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EXPERIMENTAL ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM WITH ACCUMULATOR & 2-DIFFERENT DIAMETER CAPILLARY TUBES

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Abstract

This project focuses on the Experimental analysis of vapour compression refrigeration system with accumulator and 2-different diameters capillary tubes 3.1(0.36 ID x 0.83 OD) & 3.6(0.36 ID x 0.87 OD). To express the project a domestic refrigerating unit is selected.

Majority of the refrigerators works on the vapour compression refrigeration system. The system mainly considers the components like compressor, condenser, expansion valve, capillary-tube and evaporator. The pressure gauges and temperature indicate joints are integrated with the system at appropriate positions. The performance of the system depends upon the performance of all the components of the system, including the accumulator also.

The main objective in the present work is to verify the performance of a domestic refrigerator of capacity 165ltr, R-134a as refrigerant, hermetic sealed compressor, accumulator and 2-different diameters capillary tubes (3.1 & 3.6) Condenser coil. This new system is compare with the existing system.

And also the addition of accumulator to vapour compression refrigeration system hence always Dry Compression will takes place and with this the life of compressor can be increased, with same power input to the compressor.

The project describes the simple technology of making the test rig of domestic refrigerator. An attempt is made to verify the performance of the system.

Index Terms – Hermetically sealed compressor, Wire and tube air cooled condenser, Filter, Capillary tube, Evaporator, Purpose and Design of accumulator, Selection of suction accumulator, Internal substance – Refrigerant, Pressure gauges, Temperature indicated joints, Digital thermometer, Plywood, Connections, etc .

I. INTRODUCTION

The term refrigeration may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. In other words, the refrigeration means a continued extraction of heat from a body whose temperature is already below the temperature of its surroundings. Removal of heat from a body at lower temperature is possible only with the aid of external agency according to the second law of thermodynamic.

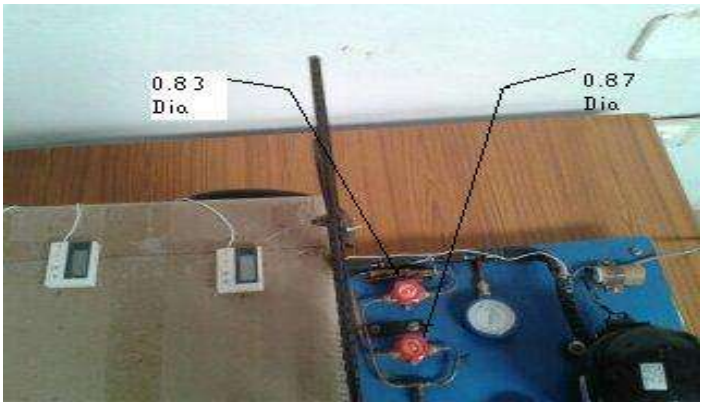
Vapour-compression refrigeration is one of the many refrigeration cycles and is the most widely used method for air-conditioning of buildings and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated 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 vapour-compression refrigeration systems.

EXPANSION DEVICE

The expansion device (also known as metering device or throttling device) is a important device that divides the high pressure side and low pressure side of refrigeration system, it is incorporated between receiver and the evaporator (if receiver not used in the system, the expansion device is introduced between condenser and evaporator). It is usual practice proved a filter and drier before the expansion device in order to prevent contaminants clogging the refrigerant flow passage. The expansion device performs the following functions:

1. It reduces the high pressure liquid refrigerant to low pressure refrigerant before being fed to the evaporator.
2. It maintains the desired pressure difference between the high and low pressure sides of the system, so that the liquid refrigerant vaporizes at the designed pressure in the evaporator.
3. It controls the flow of refrigerant according to the load on the evaporator.

CAPILLARY TUBE

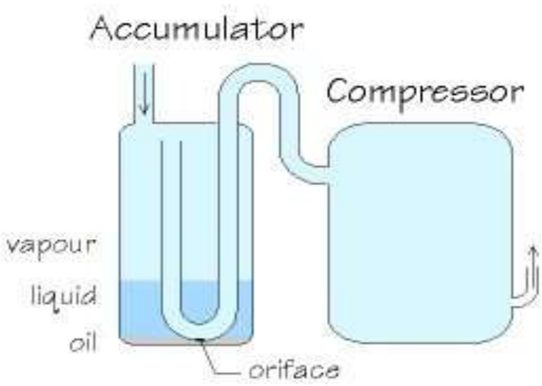


Capillary tubes

The capillary tube is used as an expansion device in small capacity hermetic sealed refrigeration units such as in domestic refrigerators, water coolers, room air-conditioners, especially in small capacity installations. It is a copper tube of small internal diameter and of varying length depending upon the application. The inside diameter of the tube used in refrigeration work is generally about 0.5 mm to 2.25mm and the length varies from 0.5 m to 5 m. it is installed in the liquid line between the condenser and the evaporator. A fine mesh is provided at the inlet of the tube in order to protect it from contaminants.

In its operation, the liquid refrigerant from the condenser enters the capillary tube. Due to the frictional resistance offered by a small diameter tube, the pressure drops, since the frictional resistance offered by a small diameter tube, the pressure inversely proportional to the diameter, therefore longer the capillary tube and smaller its inside diameter, greater is the pressure drop created in the refrigerant flow, in other words, greater pressure difference between the condenser and evaporator is needed for a given flow rate of the refrigerant. The diameter and length of the capillary tube once selected for a given set of conditions and load cannot operated efficiently at other conditions

PURPOSE OF ACCUMULATOR



Suction accumulator

Installed accumulator in test rig

The refrigeration compressor is designed to compress vapour only. A suction line accumulator prevents compressor damage from a sudden surge of liquid refrigerant and oil which could enter the compressor from the suction line. The suction line accumulator is a temporary reservoir for this mixture, designed to meter both the liquid refrigerant and oil back to the compressor at an acceptable rate. This prevents damage to the reed valves, pistons, rods and crank shaft.

Pressure gauges:

(a) High pressure gauge (b) Low pressure gauge

We placed pressure gauges at suction and discharge of the compressor. In the above fig. the red one is the high pressure gauge placed at discharge and the other (blue) is the low pressure gauge placed at suction

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II. BACKGROUND INFORMATION

Modified VCR system with capillary tube diameters (3.1&3.6)

Instead of an orifice, a length of a small diameter tube can offer the restrictive effect like expansion. Small diameter tubing is called 'capillary tube', meaning 'hair-like'. The inside diameter of the capillary used in refrigeration is generally about 0.5 to 2.28 mm (0.020 to 0.090'). The longer the capillary tube and or the smaller the inside diameter of the tube, greater is the pressure drop it can create in the refrigerant flow; or in other words, greater will be the pressure difference needed between the high side and low side to establish a given flow rate of the refrigerant.

Specifications	**Existing VCR system**	**Modified VCR system with capillary diameters (3.1&3.6)**	
		3.1(0.361IDx0.83OD)	**3.6(0.36IDx0.87OD)**
Refrigerant used:	134a	134a	134a
Capacity of the refrigerator:	165 lts	165 lts	165 lts
Compressor capacity:	0.14 H.P.	0.14 H.P.	0.14 H.P.
Capillary tube dimensions			
Length:	2428 mm	2428 mm	2428 mm
Diameter:	0.80 mm	0.83 mm	0.87 mm

READINGS & CALCULATIONS

Existing VCR system:

Suction temperature T_1	20°C
Discharge temperature T_2	50°C
Condenser coil out temperature T_3	35°C
Evaporator coil temperature T_4	-8.3°C

From the PH-chart (R-134a)

h_1=394 KJ/Kg h_3=270 KJ/Kg

h_2=426 KJ/Kg h_4=270 KJ/Kg

1. Coefficient of performance = $\frac{Refrigerant\ effect}{work\ done}$

Refrigerant effect (R.E) $= h_1 - h_{f3}$ (or) $h_1 - h_4$

= 394-270 = 124 KJ/Kg

Work done (W) $= h_2 - h_1$

= 426-394

= 32 KJ/Kg

∴ Coefficient of performance $= \frac{h1 - hf3}{h2 - h1} = \frac{124}{32}$

∴ C.O.P = 3.80

2. Mass flow rate to obtain one TR, (m_r) = $\frac{210}{Refrigerating\ effect}$

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$= \frac{210}{394-270} = 1.69$ Kg/min

3. Heat equivalent of work of compression per TR = m_r X (h_2- h_1)
= 1.69 X (426-394)
= 54.19 KJ/Kg

4. Heat to be rejected in condenser = h_2- h_3
= 426-270
= 156 KJ/Kg

Modified VCR system with accumulator & 3.1 (0.361IDx0.83OD) capillary tube diameters with load 1kg:

Suction temperature T_1	3.9°C
Discharge temperature T_2	53.5°C
Condenser coil out temperature T_3	46.3°C
Evaporator coil temperature T_4	-14.2°C

From the PH-chart (R-134a)

h_1= 393KJ/Kg h_3= hf3=260.6KJ/Kg
h_2= 417.8KJ/Kg h_4= 260.6KJ/Kg

1. Coefficient of performance = $\frac{Refrigerant\ effect}{work\ done}$

Refrigerant effect (R.E) = h_1- h_{f3} (or) h_1- h_4
= 393-260.6
= 132.4 KJ/Kg

Work done (W) = h_2- h_1
= 417.8-393
= 24.8 KJ/Kg

∴ Coefficient of performance $= \frac{h1-hf3}{h2-h1}$

$= \frac{132.4}{24.8}$

∴ C.O.P = 5.51

2. Mass flow rate to obtain one TR, (m_r) $= \frac{210}{Refrigerating\ effect}$

$= \frac{210}{393-260.6}$

= 210/132.4
= 1.58 Kg/min

3. Heat equivalent of work of compression per TR = m_r X (h_2- h_1)
= 1.58 X (417.8-393)
= 39.33 KJ/Kg

4. Heat to be rejected in condenser = h_2- h_3

= 417.8-260.6
= 157.2KJ/Kg

Modified VCR system with accumulator & 3.6 (0.36IDx0.87OD) capillary tube diameters with load 1kg:

Suction temperature T1	4°C
Discharge temperature T2	53.7°C
Condenser coil out temperature T3	47°C
Evaporator coil temperature T4	-13°C

From the PH-chart (R-134a)

h1=391KJ/Kg h3=262KJ/Kg
h2=416KJ/Kg h4=262KJ/Kg

1. Coefficient of performance $= \frac{\text{Refrigerant effect}}{\text{work done}}$

Refrigerant effect (R.E) $= h_1 - h_{f3}$ (or) $h_1 - h_4$
= 391-262
= 129KJ/Kg

Work done (W) $= h_2 - h_1$
= 416-391
= 25 KJ/Kg

∴ Coefficient of performance $= \frac{h1 - hf3}{h2 - h1} = \frac{391 - 262}{416 - 391}$

∴ C.O.P = 129/25 =5.16

2. Mass flow rate to obtain one TR, (m_r) $= \frac{210}{\text{Refrigerating effect}}$

$= \frac{210}{391 - 262}$

= 1.62 Kg/min

3. Heat equivalent of work of compression per TR = m_r X ($h_2 - h_1$)
= 1.62X (416-391)
= 40.69 KJ/Kg

4. Heat to be rejected in condenser = $h_2 - h_3$
= 416-26 = 154KJ/Kg

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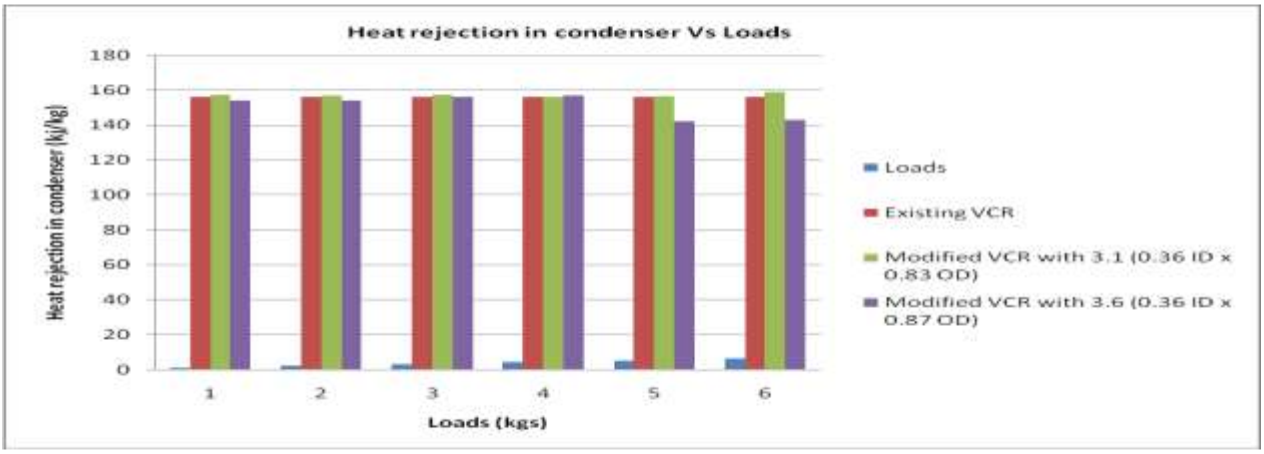
Tabular column.1: Comparing the Loads Vs Heat rejection in condenser of Existing VCR system and Modified VCR system with capillary tube diameters (3.1&3.6)

Loads	Existing VCR	Modified VCR with 3.1 (0.36 ID x 0.83 OD)	Modified VCR with 3.6 (0.36 ID x 0.87 OD)
1.	156	157.2	154
2.	156	157	154
3.	156	157.52	156
4.	156	156	157
5.	156	156.5	142
6.	156	159	143

Graph1.Comparing Loads Vs Heat rejection in condenser of Existing VCR system and Modified VCR system with capillary diameters (3.1&3.6)



Tabular column.2: Comparing the Loads Vs Net Refrigerating Effect of Existing VCR system and Modified VCR system with capillary tube diameters (3.1&3.6)

Loads	Existing VCR	Modified VCR with 3.1 (0.36 ID x 0.83 OD)	Modified VCR with 3.6 (0.36 ID x 0.87 OD)
1.	124	132.4	129
2.	124	132.5	132
3.	124	132.52	130
4.	124	130	130
5.	124	130	117
6.	124	130.4	117

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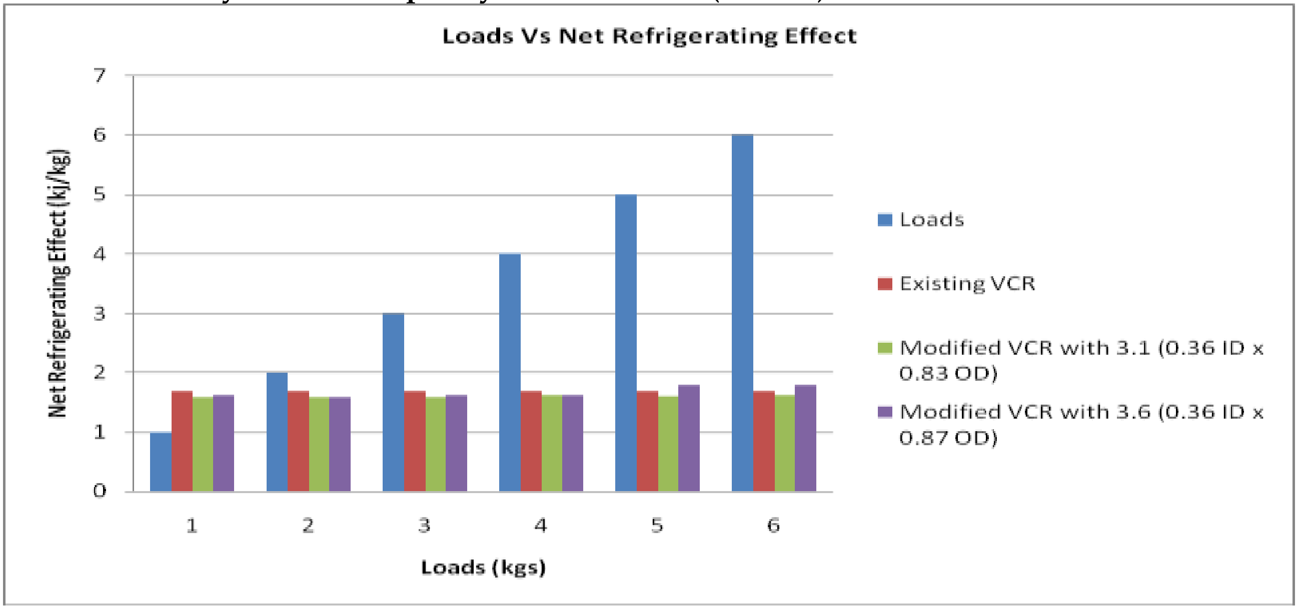
Graph.2 Comparing the Loads Vs Net Refrigerating Effect of Existing VCR system and Modified VCR system with capillary tube diameters (3.1&3.6)



Tabular column.3: Comparing the Loads Vs Mass flow rate of Existing VCR system and Modified VCR system with capillary tube diameters (3.1&3.6)

Loads	Existing VCR	Modified VCR with 3.1 (0.36 ID x 0.83 OD)	Modified VCR with 3.6 (0.36 ID x 0.87 OD)
1.	1.69	1.58	1.62
2.	1.69	1.58	1.59
3.	1.69	1.58	1.61
4.	1.69	1.61	1.61
5.	1.69	1.60	1.79
6.	1.69	1.61	1.79

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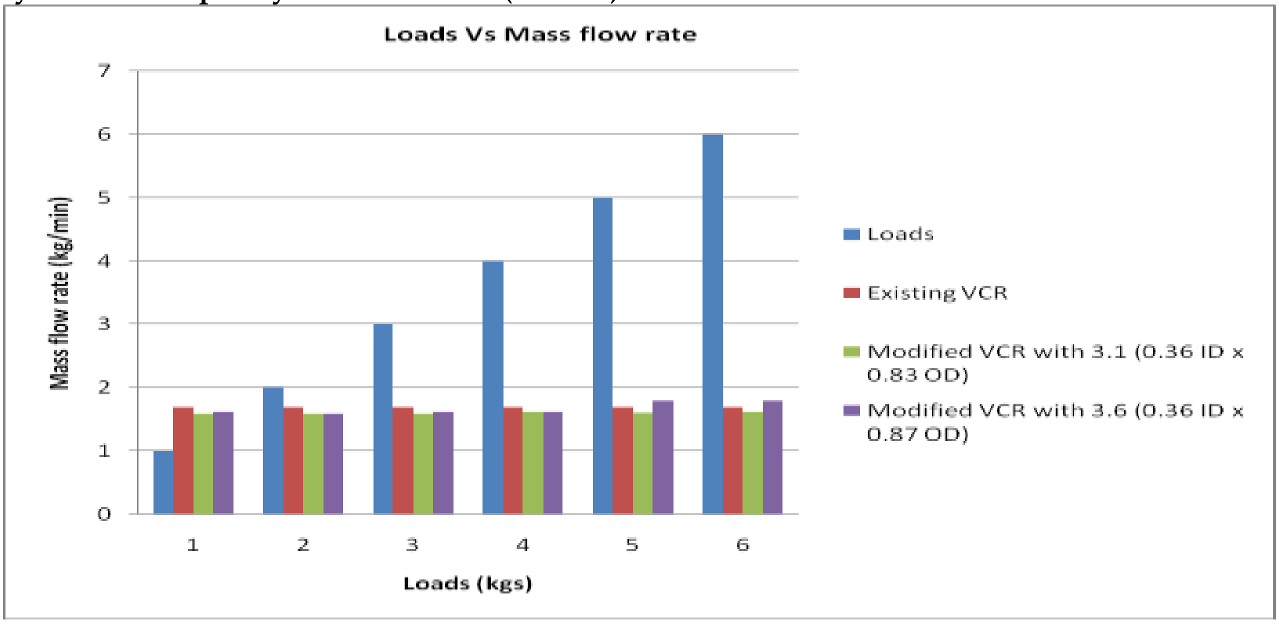
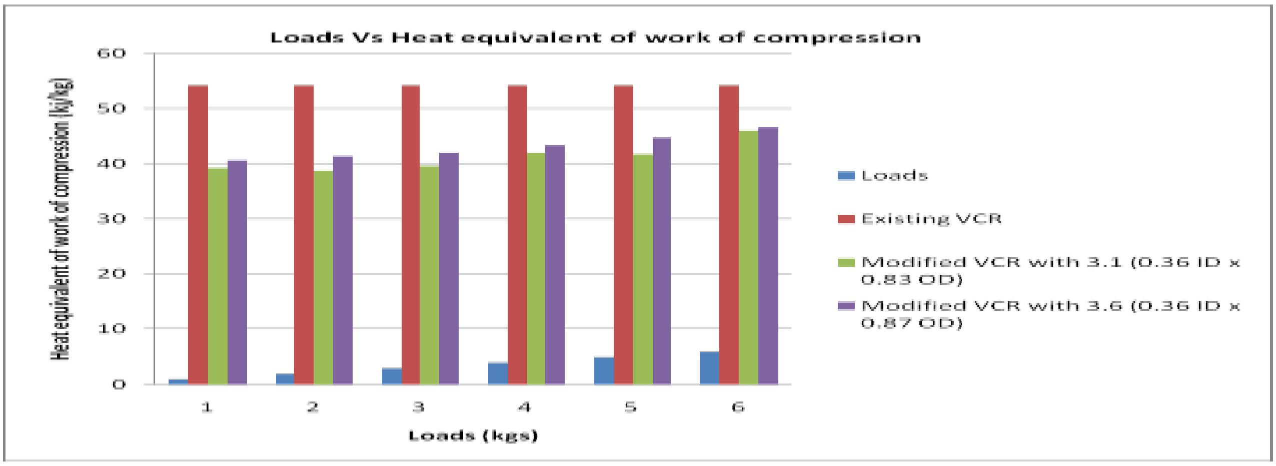
Graph.3 Comparing the Loads Vs Mass flow rate of Existing VCR system and Modified VCR system with capillary tube diameters (3.1&3.6)



Tabular column.4: Comparing the Loads Vs Heat equivalent of work of compression of Existing VCR system and Modified VCR system with capillary tube diameters (3.1&3.6)

Loads	Existing VCR	Modified VCR with 3.1 (0.36 ID x 0.83 OD)	Modified VCR with 3.6 (0.36 ID x 0.87 OD)
1.	54.19	39.33	40.69
2.	54.19	38.83	41.36
3.	54.19	39.61	42
4.	54.19	42	43.47
5.	54.19	41.83	44.87
6.	54.19	46.06	46.66

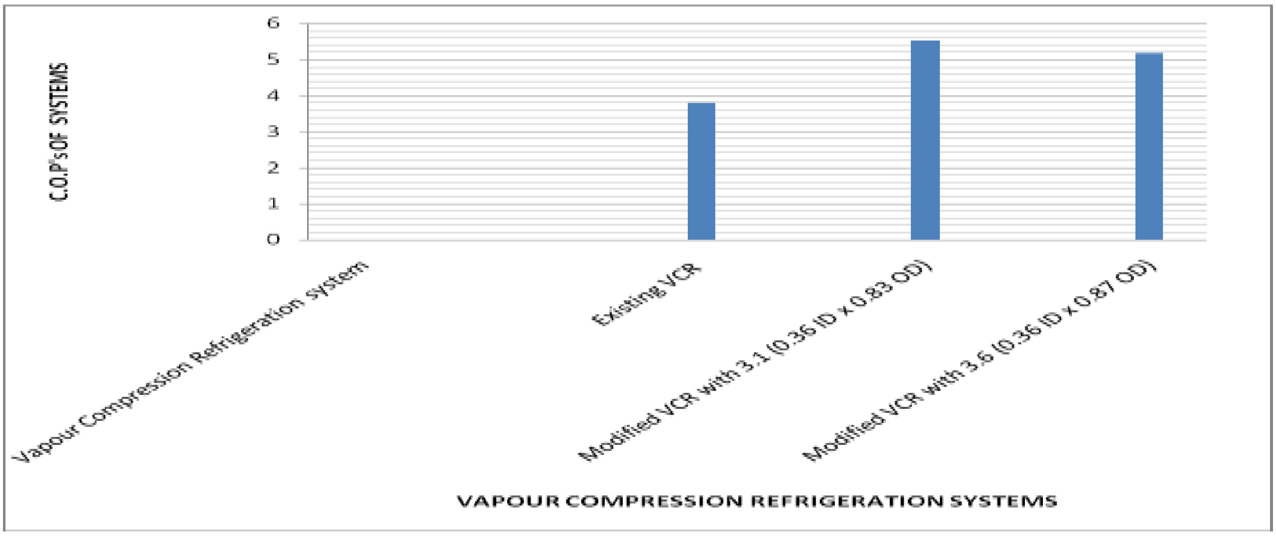
Graph.4 Comparing the Loads Vs Heat equivalent to work of compression of Existing VCR system and Modified VCR system with capillary tube diameters (3.1&3.6)



Comparing the C.O.P of Existing VCR system and Modified VCR system with capillary tube diameters (3.1&3.6)

Vapour Compression Refrigeration system	C.O.P's
Existing VCR	3.80
Modified VCR with 3.1 (0.36 ID x 0.83 OD)	5.51
Modified VCR with 3.6 (0.36 ID x 0.87 OD)	5.16

Graph.5 Comparing the C.O.P of Existing VCR system and Modified VCR system with capillary diameters (3.1&3.6)



III. CONCLUSION

From the above experimental analysis of vapour compression refrigeration system with accumulator and 2-different diameter capillary tubes (3.1&3.6), we are concluded that the Net refrigerating effect, Co-efficient of performance, Mass flow rate of refrigerant, Heat equivalent of work of compression, Heat rejected in the condenser is considered as Optimum for the capillary tube diameter 3.1 (0.36 ID x 0.83 OD) in vapour compression refrigeration system with additional component as accumulator.

From the above experimental analysis of vapour compression refrigeration system with accumulator we also concluded that with the use of accumulator hence always Dry Compression will takes place in the compressor, which increases the life of compressor.

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