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PERFORMANCE ANALYSIS OF A SPLIT TYPE ROOM AIR CONDITIONER

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ABSTRACT

This paper investigates the performance of a split room air conditioner in the special-purpose laboratory room. In order to evaluate the performance, an experimental set-up is constructed. The experimental components consist of a split room air conditioner which has, a hermetic compressor, a condenser, an evaporator, capillary tube and two fans. For on-line reading purposes, it uses data acquisition system and power meter. The unit is installed in the energy conservation laboratory with the room volume of 16.8 m^3 at Faculty of Engineering, Universiti Malaya, Kuala Lumpur. Experimental result is obtained for various ambient temperatures. The electricity consumption and coefficient of performance of the system are measured and presented as a function of the ambient temperature.

1.0 INTRODUCTION

The room air conditioner is an encased assembly designed as a unit, primarily for mounting in a window or through the wall, or as a console. It is designed to provide comfort by cooling, dehumidifying, cleaning, circulating and may also include means for heating, ventilating or exhausting air to an enclosed space, room or zone (conditioned space). Some of the appliances are provided with more than one assembly (split unit) which is designed to use together, and requirements of rating outlined in the ISO 5151 are based on the use of matched assemblies [1]. Split room air conditioner becomes very popular in the ASEAN countries especially in the Philippines, Thailand, Indonesia, Singapore, and Malaysia. In Malaysia for example, up to 94% of room air conditioners sold in the market are of this type. In order to provide comfort air, split room air conditioner uses small refrigeration system connected by copper pipe and it hangs on the outside and inside of the wall. The compressor and condenser are placed outside of the building. They are separated from the evaporator by a building wall and connected using two copper pipes. The evaporator (which is inside the room)

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conditions and recalculates air to the room using evaporator fan. Most of the air conditioners sold in this country use R 22 (cholorodifluoromethane, $CHCLF_2$) as the working fluid. The capacity of room air conditioner ranges from 4000 to 36,000 Btu/hr.

The performance of a room air conditioner is represented by a ratio of cooling capacity and power consumption, known as coefficient of performance (COP). In some countries, it is known as energy efficiency ratio (EER) which is equivalent to the COP multiplied by 3.413. There are several techniques for analyzing the performance of the room air conditioner, the common techniques are explained in any book on air conditioner. This study uses a new approach to measure the COP, which will be explained in the experimental setup and methodology. The basic principles of standard vapor-compression air-conditioner operation cycle and heat source are discussed by McQuiston and Parker [2] and by Stoecker and Jones [3].

2.0 EXPERIMENTAL SETUP

The main characteristic of a split air conditioner used in this study is given in Table 1. The unit is installed in a room attached in the wall at energy conservation laboratory, Faculty of Engineering, University of Malaya. Due to the operating cycle period of the room air conditioner, the temperatures are measured at the critical points of the system. In order to get an optimum result, the sampling time is set based on experience. Type T Thermocouple has been used to measure air temperature entering and leaving the evaporator, ambient, and room temperature. Relative humidity transmitter is also used to measure percentage of relative humidity (RH) inside and outside of the room. All of those equipments are connected to the data acquisition system in order to connect online reading to the computer using GP-IB wire. The air velocity leaving the evaporator is constant and measured manually using anemometer. The power consumption of the systems is measured using digital power meter, which is connected to a personal computer using RS-232-C interfacing cable. Both data from the digital power meter and the data acquisition system are then exported to Microsoft Excel for analysis.

Table 1 Main characteristic of split room air conditioner

Characteristic	**Technical description**
Brand	York
Type	Split unit
Model	YSL 15B AFAA
Serial Number	MSJE 65286
Made in	Malaysia
Volt/Ph/Hz	220-240/1/50
Cooling Capacity	13000 Btu/hr
Condenser Power requirement	1400 W
Fan Power Input	25 W
Nominal Ampere	6.0 A

The test chamber which is used for testing is considered fully insulated from the surrounding. There is no window available but there is one door with rubber insulation. None of the wall has direct contact with the sun and the inside of the chamber is covered with double-sided gypsum board.

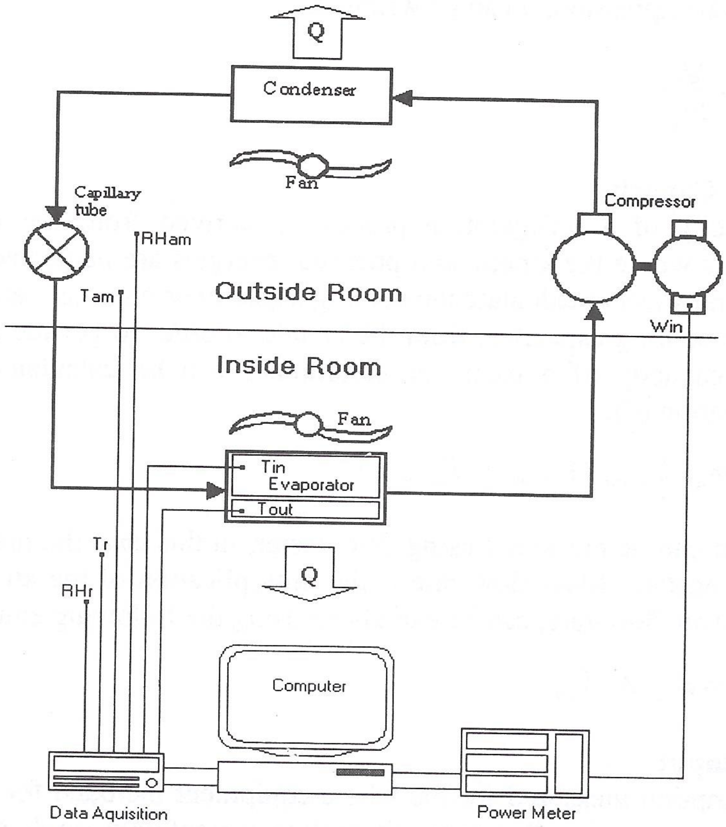

Figure 1 Diagram of the system measurement

3.0 METHODOLOGY

The components of a split room air conditioner consist of a hermetic compressor, a condenser, an evaporator, capillary tube, and two fans. All of the components of the refrigeration system are interdependent. Once all the components are connected into an operating system, they interact with one another and collectively determine the system performance. To specify the performance of a room air conditioner, the entire system must be analyzed as a unit. In order to evaluate the performance of the system, two factors were taken into consideration. First, the cooling capacities of the room air conditioner. Second the power consumption of room air conditioner. Both factors are dependent on ambient temperature.

COP is the ratio of cooling capacity and the equivalent power input to the compressor.

$$COP = \frac{Cooling\ Capacity}{Power\ Consumption} \quad (1)$$

In mathematical expression, it can be written as:

$$COP = \frac{Q_o}{W_{in}} \quad (2)$$

3.1 Cooling Capacity

Cooling capacity of a refrigeration process is derived from the first law of thermodynamic where the kinetic and potential energies are neglected. However, there are several ways to calculate the cooling capacity or cooling load. This study tries to derive cooling capacities from the airside in order to get the actual COP. The cooling capacity of a room air conditioner can be calculated using the following equation [4]:

$$Q_o = m_{air}\ C_{P-air}\ (T_{air-out} - T_{air-in}) \quad (3)$$

Velocity of air can be measured using flow meter, in this case the mass flow-rate of the air is constant. Mass flow-rate is the multiplication of the air density and the volumetric air flow-rate, can be calculated using the following equation:

$$m_{air} = \rho_{air}\ A_{ac}\ \overline{V}_{air} \quad (4)$$

3.2 Power input

Power consumption measured for the whole equipment included for compressor, fans and other accessories. Power for alternating current with single phase 208 V, 230 V and 240 V can be calculated using the following formula [5]:

$$W_{in} = I\ E\ PF \quad (5)$$

while the current input can be calculated using the following equation:

$$I = \frac{VA}{V} \quad (6)$$

3.3 Coefficient of Performance

By re-arranging the above equations, then COP of the room air conditioner can be expressed by the following equation:

$$COP = \frac{\rho_{air}\ A_{ac}\ \overline{V}_{air}\ C_{P-air}\ (T_{air-out} - T_{air-in})}{I\ E\ PF} \quad (7)$$

4.0 RESULTS

During the experiment, there are several parameters which are considered to be constant. The parameters are:

$C_{P\text{-}air}$ = 1005.7 (J/kg °C)

ρ_{air} = 1.2 (kg/m^3)

A_{ac} = 0.013 (m^2)

$\overline{V}_{air}$ = 6.5 (m/s)

The data collection was made hourly and the room air conditioner thermostat is set at 23°C. The temperature of the chamber room is measured at four points and the average of those temperatures is 23°C.

A linear regression technique has been used to determine the correlation coefficient between variation of electricity consumption of room air conditioner with ambient temperature. The correlation between electricity consumption with ambient temperature is shown in equation (8) and the result is plotted in Figure 2.

$$W_{in} = 2.6975 + 2.3687\,T_{am}\,, \quad R^2 = 0.8297 \tag{8}$$

Figure 2 shows that the electricity consumption increases when the ambient temperature increases.

The correlation between COP with ambient temperature is shown in equation (9) and the result is plotted in Figure 3.

$$COP = 5.617 - 0.0948\,T_{am}\,, \quad R^2 = 0.8111 \tag{9}$$

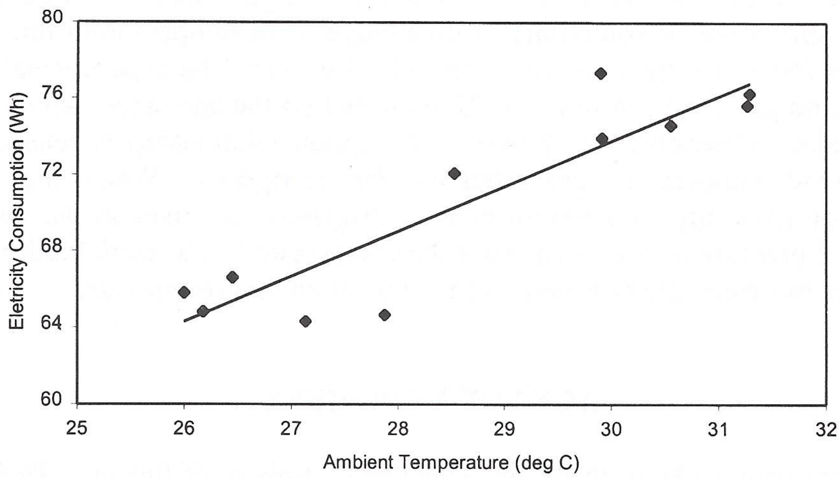

Figure 2 Variation of electricity consumption with ambient temperature

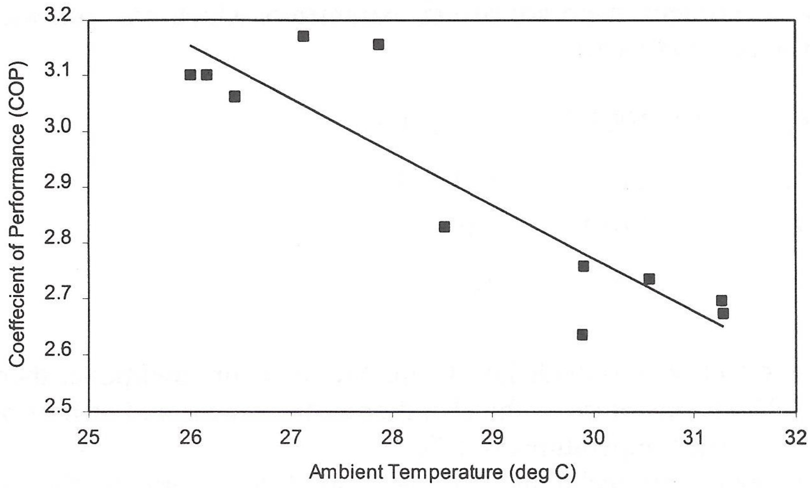

Figure 3 Variation of COP with ambient temperature

Figure 3 shows that the COP of the air conditioner decreases when the ambient temperature increases.

5.0 CONCLUSIONS

Power requirements and COP of the room air conditioner vary with the ambient temperature. For a constant indoor temperature, power requirement is directly proportional to ambient temperature. The electricity consumption of the room air conditioner becomes higher when the ambient temperature is increased. On the other hand the COP decreased when the ambient temperature increased. For this particular split room air conditioner, with a range of the temperature from 26^{o} C to 31^{o} C, it is found that the COP varies from 2.65 to 3.15. The experimental COP is within the range of the theoretical COP indicated on the appliance, which is 2.67. The ambient temperature and power consumption relationship is related to the pressure and temperature properties of the refrigerant. When the outdoor temperature rises, the temperature of the refrigerant also rises in the condenser causing the pressure to rise. As a result the compressor has to work harder and the motor uses more electricity because of the higher condenser pressure.

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NOMENCLATURE

Q_o	:	Cooling capacity	(J/h)
W_i	:	Power Consumption	(Wh)
m_{air}	:	Mass flow-rate of the air	(kg/h)
$C_{P\text{-}air}$	:	Specific heat of air	(kJ/kg °C)
$T_{air\text{-}out}$	:	Average air temperature leaving evaporator	(°C)
$T_{air\text{-}out}$	:	Average air temperature entering evaporator	(°C)
ρ_{air}	:	Air density	(kg/m^3)
A_{ac}	:	Air conditioner flow through	(m^2)
$\overline{V}_{air}$	:	Air velocity	(m/h)
P	:	Power	(W)
I	:	Amps	(A)
E	:	Volt	(V)
PF	:	Power factor	(%)
VA	:	Volt-amps	(VA)
V	:	Volts	(V)

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