Evaluation of Coefficient of Performance of a VCR System by using R404-A Refrigerant with Change in Length of Advanced Condenser

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Abstract :

VCRS is used for freezing of food products for the both trading and household purpose appliances. Advancement for the better execution of the system ends up fundamental issue and numerous examines are still on going to enhance productivity of the system. The primary target of this Project work is to Change in Length of Condenser in VCR System & Evaluation of COP by using R404-a refrigerant.

In my experimental work, it is proposed to optimize condenser length for domestic refrigerator of 165 liters capacity. It may give a chance to find a different length other than existing length will give better performance and concluded that the optimum length of coil is 9.95m and a refrigerator designed and developed to work with R134a was tested, and its performance using R-404a was evaluated and compared with its performance when R134a was used. The results obtained showed that the design temperature and pull-down time set by International Standard Organization (ISO) for small refrigerator were achieved earlier using refrigerant R-404a than using R-134a.

INDEX TERMS: Condenser, Refrigerant, Refrigerator.

I. INTRODUCTION

The vapor compression system is most widely used for refrigeration. Refrigerant used in this system undergoes a change of phase, and such a refrigerant can produce more refrigeration effect. The condenser design plays a very important role in the performance of a vapour compression refrigeration system. Condenser is a heat exchanger where heat transfer takes place between the super heated refrigerant received from the compressor and the cooling medium of the condenser.

HFCs refrigerants are having high global warming potential (GWP) which is gradually increasing earth temperature. To reduce GWP effects new alternatives like R-401a, R-404a, R-407c, R-410a are introduced. R404A is a zeotropic HFC refrigerant blend of R125, R143a and R134a. It is widely used in medium and low temperature refrigeration especially in the supermarket sector and for refrigerated transport.

1. SELECTION OF CONDENSER

Condenser is that component which is placed next to compressor in a vapor compression refrigeration system. It is a heat exchanger that affects heat transfer between refrigerant gas, vapor or super saturated vapor coming from compressor and cooling medium such as air or water. It removes heat absorbed by refrigerant in the evaporator and the heat of compression added in the compressor and condenses it back to liquid. The condenser abstracts the latent heat from high pressure refrigerant at the same pressure and constant temperature. For this purpose the condenser employs a cooling medium such as air or water.

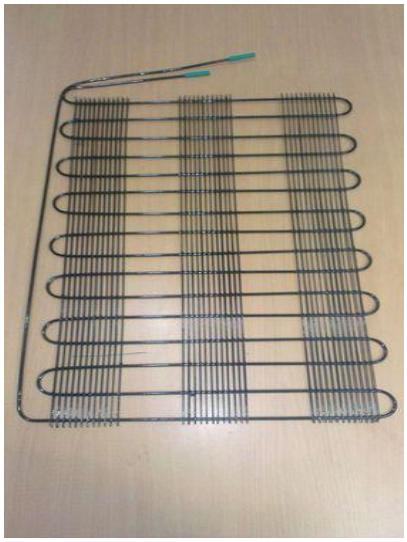


Fig : Advanced Modern Condenser

ADVANCED MODERAN CONDENSER

The condenser coil used was made of steel with copper cotted. Fins are arranged like batches on condenser.

Condenser coil length - 9.95m
Inner diameter - 10mm
Outer diameter - 12mm
Overall height of condenser - 75cm
Overall width of condenser - 50cm

FINS

Number of fins in 1 batch - 16
Number of batches - 3
Distance between batches - 3cm
Distance between fins - 1mm
Fin thickness - 0.15mm
Length of each fin - 75cm
Overall width of fins covered on coil - 40cm

2. SELECTION OF REFRIGERANT

R404A is an HFC blend that is widely used in low and medium temperature refrigeration applications, such as those used in commercial refrigeration. It possesses outstanding properties as a refrigerant for showcases, refrigerated vehicles, ice makers, and other equipment.

Product Name : R-404A
Other Name : Pentafluoroethane, 1,1,1-Tetrafluoroethane, 1,1,1,2-Tetrafluoroethane
Use : Refrigerant Gas

PHYSICAL AND THERMAL PROPERTIES

Ashrea A1 safety classification
Non Flammable & safe to use
Zero ODP
GWP of 3260 (IPCC assessment report 2)

Molecular weight	:	97.6
Boiling point at 1 ATM is	:	46.5/-45.8 °C
Critical Temperature	:	72.1°C
Critical Pressure	:	541.2pisa (3731.5Kpa)
Critical Density	:	30.23lb/ft^3 (484.5kg/m^3)
Critical Volume	:	0.0331ft^2/lb (0.00206m^3/kg)
Apperance	:	Clear, colorless liquid and vapor
Physical State	:	Gas at ambient temperatures
Chemical Formula	:	CHF2CF3, CH3CF3, CH2 FCF3
Odor	:	Faint ethereal odor
Specific Gravity (water = 1.0)	:	1.08 @ 21.1°C (70°F)
Solubility in Water (weight %)	:	Unknown
pH: Neutral Boiling Point	:	-47.8°C (-54.0°F)
Freezing Point	:	Not Determined
Vapour Pressure	:	182.9 psia @ 70°F 370.9 psia @ 130°F
Vapour Density (air = 1.0)	:	3.43
Evaporation Rate	:	>1Compared TO: CC14 = 1 %
Volaties	:	100
Odor Threshold	:	Not established
Flammability	:	Not applicable
Lel/Uel	:	None/None
Relative Density	:	1.08 g/cm3 at 21.1 C

II. Experimental Setup

This project focuses on heat rejection in the condenser this is only possible either by providing a fan or by extending the surfaces. The extended surfaces are called fins. The rate of heat rejection in the condenser depends upon the number of fins attached to the condenser. In the present domestic refrigerator copper material fins are used. The performance of the condenser will also help to increase COP of the system as the sub cooling region incurred at the exit of the condenser.

In order to know the performance characteristics of the vapor compression refrigerating system the temperature and pressure gauges are installed at each entry and exit of the component. Different types of tools are also used like snips to cut the fins to required sizes, tube cutter to cut the tubes and tube bender to bend the copper tube to the required angle. Finally the domestic refrigerator is fabricated as for the requirement of the project.

The figure 1 shows the experimental setup of the refrigerator. In order to know the performance characteristics of the vapor compression refrigeration system the temperature and pressure gauges are installed at each entry and exit of the components. Experiments are conducted on condenser with coil spacing of the condenser on a refrigerator of capacity 170liters. All the values of pressures and temperatures are tabulated.

1. Domestic refrigerator selected for the project has the following specifications:

Refrigerant used : R-134a
Capacity of The Refrigerator : 170 liters
Compressor capacity : 0.16 H.P.
Condenser Sizes : Diameter - 6.35 mm
Evaporator : Length - 7.62 m Diameter - 6.4 mm
Capillary : Length - 2.428 m Diameter - 0.8 mm

Condenser length of existing system is 9.15m and in the present work condenser lengths of 9.65m and 9.95m are tested to analyze its effect on the performance of refrigeration system.

Fig 1 Proposed System with condenser coil length

III.EXPERIMENTAL PROCEDURE

Different experimental and theoretical comparison is performed by many researchers to evaluate the performance of domestic refrigerator by using different refrigerants. In this experimental the study of R-404a is done in a domestic refrigeration system with change in condenser length. To perform the experiment 170L refrigerator is selected which was designed to work with R-134a. It is consists of an evaporator, air cooled condenser, reciprocating compressor. The refrigerator was instrumented with two pressure gauges at inlet and outlet of the compressor. The temperature at four different points is taken by 8 digital sensors, for measuring temperature on food compartment and freezer compartment 5 sensors are fitted.

The following procedure is adopted for experimental setup of the vapor compression refrigeration system

1. The domestic refrigerator is selected, working on vapor compression refrigeration system.
2. Cleaning is done with the help of nitrogen gas then evacuation is carried out with the help of vacum pump and refrigerant is charged with the help of charging system.
3. The refrigerator was first charged with 60 gm. Of R-404a at tested at various conditions. Same test were repeated with 80 and 100 gm. Of R-404a.test were carried out.
4. Leakage tests are done by using soap solution, In order to further test the condenser and evaporator pressure and check purging daily for 12 hours and found that there is no leakages which required the absolutely the present investigation to carry out further experiment.
5. Switch on the refrigerator and observation is required for 1 hour and take the pressure and temperature readings at each section.
6. The performance of the existing system is investigated, with the help of temperature and pressure gauge readings.
7. The refrigerant is discharged out and condenser is located at the inlet of the capillary tube.
8. Temperature and pressure gauge readings are taken and the performance is investigated.
9. The readings are tabulated for condenser coil length of 9.14m, 9.65m, 9.95m for refrigerant R404a.

IV.PERFORMANCE CALCULATIONS

The temperature and pressure readings are noted down and from pressure-enthalpy chart for R-404a, enthalpy values at state points 1,2,3, and are tabulated as follows shown in table 1

Parameters	**Condenser coil length(m)**		
	9.15	**9.65**	**9.95**
Compressor Suction Temperature T1(°C)	32	34	31
Compressor Discharge Temperature T2(°C)	65	66	64
Condensing Temperature T3(°C)	51	37	46
Evaporator Temperature T4(°C)	-10	-9	-11
Compressor suction pressure P1(bar)	3.2	3.0	2.5
Compressor discharge pressure P2(bar)	12	12.2	12.7
Condenser pressure P3 (bar)	12	11.5	11.4
Evaporator pressure P4(bar)	3.2	3.2	2.7
Enthalpy,h1 (kJ/kg)	425	426	429
Enthalpy,h2 (kJ/kg)	459	460	460
Enthalpy,h3 (kJ/kg)	263	253	260
Enthalpy,h4 (kJ/kg)	263	255	261

Calculation of Performance Parameters

Calculation is carried as follows for existing condenser length of 9.15m.

1. Net Refrigerating Effect
(NRE) = h1-h4 = 425-263 = 162kJ/kg

2. Mass flow rate to obtain one TR, kg/min.
mr = 210/NRE = 210/162 = 1.29 kg/min.

3. Work of Compression
h2-h1 = 459-425 = 34 kJ/kg.

4. Heat Equivalent of work of compression per TR
mr x (h2-h1) = 1.29 x 34 = 43.86 kJ/min

5. Theoretical power of compressor
43.86/60 = 0.73 kW

6. Coefficient of Performance
(COP) = h1-h4 / h2-h1 = 162/34 = **4.76**

7. Heat rejected in condenser
h2-h3 = 459-263 = 196 kJ/kg

8. Heat Rejection
per TR = (210/NRE) x (h2-h3)
= 1.29 x 196 = 252.84 kJ/min

9. Heat Rejection Ratio = 312/210 = 1.20

10. Compression Pressure Ratio

$$\frac{\text{Dishcarge Pressure}}{\text{Suction Pressure}} = P_b/P_s = \mathbf{12/0.32 = 3.7}$$

Table 1: Temperature, pressure and enthalpy readings.

Similarly calculation is carried for remaining three condenser lengths of 9.15m, 9.65m and 9.95m which are tabulated as follows shown in table 2.

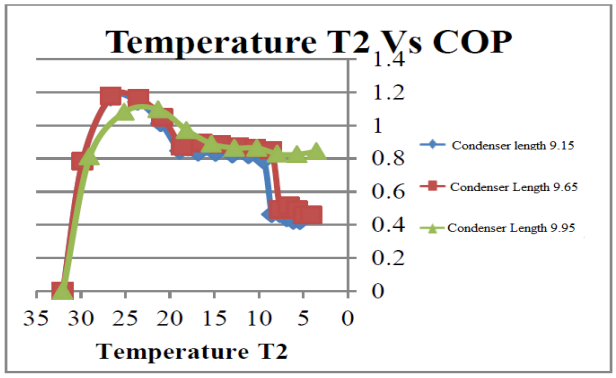
PARAMETERS	**Condenser Coil length(m)**		
	9.15	**9.65**	**9.95**
(COP)	4.78	4.99	4.4
Net refrigerating effect , kJ/kg	161	171	164
Work of Compression, kJ/kg	34	34	36
Compressor Power, kW	0.72	0.67	0.77
Mass flow rate to obtain one TR, kg/min	1.28	1.22	1.26
Heat Equivalent of work of compression per TR, kJ/kg	43.8	41.2	46
Heat rejected in condenser , kJ/kg	195	205	201
Heat Rejection per TR, kJ/min	251	251	255
Heat Rejection Ratio	1.2	1.1	1.1
Compression Pressure Ratio	3.71	3.9	4.5

Table 2: Performance parameters using different condenser lengths by using R404a

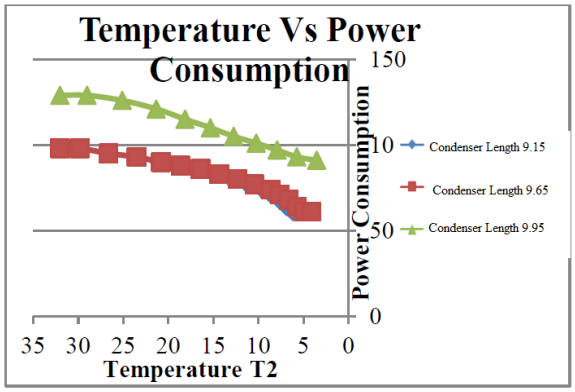
V.RESULTS AND DISSCUSSIONS

The relationship between length of condenser and performance parameters have been compared and the results are discussed with the help of graphs.

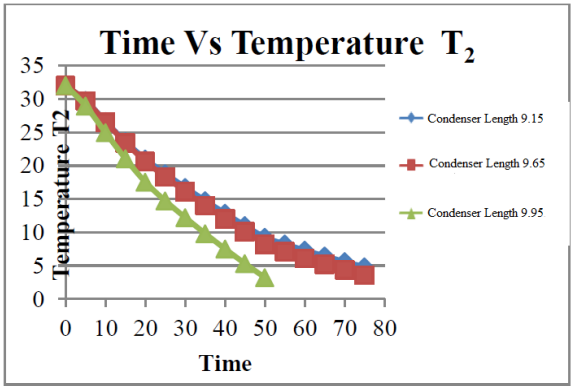
When the calculated values of COP at drop in final temperature in 5 minutes of interval using improvement by modification of refrigerator in two lengths are compared to that one of conventional refrigerator, the process showed almost similar behavior.



Initially it same as and the curves overlap to existing one and then after some drop in temperature its shows slightly improvement in COP by modification of condensor length throughout total time span but it achieve slightly more temperature drop within same time of cycle.



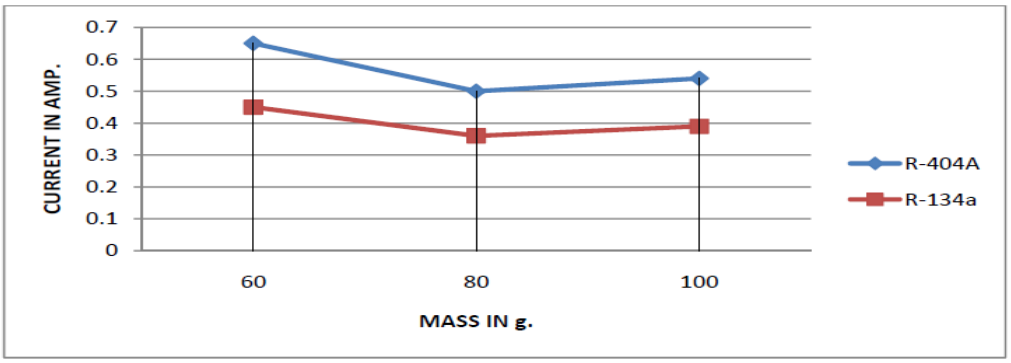
When the measured values of power consumption in 5 minutes of interval using improvement by modification of refrigerator in two condenser lengths are compared to that one of conventional refrigerator, the process showed almost similar behavior.



When the measured values of final temperatures after 5 minutes of interval using improvement by modification of refrigerator in two lengths are compared to that one of conventional refrigerator, the process showed almost similar behaviour. The slightly improvements in Temperature drop using length 9.95 i.e. by modification of condensor design throughout total time span

EFFECT OF POWER CONSUMPTION

Power consumption difference between R134a & R404a is shoe below graph.



CONCLUSIONS

With the help of this experimental study it is found that R-404a is a refrigerant which provides better cooling capacity than the R-134a ,the pull down time is achieved by different mass charge of R404a was earlier than the R-134a,missisibility of oil with R-404a was better than the R-134a which increases the compressor life.

From the experimental investigation following conclusions were drawn.

1. COP of the VCR system with 9.65m length condenser is 5.74% more than the existing system.
2. The Net Refrigeration Effect of the VCR system with 9.65m length condenser is 5.81% more than the existing system.
3. The power consumption of the VCR system with 9.65m length condenser is 5.48% less than the existing system.
4. Heat rejection in the 9.65m length condenser is 4.85% more than the existing condenser.
5. Compared to all other condensers(9.15m, 9.65m & 9.95m) the condenser of length 9.65m gives,

- The maximum net refrigeration effect
- Maximum heat rejection
- Maximum COP and minimum power consumption.

Hence it is concluded that by using R404a the condenser with 9.65m of length is the optimum length and is recommended for domestic refrigerator.

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