Experimental Investigation of Vapour Compression Refrigeration System with Spiral Shaped Condenser

B. Santosh Kumar[1] Dr. A. Raji reddy[2] C. Ramanjaneyulu[3] N. Jaya krishna[4]
[1,3,4]*(Department of Mechanical Engineering, Annamacharya Institute of Technology and Sciences, kadapa, India,*
[1]*aits.med.bsk@gmail.com,* [3]*aits.med.crmnl@gmail.com,* [4]*aits.med.njk@gmail.com)*
[2]*(Department of Mechanical Engineering, CMR Technical Campus, Hyderabad, India, r_avala@yahoo.com)*

Abstract— *Most of the household refrigerators work on the Vapor compression refrigeration system which has high coefficient of performance. The system consists of components like compressor, condenser, expansion valve and evaporator. The system performance depends on the performance of all the components of the system. The main objective of the paper is to find coefficient of performance of refrigeration system using conventional condenser (MS with Cu coating) and then verifying effect of performance using conventional condenser made of copper material on Kelvinator refrigerator of refrigeration capacity 165 lts, hermitic sealed compressor unit with R134a as refrigerant. Further an attempt is made in modifying the conventional shaped condenser to spiral shaped condenser and with varying pitch the performance of system is evaluated. Finally it is noticed that spiral shaped condenser has given the maximum COP among all observations.*

Key words: Coefficient of Performance (COP), conventional condenser, Kelvinator refrigerator, R134a, spiral shape condenser

1. INTRODUCTION

Vapour-compression refrigeration is one of the many refrigeration cycles available for use. It is the most widely used method for air-conditioning of large public buildings, offices, private residences, hotels, hospitals, theaters, restaurants and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial and industrial services. Oil refineries, petrochemical and chemical processing plants, and natural gas processing plants are among the many types of industrial plants that often utilize large vapor-compression refrigeration systems. 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. This may be achieved by modifying the existing conventional condenser design.

Basic components of a vapor compression refrigeration system are shown in Fig. 1.1. They are,

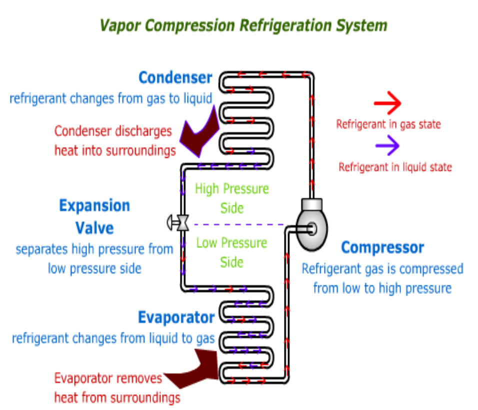

Fig. 1.1. Vapour compression refrigeration system

Compressor: It is motor driven; it sucks vapour refrigerant from evaporator and compresses.
Condenser: High pressure vapour refrigerant is condensed into liquid form in the condenser using cooling medium such as water.
Expansion Valve: High pressure refrigerant is throttled down to evaporator pressure; rate of flow is metered.
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.

2. EXPERIMENTAL WORK:

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 shape condenser in the present domestic refrigerator and galvanized iron steel material fins are used. The performance of the condenser will also help to increase COP of the system. The Performance of the condenser is investigated by using conventional condenser design with two different materials i.e., one with MS with copper coated and other of copper. The performance is also evaluated by changing the conventional condenser design to spiral shape and with varying pitch of the spiral coil.

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 condenser is fabricated to suit the requirement. All the values of pressures and temperatures are tabulated which are required to estimate the COP of the refrigeration system.

3. Experimental Setup

Domestic refrigerator selected for the project has the following specifications:

Refrigerant used: R-134a
Capacity of The Refrigerator: 165 litres
Compressor capacity: 0.16 H.P.

Condenser Sizes		
Length	-	8.5 m
Diameter	-	6.35 mm
Evaporator		
Length	-	7.62 m
Diameter	-	6.4 mm
Capillary		
Length	-	3.6 m
Diameter	-	0.9 mm


Fig.3.1. conventional(MS with Cu)


Fig.3.2 Conventional (Cu)


Fig.3.3 Spiralwith Pitch(38.1mm)


Fig..3.4 Spiral with Pitch(44.45mm)

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

The domestic refrigerator is selected, working on vapour compression refrigeration system. Pressure and temperature gauges are installed at each entry and exit of the components. Flushing of the system is done by pressurized nitrogen gas. R134a refrigerant is charged in to the vapour compression refrigeration system by the following process:


Fig.3.5 Spiral with Pitch(50.8mm)

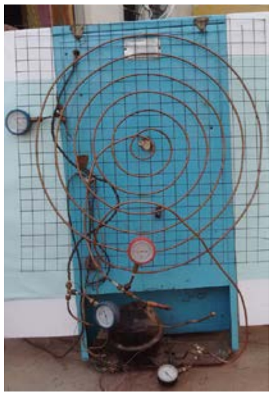
Fig.3.6 Spiral with Pitch(57.15mm)

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 V2 is closed and pressure gauge P2, vacuum gauge V are fitted as shown in the fig. the valve V5 is also closed and valves V1, V4, V6 and V3 are opened and the motor is started thus the air from the condenser receiver and evaporator is sucked through the valve V1 and it is discharged in to atmosphere through the valve V6 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 V1 and V6 are closed, the valves V5, V2 and V7 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 V7 and V5 are closed and valve V1 is opened the refrigerant cylinder is disconnected from the system the pressure gauge is used to note the pressure during the charging the system.

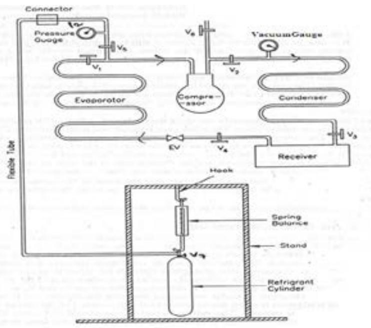

Fig.3.7. charging of refrigeration system

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. Switch on the refrigerator and observation is required for 2 hour and take the pressure and temperature readings at each section. The performance of the existing system is investigated, with the help of temperature and pressure gauge readings.

The performance of the design of spiral shaped condenser system is investigated, with the help of temperature and pressure gauge readings. Temperature and pressure gauge readings are taken and the performance is investigated. The design of spiral shaped condenser of varying the pitch of the coil condenser from 1.5 inches, 1.75 inches, 2.0 inches and 2.25 inches.

4. PERFORMANCE CALCULATIONS

Conventional Condenser Values (CU)
Condenser diameter (d) - 6.35mm

Temperatures

Compressor Suction Temp T_1= 29°C
Compressor Discharge Temp T_2 = 51°C
Condensing Temp T_3 = 34°C
Evaporator Temp T_4 = -10°C

Pressures

Compressor suction pressure P_1=1.8 bar
Compressor discharge pressure P_2=12.05 bar
Condenser pressure P_3 = 12.05 bar
Evaporator pressure P_4 = 1.8 bar

Enthalpies

h_1 = 425 kJ/kg
h_2 = 470 kJ/kg
h_3 = 264kJ/kg
h_4 = 264kJ/kg

Calculation Performance Parameters

Net Refrigerating Effect (NRE) =h_1-h_4= 425-264= 161kJ/kg

Mass flow rate to obtain one TR=Mr=210/NRE =210/161=1.304 kg/min.

Work of Compression = h_2-h_1= 470-425 = 45kJ/kg

Heat Equivalent of work of compression per TR= M_rx(h_2-h_1) = 1.304x45 = 58.68kJ/min

Theoretical power of compressor = 58.68/60 = 0.978 KW

Coefficient of Performance (COP)= 161/45 = 3.577

Heat to be rejected in condenser= h_2-h_3=470-264=206kJ/kg

Heat Rejection per TR = (210/NRE) x (h_2-h_3)
= 1.304x206= 268.624kJ/min

Heat Rejection Ratio = 268.624/210 = 1.279

$$\text{Compression Pressure Ratio} = \frac{\text{Discharge pressure}}{\text{Suction pressure}}$$

=12.057/1.8 = 6.69

5. RESULTS AND DISCUSSION

TABLE I. COMPARASION OF PERFORMANCEPARAMETERS

Performance parameters	Conventional		Spiral (Cu)			
	MS with Cu coating	Cu	Pitch of coil (mm)			
			38.1	44.50	50.8	57.15
COP	3.16	3.577	3.75	3.904	4.25	4.15
Heat rejection in condenser (KJ/kg)	204	206	209	206	210	206
Theoretical power of compression (kW)	1.1	0.978	0.932	0.896	0.823	0.843
Heat transfer rate (kW)	18.14	18.7	21.4	20.68	21.7	21.34

The relation between pitch of the condenser coil and performance parameters have been compared.

Pitch of the condenser coil on co-efficient of performance

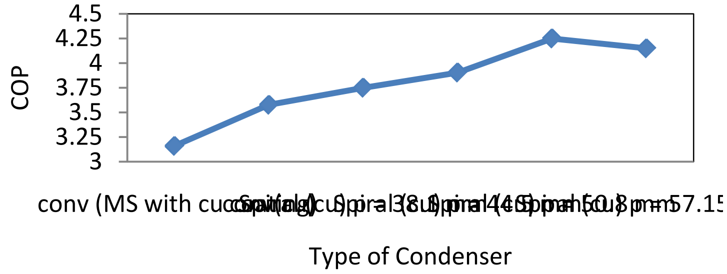

Fig.5.1.COP vs Type of Condensor

From the graph it is noticed that as the pitch of the condenser coil increases COP gradually increases and starts to decrease after 2.0 inch (50.8 mm) of the pitch of the condenser coil.

Pitch of the condenser coil on theoretical work of compressor

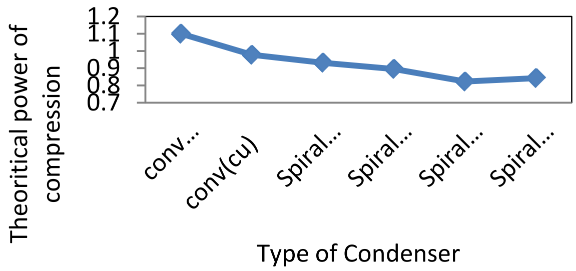

Fig.5.2. theoritical power of compression vs Type of Condensor

From the graph it is noticed that theoretical work of compressor decreases as the pitch of the condenser coil increases. It slightly increases after 2.0 inch (50.8 mm) of the pitch of the condenser coil.

Pitch of the condenser coil on heat rejected in condenser

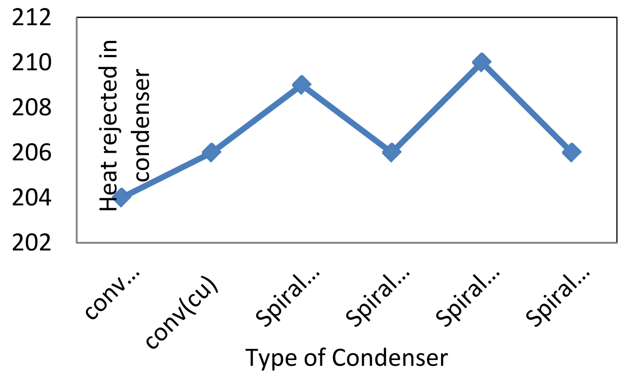

Fig.5.3. Heat Rejection vs Type of Condensor

From the graph it is noticed that heat rejected in condenser decreases as the pitch of the condenser coil varies from 1.5 to 1.75 inch. It starts to slightly increase after1.75 inch of the pitch of the condenser coil up to 2.0 inch (50.8 mm).

Pitch of the condenser coil on heat transfer rate

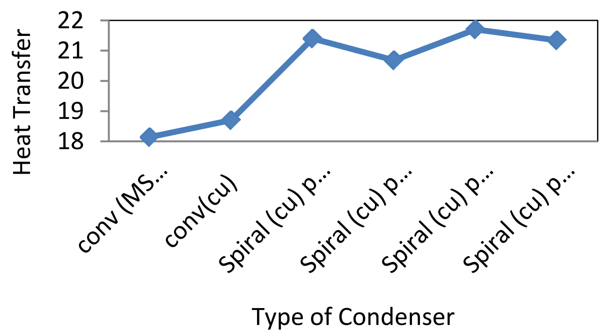

Fig.5.4. Heat Trnsfer vs Type of Condensor

From the graph it is noticed heat transfer rate decreases from 1.5 to 1.75 inch pitch and increases to maximum at 2.0 inch pitch of the condenser coil increases. Maximum heat transfer rate is observed at 2.0 inch (50.8 mm) pitch of condenser coil.

6. Conclusion

The COP of the system is investigated with the standard condenser coil of 6.35mm diameter, 8500mm length for the conventional condensers of MS with cu coating and copper. The COP of copper condenser is 3.577 which shows its increase by a value of 13% when compared to MS with Cu coating conventional condenser with COP value of 3.16.

The conventional shape of condenser is again compared with spiral shape condenser by varying pitch from 1.5 inch to 2.25 inch. The optimum COP is obtained at 2 inch pitch of the coil of the value 4.25 for the spiral shape condenser which shows an increase of 18.8% when compared to the conventional copper condenser COP of value 3.577. Finally it is concluded that spiral shaped condenser coil (Cu) of diameter 6.35 mm, 8500 mm length and 2 inch (50.8 mm) pitch is recommended for the VCR system of a domestic refrigerator of 165 litres capacity with R134a as refrigerant.

REFFERENCES

[1] Sagar W. Matte et al "Experimental study of effect of spiral tube heat exchanger in domestic refrigerator: A Literature Review" International Journal of Research in Aeronautical and Mechanical Engineering, Vol.3 Issue.2, February 2015. Pgs: 28-35.

[2] P. Naphon & S. Wongwises, 2005, ―A study of the heat transfer characteristics of a compact spiral coil heat exchanger under wet-surface conditions‖, Experimental Thermal and Fluid Science 29, 511–521.

[3] Yanuar, N. Putra, Gunawan & M. Baqi, 2011, ―Flow and convective heat transfer characteristics of spiral pipe for nanofluids‖, International Journal of RRAS, vol. 7, p. no. 3.

[4] Bibin Prasad, Sujith V, Mohammed Shaban K, Saju Haneef, Sandeep N, Vishnu Raj, 2013, "Comparison of Heat Transfer between a Helical and Straight Tube Heat Exchanger, International Journal of Engineering Research and Technology, Vol. 6, Number 1, pp. 33-40.

[5] Shinde D. & Dange M, 2013, ―Heat Transfer Analysis of a Cone Shaped Helical Coil Heat Exchanger, International Journal of Innovations in Engineering and Technology,Vol. 3 Issue 1, p. no. 56-62.

[6] A. Cavallini, D. Del Col, L. Doretti, G.A. Longo, L. Rossetto, 2000, ‖Heat transfer and pressure drop during condensation of refrigerants inside horizontal enhanced tubes‖, International Journal of Refrigeration,Vol. 23, p. no. 4-25.

[7] P. Naphon and S. Wongwises, 2005, ―A study of the heat transfer characteristics of a compact spiral coil heat exchanger under wet-surface conditions square tube, Experimental Thermal and Fluid Science., Vol. 29,pp. 511– 521.

[8] Vivek Sahu, Pooja Tiwari, K.K.Jain & Abhishek Tiwari "Experimental Investigation of the Refrigerator Condenser By Varying the Fins Spacing of the Condenser'' ISSN (Print): 2321-5747, Volume-1, Issue-1, 2013.

[9] Principles of refrigeration by Roy J. Dossat

[10] Refrigeration and Air Conditioning by S.C.ARORA and DOMKUNDWAR

[11] C.P Kodandaraman of Second edition by Fundamentals of Heat and Mass Transfer

[12] Properties of refrigerant and psychrometric tables and charts by Dr. S.S.Banwait.