CHAPTER IV

EXPERIMENT AND RESULT

According to the research objectives pointed out in chapter III, this chapter explains about the experimental procedure and testing results, which are referring to three investigation temperature parameters such as the ambient temperature, the starting ambient temperature and the heating temperature, leading to obtain the analysis result from this research thesis.

4.1. The Investigation of Ambient Temperature

4.1.1. Purpose and Studied Parameter

Purpose

In the previous research, Karno (2008) conducted the tests at a constant room temperature of 26.5 ºC by using the air conditioner to keep the room environment temperature stable throughout the whole test. Moreover, all the tests were conduct in a period of four hours, thus, a large amount of energy was used which means there was a lot of cost expense to process the experiment. Therefore, to reduce the amount energy used this experiment will conduct

between two conditions of closing and opening the air conditioner machine to be a result.

Studied Parameter

This experiment was studied by dividing into two groups of tests with same condition of the starting ambient temperature. Both groups were determined using a constant and a natural room temperature. The constant condition was applied to the experiment by using an air conditioner throughout the test, and the natural condition was without air conditioning.

First group, to simulate the natural room temperature condition, it was determined to run the test by following weather in the local area of Chiang Mai, Thailand. Three testing periods in a day were considered. Those periods were divided as morning (from 8:00 am to 12:00 am, temperature reaching up from 19 ºC to 24 ºC), afternoon (from 2:00 pm to 6:00 pm, temperature reaching up from 25 ºC to 30 ºC) and night (from 7:00 pm to 11:00 pm, temperature falling down from 30 ºC to 24 ºC) by following reporting data of TMD (2010).

Second group, the constant room temperature condition, three constant room temperatures of 19 ºC, 25 ºC and 30 ºC were set as the testing environment for the comparison with the first group.

4.1.2. Specimens

The experiment was conducted by selecting six types of EPS foams as the testing samples. All samples had the same surface of one square meter (1 m^2), but had difference in size of thickness and thermal resistance (*R*-value) as:

1) *2.5 cm or 1 inch thickness of EPS foam with R-value of 0.70 ºC•m^2/W (or 4 °F.ft^2.h/Btu).*
2) *5 cm or 2 inches thickness of EPS foam with R-value of 1.41 ºC•m^2/W (or 8 °F.ft^2.h/Btu).*
3) *7.5 cm or 3 inches thickness of EPS foam with R-value of 2.11 ºC•m2/W (or 12 °F.ft2.h/Btu).*
4) *10 cm or 4 inches thickness of EPS foam with R-value of 2.82 ºC•m2/W (or 16 °F.ft2.h/Btu).*
5) *12.5 cm or 5 inches thickness of EPS foam with R-value of 3.52 ºC•m2/W (or 20 °F.ft2.h/Btu).*
6) *15 cm or 6 inches thickness of EPS foam with R-value of 4.23 ºC•m2/W (or 24 °F.ft^2.h/Btu).*

4.1.3. Procedure

Testing Series of Samples

The original hot box was designed with a limit of four testing samples. In a series of experiments, the hot box test could be conducted with four kinds of samples, simultaneously. Therefore, to finish all five types of samples which were prepared above, the experiment was conducted in two series of the test.

The first step, a testing series was conducted by four different samples of 2, 3, 4, and 5 inches thickness and, the second was conducted by two different samples of 1 and 6 inches thickness of EPS foam and checking with, 3, 4 inches for any errors.

Heat Source and Room Temperature Control

In reference to Koch Neilson (2002), he determined that temperature in and around buildings envelop will be affected by the nature of its surrounding surfaces. During the hot weather when the air temperature was possibly increasing up to 38 ˚C to 40 ˚C, the surface temperature of concrete panels can absorb the heating around 52 ˚C to 65 ˚C depending on its painted color. Based on this condition, the limit of the heating temperature was set up as 60 ˚C, which was heated up by a 200-W light bulb with dimmer switch controller adjusted by hand. Moreover, a heater and an air conditioner were used to control the temperature of heating and cooling systems in conditions of constant room temperature test. The heater was possible used to control heat between 26 ºC to 33 ºC and the air conditioner controlled from 17 ºC to 26 ºC.

Data Collection

The experiment was conducted in a period of four hours to finish a series of testing following previous research experiment, (Karno, 2008). From the start, when the heating source was turned on, temperature in the heating cell and all metering cells were recorded simultaneously every fifteen minutes until

the experiment was finished using two kinds of thermometer sensors described in section 3.3.2. All those tools were located in the centre of all metering cells, and the heating chamber.

4.1.4. Testing Results

There were two groups of results of the different experimental conditions, except an error in the results of the 6 inches testing sample. The first group of the natural room temperature testing provided three different types of graphic result, shown in Figure 4.1 to 4.3. The second group of constant room temperature provided three different graphs of the second group of the experiment are shown in Figure 4.4 to 4.6.

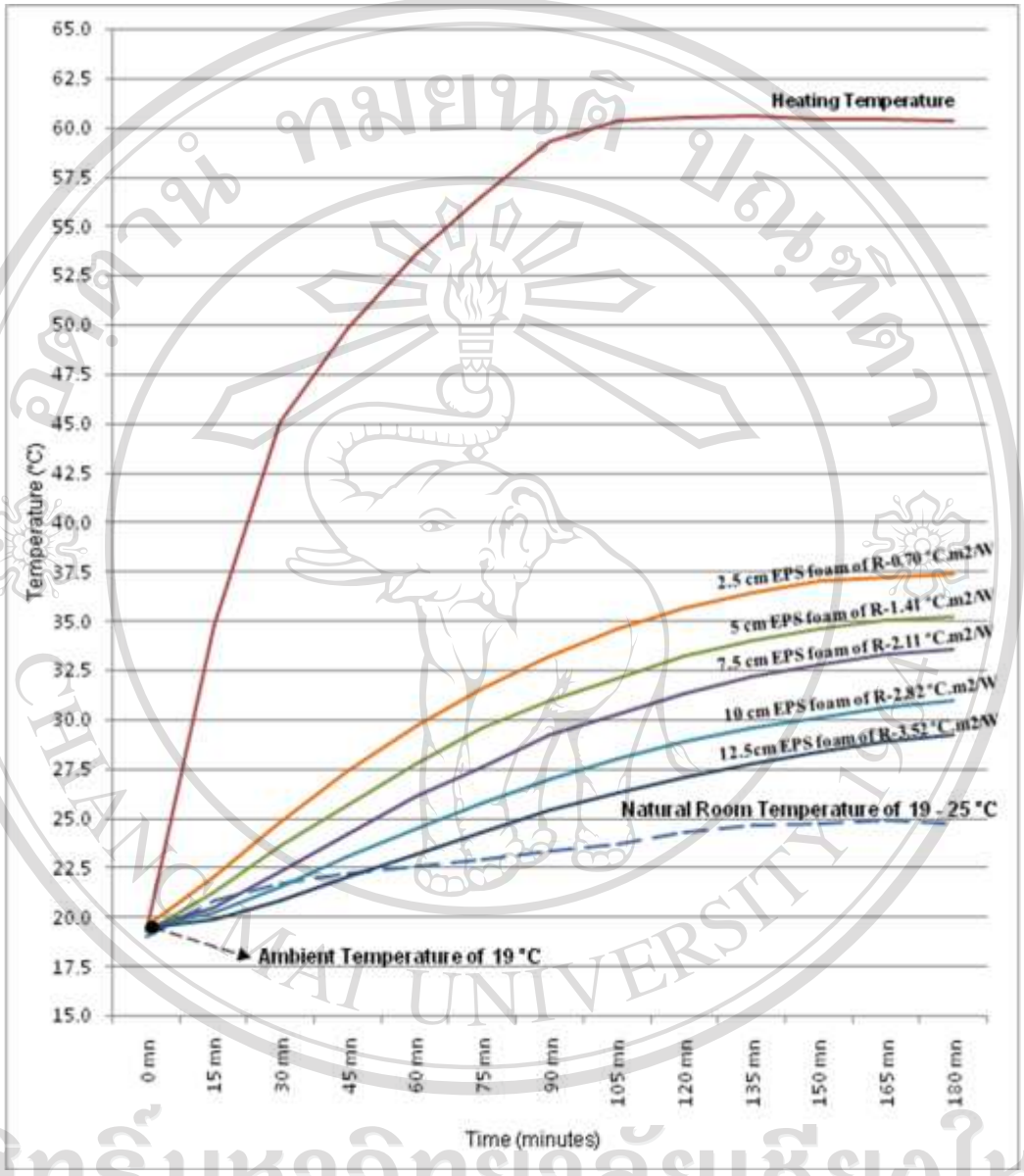

Figure 4.1 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell in morning test of natural room temperature from 19 to 25 ºC

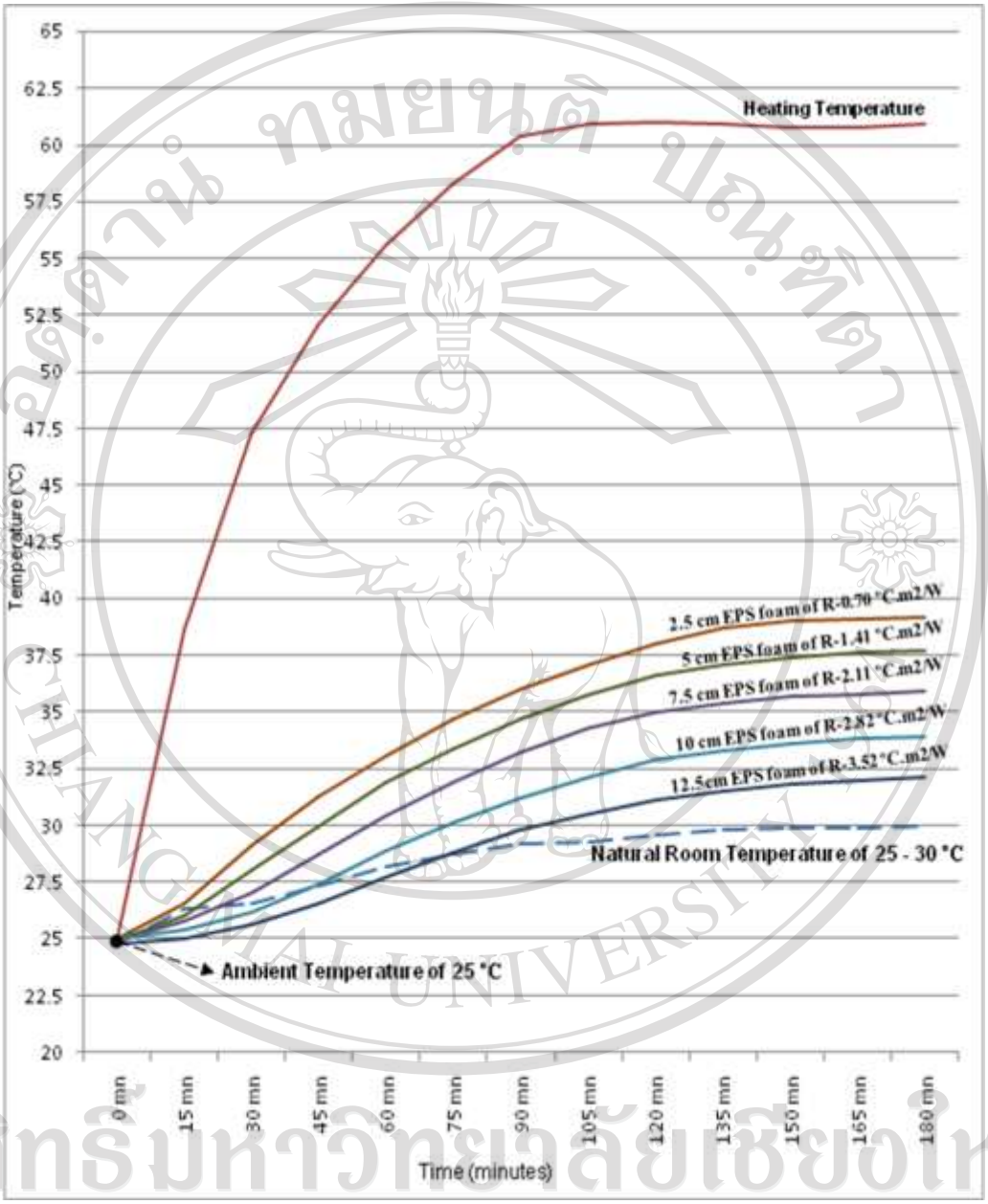

Figure 4.2 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell in afternoon test of natural room temperature from 25 to 30 ºC

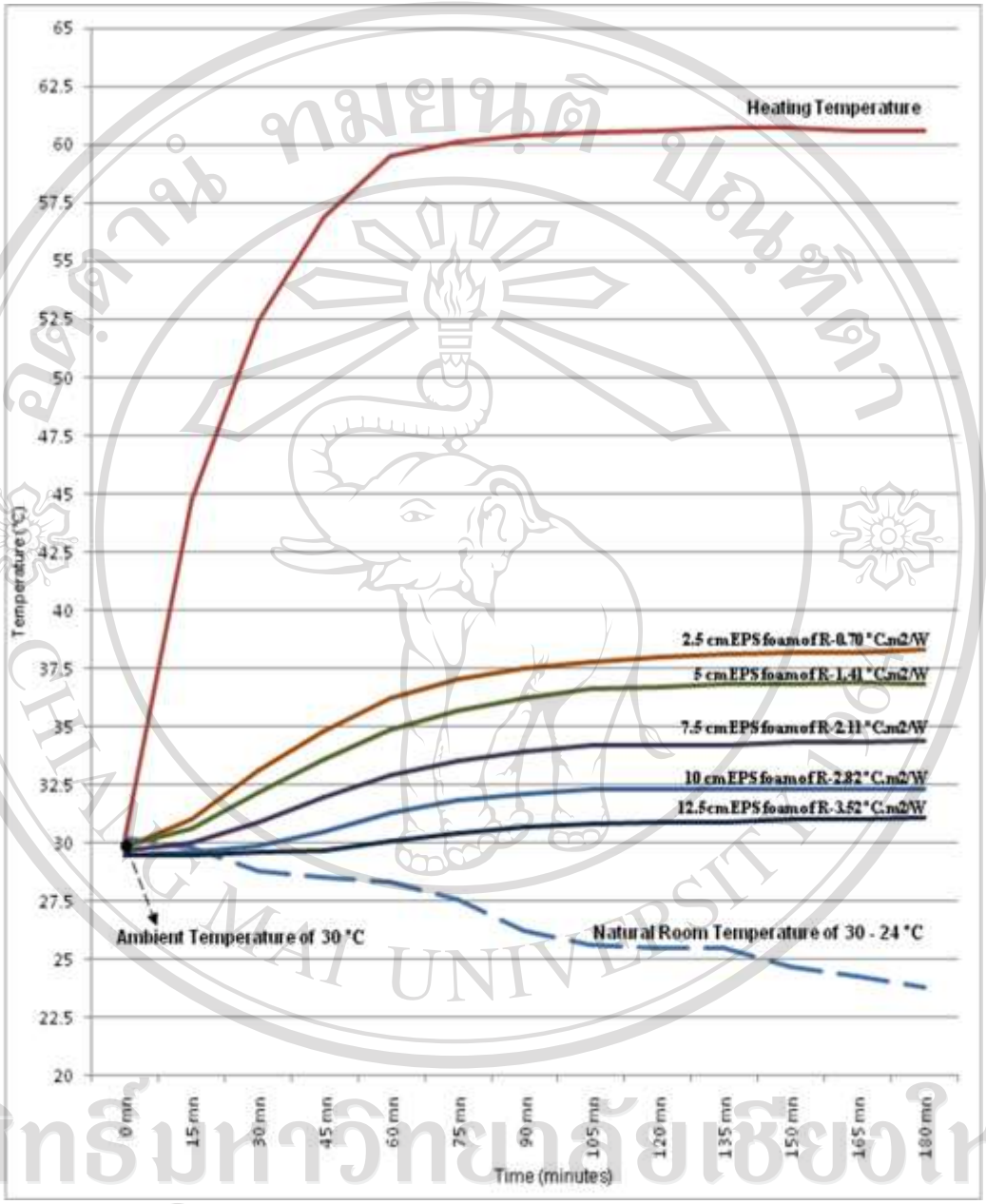

Figure 4.3 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell at night test of natural room temperature from 30 to 24 ºC

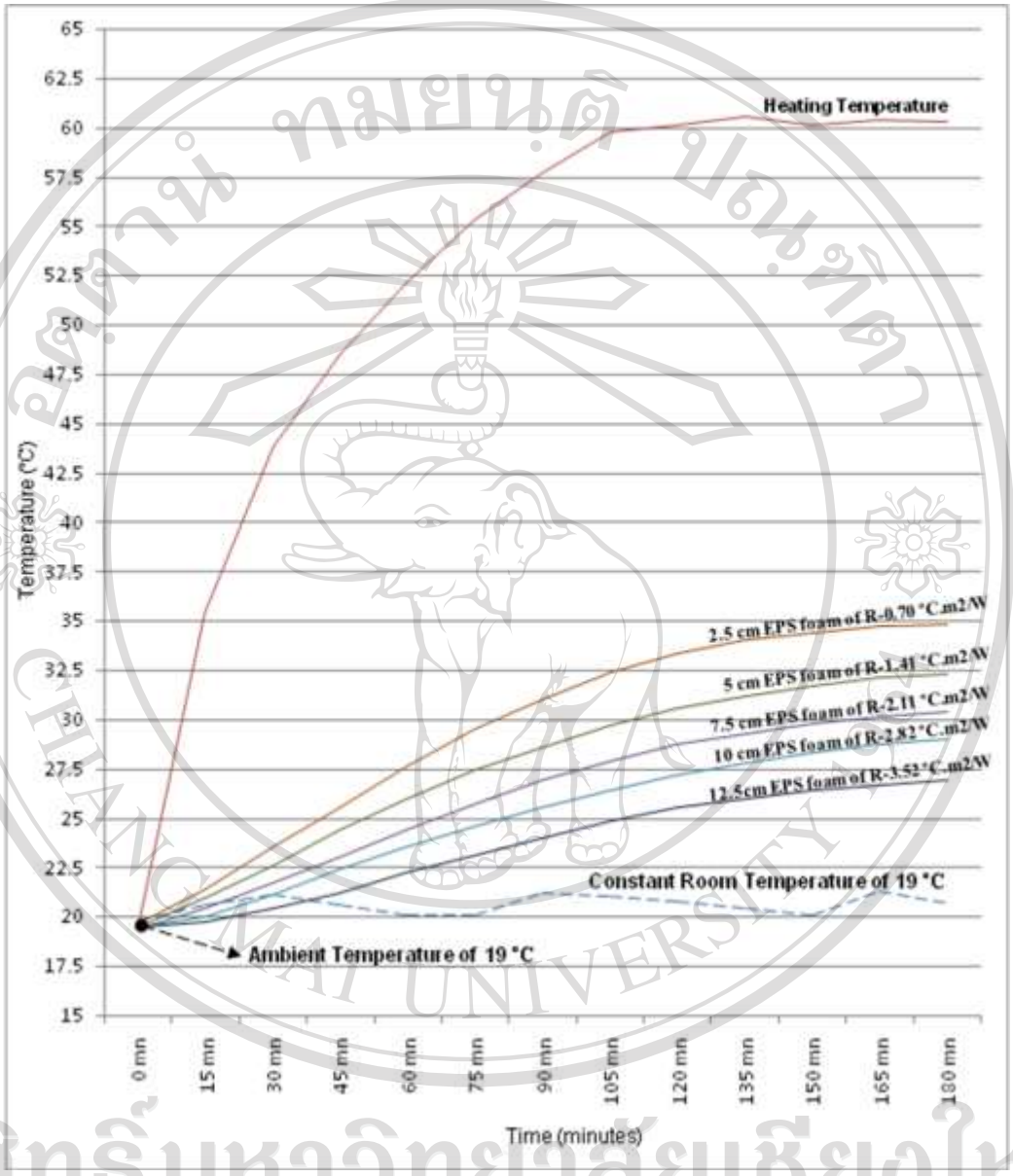

Figure 4.4 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell of constant room temperature of 19 ºC

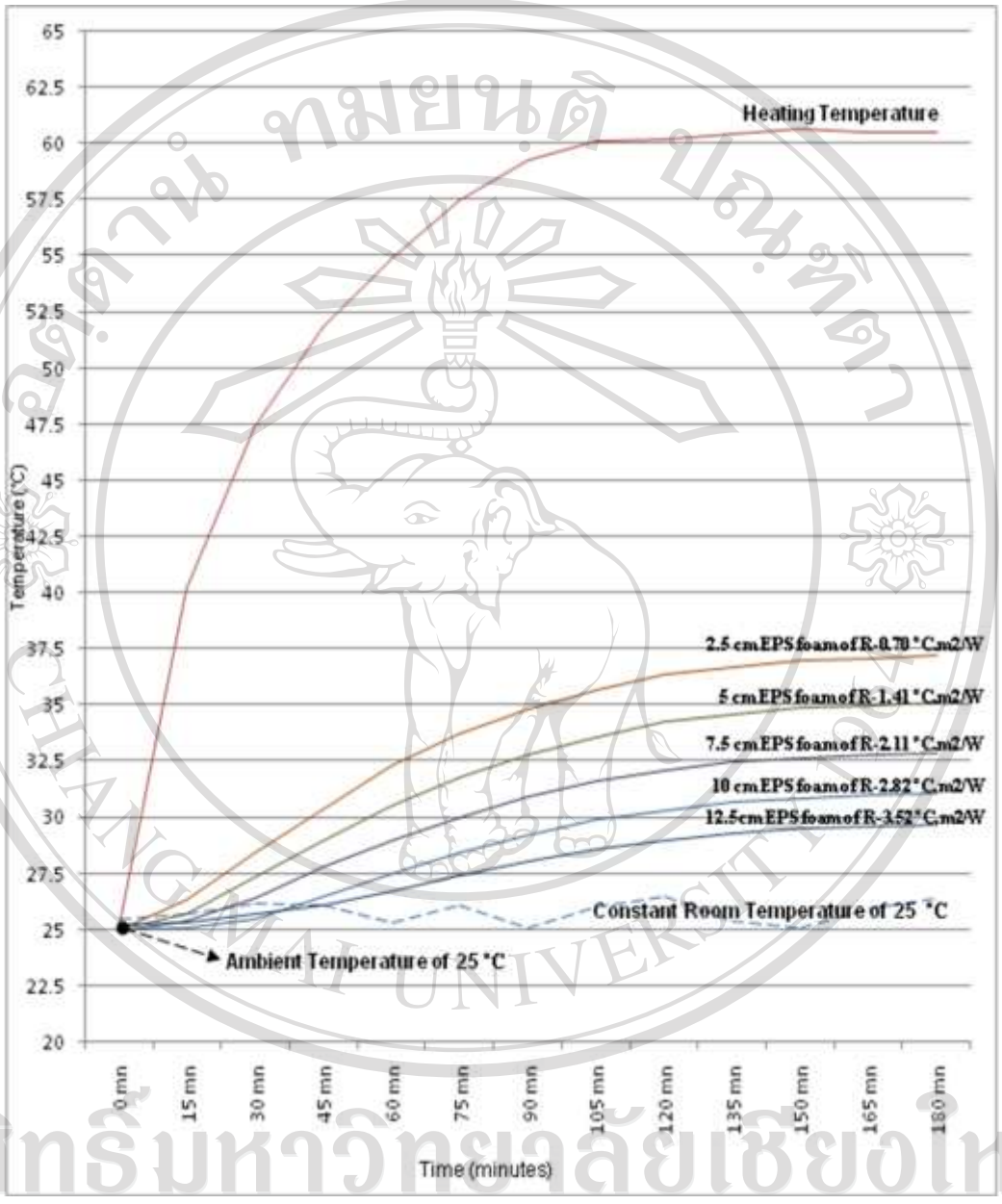

Figure 4.5 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell of constant room temperature of 25 ºC

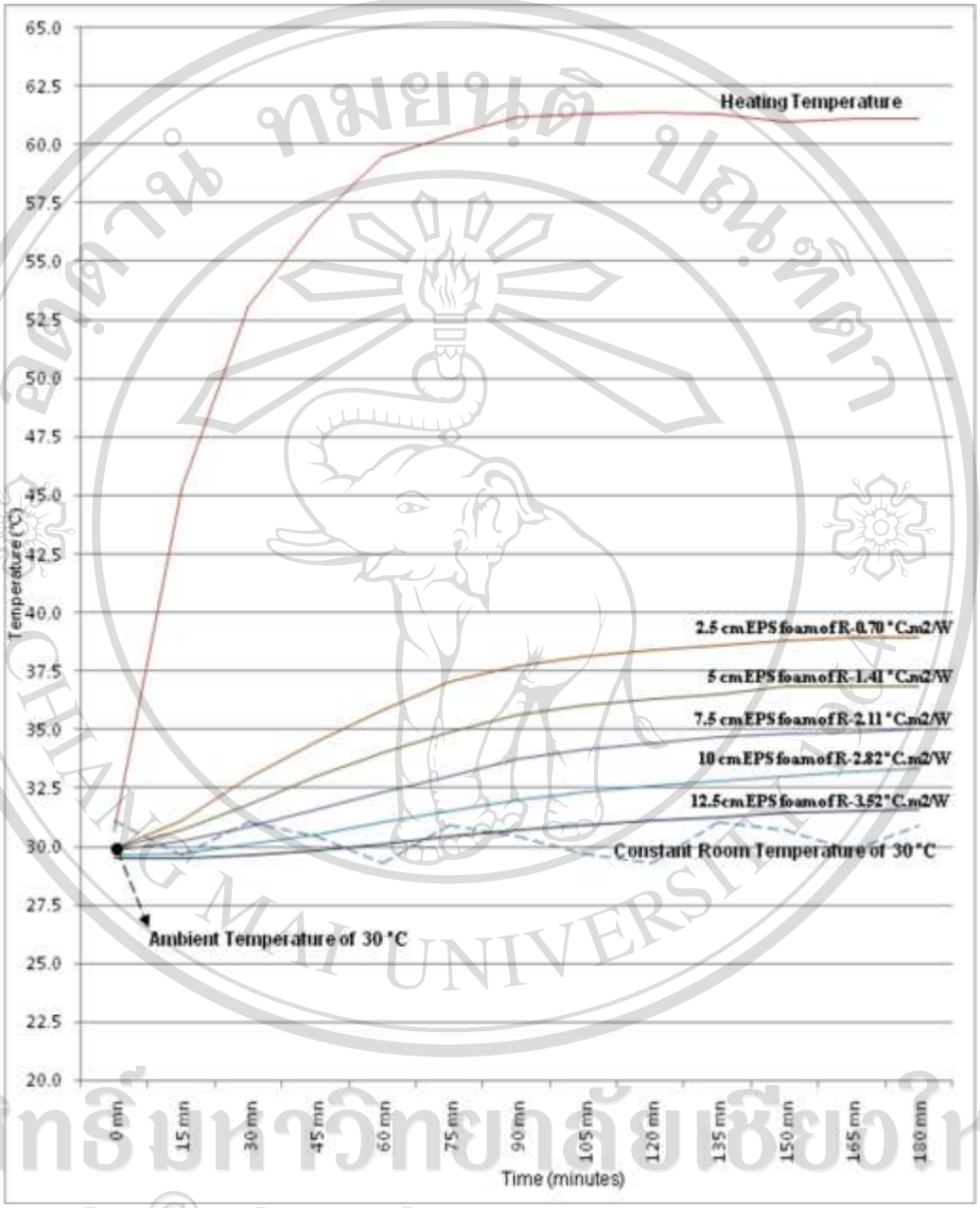

Figure 4.6 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell of constant room temperature of 30 ºC

4.1.5. Analysis of Testing Results

To find how an effect of the room temperature results in section 4.2.4, air temperatures of two different groups of the experiments were plotted and compared with the same of ambient temperature condition which was shown in Figure 4.7 to 4.9.

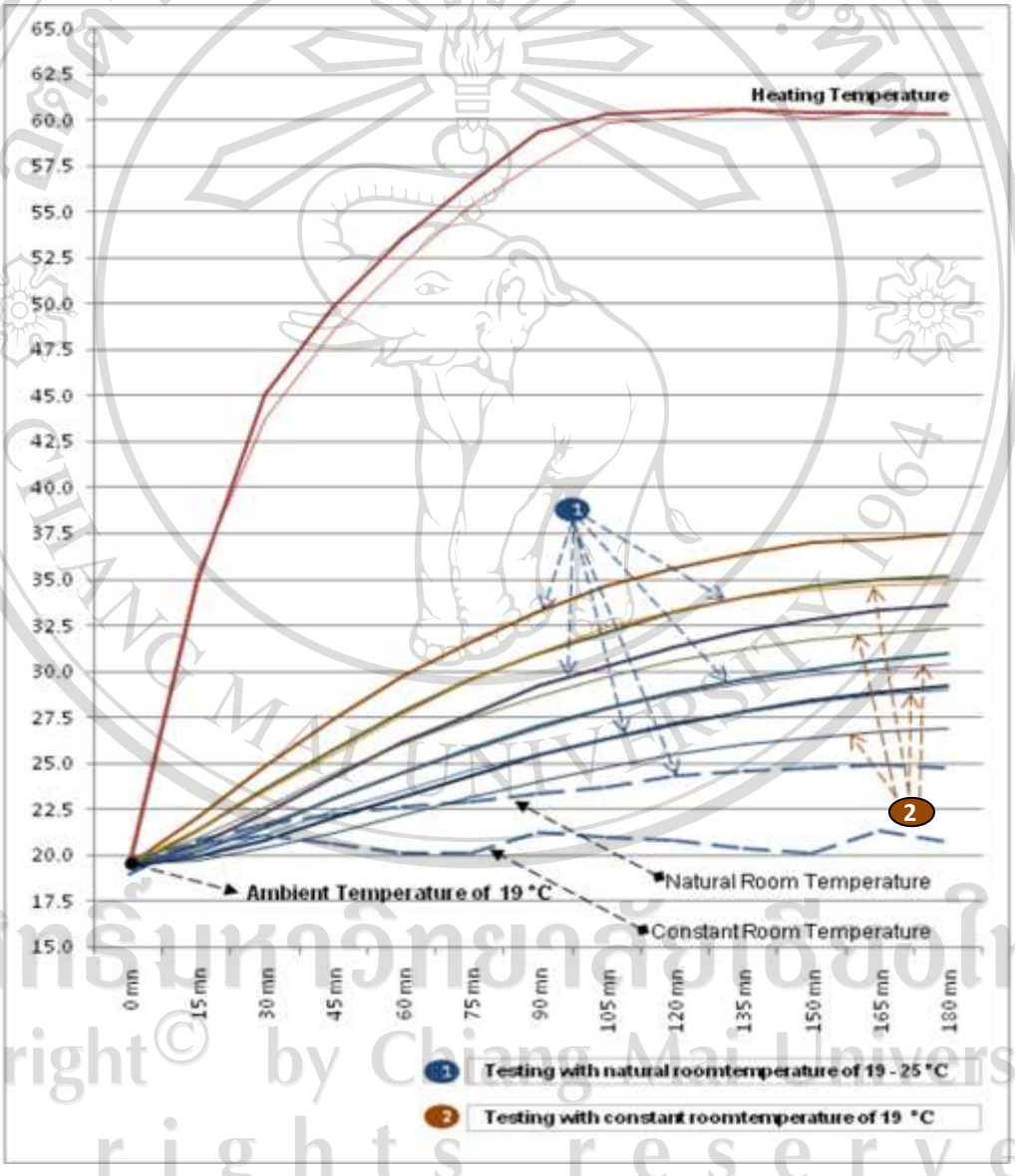

Figure 4.7 Comparison of 1, 2, 3, 4, 5 inches EPS samples between constant room temperature & natural room temperature tests with a similarity of ambient temperature of 19 ºC

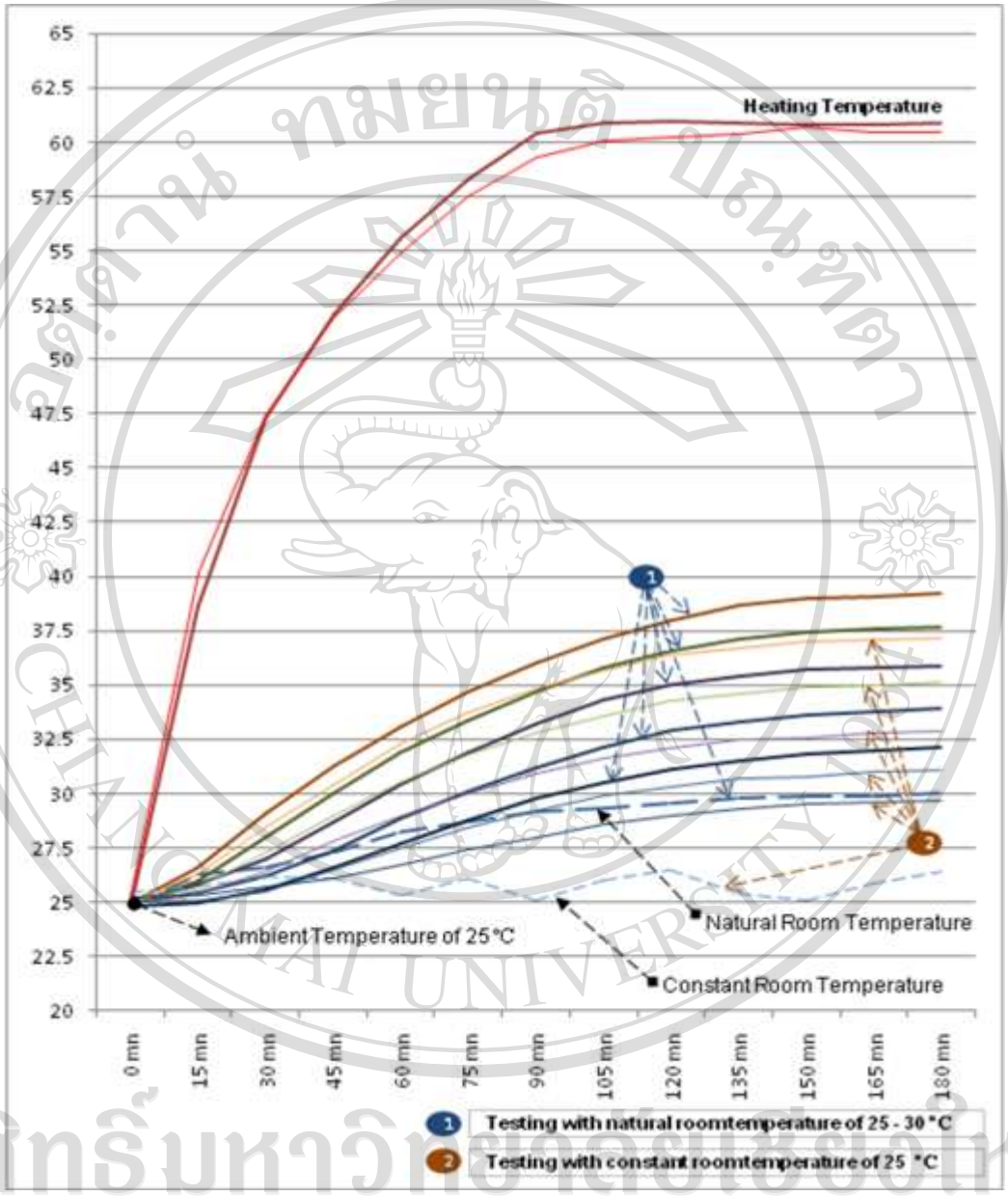

Figure 4.8 Comparison of 1, 2, 3, 4, 5 inches EPS samples between constant room temperature & natural room temperature tests with a similarity of ambient temperature of 25 °C

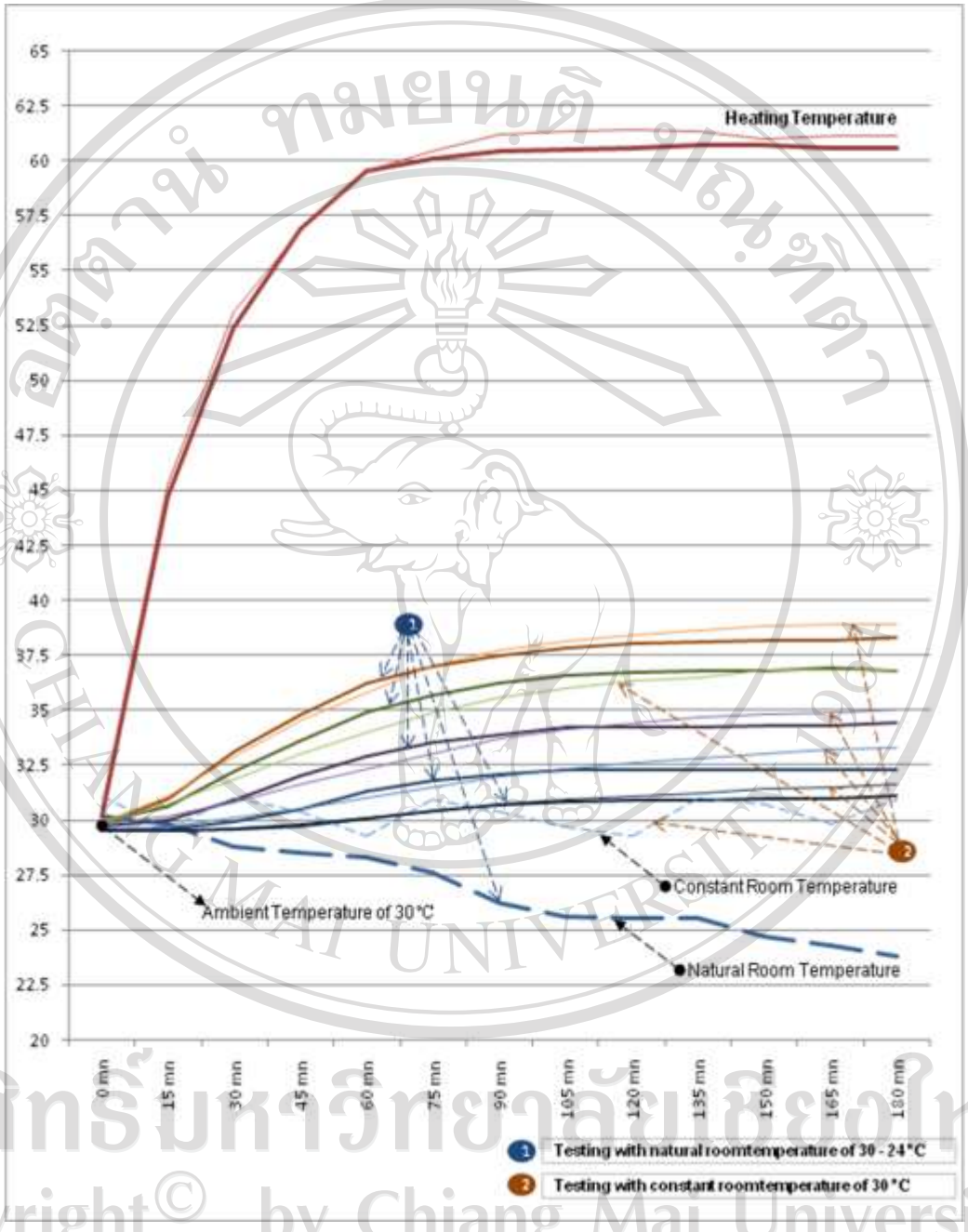

Figure 4.9 Comparison of 1, 2, 3, 4, 5 inches EPS samples between constant room temperature & natural room temperature tests with a similarity of ambient temperature of 30 ºC

Summary

According to the results of three graphic comparisons in Figure 4.7, 4.8, and 4.9, the temperature risings in the metering cells of each sample were different between the constant and natural condition of the room temperature test. In reference of heat transfer theory by Incropera and De Witt (1990), this result meant that there were different amounts of heat lost through the 10 cm exterior wall of the hot box design to room space along the process of the four-way hot box test.

4.2. The Investigation of Starting Ambient Temperature

4.2.1 Purpose and Studied Parameter

Purpose

Karno (2008) conducted the experiment up to four hours with the starting ambient temperature of 26.5 ºC to finish all series of his testing procedure. The Faculty of Architecture in Chiang Mai University (FACMU) in Thailand was selected as a testing location for his research experiment. Based on reported data of the weather in Thailand (TMD, 2010), it shows that the average temperature between hot and cool season of Thailand is variable between 18 ºC to 34 ºC all year round. In this case, the position of starting ambient temperature can be variable from 26.5 ºC if researchers cannot prepare to do the test at the same time as Karno did or cannot adjust a similarity of ambient temperature before starting the test. Therefore, this experimental part will conduct to investigate on

variable of the starting ambient temperature and find out how the testing results come out after running on every series of the experiment.

Studied Parameter

To follow the average weather of Thailand, eight types of the different starting ambient temperatures were chosen as 18 ºC, 20 ºC, 22 ºC, 24 ºC, 26 ºC, 28 ºC, 30 ºC and 32 ºC. Because of the difficulty in adjusting stable temperature by the heater and the air conditioner machines, a movement of variable temperature was set as:

1) *18 ºC was variable between 17 ºC to 19 ºC.*
2) *20 ºC was variable between 19 ºC to 21 ºC.*
3) *22 ºC was variable between 21 ºC to 23 ºC.*
4) *24 ºC was variable between 23 ºC to 25 ºC.*
5) *26 ºC was variable between 25 ºC to 27 ºC.*
6) *28 ºC was variable between 27 ºC to 29 ºC.*
7) *30 ºC was variable between 29 ºC to 31 ºC.*
8) *32 ºC was variable between 31 ºC to 33 ºC.*

4.2.2. Specimens

Six different samples of the testing specimens were used to conduct in this experiment by selecting as:

1) *2.5 cm or 1 inch thickness of EPS foam with R-value of 0.70 ºC•m^2/W (or 4 °F.ft^2.h/Btu).*

2) *5 cm or 2 inches thickness of EPS foam with R-value of 1.41 ºC•m^2/W (or 8 °F.ft^2.h/Btu).*

3) *7.5 cm or 3 inches thickness of EPS foam with R-value of 2.11 ºC•m2/W (or 12 °F.ft2.h/Btu).*

4) *10 cm or 4 inches thickness of EPS foam with R-value of 2.82 ºC•m2/W (or 16 °F.ft2.h/Btu).*

5) *12.5 cm or 5 inches thickness of EPS foam with R-value of 3.52 ºC•m2/W (or 20 °F.ft2.h/Btu).*

6) *15 cm or 6 inches thickness of EPS foam with R-value of 4.23 ºC•m2/W (or 24 °F.ft^2.h/Btu).*

4.2.3. Procedure

Testing Series of Samples

The testing series were arranged in the same way as the first experiment which was described in section 4.1.3. All series were processed in eight types of different starting ambient temperatures as the study parameter as described in section 4.2.1.

Room Temperature Control

The air conditioner and the heater, which were located inside the room, were prepared and used to determine heating and cooling systems for processing the research experiment. Moreover, an electric fan was also used in this test to fully spread out the heat.

Data Collection

This test was conducted in a period of four hours to finish a series of testing samples and all measurement tools were used the same as the first testing process described in section 4.1.3.

4.2.4. Testing Results

After finishing the experiment, there were eight graphic results found in this testing section, except an error in the results of the 6 inches testing sample. Plots of air temperature in metering cells with all types of the ambient temperature tests are shown in Figure 4.10 to 4.17.

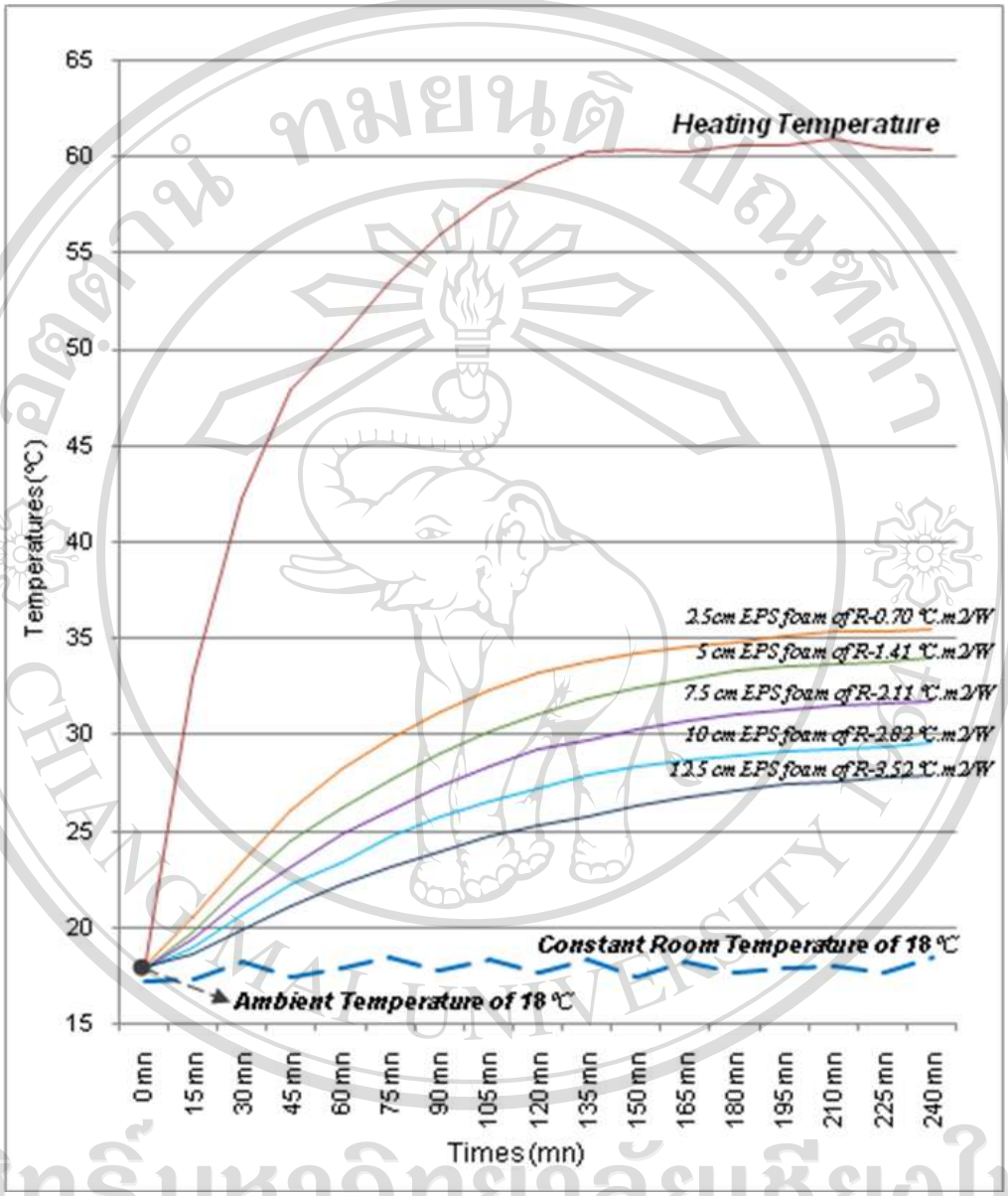

Figure 4.10 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell with the starting ambient temperature of 18 ºC

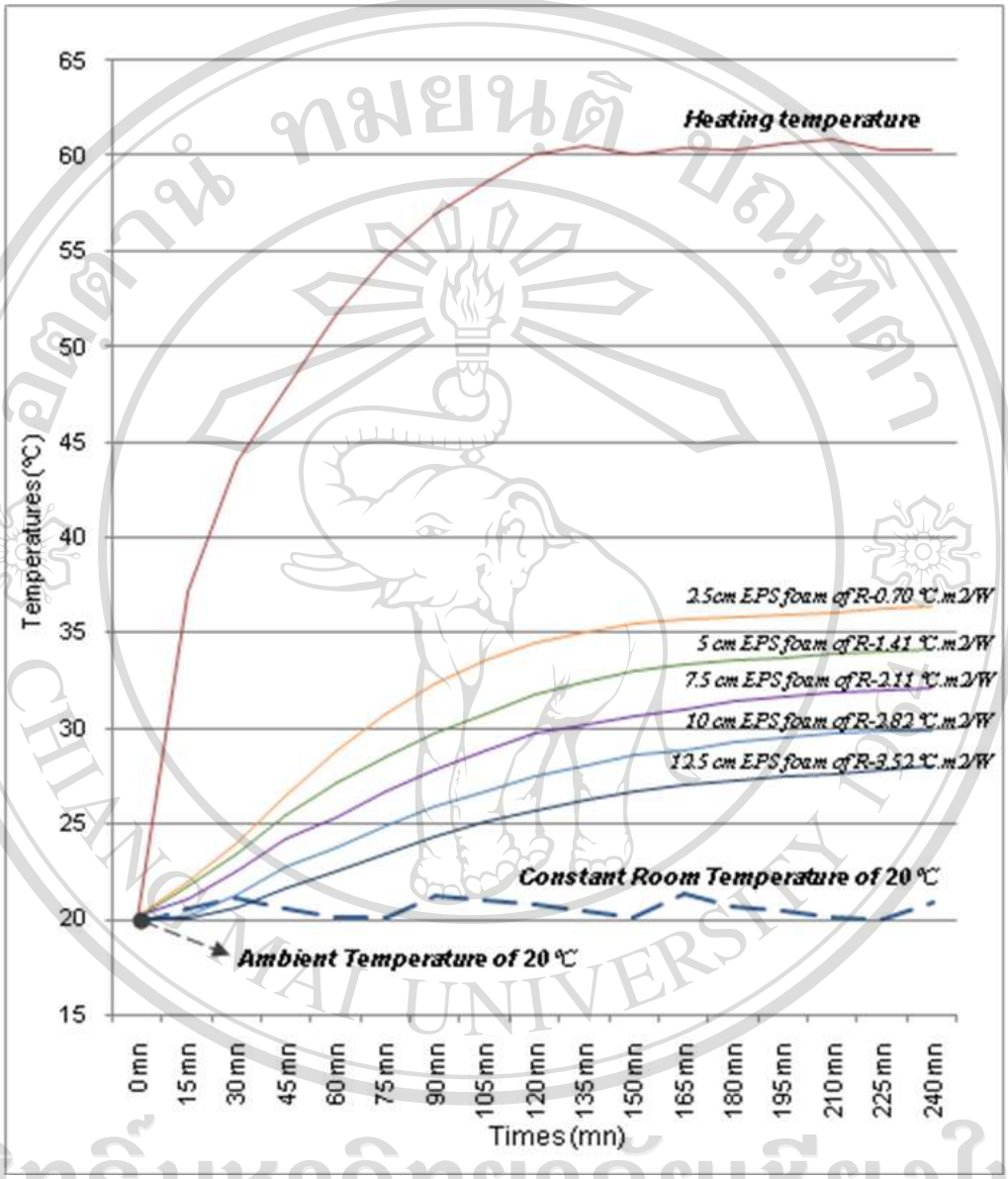

Figure 4.11 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell with the starting ambient temperature of 20 ºC

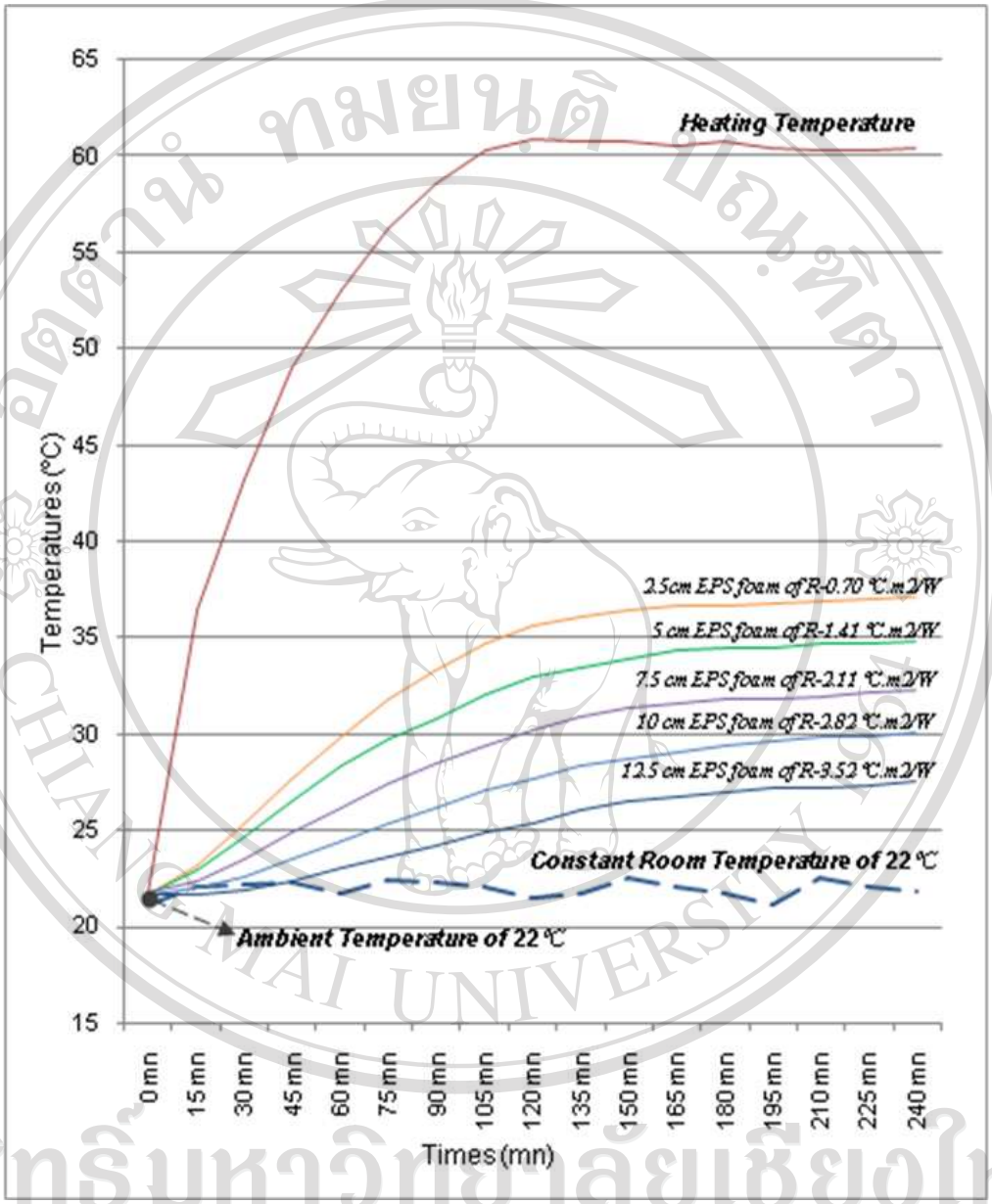

Figure 4.12 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell with the starting ambient temperature of 22 ºC

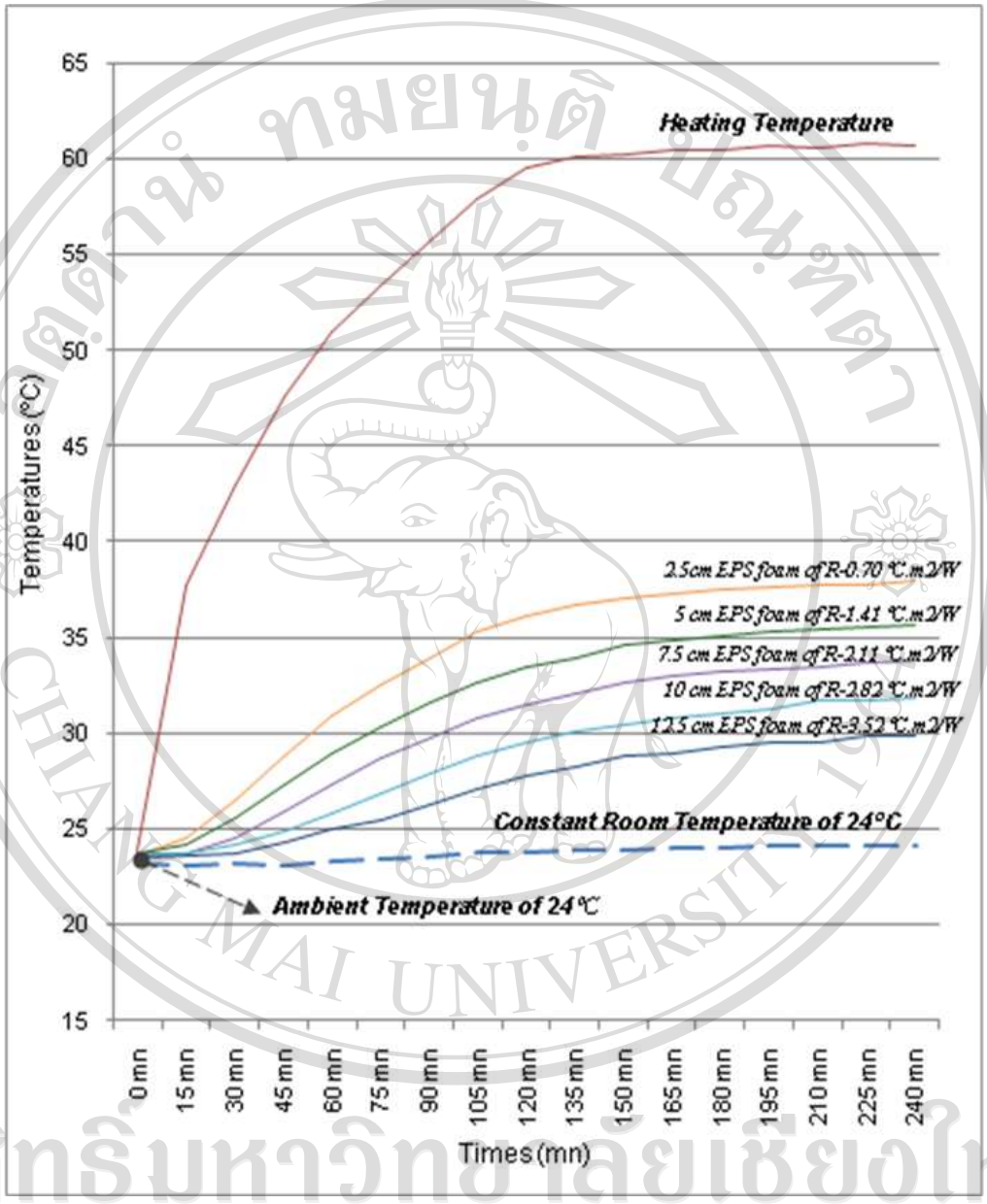

Figure 4.13 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell with the starting ambient temperature of 24 ºC

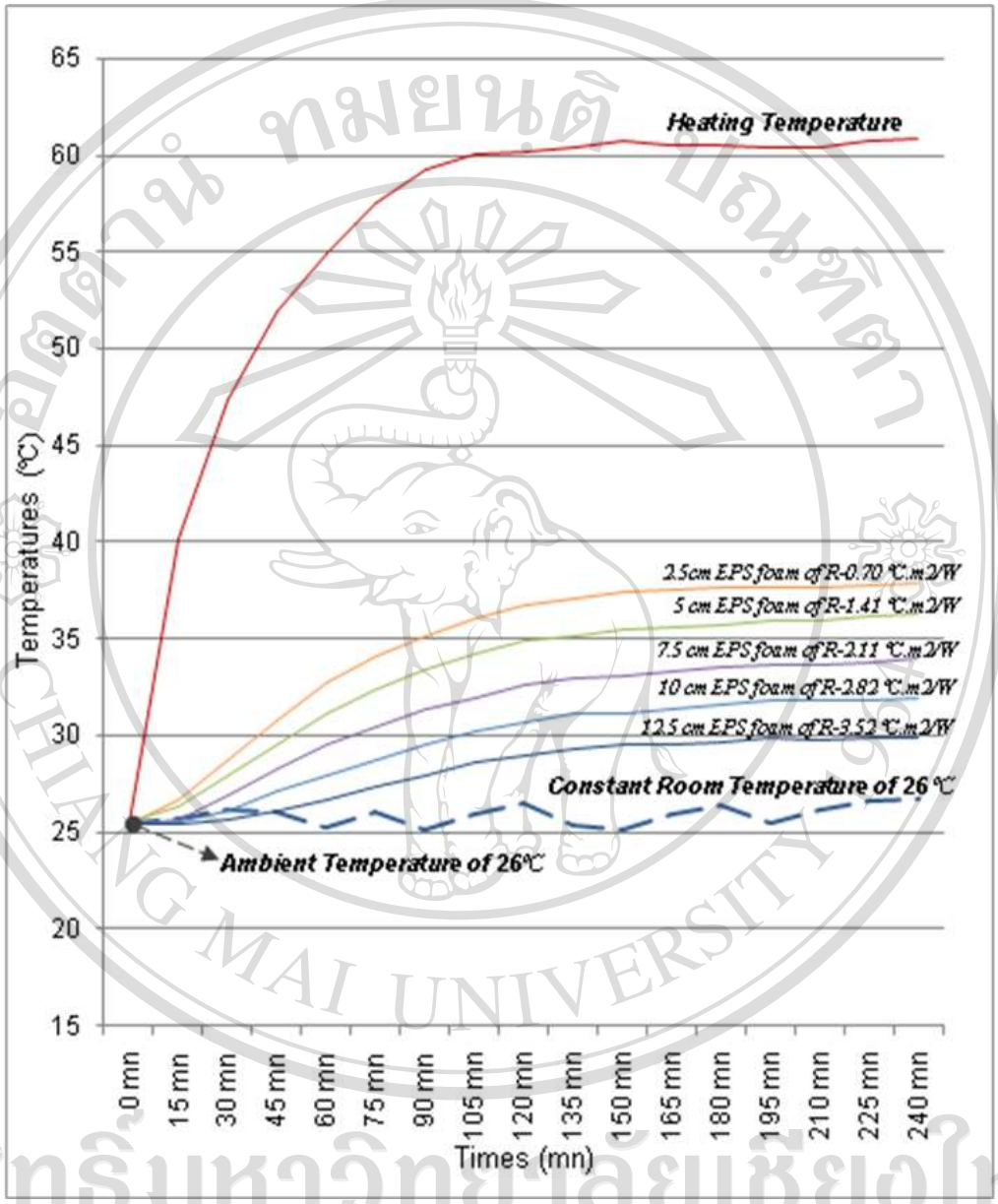

Figure 4.14 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell with the starting ambient temperature of 26 ºC

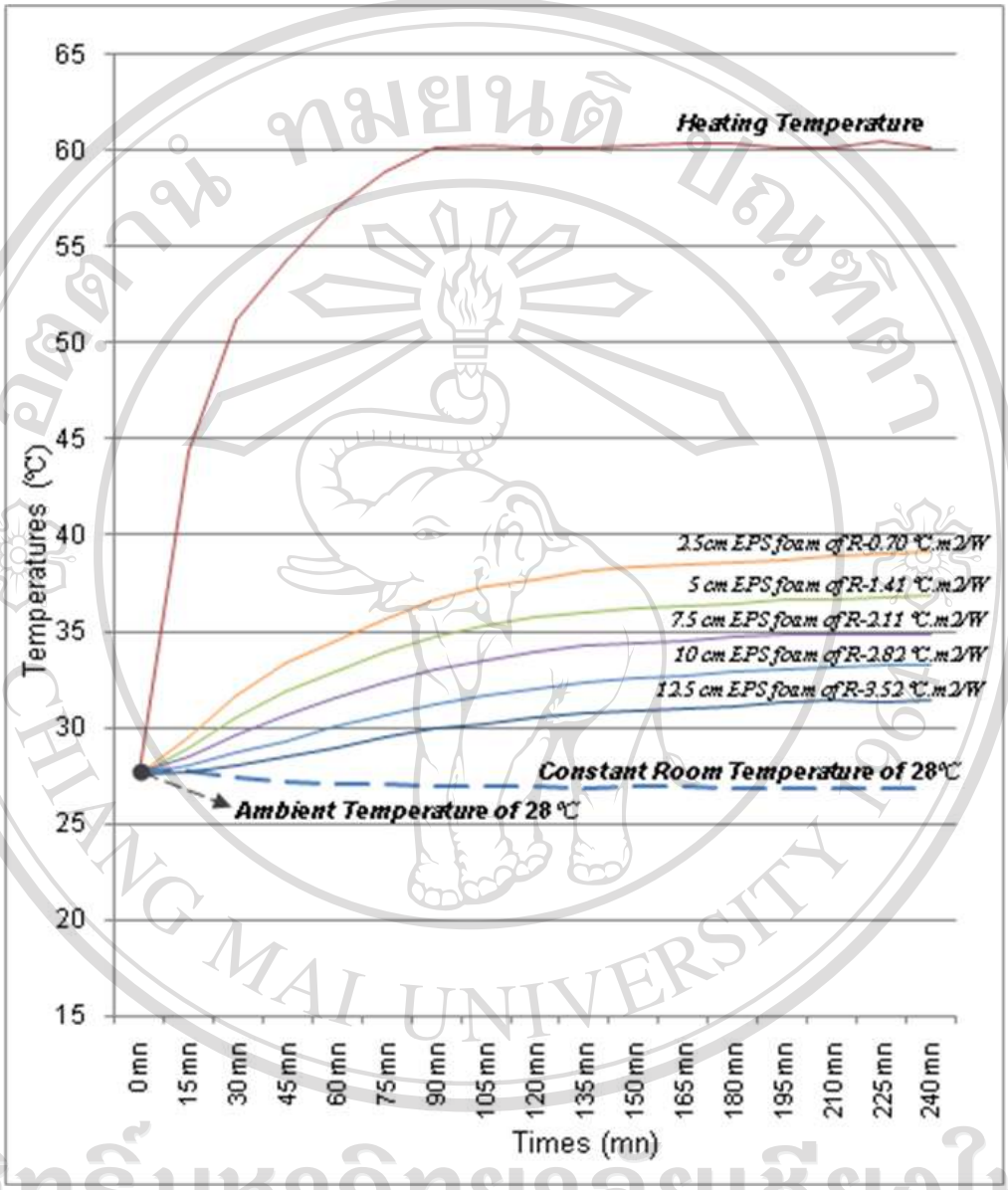

Figure 4.15 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell with the starting ambient temperature of 28 ºC

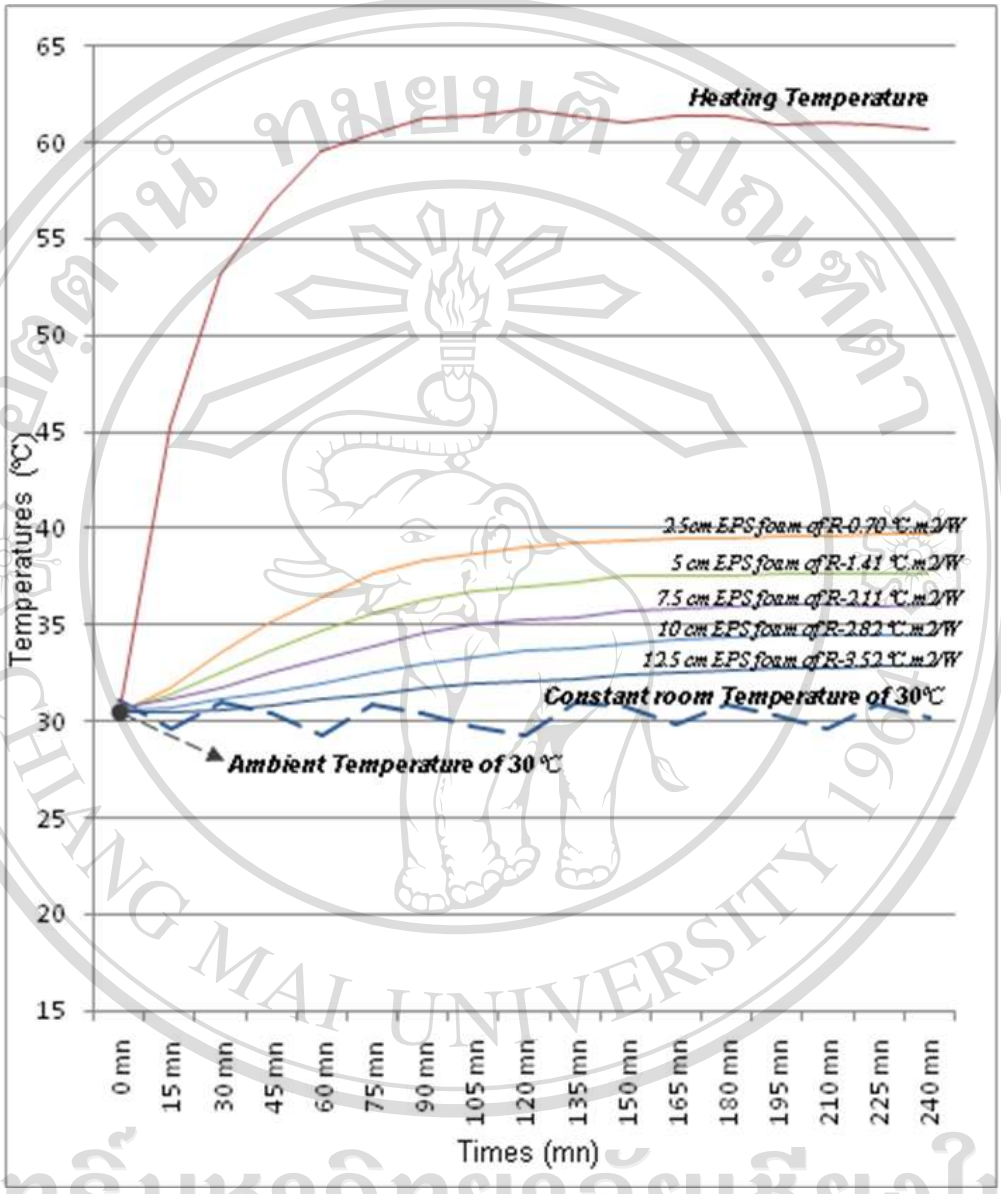

Figure 4.16 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell with the starting ambient temperature of 30 ºC

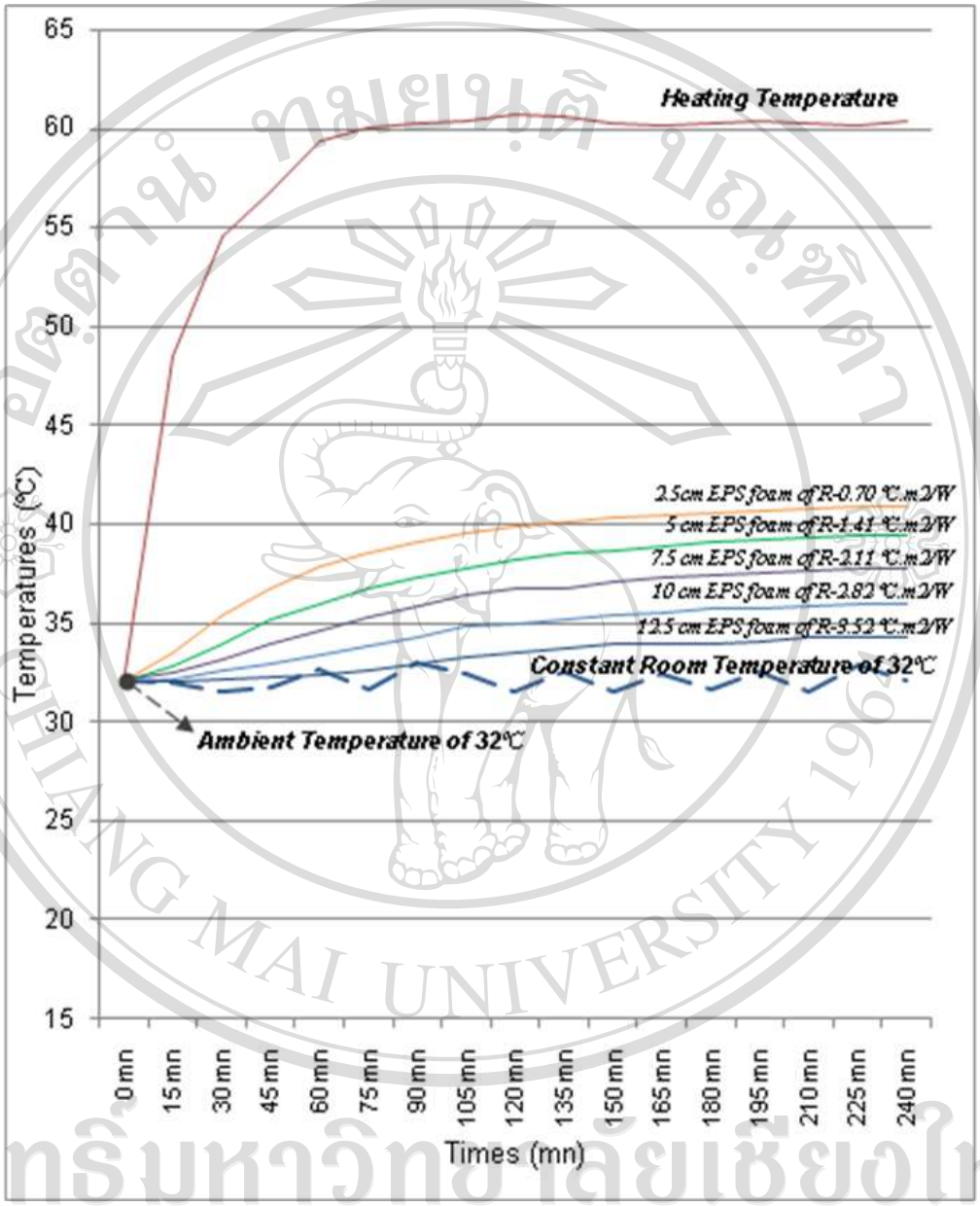

Figure 4.17 Air-temperature of 1, 2, 3, 4 and 5 inches EPS samples and heating cell with the starting ambient temperature of 32 ºC

4.2.5. Analysis of Testing Results

To investigate an effect in this experimental part, air temperature data of each type of samples was plotted in Figure 4.18 to 4.23 in all of different levels of the ambient temperature.

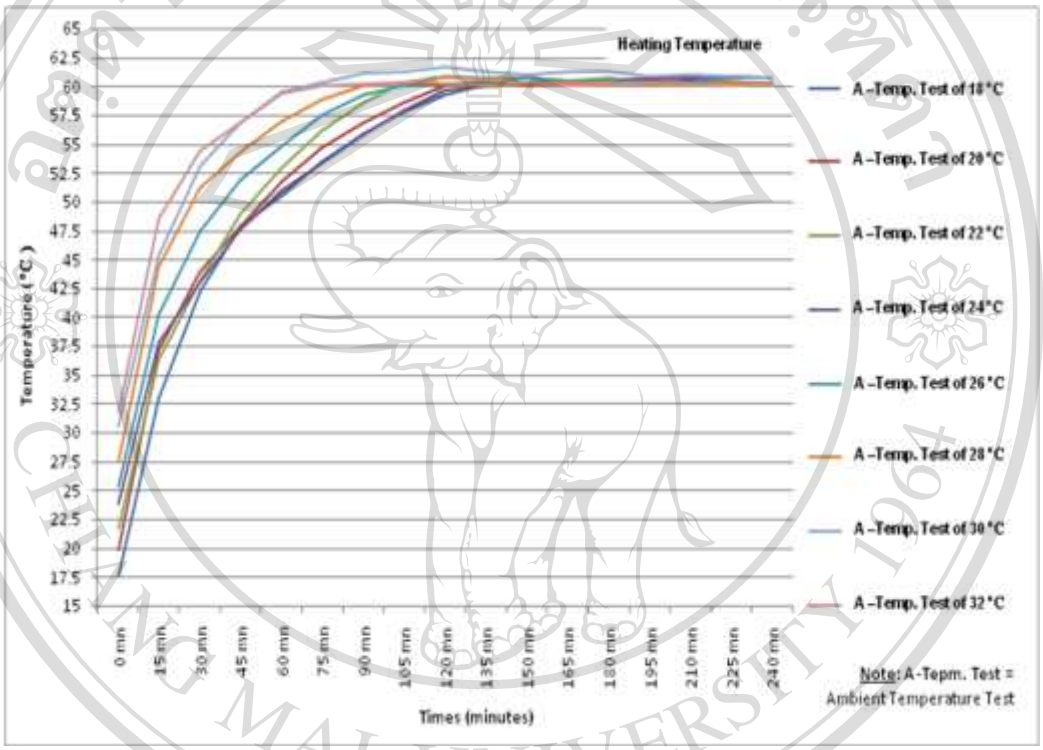

Figure 4.18 Eight types of air temperature of heating cell with the variable of starting ambient temperature from 18ºC to 32 ºC

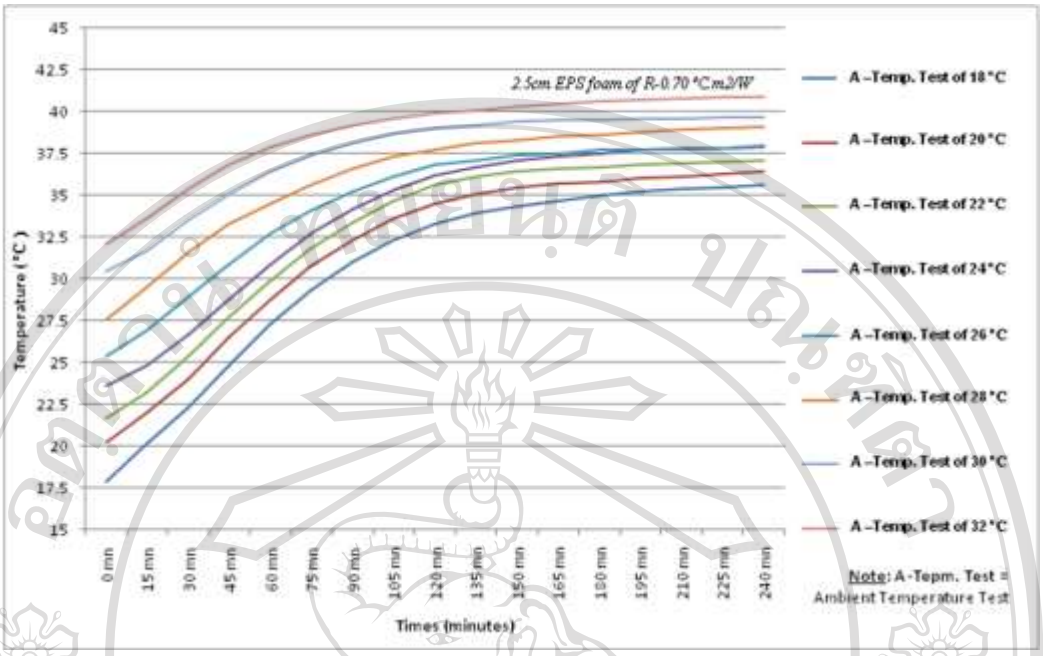

Figure 4.19 Eight types of air temperature of 1 inch EPS foam with the variable of starting ambient temperature from 18ºC to 32 ºC

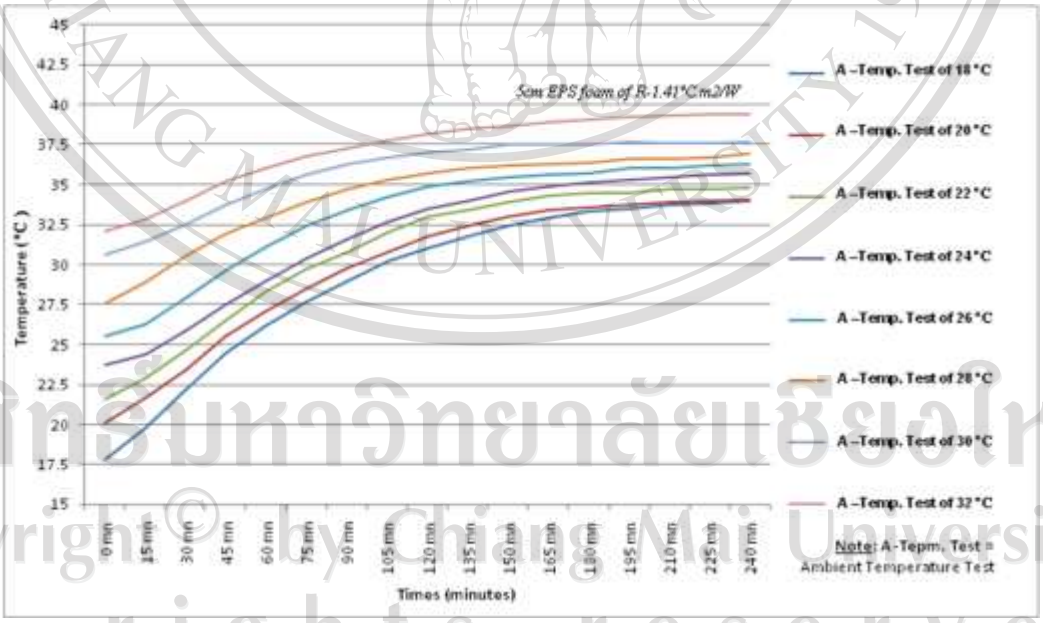

Figure 4.20 Eight types of air temperature of 2 inches EPS foam with the variable of starting ambient temperature from 18ºC to 32 ºC

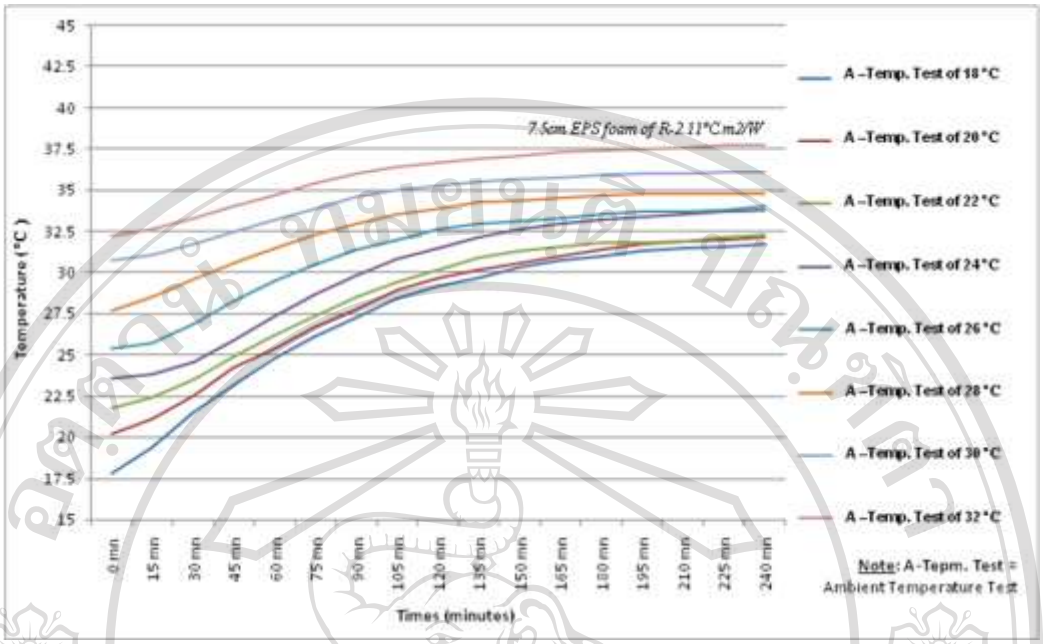

Figure 4.21 Eight types of air temperature of 3 inches EPS foam with the variable of starting ambient temperature from 18ºC to 32 ºC

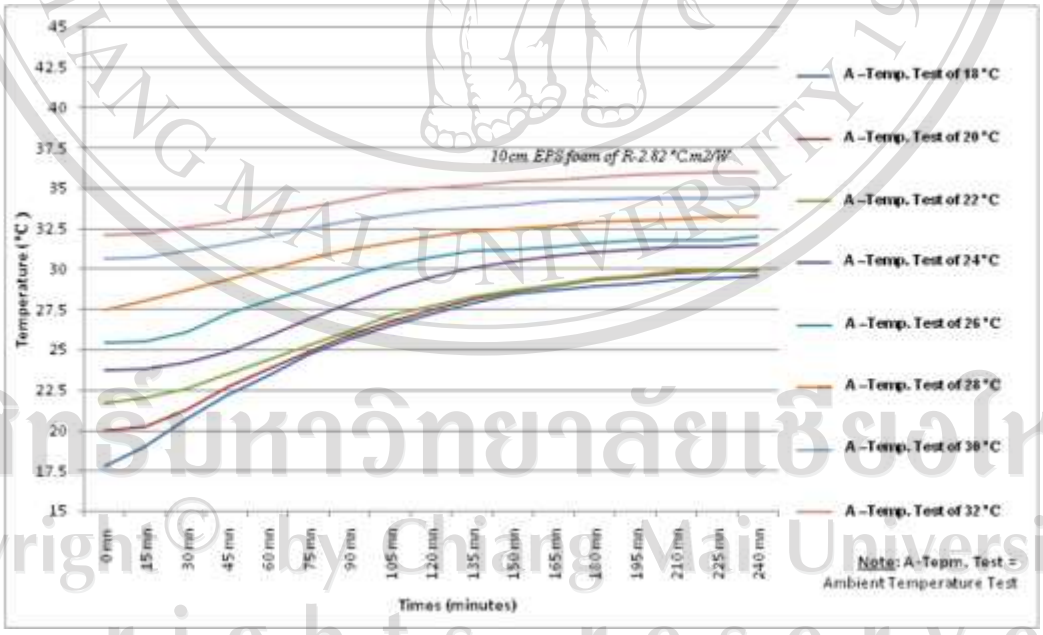

Figure 4.22 Eight types of air temperature of 4 inches EPS foam with the variable of starting ambient temperature from 18ºC to 32 ºC

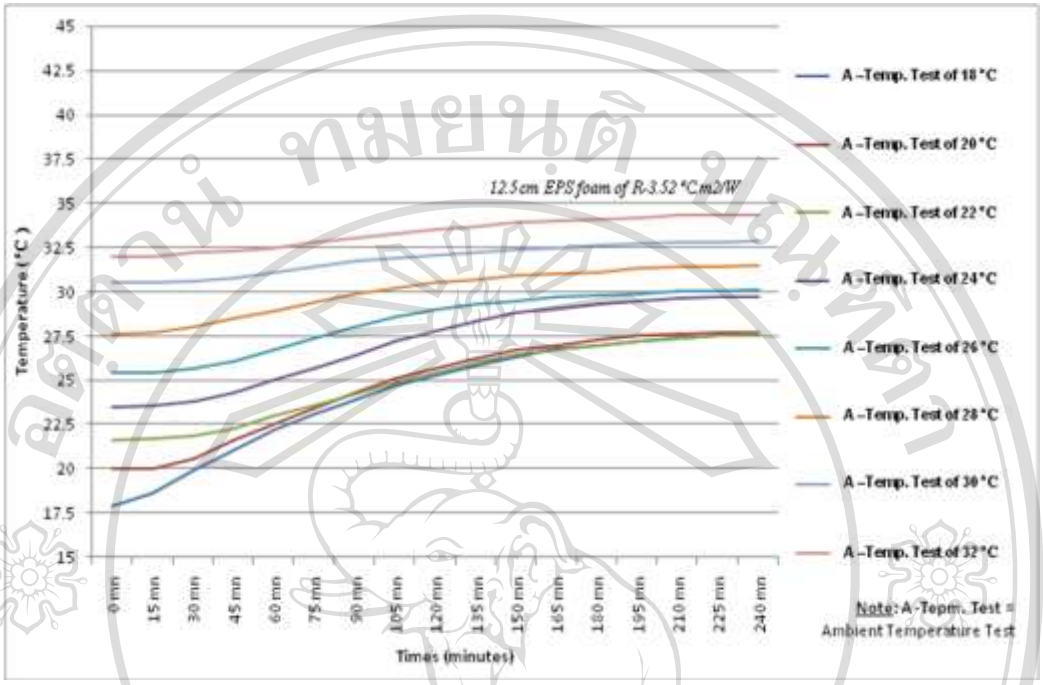

Figure 4.23 Eight types of air temperature of 5 inches EPS foam with the variable starting ambient temperature from 18ºC to 32 ºC

Summary

From the analysis result of graphic comparison in Figure 4.17 to 4.23, the test showed that the air temperature curves in metering cells and heating cell were different from each other when the ambient temperature varied.

4.3. Additional Investigation: The Investigation of Heating Temperature

4.3.1. Purpose and Studied Parameter

Purpose

The heating temperature was provided by a 200-W light bulb heat source manually controlled by an investigator through a dimmer switch. This operation may lead to an error if the investigator turns on the switch at different speed or level. Therefore, the test of heating temperature speed was performed in this research in purpose to find out any effect resulted by the difference of the heating speed.

Studied Parameter

The test of the heating temperature was conducted with two heating speed. One test was conducted by turning on the dimmer switch at 100% of its power control (Figure 4.24). Another one was conducted by turning on the dimmer switch at 70% of its power control (Figure 4.25). Moreover, an ambient temperature and constant room temperature of 18 ºC were selected to conduct this experiment.

4.3.2. Specimens

Four kinds of EPS foams were used as the samples in this experimental procedure such as:

1) *2.5 cm or 1 inch thickness of EPS foam with R-value of 0.70 $^{o}C \cdot m^2/W$ (4 $^{\circ}F.ft^2.h/Btu$).*

2) *5 cm or 2 inches thickness of EPS foam with R-value of 1.41 ºC•m^2/W (8 °F.ft^2.h/Btu).*

3) *7.5 cm or 3 inches thickness of EPS foam with R-value of 2.11 ºC•m2/W (12 °F.ft2.h/Btu).*

4) *10 cm or 4 inches thickness of EPS foam with R-value of 2.82 ºC•m2/W (16 °F.ft2.h/Btu).*

4.3.3. Procedure

Testing Series of Samples

The experiment was only conducted in a series of testing samples with four kinds of EPS foams of 1, 2, 3, and 4 inches thick which were installed and tested inside the metering cells of the hot box construction, simultaneously.

The Temperature control

To obtain a heat source inside the heating cell, a 200-W light bulb was arranged and the temperature released was controlled using a dimmer switch that adjusted by hand. Moreover, an air conditioner was also used to control constant room temperature of 18 ºC during the test and an electric fan was used to fully spread out heat inside the room.

Data Collection

The experiment was conducted in a period of four and a half hours to finish a series of experiments and all measurement tools were used the same as the testing process of section 4.2.3 above.

4.3.4. Testing Results

Two sets of results were found and shown in Figure 4.24 and 4.25 to represent the air temperature of all testing samples as:

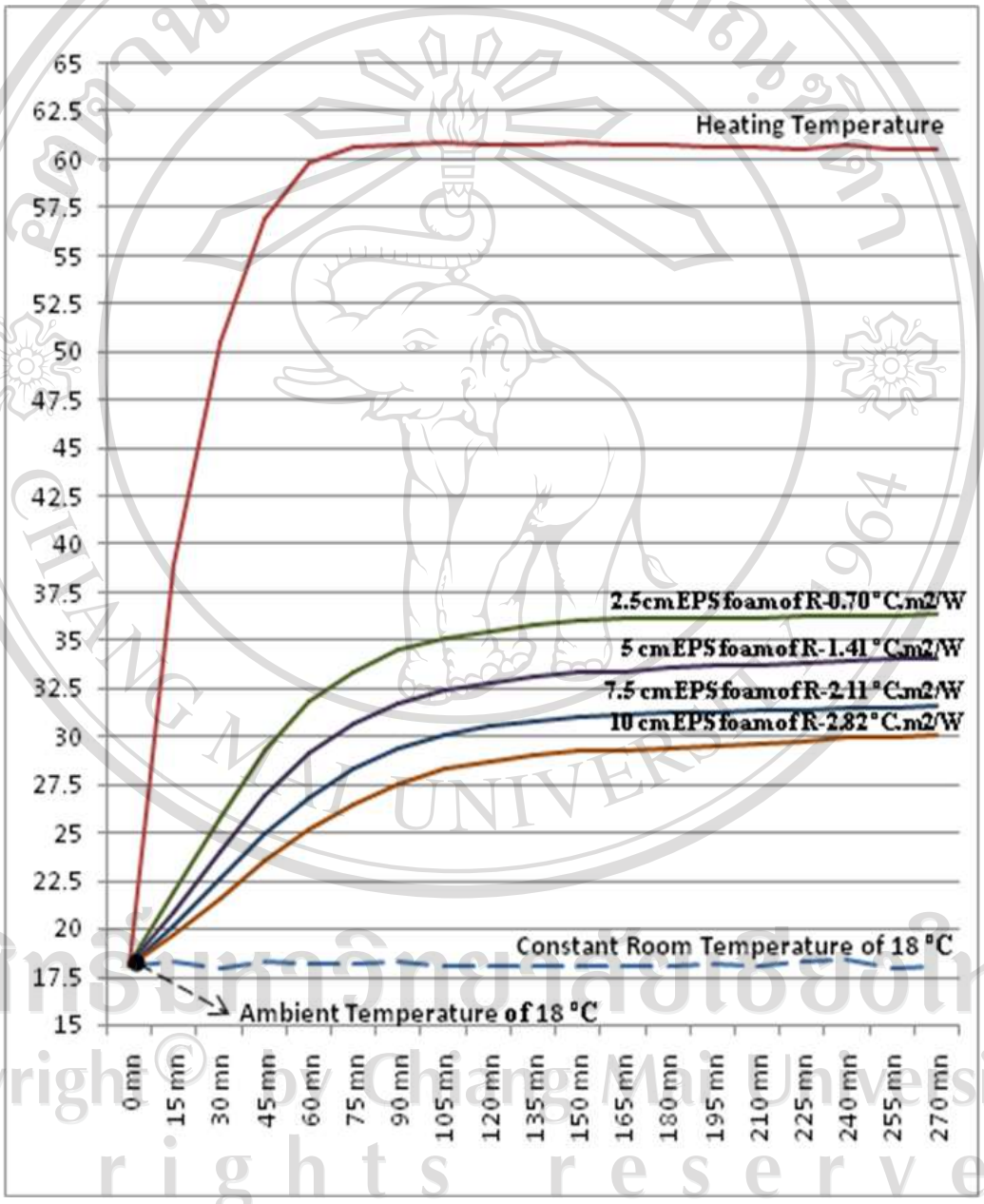

Figure 4.24 Graphic result of air temperature of metering cells and heating cell with 100% of a light bulb power.

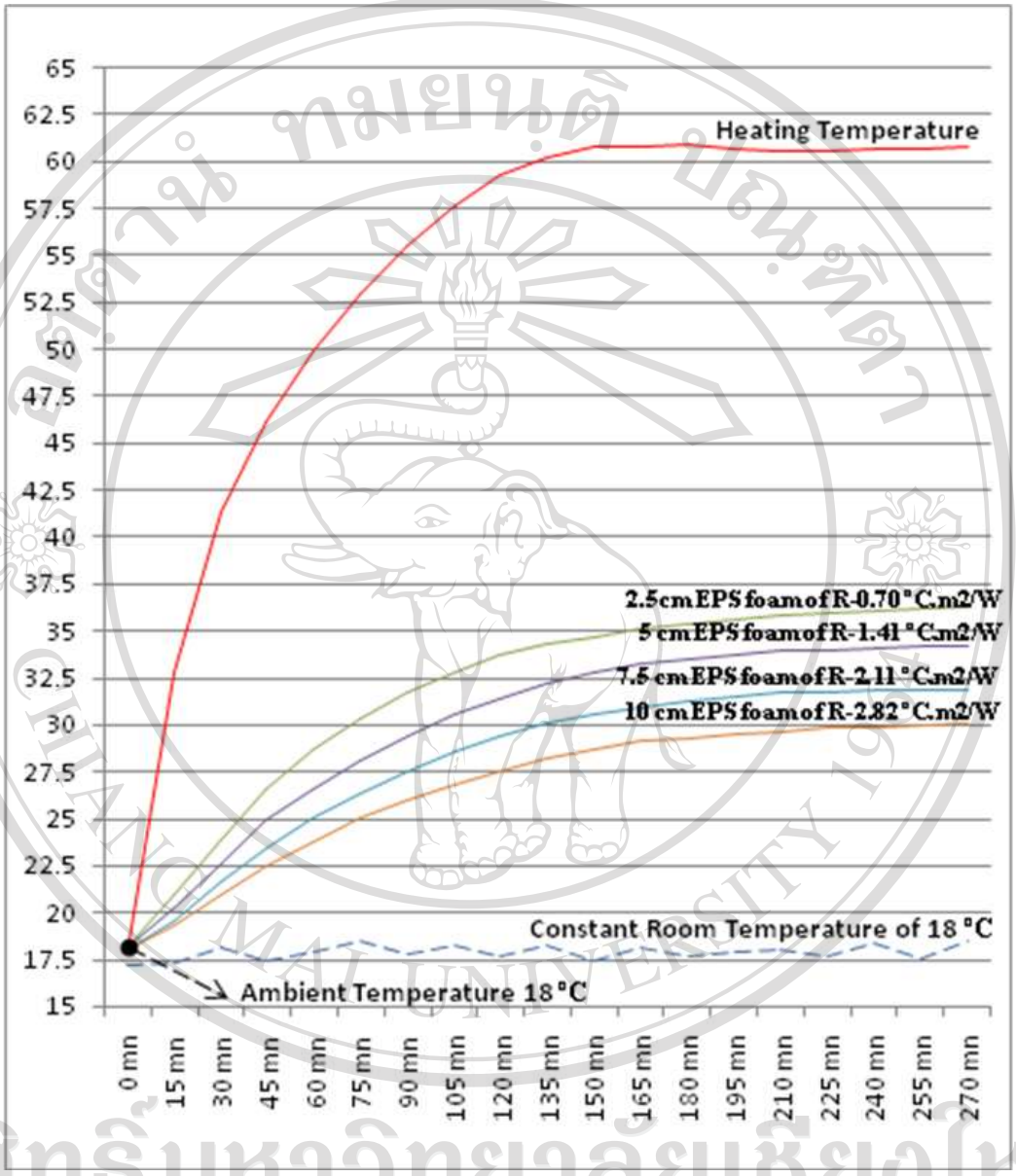

Figure 4.25 Graphic result of air temperature of metering cells and heating cell with 70% of a light bulb power.

Figure 4.24 and 4.25 show the different period of a light bulb power to reach up maximum temperature in heating cell. First graph, a period of two hours was spent to heat up 60 ºC in heating chamber. Second graph was only one hour.

4.3.5. Analysis of Testing Results

To investigate the effect of heating temperature, the results found in Figure 4.24 and 4.25 were plotted in the same graph to observe the movement of air temperature curve when the test was conducted with different heat source speeds as shown in Figure 4.26.

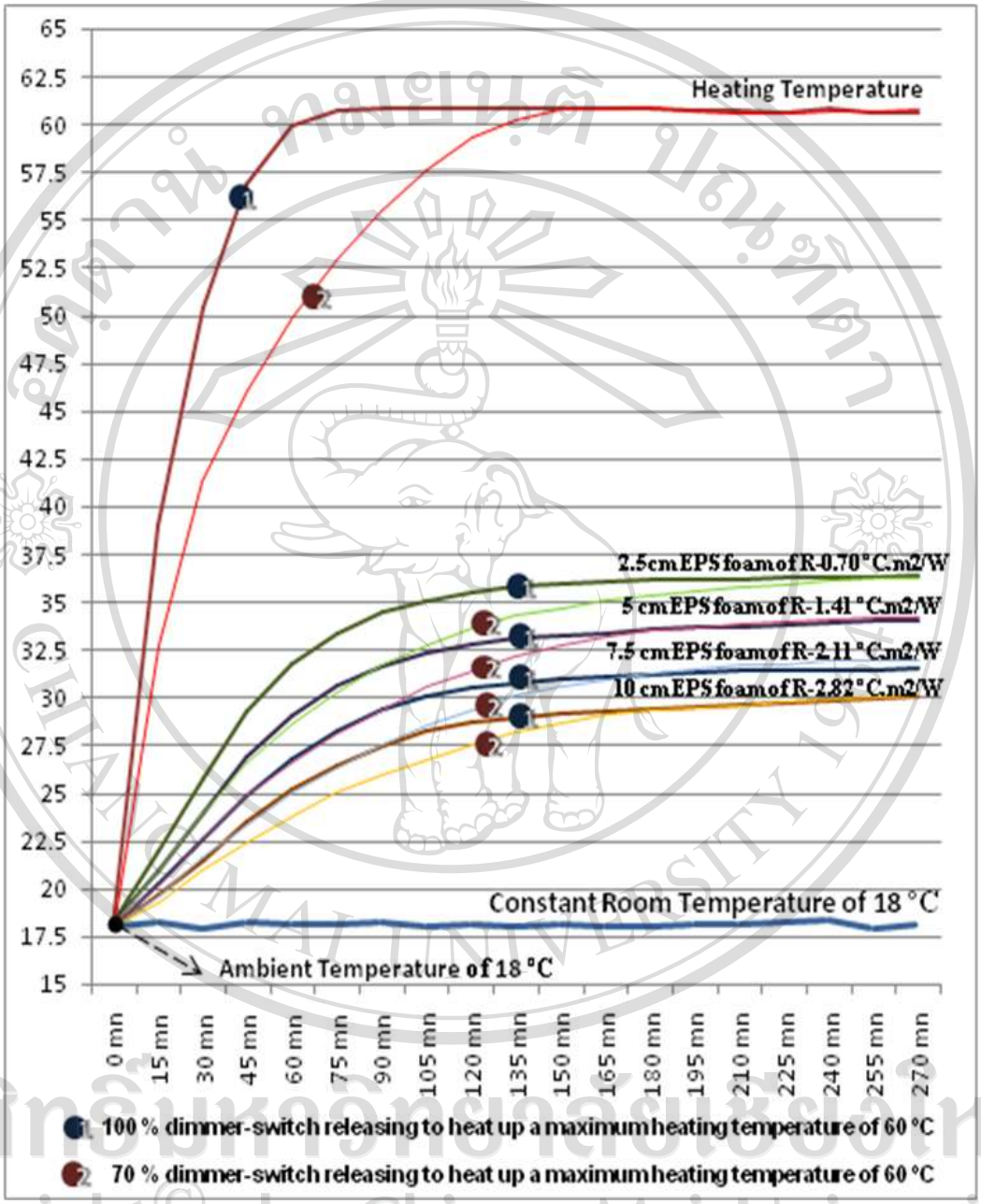

Figure 4.26 Comparison of graphic result of the test between 70% and 100% of a light bulb power to reach up the maximum temperature of 60 ºC in the heating cell

Summary

The graph of Figure 4.26 showed that the movement of heating source can change curves of air temperature in the metering cells and heating cell. A long period of experiment may be necessary if the heat from the light bulb source reached desired temperature in heating cell too slowly. Thus, the ability and even the quality of the light bulb should be considered in the hot box test research.