

# The Effect of Outdoor Temperature on the Performance of a Split-Unit Type Air Conditioner Using R22 Refrigerant

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**Abstract.** To maintain the temperature setup on an air conditioner, the compressor will use more or less energy based on the outdoor temperature. Therefore, there is a need to understand the performance of the air conditioner if the outdoor temperature is varied. In this research, a used small capacity split-unit air conditioner using R-22 refrigerant is used to study the effect of outdoor temperature on the performance of the air conditioner. From the results, it can be understood that lower outdoor temperature requires less work from the compressor. The cooling capacity and coefficient of performance drop as the outdoor temperature increases.

## 1 Introduction

Nowadays, energy is the main subject and concern anywhere in the world. With the ever-growing world population, an increase of energy demand and depletion of energy resources especially fossil, every single unit of power that can be saved will contribute to preserving the nature and environment [1]. The global energy consumption for the last decade has increased tremendously due to the lifestyle and peoples' quest for a higher standard of living. It is well known that energy produced mainly come from fossil and energy generation highly contributes to global warming and pollution [2]. With the current trend on the energy prices increases, much focus is put into the energy efficiency application in those appliances [3].

The air conditioner is well known to be the appliances that consume a large amount of energy in everyday life. Nowadays, using an air conditioner to create a comfortable environment is a common practice in residential, commercial, as well as industries. The usage has been extensive, which is why it is one of the major electrical energy consuming appliance in residential [4,5]. Globally, 50% of the energy usage by a building is air conditioner [6]. According to a report by U.S. Department of Energy (2008), the nation's total energy consumed in residential and commercial buildings accounted for 40% of total U.S. energy used [7]. In residential, the usage split-unit type air conditioner is the most common due to its flexibility and simplicity [8].

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Outdoor temperature is known to be one of the factors that affect refrigeration and the performance of the air conditioner. Previous studies by researchers also include the investigation of the effect of outdoor temperature on the performance of air conditioner [4,5,9–14].

The earliest study performed by Houcek et al. [10] discovered that the heat capacity declined as the outdoor temperature increased from 70°F to 100°F. A similar trend was also observed by Farzad et al. [4,5,12] in their studies.

Meanwhile, J.M. Choi et al. found that for every increase of 4°C in outdoor temperature, the cooling capacity at full charge dropped at 2.5 to 4.5% [15]. The statistics are of the similar rate in the study using capillary tube system and EEV.

Elgendy et al. in their experiment found that as the outdoor air temperature increases, the system cooling capacity decreases, mainly due to the decrease in the cooling effect resulting from increasing the pressure ratio [16]. They also found that the compressor power increased with the increase of outdoor temperature.

Therefore, in general, it can be concluded that as the outdoor temperature increases, the total capacity of the refrigeration system drops as well as the COP. However, all of these researches used a large capacity air conditioner. Hence, in this research, a small capacity split-unit type air conditioner using R22 refrigerant is used to determine the effect of the outdoor temperature on its performance. The total cooling capacity, total electric power consumption, and coefficient of performance will be clarified.

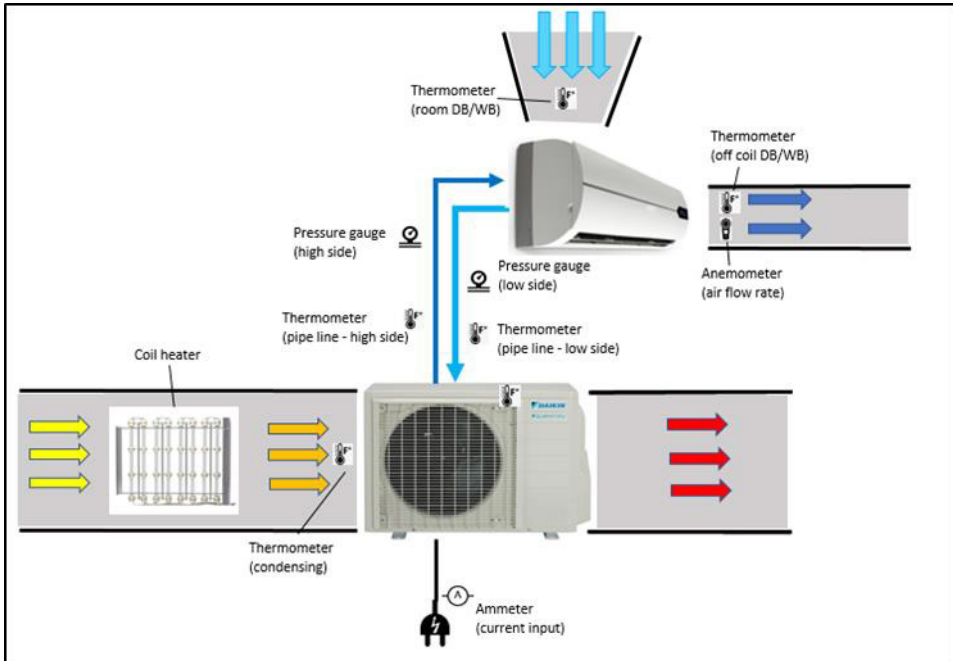
## 2 Methodology

To determine the effect of outdoor temperature on the performance of a split-unit air conditioner, an experiment setup consist of a split-unit air conditioner, and appropriate measurement tools to measure temperature and pressure was designed and fabricated. **Error! Reference source not found.** shows the schematic diagram of the experimental setup.

The Air-Conditioning & Refrigeration Institute (ARI) Standard 210/240 has to be applied in any performance testing of unitary air-conditioning equipment [17]. All the tests conducted must be in accordance with the test methods and procedures as described in the standard so that the standard ratings can be verified. However, due to the limitations of this research equipment setup, this study could not be performed to the ARI 210/240 standard. Therefore, the previous works by other researchers and the manufacturer's data sheet are not comparable to the results of this study. However, the results would show a similar trend and able to provide information on the performance of the split-unit air conditioner. In this study, the air-conditioner was set to 26°C, and the blower fan was set at the lowest setting to provide more stable air flow.

In this research, the experiment work utilised a standard 1.5 HP, 3.81 kW cooling (13,000 Btu/hr) rated used split-unit type air conditioner (2012 model). The working refrigerant gas for this unit is an R-22 refrigerant. The setup included sensors in specific locations to measure parameters such as dry-bulb and wet-bulb temperatures, refrigerant pressure (low and high), pipeline temperatures, air flow rate, as well as electrical power input.

To simulate the effect of different outdoor temperature, the temperature on condensing unit was be varied by using three-stage coil heaters with 1.5 kW power input to achieve specific outdoor temperature (see Fig. 2). Ductwork was attached at the unit's outlet with the dimension of 0.635 x 0.084 m cross section to measure the air flow rate of the indoor unit. For the purpose of high-pressure side's reading, the modification was done by installing a port for manifold gauge attachment.



**Fig. 1.** Schematic diagram of the experiment setup.



**Fig. 2.** Three stages of coil heater installed in the outdoor unit's ductwork.

In this research, the outdoor temperature is varied at 30°C, 32°C, 34°C and 36°C. In addition, the refrigerant charge is also varied from 80% to 120%.

### 3 Measurement of air conditioner performance

Three variables are used to measure the air conditioner performance which are total cooling capacity ( $C_T$ ), total electric power consumption, and coefficient of performance ( $COP$ ).

The total cooling capacity is calculated using Equation (1) [18].

$$C_r = VFR \times \rho_{air} \times \Delta h \text{ [W]} \quad (1)$$

Here,  $VFR$  is the volume air flow rate,  $\rho_{air}$  is air density, and  $\Delta h$  is the enthalpy change.

The total electric power consumption ( $TEPC$ ) is determined by using Equation (2) [18]. For a single-phase power,

$$TEPC = \frac{V \times A \times PF}{1000} \text{ [W]} \quad (2)$$

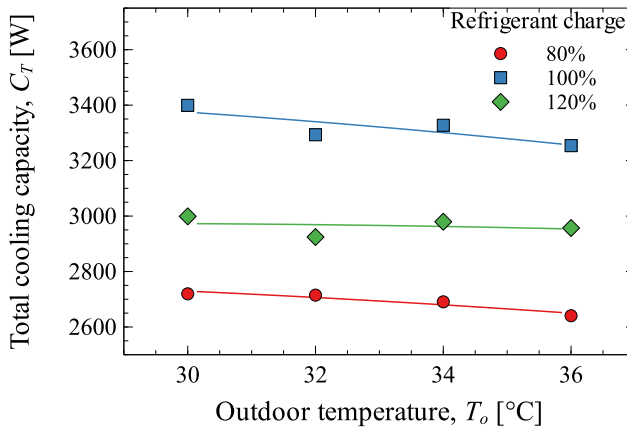
Here,  $V$  is voltage,  $A$  is current, and  $PF$  is power factor.

The coefficient of performance ( $COP$ ) is defined as the total cooling capacity divided by the work of the compressor, as shown in Equation (3) [17,19].

$$COP = \frac{C_r}{TEPC} \quad (3)$$

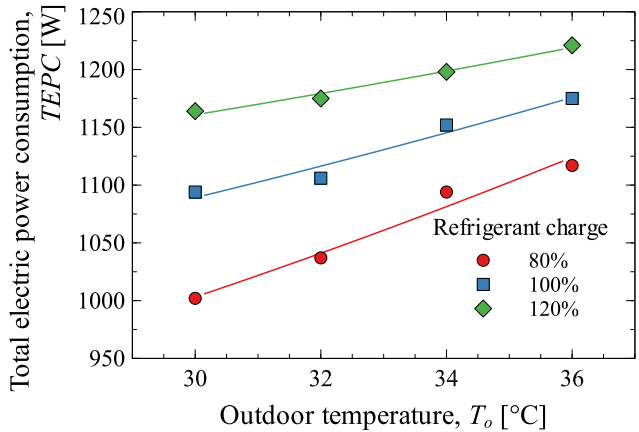
## 4 Results and discussions

Fig. 3 shows the total cooling capacity as a function of outdoor temperature. From this figure, the cooling capacity for all refrigerant charges decreased slightly with the increase of outdoor temperature. These trends were similar as reported by Houcek et al. [10], Farzad et al. [4,5,12] and J.M. Choi et al. [15]. The highest cooling capacity was obtained at 100% refrigerant charge for all outdoor temperatures. The cooling capacity dropped by 3.7% as the outdoor temperature increased from 30°C to 36°C.



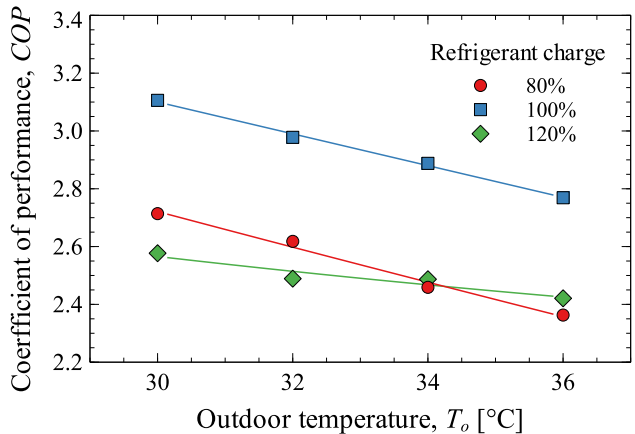
**Fig. 3.** Total cooling capacity as a function of refrigerant charge.

The result for total power electric consumption,  $TEPC$ , is shown in Fig. 4. From the result, it is clear that the  $TEPC$  increased steadily as the increase of outdoor temperature. These trends explain that more power input was required as the outdoor temperature increased. Furthermore, as the refrigerant charge increased, the  $TEPC$  also increased.



**Fig. 4.** Total electric power consumption as a function of refrigerant charge.

Based on the result from cooling capacity and *TEPC*, the coefficient of performance, *COP*, was calculated. The calculated result is shown in Fig. 5. For all outdoor temperatures, the *COP* decreased as the outdoor temperature increased. The highest *COP* was obtained at  $T_o = 30^\circ\text{C}$  for all refrigerant charges. As the outdoor temperature increased by  $6^\circ\text{C}$ , the *COP* dropped by 10.9%.



**Fig. 5.** Coefficient of performance as a function of refrigerant charge.

## 5 Conclusion

The present work emphasises on determining the performance of the air conditioner over a variation of outdoor temperatures. As previously highlighted, since the experiment work was not conducted in accordance with the ARI 210/240 standard, the results could not be compared directly to the manufacturer's data and previous works by researchers. However, it provides information on how the system performs and react with outdoor temperature variations. The conclusions are as follows:

1. The condenser performance of the air conditioner maxed at lowest outdoor temperature,  $T_o = 30^\circ\text{C}$ .

2. The total cooling capacity ( $C_T$ ) and  $COP$  dropped with the increase in the outdoor temperature. As the outdoor temperature increased from 30°C to 36°C, the  $C_T$  and  $COP$  dropped by 3.7% and 10.9% respectively.

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