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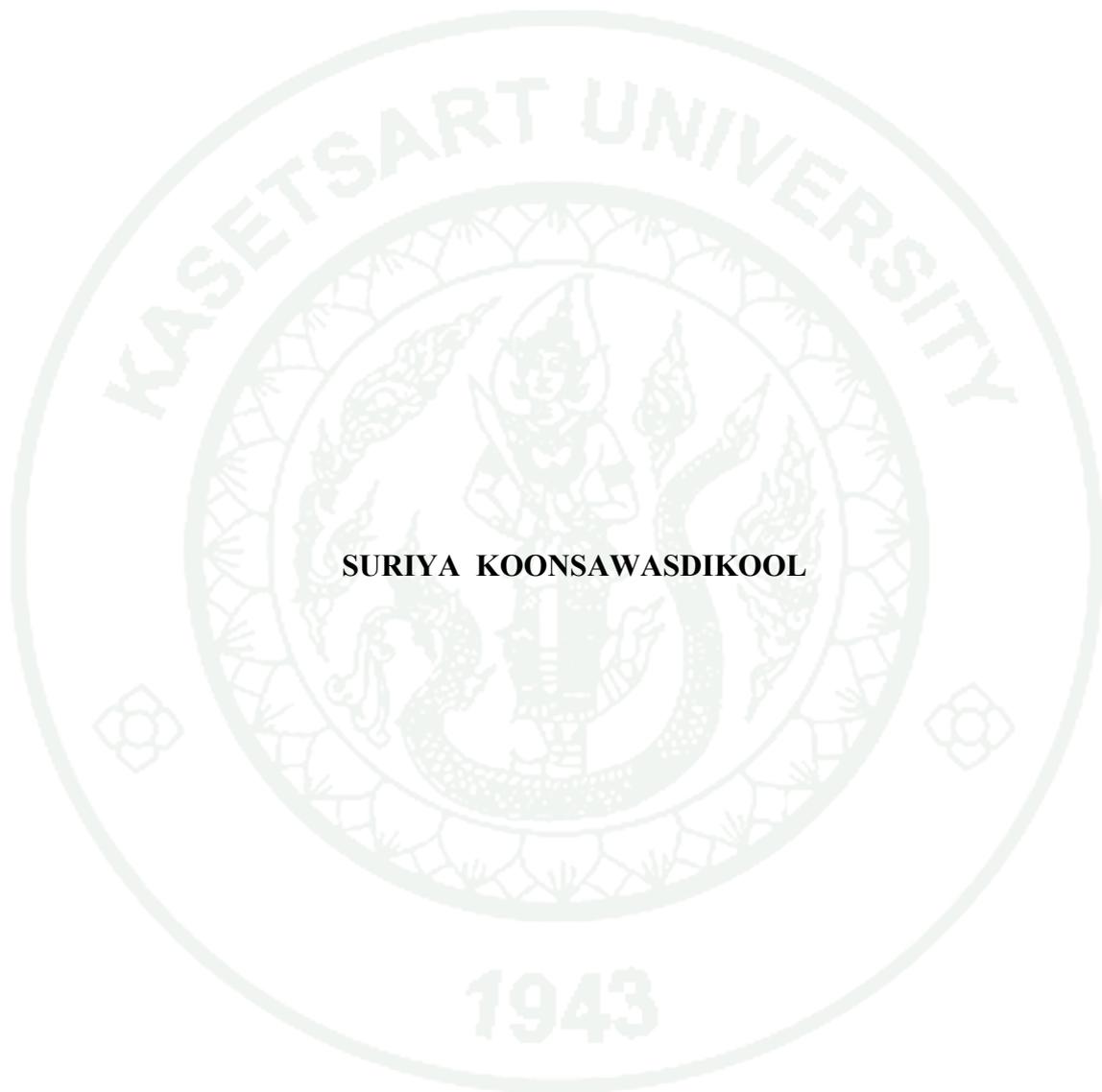
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THESIS

**AN APPROPRIATE GLASS DOUBLE SKIN FAÇADE (DSF) FOR
RETROFITTING BUILDINGS IN THAILAND**



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**A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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This research was aimed to investigate and propose an appropriate glass Double Skin Façade (DSF) for retrofitting buildings in Thailand in order to improve the thermal performance and reduce heat transmission into buildings.

This research involved an investigation of heat gain through the building primary glass wall, which also provides daylight. Investigation of glass DSF with and without air ventilation was conducted using small mock ups at Phra Nakorn Si Ayutthaya province. Three mock ups were built with dimensions of 0.9 x 0.9 x 1.2 m. Glass DSF with dimensions of 0.3 x 0.9 x 1.2 m were integrated into the South-West two mock ups for comparison and analysis while the other mock up with single glass (mock up Case-A) was used as a reference. Data record included, mainly, room temperature, air cavity temperature at each glass DSF mock up. Comparison with base case of single glass wall was conducted and the result showed that the average room temperature of mock up Case-C (glass DSF with stack ventilation) was the lowest. And room temperature difference compared with base case was lower by 1.2 °C of five days in July 2009, lower by 1.3 °C of five days in August 2009, lower by 3.0 °C of six days in October 2009 and lower by 5.6 °C in two days in January 2010. The average room temperature difference in four months was 2.7 °C. Then an appropriate glass DSF is introduced which may later help to give guideline to designers and architects to choose suitable type of glass DSF that helps reducing energy consumption for retrofitting buildings, as every 1 °C indoor temperature decrease could save about 7 % of energy consumption. This is extremely interesting mainly for high rise and office buildings in Thailand, with large cooling load.

Student's signature

Thesis Advisor's signature

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Suriya Koonsawasdikool

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LIST OF ABBREVIATIONS

| | | |
|--------------------|---|---|
| DSF | = | Double Skin Façade |
| mm | = | Millimeter |
| cm | = | Centimeter |
| m | = | Meter |
| m ² | = | Square Meter |
| m ³ | = | Cubic Meter |
| °C | = | Degree Celsius |
| OTTV | = | Overall Thermal Transfer Value |
| HVAC | = | Heating, Ventilation, Air Conditioning |
| LEED | = | Leadership in Energy and Environmental Design |
| GSCW | = | Glazed Solar Chimney Walls |
| SQ.F | = | Square Feet |
| % | = | Percent |
| Kg | = | Kilogram |
| Alu. | = | Aluminium or aluminum |
| AA | = | Aluminium Alloy |
| H | = | Heat |
| T | = | Temper |
| Thk | = | Thickness |
| Kg/m ² | = | Kilogram per square meter |
| m/s | = | Meter per second |
| m/s/m ² | = | Meter per second per square meter |
| m/s/m ³ | = | Meter per second per cubic meter |
| Hrs | = | Hours |
| h | = | Height |
| l | = | Length |
| w | = | Width |

AN APPROPRIATE GLASS DOUBLE SKIN FAÇADE (DSF) FOR RETROFITTING BUILDINGS IN THAILAND

INTRODUCTION

In many new mid and high-rise buildings today, glass curtain wall and metal cladding known as transparent and solid façade is construction technique of choice for their building envelope (Architect, 2008). This is the case for many regions throughout the world, including developing countries in hot and humid climates like Thailand.

There are many reasons for using glass as a building material for curtain wall construction in building façades. One reason is the benefit of daylight. People see well and feel better whenever there is natural light for reading and working. In addition, designing for daylight can minimize energy consumption for artificial lighting. (Yudelson, 2007).

Most glass curtain wall for buildings in Thailand used monolithic glass such as clear annealed glass, tinted annealed glass, and reflective annealed glass. Therefore heat transfer through these types of glass into the building interior is large and becomes notably higher expenses due to an increasing energy cost. This is particularly significant in hot and humid regions such as Thailand. Most buildings in Thailand are equipped with air-conditioning systems using 60 to 70% of the total energy, the largest of all electrical loads. The Overall Thermal Transfer Values (OTTV) of various buildings such as hotels, office buildings, and shopping centers is widely used as an index of energy consumption. These values could be used as a guideline for future building envelope design to achieve energy saving in buildings (Vechaphutti, 1989). Nowadays, Thailand designing buildings and houses is influenced by architectural characteristics of foreign countries. So glass wall and windows are widely used. To cope with heat from sunlight through the windows, there are various solutions. In general existing solutions cost much money and need electricity to get

light during day time and for the fans. At present, the increases in electricity consumption are 20% for light, 60% for air conditioning, and 20% for the other appliances (Chiraratananon *et al.*, 2002).

Double Skin Façade (DSF) is a term for designing a second layer of building envelope in many different ways as described by Werner Lang and Thomas Herzog in the architectural record continuing education article titled “Using multiple glass to clad buildings” (Poirazis, 2004). There is an outstanding project in Canada named TELUS building, glass DSF works well until present with natural ventilation and its flexibility of system while another project in New York, USA named Hooker building was a sample of a failure after a certain period of time in practice.

There are a few related researches about glass DSF in hot climate areas. Vijaya conducted an interesting research, evaluation and design of double-skin facades for office buildings in hot climates, which investigated DSF using ENERWIN simulation program (Yellamraju, 2004). Another research by Dutta, a study on double skin façade in hot climates, was an investigation of Energy Park of Asian Institute of technology (AIT), Thailand using simulation software, TRANSYS, (Dutta, 2007). Investigation of DSF in a hot-humid climate using physical mock ups were still short.

In Thailand, there are samples of buildings built with glass DSF with and without natural ventilation. Siam Center and Central World were aimed to display activities and media as they are department stores and fully air-conditioned. Therefore this research aims to improve building’s thermal performance by proposing an appropriate glass double skin façade (DSF) integrated with stack ventilation, which the building thermal performance were investigated by using physical mock ups.

OBJECTIVES

1. To investigate thermal effect of glass primary wall and glass Double Skin Façade (DSF) with and without stack ventilation by using small mock ups at Phra Nakorn Si Ayutthaya province.

2. To propose an appropriate glass Double Skin Façade (DSF) that can be adopted to retrofit buildings in Thailand. Simple economical analysis will also be conducted in order to asses its viability.

Key Words

Glass wall, Double Skin Façade (DSF), Heat transfer, Retrofit, Building envelope, Stack effect.

LITERATURE REVIEW

Double Skin Façade (DSF) is a term for designing a second layer of building envelope in many different ways. In Thailand, where over the past ten years, Bangkok has seen the renovated construction of a few number of DSF buildings besides those commercial townhouses which later on renovated mostly with non-glazing materials. there are few buildings built with glass DSF with and without natural ventilation. Siam Center, renovated in 2007 and Central World, renovated in late of the same year, were aimed to display activities and media as they are department stores and fully air-conditioned. The Energy Complex, has been recently completed as a new DSF building, using DSF for few top floors, façade erection commenced in 2008 and related information may be obtained soon after its opening to the public. There is an outstanding project in Canada named TELUS building, and another project in New York, USA named Hooker building. Therefore, a literature review need to bring up some related information regarding to glass DSF and its classification, heat transfer, ventilation, glass as a main material for external envelope, climate of Thailand and some related researches about glass DSF in hot climate areas.

Related research studies

1. Evaluation and design of double-skin facades for office buildings in hot climates, thesis, Texas A&M University, USA. By Yellamraju Vijaya,

The main objectives of this research are (a) to investigate the thermal effect of Double Skin Facade in office buildings in hot climates and (b) to propose guidelines for their efficient design based on this evaluation. The study involves the energy performance analysis of two buildings in India. A base case with the existing building skin was simulated for both the cities. The main source for the high cooling loads was found to be heat gain through windows and walls. This led to the evolution of a series of façade strategies with the goals of reducing heat gain, providing ventilation and day lighting. The buildings were then simulated for their energy performance with the proposed double-skin strategies. Each of these strategies was

varied according to the layers constituting the façade, the transparency of the façade and the orientation of the façade to which it is applied. Final comparisons of energy consumption were made between the proposed options and the base case to find the most efficient strategy and also the factors that affected this efficiency. The simulations were done using the building simulation software, Ener-Win. The double skin was simulated as per an approximate and simplistic calculation of the U-value, solar heat gain coefficient and transmissivity properties of the layers constituting the façade. The model relied on logically arrived at assumptions about the façade properties that were approximately within 10% range of measured values. Based on inferences drawn from these simulations, a set of design guidelines comprised of goals and parameters was generated for design of double-skin façades in hot climates typical to most of the Indian subcontinent. It was realized that the double-skin defined typically as a ‘pair of glass skins separated by an air corridor’ may not be an entirely energy efficient design strategy for hot climates. However, when used appropriately in combination with other materials, in the right orientation and with the right transparency, a double-layered façade turns out to be an energy efficient solution.

2. “A study on double skin façade in hot climates.” Thesis by Debajit Dutta is also another case that the main objective is to study the thermal effect of double skin facades in buildings in hot climates and to find the financial viability. The study concerned the cooling demand of the day lighting laboratory of Energy Park of AIT. A base case with the existing building with single skin was simulated for Thailand weather. The simulation was done using the multizone building simulation software, TRNSYS. The double skin was simulated as per an approximate and simplistic calculation of the U-value, solar heat gain coefficient and transmissivity properties of the layers constituting the façade.

And there are several other thesis and research works concerning double skin façade in hot climates but mostly were carried out by simulation software and mock ups are still short.

Definition of Double Skin Façade (DSF)

Different definitions were given by authors to introduce and define Double Skin Façade (DSF) systems. According to the Source book of the Belgian Building Research Institute “An active façade is a façade covering one or several storey constructed with multiple glazed skins. The skins can be air tighten or not. In this kind of façade, the air cavity situated between the skins is naturally or mechanically ventilated. The air cavity ventilation strategy may vary with the time. Devices and systems are generally integrated in order to improve the indoor climate with active or passive techniques. Most of the time such systems are managed in semi automatic way via control systems.” (BBRI, 2002).

“A façade that consists of two distinct planar elements that allows interior or exterior air to move through the system. This is sometimes referred to as a twin skin.” (Arons, 2001).

“A pair of glass skins separated by an air corridor (also called cavity or intermediate space) ranging in width from 20 cm to several meters. The glass skins may stretch over an entire structure or a portion of it. The main layer of glass, usually insulating, serves as part of a conventional structural wall or a curtain wall, while the additional layer, usually single glazing, is placed either in front of or behind the main glazing. The layers make the air space between them work to the building’s advantage primarily as insulation against temperature extremes and sound.” (Uttu, 2001).

“An envelope construction, which consists of two transparent surfaces separated by a cavity, which is used as an air channel. This definition includes three main elements: (1) the envelope construction, (2) the transparency of the bounding surfaces and (3) the cavity airflow.” (Saelens, 2002).

“A second skin façade is an additional building envelope installed over the existing façade. This additional façade is mainly transparent. The new space between the second skin and the original façade is a buffer zone that serves to insulate the

building. This buffer space may also be heated by solar radiation, depending on the orientation of the façade. For south oriented systems, this solar heated air is used for heating purposes in the winter time. It must be vented in order to prevent overheating in other periods.” (Claessens and DeHerde, n.d.).

“An arrangement with a glass skin in front of the actual building façade. Solar control devices are placed in the cavity between these two skins, which protects them from the influences of the weather and air pollution a factor of particular importance in high rise buildings or ones situated in the vicinity of busy roads.” (Compagno, 2002).

Double skin facades consist of an external façade, an intermediate air space and an inner façade. The outer layer provides protection against weather and acoustic insulation. The façade allows ventilation of intermediate space and also provides thermal insulation. An adjustable shading device is usually incorporated in the air cavity (Oesterle *et al.*, 2001).

Classification of Double Skin Façade (DSF)

The gathering of data on double skin façade (DSF) systems revealed that there is no universal definition or different types of systems go by different names. These include Double-Leaf Façade, Double-Skin Façade, Double Façade, Double Envelope, Dual-Layered Glass Façade, Wall-Filter Façade, Environmental Second Skin Systems, and Ventilated Façade.

In the United States, three types of DSF general systems are recognized. These refer to the method of classification contained in the Architectural Record Continuing Education article titled, “Using Multiple Glass Skins to Clad Buildings”, by Werner Lang and Thomas Herzog, 1999. Lang and Herzog cite three basic system types which are Buffer System, Extract Air System and Twin Face System. The three systems vary significantly with respect to ventilation method and their ability to reduce overall energy consumption. (Lang and Herzog, 1999).

Buffer Façade

Buffer façade consists of two layers of glazing mounted approximately 250-750 mm apart, with the air space between two layers sealed. It was invented to increase sound and heat insulation without reducing the amount of daylight entering the building (Lang and Herzog, 1999)

In this system, two layers of single glazing spaced 250 to 900 mm apart, sealed, allowed fresh air into the building through additional controlled means-either a separate HVAC system or box type windows which cut through the overall double skin. Shading devices may be included in the cavity (Boake, 2003).

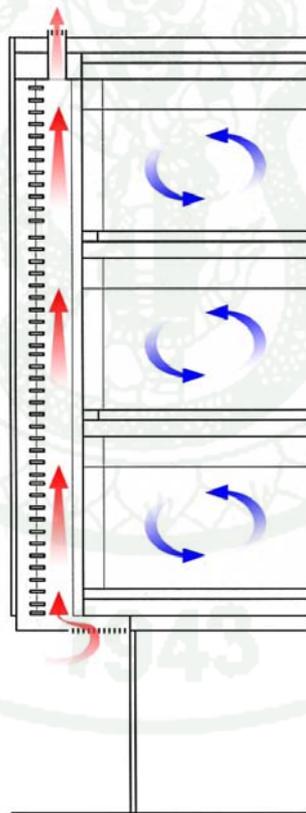


Figure 1 Buffer façade

Source: Lang and Herzog (1999)

Extract air façade

Extract air façade consists of two layers of glazing, a main of double-glazed for outer skin and single-glazed for inner skin. The air space between the two layers of glazing becomes part of heating, ventilation and air conditioning (HVAC) system.

This comprises of a second single layer of glazing placed on the interior of a main façade of double-glazing. Air space between the two layers of glazing becomes a part of the HVAC system. The heated used air between the glazing layers is extracted through the cavity with the use of fans and thereby tempers the inner layer of glazing while the outer layer of insulating glass minimizes heat transmission loss.

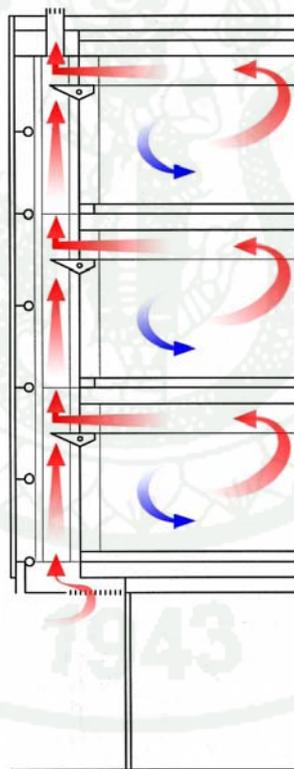


Figure 2 Extract air façade

Source: Lang and Herzog (1999)

Twin face façade

This system, it permits the opening in the skin, allowing for natural ventilation. Windows on the inner façade can be opened while ventilation windows on the outer skin moderate temperature extreme within the façade.

Twin face façade consists of a conventional curtain wall or thermal mass wall system inside a single glazed building skin. Interior space of at least 500-600 mm is needed to permit cleaning. Openings in the skin allows for natural ventilation. The outer skin protects the air cavity contents from weather, blocks wind in high- rise situations allowing interior openings an access to fresh air without associated noise or turbulence. Ventilation openings in outer skin also moderate temperature extremes within the façade. For sound control, the openings in the outer skin can be staggered or placed remotely from the windows in the interior façade. Internal skin offers the insulating properties to minimize heat loss. Use of windows allows for nighttime cooling of the interior thereby lessening the cooling loads of the building's HVAC system (Boake, 2001).

The Twin face façade is comprised of a conventional curtain or massive wall system with an outer skin of single glazing (Lang and Herzog, 1999). The single glazed outer skin is used primarily for protection of air cavity contents (shading devices) from weather. With this system, the internal skin offers the insulating properties to minimize heat loss. This system also permits opening in the skin, allowing for natural ventilation. Windows on the interior façade can be opened, while ventilation opening in the outer skin moderate temperature extremes within the façade.

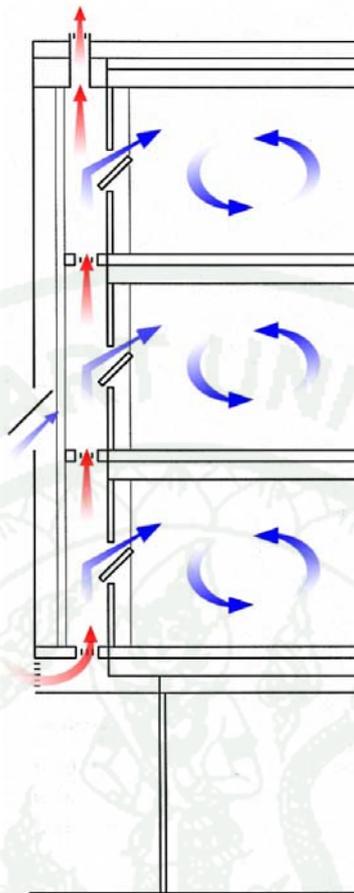


Figure 3 Twin face façade

Source: Lang and Herzog (1999)

In Thailand, Double Skin Façade (DSF) have been defined in the publication “Architectural Detail Series: Volume Four”, consists of two layers. The inner skin of the façade can be considered as a main façade layer. The second skin layer usually consists of both transparent and solid walls to control daylight and heat absorption into the building. In addition, it offers the occupants’ privacy while maintaining views to the outsides. The distance between each façade element must be carefully considered for easy maintenance and the prevention of strains created by rain as well as the prevention of birds and insects inhabiting the space between the two skins (Architect, 2008).

The Air Cavity

The air cavity is the space between the two skins of façades. It may vary depending on the design for either naturally or mechanically ventilation, maintenance requirement for such system. There are samples of buildings constructed with Double Skin Façade in North America, Europe showing different depth of cavity, which vary from 0.07 m to 1.40 m as given in table 1.

Table 1 Samples of air cavity depth for Glass Double Skin Facade

| COUNTRY | BUILDING | CAVITY (m) |
|---------|------------------------|-------------|
| Germany | City gate | 0.90 , 1.40 |
| Germany | Arag 2000 tower | 0.70 |
| Germany | Eurotheum | 0.34 |
| Germany | Debris Headquarter | 0.70 |
| Germany | GSW Headquarter | 0.90 |
| Germany | Halenseestrabe | 0.85 |
| Germany | Gallery Lafayette | 0.20 |
| Germany | Potsdamer Platz 1 | 0.22 |
| Germany | RWE AG Headquater | 0.50 |
| Germany | Print Media Academy | 0.46 |
| France | Victory life insurance | 0.80 |
| France | DB Cargo building | 0.23 |
| Finland | Sanomatalo | 0.70 |
| Finland | Sysopen tower | 0.55 |
| Finland | Martela | 0.70 |
| Finland | Itamerentori | 0.925 |
| Finland | High tech center | 0.342 |

Table 1 (Continued)

| COUNTRY | BUILDING | CAVITY |
|-----------------|-------------------------------|---------------|
| Finland | Radiolinja | 0.65 |
| Finland | Nokia K2 | 0.60 |
| Finland | ISO O mena Mall | 1.00 |
| Finland | Kone | 0.58 |
| Finland | Nokia Keilalahti | 0.69 |
| Finland | JOT Automation group | 1.00 |
| Sweden | Nokia house | 0.70 |
| Sweden | Arlanda | 0.80 |
| Sweden | ABB Business center | 0.80 |
| United Kingdom | Briarcliff house | 0.15 |
| The Netherlands | Technical university of Delft | 0.15 |
| Belgium | UCB Center | 0.143 |
| Belgium | Aula Magna | 0.07 |
| Czech Republic | Moravian library | 0.55 |
| USA | Occidental chemical center | 1.20 |
| CANADA | Telus William Farrel | 0.90 |

Heat Transfer

Heat transfer is the transition of thermal energy from a hotter object to a cooler object (“object” in this sense designating a complex collection of particles which is capable of storing energy in many different ways). Heat transfer always occurs from a higher-temperature object to a cooler-temperature one as described by the second law of thermodynamics or the Clausius statement. Where there is a temperature difference between objects in proximity, heat transfer between them can never be stopped, it can only be slowed (Clausius, n.d.).

There are three types of heat transfer, which are

1. Conduction

Conduction is the transfer of heat by direct contact of particles of matter. Conduction is greater in solids, where atoms are in constant contact. In liquids (except liquid metals) and gases, the molecules are usually further apart, giving a lower chance of molecules colliding and passing on thermal energy. Metals (e.g. copper, platinum, gold, iron, etc.) are usually the best conductors of thermal energy. This is due to the way that metals are chemically bonded, have free-moving electrons which are able to transfer thermal energy rapidly through the metal.

2. Convection

Convection is the transfer of heat energy between a solid surface and the nearby liquid or gas in motion. And there are two types of convection heat transfer.

Natural convection is when the fluid motion is caused by buoyancy forces that result from the density variations due to variations of temperature in the fluid.

Forced convection is when the fluid is forced to flow over the surface by external source such as fans or pumps.

3. Radiation

Radiation is the transfer of heat energy through empty space. All subjects with temperature above absolute zero radiate energy at a rate equal their emissivity multiplied by the rate at which energy would radiate from them if they were black body. No medium is necessary for radiation to occur, for it is transferred through electromagnetic waves. Radiation works even in and through a perfect vacuum. The energy from the Sun travels through the vacuum of space before warming the earth.

Normal clear glass is almost transparent to high frequency solar radiation, but is a barrier to low frequency or long wave radiation. The solar heat energy passing through the glazing warms up the various internal surfaces by absorption and these internal surfaces become heat radiators. This re-emitted heat is, however, low frequency and therefore is trapped within the room causing the temperatures to rise.

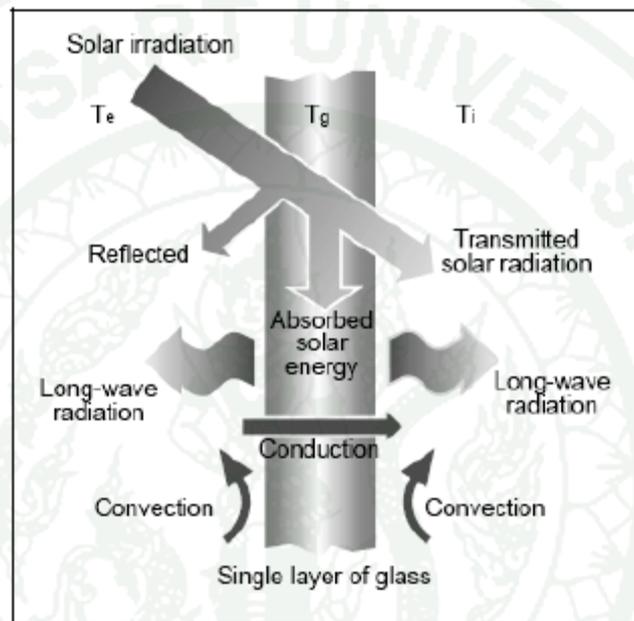


Figure 4 Heat transfer through a single plane of glass

Source: Tenhunen (2000)

Ventilation

Natural ventilation

The word "ventilation" has a Latin root of "venture" that means obviously "weather movement or displacement" (Watson, 2004) "ventilation" is a process during which the internal air flow of a building is replaced by the fresh air coming in from outside of it or on the other hand, it is said to be an interchange or exchange of inside and outside air flow on the condition that no air facilities are used in this case (state of

affairs) and no irreplaceable energy is consumed either. This method has been used since a long time as one original technical of refrigeration in the world. This acts based on a methodology by which heat transfer takes place by way of alluvial operation and air displacement wards off the heat.

Exterior glazing of the double skin creates a buffer zone of air next to the exterior wall of the building that is not affected by high velocity wind. This zone is accessible by the inhabitants for natural ventilation. In some cases the external glazing is also opened out for natural ventilation. This may not be suitable for extremely hot climates where it may not be appropriate to let high temperature winds into the building. The operability of the façade can be used for providing night time ventilation though (Arons, 2000).

Horizontal ventilation

Horizontal ventilation consists of creating a typical airflow in a structure by making a hole in the direction in which the wind blows and one more hole in another direction of it. Because the wind always blows in a horizontal direction it continues flowing in its horizontal direction. Across the structure although there are holes developed in it. Then it flows out of the structure. This process in which the air flows is called horizontal ventilation or air conditioning. The pressure the wind applies to the surface. This pressure distribution depends largely on the dimension and size of a surface.

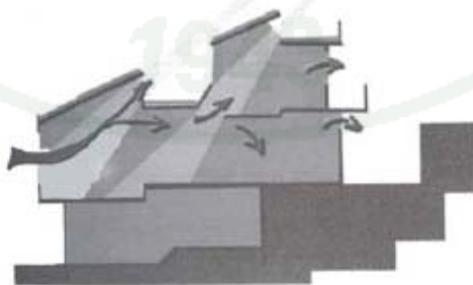


Figure 5 Horizontal ventilation

Source: Saberi (2002)

Vertical ventilation (Stack ventilation)

Stack ventilation or vertical ventilation is a name given to a number of techniques for letting natural forces distribute air in space by having cooler air displace warmer air in space. The varied temperature between inside and outside the room and its different perimeter results in a varied density as a result, the varied pressure causes the wind to move. This effect is called and known as “stack effect”. It is in this state that the natural ventilation takes place as soon as the air begins to flow in a vertical direction. As far as vertical stack ventilation goes, the gravity force of earth influences it considerably. A ventilation cavity should have a minimum of 20 mm as an optimum. This will combat condensation, assist in the evaporation of any ingresses moisture or in the case of refurbishment of projects, allow the fabric of the original building to breathe (Roderich, 2007).

In general double facades with airtight junctions and properly airflow control in the cavity is an interesting pre-heater for ventilation air. In a four storey building and a cavity width of 0.2 m an overall heat recovery efficiency of 40% can be obtained. This efficiency can be increased to 72% if the ventilation flow inside the cavity is properly controlled. (Poirazis, 2004).

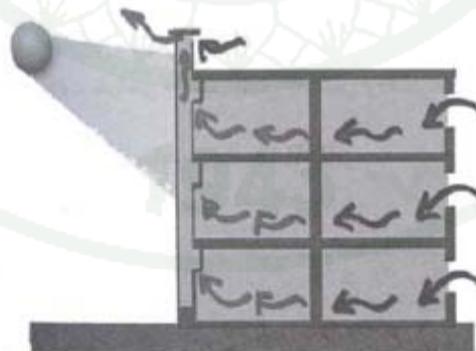


Figure 6 Stack ventilation

Source: Saberi (2002)

The following factors bring about stack ventilation. There is higher temperature in the internal air but less that of external one. Warmer air moves upwards in the structure. Negative pressure develops in downstairs heights of building. Positive pressure develops in upstairs heights of building. Warmer air flows outside of the building out of the roof holes of building and replaced by colder air inside the building from the incoming pores and entrance of floor area. A pressure difference created by using a stack depends on three factors such as acceleration, earth gravity, base point varied height and targeted point as well as on the density difference of inside and outside air.

This natural ventilation might work along with “Stack effect” where heated air rises out to the top of a building with cooler air coming in below.

Glass wall for Double Skin Façade (DSF)

It has been standard practice for buildings in Thailand to be designed using aluminum and glass materials for the external building envelope for the past 40 years when construction industry was continually developed. We commonly saw glass windows with concrete solid wall and glass wall has been replaced in later day known as glass curtain wall. In general we are familiar with monolithic glass such as clear annealed glass, tinted annealed glass, reflective annealed glass for exterior windows and walls due to cost and handling process. Once energy efficiency, environmental friendliness are considered for new buildings, safety and energy saving glasses become widely acknowledged as well as those who want to retrofit, renovate buildings or even to have new building designed.

Glass applications for building envelope

Glass are designed and used for architectural works as building envelope for such a long time and there are many applications that can be seen today as doors, windows, curtain wall, skylight, sky roof and so on. For this research, two types of glass were chosen for mock ups, namely 6.0 mm of green tinted glass for the inner layer and 6.0 + 6.0 mm clear laminated glass for the outer skin layer.

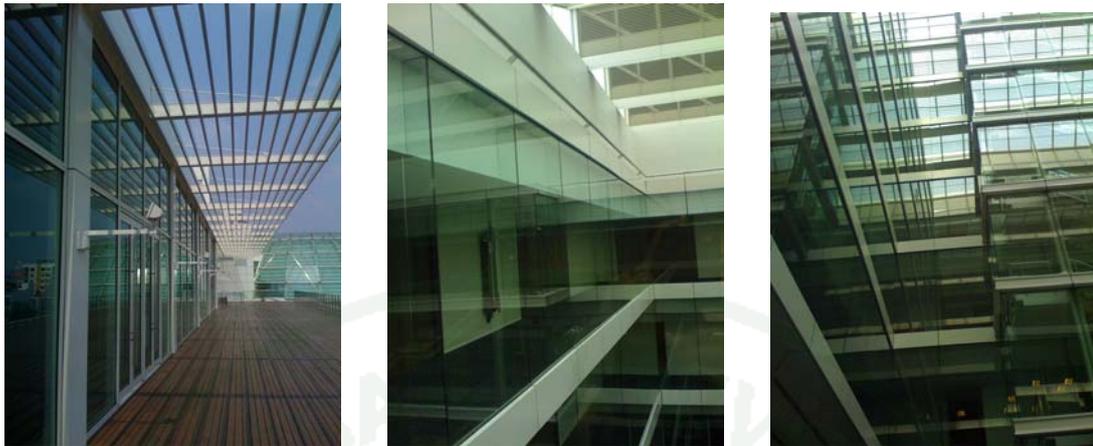


Figure 7 Sample of various kinds of glass applications for building envelope

Advantage of Glass Double Skin Façade (glass DSF)

It has been described the advantage and disadvantage of the use of Double Skin Façade (DSF) for buildings that related to goals of designer and investor. However, the following points explain the benefit of using DSF in general (Poirazis, 2004).

Acoustic insulation

It is one of the most important reasons for having DSF design as building envelope since it helps reducing the noise transmission into the building from outside source such as heavy traffic, pollutions through two layers of glass wall and hence noise level inside the building for occupants can be achieved.

DSF are now specifically being used for reduction of noise in urban settings. The degree of noise reduction increases with use of glazing that reflects sound and varies with specific details and operation of the facades.

Thermal insulation

The outer layer of glazing can increase heat transfer resistance. Moreover, the air cavity extracts warm air when it is ventilated both naturally and mechanically. “as re-radiation from absorbed radiation is emitted into the Intermediate cavity, a natural stack effect results, which causes the air to rise, taking with it additional heat” (Lee *et al.*, 2002).

Protection of shading device

In general, shading devices are placed in between the two skins, inside the cavity. They are protected from wind and the rain.

Safety and security

Some designers explain that the space between the two layers can be used for security purpose such as locating the fire escape for building occupants.

The additional skin of the façade makes it almost a transparent physical barrier increasing the feeling of security psychologically. Also it allows the windows being open in the inner skin, which also improves the security of the building in comparison to directly exposed operable windows.

Transparency for architectural design

Most of the designers like to have transparent building envelope due to the aesthetic purpose even through they have to deal with energy performance problems. And for years that they have achieved of fully glazed designed but low energy consumption by using DSF.

The double skin facades offer tremendous opportunity to designers as it enhances the qualities of transparency, depth, layering and movement in a building, in comparison to conventional masonry facades, which appear as massive and bulky (Yellamraju, 2004).

Energy saving and Ecological responsibility

Energy savings are achieved by minimizing solar loads at the perimeter of the buildings. Providing a low solar factor and low U-value minimizes the load of adjacent spaces. It is claimed that double-skin facades (DSF) save natural resources by reducing energy consumption during the operational life of the building. No study has been seen on the relationship of operational costs to construction/embodied energy impacts (Arons, 2000).

Examples of buildings with Glass Double Skin Façade (DSF)

1. The Occidental Chemical Center (Hooker Building), Niagara Falls, NY, USA

The construction of the Occidental Chemical Center dates back to the early 1980's. It is as important as it is the first North American example of a double skin façade building. It was designed by Cannon Design Inc. and completed in 1980 (Diamond, 1989). It represented a development in the recent history of glass in architecture that is cited to be of fundamental importance. The building is situated immediately on the American side of the Rainbow Bridge that connects Niagara Falls, Canada to Niagara Falls, New York. Its appearance has been likened to a conventional glass curtain wall box. It was constructed with a straightforward square plan with a central core and suspended ceilings. At all four sides a 4-foot (1.2 m) cavity allows for maintenance of the movable daylight controlling louvers and window washing, as well as ventilation of the cavity by stack effect. In modern terms, this type of double façade is known as the Buffer Façade.



Figure 8 Occidental Chemical Center (Hooker Building), Niagara Falls, NY, USA

Source: Kate Harrison (2001); Terri Meyer-Boake (2001)



Figure 9 A view inside the cavity showing its clear width to allow for maintenance

Source: Terri Meyer-Boake (2001); Kate Harrison (2001)

2. TELUS William Farrell Building, Vancouver, BC, Canada



Figure 10 Picture showing the Old and new façade for TELUS

Source: Yellamraju (2004)



Figure 11 TELUS in 2000 (Left) and 2009 (Right)

Source: Terri Meyer-Boake (2001)

This building was the first glass double skin wall constructed in Canada and it is a renovation of a building that originally constructed in 1947. As part of a larger sustainable strategy, in lieu of tear down and rebuilding, the architects chose to reuse and enhance the efficiency of the existing structure. Once again the theme of glazing as an aesthetic choice dominated the decision making process. The addition of the second skin effectively transforms the vintage facade into a contemporary icon.

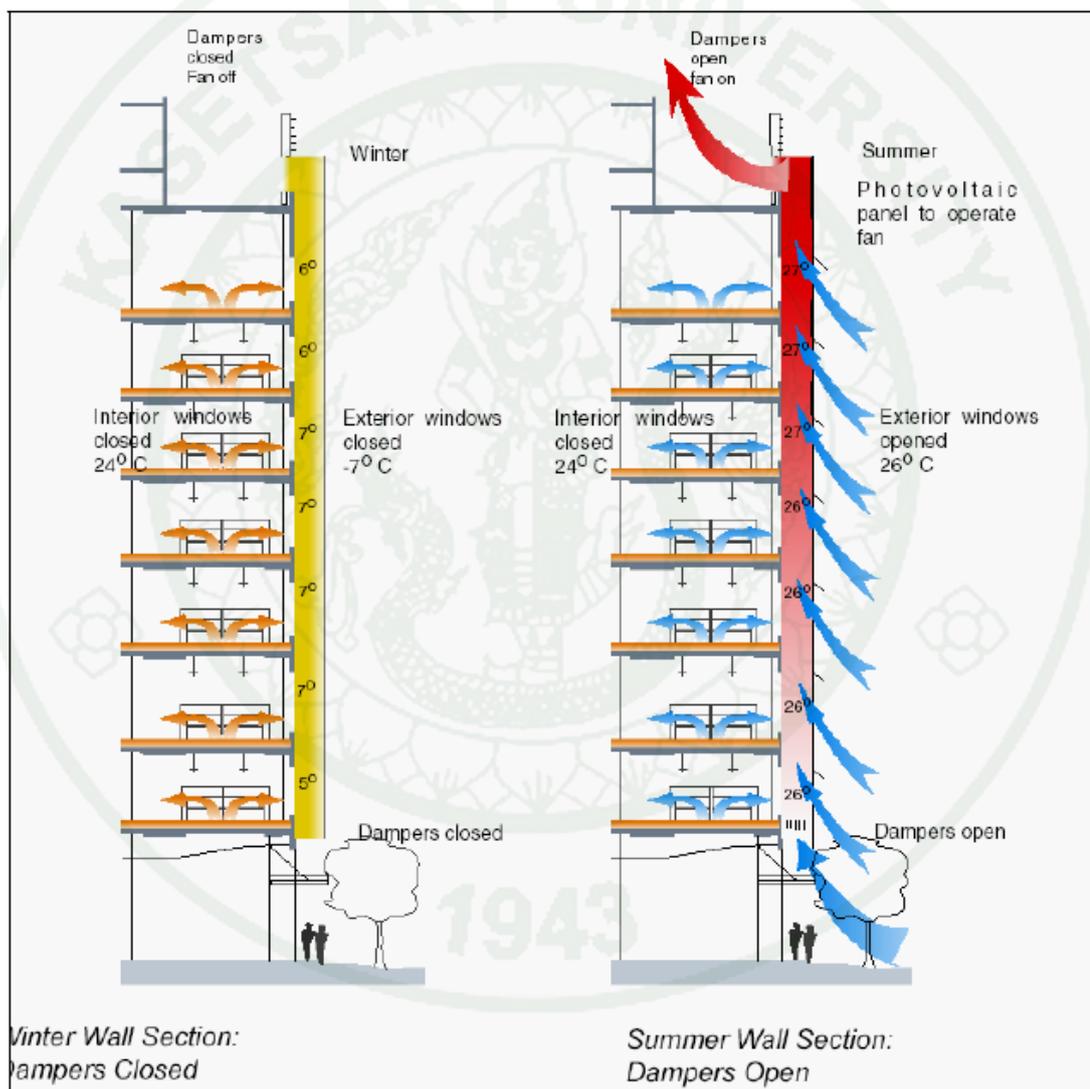


Figure 12 Diagram showing the flexibility of double skin façade for TELUS

Source: Terri Meyer-Boake (2001)

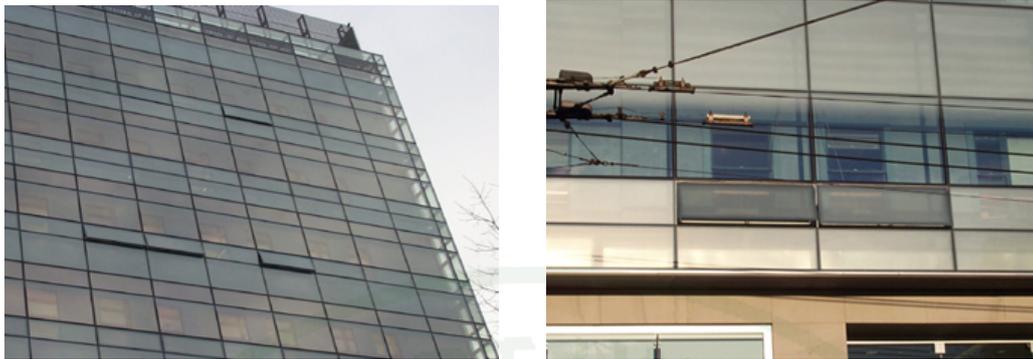


Figure 13 Details of façade on a cloudy day (Left). Clear and fritted glass on the façade with two opened windows (Right)

Source: Terri Meyer-Boake (2001)

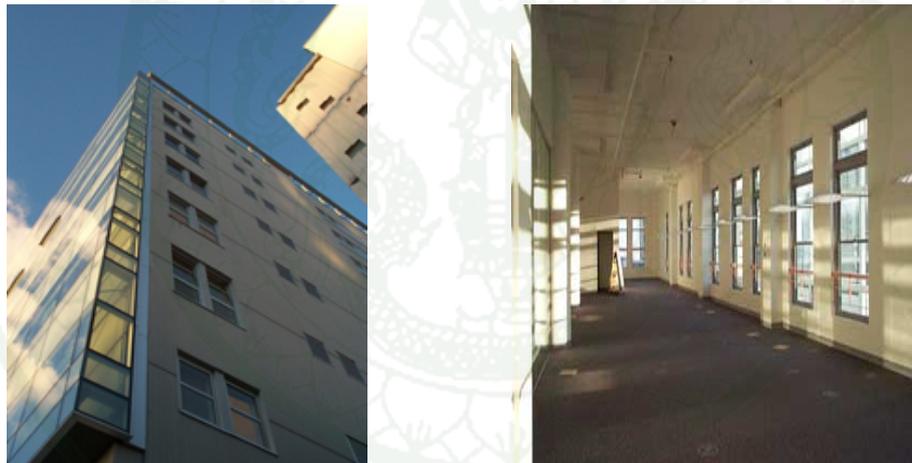


Figure 14 Side of the double skin facade, which allow daylight into the building

Source: Terri Meyer-Boake (2001)



Figure 15 View with the grilles closed. They are closed in the morning during heavy traffic hours and when fresh air is not wanted from this source

3. Siam Center, Bangkok, Thailand

Siam Center, renovated in 2007 by using glass Double Skin Façade (DSF), was designed by Design 103 Co., Ltd. The façade was executed by Permasteelisa Group of Companies. The building is situated right in the heart of the city where traffic is rather congested at all time. DSF with an appearance of fully glazing spider lock system was used along the front elevation of building, facing South-West. Many different kind of glass were used for inner wall and clear laminated glass was selected for outer skin with full building height air cavity of 0.9 m allows for advertisements and maintenance purpose. This type of DSF is known as buffer façade. The interview revealed that the stack ventilation is provided by using alu. perforated panels fixed to the bottom and top of DSF (Figure 18 and 19).



Figure 16 Demolition of solid primary wall in 2007



Figure 17 New Façade design as glass DSF (Left to Right) Day and night

1943



Figure 18 View of perforated panels of glass double skin facade



Figure 19 View of perforated panels on the rooftop



Figure 20 View of the renovated façade as glass Double Skin Façade

4. Central world, Bangkok, Thailand

Central World is one of few DSF buildings in Bangkok, designed and completed in 2007 by A 49 Ltd. It was aimed to display the movement of the users inside the building by introducing new transparent building elevation where inside activities can be seen (Architect, 2008). This DSF commonly refers to buffer façade with various glasses for inner wall and clear laminated glass for outer skin with glass curtain wall and spider lock system.



Figure 21 Curtain wall as a glass Double Skin Façade (Left to right) Day and night

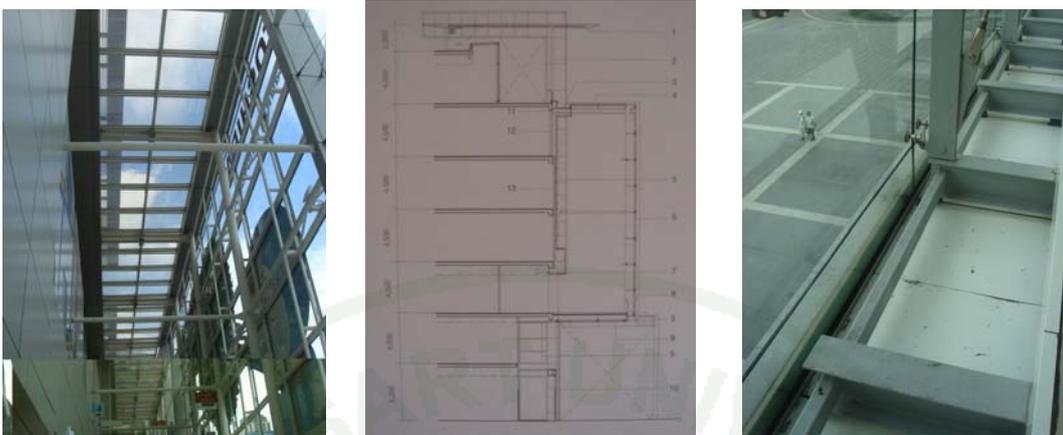


Figure 22 Showing cavity of DSF for Central world building (Buffer façade)

DSF for Central World is fully air-conditioned with various depth to maximum of 6.0 m, the air cavity acting as a buffer zone between fronts opened ground space and building interior with top and bottom of DSF sealed. Movement of users, shoppers seems to have been a motivating factor in the design of this DSF.

Building Retrofit

There are millions of homes and buildings in Bangkok and other major cities in Thailand that have been built without concern for the comfort of the occupants or their impact on the environment but the latest influence of modern technology. Buildings enclosed with concrete wall and glass windows, conventional glass curtain wall are in great number that sooner need to be rebuilt, renovated and retrofitted. A building retrofit is an improvement to building infrastructure, and often to operating and management practices, that reduces utility (energy and water) and maintenance costs. It can also involve thermal, acoustic, materials, energy, water, heating and ventilation.

Advantages of building retrofit

- Significantly reduce utility costs resulting in significant savings
- Reduce system repair and maintenance costs
- Improve occupant comfort

- Increase energy efficiency
- Reduce risk of costly repairs
- Increase productivity
- Enhance Safety

Glass Double Skin Façade (DSF) can be used to retrofit buildings to improve the cooling which will reduce the energy consumption. Good for the environment and the economy. There are number of building in Bangkok started using glass Double Skin Façade for a choice of building retrofitting such as Siam Center, Central World, and even the latest fully finished curtain wall of 119,000 m² office building named The Energy Complex. It has happened in the past. Mid rise and high rise buildings in Thailand did not require a certain environmental standard. It started in the office sector that many multi-national companies started to require environmental certification. Developers considered retrofitting office buildings, hotels, department stores, and so on in Thailand today with seriously consideration to obtain environmental certification. And building reuse is effectively environmental saving in accordance with the LEED environmental assessment system, one of the criteria that Leadership in Energy and Environmental Design (LEED) gives credit for existing building operation with a reason of the environmental concern and avoiding demolition work.

When the professionals consider retrofitting buildings, the investors need to know the benefits of each technology and strategy in specific applications. Industry has been proposing retrofit technologies that have varying levels of effectiveness and costs as well as varying degrees of applicability to particular buildings and ventilation systems. Every 1 °C reduction can significantly save about 4% of cooling load on air conditioning system in Australia (Aynsley, 2009) and every 1 °C can save about 7% of energy consumption for cooling load for buildings in Thailand (Khedari, 2009).

Thailand Climate

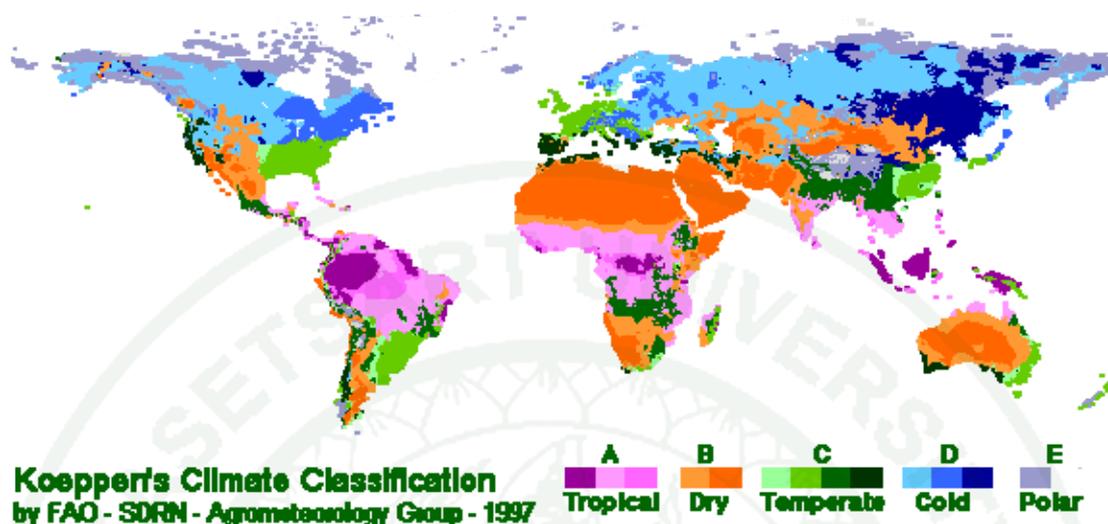


Figure 23 World climates zones

Source: Köppen (n.d.)

The Köppen Climate Classification System is the most widely used for classifying world's climates. And the system recognizes five major climates types base on the annual and monthly average of temperature and precipitation. Each type is designated by a capital letter. As A is moist tropical climates are known for their high temperature year round and for their large amount of round rain.

Thailand is situated at coordinates of 15° 00 N and 100° 00 E, Southeastern Asia, bordering the Andaman Sea and the gulf of Thailand. Most of Thailand has a tropical wet and dry or savanna climate according to Köppen climate classification, while the South and the eastern tip of the East have a tropical monsoon climate.

Thailand has a warm, tropical climate with an annual monsoon from June to October and a dry season for the rest of the year. Temperatures average 24 to 34 °C, with the highest temperatures from March to May and the lowest in December and January. There are three seasons, the cool season (November to February), the hot

season (April to May), and the rainy season (June to October), though downpours rarely last more than a couple of hours.

The seasonal variation of T max and T min are considered by dividing a year into eight periods during which average T max and T min are taken (Lasnier and Juen, 1990) and the table below listed the temperature variations for eight periods in Thailand (Wachirapuwadon, 1996).

Table 2 Average maximum and minimum ambient temperature (°C) in eight periods in Thailand

| AMBIENT TEMPERATURE | | | |
|----------------------------|----------------|--------------|--------------|
| PERIOD | RANGE | T max | T min |
| 1 | Jan. 14-Feb.26 | 33.3 | 21.8 |
| 2 | Feb.27-Apr.12 | 35.6 | 33.5 |
| 3 | Apr.13-May.28 | 35.5 | 24.9 |
| 4 | May.29-Jul.15 | 33.9 | 25.1 |
| 5 | Jul.16-Aug.31 | 32.8 | 24.9 |
| 6 | Sep.1-Oct.15 | 32.6 | 24.9 |
| 7 | Oct.16-Nov.29 | 31.9 | 23.6 |
| 8 | Nov.30-Jan.13 | 32.1 | 21.1 |

The above researcher had also listed a table of monthly mean sunshine hours (Namprakai *et al.*, 1989) which showing that number difference of sunshine hours vary from 4.65 to 8.6 hours may effect to the expenses of monthly energy consumption for those building with glass curtain wall or glass DSF.

Table 3 Monthly mean sunshine hours

| MONTH | SUNSHINE HOURS |
|-----------|----------------|
| January | 8.16 |
| February | 8.29 |
| March | 8.6 |
| April | 7.44 |
| May | 6.54 |
| June | 4.98 |
| July | 5.17 |
| August | 4.65 |
| September | 4.98 |
| October | 5.05 |
| November | 5.53 |
| December | 7.88 |

Bangkok, with hot and humid climate of extreme temperature ranges between 24.2 °C in the winter and 39.4 °C in the summer in 2009. While extreme temperature in Phra Nakorn Si Ayutthaya province was between 18.2 °C and 37.6 °C respectively. Because of the requirement of using glass wall for buildings in the tropical climates zone with high ambient temperature, this study of using glass Double Skin Façade (DSF) could be a guideline if designed properly to both providing daylight and to reduce heat transfer into the building.

A paper regarding to investigation on thermal performance of glazed solar chimney walls (GSCW) and it confirmed that GSCW can reduce heat gain through glass wall into the house by developing air circulation which during daytime, indoor temperature will be much lower than which may help reducing demand on electrical energy for air conditioning (Chantawong et al, 2006).

Design consideration for DSF accordance to the above literature review, there are consequences and limitations for this research as follows.

1. Buffer façade is chosen for this glass DSF thesis study because it's the most common façade amongst three typical types. This study relates to type one "Buffer Façade" by letting cool air flow in at the bottom part and hotter air rises and eventually flows out on the top part. It's not related to type two "Extract air façade" because HVAC system is not included in the air cavity. And it's not related to type three "Twin-face façade" because there are not opening windows in the mock ups due to the small size of mock ups (only 1.2 m).

2. The air cavity of 0.30 m was chosen because it's sufficient space for letting air flow in and out of buffer façade system and for mock ups testing with reasonable cost.

3. Two types of glass for mock ups are (a) 6.00 mm green tinted glass for inner primary glass wall because single glazing was commonly used for existing buildings and (b) 6.00 + 6.00 mm Clear laminated glass for outer skin because of the safety regulation applied for current buildings and not expensive.

4. Size of each mock up is 0.9 x 0.9 x 1.2 m (w x l x h).

5. Mock ups testing site is located at Phra Nakorn Si Ayutthaya province, close to Bangkok (~ 40 km) with similar climate. Data recorded was being executed mainly during day time (from 10.00 to 17.00) due to the limitation of temperature reading by men.

6. A thesis of "An Appropriate Glass Double Skin Façade (DSF) for retrofitting buildings in Thailand" is aimed to point out (a) it is an interest of this industry for future career path, (b) there are many buildings in Thailand that designed and built with such modern façade and (c) would like to introduce a guideline of applying glass DSF for buildings with Thailand's climate condition due to the economical reason of saving around 7% of energy consumption for cooling load if indoor temperature decrease by 1 °C (Khedari, 2009).

MATERIALS AND METHOD

Materials

1. Temperature measurement tools, Digital Thermometers model MT-1 were used to measure temperature at various positions. These units are used in the range -50 - +70 °C (Error margin ± 1 °C).



Figure 24 Thermometer used to record temperature

2. Air velocity was measured using a multi parameter model Testo 400 D-79853. This unit is to measure in the range 0-15 m/s (± 0.05 m/s).



Figure 25 Multi parameter Testo 400 D-79853 (0-15 m/s, ± 0.05 m/s)

3. Thermal insulation was rockwool Fibertex-B40, density of 40 Kg/m³ with thickness of 50 mm, manufactured by CSR insulation (Thailand) Ltd.

4. Alu. louver (AA 6063 T5) “Z Shape”, in dimension of 0.3 x 0.9 m (w x l) attached to top of mock up Case-C.

5. Extended alu. grille (AA 6063 T5) in dimension of 0.3 x 0.9 m (w x l) attached to bottom of mock up Case-C.

6. Glass used were (a) 6.00 mm Green tinted float glass manufactured by Thai Asahi glass company for first layer of façade as inner skin and (b) 6.0+6.0 mm Clear laminated glass for a second layer of façade as external skin manufactured by PMK-Central glass Co., Ltd.

Table 4 Glass specifications

| GLASS SPECIFICATION | Visible rays | | Solar Energy | | U-Value | SC-Value | Remarks |
|--|----------------------|--------------------------|----------------------|-------------------|------------------------------------|----------|-----------|
| | Transmittance (+/-2) | Reflectance (out) (+/-2) | Transmittance (+/-2) | Absorption (+/-2) | (W/m ² K) (+/-0.2) | (+/-0.2) | |
| FLOAT GLASS 3.0 mm thk. Clear annealed glass | 90 | 7 | 86 | 6 | 5.84 | 1 | Reference |
| 6.0 mm thk. Green tinted annealed glass | 72 | 7 | 42 | 51 | 6.23 | 0.65 | Mock up |
| | | | | | Source: Thai Asahi glass company | | |
| LAMINATED GLASS 6.0 mm thk. Clear float glass + 0.76 mm + 6.0 mm thk Clear float glass (Laminated) | 85 | 9 | 53 | 30 | 5.66 | 0.82 | Mock up |
| +6.0 mm thk Green tinted glass + 0.76 mm + 6.0 mm thk. Clear float glass (Laminated) | 7 | 31 | 3 | 79 | 6.06 | 0.28 | Reference |
| | | | | | Source: PMK-Central glass Co., Ltd | | |

7. Three sets of mock ups in dimension of 0.9 x 0.9 x 1.2 m (w x l x h) made of steel structure frame, clad with 2.0 mm alu. sheet (AA 3105 H24) manufactured by Otefal Spa, Italy were assembled. Apart from the glass façade, all sides covered by 50 mm thickness of rockwool insulation material to avoid heat gain admission from other sides of the mock ups.



Figure 26 Fabrication of mock ups at the site (Lad Bua Luang, Phra Nakorn Si Ayutthaya province).

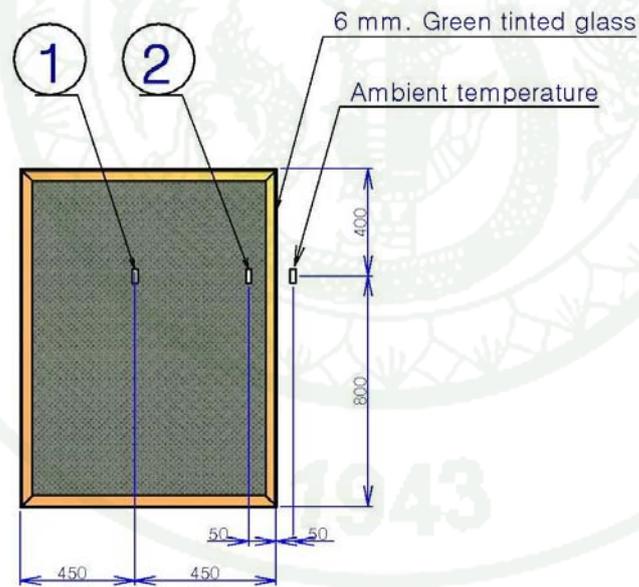
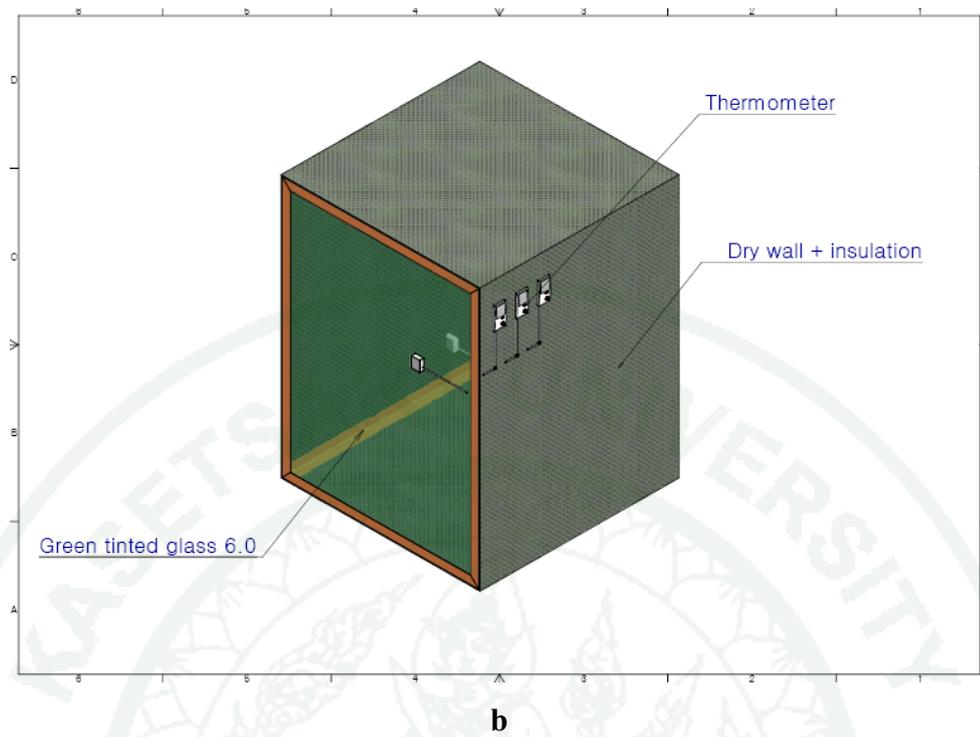


Figure 27 (Continued)

7.2 Mock up Case-B, (represents the glass DSF without ventilation), by using (a) single glass of 6.0 mm of green tinted annealed glass as an inner skin facade and (b) 6.0 + 6.0 mm clear laminated glass with 300 mm cavity, top and bottom sealed with green tinted glass. And a modification of this mock up to be mock up Case-B.1, (represents the glass DSF with air ventilation) by using (a) single glass of 6.0 mm of Green tinted annealed glass as an inner skin facade and (b) 6.0 + 6.0 mm clear laminated glass with 300 mm cavity, top and bottom fully open for air ventilation. Mock up is in dimension of 0.9 x 0.9 x 1.2 m (w x l x h), clad with 2.0 mm alu. panels and covered by 5.0 cm rockwool to prevent from variation factors. Glass DSF is in dimension of 0.3 x 0.9 x 1.2 m (w x l x h) and thermometers are installed (Figure 28), first one at the middle of the mock up and 400 mm away from the top (position 1), second one close to the glass or 50 mm from the back of 6.0 mm green tinted glass inside the mock up (position 2) and third one in the middle of the air cavity of glass DSF (position 3).

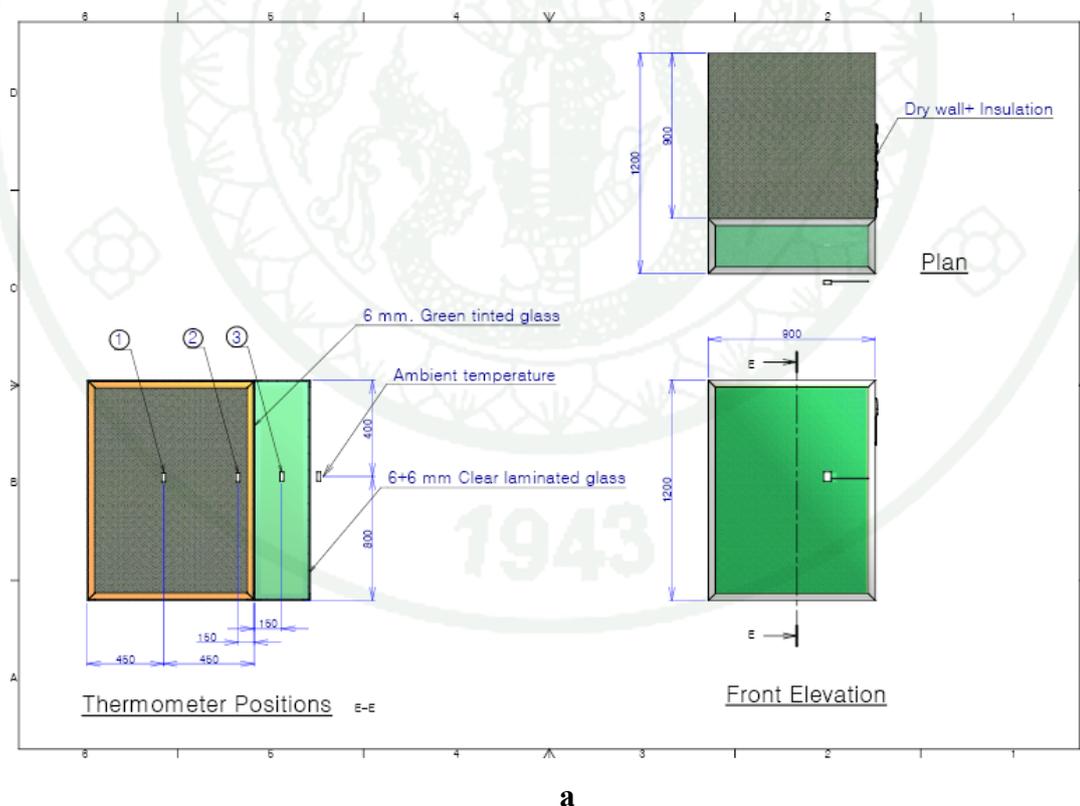
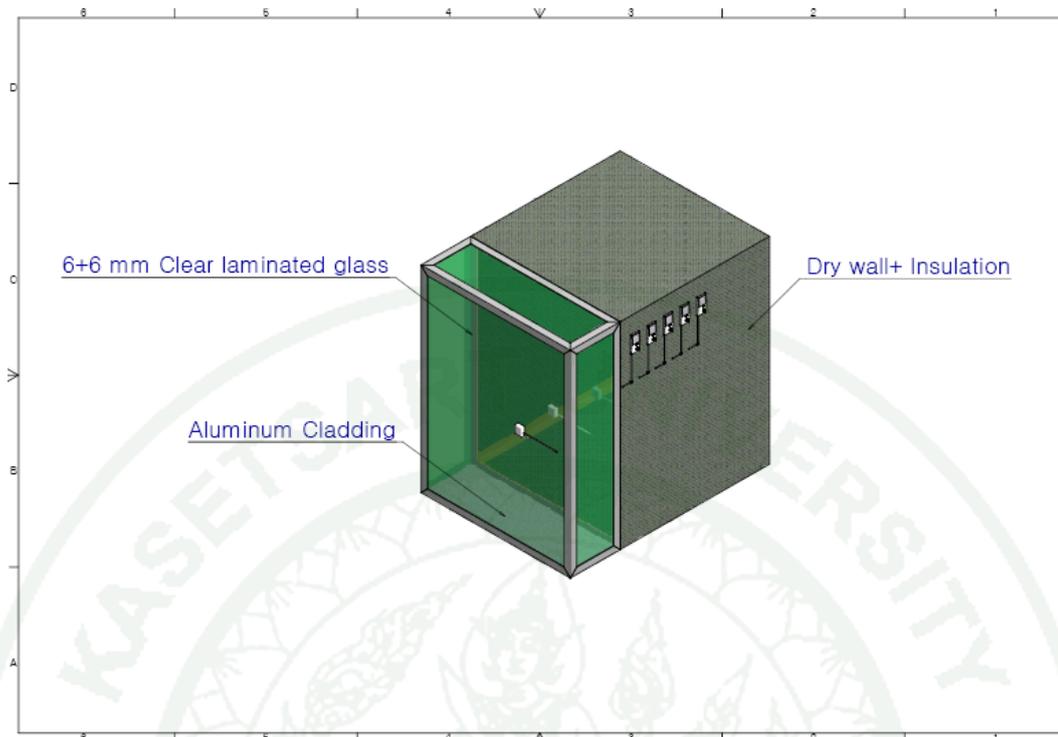
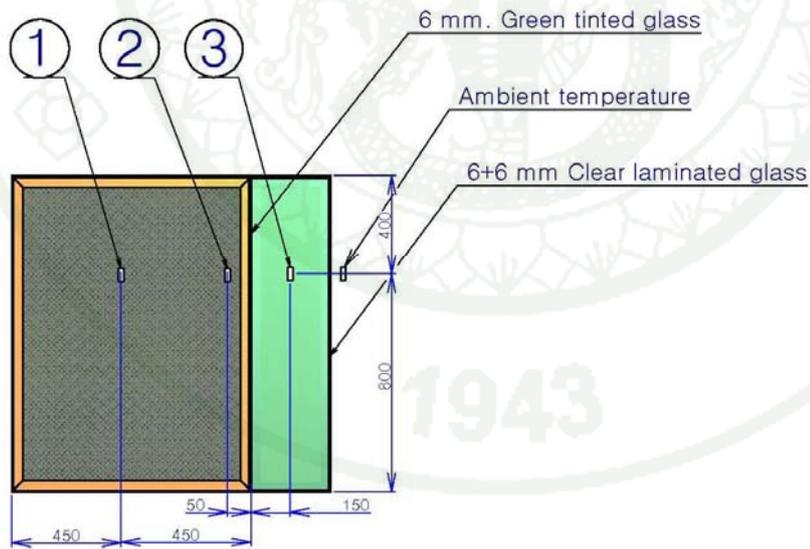


Figure 28 Drawings of mock up Case-B and / or B.1, included Plan, Elevation, Section, Isometric and temperature sensors positions.



b



c

Figure 28 (Continued)

7.3 Mock up Case-C, (represents the glass DSF with stack ventilation), by using (a) single glass of 6.0 mm green tinted annealed glass as an inner skin facade and (b) 6.0 + 6.0 mm clear laminated glass with 300 mm cavity. An attachment of a hood consists of (c) glass box in dimension of 0.3 x 0.3 x 0.9 m (w x h x l) with 2.0 mm Thk curve-black alu. sheet inserted to the top and alu. louver to the back side, facing North-East and (d) alu. extended grille attached to the bottom of DSF for “ Stack effect” air ventilation. Mock up is in dimension of 0.9 x 0.9 x 1.2 m (w x l x h), clad with 2.0 mm alu. panels and covered by 5.0 cm rockwool to prevent from variation factors. Glass DSF is in dimension of 0.3 x 0.9 x 1.2 m (w x l x h) and thermometers are installed (Figure 29), first one at the middle of the mock up and 400 mm away from the top (position 1), second one close to the glass or 50 mm from the back of the glass inside the mock up (position 2), third one in the middle of the air cavity of glass DSF (position 3) and fourth one at the bottom part of glass DSF or 100 mm above the alu. grille (position 4).

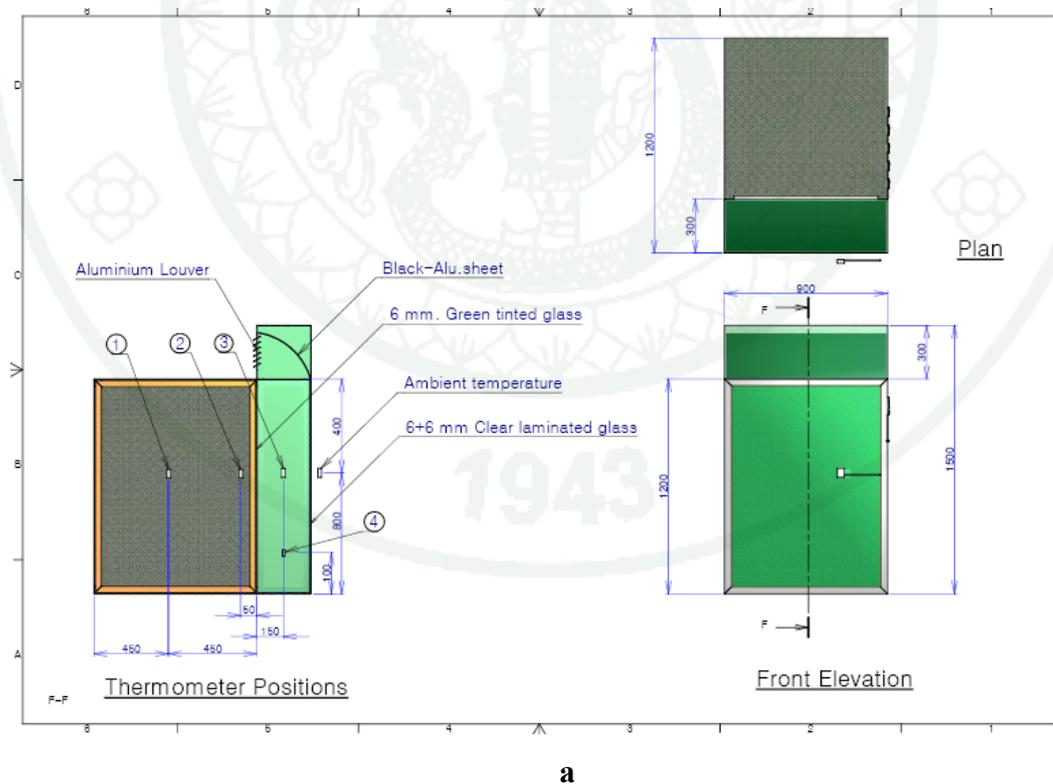
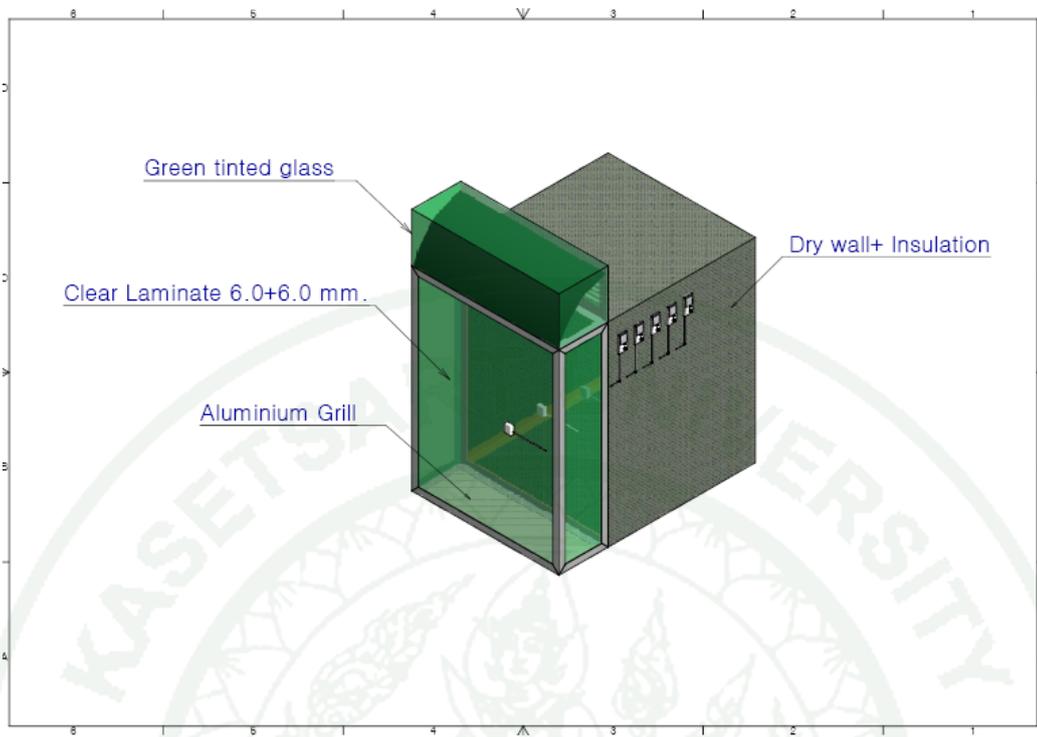
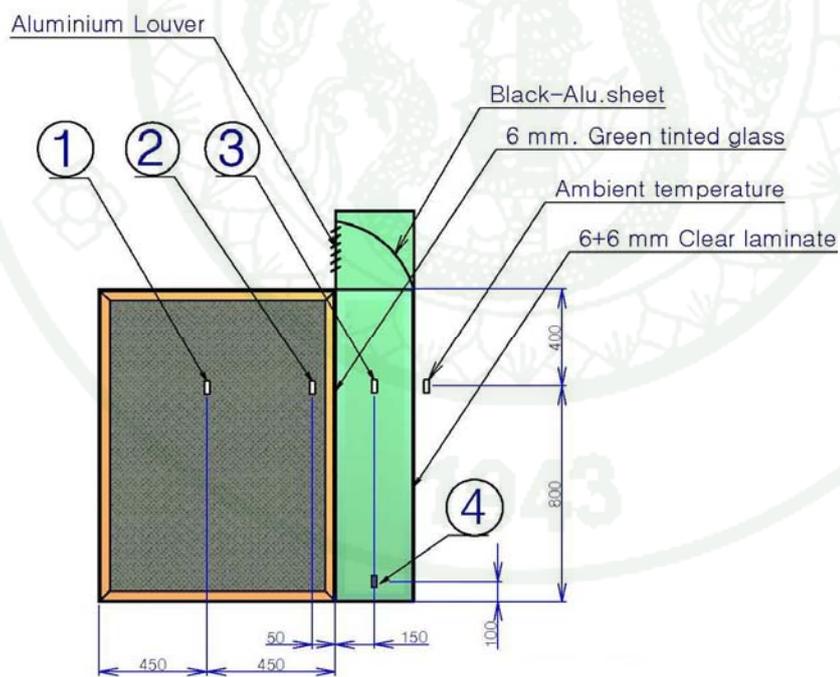


Figure 29 Drawings of mock up Case-C, included Plan, Elevation, Section, Isometric and temperature sensors positions.



b



c

Figure 29 (Continued)



Figure 30 Installation of three mock ups on rooftop at level of 3.0 m above the ground (existing building).

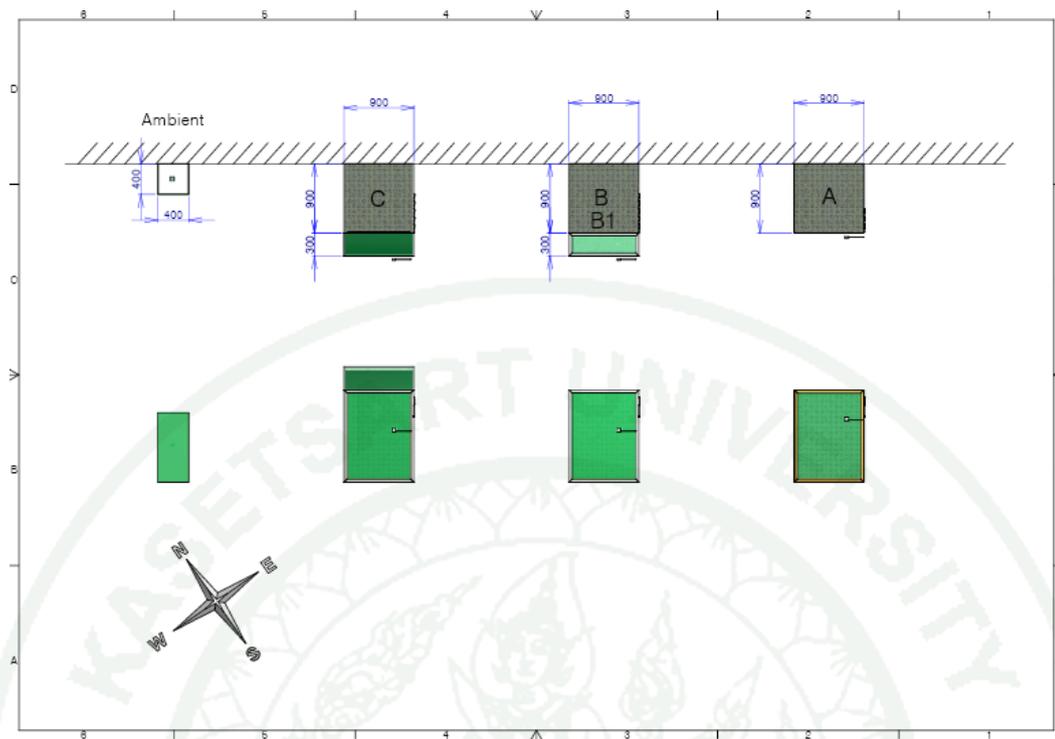


Figure 31 Lay out plan of mock ups

Three mock ups were installed (Figure 31), facing South-West. Two thermometers installed inside of each mock up, another two thermometers installed inside the air cavity of glass Double Skin Façade (DSF) at different levels. And one thermometer installed nearby to measure ambient air temperature. Testing was being carried out hourly from 10.00 to 17.00 for several weeks in several months of 2009 and from 10.00 to 22.00 for two days in January of 2010.

Method

Data were recorded during several months as follows

1. Temperatures measurement at the various positions as explained earlier were conducted for the mock ups (Case-A, B and C) in several months starting from June till August 2009. Data collection started from 10.00 and ended at 17.00.

According to temperature data recorded in June 2009, three mock ups were not covered by insulation material (rockwool) yet, so the comparison of temperature will be conducted from July 2009 onwards.

2. A second series of temperature measured for mock up Case-A (Base case), mock up Case-B.1 (glass DSF with air ventilation by having top and bottom panels fully opened) and mock up Case-C (glass DSF with stack ventilation) in October 2009. Data collection started from 10.00 and ended at 17.00.

3. Air velocity measurement was conducted for mock up Case-B.1 (glass DSF with air ventilation by having top and bottom panels fully opened) and mock up Case-C (glass DSF with stack ventilation) in November 2009. Data collection started from 14.00 and ended at 15.00.

4. The last series of temperature measurements were performed for mock ups. A (represents the single pane of primary glass wall), B.1 (glass DSF with air ventilation by having top and bottom panels fully opened) and C (glass DSF with stack ventilation) in January 2010. Data collection started from 10.00 and ended at 22.00.

RESULTS AND DISCUSSION

1. Temperature profiles of mock up Case-A (base case). (Figure 32 to 35) showed the measured data for mock up Case-A which is made of a single pane of primary glass wall used as a base case. It can be observed that temperatures varied following the ambient conditions. The higher is the incident solar radiation, the hotter ambient temperature with high indoor temperature. Air temperature at position 2 (close to the glass) was always lower than that inside of the mock up (position 1), which is evident as the single glass is in contact with ambient while the inner space was well insulated at all sides. The maximum recorded temperature at position 1 was 52.7 °C during the measured period which is significantly high.

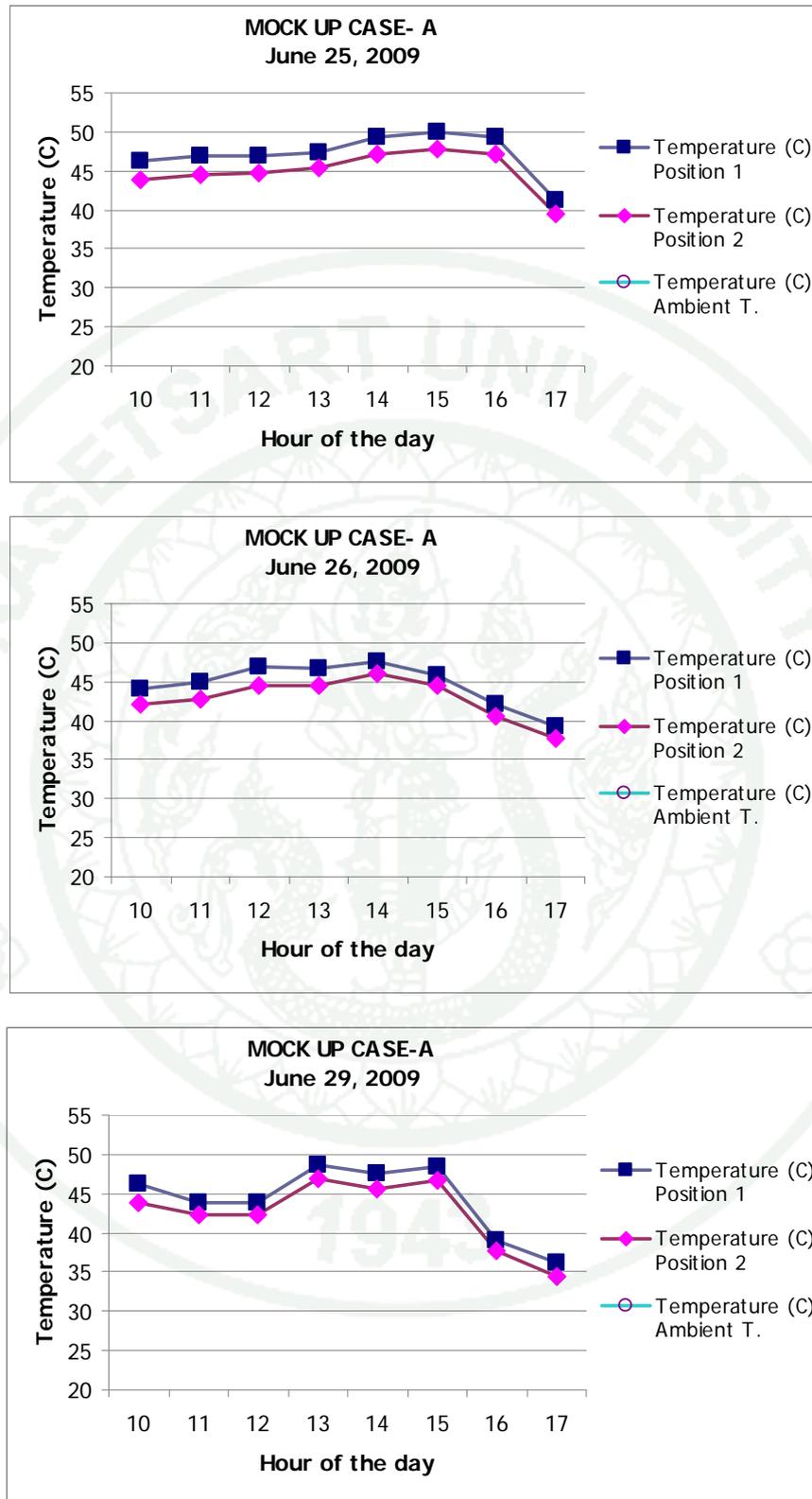


Figure 32 Temperature variations of different positions of the mock up Case-A on June 25th, 26th, 29th, 2009 (without rockwool).

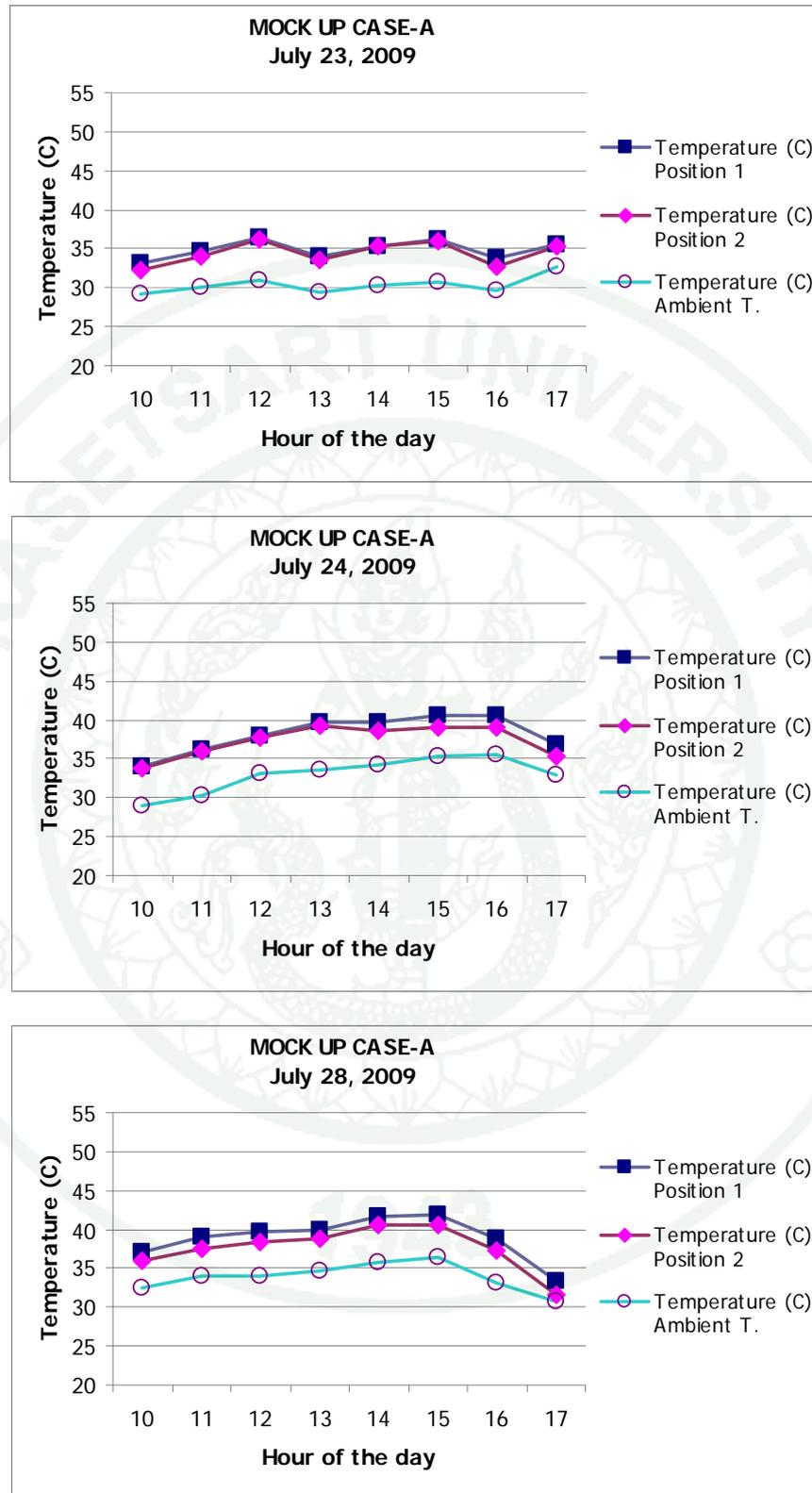


Figure 33 Temperature variations of different positions of the mock up Case-A on July 23rd, 24th, 28th, 30th, 31st, 2009.

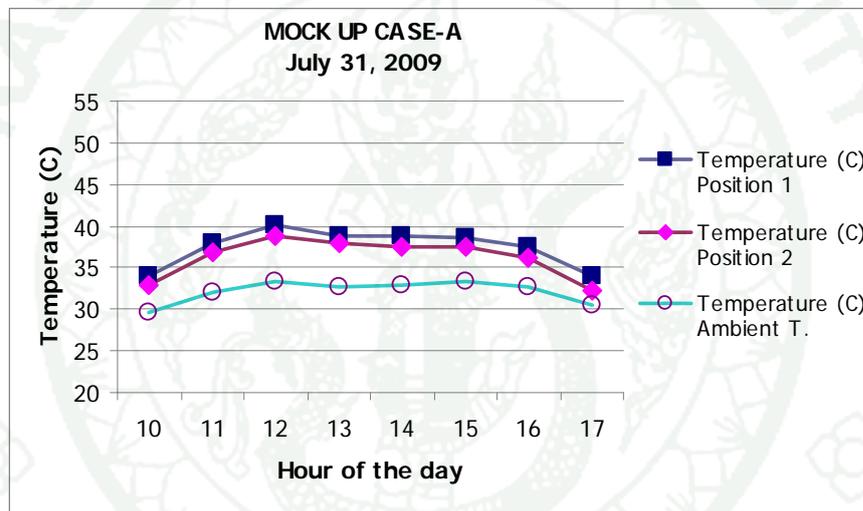
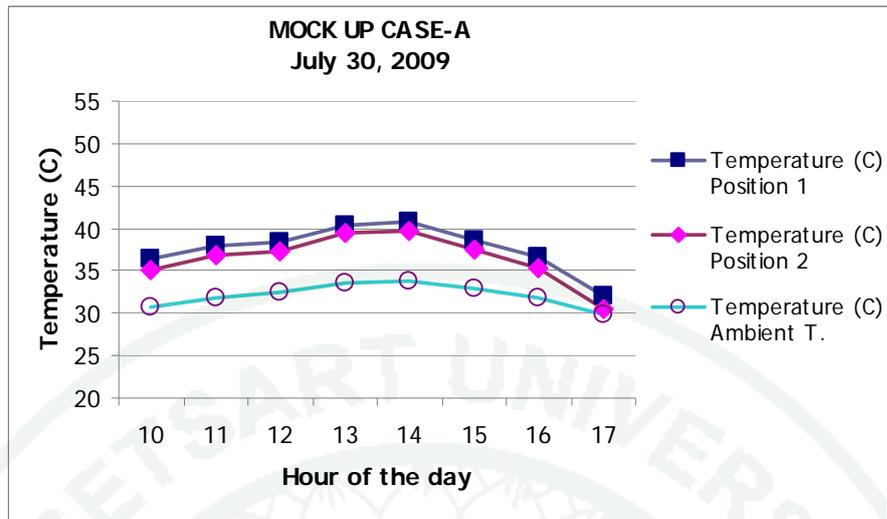


Figure 33 (Continued)

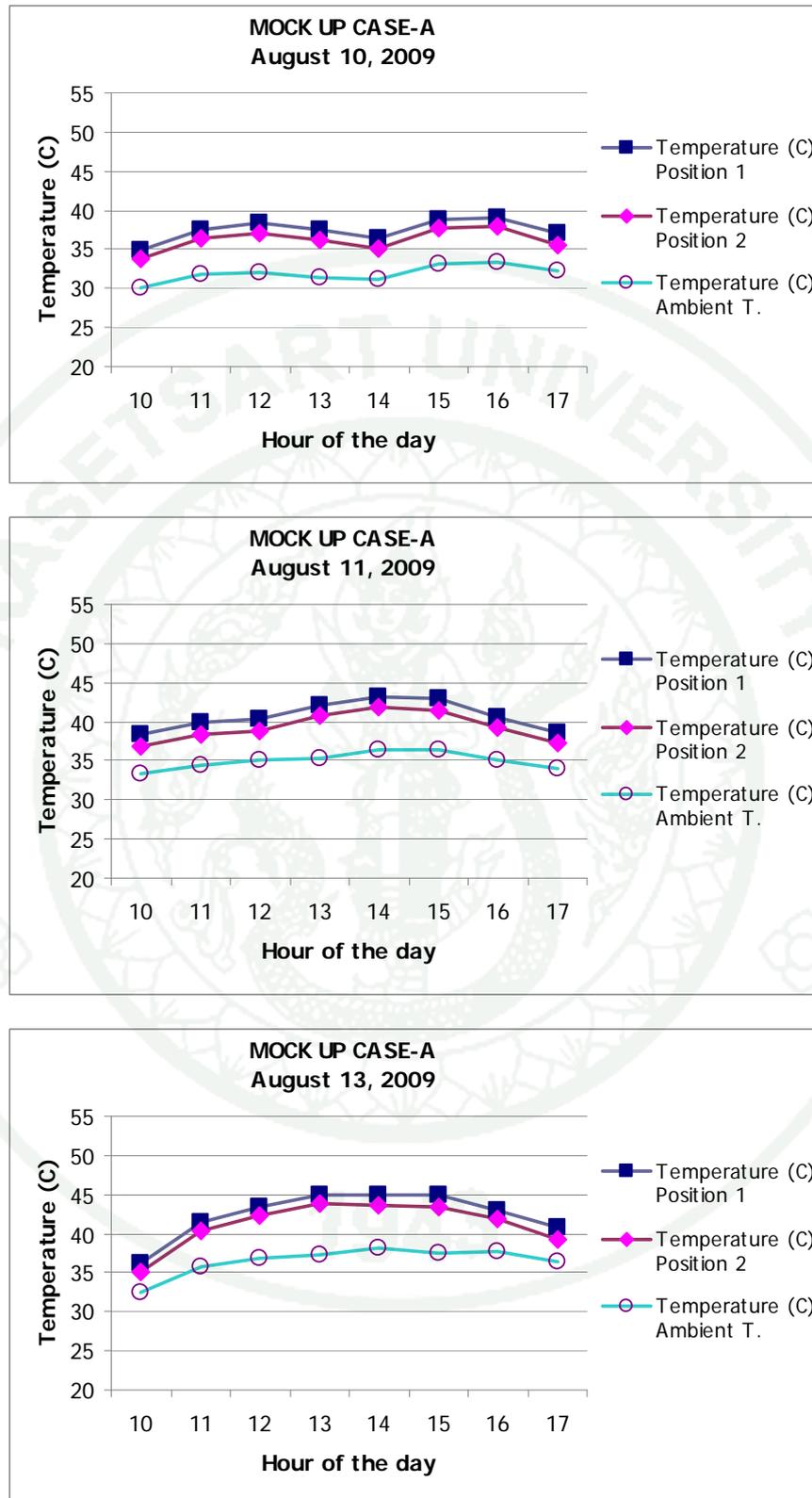


Figure 34 Temperature variations of different positions of the mock up Case-A on August 10th, 11th, 13th, 14th, 17th, 2009.

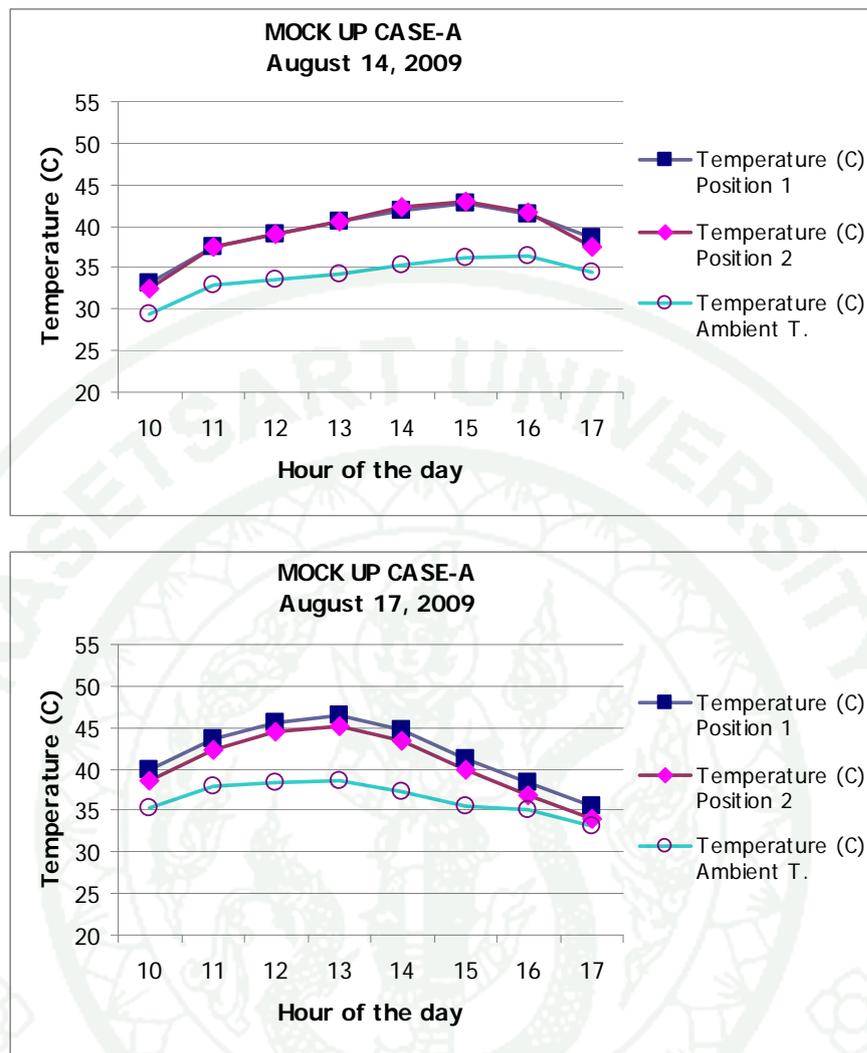


Figure 34 (Continued)

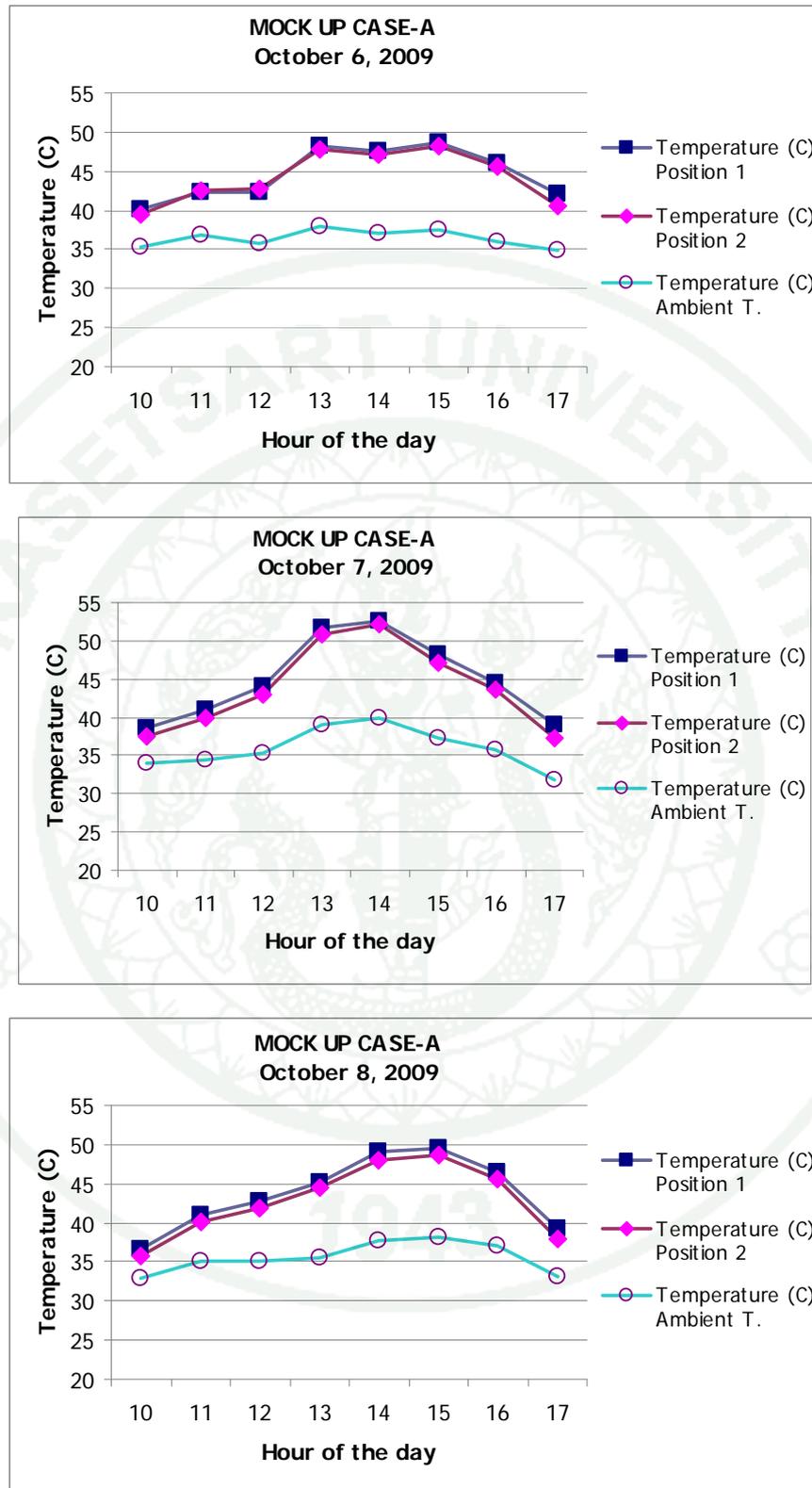


Figure 35 Temperature variations of different positions of the mock up Case-A on October 6th, 7th, 8th, 13th, 14th, 15th, 2009.

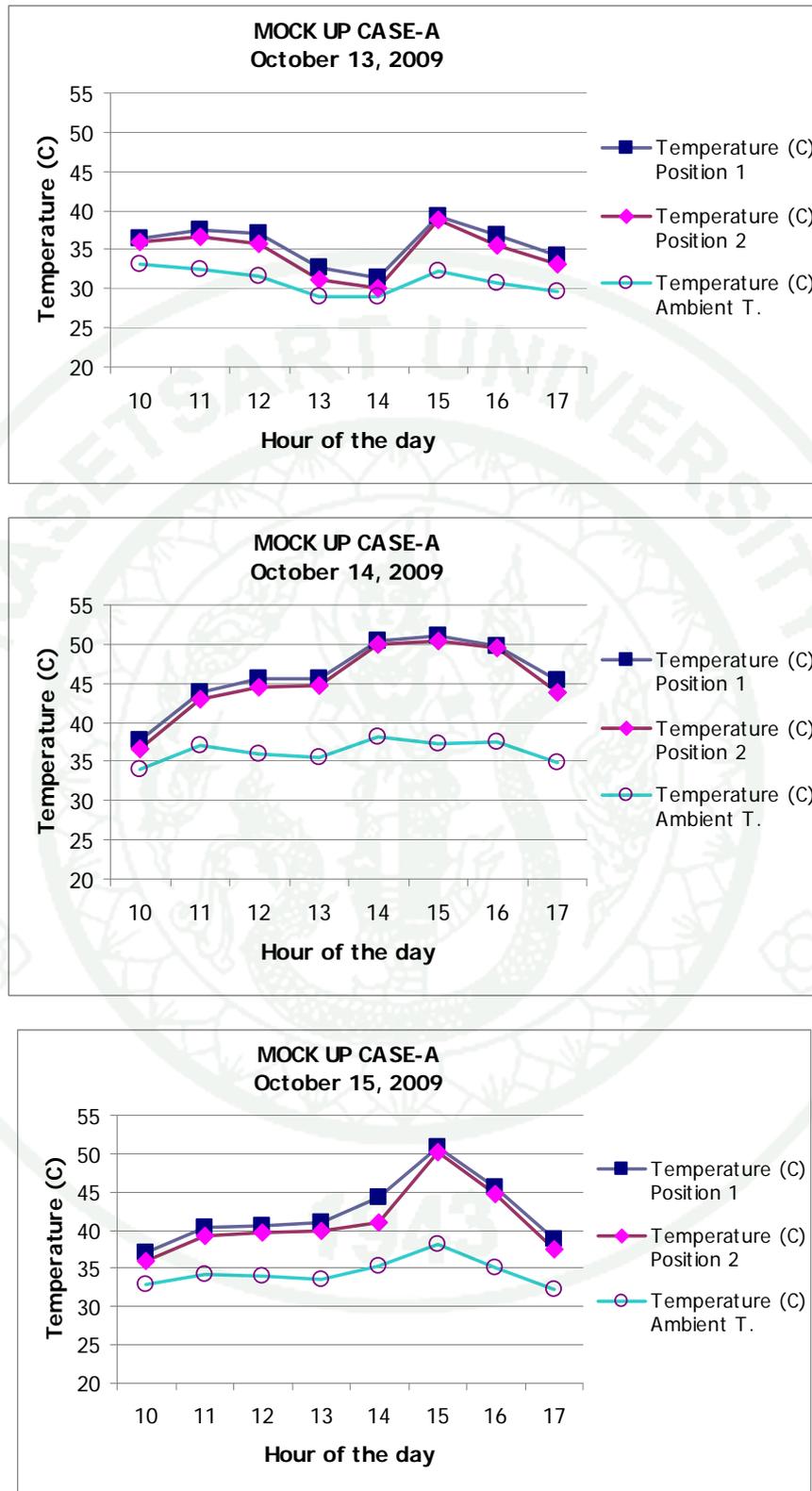


Figure 35 (Continued)

2. Temperature profiles of mock up Case-B (glass DSF without ventilation) and Case-B.1 (glass DSF with top and bottom of DSF opened for air ventilation), (Figure 36 to 39). It showed the measured data for both mock ups.

2.1 Mock up Case-B (June, July and August 2009), it can be observed that temperatures varied following the ambient conditions. The higher is the incident solar radiation, the hotter ambient temperature will high indoor temperature. Air temperature at position 2 (close to the inner glass) was very close to that inside of the mock up (position 1), while the air gab temperature (position 3) is always the highest which is evident that heat admission through outer layer of laminated glass was captured between the glass and heated up as the ambient temperature raised. The maximum recorded temperature at position 1 was 47.7 °C and at position 3 was 51.4 °C during the measured period.

2.2 Mock up Case-B.1 (October 2009 and January 2010), the same observation made earlier are still valid. The higher is the incident solar radiation, the hotter ambient temperature and high indoor temperature is recorded. Air temperature at position 2 (close to the inner glass) was very close to that of the air gab temperature (position 3), while the temperature inside the mock up (position 1) is always the highest which is evident that heat admission through outer layer of laminated glass, partly was flowed out to the top and being replaced by cooler air at the bottom of the gab. Temperature inside the mock up (position 1) heated up as the ambient temperature rose. The maximum recorded temperature at position 1 was 48.7 °C and position 3 was 44.1 °C during the measured period.

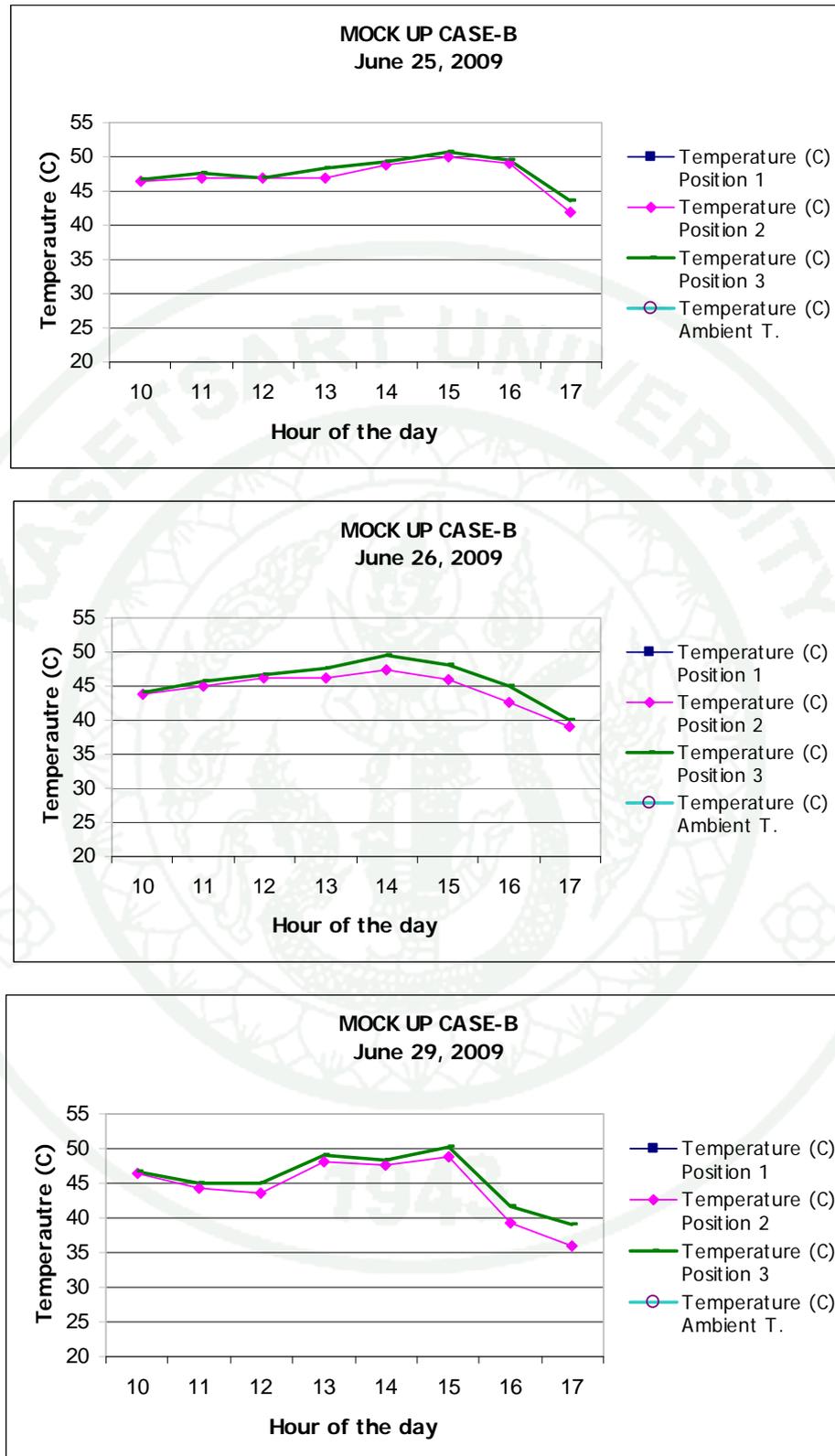


Figure 36 Temperature variations of different positions of the mock up Case-B on June 25th, 26th, 29th, 2009 (without rockwool).

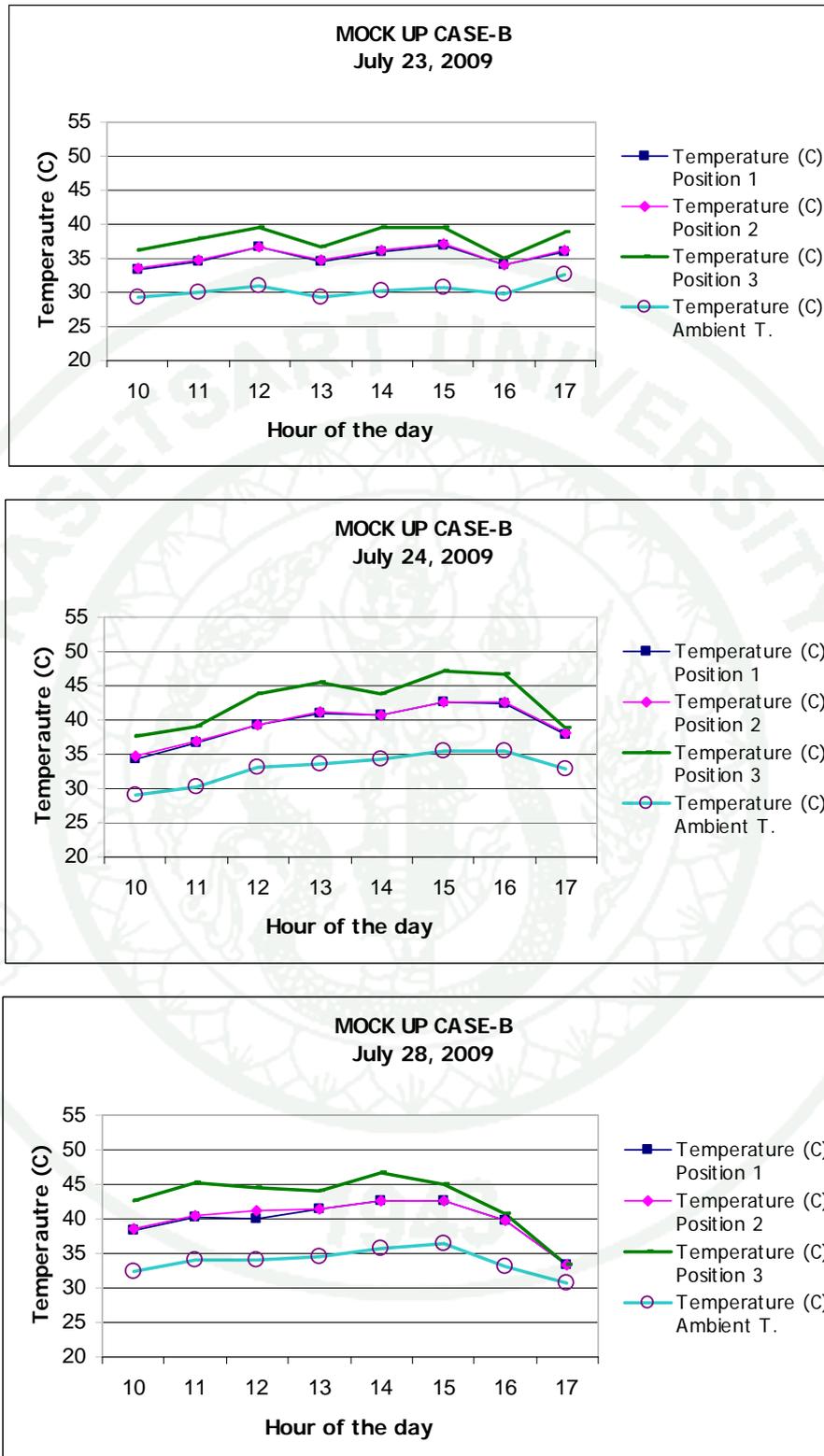


Figure 37 Temperature variations of different positions of the mock up Case-B on July 23rd, 24th, 28th, 30th, 31st, 2009.

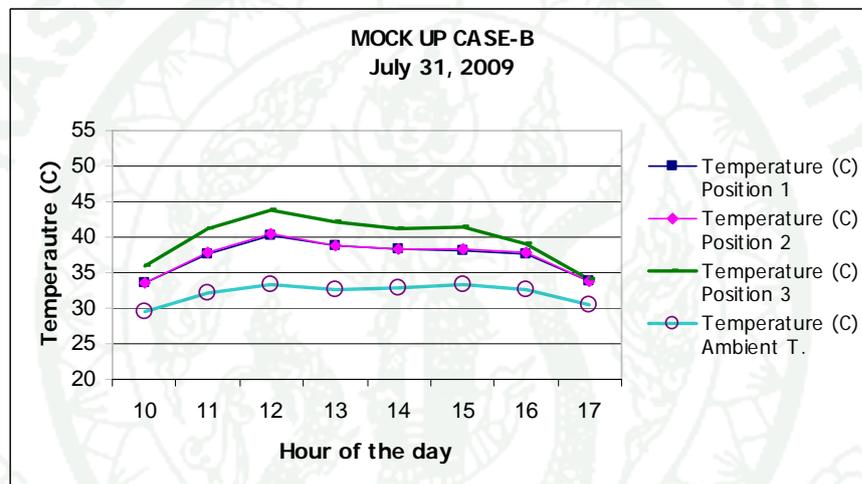
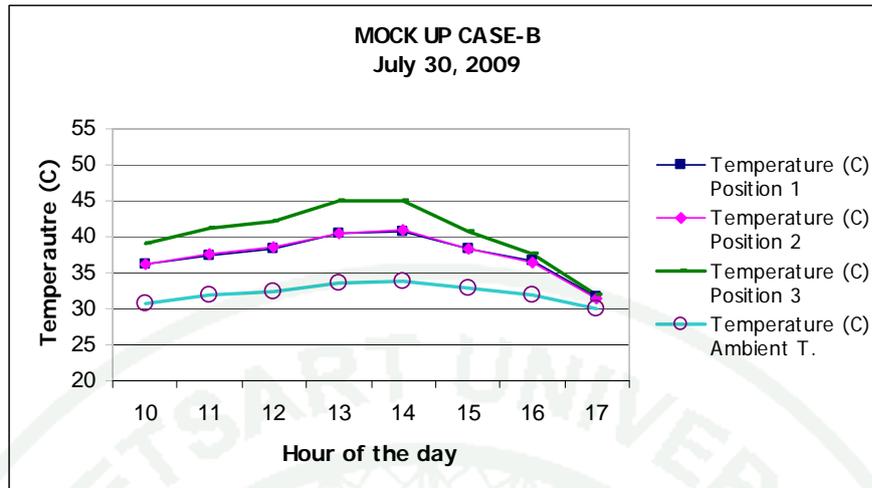


Figure 37 (Continued)

1943

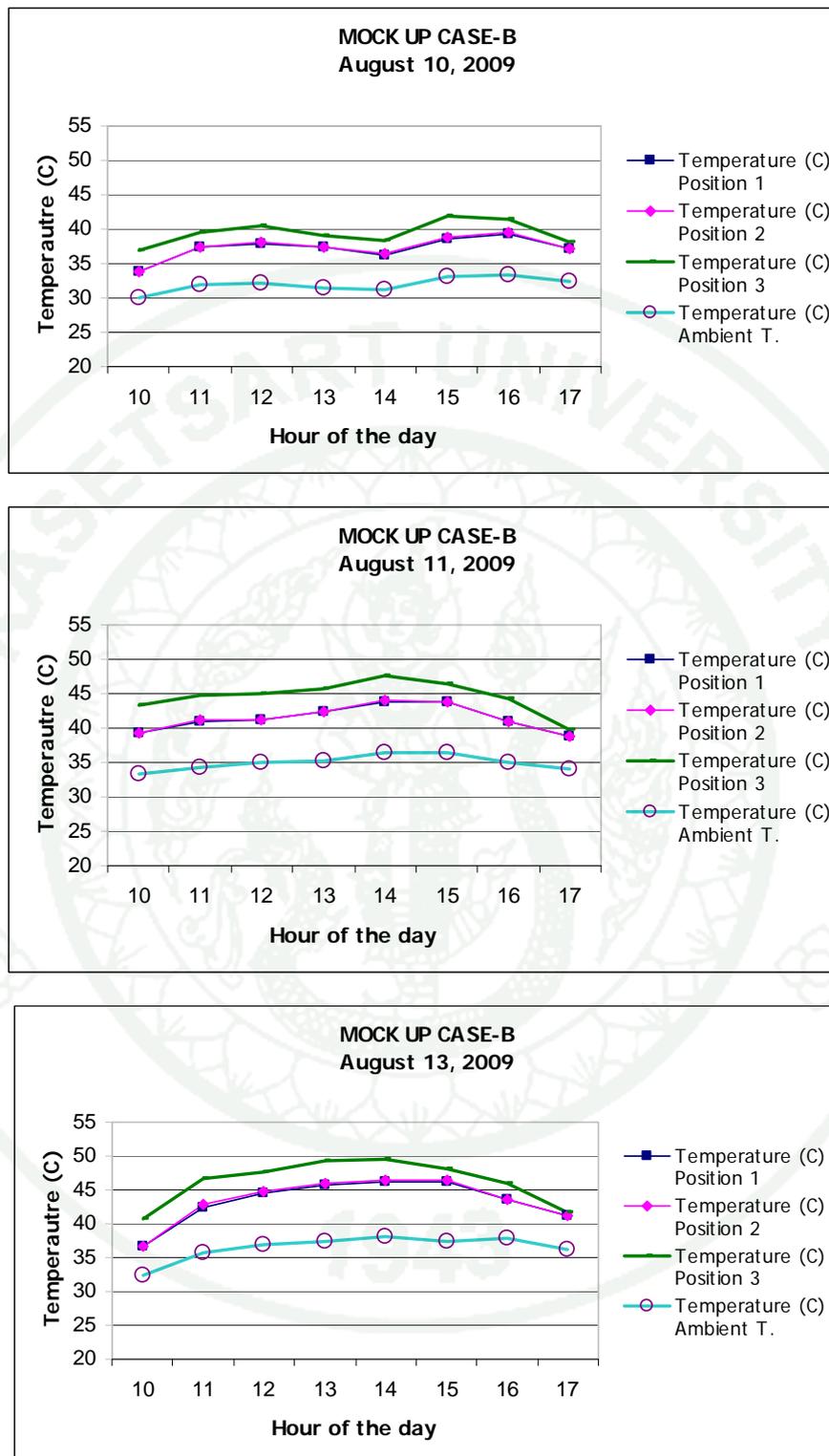


Figure 38 Temperature variations of different positions of the mock up Case-B on August 10th, 11th, 13th, 14th, 17th, 2009.

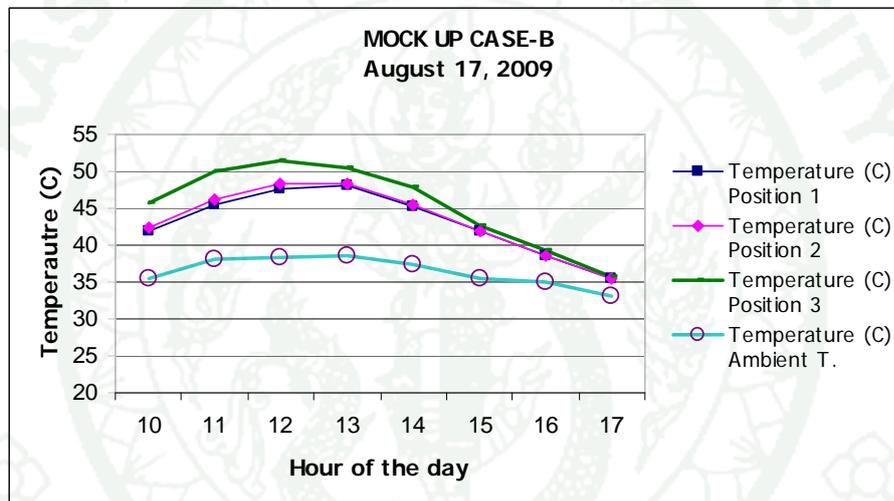
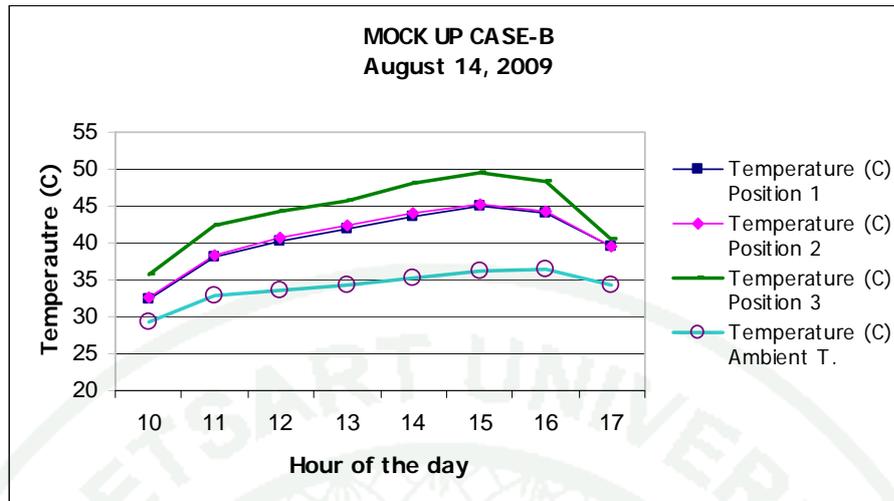


Figure 38 (Continued)

1943

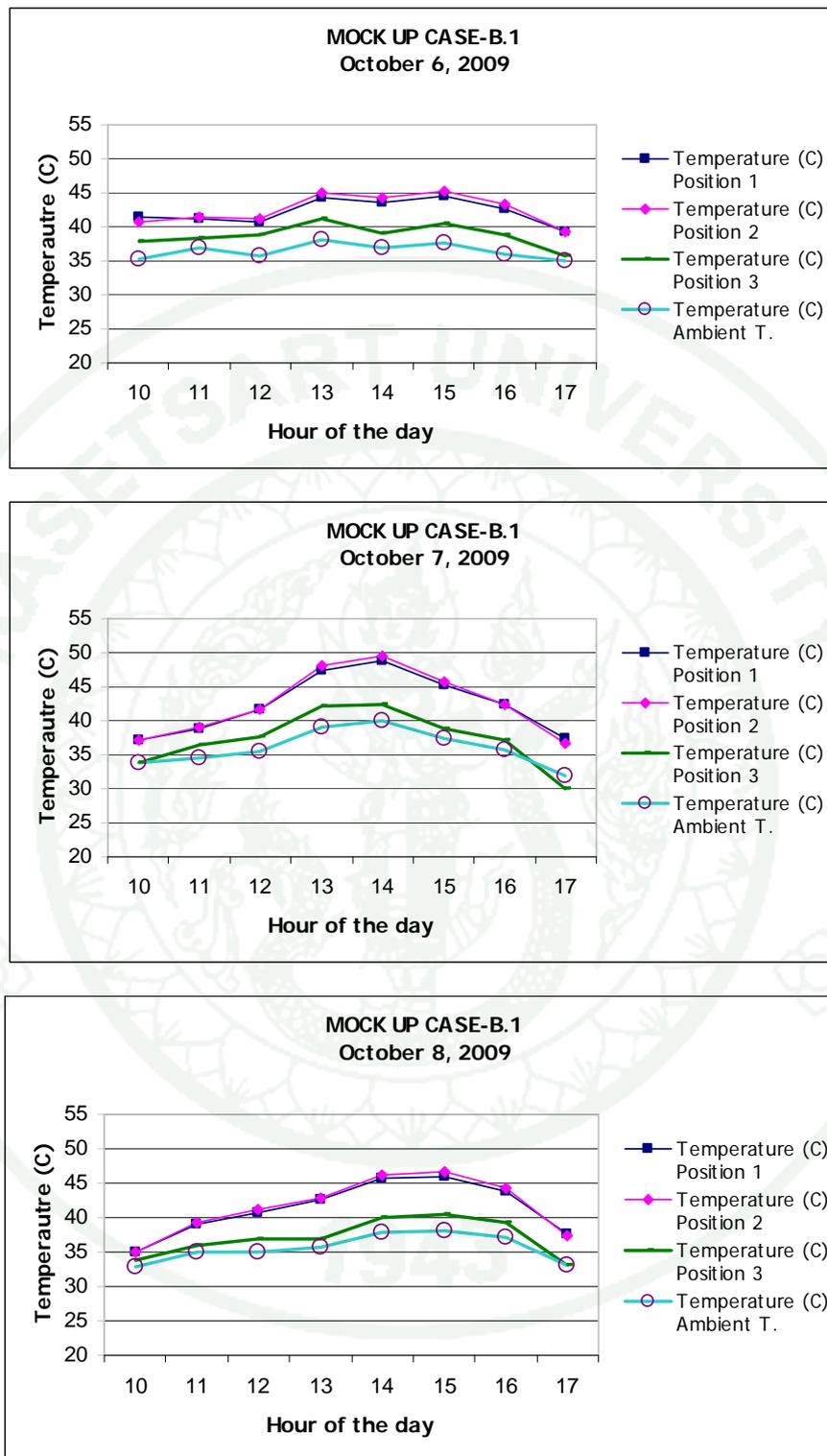


Figure 39 Temperature variations of different positions of the mock up Case-B.1 on October 6th, 7th, 8th, 13th, 14th, 15th, 2009.

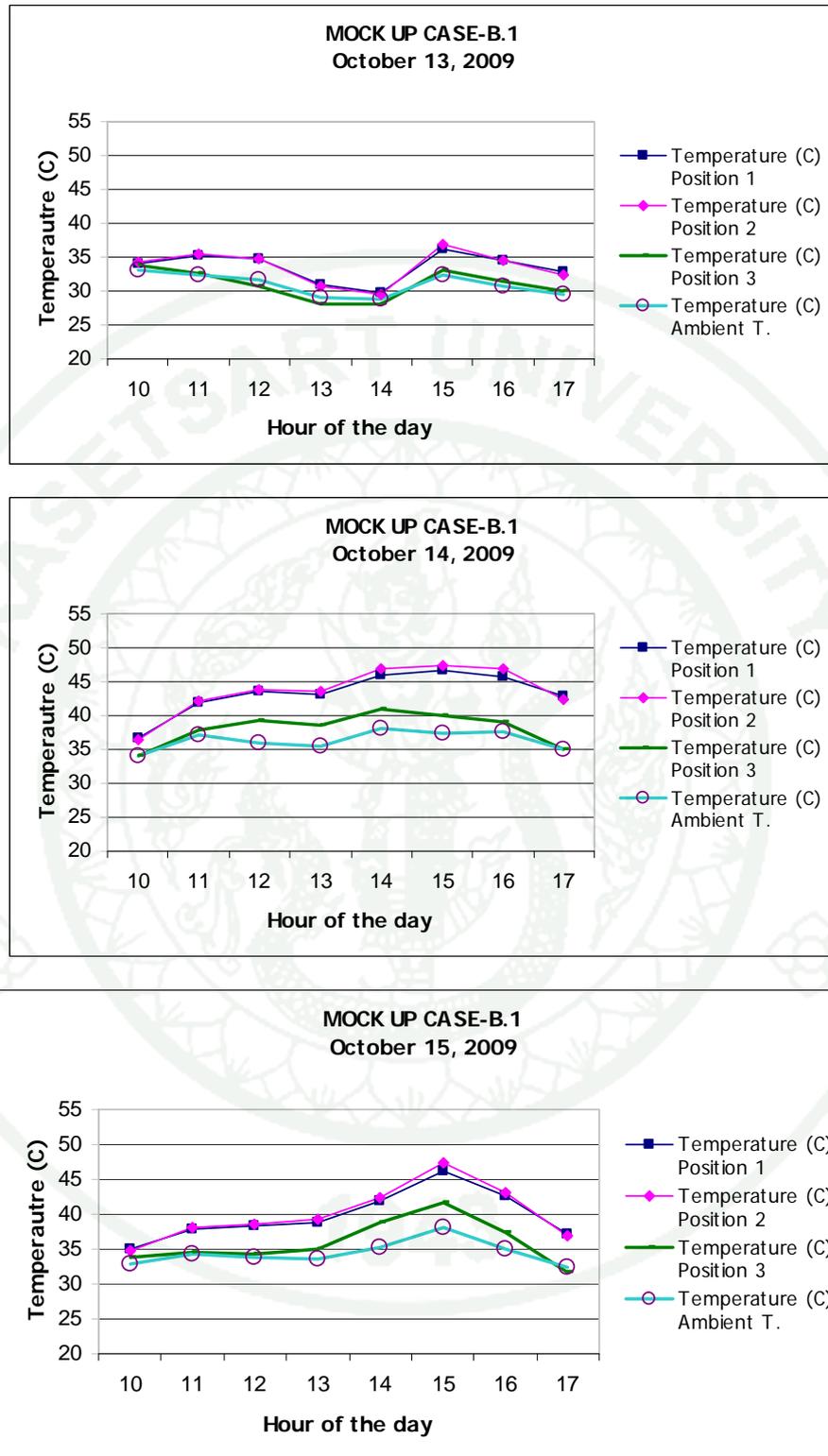
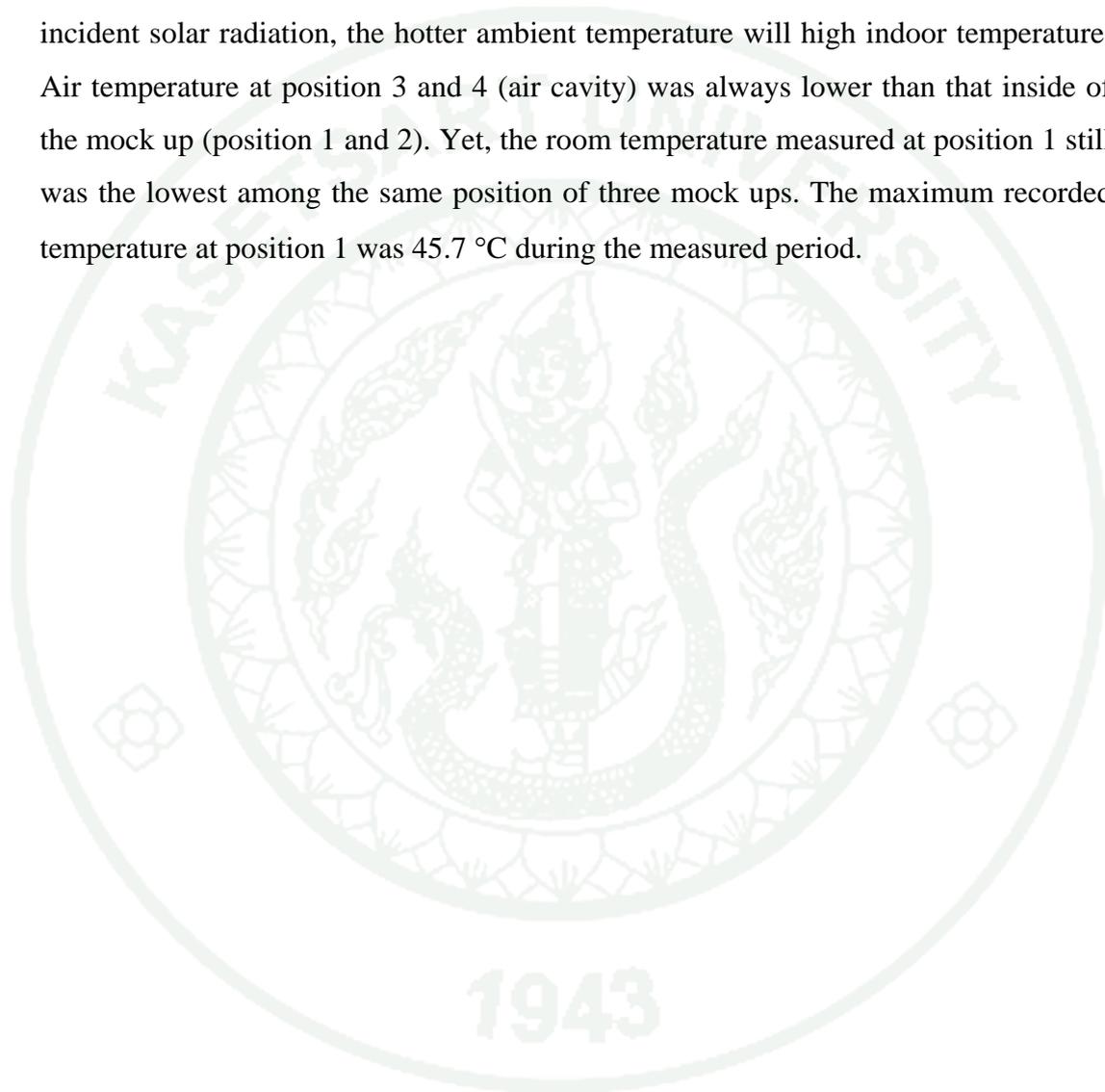


Figure 39 (Continued)

3. Temperature profiles of mock up Case-C (glass DSF with stack ventilation), (Figure 40 to 43). It showed the measured data for mock up Case-C which is made of (a) single glass of 6.0 mm green tinted annealed glass as an inner skin facade and (b) 6.0 + 6.0 mm clear laminated glass with 300 mm cavity. It can be observed that temperatures varied following the ambient conditions. The higher is the incident solar radiation, the hotter ambient temperature will high indoor temperature. Air temperature at position 3 and 4 (air cavity) was always lower than that inside of the mock up (position 1 and 2). Yet, the room temperature measured at position 1 still was the lowest among the same position of three mock ups. The maximum recorded temperature at position 1 was 45.7 °C during the measured period.



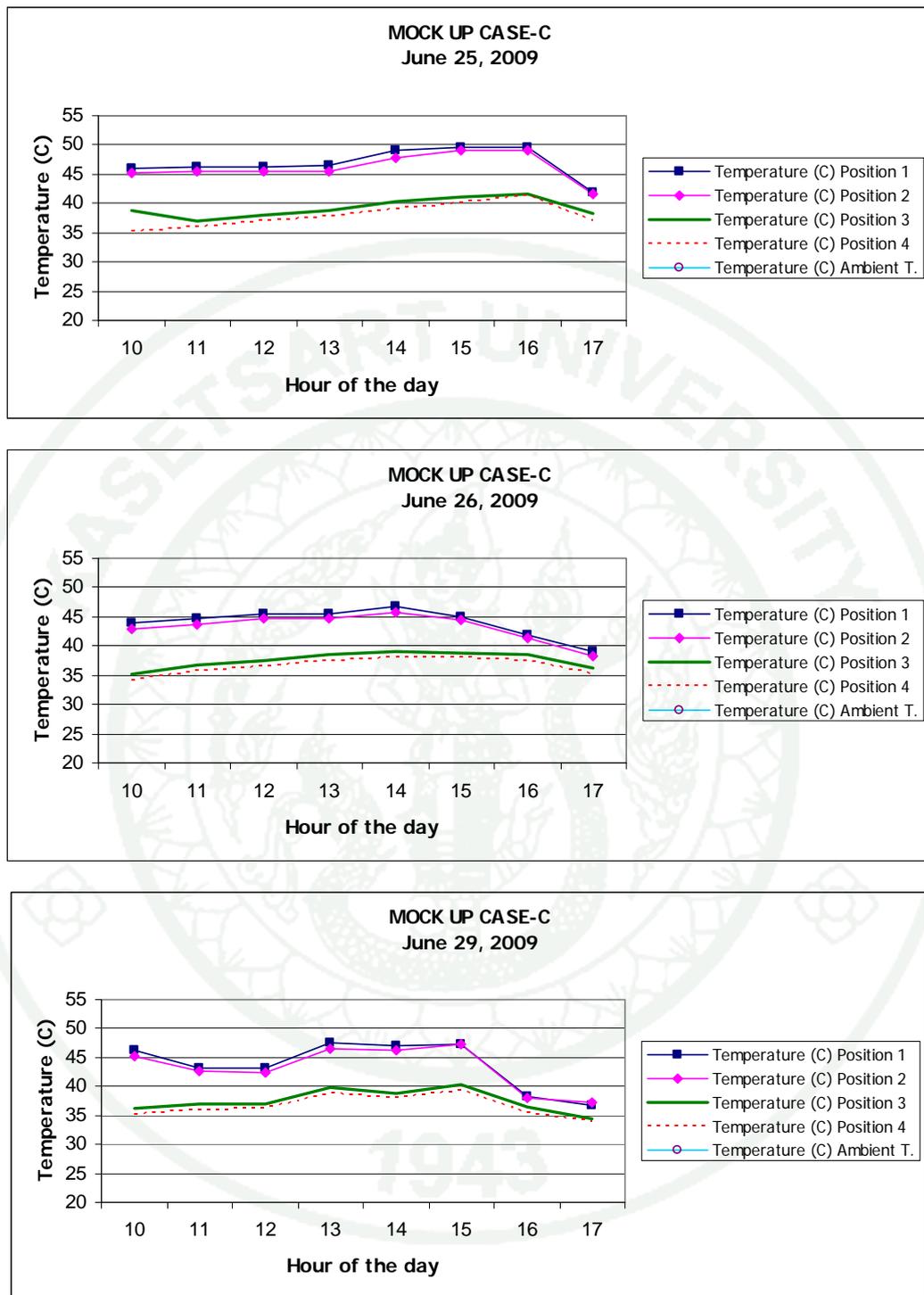


Figure 40 Temperature variations of different positions of the mock up Case-C on June 25th, 26th, 29th, 2009 (without rockwool).

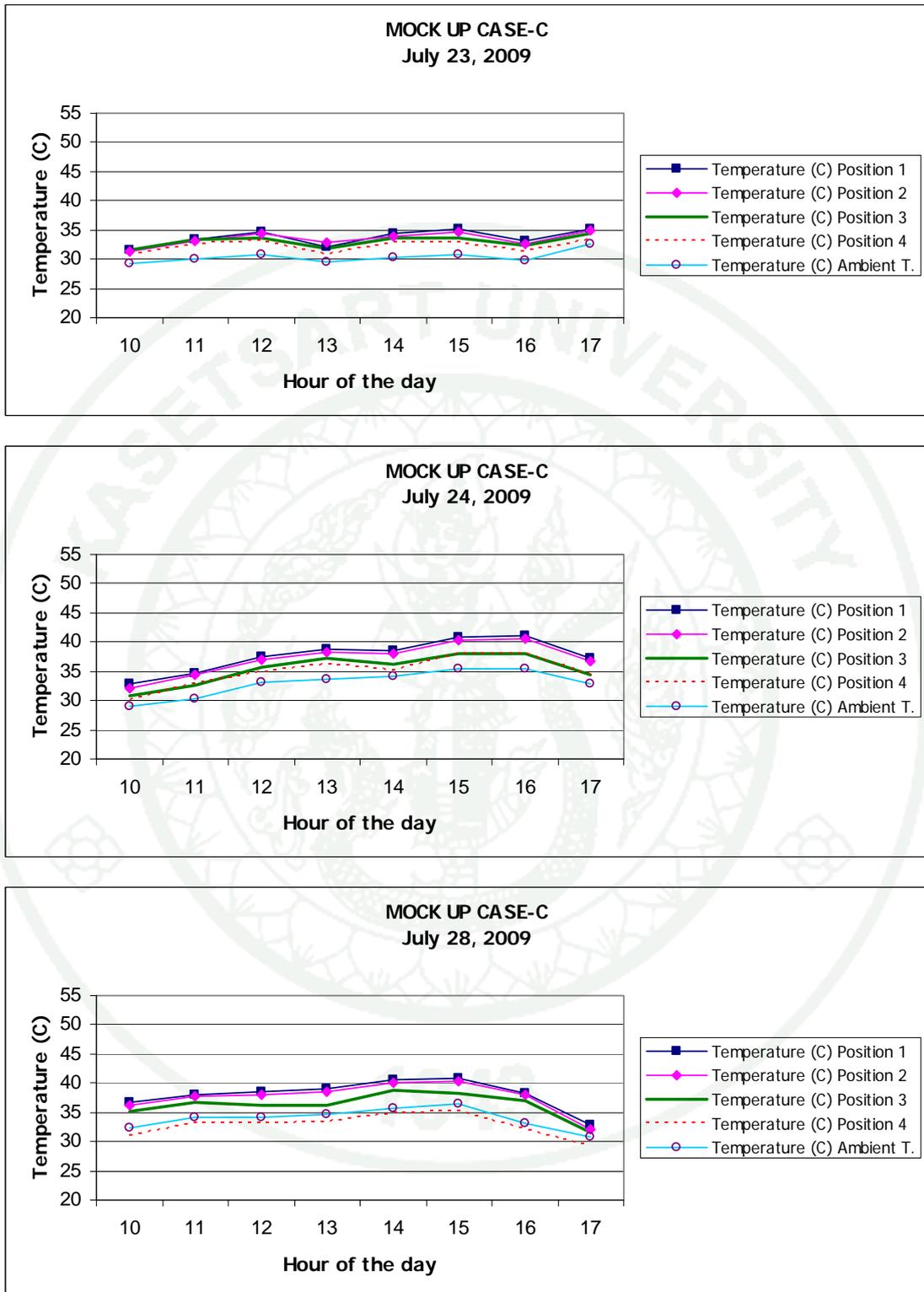


Figure 41 Temperature variations of different positions of the mock up Case-C on July 23rd, 24th, 28th, 30th, 31st, 2009.

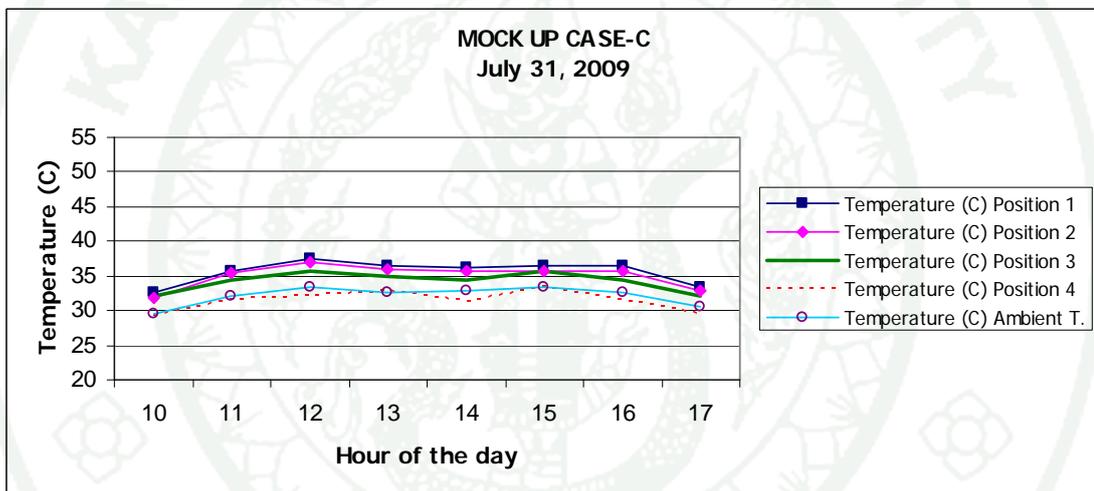
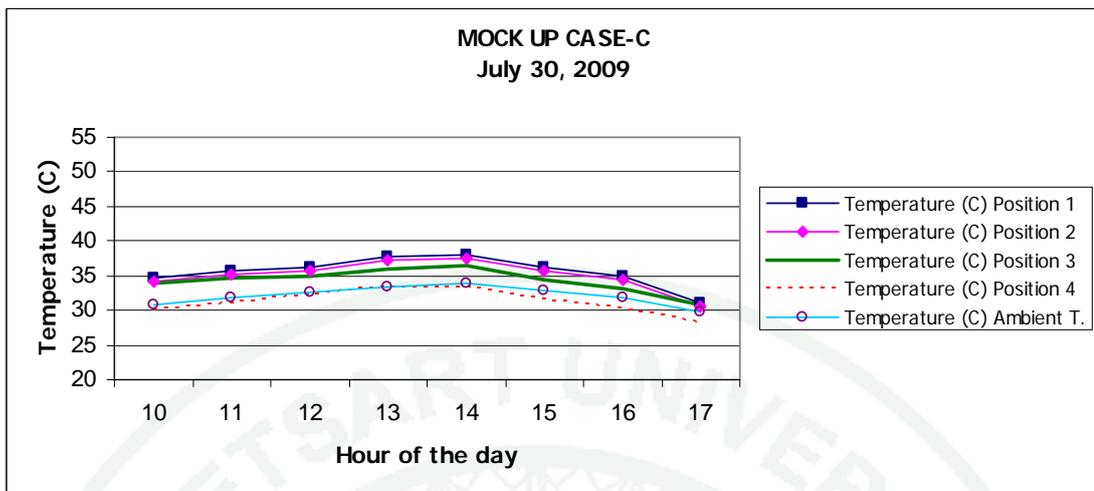


Figure 41 (Continued)

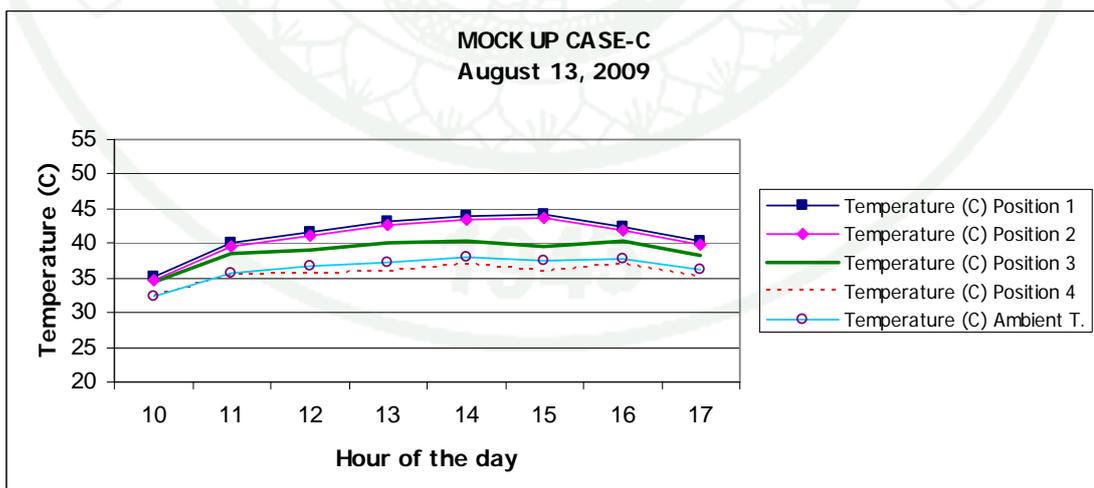
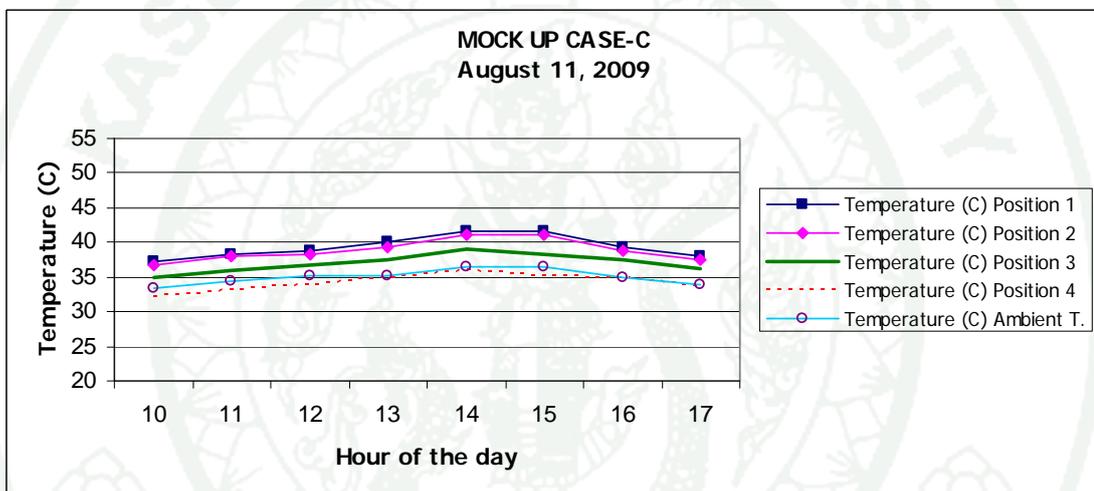
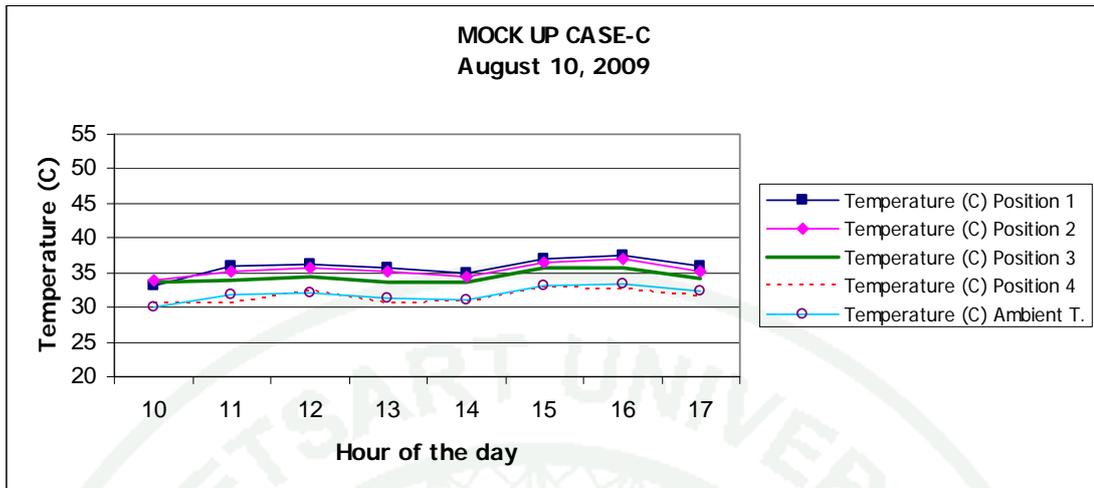


Figure 42 Temperature variations of different positions of the mock up Case-C on August 10th, 11th, 13th, 14th, 17th, 2009.

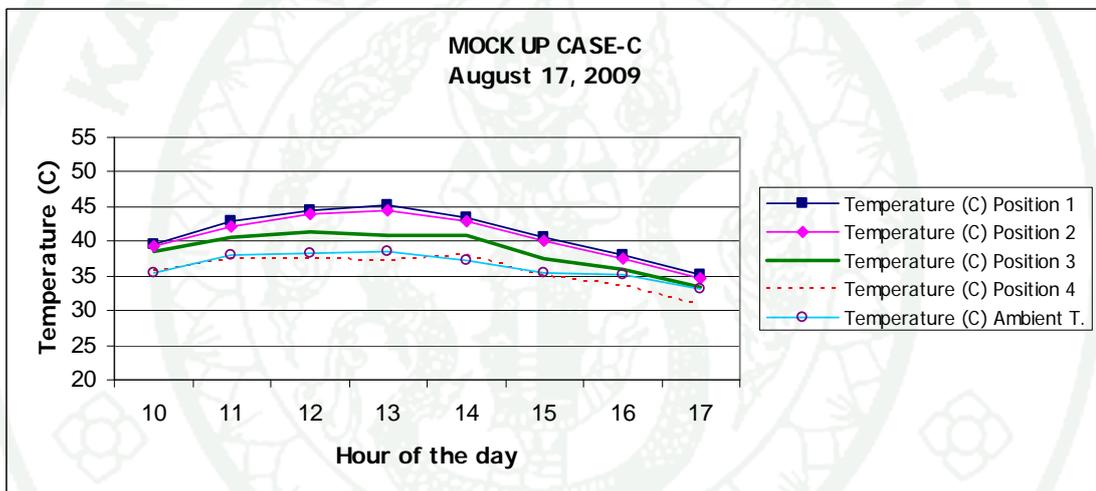
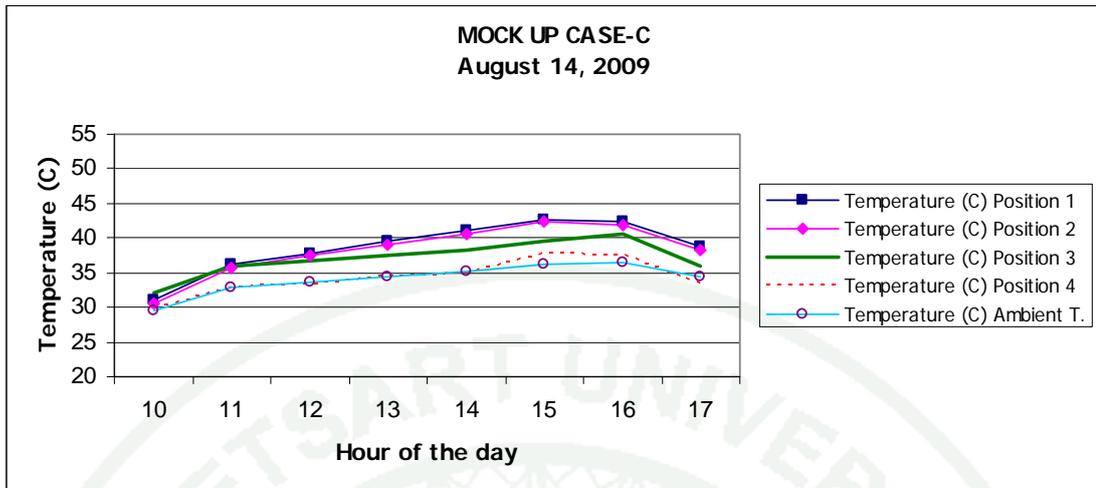


Figure 42 (Continued)

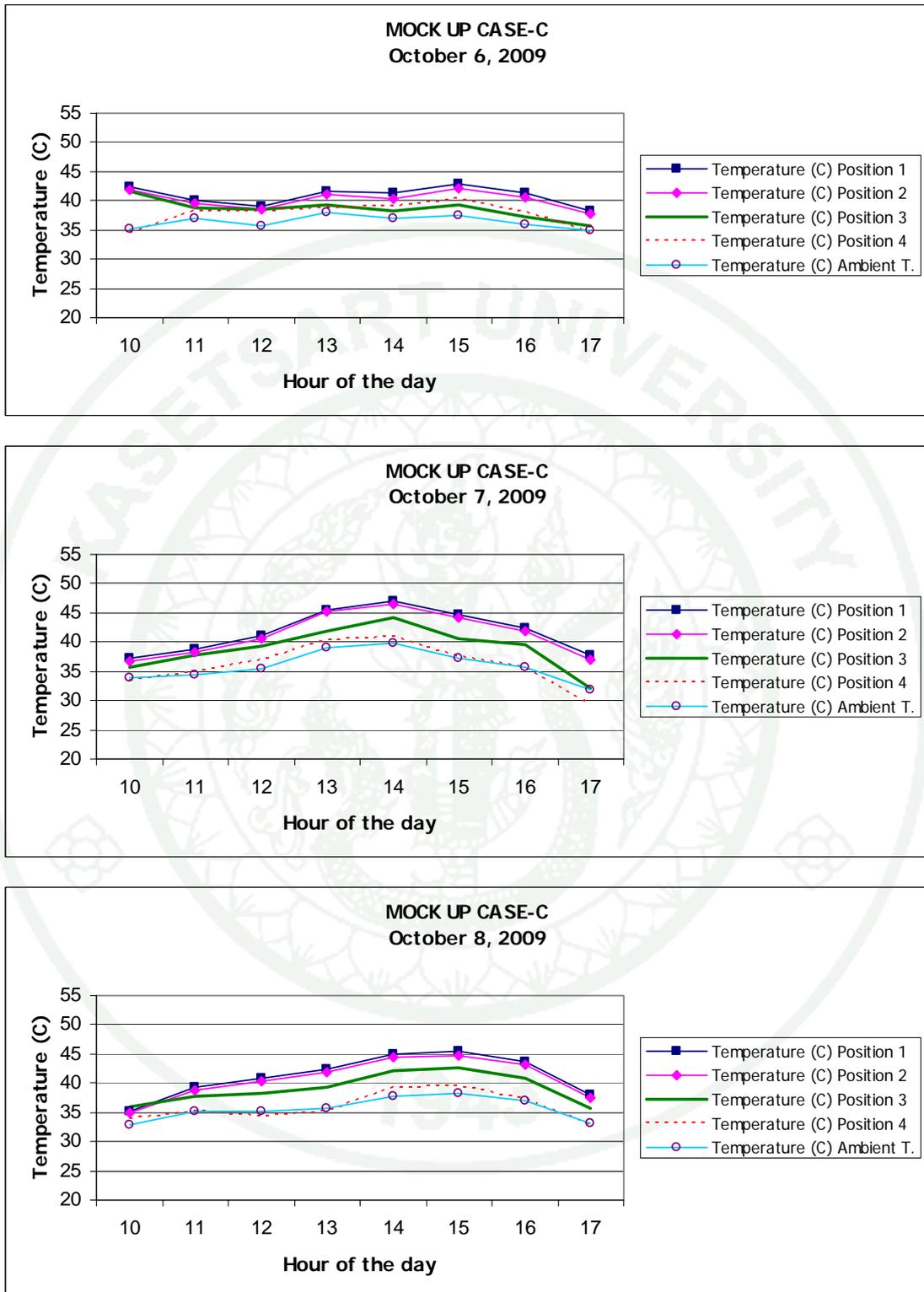


Figure 43 Temperature variations of different positions of the mock up Case-C on October 6th, 7th, 8th, 13th, 14th, 15th, 2009.

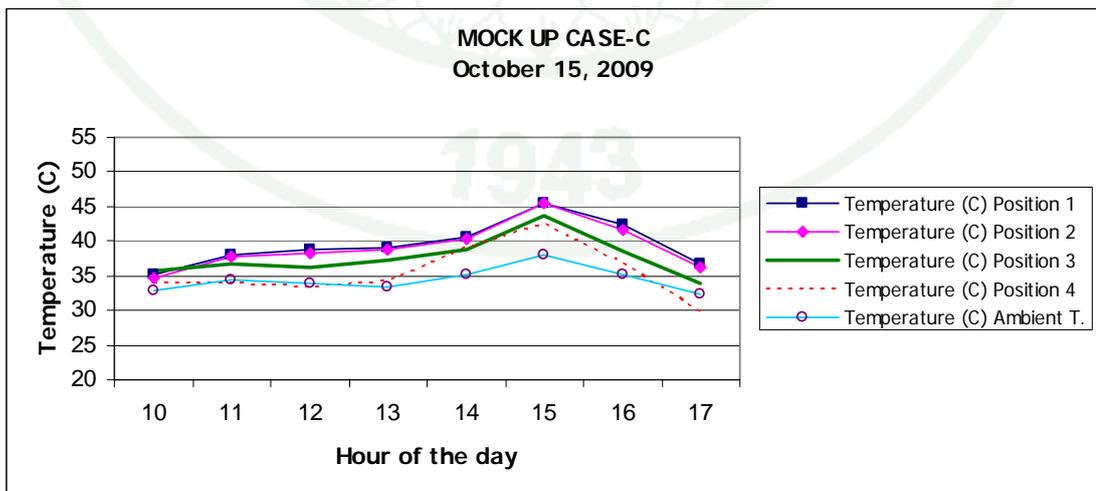
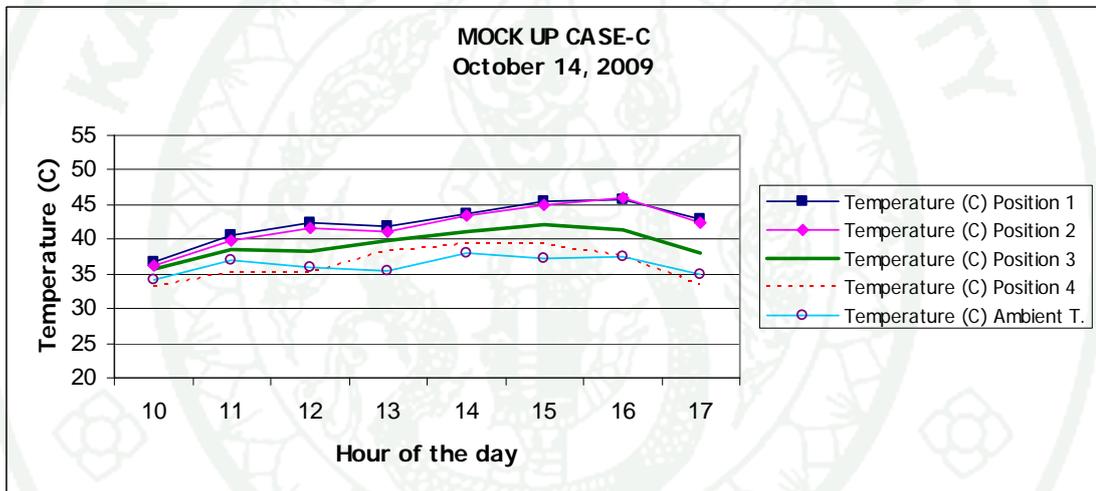
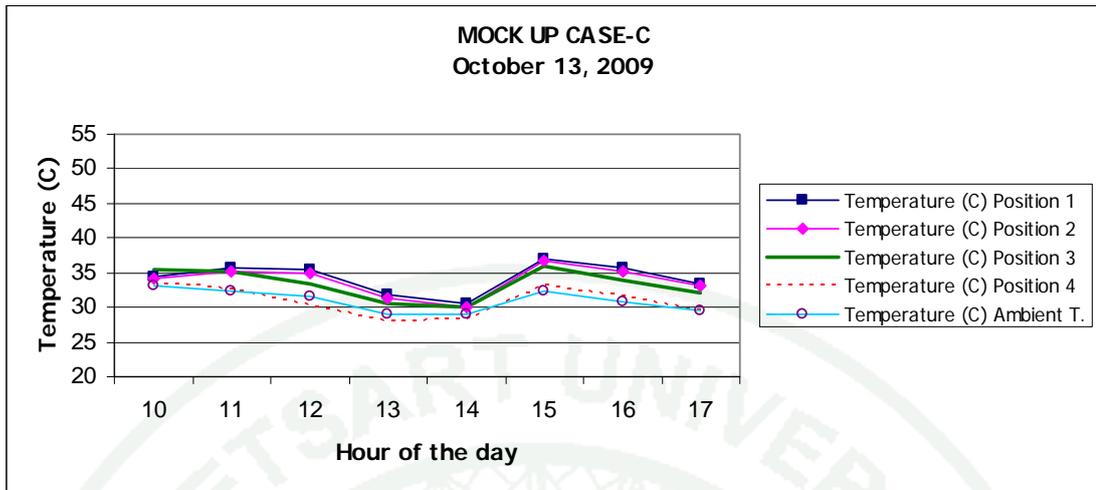


Figure 43 (Continued)

4. Temperatures comparison of three mock ups measured at position 1 (room temperature) of A, B, B.1 and C are shown in figure 44. It can be observed that temperature measured at position 1 from three mock ups are different and the one from mock up Case-A was always the highest while the one from mock up Case-C was always the lowest. Obviously temperatures varied following the ambient conditions.

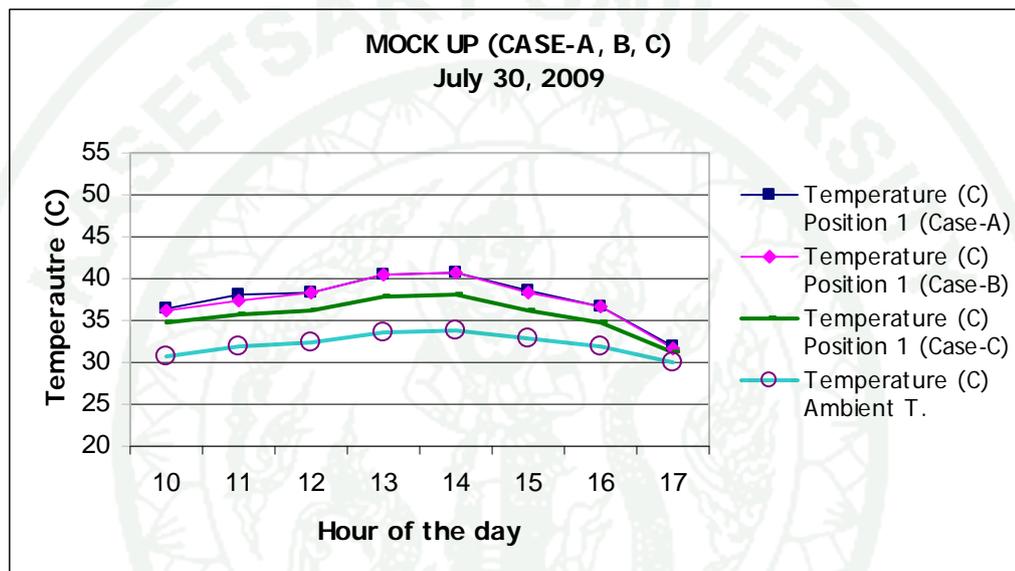


Figure 44 Comparison of room temperature at position 1 of each mock up (Case-A, B and C) on July 30th, August 11th and (Case A, B.1 and C) on October 8th, 2009.

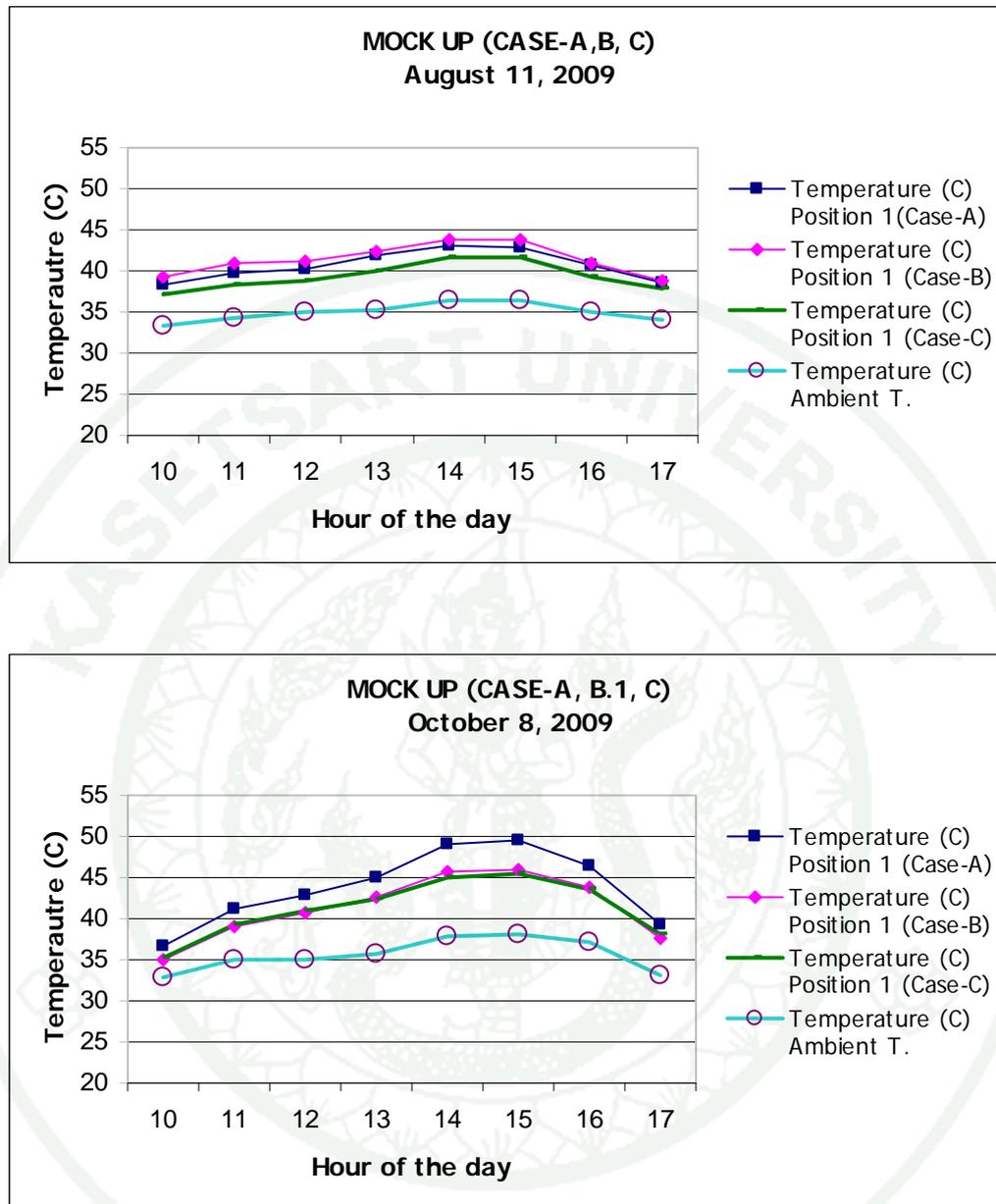


Figure 44 (Continued)

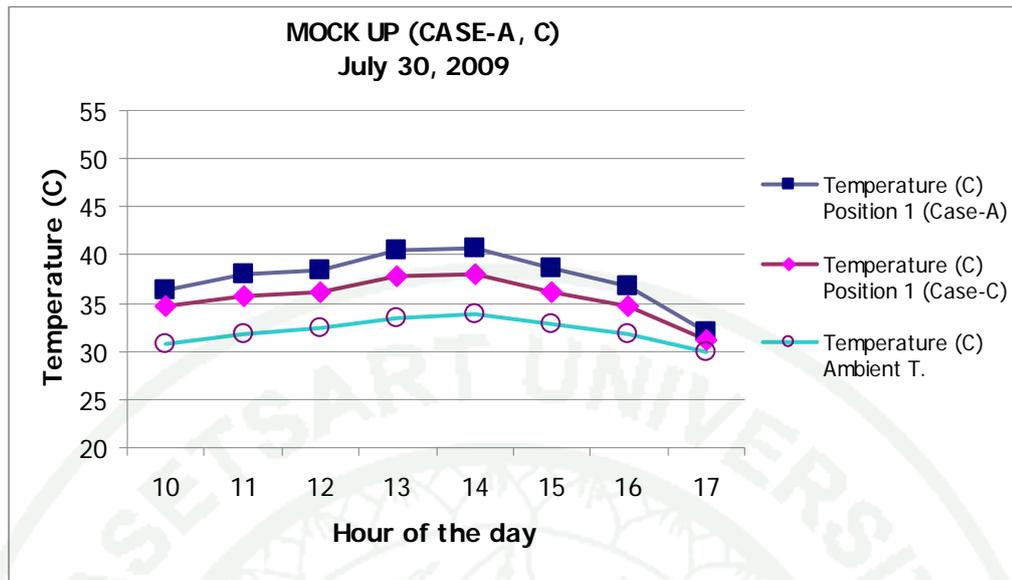


Figure 45 Comparison of room temperature at position 1 from mock ups (Case-A and Case-C) on July 30th, 2009.

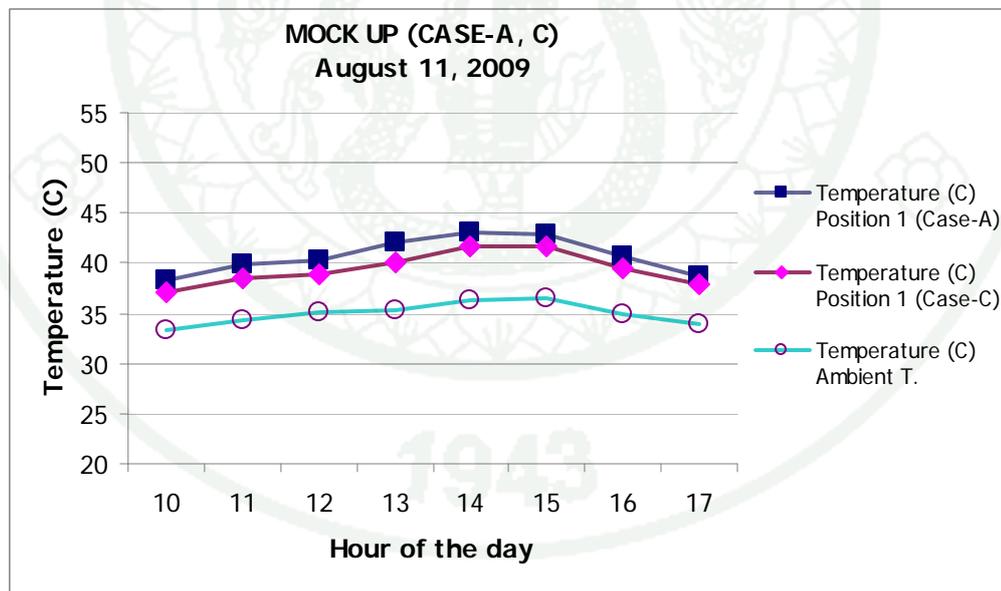


Figure 46 Comparison of room temperature at position 1 from mock ups (Case-A and Case-C) on August 11th, 2009.

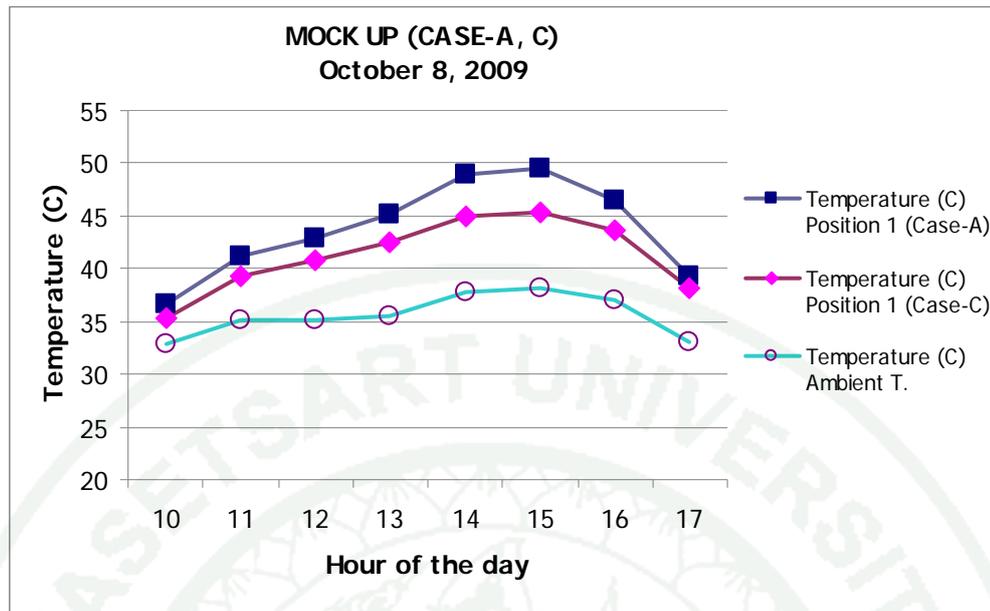


Figure 47 Comparison of room temperature at position 1 from mock ups (Case-A and Case-C) on October 8th, 2009.

Comparison between mock up Case-A and mock up Case-C (Figure 45, 46 and 47).

Data comparison showed that an average temperature difference at position 1 between mock up Case-C and mock up Case-A of five days in July 2009 is lower by 1.2 °C. The greatest difference was 2.6 °C on July 30th, 2009 at 13.00 and on July 31st, 2009 at 14.00.

Data comparison showed that an average temperature difference at position 1 between mock up Case-C and mock up Case-A of five days in August 2009 is lower by 1.3 °C. The greatest difference was 2.1 °C on August 14th, 2009 at 10.00.

Data comparison showed that an average temperature difference at position 1 between mock up Case-C and mock up Case-A of six days in October 2009 is lower by 3.0 °C. The greatest difference was 6.7 °C on October 14th, 2009 at 14.00.

5. Result and comparison of temperature measured at position 1 (room temperature) between mock up Case-B.1 (glass DSF with top and bottom fully opened for air ventilation) and mock up Case-C (glass DSF with stack ventilation) in October 2009.

Table 5 Temperature measured at position 1 of mock up Case-B.1 and mock up Case-C on October 6th, 7th, 8th, 14th and 15th, 2009

| October 6th | CASE-B.1 | CASE-C | ΔT |
|--------------------|-------------------|--------------------------------------|---------------------------------|
| TIME (Hrs) | POSITION 1 | POSITION 1 | ($^{\circ}C$) |
| 10.00 | 41.5 | 42.5 | -1 |
| 11.00 | 41.2 | 40.1 | 1.1 |
| 12.00 | 40.7 | 39.1 | 1.6 |
| 13.00 | 44.3 | 41.6 | 2.7 |
| 14.00 | 43.6 | 41.3 | 2.3 |
| 15.00 | 44.5 | 42.8 | 1.7 |
| 16.00 | 42.7 | 41.4 | 1.3 |
| 17.00 | 39.4 | 38.4 | 1 |
| | | AVERAGE ΔT | 1.3 |
| October 7th | CASE-B.1 | CASE-C | ΔT |
| TIME (Hrs) | POSITION 1 | POSITION 1 | ($^{\circ}C$) |
| 10.00 | 37.1 | 37.3 | -0.2 |
| 11.00 | 38.8 | 38.9 | -0.1 |
| 12.00 | 41.6 | 41.2 | 0.4 |
| 13.00 | 47.5 | 45.6 | 1.9 |
| 14.00 | 48.7 | 47 | 1.7 |
| 15.00 | 45.3 | 44.8 | 0.5 |
| 16.00 | 42.4 | 42.4 | 0 |
| 17.00 | 37.3 | 37.7 | -0.4 |
| | | AVERAGE ΔT | 0.4 |

Table 5 (Continued)

| October 8th | CASE-B.1 | CASE-C | ΔT |
|---------------------|-------------------|--------------------------------------|------------------------------|
| TIME (Hrs) | POSITION 1 | POSITION 1 | (°C) |
| 10.00 | 34.9 | 35.3 | -0.4 |
| 11.00 | 39 | 39.3 | -0.3 |
| 12.00 | 40.7 | 40.9 | -0.2 |
| 13.00 | 42.7 | 42.5 | 0.2 |
| 14.00 | 45.6 | 45 | 0.6 |
| 15.00 | 46 | 45.4 | 0.6 |
| 16.00 | 43.7 | 43.6 | 0.1 |
| 17.00 | 37.7 | 38.1 | -0.4 |
| | | AVERAGE ΔT | 0 |
| October 14th | CASE-B.1 | CASE-C | ΔT |
| TIME (Hrs) | POSITION 1 | POSITION 1 | (°C) |
| 10.00 | 36.6 | 36.6 | 0 |
| 11.00 | 41.8 | 40.7 | 1.1 |
| 12.00 | 43.5 | 42.3 | 1.2 |
| 13.00 | 43.2 | 41.9 | 1.3 |
| 14.00 | 46 | 43.8 | 2.2 |
| 15.00 | 46.6 | 45.5 | 1.1 |
| 16.00 | 45.7 | 45.7 | 0 |
| 17.00 | 42.9 | 42.9 | 0 |
| | | AVERAGE ΔT | 0.8 |

Table 5 (Continued)

| October 15th | CASE-B.1 | CASE-C | ΔT |
|---------------------|-------------------|--------------------------------------|------------------------------|
| TIME (Hrs) | POSITION 1 | POSITION 1 | (°C) |
| 10.00 | 34.9 | 35.2 | -0.3 |
| 11.00 | 37.8 | 38.1 | -0.3 |
| 12.00 | 38.4 | 38.9 | -0.5 |
| 13.00 | 38.8 | 39.1 | -0.3 |
| 14.00 | 41.8 | 40.7 | 1.1 |
| 15.00 | 46.3 | 45.5 | 0.8 |
| 16.00 | 42.7 | 42.3 | 0.4 |
| 17.00 | 37.2 | 36.8 | 0.4 |
| | | AVERAGE ΔT | 0.1 |

Comparison between mock up Case-B.1 and mock up Case-C (Table 5).

Data comparison showed that an average temperature difference at position 1 between mock up Case-B.1 and mock up Case-C of continues 5 days in October 2009 is higher by 0.5 °C. The greatest difference was 2.7 °C on October 6th, 2009 at 13.00.

6. Results of air velocity data recorded at various positions inside the cavity of mock up Case-B.1 (glass DSF with top and bottom fully opened for air ventilation) and mock up Case-C (glass DSF with stack ventilation) on November 9th, 2009 to evaluate the airflow occurred

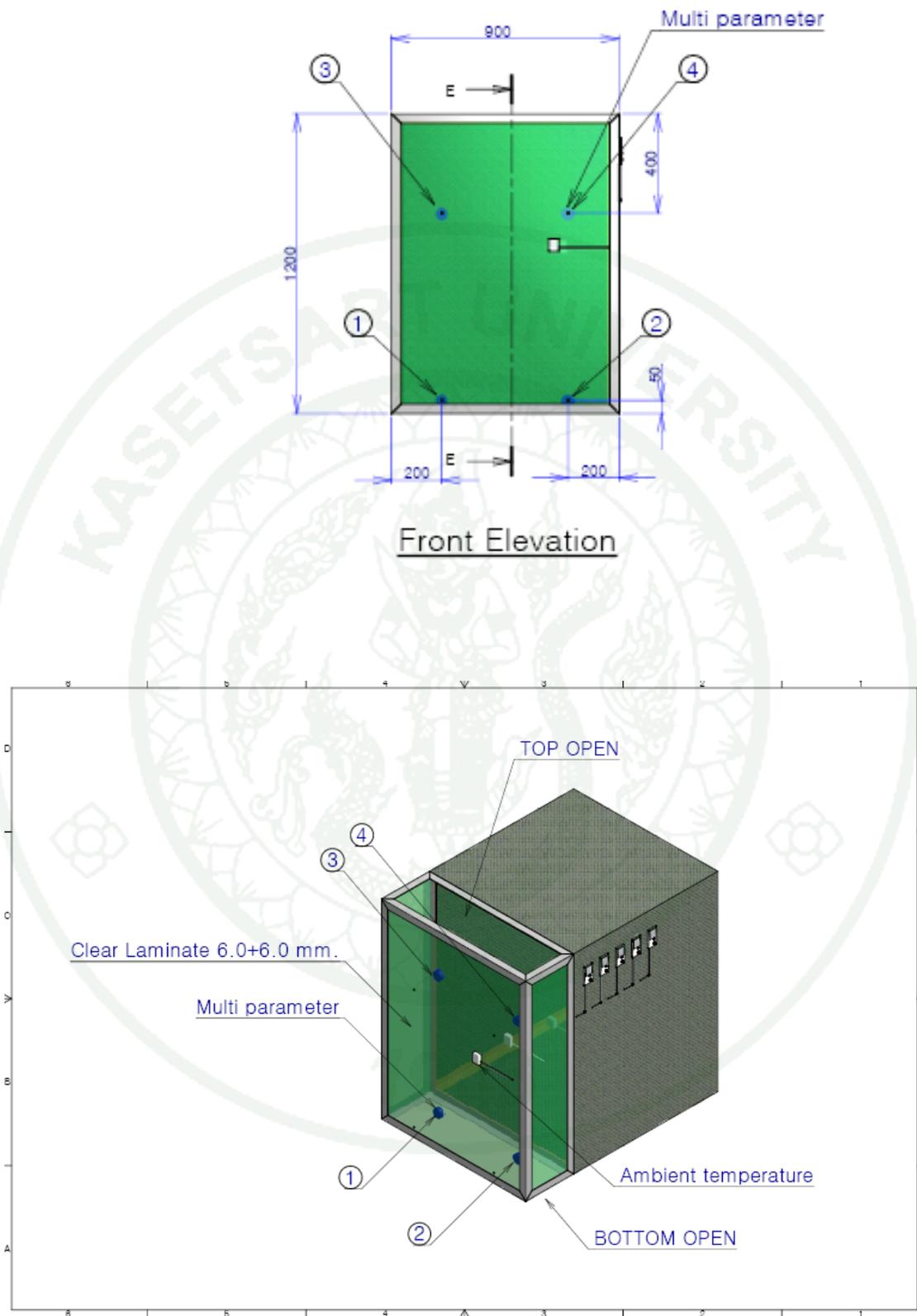


Figure 48 Multi Parameter positions in mock up case-B.1.

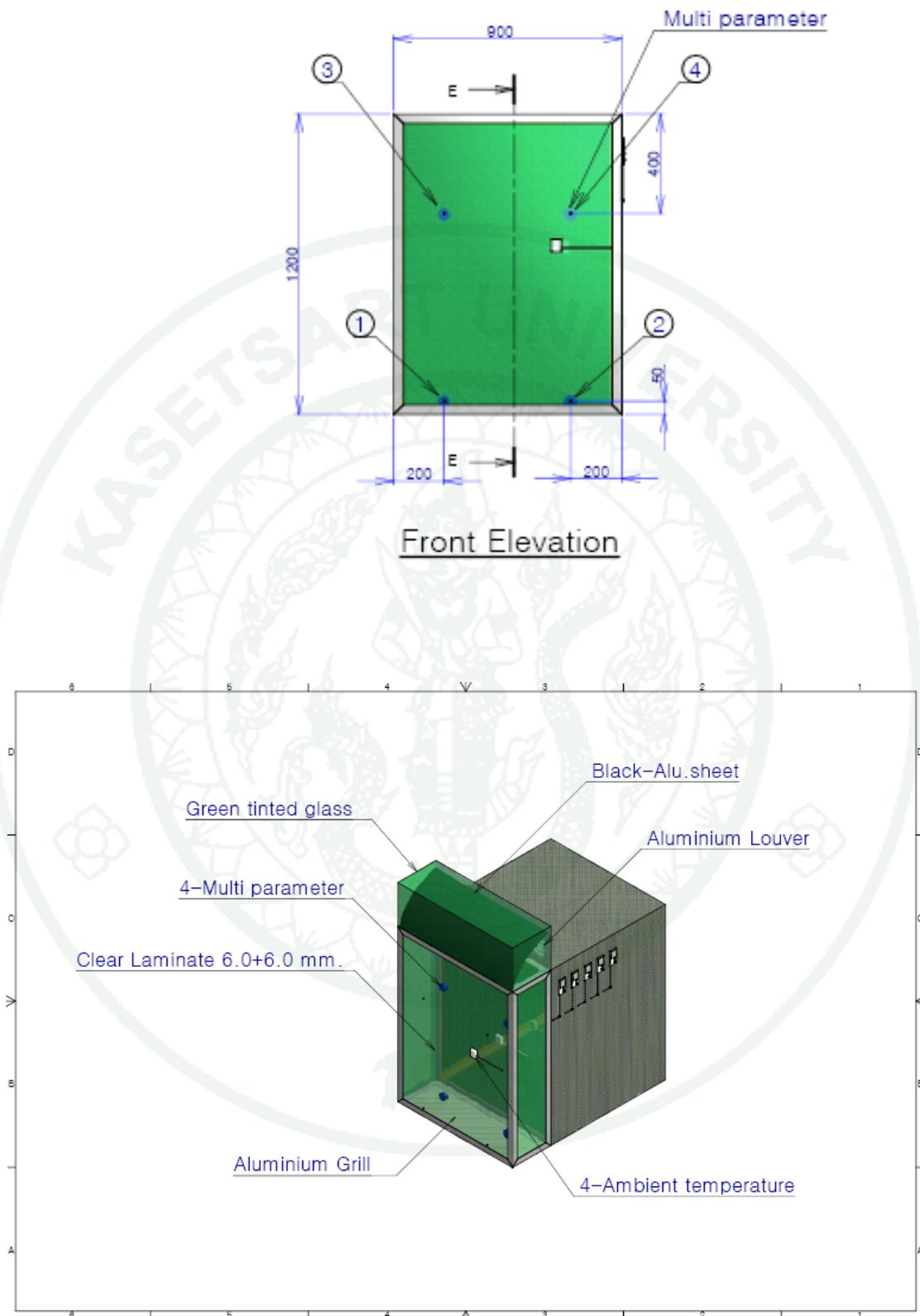


Figure 49 Multi Parameter positions in mock up Case-C.

Table 6 Air velocity measured at different positions of mock up Case-B.1 (glass DSF with air ventilation) on November 9th, 2009.

| TIME (Hrs) | POSITION 1 | POSITION 2 | POSITION 3 | POSITION 4 |
|------------|------------|------------|------------|------------|
| | (m/s) | (m/s) | (m/s) | (m/s) |
| 14.00 | 0.26 | 0.27 | 0.28 | 0.25 |
| 15.00 | 0.34 | 0.35 | 0.36 | 0.35 |

Table 7 Air velocity measured at different positions of mock up Case-C (glass DSF with stack ventilation) on November 9th, 2009.

| TIME (Hrs) | POSITION 1 | POSITION 2 | POSITION 3 | POSITION 4 |
|------------|------------|------------|------------|------------|
| | (m/s) | (m/s) | (m/s) | (m/s) |
| 14.00 | 0.21 | 0.23 | 0.24 | 0.28 |
| 15.00 | 0.34 | 0.28 | 0.28 | 0.27 |

This measurement was conducted on November 9th, 2009 during 14.00 to 15.00 using multi parameter sensor located at the positions as earlier explained in each mock up. Data of air velocity measured showed that an average velocity on November 9th, 2009 of mock up Case-B.1 at lower level (position 1 and 2) was 0.30 m/s and the higher level (position 3 and 4) was 0.31 m/s. While an average velocity of mock up Case-C on the same day at lower level (position 1 and 2) was 0.26 m/s and the higher level (position 3 and 4) was 0.26 m/s as well at the same period of measuring. So the observed average air flow in mock up B.1 was about 0.08 m³/s, the corresponding flow rate per area of 0.08 m³/s/m² and the average air flow in mock up Case-C was about 0.07 m³/s with a corresponding flow rate per area of 0.07 m³/s/m².

7. Result of temperature variations of different positions of the mock ups and comparison of temperature measured at position 1 (room temperature) of mock up Case-A (represents single pane of primary glass wall), Case-B.1 (glass DSF with air ventilation) and Case-C (glass DSF with stack ventilation) in January 2010 (from 10.00 to 22.00).

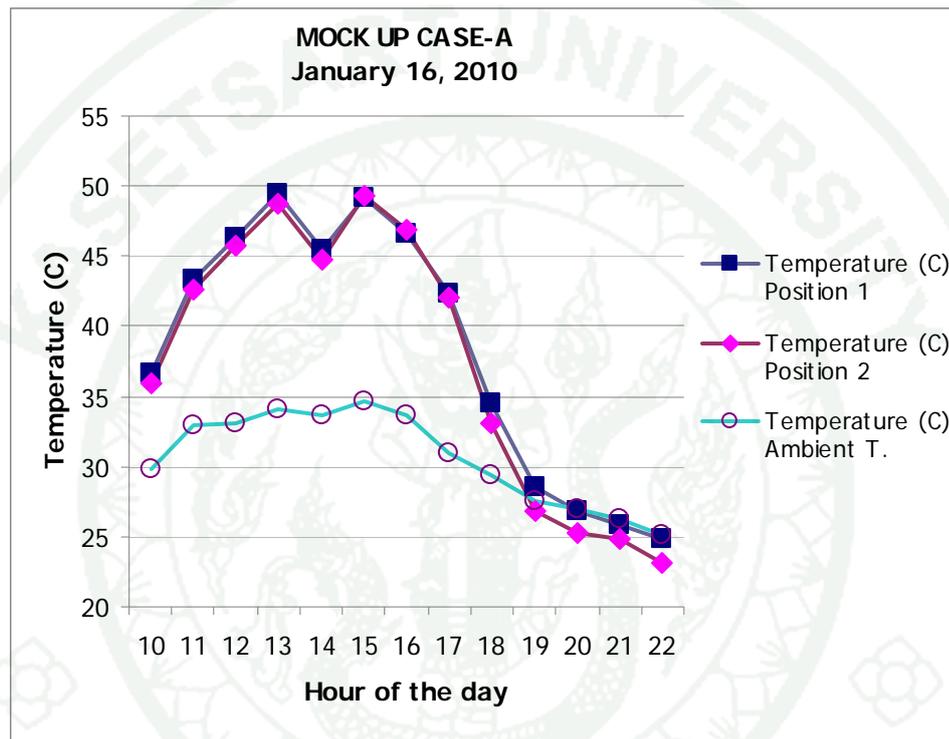


Figure 50 Temperature variations of different positions of the mock up Case-A on January 16th and 17th, 2010.

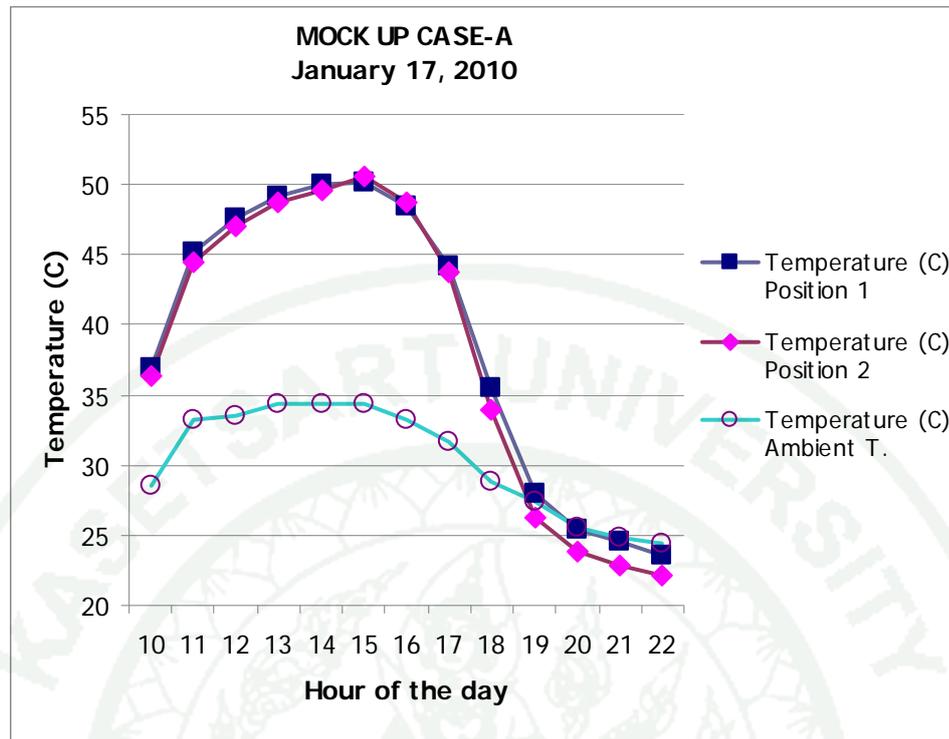


Figure 50 (Continued)

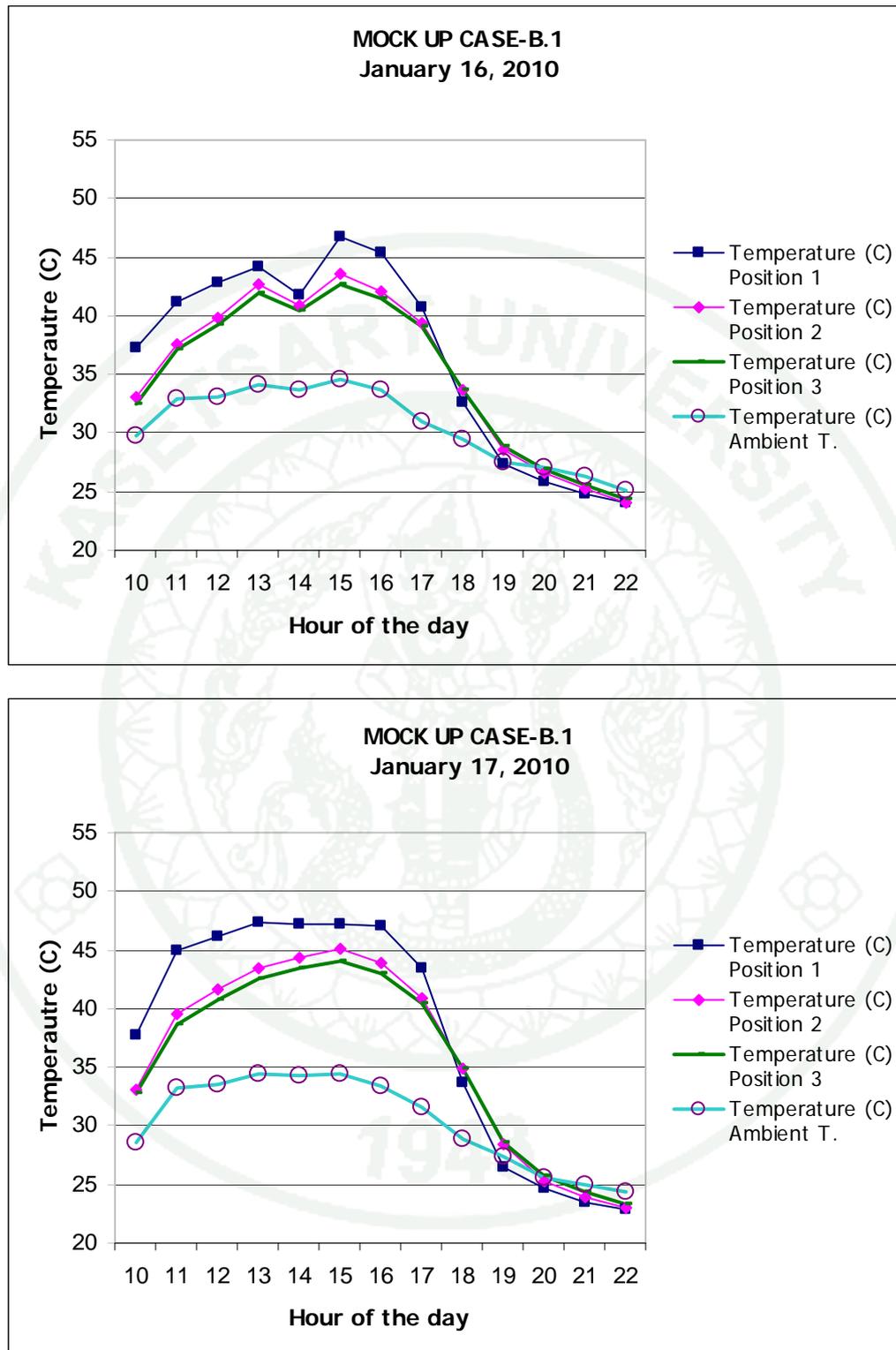


Figure 51 Temperature variations of different positions of the mock up Case-B.1 (glass DSF with air ventilation) on January 16th and 17th, 2010.

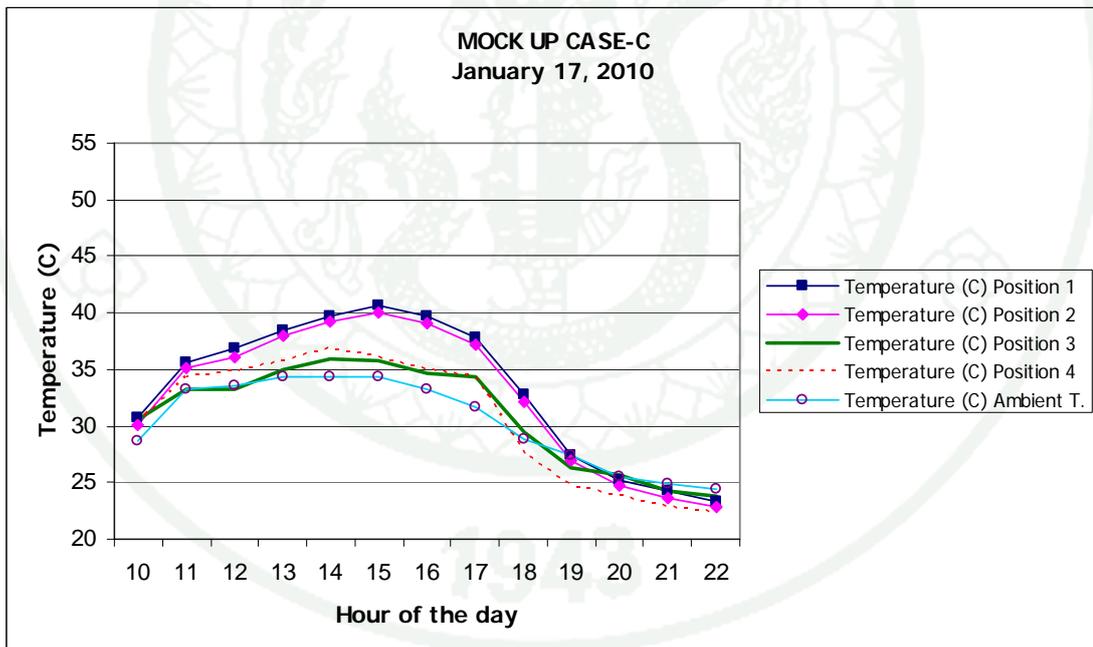
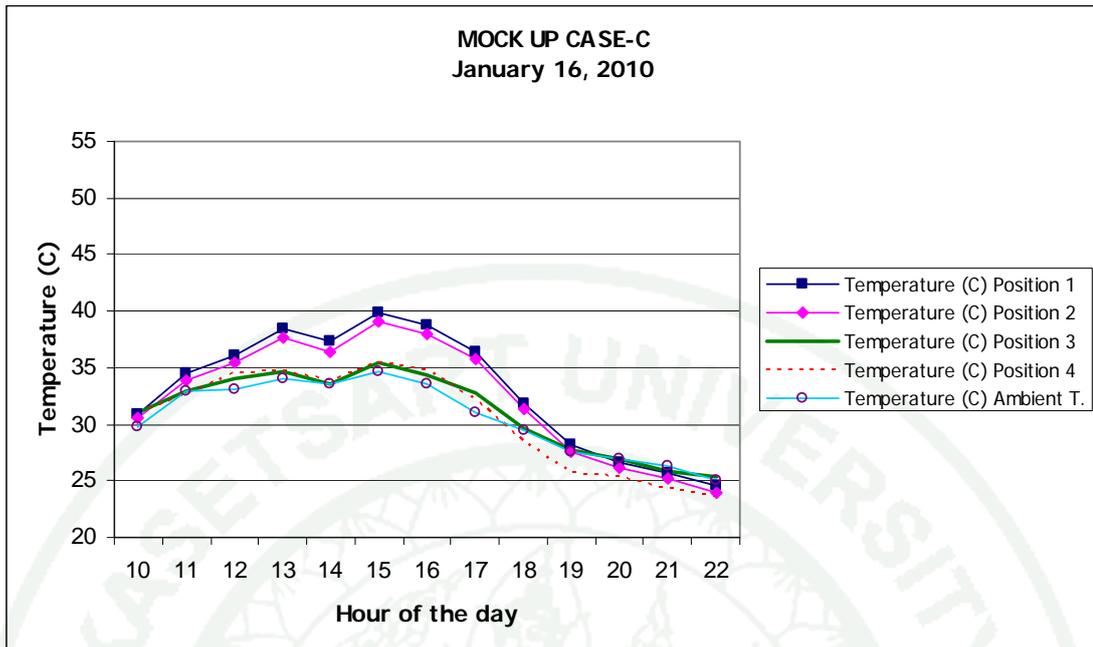


Figure 52 Temperature variations of different positions of the mock up Case-C (glass DSF with stack ventilation) on January 16th and 17th, 2010.

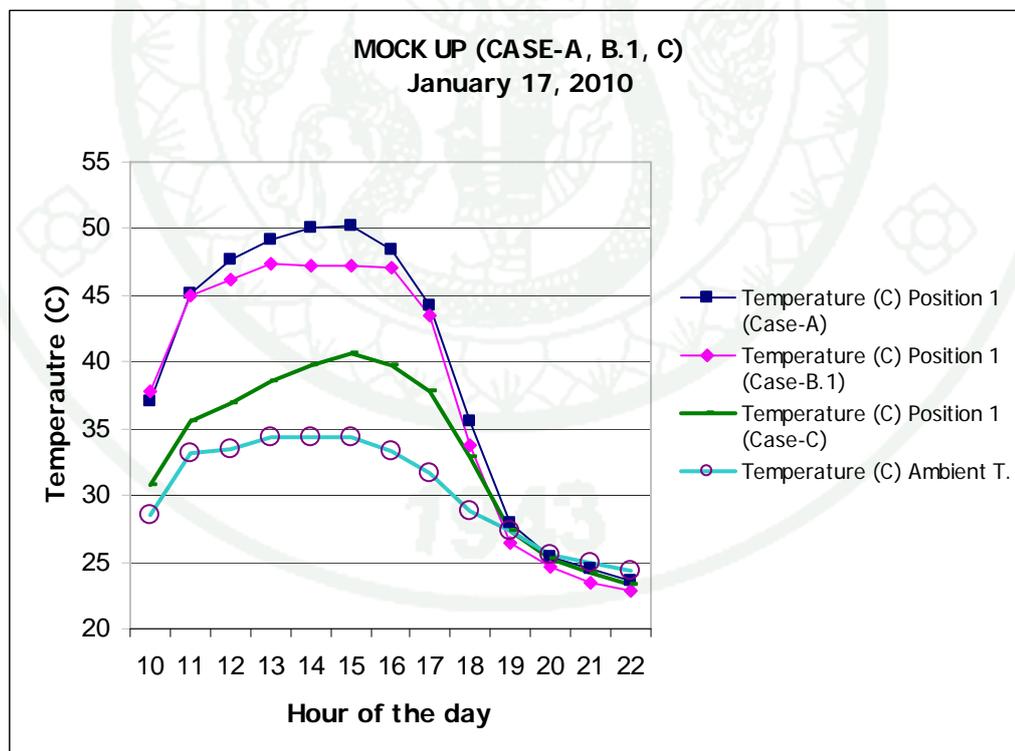
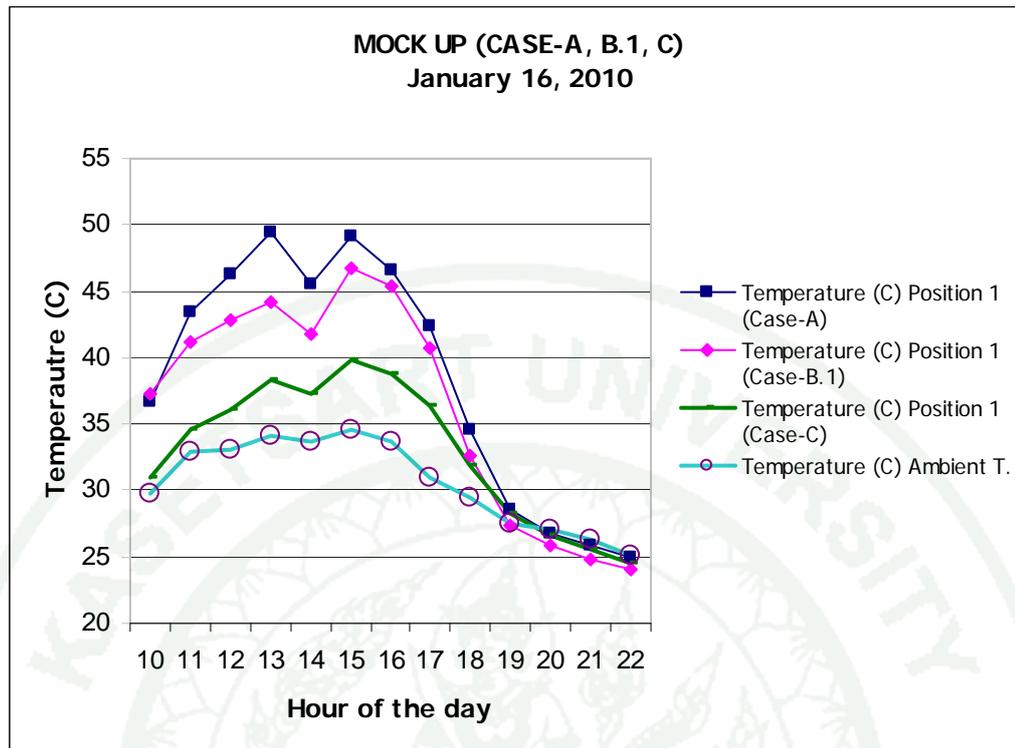


Figure 53 Comparison of room temperature at position 1 from each mock up (Case-A, Case-B.1, Case-C) on January 16th and 17th, 2010.

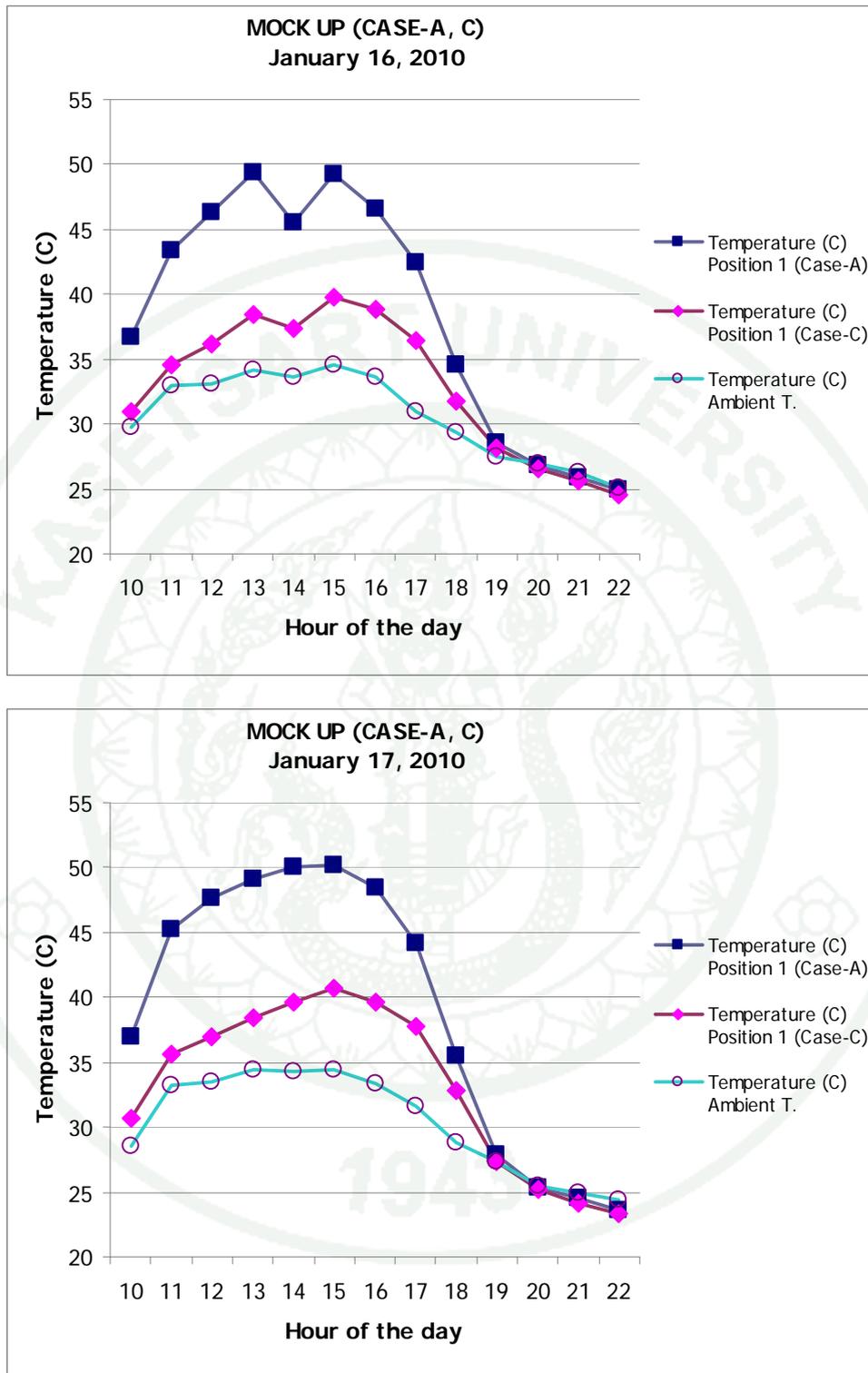


Figure 54 Comparison of room temperature at position 1 between mock up Case-A and Case-C on January 16th and 17th, 2010.

Comparison between mock up Case-A and mock up Case-C (Figure 53).

As per figure 53, January 16th, 2010, Temperature varied following ambient temperature conditions. Around 14.00, a temperature drop was observed due to cloudy sky. Data comparison showed that an average temperature difference at position 1 between mock up Case-C and mock up Case-A of two days in January 2010 is lower by 5.6 °C. The greatest observed difference was 11 °C on January 16th, 2010 at 11.00.

Table 8 Temperature data recorded from position 1 of mock up Case-B.1 and mock up Case-C on January 16th, 17th, 2010.

| January 16th | CASE-B.1 | CASE-C | ΔT |
|--------------|------------|--------------------------------------|------------|
| TIME (Hrs) | POSITION 1 | POSITION 1 | (°C) |
| 10.00 | 37.2 | 30.9 | 6.3 |
| 11.00 | 41.1 | 34.5 | 6.6 |
| 12.00 | 42.9 | 36.1 | 6.8 |
| 13.00 | 44.2 | 38.4 | 5.8 |
| 14.00 | 41.8 | 37.3 | 4.5 |
| 15.00 | 46.8 | 39.8 | 7 |
| 16.00 | 45.4 | 38.8 | 6.6 |
| 17.00 | 40.7 | 36.4 | 4.3 |
| 18.00 | 32.6 | 31.8 | 0.8 |
| 19.00 | 27.3 | 28.2 | -0.9 |
| 20.00 | 25.8 | 26.6 | -0.8 |
| 21.00 | 24.8 | 25.6 | -0.8 |
| 22.00 | 24 | 24.5 | -0.5 |
| | | AVERAGE ΔT | 3.5 |

Table 8 (Continued)

| January 17th | CASE-B.1 | CASE-C | ΔT |
|---------------------|-------------------|--------------------------------------|---------------------------------|
| TIME (Hrs) | POSITION 1 | POSITION 1 | ($^{\circ}C$) |
| 10.00 | 37.8 | 30.7 | 7.1 |
| 11.00 | 45 | 35.6 | 9.4 |
| 12.00 | 46.2 | 36.9 | 9.3 |
| 13.00 | 47.3 | 38.5 | 8.8 |
| 14.00 | 47.2 | 39.7 | 7.5 |
| 15.00 | 47.2 | 40.7 | 6.5 |
| 16.00 | 47 | 39.7 | 7.3 |
| 17.00 | 43.5 | 37.8 | 5.7 |
| 18.00 | 33.7 | 32.8 | 0.9 |
| 19.00 | 26.5 | 27.4 | -0.9 |
| 20.00 | 24.6 | 25.2 | -0.6 |
| 21.00 | 23.5 | 24.2 | -0.7 |
| 22.00 | 22.8 | 23.3 | -0.5 |
| | | AVERAGE ΔT | 4.6 |

Comparison between mock up Case-B.1 and mock up Case-C (Table 8).

According to temperature data recorded in January 2010 from mock up Case-B.1 (glass DSF with air ventilation) and mock up Case-C (glass DSF with stack ventilation), comparison showed that an average temperature difference at position 1 between the two mock ups on two consecutive days is higher by 4.0 $^{\circ}C$. The greatest observed difference was 9.4 $^{\circ}C$ on January 17th, 2010 at 11.00.

Economics benefit of glass Double Skin Façade (DSF) to retrofit buildings.

1. As a paper presentation and lectured by Khedari, J., every reduction of indoor temperature of 1 °C would save around 7% of energy consumption for cooling load for buildings in Thailand (Khedari, 2009).

2. There are many factors for cost consideration such as material used for the facade, maintenance cost, operation cost, occupants' satisfaction and productivity, healthy conditions, etc. Double Skin Façade (DSF) in Europe is twice as expensive as regular cladding systems. In USA, it can be four or five times the cost (Lang and Herzog, 1999). Retrofitting is also very important factor to recycle what you have and to extend the building's life. Regular single pane of color tinted glass wall (curtain wall - stick system), commonly used as inner layer or on the existing wall before retrofitting, is in a range of 3,500 – 6,000 Baht/m². Regular clear laminated glass wall (curtain wall – stick system), recommended to use for outer layer for economic building safety regulations, is in a range of 5,000 – 10,000 Baht/m². The outer layer construction cost could be two or three times as much as the cost of inner wall.

3. There is no such a definite calculation for glass DSF in Thailand due to many different factors as explained but simple assessment of construction cost of façade and energy saving can be brought up for serious consideration. An example of a 400 m² of office building with common ceiling height of 3.0 m using 10% - 100% of glass DSF (Minimum to maximum opening area). With a reduction of indoor temperature by about 2.7 °C, it is anticipated that about 18 % of energy consumption for cooling load (60% of total energy) could be saved. The calculated expected energy saving will be about 45 kilowatt-hour. The corresponding saving cost is about 500-1,000 Baht/hr.

CONCLUSION AND RECCOMENDATION

Conclusion

Data comparison from three small mock ups of single glass wall and glass Double Skin Façade (DSF) designed by integration of “stack effect” to allow air gap ventilation demonstrated that DSF is an effective heat barrier. A comparison of room temperature data between mock up Case-A (single pane of primary glass wall as a base case) and mock up Case-C (glass DSF with stack ventilation) was conducted. It showed that the average temperature difference of mock up Case-C is lower by 1.2 °C of five days in July 2009, lower by 1.3 °C of five days in August 2009, lower by 3.0 °C of six days in October 2009 and lower by 5.6 °C in two days in January 2010. So the experiment proved that mock up Case-C (glass DSF with stack ventilation) has a better thermal insulation than mock up Case-A as a base case. An average of 2.7 °C was calculated for the whole measured period of four months.

Comparison of room temperature data between mock up Case-B.1 (glass DSF with air ventilation) and mock up Case-C (glass DSF with stack ventilation) showed that the average temperature difference of mock up Case-C is lower by 0.5 °C of six days in October 2009 and lower by 4.0 °C of two days in January 2010. An attachment of hood of black 2.0 mm curved alu. sheet in the glass box in dimension of 0.3 x 0.3 x 0.9 m was proven to be part of stack ventilation which kept the consistency of heat arise to the top of DSF and flow out better than that of mock up Case-B.1 which has only the top glass panel of DSF opened.

This research study indicated that room temperature rises and drop in mock ups in accordance with the ambient air temperature. The single pane of glass wall (mock up Case-A) was the most effected with highest room temperature and lower in glass DSF with stack ventilation (mock up Case-C). “Stack effect”, air ventilation resulted as to improve heat barrier performance and hence lowering heat transmission into the building. This is largely sufficient to convenience designers to consider the suitability of using glass DSF. Buildings that have good thermal insulation or less

heat transfer into the building would benefit a lot from lower energy consumption and less impact to the environment, saving natural resource for next generation protecting environment and being sustainable.

Recommendation

Information revealed in this thesis confirmed that the principle of glass Double Skin Façade (DSF) design with appropriate orientation, Glass DSF can efficiently reduce the use of energy if designed properly. Further detailed research related to glass DSF construction cost and evaluation of investment is highly recommended. They are recommended to include the following.

1. A relatively large scale investigation of DSF to retrofit buildings is encouraged. This could be a government building or a small commercial building.

2. Investment, since cost of glass DSF in each country vary widely due to material costs, engineering costs, installation costs, etc. The country that energy costs are much higher could possibly have a fast return such as in Europe where energy (utility) costs are very expensive and therefore offset the original investment with a faster return. When time of use (TOU) tariffication is considered like in Thailand, this will be of the same benefit as daytime tariff is higher.

3. There are different kinds of glass DSF and applications for buildings, to comply with project requirement such as solar control by shading devices, glass maintenance, etc. So a study of combined systems can be considered with flexible, sustainable, or accessible by users.

4. This thesis described daylight as one of the advantages of glass DSF that provides daylight for building occupants and people can see well and work well. So further study of working conditions with daylight, workplace atmosphere, health and work comfort with daylight is also recommended. This would promote more DSF to penetrate to the market.

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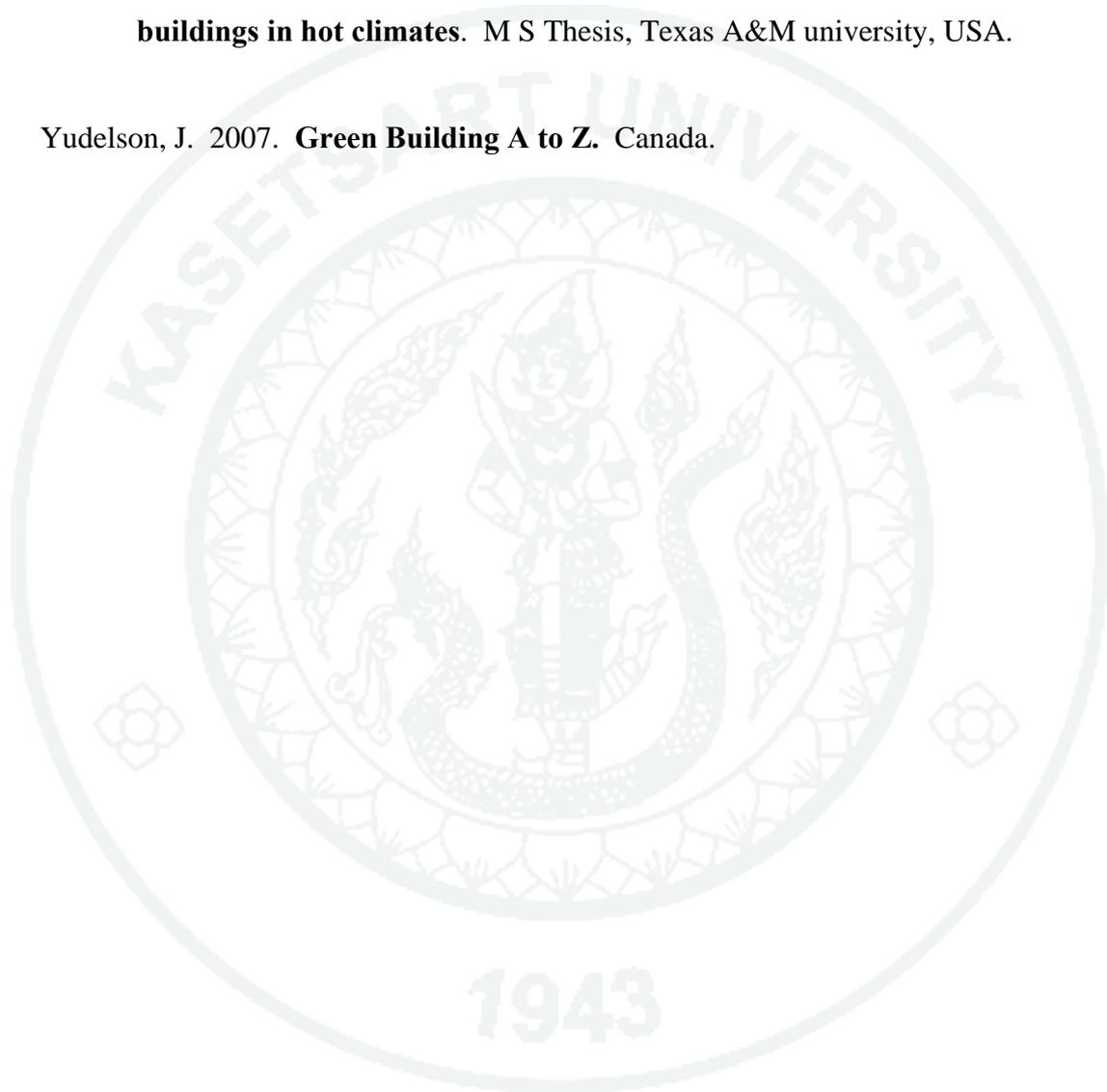
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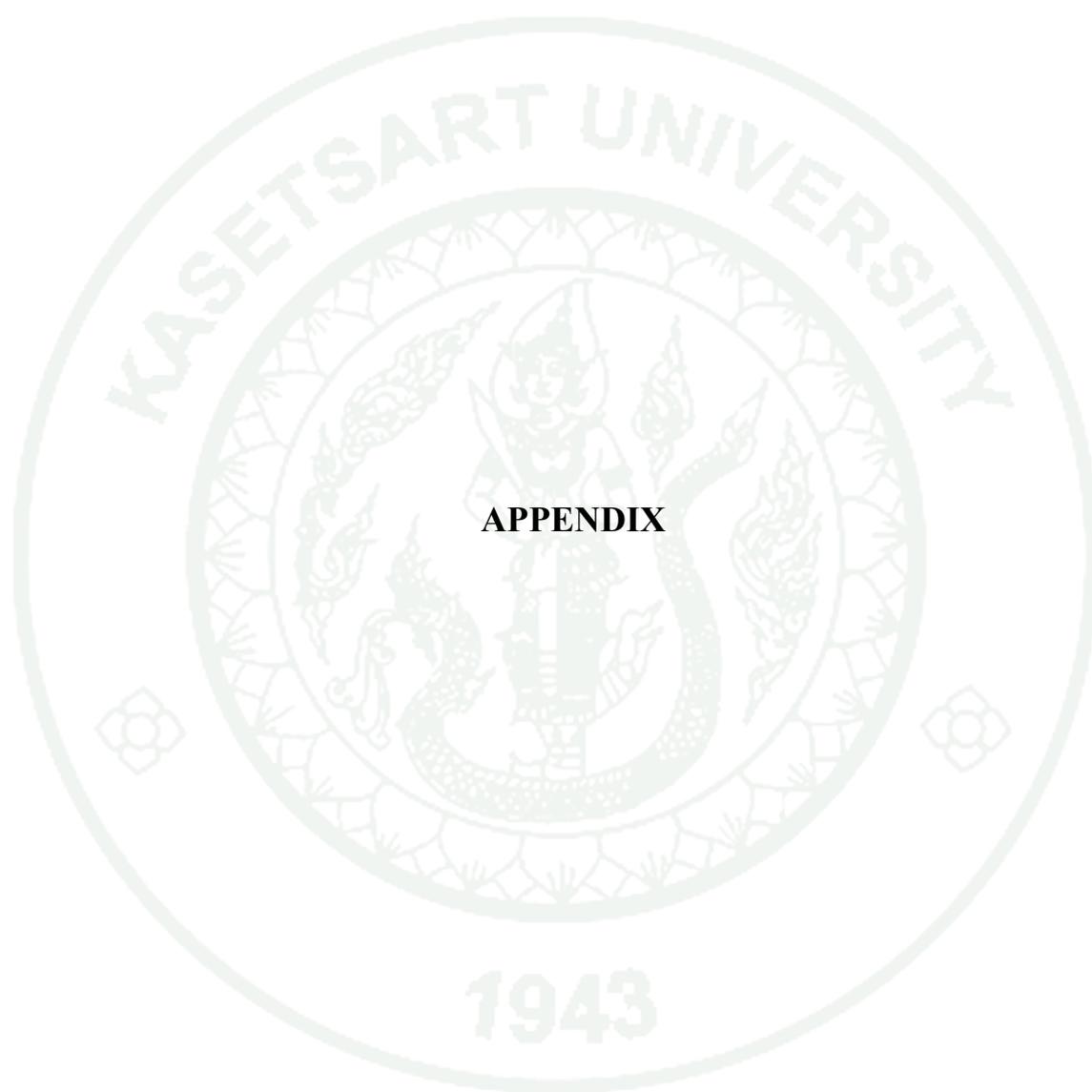
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APPENDIX

Temperature data recorded tables from three mock ups

Appendix Table 1 Temperature variations of different positions of the mock up
Case-A on June 25th, 26th, 29th, 2009 (without rockwool).

June 25, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 46.3 | 43.9 | | | |
| 11 | 46.9 | 44.5 | | | |
| 12 | 46.9 | 44.7 | | | |
| 13 | 47.3 | 45.4 | | | |
| 14 | 49.3 | 47.1 | | | |
| 15 | 49.9 | 47.8 | | | |
| 16 | 49.3 | 47.2 | | | |
| 17 | 41.2 | 39.5 | | | |

June 26, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 44.1 | 42.1 | | | |
| 11 | 44.9 | 42.7 | | | |
| 12 | 46.9 | 44.5 | | | |
| 13 | 46.6 | 44.6 | | | |
| 14 | 47.6 | 46 | | | |
| 15 | 45.9 | 44.4 | | | |
| 16 | 42 | 40.5 | | | |
| 17 | 39.3 | 37.7 | | | |

June 29, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 46.3 | 43.8 | | | |
| 11 | 43.9 | 42.4 | | | |
| 12 | 43.8 | 42.3 | | | |
| 13 | 48.6 | 46.8 | | | |
| 14 | 47.6 | 45.6 | | | |
| 15 | 48.5 | 46.7 | | | |
| 16 | 39.1 | 37.7 | | | |
| 17 | 36.2 | 34.5 | | | |

Appendix Table 2 Temperature variations of different positions of the mock up
Case-A on July 23rd, 24th, 28th, 30th, 31st, 2009.

July 23, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 33.2 | 32.3 | | | 29.2 |
| 11 | 34.6 | 34.1 | | | 30 |
| 12 | 36.5 | 36.1 | | | 30.9 |
| 13 | 34 | 33.5 | | | 29.4 |
| 14 | 35.3 | 35.4 | | | 30.3 |
| 15 | 36.2 | 36 | | | 30.7 |
| 16 | 33.8 | 32.7 | | | 29.7 |
| 17 | 35.5 | 35.3 | | | 32.6 |

July 24, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 34 | 33.8 | | | 29 |
| 11 | 36.1 | 36 | | | 30.2 |
| 12 | 38 | 37.8 | | | 33.1 |
| 13 | 39.7 | 39.3 | | | 33.6 |
| 14 | 39.6 | 38.6 | | | 34.2 |
| 15 | 40.6 | 39 | | | 35.4 |
| 16 | 40.5 | 39 | | | 35.5 |
| 17 | 36.8 | 35.4 | | | 32.8 |

July 28, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 37.1 | 35.9 | | | 32.4 |
| 11 | 39 | 37.6 | | | 34.1 |
| 12 | 39.7 | 38.4 | | | 34.1 |
| 13 | 40 | 38.9 | | | 34.6 |
| 14 | 41.6 | 40.5 | | | 35.7 |
| 15 | 41.8 | 40.5 | | | 36.4 |
| 16 | 38.8 | 37.2 | | | 33.1 |
| 17 | 33.3 | 31.7 | | | 30.7 |

Appendix Table 2 (Continued)**July 30, 2009**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.4 | 35.2 | | | 30.7 |
| 11 | 38 | 36.8 | | | 31.8 |
| 12 | 38.4 | 37.2 | | | 32.5 |
| 13 | 40.4 | 39.4 | | | 33.5 |
| 14 | 40.8 | 39.6 | | | 33.8 |
| 15 | 38.6 | 37.4 | | | 32.8 |
| 16 | 36.7 | 35.3 | | | 31.9 |
| 17 | 32 | 30.5 | | | 29.9 |

July 31, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 33.9 | 32.9 | | | 29.6 |
| 11 | 38 | 36.9 | | | 32.1 |
| 12 | 40.2 | 38.9 | | | 33.4 |
| 13 | 38.9 | 38 | | | 32.7 |
| 14 | 38.8 | 37.5 | | | 32.9 |
| 15 | 38.7 | 37.5 | | | 33.4 |
| 16 | 37.6 | 36.1 | | | 32.7 |
| 17 | 33.9 | 32.3 | | | 30.5 |

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Appendix Table 3 Temperature variations of different positions of the mock up
Case-A on August 10th, 11th, 13th, 14th, 17th, 2009.

August 10, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 34.9 | 33.7 | | | 30.1 |
| 11 | 37.5 | 36.3 | | | 31.8 |
| 12 | 38.3 | 37.1 | | | 32.1 |
| 13 | 37.4 | 36.2 | | | 31.4 |
| 14 | 36.5 | 35.2 | | | 31.1 |
| 15 | 38.9 | 37.8 | | | 33.2 |
| 16 | 39.1 | 37.9 | | | 33.3 |
| 17 | 37.1 | 35.6 | | | 32.3 |

August 11, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 38.3 | 36.9 | | | 33.4 |
| 11 | 39.8 | 38.4 | | | 34.4 |
| 12 | 40.3 | 38.8 | | | 35.1 |
| 13 | 42 | 40.7 | | | 35.3 |
| 14 | 43.1 | 41.8 | | | 36.4 |
| 15 | 42.9 | 41.5 | | | 36.5 |
| 16 | 40.6 | 39.2 | | | 35 |
| 17 | 38.6 | 37.2 | | | 34 |

August 13, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.2 | 35 | | | 32.4 |
| 11 | 41.5 | 40.3 | | | 35.8 |
| 12 | 43.5 | 42.3 | | | 36.8 |
| 13 | 45 | 43.8 | | | 37.3 |
| 14 | 45 | 43.6 | | | 38.1 |
| 15 | 44.9 | 43.5 | | | 37.4 |
| 16 | 43 | 41.8 | | | 37.8 |
| 17 | 40.8 | 39.3 | | | 36.3 |

Appendix Table 3 (Continued)**August 14, 2009**

| Time | Temperature (°C) | | | | Ambient T. |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | |
| 10 | 33.2 | 32.5 | | | 29.4 |
| 11 | 37.6 | 37.5 | | | 32.9 |
| 12 | 39.1 | 39.1 | | | 33.6 |
| 13 | 40.6 | 40.6 | | | 34.3 |
| 14 | 41.9 | 42.4 | | | 35.3 |
| 15 | 42.8 | 42.9 | | | 36.2 |
| 16 | 41.4 | 41.7 | | | 36.4 |
| 17 | 38.5 | 37.4 | | | 34.4 |

August 17, 2009

| Time | Temperature (°C) | | | | Ambient T. |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | |
| 10 | 39.9 | 38.5 | | | 35.4 |
| 11 | 43.7 | 42.3 | | | 38 |
| 12 | 45.7 | 44.5 | | | 38.4 |
| 13 | 46.5 | 45.2 | | | 38.5 |
| 14 | 44.7 | 43.5 | | | 37.3 |
| 15 | 41.3 | 39.8 | | | 35.5 |
| 16 | 38.4 | 36.8 | | | 35.1 |
| 17 | 35.6 | 34 | | | 33.1 |

Appendix Table 4 Temperature variations of different positions of the mock up
Case-A on October 6th, 7th, 8th, 13th, 14th, 15th, 2009.

October 6, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 40.1 | 39.5 | | | 35.3 |
| 11 | 42.4 | 42.5 | | | 36.9 |
| 12 | 42.4 | 42.8 | | | 35.7 |
| 13 | 48.2 | 47.7 | | | 38 |
| 14 | 47.6 | 47.2 | | | 37 |
| 15 | 48.6 | 48.2 | | | 37.6 |
| 16 | 46.1 | 45.7 | | | 35.9 |
| 17 | 42 | 40.6 | | | 34.9 |

October 7, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 38.5 | 37.5 | | | 33.9 |
| 11 | 40.9 | 39.8 | | | 34.5 |
| 12 | 44 | 43 | | | 35.4 |
| 13 | 51.7 | 50.8 | | | 39 |
| 14 | 52.7 | 52.2 | | | 39.9 |
| 15 | 48.2 | 47.2 | | | 37.3 |
| 16 | 44.6 | 43.7 | | | 35.8 |
| 17 | 39.1 | 37.2 | | | 31.8 |

October 8, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.6 | 35.7 | | | 32.9 |
| 11 | 41.1 | 40.2 | | | 35.1 |
| 12 | 42.8 | 41.9 | | | 35.1 |
| 13 | 45.1 | 44.4 | | | 35.6 |
| 14 | 49 | 48.1 | | | 37.8 |
| 15 | 49.5 | 48.7 | | | 38.2 |
| 16 | 46.4 | 45.7 | | | 37.1 |
| 17 | 39.3 | 38 | | | 33.1 |

Appendix Table 4 (Continued)**October 13, 2009**

| Time | Temperature (°C) | | | | Ambient T. |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | |
| 10 | 36.5 | 36 | | | 33.1 |
| 11 | 37.6 | 36.6 | | | 32.4 |
| 12 | 37 | 35.7 | | | 31.7 |
| 13 | 32.7 | 31.2 | | | 29 |
| 14 | 31.3 | 30 | | | 28.9 |
| 15 | 39.3 | 38.9 | | | 32.3 |
| 16 | 36.9 | 35.6 | | | 30.7 |
| 17 | 34.3 | 33.1 | | | 29.6 |

October 14, 2009

| Time | Temperature (°C) | | | | Ambient T. |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | |
| 10 | 37.7 | 36.6 | | | 34.1 |
| 11 | 43.8 | 42.9 | | | 37.1 |
| 12 | 45.6 | 44.6 | | | 35.9 |
| 13 | 45.7 | 44.8 | | | 35.5 |
| 14 | 50.5 | 49.9 | | | 38.1 |
| 15 | 51.1 | 50.5 | | | 37.3 |
| 16 | 49.7 | 49.5 | | | 37.6 |
| 17 | 45.4 | 43.9 | | | 34.9 |

October 15, 2009

| Time | Temperature (°C) | | | | Ambient T. |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | |
| 10 | 37 | 36 | | | 32.8 |
| 11 | 40.3 | 39.3 | | | 34.3 |
| 12 | 40.5 | 39.6 | | | 33.9 |
| 13 | 40.9 | 39.9 | | | 33.5 |
| 14 | 44.3 | 41.1 | | | 35.3 |
| 15 | 50.9 | 50.1 | | | 38.1 |
| 16 | 45.5 | 44.8 | | | 35.1 |
| 17 | 38.9 | 37.4 | | | 32.3 |

Appendix Table 5 Temperature variations of different positions of the mock up
Case-B on June 25th, 26th, 29th, 2009 (without rockwool).

June 25, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | | 46.5 | 46.7 | | |
| 11 | | 46.8 | 47.6 | | |
| 12 | | 46.9 | 46.9 | | |
| 13 | | 47 | 48.4 | | |
| 14 | | 48.9 | 49.2 | | |
| 15 | | 50 | 50.8 | | |
| 16 | | 49.1 | 49.6 | | |
| 17 | | 42 | 43.6 | | |

June 26, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | | 43.8 | 44 | | |
| 11 | | 45 | 45.7 | | |
| 12 | | 46.1 | 46.6 | | |
| 13 | | 46.1 | 47.6 | | |
| 14 | | 47.5 | 49.5 | | |
| 15 | | 46 | 48.2 | | |
| 16 | | 42.6 | 44.9 | | |
| 17 | | 39 | 39.9 | | |

June 29, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | | 46.5 | 46.7 | | |
| 11 | | 44.2 | 45.1 | | |
| 12 | | 43.6 | 45 | | |
| 13 | | 48.2 | 49.1 | | |
| 14 | | 47.6 | 48.4 | | |
| 15 | | 48.8 | 50.3 | | |
| 16 | | 39.4 | 41.7 | | |
| 17 | | 36 | 39 | | |

Appendix Table 6 Temperature variations of different positions of the mock up
Case-B on July 23rd, 24th, 28th, 30th, 31st, 2009.

July 23, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 33.3 | 33.5 | 36.2 | | 29.2 |
| 11 | 34.5 | 34.7 | 37.9 | | 30 |
| 12 | 36.6 | 36.7 | 39.6 | | 30.9 |
| 13 | 34.6 | 34.7 | 36.6 | | 29.4 |
| 14 | 36 | 36.2 | 39.5 | | 30.3 |
| 15 | 36.9 | 37.1 | 39.6 | | 30.7 |
| 16 | 34 | 34 | 35 | | 29.7 |
| 17 | 36 | 36.1 | 38.8 | | 32.6 |

July 24, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 34.4 | 34.8 | 37.7 | | 29 |
| 11 | 36.7 | 36.8 | 39 | | 30.2 |
| 12 | 39.2 | 39.4 | 43.7 | | 33.1 |
| 13 | 40.9 | 41.1 | 45.4 | | 33.6 |
| 14 | 40.7 | 40.8 | 43.8 | | 34.2 |
| 15 | 42.6 | 42.7 | 47.1 | | 35.4 |
| 16 | 42.5 | 42.7 | 46.7 | | 35.5 |
| 17 | 37.9 | 38 | 38.7 | | 32.8 |

July 28, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 38.4 | 38.5 | 42.7 | | 32.4 |
| 11 | 40.2 | 40.5 | 45.3 | | 34.1 |
| 12 | 40.1 | 41.2 | 44.5 | | 34.1 |
| 13 | 41.5 | 41.4 | 44.1 | | 34.6 |
| 14 | 42.6 | 42.6 | 46.7 | | 35.7 |
| 15 | 42.6 | 42.6 | 45 | | 36.4 |
| 16 | 39.7 | 39.8 | 40.8 | | 33.1 |
| 17 | 33.4 | 33.3 | 33.3 | | 30.7 |

Appendix Table 6 (Continued)**July 30, 2009**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.1 | 36.2 | 39 | | 30.7 |
| 11 | 37.5 | 37.6 | 41.3 | | 31.8 |
| 12 | 38.4 | 38.6 | 42.1 | | 32.5 |
| 13 | 40.4 | 40.5 | 44.9 | | 33.5 |
| 14 | 40.6 | 40.9 | 45 | | 33.8 |
| 15 | 38.4 | 38.4 | 40.7 | | 32.8 |
| 16 | 36.6 | 36.5 | 37.7 | | 31.9 |
| 17 | 31.6 | 31.4 | 31.8 | | 29.9 |

July 31, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 33.5 | 33.5 | 36 | | 29.6 |
| 11 | 37.7 | 37.9 | 41.2 | | 32.1 |
| 12 | 40.3 | 40.5 | 43.8 | | 33.4 |
| 13 | 38.7 | 38.8 | 42.1 | | 32.7 |
| 14 | 38.4 | 38.4 | 41.1 | | 32.9 |
| 15 | 38.1 | 38.3 | 41.5 | | 33.4 |
| 16 | 37.7 | 37.8 | 39.1 | | 32.7 |
| 17 | 33.9 | 33.8 | 34 | | 30.5 |

Appendix Table 7 Temperature variations of different positions of the mock up
Case-B on August 10th, 11th, 13th, 14th, 17th, 2009.

August 10, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 33.9 | 33.8 | 36.8 | | 30.1 |
| 11 | 37.4 | 37.5 | 39.5 | | 31.8 |
| 12 | 37.9 | 38 | 40.5 | | 32.1 |
| 13 | 37.3 | 37.4 | 39.1 | | 31.4 |
| 14 | 36.3 | 36.4 | 38.3 | | 31.1 |
| 15 | 38.6 | 38.8 | 42 | | 33.2 |
| 16 | 39.3 | 39.5 | 41.5 | | 33.3 |
| 17 | 37.2 | 37.1 | 38.2 | | 32.3 |

August 11, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 39.3 | 39.4 | 43.4 | | 33.4 |
| 11 | 41 | 41.1 | 44.8 | | 34.4 |
| 12 | 41.3 | 41.3 | 44.9 | | 35.1 |
| 13 | 42.3 | 42.4 | 45.8 | | 35.3 |
| 14 | 43.8 | 44 | 47.7 | | 36.4 |
| 15 | 43.7 | 43.8 | 46.5 | | 36.5 |
| 16 | 41 | 41 | 44.3 | | 35 |
| 17 | 38.8 | 38.8 | 39.8 | | 34 |

August 13, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.6 | 36.6 | 40.7 | | 32.4 |
| 11 | 42.5 | 42.8 | 46.6 | | 35.8 |
| 12 | 44.5 | 44.8 | 47.7 | | 36.8 |
| 13 | 45.6 | 45.9 | 49.3 | | 37.3 |
| 14 | 46.2 | 46.5 | 49.6 | | 38.1 |
| 15 | 46.1 | 46.4 | 48.2 | | 37.4 |
| 16 | 43.6 | 43.6 | 46 | | 37.8 |
| 17 | 41.2 | 41.2 | 41.6 | | 36.3 |

Appendix Table 7 (Continued)**August 14, 2009**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 32.4 | 32.7 | 35.7 | | 29.4 |
| 11 | 38.1 | 38.3 | 42.5 | | 32.9 |
| 12 | 40.3 | 40.7 | 44.3 | | 33.6 |
| 13 | 41.9 | 42.3 | 45.7 | | 34.3 |
| 14 | 43.5 | 44.1 | 48.1 | | 35.3 |
| 15 | 44.9 | 45.3 | 49.5 | | 36.2 |
| 16 | 44 | 44.4 | 48.3 | | 36.4 |
| 17 | 39.5 | 39.6 | 40.4 | | 34.4 |

August 17, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 41.9 | 42.3 | 45.8 | | 35.4 |
| 11 | 45.5 | 46.2 | 50 | | 38 |
| 12 | 47.7 | 48.3 | 51.4 | | 38.4 |
| 13 | 48 | 48.4 | 50.4 | | 38.5 |
| 14 | 45.3 | 45.4 | 47.8 | | 37.3 |
| 15 | 41.8 | 41.9 | 42.6 | | 35.5 |
| 16 | 38.6 | 38.6 | 39.3 | | 35.1 |
| 17 | 35.5 | 35.5 | 35.8 | | 33.1 |

Appendix Table 8 Temperature variations of different positions of the mock up
Case-B.1 on October 6th, 7th, 8th, 13th, 14th, 15th, 2009.

October 6, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 41.5 | 40.8 | 37.8 | | 35.3 |
| 11 | 41.2 | 41.5 | 38.4 | | 36.9 |
| 12 | 40.7 | 41.3 | 38.7 | | 35.7 |
| 13 | 44.3 | 44.9 | 41.3 | | 38 |
| 14 | 43.6 | 44.2 | 39 | | 37 |
| 15 | 44.5 | 45.2 | 40.4 | | 37.6 |
| 16 | 42.7 | 43.4 | 38.9 | | 35.9 |
| 17 | 39.4 | 39.4 | 35.6 | | 34.9 |

October 7, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 37.1 | 37.1 | 33.7 | | 33.9 |
| 11 | 38.8 | 39 | 36.4 | | 34.5 |
| 12 | 41.6 | 41.7 | 37.6 | | 35.4 |
| 13 | 47.5 | 48.1 | 42.1 | | 39 |
| 14 | 48.7 | 49.6 | 42.5 | | 39.9 |
| 15 | 45.3 | 45.6 | 38.9 | | 37.3 |
| 16 | 42.4 | 42.5 | 37.2 | | 35.8 |
| 17 | 37.3 | 36.7 | 30.1 | | 31.8 |

October 8, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 34.9 | 34.9 | 33.8 | | 32.9 |
| 11 | 39 | 39.2 | 35.9 | | 35.1 |
| 12 | 40.7 | 41.1 | 36.9 | | 35.1 |
| 13 | 42.7 | 42.9 | 36.9 | | 35.6 |
| 14 | 45.6 | 46.2 | 40 | | 37.8 |
| 15 | 46 | 46.7 | 40.5 | | 38.2 |
| 16 | 43.7 | 44.3 | 39.3 | | 37.1 |
| 17 | 37.7 | 37.4 | 33.2 | | 33.1 |

Appendix Table 8 (Continued)**October 13, 2009**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 34 | 34.4 | 33.8 | | 33.1 |
| 11 | 35.3 | 35.4 | 32.7 | | 32.4 |
| 12 | 34.8 | 34.8 | 30.7 | | 31.7 |
| 13 | 31 | 30.8 | 28.2 | | 29 |
| 14 | 29.8 | 29.5 | 28.1 | | 28.9 |
| 15 | 36.3 | 36.8 | 33.1 | | 32.3 |
| 16 | 34.6 | 34.5 | 31.5 | | 30.7 |
| 17 | 32.8 | 32.5 | 29.9 | | 29.6 |

October 14, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.6 | 36.4 | 34.1 | | 34.1 |
| 11 | 41.8 | 42.2 | 37.9 | | 37.1 |
| 12 | 43.5 | 43.7 | 39.4 | | 35.9 |
| 13 | 43.2 | 43.6 | 38.5 | | 35.5 |
| 14 | 46 | 46.8 | 40.9 | | 38.1 |
| 15 | 46.6 | 47.4 | 39.9 | | 37.3 |
| 16 | 45.7 | 46.8 | 39 | | 37.6 |
| 17 | 42.9 | 42.5 | 35.1 | | 34.9 |

October 15, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 34.9 | 34.8 | 33.9 | | 32.8 |
| 11 | 37.8 | 38 | 34.6 | | 34.3 |
| 12 | 38.4 | 38.6 | 34.2 | | 33.9 |
| 13 | 38.8 | 39.2 | 35.1 | | 33.5 |
| 14 | 41.8 | 42.4 | 38.7 | | 35.3 |
| 15 | 46.3 | 47.4 | 41.7 | | 38.1 |
| 16 | 42.7 | 43.1 | 37.4 | | 35.1 |
| 17 | 37.2 | 37 | 31.7 | | 32.3 |

Appendix Table 9 Temperature variations of different positions of the mock up
Case-C on June 25th, 26th, 29th, 2009 (without rockwool).

June 25, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 46.1 | 45.2 | 38.8 | 35.2 | |
| 11 | 46.3 | 45.4 | 37.1 | 36 | |
| 12 | 46.3 | 45.4 | 38.1 | 37.1 | |
| 13 | 46.4 | 45.5 | 38.7 | 37.7 | |
| 14 | 49 | 47.9 | 40.3 | 39.1 | |
| 15 | 49.7 | 49 | 41.1 | 40.1 | |
| 16 | 49.7 | 49.1 | 41.5 | 41.4 | |
| 17 | 41.9 | 41.5 | 38.2 | 37.1 | |

June 26, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 43.9 | 42.9 | 35.1 | 34.1 | |
| 11 | 44.6 | 43.6 | 36.7 | 35.6 | |
| 12 | 45.5 | 44.6 | 37.4 | 36.5 | |
| 13 | 45.6 | 44.8 | 38.5 | 37.5 | |
| 14 | 46.7 | 45.8 | 39 | 38.1 | |
| 15 | 45 | 44.5 | 38.9 | 37.9 | |
| 16 | 41.8 | 41.4 | 38.5 | 37.5 | |
| 17 | 39 | 38.4 | 36.2 | 35.2 | |

June 29, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 46.2 | 45.1 | 36.2 | 35.1 | |
| 11 | 43.2 | 42.6 | 37.1 | 35.9 | |
| 12 | 43.2 | 42.3 | 37 | 36.1 | |
| 13 | 47.5 | 46.6 | 39.8 | 38.8 | |
| 14 | 47.1 | 46.2 | 38.9 | 38 | |
| 15 | 47.2 | 47.4 | 40.4 | 39.4 | |
| 16 | 38.4 | 38.1 | 36.4 | 35.4 | |
| 17 | 36.8 | 37.2 | 34.5 | 33.9 | |

Appendix Table 10 Temperature variations of different positions of the mock up
Case-C on July 23rd, 24th, 28th, 30th, 31st, 2009

July 23, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 31.7 | 31.4 | 31.7 | 30.7 | 29.2 |
| 11 | 33.3 | 33 | 33.4 | 32.6 | 30 |
| 12 | 34.7 | 34.3 | 33.7 | 33 | 30.9 |
| 13 | 32.2 | 32.8 | 31.9 | 30.9 | 29.4 |
| 14 | 34.4 | 34 | 33.7 | 32.8 | 30.3 |
| 15 | 35.2 | 34.7 | 33.7 | 32.8 | 30.7 |
| 16 | 33.2 | 32.6 | 32.4 | 31.2 | 29.7 |
| 17 | 35.3 | 34.9 | 34.4 | 33.5 | 32.6 |

July 24, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 32.9 | 32.1 | 30.8 | 30 | 29 |
| 11 | 34.6 | 34.3 | 32.6 | 32.8 | 30.2 |
| 12 | 37.5 | 37 | 35.8 | 35 | 33.1 |
| 13 | 38.8 | 38.3 | 37.2 | 36.3 | 33.6 |
| 14 | 38.5 | 38.1 | 36.2 | 35.3 | 34.2 |
| 15 | 40.9 | 40.4 | 37.9 | 37.9 | 35.4 |
| 16 | 41.1 | 40.6 | 38.1 | 38.1 | 35.5 |
| 17 | 37.2 | 36.6 | 34.4 | 34.4 | 32.8 |

July 28, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.6 | 36.2 | 35.3 | 31 | 32.4 |
| 11 | 38 | 37.7 | 36.7 | 33.1 | 34.1 |
| 12 | 38.5 | 38.1 | 36.2 | 33 | 34.1 |
| 13 | 39.1 | 38.6 | 36.3 | 33.4 | 34.6 |
| 14 | 40.5 | 40 | 38.9 | 35 | 35.7 |
| 15 | 40.8 | 40.3 | 38.3 | 35.3 | 36.4 |
| 16 | 38.4 | 38.1 | 36.9 | 32.1 | 33.1 |
| 17 | 32.8 | 32.1 | 31.6 | 29.3 | 30.7 |

Appendix Table 10 (Continued)**July 30, 2009**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 34.7 | 34.1 | 33.8 | 30.1 | 30.7 |
| 11 | 35.8 | 35.2 | 34.7 | 31.1 | 31.8 |
| 12 | 36.2 | 35.6 | 34.8 | 32.4 | 32.5 |
| 13 | 37.8 | 37.2 | 35.9 | 33.3 | 33.5 |
| 14 | 38.1 | 37.6 | 36.5 | 33.3 | 33.8 |
| 15 | 36.2 | 35.6 | 34.3 | 31.6 | 32.8 |
| 16 | 34.8 | 34.3 | 33.2 | 30.3 | 31.9 |
| 17 | 31.1 | 30.6 | 30.9 | 28.3 | 29.9 |

July 31, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 32.5 | 31.8 | 32.1 | 29.3 | 29.6 |
| 11 | 35.8 | 35.4 | 34.5 | 31.7 | 32.1 |
| 12 | 37.6 | 37.1 | 35.8 | 32.2 | 33.4 |
| 13 | 36.5 | 35.9 | 35 | 32.8 | 32.7 |
| 14 | 36.2 | 35.6 | 34.3 | 31.4 | 32.9 |
| 15 | 36.4 | 35.8 | 35.6 | 33.3 | 33.4 |
| 16 | 36.4 | 35.8 | 34.4 | 31.7 | 32.7 |
| 17 | 33.3 | 32.9 | 32.2 | 29.6 | 30.5 |

Appendix 11 Temperature variations of different positions of the mock up Case-C on August 10th, 11th, 13th, 14th, 17th, 2009

August 10, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 33.2 | 33.8 | 33.6 | 30.6 | 30.1 |
| 11 | 36 | 35.3 | 33.8 | 30.5 | 31.8 |
| 12 | 36.3 | 35.7 | 34.3 | 32.3 | 32.1 |
| 13 | 35.7 | 35.2 | 33.6 | 30.6 | 31.4 |
| 14 | 34.8 | 34.3 | 33.6 | 30.9 | 31.1 |
| 15 | 37.1 | 36.5 | 35.7 | 32.8 | 33.2 |
| 16 | 37.6 | 37.1 | 35.6 | 32.6 | 33.3 |
| 17 | 35.9 | 35.3 | 34.1 | 31.6 | 32.3 |

August 11, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 37.2 | 36.7 | 35 | 32.2 | 33.4 |
| 11 | 38.4 | 38 | 35.9 | 33.2 | 34.4 |
| 12 | 38.9 | 38.4 | 36.6 | 33.8 | 35.1 |
| 13 | 40 | 39.4 | 37.4 | 35 | 35.3 |
| 14 | 41.7 | 41.1 | 39 | 35.9 | 36.4 |
| 15 | 41.6 | 41 | 38.4 | 35.2 | 36.5 |
| 16 | 39.4 | 38.8 | 37.6 | 34.8 | 35 |
| 17 | 37.9 | 37.5 | 36.2 | 33.6 | 34 |

August 13, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 35.3 | 34.7 | 34.4 | 32.4 | 32.4 |
| 11 | 40 | 39.6 | 38.6 | 35.5 | 35.8 |
| 12 | 41.7 | 41.1 | 39 | 35.6 | 36.8 |
| 13 | 43.1 | 42.6 | 40.1 | 36 | 37.3 |
| 14 | 43.9 | 43.5 | 40.3 | 37 | 38.1 |
| 15 | 44.1 | 43.7 | 39.6 | 35.9 | 37.4 |
| 16 | 42.3 | 41.8 | 40.4 | 37.1 | 37.8 |
| 17 | 40.4 | 39.9 | 38.3 | 35.1 | 36.3 |

Appendix 11 (Continued)**August 14, 2009**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 31.1 | 30.6 | 32.1 | 29.9 | 29.4 |
| 11 | 36.1 | 35.6 | 35.9 | 32.9 | 32.9 |
| 12 | 37.8 | 37.5 | 36.8 | 33.5 | 33.6 |
| 13 | 39.5 | 39 | 37.5 | 34.3 | 34.3 |
| 14 | 41 | 40.5 | 38.4 | 35 | 35.3 |
| 15 | 42.7 | 42.3 | 39.5 | 37.8 | 36.2 |
| 16 | 42.4 | 41.9 | 40.6 | 37.6 | 36.4 |
| 17 | 38.8 | 38.4 | 36 | 33.3 | 34.4 |

August 17, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 39.5 | 39.2 | 38.5 | 35.8 | 35.4 |
| 11 | 42.8 | 42.2 | 40.7 | 37.6 | 38 |
| 12 | 44.5 | 43.9 | 41.4 | 37.4 | 38.4 |
| 13 | 45.1 | 44.4 | 40.9 | 37.2 | 38.5 |
| 14 | 43.3 | 42.8 | 40.8 | 37.9 | 37.3 |
| 15 | 40.6 | 40.1 | 37.6 | 34.8 | 35.5 |
| 16 | 37.9 | 37.5 | 35.9 | 33.6 | 35.1 |
| 17 | 35.2 | 34.6 | 33.3 | 30.8 | 33.1 |

Appendix Table 12 Temperature variations of different positions of the mock up
Case-C on October 6th, 7th, 8th, 13th, 14th, 15th, 2009.

October 6, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 42.5 | 42 | 41.6 | 34.4 | 35.3 |
| 11 | 40.1 | 39.6 | 38.7 | 38.2 | 36.9 |
| 12 | 39.1 | 38.6 | 38.6 | 38.3 | 35.7 |
| 13 | 41.6 | 41.1 | 39.4 | 38.9 | 38 |
| 14 | 41.3 | 40.4 | 38.2 | 39.1 | 37 |
| 15 | 42.8 | 42.1 | 39.2 | 40.3 | 37.6 |
| 16 | 41.4 | 40.6 | 37.3 | 37.9 | 35.9 |
| 17 | 38.4 | 37.7 | 35.8 | 34.6 | 34.9 |

October 7, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 37.3 | 36.8 | 35.7 | 33.3 | 33.9 |
| 11 | 38.9 | 38.3 | 37.7 | 34.9 | 34.5 |
| 12 | 41.2 | 40.6 | 39.4 | 37.1 | 35.4 |
| 13 | 45.6 | 45.1 | 42 | 40.4 | 39 |
| 14 | 47 | 46.6 | 44.3 | 40.8 | 39.9 |
| 15 | 44.8 | 44.2 | 40.7 | 37.6 | 37.3 |
| 16 | 42.4 | 42 | 39.5 | 35.8 | 35.8 |
| 17 | 37.7 | 37 | 32.1 | 29.3 | 31.8 |

October 8, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 35.3 | 35 | 35.9 | 33.9 | 32.9 |
| 11 | 39.3 | 38.7 | 37.7 | 35.1 | 35.1 |
| 12 | 40.9 | 40.3 | 38.4 | 34.5 | 35.1 |
| 13 | 42.5 | 41.8 | 39.3 | 35.1 | 35.6 |
| 14 | 45 | 44.4 | 42.1 | 39.3 | 37.8 |
| 15 | 45.4 | 44.8 | 42.6 | 39.6 | 38.2 |
| 16 | 43.6 | 43.1 | 40.9 | 37.3 | 37.1 |
| 17 | 38.1 | 37.6 | 35.8 | 32.8 | 33.1 |

Appendix Table 12 (Continued)**October 13, 2009**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 34.4 | 34.1 | 35.5 | 33.6 | 33.1 |
| 11 | 35.8 | 35.3 | 35.2 | 32.7 | 32.4 |
| 12 | 35.5 | 34.8 | 33.5 | 30.3 | 31.7 |
| 13 | 31.8 | 31.3 | 30.5 | 28.1 | 29 |
| 14 | 30.5 | 30 | 30 | 28.2 | 28.9 |
| 15 | 37.1 | 36.6 | 36 | 33.2 | 32.3 |
| 16 | 35.7 | 35.2 | 34 | 31.6 | 30.7 |
| 17 | 33.4 | 33.1 | 32.1 | 29.6 | 29.6 |

October 14, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.6 | 36.1 | 35.6 | 33.2 | 34.1 |
| 11 | 40.7 | 39.8 | 38.6 | 35.3 | 37.1 |
| 12 | 42.3 | 41.6 | 38.4 | 35.1 | 35.9 |
| 13 | 41.9 | 41.2 | 39.7 | 38.4 | 35.5 |
| 14 | 43.8 | 43.5 | 41.2 | 39.4 | 38.1 |
| 15 | 45.5 | 45 | 42.1 | 39.4 | 37.3 |
| 16 | 45.7 | 45.9 | 41.4 | 37.4 | 37.6 |
| 17 | 42.9 | 42.4 | 38 | 33.5 | 34.9 |

October 15, 2009

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 35.2 | 34.7 | 35.6 | 33.8 | 32.8 |
| 11 | 38.1 | 37.8 | 36.6 | 33.9 | 34.3 |
| 12 | 38.9 | 38.3 | 36.3 | 33.4 | 33.9 |
| 13 | 39.1 | 38.7 | 37.2 | 34.1 | 33.5 |
| 14 | 40.7 | 40.3 | 38.7 | 39 | 35.3 |
| 15 | 45.5 | 45.4 | 43.7 | 42.5 | 38.1 |
| 16 | 42.3 | 41.6 | 38.6 | 36.8 | 35.1 |
| 17 | 36.8 | 36.3 | 33.9 | 29.8 | 32.3 |

Appendix Table 13 Sample of room temperature difference at position 1 from mock ups (Case A, B and C) on July 30th, August 11th and October 8th, 2009.

July 30, 2009

| Time | Temperature (°C) | | | |
|------|---------------------|---------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-B) | Position 1 (Case-C) | Ambient T. |
| 10 | 36.4 | 36.1 | 34.7 | 30.7 |
| 11 | 38 | 37.5 | 35.8 | 31.8 |
| 12 | 38.4 | 38.4 | 36.2 | 32.5 |
| 13 | 40.4 | 40.4 | 37.8 | 33.5 |
| 14 | 40.8 | 40.6 | 38.1 | 33.8 |
| 15 | 38.6 | 38.4 | 36.2 | 32.8 |
| 16 | 36.7 | 36.6 | 34.8 | 31.9 |
| 17 | 32 | 31.6 | 31.1 | 29.9 |

August 11, 2009

| Time | Temperature (°C) | | | |
|------|---------------------|---------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-B) | Position 1 (Case-C) | Ambient T. |
| 10 | 38.3 | 39.3 | 37.2 | 33.4 |
| 11 | 39.8 | 41 | 38.4 | 34.4 |
| 12 | 40.3 | 41.3 | 38.9 | 35.1 |
| 13 | 42 | 42.3 | 40 | 35.3 |
| 14 | 43.1 | 43.8 | 41.7 | 36.4 |
| 15 | 42.9 | 43.7 | 41.6 | 36.5 |
| 16 | 40.6 | 41 | 39.4 | 35 |
| 17 | 38.6 | 38.8 | 37.9 | 34 |

October 8, 2009

| Time | Temperature (°C) | | | |
|------|---------------------|---------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-B) | Position 1 (Case-C) | Ambient T. |
| 10 | 36.6 | 34.9 | 35.3 | 32.9 |
| 11 | 41.1 | 39 | 39.3 | 35.1 |
| 12 | 42.8 | 40.7 | 40.9 | 35.1 |
| 13 | 45.1 | 42.7 | 42.5 | 35.6 |
| 14 | 49 | 45.6 | 45 | 37.8 |
| 15 | 49.5 | 46 | 45.4 | 38.2 |
| 16 | 46.4 | 43.7 | 43.6 | 37.1 |
| 17 | 39.3 | 37.7 | 38.1 | 33.1 |

Appendix Table 14 Sample of room temperature difference at position 1 between mock up Case-A and Case-C on July 30th, 2009.

July 30, 2009

| Time | Temperature (°C) | | |
|------|---------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-C) | Ambient T. |
| 10 | 36.4 | 34.7 | 30.7 |
| 11 | 38 | 35.8 | 31.8 |
| 12 | 38.4 | 36.2 | 32.5 |
| 13 | 40.4 | 37.8 | 33.5 |
| 14 | 40.8 | 38.1 | 33.8 |
| 15 | 38.6 | 36.2 | 32.8 |
| 16 | 36.7 | 34.8 | 31.9 |
| 17 | 32 | 31.1 | 29.9 |

Appendix Table 15 Sample of room temperature difference at position 1 between mock up Case-A and Case-C on August 11th, 2009.

August 11, 2009

| Time | Temperature (°C) | | |
|------|---------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-C) | Ambient T. |
| 10 | 38.3 | 37.2 | 33.4 |
| 11 | 39.8 | 38.4 | 34.4 |
| 12 | 40.3 | 38.9 | 35.1 |
| 13 | 42 | 40 | 35.3 |
| 14 | 43.1 | 41.7 | 36.4 |
| 15 | 42.9 | 41.6 | 36.5 |
| 16 | 40.6 | 39.4 | 35 |
| 17 | 38.6 | 37.9 | 34 |

Appendix Table 16 Sample of room temperature difference at position 1 between mock up Case-A and Case-C on October 8th, 2009.

October 8, 2009

| Time | Temperature (°C) | | |
|------|---------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-C) | Ambient T. |
| 10 | 36.6 | 35.3 | 32.9 |
| 11 | 41.1 | 39.3 | 35.1 |
| 12 | 42.8 | 40.9 | 35.1 |
| 13 | 45.1 | 42.5 | 35.6 |
| 14 | 49 | 45 | 37.8 |
| 15 | 49.5 | 45.4 | 38.2 |
| 16 | 46.4 | 43.6 | 37.1 |
| 17 | 39.3 | 38.1 | 33.1 |

Appendix Table 17 Temperature variations of different positions of the mock up Case-A (represents the single pane of primary glass wall) on January 16th and 17th, 2010.

January 16, 2010

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 36.7 | 35.9 | | | 29.8 |
| 11 | 43.4 | 42.6 | | | 32.9 |
| 12 | 46.3 | 45.7 | | | 33.1 |
| 13 | 49.4 | 48.8 | | | 34.1 |
| 14 | 45.5 | 44.7 | | | 33.6 |
| 15 | 49.2 | 49.3 | | | 34.6 |
| 16 | 46.6 | 46.9 | | | 33.6 |
| 17 | 42.4 | 42 | | | 31 |
| 18 | 34.5 | 33.1 | | | 29.4 |
| 19 | 28.5 | 26.9 | | | 27.5 |
| 20 | 26.8 | 25.2 | | | 27 |
| 21 | 25.9 | 24.9 | | | 26.3 |
| 22 | 24.9 | 23.2 | | | 25.1 |

Appendix Table 17 (Continued)**January 17, 2010**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 37 | 36.3 | | | 28.6 |
| 11 | 45.2 | 44.5 | | | 33.2 |
| 12 | 47.6 | 47 | | | 33.5 |
| 13 | 49.1 | 48.7 | | | 34.4 |
| 14 | 50 | 49.6 | | | 34.3 |
| 15 | 50.2 | 50.6 | | | 34.4 |
| 16 | 48.4 | 48.8 | | | 33.3 |
| 17 | 44.2 | 43.7 | | | 31.6 |
| 18 | 35.5 | 33.9 | | | 28.8 |
| 19 | 27.9 | 26.2 | | | 27.4 |
| 20 | 25.4 | 23.8 | | | 25.5 |
| 21 | 24.5 | 22.9 | | | 24.9 |
| 22 | 23.6 | 22.1 | | | 24.4 |

Appendix Table 18 Temperature variations of different positions of the mock up Case-B.1 (glass DSF with air ventilation) on January 16th and 17th, 2010.**January 16, 2010**

| Time | Temperature (C) | | | | |
|------|-----------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 37.2 | 33.1 | 32.5 | | 29.8 |
| 11 | 41.2 | 37.6 | 37.1 | | 32.9 |
| 12 | 42.9 | 39.9 | 39.3 | | 33.1 |
| 13 | 44.2 | 42.7 | 42 | | 34.1 |
| 14 | 41.8 | 40.9 | 40.4 | | 33.6 |
| 15 | 46.8 | 43.6 | 42.7 | | 34.6 |
| 16 | 45.4 | 42.1 | 41.5 | | 33.6 |
| 17 | 40.7 | 39.4 | 39.1 | | 31 |
| 18 | 32.6 | 33.7 | 33.7 | | 29.4 |
| 19 | 27.3 | 28.6 | 28.8 | | 27.5 |
| 20 | 25.8 | 26.6 | 26.9 | | 27 |
| 21 | 24.8 | 25.3 | 25.6 | | 26.3 |
| 22 | 24 | 24 | 24.4 | | 25.1 |

Appendix Table 18 (Continued)**January 17, 2010**

| Time | Temperature (C) | | | | |
|------|-----------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 37.8 | 33.1 | 32.7 | | 28.6 |
| 11 | 45 | 39.5 | 38.7 | | 33.2 |
| 12 | 46.2 | 41.7 | 40.7 | | 33.5 |
| 13 | 47.3 | 43.4 | 42.6 | | 34.4 |
| 14 | 47.2 | 44.3 | 43.5 | | 34.3 |
| 15 | 47.2 | 45.1 | 44.1 | | 34.4 |
| 16 | 47 | 43.9 | 43 | | 33.3 |
| 17 | 43.5 | 40.9 | 40.5 | | 31.6 |
| 18 | 33.7 | 34.8 | 34.8 | | 28.8 |
| 19 | 26.5 | 28.4 | 28.6 | | 27.4 |
| 20 | 24.6 | 25.3 | 25.7 | | 25.5 |
| 21 | 23.5 | 23.9 | 24.3 | | 24.9 |
| 22 | 22.8 | 23 | 23.3 | | 24.4 |

Appendix Table 19 Temperature variations of different positions of the mock up Case-C (glass DSF with stack ventilation) on January 16th and 17th, 2010.**January 16, 2010**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 30.9 | 30.5 | 31.1 | 31 | 29.8 |
| 11 | 34.5 | 33.9 | 32.9 | 32.6 | 32.9 |
| 12 | 36.1 | 35.4 | 34.1 | 34.5 | 33.1 |
| 13 | 38.4 | 37.7 | 34.6 | 34.7 | 34.1 |
| 14 | 37.3 | 36.4 | 33.6 | 33.9 | 33.6 |
| 15 | 39.8 | 39 | 35.5 | 35.5 | 34.6 |
| 16 | 38.8 | 38 | 34.3 | 34.8 | 33.6 |
| 17 | 36.4 | 35.7 | 32.7 | 32.1 | 31 |
| 18 | 31.8 | 31.3 | 29.6 | 28.3 | 29.4 |
| 19 | 28.2 | 27.6 | 27.8 | 25.6 | 27.5 |
| 20 | 26.6 | 26.1 | 26.9 | 25.4 | 27 |
| 21 | 25.6 | 25.2 | 25.9 | 24.2 | 26.3 |
| 22 | 24.5 | 24 | 25.4 | 23.7 | 25.1 |

Appendix Table 19 (Continued)**January 17, 2010**

| Time | Temperature (°C) | | | | |
|------|------------------|------------|------------|------------|------------|
| | Position 1 | Position 2 | Position 3 | Position 4 | Ambient T. |
| 10 | 30.7 | 30.1 | 30.6 | 30.2 | 28.6 |
| 11 | 35.6 | 35.1 | 33.3 | 34.4 | 33.2 |
| 12 | 36.9 | 36.1 | 33.3 | 34.8 | 33.5 |
| 13 | 38.5 | 37.9 | 34.9 | 35.8 | 34.4 |
| 14 | 39.7 | 39.2 | 36 | 36.8 | 34.3 |
| 15 | 40.7 | 40 | 35.7 | 36.1 | 34.4 |
| 16 | 39.7 | 39 | 34.7 | 34.9 | 33.3 |
| 17 | 37.8 | 37.2 | 34.4 | 34.3 | 31.6 |
| 18 | 32.8 | 32.1 | 29.4 | 27.5 | 28.8 |
| 19 | 27.4 | 26.9 | 26.3 | 24.7 | 27.4 |
| 20 | 25.2 | 24.7 | 25.6 | 23.8 | 25.5 |
| 21 | 24.2 | 23.7 | 24.3 | 22.9 | 24.9 |
| 22 | 23.3 | 22.8 | 23.8 | 22.4 | 24.4 |

Appendix Table 20 Room temperature difference at position 1 from mock up Case-A, Case-B.1, Case-C on January 16th and 17th, 2010.**January 16, 2010**

| Time | Temperature (C) | | | Ambient T. |
|------|---------------------|-----------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-B.1) | Position 1 (Case-C) | |
| 10 | 36.7 | 37.2 | 30.9 | 29.8 |
| 11 | 43.4 | 41.2 | 34.5 | 32.9 |
| 12 | 46.3 | 42.9 | 36.1 | 33.1 |
| 13 | 49.4 | 44.2 | 38.4 | 34.1 |
| 14 | 45.5 | 41.8 | 37.3 | 33.6 |
| 15 | 49.2 | 46.8 | 39.8 | 34.6 |
| 16 | 46.6 | 45.4 | 38.8 | 33.6 |
| 17 | 42.4 | 40.7 | 36.4 | 31 |
| 18 | 34.5 | 32.6 | 31.8 | 29.4 |
| 19 | 28.5 | 27.3 | 28.2 | 27.5 |
| 20 | 26.8 | 25.8 | 26.6 | 27 |
| 21 | 25.9 | 24.8 | 25.6 | 26.3 |
| 22 | 24.9 | 24 | 24.5 | 25.1 |

Appendix Table 20 (Continued)**January 17, 2010**

| Time | Temperature (C) | | | Ambient T. |
|------|---------------------|-----------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-B.1) | Position 1 (Case-C) | |
| 10 | 37 | 37.8 | 30.7 | 28.6 |
| 11 | 45.2 | 45 | 35.6 | 33.2 |
| 12 | 47.6 | 46.2 | 36.9 | 33.5 |
| 13 | 49.1 | 47.3 | 38.5 | 34.4 |
| 14 | 50 | 47.2 | 39.7 | 34.3 |
| 15 | 50.2 | 47.2 | 40.7 | 34.4 |
| 16 | 48.4 | 47 | 39.7 | 33.3 |
| 17 | 44.2 | 43.5 | 37.8 | 31.6 |
| 18 | 35.5 | 33.7 | 32.8 | 28.8 |
| 19 | 27.9 | 26.5 | 27.4 | 27.4 |
| 20 | 25.4 | 24.6 | 25.2 | 25.5 |
| 21 | 24.5 | 23.5 | 24.2 | 24.9 |
| 22 | 23.6 | 22.8 | 23.3 | 24.4 |

Appendix Table 21 Room temperature difference at position 1 between mock up Case-A and mock up Case-C on January 16th, 2010.**JANUARY 16, 2010**

| Time | Temperature (C) | | |
|------|---------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-C) | Ambient T. |
| 10 | 36.7 | 30.9 | 29.8 |
| 11 | 43.4 | 34.5 | 32.9 |
| 12 | 46.3 | 36.1 | 33.1 |
| 13 | 49.4 | 38.4 | 34.1 |
| 14 | 45.5 | 37.3 | 33.6 |
| 15 | 49.2 | 39.8 | 34.6 |
| 16 | 46.6 | 38.8 | 33.6 |
| 17 | 42.4 | 36.4 | 31 |
| 18 | 34.5 | 31.8 | 29.4 |
| 19 | 28.5 | 28.2 | 27.5 |
| 20 | 26.8 | 26.6 | 27 |
| 21 | 25.9 | 25.6 | 26.3 |
| 22 | 24.9 | 24.5 | 25.1 |

Appendix Table 22 Room temperature difference at position 1 between mock up Case-A and mock up Case-C on January 17th, 2010.

JANUARY 17, 2010

| Time | Temperature (°C) | | |
|------|---------------------|---------------------|------------|
| | Position 1 (Case-A) | Position 1 (Case-C) | Ambient T. |
| 10 | 37 | 30.7 | 28.6 |
| 11 | 45.2 | 35.6 | 33.2 |
| 12 | 47.6 | 36.9 | 33.5 |
| 13 | 49.1 | 38.5 | 34.4 |
| 14 | 50 | 39.7 | 34.3 |
| 15 | 50.2 | 40.7 | 34.4 |
| 16 | 48.4 | 39.7 | 33.3 |
| 17 | 44.2 | 37.8 | 31.6 |
| 18 | 35.5 | 32.8 | 28.8 |
| 19 | 27.9 | 27.4 | 27.4 |
| 20 | 25.4 | 25.2 | 25.5 |
| 21 | 24.5 | 24.2 | 24.9 |
| 22 | 23.6 | 23.3 | 24.4 |

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