CHAPTER III

RESEARCH OBJECTIVES AND METHODOLOGY

This chapter provides research objectives and the theoretical tools needed in developing a methodology for the further experimental procedure.

3.1 Research Objectives

As mentioned in Chapter II, the objectives of this study was to find the most suitable form of broken down EPS packaging foam under two conditions:

1. The breaking down method must be easy at a low cost
2. That form of EPS particles, which means size and shape, should provide R-value as high as possible.

3.2 Research Methodology

3.2.1 <u>Research Design</u>

To obtain a result indicated in the research objectives, the processes involving in this research are shown in Figure 3.1, which contain the following procedures:

A. <u>Breaking down packaging EPS foam</u>: There could be several methods to break down packaging EPS foam into small particles. But the methods employed here should be the one that does not consume so much time, easy, and cheap.

B. <u>Test for thermal performance of each particle size</u>: After classification particle sizes, they were inserted into 10 cm width of cavity spaces of specimens for testing. Many tests were done with comparison thermal performance between each sample and reference insulations. Thus, thermal performance of each sample could be estimated.

C. Select the most appropriate: Depending on combination between Processes A and B, the most appropriate insulation in this research could be selected.

D. Testing for R-values of conventional wall materials with the selected scratched foam: Test the selected one, which obtained in Process C as thermal insulation inside the exterior wall panels where the outside panels were conventional materials and inside panels were gypsum.

The following Figure 3.1 shows the diagram of research process.

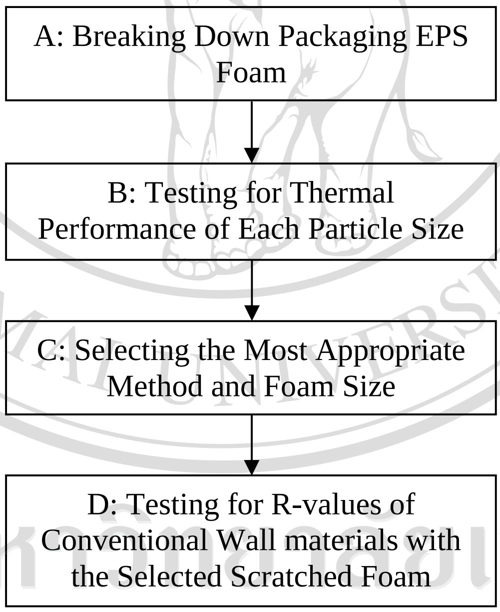

Figure 3.1 Research process

3.2.2 Review of Testing Methods and Apparatuses

In order to obtain thermal properties of specimens, researchers conducted experiments by using different test methods by the means of guarded hot boxes or hot plates on various sizes of specimens. Some researchers tested their samples of building envelopes by using test-cells or solar hot boxes by placing them underneath the sun.

Guarded Hot Plate (GHP) Method

Flynn et al (2005) described that the guarded hot plate apparatus was generally recognized as the primary method for measurement of thermal transmission properties of homogeneous insulation materials in the form of flat slabs. It is the steady-state test method has been standardized by ASTM International as ASTM Standard Test Method C-177 and by the International Standardization Organization (ISO) as ISO 8302. Instruments GHP 8302 were designed for use in test laboratories, manufacturing processes and quality control procedures for a wide range of materials with low and intermediate thermal conductivity including minerals, ceramics, glasses, plastics, mineral and glass fibers, cellular polyurethane and polystyrene etc. GHP 8302 has modular structure, which is easy for calibration of embedded instruments to ensure their metrological traceability to higher standards.

In refer to Lasercomp (2003), specimens of GHP are often rather large (0.3 x 0.3m and 0.61 x 0.61m), which usually presents no difficulty. A flat electrically heated metering section surrounded on all lateral sides by a guard heater section controlled through differential thermocouples, supplies the planar heat source introduced over the hot face of the specimens. The most common measurement configuration is the conventional, symmetrically arranged guarded hot plate where the heater assembly is sandwiched between two specimens. In the single sided configuration, heat flow is passing through one specimen and the back of the main heater acts as a guard plane creating an adiabatic environment.

Guarded Hot Box (GHB) Method

There are two types of hot-box – the guarded hot-box (an absolute method) and the calibrated hot-box (a secondary method similar in form but requires calibration using panels or materials of known thermal conductance). They are used at ambient temperatures to measure the thermal performance of building envelope components such as walls, roofs and windows. Measurement standards were designed and operated for both types of hot-box. There are several international and European standards specifying hot-box measurement procedures for specific structures (Shah and Curcija, 2000).

The Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box (GHB) has been standardized by ASTM C-236 (ASTM C-236 Document Information, 1989). In the studies of Kosney et al (1999), and Kosney and Childs (2000), this GHB was used to measure the thermal performance of the walls components. The measurements for the wall samples have a dimension of 2.4 m x 2.4 m. This apparatus consists of two chambers. One is the hot chamber and the other is the cold chamber. There is also metering box in hot chamber. At the Oak Ridge National Laboratory, Building Technology Center (ORNL BTC), structurally insulated panel (SIP) walls were tested in the guarded hot box under steady-state conditions. During the test, steady air temperatures and air velocities were set on both surfaces of the tested wall. In the study of Kosney et al (1999), the SIP walls were not covered by any finish materials. Exterior wooden siding and interior gypsum board finish were considered only for computer modeling and the test results were presented.

Heat Flow Meter Apparatus

Heat flow meter apparatus is used widely because it is relatively simple in concept, rapid, and applicable to a wide range of test specimens in accordance with international standards ISO 8301 and ASTM C-518 (ASTM C-518 Document Information, 2004). The precision and bias of the heat flow meter apparatus can be excellent provided calibration is carried out within the range of heat flow expected. This means calibration shall be carried out with similar types of materials of similar thermal conductance at similar thicknesses, mean temperatures, and temperature gradients, as expected for the test specimens. This comparative, or secondary, method of measurement since specimens of known thermal transmission properties shall be used to calibrate the apparatus. Properties of the calibration specimens must be traceable to an absolute measurement method. The heat flow meter apparatus establishes steady state one-dimensional heat flux through a test specimen between two parallel plates at constant but different temperatures. By appropriate calibration of the heat flux transducer(s) with calibration standards and by measurement of the plate temperatures and plate separation. Fourier's law of heat conduction is used to calculate thermal resistance and thermal conductance.

Base on Lasercomp (2001), specimen sizes are varied regarding ASTM C- 518 and ISO 8301. The plate size can be large 1,041 mm x 762 mm. The test chamber has front and back doors, which allows specimens that are 1050 mm wide and of unlimited length to be tested. The upper plate is lowered onto the sample to obtain good contact over the huge area of these giant plates. And temperature range from -15°C to 80°C on both plates that heat flow up or down.

Test Cell Methods and Specimens

NFRC (2001) demonstrated that reference specimen or glazing test specimen shall have sufficient size, as to reduce uncertainty in the calculated, not have less than 0.5m x 0.5 m (20” x 20”) of visible area when installed in the surround panel.

The heat flow through a 1 m x 1 m sample of vacuum glazing was measured by Simko et al (2006) in two independent ways. One measurement method uses a guarded hot box to make a direct determination of overall heat transmission coefficient under standard test conditions. Another method uses a small area guarded hot plate to measure the local radiation between the glass sheets. The overall heat flow is then obtained by combining the contributions from these processes with those due to heat flow through the conducting edge seal. The results obtained with the two methods are in very good agreement for the same external conditions.

Cheng and Givoni, (2004) conducted a research related to the effect of envelope colors and thermal mass on indoor temperatures in hot-humid climate around the world. They demonstrated that envelope colors has significant effect on building thermal performance and the use of thermal mass can usefully modify the thermo-physical signature of buildings. Their large test cell was established 1.5 m long, 1.5 m wide and 1.5 m high, which has four chambers facing four orientations. And the two small test cells were basically identical, except one painted into matt-white while another in matt-black. Each test cell was 1 m long, 1 m wide and 1 m high used for studying the effect of colors. The study reveals that the use of lighter surface colors and thermal mass can dramatically reduce maximum indoor temperatures. However, their applications in building design could be very different, and to a large extent, depend on circumstances.

Abela (2006) investigated how insulating materials such as expanded polystyrene, stone wool, glass wool with and without a reflective coating used in local construction methods may enhance the thermal performance of a typical building envelope in Malta. The test methods were intended for laboratory use and suitable for samples larger than $1m^2$. Though non-homogeneous specimens may be tested, it is important that the test area should be sufficiently representative of the complete building element. These methods give an average thermal transmittance or conductance over the test area. The study provided a practical insight on how various insulation options within the cavity of limestone and concrete block wall affects the U-Value of the wall. Results demonstrate that in order to be in compliance with the local building, insulation must be used within the cavity of the current building construction methods.

Active Building Envelope (ABE) systems represent a new thermal control technology that actively uses solar energy to compensate for passive heat losses or gains in building envelopes or other enclosures (Van Dessel et al, 2004). They explored the feasibility of ABE systems by analyzed a model of a generic enclosure that has dimensions of cell 1m ×1m × 1m. They also provided a synopsis of the results and the assumptions made during the study.

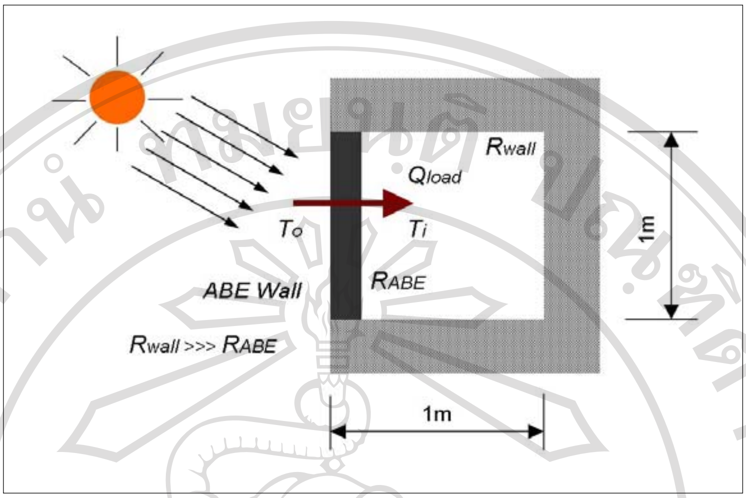

Figure 3.2 Schematic of a generic enclosure with single ABE wall

Ahmad et al, (2005) conducted an experiment on light envelopes, which are more and more frequently used in modern buildings but they do not present sufficient thermal inertia. A solution to increase this inertia is to incorporate a phase change material (PCM) in this envelope. The paper presents the performance of (0.9m x 0.9m) test-cell with a new structure of light wallboards containing PCMs submitted to climatic variation and a comparison is made with a test-cell without PCMs. To improve the wallboard efficiency a vacuum insulation panel was associated to the PCM panel. This new structure allows the apparent heat capacity of the building to be increased, the solar energy transmitted by windows to be stored without raising the indoor cell temperature and the thickness of the wallboard to be decreased compared with that of traditional wallboards. An experimental study was carried out by measuring temperature and heat fluxes on and through the wallboards. The indoor temperature, which has a special importance for occupants, was also measured.

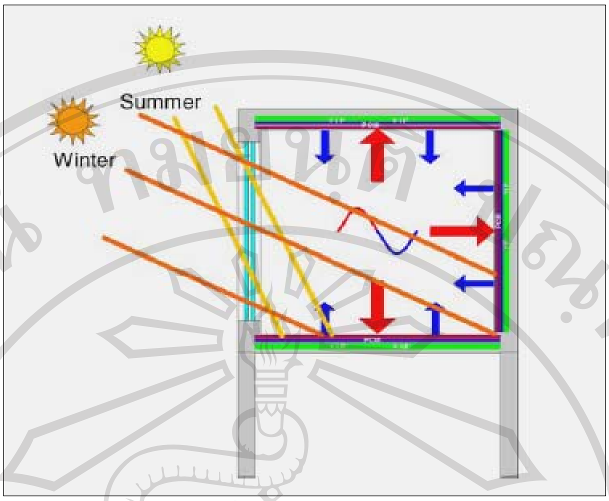

Figure 3.3 Schematic solar heat test-cell

3.2.3 Apparatus and Experimental Design for this Study

After reviewing those apparatuses and testing methods, an experimental apparatus was developed for this study. The principle of this apparatus is used for comparative experiments and approximating results.

Hot Box Design

According to NFRC (2001), the reference specimen or glazing test specimen shall have sufficient size as to reduce uncertainty in the calculation, specimen shall not have dimension less than 0.5m x 0.5 m (20” x 20”) of visible area when installed in the surrounded panel. In the previous experiments similar to this study, researchers established their test cells of 1m x 1m x 1m for conducting experiments (Cheng & Givoni, 2004; Van Dessel et al, 2004; Ahmad et al, 2005 Simko et al, 2006; and Abela, 2006). The use of large size specimens could provide more accurate result.

In this study, four well-insulated-cells, which dimension 1 x 1 x 0.6 m^3 were designed and built surrounding a heating cell. Exterior walls of all test cells were 10 cm thick of EPS. Figure 3.4 and 3.5 are hot box test designed for this research as the concept of comparison instead of the concept of absolute measurement.

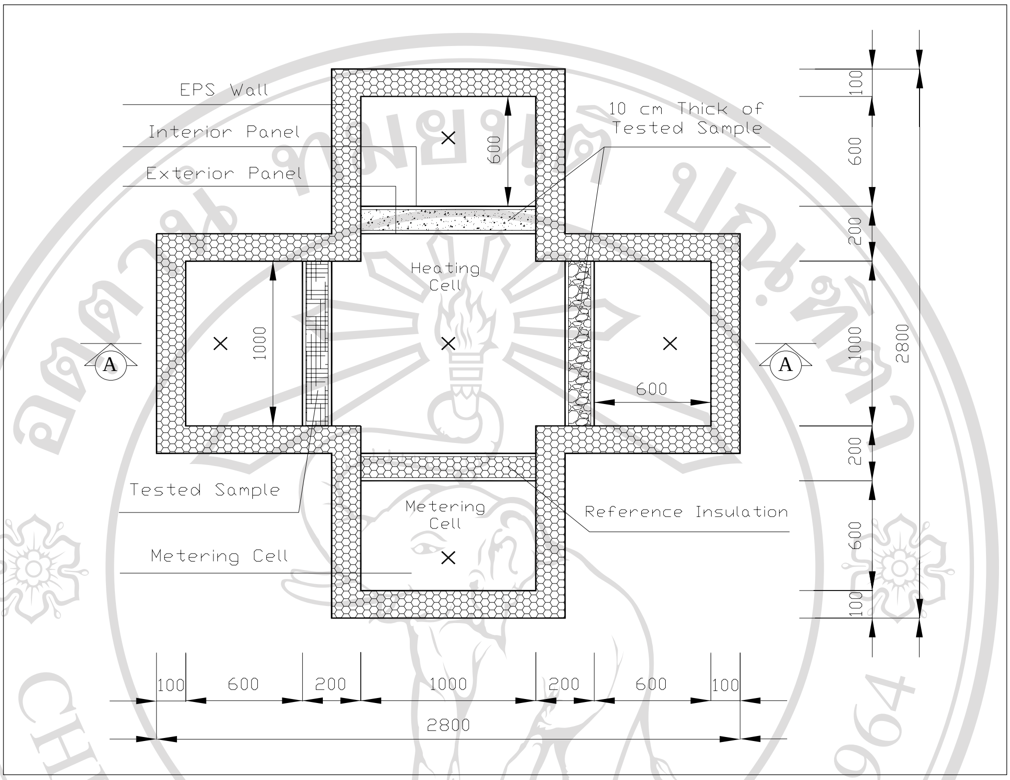

Figure 3.4 Top view outline of all heating and metering cells prepared for testing
X: thermocouple positions

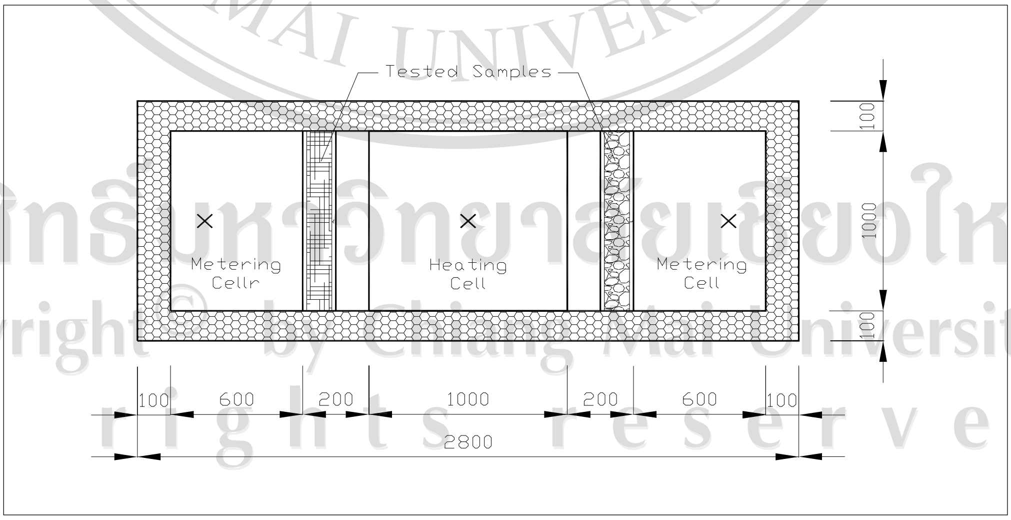

Figure 3.5 Section view (A-A) of heating and metering cells and test specimens
X: thermocouple positions

Hot Box Construction

Exterior walls of hot box were constructed by using 10cm (4-inch) of EPS panels, which has thermal resistance R-value of 2.82 ºC•m^2/W (16°F.ft^2.h/Btu). The metering cells must not have any direct contact (leaks) with the surrounding environment. Latex glue, silicone and aluminum foil were used to seal at the joints of all chambers in order to prevent leakage of air temperature. Otherwise, the inside temperatures could be decreased or increased from the experimental system due to its interaction between the outside environment. This situation could cause wrong results. The following Figure 3.6 shows assembly of the hot box construction.

Figure 3.6 Hot box assembly

In this hot box, four different materials could be tested simultaneously. However, this research was based on comparison concept. Therefore, one of the specimens should be a reference material and should be test along with other samples.

3.2.4 Limitation

In this study, all of test samples were tested together in hot boxes to find and approximate thermal performances. Thermal performance of each sample was compared with those of reference samples of which the thermal properties were previously known. Therefore, thermal properties of all test samples were obtained depending on approximation. Temperatures provided in the heating cell were increased by a heater, not the real climate condition. Therefore, this study is based on the performance of materials resulted by heat conduction from a source of light bulb. It did not deal with heat conduction and radiation source by the sun at any condition.

EPS packaging foam used as test specimens in this research were obtained from packaging or cushioning of electronic equipments around Chiang Mai City. Therefore, it is assumed that disposed packaging EPS foam was obtained for free. Thus, cost estimate of producing each test sample is dealt with labor only.