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Experimental Investigation on the Effect of Capillary Tube Geometry on the Performance of Vapor Compression Refrigeration System

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Abstract: **The study of the expansion device in simple vapor compression refrigeration system is necessary in order to understand the parameters which can enhance the overall performance of system. It is essential to study the effect of capillary tube geometry on the performance of refrigeration systems. The literature review focuses on the effect that geometrical parameters like capillary tube length, bore diameter, coil pitch, number of twist and twisted angle have on the pressure drop, coefficient of performance (COP) and mass flow rate of the system. The parameters stated above can be further optimized in order to enhance the performance of the refrigeration system. The present work is focused on the influence of tube diameter, tube length, coil pitch, and inlet condition on mass flow rate of refrigerant through helical coil capillary tube and also on investigation about the Coefficient of Performance (COP) of the system due to coiling effect of capillary tube. The use of helical capillary tube reduces the space for the refrigeration system which is the need for more compact refrigeration system in the current trend.**
***Key words*: vapor compression cycle, capillary tube, and capillary tube geometry, coefficient of performance.**

I.INTRODUCTION

A simple vapor compression refrigeration system consists of mainly five components namely compressor, condenser, expansion device, evaporator and a filter/drier. The following study is focused towards finding out the effect of the capillary tube on the performance of the refrigeration system. A capillary tube is a small diameter tube which is used for the expansion of the flowing fluid. The pressure difference between the entry and exit ends of the capillary tube is always equal to the pressure difference between the condenser and the evaporator. The diameter of the capillary tube used in the refrigeration appliances varies from 0.5mm to 2.3mm. the effect of the capillary tube has been investigated by many researchers in the past and encouraging results were obtained.

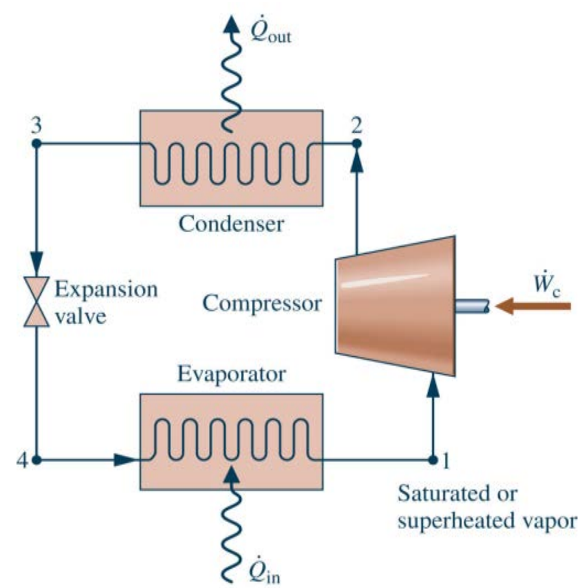


Fig.1 Vapor Compression Refrigeration System

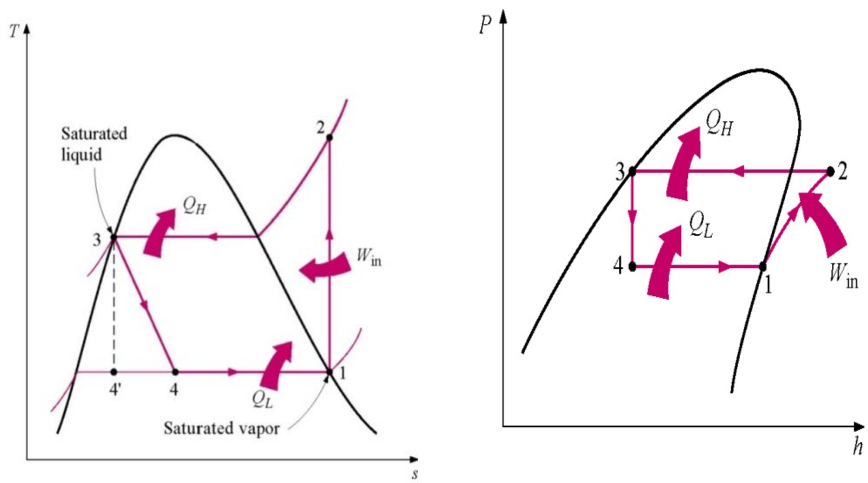


Fig. 2 T-s & ph diagram

In small refrigeration and air conditioning systems, one of the commonly used expansion devices to control the flow rate of refrigerants is the capillary tube. This is a simple tube of few millimeter internal diameters, usually ranging between 0.5 to 2 mm. Although the device lacks active function (mechanical or electrical) to actively adjust to any sudden change in the load conditions, it is still in use as a result of its simplicity, low cost and requirement of low compressor starting torque. The required length of capillary tube depends mostly on the size of the system

In a vapor-compression refrigeration cycle, the refrigerant enters the compressor as a saturated vapor and is cooled to the saturated liquid state in the condenser. It is then throttled to the evaporator pressure and vaporizes as it absorbs heat from the refrigerated space. The vapor-compression cycle consists of four processes

Process	*Description*
1-2	Isentropic compression
2-3	Constant pressure heat rejection
3-4	Throttling in an expansion valve
4-1	Constant pressure heat addition

Process 4-1: Two-phase liquid-vapor mixture of refrigerant is evaporated through heat transfer from the refrigerated space.
Process 1-2: Vapor refrigerant is compressed to a relatively high temperature and pressure requiring work input.
Process 2-3: Vapor refrigerant condenses to liquid through heat transfer to the cooler surroundings.
Process 3-4: Liquid refrigerant expands to the evaporator pressure.

Various literature sources are focused towards finding out the influence of the geometrical configurations of a capillary tube on the performance of the refrigeration system. The accurate size of the capillary tube and its configuration can be predicted with the help of the calculations for the refrigeration effect, coefficient of performance (cop) of the system and mass flow rate of the system. The effects of different geometries of capillary tubes have been studied by many researchers Mr. Mutalubi Aremu Akintunde [1] (17,18) in vestigated the performance of capillary tube geometries having R-134a as the working fluid. Two specific geometries, helical and serpentine ones, were examined. The obtained results show that the pitch variation has no significant effect on the system performance, but the coiled diameter affects the performance in the case of helical-coiled capillary tubes. Mr. Nishant Tekade and Dr. U.S. Wankhade [2] (2012) earlier studied the improvement in coefficient of performance of refrigeration appliances in case of retrofitting with the spiral capillary tube in VCR System. Ankush Sharma and Jagdev Singh [4](2013) experimentally investigated about the effects simple and twisted spirally coiled adiabatic capillary tubes on the refrigerant flow rate. Several capillary tubes with different bore diameters, lengths and pitches were taken as test sections. Sudharash Bhargava and Jagdev Singh[5] (2013) experimentally investigated the of pitch and length of the serpentine coiled adiabatic capillary tube on the flow of a eco friendly gas.

II. EXPERIMENTAL METHODOLOGY

We know that following are the factors that affect the performance of VCR system.

a. Properties of working fluid.
b. Amount of charge filled and system pressure.

c. Diameter of capillary tubes.
d. Inlet water temperature.

The present work is focused on investigation on effect of variation in capillary tube diameter of spiral coiled on the coefficient of performance of vapor compression cycle and the mass flow rate of refrigerant. The objective of the study was to compare the refrigeration performance of different capillary tube diameters with different load conditions.
Instead of an orifice, a small diameter tube can be used for the expansion of the flowing fluid. This small diameter tube is known as the capillary tube expansion device and it produces the same effect as produced by the orifice. The term capillary tube" means „hair-like". It is so called because of its very small bore diameter. The inside diameter of the capillary tube used for the purpose of refrigeration ranges from about 0.5 mm to 2.30 mm. longer the capillary tube and/or smaller the inside diameter of the capillary tube, greater is the pressure drop it can create in the refrigerant flow. In other words, greater will be the pressure difference needed between the high pressure side and the low pressure side to establish a given flow rate of the refrigerant.

Experimental Setup Details

The apparatus consist of a domestic refrigerator of desired capacity, as shown in figure (3), the connections between compressor suction ports, evaporator exit; capillary tube and evaporator inlet are modified to give an easy way to connect the tested capillary tube under study to the vapor compression cycle.

Fig. 3The apparatus consist of a domestic refrigerator

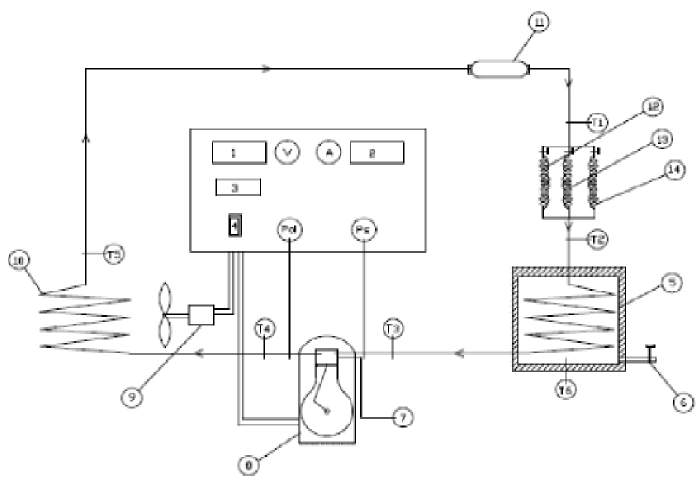


Fig Schematic diagram of experimental setup.

Fig.4 Schematic diagram of experimental setup.

TABLE 1 EXPERIMENTAL SETUP COMPONENTS DETAILS

S.No.	Equipment	Range/ Capacity	Accuracy
1	Compressor Hermeticay Sealed, Reciprocatingtype, Godrej company	410BTU/ hr, 120 watt 230V AC, 50Hz	-
2	Air-cooled condenser Tubes-Copper Fins-Al &Fan Motor	09″*09″*02 row, Diameter of tubes- 9mm, Length of tubes- 40 ft., Fan diameter – 10 ft, 1/10 HP	-
3	Capillary tube of Test Section , Material–copper	Diameter: 0.036”, 0.040” & 0.050”Length- 1meter	-
4	Evaporator coil & shell Capacity- 10 lit	Coil dia- 10”, Tube dia. - 12mm, Tube length- 40ft, Shell dia- 250 mm	-
5	Digital Temp. Indicator	0 to 9999^{0}C,	1^{0}C
6	Thermocouple (Cr-Al) K type	0 to 900^{0}C, 06 Nos.	1^{0}C
7	Pressure Gauge, Connection 1/806 NPT	0 - 500 psi, 0 - 35kg/cm^2	0.1
8	Flow-meter	15 Lph	

III. RESULTS & DISCUSSIONS

In present work, capillary tubes of diameter 0.036”, 0.040” & 0.050” were used in the test sections. The length of each test section was kept constant to 1m. Every set of readings consists of at least five readings measuring the key variables like pressure & temperature at different load conditions.

The aim of this part is to make the performance analysis the vapor compression refrigeration system & is based on the steady flow energy equation and pressure-enthalpy Diagram of R-143a (to evaluate the values of enthalpy of each points require), to study the key variables, namely, COP, power of compressor, enthalpy of each points and mass flow rate of refrigerant. therefore, many measured variables ,namely, the refrigerant temperatures of each of inlet & outlet compressor ($T1$& $T2$), outlet condenser $T3$, inlet & outlet evaporator $T1$& $T4$ and evaporator cabinet , as shown in figures. Also it measured high & low pressure of vapor compression cycle and electrical voltage & current consumed by compressor that were used in this unit.

From the above graphs, it is observed that at variable loads of 6litres, 4litres and 2litres, the coefficient of performance of vapor compression system is high, with respect to time , when the smallest diameter capillary tube is used i.e. 0.036”. As we know that for a given state of refrigerant, the pressure drop is directly proportional to length & inversely proportional to the bore diameter of tube. The required pressure drop (pressure difference between condenser & evaporator pressure) is caused due to heavy frictional resistance offered by small diameter tube.

Graph 5.1,2,3 COP Vs TIME for different tube diameters & Loads

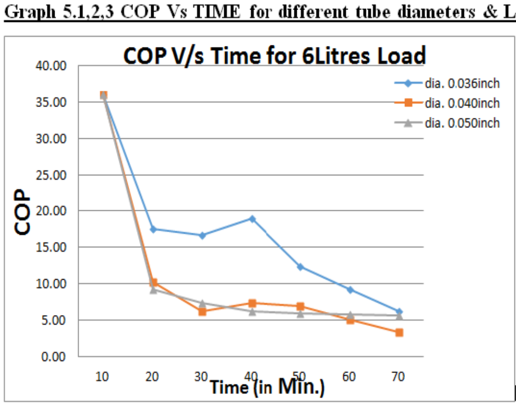


Fig.5

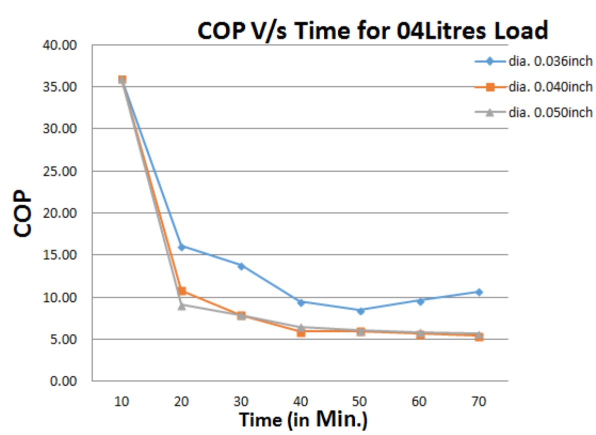


Fig.6

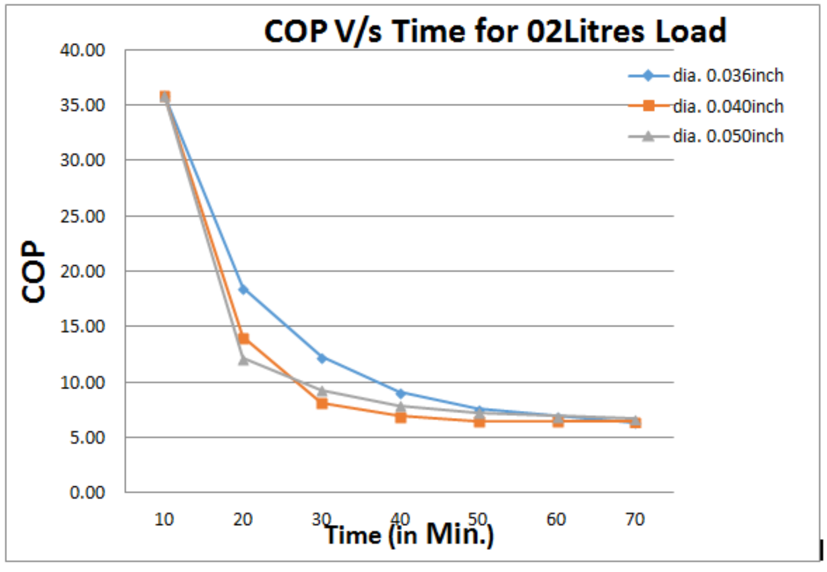


Fig.7

COP Vs TIME for different tube diameters & Loads

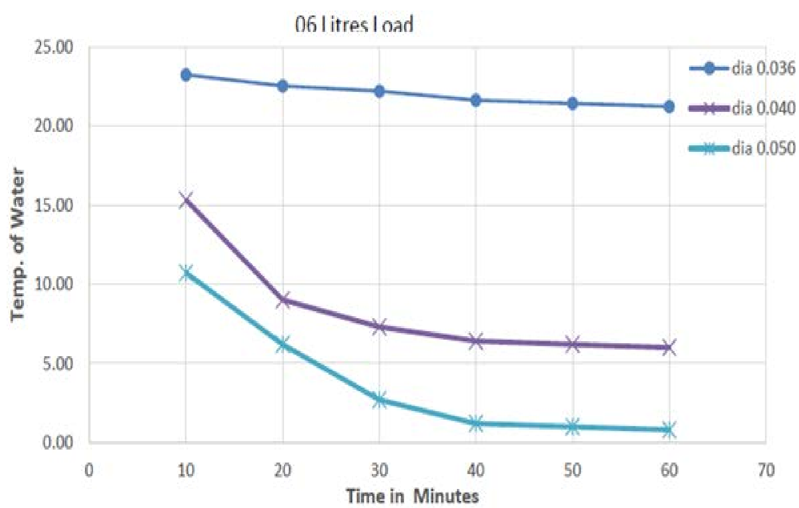
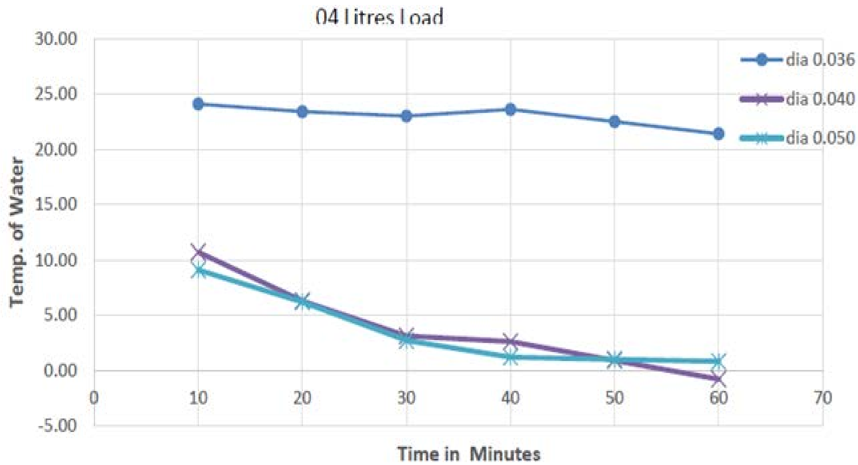


Fig.8



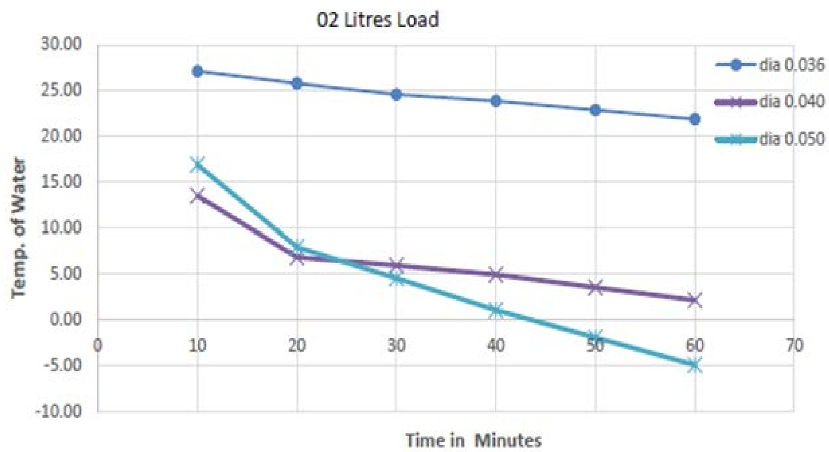


Fig. 9 & 10

From the above graphs, it is observed that for different load, of 06Litre, 04Litre & 02Litrs, the temperature of water is more in case of smaller diameter capillary tube as mass flow rate of refrigerant is less in evaporator where it can absorb less amount of heat from the water/substance to be cooled.

COP Vs TIME for 0.036 Dia.Tube at Different Loads

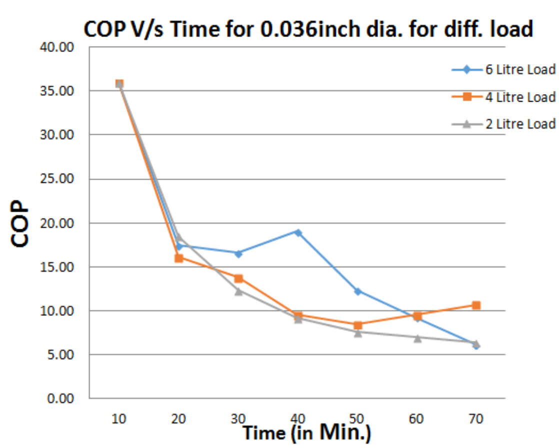


Fig.11

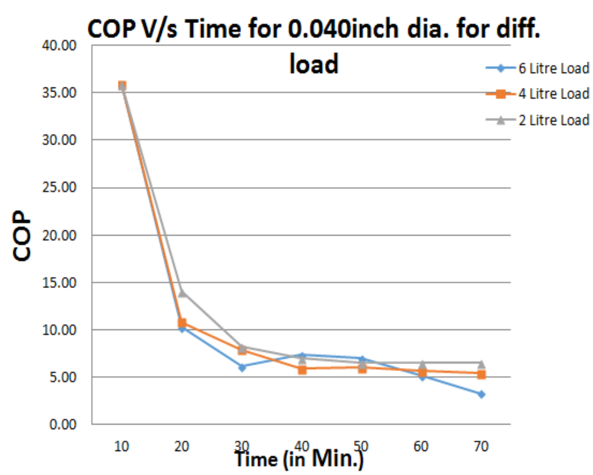


Fig.12

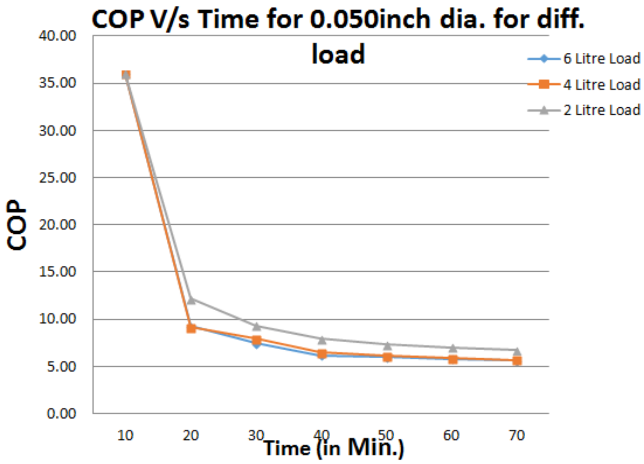


Fig.13

The rate of flow for selected capillary tube is the function of pressure difference between condenser & evaporator. From the above graphs it is observed that, as the load increase the tube supplies more quantity of refrigerant which lead to refrigeration effect. When the load on unit is decreased the flow through tube is decreased as an effect of decrease in condenser pressure.

IV. CONCLUSIONS

It is essential to study the effect of capillary tube geometry on the performance of refrigeration systems. In present research work, from the obtained results & graphs, it is found that single capillary tube having smaller inner diameter is suitable for freezing applications, whereas capillary tubes having more inner diameter are suitable for cold storage or air conditioning applications.

With smaller diameter capillary tube the COP of the system is increased with different load conditions as the pressure drop is directly proportional to length & inversely proportional to the bore diameter of tube. The required pressure drop (pressure difference between condenser & evaporator pressure) is caused due to heavy frictional resistance offered by small diameter tube.

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