EFFECT OF SPIRAL AND MICRO CHANNEL CONDENSER ON PERFORMANCE OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

[1]K.Veeranjaneyulu, [2]B.Biksham
[1]Assistant Professor, [2] Assistant Professor
[1]Department of Mechanical Engineering,
[1]Anurag Engineering College, ananthagiri,Telangana,India

Abstract: **Most of the household refrigerators work on the Vapour compression refrigeration system which are holding high coefficient of performance. The system is assembled with the components like compressor, condenser, expansion valve and evaporator etc. The system performance is governed by each individual component being the part of that system and liable to take system performance up or down ultimately. The research article elaborates work about COP enhancement of domestic refrigerator by making alternative arrangement for condenser. The use of spiral and micro channel condenser raises COP of refrigerator to the value that was never before, the geometry, enhanced surface area of such micro channels are found adding positive results in the enhancement of COP value and work is elaborate through research work drafted in the paper. The results obtained through spiral and micro channel condenser installation are compared with conventional refrigerator and found worth appreciate. The COP enhancement through spiral and micro channel type condenser installation has noted down increased by 5.06% and 13.82% respectively. The base value considered in the comparison is COP of domestic refrigerator with regular condenser system inbuilt**

***IndexTerms* - COP**

INTRODUCTION

Vapor compression Refrigeration system is an improved type of Mechanical refrigeration system. The ability of certain liquids to absorb enormous quantities of heat as they vaporize is the basis of this system. Compared to melting solids (say ice) to obtain refrigeration effect, vaporizing liquid refrigerant has more advantages. To mention a few, the refrigerating effect can be started or stopped at will, the rate of cooling can be predetermined, the vaporizing temperatures can be governed by controlling the pressure at which the liquid vaporizes. Moreover, the vapor can be readily collected and condensed back into liquid state so that same liquid can be re-circulated over and over again to obtain refrigeration effect. Thus the vapor compression system employs a liquid refrigerant which evaporates and condenses readily. The System is a closed one since the refrigerant never leaves the system.

The coefficient of performance of a refrigeration system is the ratio of refrigerating effect to the compression work; therefore the coefficient of performance can be increased by increasing the refrigerating effect or by decreasing the compression work.The Vapor compression refrigeration system is now-a-days used for all purpose refrigeration. It is generally used for all industrial purposes from a small domestic refrigerator to a big air-conditioning plant.

Basic components of a vapor compression system:

Basic components of a vapor compression refrigeration system are shown in Fig. 1. They are,

1.	Compressor	:	It is motor driven; it sucks vapor refrigerant from evaporator and compresses.
2.	Condenser	:	High pressure vapor refrigerant is condensed into liquid form in the condenser using cooling medium such as water.
3.	Expansion Valve	:	High pressure refrigerant is throttled down to evaporator pressure; rate of flow is metered.
4.	Evaporator	:	A cooling chamber in which products are placed; low pressure liquid refrigerant flows in the coils of evaporator and absorbs heat from products; the refrigerant vaporizes and leaves for compressor.

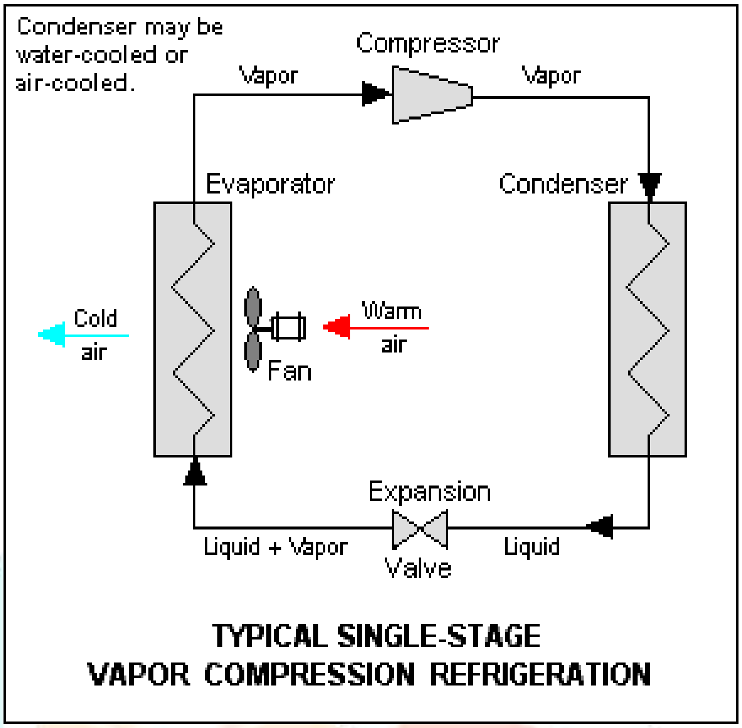

Fig 1: VCR System

P- H Diagram:

The most convenient chart for studying the behavior of a refrigerant is the p-h chart, in which the vertical ordinates represent pressure and horizontal ordinates represent enthalpy. A typical chart is shown Fig.1.2, in which a few important lines of the complete chart are drawn. The saturated liquid line and saturated vapor line merge into one another at the critical point. A saturated liquid is one which has a temperature equal to the saturation temperature corresponding to its pressure. The spaces to the left of the saturated liquid line therefore, be sub cooled liquid region. The space between the liquid and the vapor lines is called wet vapor region and to the right of the saturated vapor line is a superheated vapor region.

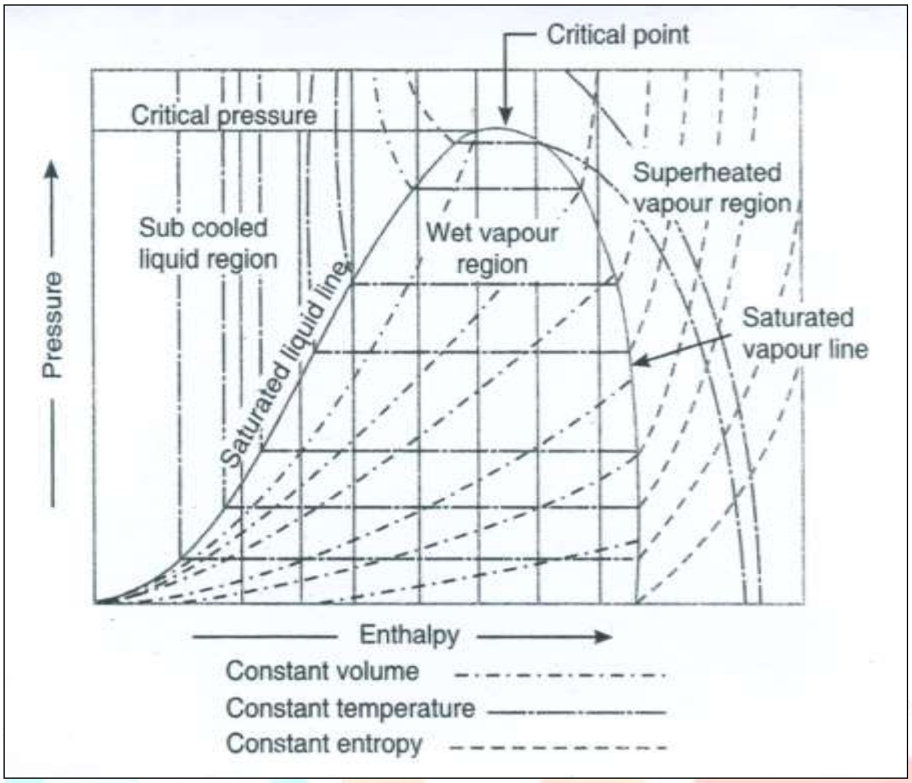

Fig 2: P-H Chart

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.

Two considerations are necessary in design for effective functioning of the condenser as given below.

a. **Effective temperature differential**
b. **High heat transfer coefficient**

There are different types of condenser and selection of condenser depends upon the capacity of the system, refrigerant used and medium of cooling available. There are three types of condensers.

Types of Condensers:

1 Air cooled condensers
2 Water cooled condensers
3 Evaporative condensers

Selection of condenser:

The condenser is one of the most important components of are refrigeration system. Its function is to dissipate heat absorbed by the refrigerant during evaporation (refrigeration effect) and compression (Heat of compression).

There are three different type of condensers classified on the basis of cooling used to dissipate heat. These are.

- **Air cooled**
- **Water cooled**
- **Evaporative type**

Air-cooled condenser can be natural convection type or forced convection type. This chapter is devoted only to the air-cooled condenser which is the most common type in use.

Before sizing a condenser, careful evaluation should include, consideration of initial cost, operating cost service life and type of load. A condenser that is too large can be expensive and create operating problems in lower ambient conditions; an undersized condenser can cause operating problems in higher ambient conditions. It is therefore important to consider the following factors before sizing a condenser.

- Gross heat rejection
- Ambient temperature
- Condensing temperature
- Temperature difference (TD)
- Air flow

Experimental setup:

In vapor compression refrigerating system basically there are two heat exchangers. One is to absorb the heat which is done by evaporator and another is to remove heat absorbed by refrigerant in the evaporator and the heat of compression added in the compressor and condenses it back to liquid which is done by condenser.

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. This project investigated the performance of condenser using spiral condenser in the present domestic refrigerator galvanized iron steel material fins are used. In this project mild steel material fins are replaced and galvanized iron steel are used for the condensers.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. The performance of the condenser is also investigated by existing and modification condenser. In general domestic refrigerators have no fans at the condenser and hence extended surfaces like fins play a very vital role in the rejection of heat.

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. Experiments are conducted on spiral condenser having fins. Different types of tools are also used like snips to cut the plated 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. All the values of pressures and temperatures are tabulated.

Domestic refrigerator selected for the project has the following specifications:

Refrigerant used: R-134a

Capacity of The Refrigerator: 215 liters

Compressor capacity: 0.16 H.P.

Condenser Size:

Length - 8.5 m

Diameter - 6.35 mm

Evaporator:

Length - 7.62 m

Diameter - 6.4 mm

Capillary:

Length - 2.428 m

Diameter - 0.8 mm

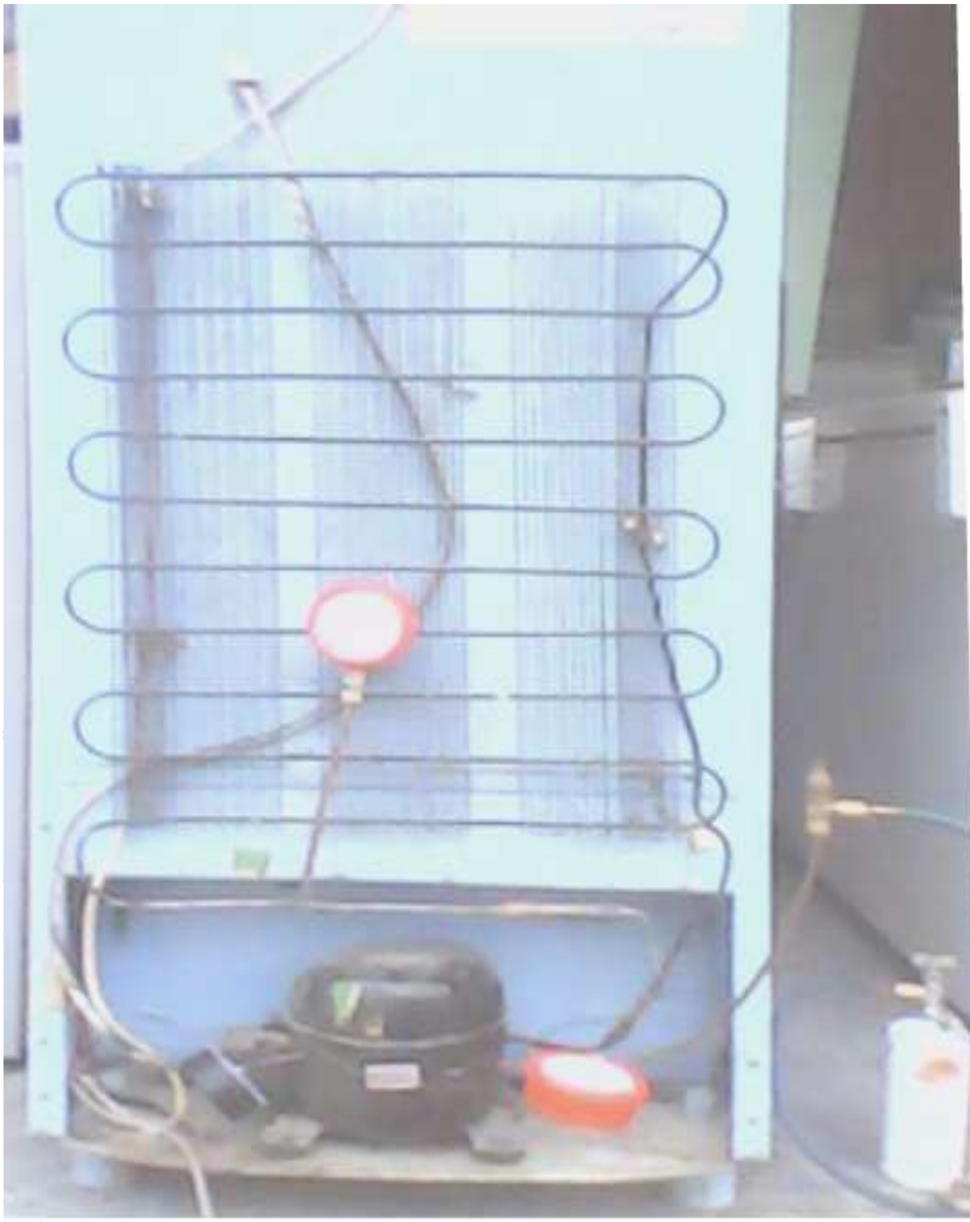

Fig 3 : Normal VCR System

Design of Spiral Condenser:

The spiral condenser is the applications for spiral tubing coils range from copper spiral coil with end fixture the aerospace industry to the refrigeration (ACR), petroleum, and brewing industry. In this present work remove the existing condenser and install the spiral design condenser to the refrigerator (215 liters).To taken the temperatures and pressure readings and calculate the performance of the system.

Parameters	**Existing condenser**	**Spiral condenser**	**Micro channel condenser**
Diameter of coil in mm	6.35mm	6.35mm	0.9mm
Spacing in mm	42mm	45mm	42mm

No. of Turns	8	5	7
Length of coil in mm	6080mm	5320mm	5320mm
Height in mm	595mm	600mm	510mm

Fig 4: Spiral Condenser VCR Setup

Experimental procedure:

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. Pressure and temperature gauges are installed at each entry and exit of the components.
3. Flushing of the system is done by pressurized nitrogen gas.
4. R 134a refrigerant is charged in to the vapor compression refrigeration system by the following process:
   The systematic line diagram for charging is shown in the fig. it is necessary to remove the air from the refrigeration unit before charging. First the valve V_2 is closed and pressure gauge P_2, vacuum gauge V are fitted as shown in the fig. the valve V_5 is also closed and valves V_1, V_4, V_6 and V_3 are opened and the motor is started thus the air from the condenser receiver and evaporator is sucked through the valve V_1 and it is discharged in to atmosphere through the valve V_6 after compressing it in the compressor the vacuum gauge V indicates sufficiently low vacuum when most of the air is removed in the system. The vacuum reading should be at least 74 to 75 cm of Hg. If the vacuum is retained per above an hour it may be concluded that

the system is free from the air. After removing the air the compressor is stopped and valves V_1 and V_6 are closed, the valves V_5, V_2 and V_7 of the refrigerant cylinder are opened and then the compressor is started whenever the sufficient quantity of refrigerant is taken in to the system which will be noted in the pressure gauges. The compressor is stopped. The valves V_7 and V_5 are closed and valve V_1 is opened the refrigerant cylinder is disconnected from the system the pressure gauge is used to note the pressure during the charging the system.

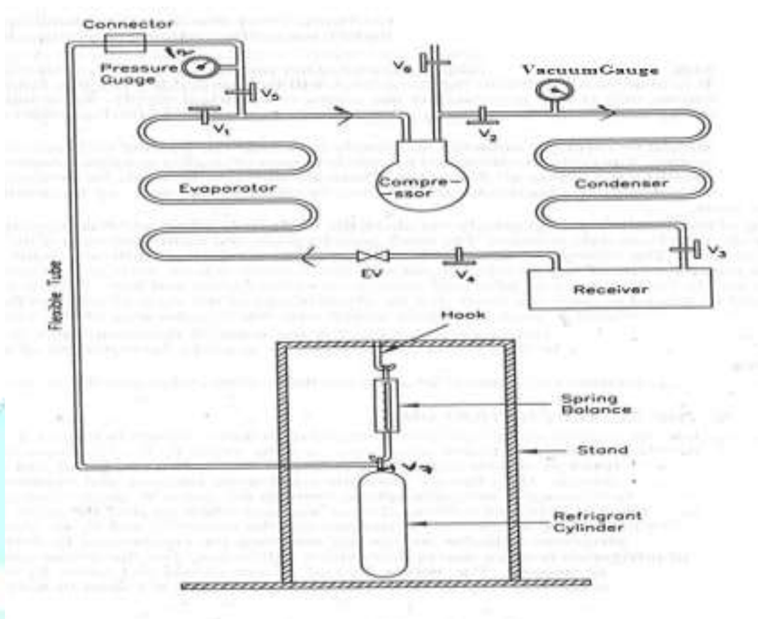

Fig. Charging of Refrigeration System.

5. 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.
6. Switch on the refrigerator and observation is required for 1 hour and take the pressure and temperature readings at each section.
7. The performance of the existing system is investigated, with the help of temperature and pressure gauge readings.
8. The refrigerant is discharged out and spiral condenser is located at the inlet of the capillary tube.
9. Temperature and pressure gauge readings are taken and the performance is investigated.

Performance calculations:

Existing system

Temperatures:

Compressor Suction Temperature T_1=27.6°C

Compressor Discharge Temperature T_2=48.5°C

Condensing Temperature T_3= 75.3°C

Evaporator Temperature T_4= -5°C

Pressures:

Compressor suction pressure P_1= 1.56 bar

Compressor discharge pressure P_2 =11.65 bar

Condenser pressure P_3 =11.65 bar

Evaporator pressure P_4 = 1.56 bar

Enthalpy Values:

From pressure-enthalpy chart for R-134a, enthalpy values at state points 1,2,3,4. The state points are fixed using pressure and temperature and each point.

h_1	=	422 kJ/kg
h_2	=	469 kJ/kg
h_3	=	248 kJ/kg
h_4	=	248 kJ/kg

Calculation Performance Parameters:

1. Net Refrigerating Effect (NRE) = h_1-h_4= 422-248 = 174 kJ/kg
2. Mass flow rate to obtain one TR, kg/min.

   m_r = 210/NRE = 210/174 = 1.2 kg/min.
3. Work of Compression = h_2-h_1=469-422 = 47 kJ/kg
4. Heat Equivalent of work of compression per TR

   m_r x (h_2-h_1) = 1.2 x 47 = 56.4 kJ/min
5. Theoretical power of compressor = 56.4/60 = 0.94 kW
6. Coefficient of Performance (COP) = h_1-h_4 / h_2-h_1 = 174/47 = 3.70
7. Heat to be rejected in condenser = h_2-h_3 = 469-248 = 221 kJ/kg
8. Heat Rejection per TR = (210/NRE) x (h_2-h_3) = 1.2x 221 = 265.2 kJ/min
9. Heat Rejection Ratio = 265.2/210 = 1.26
10. Compression Pressure Ratio = 6.83
11.

<u>Spiral Condenser Design system:</u>

<u>Temperatures:</u>

Compressor Suction Temperature T_1= 31°C

Compressor Discharge Temperature T_2=50.6°C

Condensing Temperature T_3=35.1°C

Evaporator Temperature T_4= -15°C

<u>Pressures:</u>

Compressor suction pressure P_1 = 1.70 bar

Compressor discharge pressure P_2 =10.94 bar

Condenser pressure P_3 =10.94 bar

Evaporator pressure P_4 = 1.70 bar

<u>Enthalpy Values:</u>

From pressure-enthalpy chart for R-134a, enthalpy values at state points 1,2,3,4. The state points are fixed using pressure and temperature and each point.

h_1	=	425 kJ/kg
h_2	=	471 kJ/kg
h_3	=	250 kJ/kg
h_4	=	250 kJ/kg

Calculation Performance Parameters:

1. Net Refrigerating Effect (NRE) = h_1-h_4= 425-250 = 175 kJ/kg
2. Mass flow rate to obtain one TR, kg/min.

   m_r = 210/NRE=210/175=1.2 kg/min
3. Work of Compression = h_2-h_1 = 471- 425 = 46 kJ/kg
4. Heat Equivalent of work of compression per TR

   m_r x (h_2-h_1) = 1.2 x 46 = 55.2 kJ/kg
5. Theoretical power of compressor = $\frac{55.2}{60}$= 0.92 kW
6. Coefficient of Performance (COP) = h_1-h_4 / h_2-h_1= 175/46 = 3.80
7. Heat to be rejected in condenser = h_2-h_3 = 471-250 = 221 kJ/kg
8. Heat Rejection per TR = $\frac{210}{NRE}$ x (h_2-h_3) = 1.2 x 221 = 265.2 kJ/min
9. Heat Rejection Ratio = 265.2/210 = 1.26
10. Compression Pressure Ratio = $\frac{Dishcarge\ \ Pressure}{Suction\ \ \ Pressure} = \frac{P_d}{P_s}$ = 10.94/1.70 = 6.43

<u>VCR System with Micro Channel Condenser</u>

<u>Temperatures:</u>

Compressor Suction Temperature T_1=26.2°C

Compressor Discharge Temperature T_2=48°C

Condensing Temperature T_3=37.2°C

Evaporator Temperature T_4= -15°C

<u>Pressures:</u>

Compressor suction pressure P_1= 1.78 bar

Compressor discharge pressure P_2 =11.90 bar
Condenser pressure P_3 =11.90 bar
Evaporator pressure P_4= 1.78 bar

Enthalpy Values:

From pressure-enthalpy chart for R-134a, enthalpy values at state points 1,2,3,4. The state points are fixed using pressure and temperature and each point.

h_1 = 421 kJ/kg
h_2 = 467 kJ/kg
h_3 = 253 kJ/kg
h_4 = 253 kJ/kg

Calculation Performance Parameters:

1. Net Refrigerating Effect (NRE) = h_1-h_4= 421-253 = 168 kJ/kg
2. Mass flow rate to obtain one TR, kg/min.
   m_r = 210/NRE = 210/168 = 1.25 kg/min
3. Work of Compression = h_2-h_1 = 467-421 = 46 kJ/kg
4. Heat Equivalent of work of compression per TR
   m_r x (h_2-h_1) = 1.25 x 46 = 57.5 kJ/min
5. Theoretical power of compressor = 57.5/60= 0.98 kW
6. Coefficient of Performance (COP) = h_1-h_4 / h_2-h_1=168/46 = 3.65
7. Heat to be rejected in condenser = h_2-h_3 = 467-253 = 214 kJ/kg
8. Heat Rejection per TR = $\frac{210}{NRE}$ x (h_2-h_3) = 1.25 x 214 = 267.5 kJ/min
9. Heat Rejection Ratio = 267.5/210 = 1.27
10. Compression Pressure Ratio = $\frac{Dishcarge\ \ Pressure}{Suction\ \ Pressure} = \frac{P_d}{P_s}$ = 11.90/1.70 = 7

Performance Comparison of Spiral and Micro channel Condenser with existing VCR system :

	Condenser type	**Existing**	**Micro channel**	**Spiral**
1	Net refrigerating effect , kJ/kg	168	163	175
2	Coefficient of Performance (COP)	3.65	3.70	3.80
3	Mass flow rate to obtain one TR, kg/min	1.25	1.28	1.2
4	Work of Compression, kJ/kg	46	44	46
5	Heat Equivalent of work of compression per TR, kJ/kg	57.5	56.32	55.2
6	compressor power, KW	0.98	0.93	0.92
7	Heat to be rejected in condenser , kJ/kg	214	210	221
8	Heat Rejection per TR, kJ/min	267.5	268.8	265.2
9	Heat Rejection Ratio	1.27	1.28	1.26
10	Compression Pressure Ratio	7	6.73	6.43

Results and discussions

Performance of a vapor compression refrigeration cycle:

The performance of vapor compression refrigeration cycle is the spiral condenser and compare with the existing condenser and also pitch of the coil varying the condenser has the considerable effect. The Existing condenser COP is 3.70 and spiral condenser COP is 3.80. And to illustrate these effects the calculated values of spiral condenser COP and pitch of the coil results have been plotted on Table and graphs.

S.NO	Pitch of coil (inches)	COP
1	Existing	3.65
2	Micro channel	3.70
3	Spiral	3.80

Conclusions

In the present work experiments are conducted for the spiral design condenser coil of the vapor compression refrigeration system used for a domestic refrigerator of 215 liters capacity.

The data was obtained from the experimental set-up fabricated by the present investigation and is used to analyze the performance of vapor compression refrigeration system with existing condenser and with spiral condenser.

By incorporating the spiral condenser of refrigerant in the system the C.O.P enhance of by 2.70%, as a result of 0.5% increase in refrigeration effect and 2.1% reduction in compressor work and same in heat rejection.

Further, at the condenser pressure slightly increased. The spiral condenser increased C.O.P compared to existing condenser, which is perhaps due to reduction in compressor work and **increase in** refrigeration effect.

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