Experimental Analysis of Freezer Free Domestic Refrigerator

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Abstract— The fundamental reason for a residential cooler is to give low temperature that the development of sustenance annihilating microorganisms is for capacity and appropriation of nourishments and beverages. it has been discovered much faster(about 1000 times) at a temperature of 1200C than 200C. this is sufficient to accentuation the utilization of fridge for safeguarding natural products, vegetables, fish, milk and so on which would somehow or another be ruined at higher temp. (General in summer season) in a brief timeframe.

So the point of the undertaking is to expel the cooler unit from icebox, where much cooling in not required. That is the reason by expelling cooler; we need to look after temp. Above 00 C which is required for cooling.

There by expanding the temp. Of evaporator, we additionally achieve the objective of diminishing the compressor work lastly we can expand coefficient of execution of fridge unit.

Keywords- refrigerator, hfc-134a, compressor, capillary tube

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I. Introduction

Household fridges had turned into the individual from the each family. It had made our bustling life more basic and agreeable. Likewise it turns into a vital part of the life in summer for chilled drinking water and safeguarding the nourishment stuff for brief period consistently.

1.1. Natural Refrigeration

In long time past days refrigeration was accomplished by normal means, for example, the utilization of ice or evaporative cooling. In prior times, ice was either:

1. Transported from colder districts,
2. Reaped in winter and put away in ice houses for summer use or,
3. Made amid night by cooling of water by radiation to stratosphere.

1.2. Fake Refrigeration

Refrigeration as it is known nowadays is created by fake means. In spite of the fact that it is exceptionally hard to make an unmistakable division in the middle of common and manufactured refrigeration, it is by and large concurred that the historical backdrop of simulated refrigeration started in the year 1755, when the Scottish teacher William Cullen made the primary refrigerating machine, which could create a little amount of ice in the lab. In view of the working rule, refrigeration frameworks can be delegated vapour pressure frameworks, vapour assimilation frameworks, gas cycle frameworks and so on.

Electric Company presented the primary fridge with a hermetic compressor in 1926. Before long the open sort compressors were totally supplanted by the hermetic compressors. To start with iceboxes utilized water-cooled condensers, which were soon supplanted via air cooled-condensers. Despite the fact that the advancement of mechanical household coolers was exceptionally fast in USA, it was still infrequently utilized as a part of different nations. In 1930 just rich families utilized residential fridges as a part of Europe. The household cooler in light of ingestion standard as proposed by Platen and Munters, was first made by Electrolux Company in 1931 in Sweden. In Japan the primary mechanical local fridge was made in 1924. The main double temperature (cooler fridge) residential icebox was presented in 1939. The utilization of mechanical residential iceboxes developed quickly everywhere throughout the world after the Second World War. Today, a local cooler has turned into a vital kitchen apparatus in very created nations as well as in nations, for example, India. But not very many all the present day local fridges are mechanical iceboxes that utilization a hermetic compressor and an air cooled condenser. The present day fridges utilize either HFC-134a (hydro-fluoro-carbon) or iso-butane as refrigerant.

II. Objectives

Draining nature of the ordinary vitality sources and expanding expense of electrical vitality are compelling humankind to search for conceivable alterations in the current frameworks towards lower vitality utilization without giving up the reason for which it is utilized. The family unit icebox utilized widely everywhere throughout the world for saving different nourishment items is one such framework which represents the considerable part of the house power bills. Cooler is a machine which lifts up the warmth from low evaporator temperature (weight) and pumps it against the high condenser temperatures (weight).

Taking after were the targets chose for accomplishing this point:

1. To study the writing on local fridge with higher evaporator temperature in the temperature scope of 265K-270K.
2. To study existing household cooler including lower temperatures.
3. To outline and manufacture a reasonable hairlike tube to be utilized with the altered icebox to give required evaporator temperature.
4. Redesigning the state of the evaporator utilized as a part of the cooler.
5. To assess the execution of the framework utilizing prescribed test techniques as a part of the writing.
6. To assess monetary reasonability of the framework for altering the current frameworks.

The purpose for selecting the temperature range 268K-272K for household icebox in the evaporator is to think about the impacts of the this temperature range on put away items and to build coefficient of execution of the cooler and to diminish the force utilization without influencing the zonal temperature in the different segments of fridge. When it is illustrated, then it is conceivable to use for the houses where the cooler compartment is infrequently utilized, here and there never utilized as a part of the nations like India.

III. LITERATURE REVIEW

The fact that a volatile fluid chills the skin when it evaporates has long been known. The principle of refrigeration is built on this observation, and refrigeration cycles have been invented to exploit this effect. The knowledge of turning vapours or gases into liquids by compression followed by condensation was being gathered during the second half of the 18th century. J.F. Clouet and G. Monge liquefied sulfur dioxide in 1780, and ammonia was liquefied by van Marum and van Troostwijk in 1787 (Gosney, 1982). The idea of putting together the principles of refrigeration by evaporation and liquefaction by compression seems to have been first suggested by Oliver Evans of Philadelphia, but it remains unclear whether he had tried it or not. The first complete description of a refrigerating machine working in a cycle and its subsequent manufacture was given in a patent specification by Jacob Perkins, an American inventor working in London. This machine is the prototype of all subsequent vapour compression systems [1].

K.Azzouz, D. Leducq, D. Gobin, 2008, Performance enhancement of a household refrigerator by addition of latent heat storage, International Journal of Refrigeration, 31, 892-901. K. Azzouz had studies the effect of adding a phase change material (PCM) slab on the outside face of a refrigerator evaporator. A dynamic model of the vapour compression cycle including the presence of the phase change material and its experimental validation is presented. The simulation results of the system with PCM show that the addition of thermal inertia globally enhances heat transfer from the evaporator and allows a higher evaporating temperature, which increases the energy efficiency of the system. The energy stored in the PCM is yielded to the refrigerator cell during the off cycle and allows for several hours of continuous operation without power supply.

Erik Bjork, Bjorn Palm, 2006, Performance of a domestic refrigerator under influence of varied expansion device capacity, refrigerant charge and ambient temperature, International Journal of Refrigeration, 29, 789–798.

Erik Bjork & Bjorn Palm had studied experimental results of an on/off cycling domestic refrigerator at varied expansion device capacity (EDC), quantity of charge and ambient temperature. It was found that the energy consumption is insensitive to varied EDC and charge within a wide range of settings. For the charge this is explained by the low side accumulator, which buffers over- and undercharge. It was also found that the optimum charge increased at lower ambient temperature. The paper describes an experimental procedure on how to determine the capillary tube length and the quantity of charge for a domestic refrigerator/freezer. This procedure is recommended since it takes different thermal masses and loads into consideration and since the potential for energy saving with a more sophisticated method appears to be limited.

Their study offers some insight into the question of optimum capillary tube capacity and quantity of charge for small, capillary tube throttled, on/off cycling vapour compression systems. [2].

Onrawee Laguerre, Evelyne Derens, Bernard Palagos, 2002, Study of domestic refrigerator temperature and analysis of factors affecting temperature: a French survey, International Journal of Refrigeration, 25, 653–659.

Onrawee Laguerre, et al., had conducted a survey in France on 143 families during April to June 1999, but only 119 refrigerator temperature files could be used. It was shown that 36% of families were unaware of the refrigerating system (static or ventilation) of their refrigerator. Seventy per cent of families set their thermostat at ‘‘less cold’’ positions (less than 50% of the maximum level). This may be for energy-consumption reasons or in order to achieve preferred consumption temperatures for certain foods without awareness of food safety. The temperature of 26% of surveyed refrigerators is higher than 8^0C, which is the regulatory temperature for stable foods in France. The difference between the temperature level during weekdays and weekends is not significant. [3].

O. Laguerre, S. Benamara, D. Flick, 2010, Study of water evaporation and condensation in a domestic refrigerator loaded by wet product, Journal of Food Engineering, 97, 118–126. O. Laguerre, and et al, had carried the study to gain a better insight into evaporation and condensation phenomena due to natural convection in a domestic refrigerator. An experiment was undertaken in a refrigerator loaded with 40 humid plaster cylinders (50 mm diameter). The weight variation of the cylinders was followed over 12 days and the rate of water evaporation (or condensation for some cylinders) was calculated. This measured experimental rate was compared with one obtained from a CFD simulation which took into account air flow by free convection, heat transfer (convection,

Conduction and radiation) and mass transfer (water evaporation and condensation). The position of high evaporation or condensation rate was well predicted despite the fact that the simulation most often underestimated the experimental values. Near the cold wall where condensation was observed (or near the warm wall where evaporation was observed), the cylinder temperature was lower (or higher) than that of air. This demonstrates the importance of the radioactive exchanges between the walls and the products inside a refrigerator which in turn can explain condensation or dehydration phenomena.

Zhili Lu, Guoliang Ding, 2006, Temperature and time-sharing running combination control strategy of two-circuit cycle refrigerator–freezer with parallel evaporators, Applied Thermal Engineering, 26, 1208–1217. The numerical tool developed in this study needs further adjustment. Then, it could be applied to more complex condition which is the case of a real domestic refrigerators loaded with food. This could be achieved by considering the load as a porous media with global properties such as surface/volume ratio, porosity, water content, conductivity and heat capacity etc. The simulation which gives information on temperature, velocity and humidity fields may be used to evaluate risk during food preservation in domestic refrigerator. [4].

Alan Meier, 2000, A General Design For Energy Test Procedures, Proceedings of the second International Conference on Energy Efficiency in Household Appliances, Napes (Italy), September 2000. Also published as Lawrence Berkeley National Laboratory Report LBNL-46213.

Alan Meier had described a new test procedure, which captures both the mechanical and logical features present in many new appliances. He also developed an energy test procedure for refrigerators that incorporates most aspects of the proposed new approach. Some of the strengths and weaknesses of the new test are described. Their approach also offers a novel solution to the harmonization problem. In their case of approach, everyone can agree on the same hardware tests, software tests, and simulation model. Each country may select its own output from the model. This output (which might appear on its energy-use labels, or be part of its minimum efficiency regulations) would reflect the unique conditions faced there. Their approach is considerably more complicated than current test procedures. This is not surprising, because it seeks to capture the energy impacts of complex interactions. [6].

H. M. Getu, P. K. Bansal, 2007, Modeling and performance analyses of evaporators in frozen-food supermarket display cabinets at low temperatures, International Journal of Refrigeration, 30, 1227-1243.

H.M. Getu & P.K. Bansal [7] had presented modelling and experimental analyses of evaporators in ‘‘in situ’’ frozen-food display cabinets at low temperatures in the supermarket industry. Extensive experiments were conducted to measure store and display cabinet relative humidity’s and temperatures, and pressures, temperatures and mass flow rates of the refrigerant. The mathematical model adopts various empirical correlations of heat transfer coefficients and frost properties in a fin-tube heat exchanger in order to investigate the influence of indoor conditions on the performance of the display cabinets.

IV. Methodology

In the past, various methods have been used to design a more efficient refrigerator. Among them, one of the most effective methods is to reduce the cabinet load. This is accomplished by increasing the thickness of the insulation on the walls of the refrigerator. Even though this remains one of the most effective approaches, it decreases the available storage space. Other than the thickening of refrigerator walls, the installation of an anti-sweat switch (to allow the user to turn off the electric heaters when the relative humidity is low), a better sizing of heat exchangers, improvements in compressor technology and the use of delayed defrost have all contributed to system improvement to meet the 1993 targets.

V. Experimental Setup

An experimental test set up of a FFDR was built for verifying the predictions. Basically experimental set up consist of five major components of the system, namely compressor, receiver, condenser, capillary tube and evaporator. The schematic diagram of the experimental set up is shown in fig. 4.2, the cooling capacity of existing system was 195 liters (0.682 kW).

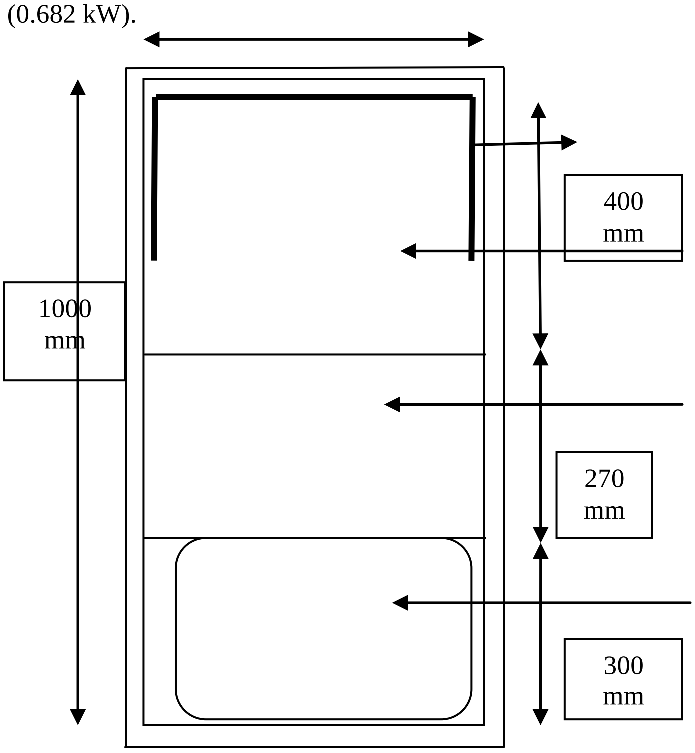

Fig.5.1 FFDR with compartment temperature measuring points

5.1 *Some Studies on Capillary Tube Design*

Capillary tube is a hollow drawn copper tube and is commonly used in refrigeration industry as an expansion device in low capacity refrigeration systems, where the load is fairly constant. Capillary tubes, in vapour compression systems, are used in two configurations – adiabatic and diabatic. In diabatic configuration, the capillary tube is bonded with the compressor suction-line by means of brazing or soldering to form counter-flow capillary tube/suction-line heat exchanger, whereas, in adiabatic configuration, there is no heat transfer from the capillary tube to the surroundings. The performance of the system enhances considerably if the capillary tube is used in diabatic mode, as heat transfer from the capillary to the cold suction-line causes a delay in vaporization, i.e., refrigerant leaves the capillary tube with lower vapour quality. This ultimately results in an increase in the refrigerating effect. On the other hand, heat transfer to the suction-line causes superheating of the vapours, thus diminishes the chances of liquid refrigerant entering the compressor and, thus, saving the compressor from being damaged. [2].

5.1.1 *Types of Capillary*

During the last few years, the behaviour of capillary tubes has been studied extensively; both experimentally and theoretically. These studies are discussed here under two groups namely, the adiabatic and the non-adiabatic capillaries.

a) Adiabatic capillary tubes

The flow inside a capillary tube was investigated in 1948 by Staebler who performed extensive tests and presented experimental data in a graphical form for selecting R12-based capillary tubes. He proposed a correlation: $L_I = Lo(dl/do)^{4.6}$ to calculate capillary length L_I, corresponding to new diameter d_a while Lo was the length corresponding to 1.07×10^{-3} m diameter tube. Later, Bolstad and Jordan presented an analytical solution for adiabatic capillary tubes. It was based on the homogeneous flow and constant friction factor throughout the flow. Marcy assumed the capillary tube to be smooth for friction factor calculations but liquid viscosity was used for the calculation of two-phase Reynolds number. In 1950, Hopkins developed a method for sizing capillary tubes. He presented a graphical method to integrate flow equations obtained from the conservation of mass, energy and momentum. These equations were also used by Bolstad and Jordan and by Marcy, who used simplified methods to solve them. Cooper *et al.* developed rating curves based on Hopkins work for capillary tube selection for 0.914 and 0.254 mm diameter tubes. Whitesel studied adiabatic capillaries assuming constant friction factor for the single-phase and two-phase regions, respectively. [5].

b) Non-adiabatic capillary tubes (NACT)

In practice, a non-adiabatic capillary tube is normally soldered to the suction line to heat and evaporate the residual liquid in the suction line. This suction line heat exchanger (or the non-adiabatic capillary) is seen to result in efficiency improvement, because it increases the refrigeration capacity of the system by the amount of heat being transferred from the capillary to the suction side.

5.2 Evaporator

An evaporator, like condenser is also a heat exchanger. In an evaporator, the refrigerant boils or evaporates and in doing so absorbs heat from the substance being refrigerated. The name evaporator refers to the evaporation process occurring in the heat exchanger.

5.2.1 Classification

There are several ways of classifying the evaporators depending upon the heat transfer process or refrigerant flow or condition of heat transfer surface.

a) Natural and Forced Convection Type

The evaporator may be classified as *natural convection* type or *forced convection* type. In forced convection type, a fan or a pump is used to circulate the fluid being refrigerated and make it flow over the heat transfer surface, which is cooled by evaporation of refrigerant.

b) Refrigerant Flow Inside or Outside Tubes

The heat transfer phenomenon during boiling inside and outside tubes is very different; hence, evaporators are classified as those with flow inside and outside tubes. In natural convection type evaporators and some other evaporators, the refrigerant is confined and boils inside the tubes while the fluid being refrigerated flows over the tubes.

c) Flooded and Dry Type

The third classification is flooded type and dry type. Evaporator is said to be *flooded type* if liquid refrigerant covers the entire heat transfer surface. This type of evaporator uses a float type of expansion valve. An evaporator is called *dry type* when a portion of the evaporator is used for superheating the refrigerant vapour after its evaporation.

5.2.2 Natural Convection type evaporator coils

These are mainly used in domestic refrigerators and cold storages. When used in cold storages, long lengths of bare or finned pipes are mounted near the ceiling or along the high sidewalls of the cold storages. The refrigerant from expansion valve is fed to these tubes.

5.2.3 Plate Surface Evaporators

These are also called bonded plate or roll-bond type evaporators. Two flat sheets of metal (usually aluminum) are embossed in such a manner that when these are welded together, the embossed portion of the two plates makes a passage for refrigerant to flow. This type is used in household refrigerators. Figure 2.9 shows the schematic of a roll-bond type evaporator. In another type of plate surface evaporator, a serpentine tube is placed between two metal plates such that plates press on to the tube.

5.3 Some Studies on Domestic Refrigerator Testing Procedure

As appliance manufacturers expand their businesses into a global market, it becomes more desirable to develop an international test procedure for the rating of their products. An international test procedure would allow manufacturers to reduce their use of valuable resources required to perform different tests for each appliance. Although the intent of each test procedure is the same for a given product, the differing needs and preferences have resulted in differences in the test procedures.

VI. RESULTS AND DISCUSSION

Pure HFC-134a used as refrigerant as it is ecofriendly and commonly used in recent all types of domestic refrigerators, is used in the FFDR and conventional refrigerator for the experimentation purpose. Discussion of the results will be given in turn as follows:

a) Comparision of Compressor Power for conventional and FFDR

The cycle had been drawn on P-h chart of R134a and power required to run the Compressor had been calculated from P-h chart of R134a interms of kJ/kg of refrigerant for both the rerigerators i.e. conventional and FFDR.

Fig.6.1 shows the bar chart for comparing the theorotical compressor power and it can be observed from it that FFDR requires less power as compared to the conventional one. This results in less electric power consumption during actual testing.

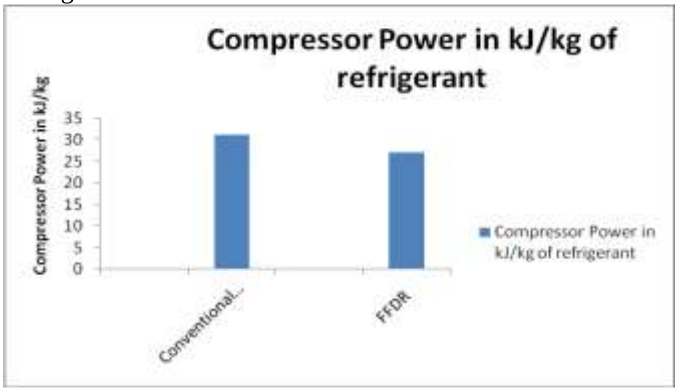

Fig.6.1 Compressor power in kJ/kg of refrigerant

b) Comparision of Refrigerating Effect for conventional and FFDR

Refrigerating effect is used to measure &/or dicide the capacity of domestic refrigerator. In this case the refrigerating effect is firstly calculated on the basis of kJ/kg of refrigerant for conventional and FFDR and it is comapred as shown Fig. 6.2. From this figure it is clear that refrigerating effect is reduced by approximatly 4% in FFDR on the basis of kJ/kg of refrigerant.

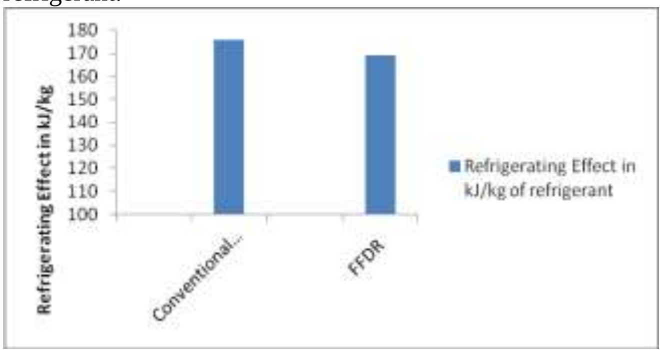

Fig.6.2 Refrigerating Effect in kJ/kg of refrigerant

But if refrigerating effect is calculated in terms of kW then it is observed that refrigerating effect had been increased by approximately 9% in the FFDR as compared to conventional one as shown in Fig. 6.3

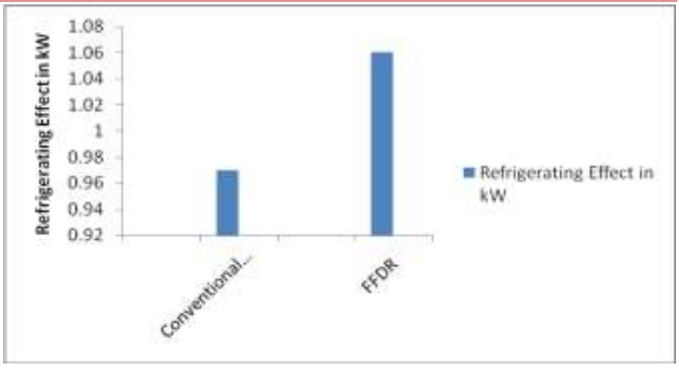

Fig.6.3 Refrigerating Effect in kW

c) Comparisons of COP for conventional and FFDR

Coefficient of performance (COP) is calculated to evaluate and compare the performance of the refrigerator with other type of refrigerators. Here the COP is calculated from P-h chart of R134a and it is compared with the COP of conventional one. From this comaprision it is found that COP of the FFDR system had been increasd by approximately 10% as shown in Fig. 6.4

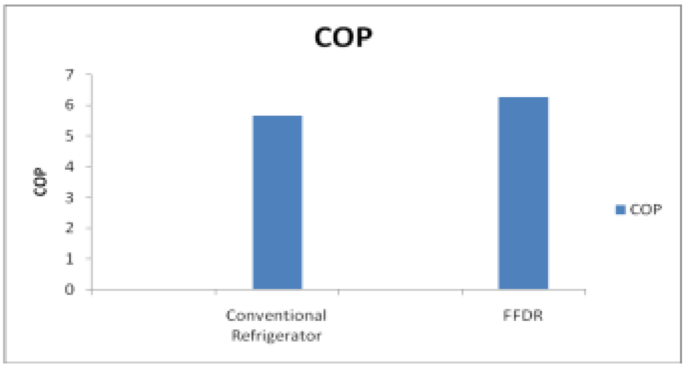

Fig.6.4 Comaparision of Coeficient of Performance

VII. CONCLUSIONS AND FUTURE SCOPE

The aim of this study was to design, fabricate and test the domestic refrigerator over the higher evaporator temperature range so that it can used in the houses where freezers compartment is normally underutilized. The conventional refrigerator has been modified by changing the temperature range for the evaporator to be 270 K to 265 K in place of 255 K to 229 K. The purpose of selecting the evaporator temperature range of 265K-270K for domestic refrigerator was to maintain the compartment temperature conditions unaltered in FFDR and to study the effects of the this temperature range on power consumption and coefficient of performance (COP) of the refrigerator.

After conducting various tests on conventional refrigerator and FFDR having same compressor power rating and refrigerating capacity before modification are selected and the coefficient of performance (COP), refrigerating effect and power consumption were studied. The major conclusions drawn based on the experimental investigations are summarized below:

a) The COP of the FFDR has been increased by 10% as compared to conventional refrigerator.

b) The refrigerating effect (in kJ/kg of refrigerant) of the FFDR had been decreased by 4% in comparison with conventional refrigerator on the other hand it had been increased by 9%, when calculated in kW due to the increase in mass flow rate of refrigerant.

c) The electric power consumption of the modified refrigerator has been reduced by approximately 25% when the system is running in continuous on-off cycle as compared to conventional one. This drastic increase is due to the less on time of the FFDR in comparison with conventional refrigerator.

d) The temperature variation in fresh food compartment of the FFDR is very less i.e. in between 276 K to 278 K. So more uniform temperature had been achieved in the FFDR as compared to the conventional refrigerator.

FFDR can be used as domestic refrigerator for the families those doesn't store meat or deserts in their refrigerator or for those families in which the freezer compartment is underutilized, rarely by using either in summer for making ice cubes, for quick chilling of water. For this families the freezer compartment becomes redundant here the FFDR can be an option for conventional refrigerator on account of compromising with freezer compartment and short term storages of deserts.

By using FFDR instead of conventional refrigerator such families can save 24% - 30% electric power consumption for the refrigerator result into reduction in electric cost with more uniformity in compartment temperatures in the domestic refrigerator which will leads to better performance.

So FFDR can be a better option for conventional refrigerator in near future by compromising the freezer facility if it becomes redundant or underutilized for the specific group of people.

Future Scope

The present study was carried out on FFDR by using R134a the refrigerant and the results are compared with the conventional refrigerator. The following modifications can be made to further studying the performance of the system.

a) The automated measuring instruments can be used for the closed control of the parameters.

b) Performance of FFDR can be evaluated using some other synthetic refrigerants.

c) FFDR can be tested by modifying the condenser and varying the refrigerant mass flow rate.

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