Variation in Coefficient of Performance of Domestic Refrigerator by Water Cooling Jacket and Heat Recovery

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Abstract- *Increasing the coefficient of performance is essential due to energy crisis, there is vast scope exist in domestic refrigerator system. Many researches are still going to improve the COP (coefficient of performance) and efficiency of domestic refrigerator also day by day increase in electricity charges or bill also motivated me to study the refrigeration system so that we can improve the COP and reduce the electric consumption because domestic refrigerator is one of the most electric consuming appiliance.We usually see that COP of domestic refrigerator decreases in summer seasons. To solve above problem ,we have find alternative method to improve the COP of domestic refrigerator along with refrigeration effect in summer season so that we can reduce the consumption of electricity. And for this we are going introduce the water cooling jacket model of domestic refrigerator for subcooling the refrigerants in which water will circulate without any external pump in complete cycle and to increase the heat rejection rate from the condenser we will cool the condenser by cold water obtained from desert cooler. In this setup water will surround the condenser coil by help water cooling jacket so that better heat rejection takes place. Our system will also work as heat recovery unit and from this manually water filling problem in desert cooler can also be solved.*

Keywords- COP, R-134a, Water Cooling Jacket, Water Cooled Condenser, Domestic Refrigerator, Desert Cooler.

I. INTRODUCTION

Refrigerator is a device which extracts heat continuously from the system and dissipates that heat into the surroundings with the help of an external aid like electrically driven compressor which is described in second law of thermodynamics. There are many statements for second law of thermodynamics, but two of them are very important they are, i) Kelvin and Planck Statement- "According to this statement it is impossible to develop a cyclic device which produces work by exchanging heat with single reservoir." and ii) Clausius Statement- "It is impossible to develop a device which transfer heat from lower temperature to higher temperature without any external energy input ." The term "Refrigeration" is defined as a process of removing heat from a substance and maintaining its temperature well below the atmospheric temperature under controlled conditions. And "Refrigeration Effect" is the amount of heat which is required to extract from storage space in order to provide and maintain lower temperature then that of surrounding. Refrigeration has been adopted from ancient times where they had used method of artificial cooling in ice making; now a days they are used for preservation of the perishables such as milk, food, drinks, medicines, etc. and indoor air cooling to provide human comfort and cool environment is required In electronic, precision manufacturing and process industries, and also in various other applications like cryogenics, etc.

COP (Coefficient of Performance): It is defined as the ratio of desired effect to the work input or it is defined as the ratio refrigeration effect to work input ,COP is also known as energy performance ratio (EPR).

In conventional Refrigeration System the condenser is cooled by air which can be free convection or in some cases by forced convection where a forced draught fan forces the air over the condenser but the COP of such a system is relatively low since heat carrying capacity of air is less .The COP can be increased by using water as a cooling medium because water has more heat carrying capacity than air. In this experiment the air cooled condenser of a domestic refrigerator has been replaced by a water cooled condenser. In refrigeration system, there are four main components:

1) Evaporator
2) Compressor
3) Condenser
4) Expansion Device.

Evaporator, Compressor and Expansion Device are the inbuilt inner parts of the system body so we can't change in them. Condenser is the outer part of the system body. Doing various changes on condenser we can improve in refrigeration system. To increase COP, condenser is the best option so that we are going to work on condenser. The condenser is an important device used in high pressure side of refrigeration system. Its function is to remove heat of the hot vapour refrigerant discharged from compressor. The hot vapour refrigerant consists of the heat absorbed by the evaporator and the heat of compression added by the mechanical energy of the compressor motor. The heat from hot vapour refrigerant in a condenser is removed first by transferring it to the walls of the condenser tubes and then from the tubes to the condensing or cooling medium.

1.1 Condenser

The condenser is an important heat exchanger device used in high pressure side of refrigeration system. Its function is to remove heat of the hot vapour refrigerant discharged from compressor. The hot vapour refrigerant consists of the heat absorbed by the evaporator and the heat of compression added by the mechanical energy of the compressor motor. The heat from hot vapour refrigerant in a condenser is removed first by transferring it to the walls of the condenser tubes and then from the tubes to the condensing or cooling medium.

1.2 Classification

1.2.1 Air cooled condensers
1.2.2 Water cooled condensers
1.2.3 Evaporative condensers

1.21 Air-cooled condensers

An air-cooled condenser is one in which the removal of heat is done by air. It consists of steel or copper tubing through which the refrigerant flows. The size of tube usually ranges from 6 mm to 18 mm outside diameter, depending upon the size of condenser. Generally copper tubes are used because of its excellent heat transfer ability.

1.2.1 Types of air cooled condenser

a. Natural convection type
b. Forced convection type

1.2.2 Water cooled condenser

A water cooled condenser is one in which water is used as the condensing medium. They are always preferred where an adequate supply of clear inexpensive water and means of water disposal are available. These condensers are commonly used in commercial and industrial refrigerating units. The water cooled condensers are classified, according to their construction, into the following three Groups.

a. Tube-in-tube or double tube condensers
b. Shell and coil condensers
c. Shell and tube condense

1.2.3 Evaporative condensers

In evaporative condensers, both air and water are used to extract heat from the condensing refrigerant. Evaporative condensers combine the features of a cooling tower and water-cooled condenser in a single unit. In these condensers the water is sprayed from top part on a bank of tubes carrying the refrigerant and air is induced upwards. There is a thin water film around the condenser tubes from which evaporative cooling takes place.

Objective of this review paper is to investigate effect of water cooled condenser in household refrigerator by using the water cooling jacket in comparison to air cooled condenser along with this solving the issue filling water inside the desert cooler in day and night manually. As we that know that in desert cooler normally water evaporate in 2-3 hour of working after which we need to fill the tank of cooler again manually but from our experimental setup there will no need to fill the tank of desert cooler manually and in winter season by removing the desert cooler, system can be used as waste heat recovery unit. The hot water can be utilized for household application like cleaning, dish washing, laundary, bathing etc.The variation in energy consumption in water cooled and air cooled condenser will also be investigate at different load condition.

II. LITRATURE SURVEY

The literature review has been done to determine the variations in the coefficient of performance of air cooled condenser and water cooled condenser of domestic refrigerator and various methods of heat recovery, also various other methods have been studied through review paper to improve the COP of domestic refrigerator. Variation in refrigeration effect and percentage saving in electricity are also reviewed.
A study was performed in 16th july 2017 on "Comparison of performance VCRS with difference modes of condenser cooling with different refrigerant", this thesis compares the performance of refrigeration system employing two types of condensers, namely the air-cooled condenser and the water-cooled condenser. The experiment was done using R-134a and

HC (mixture of R290 and R600a) as the refrigerant. The performance of the refrigeration system with air-cooled and water-cooled condenser was compared with refrigerant R-134a and HC (Hydro carbon).The results indicate that the refrigeration systems performance had improved when water-cooled condenser was used with refrigerant HC.Water-cooled condenser reduced the energy consumption when compared with the air-cooled condenser. The water-cooled heat exchanger was designed and the system was modified by retrofitting it, instead of the conventional air-cooled condenser by making a bypass line and thus the system can be utilized as a waste heat recovery unit. The hot water obtained can be utilized for household applications like cleaning, dish washing, laundry, bathing etc.By this research we come to know that by sub cooling coefficient of performance of refrigerator get increased and water cooled condenser consume less power than air cooled condenser.[1].

A paper was published in 1st May 2017 on "Parametric study of the wire-on-tube condenser subcooling effect on the performance of vapor compression refrigeration system", in this paper a parametric study of the condenser subcooling effect on the performance of vapor compression refrigeration system was presented. The first shutter consists in introducing of an analysis methodology which makes it possible to determine the COP of the refrigeration cycle with subcooling for the three used R12, R134a and R600a as refrigerants. While in the second part, an analytical approach was developed in order to calculate the additive surface of the wire on-tube condenser used in application apparatus. Variation in subcooling temperature and pressure ratio for all three refrigerants is taken in all stages of this study. The results obtained through this study have shown that, in the subcooling temperature interval from 0°C to 14°C, the condenser additive surface is lower for R600a refrigerant compared to R134a. Moreover, the increase in subcooling temperature plays a significant role in the rise of refrigeration cycle efficiency. This study provides the parametric analysis of the subcooling effect on the COP of vapor compression refrigeration system and its wire-on-tube condenser additive surface by using the R134a, R12 and R600a under various pressure ratios. It presents a contribution to the development of an analysis methodology making it possible to predict the condenser subcooling impact and its additive surface. By this study we come to know that the COP increases with the increase of the subcooling temperature for different refrigerant in the range of subcooling temperature from 0°C to 8°C, R600a presents the greatest COP improvement and less condenser additive surface compared to R134a. Therefore, the substitution of R134a by R600a in this range of subcooling is useful in order to generate a good thermo-economic output. [2].

A study was performed in 12th December 2017 on "Adaptive defrost methods for
Improving defrosting efficiency of household refrigerator", in this paper they highlighted that the defrosting method of the conventional household refrigerator increases freezer temperature during the defrosting operation and defrosting efficiency reduces because the heater consumes more power than the amount of frost on the surface of the heat exchanger. To solve this problem, three defrost heater control methods, applicable to refrigerators equipped with conduction and radiation heaters, was being proposed. The control methods were classified as a method of simultaneously pulsating two heaters, method of individually pulsating two heaters, and method of step-by-step reduction of radiation heater power. The operation effect of each heater on freezer temperature was analyzed. For the three methods, a heater control optimization process was performed to reduce the temperature increase in the freezer. From this experiment they conclude that power consumption of heater gets minimized and defrosting efficiency improved The Best performance was observed when two heaters pulsated individually. For this method, the variation in freezer temperature, between before and after the defrost process, was reduced from approximately 11 °C to 5 °C. Additionally, the defrosting efficiency improved by 15%.From this paper we learn that the in the individual pulsating mode, the heater power was controlled more efficiently by controlling the two heaters separately unlike the simple pulsating mode. The effect of the sheathed heater operating rate on the freezer temperature was the most significant. [3].

The experimental investigation was done in 2nd May 2017 on "Experimental study of R1234yf as a drop-in replacement for R134a in a domestic refrigerator" This paper presents an experimental study for three identical domestic refrigerators using R1234yf as a drop-in replacement for R134a. An alternative methodology was proposed to estimate the optimal mass charge for R1234yf with the use of such methodology, new evidences were sought on the thermal behavior of the refrigerator compartments as well as at the heat exchangers. Additionally, energy performance for both refrigerants was measured and finally, a TEWI analysis was conducted. For the type of refrigerator evaluated, results showed that R1234yf presented an average (for the 3 refrigerators) of 0.4°C for the fresh food compartment, and 1.2°C for the freezer, among different charges with respect to R134a. The optimal charge for R1234yf was 92.2 g, which is about 7.8% lower than the one for R134a, which represents a small increase of 4% in energy consumption in comparison to R134a. Finally, the TEWI analysis for the R1234yf was 1.07% higher than the R134a. [4].

A paper was published in 4th April 2017 on "Experimental Investigation of a Household Refrigerator Using Evaporative-Cooled Condenser", in this research paper they investigated the effect of evaporative-cooled condenser in a household refrigerator. The experiment was done using HFC-134 as refrigerant and polyol Easter as the lubricant. In this experiment household refrigerator with air cooled and water cooled condenser was compared for different condition after experiment they got the result that load on water cooled condenser reduced. In their experiment they have used the tube in tube water cooled condenser, from this experiment they concluded that on using water cooled condenser the energy consumption of household refrigerator reduced between 8% and 11% for different load and about 200 lit. Of hot water at temp about 58'C over a day from outlet of water cooled cooled condenser can be achieved. From this paper review we come to know that from evaporative cooled condenser we can improve the performance of refrigerator and also energy consumption decreases from this type of condenser. [5].

A study was performed in 11th August 2017 on "Performance analysis of vapor compression cycle water chiller with magnetic flux at the condenser exit", in this study four pairs of the permanent magnet of 3000 gauss field strength were installed on the condenser tube (between exit of the condenser and inlet of the capillary tube) of the VCC (vapour compression cycle) water chiller test setup. The performance of the test setup was compared by applying and removing a magnetic field from the condenser tube to estimate an enhancement in the VCC water chiller system with a magnetic field. Experiments were carried out using R404A as a primary refrigerant in the VCC system. This work discusses the outcomes of magnetic flux applied to the condenser tube at various locations of VCC on COP and power consumption of the water chiller unit. From this paper they concluded that there is growth of 0.52 to 8.82 percentages in refrigeration effect also experimental outcomes show that compressor power consumption decreased by 4.43% with an increase in the number of magnet pairs from 1 to 4. The VCC system performance was improved by 8.94%.By this study we come to know that magnetic field on condenser tube (between the condenser outlet and the capillary tube) is a new technique that helps in improving efficiency and cooling Capacity of air-cooled vapour compression cycle (VCC) water chiller. [6].

A paper was presented in International Conference on Recent Advancement in Air Conditioning and Refrigeration in November 2016 on "Empirical correlation based models for estimation of air cooled and water cooled condenser's performance", in this paper an experimental investigation was carried out in order to validate the predicted performance data of air cooled and water cooled condensers (using R134a as a refrigerant) from the developed correlation models. The heat rejection capacity is used as a performance indicator for aforementioned condensers. Three correlation based models using DOE, identified parameters and dimensionless groups have been developed for predicting the performances of the air cooled and the water cooled condensers. Comparison of these correlation based models with the experimental data were found to have good agreement and match within13%, 5% for DOE, 18%, 5% for identified parameters and 15%, 8% for dimensionless groups of air cooled and water cooled condensers, respectively. Also, a comparison of these correlations with the catalogue data provided by different manufacturers (Trane, Carrier and Clamaveneta) of air cooled and water cooled condensers found to have good agreement. The correlation based models developed in the present study can be extended to any practical applications for continuous online monitoring of the performance of the condensers and also for comparing the performance of the condensers manufactured by different industries. The performance analysis presented in this manuscript can be used as a reference tool for estimating the condenser performance of both air cooled and water cooled condensers. [7].

A study was performed in 6th June 2016 on "Hydrocarbon Refrigerant mixtures as an alternative to R134a in Domestic Refrigeration system", the objective of this paper was to present review on the alternative refrigerants used in the domestic refrigerators to have better performance with minimum losses this paper represents the recent developments done in domestic refrigerator. They have explained the performance variation of refrigerator by using different refrigerants. By this research we come to know that R134a is having zero ozone depletion potential (ODP) and almost good thermodynamic properties, but it has a high Global Warming Potential (GWP) of 1300. The higher GWP due to R134a emissions from domestic refrigerators leads to identifying a long term alternative to meet the requirements of system performance. Therefore it is going to be banned very soon for environmental safety. [8].

A paper was published in 4th April 2016 on "Study performance comparison of air cooed and water cooled condenser in vapor absorption and compression refrigeration system", they performed an experiment on the performance comparison of air cooled and water cooled condenser using evaporative pad in VARS and VCRS . In which the evaporative pad which they have used in made up of cellulose material this drops the condensing temperature up to great extent and ultimately improve the cop of the system. In this experiment firstly they have analyzed the forced air condenser type refrigerator in which they get condensing temperature

40'C and -22'C evaporative temperature and after that water cooled condenser using evaporative cooling pad is analyzed through their experiment. They conclude that from water cooled condenser using evaporative pad placed in front of the condenser rises the cooling effect or capacity by 2.9% to 14.4% and COP is improved 1.5% to 10.22% also they conclude, the evaporative cooler is able to save the power by 20% and increases the COP by 39% and water spray system increases the COP up to 55% if employs in front of the condenser. [9].

A paper was presented in The 7th International Conference on Applied Energy (ICAE) in 2015 on "An experimental investigation of condensation heat transfer coefficient using R-410A in horizontal circular tubes", in this study condensation heat transfer coefficient has been evaluated experimentally on the tube side of three different circular tubes with inner diameter of 6.61, 7.5 and 9.2mm, respectively. Two-phase fluid flow conditions include mass fluxes from 200 to 320kg/m2s, qualities between 0.1 to 0.9, and heat flux range from 5 to 20kW/m2 at a fixed saturation temperature of 48'C. Results showed that the average heat transfer coefficient increased with the increase of vapor quality, mass flux and heat flux, but decreased with inner diameter. The data show that the condensation heat transfer coefficient increase with increasing mass velocity and vapour quality. The effect of mass flux on the heat transfer coefficient suggests that the contribution of forced convective heat transfer is dominant. [10].

A study was performed in 27th December 2015 on "Performance improvement of vapor compression cooling systems using evaporative condenser", in this study they gives that Evaporative condenser enhance the heat rejection process by using the cooling effect of evaporation and therefore improve energy-usage efficiency. This paper presents an extensive review of the state of the art of evaporative condensers used in residential cooling systems, refrigeration, air-conditioning, and heat pump systems. The paper primarily concentrates on the energy consumption of residential cooling systems worldwide and its related problems. In addition, the paper covers the operation principles of evaporative - condensers, theory of heat rejection, and water evaporation rate. Finally, comparison between different types of condensers was presented. It was found that by using evaporative-cooled condenser instead of air cooled condenser, the power consumption can be reduced to 58% and the coefficient of performance improved by about 113.4% with systems of different cooling capacities ranging from 3 to 3000 kW. By study of this research paper we come to know that evaporative condenser are most efficient then an air cooled condenser and by use of this type of condenser we can reduce power consumption. [11].

A paper was published in 10th November 2014 on "Effect of the condenser sub cooling on the performance of vapor compression systems", this paper presents a theoretical study about the effect of condenser subcooling on the performance of vapor-compression systems. It is shown that, as condenser subcooling increases, the COP reaches a maximum as a result of a trade-off between increasing Refrigeration effect and specific compression work. The thermodynamic properties associated with the relative increase in refrigerating effect, i.e. liquid specific heat and latent heat of vaporization, are dominant to determine the maximum COP improvement with condenser subcooling. Refrigerants with large latent heat of vaporization tend to benefit less from condenser subcooling. For an air conditioning system, results indicate that the R1234yf (þ8.4%) would benefit the most from condenser subcooling in comparison to R410A (7.0%), R134a (5.9%) and R717 (2.7%) due to its smaller latent heat of vaporization. On the other hand, the value of COP maximizing subcooling does not seem to be a strong function of thermodynamic properties this paper also showed that the thermodynamic properties associated with the relative increase in refrigerating effect, i.e. Liquid specific heat and latent heat of vaporization, are dominant to determine the maximum COP improvement with condenser subcooling. Refrigerants with large latent heat of vaporization, such as R717 and R718, tend to benefit the least from condenser sub cooling. For a typical AC system, simulation results indicated that R1234yf would benefit the most from condenser subcooling in comparison to R410A, R134a and R717 due to its smaller latent heat of vaporization. [12].

A study was performed in 30th August 2013 on "Improved energy performance of a refrigerating machine using water spray upstream of the condenser" An experimental and numerical study had been carried out on the improvement of the energy performance of a refrigerating machine using a water spray upstream of the condenser. A reversible heat pump has been used in cooling mode and coupled with a spraying system upstream from the condenser. The spray has been simply added upstream from the heat pump. By this research we come to know that that condenser can be subcooled by spraying water on condenser and with leads to increase the coefficient of performance and refrigeration effect. [13].

A paper was published in March 2013 on "Effect of capillary diameter on the power consumption of VCRS using different", in this paper, experimental study was conducted to observe the power consumption of different environmental

friendly refrigerant mixtures (HC mixture and R401a). It was also observed the effect of working parameters like diameter of capillary tube, working pressure and inlet water temperatures, which affect the power consumption of vapour compression refrigeration system. It was observed that R401a consumed more power than HC mixture and R134a, but there is less mass quantity of HC mixture and R401a is required in the same system. So there is less effect in environment due to leakage. [14].

III. CONCLUSION OF LITRATURE SURVEY

From the above literature survey it is found that there is possibility to change the condenser design to improve the heat transfer rate which gives easy subcooling of refrigerant after condensation. This is further responsible for increment in the refrigerating effect of any refrigeration system. Increment in the refrigeration effect indicates that improvement in COP of refrigeration system. There are numbers of condenser design available for domestic refrigerator to enhance its COP like use of helical coil condenser, we can improve the cop by use of water cooled evaporative pad which can made from cellulose etc. Many researchers have already done experiment to cool the condenser with the help of water and for this they have used different method like using spray type water cooled condenser in which they have made the arrangement to spray water from top by the help of pump and finally water would be collected at the bottom of the tank .Some researcher have used tube in tube water cooled condenser in which also they have used the pump to circulate water .After review paper we come in conclusion that many research have already done on water cooled condenser but in most of experiment for circulating water they have used the pump which increases the electric consumption and also circulating the same water which quiet not give sufficient cooling effect, but in our experiment we are not going use any pump for circulating water also in your setup same water will not be circulated and water which circulate will be also colder than the normal room water temperature.

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