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# Effect of Capillary Tube Shapes on the Performance of Vapour Compression Refrigeration Cycle Using Nano-Refrigerant

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***Abstract* - The main aim of this experimental study was to check the coefficient of performance on the Vapour Compression Refrigeration System by changing the shape of the capillary tube and by changing the refrigerants. Investigated the effect of Nano Refrigerant on the Coefficient Of Performance of Vapour Compressor Refrigeration Cycle. Compared the Coefficient Of Performance on the basis of R-22 (Difluoro-Monochloro Methane ($CHF_2CL$) or R-22) and $Al_2O_3$ Nano particles mixed R-22. The shape of the capillary tubes and the refrigerants is altered to study its effect on the performance of vapour compression refrigeration cycle. The shapes of Capillary tubes used were Serpentine Shape and Cubic Shape.**

## I.INTRODUCTION

The VCRC i.e. Vapour Compression Refrigeration Cycle is one of the most widely used cycle in the field of refrigeration and air–conditioning. The major components of this system are compressor, condenser, expansion and evaporator, etc. Out of these components the expansion device plays an important role. In vapor compression refrigeration system the capillary tubes used for the expansion purpose are only used in the helical form. Capillary tube is a copper tube of very small internal diameter is one of the most commonly used throttling devices in the domestic refrigerators, air conditioning system, Water coolers and freezers. It is of very long length coiled to several turns so it would occupy less space.

### *Refrigeration System*

Refrigeration is the purpose being to cool some product or space to the required temperature and it is the process of attaining and maintaining a temperature lower that of the surroundings. Vapour compression refrigeration is the most widely used method for air-conditioning of public houses, workplaces, private residences, hotels, hospitals, theatres, eateries and automobiles. It is also used in large-scale warehouses for chilled or frozen storage of foods and meats, domestic and commercial refrigerators, refrigerated trucks and railroad cars, and a host of other commercial and industrial services. Air Conditioning denotes the treatment of air so as to control its temperature, moisture content, cleanliness and circulation, a process or products in the space.

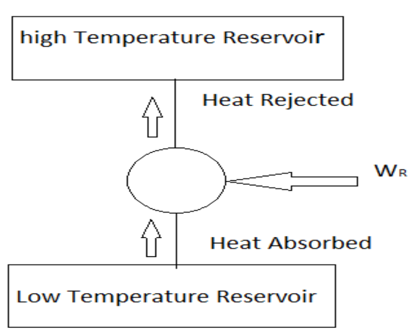

Fig. 1 Refrigeration System

### *Process of Vapour Compression Cycle*

The vapour compression refrigeration cycle is consists of four refrigeration processes, Compression, Condensation, Expansion and Evaporation.

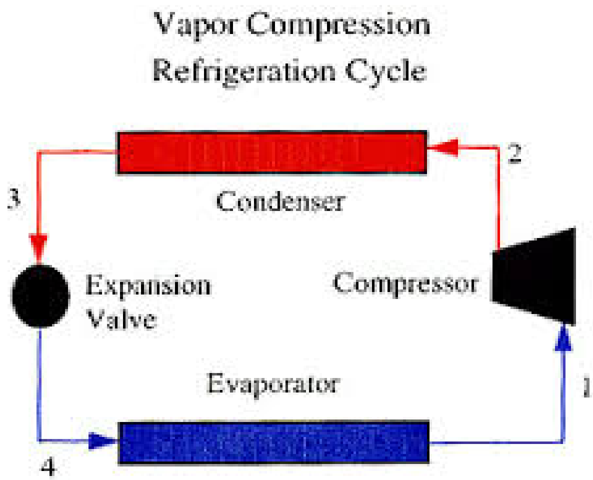


Fig. 2 Simple Vapour Compression Cycle

***1. Compression***

The vapour refrigerant at low pressure $p_1$ and temperature $T_1$ is compressed isentropically to dry saturated vapour as shown by the vertical line 1-2 on T-s diagram and by the curve 1-2 on P-h diagram. The pressure increases from $p_1$ to $p_2$ and temperature from $T_1$ to $T_2$ respectively. The work done during isentropic compression per kg of refrigerant is given by

$$W = h_2 - h_1$$

$h_1$=enthalpy of vapour refrigerant at temperature $T_1$, i.e. at suction of the compressor.

$h_2$=enthalpy of the vapour refrigerant at temperature $T_2$, ie at discharge of the compressor.

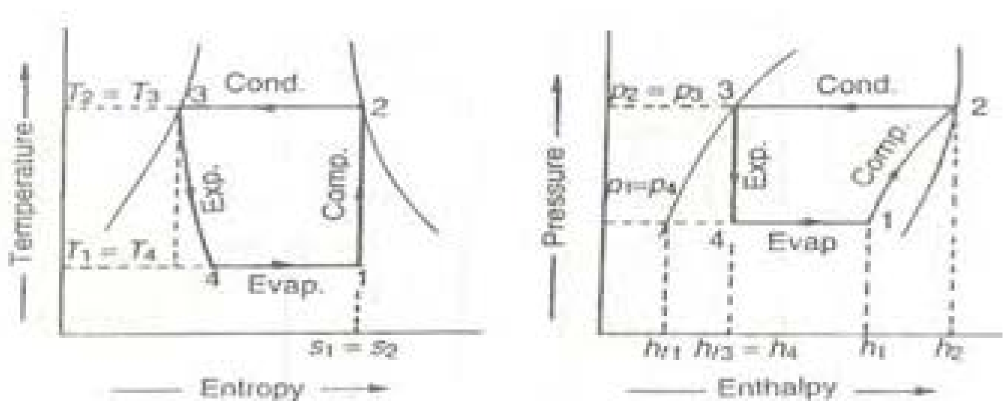


Fig. 3 P V and T S Diagram of Compression

A compressor is a mechanical device which rises the pressure of a gas by volume. Hermetically sealed compressor is use since leakage of refrigerant is completely more compact and requires small space less noisy.

Fig. 4 Compressor

***2. Condensation***

The vapours are cooled at a constant pressure and changed the vapour into the liquid state. So heat is given to the condensing fluid. The high pressure and temperature vapour refrigerant from the compressor is passed through the condenser where it is completely condensed at constant pressure $P_2$ and temperature $T_2$, as shown by the horizontal line 2-3 on T-S and P-H diagram. The refrigerant, while passing through the condenser gives its latent heat to the surrounding condensing medium Condensers are heat exchanger. Function of condenser is to get ride absorbed previously and reliquefy the refrigerant. The vapour refrigerant condenses a liquid at constant pressure.

Fig. 5 Condenser

***3. Expansion***

The liquid refrigerant from the condenser passed through the expansion device where it is throttled to lower pressure and at constant enthalpy. The liquid refrigerant is partly vaporized at lower temp after throttling. The liquid refrigerant at pressure $P_3$=$P_2$ and temperature $T_3$=$T_2$is expanded by a throttling process through the expansion valve to a low pressure $P_4$=$P_1$ and temperature $T_4$=$T_1$ as shown by the curve 3-4 on t-s diagram and by the vertical line 3-4 on P-H diagram. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the larger portion is vaporized in the evaporator. No heat is absorbed or rejected by the liquid refrigerant during the throttling process.

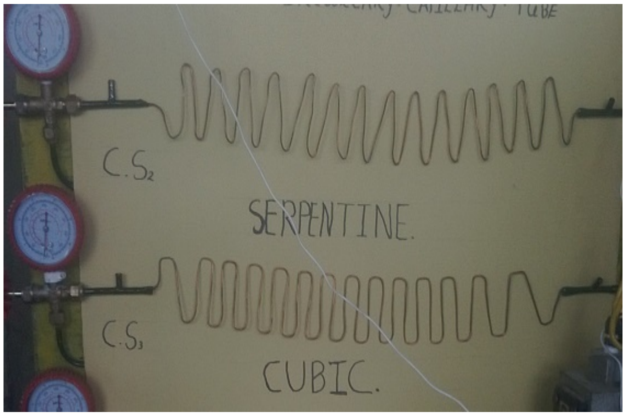


Fig. 6 Capillary Tube

***4. Evaporation***

In the evaporation the partly vaporized refrigerant completely evaporates at constant pressure by absorbing latent heat from the space. The liquid vapour mixture of the refrigerant at pressure $P_4$ =$P_1$ and temperature $T_4$= $T_1$ is evaporated and changed into vapour refrigerant at constant pressure and temperature as shown by the horizontal line 4-1 on T-s and p-h diagram. During evaporation, the liquid-vapour refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.

The liquid refrigerant from expansion enters into evaporator coil at a temperature below the temperature of evaporator. It extracts heat from evaporator and coldness.

Fig. 7 Evaporator

## II. LITERATURE REVIEW

Soni et al. (2013) investigated the **“**Experimental Performance of Window Air Conditioner Using Alternative Refrigerants with Different Configurations of Capillary Tube”. R-22, R-410A was the refrigerants used in this experiment and capillary tube was used in air conditioners with various refrigerants. Performance is carried out by using different type of capillary tubes (straight, twisted and coiled) in different length and diameter. Various parameters like coefficient of performance (COP), cooling capacity, energy efficiency ratio (EER) of the system were determined. If the diameter is smaller then the length is shorter and if the diameter is larger then length is longer and all these factors enable the exit pressure from the capillary tube to be reduced corresponding with the cooling requirements.

Patil A.S. and Patil A.M. (2013) study on a “Selection of Capillary Tube for Refrigeration System”. This study aims to select a best capillary tube for a refrigeration system. The study is focused on the influence of geometrical parameters like tube length, diameter, and coil pitch, number of twist and twisted angle on pressure drop and coefficient of performance (COP) of the system. The parameters can be optimized using mathematical modeling, experimental methods and maintaining proper pressure between condenser and evaporator.

Salim T.K. (2012) studied that “The Effect of the Capillary Tube Coil Number on the Refrigeration System Performance”. The refrigerant is used in this experiment is (R134a) and capillary tube is straight and coil Capillary tube. All properties of the refrigeration system are measured for various mass flow rate from (13 – 23 kg/hr) and capillary tube coil number (0-4) with constant length (150 cm) and capillary diameter (2.5mm). Through this study, it was found that the best coil number in refrigeration cycle at the lowest mass flow rate (31 Kg/hr) and at high mass flow rate (23 Kg/hr) is (coil number = 4), this will give the maximum performance, cooling capacity and deepest theoretical compression power.

Akintunde M.A. (2008) investigated “The effects of various geometries of capillary tubes based on the coil diameters and lengths alone”. The effects of pitches of helical and serpentine coiled capillary tubes on the performance of a vapor compression refrigeration system were examined. Some capillary tubes of equal lengths (2.03 m) and changing pitches, coiled diameters and serpentine elevations were used. The inlet and outlet pressure and temperature of the capillary tube were measured and used to estimate the COP of the system. The pitch has no significant effect on the system performance in the case of helical coiled geometries. The COP obtained was 0.9841 in the case of serpentine geometries for mass flow rates of helical and serpentine with straight tubes, 0.9864 and 0.9996 for mass flow rates of serpentine and helical coiled tube respectively. This study examined the performance of capillary tube geometries having R-134a as the working fluid.

## III. EXPERIMENTAL SETUP

The experimental setup contains the compressor and valves that are shut off valves, rotameter by pass, expansion valve and tube expansion valve capillary. The control unit includes the main switch and measuring instruments like voltage, amp, meters, energy meters, pressure gauges, dial type thermometers and glass thermometers, pressure gauges.

Fig.8 Installation of Pressure Guages

The two temperature gauges were installed in capillary tube line. After installation of pressure gauges, the 750 gm of refrigerant was filled into the compressor.


Fig. 9 Installation of Refrigerant in Compressor

| | |
|---|---|
| Nano Particle | Aluminium Oxide (Al2O3) |
| Purity | 99.8% |
| Particle Shape | Spherical |
| Particle size range | 5-150 nm |
| Purchased from | Reinste Nano Venture Pvt. Ltd. |

TABLE I INPUT PARAMETERS

| **Sr. No.** | **Capillary Coil Material** | **Capillary Shape** | **Refrigerant** |
|---|---|---|---|
| 1 | Aluminum tube | Serpentine | R-22 |
| 2 | Aluminum tube | Cubic | R-22 with Nano-particle $Al_2O_3$ |

TABLE II TECHNICAL SPECIFICATIONS

| | |
|---|---|
| Pressure at compressor discharge | 15 to 16 kgf/cm$^2$ (220 psi guage) |
| Pressure at compressor inlet | 4.0 8to 5.08 kgf/cm$^2$(60 psi guage) |
| Temperature at compressor discharge | 80$^0$c |
| Temperature at compressor inlet | 22$^0$c |
| Temperature at condenser outlet | 40$^0$c |
| Pressure at condenser outlet | 16 kgf/cm$^2$ |
| Refrigerant flow rate (rotameter) | 2.2 kg/min |

**Co-efficient of Performance (COP):**

Refrigerating Effect=$h_1$-$h_{f3}$

Compressor work done=$h_2$-$h_1$

Coefficient of Performance= Refrigerating Effect/ Compressor work done= $h_1$-$h_{f3}$/ $h_2$-$h_1$

$h_1$ = Enthalpy of the refrigerant leaving the evaporator and incoming the compressor

$h_2$ =Enthalpy of the refrigerant leaving the compressor and incoming the condenser

$h_{f3}$=Enthalpy of the refrigerant leaving the condenser and incoming the expansion valve.

TABLE III REFRIGERANT R22

| Sr. No. | $h_1$ (kJ/kg) | $h_2$ (kJ/kg) | $h_{f3}$ (kJ/kg) | Refrigeration Effect ($h_2$-$h_1$) | Compressor work ($h_2$-$h_{f3}$) | COP |
|---|---|---|---|---|---|---|
| AS 1 | 235.65 | 260.11 | 76.04 | 24.46 | 159.61 | 6.53 |
| AS 2 | 235.65 | 260.38 | 77.39 | 24.73 | 158.26 | 6.40 |

TABLE IV REFRIGERANT WITH $AL_2O_3$ NANO-PARTICLE R22

| Sr. No. | h1 (kJ/kg) | h2 (kJ/kg) | hf3 (kJ/kg) | Refrigeration Effect (h2-h1) | Compressor Work (h2-hf3) | COP |
|---|---|---|---|---|---|---|
| 1 | 243.25 | 263 | 95.63 | 19.75 | 147.62 | 7.47 |
| 2 | 243.25 | 263.13 | 97.03 | 19.88 | 146.22 | 7.36 |

TABLE V RESULT TABLE FOR CAPILLARY TUBE

| Shape | COP for R 22 | COP for R 22 with $Al_2O_3$ Nano-particle | Percentage increase |
|---|---|---|---|
| AS 1 | 6.53 | 7.47 | 14.395 |
| AS 2 | 6.40 | 7.36 | 14.099 |

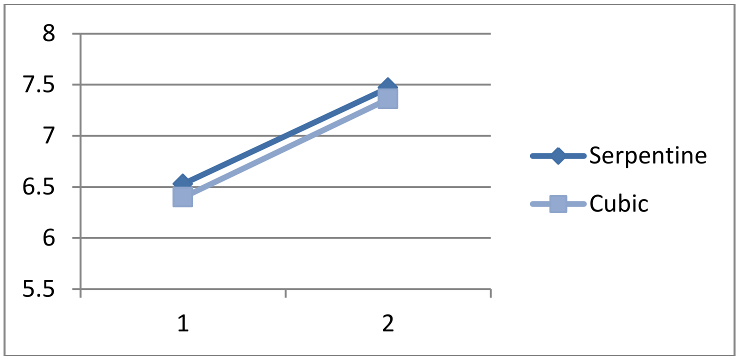


Fig. 10 Variation of Coefficient of Performance R-22 and Nano particle with R-22

## IV.RESULT ANALYSIS AND DISCUSSION

The measured parameters pressure (P) and temperature (T) was used to evaluate the coefficient of performance (COP). From the resultant values of the coefficient of performance and the graphical representation for the serpentine and cubic coiled capillary, it can be analyzed that with change in shape of the capillary tube the serpentine shape capillary tube gives better Coefficient of Performance than the cubic shape due to the resistance occurs in cubic shape is more comparatively.

The Nano particle mixed with refrigerant enhances the thermal conductivity of the refrigerant and that by the rate of heat transfer increase and ultimately enhances the coefficient of performance of the refrigeration system.

## V.CONCLUSION

This study investigated the coefficient of performance of refrigeration system on the basis of capillary tube shapes having R-22 as the working fluid. It reaches the following conclusion:

1. AS 1 i.e. Serpentine shape capillary tube provides better flow of the refrigerant due to less resistance in flow and enhances the Coefficient of Performance of the refrigeration system.
2. Cubic shape capillary tube offers more resistance to flow of refrigerant, so its pressure reduction is less comparatively.
3. Refrigerant having mixed $Al_2O_3$ Nano particle with R-22 gives better Coefficient of performance of the refrigeration system. This is happens because the thermal conductivity property of $Al_2O_3$ Nano particle is high which increase the conductivity rate of refrigerant and ultimately enhances the COP.
4. Nano particle $Al_2O_3$ enhances the refrigerating effect by R-22 by around 15% in case of serpentine shape capillary tube.

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