International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Comparing the performance of Domestic Refrigerator by changing the Design of Condenser and by using Refrigerant R-600a

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Accepted 16 Sept 2016, Available online 26 Sept 2016, **Vol.6, No.5 (Oct 2016)**

Abstract

Now a days cooling is pre dominant in day today life.In this study mainly the design of condenser is changed and also R-600a is replaced with R-134a and comparison is made between them. In this experiment a refrigerator setup is made and the helical shaped condenser is replaced with normal condenser and coefficient of performance for R-134a with normal condenser and coefficient of performance for R-600a with helical condenser are compared.

Keywords: *coefficient of performance,R-600a,R-134a, Helical*

1. Introduction

Vapor compression Refrigeration system is an improved type of Mechanical refrigeration system. The ability of certain liquids to absorb enormous quantities of heat as they vaporize is the basis of this system. Compared to melting solids (say ice) to obtain refrigeration effect, vaporizing liquid refrigerant has more advantages. To mention a few, the refrigerating effect can be started or stopped at will, the rate of cooling can be predetermined, the vaporizing temperatures can be govern by controlling the pressure at which the liquid vaporizes. Moreover, the vapor can be readily collected and condensed back into liquid state so that same liquid can be re-circulated over and over again to obtain refrigeration effect. Thus the vapor compression system employs a liquid refrigerant which evaporates and condenses readily. The System is a closed one since the refrigerant never leaves the system.

The coefficient of performance of a refrigeration system is the ratio of refrigerating effect to the compression work; therefore the coefficient of performance can be increased by increasing the refrigerating effect or by decreasing the compression work.

The Vapor compression refrigeration system is now-a-days used for all purpose refrigeration. It is generally used for all industrial purposes from a small domestic refrigerator to a big air-conditioning plant.

2. Literature Review

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2.1 Introduction

In study of applied thermo dynamics all the while we have been observing heat transfer from a system at higher temperature to that at lower temperature. Now in the study of refrigeration we will be observing various methods of cooling the objects and maintaining the temperature of bodies at values lower than surrounding temperature.

According to American society of Heating, Refrigeration and Air-conditioning Engineers (ASHARE) “Refrigeration is the science of providing and maintaining temperature below that of the surrounding (ambient) temperature”.

In the olden days around 2500 years B.C. Indians, Egyptians, etc., were producing ice by keeping water in the porous posts open to cold atmosphere during the night period. The evaporation of water in almost cool dry air accompanied with recitative heat transfer in the clear night caused the formation of ice even when the ambient temperature was above the freezing temperature. Further references are available which support the use of ice in China 1000 years BC. Nero, the emperor, was using ice for cooling beverages. Further, the East Indians were able to produce refrigeration by dissolving salt in water as early as 4th century A.D., of course, on very small scale. The use of evaporative cooling is another application of refrigeration used olden days. The cooling of water in earthen pots for drinking purpose; is the most common example where the evaporation for water through the pores of earthen pot is accompanied with cooling of water.

2.2 R134a Refrigerant

M.S.Kim *et. al*., have experimentally investigated the performance of a heat pump with two azeotropic refrigerant mixtures of R290/R134a and R134a/R600a with the mass fractions of 45%/55% and 80%/20%. The performance parameters of the azeotropes were compared with pure R12, R134a, R290 and R22 at the both heating and cooling conditions with suction-liquid heat exchanger. The COP of R134a/R290 was lower than that of R22 and R290, and R600a/R134a shows higher COP than R12 and R134a. The capacity for R134a/R290a was higher than that for R290 and R22, and R600a/R134a exhibits higher system capacity than R12 and R134a. Experimental results show that the compressor discharge temperatures of the considered azeotropic mixtures are lesser than those of the pure refrigerants i.e., R22 and R12.

H.M.Hughes *et. al*., have addressed the issues by blending the components of zeotropic mixtures and subsequent packing. Assessment was carried out with the blend of R32, R125 and R134a with the mass fraction of 23%, 25% and 52% respectively. He focused on the issues related to blending equipment and techniques, the number and quantity of components and the temperature of the blend. While preparing the blends in the cylinder, introduce the individual components of the mixture serially starting with the lowest vapour pressure component and progressing to the highest.

Ashish Kumar Pahariaet*. al*., This paper presents performance of three hydrofrulocarbon (HFC) refrigerants (R-410A, R -507A, R-407C) selected to replace R-22 in a vapour compression refrigeration system using thermodynamic simulation. The effects of the main parameters of performance analysis such as refrigerant type, degree of sub cooling and super heating on the refrigerating effect, coefficient of performance and volumetric refrigeration capacity were also investigated for various evaporating temperature. The result showed that R410A and R407C have thermodynamic performance similar to R-22. The result obtained showed that R410a and R407c have physical properties and thermodynamic Performance similar to R22. R410a has slightly lower coefficient of performance (COP), higher refrigerating capacity than R22. Considering the comparison of performance coefficients (COP) and pressure ratios of the tested refrigerants and also the main Environmental impacts of ozone layer depletion and global warming, refrigerant R410A and R407Care found to be the most suitable alternatives refrigerants to refrigerant R22.

2.3 R600a refrigerant

R.S.Agarwal *et. al*., have discussed the salient features of R600a and mixtures of 50%R290/50%R600a for domestic and small capacity commercial refrigerators working with R12. The performance of the refrigerator with the alternative refrigerants R600a and mixtures of R290/R600a was compared with R12. Hydrocarbons have a zero ODP and negligible GWP, compatible with most of the materials and commonly used lubricating oils. HC refrigerants in comparison with R12 have high latent heat of vaporisation and low value of density which makes the refrigerant attractive inspite of their flammability because of low charge and circulation rate. The charge levels are approximately 40% that of R12. Compressor discharge temperature in case of HC refrigerants is lower than R12. Based on the thermodynamic and heat transfer considerations for HC technology the following conclusions were made. Heat rejected in the condenser is almost the same as in case of R12. The size of condenser remains same as overall heat transfer coefficient is governed mainly by the air side heat transfer coefficient. Thus no change is required in the condenser.

2.4 The effect of condensation temperature on capacity

The condensation temperature of the refrigerant is considered to be 6°C – 20°C above air inlet temperature for general purposes. The condensation temperature varies according to the ambient temperature in which the system will operate. This said, the condensation temperature for applications is commonly taken as 30-60°C.

Factors taken into consideration for determining the condensation temperature

- Ambient temperature,
- Thermo physical properties of the refrigerant,
- Properties of the selected compressor and
- The dimensions of the condenser.

While providing the nominal condenser capacity in condensers as per the Euro vent Standard, the air inlet temperature and condensation temperature are taken as 25°C and 40°C respectively. In other words, T = 15 °C.

A low value should be selected for the temperature differential T, in places of high ambient temperature. For instance, while designing for the conditions of Antalya the T value should be selected within the range of 7° - 10° C. For systems that will operate in outdoor environments in conditions of Turkey, the temperature differential should be lowered as one goes from the north to the south and selections should be made accordingly. It must always be considered that High Compression Temperature creates a load on the compressor that reduces efficiency and shortens its useful life. It will be quite beneficial in the design for the condensation temperature to be specified as low as possible. However, in some conditions it is not possible to take a low value for the condensation temperature. For example in Middle East countries where the outdoor temperature is 50°C-55°C, high condenser temperature is unavoidable.

3. Neural Networks

3.1 Components of Refrigeration

There are four basic components of a refrigeration system, these are:

- Compressor
- Condenser
- Expansion Valve
- Evaporator

Compressor

The compressor is considered the heart of the refrigeration system. It is a pump, like the heart in the circulatory system of the human body. The purpose of the compressor is to draw the low-temperature, low-pressure vapour from the evaporator via the suction line. Once drawn, the vapour is compressed. When vapour is compressed it rises in temperature. Therefore, the compressor transforms the vapour from a low-temperature vapour to a high-temperature vapour, in turn increasing the pressure. The vapour is then released from the compressor in to the discharge line.

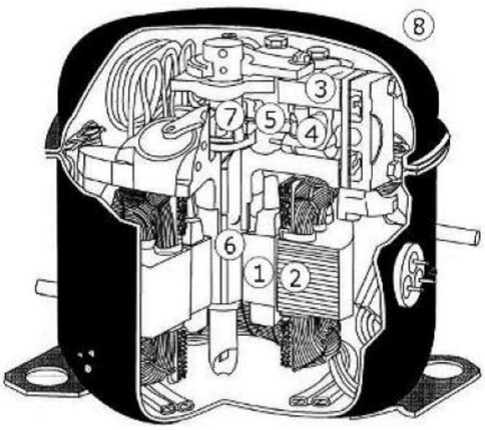

Figure 1.1 Schematic Representation of Compressor

Condenser

The purpose of the condenser is to extract heat from the refrigerant to the outside air. The condenser is usually installed on the reinforced roof of the building, which enables the transfer of heat. The temperature of the high-pressure vapour determines the temperature at which the condensation begins. As heat has to flow from the condenser to the air, the condensation temperature must be higher than that of the air; usually between -12°C and -1°C. The high-pressure vapour with in the condenser is then cooled to the point where it becomes a liquid refrigerant once more, whilst retaining some heat. The liquid refrigerant then flows from the condenser in to the liquid line.

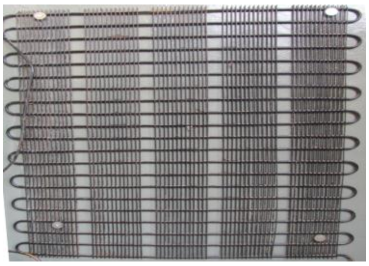

Figure 1.2 Schematic Representation of Condenser

Expansion Valve

The expansion valve is located at the end of the liquid line, before the evaporator. The high-pressure liquid reaches the expansion valve, having come from the condenser. The valve then reduces the pressure of the refrigerant as it passes through the orifice, which is located inside the valve. On reducing the pressure, the temperature of the refrigerant also decreases to a level below the surrounding air. This low-pressure, low-temperature liquid is then pumped in to the evaporator.

Figure 1.3 Schematic Representation of Capillary Tube

Evaporator

The purpose of the evaporator is to remove unwanted heat from the product, via the liquid refrigerant. The liquid refrigerant contained within the evaporator is boiling at a low-pressure. The level of this pressure is determined by two factors:

- The rate at which the heat is absorbed from the product to the liquid refrigerant in the evaporator.
- The rate at which the low-pressure vapour is removed from the evaporator by the compressor.

Figure 1.4 Schematic Representation of Evaporator

To enable the transfer of heat, the temperature of the liquid refrigerant must be lower than the temperature of the product being cooled. Once transferred, the liquid refrigerant is drawn from the evaporator by the compressor via the suction line. When leaving the evaporator coil the liquid refrigerant is in vapour form.

3.2 Working of Domestic Refrigerator

In vapour compression systems, compressors activate the refrigerant by compressing it to a higher pressure and higher temperature level after it has produced its refrigeration effect. The compressed refrigerant transfers its heat to the sink and is condensed to liquid form. This liquid refrigerant is then throttled to a low-pressure, low temperature vapour to produce refrigerating effect during evaporation. Vapour compression systems are the most widely adopted refrigeration systems in both comfort and process air conditioning.

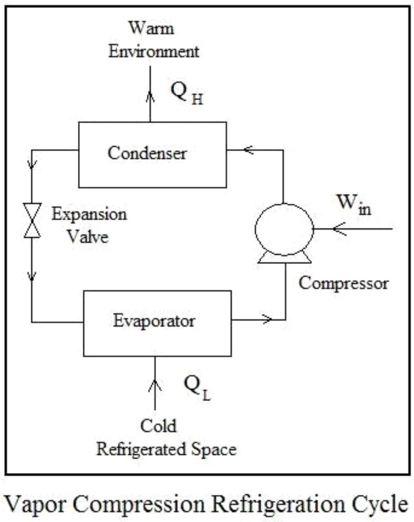

Figure 1.5 Representation of Vapour compression cycle

3.3 Classification of Refrigerants

A refrigerant is the primary working fluid used for absorbing and transmitting heat in a refrigeration system. Refrigerants absorb heat at a low temperature and low pressure and release heat at a higher temperature and pressure. Most refrigerants undergo phase changes during heat absorption evaporation and heat releasing condensation. The refrigerants may, broadly, be classified into the following two groups:

Primary refrigerants
Secondary refrigerants

The refrigerants which directly take part in the refrigeration system are called primary refrigerants whereas the refrigerants which are first cooled by primary refrigerants and then used for cooling purposes are known as secondary refrigerants.

4. New Proposed Scheme

This project investigated the performance of condenser using helical condenser in the present domestic refrigerator galvanized iron steel material fins are used. In this project mild steel material fins are replaced and galvanized iron steel are used for the condensers.

The main objective in present dissertation has been focused on alternative refrigerant to conventional CFC refrigerant, CFC like R12, R22, R134a, etc. are not eco friendly. The emission of these refrigerants causes the depletion of ozone layer etc. Hence to avoid above difficulty the alternative of refrigerant in the form of R600a has been choosing. R600a refrigerant are natural refrigerant consist of hydrocarbon.

In the present work, the performance of the domestic refrigerator is determined using R600a (Isobutane) and comparison with R134a (Tetrafluoro-ethane) by changing the design of the condenser as helical shape. As the part of project work the refrigerator setup consists of evaporator, compressor, condenser and expansion valve are chosen with suitable specification.

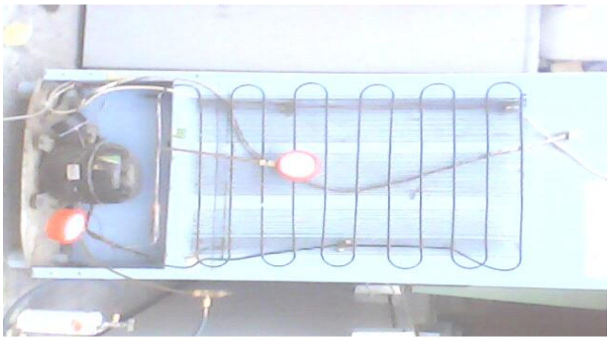

Fig 5.5 Normal Set up

Fig 5.6 Helical design Set up

Table 4.1.2 Reading of R134a Refrigerant

Operating freezer point	N	T_1	T_2	T_3	P_1	P_2	P_3
	(rev/sec)				bar	bar	bar
1	46:10:00	-7.9	54.8	44.3	0.68	17.2	16.5
2	49:18:00	-7.9	54.9	42.3	0.55	15.5	14.6
3	50:30:00	-9.6	55.6	41.6	0.58	15.7	15
4	49:29:00	-12	57	42.6	0.58	15.8	15.1
5	51:20:00	-15	58.5	43	0.37	15.1	14.4
6	53:12:00	-17	59.2	43.1	0.34	15.1	14.4
7	52	-19	60.1	43.1	0.31	14.4	14.1

Table 4.1.2.2 Reading for R600a Refrigerant

Operating freezer point	N (rev/sec)	T_1 °C	T_2 °C	T_3 °C	P_1 (bar)	P_2 (bar)	P_3 (bar)
1	55:10:00	-11	51.9	41.3	0.13	8.2	7.93
2	55:10:00	-11	51.7	39.4	0.13	8.4	7.93
3	56:60	-12	52.3	41.7	0.14	8.2	7.91
4	56:10:00	-14	53.6	39.6	0.06	8	7.79
5	60:20:00	-17	53.7	38	0.06	7.9	7.58
6	60:09:00	-19	53.3	39.2	0.07	7.4	7.24
7	60:05:00	-19	53.5	38.6	0.06	7.3	7.17

Results and Analysis

Normal System

Calculations

Evaporator temperature: T_1 : -9.6°c
Pressure (bar) :P_1: 0.58
Compressor temperature (outlet): $T_{2°C}$:55.6
Pressure (bar):P_2:15.72
Condenser temperature (outlet):$T_{3°C}$:41.6
Pressure (bar):P_3 :15.03
Taking reading and seeing enthalpy values from the data handbook with having refrigerant R134a P-H chart
Evaporator enthalpy, H_1:587kJ/kg K
Compressor enthalpy,H_2:617kJ/kg K
Condensed enthalpy ,H_3:458kJ/kg K
C.O.P :(H_1-H_3)/ (H_2-H_1)
:(587-458)/ (617-587)
C.O.P: 4.3

Evaporator temperature:$T_{1°C}$:-9.6
Pressure (bar) : P_1:0.58
Compressor temperature (outlet): $T_{2°C}$:55.6
Pressure (bar):P_2:15.72
Condenser temperature (outlet):$T_{3°C}$:41.6
Pressure (bar):P_3:15.03

Taking reading and seeing enthalpy values from the data handbook with having refrigerant R600a P-H chart
Evaporator enthalpy H_1:587kJ/kg K
Compressor enthalpy H_2:617kJ/kg K
Condensed enthalpy H_3:458kJ/kg K
C.O.P :(H_1-H_3)/ (H_2-H_1)
:(587-458)/ (617-587)
C.O.P : 4.4

Design system

Calculations of R134a for helical shaped condenser

Taken condenser coil spacing = 2.5 inches
Temperatures
Compressor Suction Temperature T_1= 31°C

Compressor Discharge Temperature T_2=50.6°C
Condensing Temperature T_3=35.1°C
Evaporator Temperature T_4= -15°C
Pressures
Compressor suction pressure P_1 =1.70 bar
Compressor discharge pressure P_2 =10.94 bar
Condenser pressure P_3=10.94 bar
Evaporator pressure P_4 =1.70 bar

Enthalpies

From pressure-enthalpy chart for R-134a, enthalpy values at state points 1,2,3,4. The state points are fixed using pressure and temperature and each point.

h_1 = 425 kJ/kg
h_2 = 471 kJ/kg
h_3 = 250 kJ/kg
h_4 = 250 kJ/kg

Calculation Performance Parameters

- Net Refrigerating Effect (NRE) = h_1-h_4 =425-250=175kJ/kg
- Mass flow rate to obtain one TR, kg/min.
  m_r= 210/NRE=210/175=1.2 kg/min

- Work of Compression = h_2-h_1 = 471- 425 = 46 kJ/kg
- Heat Equivalent of work of compression per TR
- m_r x (h_2-h_1) = 1.2 x 46 = 55.2 kJ/kg
- Theoretical power of compressor= 0.92 kW
- Coefficient of Performance (COP)= h_1-h_4 / h_2-h_1= 175/46 = 3.80
- Heat to be rejected in condenser = h_2-h_3 = 471-250 = 221 kJ/kg
- Heat Rejection per TR= x (h_2-h_3) = 1.2 x 221 = 265.2 kJ/min
- Heat Rejection Ratio= 265.2/210 = 1.26
- Compression Pressure Ratio=10.94/1.70 = 6.43

Operating freezer point	N	T_1	T_2	T_3	P_1	P_2	P_3
	(rev/sec)	°C	°C	°C	(bar)	(bar)	(bar)
1	54	-10.6	55.9	45.2	0.14	9.2	8.21
2	55	-11.6	57.4	45.1	0.13	8.9	8.12
3	54	-12.2	56.8	43.9	0.6	9.1	7.94
4	57	-14.1	57.2	43	0.9	8.06	7.79
5	60	-16.8	58.4	44	0.12	8.34	7.94
6	57	-17.7	59.3	43.8	0.13	8	7.35
7	60	-18.3	60	44.3	0.14	7.92	7.24

Calculations for R600a with helical shaped condenser

Evaporator temperature: $T_{1°C}$:-12.2
Pressure (bar) : P_1 :0.14
Compressor temperature (outlet) : $T_{2°C}$:56.8
Pressure (bar):P_2:9.1
Condenser temperature (outlet): $T_{3°C}$:43.9
Pressure (bar):P_3:7.94
Taking reading and seeing enthalpy values from the data handbook with having refrigerant R410a P-H chart
Evaporator enthalpy H_1: 613.5kJ/kg K
Compressor enthalpy H_2: 628.97kJ/kg K
Condensed enthalpy H_3 : 539.71kJ/kg K
C.O.P: (H_1-H_3)/ (H_2-H_1)
:(613.5-539.71)/ (628.97-613.5)
C.O.P: 4.76

Conclusions

In this paper, refrigerator setup is made and then coefficient of performance of R-134a with and without helical condenser is calculated and also coefficient of performance of R-600a with and without helical condenser are calculated. coefficient of performance for R-600a with helical condenser is more than without helical condenser. And also coefficient of performance of R-134a with helical condenser is less than R-134a without helical condenser.

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