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Research Paper

AN EXPERIMENTAL INVESTIGATION AND PERFORMANCE EVALUATION OF VAPOR COMPRESSION REFRIGERATION SYSTEM WITH HELICAL TYPE CONDENSER BY USING R-134A AND R-410A REFRIGERANTS

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In vapor compression refrigerating system basically there are two heat exchangers. One is to absorb the heat which is done by evaporator and another is to remove heat absorbed by refrigerant in the evaporator and the heat of compression added in the compressor and condenses it back to liquid which is done by condenser. The performance of the condenser will also help to increase COP of the system. In this project the shape of the condenser coil is modified to helical type and also investigate the performance of present domestic refrigerator using of two different type of refrigerants R134a and R410a, these refrigerants are alternatives of the R12 and R22. Due to ecological problems like Ozone depletion and Global warming refrigerants like R12 and R22 have to be replaced. The refrigerants' R12 and R22 are Hydro Chloro Fluoro Carbon (HCFC's). HFC's (Hydro Fluoro Carbon) are substantially less damaging to the Ozone layer than HCFC's. The refrigerants R134a and R410a are Hydro Fluoro Carbons (HFC) the ozone depleting potential of HFC is zero. From the results it is evident that the refrigerant R410a with a helical type condenser diameter of 6.35 mm gave the best Coefficient of performance. The retrofitting of R410a in all conditions showed better performance than R134a.

Keywords: Vapor compression refrigeration system, Refrigerant, COP, ODP, GWP.

INTRODUCTION

The vapor-compression cycle is used in most household refrigerators as well as in many large commercial and industrial refrigeration systems. Figure 1 provides a schematic diagram of the components of a typical vapor-compression refrigeration system. In the thermodynamics

cycle, a circulating refrigerant such as Freon enters the compressor as a vapor. From point 1 to point 2, the vapor is compressed at constant entropy and exits the compressor as a vapour at a higher temperature, but still below the vapour pressure at that temperature. From point 2 to point 3 and on to point 4, the vapor travels through the

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condenser which cools the vapour until it starts condensing, and then condenses the vapor into a liquid by removing additional heat at constant pressure and temperature. Between points 4 and 5, the liquid refrigerant goes through the expansion valve (also called a throttle valve) where its pressure abruptly decreases, causing flash evaporation and auto-refrigeration of, typically, less than half of the liquid.

That results in a mixture of liquid and vapor at a lower temperature and pressure as shown at point 5. The cold liquid-vapor mixture then travels through the Evaporator coil or tubes and is

completely vaporized by cooling the warm air (from the space being refrigerated) being blown by a fan across the Evaporator coil or tubes. The resulting refrigerant vapor returns to the compressor inlet at point 1 to complete the thermodynamic cycle.

The above discussion is based on the ideal vapor-compression refrigeration cycle, and does not take into account real-world effects like frictional pressure drop in the system, slight thermodynamic irreversibility during the compression of the refrigerant vapor, or non-ideal gas behavior.

Figure 1: Vapour Compression Refrigeration System

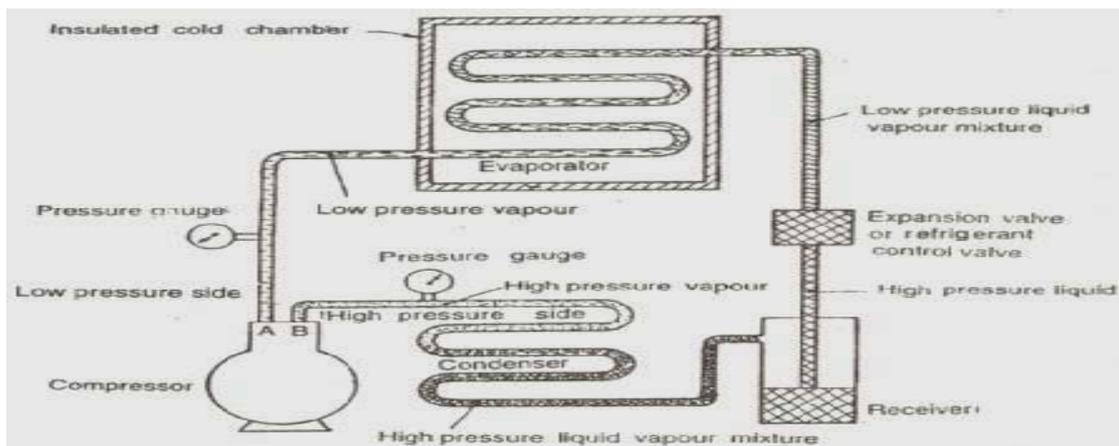


Figure 2: Pressure-enthalpy Diagram

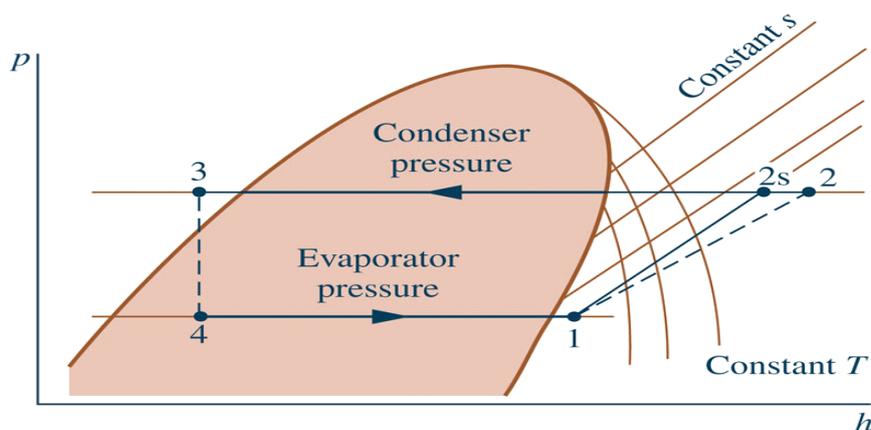
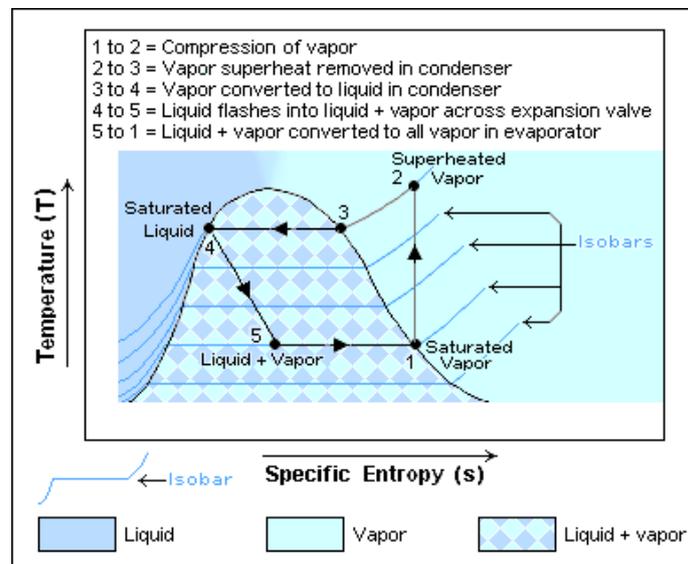


Figure 3: Temperature-Entropy Diagram



Components Of Vapour Compression Refrigeration System

a. Compressor

The low pressure and temperature vapor refrigerant from Evaporator is drawn into the compressor through the inlet or suction valve A, where it is compressed to a high pressure and temperature. This high pressure and temperature vapour refrigerant is discharged into the condenser through the delivery or discharge valve B.

b. Condenser

The condenser or cooler consists of coils of pipe in which the high pressure and temperature vapor refrigerant is cooled and condensed.

The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water.

c. Receiver

The condensed liquid refrigerant from the condenser is stored in a vessel known as

receiver from where it is supplied to the Evaporator through the expansion valve or refrigerant control valve.

d. Expansion Valve

It is also called throttle valve or refrigerant control valve. The function of the expansion valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporised in the evaporator at the low pressure and temperature.

e. Evaporator

An evaporator consists of coils of pipe in which the liquid-vapor refrigerant at low pressure and temperature is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapor refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.

EXPERIMENTAL STUDIES AND PROCEDURE

Selection of Refrigerants

The thermodynamic efficiency of a refrigeration system depends mainly on its operating temperatures. However, important practical issues such as the system design, size, initial and operating costs, safety, reliability, and serviceability, etc. depend very much on the type of refrigerant selected for a given application. Due to several environmental issues such as ozone layer depletion and global warming and their relation to the various refrigerants used, the selection of suitable refrigerant has become one of the most important issues in recent times. Replacement of an existing refrigerant by a completely new refrigerant, for whatever reason, is an expensive proposition as it may call for several changes in the design and manufacturing of refrigeration systems. Hence it is very important to understand the issues related to the selection and use of refrigerants. The following parameter shows the properties of refrigerants.

Selection of Condenser

The condenser is one of the most important component of the refrigeration system. Its function is to dissipate heat absorbed by the

refrigerant during evaporation (refrigeration effect) and compression (Heat of compression).

There are three different type of condensers classified on the basis of cooling used to dissipate heat. These are.

- Air cooled
- Water cooled
- Evaporative type

Air-cooled condenser can be natural convection type or forced convection type. This chapter is devoted only to the air-cooled condenser which is the most common type in use.

Before sizing a condenser, careful evaluation should include, consideration of initial cost, operating cost service life and type of load. A condenser that is too large can be expensive and create operating problems in lower ambient conditions; an undersized condenser can cause operating problems in higher ambient conditions.

Design of Helical Condenser

The helical condenser is the applications for helical tubing coils range from copper helical coil with end fixture the aerospace industry to the refrigeration (ACR), petroleum, and brewing industry. In this present work modify the existing

Substance	Natural	ODP	GWP (100 Years)	Atmospheric life time(years)
R12	NO	0.9	8500	130
R22	NO	0.05	1700	15
R134a	NO	0	1300	16
R744	YES	0	3	<1
R600a	YES	0	3	<1
R410a	NO	0	1725	14

condenser and install the helical design condenser to the refrigerator (165 L).The specifications of the helical type condenser as follows.

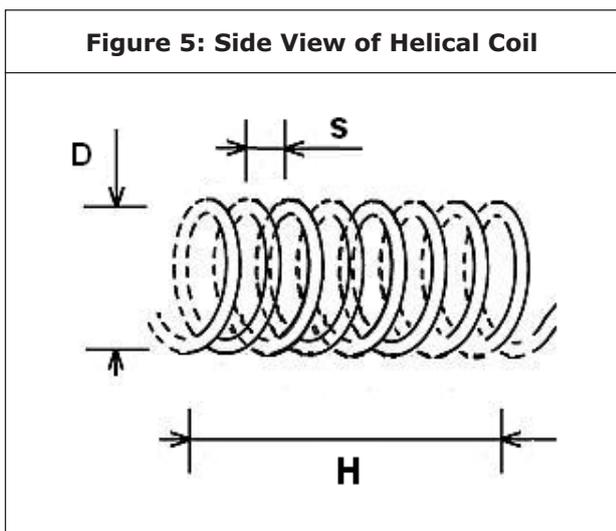
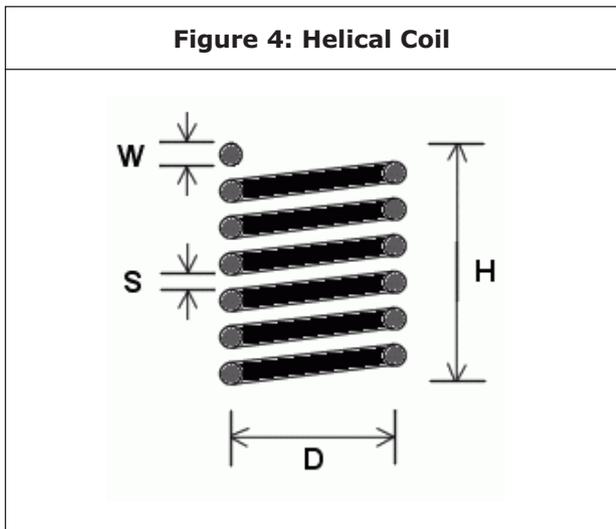


Table 2: Tabular Column of Helical Condenser Coil

Diameter of design coil D [mm]	268
Diameter w [mm]	6.35
Spacing s [mm]	50
Turns	11
Length[mm]	750
Height H [mm]	520

Experimental Setup

The Figure 6. shows the experimental setup of the refrigerator. In order to know the performance characteristics of the vapor compression refrigeration system the temperature and pressure gauges are installed at each entry and exit of the components. Experiments are conducted on helical condenser with coil spacing of the condenser on a refrigerator of capacity 165 L. All the values of pressures and temperatures are tabulated.

Domestic refrigerator selected for the project has the following specifications:

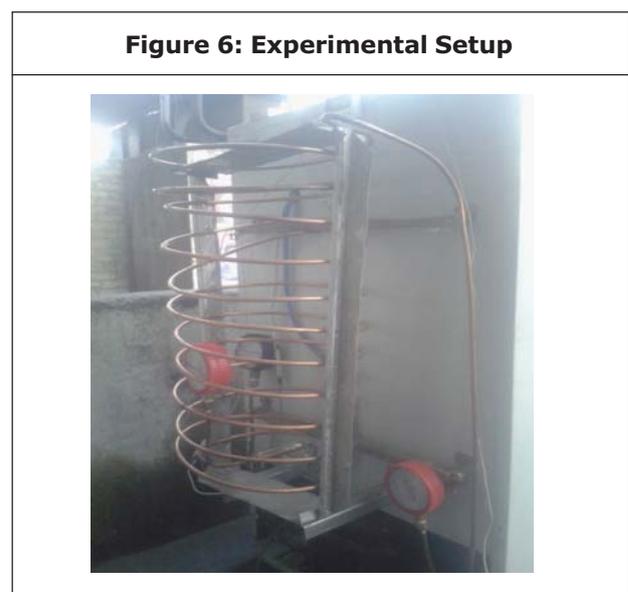
Refrigerant used: R-134a and R-410a.

Capacity of The Refrigerator: 165 L.

Compressor capacity: 0.16 HP.

Table 3: Specifications of Experimental Setup

Equipment	Length (meter)	Diameter(mm)
Condenser	7.50	6.35
Capillary	7.62	6.4
Evaporator	3.6	0.9



Experimental Procedure

The following procedure is adopted for experimental setup of the vapor compression refrigeration system.

1. The domestic refrigerator is selected, working on vapor compression refrigeration system.
2. Pressure and temperature gauges are installed at each entry and exit of the components.
3. Flushing of the system is done by pressurized nitrogen gas.
4. R 134a and R410a refrigerants are charged in to the vapor compression refrigeration system
5. Leakage tests are done by using soap solution, in order to further test the condenser and Evaporator pressure and check purging daily for 12 h and found that there is no leakages which required the absolutely the present investigation to carry out further experiment.

6. Switch on the refrigerator and observation is required for 1 h and take the pressure and temperature readings at each section.
7. The performance of the existing system and helical system is investigated, with the help of temperature and pressure gauge readings at each section.
8. Temperature and pressure gauge readings are taken and the performance is investigated.
9. The results are tabulated for helical type and existing condensers as follows.

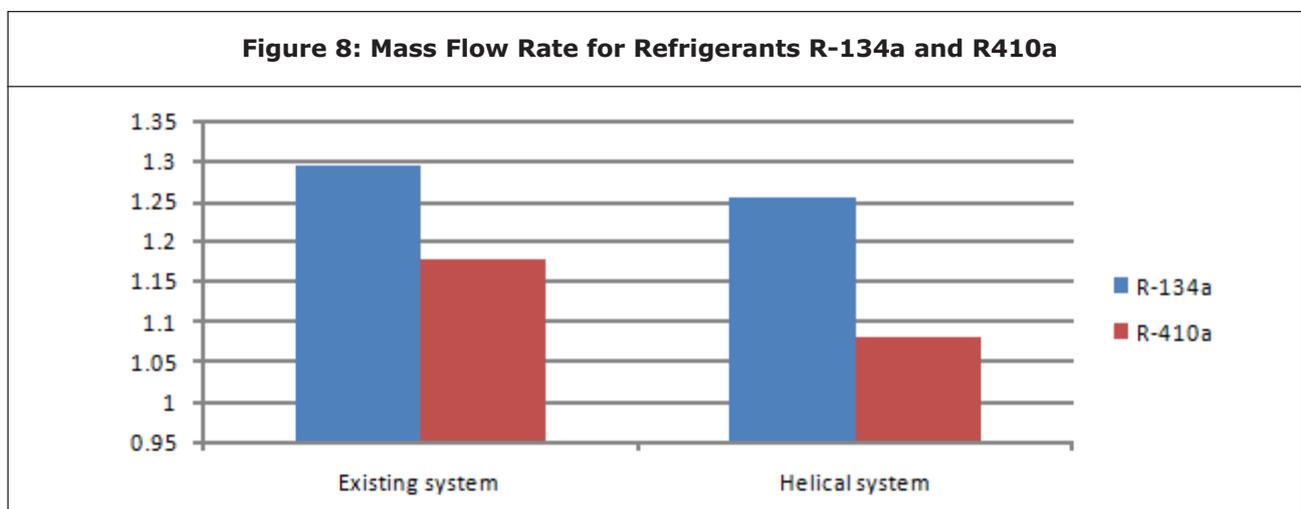
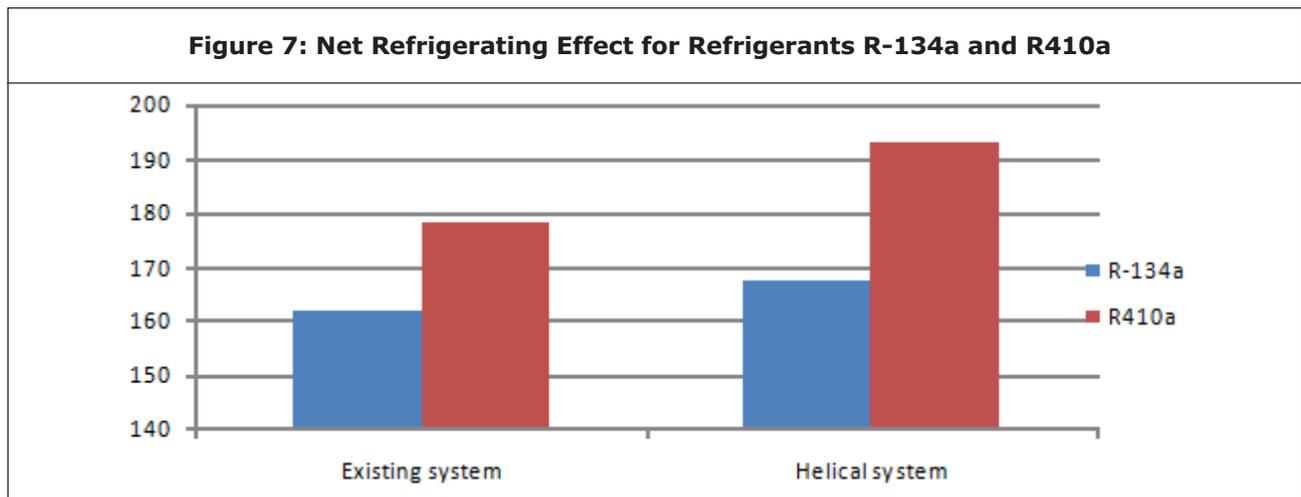
RESULTS AND DISCUSSION

Effect of Shape of The Condenser Coil on The Net Refrigerating Effect (kJ/kg)

The refrigeration effect of both refrigerants R-134a and R410a for existing and new system with helical condenser coil shown in bellow Figure 7. The Net refrigeration effect is more with using of helical type condenser coil compare to existing system and also R410a gives better performance than R134a.

Table 4: Tabular of Existing and Helical System Results

S. No	Parameters	Existing System Helicalcondenser System			
		R-134A	R-410A	R-134A	R-410A
1	Net refrigerating effect , kJ/kg	162	178	167	193
2	Coefficient of performance (COP)	5.53	7.12	6.95	8.39
3	Mass flow rate to obtain one TR, kg/min	1.296	1.179	1.257	1.088
4	Compressor work, kJ/kg	29	25	24	23
5	Heat equivalent of work of compression per TR, KJ/min	37.6	29.5	30.17	25.02
6	Compressor power, KW	0.62	0.49	0.5	0.41
7	Heat to be rejected in condenser , KJ/kg	191	203	191	216
8	Heat rejection per TR, KJ/min	247.51	239.33	240.53	233.28
9	Heat rejection ratio	1.18	1.14	1.14	1.11
10	Compression pressure ratio	14	8.12	13.3	8.96



Effect of Shape of The Condenser Coil on The Mass Flow Rate (kg/min)

Figure 8 shows the mass flow rate for refrigerants R-134a and R410a for both existing and new system with helical coil. Mass flow rate is less in helical system by using of helical condenser coil compare to existing system.

Effect of Shape of Condenser Coil on Compressor Work (kJ/kg)

The Figure 9. shows the effect of compressor work on both existing and helical condenser coil system with R134a and R410a refrigerants. The results are shows helical system lowers the compressor work compare to the existing system

Effect of Shape of Condenser Coil on Compressor Power (kW)

In the present work, compare the helical shaped condenser coil with existing system. It is seen that in above Figure 9, helical shape condenser having the compressor work is less. Than the compressor power is decreased shown in the bellow Figure 10. and R410a gives better performance in both existing and helical system.

Effect of Shape of Condenser Coil on Coefficient of Performance

In the helical system the net refrigeration effect is more and compressor work is less than the coefficient of performance is increases. The

below Figure 11 shows the cop of helical system is more than the cop of existing system. In both cases R410a gives higher cop than R134a.

Effect of Shape of The Condenser Coil on Heat Rejection (kJ/kg)

Figure12 shows the heat rejection for refrigerant

R134a and R410a for both existing and new system with helical condenser coil. The heat rejection is more in helical system compared to the existing system shown in below Figure 12 and heat rejection rate of R410a is morethan R134a.

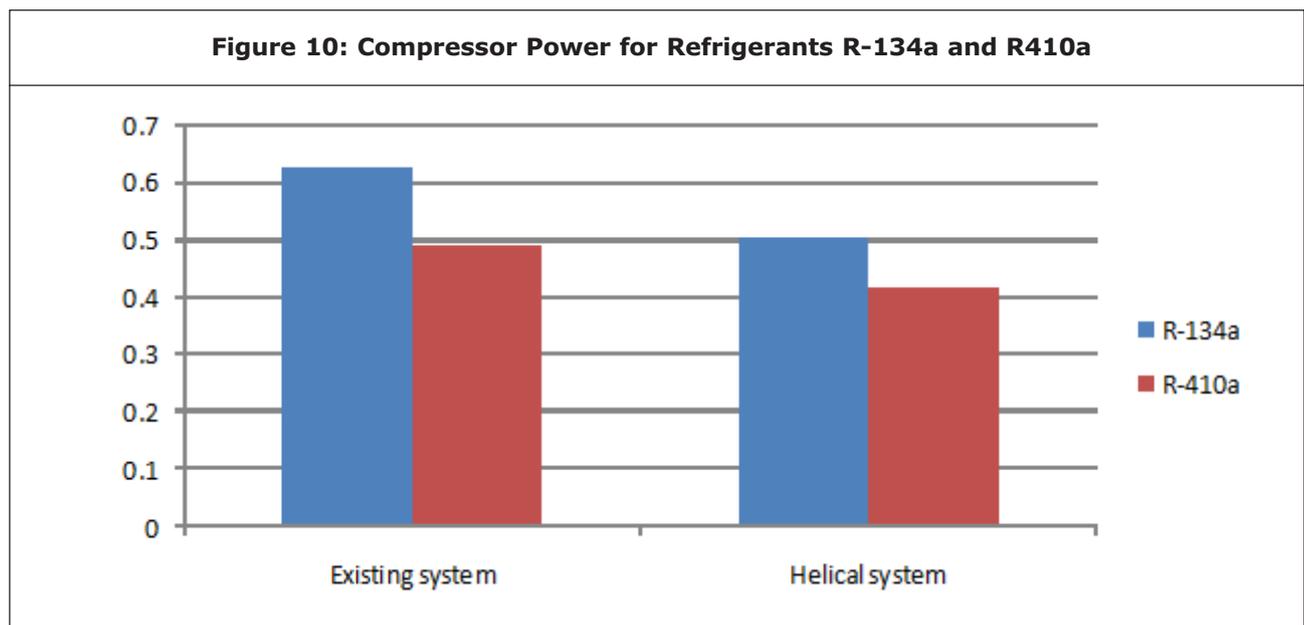
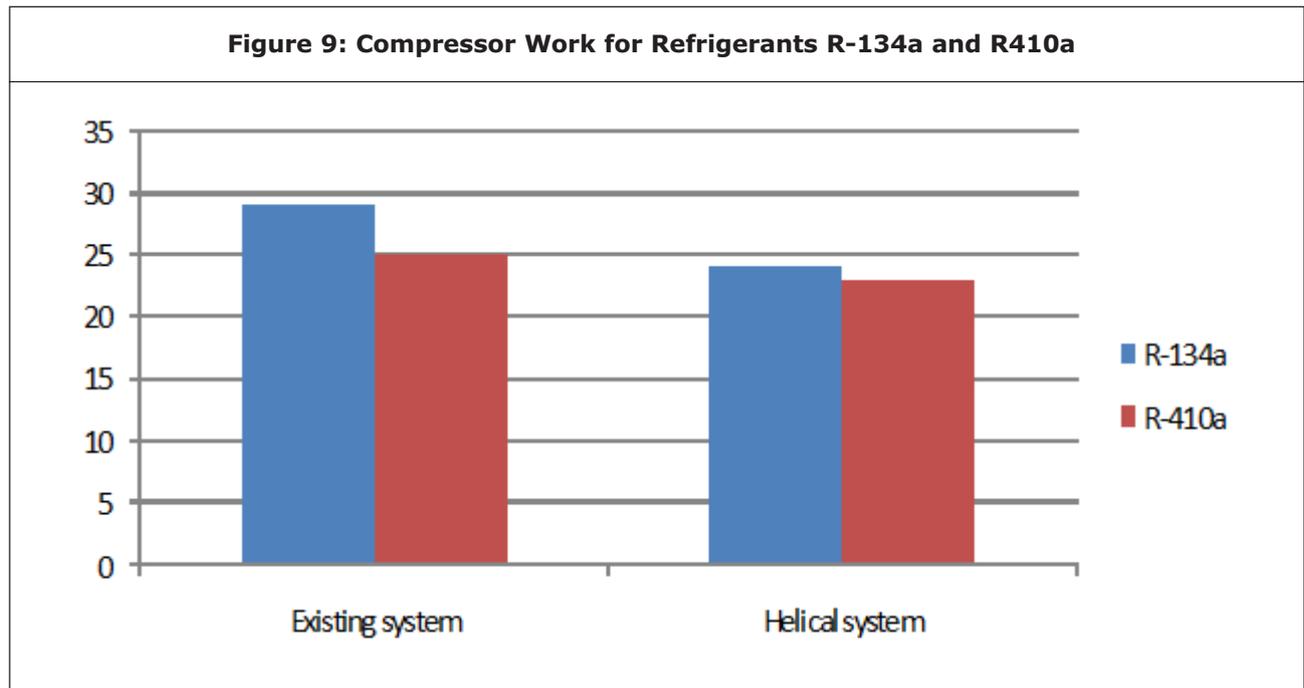


Figure 11: Coefficient of Performance for Refrigerants R-134a and R410a

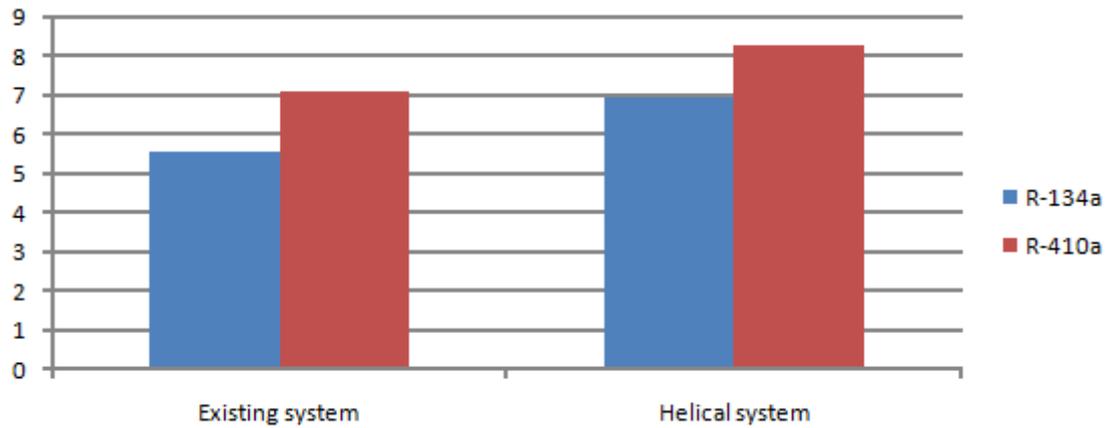
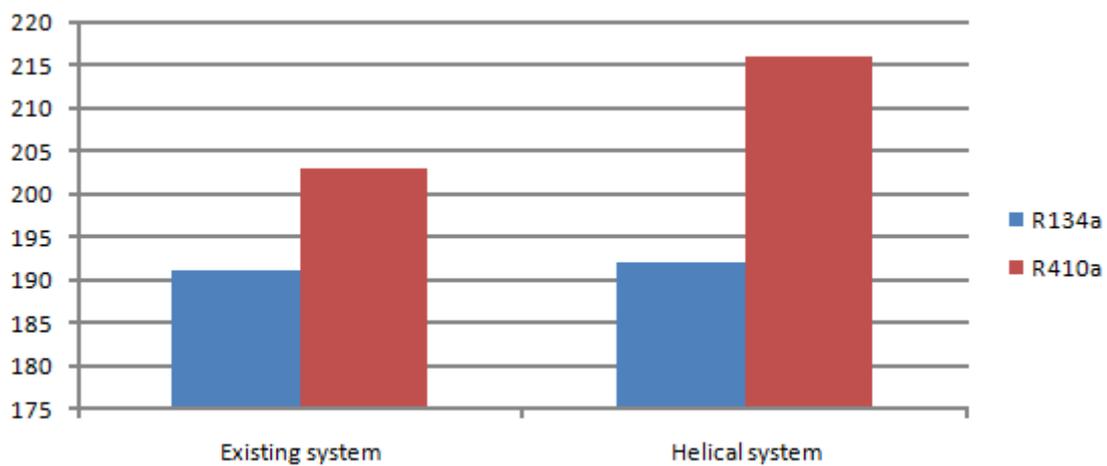


Figure 12: Compressor Power for Refrigerants R-134a and R410a



CONCLUSION

In the present work experimental investigation is carried out to investigate the performance of vapor compression refrigeration system of a domestic refrigerator of 165 L capacity, with R 134a and R410a as refrigerants. The existing system condenser coil having 6.35 mm diameter, 7500 mm length is compared with helical shaped condenser coil as same diameter and length.

- In the proposed system the refrigeration effect is found to be more than the refrigeration effect

of existing system. The percentage of increase in refrigeration effect by using R134a is 3.09%.

- In the proposed system the refrigeration effect is found to be more than the refrigeration effect of existing system. The percentage of increase in refrigeration effect by using R410a is 8.42%.
- In the proposed system the coefficient of performance is found to be greater than the coefficient of performance of existing system. The percentage of increase in COP by using R134a is 25.67%.

- In the proposed system the coefficient of performance is found to be greater than the coefficient of performance of existing system. The percentage of increase in COP by using R410a in no load condition is 17.83%.
- In the proposed system the compressor power is found to be less than the compressor power of existing system. The percentage of decrease in compressor power by using R134a is 24%.
- In the proposed system the compressor power is found to be less than the compressor power of existing system. The percentage of decrease in compressor power by using R410a is 20.10%.

From the above discussions, it can be concluded that the performance of vapor compression refrigeration system of domestic refrigerator can be increased by using helical shaped condenser coil and compared by using of two different refrigerants.

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