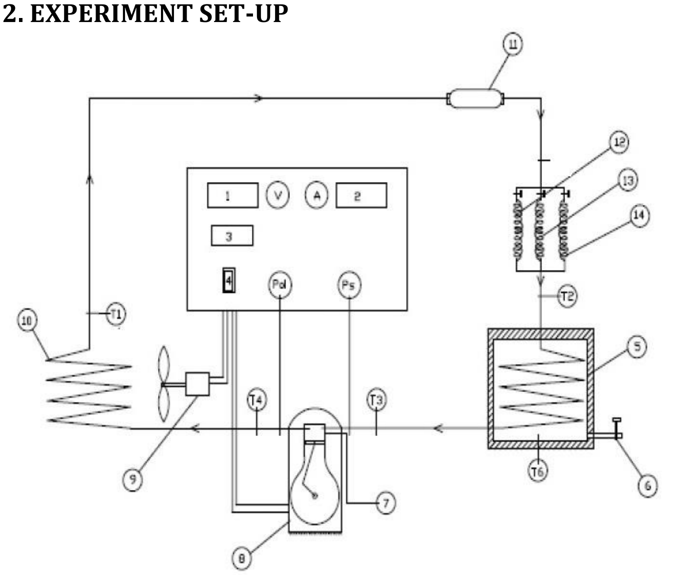


Figure-2: P-V diagram of VCRS.

The VCR cycle is useful in most of the refrigerators, deep freezers and water coolers. In this cycle the refrigerant entering the compressor at low pressure is compressed to high pressure superheated vapour. Now this refrigerant in superheated vapour form travels to condenser which has coils or tubes. Here the refrigerant is cooled and liquefied. After condenser the liquid refrigerant passes through throttling device (Expansion valve or capillary tube). In the throttling device there is sudden decrease in refrigerant pressure which results in flash evaporation of one third of liquid refrigerant. The latent heat required for this flash evaporation is absorbed mostly from adjacent liquid refrigerant; this phenomenon is called auto refrigeration. Now this liquid – vapour mixture of refrigerant enters the evaporator section. The evaporator section consist of a storage tank which has evaporator coil soldered on its outer walls. When refrigerant leaves evaporator, it is fully vaporized and slightly heated as it absorbs heat from evaporator section. Finally the refrigerant returns to the compressor to continue the cycle.

2. EXPERIMENT SET-UP



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	

Figure-3: Experimental Setup

The setup composed of five main components which are a compressor, a condenser, capillary tubes, a filter-drier, an evaporator as shown in figure. A 220V, reciprocating compressor with input power varied between 230 to 300W was used. Compressor lubricant is polyol ester oil. A silica gel drier filter is used for absorption of moisture. Condenser is air cooled type. Capillary tubes used have different internal diameter. Evaporator section has a steel tank and copper tubes that means it is shell and tube type. Puff insulation is applied to evaporator tank to avoid heat transfer. The refrigerants used were R407C, R507 and R134a.

The other components used were a voltmeter, an ampere meter, an energy meter, a digital thermostat, an electrical switch, bourdon tube type low pressure and high pressure gauges, J type thermocouple and indicator and control valve.

Table.1. Specifications of Experimental Set-up

Notation	Component	Description
V	Voltmeter	Range 0-300
A	Ampere Meter	Range 0-10
Pd	Discharge Pressure Gauge	Range 0-300 Psi
Ps	Suction Pressure Gauge	Range 0-150 psi
Ts	Thermocouple	J and T type
1	Energy meter Electronic	Range 0-20A
2	Temperature Indicator	J Type range 0-750c
3	Thermometer	Digital Controller
4	Switch	15A
5	Evaporator Tank	Steel tank insulated by Puff
6	Water Drainage Valve	Plastic Valve
7	Gas Charging Line	¼ inch diameter line
8	Compressor	MA72LHEG, Hermetically sealed, Reciprocating Type
9	Condenser Fan Motor	1/83 HP
10	Condenser	10inch*11inch*3row
11	Filter Drier	DM 50type containing Silica gel
12	Expansion Valve	Capillary tube of different diameter

3. DATA REDUCTION

1. Initially vacuum was created in the VCRS setup with the help of vacuum pump.
2. Refrigerant was charged within the system by charging line and charging valve.
3. To the storage tank of the evaporator tank 7kg of water was supplied.
4. Start the system and note the temperature of water, initial energy meter reading and system pressure.
5. Note the final pressure at suction and discharge section, temperature at all silent points, final energy meter reading.
6. With the help of relations, readings, observation table is prepared.
7. Given procedure was repeated for the working fluids R407C, R507 and R134a.
8. COP of the system was calculated by using the given relation.
9. Heat abstracted in evaporator : $Qa = mev \times Cpw \times \_Tew$
10. Work input in compressor: W*in* = Energy meter reading
11. Coefficient of performance: $COP = Qa/Win$

Where, *mev* = Mass of evaporator tank water in kg. T*ew* = Evaporator water temperature difference in K
C*pw* = Specific heat of water in kJ/kg-K, Q*a* = Heat abstracted in evaporator in kJ
W*in* = Work input in compressor in kJ

4. RESULTS AND DISCUSSION

The series of experiments were carried out on the experimental test rig. The experiments were first carried out with R134a then R407C and finally R507. All experiments were performed with three different capillary tube diameters (0.036, 0.04, 0.05 inches) at three different ambient air temperatures which are 32, 36 and 40°C.

4.1. COP Vs Ambient Air Temperature

Following are graphs showing COP against Ambient air Temperature for respective capillary diameters.

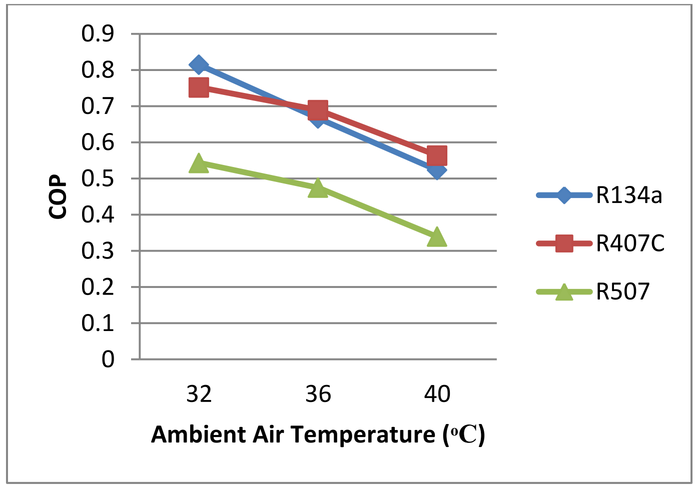


Chart –1: COP Vs Ambient Air Temperature for capillary diameter 0.036 inch

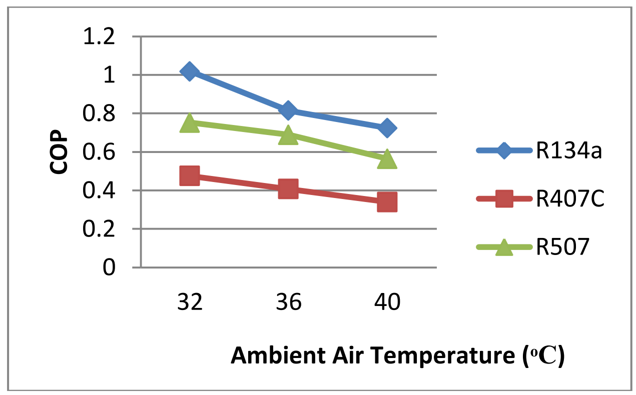


Chart –2: COP Vs Ambient Air Temperature for capillary diameter 0.040 inch

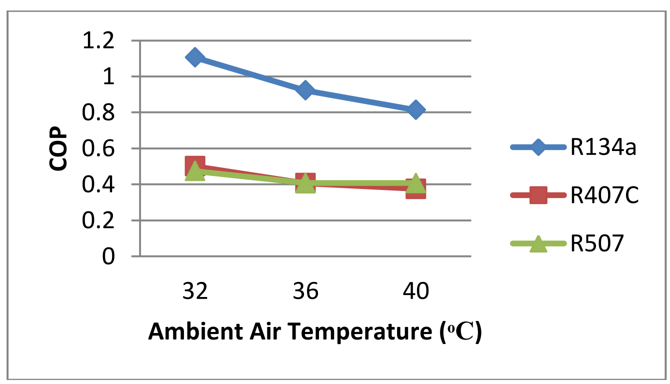


Chart –3: COP Vs Ambient Air Temperature for capillary diameter 0.050 inch

Above figures show the COP of different refrigerants at different ambient air temperature.
By observing these three graphs of COP v/s Ambient Air Temperature, we can define the following results
1. COP of all refrigerants decreases with increase in ambient air temperature.
2. COP of R134a is more than R407C and R507.

4.2. Compressor Discharge Temperature Vs Ambient Air Temperature

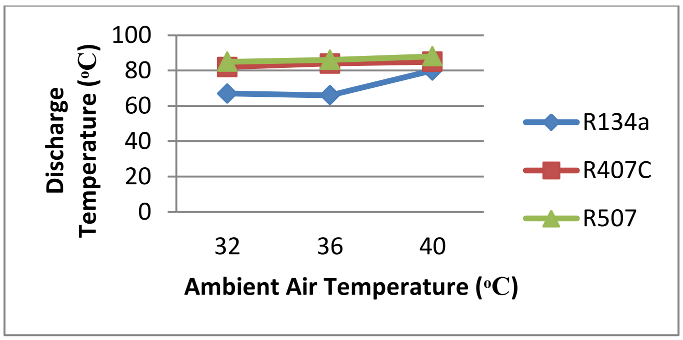


Chart –4: Discharge Temperature Vs Ambient Air Temperature for capillary diameter 0.036 inch

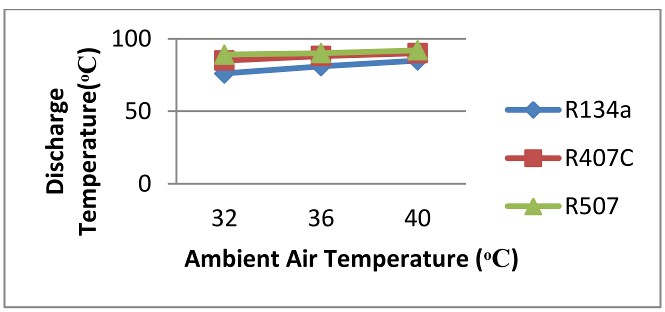


Chart –5: Discharge Temperature Vs Ambient Air Temperature for capillary diameter 0.040 inch

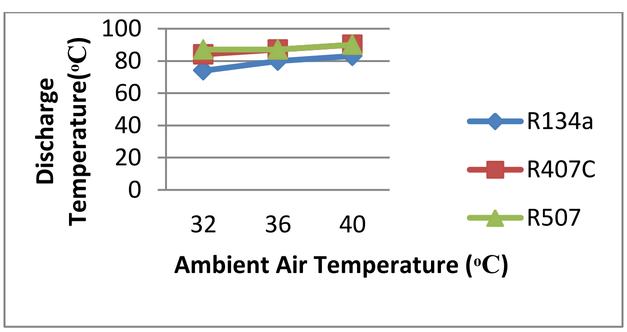


Chart –6: Discharge Temperature Vs Ambient Air Temperature for capillary diameter 0.050 inch

Above figures show the compressor discharge temperature at different ambient air temperature. By observing these three graphs of Discharge Temperature v/s Ambient Air Temperature, we can define the following results,
1. Discharge temperature increases with increase in ambient air temperature for all refrigerants.
2. For R134a discharge temperature is lowest.

4.3. Refrigeration Capacity Vs Ambient Air Temperature

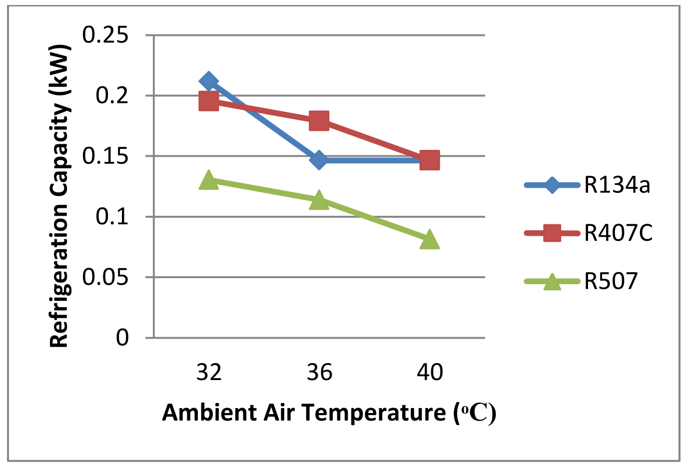


Chart –7: Refrigeration capacity Vs Ambient Air Temperature for capillary diameter 0.036 inch

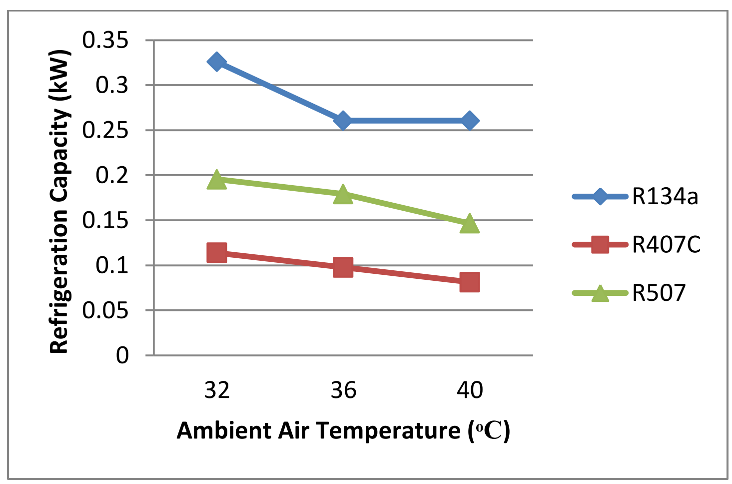


Chart –8: Refrigeration capacity Vs Ambient Air Temperature for capillary diameter 0.040 inch

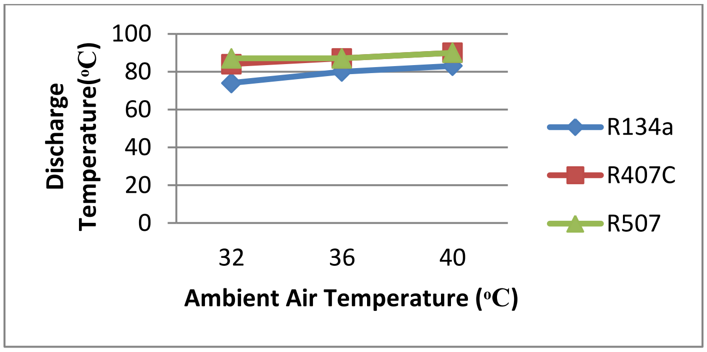


Chart –9: Refrigeration capacity Vs Ambient Air

Above figures show the refrigeration capacity at different ambient air temperature. By observing these three graphs of Refrigeration capacity v/s Ambient Air Temperature, we can define the following results,

1. Refrigeration capacity decreases with increase in ambient air temperature.
2. Refrigeration capacity of R134a is more than R407C and R507 for all ambient air temperatures.

5. CONCLUSIONS

Performance evaluation of vapour compression refrigeration system by using different refrigerants was studied, based on the experimental study; the effect of different working parameters such as ambient air temperature, dimensions of capillary tube etc. was studied.

R134a is one of the important refrigerants used in air-conditioning and refrigeration systems all over the world. R134a, R407C and R507 all are HFC refrigerants and all of them have zero ozone depletion potential (ODP).

The results obtained showed that as ambient air temperature increases, discharge temperature and energy consumption increase, while the COP and refrigeration capacity reduce for all the investigated refrigerants. Discharge temperature of R134a was lowest, followed by R407C with average value of 11.34% higher, while that of R507 was 13.65% higher than that of R134a. The refrigeration capacity obtained from R134a is more than those obtained from R407C and R507. The average refrigeration capacity of both R407C and R507 are lower by around 43%.

The result of COP showed that R134a has the highest COP than those of R407C and R507 at any ambient temperature. Compared with R134a, the average COP of R507 is decreased by 32.79% and that of R407C is decreased by 37.19%. Refrigerant R134a has the highest energy consumption. Compared with R134a, the average energy consumption of R407C is decreased by 12.77% and that of R507 is decreased by 15.45%. R407C gave optimum performance at 0.036 inch capillary diameter. R507 gave optimum performance at 0.040 inch capillary diameter. Performance of R134a was similar at 0.040 and 0.050 inch capillary diameter. Finally, the overall assessment of the results showed that R134a has the best performance as compared to R407C and R507 in all aspects.

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