FABRICATION AND ANALYSIS OF PERFORMANCE OF VAPOUR COMPRESSION REFRIGERATION SYSTEM FOR 3/16 AND 1/4 INCH CONDENSER TUBE

K.GOWRISANKAR, G.NARESH*, D.TEJA RASAJNA DEVI, SK.MD.KHALEEL, S.VAMSI KRISHNA MURTHY , G.NAVEEN*

******Assistant Professor M.E.,, B.Tech*

Department Of Mechanical Engineering,

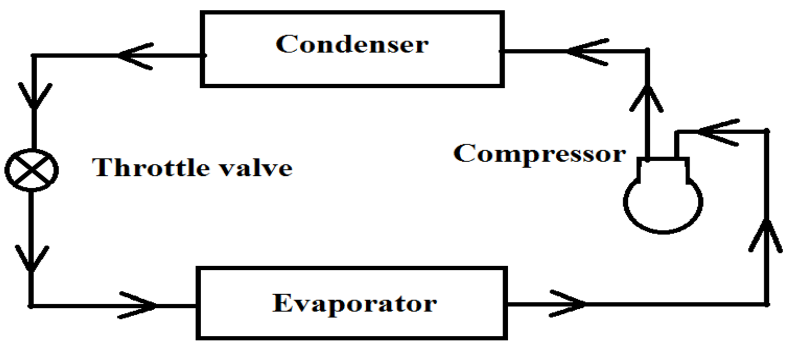
Anil Neerukonda Institute Of Technology And Sciences, Visakhapatnam-531162, A.P., India.

Abstract: Refrigeration is the process of maintaining the temperatures of a system lower than that of its surroundings. The equipment used for this process is called as refrigerator. There are many types of refrigeration equipment which run on different cycles and principles. A domestic refrigerator system works on Vapour Compression Refrigeration System (VCRS). A VCRS has 4 main components Compressor, Condenser, Expansion Valve and Evaporator. A fluid called as refrigerant runs continuously inside these equipments in order to produce the refrigeration effect at evaporator by taking work input at compressor. By varying the state, quality or parameter of refrigerant at inputs at various levels the performance of the VCRS can be increased. This Project mainly concerned with the decrease in temperature of the refrigerant at the output of the condenser by increasing the diameter of the condenser tube, thereby increasing the surface area of the heat exchange with surroundings. For this purpose the equipment of VCRS has been fabricated with 2 condensers in parallel one of which is 3/16' inch and other is 1/4 inch. The equipment is provided with valves so the refrigerant flows in the desired tube by turning the valves on and off. By using pressure gauges, thermometers, voltmeter and ammeter, Pressures, Temperatures, voltage and current were determined at various instances at various points and are used to calculate and compare the Coefficient Of Performance (COP) of the VCRS while using 3/16 inch condenser and 1/4 inch condenser.

Keywords: Condenser diameter, Vapour Compression Refrigerating System, Coffiecient of performance.

I. *Introduction:*

The refrigerant is continuously circulated in these devices in order to obtain cooling effect at the evaporator by supplying work to the compressor. The refrigerant undergoes isentropic compression inside the compressor it is converted from low pressure vapour to high pressure liquid. It is then sent into the condenser where it this high-pressure liquid is cooled nearly to the room temperature. Then it is sent into the Throttling valve where it undergoes isenthalpic expansion due to sudden expansion in the diameter of the pipe. At the end of the expansion valve the refrigerant will be at least possible temperature in the cycle at low pressure. It is then passed into the evaporator where the refrigerant absorbs heat from the body to be cooled and is sent to the compressor again to repeat the processes and continue to generate the refrigeration effect.



A VCRS works on VCRS cycle with 4 processes namely
1. Isentropic compression
2. Isobaric heat rejection
3. Isenthalpic expansion
4. Isobaric heat addition

1. Isentropic compression: A low pressure, slightly high temperature vapour refrigerant is pressurised to a high pressure, high pressure liquid isentropically in a compressor.
2. Isobaric heat rejection: The high pressure, high temperature liquid refrigerant from the compressor is cooled to high pressure, slightly low temperature liquid refrigerant at constant pressure in a condenser by enabling heat exchange with the atmosphere.
3. Isenthalpic expansion: The high Pressure, slightly low temperature liquid refrigerant from the condenser is expanded isenthalpically in an expansion valve to low pressure and very low temperature refrigerant.
4. Isobaric Heat addition: The low pressure, low temperature refrigerant is then allowed into the evaporator tubes where heat from the cooling space is absorbed and the refrigerant turns into low pressure slightly low temperature refrigerant.

1-2 : Isentropic compression
2-3 : Isobaric heat rejection
3-4 : Isenthalpic expansion
4-1 : Isobaric heat addition

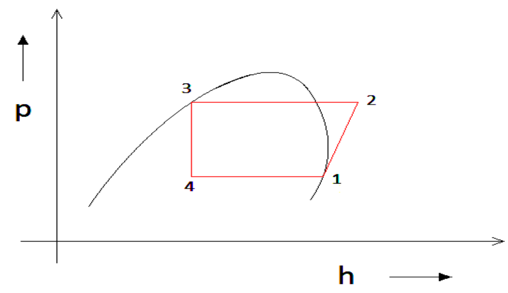


Fig 1. P – h cart for a VCRS

Coefficient Of Performance (COP) : COP of a Refrigerator is defines as ratio of the net refrigeration effect produced in the evaporator to the work supplied to the compressor.

$$COP = \frac{\text{net refrigeration effect}}{\text{Work supplied}} = \frac{h_4 - h_1}{h_2 - h_1}$$

From the above it is evident that to increase COP we should either increase the refrigeration effect or decrease the work input. We have focussed on the former and for that to happen the enthalpy difference at the ends of the evaporator should. Therefore when the temperature of the refrigerant coming out of the condenser increases it would lead to the development of least pressures after the expansion valve.

A condenser is a heat exchanger which transfers heat from the refrigerant to the atmosphere. The amount of heat transferred is governed by the below equation

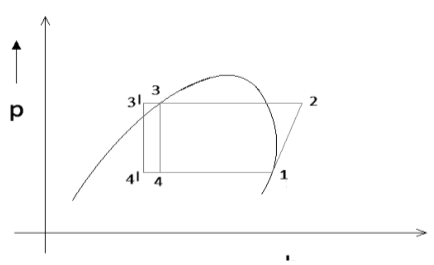


Fig.2

1-2-3-4-1 VCRS Cycle

1-2-3'-4'-1 : VCRS cycle with improved COP due to subcooling of refrigerant after condenser

Heat Transfer due to convection :

$$Q = h\ A\ \Delta T$$

Where, h - convective heat transfer coefficient ($W/m^2\ K$)
A - Surface Area of Heat Transfer (m^2)
ΔT - temperature difference at the ends of the condenser

Therefore if the surface area increases the heat transfer also increases and more heat transfer rate in condenser accounts for lesser enthalpies at exit as a result the enthalpy after expansion also decreases hence to increase surface area we are increasing the diameter of the condenser tube from 3/16 inch to 1/4 inch.

II. Literature Review

Gaurao S. Deshmukh et al [1] and his team have worked on a paper named Performance analysis and fabrication of Refrigerator using Deep-cooling condenser to increase COP of Refrigerator. In their experiment they have used a deep cooling condenser between compressor and condenser to obtain subcooling n the refrigerant after the condenser and obtaining higher refrigeration effect and higher COP.

Poltker And Hrnjak et al [2] investigated experimentally that the system COP can be increased up to 9% by subcooling R134a after condenser because the state of the refrigerant entering the expansion device of conventional vapour compression cycles is usually assumed to be saturated liquid. However, liquid cooling below saturation reduces the throttling losses and increases COP. Actually, COP of refrigeration system is governed by corresponding refrigerating effect produced in the evaporator for the given compressor work.

Bergander et al [3] investigated new regenerative cycle for vapour compression refrigeration which described a novel approach to the Rankine vapour compression cycle for cooling and refrigeration. Generally expansion valve, capillary tube and other throttling valves are used in vapour compression refrigeration system to lower the pressure of liquid refrigerant and low pressure refrigerant delivers to the evaporator. Specific innovation was two phase ejector applied as second step of compression, which results reduction in mechanical work required for compressor for the process of compression of gas at the expense of available kinetic energy of gas in the ejector. Injected liquid phase into accelerated flow of the vapour phase and separated working medium to high and low density phases achieved gain in efficiency. In this, compression ratio was lowered by decreasing discharge pressure from the compressor, not by increasing suction pressure. Results obtained were showed that pressure on the ejector increased by 15-16% and prototype achieved energy saving of 16%.

B.O. Bolaji et al [4] investigated experimentally the performances of three ozone friendly Hydrofluoro carbon (HFC) refrigerants R12, R152a and R134a. R152a refrigerant found as a drop-in replacement for R134a in vapour compression system. He discussed the process of selecting environmental-friendly refrigerants that have zero ozone depletion potential and low global warming potential. R23 and R32 from methane derivatives and R152a, R143a, R134a and R125 from ethane derivatives are the emerging refrigerants that are nontoxic, have low flammability and environmental-friendly. These refrigerants need theoretical and experimental analysis to investigate their performance in the system.

Oliver Evans et al [5] in 1805, he described a closed vapor-compression refrigeration cycle for the production of ice by ether under vacuum. Heat would be removed from the environment by recycling vaporized refrigerant, where it would move through a compressor and condenser and would eventually revert to a liquid form in order to repeat the refrigeration process over again.

Shayne Smyth et al [6] have worked on a paper named Performance Evaluation of an Economised Indirect Muti-Temperature Transport Refrigeration System. In their paper they have experimentally suggested that an indirect circuit with economizer in primary circuit can increase the cooling effect of the overall refrigerator.

Chetan P. Waykole et al [7] have worked on a paper named Performance Evaluation of Water Cooler with Modifications of liquid Suction Heat Exchanger. In this paper they have stated that they have fabricated a VCRS device with a heat exchanger between condenser outlet and expansion valve inlet so that the presence of water would further decrease the temperature of the refrigerant and adds subcooling. They have found an increase in 9 to 32 percent in refrigeration effect.

Jeetendra Kumar Patel et al [8] have worked on a paper named Evaluation of COP in Refrigeration System by using Different Refrigerants. They have evaluated the COP of a refrigeration system using different refrigerants one at a time and predicted the suitable refrigerant for the system to work efficiently.

Miguel Padilla et al [9] found that R413A (mixture of 88% R134a, 9%R218, 3%R600a) can replace R12 and R134a in domestic refrigerator. Molina and Rowlands (1974) have been expanded into a comprehensive and very complex theory emphasis about 200 reactions that CFCs are significantly destroyed by UV radiation in the stratosphere. In the year 1987 Hoffman predicted 3 % global ozone depletion with contact of CFCs emissions of 700 thousand ton per year.

S. Wongwises Somchai et al [10] found that 6/4 mixture of R290 and R600 is the most appropriate refrigerant to replace HFC134a in a domestic refrigerator.

R. Hanuma Naik et al [11] have worked on a paper named The Performance Analysis of Cascade Refrigeration System with and without phase change material. In their work they have used Phase Change Material (PCM) to save the cooling effect from the refrigerator for few hours. Which can be used to cool the required space even after the Refrigerant stopped working for few hours. They have conducted experiment with and without PCM and concluded that the PCM has increased the performance of the refrigerator.

III. Methodology

The experimental study was done on the equipment which consists of hermetic sealed compressor unit and tubular condenser units were used. The evaporator unit was properly insulated to the best of the effort so as to minimize the heat leakage into the system from the surrounding. Copper tubes of diameter ¼ inches and 3/16th inches were used for providing the supply and return lines to the flowing fluid in the system. Refrigerant R134a was used as the cooling fluid. A filter/drier, specific for R134a, was installed just after the condenser unit in order to avoid any situation of choking of the flow lines. The filter/drier does not allow the ice to be formed in the flow lines by absorbing all the moisture particles present in the flowing fluid. Two analogue pressure gauges were used to determine the pressure of the flowing fluid in the high pressure and the low pressure line. The pressure gauge in the high pressure line was installed just after the filter/drier and just before the capillary tube. Another pressure gauge was installed in the low pressure return line to measure the pressure of the fluid returning back to the compressor. A thermometer was used to determine the temperatures that were to be used in the analysis of the system. The readings of the temperature and pressure were plotted on the PH chart and the corresponding enthalpies were noted down and from the obtained values of the enthalpies, the parameters like the refrigeration effect and the compressor work were determined. The carnot COP of the system was determined by using the temperature limits of the system and the actual COP of the system was determined by taking the ratio of the refrigeration effect and the compressor work obtained from the PH chart.

IV. *Experimental Observations*

Condenser tubes of 1/4inch and 3/16 inch diameters with length of 10.41 meters were the test sections for the experiment.

From the experimentation the following readings were obtained.

Table 1

Parameter	3/16 Inch Condenser	1 / 4 Inch Condenser
Condenser Pressure (P_1)	135 Psi	135 Psi
Evaporator Pressure (P_2)	-9.5 Psi	-9.5 Psi
Compressor Inlet Temperature (T_1)	16.6 ^{O}c	15 ^{O}c
Compressor Outlet Temperture (T_2)	58.2 ^{O}c	58.4 ^{O}c
Condenser Outlet Temperature (T_3)	35.8 ^{O}c	34.6 ^{O}c
Initial Water Temperature (T_i)	26.8 ^{O}c	26.8 ^{O}c
Final Water Temperature (T_f)	20.3 ^{O}c	17.1 ^{O}c
Time For Cooling	16 Min	16 Min

Temperatures attained for a minute interval

Table 2

Temperature (°C) / TIME (min)	3/16 inch	1/4 inch
1	25.8	26.1
2	25.3	25.8
3	24.9	24.9
4	24.4	24.1
5	24.1	23.2
6	23.7	22.5
7	23.3	21.9
8	23.0	21.2
9	22.7	20.7
10	22.4	20.1
11	22.1	19.5
12	21.7	19.1
13	21.4	18.5
14	21.1	18.0
15	20.8	17.6
16	20.4	17.1

Using these pressures and Temperatures from the readings enthalpies of the refrigerant at different conditions from the P-h chart of R134a refrigerant are as follows.

Table 3

ENTHALPIES	3/16 inch	1 / 4 inch
COMPRESSOR INLET (h_1) kJ/kg	400	405
COMPRESSOR OUTLET (h_2) kJ/kg	442	442
CONDENSER OUTLET (h_3) kJ/kg	245	240
EVAPORATOR INLET (h_4) kJ/kg	245	240

V. *Calculations:*

Pressure conversion (From psi to Mpa)

1Psi = 0.0689 bar

135 Psi = 135 x 0.0689

= 9.3015 bar

Here pressure is gauge pressure (P_g)

Absolute Pressure (P_{abs}) = Atmospheric pressure (P_{atm}) + Gauge Pressure (P_g)

Absolute Condenser Pressure (P_c) = 1.01325 + 9.3015

= 10.3 bar

= 1MPa

Similarly, Absolute Evaporator Pressure (P_e) = 0.5 MPa

CONDENSER 1 : (3/16 INCH)

Work of Compression (W) = (h_2 - h_1)

= 442 - 400

= 42 kJ / kg

Net Refrigeration Effect (Q_2) = (h_1 - h_4)

= 410 – 245

= 165 kJ / kg

Coefficient of Performance (COP) [theoretical] = Q_2 / W

= 165 / 42

= 3.9

Actual COP = $\frac{\text{m c dt / Time}}{\text{power}}$

= $\frac{1 \times 4816 \times (26.8 - 20.3) / (16 \times 60)}{220 \times 0.7}$

= 0.2

CONDENSER 2 : (1/ 4 INCH)

Work of Compression (W) = (h_2 - h_1)

= 442 - 405

= 37 kJ / kg

Net Refrigeration Effect (Q_2) = (h_1 - h_4)

= 405 – 240

= 165 kJ / kg

Coefficient of Performance (COP) [Theoretical] $= Q_2 / W$

$= 165 / 37$

$= 4.5$

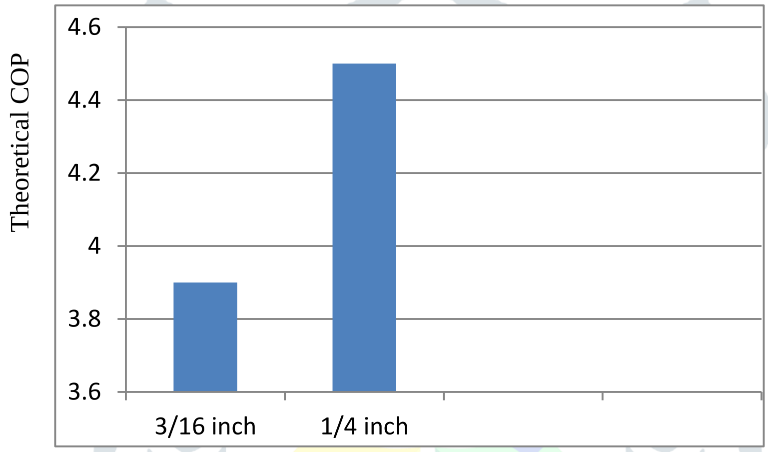
Actual COP $= \dfrac{m\ c\ dt / Time}{power}$

$= \dfrac{1 \times 4816 \times (26.8 - 17.1) / (16 \times 60)}{220 \times 0.7}$

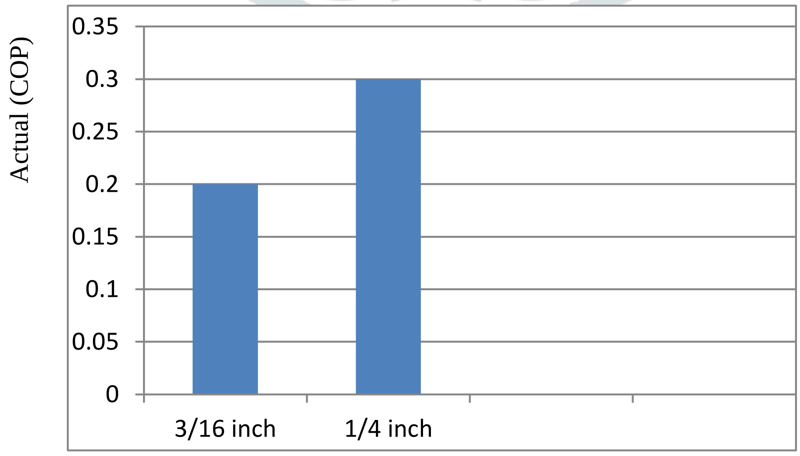
$= 0.31$

VI. Graphs:

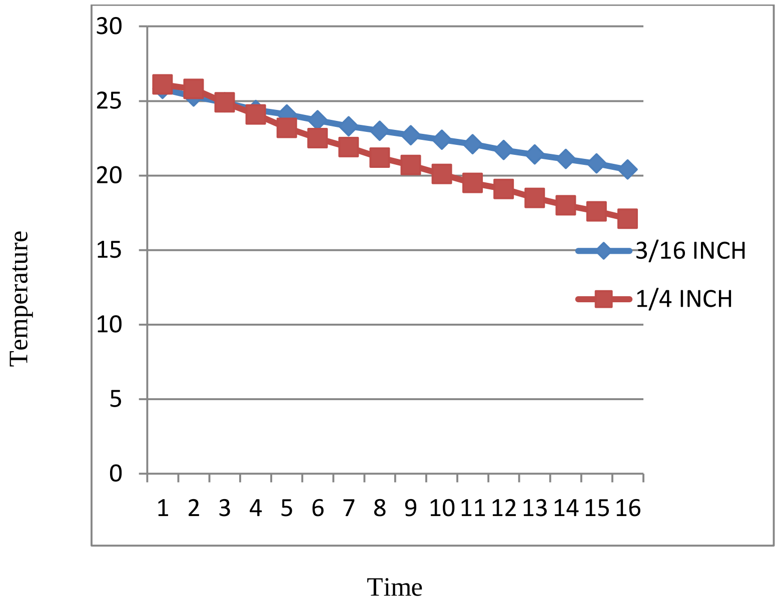
Theoretical COP VS Condenser Diameter



Actual COP VS Condenser diameter



Temperature Vs Time:



VII. Conclusion

From the experiment the above readings,the values and graphs are obtained..
1. It is found that the COP of the refrigerator while using 1/4-inch condenser is more than that of the COP of the refrigerator while using 3/16-inch condenser tube.
2. As the condenser tube diameter increases the evaporator temperature goes on decreases as well.
3. The refrigeration effect produced for the ¼ inch condenser is more than the 3/16 inch condenser tube.

VIII. References

i. Gaurao S. Deshmukh, Chetan Agarwal, Sumit Raut, Mheghesg Bhusari And Satyandra Singh, Performance analysis and fabrication of refrigerator using Deep-cooling condenser to increase COP of refrigerator. IJARIIE-ISSN(O)-2395-4396, Vol-3 Issue-2 2017.
ii. Poltker and Hrnjak "Effect of Condenser Subcooling of the Performance of Vapor Compression Systems: Experimental and Numerical Investigation", International Refrigeration and Air Conditioning Conference, July 16-19, 2012, Purdue ePubs, 2512.
iii. Mark J. Bergander, New Regenerative Cycle for Vapour Compression Refrigeration, Final Scientific Report, DOE Award Number: DE-FG36-04GO14327, 30th Sept. 2004 to 30th Sept. 2005.
iv. B. O. Bolaji. (2010), Experimental study of R152 a and R32 to replace R134a in a domestic refrigerator, Energy 353793-3798.
v. Oliver Evans 1805, the American inventor Oliver Evans described a closed vapor-compression refrigeration cycle for the production of ice by ether under vacuum.
vi. Shane Smyth, Donal P. Finn And Barry Brophy, Performance Evaluation of economised indirect multi-temperature transport refrigeration system, Purdue University, Perdue E-pubs, International Refrigeration and Air conditioning conference, School of Mechanical Engineering, 2010.
vii. Chetan P. Waykole And H.M. Dange, Performance evaluation of water cooler with modification of liquid suction heat exchanger, INPRESSCO International Journal of Current Engineering and Technology, ISSN 2277-4106, Special Issue-3, (April 2014).
viii. Jeetendra Kumar Patel, Yogesh Parkhi And Rajesh Soni, Evaluation of COP in refrigeration system by using different refrigerants. IJRASET ISSN: 2321-9653; IC Value 45.98;p SJ Impact Factor :6.887, Vol-6 Issue 1, January 2018.
ix. Miguel Padilla, Remi Revellin And Jocelyn Bonjour (2010), "Exergy Analysis ofR413A as Replacement of R12 in a Domestic Refrigeration System", Energy Conversion and Management, Vol. 51, pp. 2195-2201.
x. S.Wongwises, Somchai and Chimres, Nares, Experimental study of hydrocarbon mixture to replace HFC-134a in a domestic refrigerator, Energy Conversion and Management, Vol 45, Elvisar, 2005 pp. 85-100.
xi. R. Hanuma Naik And K. Ramachandra Manohar, The performance analysis if cascade refrigeration system with and without phase change material, IOSR-JMCE, e-ISSN: 2278-1684, P-ISSN:2320-334X, PP.07-16.