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Design of Domestic refrigerator using Propylene (R1270) as refrigerant

AbhishekKumar[1], Neel Kamal[2]
(Mechanical Engineering, Kailash Narayan Patidar College of Science & Technology, Bhopal (M.P.), INDIA)[1]
(Mechanical Engineering, Kailash Narayan Patidar College of Science & Technology, Bhopal (M.P.), INDIA)[2]

Abstract: In this present work, It is proposed to introduce the hydrocarbon as refrigerant in domestic refrigerator. The refrigerant R134a is replaced by hydrocarbon refrigerant R1270. It is refrigerant grade propylene and non-toxic in addition to this it has low Global Warming Potential (GWP). Hence, amount of heat trapped will be less by atmosphere as compared to R134a. Further zero Ozone Depletion Potential (ODP) makes it suitable to replace R134a as refrigerant. COP values of refrigerants are almost kept same. R1270 will be suitable for use in low and medium temperature refrigeration applications. Use of Greenhouse gases should be avoided as much as possible. In 21st century it has been predicted that the earth's global surface temperature can rise from 0.3 □ C to 1.7 □ C. Since, the global warming is world's serious problem for the environment; it should be minimized as much as possible. Otherwise it may lead to adverse climatic change resulting in extinction of life from the earth. Hence idea behind this work is to work for the reduction in global warming. Almost every dwelling has got a space for refrigerators and residents are using it frequently for their basic requirements. However most of them are unaware of the fact that R134a (Tetrafluroethane) used in this refrigerants emits greenhouse gases. In this present work, the design of all the components of the domestic refrigerator is made by using R1270 as refrigerant. Also, a comparison between present design and the existing design is made and the chance of retro fitting of the refrigerator is made to achieve the desired performance. As this refrigerant satisfies the desired performance hence the design of components of refrigerator can be done for eco-friendly and clean environment.

I. Introduction

It is well known that domestic refrigerator is generally available in each household. It has become a very useful commodity for preserving the food which could be spoiled. It is also used for making ice in small amount for a domestic purpose. It has some undesirable effects for our environment, like ozone depletion, global warming. It should be tried to prevent these effects, hence presently it is using R134a as refrigerant in place of R12 due to its lower Global Warming Potential (GWP). But still there is a problem with R134a, as it has zero ODP and GWP as 1300 over one hundred years. This means that it is not completely eco-friendly, hence we have to use alternatives to these refrigerants. The best option for totally eco-friendly refrigerants are hydrocarbons. Hydrocarbons have similar thermodynamic and transport properties as presently used refrigerants and also hydrocarbons have zero ODP and negligible GWP. Hence hydrocarbons should be used to protect our environment. Hydrocarbons like, Propane (R190), Butane (R600), Iso-butane (R600a), Propylene (R1270) etc. are generally used as refrigerant in refrigeration system because of their similar properties with R12 andR134a and very low GWP and zero ODP. A refrigerant may be a composition of halogen and H-atom. The Cl- atom in the refrigerant is considered responsible for the depletion of the ozone layer in the stratosphere, thus allowing harmful ultra-violet radiation to penetrate through the atmosphere and reach the earth's surface. The F-atom in the refrigerant makes the refrigerant physiologically more favourable. The H-atom in the refrigerant imparts a degree of flammability to the refrigerant depending upon the number of these atoms. In ancient times, there were the lack of knowledge about the refrigeration system; hence the refrigeration was done by using vaporization of water and using ice which is stored. After that some scientists proposed to use the fluid in the closed cycle for making ice from water. After that Richard Trevithick and Perkins proposed to the vapour compression refrigeration machine. This was the introduction of refrigerants used in refrigeration system by these scientists. [1]

Firstly, there were the refrigerants which were workable for refrigeration. There were not any criteria to select the refrigerants; hence this was called as the first generation of the refrigerants. After that the safety criterion was used for selection and called as second generation of the refrigerants. In 20th century, the criteria of ODP and GWP were used and called as the third and fourth generation of the refrigerants, respectively. Nowadays, the concept of GWP for selection of refrigerants is used for the better and eco-friendly environment. Fig. 1shows all the generations of the refrigerants according to their use. [6]In the 1930, CFCs have been most widely used in the field of refrigeration since they almost satisfied the requirements for good thermodynamic properties, chemical stability, non-toxicity, non-flammability etc. However, CFCs are harmful to the global environment, and hence regulations against the production and use of CFCs are in progress. These days, researches are going on to develop a domestic refrigerator with alternatives of CFCs, and to improve the performance of the system. R-134a, R-600a andR-22 are mostly used as the substitutes for CFCs. R-134a, a HFC with an ODP of zero and a GWP of 1400 has lower performance than R-12 and is not suitable as environmentally favourable refrigerant with respect to total equivalent warming impact which is defined as the overall evaluation of the influence on the global environment. [2]

For the small refrigeration systems, the refrigerator is the main domestic appliance. The domestic refrigerator works on the vapour compression refrigeration system, in which the heat is absorbed by the refrigerant from the space to be cooled. A condenser is used for the rejection of heat from the vapour refrigerant to the surrounding air and the refrigerant becomes the saturated liquid. [3]

To give the proposal of a more theoretical global optimization method for vapour compression refrigeration systems, it is highly desired to introduce a new optimization technique. Researchers have introduced and applied a new principle, which is termed as the entransy dissipation optimization principle, in the optimization of some energy utilization systems containing a number of heat transfer processes in various heat exchangers, i.e. evaporative cooling systems and heat exchanger networks in buildings and thermal management systems in space crafts, which are also nonlinear and tough to tackle.
[4]

On the basis of the given literature survey, it is found that the Global Warming Potential of conventional refrigerants including R134a, is more, hence it is desired to make a safe and eco-friendly refrigeration system for household purpose. It is proposed -

I. To select a suitable refrigerant for the domestic refrigerator application.
II. To design the domestic refrigerator components.
III. Feasibility of retrofitting of the existing system.

In order to achieve the given objective, following steps will be taken,

I. Property data for R1270 and R134a will be collected.
II. Main components of vapour compression refrigeration system for domestic refrigerator will be designed.
III. Size of typical domestic refrigerator will be kept same.
IV. Possibility of retrofitting of old refrigerator will be envisaged.

II. Design of Components of Domestic Refrigerator

1. Domestic refrigerator

A refrigeration system works on the vapour compression refrigeration cycle, which consists of mainly four components which are compressor, condenser, expansion valve and evaporator (Fig. 2**)**A domestic refrigerator is a commonly used appliance in the household. The heat is extracted from the air inside the refrigerator by the refrigerant, thus the air becomes cold and this helps to preserve the food and vegetables and reduce the rate of spoilage. This is commonly used for the food preservation and ice making. For food preservation, the temperature should be about 5°C and for ice, this is about -5°C. These two temperatures are maintained in two different sections of the refrigerator.

1.1 Source of data collection

The data for the design of the components is collected on the basis of survey of the popular domestic refrigerator in the market. The survey is done for the 'Whirlpool 230 litre Fus New Refrigerator' in the Whirlpool service Centre. The following data of the existing refrigerator are collected from this survey-

Gross volume = 230 litres
Dimension = 134.5×64.7×55.8 cm
EER of the compressor = 3.88
Outer diameter of condenser tube = 9.42 mm
Inner diameter of condenser tube = 7.76 mm
Distance between tubes of condenser = 45 mm
Distance between fins of condenser = 6.5 mm
Diameter of capillary tube = 0.91 mm
Length of capillary tube = 3.60 m
Outer diameter of evaporator tube = 9.42 mm
Inner diameter of evaporator tube = 7.76 mm.

2. Design of components

2.1 comparison of COP for R134a and R1270

Experimental determination of COP using the setup "Refrigeration Test Rig" (Fig. 3)while using R1270 the COP of the system is 2.36319. Whereas using R134a the COP of the system is 2.378.
From above calculation we find that the COP of the system using R134a is slightly more than that of using R1270.

2.2 Design of compressor

For designing compressor some parameters considering a household refrigerator are considered.
Total heat load that generates is 95.62 kJ/kg. Calculating the capacity of compressor considering EER value which is assigned as 3.88 is 173.8 watt. Comparing it to the previous one power requirement is slightly more about 1.8 watt. Hence, compressor of TECUMESH COMPANY model no. TWB1390YGS can be used.**(TABLE NO. 1.1)**

2.3 Design of Condenser

The basic design for the condenser is to calculate the heat transfer coefficients and face area for the condenser. For this, it is desired to select the specific value of the diameter of condenser tube. Now, selecting the diameter of the tube which is used in the 230 litre capacity domestic refrigerator. The capacity of condenser unit is given as 2.27 kW for R1270.
Calculating overall heat transfer coefficient which is 115.369 W/m^2K and face area for the condenser will be 0.1477 m^2.**(TABLE NO. 1.2)**

2.4 Design of Capillary tube

In the capillary tube, the refrigerant is expanded from high pressure, i.e. condenser pressure to low pressure, i.e. evaporator pressure, by the process of constant enthalpy. For the design of the capillary tube, the length should be calculated. The length of the capillary tube using R1270 will be 3.246 m upon calculation, while usingR134a; the length should be 3.30m. Therefore, R1270 can be used as refrigerant in refrigerator.**(TABLE NO. 1.3)**

2.5 Design of Evaporator

In the evaporator, the air outside the evaporator coils is cooled and become moist in the direct expansion type evaporator, so that it comes below to cool the refrigerator cabinet. Upon calculation face area of designed evaporator should be 0.02034 m^2.**(TABLE NO. 1.4)**

III. Figures And Tables

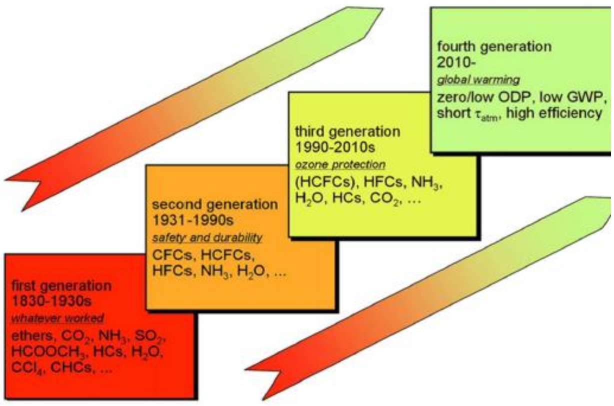

Fig. 1 Progression of refrigerants [6]

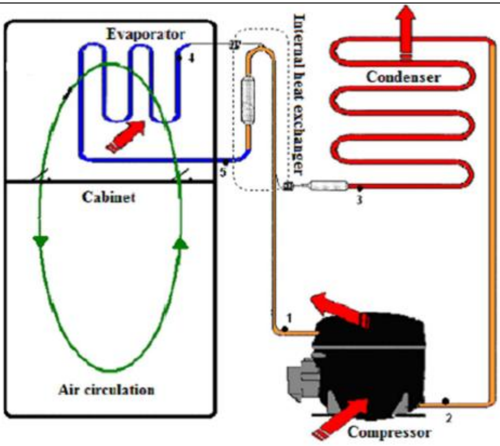

Fig.2Components and working of a typical domestic refrigerator

Fig.3Refrigeration Test Rig

Table No. 1.1 Parameters showing design of compressor

Refrigerant	**R1270**	**R134a**
Capacity (Watt)	175	172
Model	TWB1390YGS	KCE345LAG
Oil	Synthetic Oil	Synthetic Oil

Table No.1.2 Parameters showing design of condenser

Condensation heat transfer coefficient (W/m2-K)	3288.96
Air side heat transfer coefficient (W/m2-K)	714.58
Overall heat transfer coefficient (W/m2-K)	115.369
Face area (m2)	0.1477

Table No.1.3 Parameters showing design of capillary tube

	R1270	**R134a**
Diameter of tube (mm)	0.981	0.981
Length of tube (m)	3.246	3.3

Table No. 1.4 Parameters showing design of Evaporator

Evaporative heat transfer coefficient (W/m2-K)	4537.63
Air side heat transfer coefficient (W/m2-K)	332.142
Overall heat transfer coefficient (W/m2-K)	221.7
Face area (m2)	0.02034

IV. CONCLUSION

From the previous calculations and results, following conclusions may be drawn:

1. Refrigerant 1270 can be used as replacement for R134a systems.
2. Although, R134a is eco-friendly refrigerant but the Global Warming Potential (GWP) is nil in comparison to the GWP of R134a (1400).
3. The design dimension of domestic refrigerator of 230 litre capacity withR1270 is nearly those of R134a systems.
4. The existing R134a systems can be retrofitted to the R1270 systems
5. Freezing point of R1270 is 88 K which is appreciably lower than 176.55 K for R134a and the normal boiling point of R1270 is 225.4 K which is appreciably lower than 247 K for R134a. Thus, R1270 provides large temperature range of working of this system.

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