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Power Consumption Minimisation with Effective Temperature Control in Domestic Refrigerator

C. Ganesh (Guide), Nishant Sharma, Swapnil Gadekar, Piyush Chaudhari, Deepak Badhe
Mechanical Engineering Department
St. John College of Engineering & Management Palghar, India

Abstract:- The aim of this work is to experimentally investigate the performance of a domestic refrigerator to minimise power with proper control of temperature. A small fan is placed behind the defreezer, so as to convert natural flow of cold air to forced flow of cold air which eventually would result into more efficient cooling. Different lengths of condenser were tested in order to obtain reduction in power consumption. Among different lengths of condenser better length of condenser is selected and calculations are performed.Data are collected in order to evaluate the refrigerator performance. Each data was collected for a cycle of operation for 1 hour, 2 hour, 3 hour and 24 hrs.Result and analysis of Normal Refrigerator were compared with new modified refrigerator on basis of power consumption and COP. Power consumption decreased from 218 watt/hr to 36 watt/hr with modified refrigerator.

Keywords:- *Refrigerator, R134a, Micro-Controller, Condenser, Refrigerator fan motor,Power Consumption, COP.*

I. INTRODUCTION

Refrigerator is one of the home appliance which utilizes Vapour Compression Cycle. Performance of the system becomes main issue and many researches are still ongoing to evaluate and improve efficiency of the system. Therefore, this experiment presents the power consumption minimization with effective temperature control in domestic refrigerator. The refrigeration cycle begins with the refrigerant in the evaporator. At this stage the refrigerant in the evaporator is in liquid form and is used to absorb heat from the product. When leaving the evaporator, the refrigerant has absorbed a quantity of heat from the product and is a low-pressure, low-temperature vapour. This low-pressure, low-temperature vapour is then drawn from the evaporator by the compressor. When vapour is compressed its temperature rises. Therefore, the compressor transforms the vapour from a low-temperature vapour to a high-temperature vapour, in turn increasing the pressure. This high-temperature, high-pressure vapour is pumped from the compressor to the condenser; where it is cooled by the surrounding air, or in some cases by fan assistance. The vapour within the condenser is cooled only to the point where it becomes a liquid once more. The heat, which has been absorbed, is then conducted to the outside air. At this stage the liquid refrigerant is passed through the expansion valve. The expansion valve reduces the pressure of the liquid refrigerant and therefore reduces the temperature. The cycle is complete when the refrigerant flows into the evaporator, from the expansion valve, as a low-pressure, low-temperature liquid.

II. MAIN FUNCTION OF COMPONENTS

A. Compressor

A refrigerant compressor is a machine used to compress the vapour refrigerant from the evaporator and to raise the pressure so that the corresponding saturation temperature is higher than that of the cooling medium.

B. Condenser

The condenser is an important device used in high pressure side of a refrigeration system. Its function is to dissipate the heat from the vapour refrigerant. The heat from the 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.

C. Expansion device

The expansion device is an important device that divides the high pressure side and the low pressure side of refrigerating system. It is connected between the receivers (containing liquid refrigerant at high pressure) and the evaporator (containing liquid refrigerant at low pressure).

D. Evaporator

The evaporator is used in the low vapour side of refrigeration system where liquid refrigerant from the expansion valve enters in to the evaporator & phase changes occurs. Thefunction of evaporator is absorbing heat from the surrounding location of medium which is cooled, by means of refrigerant.

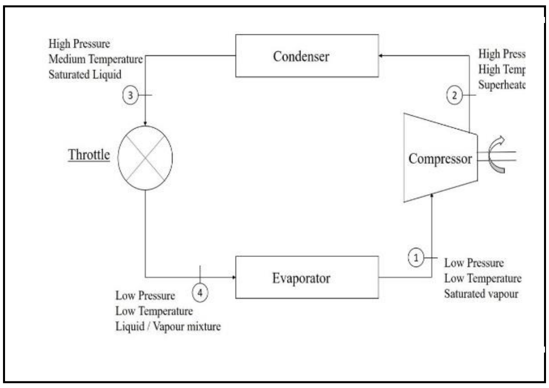

Fig. 1: Refrigeration Cycle

III. EXPERIMENTAL SETUP

Consider single door old refrigerator. Connect pressure gauges, and temperature sensors. Make sure gas evacuation and filing is done under supervision of technician. Take down some sets of readings without any modifications. Do calculate coefficient of performance (COP) and power consumption of normal refrigerator. Connect Microcontroller in series with thermostat. Take down readings and again calculate COP and power consumption. After this connect small rating fan behind defreezer which will convert natural flow of cold air to forced flow of cold air. Again take readings and perform calculations. Also tried connecting various lengths of condensers. Take readings and perform calculations.

IV. METHODOLOGY

- Consider a single door refrigerator having R134a refrigerant, take readings for 1hr, 2hr, and for 3hr. (Normal refrigerator without any modifications)
- Tabulate all readings with pressures and Temperatures. (Pressure gauges and temperature sensors are connected at various sections of refrigerators just to get pressure and temperature.)
- Based on the readings, calculate the work done by compressor, refrigeration effect, heat rejected by condenser, coefficient of performance, actual coefficient of performance.
- After this modifications, again tabulate readings for 1hr, 2hr and for 3 hr. Calculate work done by compressor, refrigeration effect, heat rejected by condenser, coefficient of performance, actual coefficient of performance. Evaluate and draw the conclusion.
- Evaluate and draw the conclusion. Now, connect Sub-Zero Micro-Controller with the thermostat and change the preset value of the thermostat.
- Now, connect Evaporator Fan (low rating ampere) behind the defreezer such that it converts natural circulation of cold air to forced circulation of cold air.
- Again tabulate readings for 1hr, 2hr and for 3 hr. Calculate work done by compressor, refrigeration effect, heat rejected by condenser, coefficient of performance, actual coefficient of performance. Evaluate and draw the conclusion.
- Check with the various lengths of condenser. Take respective readings and compare with test cases. Evaluate and select the better condenser which has higher COP and less power consumption.
- Finally now check test cases for all parameters (modified refrigerator). Tabulate readings for 1hr, 2hr and for 3 hr. Calculate work done by compressor, refrigeration effect, heat rejected by condenser, coefficient of performance,actual coefficient of performance. Evaluate and draw the final conclusion and compare with original refrigerator.

Fig. 2: Domestic Refrigerator with pressure gauges

Fig. 3: Different lengths of Condenser

PERFORMANCE CALCULATIONS

(Normal Refrigerator for 3 hrs.)

- Compressor work:
- $= \frac{\text{No.of pulses x 3600 x 1000}}{\text{Time taken for 10 pulses x Energy meter constant} \times 3200}$
- $= \frac{10 \times 3600 \times 1000}{53 \times 3200}$ = 218 Watt
- Defreezer Temperature = -11.2°C
- Temperature at Middle Section = 10.3°C
- Temperature at Bottom Section = 13.2 °C
- Mass flow rate of Refrigerant :-
- (Refer from R134a P-H chart)
- $\dot{m} = \frac{210}{(h1 - h4)} = \frac{210}{249.2 - 132.4}$ = 1.79 kg/min-TR
- Theoretical Compressor Work :
- $Wc = (h2 - h1) = (292.2 - 249.2) = 43$ KJ/kg
- Theoretical Refrigeration effect (RE) :-
- RE = $(h1 - h4)$ = (249.2 – 132.4) = 116.8 KJ/kg
- Coefficient of Performance :-
- COP = $\frac{h1 - h4}{h2 - h1}$ = 2.714

- Ideal Coefficient of Performance :-
- Ideal COP = $\frac{TL}{Th - TL}$ = 4.68
- (Modified Refrigerator for 3 hrs.) :
- Compressor work:
- = $\frac{\text{No.of pulses x 3600 x 1000}}{\text{Time taken for 10 pulses x Energy meter constant} \times 3200}$ = $\frac{10 \times 3600 \times 1000}{305 \times 3200}$ = 36.88 Watt
- Defreezer Temperature = 7 °C
- Temperature at Middle Section = 13.2 °C
- Temperature at Bottom Section = 14.3 °C
- Mass flow rate of Refrigerant :-
- (Refer from R134a P-H chart)
- $\dot{m} = \frac{210}{(h1 - h4)} = \frac{210}{259.7 - 101.1}$ = 1.32 kg/min-TR
- Theoretical Compressor Work :
- Wc = $(h2 - h1) = (271.4 - 259.7) = 11.7$ KJ/kg
- Theoretical Refrigeration effect (RE) :-
- RE = $(h1 - h4)$ = (259.7 – 101.1) = 158.6 KJ/kg
- Coefficient of Performance :-
- COP = $\frac{h1 - h4}{h2 - h1}$ = 13.55
- Ideal Coefficient of Performance :-
- Ideal COP = $\frac{TL}{Th - TL}$ = 15.42

RESULT

Details	Normal Refrigerator	With MC, EF and Condenser of 9.85m length
Energy Consumed Per Hour (Watts)	218	36
Hours of use per Day	24	24
Energy Consumed Per Day (KWh)	5.232	0.864
Energy Consumed Per Month (KWh)	156.96	25.92
Energy Consumed Per Year (KWh)	1909.86	315.36
1 KWh cost(MSEB)	₹ 3	₹ 3
Energy Cost Per Day (KWh)	₹ 15.696	₹ 2.592
Energy Cost Per Month (KWh)	₹ 470.88	₹ 77.76
Energy Cost Per Year (KWh)	₹ 5729.04	₹ 946.08
Savings per Year	-	**₹ 4782.96**

Table 1: Result

V. CONCLUSION

Using all the modifications-microcontroller, evaporator fan and 9.85m length of condenser, we came to know that

- Normal refrigerator consumes 218 Watts/hr.
- Installation of Micro-controller consumes power of 41.66 Watts/hr,
- Installation of Evaporator Fan along with Micro-controller consumes 55.98 Watts/hr,
- And installation of 9.85m length of condenser along with Evaporator fan & Micro-controller consumes 36.88 Watts/hr.

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