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EFFECT OF DIFFERNET CAPILLARY TUBE DIAMETERS & LENGTHS ON THE PERFORMANCE OF VCR SYSTEM USING R-600A AND HC MIXTURE AS WORKING MEDIUM

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Abstract:** The performance of heat transfer is one of the most important research areas in the field of Refrigeration. There are a large number of refrigerants, which are used to transfer heat from low temperature reservoir to high temperature reservoir by using vapor compression refrigeration system. There are various obstacles faced in working of different refrigerants due to their environmental impact (R11, R12), toxic(NH3)and high pressure (CO2) which makes them more hazardous than other working fluids according to safety and environmental issues. The performance of different environmental friendly refrigerants and their mixtures of Hydrocarbons & R-600a as refrigerant. This seems to be need of new efficient, minimum global warming potential (GWP), minimum ozone depletion potential (ODP) and environmental friendly nature refrigerants. This project deals on performance analysis of an alternative eco-friendly refrigerants R-600a & Hydrocarbon Mixtures which reduced Global Warming Potential (GWP) and Ozone Depletion Potential (ODP).The performance characteristics of the VCR System were predicted using continuous running tests under different ambient temperatures and cyclic running (On/Off) tests at the fixed temperatures i.e., evaporation temperature (-5˚C) and condensation temperature (30˚C).And also This project will deals with different diameters of capillary tube to analyze the performance.

***Keywords:** Vapour Compression Refrigeration system (VCRS), Refrigerants, COP, ODP, GWP*

1. INTRODUCTION

Refrigerator is one of the home appliance utilizing mechanical vapor compression cycle in it process. The Vapor Compression Refrigeration Cycle is a process that cools an enclosed space to a temperature lower than the surroundings. To accomplish this, heat must be removed from the enclosed space and dissipated into the surroundings. However, heat tends to flow from an area of high temperature to that of a lower temperature. Figure (1) shows an ideal single-stage vapor compression refrigeration cycle in which compression occurs in the superheated region. Many investigators have reported that GWP of HFC refrigerants is more significant even though it has less than that of chlorofluorocarbons (CFC) refrigerants. HCFCs (hydro chlorofluorocarbons) and CFCs (chlorofluocarbons) have been applied extensively as refrigerants in air conditioning and refrigeration systems from 1930s as a result of their outstanding safety properties. However, due to harmful impact on ozone layer, by the year 1987 at Montreal Protocol it was decided to establish requirements that initiated the worldwide phase out of CFCs. By the year 1992, the Montreal Protocol was improved to found a schedule in order to phase out the HCFCs. Moreover in 1997 at Kyoto Protocol it was expressed that concentration of greenhouse gases in the atmosphere should be established in a level which is not intensifying global warming ozone layer. Subsequently it was decided to decrease global warming by reduction of greenhouse gases emissions.

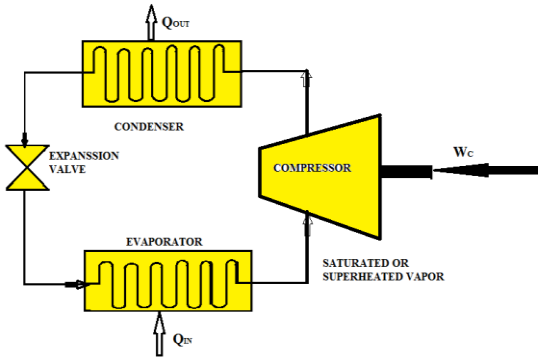


Fig1-Basic VCR system

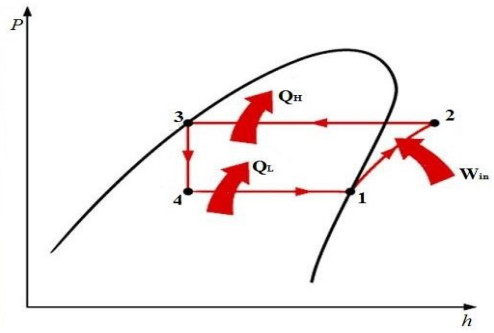


Fig2-ph chart of VCR system

2. LITERATURE REVIEW

Literature Review gives an insight into the developments in the field of study and helps to identify the problems, techniques and methodologies to be adapted. **Mohd.Aasim, Nazeer Ahmad, et.al [1]** Investigated an experimental study of isobutene (R-600a), an environment friendly refrigerants with zero ozone depletion potential (ODP) and very low global warming potential (GWP), to replace R-134a in domestic refrigerators. The experimental results showed that R-600a can be used as replacement for R-134a in domestic refrigerator. Hence, it can be concluded that R-600a can be used as a replacement to R-134a with better performance lesser energy consumption, pull down time and ON time ratio. **Eric Granryd [2],** has enlisted the different hydrocarbons as working medium in refrigeration system. He studied the different safety standards related to these refrigerants. He showed the properties of hydrocarbons (i.e. no ODP and negligible GWP) that make them interesting refrigerating alternatives for energy efficient and environmentally friendly. But safety precautions due to flammability must be seriously taken into account. **Samira Benhadid-Dib and Ahmed Benzaoui [3**], have showed that the uses of halogenated refrigerants are harmful for environment and the use of "natural" refrigerants become a possible solution. Here natural refrigerants are used as an alternative solution to replace halogenated refrigerants. The solution to the environmental impacts of refrigerant gases by a gas which contains no chlorine no fluorine and does not reject any CO_2 emissions in the atmosphere. The researchers showed that emissions have bad effects on our environment. They also concerned by a contribution to the reduction of greenhouse gases and by the replacement of the polluting cooling fluids (HCFC). Most of the investigations are mentioned that R-134a, R-12, R-22 are much global warming & ozone depletion for that it is better to take zero ozone depletion & global warming for that sake hydrocarbons & R-600a are using to check the performance in this project.

3 OBJECTIVE

The main objective of this are given below,

1) In the present work The capillary tubes of different diameters & lengths such as **0.775mm, 0.9mm, 1mm & 3.8m, 3.6m, 3.4m** are used in the domestic refrigerator.
2) By each capillary tube finding the performance of coefficient of performance& Energy consumption valves at load & without load conditions
3) In finding the performance refrigerants are using R-600a & Hydrocarbon to reduce the global warming potential & ozone depletion layer

4. EXPERIMENTAL SETUP

A conventional household refrigerator generally uses the capillary tube of diameters 0.9mm & 3.6m but in this experiment adding one small diameter ,more length & one large diameter, small length is using compared with regular capillary tube to find the performance.

Fig 3 Experimental setup of refrigeration system after using different capillary tube daimeters

Capillary Tube:

Capillary tube is one of the most commonly used throttling devices in the refrigeration and the air conditioning systems. The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration and air conditioning applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inches). Capillary tube used as the throttling device in the domestic refrigerators, deep freezers, water coolers and air conditioners. When the refrigerant leaves the condenser and enters the capillary tube its pressure drops down suddenly due to very small diameter of the capillary. In capillary the fall in pressure of the refrigerant takes place not due to the orifice but due to the small opening of the capillary. The decrease in pressure of the refrigerant through the capillary depends on the diameter of the capillary and the length of the capillary. Smaller is the diameter and more is the length of the capillary more is the drop in pressure of the refrigerant as it passes through it.

1. Refrigerant used	:	R-600a, Hydrocarbons
2. Capacity of refrigerator	:	195Liters
3. Compressor Capacity	:	0.14 HP
4. Condenser Sizes	:	
Length	--	8.5m
Diameter	--	6.5mm
5. Capillary Tube	:	
Length	--	3.6m
Diameter	--	0.9mm
Length	--	3.8m
Diameter	--	0.775mm
Length	--	3.4m
Diameter	--	1.00mm
6. Evaporator		
Length	--	7.62m
Diameter	--	6.5mm

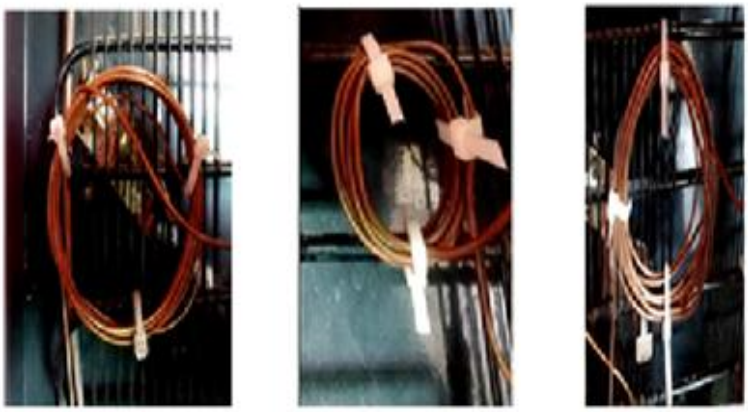


Fig4: Different diameters and lengths of capillary tube

Refrigerants:

R-600a or isobutene:

R600a or isobutane is a possible replacement of other refrigerants, which have high impact on the environment, in domestic refrigerators. It has zero ozone depletion potential ODP and a negligable global warming potential GWP. Because of the availability of isobutene R600a is a possible refrigerant for this application, with good energy efficiency, but with a very different characteristic in several points, which implies the design to be made or adopted for this refrigerant. Special care has to be taken to the flammability of isobutane.

Hydrocarbon mixture:

Alternative to HFC refrigerants can be HC (Hydrocarbon) as there is no fluorine content. Hydrocarbons (HCs) are the class of natural occurring substances that include propane and isobutane.. HCs are excellent refrigerants in many ways energy efficiency, critical point, solubility, transport, heat transfer properties and environmentally sound but their major concern is their flammability. Propane (R-290) and isobutane (R-600a), among other hydrocarbons, can be used as refrigerants in the vapor compression process. In Northern Europe, about 35% of refrigerators are based on hydrocarbons. HCs are excellent refrigerants in many ways energy efficiency, critical point, solubility, transport, heat transfer properties and low toxicity, good efficiency but their major concern is their flammability.
The properties of both refrigerants are R-600a & Hydrocarbon are given in below

5. RESULTS AND DISCUSSIONS

Tabular column for R-600a at no load condition for 0.775mm capillary tube diameter

S.no.	Time (in min)	Pressure (psi)		Evaporator Temperature	Temperature (^{0}C)			Energy Consumption(kWh)
		P_s	P_d	T_e	T_1	T_2	T_3	
1	0	11	30	30	31.6	32.1	31.5	4392
2	1.05	11	65	25	31.1	32.6	31.9	4392.01
3	2.27	10	70	20	30.4	33.2	32.5	4392.01
4	3.32	10	70	15	30.1	33.7	33.1	4392.02
5	5.05	10	85	10	29.8	34.2	33.9	4392.03
6	6.57	9	85	7	29.6	34.5	34.2	4392.04
7	8.35	9	90	5	29.2	35.3	34.7	4392.05
8	10.32	9	90	0	28.9	35.9	35.1	4392.06
9	25.38	9	90	-5	28.5	36.1	35.6	4392.07

Compressor Suction Pressure P_s = 9 psi

Compressor Discharge Pressure P_d = 90 psi

Compressor Inlet Temperature T_1 = 28.5^{0}C

Compressor Outlet Temperature T_2 = 36.1^{0}C

Condenser Outlet Temperature T_3 = 35.6 ^{0}C

Power consumption P = 0.07kWh

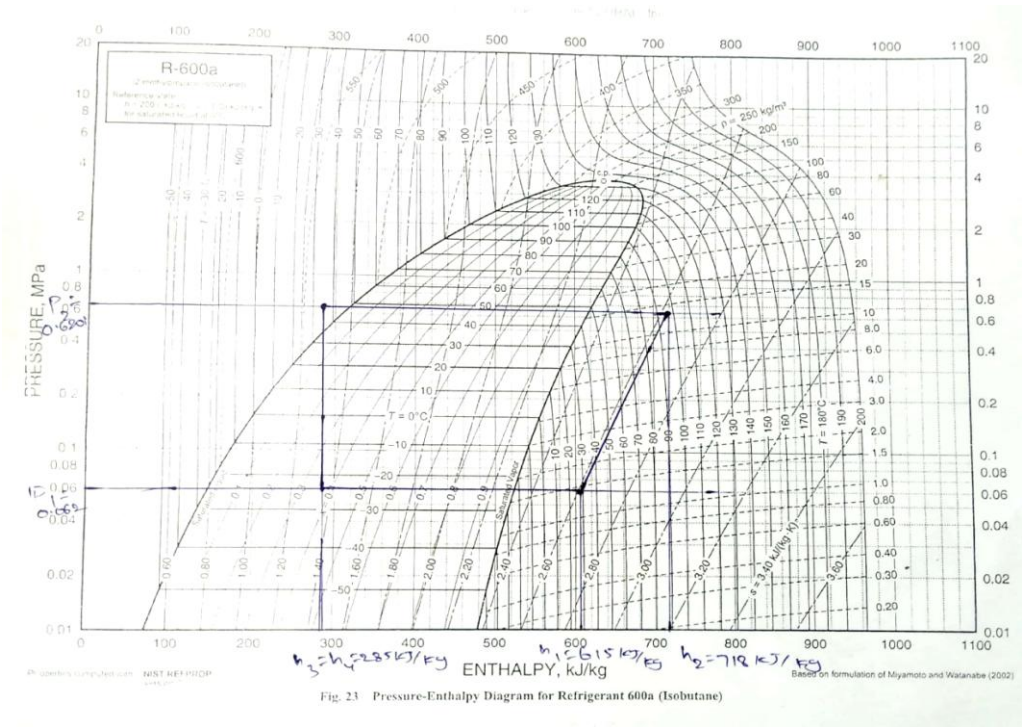


Fig. 23 Pressure-Enthalpy Diagram for Refrigerant 600a (Isobutane)

From p-h chart of R-600a Enthalpy values of 0.775mm are:

h_1 = 609kJ/kg

h_2 = 710 kJ/kg

h_3 = h_4 = 295 kJ/kg

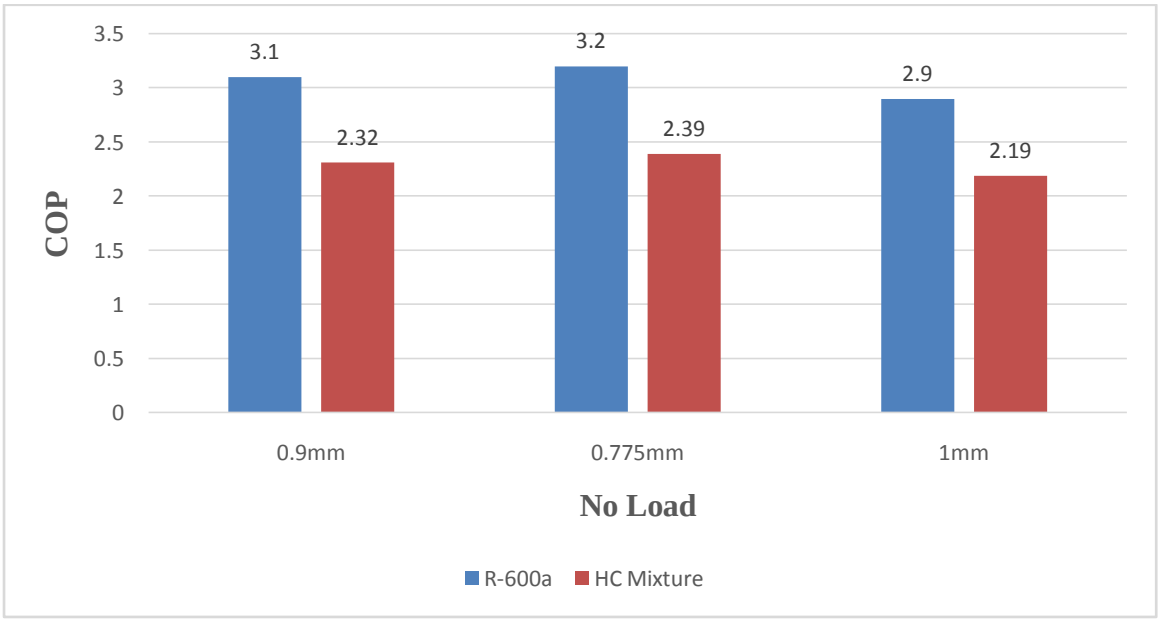
Performance Parameters:

Net Refrigerating Effect (NRE) = $h_1 - h_4$ = 615-285 =330kJ/kg

Work of Compression (W) = $h_2 - h_1$ = 718-615 =103 kJ/kg

Coefficient of Performance (COP) = NRE / W = 330 / 103 = 3.20

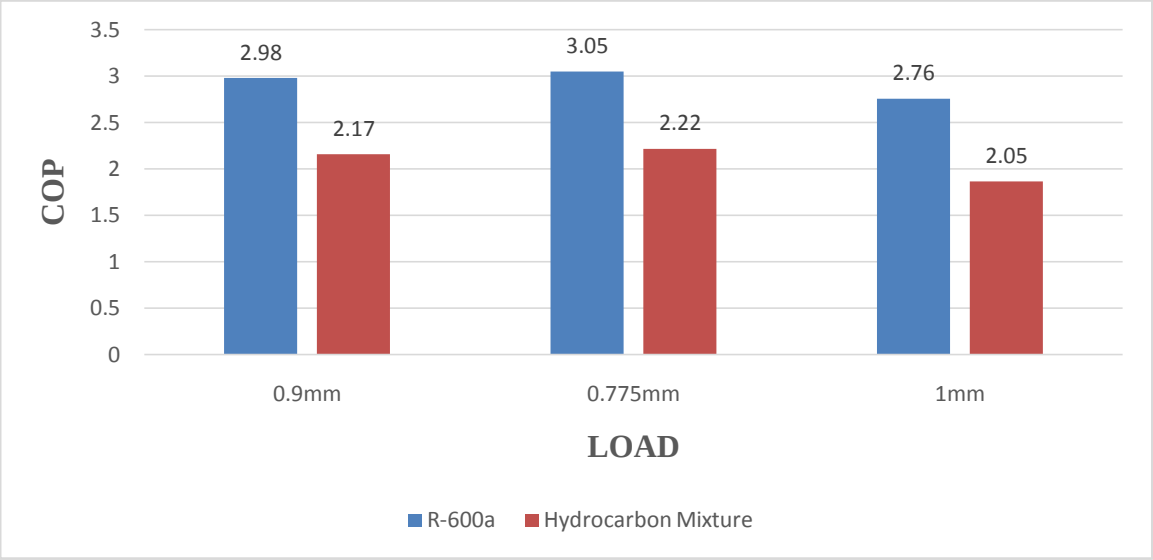
All below coefficient of valves are done by doing above procedure by taking readings at -5^0 C



Graph 5.1: COP values of R-600a & Hydrocarbon for different capillary diameters at no load condition

From above graph it is observed that,

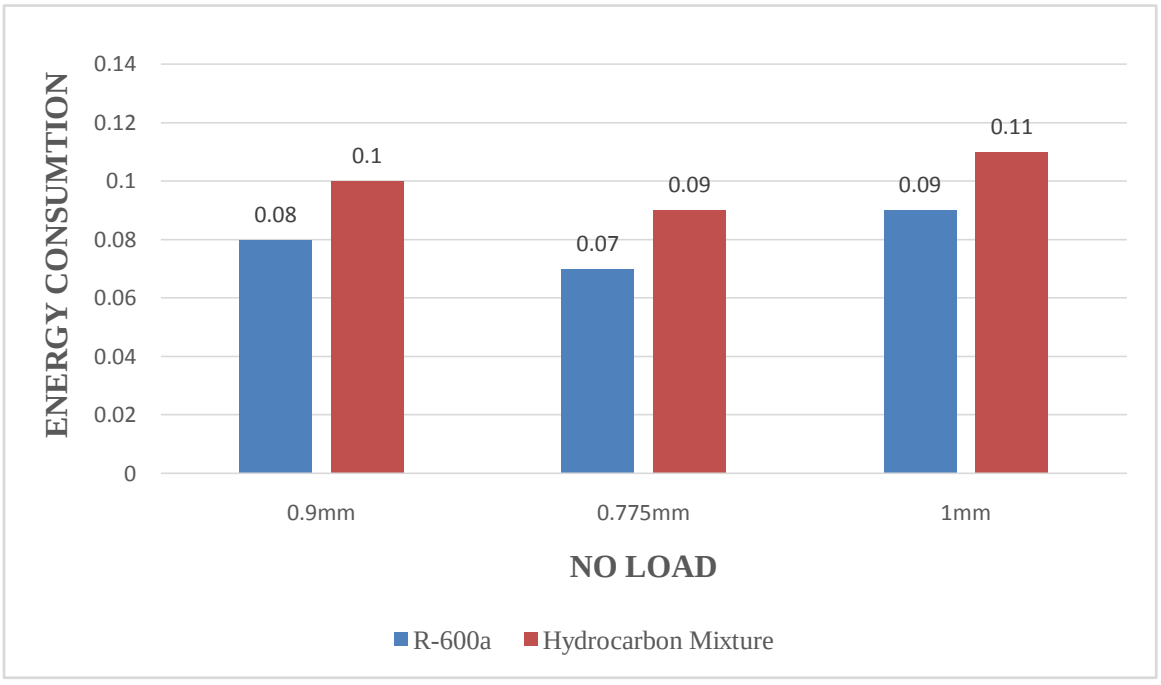
- COP of refrigerator with capillary diameter 0.775mm is higher when compared to 0.9mm & 1mm at no load condition by 3.22% and 10.34% respectively at R-600a.
- COP of refrigerator with capillary diameter 0.775mm is higher when compared to 0.9mm & 1mm at no load condition by 3.01% and 9.13% respectively at Hydrocarbon mixture.
- COP of R-600a Refrigerant has 33.6% higher than the Hydrocarbon at 0.9mm.
- COP of R-600a Refrigerant has 33.8% higher than the Hydrocarbon at 0.775mm.
- COP of R-600a Refrigerant has 32.42% higher than the Hydrocarbon at 1mm.



Graph 5.2: COP values of R-600a & Hydrocarbon for different capillary diameters at load condition

From above graph 5.2 it is observed that,

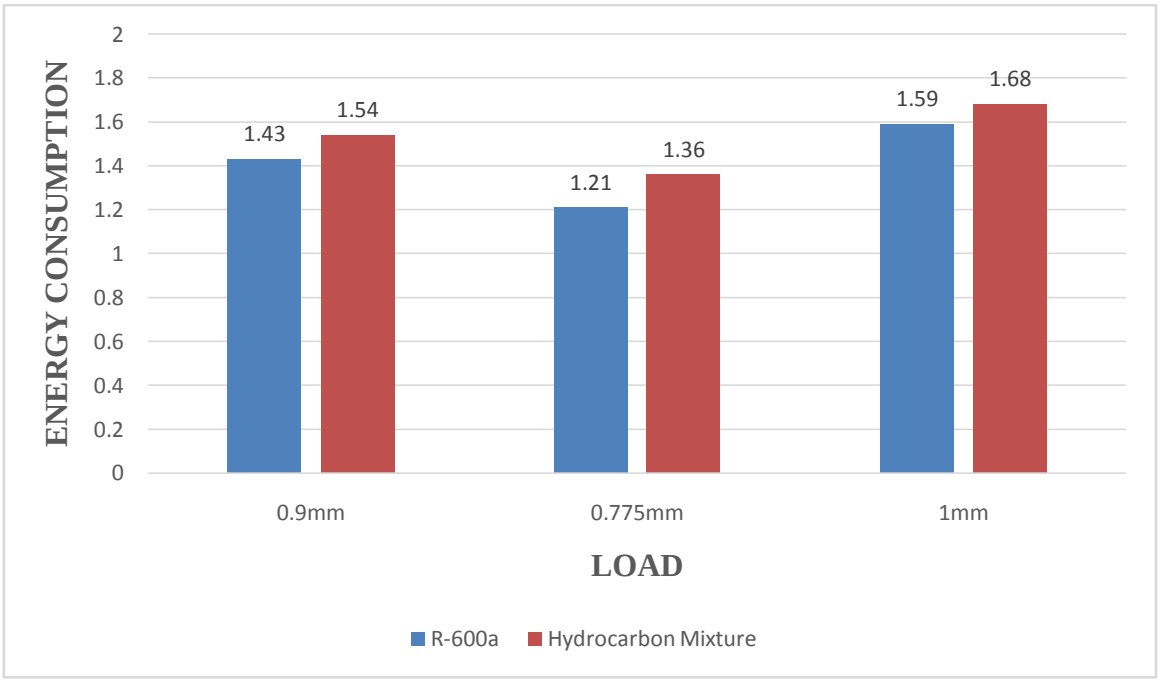
- COP of refrigerator with capillary diameter 0.775mm is higher when compared to 0.9mm & 1mm at no load condition by 2.34% and 10.50% respectively at R-600a.
- COP of refrigerator with capillary diameter 0.775mm is higher when compared to 0.9mm & 1mm at no load condition by 2.30% and 8.29% respectively at Hydrocarbon mixture.
- COP of R-600a Refrigerant has 37.96% higher than the Hydrocarbon at 0.9mm.
- COP of R-600a Refrigerant has 37.38% higher than the Hydrocarbon at 0.775mm.
- COP of R-600a Refrigerant has 35.96% higher than the Hydrocarbon at 1mm.



Graph 5.3: Energy Consumption values of R-600a & Hydrocarbon for different capillary diameters at no load condition

From above graph it is observed that,

- Energy consumption at no load for the capillary diameter 0.775mm is decreased when compared to 0.9mm & 1mm by 12.5% & 22.2% at R-600a.
- Energy consumption at no load for the capillary diameter 0.775mm is decreased when compared to 0.9mm & 1mm by 10% & 18.18% at R-600a.
- Energy consumption of R-600a Refrigerant has 20% decreased than the Hydrocarbon at 0.9mm.
- Energy consumption of R-600a Refrigerant has 22.2% decreased than the Hydrocarbon at 0.775mm.
- Energy consumption of R-600a Refrigerant has 18.18% decreased than the Hydrocarbon at 1mm.



Graph 5.4: Energy Consumption values of R-600a & Hydrocarbon for different capillary diameters at load condition

From above graph it is observed that,

- Energy consumption at load condition for the capillary diameter 0.775mm is decreased when compared to 0.9mm & 1mm by 12.5% & 22.2% at R-600a refrigerant.
- Energy consumption at load condition for the capillary diameter 0.775mm is decreased when compared to 0.9mm & 1mm by 11.6% & 19.04% at R-600a refrigerant.
- Energy consumption of R-600a Refrigerant has 20% decreased than the Hydrocarbon at 0.9mm.
- Energy consumption of R-600a Refrigerant has 22.2% decreased than the Hydrocarbon at 0.775mm.
- Energy consumption of R-600a Refrigerant has 5.35% decreased than the Hydrocarbon at 1mm.

6. CONCLUSIONS

The experimental work is carried out and performance of domestic refrigerator is evaluated with R-600a, Hydrocarbon mixture has refrigerants. The present experimental work has been taken up to study compare the Coefficient of performance, energy consumption by using three various capillary tube lengths & diameters are using in this experiment.

- Coefficient of performance is higher for capillary tube diameter of 0.775mm & 3.8m length for both the refrigerants at no load & load conditions.
- Coefficient of performance is always higher for R-600a when compared to hydrocarbon at no load & load conditions.
- Energy consumption of the domestic refrigerator of 0.775mm & 3.8m is less consumed when compared to other two diameters & lengths.
- Energy consumption of domestic refrigerator by using R-600a is less consumed when compared to hydrocarbon mixture at all conditions.

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