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Testing Parameters Of VCR Unit Effect By Varying Size Of Capillary Tube And Quantity Of Refrigerant Charge Of R134a

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Abstract— In the modern day living, refrigerators have become the most essential part for the human life. Every domestic home uses a minimum of one refrigerator; also the refrigerators are used for industrial purposes. Thus, energy usage is the main criterion as the refrigerator (Vapour Compression system) uses the power to run the compressor. The quick diminution of traditional fuel sources and ecological contamination are the main problems by the plentiful usage of present oils. Hence a systematic approach is to be prepared in order to achieve the optimized design parameters of unit, which raises the overall performance of the refrigerator, and decrease the compressor work. An effective fabrication is achievable by hypothetical estimates, still may be unsuccessful owing to cause that uncertainty and complexity in completion of transfer of heat from refrigerant contained by condenser tube to the atmospheric air, and therefore practically examination is preferred for present work. The test trail conducted on a VCR unit by changeable diameters of capillary-tube and various amount of refrigerant charge. Investigation performed to enhance the performance with suitable geometry of capillary tube for specific refrigerant-charge.

The refrigerant used in the experiment was R134a. It is found with 150g of R134a charge has the highest COP with the system running on the capillary tube diameter of 0.042 inches. The cooling effect gained by the system and mass flow rate is highest with the capillary tube diameter of 0.036 inches with 100g of refrigerant charge than the remaining ones. Compressor Pressure Ratio is highest for 0.031inch diameter with 100g of Refrigerant Charge.

Keywords— Vapour Compression Refrigeration System, Coefficient of Performance, Capillary Tube, Refrigerant charge, Refrigerants.

1.Introduction

Refrigeration might expressed as the procedure of attaining and preserving a temperature lower than the environs. The goal is to chill several item or room to the requisite temperature. One of the significant functions of refrigeration is maintenance of perishable cooking items at least possible temperatures. Refrigeration units were even employed broadly for giving thermal leisure to humans through air-conditioning. Air-conditioning means handling of air so as to all-together manage its temperature, dampness amount, hygiene, outdoor and flow, as necessary by inhabitants, a procedure, or items in the room.

2. LITERATURE SURVEY

R. Cabello et.al [1] analysed about the characteristics of a VCR unit by 3 dissimilar operational refrigerants (R134a, R407c and R22). The operational parameters are the evaporating-pressure, condensing-pressure and degree of superheating at the compressor inlet. Also concluded that power-use reduces while compression-ratio raises with R22 compared to former operational refrigerants.

B O Bolaji et.al [2] examined practically the functioning of 3 O_3-friendly Hydro-fluoro-carbons (HFCs) R12, R152a and R134a. R152a refrigerants institutes as a fall in substitute for R134a in VCR.

Bolaji, B O [3] conferred the method of choosing ecological-refrigerant that ensures zero-O_3 diminution and least worldwide heating. R23 & R32 from methane-derives and R152a, R143a, R134a and R125 from ethane-derives are the budding fluids that are harmless, have small ability to produce flame and eco-friendly. Above fluids require hypothetical and investigational analysis to examine their functionality in the unit.

James .M .C et.al [4] deliberated the discharge of harmful pollutants and ecological consequences of R11, R123, R134a owing to leak from centrifugal chilled unit. Also explored overall outcome in the form of TEWI and alteration in unit competence or functionality owing to escape of fluid. Even concised the techniques to decrease the fluid leakage by the unit similar to propose alterations, development in defensive protection methods, usage of cleanse-system for fluid vapour recuperation, maintaining and lubricant changing in unit.

Amira Benhadid Dib et.al [5] demonstrated that the exploits of halogenated-refrigerants are injurious for surroundings and the employment of "usual" fluids suit a probable answer. Usual fluids are employed as an option result to restore halogenated--refrigerants. The result to the ecological consequences of fluids by a fluid which includes no-chlorine, no-fluorine and no ejection of any CO_2 in the ambience. Also proved that discharges have terrible possessions on our surroundings. And also worried through a giving to the decrease of GHGs and by the substitute of the harmful cool refrigerants (HCFCs).

E Granryd et.al[6], enrolled the various hydro-carbons as operational means in unit. Studied the various protection principles associated to these fluids. Results depicted that the characteristics of hydro-carbons (that is. No-ODP and negligible-GWP) that formulated for motivating fluid options for powerful and eco- friendly. However, security provisions owing to ability to catch flame should be critically considered for report.

Y. S. Lee et.al [7] tested the functionality of VCR unit with iso-butene, and compared the outcomes with R12 and R22. They used R600a around 150 g and fixed the refrigeration-temperature about 4°C and -10°C to preserve the condition of cold-storage and freezing-uses. They employed 0.7mm inner dia. and 4 to 4.5m extent of capillary-tube for cold-storage purposes and 0.6mm inner dia. and 4.5 to 5m extent of capillary-tube for sub-zero functions. It is monitored that the COP lies between 1.2 and 4.5 in cold-storage purposes and between 0.8 and 3.5 in freezing-applications. It is also scrutinized that the unit with 2-tubes in parallel-form executes superior in the cold-preserving and air-conditioning uses, while that by a 1-tube is appropriate in the freezing-purposes.

Mao-Gang He et.al[8], analyzed that the R152a/R125 mixture in the concerto of 0.85 mass-fraction of R152a has a same refrigeration performance with the present refrigerant R12. Experimental research on the major refrigeration performances of residential-refrigerators was performed, under the various portions and charge quantities, that is., R152a/R125 is employed to alternative R12 as a ‘‘drop-in’’ fluid. The trial results show that R152a/R125 can be employed to substitute R12 as a new-generation refrigerant of domestic-refrigerators, since of its well-environmentally satisfactory characteristics and its favourable refrigeration operations.

Ki-Jung Park et.al [9], analyzed trails of 2 pure hydro-carbons and 7 mixtures consists of propylene, propane, R152a, and dimethylether were calculated to replacement for R22 in residential air-conditioners and heat-pumps at the evaporation and condensation temperatures of 7°C and 45°C, correspondingly. Test trails illustrate that the COP of these mixes is up to 5.7% more than that of R22. Whereas propane showed 11.5% reduction in capacity, most of the fluids had a same ability to that of R22. For these fluids, compressor-discharge temperatures decreased by 11–17°C. For all fluids tested the amount of charge reduced by upto 55% as compared to R22.

Overall, these fluids provide good performances with rational power savings without any ecological issue and thus can be used as long-term options for residential air- conditioning and heat-pumping purposes.

Ki-Jung Park. et.al[10], tested thermo-dynamic functionality of 2-pure hydro-carbons and 7-mixtures consists of propylene (R1270), propane (R290), R152a, and di-methylether (R170) was quantified in an effort to replace R22 in housing air-conditioners. The pure and assorted fluids measured have GWP of 3–58 as contrasted to that of CO_2 at the evaporation and condensation temperatures of 7°C and 45°C, respectively. Examination outcomes confirm that the COP of these mixes is up to 5.7% more than that of R22. Whereas propane showed 11.5% decrease in capability, most of the refrigerants had the same ability to that of R22. Compressor discharge temperatures were also decreased by 11°C –17°C with these gases. There was no-issue institute with mineral-oil, since the mixes were mostly constitute of hydro-carbons. The quantity of gas was decreased up to 55% as contrast to R22.

K. Mani et.al [11], experimented with VCR unit by fresh R290/R600a gas blends as drop-in substitute and contrasted with R12 & R134a. The unit firstly intended to function with R12. The output depicts that the gas R134a resulted somewhat lesser COP than R12. The discharge-temperature and discharge-pressure of the R290/R600a gas mix was extremely nearer to R12. The R290/R600a (68/32 by wt %) blend can be measured as a drop-in substitution fluid for R12 and R134a.

A S Dalkilic et.al[12], performed trail on a VCR unit with refrigerant-combinations based on R134a, R152a, R32, R290, R1270, R600 and R600a for different portions and their outputs are contrsasted with R12, R22 and R134a as probable options. And also observed that all of the other gases explored in the testing have a little lesser COP than R12, R22, and R134a for the condensation-temperature of 50°C and evaporating-temperatures ranging between −30°C and 10°C. Fluid mixes of R290/R600a (40/60 by wt.%) in its place of R12 and R290/R1270 (20/80 by wt.%) as a substitute of R22 are established to be substitution gases between previous choices.

Vincenzo. La. Rocca. et.al[13], worked and evaluated the functionality of a VCR unit functioning with R22, and with 3 novel HFC-fluids, replacing the previous based to Regulation-No:2037/2000. System running effectiveness was initially experienced with R22 and then with 3 fresh HFC-gases R417a, R422a and R422d. Output with the innovative experienced gases did not produce as efficient as while with R22.

3. Experimental Setup

3.1. Schematic Layout

The major loop of the unit in experiment was consists of 5 fundamental elements, that is, compressor, evaporator, condenser, capillary tubes and a liquid line filter– dehumidifier, as shown in Fig.5. The reciprocating compressor originally designed for R134a refrigerant unit of 3-phase, 220V and input-power of the compressor inside the unit can be changed between 230W to 300W was utilized. The main element of the compressor lubricant was mineral-oils. A silica-gel dehumidifier utilized to suck-up the dampness. Compacted artificial air-cooled type condenser utilized for its superior heat-transfer efficiency. In the current study length is kept Constant for capillary-tubes of altered inner diameter employed to find the best suitable working situations of the unit. Evaporator part is prepared like shell and tube type by copper material, for reducing the loss of heat fibre-tank of evaporator is fully shielded by puff. Refrigerant employed is R134a. Some other measuring and controlling components are used in the system, that are, an electrical switch, an, a digital thermometer for controlling the evaporator temperature, bourdon tube type low pressure gauge and high-pressure gauge, and gas flow control valves.

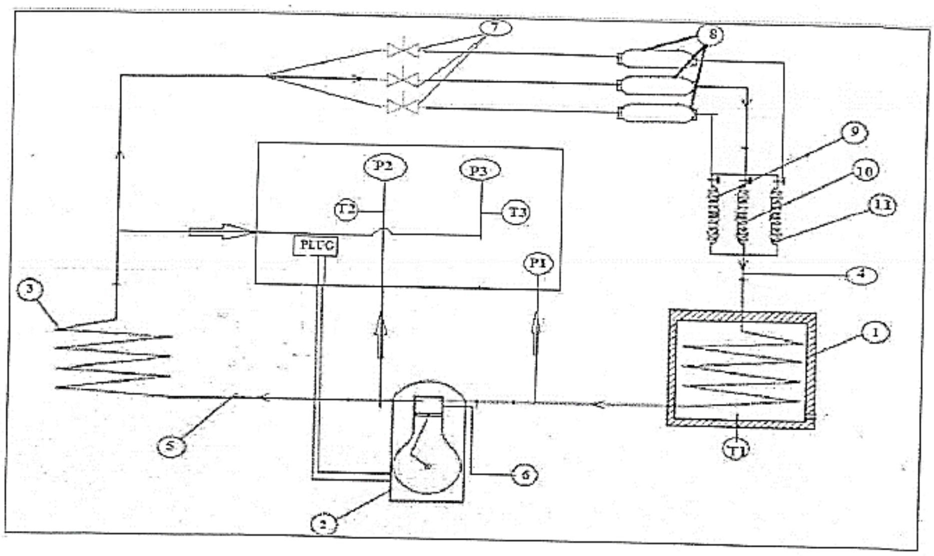

Fig.2.1 Schematic Layout of the experimental setup

TABLE I

Fig.2.2 Experimental Setup

3.1.2Evaporator Box

The evaporator box used for the refrigeration unit contains usual convection evaporator coils. The Evaporator box utilized in this unit is an inner plastic cold storage box with shielded puff, having load capacity of 40Litres.

Fig.2.3: Evaporator Box With Evaporative Coils

Fig. 2.4 : Capillary tubes of different diameters

Different mixtures of length and bore are available for the identical mass flow rate and pressure drop. However, once a capillary-tube of unique diameter and length has been fitted in a refrigeration unit, the mass flow rate and the total pressure drop through it will vary in such a manner that it matches with the pressure variation between condenser and evaporator. Its mass flow rate is extremely reliant upon the pressure variation across it, and it cannot regulate itself to difference of load successfully.

The compressor and the capillary-tube, in steady state must land at some suction and discharge pressures, which allow the identical mass flow rate by the compressor and the capillary-tube. This condition is named as the equilibrium point.

Capillary Tubes used in this System

- Material- Copper
- Operation Used for Joining- Brazing
- Diameters - 0.031”, 0.036”, 0.042”.
- Length of three tubes -10ft.

3.2 Experimental Observations

Table 3.1 Experimental data for capillary tube of diameter 0.031 inches with various amount of Refrigerant charge

100	0.138	8.412	8.20	-0.6	46.5	33.2
150	0.207	8.825	8.20	-2.3	41.3	33.5
200	0.345	8.963	8.34	-2.8	39.8	34.2

Table 3.2: Experimental data for capillary tube of diameter 0.036 inches with various amount of Refrigerant charge.

Refrigerant Charge (g)	P1(bar)	P2(bar)	P3(bar)	T1(^{O}C)	T2(^{O}C)	T3(^{O}C)
100	0.207	8.274	7.929	0.1	44.5	32.7
150	0.552	9.101	8.825	-0.5	40.5	35.1
200	0.689	9.584	9.308	-1	38.4	37.9

Table 3.3: Experimental data for capillary tube of diameter 0.042 inches with various amount of Refrigerant charge.

Refrigerant Charge (g)	P1(bar)	P2(bar)	P3(bar)	T1(oC)	T2(oC)	T3(oC)
100	0.345	8.618	8.549	4.1	43.8	33.8
150	0.689	9.308	8.963	0	37.5	35.6
200	0.827	9.515	9.23	-1.1	32.4	38.2

3.2.1 Experimental Calculations

Graphs were plotted to obtain the COP of the experimenting VCRS for different capillary tube diameters. The graph was plotted

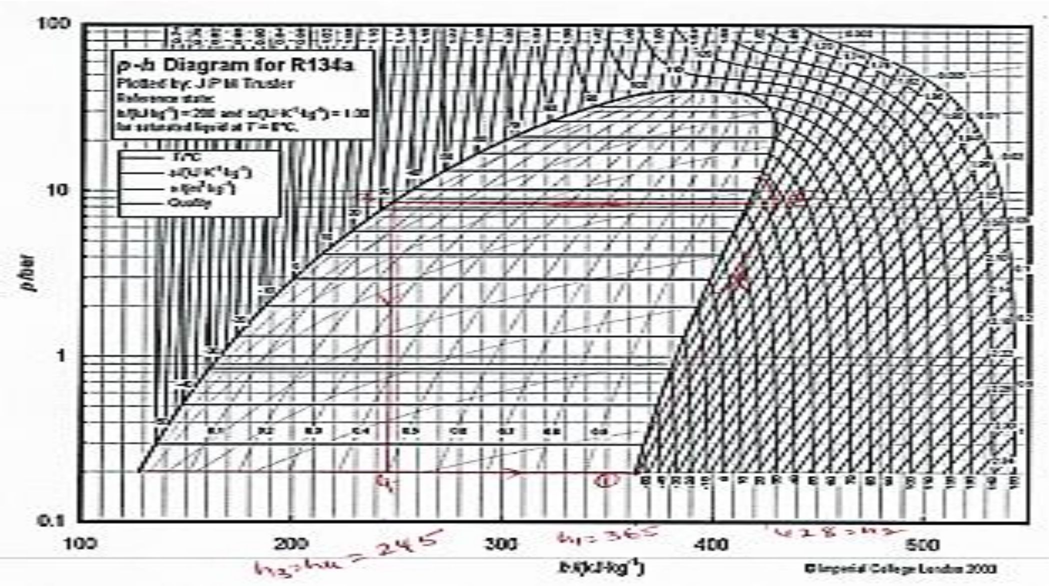

Fig.3.1 P-h graph of Vapour Compression Refrigeration System for capillary tube of diameter 0.031 inch with 100g of Refrigerant Charge. The COP obtained from the graph was COP = 1.90

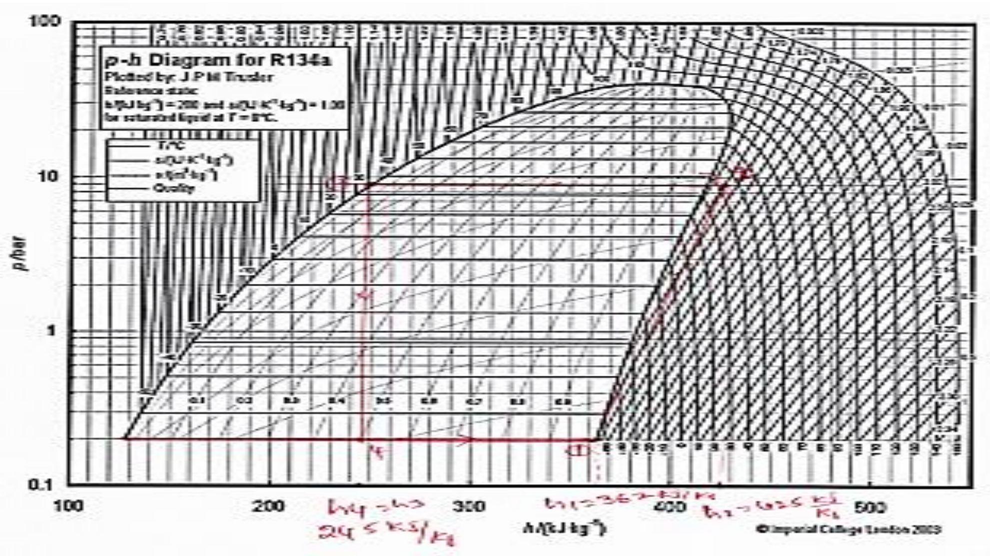

Fig.3.2: P-h graph of Vapour Compression Refrigeration System for capillary tube of diameter 0.031 inch with 150g of Refrigerant Charge. The COP obtained from the graph was COP = 1.85

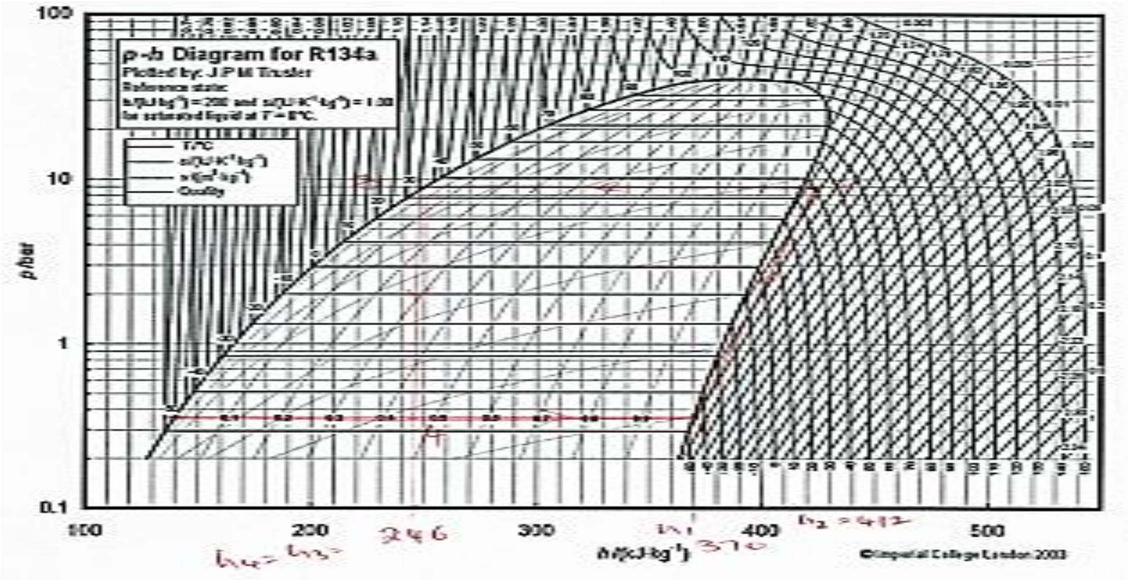

Fig.3.3: P-h graph of Vapour Compression Refrigeration System for capillary tube of diameter 0.031 inch with 200g of Refrigerant Charge. The COP obtained from the graph was COP = 2.95

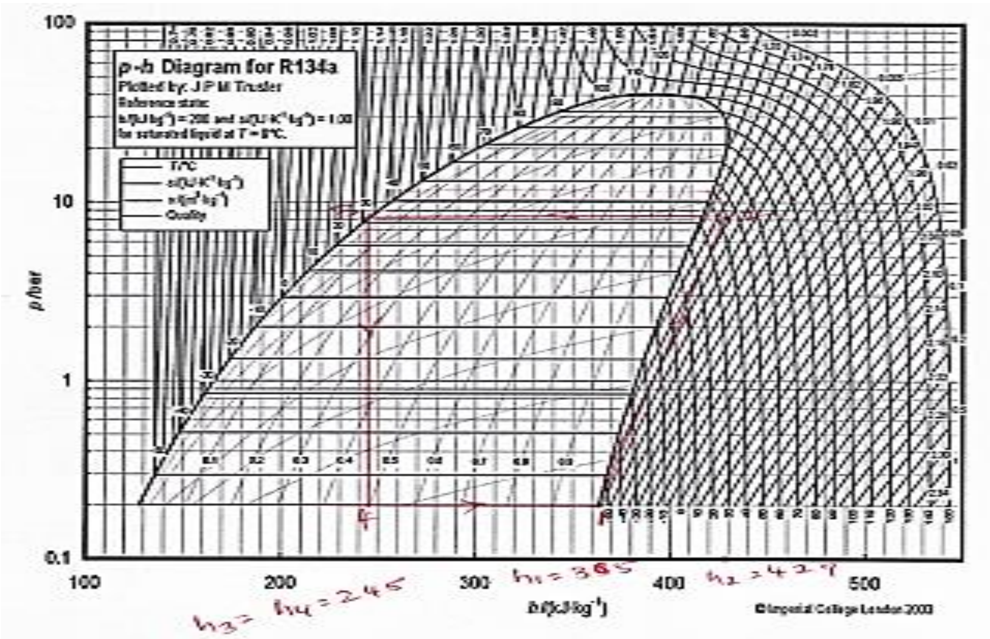

Fig.3.4: P-h graph VCR unit for capillary tube diameter 0.036 inch with 100g of Refrigerant Charge. The COP obtained from the graph was COP = 1.87

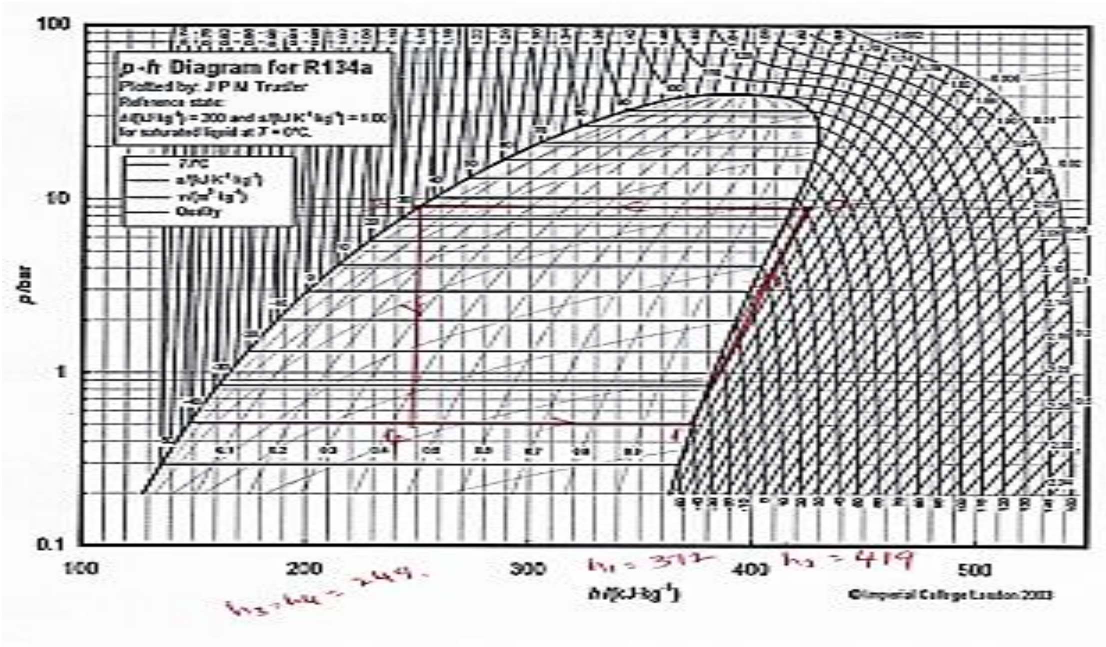

Fig.3.5: P-h graph of Vapour Compression Refrigeration System for capillary tube of diameter 0.036 inch with 150g of Refrigerant Charge. The COP obtained from the graph was COP = 2.61

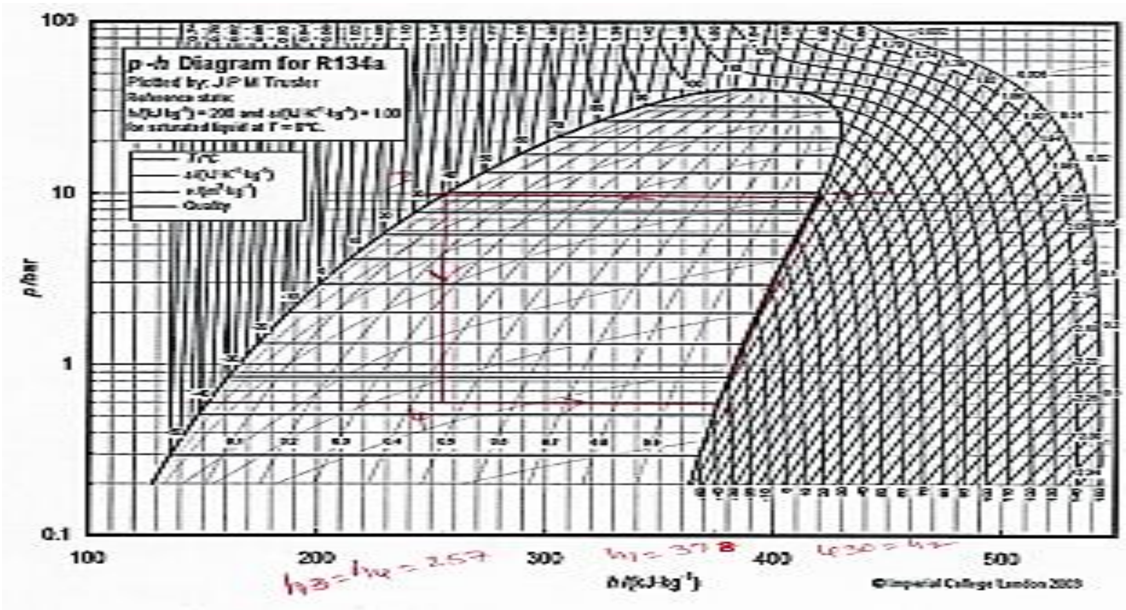

Fig.3.6: P-h graph VCR unit for capillary tube diameter 0.036 inch with 200g of Refrigerant Charge. The COP obtained from the graph was COP = 2.32

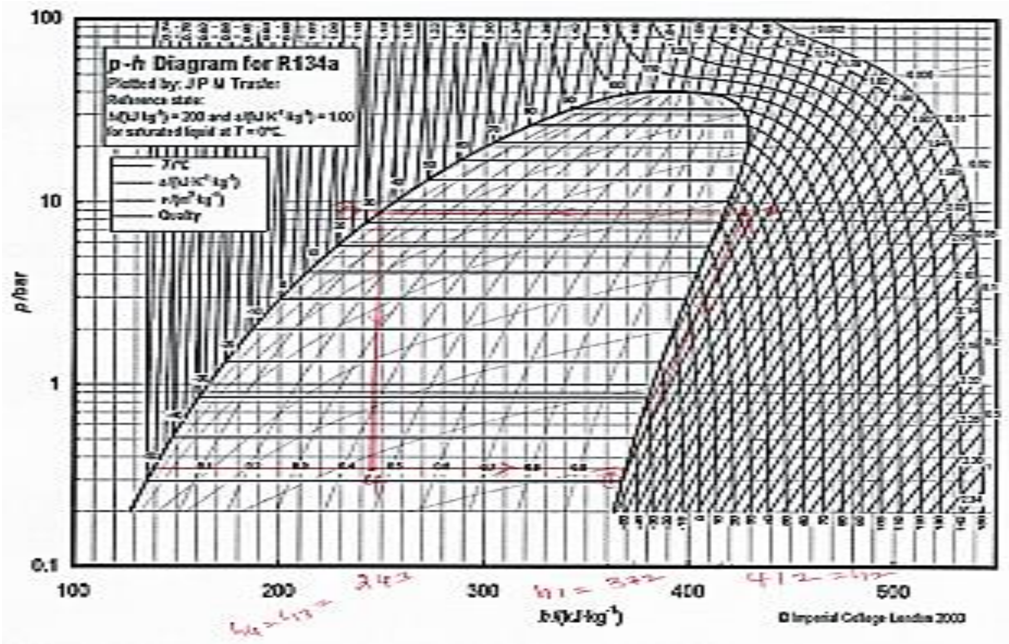

Fig.3.7: P-h graph of Vapour Compression Refrigeration System for capillary tube of diameter 0.042 inch with 100g of Refrigerant Charge. The COP obtained from the graph was COP = 3.22

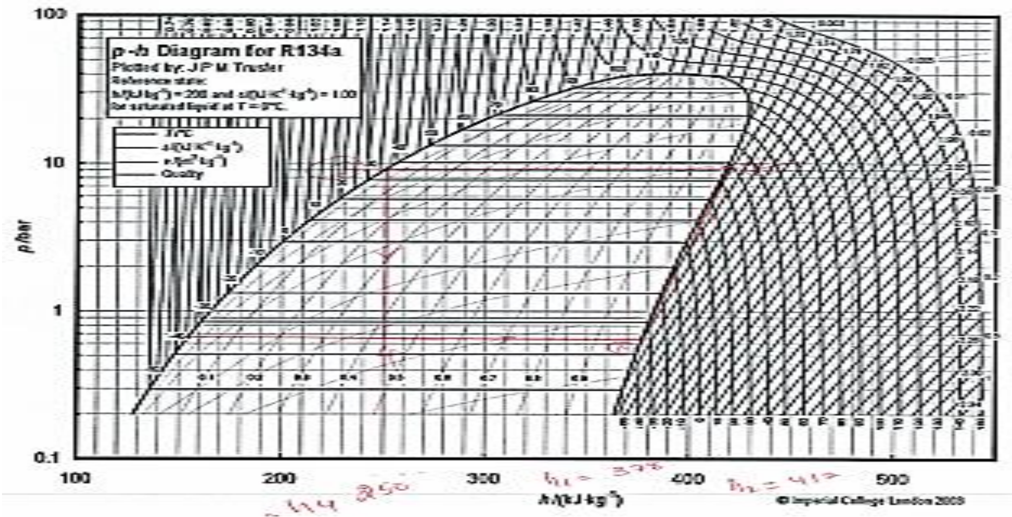

Fig. 3.8: P-h graph of Vapour Compression Refrigeration System for capillary tube of diameter 0.042 inch with 150g of Refrigerant Charge .The COP obtained from the graph was COP = 3.76

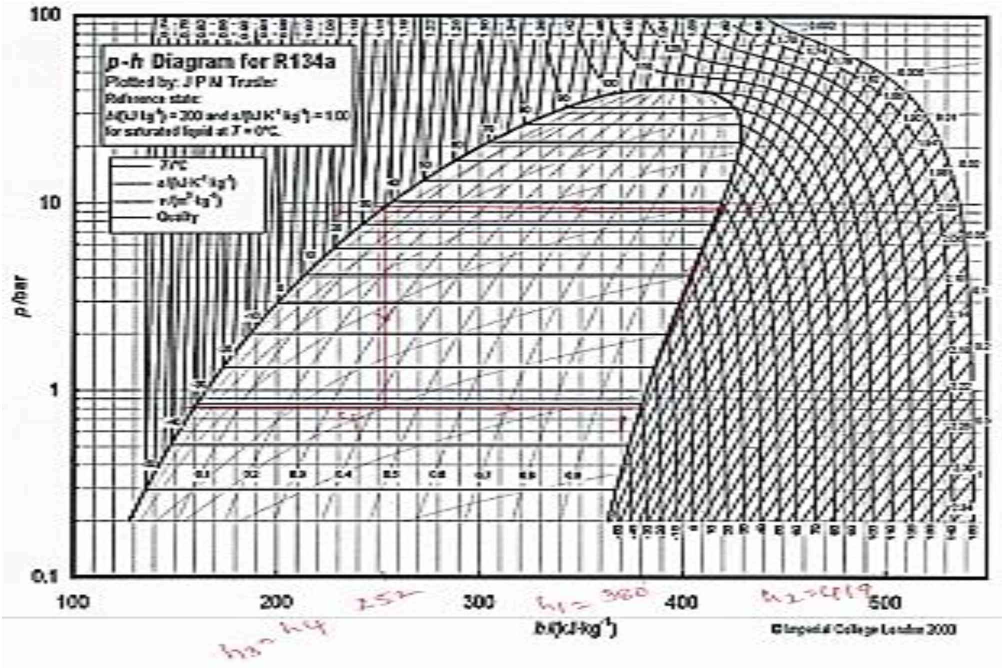

Fig. 3.9: P-h graph of Vapour Compression Refrigeration System for capillary tube of diameter 0.042 inch with 200g of Refrigerant Charge. The COP obtained from the graph was COP = 3.28

Table 3.4 : COP of VCR unit for capillary-tubes of different diameters with Variable Refrigerant charge.

REFRIGERANT Charge	COP 0.031"	COP 0.036"	COP 0.042"
100g	1.90	1.87	3.22
150g	1.85	2.61	3.76
200g	2.95	2.32	3.28

- For 0.031" Capillary tube diameter with 100g of Refrigerant Charge, From p-h chart,

h_1 = 365, h_2 = 428, $h_3 = h_4$ = 245 kJ/kg.

Work Input (W) = $h_2 - h_1$ = 428 – 365 = 63 kJ/kg.

Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 365 - 245 = 120 kJ/kg.

Coefficient of Performance COP = $\frac{Q}{W} = \frac{120}{63} = 1.90$

Mass flow rate = $\frac{210}{R.E.} = \frac{210}{120} = 1.75\ kg/min$

Compression Ratio = $\frac{8.412}{0.138}$ = 60.95

- For 0.031" Capillary tube diameter with 150g of Refrigerant Charge, From p-h chart,

h_1 = 362, h_2 = 425, $h_3 = h_4$ = 245 kJ/kg.

Work Input (W) = $h_2 - h_1$ = 425 – 362 = 63 kJ/kg.

Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 362 - 245 = 117 kJ/kg.

Coefficient of Performance COP = $\frac{Q}{W} = \frac{117}{63} = 1.85$

Mass flow rate = $\frac{210}{R.E.} = \frac{210}{117} = 1.79\ kg/min$

Compression Ratio = $\frac{8.825}{0.207}$ = 42.6

- For 0.031" Capillary tube diameter with 200g of Refrigerant Charge, From p-h chart,

h_1 = 370, h_2 = 412, h_3 = h_4 = 246 kJ/kg.
Work Input (W) = $h_2 - h_1$ = 412 – 370 = 42 kJ/kg.
Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 370 - 246 = 124 kJ/kg.
Coefficient of Performance COP = $\frac{Q}{W}$ = $\frac{124}{42} = 2.95$
Mass flow rate = $\frac{210}{R.E.}$ = $\frac{210}{124} = 1.69\ kg/min$
Compression Ratio = $\frac{8.963}{0.345}$ = 25.97

- For 0.036" Capillary tube diameter with 100g of Refrigerant Charge, From p-h chart,

h_1 = 365, h_2 = 429, h_3 = h_4 = 245 kJ/kg.
Work Input (W) = $h_2 - h_1$ = 429 – 365 = 64 kJ/kg.
Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 365 - 245 = 120 kJ/kg.
Coefficient of Performance COP = $\frac{Q}{W}$ = $\frac{120}{64} = 1.87$
Mass flow rate = $\frac{210}{R.E.}$ = $\frac{210}{120} = 1.75\ kg/min$
Compression Ratio = $\frac{8.274}{0.207}$ =39.97

- For 0.036" Capillary tube diameter with 150g of Refrigerant Charge, From p-h chart,

h_1 = 372, h_2 = 419, h_3 = h_4 = 249 kJ/kg.
Work Input (W) = $h_2 - h_1$ = 419 – 372 = 47 kJ/kg.
Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 372 - 249 = 123 kJ/kg.
Coefficient of Performance COP = $\frac{Q}{W}$ = $\frac{123}{47} = 2.61$
Mass flow rate = $\frac{210}{R.E.}$ = $\frac{210}{123} = 1.70\ kg/min$
Compression Ratio = $\frac{9.101}{0.552}$ = 16.48

- For 0.036" Capillary tube diameter with 200g of Refrigerant Charge, From p-h chart,

h_1 = 378, h_2 = 430, h_3 = h_4 = 257 kJ/kg.
Work Input (W) = $h_2 - h_1$ = 430 – 378 = 52 kJ/kg.
Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 378 - 257 = 121 kJ/kg.
Coefficient of Performance COP = $\frac{Q}{W}$ = $\frac{121}{52} = 2.32$
Mass flow rate = $\frac{210}{R.E.}$ = $\frac{210}{121} = 1.73\ kg/min$
Compression Ratio = $\frac{9.584}{0.689}$ = 13.91

- For 0.042" Capillary tube diameter with 100g of Refrigerant Charge, From p-h chart,

h_1 = 372, h_2 = 412, h_3 = h_4 = 243 kJ/kg.
Work Input (W) = $h_2 - h_1$ = 412 – 372 = 40 kJ/kg.
Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 372 - 243 = 129 kJ/kg.
Coefficient of Performance COP = $\frac{Q}{W}$ = $\frac{129}{40} = 3.22$
Mass flow rate = $\frac{210}{R.E.}$ = $\frac{210}{129} = 1.627\ kg/min$
Compression Ratio = $\frac{8.618}{0.345}$ = 24.979

- For 0.042" Capillary tube diameter with 150g of Refrigerant Charge, From p-h chart,

h_1 = 378, h_2 = 412, h_3 = h_4 = 250 kJ/kg.

Work Input (W) = $h_2 - h_1$ = 412 – 378 = 34 kJ/kg.
Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 378 - 250 = 128 kJ/kg.
Coefficient of Performance COP = $\frac{Q}{W}$ = $\frac{128}{34} = 3.76$
Mass flow rate = $\frac{210}{R.E.}$ = $\frac{210}{128} = 1.64\ kg/min$
Compression Ratio = $\frac{9.308}{0.689}$ = 13.50

- For 0.042" Capillary tube diameter with 200g of Refrigerant Charge, From p-h chart,

h_1 = 380, h_2 = 419, $h_3 = h_4$ = 252 kJ/kg.
Work Input (W) = $h_2 - h_1$ = 419 – 380 = 39 kJ/kg.
Refrigeration Effect R.E. (Q) per kg = $h_1 - h_4$ = 380 - 252 = 128 kJ/kg.
Coefficient of Performance COP = $\frac{Q}{W}$ = $\frac{128}{39} = 3.28$
Mass flow rate = $\frac{210}{R.E.}$ = $\frac{210}{128} = 1.64\ kg/min$
Compression Ratio = $\frac{9.515}{0.827}$ = 11.50

4. RESULTS - DISCUSSION

The presentation of VCR sequence and working of household-refrigerator differs significantly with diameter of capillary tubes as well as Refrigerant Charge. The COP of the refrigeration system is obtained by using the calculation graphs and are as follows

1) COP of the refrigeration unit with 0.031 inch capillary tube diameter with 100g of Refrigerant Charge = 1.90
2) COP of the unit with 0.031 inch capillary tube diameter with 150g of Refrigerant Charge = 1.85
3) COP of the unit with 0.031 inch capillary tube diameter with 200g of Refrigerant Charge = 2.95
4) COP of the system with 0.036 inch capillary tube diameter with 100g of Refrigerant Charge = 1.87
5) COP of the unit with 0.036 inch capillary tube diameter with 150g of Refrigerant Charge = 2.61
6) COP of the refrigeration unit with 0.036 inch capillary tube diameter with 200g of Refrigerant Charge = 2.32
7) COP of the system with 0.042 inch capillary tube diameter with 100g of Refrigerant Charge = 3.22
8) COP of the refrigeration unit with 0.042 inch capillary tube diameter with 150g of Refrigerant Charge = 3.76
9) COP of the refrigeration unit with 0.042 inch capillary tube diameter with 200g of Refrigerant Charge = 3.28

The association among capillary tube diameter and chosen variables depicted in the subsequent figures.

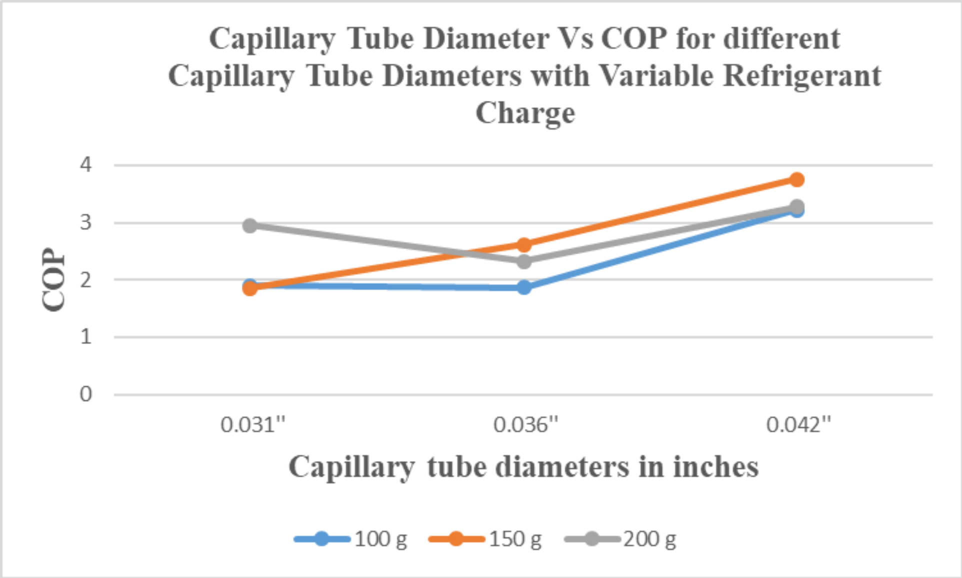

Fig. 4.1: Capillary Tube Diameter Vs COP for different Capillary Tube Diameters with Variable Refrigerant Charge.

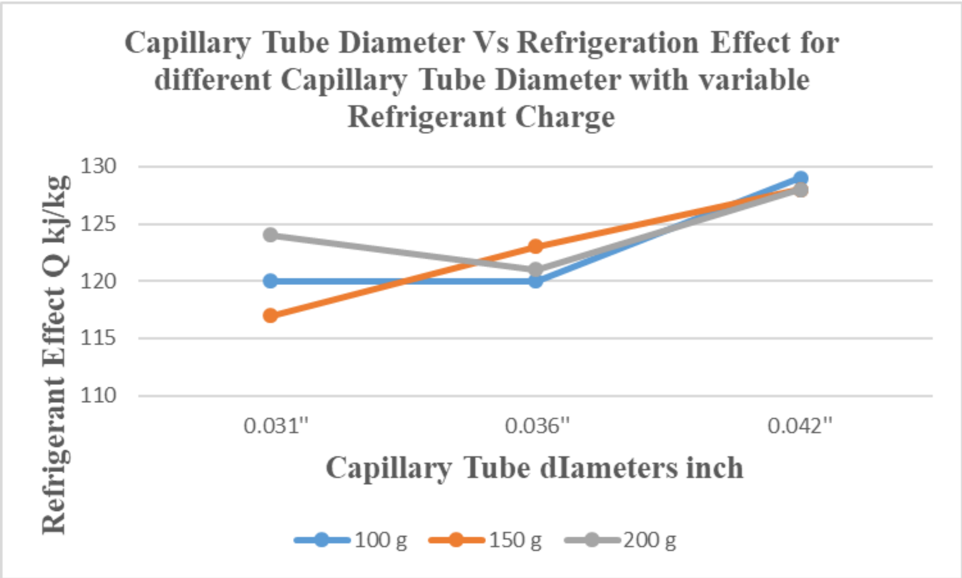

Fig. 4.2: Capillary Tube Diameter Vs Refrigeration Effect for different Capillary Tube Diameter with variable Refrigerant Charge.

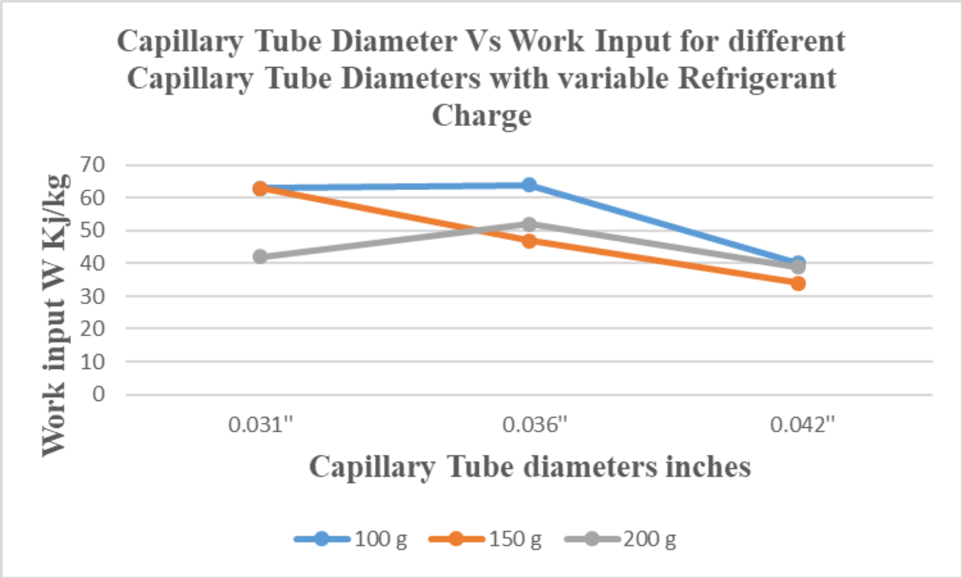

Fig. 4.3: Capillary Tube Diameter Vs Work Input for different Capillary Tube Diameters with variable Refrigerant Charge

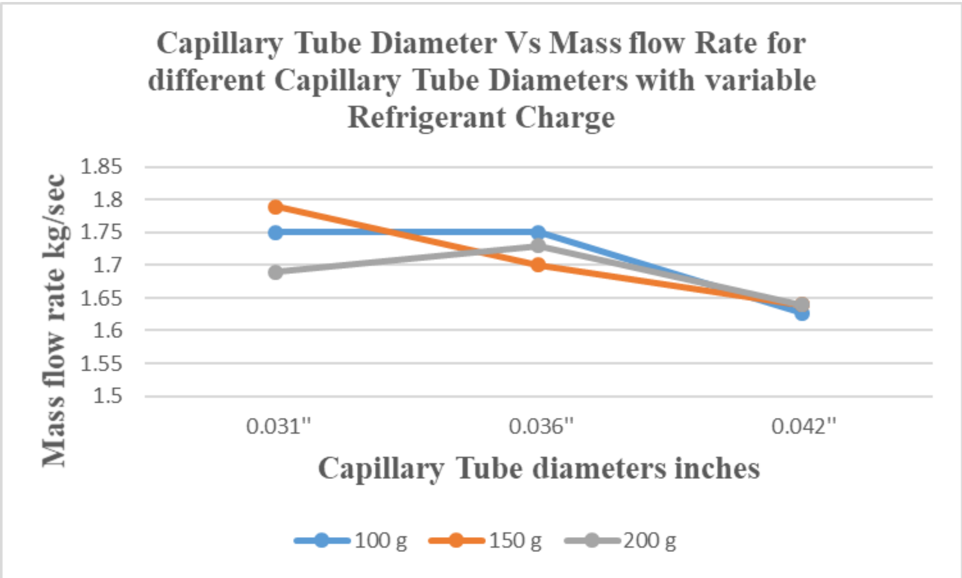

Fig. 4.4: Capillary Tube Diameter Vs Mass flow Rate for dissimilar Capillary-Tube Diameters with variable Refrigerant Charge.

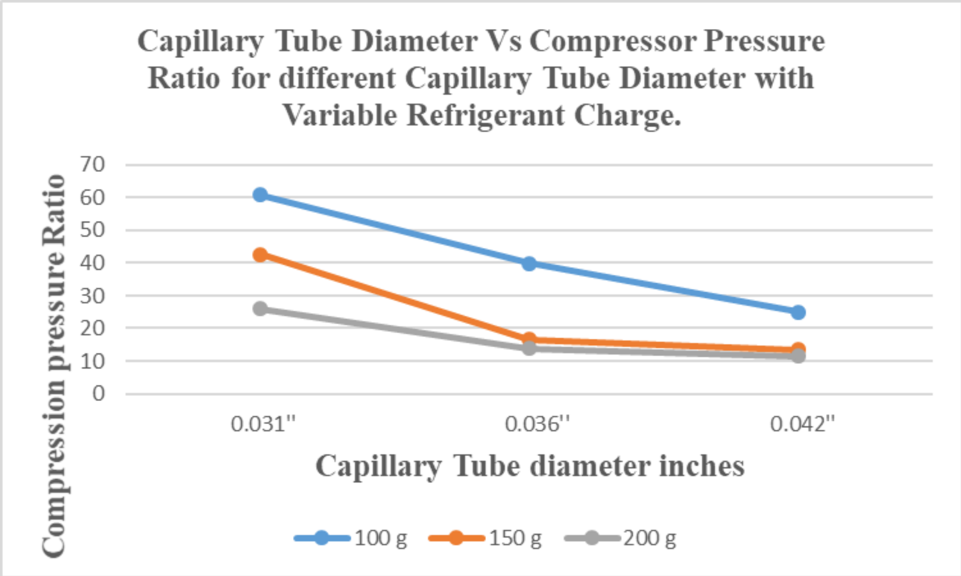

Fig. 4.5: Capillary Tube Diameter Vs Compressor Pressure Ratio for different Capillary Tube Diameter with Variable Refrigerant Charge.

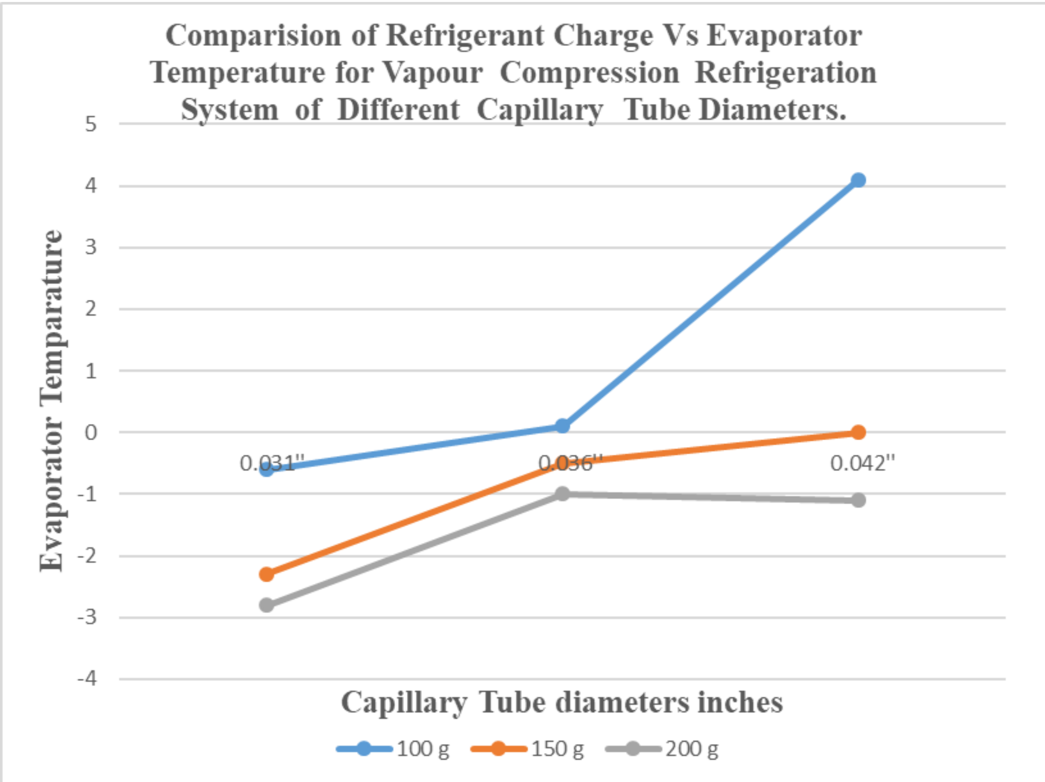

Fig. 4.6: Comparison of Refrigerant Charge Vs Evaporator Temperature for VCR unit of dissimilar Capillary-Tube Diameters.

5.CONCLUSION

From the above examinations, the subsequent outcomes are described

- By all graphs it is concluded that the refrigerant R134a with 150g of its charge that the VCR unit has the highest COP with the unit running on the capillary tube diameter of 0.042 inches.
- The best capillary tube used for the domestic single door refrigerator is of Inner Diameter (ID) 0.042 inches.

- The cooling effect gained by the system with the capillary tube diameter of 0.036 inches with 100g of refrigerant charge is more than the remaining ones.
- Mass flow rate of unit is observed highest in 0.036 inch diameter with 100g of Refrigerant.
- The Compressor-Pressure Ratio reduces as the diameter of capillary-tube raises.
- Compressor Pressure Ratio is highest for 0.031 inch diameter with 100g of Refrigerant.
- Enhancement of refrigerant charge reduces the evaporator temperature.
- Noteworthy development in refrigeration effect as the diameter of the Capillary-tube raises.

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