Comparative Study of Domestic Refrigerator by Using Parallel Coil and Helical Coil Condenser

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Abstract - *Domestic refrigerators had become the member of the every family. It had made our busy life more simple and comfortable. Also it becomes an essential part of the life in summer for chilled drinking water and preserving the food stuff for short period throughout the year.*

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.

Helical coils are compact in size and provides distinct benefit like higher film coefficient, more effective utilization of available pressure drop, which results in efficient and less expensive design. Helical coil permits handling of high temperature and extreme temperature differentials without high induced stresses or costly expansion joints. Helical coil offer advantages over straight tubes due to their compactness and increased heat transfer coefficient. The increased heat transfer coefficients are a consequence of the curvature of the coil, which induces centrifugal forces to act on the moving fluid, resulting in secondary flow. So helical coil condenser heat transfer to the surrounding is more as compare to parallel coil condenser so due to this the COP of refrigerator increases and power required to compressor deceases

Key Words: **refrigerator, Parallel coil, Helical coils, VCR, Coefficient of performances**

1. INTRODUCTION

1.1 Background

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures. Refrigeration systems are also used extensively for providing thermal comfort to human beings by means of air conditioning. Air Conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odour and circulation, as required by occupants, a process, or products in the space. The subject of refrigeration and air conditioning has evolved out of human need for food and comfort, and its history dates back to centuries. The history of refrigeration is very interesting since every aspect of it, the availability of refrigerants, the prime movers and the developments in compressors and the methods of refrigeration all are a part of it.[1-3]

1.2 Helical Coil

When a fluid flows through a parallel tube the velocity is maximum at the tube center, zero at the tube wall and symmetrically distributed about the axis. However when a fluid flows through a curved tube, the primary velocity profile shown in Figure 1.1 is distorted by the addition of secondary flow pattern. The secondary flow is generated by the centrifugal action and acts in the plane perpendicular to the primary flow.

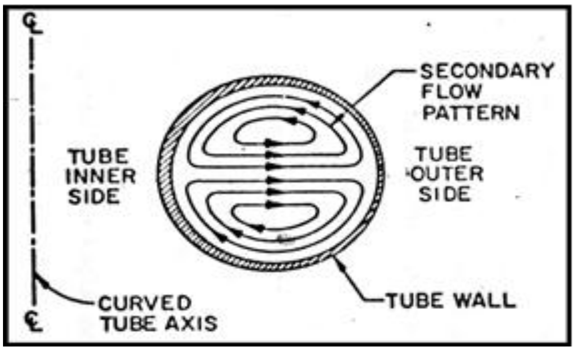

Fig: 1.1 Sketch of secondary flow pattern in curved tube

Since the velocity is maximum at the tube center the fluid at the center is subjected to maximum centrifugal action, which pushes the fluid towards outer wall. The fluid at the outer wall moves inward along the tube wall to replace the fluid ejected outwards. This results in the formation of two vortices symmetrically about a horizontal plane through the tube center[9-12].

1.3 Scope of the Work

As Figure 1.2 shows, refrigerators are typically among the largest consumer of electrical energy in an American home. In the United States alone, over 8.5 million refrigerators, which range from 1.7 cubic feet compact models to the 30.1 cubic feet side-by-side models, are sold annually. There are many of these appliances in use and they operate more or less continuously, so they have a significant impact on the utilities. They consume 18% of electric energy which is consumed by the any household appliances. In an effort to reduce their energy consumption, one can go for retrofitting or modifications in the existing system. One of the modifications is to redesign the refrigerator to operate under different conditions like higher evaporator temperature which will lead to reduce the power consumption[17].

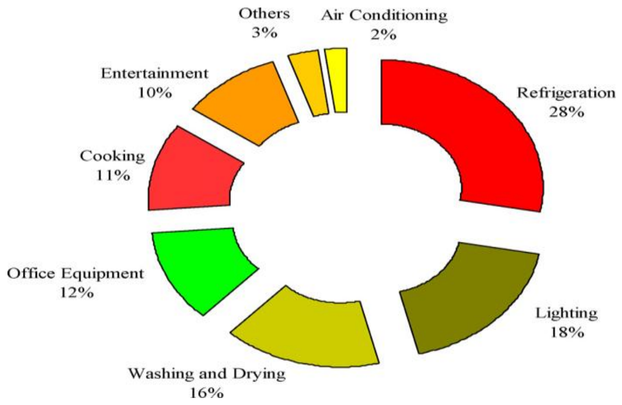

Fig: 1.2 Distribution of household electrical energy consumption in a household [17].

2. LITERATURE SURVEY

In 1994, R. N. Richardson and J. S. Butterworth, [1] Experiments have been conducted to investigate the performance of hydrocarbon refrigerants in a hermetic vapour-compression system. It is shown that propane and propane/isobutene mixtures may be used in an unmodified R12 system and give better COPs than R12 under the same operating conditions.

In 1995, Alan Meier,[2] studied methods for energy tests of refrigerator. First method is "Department of Energy ANSI", second method is "Japan Industrial Standard JIS" and third method is "International Standards Organization ISO/DIS". He found "Department of Energy ANSI" is the efficient energy test method for refrigerator. The most reliable way to reduce refrigerator energy use is to replace old units with new ones. This action often cuts electricity use 60%. Programs to collect old refrigerators and encourage consumers to buy new, high-efficiency ones are likely to be highly effective for many years.

In 1996, W. L. Martz, C. M. Burton and A. M. Jacobi, [3]studied The VLE predictive performance of six local composition mixture models was compared for seven refrigerant and oil mixtures. The mixtures exhibited positive, negative and mixed deviations from the Lewis-Randall rule. Interaction parameters for the mixture models were related to mixture behavior and he found The utility of any model depends on its simplicity, accuracy and generality. Models with many empirically determined parameters usually require more experimental data and are more complicated than models with fewer parameters. However, purely empirical models, like those of Grebner and Crawford and Thome , may be more attractive in some situations.

In 1996, R. Radermacher and K. Kim, [4] he found the refrigerator/freezer is one of the most important and the biggest energy-consuming home appliances. There are several literature references that discuss the historical development of refrigeration. Recent environmental concerns led to a considerable boost in development efforts emphasizing two aspects: (1) environmentally safe fluids; and (2) reduced energy consumption.

In 1998, C. Nikolaidis a & D. Probert b,[5] studied The behavior of two-stage compound compression-cycle, with dash intercooling, using refrigerant R22, has been investigated by the exergy method. The condenser's saturation- temperature was varied from 298 to 308 K and the evaporator's saturation-temperature from 238 to 228 K. The effects of temperature changes in the condenser and evaporator on the plant's irreversibility rate were determined.

In 2001, Onrawee Laguerre, Evelyne Derens& Bernard Palagos, [6] A survey was carried out in France from April to June 1999. Temperatures were recorded at three levels (top, middle and bottom) of the refrigerator compartment and This study shows that the combination of the use conditions (temperature setting, frequency of door openings, heat sources and built-in) seems to have a major impact on the refrigerator temperature.

In 2002, Cemil Inan, Turgay Gonul & M. Yalcin Tanes, [7] the transient behavior of a domestic refrigerator is investigated by the use of an X-ray system. The studies are made on a two-door upright freezer with a volume of 435 liters, and which has an automatic defrost feature. The refrigerant is R134a. X-ray system is very beneficial to understand some transient behaviors of the refrigerator. Tubes like steel and copper are not good for clear images. Aluminum tubes are recommended for clear observations. If the flow inside the steel tubes are a point of interest then the ''Neutron Radiography Technique'' is recommended.

In 2003, R. Paul Singha & Ferruh Erdogdub, [8] In this, the time required for freezing and thawing different meat products was determined for five different models of household refrigerators. Two refrigerators had "quick thaw" compartments and three refrigerators had ''quick freeze'' capabilities. This research showed that some refrigerator models froze and thawed foods significantly faster than others. The refrigerators with quick freezing capabilities were successful in freezing the tested meat products in less time than the models without that capability Running the refrigeration system continuously in the ''quick freeze'' operation lowered the temperature in the freezer and caused faster freezing.

In 2016, R.Hussain Vali , P.Yagnasri & S.Naresh Kumar Reddy, [9] The design of condenser plays a very important role in the performance of a vapor compression refrigeration system. Effective new designs are possible through theoretical calculations, however may fail due to the reason that the uncertainties in the formulation of heat transfer from the refrigerant inside the condenser tubes to the ambient air. Hence experimental investigations are the best in terms of optimization of certain design parameters. The main objective in the present work is an attempt is made to verify the performance of existing condenser design to helical shaped condenser design and varying the length of the helical condenser coil to verifying the effect on the performance of a domestic refrigerator capacity 165lts, R-134a as refrigerant, hermetic sealed compressor. It is expected that the helical shaped condenser installation may give optimum results. Finally it is observed that by changing the conventional design to Helical shaped condenser the performance of the refrigeration system is increased.

In 2016, Suresh.B & Venkatesh.G, [32] 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. 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.

In 2017, Christian James, Bukola A. Onarinde, and Stephen J. James, [33] The domestic refrigerator is now a common household device with very few households in the developed world not possessing 1, or more, for the storage of chilled foods. Domestic storage is the last, and in many respects the most important, link in the food chill chain. Inadequate domestic refrigeration or cooling is frequently cited as a factor in incidents of food poisoning. The authors reviewed the temperature performance of refrigerators in 2008. This new review builds on that review, covering studies that have been published since (and those that were unfortunately missed in the first review), and also seeks to put this important stage of the food cold chain in its context.

In 2017, Divya Jyothi & K.Shiva Ramakrishna Rao, [10] in this paper Helical coil heat exchangers are widely used in industrial applications such as power sector, nuclear power generation, food processing plants, heat recovery systems, refrigeration, food industry, industrial HVACs etc. Refrigerator the condenser coil is used to discharge the heat from the refrigerant after operating the compression to the atmosphere. In General this heat rejection rate depends is mainly on various parameters for example, ambient air temperature, dimensions of the coil, diameter of the coilIn 2017, Ashkan Alimoradi, [11] in the present study, the effect of operational and geometrical parameters on the thermal effectiveness of shell and helically coiled tube heat exchangers was investigated. Analysis was performed for the steady state. The working fluid of both sides is water, that its viscosity and thermal conductivity were assumed to be dependent on temperature. Based on the results, two correlations have been developed to predict the thermal effectiveness, for wide ranges of mass flow rates ratio, dimensionless geometrical parameters and product of Reynolds numbers. Furthermore, it was found for same values of NTU and Cr, the effectiveness is averagely 12.6% less than the effectiveness of parallel flow heat exchangers and this difference is approximately constant.

In 2017, Mohammad Reza Salimpour, Ali Shahmoradi & Davood Khoeini, [12] In this research, the heat transfer coefficients of R-404A vapor condensation inside helically coiled tubes are studied, experimentally. The effects of different coil pitches and curvature radii at different vapor qualities and mass velocities are considered. The vapor is condensed inside the helically coiled tubes by transferring heat to the cooling water flowing in annulus. Results show that the coil diameter has significant effect on condensation heat transfer coefficient.

In 2017, Nadia Essalhi & Ali Fguiri, [13] Absorption machines are considered as a good alternative to vapor compression systems in terms of energy efficiency and environmental impacts. However, they use undeveloped resources (industrial waste heat) and renewable energy (solar energy) as primary energy sources. These considerations focus on the intent of the market on small-capacity absorption machines for domestic applications. The major problem of absorption machines is the high investment cost, which is mainly due to the prices of different components of the machine.

In 2017, Lingjian Kong & Jitian Han, [14] The helically coiled tubes with two-phase flow are widely used as heat transfer equipment in power stations, chemical plants, nuclear reactors, refrigeration systems, and many others. This paper investigates experimentally the sub cooled boiling heat transfer characteristics of R134a in vertical helically coiled tubes with heat flux varying from 0.1 to 14.5 kW m 2, mass flux from 147.5 to 443.7 kg m 2 s 1, inlet sub cooled temperature from 4.7 to 15.0 C and pressure from 450 to 850 kPa. Experimental results indicate that the generated bubbles always slide along the heated surface in the vertical helically coiled tube while the radial component force is negative, which contributes significantly to the heat transfer enhancement and non-uniformity of the wall temperature in sub cooled flow boiling. Moreover, the temperature distribution in the vertical helically coiled tube is totally different from that of the horizontal one which is affected by the secondary flow, velocity profile of main flow and bubble behaviors.

3. OBJECTIVES

Following were the objectives decided for achieving this aim:

1. To study the literature on domestic refrigerator with higher evaporator temperature in the temperature range of 265K-270K.

2. To study existing domestic refrigerator including lower temperatures.
3. To design and fabricate the modified refrigerator to provide required evaporator temperature.
4. To calculate the COP of domestic refrigerator by using parallel coil condenser.
5. To calculate the COP of domestic refrigerator by using helical coil condenser.
6. Comparison between parallel coil condenser and helical coil condenser for refrigerator.

4. EXPERIMENTAL WORK

For experimentation taking old refrigerator having capacity of 180 liters with energy meter arrangement,

Fig.4.1 Experimental Setup

Existing system having parallel coil condenser, We design the helical coil of same length having diameter of 262.5mm and spacing of 50 mm & fabricate in to the old system. We also put four valves at different position as follows.

1) In between outlet of compressor and inlet of parallel coil condenser.

2) In between outlet of compressor and inlet of helical coil condenser.

3) In between outlet of parallel coil condenser and inlet of capillary tube.

4) In between outlet of helical coil condenser and inlet of capillary tube.

For avoiding refilling of refrigerant at every time .

4.1 Leak detection methods

Bubble Solutions. The oldest method of leak detection is the bubble solution. In a nutshell, soap solution is applied at suspected leak points, usually with a squeeze bottle, brush, or dauber. Theoretically, the escaping refrigerant will produce bubbles at the leak sites. However, very small leaks or windy conditions may make this method ineffective.

4.2 Joining methods

Brazing:- brazing is a metal-joining process in which two or more metal items are joined together by melting and flowing a filler metal into the joint, the filler metal having a lower melting point than the adjoining metal.

5. RESULTS AND DISCUSSION

1. Net Refrigerating Effect For parallel coil condenser Vs Helical coil condenser

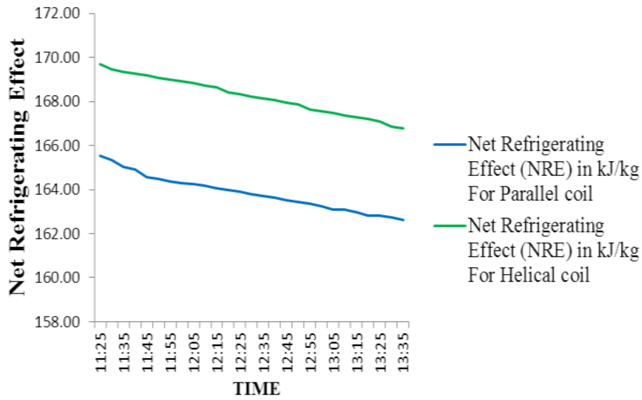

Chart -1: NRE For parallel Vs Helical coil condenser

From the chart 1 we see the Net refrigerating effect goes down with respect of time for both the coil. But the net refrigerating effect of helical coil condenser is more as compare with parallel coil condenser.

2. Circulating rate to obtain one tone of Refrigeration,

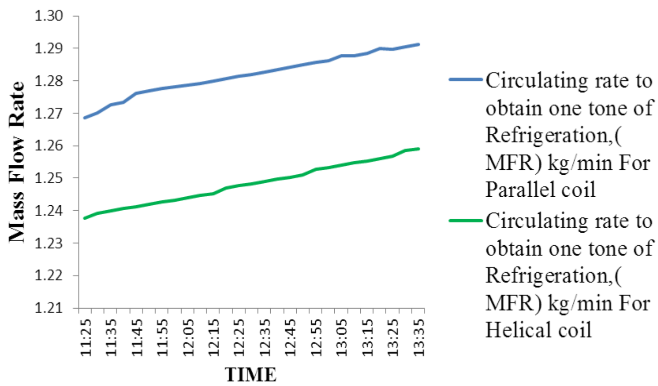

Chart -2: Mass Flow Rate For parallel Vs Helical coil condenser

From chart 2 we see the mass flow rate increases with respect to time for both the coil. But the value of mass flow rate for parallel coil condenser is more as compare with helical coil condenser.

3. Heat of compression(CW)

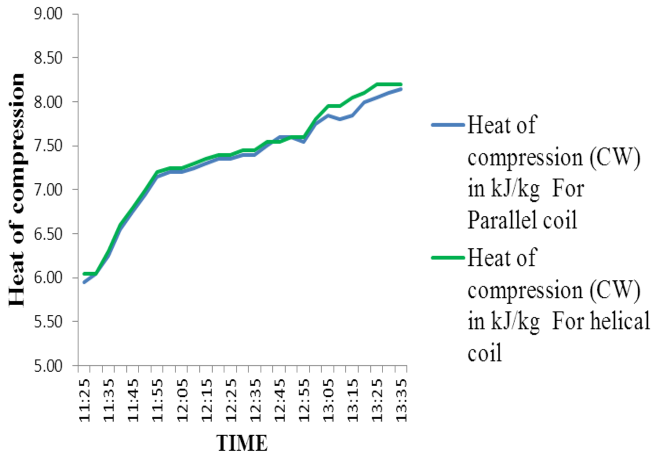

Chart -3: Compressor work For parallel Vs Helical coil condenser

From the chart 3 we see the Compressor work goes up with respect of time for both the coil. But the Compressor work of helical coil condenser is little more as compare with parallel coil condenser.

4. Heat Equivalent of work of compressor

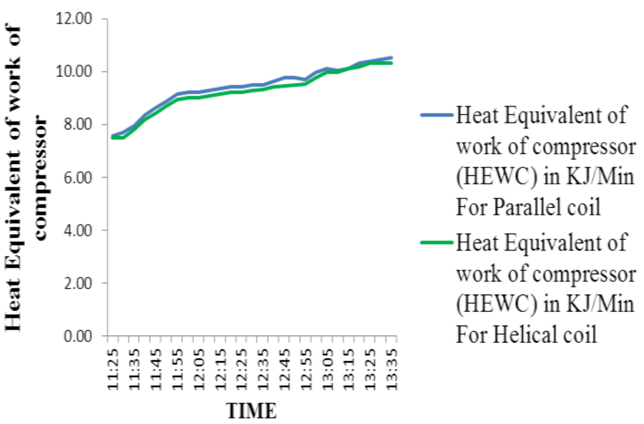

Chart -4: Equivalent work For parallel Vs Helical coil condenser

From chart 4 we see the Heat Equivalent of work of compressor increases with respect to time for both the coil. But the value of Heat Equivalent of work of compressor for parallel coil condenser is more as compare with helical coil condenser.

5. Compressor power.

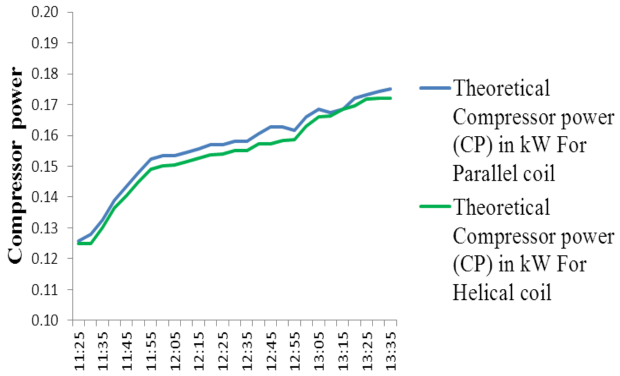

Chart -5: Theoretical power For parallel Vs Helical coil condenser

From chart 5 we see the Compressor power increases with respect to time for both the coil. But the value of Compressor power for parallel coil condenser is more as compare with helical coil condenser.

6. Coefficient of performance (COP)

From the chart 6 we see the COP goes down with respect of time for both the coil. But the COP of helical coil condenser is more as compare with parallel coil condenser.

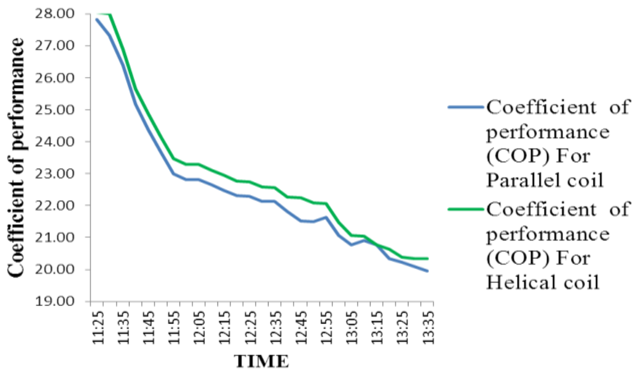

Chart -6: COP For parallel Vs Helical coil condenser

7. Heat rejected in condenser

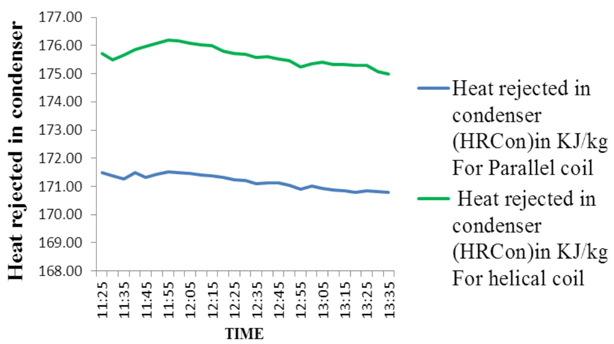

Chart -7: Heat rejected in condenser For parallel Vs Helical coil condenser

From the chart 7 we see the Heat rejected in condenser goes down with respect of time for both the coil. But the Heat rejected in condenser of helical coil condenser is more as compare with parallel coil condenser.

8. Heat Rejection Ratio

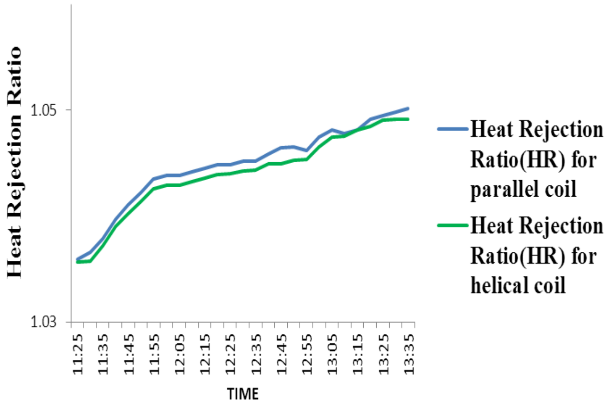

Chart -9: Heat rejection ratio For parallel Vs Helical coil condenser

From chart 8 we see the Heat rejection Ratio increases with respect to time for both the coil. But the value of Heat Rejection ratio for parallel coil condenser is more as compare with helical coil condenser.

6. CONCLUSION

After conducting various tests on Domestic refrigerator 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:

- The COP of the refrigerator is very small increased by using helical coil condenser as compared to parallel coil condenser
- The refrigerating effect (in kJ/kg of refrigerant) of the refrigerator is very small increased by using helical coil condenser as compared to parallel coil condenser.
- The compressor Work for helical coil condenser is More as compare with parallel coil condenser.
- The electric power consumption of refrigerator is more by using helical coil condenser as compared to parallel coil condenser
- Heat rejection ratio of parallel coil is more.

The energy required for running compressor is re for helical coil due to friction losses also space required for helical coil is more as parallel setup is compact.

So conclusion from above result and discussion is that parallel coil condenser is better than the helical coil condenser.

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