Effect of Piping Distance on the Energy Consumption of a Split-Unit Air Conditioner

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Abstract

Air conditioning is sometimes necessary to help maintain the required level of thermal comfort in modern buildings. Split-unit air conditioning equipment generally consumes significant amount of electricity for operation. The energy consumed depends on several environmental and technical variables. One important variable is the refrigerant pipe length installation between the indoor and outdoor units. However, information on the extent of how the pipe length affects energy consumption is scanty in literature. This research used a single-phase energy meter to study the energy consumption of a 3500 W cooling capacity split-unit air conditioner for three refrigerant pipe lengths of 3m, 5m and 7m for runtime of 4 hours. Generally, the energy consumption increased with increasing pipe length. The recorded energy consumptions were 3.54 kWh, 4.29 kWh, and 5.08 kWh for the refrigerant pipe lengths of 3m, 5m, and 7m respectively. Increasing the pipe length from 3m to 5m caused 21.2% increase in energy consumption. Again, increasing the pipe length from 3m to 7m caused 43.5% increase in energy consumption. However, increasing the pipe length from 5m to 7m led to 18.4% increase in energy consumption. These results demonstrate increases in the air conditioning energy consumption with increasing refrigerant pipe length between the indoor and outdoor units, but with a reducing effect as the length gets longer.

Keywords: ***Air conditioning, energy consumption, energy efficiency, pipe length***

Introduction

Air conditioning (AC) use in buildings is necessary for various reasons including human thermal comfort, preservation of sensitive equipment, creation of specifically required ambience, etc. (Ning et al., 2016; Kindaichi et al., 2017; Oropeza-Perez, 2016). One common type of AC equipment design used in modern buildings is the split-unit air conditioner. This type of AC equipment has two main units namely the Air Handler Unit which is installed inside the conditioned space and the Compressor/Condenser Unit which is installed outside the conditioned space. Refrigerant pipes connecting the two units allow refrigerant to flow back and forth between them. Figure 1 shows a schematic of a typical Split Unit AC. This type of air conditioner has several advantages including quiet operation, ease of installation, ability to have separate units in different rooms, energy efficiency, precise temperature control, etc. (Joudi and Al-Amir, 2014; Li et al., 2017).

The actual energy consumption of a split-unit AC equipment in any situation is influenced by several factors including ambient conditions (temperature, humidity), equipment specification and condition, required indoor temperature and humidity, etc. (Chen, 2008; Aktacir et al., 2010). One important factor that also influences the energy consumption that is often overlooked is the refrigerant pipe length installation between the Indoor Air Handler Unit and the Compressor/Condenser Unit. For a longer pipe length, the AC compressor has to perform more work to move the refrigerant around through the circuit. For energy efficiency purposes, consideration of the refrigerant pipe length is important because for an AC unit, once the refrigerant pipe is installed, it is fixed and cannot be managed throughout the life of the AC equipment. However, empirical data is scanty on the extent of the effect of the refrigerant pipe length on the energy consumption of a typical AC equipment.

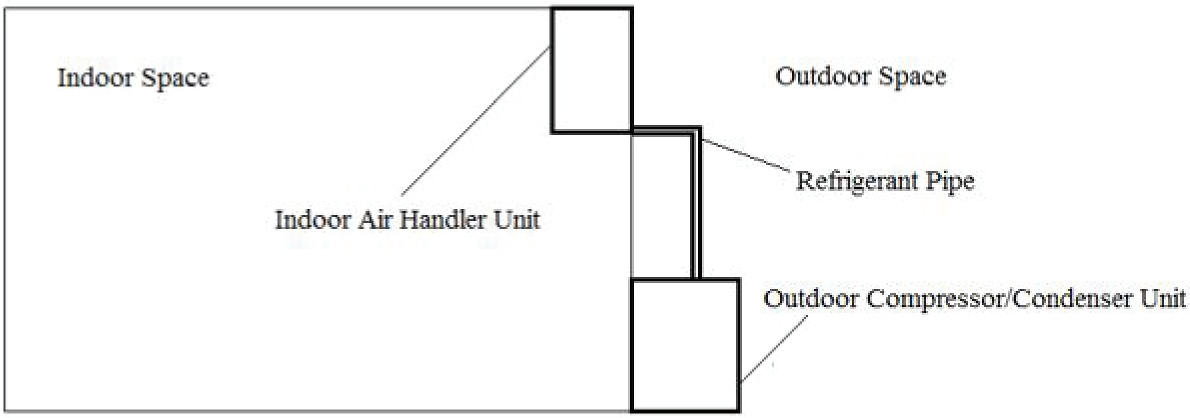

Figure 1: Schematic of a typical Split Unit AC

This paper measures the energy consumption of 3.5 kW cooling capacity split-unit AC equipment for refrigerant pipe lengths of 3m, 5m, and 7m. This provides a glace into the extent to which the energy consumption is affected by the pipe length. The results are analysed and presented.

Materials and Methods

Overview

An air-tight indoor space (5m × 5m × 5m) was created with ply-wood for the experimentation. The indoor and outdoor units of the AC equipment were installed inside and outside the space respectively. The refrigerant pipe length was initially installed at 7m and later reduced to 5m, then finally to 3m. At each pipe length, an energy meter was used to measure the electricity consumption (in kWh) for running the AC equipment for 4 hours at a temperature set point of 16°C. For each refrigerant pipe length, the experiment was run for three consecutive days and the average energy consumption estimated.

Analytical Framework

The average energy consumption for the duration of the experiment for each pipe length was estimated with equation 1. The percentage differences in energy consumptions were estimated with equation 2.

$$E_{ave} = \frac{1}{3} \times \sum_{i=1}^{3} E_i \quad (1)$$

$$\Delta E = \frac{E_2 - E_1}{E_1} \times 100\ \% \quad (2)$$

Specifications for Air Conditioning Equipment

The AC equipment was a 3500 W cooling capacity equipment. It had a Running Input Power Rating of 1320 W. The detailed specifications are given in Table 1

Table 1: Specifications for AC equipment

Parameter	**Value**
Maximum Electric Input (Power; Current)	1700 W; 8.5 A
Running Input Power	1320 W
Running Amps	6.3 A
Cooling Capacity	3500 W
Operating Voltage	220 – 230 V
Frequency	50 Hz

Results and Discussions

Figure 2 shows the AC energy consumption for each pipe length. The results showed increase in energy consumption for increasing pipe length. At the pipe lengths of 3 m, 5 m, and 7 m, the AC energy consumptions were 3.54 kWh, 4.29 kWh, and 5.08 kWh respectively. Table 2 shows the percentage increase in energy consumption for each pipe length using the 3 m length as basis. Increasing the pipe length from 3 m to 5 m led to 21.2% increase in energy consumption. Again, increasing the pipe length from 3 m to 7 m led to 43.5% increase in energy consumption. Increasing the pipe length from 5 m to 7 m led to 18.4% increase in energy consumption. The observation of the direct correlation between refrigerant pipe length and energy consumption is consistent with the fact that the AC unit compressor has to perform relatively more work to move refrigerant around in a longer refrigerant pipe circuit.

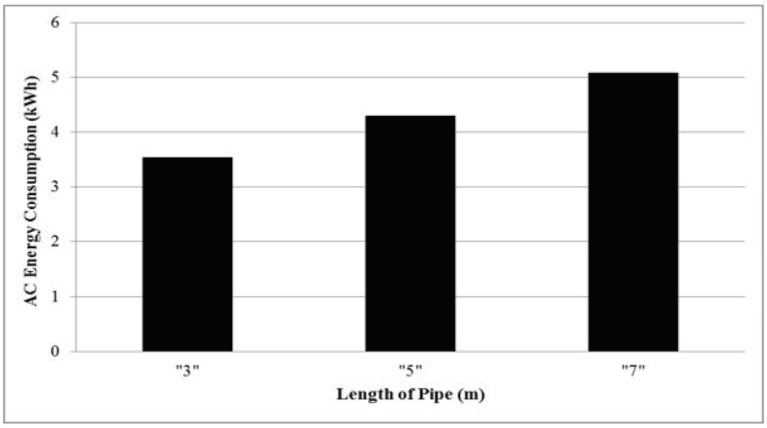

Figure 2: Electrical energy consumption for AC equipment for 4 hours

Table 2: Percentage increase in energy consumption for each pipe length (3 m as basis)

Length of Pipe (m)	Percentage Increase (%)
3	0
5	21.2
7	43.5

Conclusions

This study observed the effects of refrigerant pipe length on the energy consumption of a split-unit AC equipment. The refrigerant pipe lengths used for the experiment were 3 m, 5 m, and 7 m. A direct correlation was noticed and the AC energy consumption increased with increasing refrigerant pipe length. Increasing the pipe length from 3 m to 5 m, 3 m to 7 m, and 5 m to 7 m, led to 21.2%, 43.5%, and 18.4% increases in AC energy consumption respectively. This proportional trend in energy consumption is consistent with the theoretical fact that the AC compressor has to work harder to move refrigerant through a longer pipe length for the same given conditions. However the results also show that the rate of increase in energy consumption reduces as the pipe length increases.

Further Research

In view of the observations made in this research, the following points are noted for further research.

1. Measurement and correlation of outside temperature and humidity in relation to AC energy consumption.
2. Extension of experiment to cover much longer duration.
3. Detailed observation of compressor power characteristics for each pipe length.
4. Consideration of other pipe lengths.

Nomenclature

ΔE	Percentage change in energy consumption
E_1	Energy consumption at initial pipe length
E_2	Energy consumption at next pipe length
E_{ave}	Average energy consumption
AC	Air conditioning

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