A Comparative Energy Consumption Study of Air Conditioning Room between using Double Door and Electrical Air Curtain in Hot and Humid Climate

Wannawit Taemthong, Ph.D.
(Assistant Professor, King Mongkut's Institute of Technology North Bangkok, Bangkok, Thailand)

Abstract
In Thailand, an electrical air curtain is extensively used in commercial buildings at theirs entrances as a mean to save energy in operating air conditioning system. Electricity is used all the time while the air curtain is operating. Double door system, which has two sets of doors constructing next to each other, should be used instead. The objective of this research is to demonstrate to the public in Thailand, as well as to others in hot and humid climate regions, that how much of the electricity expenses can be saved using the double door system. This study was done through constructing an experimental room with nine types of doors. Electrical consumptions during experimental studies with simulating normal usage were recorded and compared in determining whether using double door system is sufficient enough in maintaining room temperature. On average, an air conditioning room with a double door system consumes electricity approximately 63% of the same room which has a single door attached with the electrical air curtain.

Keywords
Double Door, Energy Consumption, Hot and Humid, Air Curtain

1. Introduction

Energy conservation house is a house which minimizes the use of energy, while maintains temperature and humidity inside a comfort zone. It should have temperature between 22°C and 27°C, and relative humidity between 20% and 75% (Olgyay 1973). Air conditioning buildings in hot and humid climate which allow air leakage creating considerable energy losses. Appropriate door layout designing is essential in order to prevent outside temperature and humidity, which are higher, entering into buildings (Boonyatikarn 2002). Energy consumption increases every year due to an economic growth in Thailand. Opening of numerous super stores and shopping malls in Thailand is a sign of the growth. Typically, at the entrances of these stores they usually install air curtains. They are designed to keep cold air generating by air conditioning system on the inside and prevent hot air on the outside getting into buildings. A laminar stream of air with sufficient quantity and speeds generating by several fans or air blowers is a main mechanism of this appliance. As a result, electricity is used in operating the appliance. However, there is an alternative in preventing loss of cold air from the inside. It is a double door system. The system composes of two series of doors with spaces in between them working as a mix temperature room and consumes no electricity. However, which layouts of double door systems should be installed and what percentage of the electricity could be saved are not known. As a result, an experimental study should be implemented in order to determine what kind of double door system is appropriate for using in hot and humid climate.

2. Objective

The objective of this study is to compare the energy consumption between using the air curtain together with single door and the double door system in maintaining temperature in the air conditioning room in hot and humid area.

3. Scope of work

Nine types of doors are attached with a standard room, which is equipped with a wall mounted air conditioning unit. During the data collection, room temperature is maintained at 25°C and the frequency of traffic using the doors are specified at 30 openings per hour.

3. Methodology

In this study, nine experiments are performed in an 18 square meter room, which is attached with a wall mounted air conditioning unit. It has a cooling capacity of 12,129 Btu/Hr or 3,555 Watts, and an energy efficiency rating (EER) of 3.19. Four sides of walls are drywall systems, which are a combination of 12 millimeter thick gypsum boards and galvanized steel studs. Ceiling is finished by a t-bar system, which is a combination of 9 millimeter thick gypsum boards and T shaped aluminum frame. Each experiment has specific characteristics and construction costs as presented in Table 1. The attached air curtain has a total input of 50 Watts and an air velocity of 8.8 meter per second. Figure 1 presents floor plans of experiments one to three for rooms equipped with air curtain and attached with single doors opening out, opening in, and sliding, respectively.

Table 1: Characteristic and Cost Information of Nine Experiments

	Characteristic of Each Experiment			Costs (Baht)		
Experiment	**Single Door**	**Double Door**	**Air Curtain**	**Door+Ceiling+Wall**	**Air Curtain**	**Total System**
1	Open Out	-	Yes	-	12,000	12,000
2	Open In	-	Yes	-	12,000	12,000
3	Slide	-	Yes	-	12,000	12,000
4	-	Parallel - Open Out	No	15,060	-	15,060
5	-	Parallel - Open In	No	15,060	-	15,060
6	-	Parallel - Slide	No	15,260	-	15,260
7	-	Perpendicular - Open Out	No	15,060	-	15,060
8	-	Perpendicular - Open In	No	15,060	-	15,060
9	-	Perpendicular - Slide	No	15,260	-	15,260

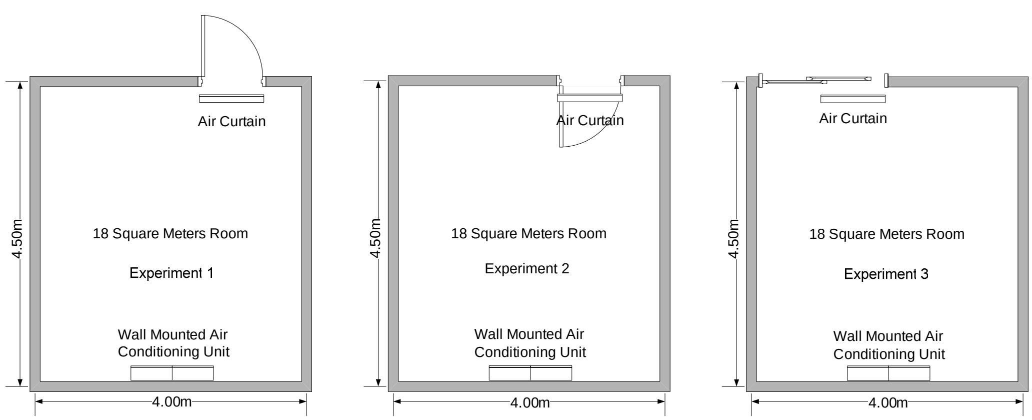

Figure 1: Floor Plan of Experiments 1 – 3: A Single Door with Air Curtain

Figure 2 presents floor plans of experiments four to six for rooms attached with parallel double doors opening out, opening in, and sliding, respectively.

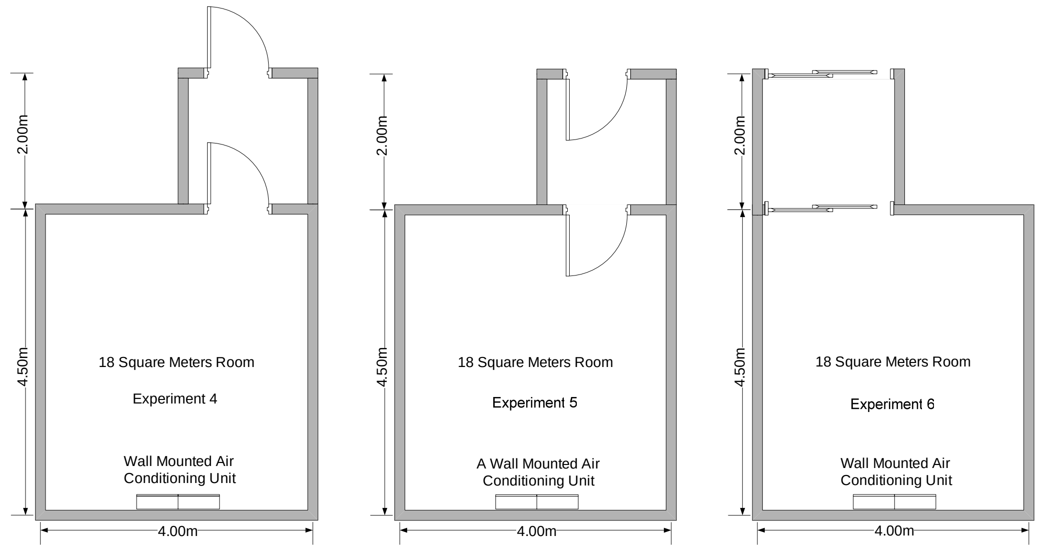

Figure 2: Floor Plan of Experiments 4 – 6: A Double Parallel Door

Figure 3 presents floor plans of experiments seven to nine for rooms attached with perpendicular double doors opening out, opening in, and sliding, respectively.

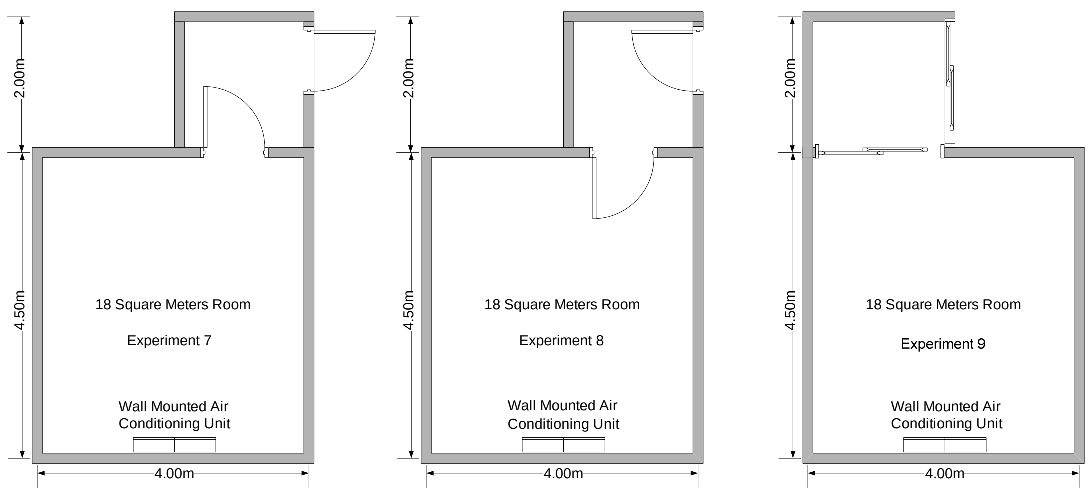

Figure 3: Floor Plan of Experiments 7 – 9: A Double Perpendicular Door

Figure 4 presents an exterior view of an experimental room which is air tight. Each experiment is performed for two days. In each day, the experiments are performed two times, which are between 6:00 to 8:00 and 18:00 to 20:00. The experiments start when an air conditioning is turned on and room temperature cool down to 25°C. Energy consumptions in kilo Watts (kW) are recorded during data collection using a digital electricity consumption reader which transfers data to a computer by a data logger software. Examples of recorded data for a period of two hours are presented in Figure 5. During the two hour experiment, there are 7,200 seconds as shown on the x-axis. The kilowatt-second is dropped from 0.31 to 0.03 kilowatt-second where the air compressor did not work. While the data is logged, a lab boy walks through the door by open it at full swing or slide for 60 times at 2 minutes interval in each two hour period. Two thermocouples type K and two humidity transmitters are placed inside the room and outside the room in order to record room temperature and humidity and climate temperature and humidity. These tools are placed at the same position in every experiments. The temperature and humidity are read three times during the two hour period. The first time is recorded after the first opening; the second time is recorded after the 30th opening, and the last time after the 60th opening. These three values of the temperature and humidity are then averaged and presented in the forth and fifth columns of Tables 2 and 3 for the morning and afternoon periods, respectively. Due to impact of high humidity during raining, data collection was not permitted during raining and before or after rain for one hour.

Figure 4: An Experimental Room

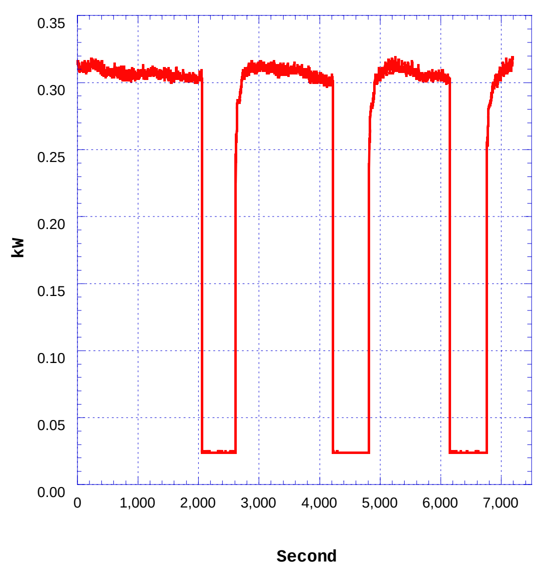

Figure 5: An Example of a Kilo-Watt Profile During the Two Hour Experiment

4. Analysis

After completing data collection for nine experiments, the kilo Watt – Hours are determined by cumulating the kilo Watt – Seconds during the two hour period and divided with 3,600 seconds. Since we performed experiments for two consecutive days, therefore, the averaged kilo Watt – Hours for the morning and afternoon periods are calculated and presented separately in the last column of Table 2 and Table 3, respectively. Experiments one to three are considered as based alternatives, which are compared to experiments four to nine. Alternatives 4, 5, 7, and 8 require more installation costs than alternatives one to three for 3,060 Baht. Meanwhile, alternatives 6 and 9 require more installation costs than alternatives one to three for 3,260 Baht. The alternatives, moreover, require more spaces than the based alternatives for 4 square meters. Each experiment is performed individually at different times due to limited spaces and budget. As a result, certain inconsistency variables are expected such as different climate temperature and humidity varies throughout experimental programs.

Table 2: Incremental Costs, Extra Spaces, Average Temperature and Humidity of the Experiments for *Morning* Period

Experiment	Incremental Costs (Baht)	Extra Spaces Required (sq.m.)	Average Temperature	Average Humidity	Average kWH
1	-	0	27.50	82.00	0.34
2	-	0	27.50	83.50	0.44
3	-	0	28.50	86.00	0.35
4	3,060	4	29.50	85.00	0.36
5	3,060	4	30.00	72.00	0.32
6	3,260	4	27.50	76.00	0.17
7	3,060	4	28.00	76.50	0.16
8	3,060	4	28.00	77.00	0.20
9	3,260	4	29.50	77.00	0.20

Table 3: Incremental Costs, Extra Spaces, Average Temperature and Humidity of the Experiments for *Afternoon* Period

Experiment	Incremental Costs (Baht)	Extra Spaces Required (sq.m.)	Average Temperature	Average Humidity	Average kWH
1	-	0	25.00	81.00	0.47
2	-	0	28.00	84.00	0.51
3	-	0	27.00	84.00	0.48
4	3,060	4	28.50	73.50	0.38
5	3,060	4	25.50	70.00	0.22
6	3,260	4	29.00	83.00	0.39
7	3,060	4	28.00	73.50	0.29
8	3,060	4	27.50	72.00	0.28
9	3,260	4	27.50	70.50	0.30

5. Result

From the averaged kilo Watt – Hours shown in Tables 2 and 3, we can calculate monthly kilo Watt – Hours based on an operating assumption of 8 hours per day and 30 days per month. Monthly electricity expenses are calculated using combination of two unit rates, which are electricity costs of 1.8047 Baht/kW and FT Costs of 0.7584 Baht/kW. FT cost is varied based on energy price in the world market. Therefore, total monthly electricity expenses for morning and afternoon are calculated as presented in the third columns of Tables 4 and 5, respectively.

Table 4: Monthly kW, Cost, and Annual Return of the Experiments for *Morning* Period

Experiment	Monthly kW	Total Monthly Electricity Expenses (Baht)	Monthly Saving (Baht)	Yearly Saving (Baht)	Annual Return %
1	82.03	210.25	-	-	-
2	104.77	268.53	-	-	-
3	84.04	215.41	-	-	-
4	86.24	221.05	10.35	124.16	4%
5	76.00	194.79	36.61	439.28	14%
6	41.49	106.34	125.06	1500.68	46%
7	38.97	99.87	131.53	1578.32	52%
8	47.19	120.96	110.44	1325.24	43%
9	47.64	122.12	109.28	1311.32	40%

Table 5: Monthly kW, Cost, and Annual Return of the Experiments for *Afternoon* Period

Experiment	Monthly kW	Total Monthly Electricity Expenses (Baht)	Monthly Saving (Baht)	Yearly Saving (Baht)	Annual Return %
1	113.26	290.30	-	-	-
2	122.71	314.52	-	-	-
3	114.88	294.45	-	-	-
4	90.31	231.48	68.28	819.32	27%
5	52.30	134.04	165.72	1988.60	65%
6	94.32	241.75	58.01	696.08	21%
7	70.40	180.45	119.31	1431.68	47%
8	67.04	171.83	127.93	1535.12	50%
9	71.68	183.71	116.05	1392.56	43%

Averaged monthly expenses of the first three experiments can be calculated as following:

$$\text{Average Monthly Expenses for Morning Period} = \frac{210.25 + 268.53 + 215.41}{3} = 231.40$$

$$\text{Average Monthly Expenses for Afternoon Period} = \frac{290.30 + 314.52 + 294.45}{3} = 299.76$$

These two averaged values are used to compare with monthly expenses for experiments 4 to 9, and presented in terms of monthly cost saving and yearly cost saving as presented in Columns 4 and 5 of Tables 4 and 5. Annual return in percentage can be calculated by dividing yearly cost saving with incremental cost from Tables 2 and 3 for each experiment and presented in the last column of Tables 4 and 5.

6. Conclusion and Recommendation

Temperature, humidity, and electricity expense for single and double doors are grouped, averaged, and presented in Table 6. It is obvious that averaging humidity of experiments 1 to 3 are higher than experiments 4 to 9 since experiments 1 to 3 are performed during the end of rainy season. While averaging temperature of experiments 4 to 9 are higher than experiments 1 to 3 since they are performed during the beginning of summer season. Moreover, afternoon experiments use more energy power than morning experiments in maintaining room temperature at 25°C due to cumulative heat absorbed by a building during a day. As a result, yearly electricity expenses of afternoon experiments are higher than morning experiments. Yearly electricity expenses between single and double door systems are compared. It is found that the electricity expenses of the double door systems are 37.69% and 36.43% less than the single door systems for morning and afternoon experiment, respectively. However, these saving percentages have not considered impacts from varying temperature and humidity. Temperature has more impact on electricity expenses than humidity since hot air decreases energy efficiency of air conditioning when entering its fan coil unit. Hot day require more energy in maintaining room temperature than rainy day. Morning data will be used to conclude these experimental studies in terms of door layouts and openings due to impacts from accumulated heat inside building. Table 7 summarizes yearly electrical expenses for different door layouts and openings which are calculated from monthly expenses from Table 4.

Table 6: Comparing Averaged Temperature, Humidity, and Electricity Expenses of Single VS Double Door Experiments

		Averaged Temperature	Averaged Humidity	Yearly Electricity Expenses	% Saving
Morning	Experiment 1-3	27.83	83.83	฿ 2,776.76	-
	Experiment 4-9	28.75	77.25	฿ 1,730.26	37.69%
Afternoon	Experiment 1-3	26.67	83.00	฿ 3,597.08	-
	Experiment 4-9	27.67	73.75	฿ 2,286.52	36.43%

Table 7: Electricity Expenses of Double Door System for *Morning* Experiments

	Types of Layout				
Types of Opening	Double Parallel Door		Double Perpendicular Door		Average Cost
	Experiments	Yearly Expenses	Experiments	Yearly Expenses	
Open Out	4	฿ 2,653	7	฿ 1,198	฿ 1,926
Open In	5	฿ 2,337	8	฿ 1,452	฿ 1,895
Slide	6	฿ 1,276	9	฿ 1,465	฿ 1,371
Average Cost		฿ 2,089		฿ 1,372	

Yearly electricity expenses for experiments 4 and 7 can be calculated as follows, while for other experiments can be calculated in the same manner.

Yearly electricity expenses for experiment 4 = $12 \times 221.05 = 2{,}653$ Baht, and

Yearly electricity expenses for experiment 7 = $12 \times 99.87 = 1{,}198$ Baht.

Based on the average yearly electricity expenses shown in Table 7, a sliding double perpendicular door is recommended to replace a single door attached with air curtain because they offer the lowest average costs for both layout and opening categories. The yearly electrical expenses of experiment 9 are higher than of experiment 6 due to higher temperature for 2°C and humidity for 1%. Sliding double doors require slightly more installation cost than double opening doors. However, they offer more energy saving than using opening out and in for 29% and 28%, respectively. Meanwhile, double perpendicular doors offer more energy saving than double parallel door for 34%. In conclusion, sliding double door is recommended for using in hot and humid climate temperature because it offers the most saving when compared to other types of doors. The reasons why using sliding doors can save more energy than using opening doors because of the air pressure generating when open and close the opening doors is higher than open and close the sliding doors. Relative humidity and temperature can be fluctuated rapidly in rainy season. Therefore, these two factors are direct impacts to result of this research. For better comparison results in future, we recommend to perform data collection simultaneously for different room layouts and door openings in order to minimize impacts from such factors.

7. Acknowledgement

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8. References

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