Evaporative Cooling Technique for Domestic Refrigerator

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Abstract-*In day to day life importance of refrigeration increasing in India, so we have to increase cop of refrigeration. In this paper we analyze about evaporative cooling to implement in refrigeration. Due to more heat rejected in condenser evaporative cooled refrigeration system is more effective as compared to air cooled condenser. As the air cooled condenser (standard system) approach practical limits, experimental modification should be performed to improve the system cop and capacity.*

Keywords:-COP, Evaporative Cooling, VCRS, Cooling tower.

I. INTRODUCTION

A. Refrigeration

Refrigeration is defined as the process of removing heat from a body or enclosed space so that its temperature is first lowered and then maintained at a level below the temperature of surroundings. In such case the body or refrigerated space is said to be refrigerated space. The equipment used to maintain the required temperature is called as refrigerating equipment or refrigerator. The working substance used to produce refrigeration is called refrigerant. The heat withdrawn from the refrigerated space is finally rejected to atmosphere which acts as a natural receiver of heat. A refrigerator (commonly abbreviated as fridge) is a cooling apparatus. The refrigerator is a relatively modern invention among kitchen appliances. The common household appliance comprises a thermally insulated compartment and a heat chemical or mechanical means to transfer heat from it to the external environment (i.e. the room in which it is located), cooling the contents to a temperature below ambient. Cooling is a popular food storage technique all over the world and works by decreasing the reproduction rate of *bacteria. The device is thus* used to reduce the rate of spoilage of foodstuffs. A refrigerator maintains a temperature a few degrees above the freezing point of water. Optimum temperature range for perishable food storage is 3 to 5 °C.

Basic refrigeration principles:

If you were to place a hot cup of coffee on a table and leave it for a while, the heat in the coffee would be transferred to the materials in contact with the coffee, i.e. the cup, the table and the surrounding air. As the heat is transferred, the coffee in time cools. Using the same principle, refrigeration works by removing heat from a product and transferring that heat to the outside air.

B. Refrigeration system components

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

- Compressor
- Condenser
- Expansion Valve
- Evaporator

II. PROBLEM DEFINITION

All domestic refrigerator, including modern refrigerators uses air cooled condenser. The refrigerant after compression is passed through this condenser where it rejects heat to the surrounding ideally at constant pressure. But this air cooling has following disadvantages:

1. It is less efficient system and hence suitable only for low capacity.
2. Heat rejection in air cooled condensers is low; hence we will get less refrigerating effect.
3. Compressor power required is high with conventional air cooling; hence electricity consumption of the system is more as compared to water cooling.
4. Mass flow rate of refrigerant required per ton of refrigeration is high as compared to water cooling.
5. COP of the system is less.

Due to above limitations of air cooling, evaporative cooling is employed in the domestic refrigerator due to which all above limitations of air cooling are eliminated.Water is used to remove heat from the refrigerant and at the same time

reduce the work of the compressor as well as electricity consumption.Water removes heat from the condenser coils far more efficiently than air. The heat transfer and evaporative process is increased via a fan in the middle of the condenser.

III. LITERATURE REVIEW

1. Jose Rui Camargo gives useful information to evaluate the technical viability of evaporative system for human thermal comfort. This paper allows to correct determination of where and how evaporative cooling system can be efficiently used. From this paper, he concludes that evaporative cooling systems have a very large potential to propitiate thermal comfort and can still be used as an alternative to conventional system in regions in which wet bulb temperature is under 24^{o} C.

2. E Velasco Geomez et al works on theoretical evaporative cooling process. In this paper they recognized the necessity of reducing the energy consumption in buildings to fit the numerous international normative and protocols, ensuring an adequate comfort level inside, lead to the importance of developing alternative processes to reduce the dependence of this sector on fossil fuels. On the other hand, to cool air in summer, mainly in hot and dry climates, the process of evaporative or adiabatic cooling is found as an alternative.

3. Performance Studies on Vapour Compression Refrigeration System: This paper is presented S.R.Arunkumar; P.Koshy Mathews &C.Prabha .It deals with the therotical study and prediction of performance of the vapour compression refrigeration system with R134a & the selected Hydrocarbon refrigerants R290/R600, R290/R600a & LPG.

   They presents the effects of refrigeration system parameters namely such as evaporative temperature, condensing temperature and mass of the refrigerant charge used. The direct effect of the system variables on the performance was calculated and ploted graphically for the hydrocarbon refrigerants R290/R600, R290/R600a & LPG.

   They did the theoretical analysis of various performance parameters like Pressure ratio, refrigerating effect, compressor work and COP. from this they made following conclusions:
   a) The pressure ratios of the hydrocarbon mixtures are lower than that of r134a.
   b) The refrigerating effect of the selected refrigerant mixtures of R290/R600, R290/R600a &LPG are higher than that of the r134a.
   c) The compressor work of all the selected hydrocarbon refrigerants mixtures is higher than that of r134a.The compressor work of all the refrigerants increases with the decreasing evaporating temperature.
   d) The COP of the hydrocarbons is higher than that of R134a due to higher refrigerating capacity.

4. Experimental Investigation of Comparison Of Normal Cooling Tower And Evaporative Cooling Tower In Vcrs System:

   According to Gourav Roy, TalivHussain and Rahul Wandra evaporative cooling tower design is very simple and we can easily applied to normal VCRS system. This can be done by employing cellulose pad in front of draught fan within cooling tower and circulate water over the cellulose pad. Due to which when incoming air pass through cellulose pad take some moisture content and then it enter into cooling tower at the same time hot water from condenser is pumped to cooling tower, which is cooled down by this circulated air. VCRS system requires certain economical modification with no extra skill require. So we can easily installed evaporative cooling tower in VCRS system.

   They present a novel design of evaporative cooling tower concept in which cellulose pad is to be installed in front of draught fan. From (graph) which shows that as increase in ambient temperature compressor work increase. But compressor work of evaporative cooling tower is less as compared to normal cooling tower. Similarly from (graph) COP of system decrease as the ambient temperature goes on increase. But COP of system with evaporative cooling tower is more as compared to normal cooling tower. The test result shows that evaporative cooling tower has high COP for both ambient temperature 25°C and 30°C. 4.8% change in COP as we move from normal cooling tower to evaporative cooling tower at ambient temperature 25°C.Similarly 2.9%

   change in COP when temperature changes from 25°C to 30°C.The test result explain that it have high cooling capacity as compared to normal cooling tower.

5. Effect of Water Temperature During Evaporative Cooling On Refrigeration System: MohitYadhav , S.S. Pawar.- In this paper they studied that lower the condenser temperature means higher the performance of refrigeration system.COP of refrigeration system mainly depends upon temperature difference between the condenser and its medium where heat is to be rejected

,more temperature difference ,more heat rejection ,so more cooling effect of same work to refrigeration system or vice-versa. By using evaporative Condenser cooling performance of refrigeration system is improved by 39.04% which is great achievement. Hence improve the COP of the refrigeration system by using evaporative condenser cooling instead of air condenser cooling.

6. W.L. Lee et al.: performed the experiments to study the effect of water cooled air conditioning systems in residential building in Hong Kong with outdoor at 35^0C DBT. The test results shows that COP was increased by 14-20% as compared to the air cooled condenser which reduce the peak load in the month of July by 27%.later in 2008 he also studied the performance of domestic water cooled air conditioning using tube-in –tube helical heat exchanger condenser. The outdoor condition was 33^0C DBT and 68% RH. The mass flow rate of water was 5-8 Lt/min. An increase of 12-20% in COP was recorded.

7. A review of evaporative cooling technologies
   O.amer, R.boukhanouf&H.G.Ibrahim-In this paper they worked on various parameters which affect on COP of system. These parameters are ambient temperature, relative humidity, geometry &surface area of refrigerator, thermal conductivity of material used to hold water &movement of air. From this experiment they conclude following points:
   a) Higher the ambient temperature higher will be the rate of evaporation ,ensuring better cooling of storage .
   b) When the relative humidity of surrounding air of refrigerant is low better will be the cooling.
   c) Amount of evaporation take places is directly proportional to area available for evaporation. Hence increase in area for evaporation around the storage space enhances the cooling process.
   d) Material has low thermal conductivity to obtain lesser time in storage space for a given ambient temperature &relative humidity.
   e) The movement of air enhances the evaporation process and hence the cooling.

8. Experimental investigation of enhancing the COP of VCRS system by using cooling tower:

   GouravRoy,TalivHussain, Rahul Wandra-In this paper they studied that the cooling tower is simple and easy to install in normal water cooled VCRS system. Cooling tower is used to cool down the hot water from condenser which is circulated with help of water pump. This cool water it is again circulated at the water condenser where it act as cooling medium. from our experiment there is increase in COP of the system as we move from simple water condenser ton water condenser with cooling tower which at 29^oC is 5.11%&at 32^oC is 0.21%.aiso as the ambient temperature is increases compressor changes 7.02%&32C it is 13.82% when we cooling tower.

IV. EXPERIMENTAL SET UP

The system consists of following components:

i. Normal domestic refrigerator.
ii. Water reservoir
iii. Overhead water tank.
iv. Submersible pump.
v. Axial fan
vi. Energy meter.
vii. Digital temperature indicator.
viii. Pressure indicators.
ix. Non return valve(NRV)

Fig: Actual model of project

The experimental setup consist of a single stage VCR system with the basic components i.e. compressor, condenser, expansion valve and evaporator (Refrigerator). In this setup we kept condenser coil at some distance from refrigerator body as shown in figure. A tank of 10-20 lit is built at bottom and top of refrigerator. Both tanks contain water in it. From bottom tank by using a small water pump, water is pumped to upper tank. From upper tank two pipes are taken out & through which water in it. From bottom tank by using a small water pump, water is pumped to upper tank. From upper tank two pipes are taken out & through which water is dripped on

condenser coils through small nozzles on pipe .Cellulose pad is attached to condenser at evaporator (Refrigerator). In this setup we kept condenser coil at some distance from refrigerator body as shown in figure. A tank of 10-20 lit is built at bottom and top of refrigerator. Both tanks contain water in it. From bottom tank by using a small water pump, water is pumped to upper tank. From upper tank two pipes are taken out & through which water is dripped on condenser coils through small nozzles on pipe .Cellulose pad is attached to condenser at some distance from condenser water circulated rate is constant during the process. Hot ambient water passes over the evaporative media (cellulose pad)and gets cooled due to evaporation . this cooled water cools the surrounding air causing fast cooling of condenser i.e. fast cooling of refrigerant in condenser.

In evaporative cooling cellulose pad has main function is to provide the evaporative action by transferring the latent heat of water .cellulose pad works on evaporative cooling technique.

We connected the pressure gauges at suction line & discharge line of compressor by using NRV to measure the pressure of the refrigerant at suction & discharge line of compressor.

In our set-up we used K type thermocouples to measure the temperature of suction & discharge line of compressor, inlet of evaporator & thermostat (body itself) and at the each row of the condensing coil. Axial fan is mounted at back side of refrigerator.

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