Experimental Investigations of Different Types of Condensers on the Performance of Household Refrigerators

Aby Mathew Joshy  
UG Student  
Department of Mechanical Engineering  
Saintgits College of Engineering Kottayam-686532, Kerala, India

Biphin Devasia  
UG Student  
Department of Mechanical Engineering  
Saintgits College of Engineering Kottayam-686532, Kerala, India

Dithin Mathew  
UG Student  
Department of Mechanical Engineering  
Saintgits College of Engineering Kottayam-686532, Kerala, India

Jacob Damy  
UG Student  
Department of Mechanical Engineering  
Saintgits College of Engineering Kottayam-686532, Kerala, India

Easwaran Nampoothiry K  
Assistant Professor  
Department of Mechanical Engineering  
Saintgits College of Engineering Kottayam-686532, Kerala, India

Abstract

Reduction of energy consumption is a major concern in vapor compression cooling systems, especially in areas with very hot weather conditions. During summer seasons, performance of these systems decrease sharply and electrical power consumption increases considerably. Air cooled condensers are usually employed in Household Refrigerators and Heat pumps. The heat rejection rate from the condenser significantly reduces as surrounding temperature increases. There is a scope to enhance the performance of a household refrigerator by utilizing forced convection heat transfer and evaporation. This work investigates the effect of various types of condensers on the performance of household refrigerators. Evaporative condensers enhance the heat rejection process by using the cooling effect of evaporation and therefore improve energy usage efficiency. This work primarily concentrates on the energy consumption of domestic refrigerators and related performance issues. In addition to the above, the work investigates the effects of critical parameters such as air flow rate, humidity, heat transfer coefficient on the COP of the system. Finally, comparison between different types of condensers is presented.

Keywords: Condenser, COP, Energy saving, Evaporative cooling, Refrigerator, Vapour compression refrigeration system

I. INTRODUCTION

Increasing living standards and demand for human comfort has caused an increase in energy consumption. The amount of energy consumed by air conditioners, refrigerators, and water heaters is increasing rapidly, and occupies about 30% of the total power consumption. Therefore, any attempt to decrease the energy consumption of cooling systems as a whole will contribute to large scale energy savings at the international level. Reduction of energy consumption of cooling units can be achieved by improving the performance. In this study, the experimental investigations on different types of condensers in household refrigerators are conducted. The application of evaporative condenser in residential refrigerators is evaluated. Also the effect of the design modifications on the performance of the refrigeration system is studied.

II. PROPOSED SYSTEM

The methodology includes the following procedures. A load of 15 litres of water is placed inside the refrigerator. A laboratory thermometer is used to measure the cabin temperature. An energy meter is used to determine the power consumed.

The total length of the condenser coil is measured and points are marked on the condenser 160cm apart and the condenser temperatures are measured using an infrared thermometer. An infrared thermometer is also used to measure the load temperature. Pressure gauges are connected to determine the suction and discharge pressure. The humidity is measured using a hygrometer.
**A. The Basic System**

The basic system consists of a refrigerator in which the condenser undergoes cooling through natural convection. The working of the basic system is analyzed. The condensers are cooled by natural convection of air. The readings are noted and tabulated.

**B. Forced Convection System**

In forced convection system, a fan or propeller is used to force the air over the condenser coils to increase its heat transfer capacity. Here a cooling fan is used to blow air on the condenser tubes. The air flow is measured using anemometer. Flow velocities of 1.6 m/s, 2.4 m/s and 3 m/s are used for the analysis. The readings are noted and tabulated.

**C. Evaporative Condensing System Using Cooling Pads**

Evaporating condensers use both air and water as condensing mediums to condense the hot vapour refrigerant to liquid refrigerant. The heat of vaporising the water is taken from the refrigerant. A cooling pad unit is provided before the condensing unit, with water sprayers, a water source and a pump. A fan is also provided to ensure ambient air flow.

![Fig. 1: The basic system](image1)

![Fig. 2: Forced convection system](image2)

![Fig. 3: Evaporative condensing system using cooling pads](image3)

**III. EXPERIMENT AND RESULTS**

The working of the three systems are analysed and the corresponding readings are noted and the performance of the three systems are evaluated.

\[
COP_{\text{theoretical}} = \frac{\text{Refrigerating effect}}{\text{Work done}} = \frac{h_1 - h_3}{h_2 - h_1}
\]

where \( h_1, h_2 \) and \( h_3 \) are the enthalpies at the corresponding points in the ph diagram.

\[
COP_{\text{actual}} = \frac{mc_p \Delta T / t_s}{p / t_h}
\]

where \( m = \text{mass of load applies}, c_p = \text{specific heat of water}, \Delta T = \text{change in load temperature}, p = \text{power consumed}, t_s = \text{time in seconds}, t_h = \text{time in hours} \)
A. The Basic System

- Load applied = 15 L of water
- Power consumed = 0.3 kWh in 2.5 h
- Relative humidity = 55%
- Cabin temperature = 11.2 °C
- Suction pressure = 1.013 bar
- Discharge pressure = 16.2 bar
- COP\(_{\text{actual}}\) = 0.789
- COP\(_{\text{theoretical}}\) = 2.15

B. Forced Convection System

- Load applied = 15 L of water
- Air flow velocity = \(V\)
- Compressor outlet temperature = 67.3 °C
- \(V = 1.6 \text{ m/s}\)
- Power consumed = 0.1 kWh in 40 minutes
- Relative humidity = 65%
- Suction pressure = 1.013 bar
- Discharge pressure = 9.6 bar
- COP\(_{\text{actual}}\) = 1.010
- COP\(_{\text{theoretical}}\) = 3.09

1) \(V = 2.4 \text{ m/s}\)
- Power consumed = 0.1 kWh in 35 minutes
- Relative humidity = 65%
- Suction pressure = 1.013 bar
- Discharge pressure = 9.6 bar
- COP\(_{\text{actual}}\) = 1.027
- COP\(_{\text{theoretical}}\) = 3.09

2) \(V = 3.0 \text{ m/s}\)
- Power consumed = 0.1 kWh in 35 minutes
- Relative humidity = 65%
- Suction pressure = 1.013 bar
- Discharge pressure = 9.6 bar
- COP\(_{\text{actual}}\) = 1.079
- COP\(_{\text{theoretical}}\) = 3.090

C. EVAPORATIVE COOLED CONDENSER

- Velocity of air flow = 0.83 m/s
- Load applied = 15 L of water
- Power consumed = 0.2 kWh in 1 hr
- Relative humidity = 70%
- Cabin temperature = 14.8 °C
- Suction pressure = 1.013 bar
- Discharge pressure = 9.6 bar
- COP\(_{\text{actual}}\) = 1.088
- COP\(_{\text{theoretical}}\) = 3.09

It is observed that the actual COP is maximum in the case of an evaporative cooled system. The refrigerating effect is improved, at the same time work done also increases. However, the increase in the refrigerating effect is large as compared to the increase in the work done; therefore, the net effect of an evaporative cooled system is an improvement in the COP compared with the basic system and the forced convection system.
IV. CONDENSER LENGTH VS CONDENSER TEMPERATURE

(a) The basic system
(b) Forced convection system
(c) Evaporative cooled system
(d) Condenser profile comparison

A. P-H Diagram

It can be seen from the p-h diagram that the refrigerating effect \( (h_1-h_3) \) produced by the basic system is lesser compared to the other two systems. Also the compressor work \( (h_2-h_1) \) is comparatively higher in the basic system. This results in the low value of
theoretical COP. With the use of a forced convection system, the refrigerating effect \((h_1-h_3)\) is improved and the work done by the compressor \((h_2-h_1)\) is reduced. As a result, theoretical COP value increases. Similar is the case with the evaporative cooled system and the theoretical COP value is increased.

It can be seen that the condenser temperatures are maximum in the case of the basic system. The air flow rate is very low in the case of natural convection, so the heat transfer rate is lesser. However, the condenser temperatures can be significantly reduced in the case of forced convection system and evaporative cooled system. In the forced convection system, the increased air flow rate improves the heat transfer rate between the condenser coils and air, thereby reducing the condenser temperatures. In the case of evaporative cooled system, the cooling is achieved by the evaporation of water into the air stream. The heat of vaporising the water is taken from the refrigerant in the condenser coils. The latent heat transfer provides more heat transfer for the evaporative condenser, improving the overall heat transfer coefficient of the evaporative condenser. As a result the temperature on the condenser tubes are reduced compared with the basic system and forced convection system.

V. CONCLUSION

Experimental data for the measurement of the COP and performance of the household refrigerator is recorded. The application of evaporative cooled condensers in household refrigerators is studied. The results obtained using forced convection air cooled condenser and evaporative cooled condenser is compared with the basic system. Actual COP of the refrigerator is less than theoretical COP. COP of evaporative cooled system is found to be the highest. COP in the case of evaporative condenser has been improved by about 37.9 % compared to that of the basic system.

REFERENCES