International Journal of Research in Advent Technology, Vol.6, No.8, August 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

Performance Evaluation of VCRS with Nested Helical Shaped Condenser by Using R134a as Refrigerant

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Abstract-Nowadays refrigerator is a important cooling equipment in industrial and domestic appliances. The refrigerator is a cooling device which maintains a low temperature based on the user requirement. Most of the refrigerators works depend on the vapor compression refrigeration system. VCRS consists of two heat exchangers (evaporator, condenser), one expansion valve and one compressor. The performance of the system mainly depends on the design of heat exchangers. The conventional refrigeration system consists of a straight iron tube condenser, hermetically sealed compressor, expansion valve, and evaporator. The objective of the present work is to compare domestic refrigerator of capacity 165L by using R134a as a refrigerant with a nested helical shaped condenser (copper material) with two different diameters with conventional refrigerator. The modified condenser is nested helical shape where inner helical coil tube diameter is 4.7mm, outer helical coil diameter is 6.4mm and pitch as 1.5 and 2 inches respectively. In present work, an attempt is done to verify the COP of conventional condenser design to nested helical coil condenser. Finally, it is observed that the COP of nested helical shape condenser refrigerator is a more compared conventional refrigerator.

Index terms- VCRS, Refrigerant, Nested helical shape, Straight tube, COP

1. INTRODUCTION:-

Refrigeration is a technique for expelling the heat from a system under controlled conditions. one of the best way to increase the expelling the heat from the system is to change the design and properties of the heat removal device which is condenser in the VCRS. In a conventional refrigerator, the material used for the condenser is Iron which will have low thermal conductivity and the shape of the condenser is a straight tube which will provide low heat removal rate. To improve the efficiency of the system have to do some changes in the system. Here using copper as a condenser material which has more thermal conductivity compared to iron. The shape of the condenser is nested helical shaped, in helical shape coil heat transfer rate increase due to the secondary circulation where centrifugal forces come into action. If helical coil with the same diameter through the length uses then there is a large pressure drop. To decrease the pressure drop here using a nested helical coil with two variable diameters. Due to the changes in the design of the condenser enhances the COP of the system and increases the heat removal rate of the condenser increases.

2. SELECTION OF CONDENSER AND SPECIFICATIONS:-

The first and foremost step of the experiment is to optimize the dimensions of the condenser. There are two methods to change the design of the condenser active and passive heat transfer augmentation methods. In the active method, external power input is added but in passive method no need of any external power to enhance the heat transfer. In the passive method, heat transfer is increased by increasing heat transfer for the same surface area by using available power. Here increasing the heat transfer surface area with the helically shaped condenser. In conventional VCRs, iron is used as condenser material which is having less thermal conductivity(79.5W/mK), high power consumption and have a chance of corrosion. So there is the necessity of material change to get optimum performance of the system. Here copper is using as condenser material which is having higher thermal conductivity(385W/mK) and corrosive resistive compared to iron.

Table.1 Parameters of nested helical coil

Parameters	Inner helical coil	Outer helical coil
Tube diameter	4.7mm	6.4mm
Pitch	38.1mm	50.8mm

Coil diameter	125mm	262mm
Turns	17	12
Length of the tube	375mm	375mm

Fig.1 Nested helical coil

3. EXPERIMENTAL SET UP:-

The overall efficiency of the VCRS depend upon every component of the system but in this work concentrated on the heat rejection component of the vapor compression refrigeration system. Condenser contributes more in COP of the system by taking heat which is rejected in the evaporator from the system. Condenser heat rejection capacity increases then the COP and power consumption of the system decreases. Modification in the condenser of the system is worthy and low cost too.

The research work strenuous nested helical shaped condenser of VCRS by holding refrigerant as R134a.

Fig.2Cu tube Fig.3 Helical coil Fig.4 Nested coil

Step1:-Straight copper coil is converted into helical shape with specified diameters.

Step2:-Inserted two helical coils are as nested shape then join both helical coils using soldering process with specified spacing or pitch respectively.

Step3:-Nested helical coil shape condenser is designed as shown in the fig.4.

Fig.5 Refrigerant R134a

Table.1 Properties of refrigerant

Refrigerant	R134a
Name	1.1.1.2-Tetrafluoro-ethane
Formula	CH2FCF3
Critical Temperature in ºC	101.06
Molecular weight in Kg/Kmol	102.03
Normal boiling point in ºC	-26.3
Pressure at -25ºC in bar(absolute)	1.07

3.1.Specification of existing VCRS:

Capacity of the refrigerator :165L

Compressor capacity :0.16HP

Condenser : length-8.5m,diameter-6.4mm

Evaporator: length-7.62m,diameter-4.7mm

Capillary tube:length-2.428m,diameter-0.8mm

Fig.6 Existing system

Fig.7 Proposed system

3.2.Procedure:-

1. The domestic refrigerator is selected, which works on VCRS.

2.Pressure and temperature gauges installed at each entry and exit of the component.

3.flushing of the system is done by pressurized nitrogen gas.

4.160grams of R134a is charged into VCRS and leakage test is done by using soap solution.

5. Further, test the condenser and evaporator pressure and check to purge for 12 hours and found that there is no leakage.

6. Switched on the refrigerator and observation is required for one hour and take pressure and temperature at each section of the system and investigated the performance of the existing system.

7. The refrigerant is discharged and nested helical shape condenser is located in between the compressor and capillary tube.

8. Temperature and pressure gauge reading is taken and the performance of the proposed system was calculated.

Table.2 Comparision of Performance Parameters

S.No	Parameters	Conventional system	Proposed system
1.	Net Refrigeration Effect In KJ/Kg	164	170
2.	COP	2.9	3.09
3.	Mass flow rate to obtain 1TR Kg/min	1.28	1.23
4.	Work of compressor in KJ/Kg	57	55
5.	Power consumption in KW	1.216	1.1275
6.	Heat to be rejected in condenser in KJ/Kg	214	225

4. RESULTS & DISCUSSION :

The performance of the VCRS with normal condenser and VCRS with nested helical copper condenser experiments were done and compared both the system performances.

Comparison of Net Refrigeration Effect:-

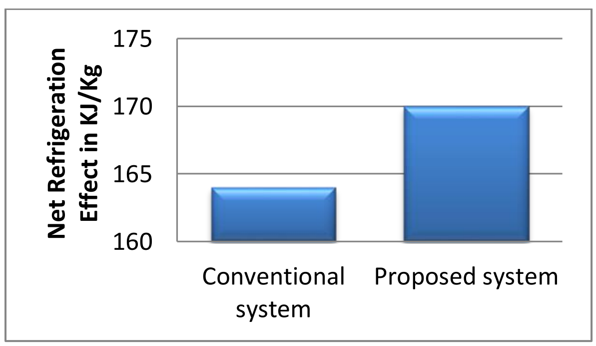

Fig.8 Comparison of Net Refrigeration Effect

Fig.8 shows that the variation of net refrigeration effect in both conventional and proposed system.Net refrigeration effect is more in the proposed system compared to a conventional system. The refrigeration effect of the system increased due to secondary circulation which increases the heat rejection of the condenser and decreases the outlet temperature of the condenser. The net refrigeration effect increases from 164KJ/Kg to 170 KJ/Kg.

Comparison of Coefficient of Performance :

The coefficient of performance increased from 2.9 to 3.09 because of more amount the fluid getting in contact with the condenser due to the helical shape. The heat rejection in this system is more and work input to the system is less. So the COP of the proposed system is increased.

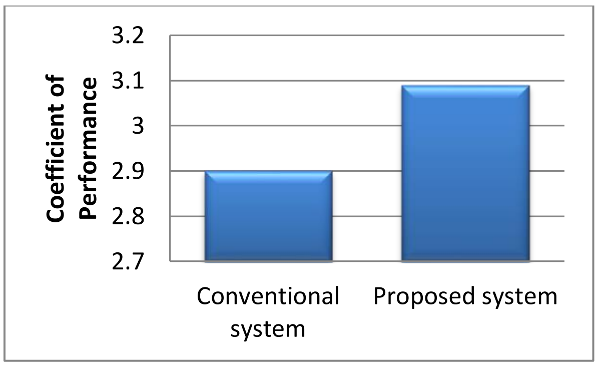

Fig.9 Comparison of Coefficient of Performance

Fig.9 shows the variation of COP in both conventional and proposed system. The COP of the proposed system with the nested helical coil is more than the conventional system.

Comparison of Power consumption :

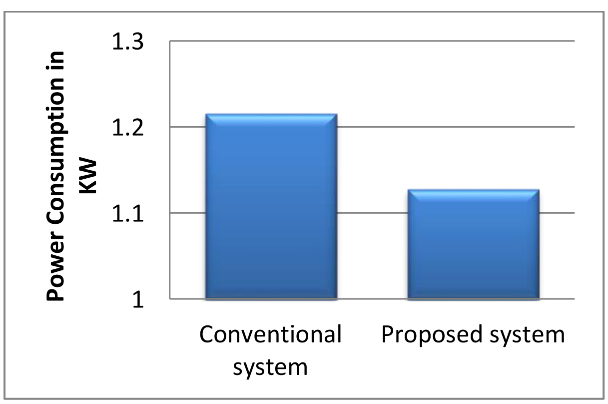

Fig.10 Comparison of Power Consumption

Fig.10 shows the difference between power consumption in both the conventional and proposed system. Power consumption in the proposed system is slightly less than the conventional system. The mass flow rate decrease in this proposed system due to the nested helical shaped condenser with a variable diameter. The power consumption of the system decreased from 1.216KW to 1.1275KW.

Comparison of heat rejection in the condenser:

The heat rejection of the proposed system increases due to the secondary circulation of the helical coil. The surface area is the same as a normal system but heat rejection more. The reason behind it is fluid is coming in contact with refrigerant more due to the helical shape of the condenser. The heat rejection is increased from 214KJ/Kg to 225KJ/Kg.

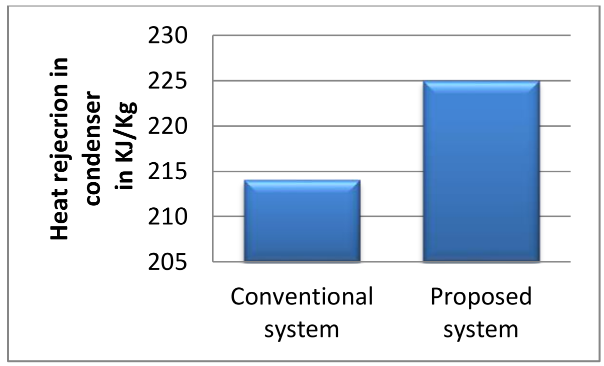

Fig.11 Comparison of heat to be rejected in the condenser

Fig.11 shows the heat rejected in the condenser in both conventional and proposed system . Heat rejection in the proposed system is more than the conventional system.

5. CONCLUSION:

Experimental analysis shows that the performance of the VCRS improved in the proposed system due to modification of condenser shape. The COP of the existing system is 2.9 and modified system COP is 3.09. The overall enhancement in COP is 6.55%. The increased heat rejection in the condenser is 5.14 %. The power consumption for the proposed system decreased by 7.2%. The percentage increase in the net refrigeration effect of the modified system is 5.59%.

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