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Experimental Investigation of a Household Refrigerator Using Evaporative-Cooled Condenser

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ABSTRACT: *The objective of this paper was to investigate experimentally the effect of Evaporative-cooled condenser in a household refrigerator. The experiment was done using HCF134a as the refrigerant. The performance of the household refrigerator with air-cooled and Evaporative-cooled condenser was compared for different load conditions. The results indicate that the refrigerator performance had improved when evaporative-cooled condenser was used instead of air-cooled condenser on all load conditions. Evaporative-cooled condenser reduced the energy consumption when compared with the air-cooled condenser. There was also an enhancement in coefficient of performance (COP) when* ***evaporative-cooled condenser*** *was used instead of* ***air-cooled condenser****. The Evaporative cooled heat exchanger was designed and the system was modified by retrofitting it, instead of the conventional air-cooled condenser by making drop wise condensation using water and forced circulation over the condenser. From the experimental analysis it is observed that the* ***COP*** *of evaporative cooled system increased by* ***13.44%*** *compared to that of air cooled system. So the overall efficiency and refrigerating effect is increased. In minimum constructional, maintenance and running cost, the system is much useful for domestic purpose. This study also revealed that combining a evaporative cooled system along with conventional water cooled system under the condition that the defrost water obtained from the freezer is used for drop wise condensation over condenser and water cooled condensation of the condenser at the bottom using remaining defrost water would reduce the power consumption, work done and hence further increase in refrigerating effect of the system. The study has shown that such a system is technically feasible and economically viable*

Keywords: *165 litre domestic refrigerator, HCF134a, Evaporative-cooled condenser, experimental analysis, COP of refrigeration.*

I. INTRODUCTION

A household refrigerator is a common household appliance that consists of a thermally insulated compartment and which when works, transfers heat from the inside of the compartment to its external environment so that the inside of the thermally insulated compartment is cooled to a temperature below the ambient temperature of the room. Heat rejection may occur directly to the air in the case of a conventional household refrigerator having air-cooled condenser or to water in the case of a water-cooled condenser. Tetrafluoroethane (HFC134a) refrigerant was now widely used in most of the domestic refrigerators and automobile air- conditioners and are using POE oil as the conventional lubricant. This research includes the design and the experimental investigation of an evaporative cooled condenser in an household refrigerator. The air cooled condenser is normally used in the refrigerator. Evaporative cooled condenser is designed in such a way that it can fit into the system. Evaporative Cooled Condenser is operated by spraying water from the storage tank and also by running a cooling fan. Initially a performance test was done for calculating the accurate length for the evaporative cooling condenser. The design for the length of the condenser was done. Fabrication for the design was done. The aim of the study is to increase the COP of the system. Heat can be recovered by using the evaporative-cooled condenser. Therefore by retrofitting an evaporative-cooled condenser it produce hot water and even reduce the utility bill of a small family. In this system the evaporative-cooled condenser is designed as a tube in tube heat exchanger.

II. EXPERIMENTAL SETUP

II.1. Experimental System

The refrigerator was of 165L capacity, single door, manufactured by kelvinator. The system was retrofitted with a Evaporative Cooled Condenser. . A storage tank is attached at the top for spraying of water and a fan is also attached for the forced circulation of air. Fan is used to enhance the air for cooling of condenser. A collecting tank is also placed for collection of the water and the water can also be used for recirculation. The system was retrofitted with a evaporative-cooled condenser instead of the conventional air-cooled condenser by making a drop-wise condensation method.

The temperature at various points was noted using digital thermometer. Evaporator and condenser pressure are noted using calibrated pressure gauges. The power consumption of the domestic refrigerator was measured by using a digital energy meter. Figure 1 shows the evaporative cooled condenser modeled in solidworks. The retrofitted evaporative-cooled condenser can also been seen in figure 2. The refrigerator specifications are given in Table 1.

Figure 1: Evaporative Cooled Condenser

Figure 2: Experimental Test Rig

Table 1: Refrigerator Specifications

Gross capacity	165 L
Refrigerant	HFC134a
Charged mass	140 g
Compressor type	Hermetic

II.2. Experimental Procedure

The refrigerator of 165L capacity is selected was charged with refrigerant R134a for the carrying the performance test with a load of 5L of water. The test was done and the COP of the air cooled condenser with 5L of water. In this, the COP was found to be 2.22.The further results from the test is that the equivalent condenser length for the evaporative cooled condenser is 12m. A performance test should be done for the analysis of the refrigeration device which is evaporative cooled. The COP of the device will help for the comparison of the test. Schematic diagram of the experimental apparatus is shown in Figure 3. After the integration of the components, work system was operated and the initial conditions were observed. The method of drop-wise condensation was introduced in to the system. A jar of 5L of water was introduced into the system for experimental purpose. The initial temperature of the water was noted down until the energy consumption of the system is measured using a digital energy meter. The performance of the refrigerator with air-cooled and evaporative-cooled condenser was measured. The test results of air-cooled and evaporative-cooled condensers were compared. Then test is performed with load of 10L.

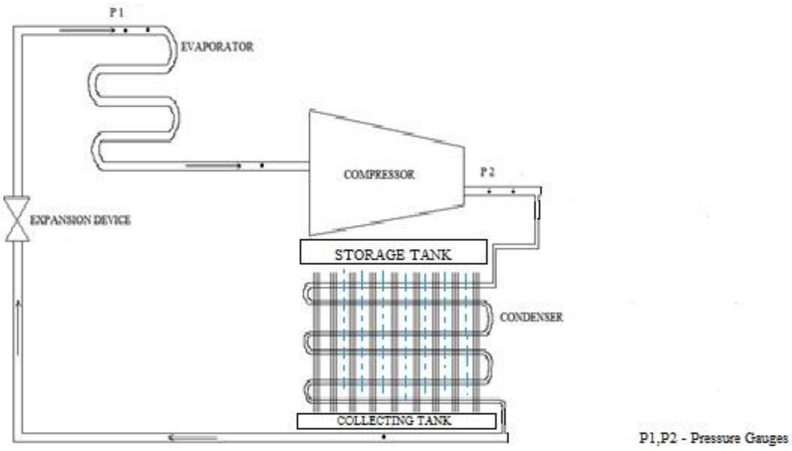

Figure 3: Schematic diagram of the experimental test rig

II.3. Equations Used

The following equations are used for the calculation in this research.

- Work done = $h_{compout}$ - h_{compin} , KW
- Theoretical COP = {q/w} ,
  where $q = h_1 - h_4$, $w = h_2 - h_1$, KJ/Kg
- Refrigerating effect = { Q*14000 / 3600},Q in tonnes or COP * Work done , KW
- For Actual COP = {Q/W}
  Where $Q = m\, C_p \Delta T / t_m$, KW
  Where m = mass, ΔT = Temperature difference , t_m = time taken , C_p = Specific heat
- $W = P * 60/ t_m$, KW
- Power Consumption is from direct reading from the energy meter, kwhr

III. RESULTS AND DISCUSSIONS

Graphs are plotted between COP and load, Work with load & Power consumption with load for the comparisons. The values in the table 2 are used for plotting the graphs. The results obtained are plotted in graphs and it shows that the COP of the evaporative-cooled condenser is higher than the air-cooled condenser; work done is lesser for evaporative cooled condenser. The power consumption varies with loads for evaporative-cooled condenser. Power consumption can be controlled by applying solar power for the further development of the system.

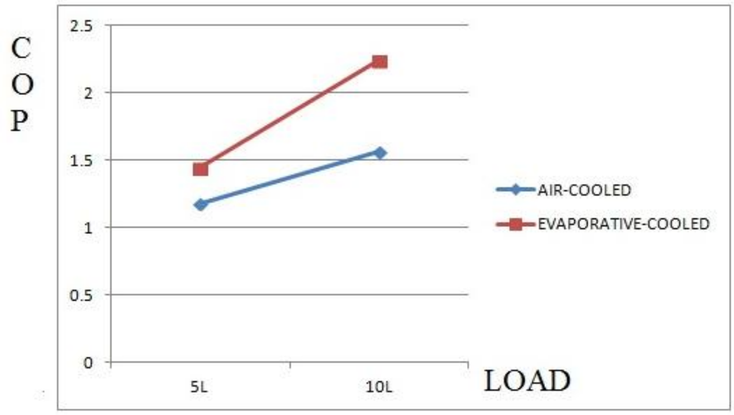

Figure 4: COP vs Load

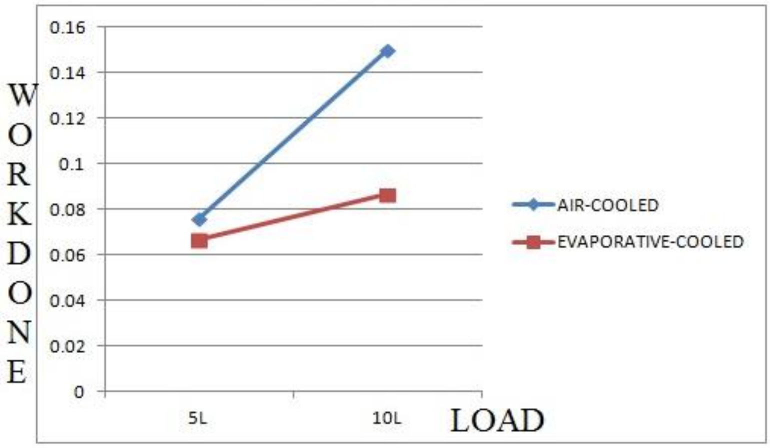

Figure 5: Work vs Load

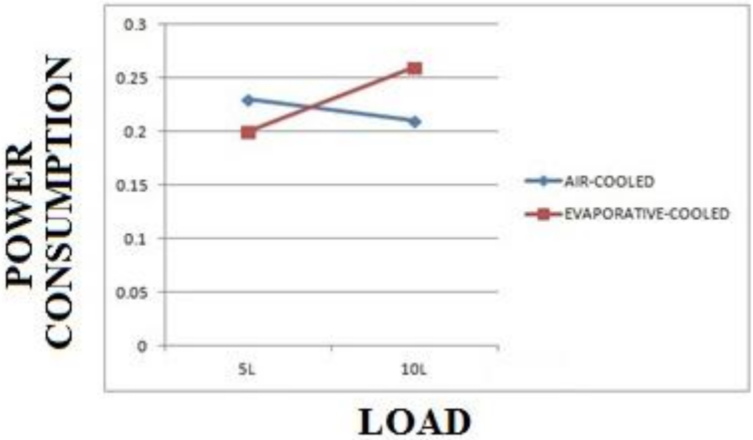

Figure 6. Power consumption vs Load

Table 2: Experimental performance of Evaporative Cooled Condenser

LOAD, L	5L		10L	
CONDENSER	AIR-COOLED	EVAPORATIVE COOLED	AIR-COOLED	EVAPORATIVE COOLED
COP	1.18	1.4469	1.56	2.24
WORKDONE,KW	0.0766	0.0666	0.15	0.0866
POWER CONSUMPTION, KWhr	0.23	0.2	0.21	0.26

IV. CONCLUSIONS

1. From the experimental research it reveals that the COP of Evaporative cooled refrigeration system increased by 13.44% compared to that of air-cooled system. So the overall efficiency and the refrigerating effect is increased.
2. In minimum construction, maintenance and running cost, the system is much useful for domestic purpose.
3. The system is highly reliable because there is only small variation in power consumption and performance is much better.
4. This study also reveal that combining a evaporative cooled system along with conventional water cooled system under the condition that the de-frost water obtained from the freezer is used for drop-wise condensation over condenser and water cooled condensation of the condenser at the bottom using remaining de-frost water would reduce the power consumption, work done and hence further increase in the refrigerating effect.
5. This system can be used in the water plenty areas and the water can be re-circulated.

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