THERMAL PERFORMANCES OF WATER AND HEAT INSULATION MATERIALS - A CASE STUDY IN NICOSIA (LEFKOŞA)

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF APPLIED SCIENCES
OF
NEAR EAST UNIVERSITY

by

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**In Partial Fulfillment of the Requirements
for
The Degree of Master of Science
in
Architecture**

NICOSIA 2010

Hülya Kocagöz: Thermal Performances of Water and Heat Insulation Materials – A Case Study in Nicosia (Lefkoşa)

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ABSTRACT

The design structures in climatic comfort conditions are an important factor to decrease building operating costs. To reduce the building cost one has to use the correct insulation materials on building exterior walls. This study is based on the study of the insulation materials which are used on the building roof to minimize the heat lost in winter and minimize heat gain in summer.

When the building roofs in TRNC are considered, it seems that the heat insulation materials are not enough to prevent heat loses. To reduce the heat losses firstly, the climatic and building parameters must be taken into account and the solar radiation which comes from the Sun should be used correctly and effectively. As it is known, in architectural design spaces that are used the most are directed toward the south. The reason for that is that, the solar radiations at the south facade of the building at the maximum level. Secondly, roof water and heat insulation materials should be appropriate for Northern Cyprus climate.

The experimental study described in this thesis was done in Lefkoşa, TRNC for this reason TRNC land climate, annual heat temperature table and prevailing wind direction was defined. The experimental study consists of two hip roofs called L1 and L2 with sizes 200cm x 200cm. Both roofs were studied at their south facade. The study was done at two stages. At the first stage The L1 roof has yalteks water insulation material on its four sides at the first stage. The L2 roof has yalteks water insulation material on its three sides, excluding the south facade at the first stage. Data was collected for ten days at the first stage. At the second stage the data collection was repeated by covering four sides of L1 roof with polyester foam board heat insulation and three sides, excluding south facade of L2 roof with the same material. Data was collected for twenty one days at the second stage.

Keywords: Roof heat insulation, Roof water insulation, South facade

ÖZET

Yapıların iklimsel konfor koşullarına uygun olarak tasarlanması, yapı işletme maliyetini indirgemede önemli bir unsurdur. Yapı maliyetini indirgemek için binalarda doğru izolasyon malzemesi kullanılmalıdır. Bu çalışmada bina çatılarından kullanılan yalıtım malzemelerinin kışın ısı kaybını azaltmaları ve yazında ısı kazancını azaltmaları baz alınmıştır.

KKTC'deki bina çatılarında kullanılan yalıtım malzemeleri incelendiğinde ısı izolasyonunun binadaki ısı kaybını önlemeye yeterli olmadığı görülmüştür. Bu durumu tersine çevirmek için öncelikle binalarda güneşten gelen enerjiyi en verimli şekilde kullanma yolları ele alınmıştır. Mimari tasarımda etkili olan iklimsel parametreler ve binaya ait parametreler göz önünde bulundurulmuştur. Bilindiği üzere mimari tasarımda en çok kullanılan alanlar güney cephesine yönlendirilmiştir. Çünkü solar radyasyonlar güney cephesinde maksimum seviyededirler.

Deneysel çalışma KKTC, Lefkoşa da yapılmıştır. Bu yüzden KKTC'nin arazi iklimi, yıllık sıcaklık tablosu ve hakim rüzgar yönü ele alınmıştır. Deneysel Çalışma 200 cm x 2 00 cm ebatlarında L1 ve L2 adında iki kırma çatı üzerinde yapılmıştır. Her iki çatının da güney cepheleri üzerinde çalışılmıştır. Çalışma iki aşamalı olarak yapılmıştır. Birinci aşamada L1'in dört tarafı su yalıtımı ile kaplanmıştır. L2'nin ise güney cephesi hariç diğer üç cephesi su yalıtım malzemesi ile kaplanmıştır. Bu şekilde on gün veri alınmıştır. İkinci aşamada L1'in dört cephesine köpük ısı yalıtımı konularak veri alınmaya devam edilmiştir. L2'nin ise güney cephesi hariç üç cephesi ısı yalıtım malzemesi ile kaplanmıştır. Bu şekilde yirmi bir gün veri alınmıştır.

Anahtar sözcükler: Çatı ısı yalıtımı, Çatı su yalıtımı, Güney cephesi

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DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Hülya KOCAGÖZ
Signature :
Date: 28/10/2010

ACKNOWLEDGEMENTS

First, I would like to thank to my supervisor Asist. Prof. Dr Lida EBRAHIMI VAFAEI for her invaluable advice and belief in my work and Assoc. Prof. Dr Cemil YAMALI for his support my thesis.

I would like to express also my gratitude to NEU Design providing facilities.

DEDICATION

I dedicate this humble work to my parents, Yurdanur and Müslüm KIRGIL and to my husband Yavuz Selim KOCAGÖZ for his constant encouragement and support during the preparation of this thesis.

CONTENTS

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LIST OF ABBREVIATIONS

CEN	European Standardization Committee
EN 13162	Thermal insulation products for buildings - Factory made mineral wool (MW) products - Specification
EN 13172	Thermal insulating products. Evaluation of conformity
FSC	Forest Stewardship Council
GB standards	GB standarts are the Chinese national standards issued by the Standardization Administration of China (SAC)
GSM	Grams Per Square Metre
ISO	International Organization for Standardization
MDF	Medium Density Fibreboard
OSB	Oriented Standard Boards
TNO	Nederlandse Organisatie voor toegepast
VOC	Volatile Organic Compound

LIST OF SYMBOLS

i	Declination angle
ρ	Density (kg/m^3)
k	Measure of heat conductivity of a particular material units
H	Hour angle
h	Hours (time)
N	Latitude
E	Longitude
R-value	Thermal resistance
s	Solar constant
sqm	Square meter
λ	Thermal conductivity (W/mK)
W/m^2	Watts per square meter
Z	Zenith angle
V	Volt
Δ	Pressure probe.

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CHAPTER 1, INTRODUCTION

Insulating buildings, such as walls, roofs and floors is an important matter for reducing the rate of heat flowing into (in time of summer) and from (in time of winter) the houses. To reduce the heat flow efficiently we should select the proper insulation by accounting for the purpose, environment, ease of handling and installation, and the cost [1].

North Cyprus, Lefkoşa is characterised by a mediterranean climate and an intense solar radiation. Such a climate imposes extreme solicitations to the various components of a building and often creates totally unaffordable discomfort situations [2]. To face this problem, the use of effective roof insulation materials should be used to prevent comfort.

The place of a building, air temperature, wind direction, humidity etc. climate members value are known to be effective components that provide energy efficiency. Therefore according to the bioclimatic requirements of the climate region positioned of the building, the building should be directed when they benefit or protected from the sun, wind and space organization should be done according to the criteria of the direction.

One of the design parameters of a building form is directly related with the climatic parameters. This can be understood by the different districts from different architectural design samples [3].

The building's roofs are one of the most problematic parameters in the TRNC. In our observation the reason of building roofs appears the least visible unit that has the least care taken care least. Same evaluation is valid on roof materials [4]. This paper describes a detailed study carried out on performance comparison of water and heat insulation materials on southern directed hip roofs in Nicosia.

CHAPTER 2, THE SUN

2.1 Solar Radiation

Solar radiation drives atmospheric circulation. Since solar radiation represents almost all the energy available to the earth, accounting for solar radiation and how it interacts with the atmosphere and the earth's surface is fundamental to understanding the earth's energy budget. Solar radiation reaches the earth's surface either by being transmitted directly through the atmosphere ("direct solar radiation"), or by being scattered or reflected to the surface ("diffuse sky radiation"). About 50 percent of solar (or shortwave) radiation is reflected back into space, while the remaining shortwave radiation at the top of the atmosphere is absorbed by the Earth's surface and re-radiated as thermal infrared (or long wave) radiation [5].

Figure 2.1, a schematic of the global shortwave radiation budget, illustrates the effectiveness of clouds in intercepting and scattering radiation. Because of the effectiveness of clouds in this process, changes in global cloud cover can play a significant role in changing the Earth's climate [6].

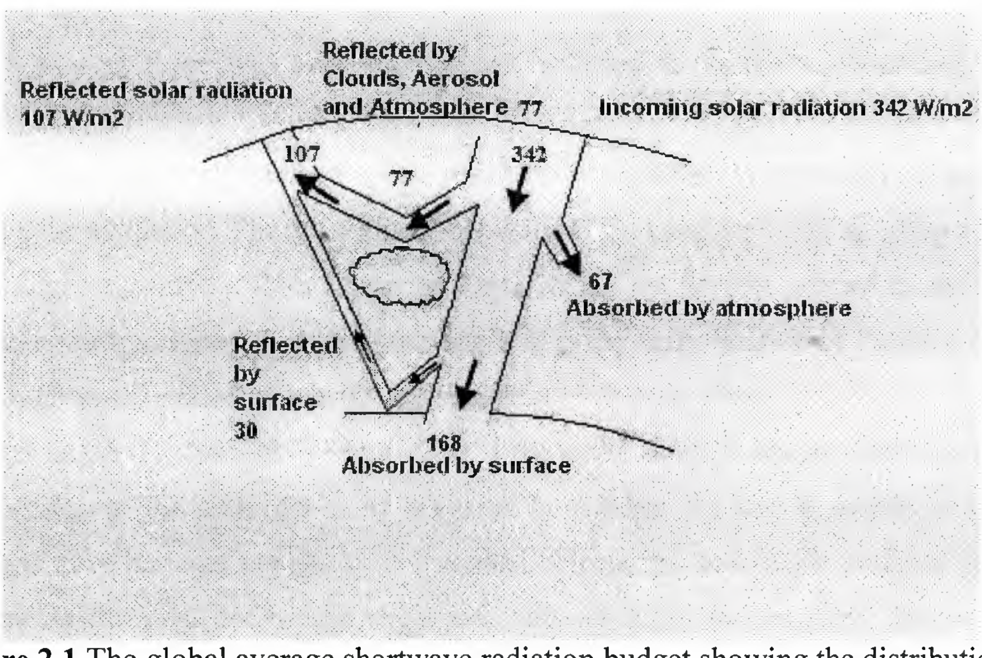


Figure 2.1 The global average shortwave radiation budget showing the distribution of solar radiation in the atmosphere and at the surface [6].

2.2 Available solar radiations on the earth

The amount of energy that is received from the sun rays that strike the surface of our planet is referred to as insolation. The amount of energy that reaches the surface of Earth is by and large subject to climatic conditions such as seasonal temperature changes, cloudy conditions, and the angle at which solar rays strike the ground.

Because our planet revolves around the sun in an oval-shaped orbit with its axis tilted at approximately 23.5 degrees, the solar declination angle (i) shown in Figure 2.2 constantly varies throughout the revolution, gradually changing from +23.5 degrees on June 21-22, when Earth's axis is tilted toward the sun, to -23.5 degrees by December 21-22, when Earth's axis is tilted away from the sun.

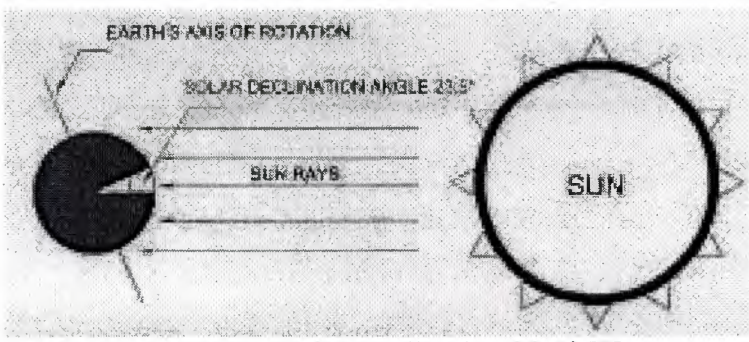


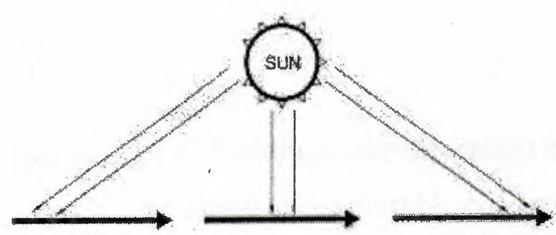
Figure 2.2 Solar Declination 23.5° [7].

Earth's axis at these two seasonal changes, referred to as the summer and winter equinoxes, is 0 degrees.

The solar declinations described above result from seasonal cyclic variations and solar variations in insolation. For the sake of discussion if we consider Earth as being a sphere of 360 degrees, within a 24-hour period Earth rotates 15 degrees around its axis every hour, commonly referred to as the hour angle. It is the daily rotation of Earth around its axis that gives the notion of sunrise and sunset.

The hour angle (H) (shown in Figure 2.3) is the angle through which Earth has rotated since midday or the solar noon. At the noon hour when the sun is exactly above our heads and does not cast any shadow of vertical objects, the hour angle equals 0 degrees. By knowing the solar declination angle and the hour angle we can apply geometry and find the angle from observer's zenith point looking at the sun, which is referred to as the zenith angle.(Z) (shown in Figure 2.4)

The amount of average solar energy striking the surface of Earth is established by measuring the sun's energy rays that impact perpendicular to a square meter area, which is referred to as the solar constant(s). The amount of energy outside Earth's atmosphere measured by satellite instrumentation is 1366 Watts per square meter (W/m^2). Because of the scattering and reflection of solar rays when they enter the atmosphere. Solar energy loses 30 % of its power; as a result on a clear, sunny day the energy received on Earth's surface is reduced to about $1000W/m^2$.



9:00 am **12:00noon** **3:00pm**

Figure 2.3 Solar hour angle [7].

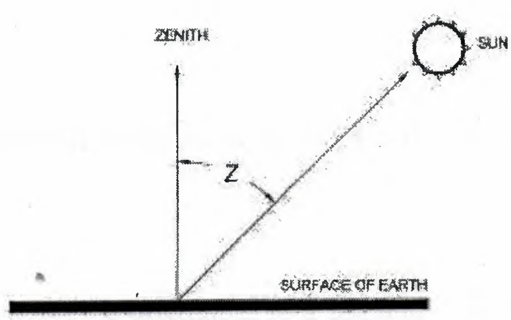


Figure 2.4 Zenith angle [7].

The net solar energy received on the surface of Earth is also reduced due to cloudy conditions and is also subject to the incoming angle of radiation [7].

CHAPTER 3, CLIMATE

The sun drives weather and climate. This includes not only visible light but also infrared rays, which we detect as heat and ultraviolet rays, which we cannot detect without special equipment. receiving the sun's rays eight minutes after they leave the Sun. Partly because of Earth's distance from the sun, only a tiny portion less than one two-billionth-of the Sun's radiation reaches Earth. That has been enough to sustain life throughout Earth's history [8].

3.1 Climate Sensible Buildings

Climate sensible and energy efficient buildings take advantage of natural energy flows (such as heat, light and breezes) to maintain comfortable conditions, which require less heating, cooling and lighting than poorly designed homes. There are many resources available that encompass general house principals, as well as technical specifics of house design. This information file is a useful addition to available information, as it contains tools, and considers aspects of creating an energy efficient home specific to Perth, Western Australia:

3.1.1 The Building Envelope and Passive Design for Perth's Temperate Climate

3.1.1.1 The Orientation

To appreciate why houses should be orientated in a particular direction, it is important to understand the seasonal and daily changes in energy flow. When we see the Sun's position changing in the sky it is of course the Earth that is moving, not the Sun. While recognizing this, for convenience, in this information file we will refer to it as the Sun's 'movement'. By appreciating how the Sun's movement throughout the day varies from season to season, we can predict the performance of solar equipment and buildings. We will know when the Sun is shining on them and for how long.

The seasonal variation in the times of sunrise and sunset, and the variation in the Sun's altitude are caused by the Earth's axis being tilted at an angle to the plane of its rotation around the Sun. In Figure 3.1, we see that the Earth's axis of rotation is tilted (inclined at 23.5 degrees) to its plane of revolution around the Sun, and constantly points to one direction in space.

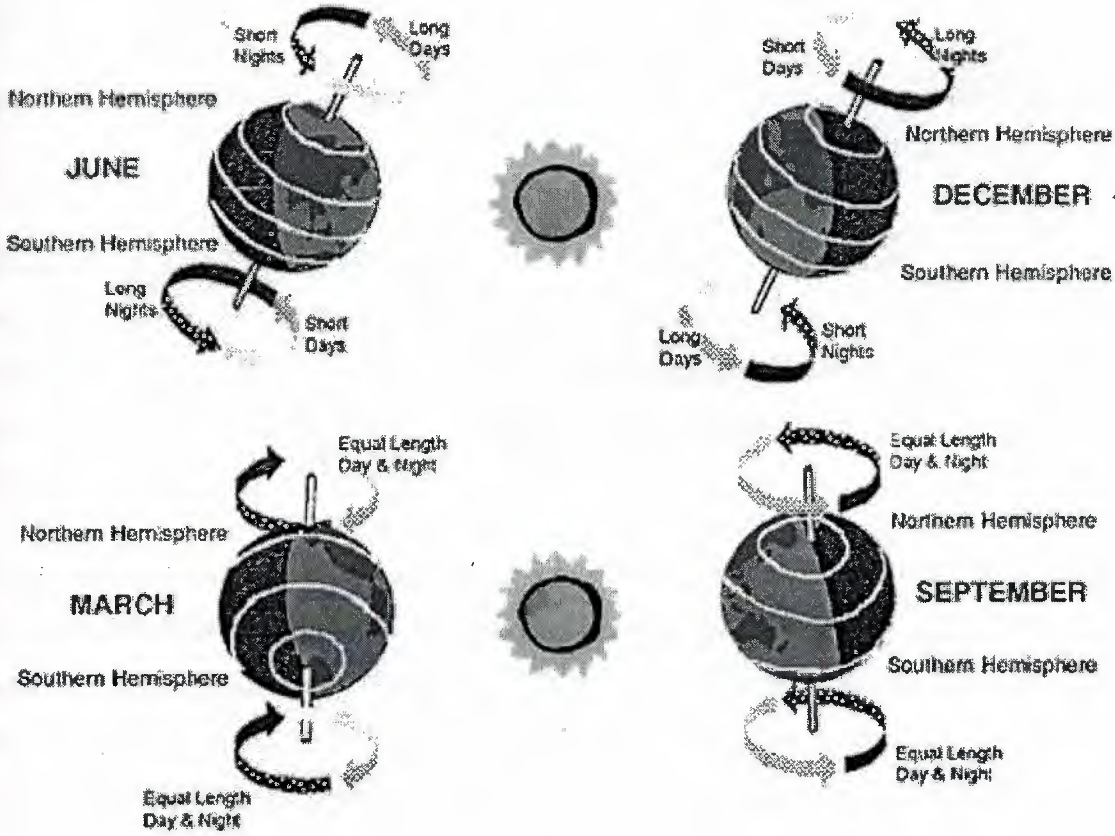


Figure 3.1 Earth's axis of rotation is tilted (inclined at 23.5 degrees) to its plane of revolution around the Sun, and constantly points to one direction in space [9].

3.1.1.2 Using the Sun Angles

Sun Angles are used to determine the best orientation for houses and other buildings so that they make the best use of the Perth's available sunlight, or solar access. As shown previously, the Sun rises earlier in the summer months than it does in the winter months, and its position in relation to the horizon (altitude) also changes throughout the year. Figure 3.2(a), Figure 3.2(b) shows the path of the Sun's movement, in relation to a house, during mid summer and mid winter.

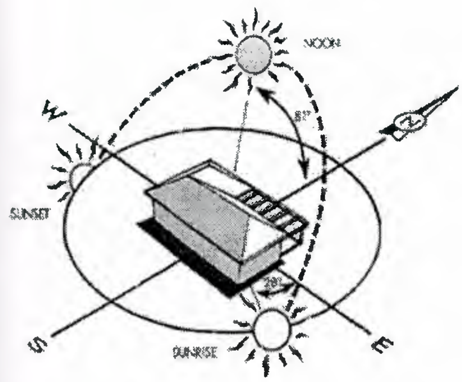


Figure 3.2(a) Sun's movement in mid summer [9].

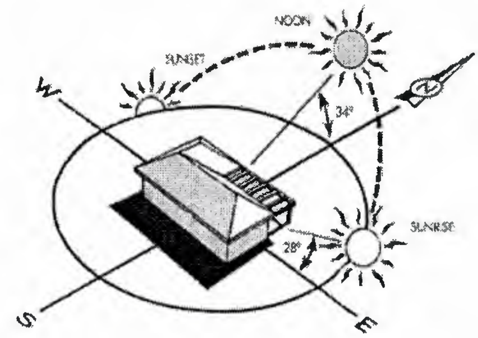


Figure 3.2(b) Sun's movement in mid winter [9].

As can be seen in Figures 3.3, the majority of heat transfer occurs through the roof, as well as the west and east facing walls of the building. In contrast, during winter it is the north facing walls that are exposed to the most sunlight. Efficient houses use designs with good solar access and landscaping that takes advantage of the seasonal changes in the Sun's movement.

Whilst windows facing north are ideal, windows which are less than 20 degrees east or west of north will still allow the Sun to enter through them in winter, whilst excluding much of the summer Sun if your eaves are well designed as shown in Figure 3.3 Windows facing east or west are more difficult to shade during the summer months without the use of landscaping. South facing windows will lose heat during winter and gain some heat in the late afternoon and early evening during the summer months in temperate latitudes such as Perth.

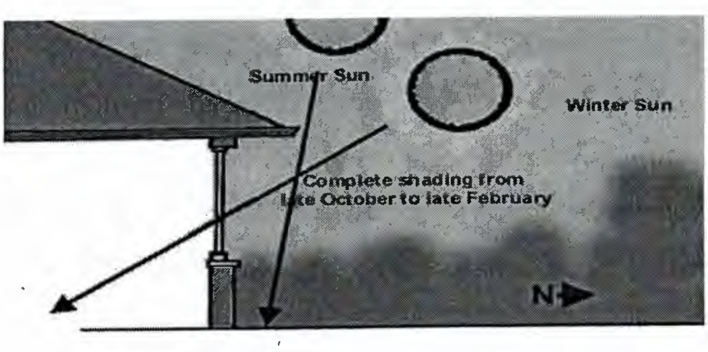


Figure 3.3 Eave design for north facing windows, which exclude summer Sun in the southern hemisphere [9].

To calculate the ideal overhang required for eaves, multiply the distance from the eaves line to the base of the window by 0.4 for shading from October to February and 0.7 for shade from September to March [9].

3.2 Climate and the Effects of Solar Energy

3.2.1 Desert Cities and the US Southwest

In Arizona, we live in a desert environment that uses the definition of extremely arid and semi-arid land. Over one-third of the worlds' surface and an estimated 25% of the population live in similar conditions. Desert cities survive in an environment which is characterized by: 1) aridity and scarcity of natural resources, such as water, and 2) extreme climatic conditions manifested by high temperatures and heat. Other typical conditions of such arid region we can perceive as opportunities. These are: 3) abundant energy in the form of solar radiation and light and 4) plentiful clear sky conditions attributing to the large diurnal temperature swing and blackbody radiation (see Figure 3.4).

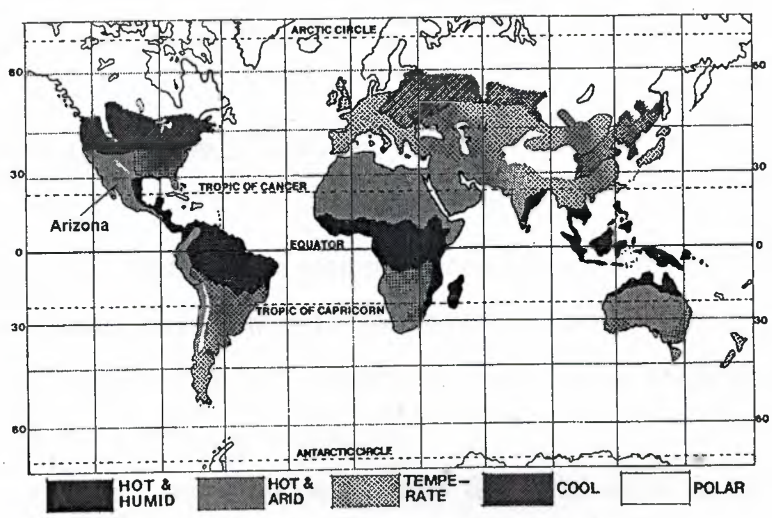


Figure 3.4 Desert Regions of the World [10].

Desert cities vulnerability strengthens their need to survive in harmony with the natural environment. To sustain and support population growth and urban sprawl, desert cities must transform it self by moving toward innovative urban development that integrates new technologies into the building, transportation, infrastructure and social fabric of the community. Desert cities have the opportunity to take the lead and serve as models for the solution to urban ecology problems of our time.

3.2.2 Climate Specific Design

Houses should be designed to suit their environments. In the home-building industry, we have accepted that design and construction must be responsive to varying seismic risks, wind loads and snow loads. We also consider soil conditions, frost depth, orientation and solar radiation. Yet we typically ignore the variances in temperature, rainfall, exterior and interior humidity and their interaction.

The Habitat Congress Building America houses are designed for a specific hygro-thermal region, rain exposure and interior climate. This means that the building enclosure and mechanical systems that are recommended in this package are generally suited to the Hot-Humid climate region. Notice that while there are similarities between regions, there are also differences. It is cold and dry in Wyoming; it is cold and somewhat wet in Wisconsin. Local climate may also differ significantly from the regional climate descriptions, and if so, the differences must be addressed when implementing the house design provided here.

3.2.3 Building for a Hot-Humid Climate

A Hot-Humid climate is defined as a region that receives more than 20 inches of annual precipitation and where one or both of the following conditions occur:

a 67°F (19.5°C) or higher wet bulb temperature for 3,000 or more hours during the warmest 6 consecutive months of the year, or

a 73°F (23°C) or higher wet bulb temperature for 1,500 or more hours during the warmest 6 consecutive months of the year.

The intense solar radiation in this climate imposes a large thermal load on the house that can increase cooling costs and affect comfort. Moisture is a significant problem in this climate, more so in those areas that receive more than 40 inches of annual precipitation. The ambient air has significant levels of moisture most of the year. Because air conditioning is installed in most new homes, cold surfaces are present on which condensation can occur. Controlling the infiltration of this moisture-laden air into the building envelope and keeping moisture away from cold surfaces are major goals of design and construction. Housing types vary greatly throughout all of the different climate zones.

3.2.4 The Type of Climates

Mixed-Humid

A mixed-humid climate is defined as a region that receives more than 20 inches of annual precipitation, has approximately 5,400 heating degree days (65˚F basis) or less and where the monthly average outdoor temperature drops below 45˚F during the winter months.

Hot Humid

A Hot humid climate is defined as a region that receives more than 20 inches of annual precipitation and where one or both of the following occur:

- a 67˚F or higher wet bulb temperature for 3,000 or more hours during the warmest six consecutive months of the year; or
- a 73˚F or higher wet bulb temperature for 1,500 or more hours during the warmest six consecutive months of the year

Hot Dry

A hot dry climate is defined as a region that receives less than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45˚F throughout the year

Mixed- Dry

A mixed- dry climate is defined as a region that receives less than 20 inches of annual precipitation, has approximately 5,400 heating degree days (50˚F basis) or less, and where the monthly average outdoor temperature drops below 45°F during the winter months.

Marine

A marine climate meets all of the following criteria:

- -A mean temperature of coldest month between 27°F and 65°F
- -A warmest month mean of less than between 72°F
- -At least four months with mean temperatures over 50°F
- -A dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere [11].

3.3 Cyprus Climate

The Figure 3.5, acquired by NASA's Terra satellite on 30 January 2001, shows the three distinct geologic regions of the island. In the central and western part of the island is the Trodoos Massif, a mountain range whose surface layer is mostly basaltic lava rock, and whose maximum elevation is 1953 m (6407 ft). Running in a thin arc along the northeast margin of the island is Cyprus's second mountain range, a limestone formation called the Kyrenia Range. The space between these ranges is home to the capital Nicosia, visible as a grayish-brown patch near the image's center (see Figure 3.6) [12]. Cyprus land is on the latitude of 34-35 North and Longitude of 32-34 East. [13].

Figure 3.5 The map of Cyprus was acquired by NASA's Terra satellite on January 30, 2001. Image courtesy Jacques Descloitres, MODIS Land Team [12].

Figure 3.6 North Cyprus Map [14].

Cyprus has an intense Mediterranean climate marked by strong seasonal differences. Summer lasts from June to September, while the winter stretches from November to March. Spring and autumn area short and are characterized by rapid changes in climate and on equally fast transformation of local plant life. Summers are hot and dry, but not humid. The central plain is usually the hottest, with temperatures averaging 99°F (37°C) in Nicosia. Winters are mild, and the weather varies, with average temperatures a cool 41°F-59°F (5°C-15°C) shown in Figure 3.7 The higher reaches of the Trodoos Mountains experience several weeks of below-freezing night temperatures in the winter. Rain generally occurs between October and March, with average annual rainfall of about 20 inches (51 cm). The island's agriculture is dependent on this rainfall, which is often unreliable.

The mountain areas receive far more rain than, the Mesaoria Plain. Average annual rainfall in Nicosia, for example, is only 14 inches (36 cm), while in the Trodoos Mountains, it can be nearly 40 inches (102 cm) [15].

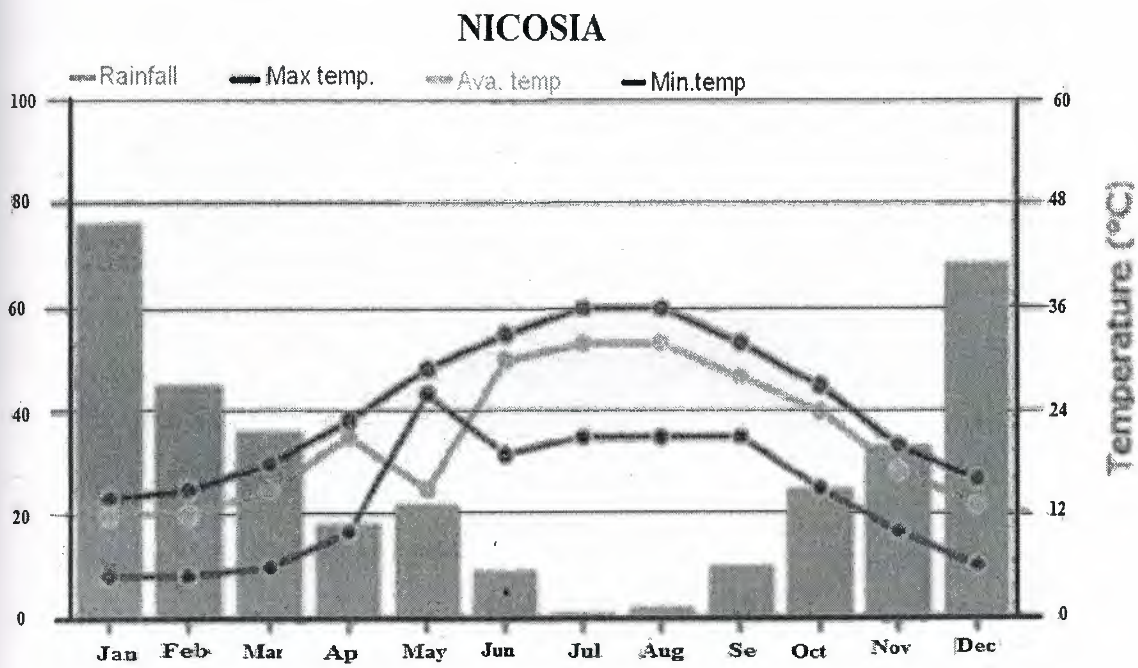


Figure 3.7 Nicosia maximum, minimum and average temperatures in a year [16].

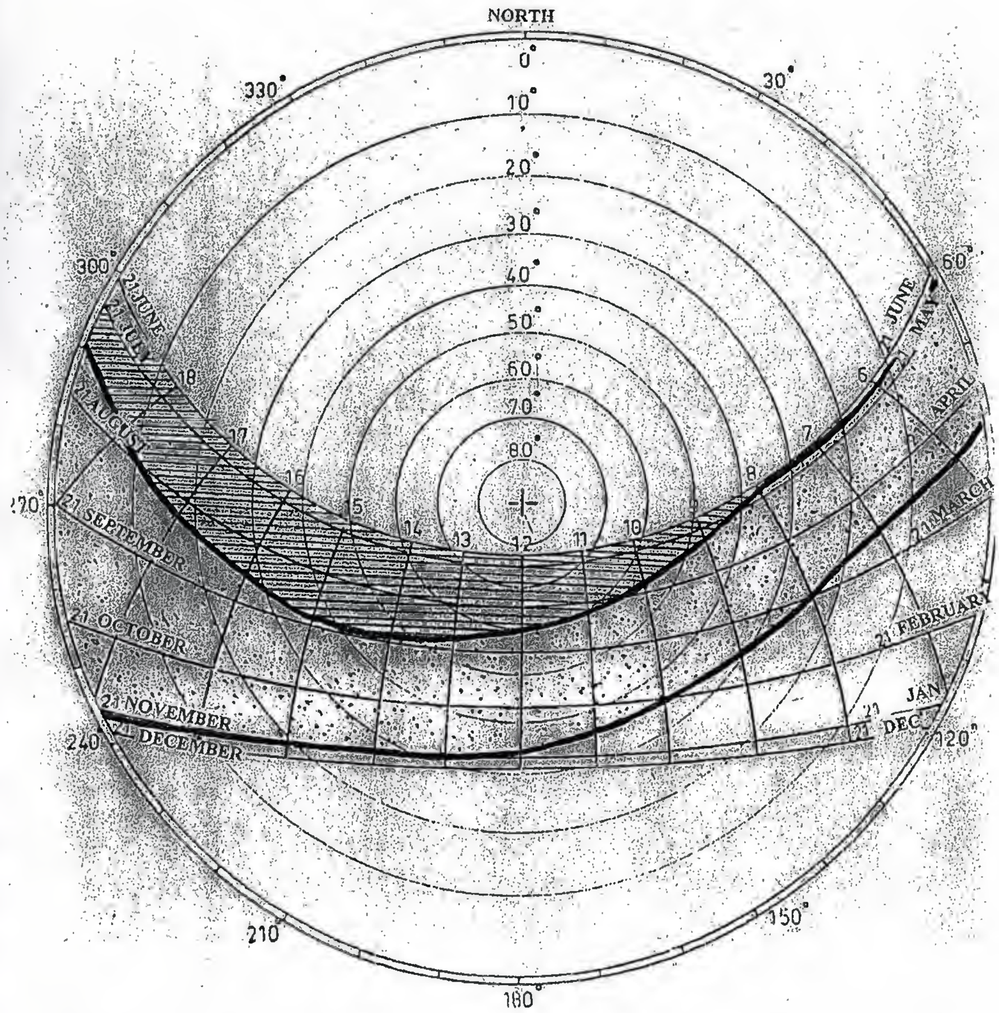


Figure 3.8 Lefkoşa sun path diagram with the overheated period [17].

3.3.1 North Cyprus Prevailing Wind Direction

The prevailing wind direction is westerly and there are occasional easterly gales in the winter (see Figure 3.9) [18].

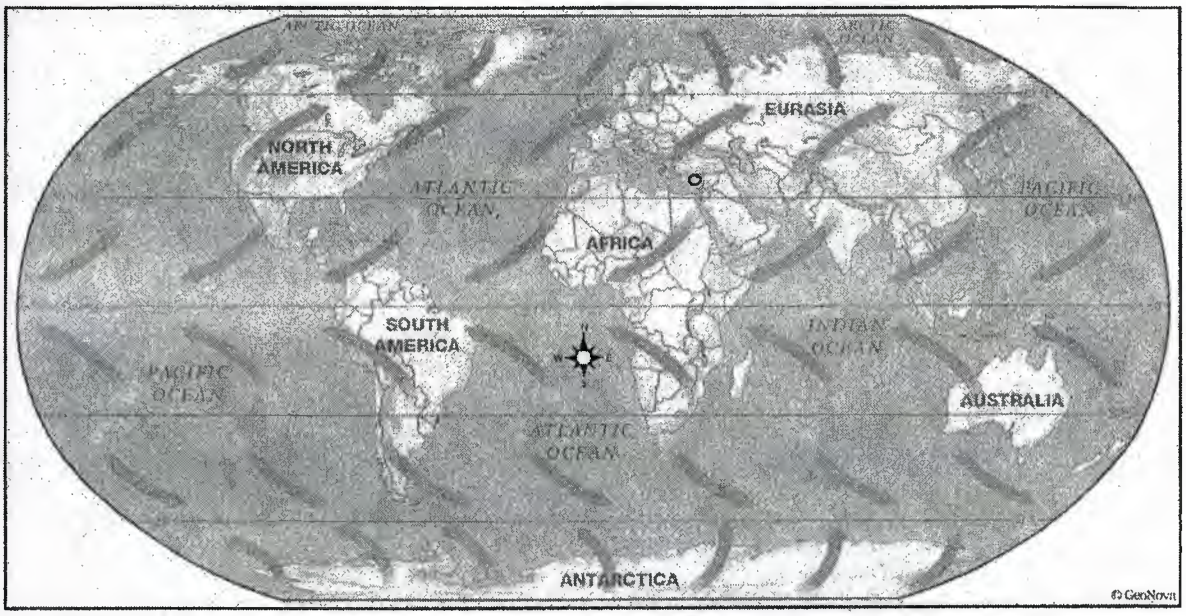


Figure 3.9 Prevailing wind direction of Cyprus (Red circle shows Cyprus) [18].

3.4 Types of Roofs

The most commonly used types of roofs are shown in Figure 3.10

The flat roof is built either absolutely flat or with a slight slope. It is the type most of likely to eventually leak. The rafters serve as both ceiling joists and roof joists, and therefore they are often larger than those used in others types of roofs. The insulation is placed between the ceiling and roof dect, and an air space must remain between it and the roof deck.

A gable roof is possibly the most commonly used type. It is not difficult to build, sheds rain and snow, and permits insulation to be placed between ceiling joists, allowing a large area to be ventilated.

A hip roof has four sloping sides. The main roof is much like the gable roof, but the ends are sloped and shingled, eliminating the gable end.

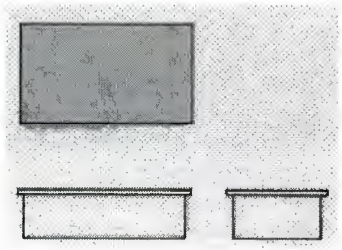
A shed roof is a single sloping surface. It is built like the flat roof but has slope.

A dutch or **modified hip roof** has the ridge extended to procedure a small vertical surface, which usually contains a louvre.

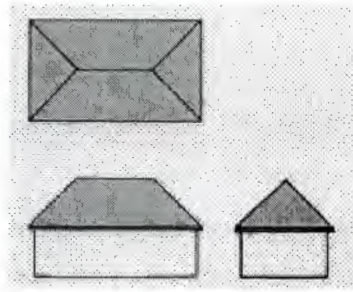
The gambrel roof is a variation of the gable. It has two sloped surfaces, each with different pitches. This provides more space on the second floor for living area. Dormers are frequently added to provide light and ventilation.

The mansard roof resembles both the hip roof and the gambrel roof. It has two sloped surfaces on each side of the building. Therefore ıt does not have a gable end. Dormers are frequently added.

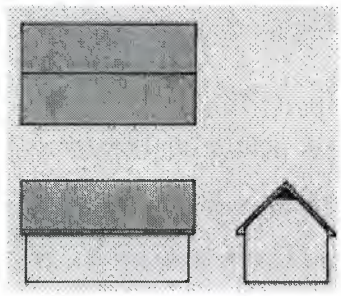
The pyramid roof slopes from eachside of the building to a center point. It eliminates the need for a gable end [19].



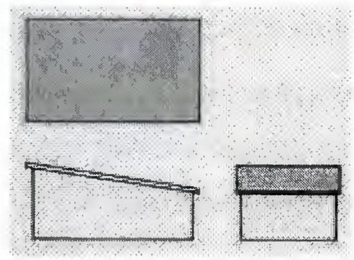
1. Flat Roof



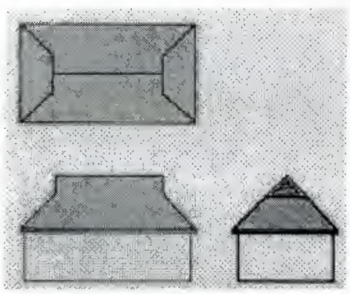
2. Hip Roof



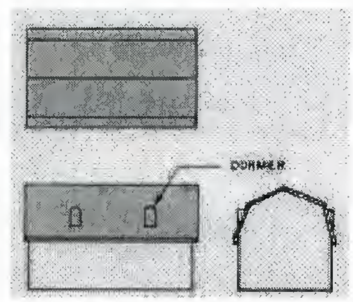
3. Gable Roof



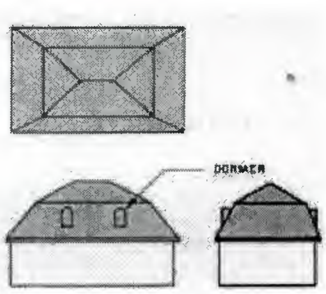
4. Shed Roof



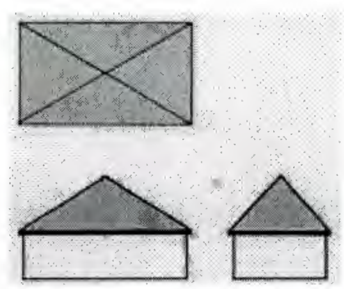
5. a Dutch or **Modified Hip Roof**



6. Gambrel Roof



7. Mansard Roof



8. The Pyramid Roof

Figure 3.10 Types of Roofs [19].

3.5 Materials for Roofs and Walls

Construction materials suitable for summer thermal protection are materials that guarantee a very slow temperature permeation, i.e. as low a thermal conductivity as possible. These are materials that insulate well, but which, alongside their low thermal conductivity, also have a high bulk density and high specific heat storage capacity. With many materials, e.g. steel, high density stands in contrast to low thermal conductivity. Materials with a high density are generally bad insulators. Ideal construction materials from the point of view of slow temperature permeation are timber and timber based materials, followed by wood fibre or cellulose sheets and plasterboard. With these construction materials, which are used in modern timber frame constructions, correct planning and configuration makes it possible to easily combine low energy standards with effective summer thermal protection (see Figure 3.11).

Figure 3.11 Calculation of the coefficient of thermal conductivity of building materials [20].

3.5.1 Roof Surfaces

In the loft space the significance of construction materials is somewhat different: The pitch of the roof means that it absorbs more heat than the walls. Drawing off heat from the airspace beneath the roof covering does not function as well as with a ventilated facade.

For this reason, temperatures under the roof covering may reach up to 80°C. In addition, the roof surface, which conducts heat, is awkwardly large in relation to the space contained beneath it. With the exception of plasterboard on the interior side, a roof seen from the airspace below the roof covering consists largely of insulating material. There is hardly any storage mass.

Here it is particularly important that amplitude suppression and phase displacement are achieved with an insulating material with a low thermal conductivity.

3.5.2 Cellulose and Wood Fibre Insulation Products

Measurements in a roof construction by the TNO Delft in Holland in summer '97 show clear differences in the behaviour of roofs fitted with different insulation materials.

At the same k-value, the roof insulated with cellulose sheeting displays a significantly slower temperature conductivity than the one insulated with mineral insulating material. The roof insulated with wood fibre insulation performs even better.

The observed build up of room temperature over a period of days is avoided by the ventilation of the rooms. In the trials in Holland the rooms were not ventilated.

The findings of the TNO indicate clearly that simulation calculation and temperature behaviour of the roof are in practice comparable, and confirm the advantages of wood fibre and cellulose insulation sheeting for summer thermal protection.

The natural construction materials timber, timber based materials, wood fibre and cellulose fibre insulation batts, together with plasterboard, provide the opportunity in modern timber frame construction to employ reduced component cross sections to create low energy standards and guarantee a comfortable, balanced living climate in summer [20].

CHAPTER 4, INSULATION MATERIALS

Insulation acts as a barrier to heat flow and is essential to keep your home warm in winter and cool in summer. A well insulated and well designed home will provide year round comfort, cutting cooling and heating bills by up to half.

Climatic conditions will influence the appropriate level and type of insulation. Establish whether the insulation will be predominantly needed to keep heat out or in (or both). Insulation must cater for seasonal as well as daily variations in temperature.

Passive design techniques should be used in conjunction with insulation. For example, if insulation is installed but the house is not properly shaded, built up heat can be kept in by the insulation creating an 'oven' effect. Draught sealing is important, as draughts can account for up to 25 percent of heat loss from a home in winter.

4.1 Choosing Insulation

Insulation products come in two main categories – bulk and reflective. These are sometimes combined into a composite material. There are many different products available,

To compare the insulating ability of the products available look at their R-value, which measures resistance to heat flow. The higher the R-value the higher the level of insulation. Products with the same R-value will provide the same insulating performance if installed as specified.

Bulk insulation mainly resists the transfer of conducted and convected heat, relying on pockets of trapped air within its structure. Its thermal resistance is essentially the same regardless of the direction of heat flow through it.

Bulk insulation includes materials such as glass wool, wool, cellulose fibre, polyester and polystyrene. All products come with one Material R-value for a given thickness.

4.2 Where to Install Insulation

Roofs and ceilings work in conjunction when it comes to insulation.

> Install insulation under the roofing material to reduce radiant heat gain.

> Install insulation in the ceiling to reduce heat gain and loss. In most cases ceiling insulation is installed between the joists.

Verandah roofs should be insulated in hot climates where outdoor living spaces are used extensively, to reduce radiant heat gain. Heat build up under verandahs not only affects the space below but can affect conditions inside the house.

Save up to 45 percent on heating and cooling energy with roof and ceiling insulation. [21]

4.3 Ceilings and Roofs

Tiled roofs without sarking can have it added easily if the roof is being re-tiled. If the tiles are to remain in place and access is available to the roof space, double sided foil or foil batts can be added between the rafters or trusses, directly under the tile battens. [22]

4.4 Heat Insulation Materials Used

4.4.1. Glass Wool Batts

Glasswool batts are made from melted glass spun into a mat of fine fibres. They are easy to cut and install, commonly sold in DIY packs as rolls or bath. It should not be compressed or moistened. It can cause irritation, wear protective clothing during installation. [21]

-Features: With excellent rebound property, when reaches the destination, will rebound almost to the original level in 24 hours after been unpacked.

-Usage: Heat preservation for steel structure building. Heat insulation for wall and roof of house to save energy
for indoor partition wall, Train compartment Special specification can be made upon on request.

- Standards: According to GB STANDARDS, EN13162, EN13172, ISO9001:2000. (see Figure 5.1) [23].

-Pack: Vacuum packing

Figure 4.1 Glass Wool Batts 3D picture [23].

Table 4.1 - Glass Wool product specification. [23]

Product		Length (mm)			Width (mm)		Thickness (mm)		Density (kg/m3)	
Glass wool Batts		1200-4800			600-1200		25-200		10-48	
R value (Thermal Resistance) Data Sheet										
Density(kg/m^3)		10	12	14	16	18	20	24	32	48
Thermal Conductvity (w/m.k)		0.044	0.043	0.041	0.039	0.038	0.037	0.036	0.034	0.033
Thickness (mm)	25				0.64	0.66	0.68	0.69	0.74	0.76
	50	1.14	1.16	1.22	1.28	1.32	1.35	1.39	1.47	1.52
	100	2.27	2.33	2.44	2.56	2.63	2.70	2.78	2.94	3.03
	150	3.41	3.49	3.66	3.85	3.95	4.05	4.17	4.41	
	200	4.55	4.65	4.88	5.13	5.26	5.41	5.56		

4.4.2 OSB (Oriented Standard Boards)

Physical and mechanical Specification characteristics	**Standard**	**Specification**

-Some chipboard uses recycled wood
-Reusable
-High embodied energy
-Likely to use wood from non FSC sources
-Large quantities of VOC's released as part of the manufacturing process (see Figure 5.2) [24].

Table 4.2 General properties of OSB used in the study [25].

Formaldehyde contesnt	EN 120	in conformity with E1 (8 mg/100g) and the ordinance on the prohibition of chemicals
Combustibility (classification)	DIN 4102 T1	B 2 (normal incendiary)
Density	DIN 52 361	600 kg/m3
Moisture content	EN 322	9 +– 3 %
Swelling in thickness (mean value)	DIN 52 364	≤10 %
Thickness tolerance 1)	EN 300	+– 0,8 mm unsanded surface
Tolerance of length and width 1)	EN 300	+– 3 mm
Squareness (Diagonal Difference) 1)	EN 300	2 mm for each 1000 mm in length
Thermal conductivity	DIN 4108 T2	0.13 W/m K

Dimensional change length/width	change of relative humidity from 30 to 85 % at 20 □C	0.30 %
Vapour diffusion resistance factor	DIN 52615	15 mm 18 mm 22 mm
	□-factor	190/270--160/220--300/380
	sD value (m)	2.8/4.0 --2.7/3.8 --6.3/8.2
Binders/glue	surface layer	modified melamine resin
	core layer	formaldehyde-free with PUR

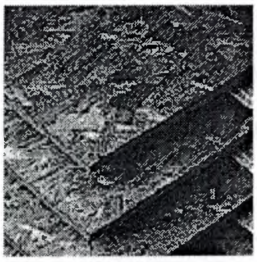


Figure 4.2 OSB (Oriented Standard Boards) 3D picture [24].

4.4.3 Polystyrene Foam Board

White rigid material formed by the fusion together of expanded beads of polystyrene. Also available in a pre-compressed form that is more flexible and resilient.

Availability:

In sheets a few millimetres thick. In slabs from 13mm. Also shaped forms for special insulating jobs. As tiles. Density normally 16-40 kg/m3.

Applications:

Lining of walls and skin roofs, insulation of flat roofs and concrete floors. Wall and ceiling tiles. Insulation of cold water pipework.

Comments:

Attactive appearance. Good thermal insulation. Relatively low softening point. Attacked by some organic solvents. [26].

Rigid boards that retain air but exclude water. It has high R- value per unit thickness, suitable where space is limited. It is easy to cut and install and can be rendered. It is greater structural strength and moisture resistance than EPS. [21]

-Material : Polystyrene Measures 1.22 x 2.44m, for Long-lasting Indoor Signs, Available in Various Colors

-Color : white, black ,yellow. Green, blue, red (colors on customers request)

-Character: The surface is entirely polystyrene foam

2. Lightweight but durable and easy to cut and form

3. Perfect for signs, displays and dramatic in-store lettering

-Fabrication: Mounting, Repositioning Vinyl, Direct Digital Printing, Direct Screen-printing, Painting, Knife Cutting, Saw Cutting, Routing, Die Cutting, Embossing, Forming Curves, Framing

-Specifications: Thickness: 2mm, 3mm, 5mm, 7mm, 9mm, 10mm

density range: 80 gsm or upward

2 Special sizes available upon requests (see Figure 5.3) [26].

-Thermal Conductivity: 0,030 W/mK [27].

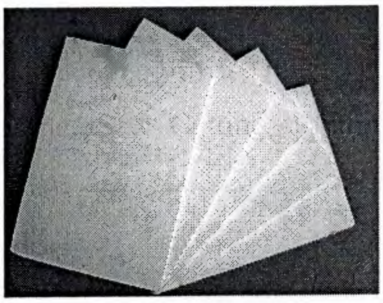


Figure 4.3 Polystyrene Foam Board 3D picture [27].

4.5 Water Insulation Material Used

In most climates, insulation is included in the roof system to improve comfort and to minimize energy use. In addition, roof insulation may decrease the range of thermal expansion of the structure. For low slope roof systems, the best location is usually above the structural deck. For conventional membrane roof systems, the insulation is under the membrane. For protected membrane roof systems, the insulation is above the membrane.

Except in protected membrane roof systems, rigid roof insulation usually provides in low slope systems both the insulation for the building and a substrate to which the roofing membrane is applied. Therefore roof insulation must be compatible with and provide adequate support for, the membrane and other rooftop materials and permit limited rooftop traffic, such as for roof inspection and maintenance.

For protected membrane roof systems, the only approved insulation is extruded, expanded polystyrene. It is resistant to water penetration, but it is vulnerable to attack from high heat and ultraviolet radiation. For roofing areas without adequate strength to support ballast, a proprietary system is available, composed of tongue and groove expanded, extruded polystyrene panels with a thin latex mortar cap, to protect against sunlight [28].

4.5.1 Yalteks POLISER 200-C

YALTEKS POLISER 200-C is a high performance modified bituminous waterproofing membrane reinforced with Glass Fiber tissue. Bitumen is modified with APP (AtacticPolypropylene) which provides an excellent elasticity. (see Figure 5.4) [29].

Table 4.3 Yalteks water insulation features [29].

CHARACTERISTICS	STANDARDS	UNIT	VALUES
Bituminous Sheet	ASTM D6509/97	-	APP Modified
Thickness	EN 1849-1	mm	> 1.9
Roll Length	UNI 8202/03 TS 11758-1	m	15

Roll Width	UNI 8202/04 TS 11758-1	m	1
Weight	UNI 8202/07	kg./ m²	> 2.4
Surface	-	-	Polyethylene or Fine sand
Cold Flexibility	EN 1109	°C	- 10
Heat Flow	DIN 52123 TS 11758-1	°C	120
Water Impermeability	prEN 1928	-	Absolute
Fire Resist (Flammability)	prEN ISO 11925-2	°C	250

Figure 4.4 Yalteks water insulation material picture [30].

CHAPTER 5, EXPERIMENTAL STUDY

5.1 Experimental Procedure

The experimental study relates to the effects of water and heat insulation materials on hip roofs in TRNC. The study consists of two stages; the first stage tests the effects of water insulation material on hip roofs was. The second stage was continued by covering heat insulation material over water insulation material. At the second stage the effects of heat insulation material on hip roofs was tested. The study was continuously done between the months of December and January.

At the first stage two hip roofs were compared with water insulation material in the month of December. Both roofs were studied on their South facade. The reason for this is the South facade takesmore solar radiation rays than the other facades. The roof with water insulation material is named L1 the roof without water insulation material is named L2. The test roofs were constructed on top of the Mechanical Engineering Solar Laboratory Building in NEU, Lefkoşa. The solar laboratory is on the roof terrace of the M.E department. The roofs were placed next to each other and the data machine was put in the middle of these two hip roofs.

At the second stage two hiproofs were compared with heat insulation material on January month. Both roofs were studied on their south facade. The plan of the roofs is shown in Figure 5.1

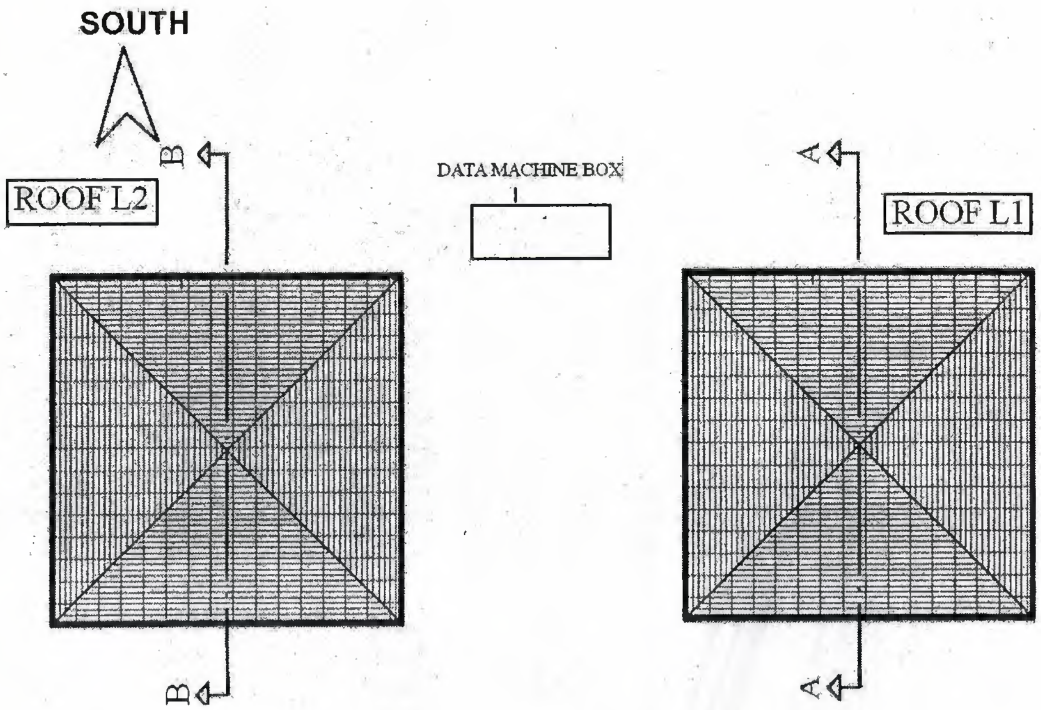


Figure 5.1 The plan of L1 and L2 hip roofs.

The section of roofs is shown in Figure 5.2, 5.3, 5.6, 5.7 and the 3D Picture of the roofs are shown in Figure 5.4, 5.5, 5.8, 5.9

As it is shown on Figure 5.2, 5.3, 5.6 and 5.7 L1 roof has water insulation material and L2 hasn't water insulation material on its south facade at the first stage. On Figure 5.4, 5.5, 5.8 and 5.9 L1 roof has heat insulation material and L2 hasn't heat insulation material on its south facade.

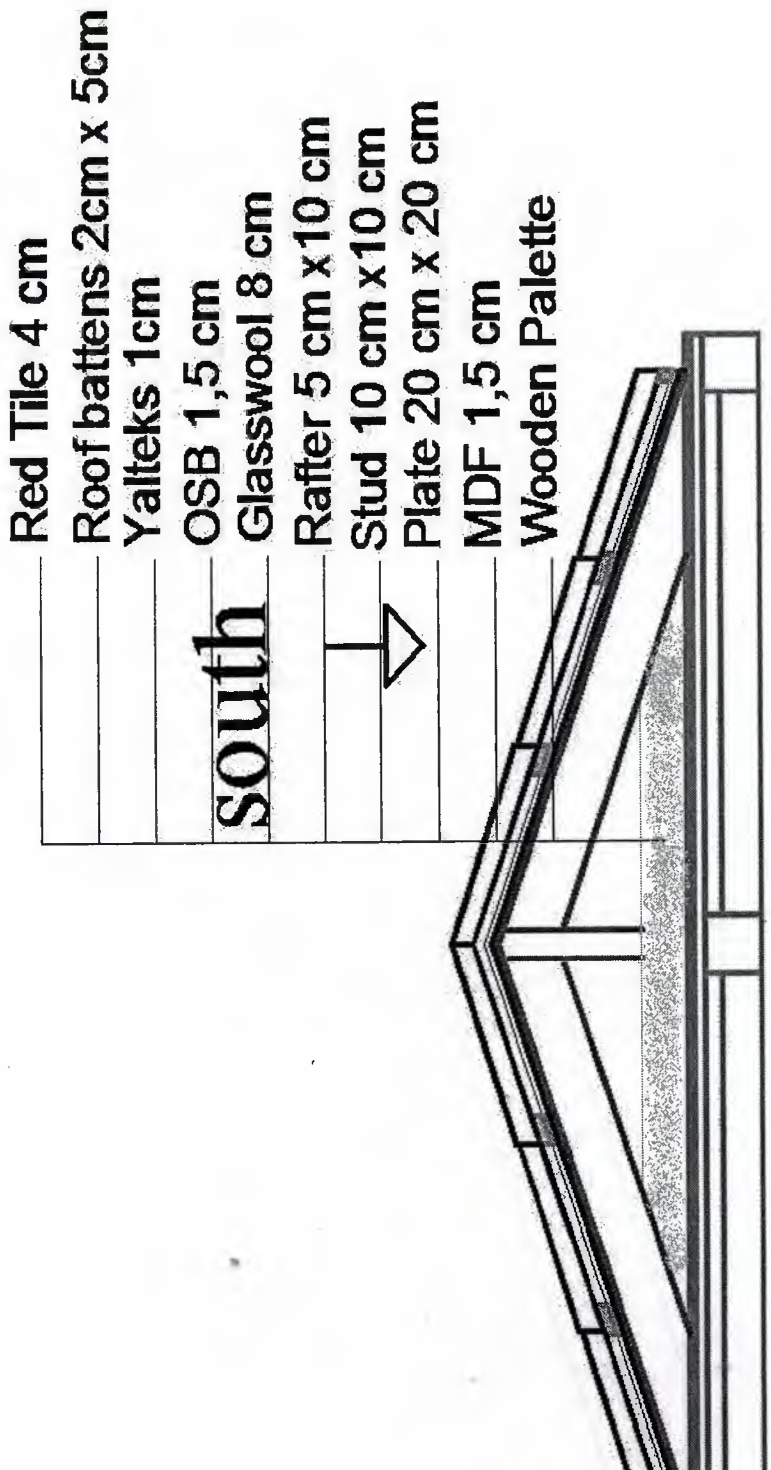


Figure 5.2 A-A section for roof L1 at the first stage.

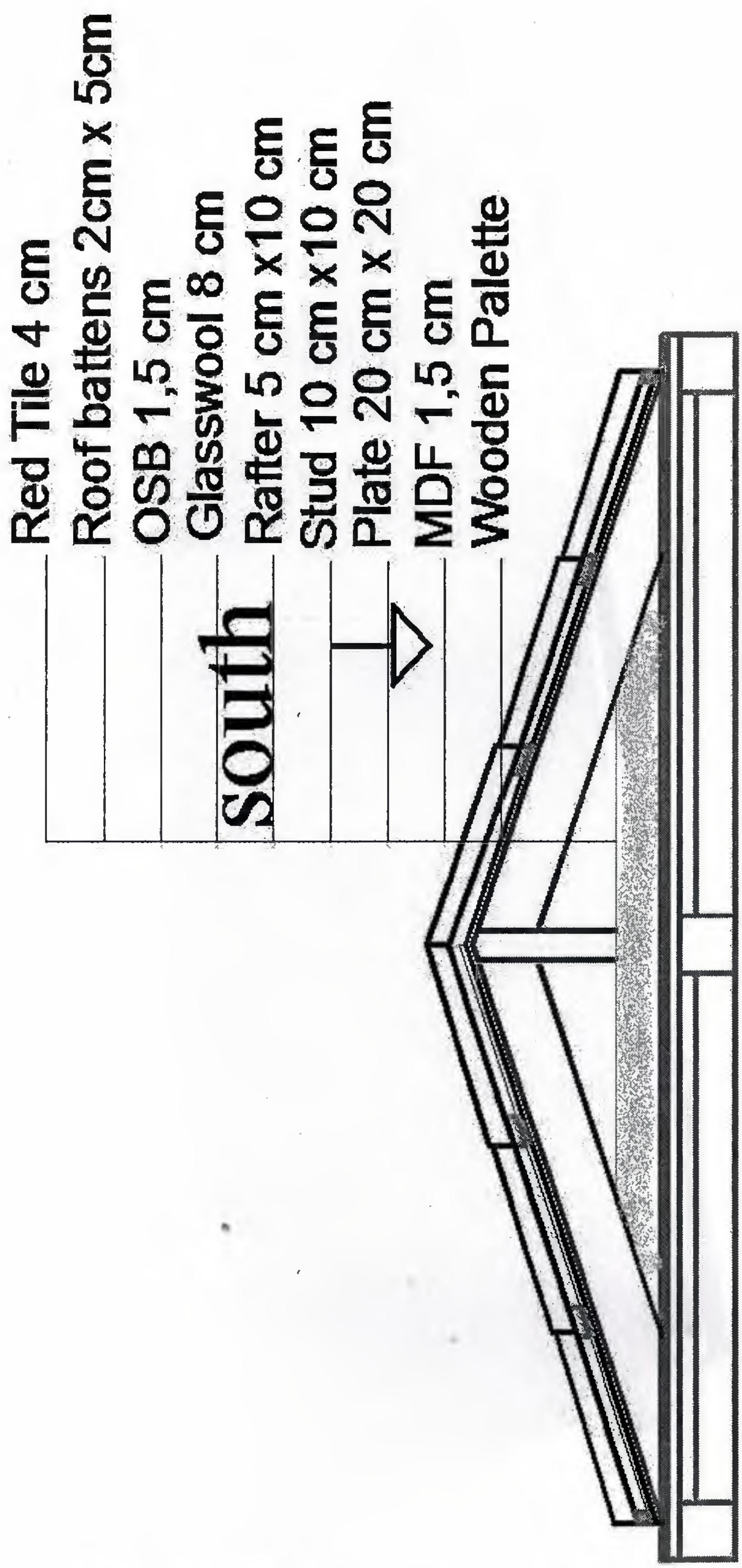


Figure 5.3 A-A section for roof L2 at the first stage

Figure 5.4 3D picture of roof L2 at the first stage.

Figure 5.5 3D picture of roof L1 at the first stage.

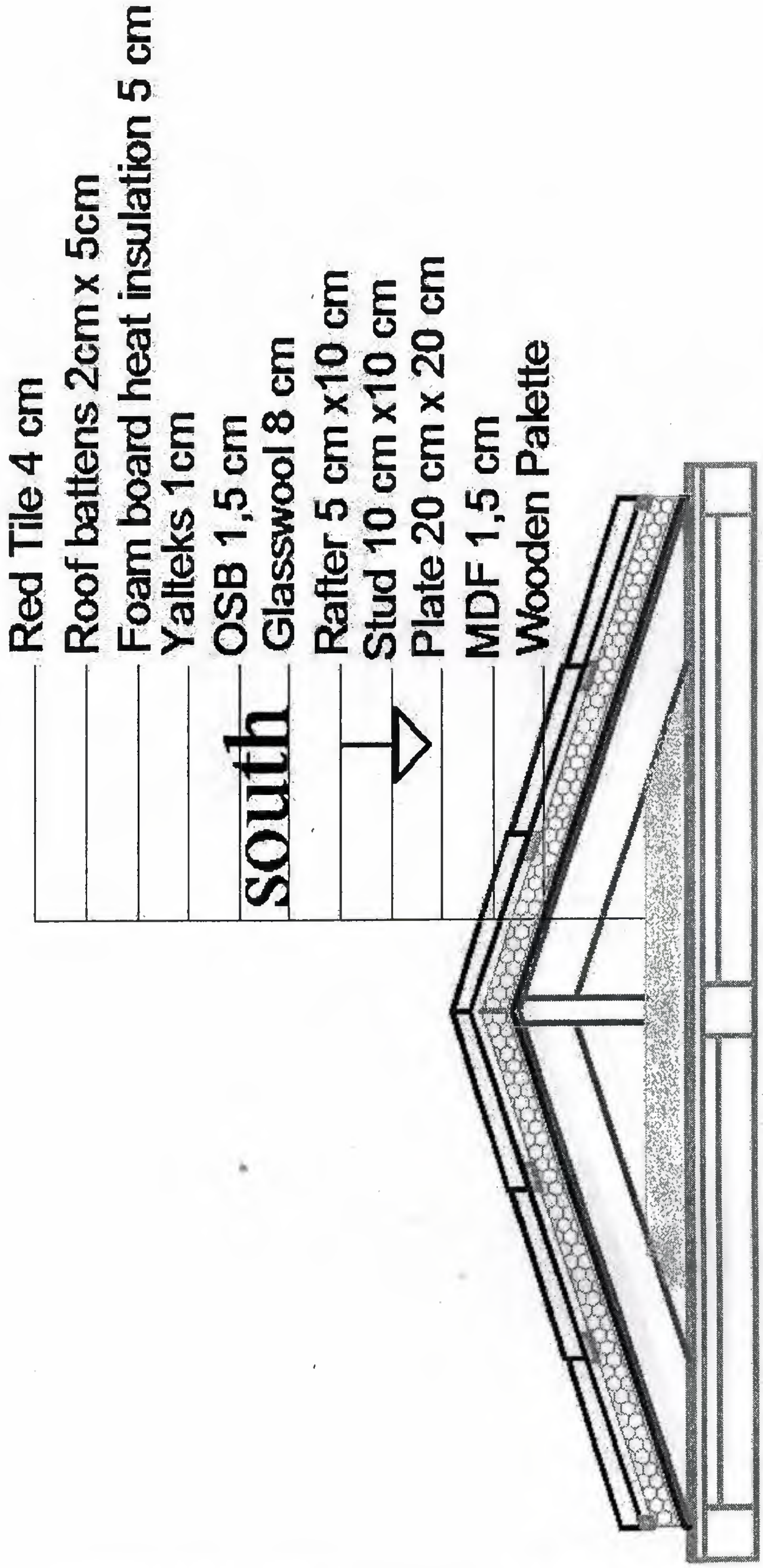


Figure 5.6 B-B section for roof L1 at the second stage.

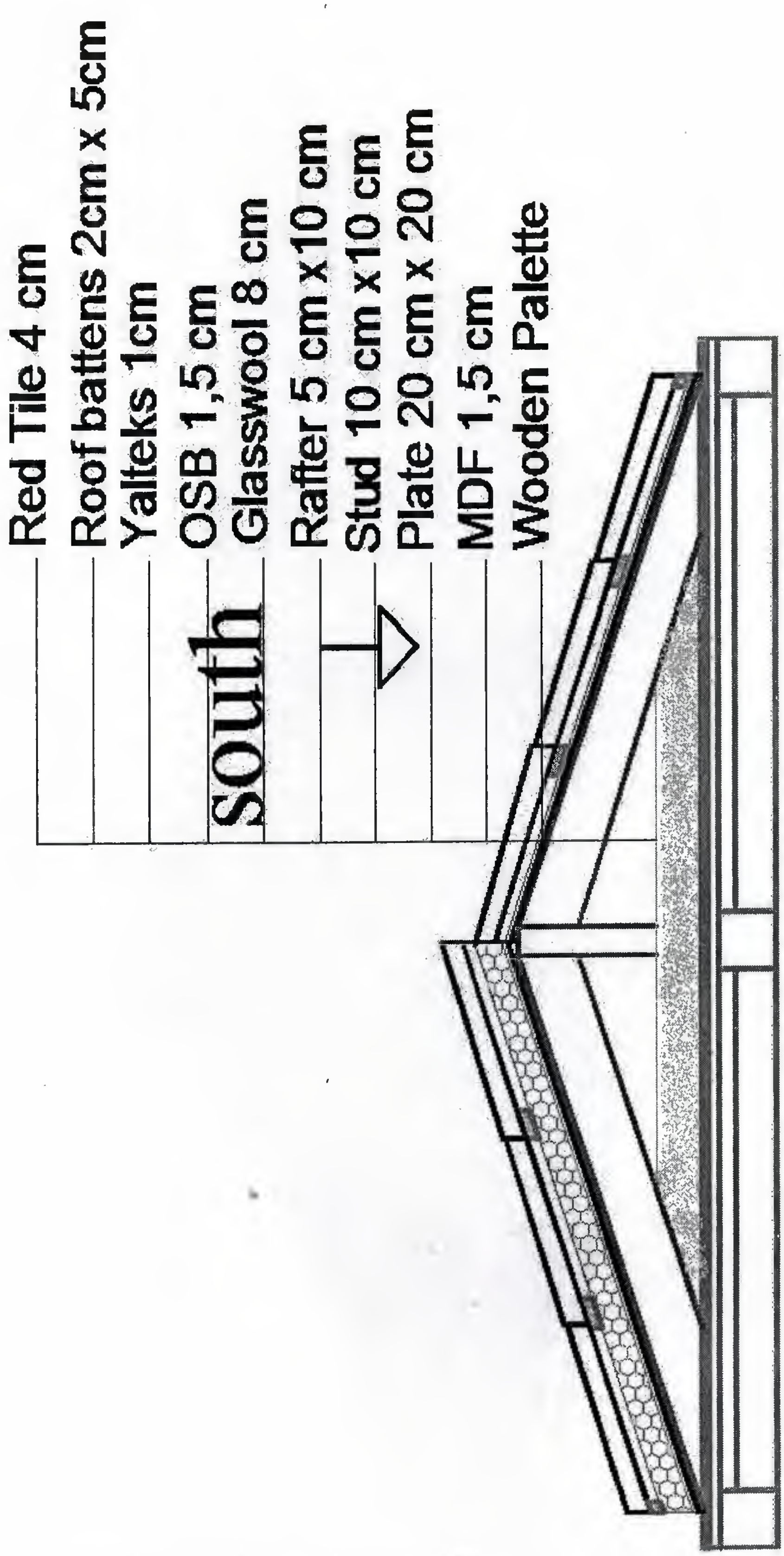


Figure 5.7 B-B section for roof L2 at the second stage.

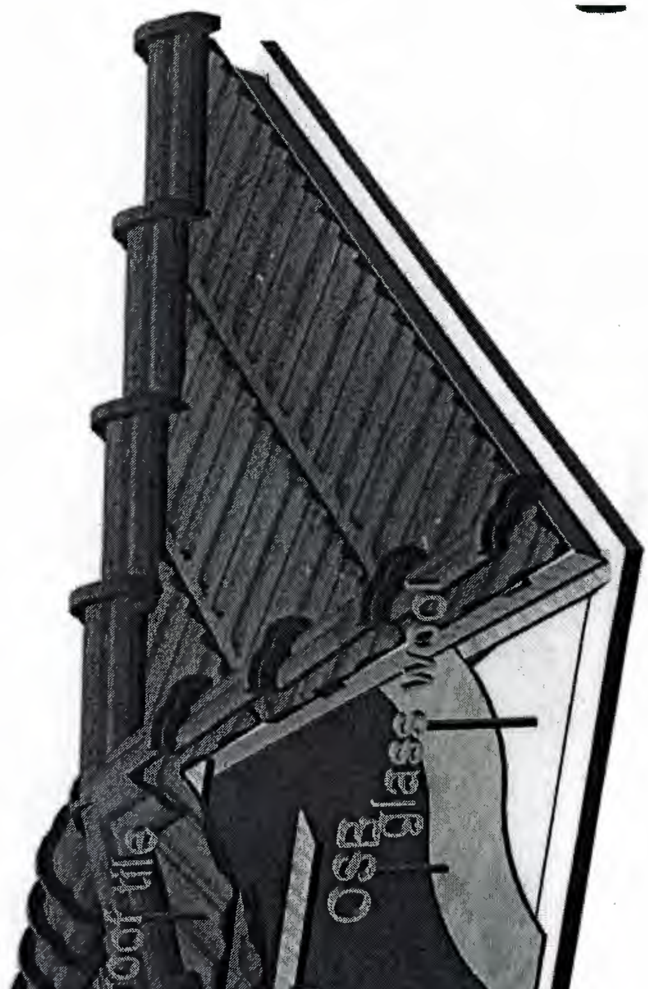


Figure 5.8 3D picture of roof L2 at the second stage.

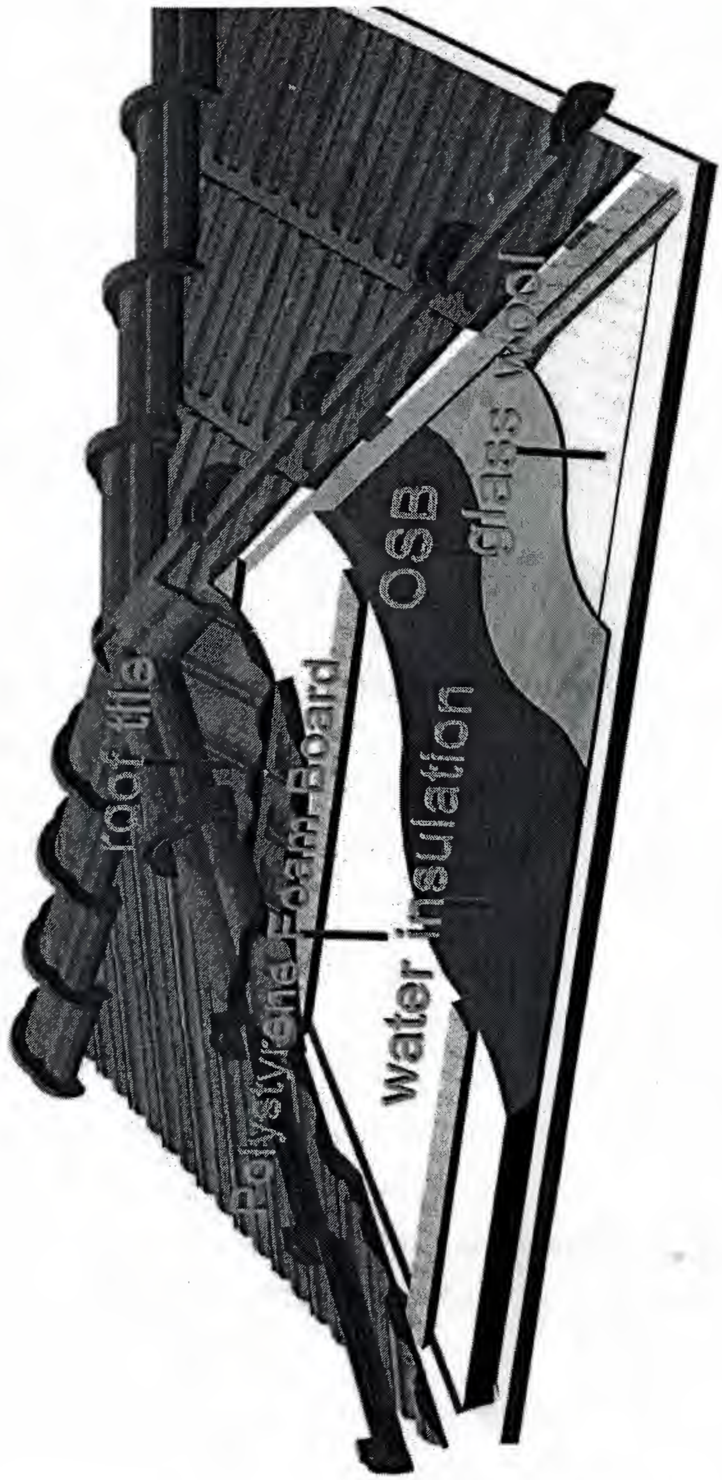


Figure 5.9 3D picture of roof L1 at the second stage.

5.2 The Materials Used on the Hip Roofs

- MDF; is a pressed wood .The dimension of MDF 200 cm x 200 cm and the height is 1.5 cm
- Glass wool; is a heta insulation material 200 cm x 200 cm and the height is 8 cm.
- Stud and plate materials are made by wood. Stud dimension is 10 cm x10 cm and the height of stud is 33cm The plate material 20 cm x 20 cm and the height is 2 cm.
- Rafters are made by wood. The dimension of rafter is 5 cm x10 cm
- The OSB material is a heat insulation material height of OSB is 1.5 cm.
- Yalteks water insulation material The height of yalteks is 1 cm.
- Polystyrene Foam Board is a heat insulation material the height of this material is 5 cm.
- Roof battens are wooden materials. The dimension of them are 2 cm by 5 cm
- Roof tiles has 4 cm height.

5.3 Roof Construction Stages

The NEU Design Department provided us with the roof construction materials. Then the workers who are working in the University helps us to construct the roofs.

- Firstly 200cm x 200 cm palettes were put on roof terrace than 200 cm x 200 cm MDF material were cut on palettes
- After that 20cm x 20cm plate was fixed at the middle of the 200cmx200cm medium density fibreboard(MDF). Than 10x10 and 33 cm height stud was fixed on to the purlin.
- The rafters were fixed from stud to the corners and middle points of the MDF.
- Glass wool heat insulation material was layed on to the MDF.
  OSB was cut off and ploughed on to the rafters.
- Yalteks water insulation material was screwed on to the OSB. Yalteks wasmapplied on four sides of L1. For L2 Yalteks was applied all facades except the south facade. Data were taken for ten day by this position at the first stage.

- The roof tiles were put above the roof battens for both L1 and L2. This data were taken for eleven day by this position at the first stage.
- The difference from stage one; L1 four sides were covered with polyester foam board heat insulation material. This heat insulation comes above the yalteks water insulation material.

Stage two;

- After Polystyrene Foam Board heat insulation 2 cm x 5 cm roof battens were ploughed above to the foam board.
- Three side of L2 is covered by Polystyrene Foam Board heat insulation material except the south facade.
- The difference between L1 and L2. L2 hasn't got Polystyrene Foam Board on it's south facade.
- The roof tiles were put above the roof battens for both L1 and L2. This data were taken for twenty one days in this position at the second stage.

In TRNC roof slope angle is taken %33 in the Architecture Office. The reason of that both hip roofs height are taken 33 cm. In Figure 5.10 is shown each 100cm the height goes 33 cm up.

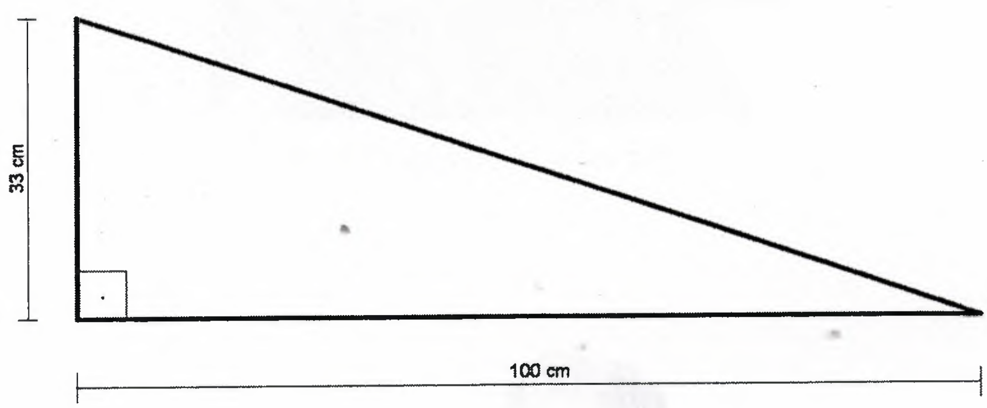


Figure 5.10 The roof slope angle of the hip roofs

5.4 The Control Unit

The Control Unit displays all flue gas measurements, up to 6 parameters simultaneously per page, as well as all instrument diagnosis and operating information. The Analyzer

Box can be controlled by the Control Unit or through the software. The Control Unit can operate the analyzer box remotely using standard cables 6', 16' and 65', custom lengths up to 3,000', or with Blue tooth 2.0 up to 325' away (testo 350S only). The integrated printer provides a record of the emissions data. You operate the instrument with userdefined function keys, the keypad. The 350/454 Control Unit has a multi probe input and an integrated Δ pressure probe.

Figure 5.11 All the data's were measured by the data machine.

Figure 5.12 The control unit 350/454 [31].

These 6 parameters are;

Temperature with surface, immersion, penetration, air or precision probes

• Humidity with ambient air conditions, duct and reference probes, material moisture probes and pressure dew point probes

• Velocity and volume flow with vanes, hot wire, hot bulb probes and Pitot tubes

• Indoor Air Quality using CO2 probe and comfort level probe

• Pressure with differential/absolute/low/high pressure probes

• rpm

• Current, voltage

5.4.1 Operate the Instrument with the Control Unit

You operate the instrument by pull-down menu driven selections. Customize the function keys with the most needed functions you desire, i.e. "Pump" or "Zero". The keyboard allows quick alphanumeric input, with the cursor keys or optional by touch screen pen.The Control Unit is used for simple data management as well.

5.4.2 The Display

The Control Unit displays all flue gas measurements up to 6 parameters simultaneously on one screen [31].

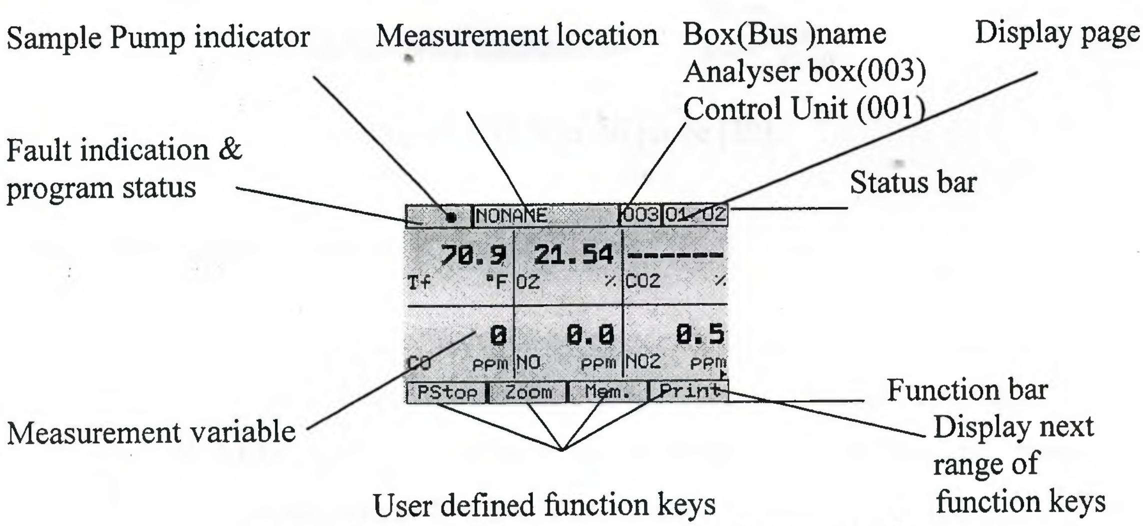


Figure 5.13 The display of control unit screen [31].

5.4.3 Control Unit 350/454 Charge Status

Control Unit 350S contains non-rechargeable batteries. When the Analyzer Box is plugged into AC, the display will show the charge in the Analyzer Box. A fully charged Analyzer Box is approximately 10 volts [32].

5.4.4 Nicr-Ni PROBE

Table 5.1 Features of Nicr-Ni PROBE [32].

Air probes	Illustration	Meas. Range	Accuracy	t99	Conn.	Part no.
Thermocouple, made of fibre-glass insulated thermal pipes, pack of 5 Insulation: twin conductor, flat, oval, opposed and covered with fibre-glass, both conductors are wrapped together with fibre-glass and soaked with lacquer, please order adapter	2000 mm	Ø 0.8 mm -200... +400 °C	Class 1	5 s	Please order adapter 0600 1693	0644 1109

Figure 5.14 Nicr-Ni probe [32].

5.4.5 Ordering Data for System and Accessories

- Control unit displays measurement data and controls the measuring system, 0563 0353 incl. built-in printer, pressure measurement 80/200 hPa, 1 user defined probe socket, programmable measurements and memory space for 250,000 readings, connection for Testo data bus, incl. terminal plug
- Touch screen with pen (available only with original order) 0440 0559

For easy input of text and values

- Logger, measures and saves (max. 250,000 readings), incl. 4 user defined probe sockets, alarm output/event trigger socket, stand/wall holder
- Alarm/trigger cable
- Recharger for control unit or logger (with 4 standard rechargeable batteries) Rechargeable batteries are recharged externally
- Testo rechargeable battery pack NiMH for control unit, logger
- Mains unit 230 V, for control unit, logger and analog output box

For mains operation and to recharge testo rechargeable battery packs in instrument [32].

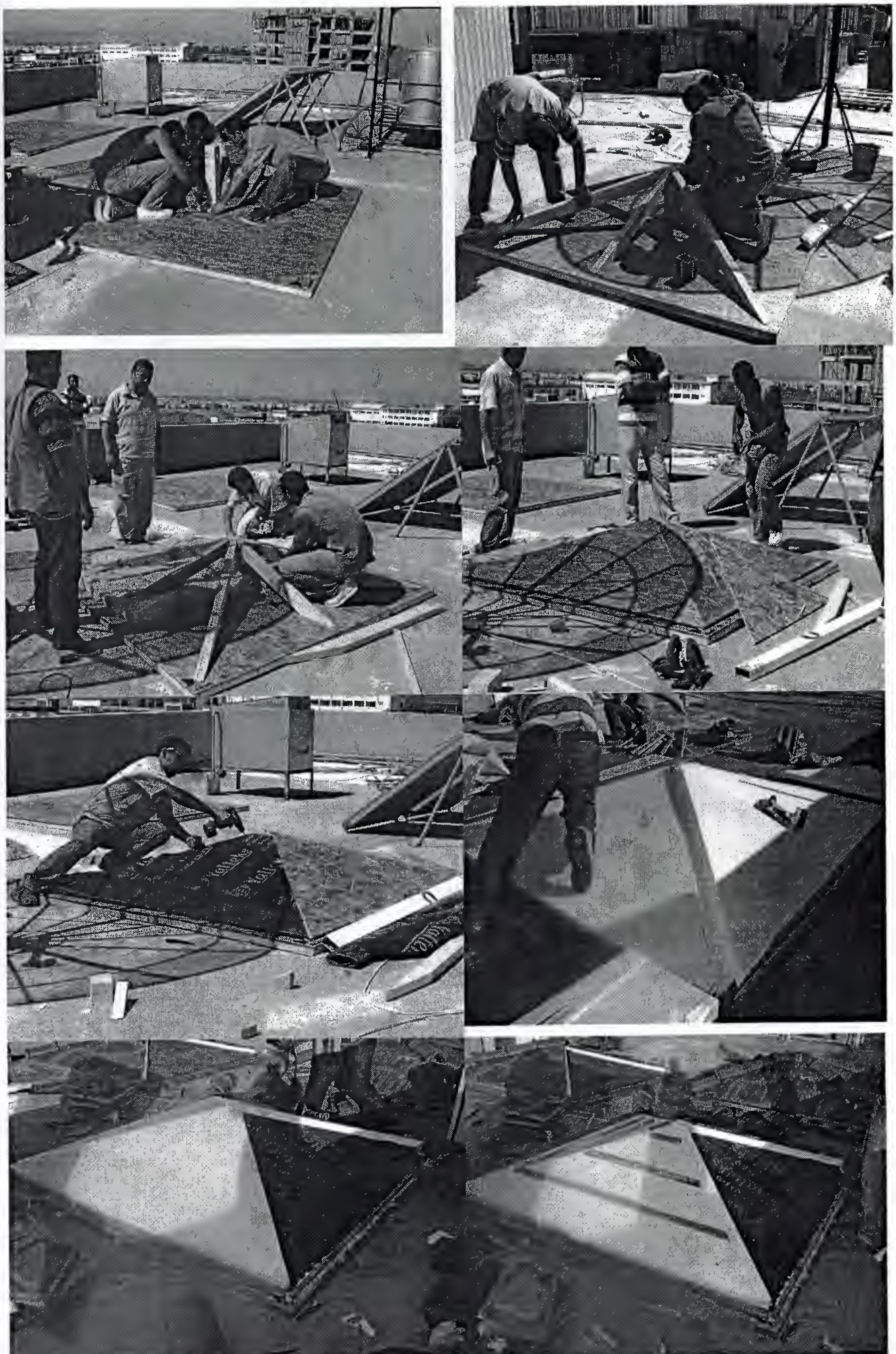


Figure 5.15 The picture of the hip roofs stages.

Figure 5.16 Arrangement of small scale models of roof L1 and L2.

5.5 First Stage of Experimental Study

5.5.1 The arrangment of termocouple cable at the first stage

While the roof material layers were being done by the workers thermo couple cables were put on each of the layers of materials to measure the temperature. The thermo couple cables are arranged by this numbers at below. The temperatures of each material were taken every 10 minutes. The outdoor temperature was measured by the data machine but we made a mistake and we lost the outdoor temperatures. We took outdoor and solar radiation temperatures from the meteorology office in Lefkoşa. There were four thermo couple cables for each of the hip roofs. Both of the hip roof south facades roof material temperatures were measured by the termocouple cables.

Stage one Thermo couple cables for L1;

L1 Thermo couple cables arrangement;

- No:1 Inside temperature
- No:2 Above the OSB
- No:3 Above Yalteks (water insulation)
- No:4 Above the roof tile.

Stage one Thermo couple cables for L2;

L2 Thermo couple cables arrangement;

- No:1 Inside temperature
- No:2 Above the OSB
- No:3 Under the tile
- No:4 Above the tile.

5.5.2 The arrangment of termocouple cable at the second stage

At the second stage for L1 (with heat insulation) roof four thermo couple cables are used. The arrangment of the thermo couple cables are shown at below. For L2 (without heat insulation) hip roof also four thermo couple cables were used.The arrangment of thermo couple cables are shown below.

5.6 Second Stage of Experimental Study

Stage two Thermo couple cables for L2;

L1 thermal couple cables arrangement;

- No:1 Inside temperature
- No:2 Above yalteks water insulation
- No:3 Above polystyrene foam board
- No:4 Above the roof tile.

Stage two Thermo couple cables for L2;

L2 Thermo couple cables arrangements;

- No:1 Inside temperature
- No:2 Above OSB
- No:3 Above yalteks water insulation
- No:4 Above the roof tile
-

In the Experimental study the thermo couple cable sensors were mounted at different points of the roofs and the temperatures were recorded continuously every ten minutes. The figure 5.17 below shows thermo couple cables were used on each layer of hip roofs. The collected data was then analysed to find the effectiveness of the insulating material used.

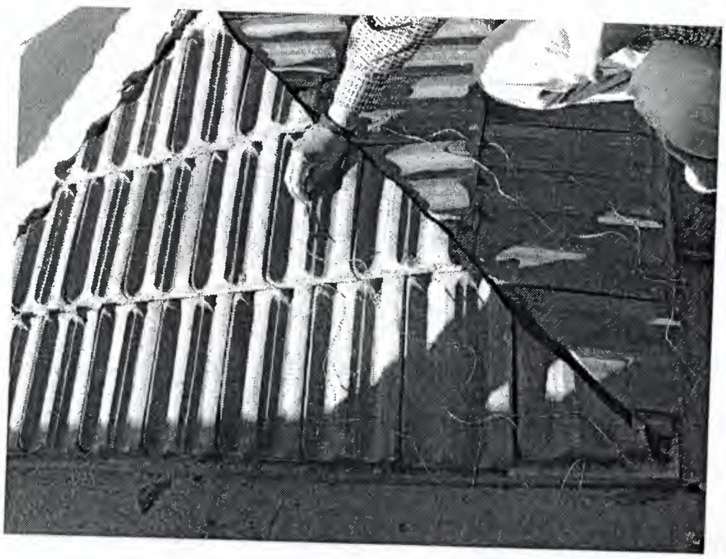


Figure 5.17 The roof tiles were put above the roof battens for both L1 and L2. Thermo couple cables were put to the layers of both hip roofs on their south facades.

5.7 The Negative Conditions

The Mechanical Engineering Department had been under construction when we started our experimental study. So that the workers who are working there effected our data.

Because they use vibration machines or they are walking surround the roofs. The other negative condition was that the electricity connection was interrupted sometimes. Also reading the data machine is so difficult. For example if I want to read 11th day information from the data machine without taking print, I must go through every 10 minutes from the first day to the 11th day. The other problem was the weather conditions. When we were doing our experimental study, it was winter season. The weather was rainy and we were working outside. As a result of these problems I needed to go to the University to check the control unit every day.

5.8 The calculations

5.8.1 Heat Loss Calculation

The heat loss calculation were done for one hour at day time and one hour at night time for the first stage . The heat loss is calculated by Ø°=∑.A.U.ΔT(W) formula.

Ø°=Heat Loss(W)

A.=Area(m^2)

U= Heat Conduction Coefficient (W/m^2K)

ΔT=Heat Difference ΔTin-ΔTout (K)

The data of 18/12/2008 between 12:00-13:00 day time and between 00:00-01:00 night time the heat loss were calculated at the first stage. The area of L1 and l2 south facade are 1 m^2.Heat conduction values (λ)W/mK are found from resources The heat conduction coefficient (U)W/m^2K values are calculated by dividing Heat conduction values (λ)W/mK to the thickness of the materials. We took one hour at day time and one hour at night time heat loss or gain for both stages. Because by this way we can see the sun effects to the insulation materials clearly.

5.8.1.1 Heat loss calculation in day time at the first stage

The table below shows that the day time heat loss of the L1 and L2 roofs on the date of 18/12/2008 between 12:00-13:00 at the first stage.

Table 5.2 The Heat loss L1 hip roof (with water insulation) in the daytime at the first stage.

				DATE	18.12.2008
				TIME	12:00-13:00
ROOF TYPE L1 (has water insulation)	**DIRECTION**	**THICKNESS(m)**	**AREA (m^2)**	**HEAT CONDUCTION VALUE (λ)W/mK**	**HEAT CONDUCTION COEFFICIENT (U)W/m²K**
Roof Tile	South	0,4	1	0,9	2,25
Roof Tile Battens	South	0,2	0,1	0,17	0,85
Yalteks (water insulation)	South	0,1	1	0,17	1,7
OSB	South	0,15	1	0,13	0,86
Rafter	South	0,1	0,18	0,17	1,7

$Ø° = \sum .A.U.\Delta T$ (W)

$\sum .A.U = 1m^2 \times 2.25\ W/m^2K + 0.1\ m^2 \times 0.85W/m^2K + 0.1\ m^2 \times 1.7\ W/m^2K + 0.1\ m^2 \times 0.86\ W/m^2K + 0.18\ m^2 \times 1.7\ W/m^2K = 5.2\ W/K$

$\Delta T = \Delta Tout - \Delta Tin = 5.25°C$

$°C = K - 273.15$

$5.25°C = K - 273.15$

$K = 5.25°C + 273.15$

$\Delta T = 278.4\ K$

$Ø° = \sum .A.U.\Delta T$ (W)

$\sum .A.U = 5.2\ W/K$

$Ø° = 5.2\ W/K \times 278.4\ K$

$Ø° = 1447.68W$

W=PxT

Joule=Watt x Second

Joule =1447.68Wx60 Second =86.860Joule

Table 5.3 The Heat loss L2 hip roof (without water insulation) in the daytime at the first stage.

				DATE	18.12.2008
				TIME	12:00-13:00
ROOF TYPE L2 (hasn't water insulation)	**DIRECTION**	**THICKNESS(m)**	**AREA (m^2)**	**HEAT CONDUCTION VALUE (λ)W/mK**	**HEAT CONDUCTION COEFFICIENT (U)W/m²K**
Roof Tile	South	0,4	1	0,9	2,25
Roof Tile Battens	South	0,2	0,1	0,17	0,85
OSB	South	0,15	1	0,13	0,86
Rafter	South	0,1	0,18	0,17	1,7

Ø°=∑.A.U.ΔT(W)

∑.A.U=1 m^2 x 2.25 W/m^2K + 0.1 m^2 x 0.85 W/m^2K +1 m^2x 0.86 W/m^2K + 0.18 m^2 x 1.7 W/m^2K =3.5 W/K

ΔT=ΔTout-ΔTin=9.41°C

°C = K-273.15

9.41°C=K-273.15

K=9.41°C +273.15

K=282.56

Ø°=∑.A.U.ΔT (W)

∑.A.U=3.5 W/K

Ø°=3.5 W/K x 282.56 K

Ø°=988.96W

W=PxT

Joule=Watt x Second

988.96W x 60=59.337Joule

5.8.1.2 Comments for roof L1 and L2 at the first stage in day time;

The day hours between 12:00-13:00 hours the L1 roof heat loss is 86.860 Joule. In addition to this L2 roof at the day hours between 12:00-13:00 hours heat loss is 59.337 Joule.It is understood from the result L1 roof heat loss is more than L2 heat loss at day time.

5.8.1.3 Heat loss calculation in night time at the first stage

The table below shows that the night time heat loss of the L1 and L2 roofs on the date of 18/12/2008 between 00:00-01:00 at the first stage.

Table 5.4 The Heat loss L1 hip roof (with water insulation) in the night time at the first stage.

				DATE	18.12.2008
				TIME	00:00-01:00
ROOF TYPE L1 (has water insulation)	**DIRECTION**	**THICKNESS(m)**	**AREA (m^2)**	**HEAT CONDUCTION VALUE (λ)W/mK**	**HEAT CONDUCTION COEFFICIENT (U)W/m²K**
Roof Tile	South	0,4	1	0,9	2,25
Roof Tile Battens	South	0,2	0,1	0,17	0,85
Yalteks (water insulation)	South	0,1	1	0,17	1,7
OSB	South	0,15	1	0,13	0,86
Rafter	South	0,1	0,18	0,17	1,7

$\emptyset° = \sum.A.U.\Delta T(W)$

$\sum.A.U = 1\ m^2 \times 2.25\ W/m^2K + 0.1\ m^2 \times 0.85\ W/m^2K + 1\ m^2 \times 1.7\ W/m^2K + 1\ m^2 \times 0.86\ W/m^2K + 0.18\ m^2 \times 1.7\ W/m^2K = 5.2\ W/K$

$\Delta T = \Delta Tin - \Delta Tout = 4.68°C$

°C = K-273.15

4.68°C=K-273.15

K=4.68°C +273.15

K=277.83

Ø°=∑.A.U.ΔT (W)

∑.A.U=5.2W/K

Ø°=5.2 W/K x 277.83 K

Ø°=1444.71 W

Joule=Watt x Second

1444.71 x 60=86.682 Joule

Table 5.5 The Heat loss L2 hip roof (without water insulation) in the night time at the first stage.

				DATE	18.12.2008
				TIME	00:00-01:00
ROOF TYPE L2 (hasn't water insulation)	**DIRECTION**	**THICKNESS(m)**	**AREA (m^2)**	**HEAT CONDUCTION VALUE (λ)W/mK**	**HEAT CONDUCTION COEFFICIENT (U)W/m²K**
Roof Tile	South	0,4	1	0,9	2,25
Roof Tile Battens	South	0,2	0,1	0,17	0,85
OSB	South	0,15	1	0,13	0,86
Rafter	South	0,1	0,18	0,17	1,7

Ø°=∑.A.U.ΔT(W)

∑.A.U=1 m^2 x 2.25 W/m²K + 0.1 m^2 x 0.85 W/m²K + 1 m^2 x 0.86 W/m²K + 0.18 m^2 x 1.7 W/m²K =3.5 W/K

ΔT=ΔTin-ΔTout=2.85°C

°C = K-273.15

K=2.85°C+273.15

K=276

Ø°=∑.A.U.ΔT (W)

∑.A.U=3.5W/K

Ø°=3.5 W/K x 276K

Ø°=966W

W=PxT

Joule=Watt x Second

966 x 60=57.960 Joule

5.8.1.4 Comments for roof L1 and L2 at the first stage in night time;

The night hours between 00:00-01:00 hours the L1 roof heat loss is 86.682 Joule. In addition to this L2 roof at the night hours between 00:00-01:00 hours heat loss is 57.960 Joule. It is understood from the result L1 roof heat loss is more than L2 heat loss at night time.

5.8.1.5 Heat loss calculation in day time at the second stage

The table below shows that the night time heat loss of the L1 and L2 roofs on the date of 08/01/2009 between 12:00:00-13:00 at the second stage.

Table 5.6 The Heat loss L1 hip roof (with heat insulation) in the day time at the second stage

				DATE	08.01.2009
				TIME	12:00-13:00
ROOF TYPE L1 (has heat insulation)	**DIRECTION**	**THICKNESS(m)**	**AREA (m^2)**	**HEAT CONDUCTION VALUE (λ)W/mK**	**HEAT CONDUCTION COEFFICIENT (U)W/m²K**
Roof Tile	South	0,4	1	0,9	2,25
Roof Tile Battens	South	0,2	0,1	0,17	0,85
Yalteks (water insulation)	South	0,1	1	0,17	1,7
Foam board	South	0,5	1	0,03	0,06

(heat insulation)					
OSB	South	0,15	1	0,13	0,86
Rafter	South	0,1	0,18	0,17	1,7

$Ø°=\sum.A.U.\Delta T(W)$

$\sum.A.U=1\ m^2x2.25\ W/m^2K\ +0.1\ m^2x0.85\ W/m^2K\ +1\ m^2x1.7\ W/m^2K\ +1\ m^2x0.06\ W/m^2K\ +1\ m^2x0.86\ W/m^2K\ +0.18\ m^2x1.7\ W/m^2K\ =5.26\ W/K$

$\Delta T=\Delta Tout-\Delta Tin=7.23°C$

$°C = K-273.15$

$7.23°C =K-273.15$

$K=7.23°C +273.15$

$K=280.38$

$Ø°=\sum.A.U.\Delta T\ (W)$

$\sum.A.U=5.26\ W/K$

$Ø°=5.26\ W/K\ x\ 280.38K$

$Ø°=1474W$

Joule=Watt x Second

1474 x 60=88.487 Joule

Table 5.7 The Heat loss L2 hip roof (without heat insulation) in the day time at the second stage

				DATE	08.01.2008
				TIME	12:00-13:00
ROOF TYPE L2 (hasn't heat insulation)	**DIRECTION**	**THICKNESS(m)**	**AREA (m^2)**	**HEAT CONDUCTION VALUE (λ)W/mK**	**HEAT CONDUCTION COEFFICIENT (U)W/m²K**
Roof Tile	South	0,4	1	0,9	2,25
Roof Tile Battens	South	0,2	0,1	0,17	0,85

Yalteks (water insulation)	South	0,1	1	0,17	1,7
OSB	South	0,15	1	0,13	0,86
Rafter	South	0,1	0,18	0,17	1,7

Ø°=∑.A.U.ΔT(W)

∑.A.U=1 m^2x2,25 W/m^2K +0,1 m^2x0,85 W/m^2K +1 m^2x1,7 W/m^2K +1 m^2x0,86 W/m^2K +0,18 m^2x1,7 W/m^2K =5,2 W/K

ΔT=ΔTout-ΔTin=11,91°C

°C = K-273.15

11,91°C =K-273.15

K=11,91°C +273.15

K=285.06

Ø°=∑.A.U.ΔT (W)

∑.A.U=5.2 W/K

Ø°=5.2 W/K x 285.06K

Ø°=1482W

W=PxT

Joule=Watt x Second

1482W x 60=88.920 Joule

5.8.1.6 Comments for roof L1 and L2 at the second stage in day time;

The day hours between 12:00-13:00 hours the L1 roof heat loss is 88.487 Joule. In addition to this L2 roof at the day hours between 12:00-13:00 hours heat loss is 88.920 Joule. It is understood from the result L1 roof heat loss is less than L2 heat loss at day time.

5.8.1.7 Heat loss calculation in night time at the second stage

The table below shows that the night time heat loss of the L1 and L2 roofs on the date of *08/01/2009* between *00:00-01:00 at the second stage.*

Table 5.8 The Heat loss L1 hip roof (with heat insulation) in the night time at the second stage.

				DATE	08.01.2009
				TIME	00:00-01:00
ROOF TYPE L1 (has heat insulation)	**DIRECTION**	**THICKNESS(m)**	**AREA (m^2)**	**HEAT CONDUCTION VALUE (λ)W/mK**	**HEAT CONDUCTION COEFFICIENT (U)W/m^2K**
Roof Tile	South	0,4	1	0,9	2,25
Roof Tile Battens	South	0,2	0,1	0,17	0,85
Yalteks (water insulation)	South	0,1	1	0,17	1,7
Foam board (heat insulation)	South	0,5	1	0,03	0,06
OSB	South	0,15	1	0,13	0,86
Rafter	South	0,1	0,18	0,17	1,7

Ø°=∑.A.U.ΔT(W)

∑.A.U=1 m^2x2,25 W/m^2K +0,1 m^2x0,85 W/m^2K +1 m^2x1,7 W/m^2K +1 m^2x0,06 W/m^2K +1 m^2x0,86 W/m^2K +0,18 m^2x1,7 W/m^2K =5.26 W/K

ΔT=ΔTin-ΔTout=6.95°C

°C = K-273.15

6.95°C=K-273.15

K=6.95°C+273.15

K=280.1

Ø°=∑.A.U.ΔT (W)

∑.A.U=5.26 W/K

Ø°=5.26 x 280.1K

$Ø°=1473W$

Joule=Watt x Second

W=1473W x 60=88.399 Joule

Table 5.9 The Heat loss L2 hip roof (without heat insulation) in the night time at the second stage

				DATE	08.01.2008
				TIME	00:00-01:00
ROOF TYPE L2 (hasn't heat insulation)	**DIRECTION**	**THICKNESS(m)**	**AREA (m^2)**	**HEAT CONDUCTION VALUE (λ)W/mK**	**HEAT CONDUCTION COEFFICIENT (U)W/m^2K**
Roof Tile	South	0,4	1	0,9	2,25
Roof Tile Battens	South	0,2	0,1	0,17	0,85
Yalteks (water insulation)	South	0,1	1	0,17	1,7
OSB	South	0,15	1	0,13	0,86
Rafter	South	0,1	0,18	0,17	1,7

$Ø°=\sum.A.U.\Delta T(W)$

$\sum.A.U=1\ m^2 x2.25\ W/m^2K +0.1\ m^2 x\ 0.85\ W/m^2K +1\ m^2 x1.7\ W/m^2K +1\ m^2 x0.86\ W/m^2K +0.18\ m^2 x1.7\ W/m^2K =5.2\ W/K$

$\Delta T=\Delta Tin-\Delta Tout=0.41°C$

$°C = K-273.15$

$0.41°C =K-273.15$

$K=0.41°C+273.15$

$K=273.56$

$Ø°=\sum.A.U.\Delta T\ (W)$

$\sum.A.U=5.2\ W/K$

$Ø°=5,2 \times 273.56$

$Ø°=1422.51W$

Joule=Watt x Second

1422.51Wx 60=85.350 Joule

5.8.1.8 Comments for roof L1 and L2 at the first stage in night time;

The night hours between 00:00-01:00 hours the L1 roof heat loss is 88.399Joule. In addition to this L2 roof at the day hours between 00:00-01:00 hours heat loss is 85.350 Joule. It is understood from the result L1 roof heat loss is more than L2 heat loss at night time.

5.9 One day evaluation at the first stage and second stage

The chart of 18-12-2008 at the first stage Chart 1.1 is shown that L1 with water insulation roof inside temperature is more than L2 without heat insulation material inside temperature. That means L1 roof which is used in TRNC widely keeps the inside roof temperature warmer all the day.

The chart of 21-01-2009 is shown in Chart 1.2 L1 with heat insulation roof inside temperature higher at night time than L2 without heat insulation material roof. According to this L2 without heat insulation material roof inside temperature is higher L1 with heat insulation material at day time and L2 inside roof temperature is lower than L1 at night time.

Chart 1.1 Chart for 18-12-2008 at the first stage

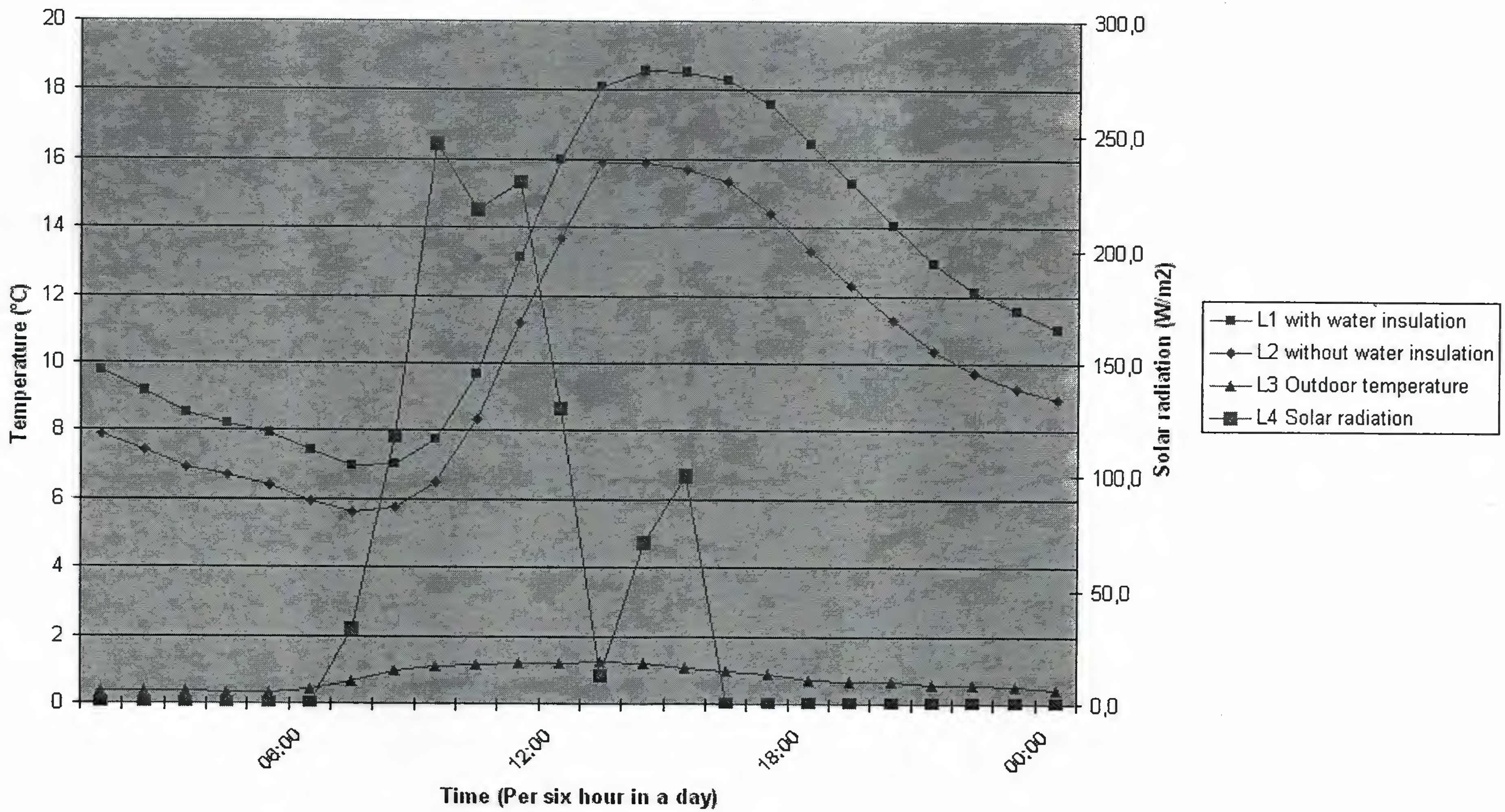
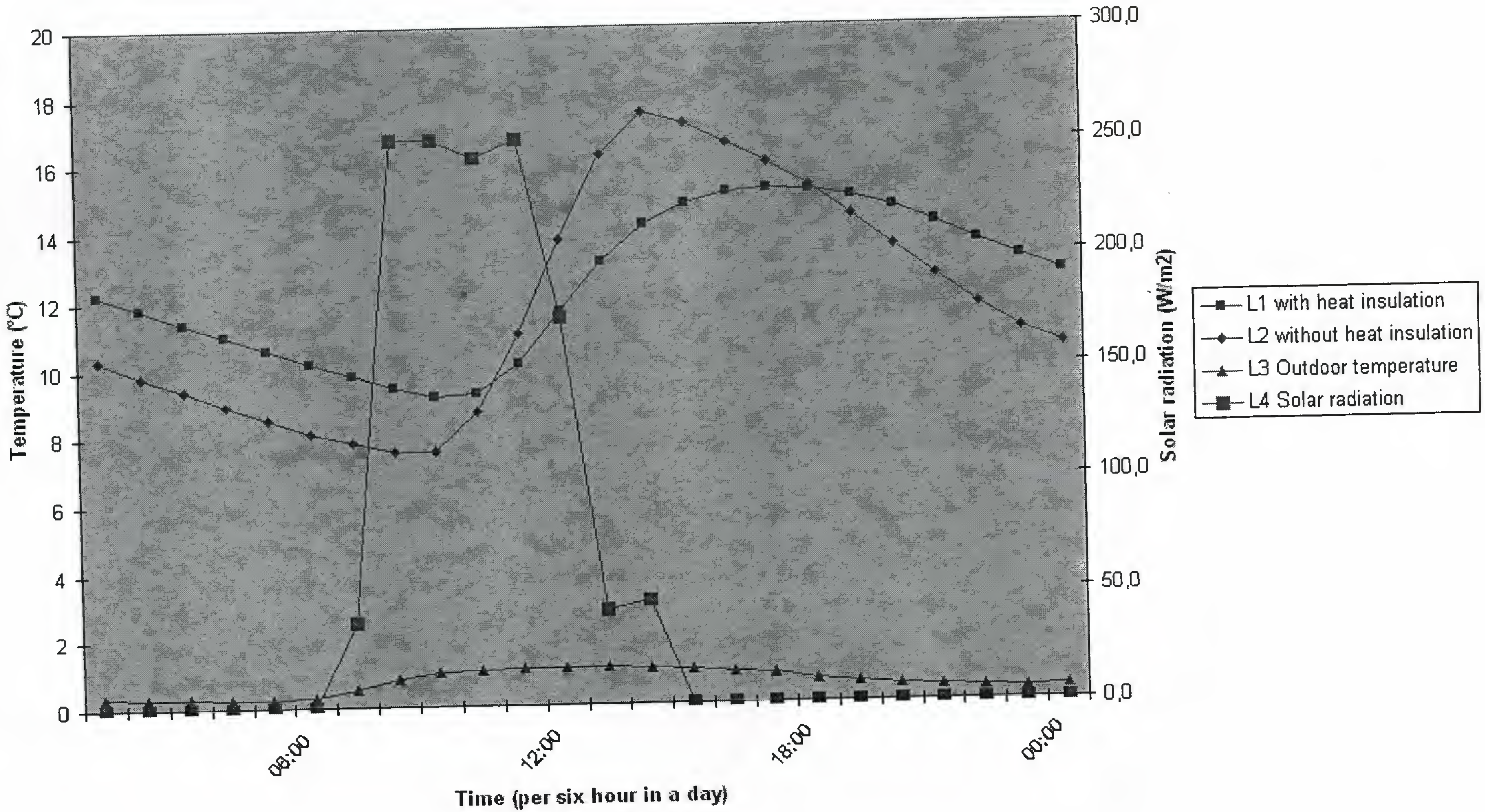


Chart 1.2 Chart for 21-01-2009 at the second stage



5.10 The Average for the first stage and second stage

Chart for the average of the first stage is shown in Chart 1.3 that L1 (with water insulation material) roof inside temperature is higher than L2 (without water insulation material) inside temperature.

The average of the second stage Chart 1.4 shown that L1 with heat insulation material roof inside temperature is higher than L2 without heat insulation material roof. That means heat insulation material provides heat gain in winter.

Chart 1.3 Chart for the average of the first stage

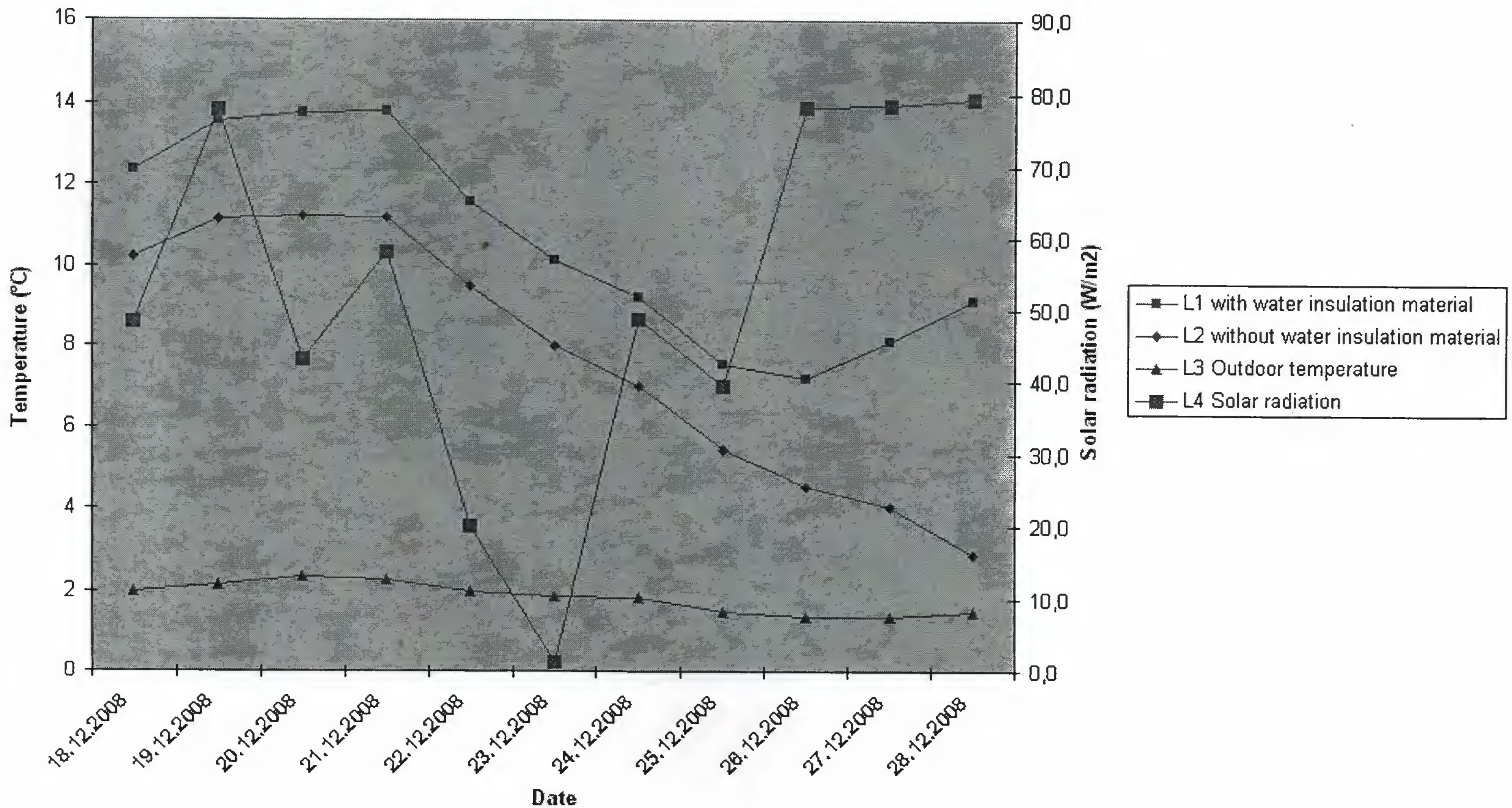
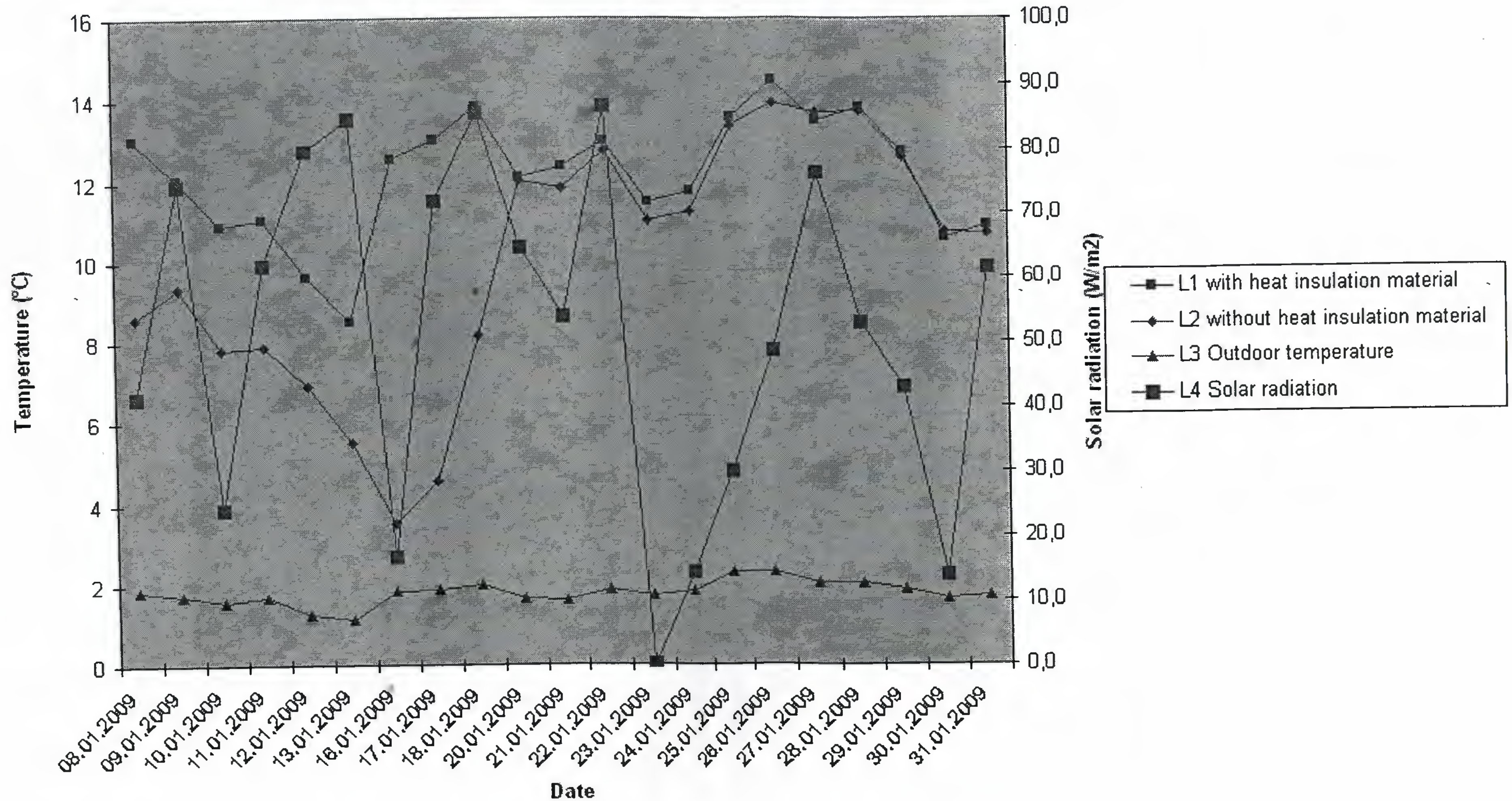


Chart 1.4 Chart for the average of the second stage



5.11 Result of the Experimental Study

The calculation results were shown that when the morning hour at the first stage the date of 18-12-2008 between 12:00-13:00 L1 heat gain is lower than L2 heat gain. When the night hour at the first stage the date of 18-12-2008 between 00:00-01:00 L1 heat gain is higher than L2.

At the second stage the date of 08-01-2009 between 12:00-13:00 at day time. L1 heat gain is lower than L2. When the night hour of 08-01-2009 between 00:00-01:00 at night time L1 heat gain is higher than L2.

The experimental study conducted at Near East University Mechanical Engineering, Solar Labarator, Nicosia, TRNC. We choose roof materials which are used in TRNC. The two separate pyramid roofs we placed on 200cm x 200cm MDF, then layered Glasswool on them to provide insulation from the ground. Then 5x10 rafters were fixed on to the MDF. The rafters are covered by OSB on four sides. The OSB material has low heat conductivity. It helps to provide heat insulation. Then the four sides of L1 roof was covered by Yalteks water insulation material and on L2 three sides except south facade was covered by water insulation material. Then roof tile batons are fixed onto the water insulation material for both roofs. Finally roof tiles are fixed above the Yalteks. Data is taken from both roof's south facades for eleven days.

At the first stage between 18-12-08 and 28-12-08 we chose the data from 19-12-08 for an example to evaluate the first stage. The roof which has water insulation (L1), its temperature was higher than the roof which hasn't water insulation material (L2) in the day time and night time. Then we chose the data from 22-01-09 which is in the second stage. L1 roof which has heat insulation roof temperature is higher in the early hours and night hours than L2, which hasn't heat insulation material and L1 temperature is lower than L2 at the noon hours. It is understood that in winter months, water insulation material should be used with heat insulation on the roof. Heat insulation material keeps roof inside temperature at maximum level when the outside temperature is low in night time hours.

It is understood that during winter days heat insulation material keeps heat-in, in the coldest hours in the day and protects the building from unnecessary solar radiation when the air temperature is higher.

In the first stage each of eleven day average shows that L1 is higher than L2.

In the second stage each of twenty one day average shows that L1 is higher than L2.

The results show that if the water insulation material used with heat insulation material it is effective to provide heat comfort in buildings. We researched the answer to our question which is "Do the South facade of roofs need heat insulation material?". According to the south facade of pyramid roofs; It is understood that during the winter days heat insulation material keeps heat-in in the night time and prevents the heat gain in the day time.

During the summer days heat insulation material protects the building summer sun in the day time and prevents the heat loss in the night time.

5.1.7 Discussions

To provide building heat comfort, possible by using building roof insulation which are suitable for TRNC climatic conditions energy and economical possession.

When we choose heat and water insulation materials we must be careful about these points:

a) When we choose heat insulation and water insulation materials we should choose a material, which has low heat conductivity. Furthermore the heat insulation material vapour diffusion index, density, heat resistance and resistance for mechanical effects are important. These features of material should be thought where the material is used.

b) Water and heat insulations to be used together at the project design stage to make insulation materials effective and have economical solutions.

c) The most important thing with insulations is to combine them. Especially applying heat insulation to stop heat transfer and so reduce the risk of condensation, by covering the whole structure.

CHAPTER 6, CONCLUSIONS

The aim of this study was to evaluate the effects of hip roofs water and heat insulation materials which are appropriate for Northern Cyprus, Nicosia climate.

Today the energy sources have been nearly exhausted and this causes us to use new/alternative sources in a radical way. In this context not waisting the existing energy resources is of great importance. In TRNC buildings which are built and under construction have been using insulation materials but it is seen that they aren't enough to make energy disposition. Especially water and heat insulation is to have an important role. Using heat-prevention insulation on buildings provides large heat disposal.

Before the experimental work, water and heat insulation materials, which are used on TRNC hip roofs are analysed. It is worked on the south facade of the both two stages of experimental studies. The reason is that the south facade takes the sun's radiation in an efficient way.

In the experimental study, two hip roofs, called L1 and L2, are built. At the first stage L1 roof's four sides have yalteks water insulation material. On L2 three sides of the roof have yalteks water insulation material (except the south facade). The data was taken for eleven days from the south facade of L1 and L2. At the second stage four sides of L1 were covered in polyester foam board heat insulation material and three sides of L2 were covered in polyester foam board heat insulation material (except the south facade). The reason for covering the other facades both of hip roofs with foam board insulation material is to provide decreasing the heat loss. The data was taken twenty one days from the south facade of L1 and L2.

The result of the first stage was that, considering the average between sunrise to sunset and the average between sunset to sunrise, L1 inside roof temperature was higher than L2 inside roof temperature. The result of the second stage was that considering the average between sunrise to sunset L1 roof inside temperature was lower than L2. For L2 the average between sunset to sunrise, L1 inside temperature is higher than L2.

It is understood from the data that yalteks water insulation material has a very little effect to provide heat insulation. If yalteks water insulation material is used with foamboard heat insulation material it provides an efficient heat insulation. The foamboard heat insulation material, which has lowest heat conduction value of (0.030 W/mK), provides high heat insulation.

In this way the question 'Does the south facade of roofs need heat insulation material?' was answered. According to the data; hip roofs south facade's need heat insulation material the same as the other facades, otherwise the roof will loose large amounts of energy.

An alternative for the hip roofs, which haven't got foam board heat insulation material is the use of covering heat insulation material. The covering heat insulation material works with a mechanical system, which can open and close. The roof pool cover systems can be given as an example for that. Siliding roof system is used as prevention from the bad weather conditions, and harmful UV radiation and is effective at decreasing infrared radiation. For L2 hip roof top can be closed by the covering heat insulation material at day time to provide not to gain heat and open at night to provide heat loss in summer. For winter the covering heat insulation material open to provide heat gain at day time and it can be closed by the covering heat insulation material to provide not to loss heat at night time.

As a conclusion, TRNC building's hip roofs should be orientated to the south facade, where the architectural spaces are used oftenly for benefit from the summer sun, in winter providing natural climatization with heat insulation material and to spare no cost of labour with design knowledge.

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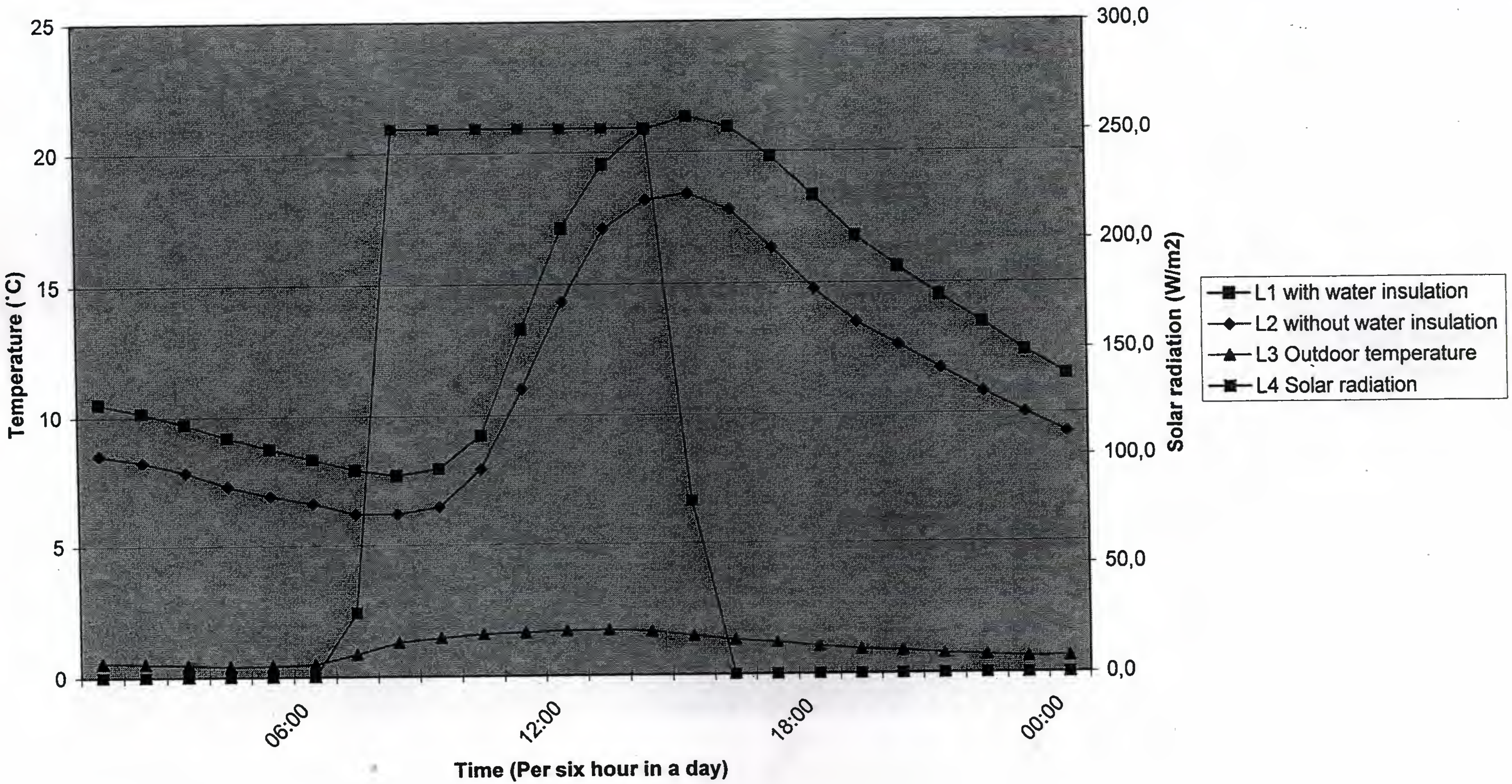
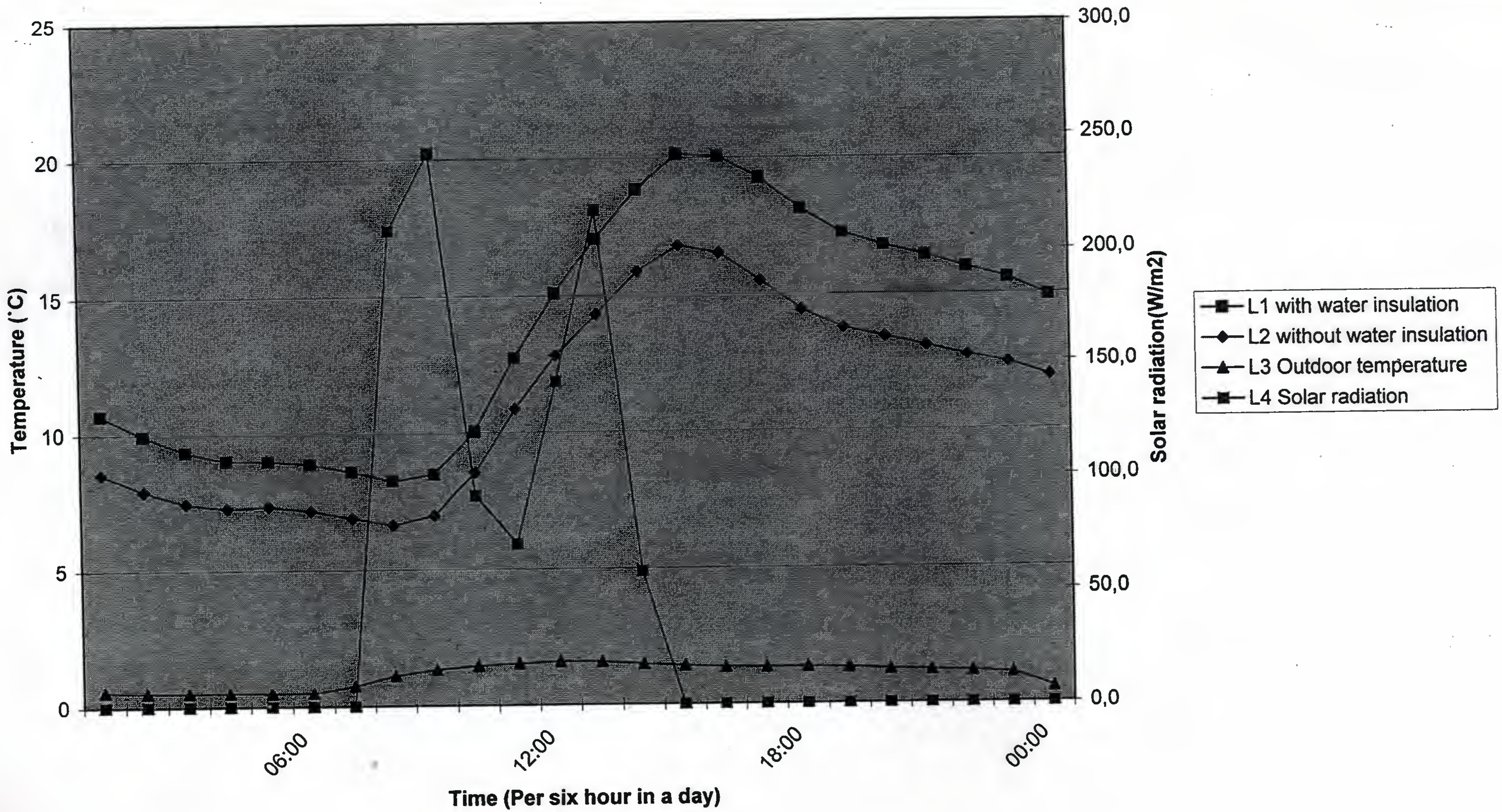
From measuring instrument to measuring system

APPENDIX, First And Second Stage Daily Charts

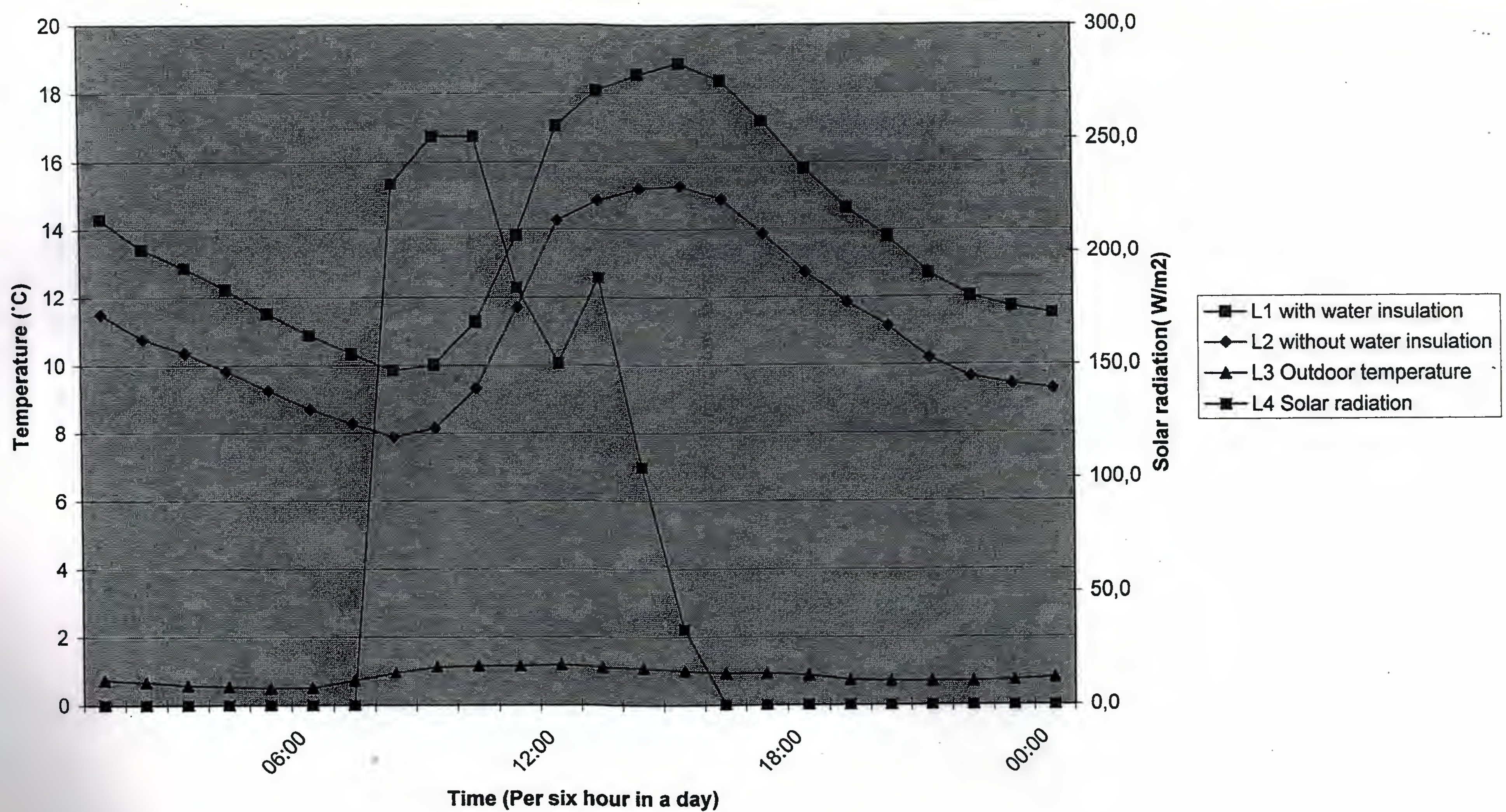
Appendix 1.1 Chart for 19-12-2008 at the First Stage



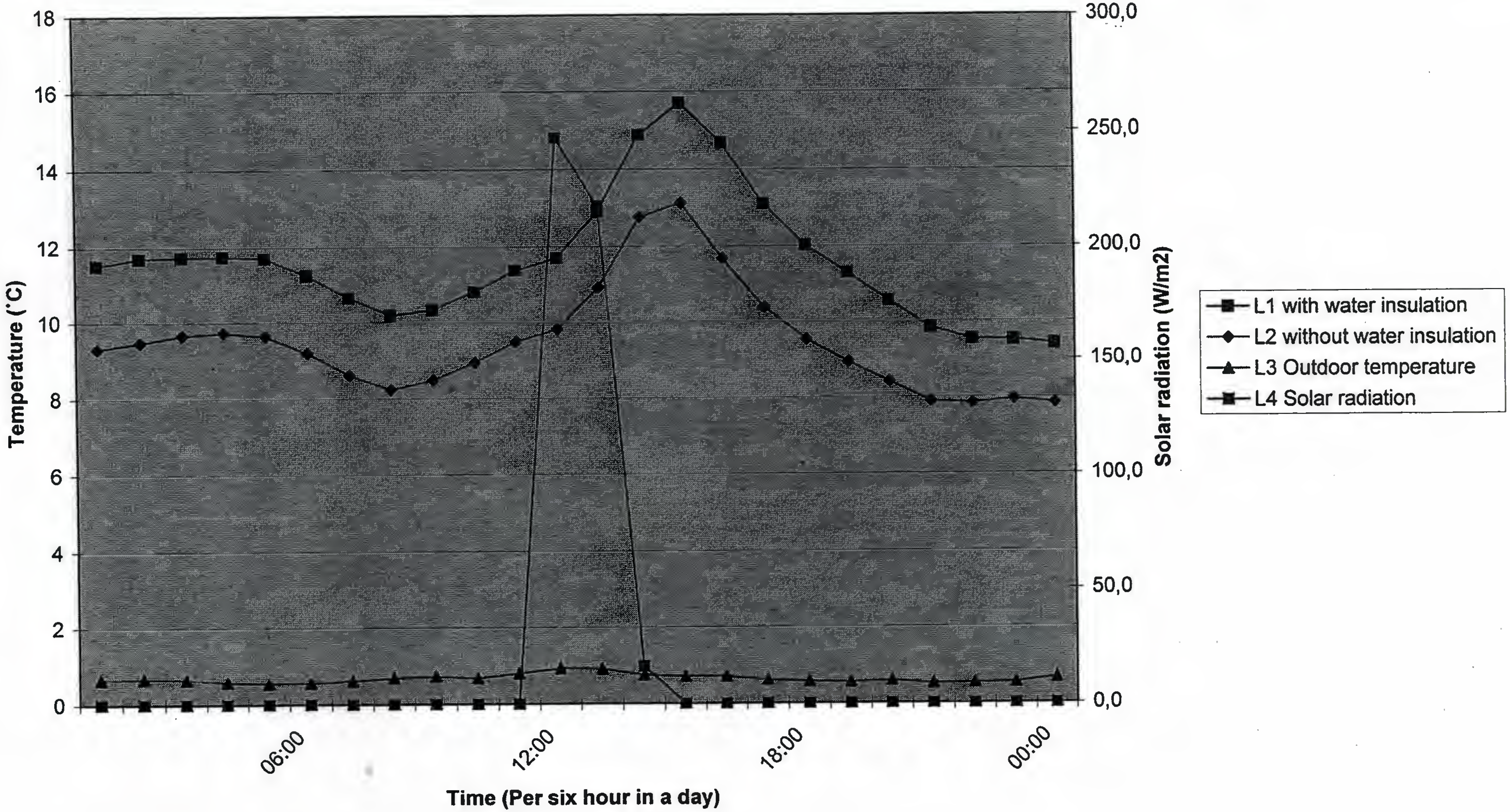
Appendix 1.2 Chart for 20-12-2008 at the First Stage



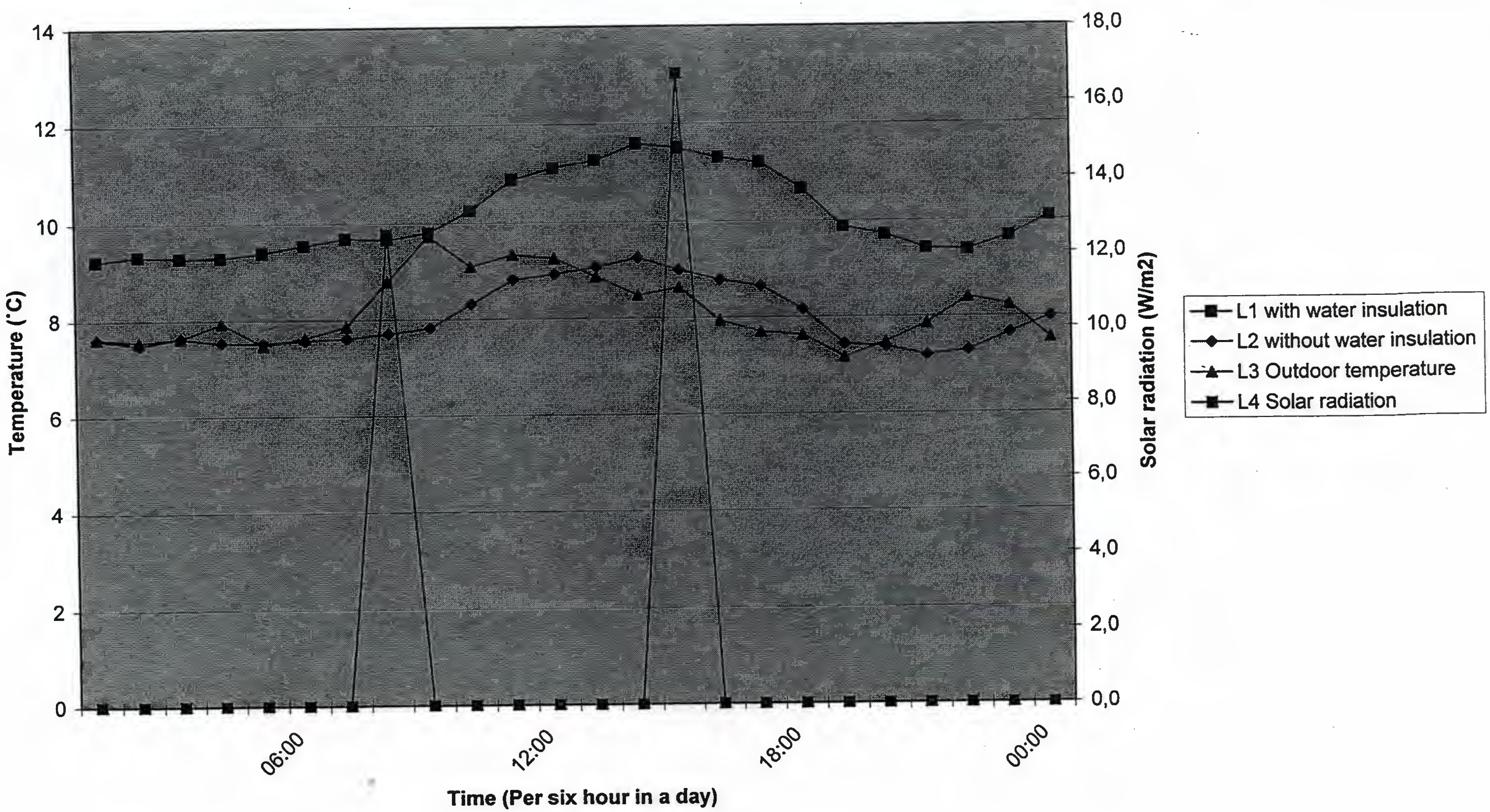
Appendix 1.3 Chart for 21-12-2008 at the first stage



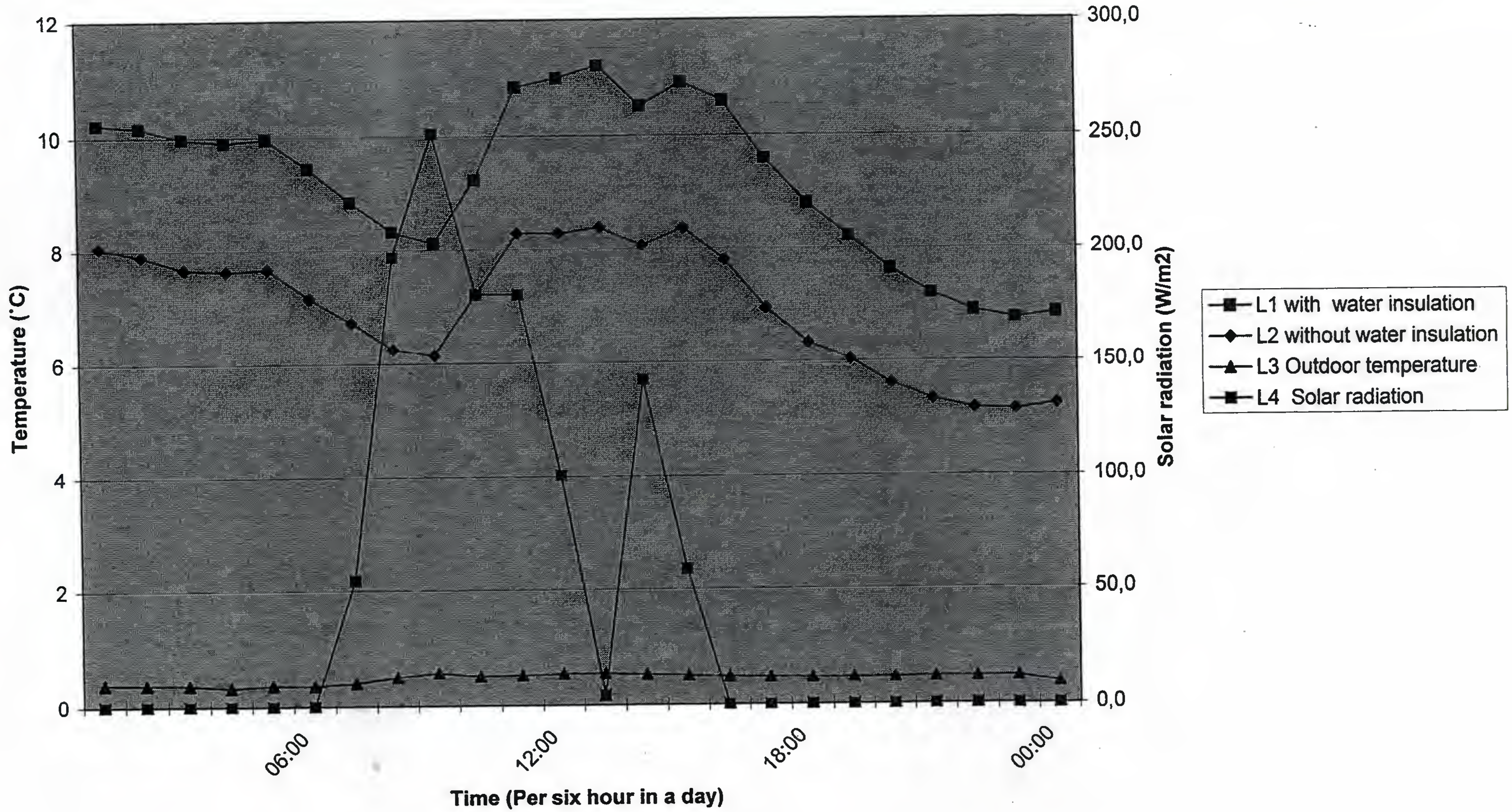
Appendix 1.4 Chart for 22-12-2008 at the first stage



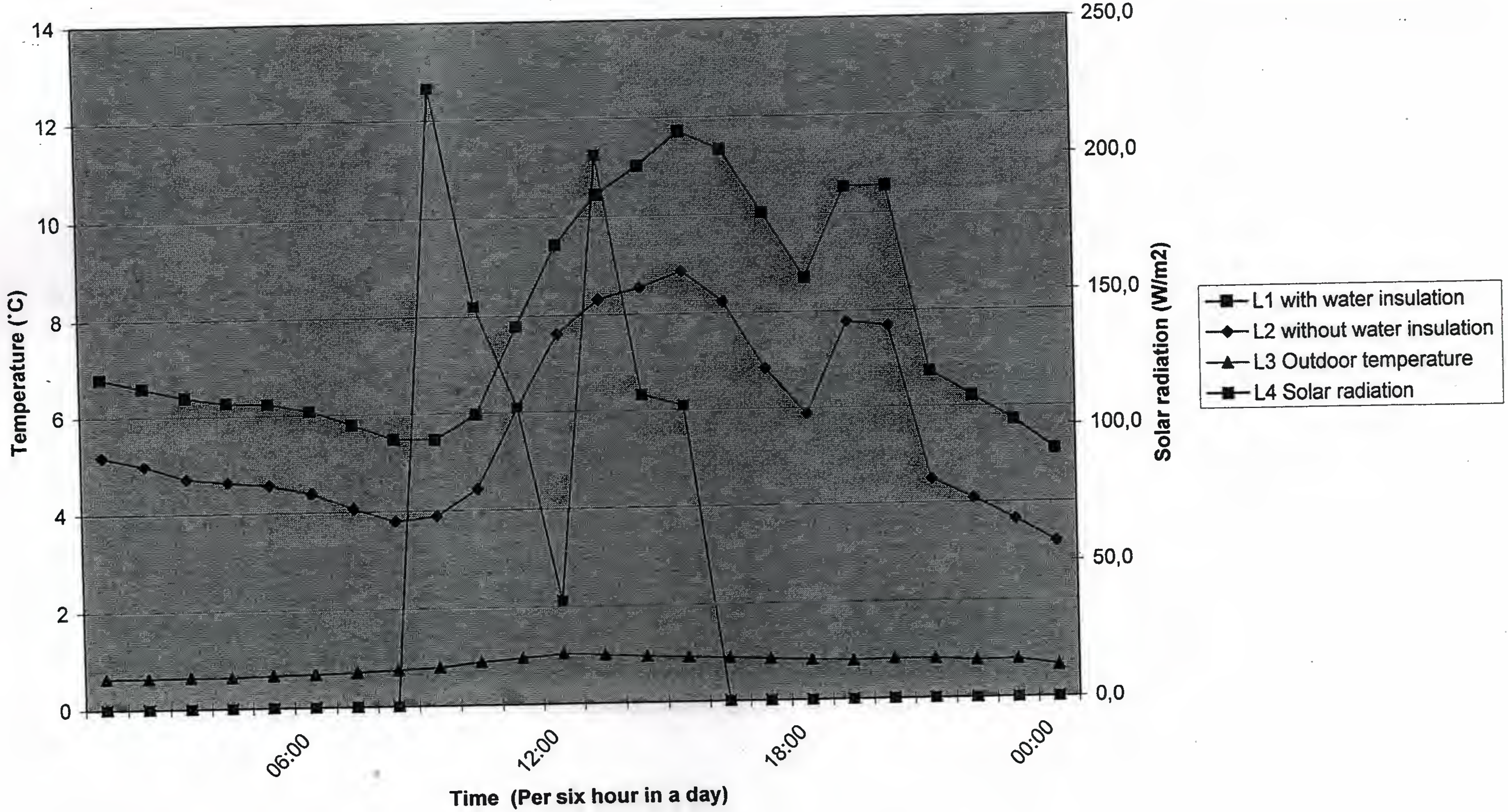
Appendix 1.5 Chart for 23-12-2008 at the first stage



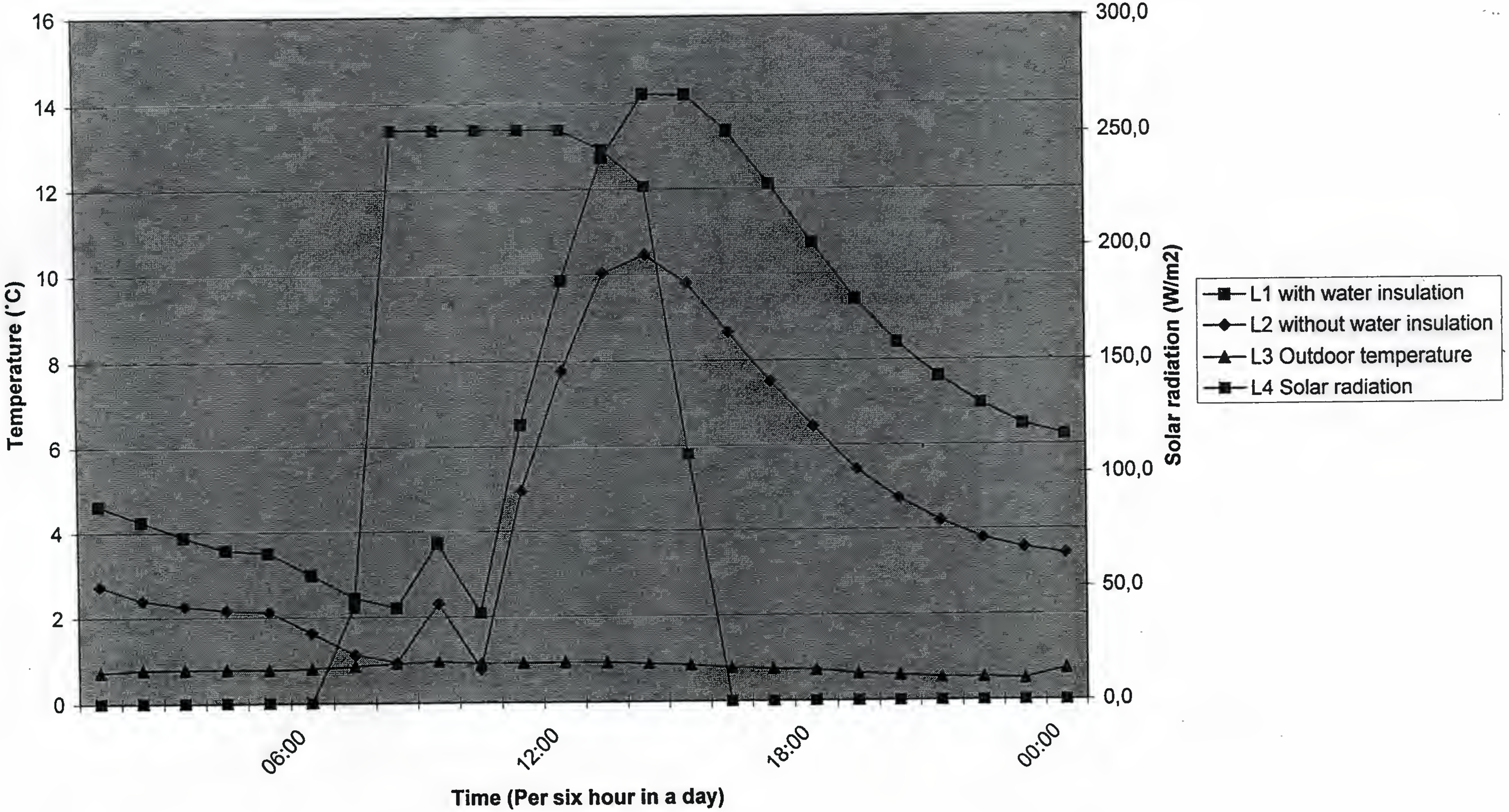
Appendix 1.6 Chart for 24-12-2008 at the first stage



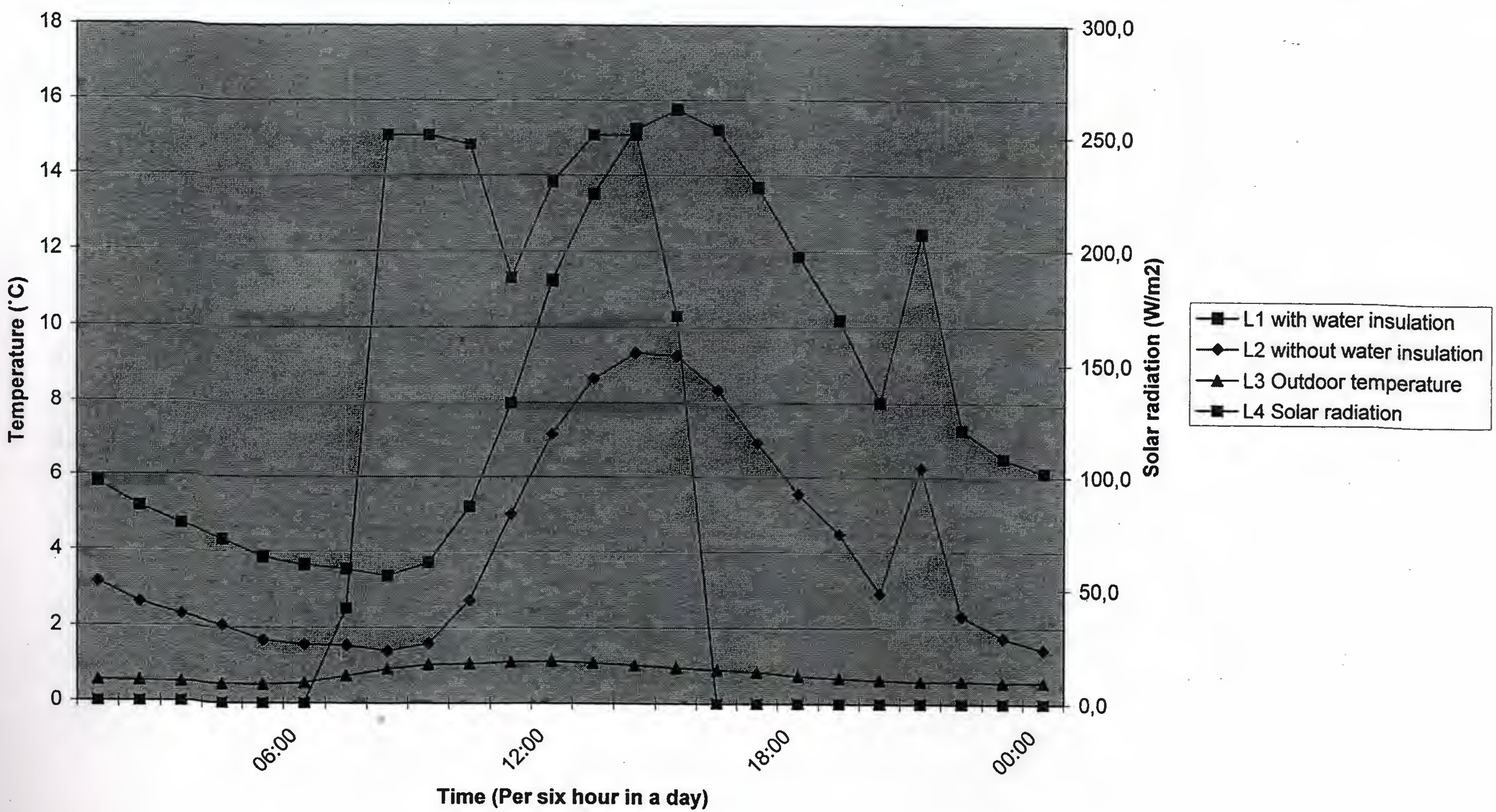
Appendix 1.7 Chart for 23-12-2008 at the first stage



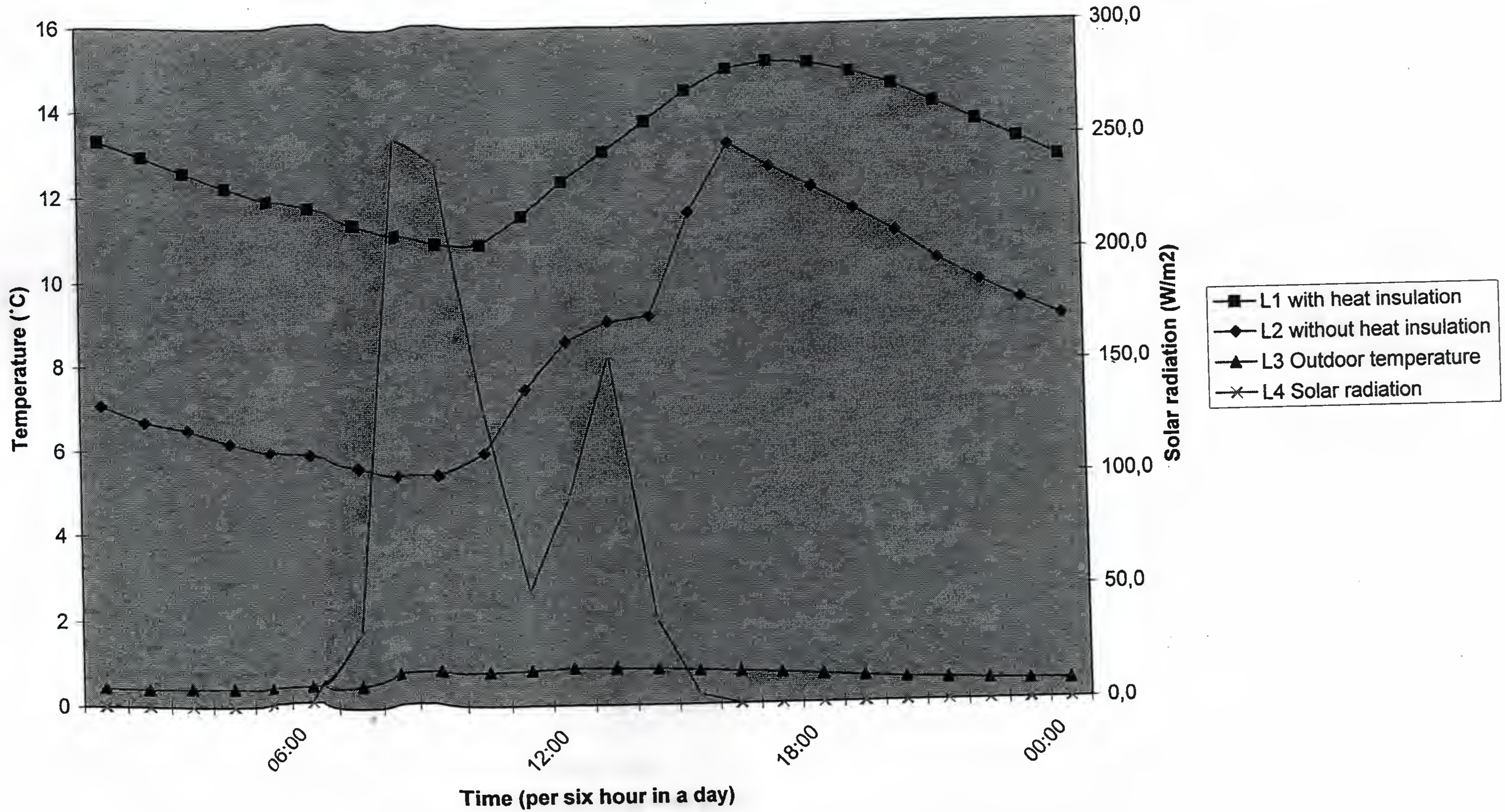
Appendix 1.8 Chart for 26-12-2008 at the first stage



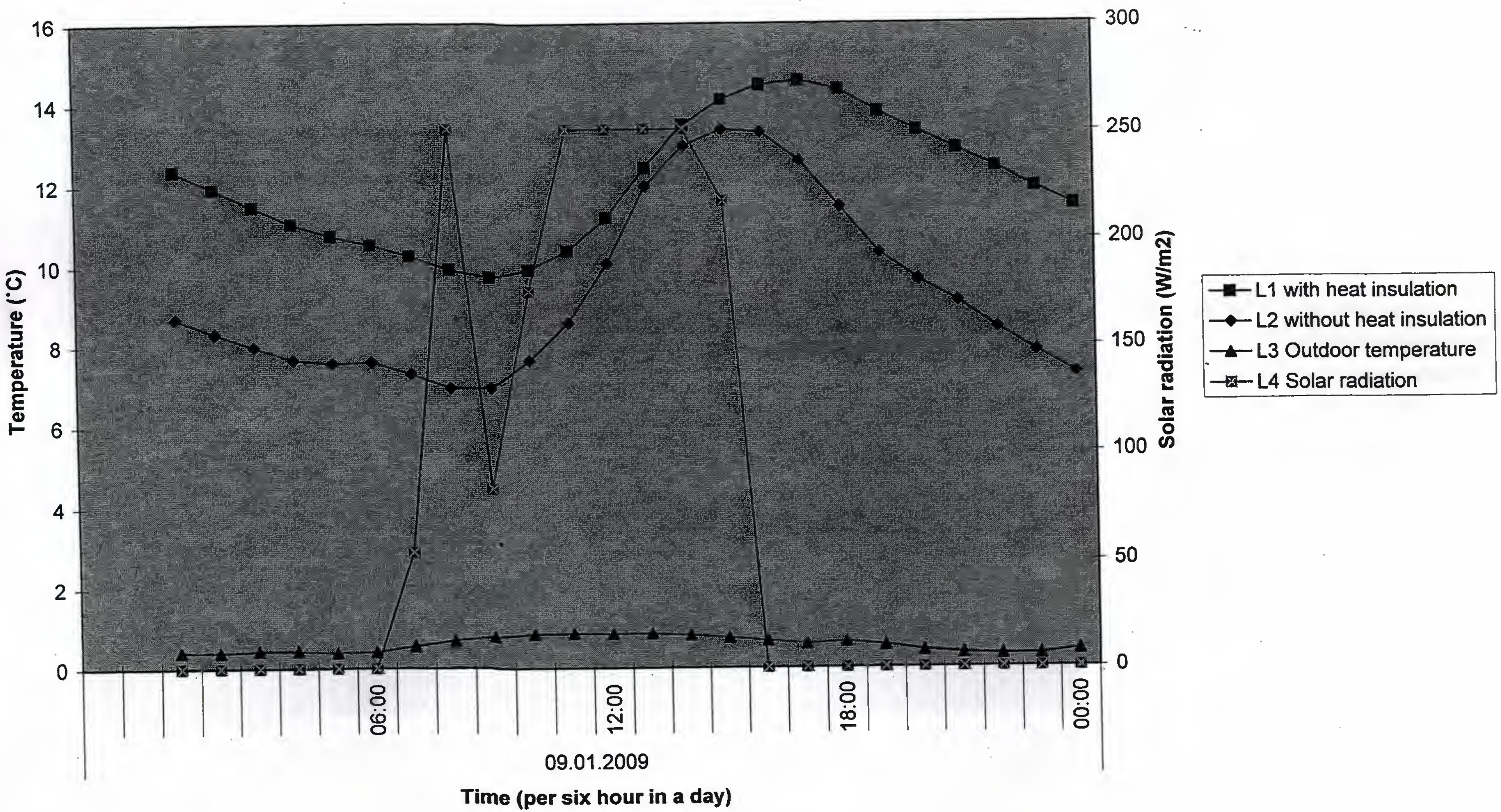
Appendix 1.9 Chart for 27-12-2008 at the first stage



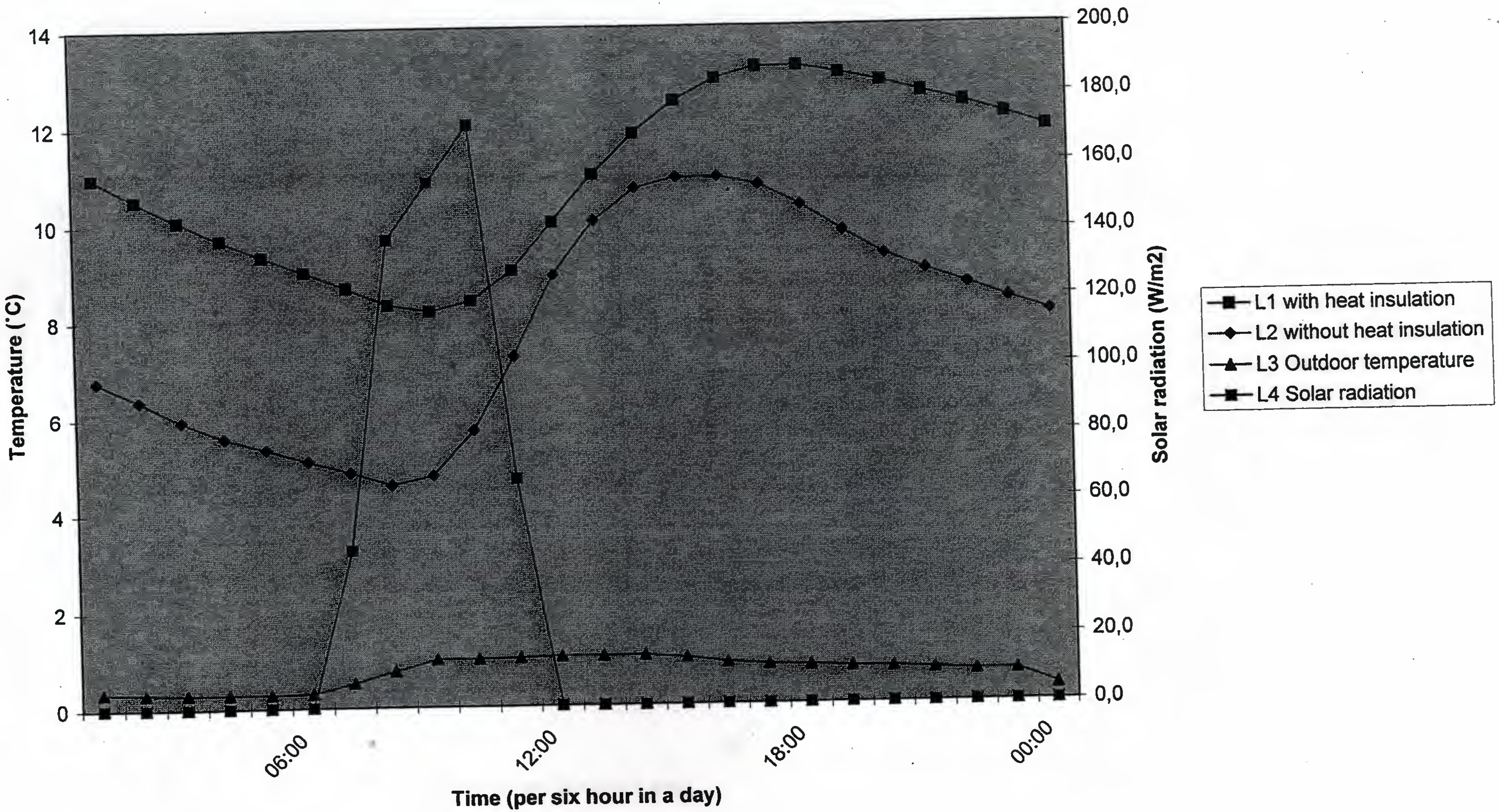
Appendix 1.10 Chart for 08-01-2009 at the second stage



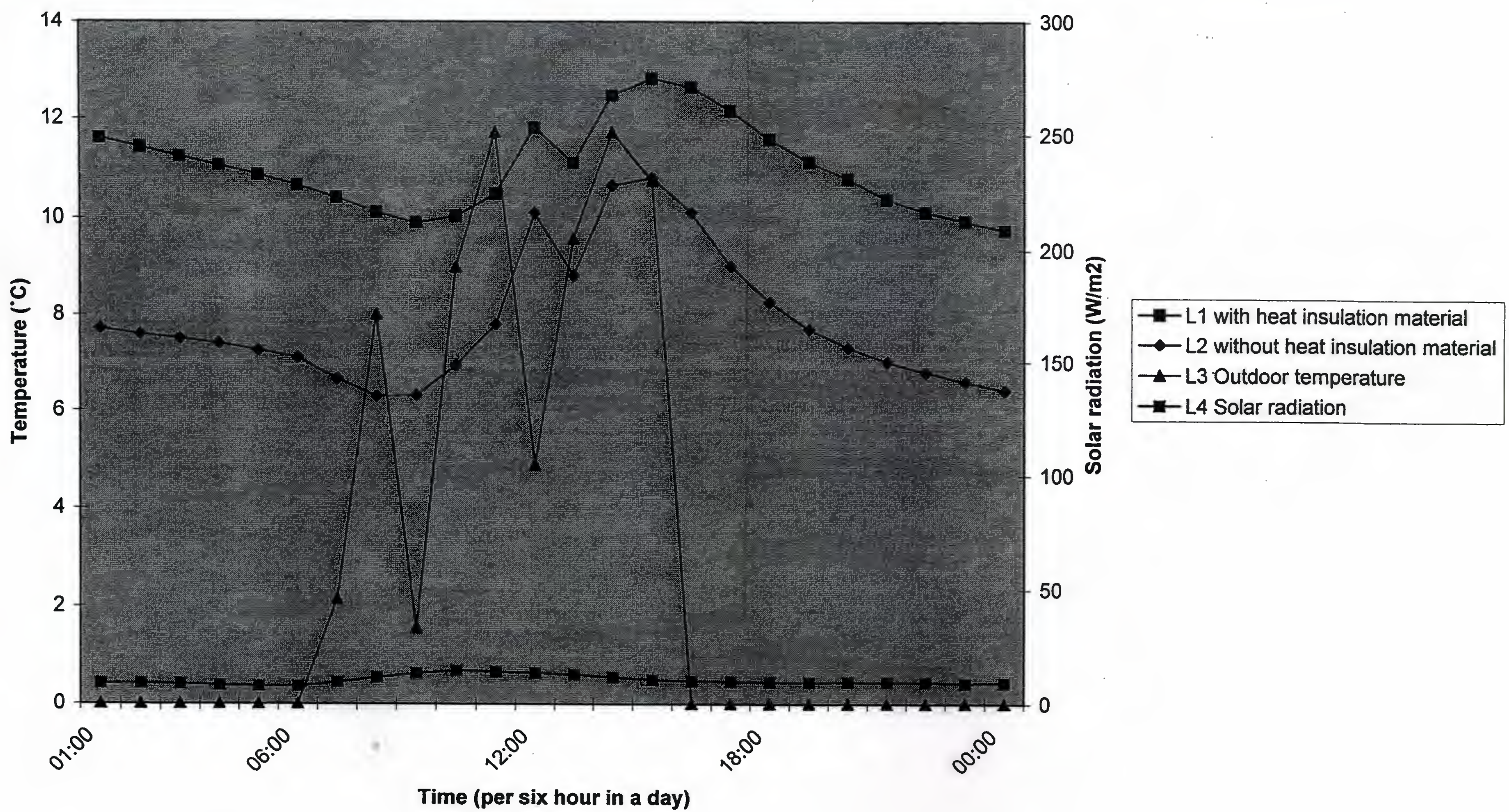
Appendix 1.11 Chart for 09-01-2009 at the second stage



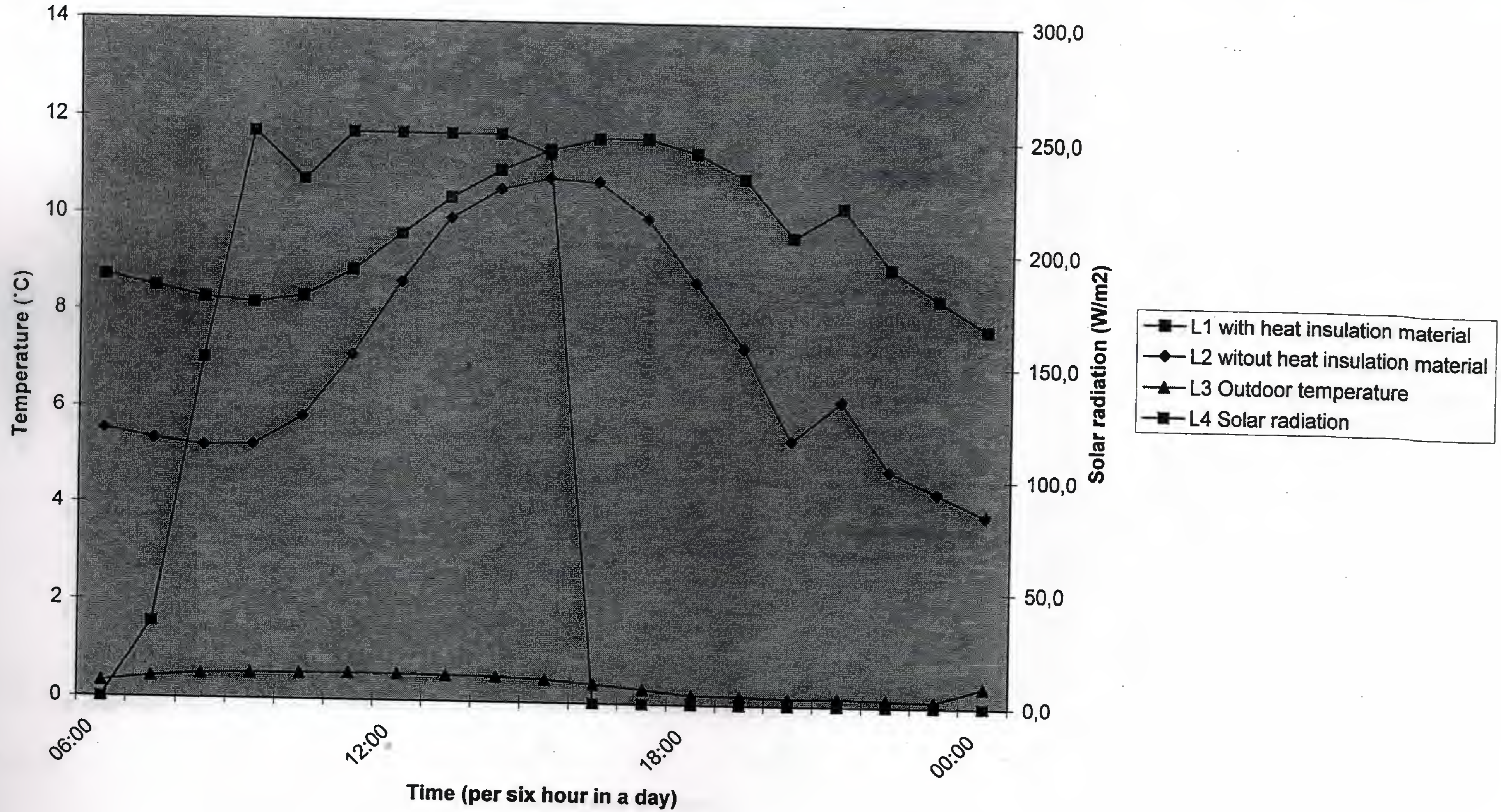
Appendix 1.12 Chart for 10-01-2009 at the second stage



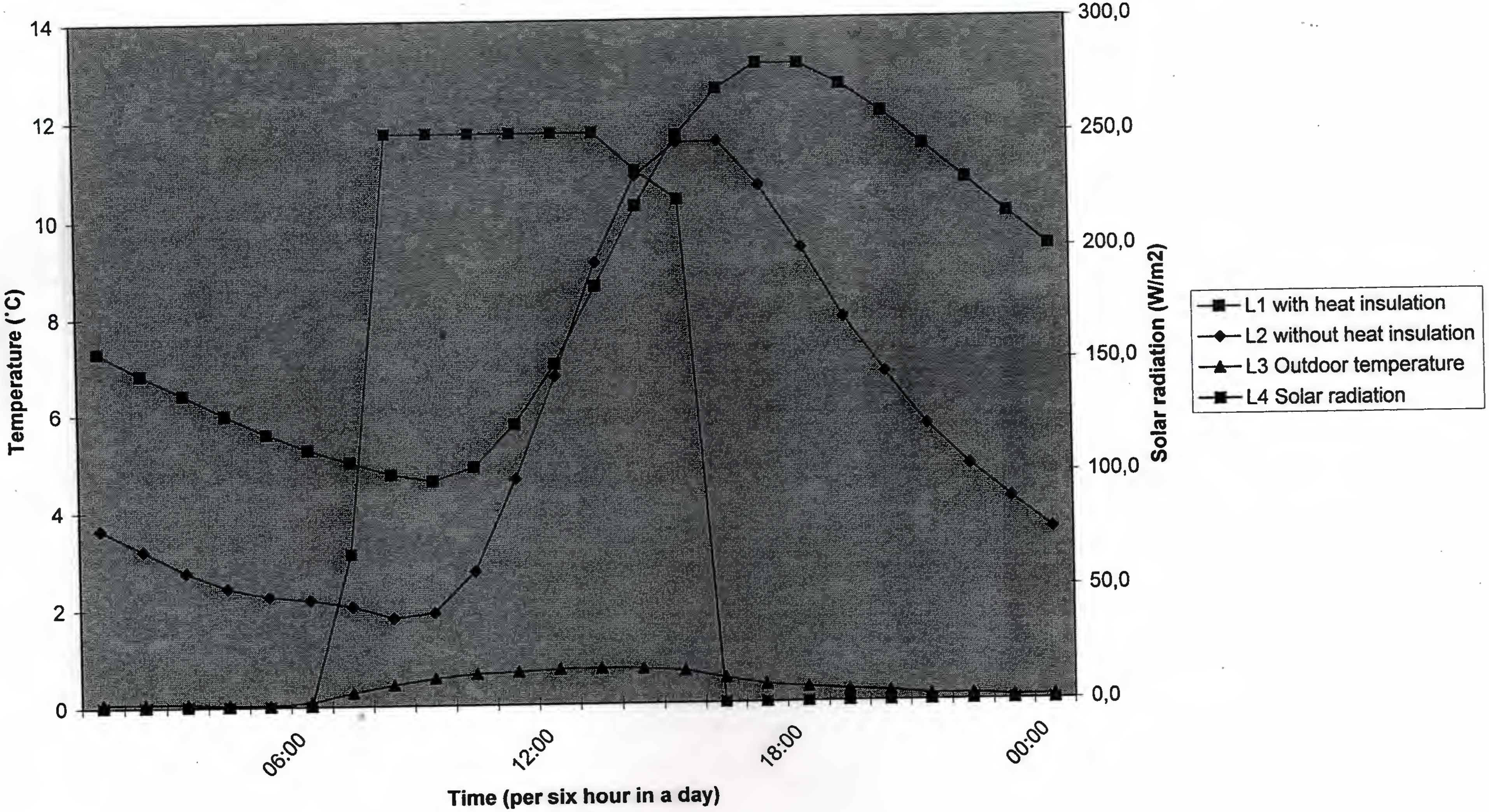
Appendix 1.13 Chart for 11-01-2009 at the second stage



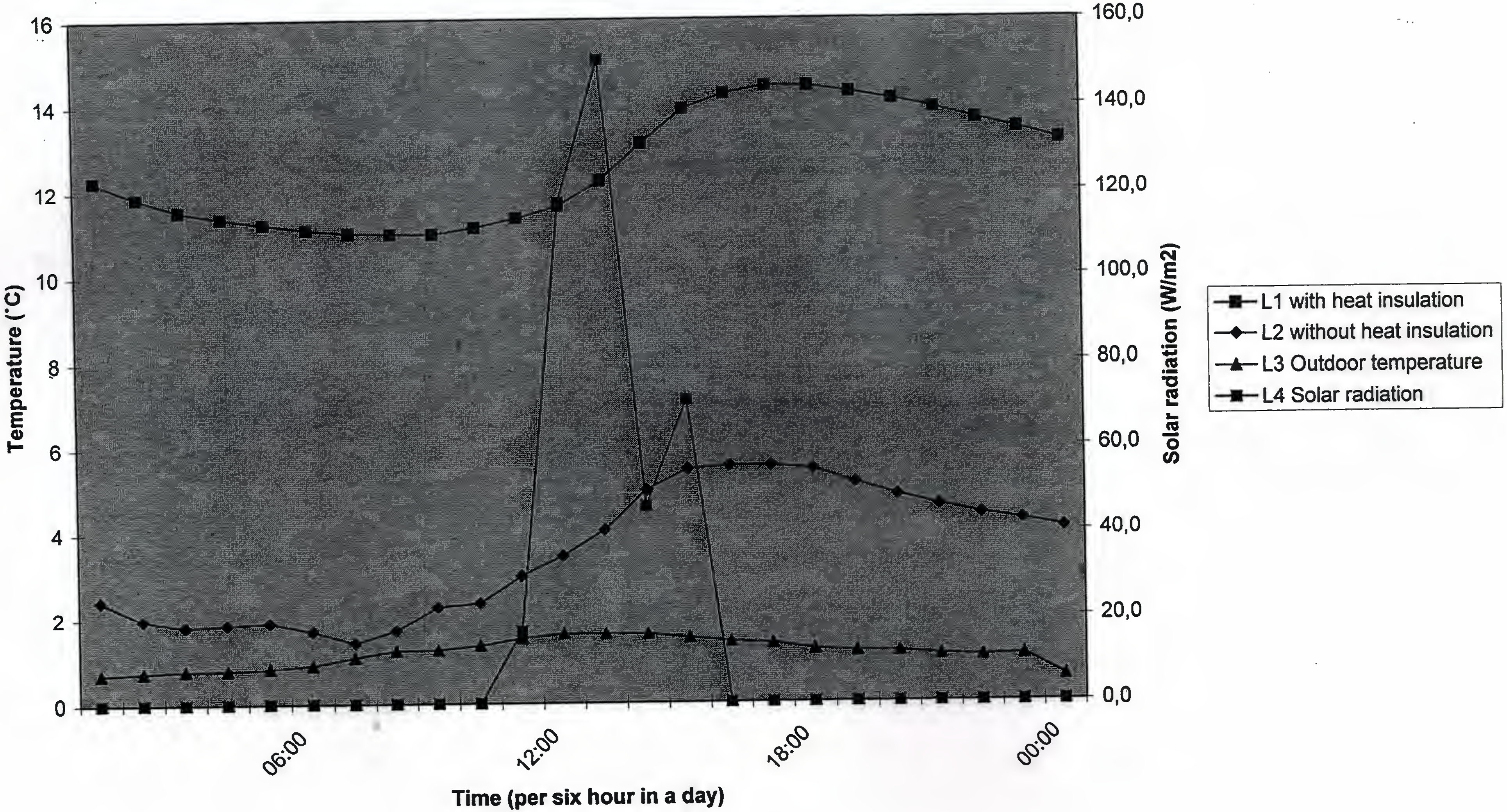
Appendix 1.14 Chart for 12-01-2009 at the second stage



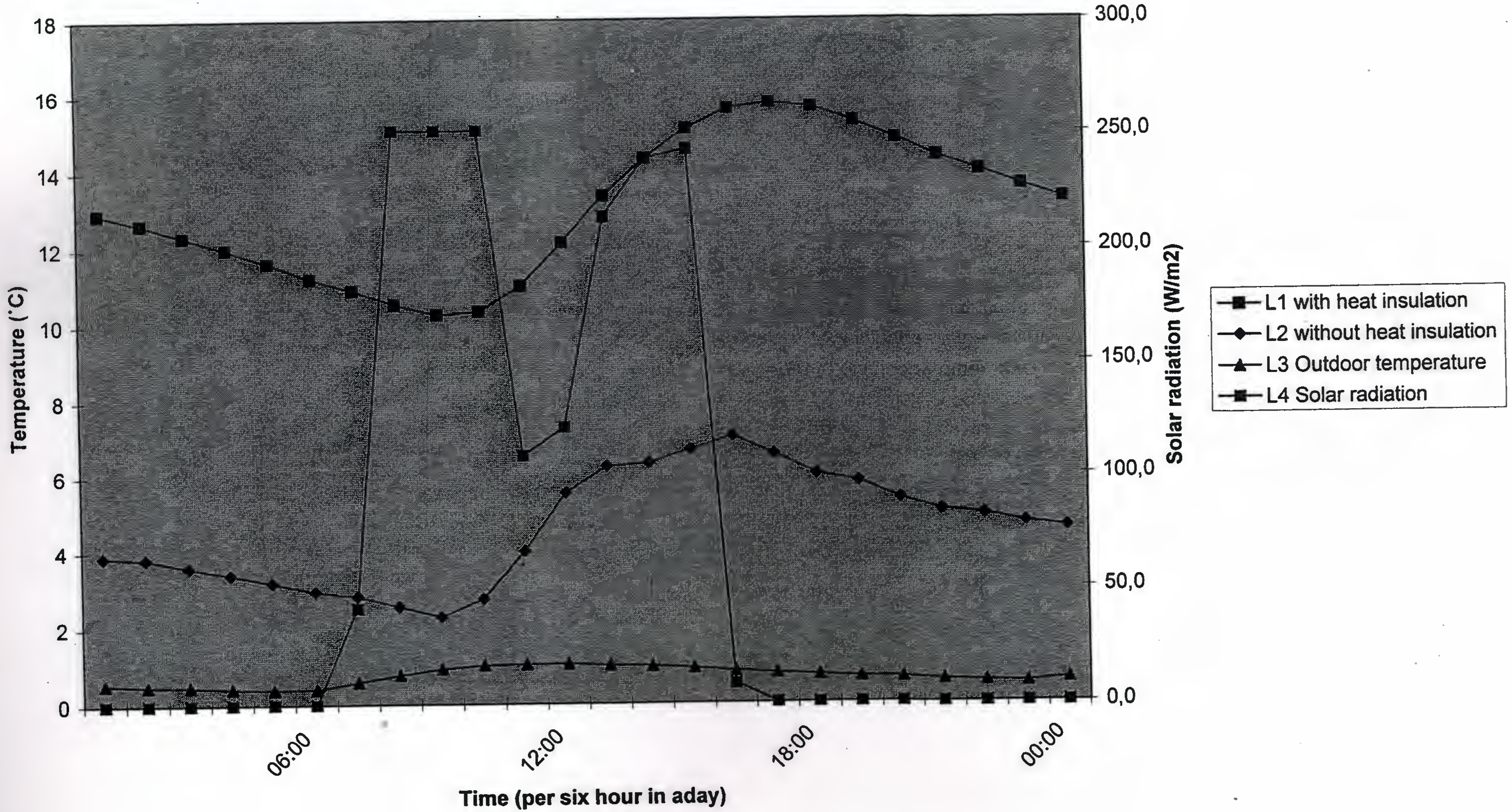
Appendix 1.15 Chart for 13-01-2009 at the second stage



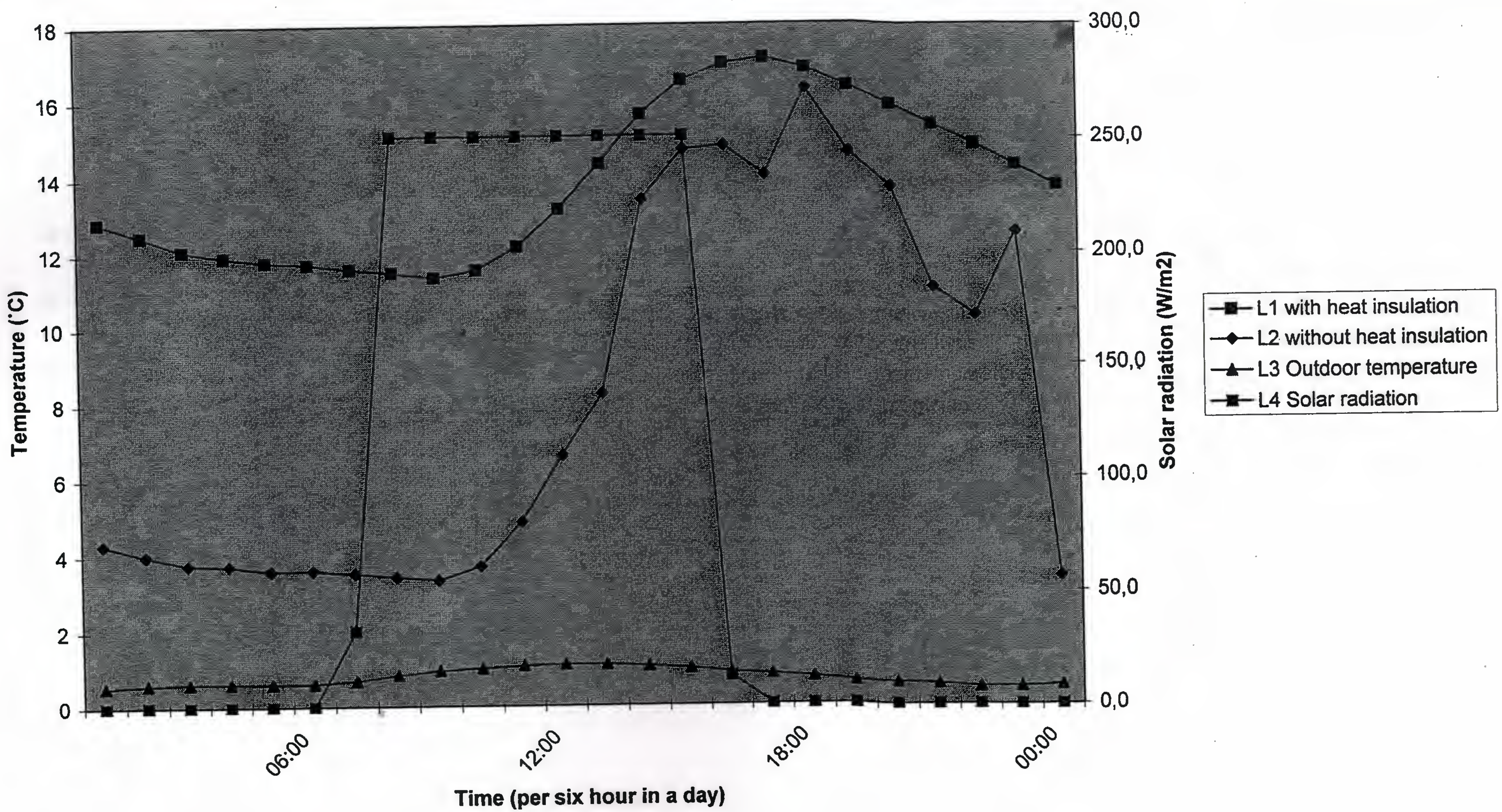
Appendix 1.16 Chart for 16-01-2009 at the second stage



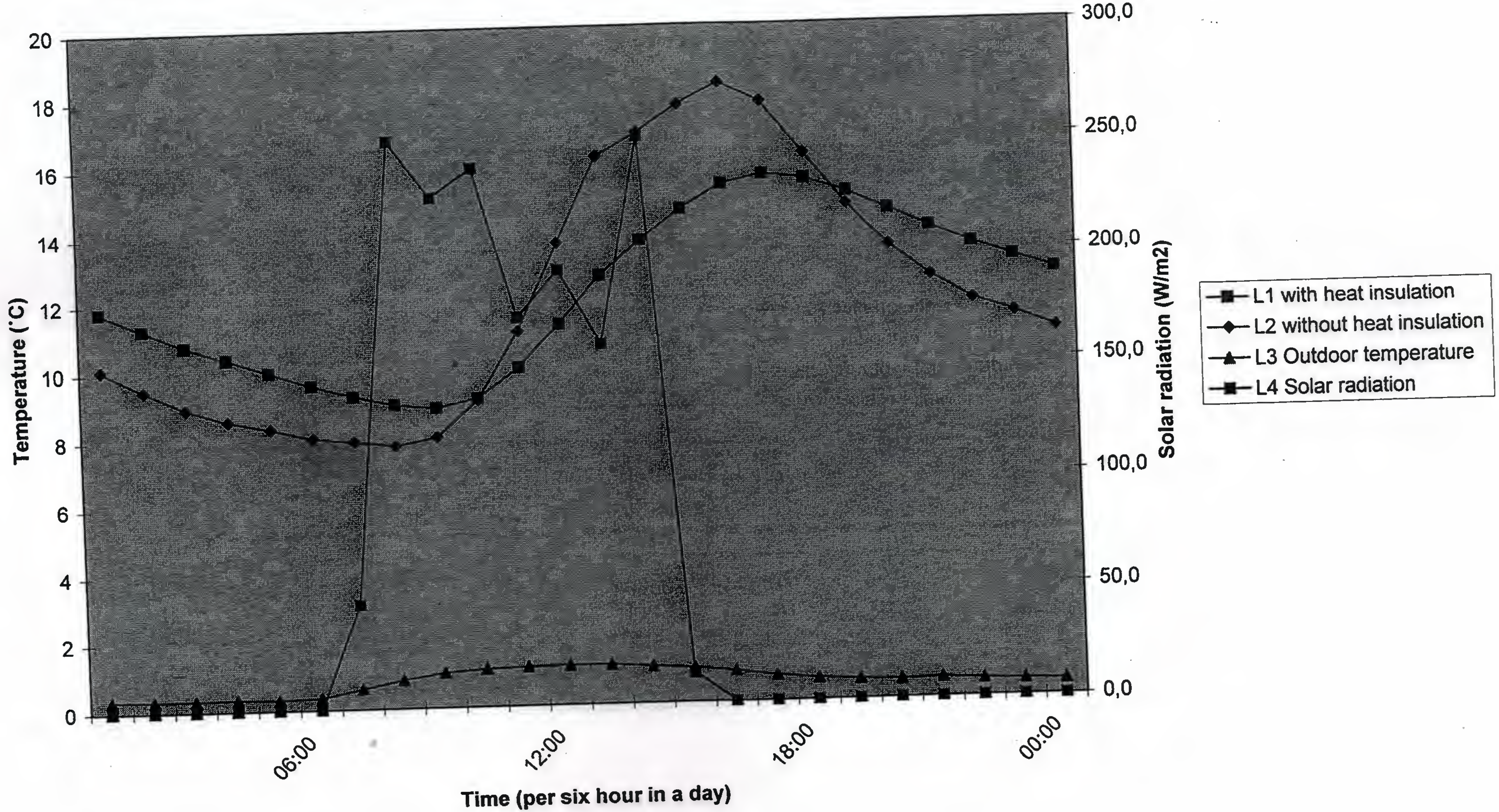
Appendix 1.17 Chart for 17-01-2009 at the second stage



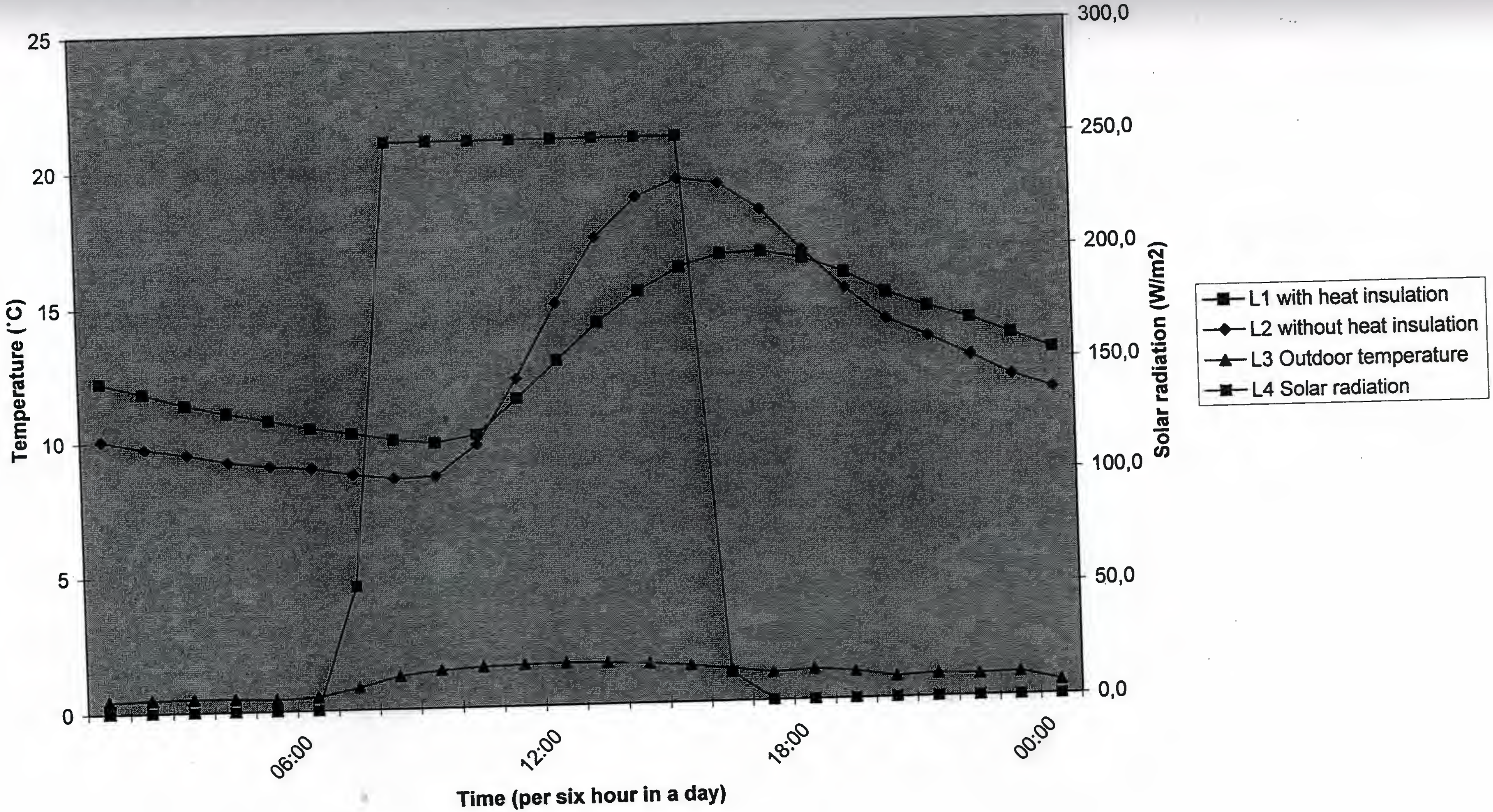
Appendix 1.18 Chart for 08-01-2009 at the second stage



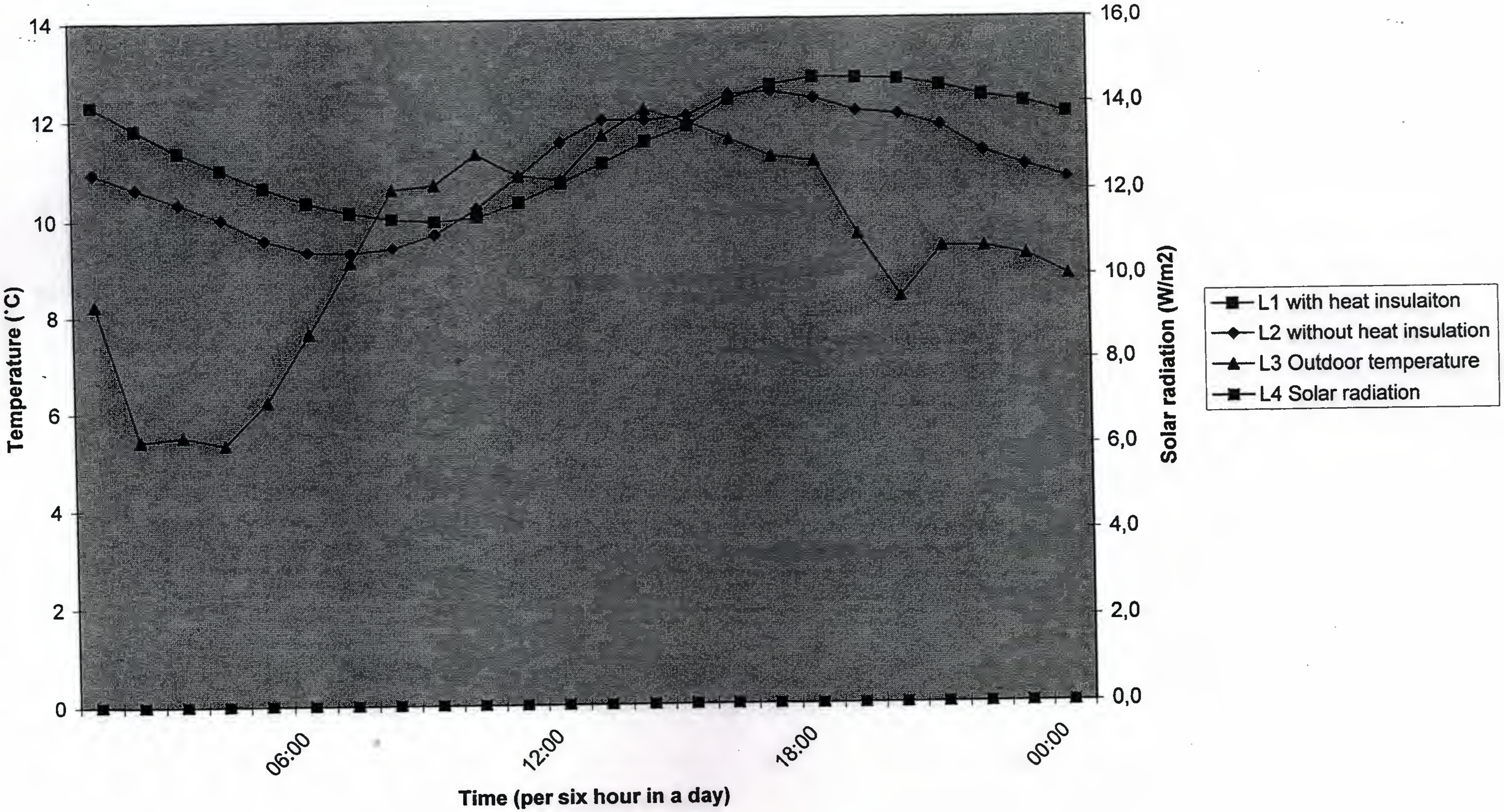
Appendix 1.19 Chart for 20-01-2009 at the second stage



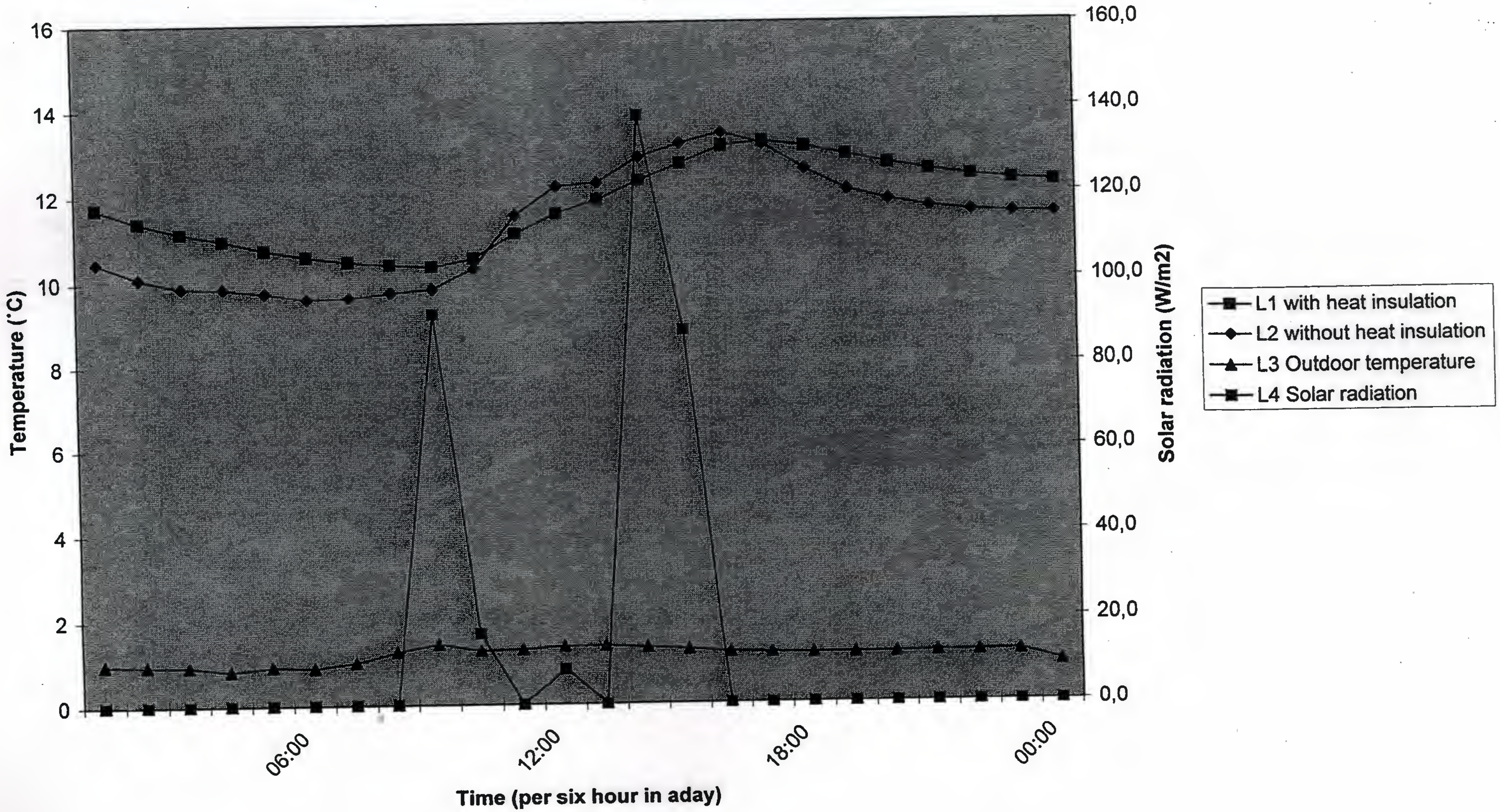
Appendix 1.20 Chart for 22-01-2009 at the second stage



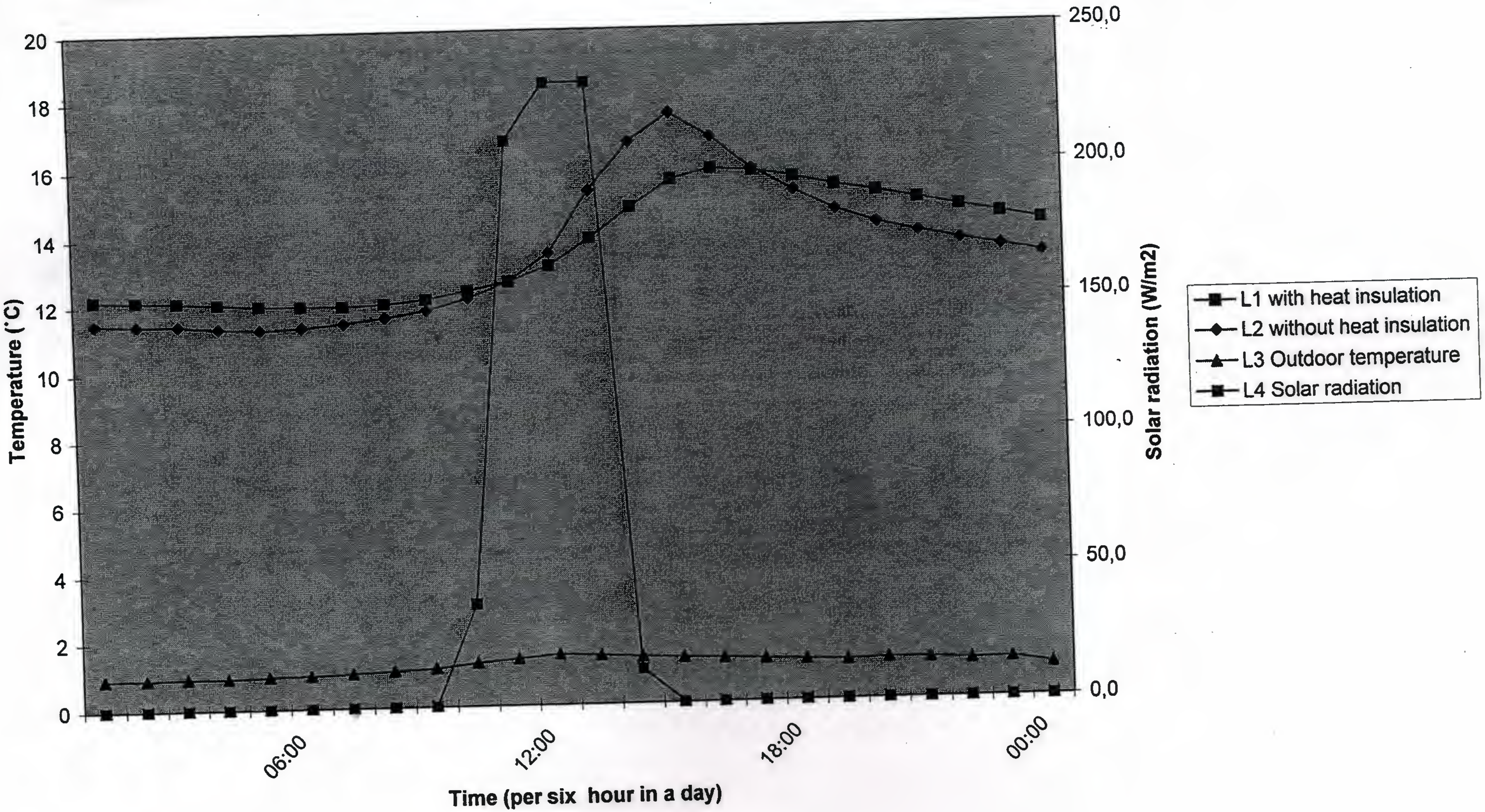
Appendix 1.21 Chart for 23-01-2009 at the second stage



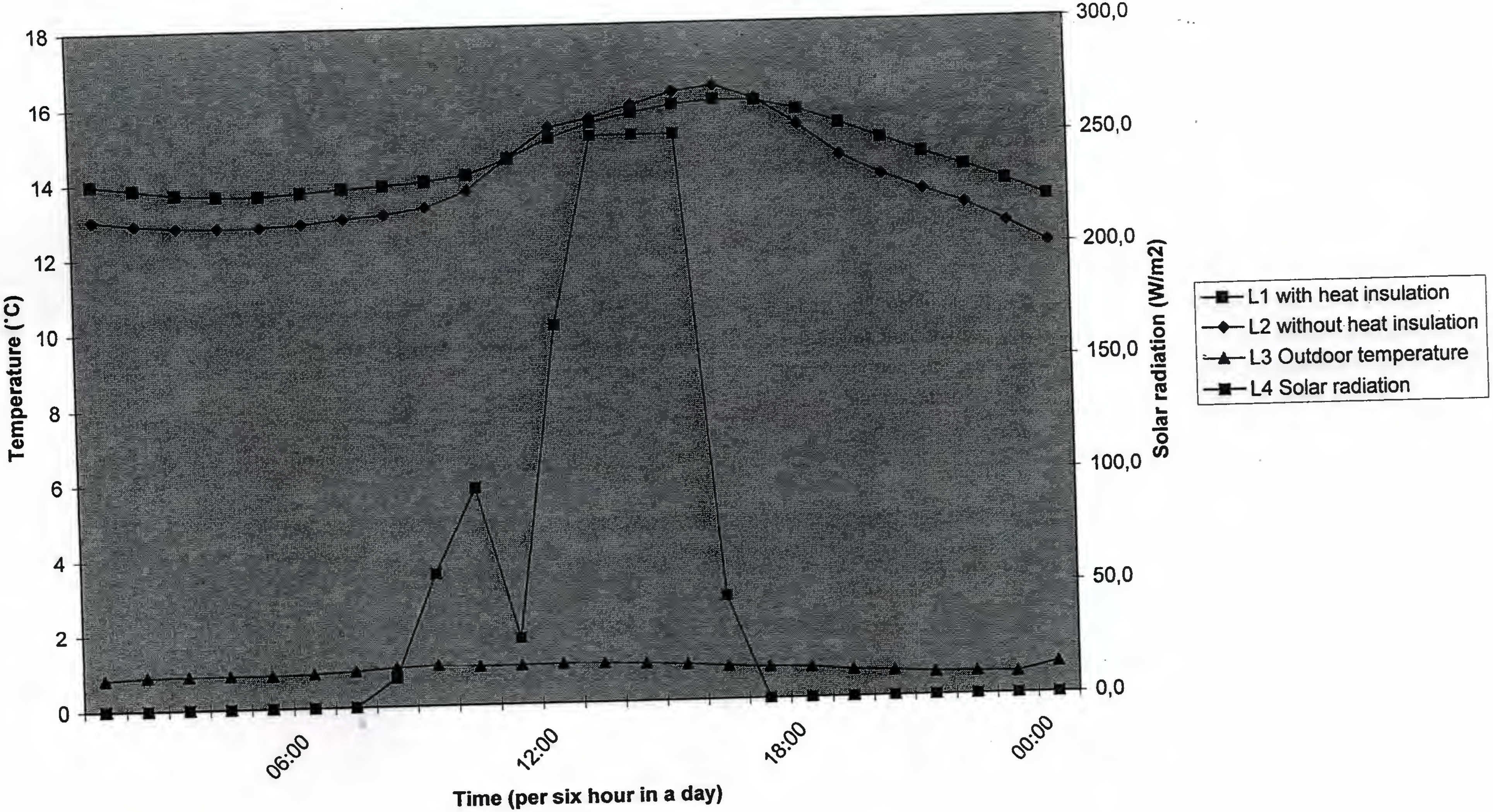
Appendix 1.22 Chart for 24-01-2009 at the second stage



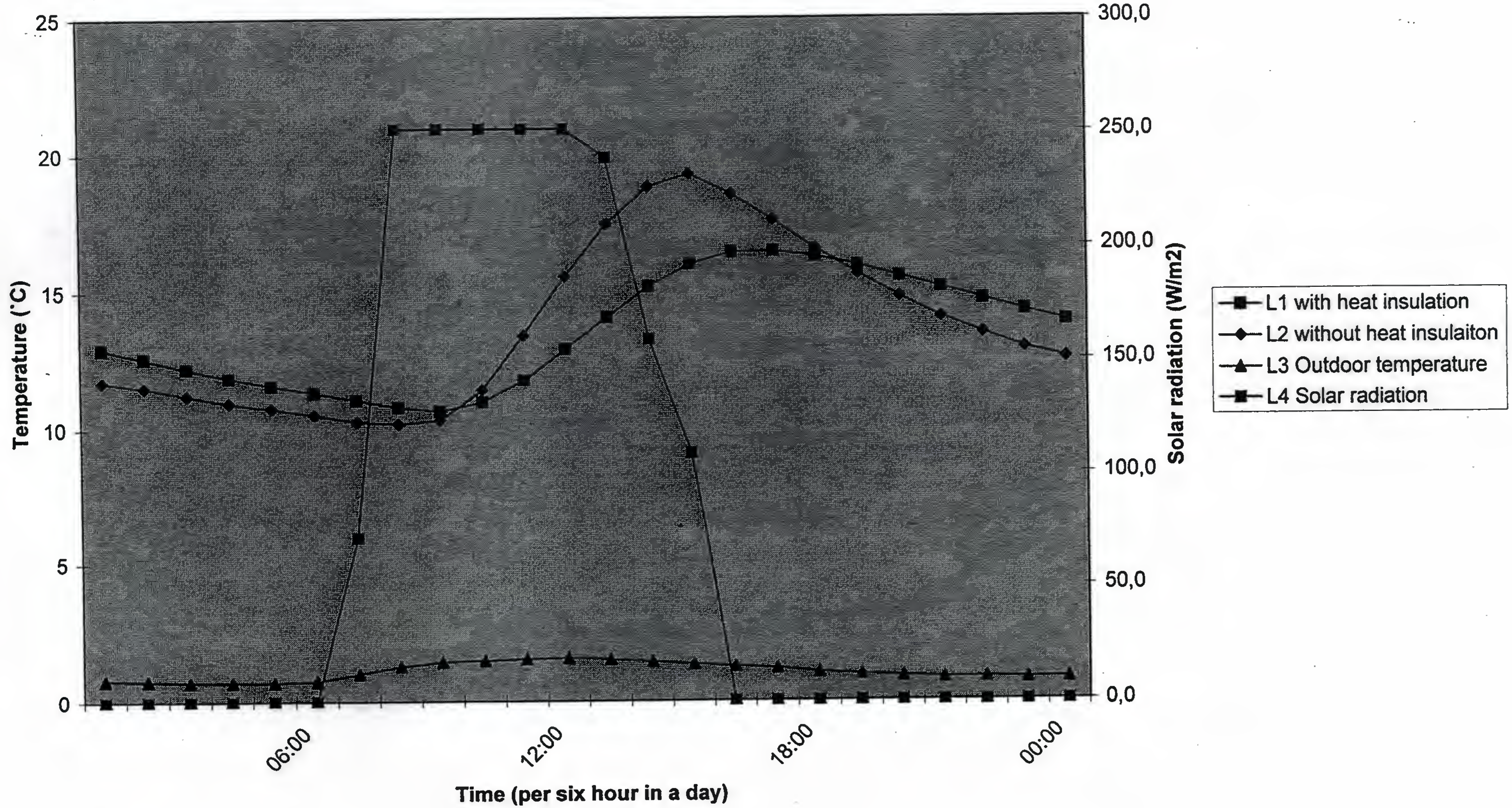
Appendix 1.23 Chart for 25-01-2009 at the second stage



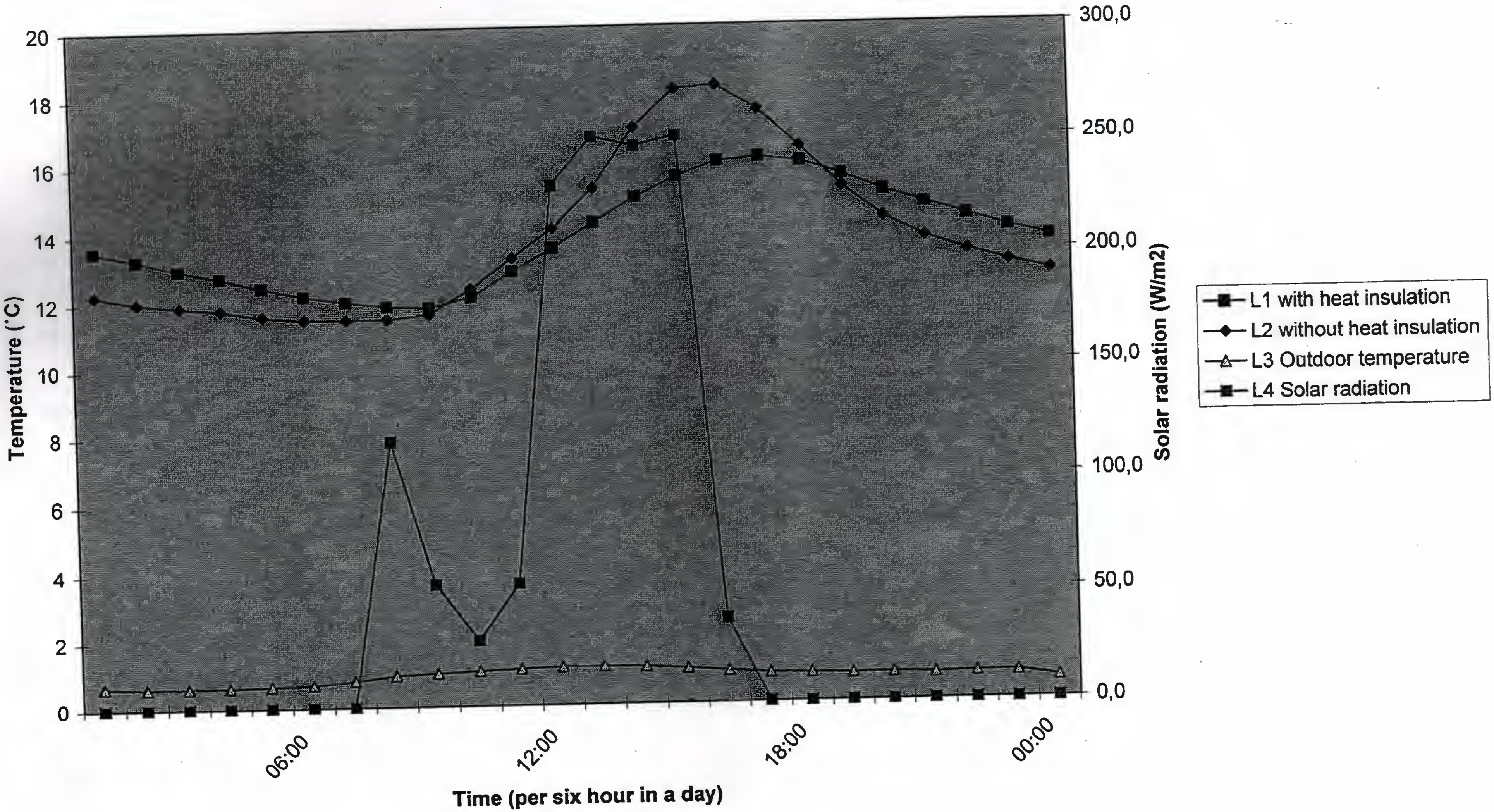
Appendix 1.24 Chart for 26-01-2009 at the second stage



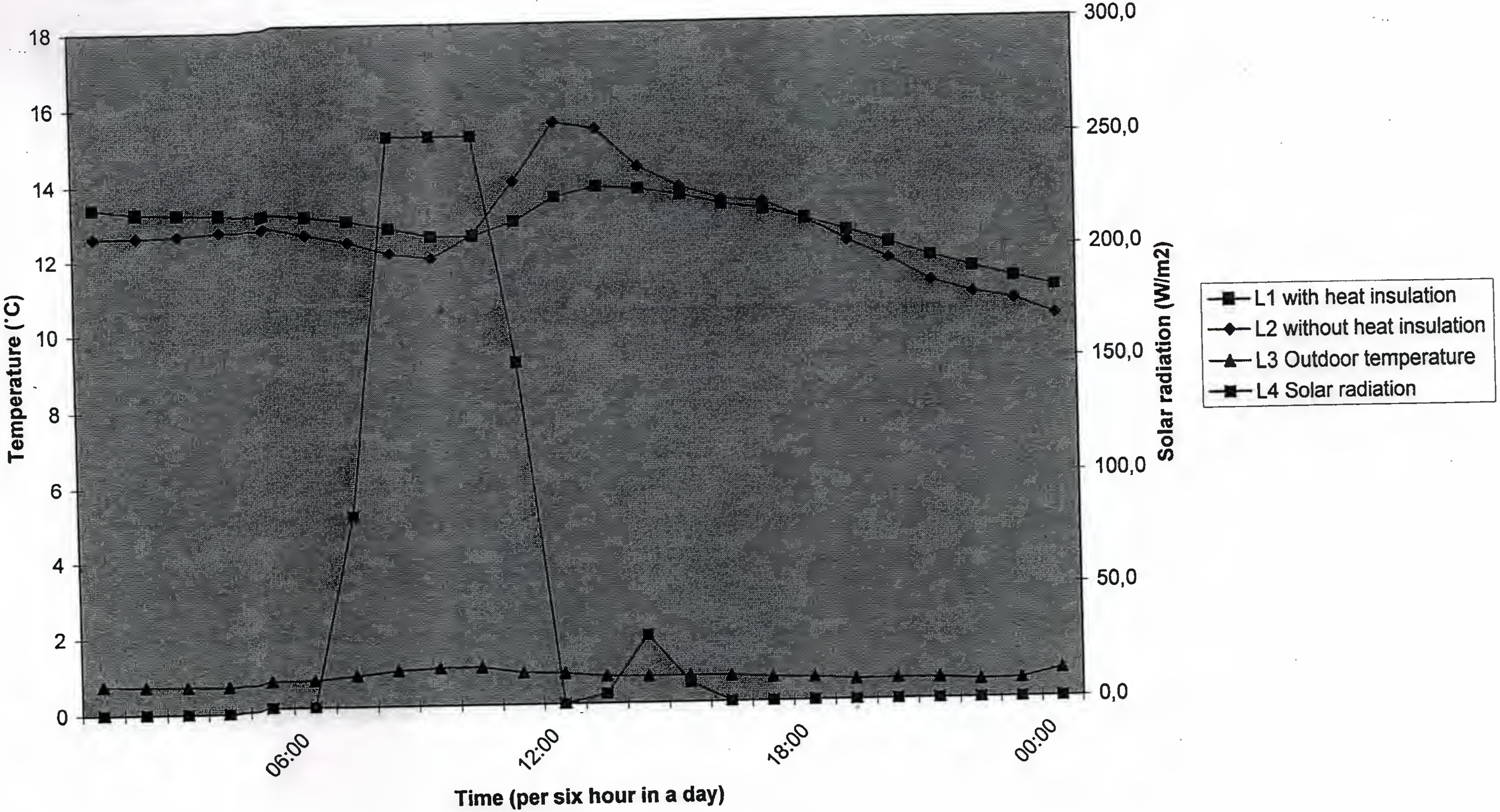
Appendix 1.25 Chart for 27-01-2009 at the second stage



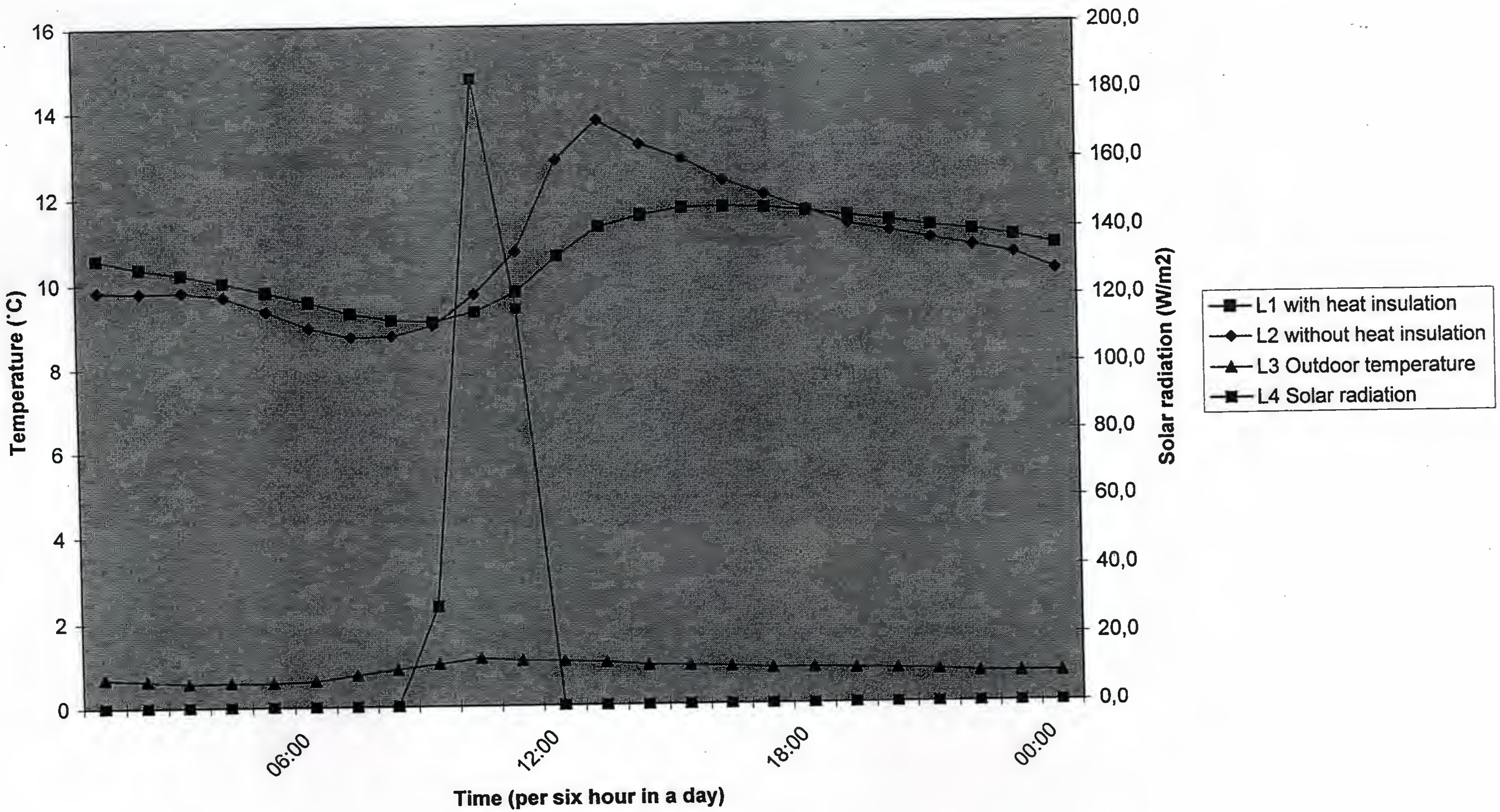
Appendix 1.26 Chart for 28-01-2009 at the second stage



Appendix 1.27 Chart for 29-01-2009 at the second stage



Appendix 1.28 Chart for 30-01-2009 at the second stage



Appendix 1.29 Chart for 31-01-2009 at the second stage