SOLAR-POWERED AIR-CONDITIONING SYSTEM FOR DOMESTIC APPLICATION

By

AINUL SHAHRAZAD AB RAZAK

FINAL YEAR PROJECT
FINAL REPORT
Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

JUNE 2006

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

____

(Dr. Balbir Singh Mahinder Singh)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that original work contained herein have not been undertaken or done by unspecified sources or persons.

AINUL SHAHRAZAD AB RAZAK

ABSTRACT

The aim of the Solar- Powered Air-conditioning System's project is to harness solar radiation and use its energy to drive low power consuming air-conditioning system. Solar power was chosen because conventional domestic air-conditioner consumes high electricity, which is quite costly. The cost can add up to hundreds and thousands of ringgit per year and with the rising fuel prices, it will be unaffordable for people in the lower income group to utilize a conventional air-conditioner unit. Due to global warming, air-conditioning has become a necessity in human's life and with the assistance of modern technology that can be implemented, solar energy can be harnessed by using photovoltaic. Through this research work, it has been identified that the major components in photovoltaic-based air-conditioning systems are battery storage, system controller, auxiliary energy sources and a new air-conditioning unit. This system is designed to operate in parallel, interconnected with the grid electricity as a backup power. The controller connected to the photovoltaic will act as an intelligent controller whereby it will draw the power from the grid electricity whenever the electrical loads are greater than the PV system output. The total power required from the solar photovoltaic is determined by considering the heat gain and the cooling load calculation of a building. The prototype for this project has been successfully developed according to the theoretical and calculation value.

ACKNOWLEDGEMENT

My heartfelt gratitude is forwarded to my supervisor, Dr. Balbir Singh Mahinder Singh for his invaluable advice and supervision throughout the two semesters of my final year project. Thanks for the time, guidance and patience.

I would also like to dedicate this appreciation to all the technical staffs within Electrical and Electronic Engineering and Mechanical Department especially Miss Siti Hawa Mat Tahir, Mr. Zailan Alang Ahmad, Mr. Zamil and Mr. Jani Alang Ahmad who have been very co-operative in helping and sharing their experience throughout the project work.

I wish to dedicate this work to my parents, Mr. Abdul Razak Talib and Mrs. Siti Atikah Tukimin, my brothers and my sisters, and my fellow families for their support, encouragement and understanding throughout one year I have been involved in this project.

I wish to thank to my entire colleagues who have been together contributing their ideas and knowledge for my project.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Solar-powered air-conditioning system has a great potential to be developed in our country since Malaysia receives sunlight throughout the whole year. Moreover, solar air conditioning potentially offers an elegant exemplar of a clean, sustainable technology, which is consistent with international commitment to sustainable development. The underlying advantage of using solar energy directly is that it is free, abundant and inexhaustible. The total amount of energy radiated from the sun onto the earth's surface is more than 10 000 times the annual global energy consumption and its usage can also avoid degradation of the environment (Pearson & Farhi, 2005).

1.2 Problem statement

Sunny days can be considered as a blessing, but yet in the house, a hot day can be altogether stressful. The arising in temperature due to global warming has led to the decreasing of human comfortability. This can probably affect the productivity of human himself. Due to productivity under these conditions, more and more buildings are being fitted with air-conditioning systems. This is where the need for solar air conditioning becomes obvious. Days that have the greatest need for cooling are also the very same days that offer the maximum possible solar energy gain.

The use of conventional air-conditioning system consumes electricity where one horsepower air-conditioner needs 746 Watts of power. Due to the high electricity consumptions, and arising in fuel prices, consumer might have to pay more on their utility bills (Terry, 2001).

1.3 Objectives and Scope of study

The whole project's implementation needs a very high determination in terms of the objectives as well as the scope of the work so that there is no waste of time during the project completion. These are also to ensure the project work is well-organized.

1.3.1 Objectives

Many reasons can be listed for the need to design a solar-powered air-conditioning system. The main objectives, is to reduce the dependence on fossil fuel, such as natural gas, which is widely used to generate electricity in Malaysia.

Apart from that, air-conditioning system must also be made affordable for the lower income group. Thus it is objective of this project to design a low power consuming air-conditioning system based on our country's solar insolation pattern and temperature. The system should be designed in such a way that it can provide a reasonably good comfort level for everybody, from the rural folks all the way to urban and suburban population.

The system that has to be designed must reach some criterions. First it can be used to harness solar radiation based on Sun's geographical location in Malaysia and secondly, the system designed can reduce room temperature by at least 5^0C.

1.3.1 Scope of study

Photovoltaic systems are chosen in harnessing the solar power because of the sunlight received in Malaysia throughout the year, which is 800W/m^2 (NSTP, 2005) When the Sun rises, that is the time an air-conditioner is needed and PV can be used to generate electricity to drive the new air-conditioning system.

However, there are some issues regarding implementation of photovoltaic system, which needs comprehensive considerations. These issues are the low conversion efficiency of the photovoltaic cells, location and tracking requirements and also high installation cost. The last issue that poses a major problem is the ability to sustain the operation in bad weather condition. A thorough study was carried out on the various design of air-conditioning system. Based on the weaknesses of the existing systems, a model was proposed, and the details of the design are given in Chapter 3. The total cooling load calculation has also been carried out manually and it is presented in Chapter 4.There are a few experiments that have been conducted outside Building 15 in Universiti Teknologi PETRONAS to collect solar insolation data using PV panels. Some experiments on the developed prototype also have been carried out to measure the temperature drops and the results are presented in Chapter 4.

CHAPTER 2

LITERATURE REVIEW/ THEORY

Before goes into details in the project' design and execution, it is a good idea to understand and review the existing system in the market nowadays such as conventional air-conditioner, photovoltaic application and also the process of heat transfer to a building. These to give a clear picture of the methods and design chosen in the project work.

2.1 Basic air-conditioning system

An air-conditioning system is a mechanical refrigeration system, which controls the temperature, moisture content (humidity), movement and cleanliness of air in a definite space. The purpose of air-conditioner is to maintain a needed or desired atmosphere in a defined space.

Figure 2.1 shows the major parts in air-conditioning system. There are two sides of operation which are low pressure side and high pressure side.

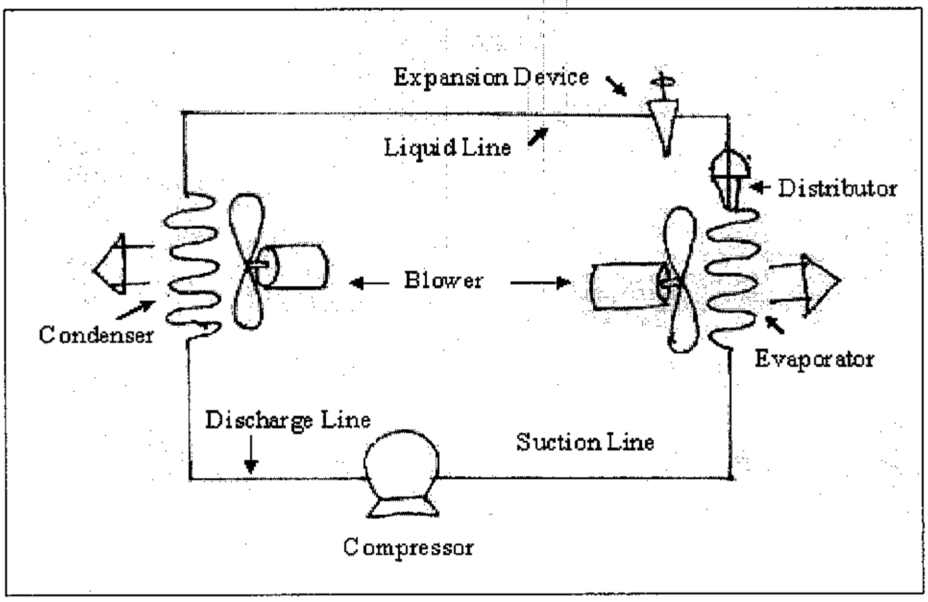


Figure 2.1: Major parts of air-conditioning system

2.1.1 Low pressure side

Low pressure side consists of the expansion device and evaporator section. Each part has its own task.

2.1.1.1 Expansion device

It is also known as metering device, which is located in the liquid line just ahead of the evaporator coil. It produces a pressure drop in the refrigerant at the point at which it is located, accompanied by a drop in temperature. Expansion device may produce a pressure drop in one of the three ways or methods:

1. Control volume of refrigerant
2. Control pressure in evaporator coil
3. Control temperature of refrigerant in evaporator coil

2.1.1.2 Evaporator section

It is the part in which the refrigerant vaporizes as it picks up heat from the evaporating medium. This section consists of

1. Evaporate coil – formed of copper or aluminum tubing and has aluminum fin pressed onto it to increase its heat transfer efficiency.
2. Blower fan – moves air across the evaporator coil and is usually connected to the air distribution system by a return duct on the inlet side and by a supply duct on the outlet side.
3. Refrigerant lines – there are lines located at the low pressure side:
   Distribution line: Runs from the expansion device to the evaporator coil
   Suction line: Runs from the coil to the compressor inlet. It is the larger refrigerant line in the system because it must carry the refrigerant vapor.
4. Some accessories – Distributor, suction accumulator and filter drier

2.1.2 High pressure side

While for the high pressure side, it consists of a compressor, condenser section and refrigerant lines. Their specifically task are as follow:

2.1.2.1 Compressor

A compressor is a component that maintains a pressure different between the high-pressure and low-pressure side and it also moves the refrigerants circulate through a system. It can be categorized by their physical characteristics and mechanical action.

2.1.2.2 Condenser section

It is basically a heat exchanger in which heat from the refrigerant is given off to the condensing medium. The heat given off is the heat picked up from the evaporator and the compressor. The most common type of air-cooled condenser is a finned-tube coil with a blower moving air across it. When high temperature refrigerant leaves the compressor through the hot gas discharge line, it enters the condenser coil as a saturated vapor. In the coil, heat flows from the refrigerant to the condenser air because of the temperature difference and the refrigerant condenses to a liquid.

2.1.2.3 Refrigerant line

There are 2 refrigerant lines in the high pressure side which are:

1. Hot gas discharge line – also known as discharge line, running from compressor to the condensing unit and carry hot gas refrigerant.
2. Liquid line – Running from the condensing unit to the expansion device and carry a liquid refrigerant.

2.1.3 Conventional air-conditioner

The basic operating principle of air-conditioners involves the mechanism of heat transfer. It works very much like a refrigerator, although the actual construction details are different.

A refrigerant such as freon mixed with a small amount of lubricating oil is compressed by the compressor causing it to become a hot, high-pressure gas. This hot gas runs through a series of coils, as shown in Figure 2.2 and with the help of the fan, dissipates this heat to the outside. In this process, the freon cools and condenses into a liquid, which then runs through an expansion valve, at which point the liquid evaporates to become cold low-pressure gas. Then it will go through another series of coils and with assistance of a second fan, absorbs the heat and thereby cools the air inside of the building.

The cooling coils causes moisture in the warmer inside air to condense into water, which drips and runs to the outside of the building. This condensation process lowers the humidity on the inside. This condensation principle is also explaining how de-humidifiers work. Thermostats are added to set desired temperature and protection devices are added to protect the compressor from overheating (Wang, 2001).

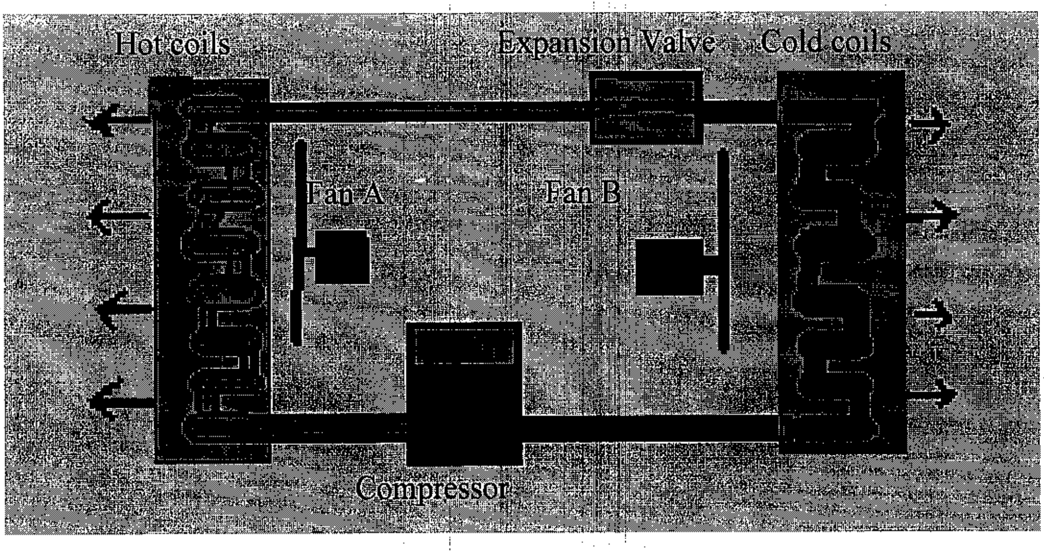


Figure 2.2: Schematic diagram of a typical refrigerant based air-conditioner

There are four types of air-conditioner which can be found in the market nowadays. There are water-cooled conditioner, air-cooled air conditioner, air-cooled water chiller and water-cooled water chiller. (Wang, 2001)

2.2 New air-conditioning system

The new air-conditioning system which will be designed use the concept of evaporative cooling system. Evaporative coolers are a cost effective cooling system over the medium to long term. Evaporative coolers cool and filter the air. Hot outside air is drawn through a water-moistened filter and then blown through the house as shown in Figure 2.3 below.

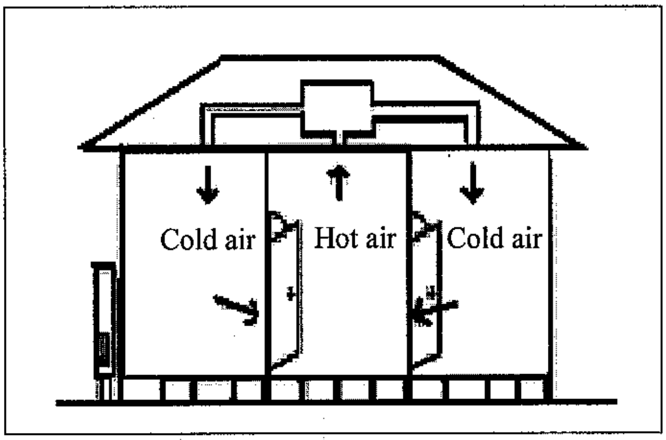


Figure 2.3: Airflow of evaporative cooler

There are many advantages of evaporative cooling system compared to air-conditioner. Evaporative cooling is one of the most energy-efficient methods of cooling a home. Besides, it long has been regarded as environmentally safe, since the process typically uses no ozone-depleting chemicals and demands one-fourth as much energy as refrigeration during the peak cooling months of the year. In dry climates, evaporative cooling can be used to inexpensively cool large homes. (Poenix.gov, 2006)

Evaporative cooling system is an air-conditioning system in which more than 50 percent of the total cooling provided annually is evaporatively cooled. There are three types of evaporative cooling process which are direct evaporative cooling, indirect evaporative cooling and indirect-direct evaporative cooling. (Wang, 2001)

2.2.1 Direct evaporative cooling process

In a direct evaporative cooling process, the airstream to be cooled comes directly into contact with the wetted medium or water spray. A direct evaporative cooler can provide cooled air for a conditioned space independently consists of a wetted medium, a fan, dampers, a control system and a sump at the bottom.

2.2.2 Indirect evaporative cooling process

In an indirect evaporative cooling process, the primary airstream to be cooled is separated from a wetted surface by a flat plate or a tube wall. The cooled air does not directly contact the evaporating liquid. In an indirect evaporative process, the cooled airstream's humidity ratio remains constant because the air to be cooled does not contact the evaporating liquid.

2.2.3 Indirect-direct evaporative cooling process

In an indirect-direct evaporative cooling process, a direct evaporative cooler is always connected in series after an indirect evaporative cooler to form an indirect-direct evaporative cooler. It can provide cooled air with a dry-bulb temperature of 19.4^0C and a relative humidity of about 95 percent when the entering outdoor is at dry-bulb temperature of 33.9^0C and a wet-bulb of 21.1^0C. (Wang, 2001)

2.3 Solar photovoltaic

A photovoltaic cell is an integrated device consisting of layers of semiconductor materials and electric contacts. A group of photovoltaic is often referred as solar cells where they convert sunlight into direct current (DC) electricity. The solar cells are electrically configured into modules and arrays, which can be used to charge batteries, operate motors, and to power any number of electrical loads. With the appropriate power conversion equipment, PV systems can produce alternating current (AC) compatible with any conventional appliances, and operate in parallel with and interconnected to the utility grid.

Photovoltaic (PV) components are divided into three categories by product type: (1) crystalline silicon cells and modules which include single-crystal, cast silicon, and ribbon silicon; (2) thin-film cells and modules made from a number of layers of photosensitive materials such as amorphous silicon; and (3) concentrator cells and modules in which a lens is used to gather and converge sunlight onto the cell or module surface. (Solar Server, 2005)

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load. Figure 2.4 shows the diagram of photovoltaic cell.

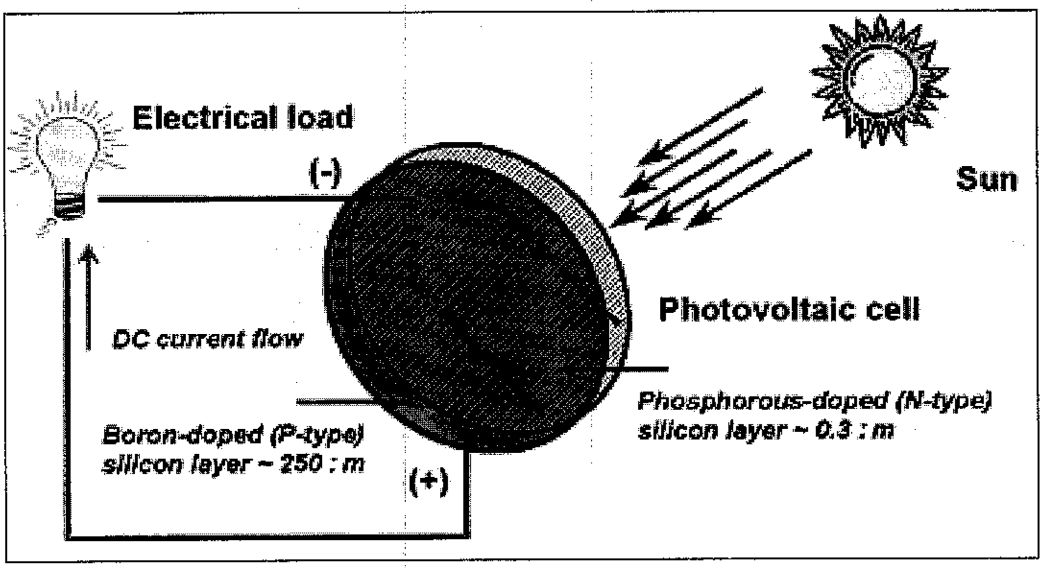


Figure 2.4: Diagram of photovoltaic cell.

Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 volt DC under open-circuit, no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional the intensity of sunlight striking the surface of the cell. For example, under peak sunlight conditions a typical commercial PV cell with a surface area of 160 cm^2 (~25 in^2) will produce about 2 watts peak power. If the sunlight intensity were 40 percent of peak, this cell would produce about 0.8 watts.

The solar photovoltaic system (PV system) includes major components such as battery storage, system controller, auxiliary energy sources and the specified electrical load.

Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather). Other reasons batteries are used in PV systems are to operate the PV array near its maximum power point, to power electrical loads at stable voltages, and to supply surge currents to electrical loads and inverters. In most cases, a battery charge controller is used in these systems to protect the battery from overcharge and over discharge (Green, 1992). Figure 2.5 shows the basic components of a photovoltaic system.

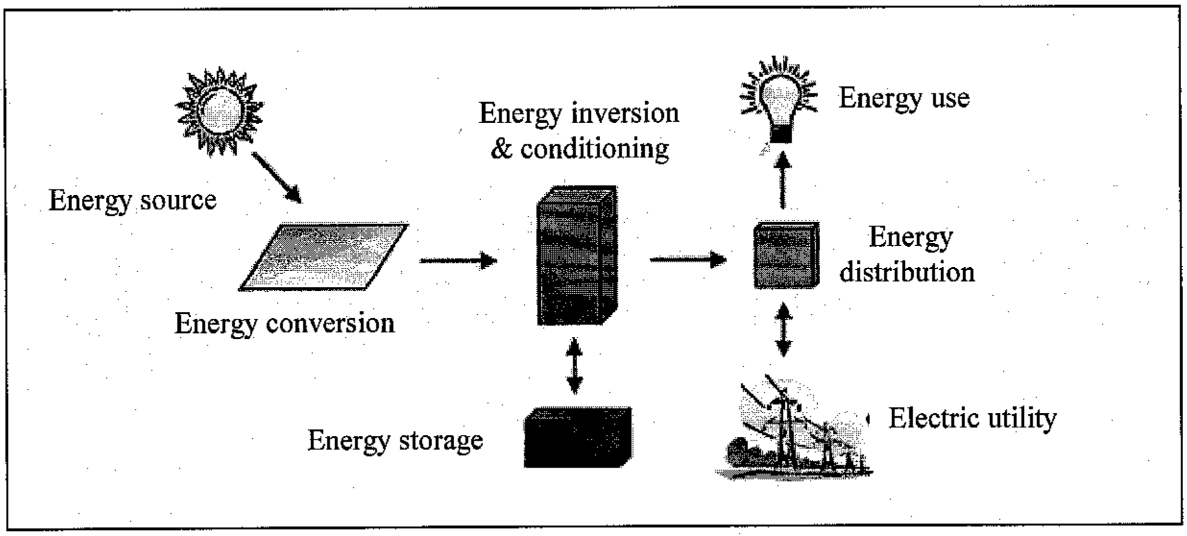


Figure 2.5: Photovoltaic system components

2.3.1 Production of Solar Energy

Figure 2.6 shows block diagram of the interconnection between each components of the solar energy system.

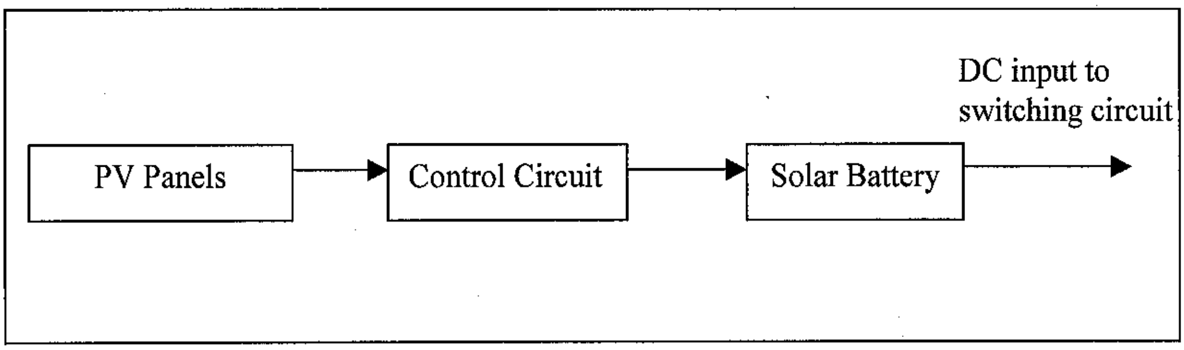


Figure 2.6: Block Diagram for production of solar energy

For solar system part, the solar panels are connected to the solar battery through a solar control circuit. This control circuit is essential because it will monitor the flow of the current in and out to the solar battery. Basically, it will ensure that the battery is not over charging and also over discharging. This will protect the solar battery and increase it lifespan.

2.4 Regulating system

Regulating system is the controller part which consists of some circuits that control the flow of the power supply to a system. Figure 2.7 shows the block diagram of the regulating system.

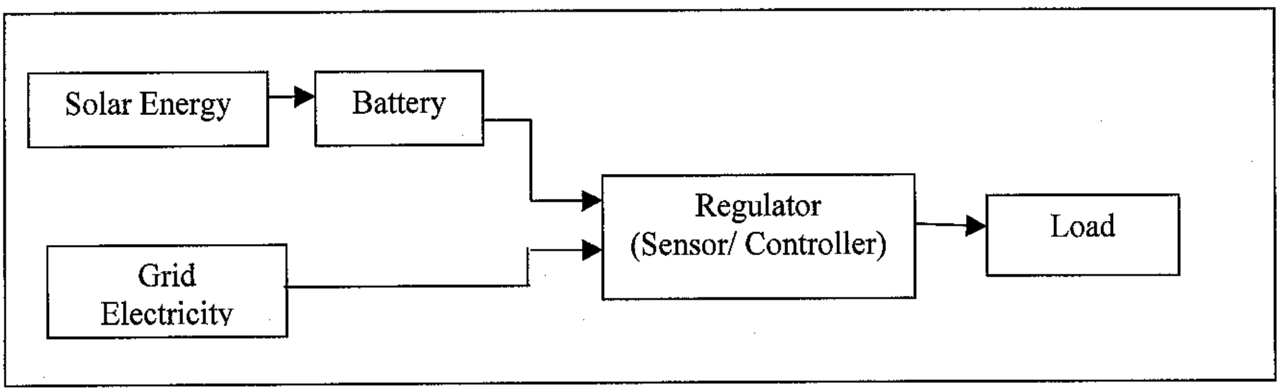


Figure 2.7: Project Block Diagram

As shown in figure, there will be two inputs to the system which are solar energy and Grid power supply. The solar energy will be charged and stored in a battery in order to increase the voltage. These two inputs will be sent to the regulator. The regulator acts like a switch that can choose automatically either to use the solar energy or the Grid power supply as the power source to the load (air-conditioning system). The input power will be chosen based on the availability of input supply. The output of the regulator will be connected to the load.

The AC signal of main supply has to be converted to DC signal in order to compare the power with the input from the solar system; this is called as switching implementation. To do the conversion, several circuits are implemented which are **rectifier circuit**, **filter circuit**, and **regulator circuit.**

2.4.1 Rectifier Circuit

Basically, a rectifier circuit is used to convert AC voltage to DC voltage. The output resulting form a rectifier is a pulsating DC voltage and not yet suitable as a battery replacement (not a pure DC voltage). Figure 2.8 shows the rectifier circuit.

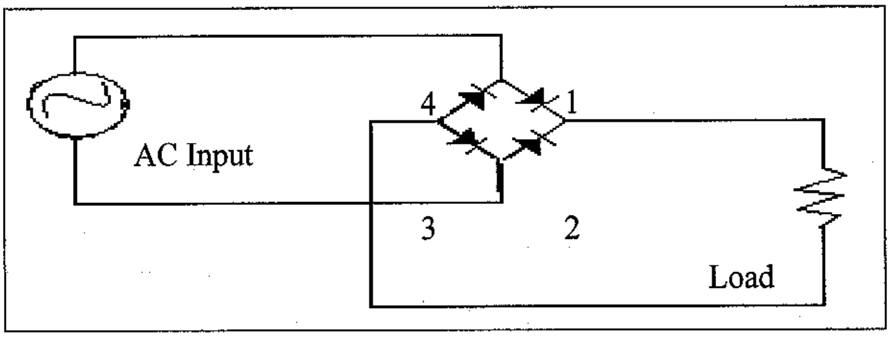


Figure 2.8: Rectifier circuit

2.4.2 Filter Circuit

For DC supply voltages, as those used in a radio, stereo system, computer, DC fan and pump, the pulsating DC voltage from a rectifier is not good enough. A filter circuit is necessary to provide a smooth DC voltage (Robert, 2002). Figure 2.9 shows the concept of the filter circuit.

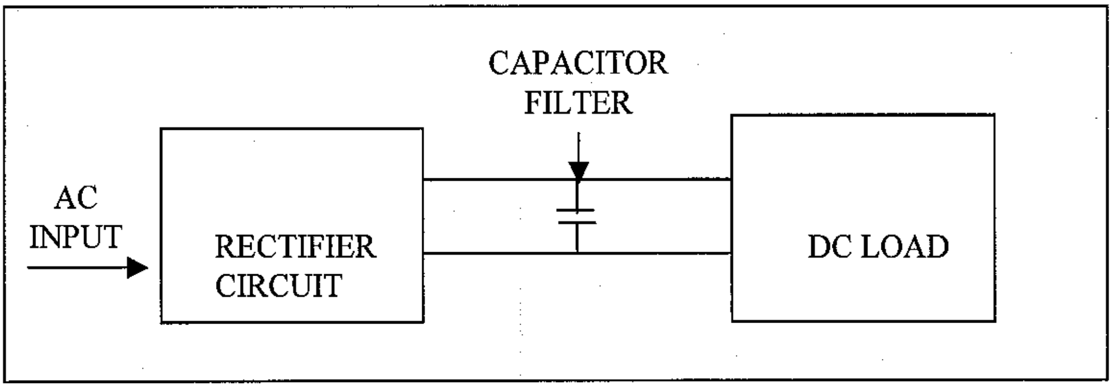


Figure 2.9: Concept of filter circuit

For the filter circuit, a capacitor filter circuit is been used. The purpose of the capacitor filter is to pass most of DC components while attenuating (reducing) as much as the AC component as possible.

2.4.3 Regulator Circuit

A voltage regulator circuit provides a constant DC output voltage that is essentially independent of the input voltage, output load current and temperature. The voltage regulator is one part of a power supply. Its input should come either form solar battery or output of a rectifier derived from AC supply. Figure 2.10 shows a regulator circuit. Figure 2.11 shows the basic components in a block diagram of a series type of regulator circuit.

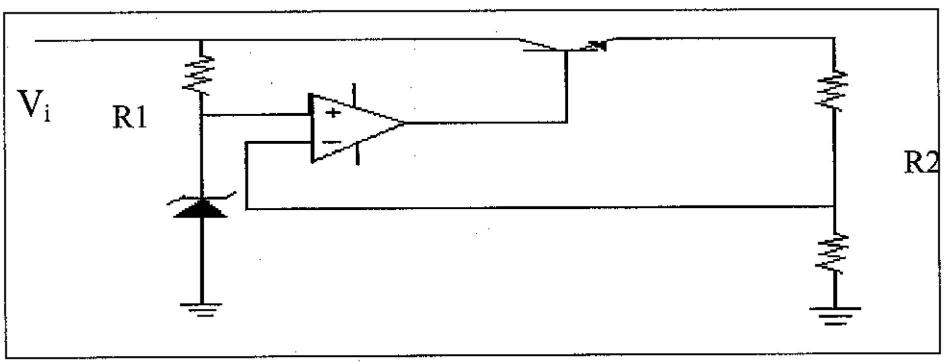


Figure 2.10: Regulator Circuit

R3

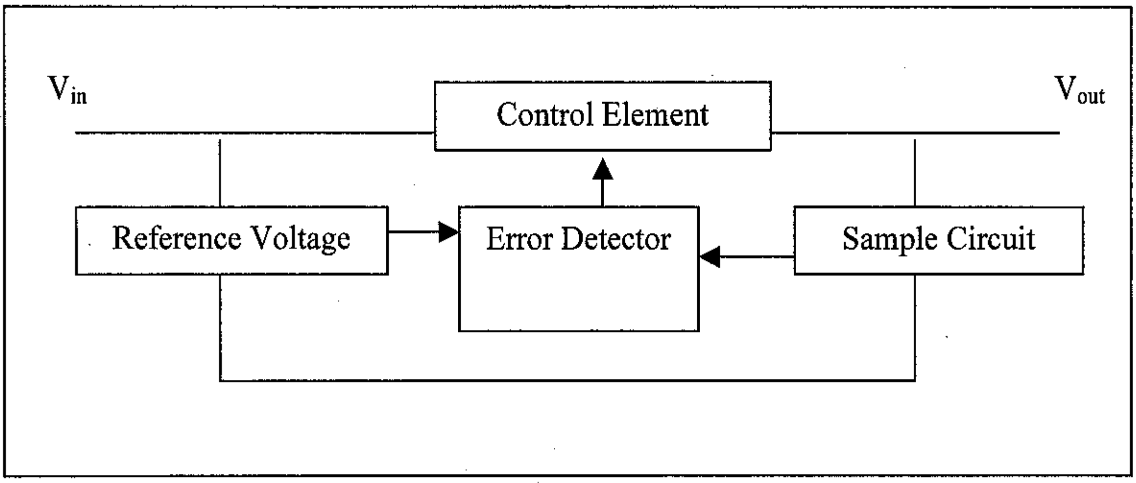


Figure 2.11: Series Regulator Block Diagram

The control element is in series with the load between the input and output. The output sample circuit senses a change in the output voltage. The error detector compares the sample voltage with a reference voltage and causes the control element to compensate in order to maintain a constant output.

The operation of regulator circuits can be summarized as follow:

i. If the output voltage decreases, the increased base-emitter voltage causes the transistor to conduct more, thereby raising the output voltage, maintaining the output constant.

ii. If the output voltage increases, the decreased base-emitter voltage causes the transistor to conduct less, thereby reducing the output voltage, maintaining the output constant.

CHAPTER 3

METHODOLOGY/ PROJECT WORK

3.1 Procedure Identification

Basically, the procedure developed to complete the whole project is as follow:

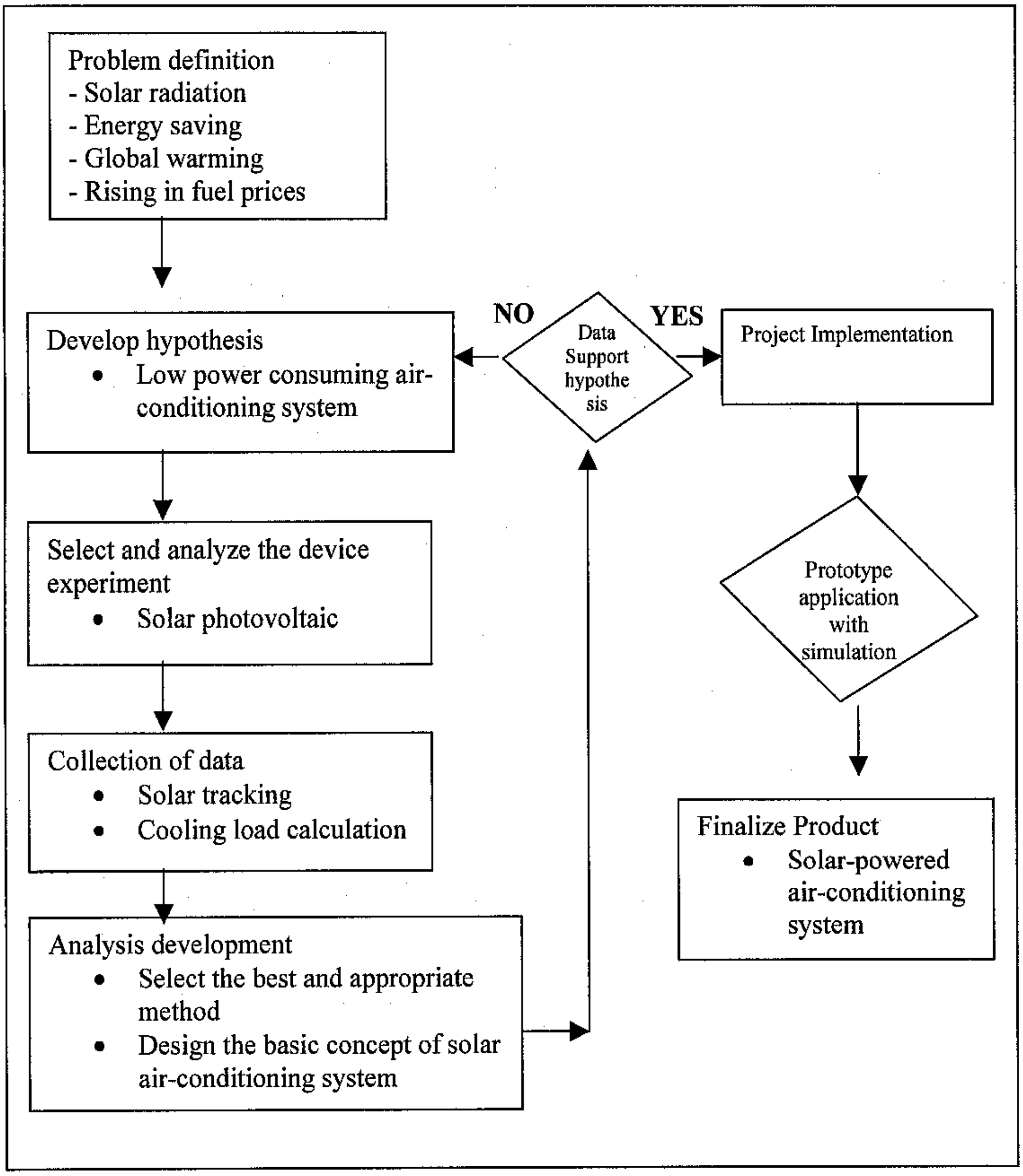


Figure 3.1: Flow chart of project work

3.2 Selection of the device experiment

For this step, the device chosen for implementing the solar air-conditioning system is photovoltaic. This device has certain advantages compared to other solar collectors since the price is reducing due to new technologies invested in the market now.

However, there are some issues need to be considered. The problems might come from the photovoltaic panels are low conversion efficiency of the photovoltaic cells, location, and tracking requirements and also high installation cost.

For this project, the photovoltaic cells used are found in Building 15 and they are under Mechanical department's supervision. The cells are shown in figure 3.2 and figure 3.3 below.

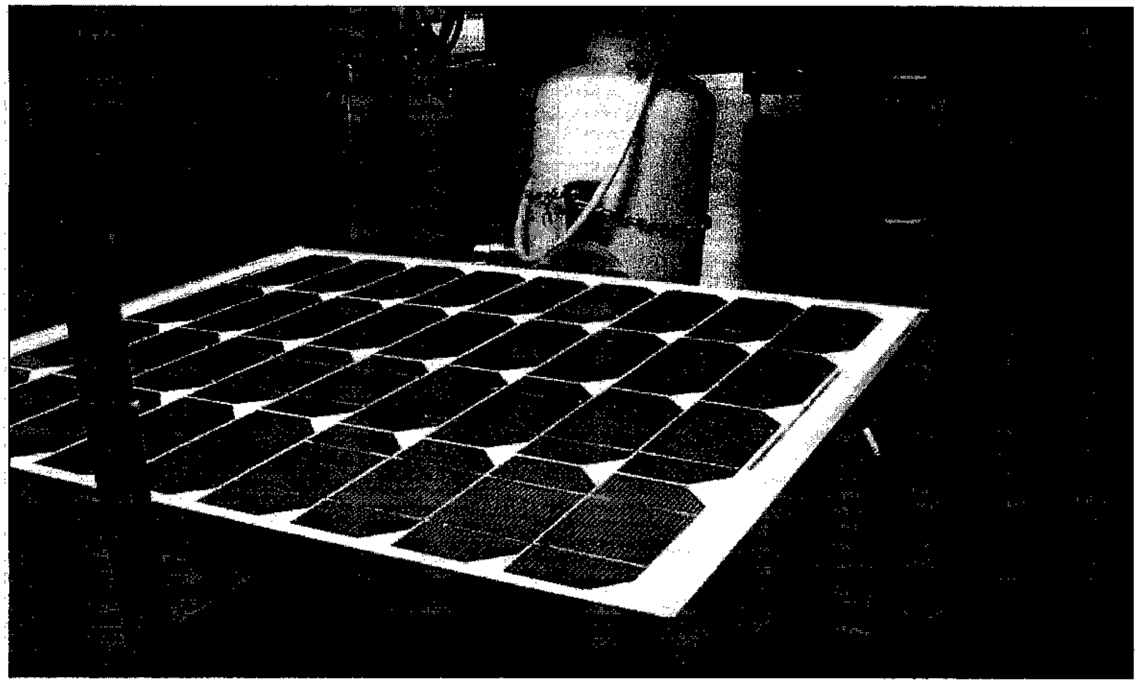


Figure 3.2: Solar photovoltaic panels

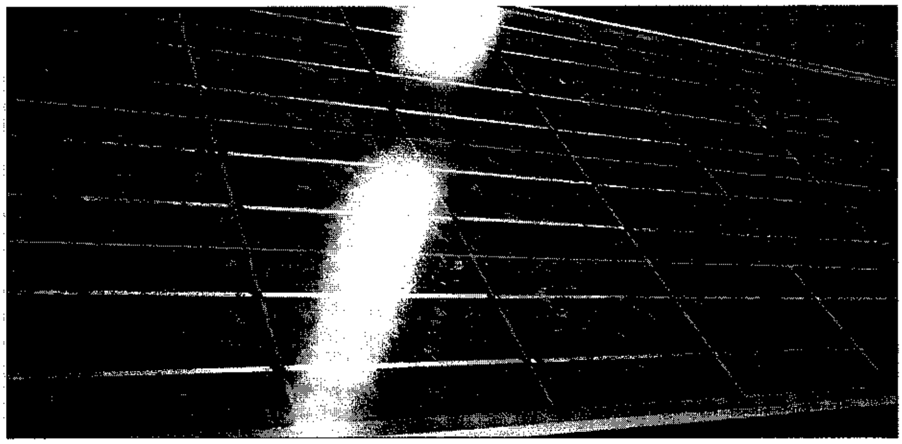


Figure 3.3: Solar photovoltaic panels

3.3 Data collection

This is the stage where the total power required by the system is determined. For the calculation involved, there are some data to be collected in designing an air-conditioning system. The procedures involved are the calculation of the total cooling loads, selection of system piping arrangement, determination of water flow rates and temperature throughout the system, selection of pipe sizes and pump, and lastly the preparation for the final plans and specifications.

3.3.1 Data collection from solar panels

For the solar panels, the data of solar insolation need to be collected. From the experiments that have been conducted in Building 15 in Universiti Teknologi PETRONAS, the data collection is gathered and accumulated in the table 3.1 below.

Table 3.1: Records of hourly global radiation in August 2005

day								Time in Hours							Daily Total
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	MJm-2
1	0	0.21	0.87	1.63	2.33	2.9	3	3.18	2.8	2.15	1.03	0.59	0.18	0	20.87
2	0	0.19	0.67	1.62	2.02	2.14	2.94	2.17	2.26	2.28	2.13	0.79	0.07	0	19.28
3	0	0.03	0.46	1	1.08	0.92	1.31	1.53	1.36	1.62	0.92	0.51	0.1	0	10.84
4	0	0.13	0.73	1.85	2.41	2.59	3.43	3.21	2.74	2.3	1.57	1.09	0.28	0	22.33
5	0	0.13	0.81	1.58	0.91	1.63	1.99	2.2	2.12	1.13	0.79	0.47	0.27	0	14.03
6	0	0.15	0.64	1.34	1.38	1.65	1.93	1.75	2.14	1.79	1.11	0.64	0.18	0	14.7
7	0	0.13	0.43	0.73	1.35	1.69	2.3	1.83	2.07	1.71	1.29	0.56	0.18	0	14.27
Weekly Total	0	0.97	4.61	9.75	11.48	13.52	16.9	15.87	15.49	12.98	8.84	4.65	1.26	0	35.14
Monthly Mean	0	0.1386	0.659	1.393	1.64	1.931	2.414	2.267	2.213	1.854	1.263	0.6643	0.18	0	5.02

A graph of daily solar radiation versus time and monthly mean solar radiation versus time is plotted as shown in figure 3.4 and 3.5 respectively.

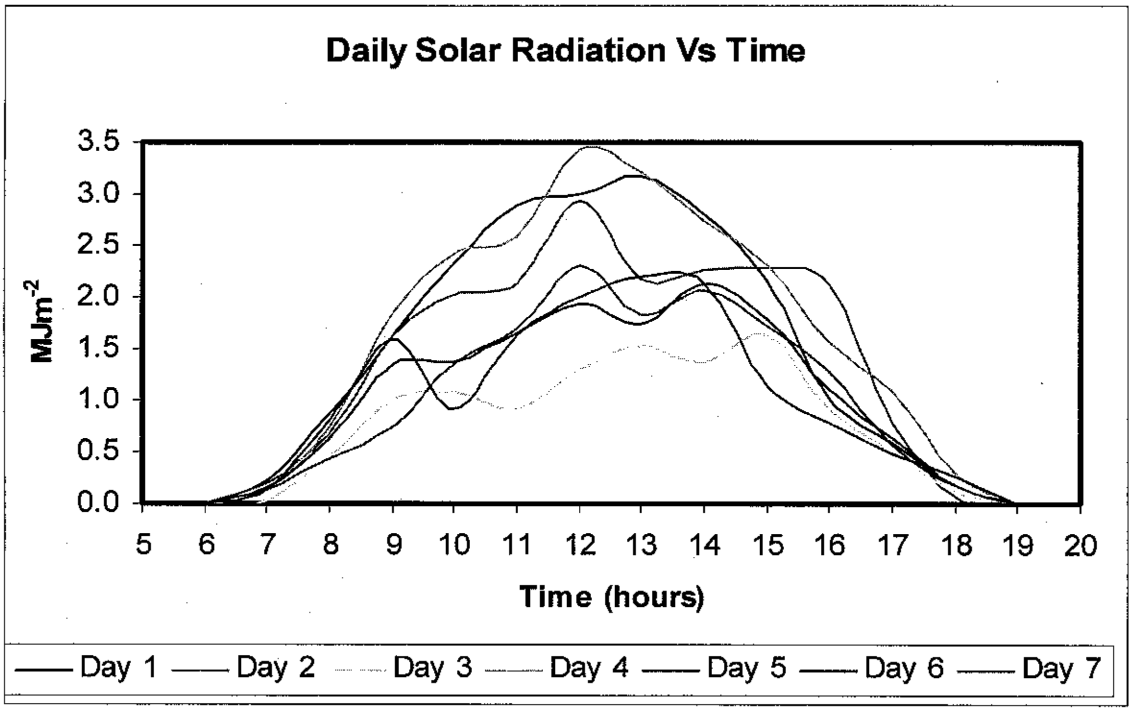


Figure 3.4: Graph of daily solar radiation versus

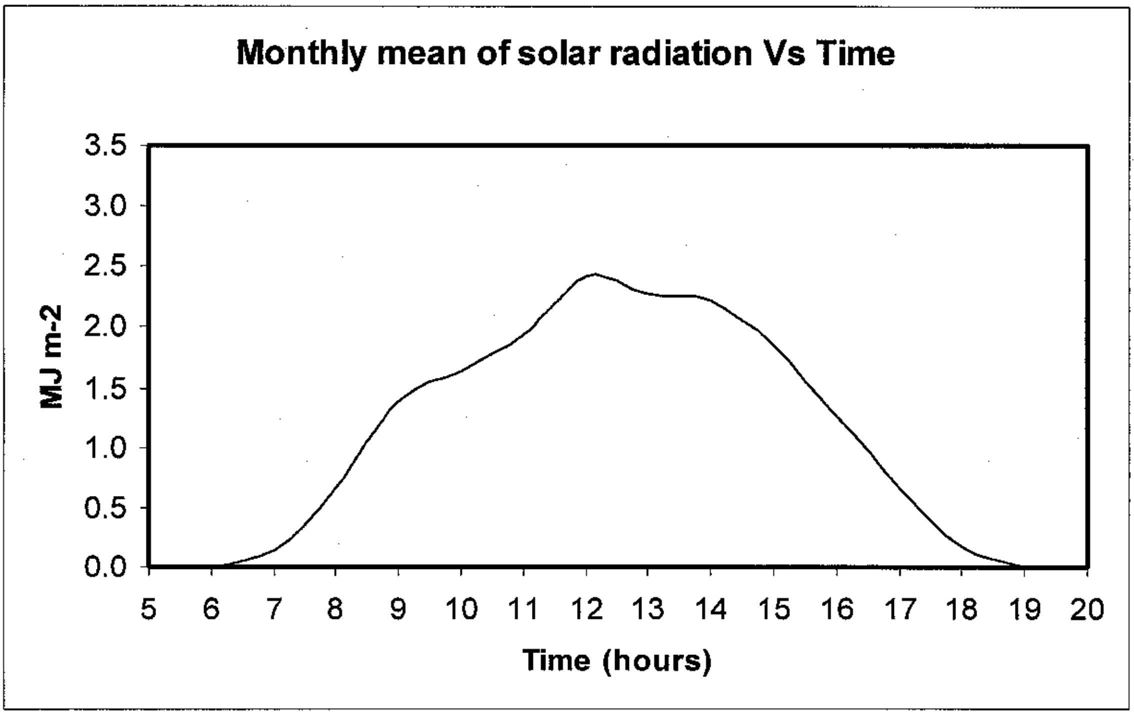


Figure 3.5: Graph of monthly mean solar radiation versus time

3.4 Analysis development

When come to this step, an analysis has been made in choosing the best design of solar-powered air-conditioning system. For this project, the design will involved the photovoltaic system, which consists of battery storage, an intelligent controller, auxiliary energy sources from the grid electricity and the new air-conditioning unit as shown in figure 3.6.

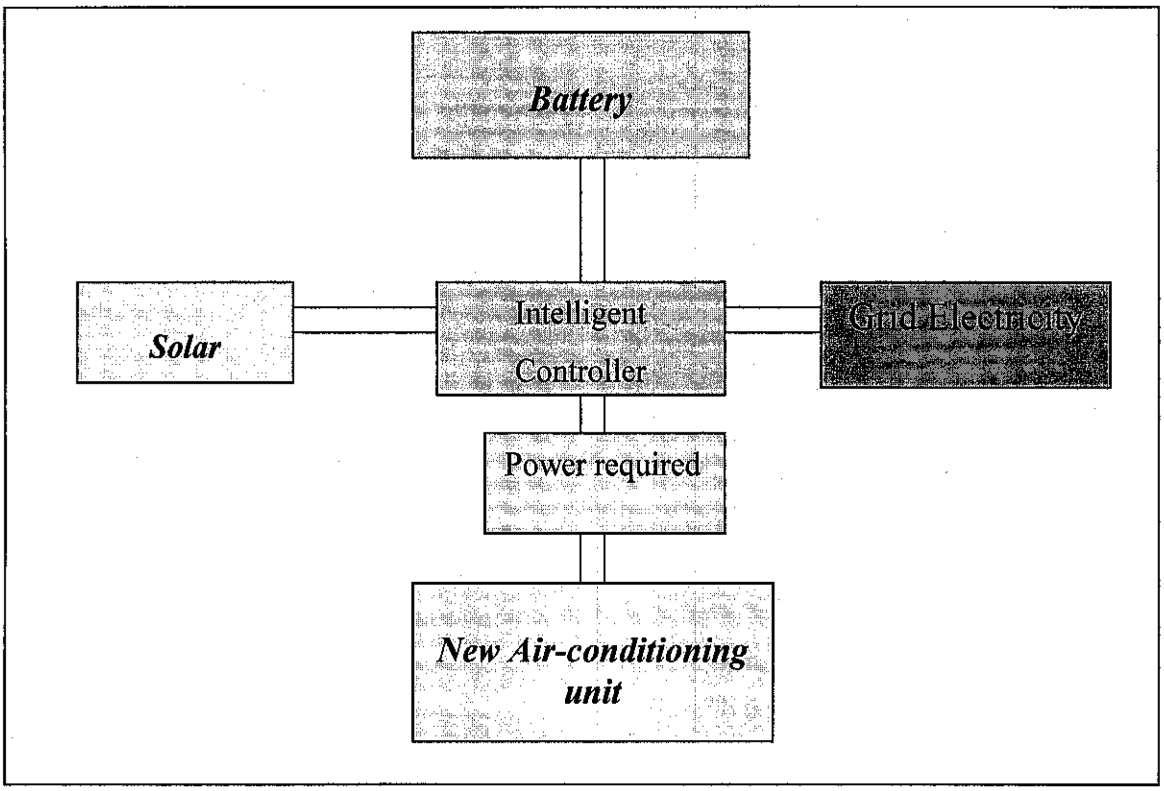


Figure 3.6: Basic design of solar photovoltaic system.

For the air-conditioning system, the design consists of winding coils made from copper, a fan, a pump and water storage. Figure 3.7 and 3.8 show the basic design of the prototype and the block diagram of the process flow.

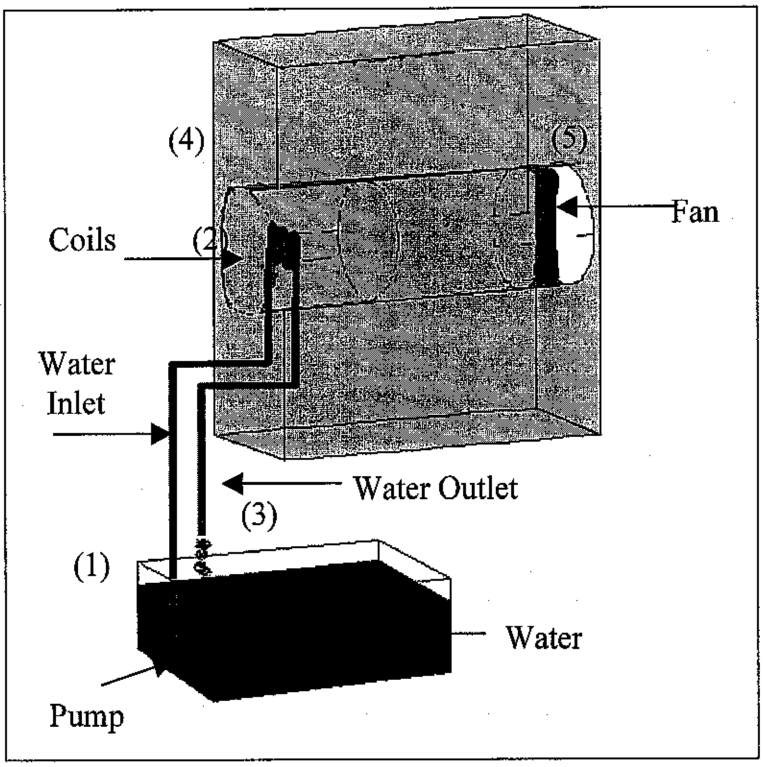


Figure 3.7: Schematic diagram of solar air-conditioning system.

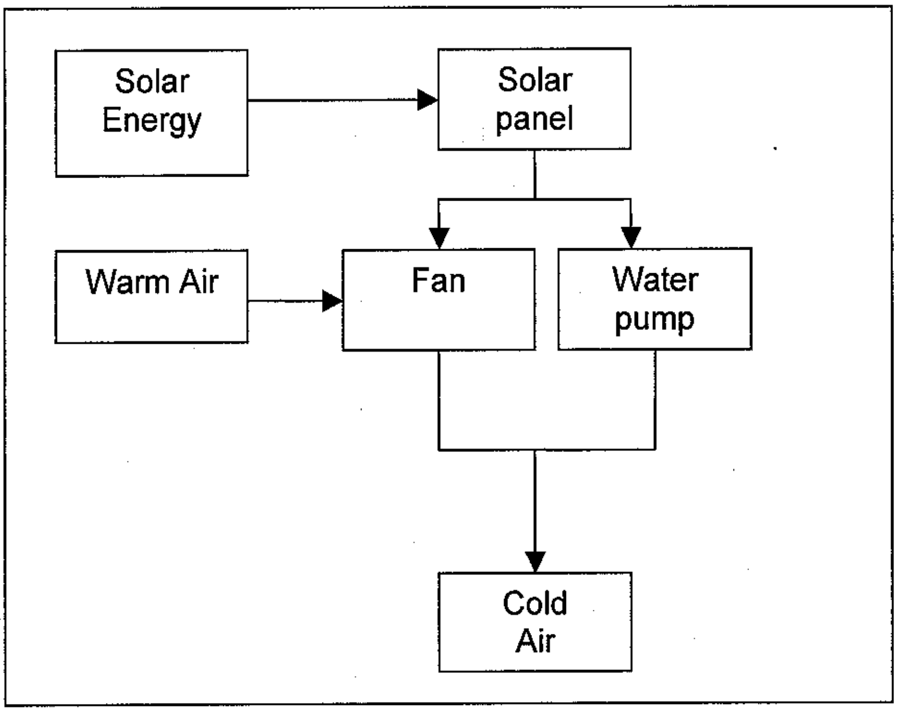


Figure 3.8: Block Diagram of Flow Process

Starting from the energy conversion of the solar panel to the air-cooling process, each part has its own task. The system will be explained according to the parts involved.

3.4.1 Power Source

The solar panels will convert the solar energy to electrical source. This will generate a water pump and a fan that works together in the cooling system. Solar panels are used to transfer the energy into electricity, which supplies the required power for the pump and the fan since it is based on a DC source.

3.4.2 Pump and Water Duct

This part is referred to **process (1)** in Figure 3.7. When the energy is transferred into direct current, the pump will be generated. A pump provides the pressure necessary to overcome the resistance to flow of a liquid in a piping system (Pita, 2002). Water will be pumped from a water tank placed below the system and flows through a rubber pipe to the cooling part. The water inlet supplies water to the pump. The pump then increases the pressure of the water by increasing its velocity first, and then converting the velocity energy to pressure energy.

The items of major importance in the performance of a pump are the pressure (head) it will develop, the flow rate it will deliver, the horsepower required to drive the pump, and its efficiency. These are called the pump characteristics (Pita, 2002).

The water tank provides water supply for the flowing process of the cooling system. The water supply is cold since it is taken from the lower part of the tank. The cold water will be used in the next stage where it is going to flow into another part of the system.

3.4.3 Cooling coil

The water then will go through a coil of pipe that will purposely cool down the temperature of the water due to the length and type of material used. Refer to Figure 3.7, **process (2)**.

Cooling coils may use either chilled water or evaporating refrigerant (Pita, 2002). Cooling coils are usually made of copper tubing with aluminum fins, but copper fins are sometimes used. The coils are arranged in a serpentine shape, in a number of rows, depending on the need. The fins increase the effective surface area of tubing, thus increasing the heat transfer for a given length of tube. The coil may be constructed either with tubes in series or in parallel to reduce water pressure drop.

The pipe will be made out of a coil from copper material as it has its own advantage. The longer the coil is, the longer the path of the flow will be taken, and thus more heat will be exchanged. The water that flows through the coil will experience heat transfer since it goes on a long path that is made of copper, which has high conductivity. Heat transfers from the water, and thus the water will be cold from the copper coil. By then, the temperature of the water will be just right to proceed to next level.

3.4.4 Water storage

When water-cooled coils are used, a steady supply of cooling water must be available every second. The water supply is limited within the water tank. Therefore the cooled water must be returned to the tank after it passes through the cooling coils. Refer to **process (3)** in Figure 3.7. This is where the cooling tower concept is used (Pita, 2002). The cooling tower is the equipment that accomplishes this. It transfers heat from the condenser water to the atmospheric air. From the diagram, we can see the water is returned to the tank after it passes through the whole system. The water outlet brings back the cooled water. Thus cooled water supply will always be available for the system in a longer period of time.

3.4.5 Air Distribution

Hot air will come from other side of the system, and goes through the coil. The air will then be cooled after flowing through the copper coil since the water flow is cold. The heat of the air will be transferred and trapped in the coil, which then produces cold air. This process is referred to **process (4)** in Figure 3.7.

When cooling coils have a number of rows, they are usually connected so that the flow of water and air are opposite to each other, called counter flow. In this way, the coldest water is cooling the coldest air, fewer rows may be needed to bring the air to a chosen temperature than if parallel row were used, and the chilled water temperature can be higher (Pita, 2002).

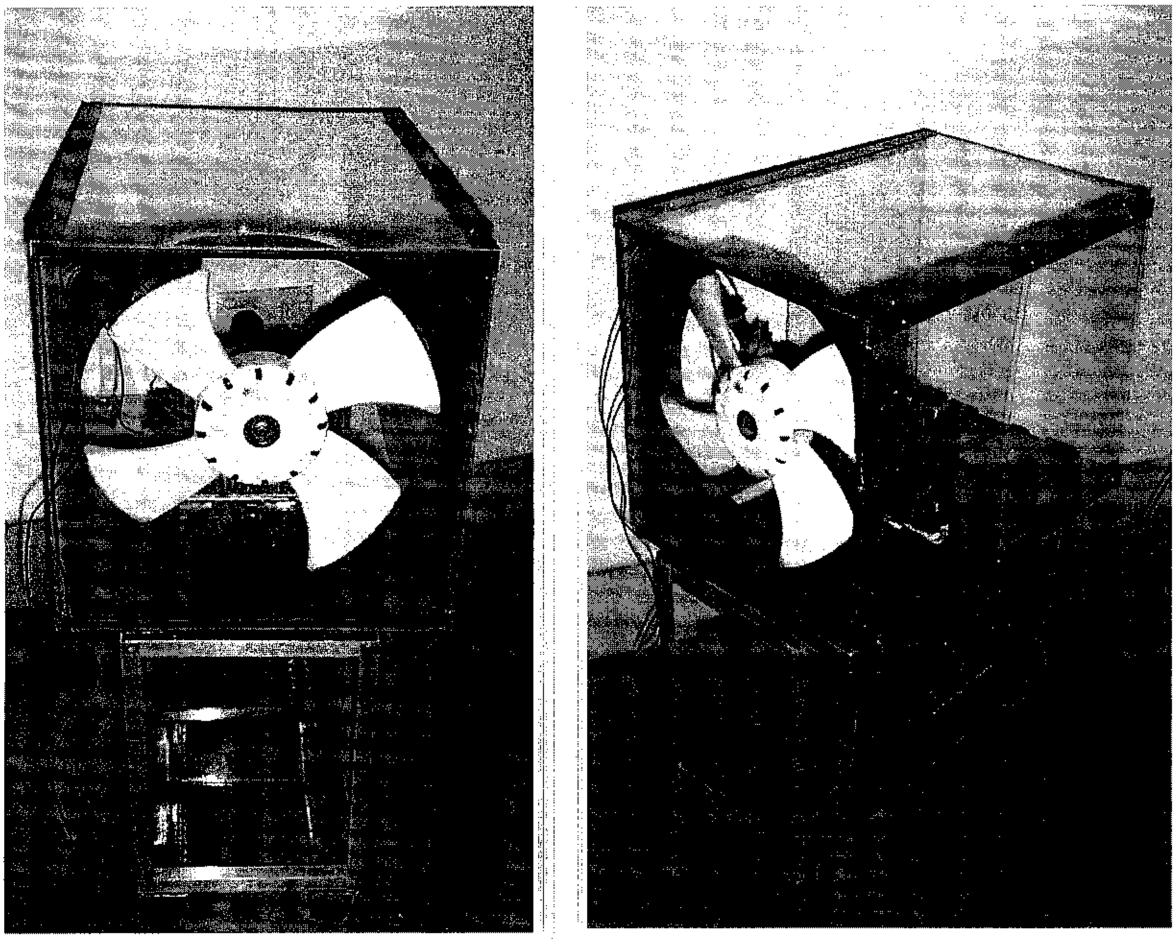
The cold air will then flow through the space provided and straight into a fan. Refer to the Figure 3.7, **process (5)**. The electricity produced from the energy conversion discussed in the previous part generates the fan. It is used to help the distribution of the cold air obtained, by speeding up the airflow depending on the power source. The fan will generate and draw the cold air into it to fasten the process. When the fan is operating, it will blow out the cold air that has been drawn to it to the outer part of the system. Thus creates the cold air that the project intends to produce.

3.5 Project implementation

After the best and appropriate design being chosen, the design will be analyzed back to achieve the objectives i.e. all data collected in the design should be supported by the hypothesis. When data supports the hypothesis, the project is then be implemented. This is where the theory and practical are combined to achieve the design objectives.

3.6 Product (prototype) development

The final step of this project is to develop a working prototype of a solar-powered air-conditioning system. The prototype has been developed according to all data collected and it is shown in figure 3.9 below.



(a) (b)

Figure 3.9: Prototype developed (a) Front view (b) Side view

CHAPTER 4

RESULTS AND DISCUSSION

This section will cover towards the calculation steps in determining the cooling load capacity required to drive the new air-conditioning unit and the results from the experiments on the prototype.

4.1 Cooling load calculation

The air inside a building receives heat from a number of sources. If the temperature and humidity of the air are to be maintained at a comfortable level, this heat must be removed. The amount of heat that must be removed is called the *cooling load* (Pita, 2002).The cooling load must be determined because it is the basis for selection of the proper size air-conditioning equipment and distribution system. It is also used to analyze energy use and conversion.

The cooling load calculation can be calculated using the software given or it is also can be calculated manually by collecting some appropriate data. The cooling load calculation procedure that will be explained here is called the CLTD method. The first step is the selection of inside and outdoor design temperatures from table 4.1 and 4.2 below.

Table 4.1: Recommended Energy Conserving Indoor Air Design Conditions For Human Comfort

Air Temperature (DB) °C	Relative 'humidity (RH) %	Maximum Air Velocity m / s	Clothing Insulation clo
25	85	3.72	0.5

Table 4.2: Outdoor Cooling Design Conditions- World Locations

Location	Latitude	Cooling				
		DB	MWB	WB	MDB	DR
MALAYSIA	1° North	32.8	26.1	27.2	31.1	-11.7

DB = dry bulb temperature, °C

MWB = mean coincident wet bulb temperature, °C

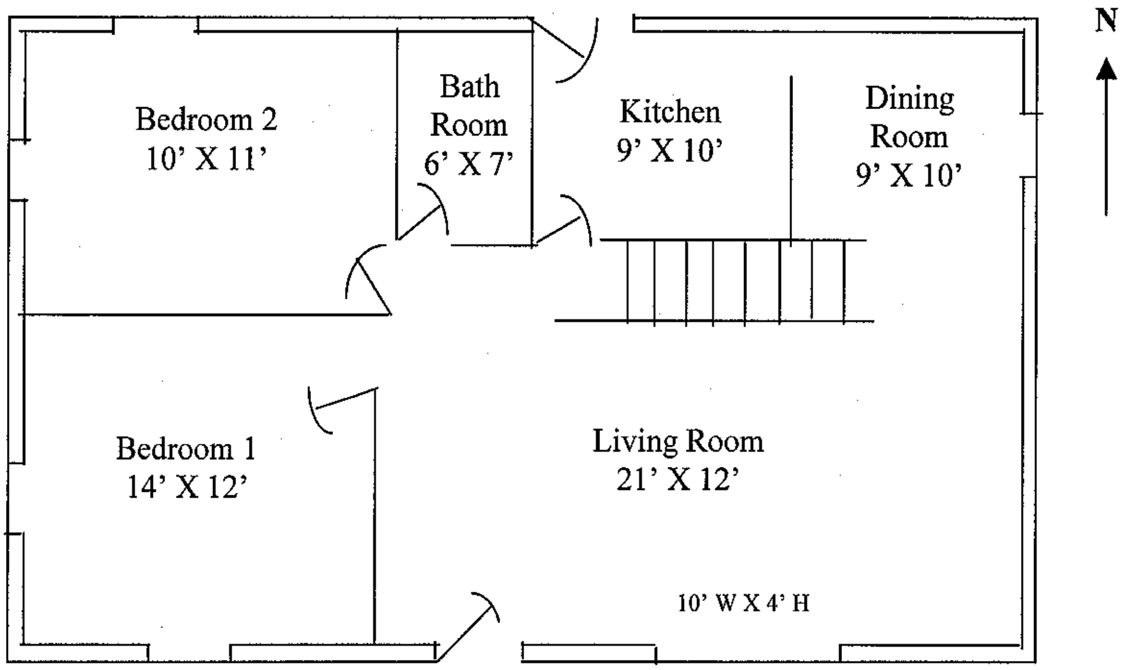
MDB = mean coincident dry bulb temperature, °C

DR = mean daily range of DB temperature, °C

From the table given, the indoor and outdoor design temperature chosen was 25°C and 32°C respectively. They were chosen based on average human comfortability in our country. The subsequent steps in determining the total cooling loads are as follow:

4.1.1 Use architectural plans to measure dimensions of all surfaces

The dimensions are taken from the building plans in figure 4.1 and the gross and net areas of each element are calculated and recorded in Figure A.4 in the appendices.



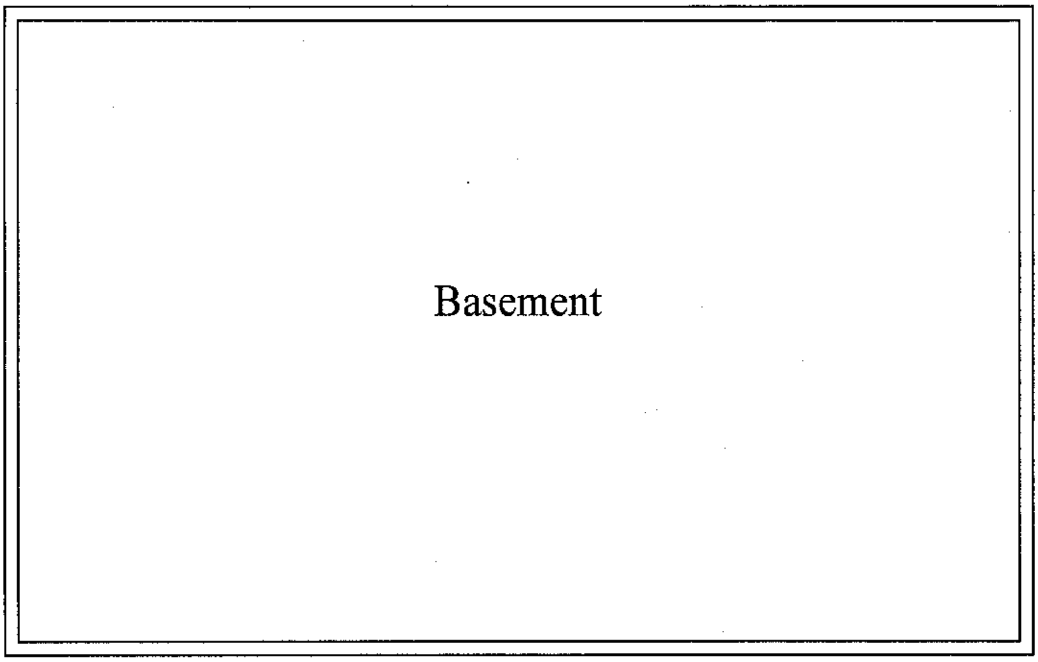


Figure 4.1: Architectural plan

NOTES:
Ceiling height = 2.4 m
Single clear glass, blinds
Windows = 1.06 m W X 1.2 m H except as noted
Doors = 0.9 m X 2.1 m

From the plan, gross and net areas of each element are accumulated in the table 4.3:

Table 4.3: Gross and net areas of plan architecture.

Room Name	Plan Size
Living room	7 m x 4 m = 28 m^2
Dining room	2.5 m x 3 m = 7.5 m^2
Bedroom No. 1	4m x 3.4m = 13.6 m^2
Bedroom No. 2	3m x 3.2m = 9.6 m^2
Bathroom	1.8 m x 2 m = 3.6 m^2
Kitchen	2.5 m x 3 m = 7.5 m^2

The entire dimensions are calculated using standard unit used in Malaysia. The standard unit used by the European country is in ft^2.

4.1.2 Select heat transfer coefficient, U for each element.

Heat transfer coefficients for the materials listed are found from Tables A.7 and A.8 in the appendices. All the calculation values can be recorded in Figure A.4 in the appendices. From the tables, the coefficient values for window, roof and doors are:

$U_W = 0.20$ $U_r = 0.10$ $U_d = 0.47$

4.1.3 Calculate the heat gains through walls, roof, and floors for each room

Using the CLTD values from Table 6.19 in the appendices, the outdoor temperature range is $90^oF = 32^oC$, in the M class. The wall heat gains in each room are then calculated using equation:

$$Q = U \times A \times CLTD \tag{4.1}$$

where

Q = sensible cooling load, kW
U = overall hate transfer coefficient, kW/ m^2
A = area, m^2
CLTD = cooling load temperature difference, ^0C

All values are recorded in Figure A.4 in the appendices. The CLTD values obtained are for wall, roof/ceiling, doors, windows, infiltration and people.

4.1.4 Calculate heat gains through glass for each room

Using Table 6.20 in the appendices, the heat gains for windows through windows are calculated using equation:

$$Q = A \times GLF \tag{4.2}$$

Where

Q = sensible cooling load due to heat gain through glass, kW

A= area of glass, m^2

GLF = glass load factor, kW/ m^2

From table 6.20 in appendix, for the windows on the south side, the GLF for the type of glass and shading is 28 Btu/ hr.ft^2 = 302 Btu/ hr. m^2 at 32^0C outdoors and 25^0C indoors.

4.1.5 Determine occupancy and appliance load

The sensible heat gain per person is assumed to be an average of 225 Btu/ hr = 65.925 kW (1 Btu/hr = 0.293 W). If the number of occupants is not known, it can be estimated as two times the number of bedrooms. Because the maximum load usually occurs in late afternoon, it is usual to assume that the occupants are in living and dining areas for purposes of load distribution.

For a two-bedroom house, it is assumed that occupancy of four; two in the living room, two in the dining area at peak load times. The kitchen appliance load is assumed to be a 0.35 kW. A sensible heat gain allowance of 0.35 kW – 0.46 kW is typical for kitchen appliances.

4.1.6 Determine infiltration or ventilation load

The infiltration is found from table 6.22 is the appendices and it is calculated using equation:

$$Q=1.1\times CFM\times\Delta T \qquad (4.3)$$

Where

Q = sensible cooling load due to infiltrating air, kW

CFM = air infiltration rate into room, CFM

ΔT = temperature change between inside and outside air, ^{0}C

While for the quantity of air infiltrating into the room, the value is found from equation:

$$CFM = ACH \times V/60 \tag{4.4}$$

where

CFM = air infiltration rate into room, CFM
ACH = number of air changes per hour (from table 6.22)
V = room volume, m^3

4.1.7 Add individual loads to find sensible load for each room and building

The individual gains are added to find the RSCL (residential sensible cooling load) for each room and the building. All values can recorded in Figure A.4 in the appendices.

4.1.8 Add duct heat gains and leakage to SCL of building

The duct system is in the basement. Allow 5% for heat gain and 5% for leakage to the building sensible cooling load (BSCL).

4.1.9 Multiply the building sensible load by the latent factor, LF.

Figure 4.2 is used to find the LF value, using the outdoor design humidity ratio from the psychometric chart. From the figure, the LF obtained form the design humidity is 1.25

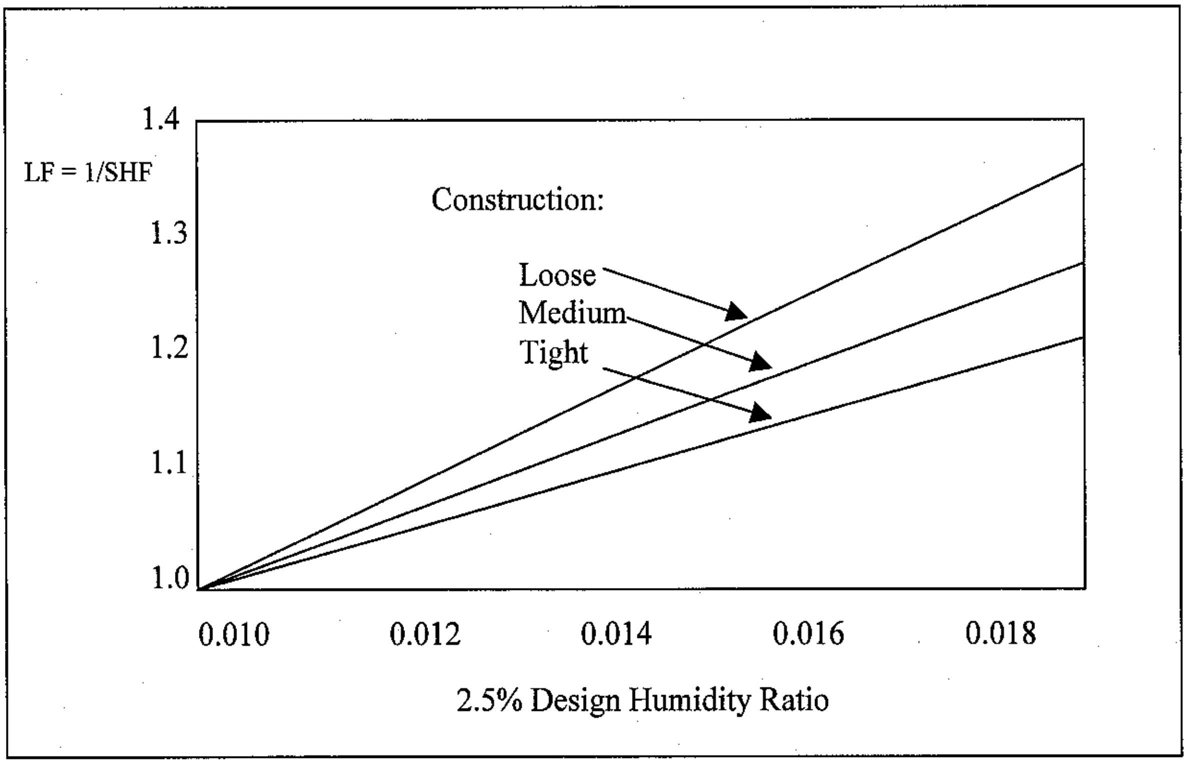


Figure 4.2: Effect of infiltration on latent load factor

This final step is the result of the air conditioning equipment total cooling load. From the calculation done, the total cooling loads obtained are:

Sum RSCL = 15 405 Btu/ hr

Duct gain 5% = 770 Btu/ hr

Duct leak 5% = 770 Btu/ hr

BSCL = 16, 945 Btu/ hr

BTCL = 1.25 (LF) X BSCL = 21,181 Btu/ hr = 6.2 kW

Note: RSCL = Residential cooling load

BSCL = Building sensible cooling load

BTCL = Building total cooling load

For this project, a new air-conditioning system is based on the cooling load calculation for bedroom 2 and the total cooling load is summarized in table 4.4 below.

Table 4.4: Total cooling load for bedroom 2:

Room Name	**Bedroom No. 2**				
Plan Size	**10' X 11' + 3' X 4'**				
Wall	***Direction***	***Area (ft^2)***	***U-Value (Btu/ hr-ft^2-F)***	***CLTD (F)***	***Btu/ hr***
	North	74	0.20	13	340
	West	74	0.20	23	192
Windows	***Direction***	***Area (ft^2)***	***GLF (F)***		
	North	14	23		322
	West	14	50		700
Roof/ Ceiling	***U-Value (Btu/ hr-ft^2-F)***		***Area (ft^2)***	***CLTD (F)***	
	0.10		122	47	573
RSCL					**2127**

The total cooling load is 2127 Btu/ hr which is equal to 0.6kW. This is the required cooling load that needs to be removed by the system.

4.2 Experiments' result

Some experiments have been conducted to measure the temperature drops from the system designed. The data for the temperature was taken before and after the system is running. The results are as follow:

Location: Building 21 (21-00-01)

Time: 12.30 pm

- Before

Room temperature (0C)	Reading 1	Reading2	Reading 3	Average
	22.2	23.0	22.5	22.6

- After

Room temperature (0C)	Reading 1	Reading2	Reading 3	Average
	20.7	20.9	20.6	20.7

CHAPTER 5

CONCLUSION AND FUTURE WORK

In a nutshell, the idea of solar powered air-conditioning system is really a brilliant idea and a good investment for Malaysia since we receive the Sun's radiation throughout the year. When there is Sun, that is the time where air-conditioner is needed and that is the time where the photovoltaic can be functioned. It is important to note that a PV system will not save energy. People invest in PV because it is an energy producer, which releases no noxious gases into the air, and it can minimize or eliminate monthly utility bills. When PV technologies are combined with energy efficiency measures, PV's investment value is magnified. When a home's energy efficiency increases, PV can offset more of the utility bill. Eventhough there are up-front costs incurred with purchasing the PV system and installing certain energy efficiency measures but, in many cases, these costs can be recouped over time by the savings on the monthly energy bill. Modeling shows that the solar-powered air conditioning system using photovoltaic has the potential to be developed in Malaysia.

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APPENDICES

Photovoltaic Cells; Poly-Crystalline Silicon

Electrical Characteristics										
Module Type (Watt)	62	72	80	123	125	142	162	167	170	200
Open circuit Voltage, V_{oc}	10.8 V	12.43 V	21.6 V	21.3 V	21.7 V	24.9 V	28.4 V	28.9 V	43.2 V	35.5 V
Max. Power Voltage, V_{pm}	8.6 V	9.98 V	17.3 V	17.2 V	17.2 V	20.0 V	22.8 V	22.8 V	34.8 V	28.5 V
Short Circuit Current, I_{sc}	8.0 A	8.04 A	5.16 A	8.04 A	8.14 A	7.92 A	7.92 A	8.16 A	5.47 A	7.82 A
Max. Power Current, I_{pm}	7.2 A	7.22 A	4.63 A	7.16 A	7.3 A	7.11 A	7.11 A	7.33 A	4.9 A	7.02 A
Max. Power, P_{max}	62 W	72 W	80 W	123 W	125 W	142 W	162 W	167 W	170 W	200 W
Module efficiency, η			12.4 %	12.39 %	12.6 %	12.31 %	12.4 %	12.7 %	13.1 %	12.3 %
Max. System voltage	600 V	600 VDC	600 VDC	600 VDC	600 VDC	600 VDC	600 VDC	600 VDC	600 VDC	600 VDC
Series Fuse rating	15 A	15 A	10 A	15 A	15 A	15 A	15 A	15 A	10 A	15 A

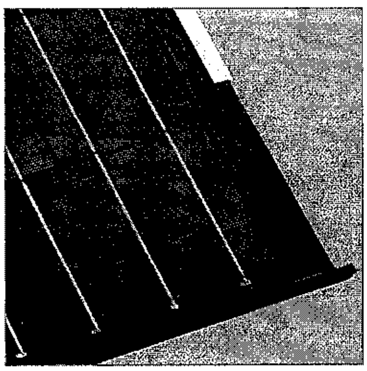
RESIDENTIAL SYSTEM MODULE **ND-62RU1**

62 WATT

AESTHETIC APPEAL. EFFICIENT INSTALLATION.

POLY-CRYSTALLINE SILICON PHOTOVOLTAIC ROOF MODULE WITH 62W MAXIMUM POWER

Beautifully complementing roof tiles of many shapes and sizes, Sharp's ND-62RU1 solar modules offer a clean, unobtrusive look that's especially pleasing to homeowners. These solar roof shingles are quick and easy to integrate into the roof in the same manner as common, flat concrete tiles. They're designed for weather blocking, with water channel design similar to concrete tiles, and because the module brackets screw to the existing roof battens, no additional framing materials or extra roof penetrations are required. Offering superior durability, they are resistant to moisture, impact and high winds. Sharp's ND-62RU1 solar roof modules are an ideal combination of aesthetics, performance and ease of installation for a wide range of residential new construction.



Compatible with most roof tiles used in new residential construction, like Eagle and Monier, each solar roof module replaces five concrete tiles.

Sharp's solar roof tiles integrate beautifully with standard roof tiles of many colors, becoming nearly "invisible" to the eye.

FEATURES

- High-power module (62W) using 155mm square poly-crystalline silicon solar cells
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, natural look
- Bypass diodes minimize the power drop caused by shade
- Non-reflective white tempered glass, EVA resin, weatherproof film and black double-anodized aluminum frame for extended outdoor use
- UL Listings: UL 1703, cUL
- Sharp modules are manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output (see dealer for details)

RESIDENTIAL SYSTEM MODULE

62 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	18 in series
Open Circuit Voltage (Voc)	10.8V
Maximum Power Voltage (Vpm)	8.6V
Short Circuit Current (Isc)	8.0A
Maximum Power Current (Ipm)	7.2A
Maximum Power (Pmax)*	62W (+10% / -5%)
Maximum System Voltage	600V
Series Fuse Rating	15A
Type of Output Terminal	Lead Wire with ONAMBA Connector

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

MECHANICAL CHARACTERISTICS

Dimensions (L x W x D)	59" x 15.6" x 1.3" (1498mm x 396mm x 34mm)
Weight	16.5lbs (7.5kg)
Size of Carton	59.4" x 16.3" x 10.2" (1508mm x 413mm x 260mm)
Carton Quantity	6 pcs per carton
Pallet Quantity	72 pcs per pallet
Loading capacity (48 ft container)	1152 pcs (16 pallets)
Loading capacity (53 ft container)	1296 pcs (18 pallets)

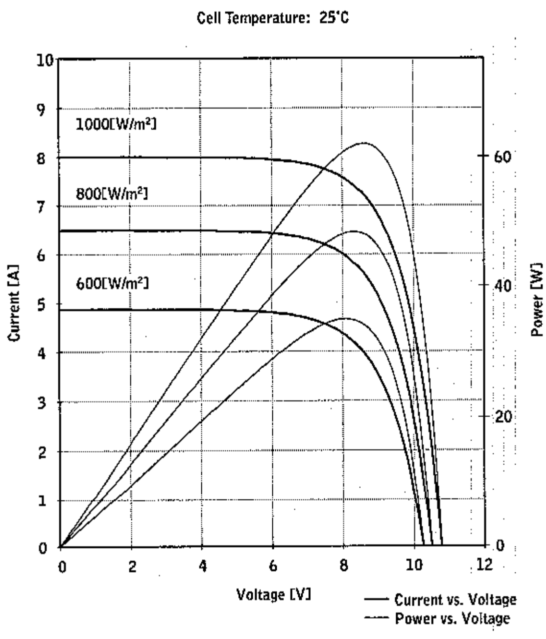
COMPATIBLE ROOF TILES

Eagle Roofing, Monier Life Tile, and other Roof Tiles	Consult Sharp or a Sharp reseller for more information

ABSOLUTE MAXIMUM RATINGS

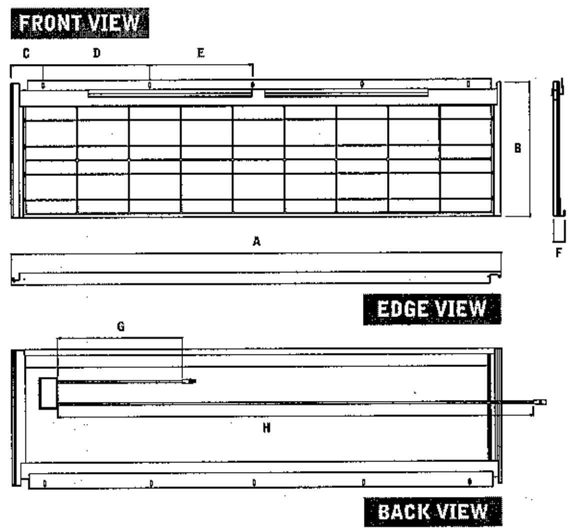
Operating Temperature (min to max, °F/°C)	-40 to +194°C / -40° to +90°C
Storage Temperature (min to max, °F/°C)	-40 to +194°F / -40° to +90°C

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



A	B	C	D
59"/1498mm	15.6"/396mm	3.9"/99mm	16.7"/424mm
E	**F**	**G**	**H**
29.1"/739mm	1.3"/34mm	15"/381mm	57.25"/1454mm

Design and specifications and design are subject to change without notice.

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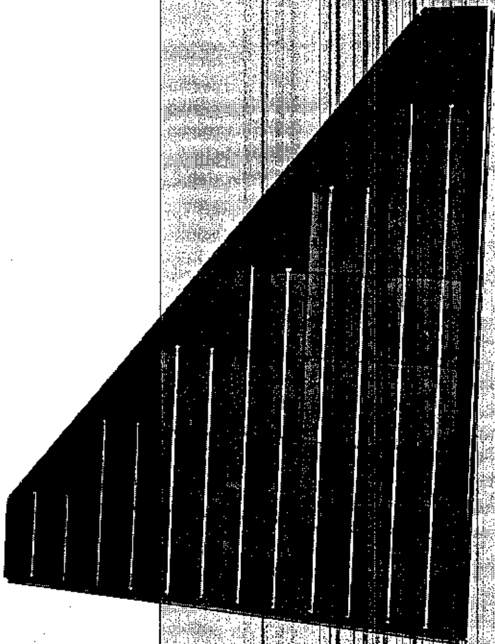
SHARP®

RESIDENTIAL SYSTEM MODULE

ND-072ERU
ND-072ELU

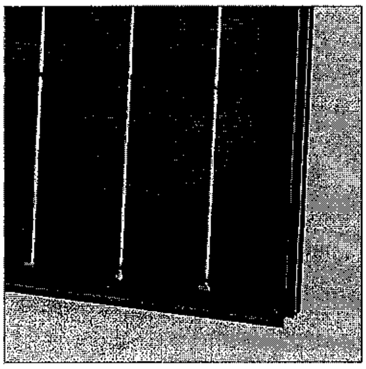
72 WATT

ATTRACTIVE LOOK. FLEXIBLE DESIGN.



LEFT AND RIGHT TRIANGULAR PHOTOVOLTAIC MODULES WITH 72W MAXIMUM POWER

Sharp's new triangular photovoltaic modules offer the clean, pleasing look of a high-tech skylight while increasing design flexibility with balanced and attractive rooftop arrays. Engineered specifically for residential hip roofs and complex roof lines, these modules set a new standard in aesthetics. The black anodized aluminum frames, trim strips, and backing sheets blend beautifully with the home's exterior. In addition, an "L" hook design located along the frame's perimeter ensures easy integration with the residential system mounting hardware. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. They are also designed to withstand extreme heat and wind. Sharp's ND-072ERU/LU triangular residential system modules are an ideal combination of form and function from the global leader in solar technology.



The laminated glass module is glazed into a high torsion black anodized aluminum frame.

Sharp's triangular modules with black frames, trim strips, and backing sheets allow for the seamless integration of the system into the home's design.

FEATURES

- High-power module (72W) using 155mm square poly-crystalline silicon solar cells
- Left and right triangular modules offer greater design flexibility and greater integration for roofline aesthetics
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, "natural" look
- Bypass diodes minimize the power drop caused by shade
- Black anodized aluminum frame and "L" hook design located along frame perimeter for easy integration with residential system mounting hardware
- Nominal 7 VDC output is ideal for residential system applications
- Manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output (see dealer for details)
- UL Listings: UL 1703, cUL

RESIDENTIAL SYSTEM MODULE

72 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	21 in series
Open Circuit Voltage (Voc)	12.43V
Maximum Power Voltage (Vpm)	9.98V
Short Circuit Current (Isc)	8.04A
Maximum Power Current (Ipm)	7.22A
Maximum Power (Pmax)*	72W (+10% / -5%)
Maximum System Voltage	600VDC
Series Fuse Rating	15A
Type of Output Terminal	Lead Wire with MC Connector

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

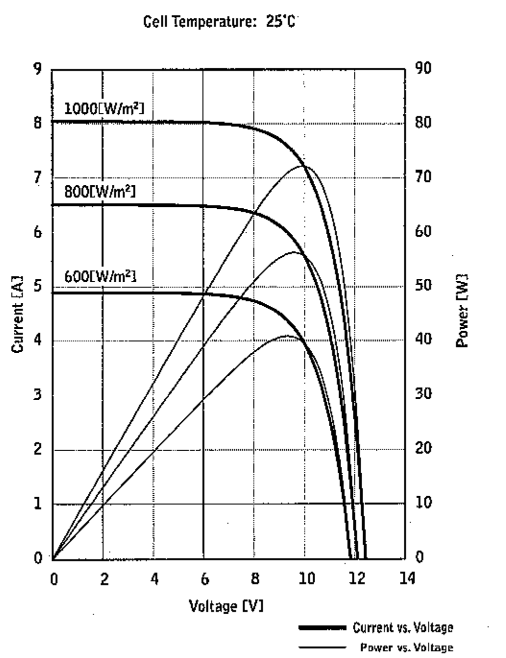
MECHANICAL CHARACTERISTICS

Dimensions (A x B x C below)	45.86" x 38.98" x 1.81" 1165mm x 990mm x 46mm
Weight	26.9lbs / 12.2kg
Packing Configuration	2 pcs per carton
Size of Carton	46.06" x 42.5" x 5.12" 1170mm x 1080mm x 130mm

ABSOLUTE MAXIMUM RATINGS

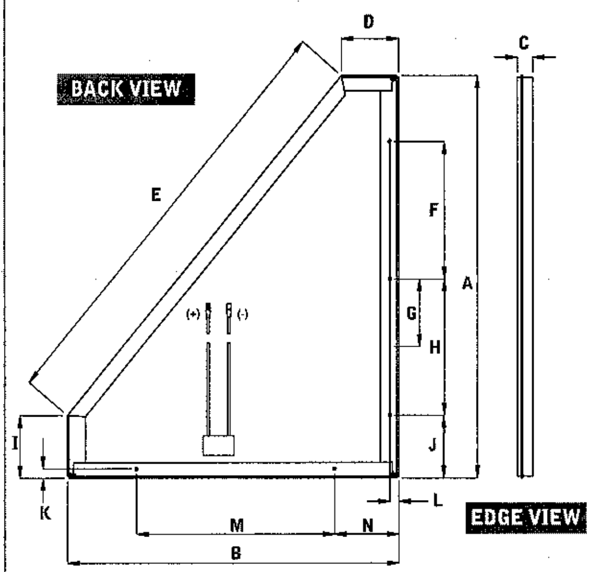
Operating Temperature	-40 to +194°F / -40 to +90°C
Storage Temperature	-40 to +194°F / -40 to +90°C

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



A	B	C	D	E	F	G
45.86"/1165mm	38.98"/990mm	1.81"/46mm	6.81"/173mm	50.3"/1277.5mm	15.75"/400mm	7.9"/200mm
H	**I**	**J**	**K**	**L**	**M**	**N**
15.75"/400mm	7.2"/183mm	7.2"/182.5mm	1.06"/27mm	1.06"/27mm	23.62"/600mm	7.688"/195mm

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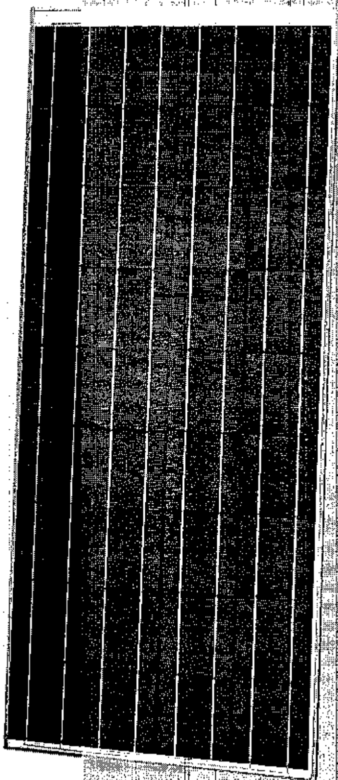
HARP® **MULTI-PURPOSE MODULE**

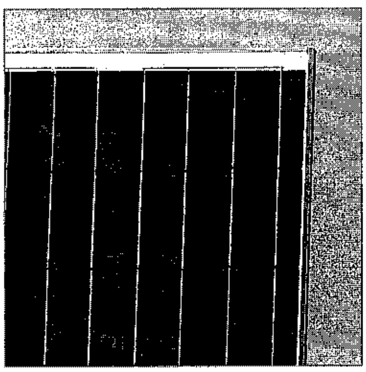


80 WATT

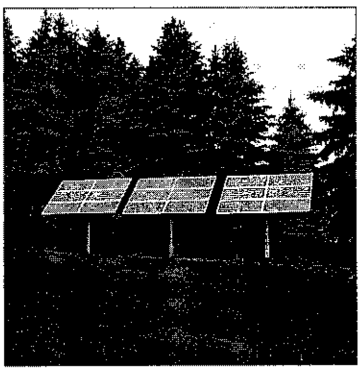
POWERFUL PERFORMANCE. SHARP RELIABILITY.

POLY-CRYSTALLINE SILICON PHOTOVOLTAIC MODULE WITH 80W MAXIMUM POWER

Sharp's NE-80EJEA photovoltaic modules offer industry-leading performance, durability, and reliability for a variety of electrical power requirements. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include cabins, solar power stations, pumps, beacons, and lighting equipment. Designed to withstand rigorous weather conditions, a junction box is also provided for easy electrical connections in the field, making Sharp's NE-80EJEA modules the perfect combination of advanced technology and reliability.



Solder-coated grid results in high fill factor performance under low light conditions.



Sharp multi-purpose modules offer industry-leading performance for a variety of applications.

FEATURES

- High-power module [illegible] 125mm [illegible] poly-crystalline silicon [illegible] module conversion efficiency
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, natural look
- Bypass diodes minimize the power drop caused by shade
- Water white, tempered glass, EVA laminate, plus aluminum frame for extended outdoor use
- Junction box for easy electrical connections in the field
- Nominal 12VDC output for battery charging applications
- UL Listings: UL 1703, cUL
- Sharp modules are manufactured in ISO 9001 certified facilities
- 25-year limited warranty [illegible] on power output (see dealer for details)

MULTI-PURPOSE MODULE

80 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	36 in series
Open Circuit Voltage (Voc)	21.6V
Maximum Power Voltage (Vpm)	17.3V
Short Circuit Current (Isc)	5.16A
Maximum Power Current (Ipm)	4.63A
Maximum Power (Pmax)*	80W (+10% / -5%)
Module Efficiency (ηm)	12.40%
Maximum System Voltage	600VDC
Series Fuse Rating	10A
Type of Output Terminal	Junction Box

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

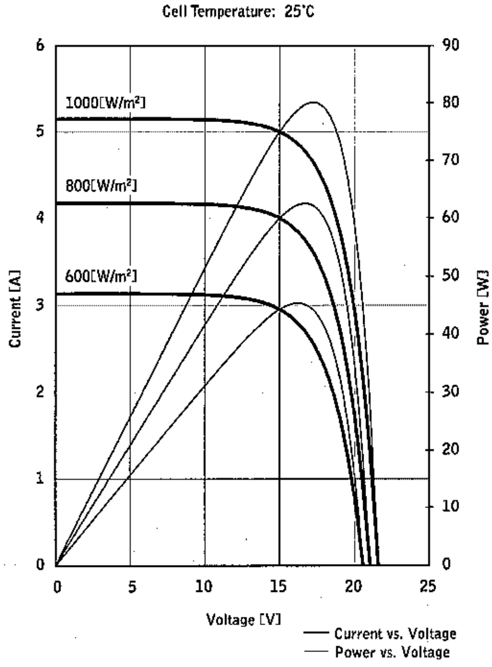
MECHANICAL CHARACTERISTICS

Dimensions (H x W x D)	47.28" x 20.14" x 1.81" 1200mm x 512mm x 46mm
Weight	20.94lbs / 9.5kg
Packing Configuration	1 pc per carton
Size of Carton	53.15" x 27.56" x 2.95" 1350mm x 700mm x 75mm
Loading Capacity (20 ft container)	242 pcs (242 cartons)
Loading Capacity (48 ft container)	506 pcs (506 cartons)

ABSOLUTE MAXIMUM RATINGS

Operating Temperature	-40 to +194°F / -40 to +90°C
Storage Temperature	-40 to +194°F / -40 to +90°C

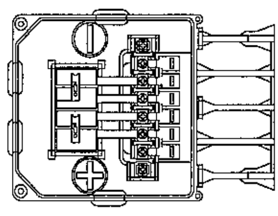
IV CURVES

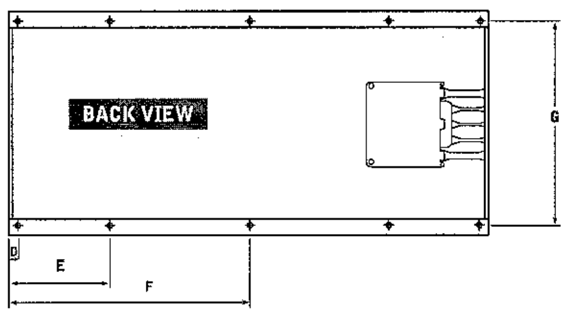


Current, Power vs. Voltage Characteristics

DIMENSIONS

JUNCTION BOX





D	E	F	G
.99"/25.1mm	9.84"/250.0mm	23.62"/600.0mm	18.9"/480.0mm

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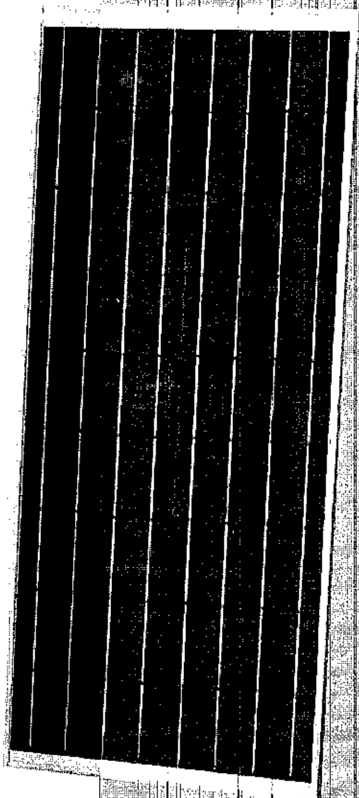
MULTI-PURPOSE MODULE

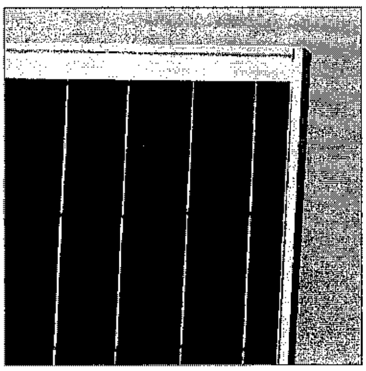


123 WATT

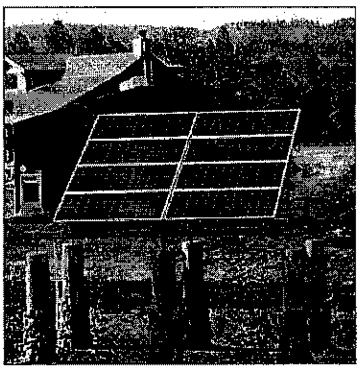
SUPERIOR DURABILITY. HIGH EFFICIENCY.

POLY-CRYSTALLINE SILICON PHOTOVOLTAIC MODULE WITH 123W MAXIMUM POWER

Sharp's ND-L3EJEA photovoltaic modules offer industry-leading performance, durability, and reliability for a variety of electrical power requirements. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include cabins, solar power stations, pumps, beacons, and lighting equipment. Designed to withstand rigorous weather conditions, a junction box is also provided for easy electrical connections in the field, making Sharp's ND-L3EJEA modules the perfect combination of advanced technology and reliability.



Solder-coated grid results in high fill factor performance under low light conditions.



Sharp multi-purpose modules offer industry-leading performance for a variety of applications.

FEATURES

- [illegible] power module (123W) using [illegible] poly-crystalline [illegible] cells with 12.3% module conversion efficiency
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, "natural" look
- Bypass diodes minimize the power drop caused by shade
- Water white tempered glass, EVA laminate, plus aluminum frame for extended outdoor use
- Junction box for easy electrical connections in the field
- Nominal 12VDC output for battery charging applications
- UL Listings: UL 1703, cUL
- Sharp modules are manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output (see dealer for details)

MULTI-PURPOSE MODULE

123 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	36 in series
Open Circuit Voltage (Voc)	21.3V
Maximum Power Voltage (Vpm)	17.2V
Short Circuit Current (Isc)	8.04A
Maximum Power Current (Ipm)	7.16A
Maximum Power (Pmax)*	123W (+10% / -5%)
Module Efficiency (ηm)	12.39%
Maximum System Voltage	600VDC
Series Fuse Rating	15A
Type of Output Terminal	Junction Box

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

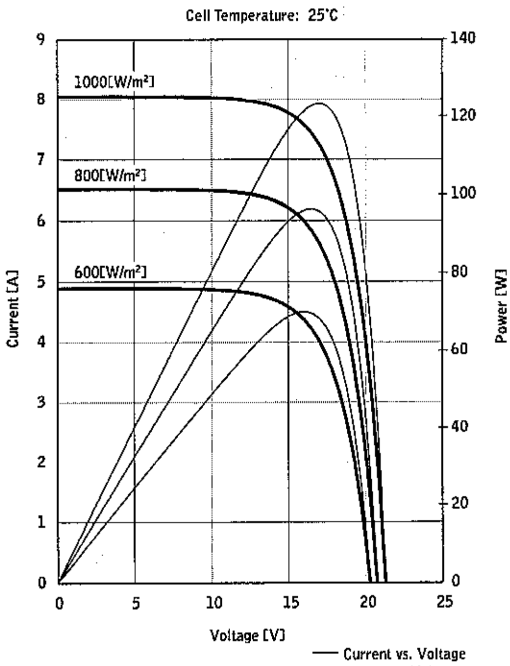
MECHANICAL CHARACTERISTICS

Dimensions (H x W x D)	59.02" x 26.06" x 1.81" 1499mm x 662mm x 46mm
Weight	30.86lbs / 14.0kg
Packing Configuration	2 pcs per carton
Size of Carton	62.99" x 30.71" x 5.12" 1600mm x 780mm x 130mm
Loading Capacity (20 ft container)	196 pcs (98 cartons)
Loading Capacity (40 ft container)	420 pcs (210 cartons)

ABSOLUTE MAXIMUM RATINGS

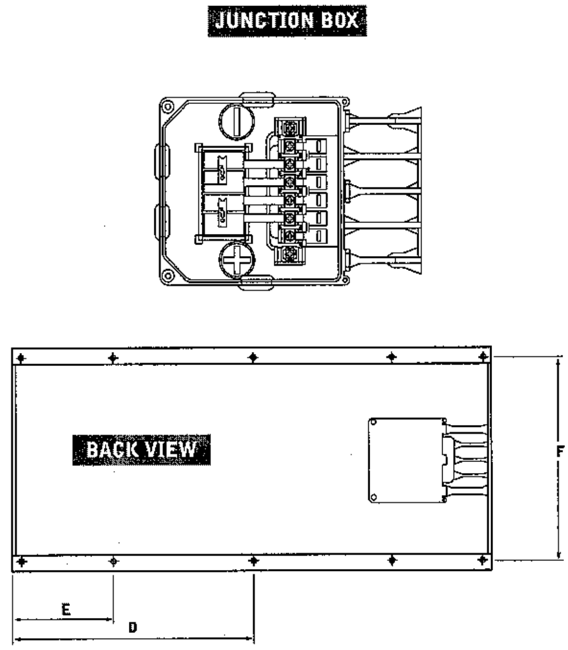
Operating Temperature	-40 to +194°F / -40 to +90°C
Storage Temperature	-40 to +194°F / -40 to +90°C

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



D	E	F
29.5"/749.5mm	9.8"/249.5mm	24.37"/619.0mm

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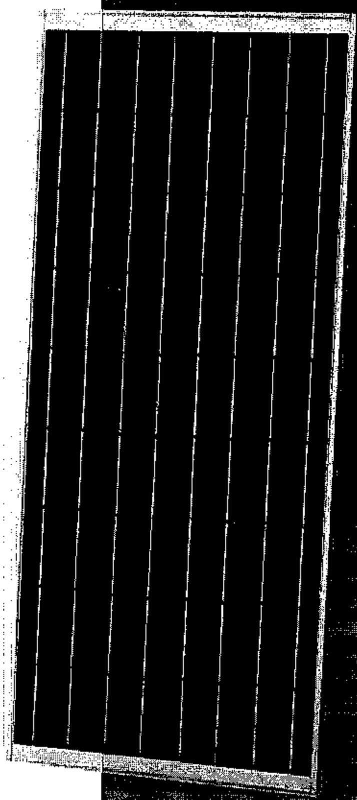
MULTI-PURPOSE MODULE

ND-L5E1U

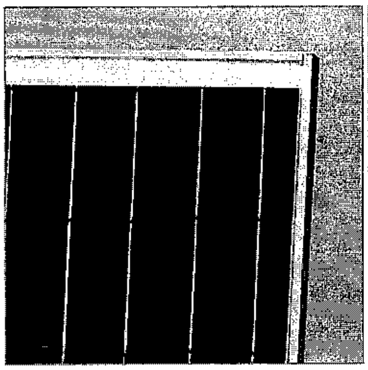


125 WATT

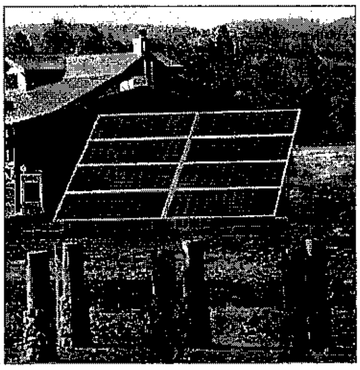
SUPERIOR DURABILITY. HIGH EFFICIENCY.

POLY-CRYSTALLINE SILICON PHOTOVOLTAIC MODULE WITH 125W MAXIMUM POWER

Sharp's ND-L5E1U photovoltaic modules offer industry-leading performance, durability, and reliability for a variety of electrical power requirements. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include cabins, solar power stations, pumps, beacons, and lighting equipment. Ideal for grid-connected systems and designed to withstand rigorous weather conditions, Sharp's ND-L5E1U modules are the perfect combination of advanced technology and reliability.



Solder-coated grid results in high fill factor performance under low light conditions.



Sharp multi-purpose modules offer industry-leading performance for a variety of applications.

FEATURES

- High-power module (125W) using 155mm square poly-crystalline silicon solar cells with 12.60% module conversion efficiency
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, "natural" look
- Bypass diodes minimize the power drop caused by shade
- Water white, tempered glass, EVA laminate, plus aluminum frame for extended outdoor use
- Nominal 12VDC output for battery charging applications
- UL Listings: UL 1703, cUL
- Sharp modules are manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output (see dealer for details)

MULTI-PURPOSE MODULE

125 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	36 in series
Open Circuit Voltage (Voc)	21.7V
Maximum Power Voltage (Vpm)	17.2V
Short Circuit Current (Isc)	8.14A
Maximum Power Current (Ipm)	7.3A
Maximum Power (Pmax)*	125W (+10% / -5%)
Module Efficiency (ηm)	12.60%
Maximum System Voltage	600VDC
Series Fuse Rating	15A
Type of Output Terminal	Lead Wire with MC Connector

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

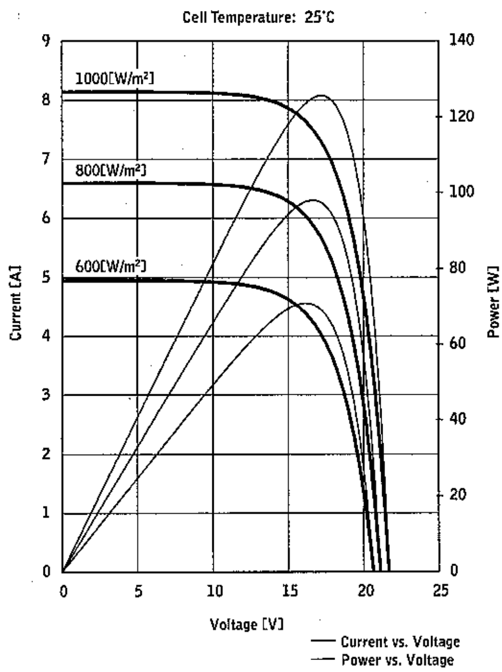
MECHANICAL CHARACTERISTICS

Dimensions (H x W x D)	59.02" x 26.06" x 1.81" 1499mm x 662mm x 46mm
Weight	30.86lbs / 14.0kg
Packing Configuration	2 pcs per carton
Size of Carton	63.39" x 30.71" x 5.12" 1610mm x 780mm x 130mm
Loading Capacity (20 ft container)	196 pcs (98 cartons)
Loading Capacity (40 ft container)	420 pcs (210 cartons)

ABSOLUTE MAXIMUM RATINGS

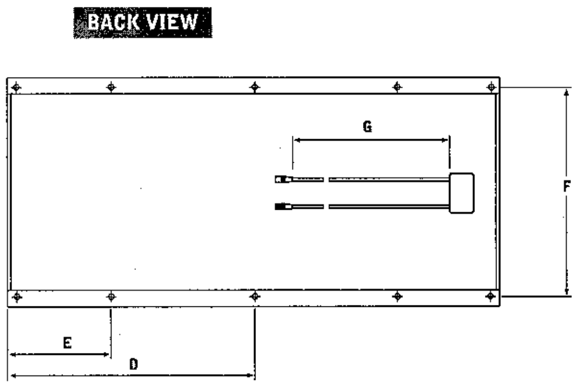
Operating Temperature	-40 to +194°F / -40 to +90°C
Storage Temperature	-40 to +194°F / -40 to +90°C

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



D	E	F	G
29.5"/749.5mm	9.8"/249.5mm	24.37"/619.0mm	51.2" +/- 2"/1300mm+/-50mm

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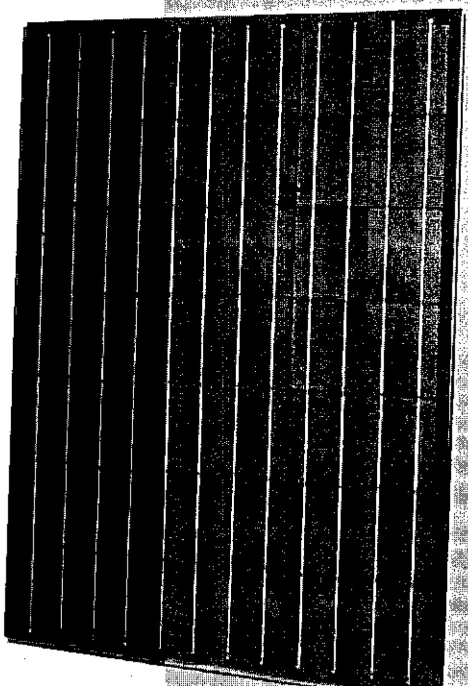
HARP®

RESIDENTIAL SYSTEM MODULE

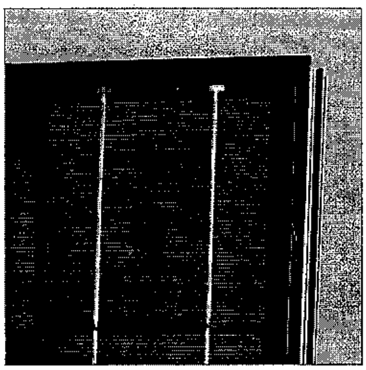
142 WATT

ATTRACTIVE LOOK. FLEXIBLE DESIGN.



POLY-CRYSTALLINE SILICON PHOTOVOLTAIC MODULE WITH 142W MAXIMUM POWER

Sharp's ND-N2ECU photovoltaic modules offer increased aesthetics and revolutionary design integration. These residential photovoltaic modules give the clean, attractive appearance of a high-tech skylight while the black anodized aluminum frames, trim strips, and backing sheets blend beautifully with the home's exterior. In addition, an "L" hook design located along the frame's perimeter ensures easy integration with the residential system mounting hardware. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. And, as the global leader in solar manufacturing, Sharp has designed these modules with superb durability and efficiency to withstand extreme heat and high winds. Sharp's ND-N2ECU is the perfect combination of technology and aesthetics.



The laminated glass module is glazed into a high torsion black anodized aluminum frame.

Sharp's residential modules with black frames, trim strips, and backing sheets allow for the seamless integration of the system into the home's design.

FEATURES

- High-power module (142W) using 155mm square poly-crystalline silicon solar cells with [illegible] module conversion efficiency
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, natural look
- Bypass diodes minimize the power drop caused by shade
- Black anodized aluminum frame and "L" hook design located along frame perimeter for easy integration with residential system mounting hardware
- Nominal 14 VDC output is an ideal match for the Sharp multi-string inverter
- Manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output (see dealer for details)
- UL Listings: UL 1703, cUL

RESIDENTIAL SYSTEM MODULE

142 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	42 in series
Open Circuit Voltage (Voc)	24.9V
Maximum Power Voltage (Vpm)	20.0V
Short Circuit Current (Isc)	7.92A
Maximum Power Current (Ipm)	7.11A
Maximum Power (Pmax)*	142W (+10% / -5%)
Module Efficiency (ηm)	12.31%
Maximum System Voltage	600VDC
Series Fuse Rating	15A
Type of Output Terminal	Lead Wire with MC Connector

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

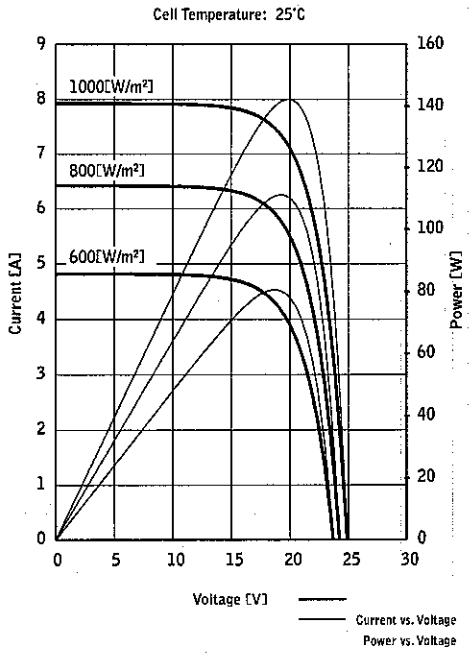
MECHANICAL CHARACTERISTICS

Dimensions (A x B x C below)	45.87" x 38.98" x 1.81" 1165mm x 990mm x 46mm
Weight	31.96lbs / 14.5kg
Packing Configuration	2 pcs per carton
Size of Carton	49.6" x 42.52" x 5.12" 1260mm x 1080mm x 130mm
Loading Capacity (20 ft container)	196 pcs (98 cartons)
Loading Capacity (40 ft container)	420 pcs (210 cartons)

ABSOLUTE MAXIMUM RATINGS

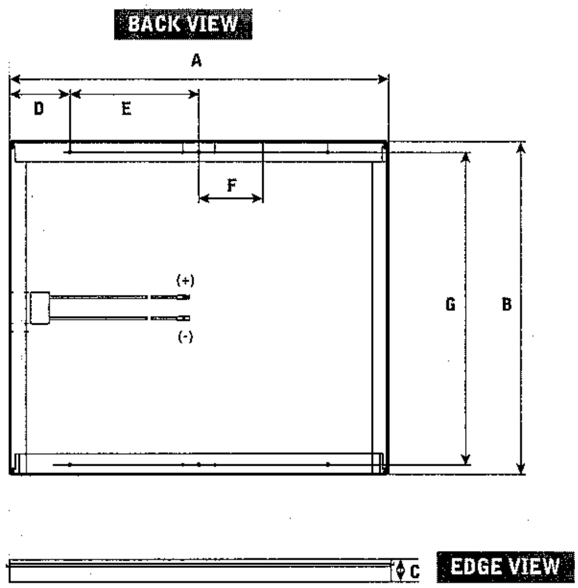
Operating Temperature	-40 to +194°F / -40 to +90°C
Storage Temperature	-40 to +194°F / -40 to +90°C

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



A	B	C	D	E	F	G
45.87"/1165mm	38.98"/990mm	1.81"/46mm	7.2"/182.5mm	15.75"/400mm	7.87"/200mm	36.85"/936mm

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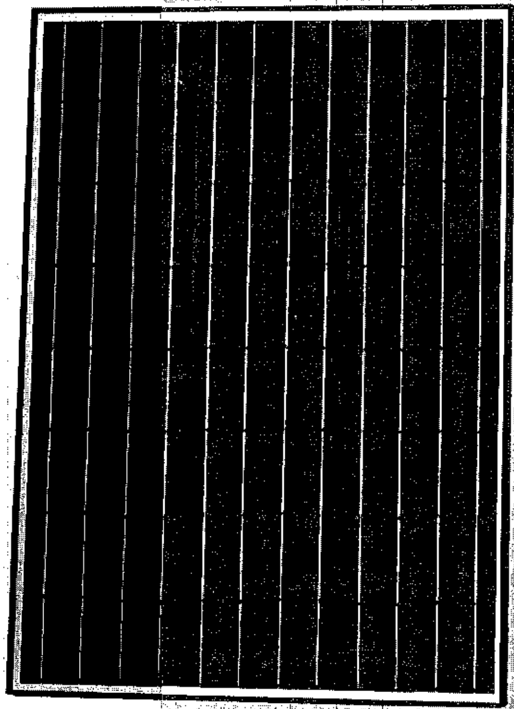
RESIDENTIAL SYSTEM MODULE

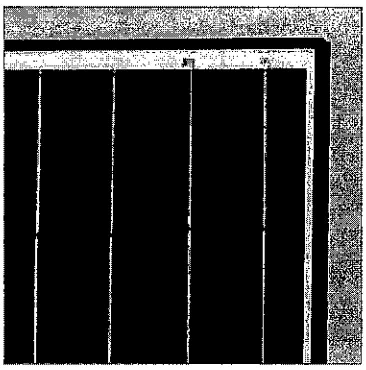
162 WATT

POWERFUL. ATTRACTIVE. RELIABLE.



POLY-CRYSTALLINE SILICON PHOTOVOLTAIC MODULE WITH 162W MAXIMUM POWER

Designed specifically for peak roofs, Sharp's ND-162U1 photovoltaic modules offer industry-leading performance and aesthetics. These residential modules give the clean, attractive appearance of a high-tech skylight while the black anodized aluminum frames and trim strips blend beautifully with the home's exterior. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. Sharp's ND-162U1 modules are the perfect combination of technology and aesthetics.



The laminated glass module is glazed into a high torsion black anodized aluminum frame.

Sharp's residential modules with black frames and trim strips are ideal for peak roofs, and allow for the seamless integration of the system into the home's design.

FEATURES

- [illegible] 162W using [illegible] poly-crystalline silicon solar cells with [illegible] module conversion efficiency
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, "natural" look
- Bypass diodes minimize the power drop caused by shade
- Water white tempered glass, EVA laminate, and a weatherproof film yield long-life modules while enhancing cell performance
- Nominal 16VDC output is an ideal match for the Sharp multi-string inverter
- Manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output (see dealer for details)
- UL Listings: UL 1703, cUL

RESIDENTIAL SYSTEM MODULE

162 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	48 in series
Open Circuit Voltage (Voc)	28.4V
Maximum Power Voltage (Vpm)	22.8V
Short Circuit Current (Isc)	7.92A
Maximum Power Current (Ipm)	7.11A
Maximum Power (Pmax)*	162W (+10% / -5%)
Module Efficiency (ηm)	12.40%
Maximum System Voltage	600VDC
Series Fuse Rating	15A
Type of Output Terminal	Lead Wire with MC Connector

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

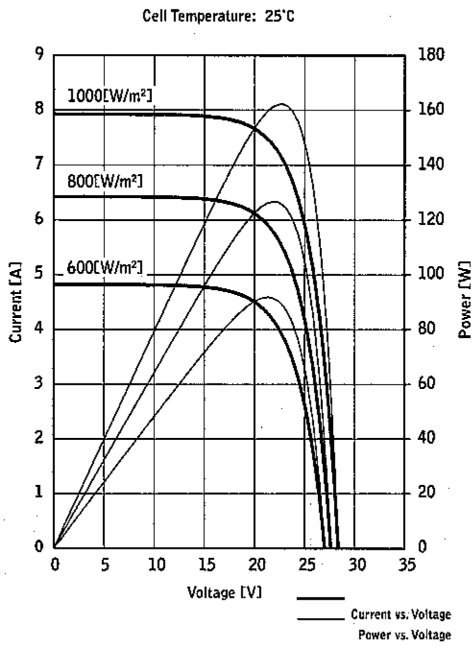
MECHANICAL CHARACTERISTICS

Dimensions (A x B x C below)	51.9" x 39.1" x 1.8" 1318mm x 994mm x 46mm
Weight	36.4lbs / 16.5kg
Packing Configuration	2 pcs per carton
Size of Carton	56.3" x 42.5" x 5.1" 1430mm x 1080mm x 130mm
Loading Capacity (20 ft container)	224 pcs (112 cartons)
Loading Capacity (40 ft container)	504 pcs (252 cartons)
Loading Capacity (53 ft container)	560 pcs (280 cartons)

ABSOLUTE MAXIMUM RATINGS

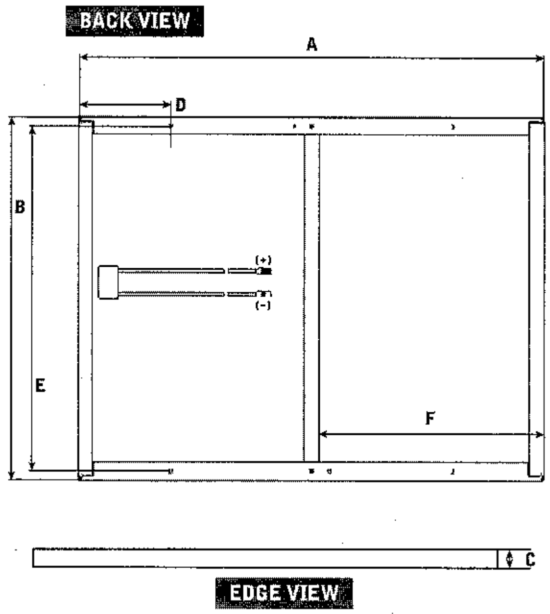
Operating Temperature	-40 to +194°F / -40 to +90°C
Storage Temperature	-40 to +194°F / -40 to +90°C

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



A	B	C	D	E	F
51.9"/1318mm	39.1"/994mm	1.8"/46mm	10.2"/259mm	37.1"/943mm	25.2"/639mm

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SSD-162-805 Printed in the USA

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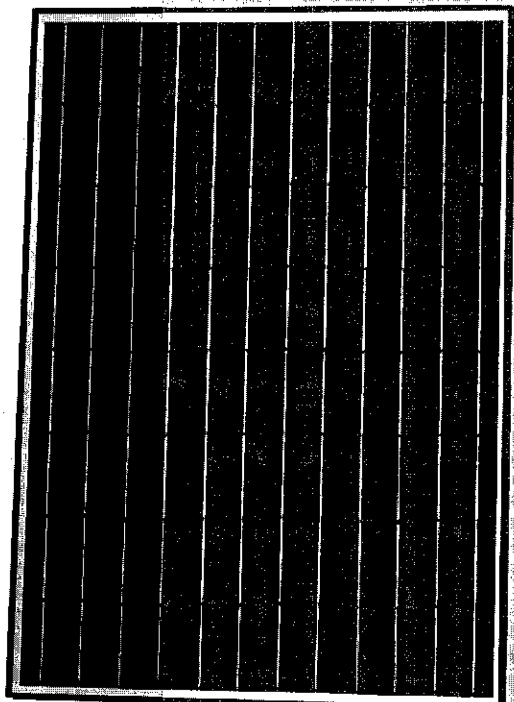
RESIDENTIAL SYSTEM MODULE

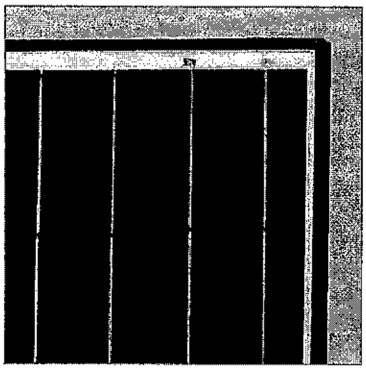
167 WATT

POWERFUL. ATTRACTIVE. RELIABLE.



POLY-CRYSTALLINE SILICON PHOTOVOLTAIC MODULE WITH 167W MAXIMUM POWER

Designed specifically for peak roofs, Sharp's ND-167U3A photovoltaic modules offer industry-leading performance and aesthetics. These residential modules give the clean, attractive appearance of a high-tech skylight while the black anodized aluminum frames and trim strips blend beautifully with the home's exterior. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. Sharp's ND-167U3A modules are the perfect combination of technology and aesthetics.



The laminated glass module is glazed into a high torsion black anodized aluminum frame.

Sharp's residential modules with black frames and trim strips are ideal for peak roofs, and allow for the seamless integration of the system into the home's design.

FEATURES

- High-power module (167W) using [illegible] poly-crystalline silicon solar cells with 12.7% module conversion efficiency
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued "natural" look
- Bypass diodes minimize the power drop caused by shade
- Water white tempered glass, EVA laminate, and a weatherproof film yield long-life modules while enhancing cell performance
- Manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output (See back for details)
- UL listings: UL 1703, cUL

RESIDENTIAL SYSTEM MODULE

167 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	48 in series
Open Circuit Voltage (Voc)	28.9V
Maximum Power Voltage (Vpm)	22.8V
Short Circuit Current (Isc)	8.16A
Maximum Power Current (Ipm)	7.33A
Maximum Power (Pmax)*	167W (+10% / -5%)
Module Efficiency (ηm)	12.7%
Maximum System Voltage	600VDC
Series Fuse Rating	15A
Type of Output Terminal	Lead Wire with MC Connector

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

MECHANICAL CHARACTERISTICS

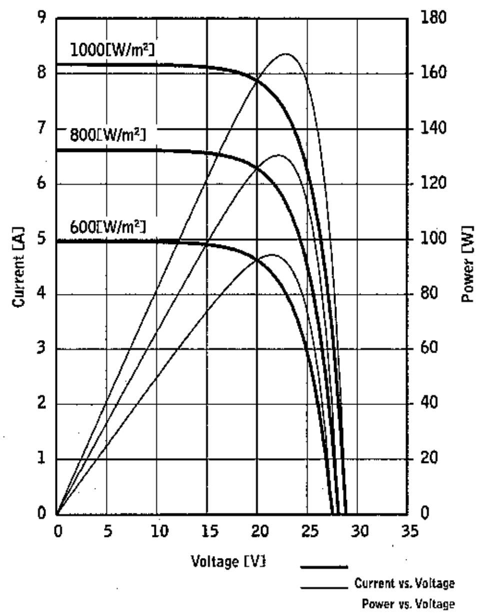
Dimensions (A x B x C below) 1318mm x 994mm x 46mm	51.9" x 39.1" x 1.8"
Weight	36.4lbs / 16.5kg
Packing Configuration	2 pcs per carton
Size of Carton	56.3" x 42.5" x 5.1" 1430mm x 1080mm x 130mm
Loading Capacity (20 ft container)	224 pcs (112 cartons)
Loading Capacity (40 ft container)	504 pcs (252 cartons)
Loading Capacity (53 ft container)	560 pcs (280 cartons)

ABSOLUTE MAXIMUM RATINGS

Operating Temperature	-40 to +194°F / -40 to +90°C
Storage Temperature	-40 to +194°F / -40 to +90°C

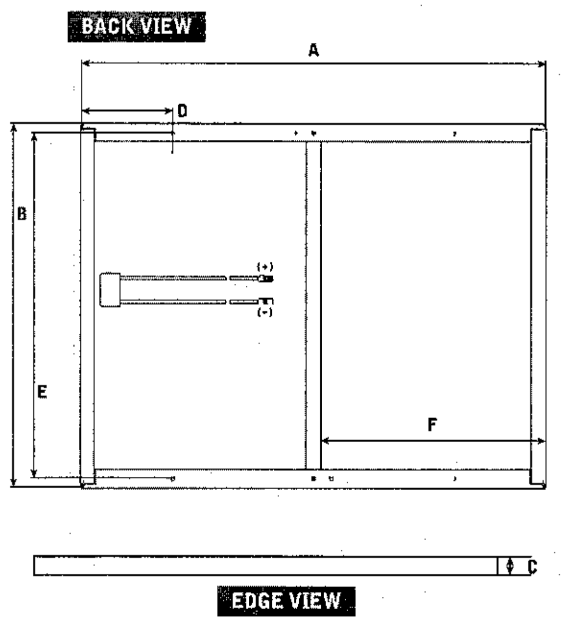
IV CURVES

Cell Temperature: 25°C



Current, Power vs. Voltage Characteristics

DIMENSIONS



A	B	C	D	E	F
51.9"/1318mm	39.1"/994mm	1.8"/46mm	10.2"/259mm	37.1"/943mm	25.2"/639mm

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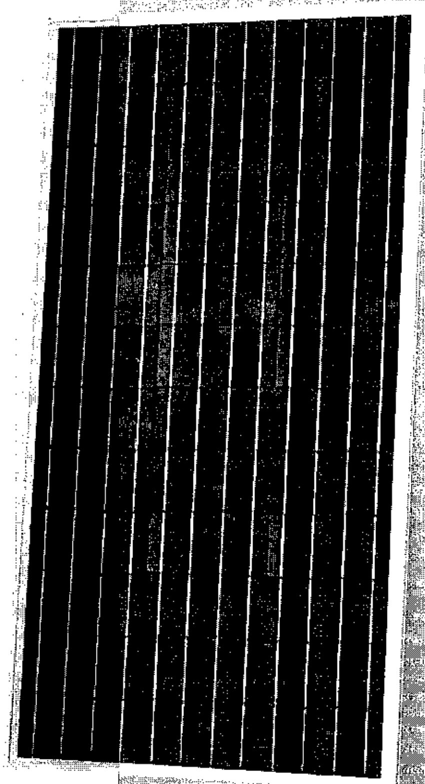
US

SHARP

MULTI-PURPOSE MODULE

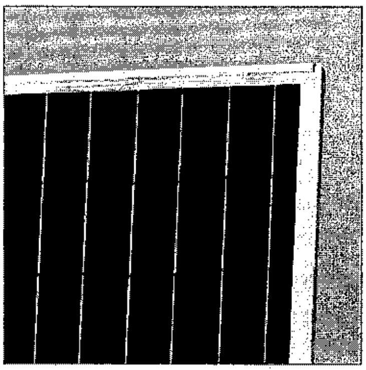
170 WATT

HIGH-POWERED MODULE. SUPERIOR PERFORMANCE.

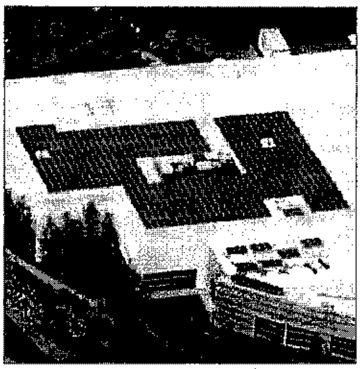


POLY-CRYSTALLINE SILICON PHOTOVOLTAIC MODULE WITH 170W MAXIMUM POWER

Sharp's NE-170U1 photovoltaic modules offer high-powered performance and industry-leading durability for large electrical power requirements. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include office buildings, houses, cabins, solar power stations, solar villages and traffic lights. Ideal for grid-connected systems and designed to withstand rigorous operating conditions, Sharp's NE-170U1 modules are the perfect combination of technology and reliability.



Solder-coated grid results in high fill factor performance under low light conditions.



Sharp multi-purpose modules offer industry-leading performance for a variety of applications.

FEATURES

- High-powered module (170W) using 125mm square poly-crystalline silicon solar cells with 13.10% module conversion efficiency
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, natural look
- Bypass diodes minimize the power drop caused by shade
- Water white, tempered glass, EVA laminate, plus aluminum frame for extended outdoor use
- Nominal 24VDC output is perfect for grid-connected systems
- UL Listings: UL 1703, cUL
- Sharp modules are manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output (see dealer for details)

MULTI-PURPOSE MODULE

170 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	72 in series
Open Circuit Voltage (Voc)	43.2V
Maximum Power Voltage (Vpm)	34.8V
Short Circuit Current (Isc)	5.47A
Maximum Power Current (Ipm)	4.9A
Maximum Power (Pmax)*	170W (+10% / -5%)
Module Efficiency (ηm)	13.10%
Maximum System Voltage	600VDC
Series Fuse Rating	10A
Type of Output Terminal	Lead Wire with MC Connector

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

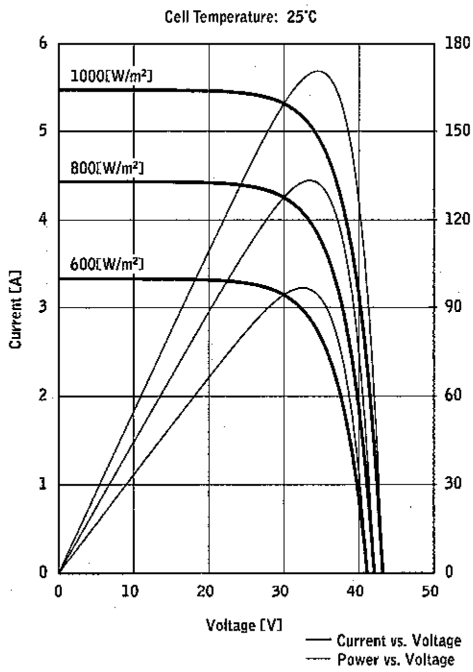
MECHANICAL CHARACTERISTICS

Dimensions (A x B x C below)	62.01" x 32.52" x 1.81" 1575mm x 826mm x 46mm
Weight	37.485lbs / 17.0kg
Packing Configuration	2 pcs per carton
Size of Carton	66.93" x 38.19" x 5.12" 1700mm x 970mm x 130mm
Loading Capacity (20 ft container)	168 pcs (84 cartons)
Loading Capacity (48 ft container)	448 pcs (224 cartons)
Loading Capacity (53 ft container)	504 pcs (252 cartons)

ABSOLUTE MAXIMUM RATINGS

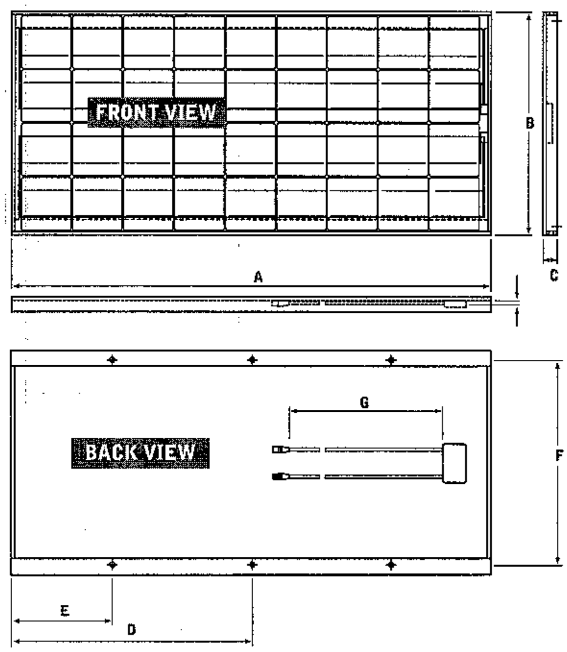
Operating Temperature	-40 to +194°F / -40 to +90°C
Storage Temperature	-40 to +194°F / -40 to +90°C

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



D	E	F	G
30.93"/785.5mm	7.3"/185.5mm	30.47"/774mm	35.4"/900mm

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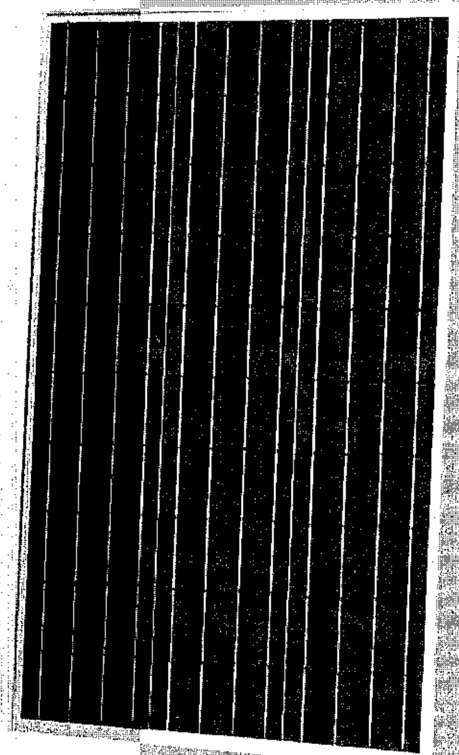
HARP®

MULTI-PURPOSE MODULE

ND-200U1

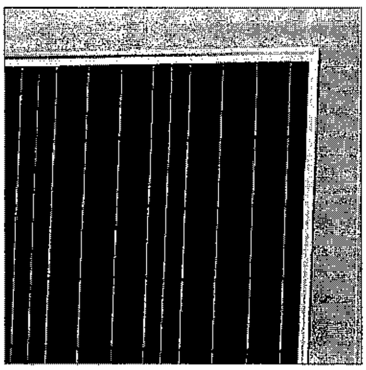


200 WATT

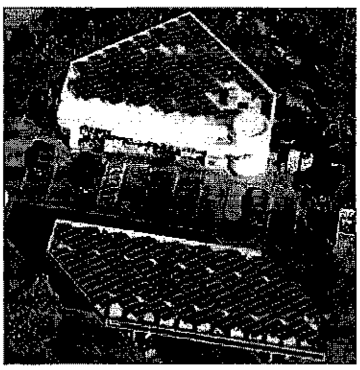
NEXT GENERATION. BREAKTHROUGH PERFORMANCE.

POLY-CRYSTALLINE SILICON PHOTOVOLTAIC MODULE WITH 200W MAXIMUM POWER

This poly-crystalline 200 watt module features 12.3% module efficiency for an outstanding balance of size and weight to power and performance. Using breakthrough technology perfected by Sharp's 45 years of research and development, these modules incorporate an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include office buildings, cabins, solar power stations, solar villages, radio relay stations, beacons, traffic lights and security systems. Ideal for grid-connected systems and designed to withstand rigorous operating conditions, Sharp's ND-200U1 modules offer maximum power output per square foot of solar array.



Solder-coated grid results in high fill factor performance under low light conditions.



Sharp multi-purpose modules offer industry-leading performance for a variety of applications.

FEATURES

- High-power module (200W) using 155mm square poly-crystalline silicon solar cells with 12.3% module conversion efficiency
- Sharp's advanced surface texturing process increases light absorption and efficiency while providing a more subdued, "natural" look
- Bypass diodes minimize the power drop caused by shade
- White tempered glass, EVA resin and a weatherproof film, plus aluminum frame for extended outdoor use
- UL Listings: UL 1703, cUL
- Sharp modules are manufactured in ISO 9001 certified facilities
- 25-year limited warranty on power output. (See dealer for details)

MULTI-PURPOSE MODULE

200 WATT

ELECTRICAL CHARACTERISTICS

Cell	Poly-crystalline silicon
No. of Cells and Connections	60 in series
Open Circuit Voltage (Voc)	35.5V
Maximum Power Voltage (Vpm)	28.5V
Short Circuit Current (Isc)	7.82A
Maximum Power Current (Ipm)	7.02A
Maximum Power (Pmax)*	200W (+10% / -5%)
Module Efficiency (η_m)	12.3%
Maximum System Voltage	600VDC
Series Fuse Rating	15A
Type of Output Terminal	Cable with MC Connector

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

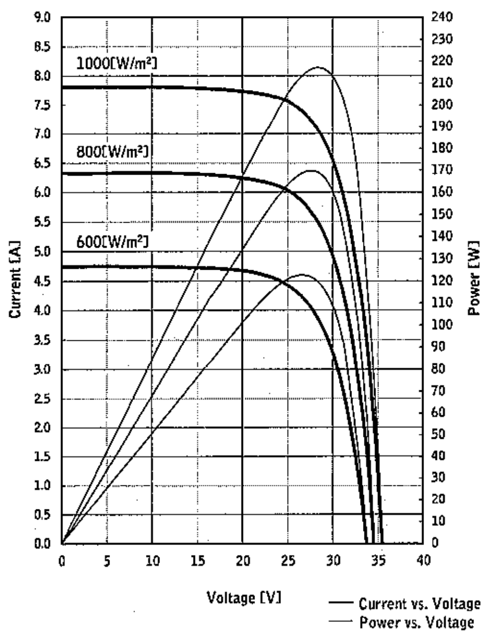
MECHANICAL CHARACTERISTICS

Dimensions (L x W x D)	64.6" x 39.1" x 1.8" / 1640mm x 994m x 46mm
Weight	46.3lbs / 21kg
Size of Carton	68.3" x 43.2" x 4.5" / 1735mm x 1097mm x 114mm
Carton Quantity	2 pcs per carton
Pallet Quantity	28 pcs per pallet
Loading Capacity (48 ft container)	448 pcs (16 pallets)
Loading Capacity (53 ft container)	476 pcs (17 pallets)

ABSOLUTE MAXIMUM RATINGS

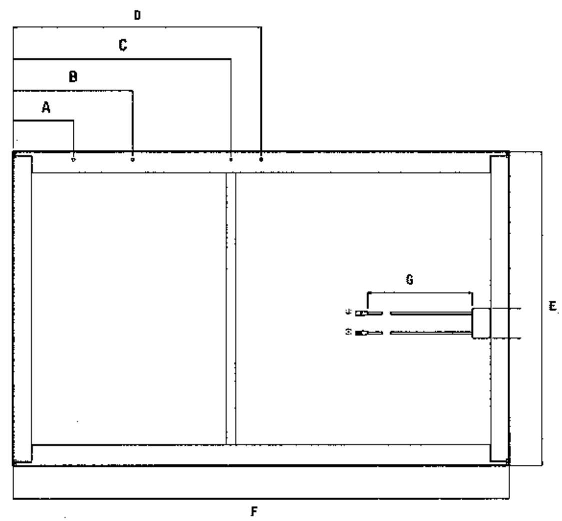
Operating Temperature (min to max, °F/°C)	-40 to +194°F / -40 to +90°C
Storage Temperature (min to max, °F/°C)	-40 to +194°F / -40 to +90°C

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



A	B	C	D
7.87"/200mm	15.55"/395mm	28.35"/720mm	32.28"/820mm
E	**F**	**G**	
39.13"/994mm	64.57"/1640mm	51.18"/1300mm	

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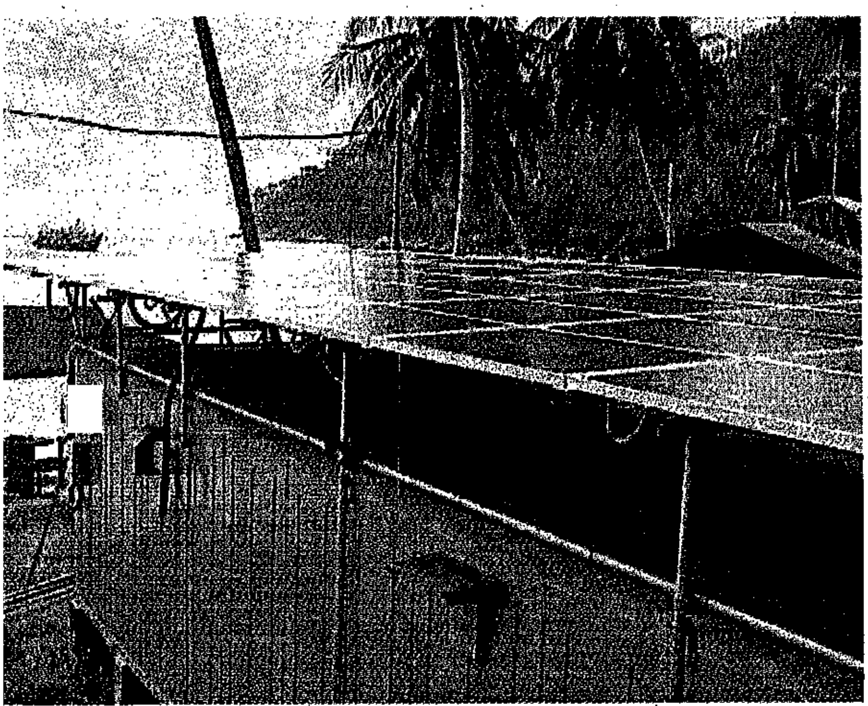
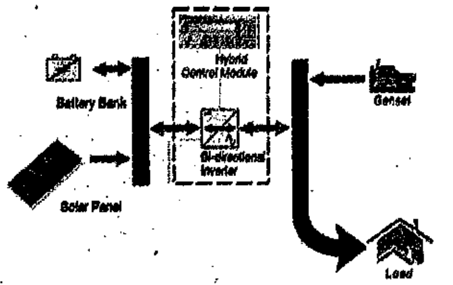
Cover photo: Solar installation by Pacific Power Management, Auburn CA SSD-200-805

NST 6/1/2005 - 5 :CISB PRECISB

B provides Solar Hybrid Power d economic power



g Pak Kaleh in Pulau Pemanggil



Concept of Solar Hybrid System

JOHOR BAHRU: Life has changed for the better for the inhabitants on remote islands off the coast of Mersing. In cooperation with the Government's Five Fuel Strategy, TNB is electrifying remote islands and villages throughout Malaysia by means of Solar Hybrid Systems (SHS).

The reliable and constant energy supply means fishermen, from six of these islands, can now keep their daily catch fresh for market in deep freezers. Prior to SHS, fish had to be eaten or sold the same day. This is only one, but clearly beneficial, improvement to the islander's lives and the economies of the islands.

SHS are a combination of solar power panels and generator sets. Battery packs store solar power generated through the day to deliver a 24-hour power supply. Fuelled predominantly by solar power, the generator sets kick-in during overcast days.

Supplied and operated by TNB, SHS can positively impact the lives of thousands of Malaysians living on remote islands and within jungle interiors. Realising the human benefits the systems offer, TNB is looking into ways of further promoting solar and other renewable energy sources into the future.

ile

SHS, standalone solar panels were fitted to many homes in remote These offered only 4 to 5 hours of minimal power a day

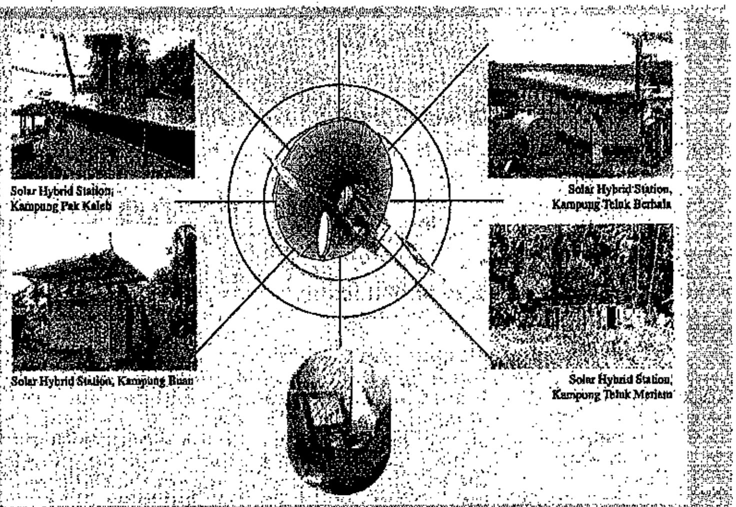
SHS to be installed in Malaysia was in Langkawi, Kedah in 2001. It provides r facilities at a tourist cable car attraction on Gunung Machinchang. SHS sen so as the views from the cable car would not be spoilt by power lines

monitored remotely and no permanent TNB staff are required on site

stations were recently installed to islands near Pulau Tioman at a cost million, two villages on a nearby island will soon be enjoying the cilities

five islands around Malaysia enjoy SHS and soon, 16 remote villages in five ill also benefit from the service

ICIARY	Pulau Besar	Pulau Pemanggil	Pulau Sibu	Pulau Aur
use	20	32	68	42
hool	0	1	1	1
sque	1	1	1	2
munity nter	1	1	1	1
estay	8	4	13	10
tal	30	39	84	56



Remote Monitoring and SCADA features

ly a fisherman electricity and an eat for life

When they sat ir first meal with ien on Pulau Aur, and technicians Nasional Berhad the veritable feast hem.

as so much fish to naga-ES (a wholly sidiary of TNB) ohd. Azhar Abdul iember of the team rs and technicians to the island to install Solar Hybrid Systems (SHS) on the island last year.

"I realised after the meal that without freezers to store their catch, the fishermen had to eat almost everything they caught each day.

Before SHS, electricity was provided by diesel-fuelled generators which cost as much as RM500 a month to supply electricity 12 hours a day to 6 homes.

Since the deployment of the SHS, the same households now enjoy uninterrupted power supply at a fraction of the cost – just RM60 per month.

So what of the "fish feasts" of last year?

"Well, now they have freezers, on our last visit the feast was definitely not as much as it was.

"But, the hospitality remained the same. They made us feel proud to work for TNB," said Mohd. Azhar, smiling.

Islanders' bountiful daily catch

Power supply to industry buildings and thousands of homes

Renewed interest in renewable energy

NST 23/8/2005 - 7

PRECISB

PORT DICKSON: Tenaga Nasional Berhad (TNB) reinforced the organisation's commitment to the Government's Five Fuel Strategy with the launch of the gas-fuelled PD1 power plant.

Introduced in the 1990's, the policy was aimed at the diversification of the nation's electricity generation mix through the development of indigenous energy resources.

TNB's current energy generation mix is approximately 35% coal, 34.7% natural gas and 18.2% hydro with the remaining 12.1% from oil, gas and diesel for a combined installed capacity of 10,481MW.

TNB has also driven the development of Renewable Energy (RE) resources into commercially viable ventures through Renewable Energy Power Purchase Agreements (REPPA).

Under the agreements, power generated from RE fuels is linked to the National Grid.

Five such agreements have been signed in Peninsular Malaysia to date, with a total generation capacity of 26.2MW fuelled by oil palm waste, landfill gas and municipal waste.

TNB is also negotiating REPPA with developers of small Government-backed renewable energy programmes utilising mini hydro, landfill gas and other biomass resources such as wood waste and rice husk.

Growing up in a green environment

TNB may get Govt nod to up power prices by 10pc

mm 16/8/2005 - 36

PRECISE

TENAGA Nasional Bhd (TNB) may get Government approval by December to raise electricity prices by as much as 10 per cent, a Credit Suisse First Boston (CSFB) analyst said.

The company may receive a 2.35 sen per kilowatt-hour increase in gross rates because of a higher cost of natural gas, Tan Ting Min, a CSFB analyst, wrote in the daily note yesterday.

TNB has been seeking Government approval to increase power prices that were last raised in May 1997. The company said last month that power failures may occur if it doesn't get a rate increase within four years because the company would lack funds to upgrade and maintain its power lines.

The analyst left her "neutral" recommendation on TNB's shares unchanged. TNB buys natural gas from Petroliam Nasional Bhd (Petronas) at a subsidised rate.

TNB has to raise its power prices by 0.8 sen per kilowatt-hour, or 3.4 per cent, to cover every RM1, or 16 per cent, increase in per million British thermal units of gas, CSFB said. – Bloomberg

TNB in talks with firm to save fuel costs

S 5/5/05 - 3

PRECISE

TENAGA NASIONAL BERHAD

TENAGA Nasional Bhd (TNB) is said to be currently exploring the use of a technology that would enable coal-fired power plants to use high sulphur coal and save the power industry billions of ringgit in fuel cost.

The process, which involves applying a chemical to crushed coal, is said to lower emissions of pollutants created by the burning of coal and increases the efficiency of the burn. "This GTS technology works on all types of coal and hence offers a large profit margin for the end user. It is fundamentally a pre-combustion technique that offers flexibility in operations, and users do not have to retrofit existing plant facilities to use it," said Alpha Beyond Sdn Bhd director Adrian Ooi.

Alpha Beyond has been granted an exclusive licence to operate, develop and commercialise the technology. It calculates that based on coal consumption of 20 million tonnes per annum, power companies in Malaysia would be able to save RM1.9bil per annum in coal costs assuming the price of coal remains at current prices.

"The GTS technology will provide power generation companies such as TNB and other independent power producers an amazing economic advantage," Ooi said in a statement. "Together with YTS Engineerings Sdn Bhd, we are in final discussions with TNB for the long-term utilisation of coal treated with GTS technology in Malaysia. TNB has established a special task force to explore the beneficial technology for the major coal-fired power plants in Malaysia," he added. Alpha Beyond has formed a marketing alliance with YTS Engineerings to market the technology to all coal-fired power generation plants in Malaysia.

The statement said high sulphur coal had not been a viable option thus far as burning of such coal did not meet environmental and quality laws and guidelines and due to significant increase in demand for low sulphur coal for generation activity, the cost of low sulphur coal had doubled over the past two years.

APPENDIX

RESIDENTIAL COOLING LOAD CALCULATIONS

Project ______ Location ______

Out DB ____ F In DB ____ F DR ____

Out WB ____ F In RH ____ % ACH ____

Room Name																				
Plan Size																				
	D.	U	A	CLTD	BTU/hr	D.	U	A	CLTD	BTU/hr	D.	U	A	CLTD	BTU/hr	D.	U	A	CLTD	BTU/hr
Wall																				
Roof/ceiling																				
Floor																				
Partition																				
Door																				
	D.		CLF			D.		CLF			D.		CLF			D.		CLF		
Windows																				
Infiltration																				
People																				
Appliances																				
RSCL																				

Room Name																				
Plan Size																				
	D.	U	A	CLTD	BTU/hr	D.	U	A	CLTD	BTU/hr	D.	U	A	CLTD	BTU/hr	D.	U	A	CLTD	BTU/hr
Wall																				
Roof/ceiling																				
Floor																				
Partition																				
Door																				
	D.		CLF			D.		CLF			D.		CLF			D.		CLF		
Windows																				
Infiltration																				
People																				
Appliances																				
RSCL																				

Building Total

Sum RSCL = ____________

Duct gain ____ % = ____________

Duct leak ____ % = ____________

BSCL = ____________

BTCL = ____ × BSCL = ____________

Unit size = ____________

NOTES:

Figure A.4
Residential cooling load calculations form.

ABLE 6.19 CLTD VALUES FOR SINGLE-FAMILY DETACHED RESIDENCES[a]

	Design Temperature, °F											
	85		90			95			100		105	110
Daily Temp. Range[b]	L	M	L	M	H	L	M	H	M	H	M	H
ll walls and doors												
North	8	3	13	8	3	18	13	8	18	13	18	23
NE and NW	14	9	19	14	9	24	19	14	24	19	24	29
East and West	18	13	23	18	13	28	23	18	28	23	28	33
SE and SW	16	11	21	16	11	26	21	16	26	21	26	31
South	11	6	16	11	6	21	16	11	21	16	21	26
oofs and ceilings												
Attic or flat built-up	42	37	47	42	37	51	47	42	51	47	51	56
loors and ceilings												
Under conditioned space, over unconditioned room, over crawl space	9	4	12	9	4	14	12	9	14	12	14	19
Partitions												
Inside or shaded	9	4	12	9	4	14	12	9	14	12	14	19

[a]Cooling load temperature differences (CLTDs) for single-family detached houses, duplexes, or multifamily, with both east and west exposed walls or only north and south exposed walls, °F.

[b]L denotes low daily range, less than 16 °F; M denotes medium daily range, 16 to 25 °F; and H denotes high daily range, greater than 25 °F.

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TABLE 6.20 WINDOW GLASS LOAD FACTORS (GLF) FOR SINGLE-FAMILY DETACHED RESIDENCES[a]

Design Temperature, °F	Regular Single Glass						Regular Double Glass						Heat-Absorbing Double Glass						Clear Triple Glass		
	85	90	95	100	105	110	85	90	95	100	105	110	85	90	95	100	105	110	85	90	95
No inside shading																					
North	34	36	41	47	48	50	30	30	34	37	38	41	20	20	23	25	26	28	27	27	30
NE and NW	63	65	70	75	77	83	55	56	59	62	63	66	36	37	39	42	44	44	50	50	53
E and W	88	90	95	100	102	107	77	78	81	84	85	88	51	51	54	56	59	59	70	70	73
SE and SW[b]	79	81	86	91	92	98	69	70	73	76	77	80	45	46	49	51	54	54	62	63	65
South[b]	53	55	60	65	67	72	46	47	50	53	54	57	31	31	34	36	39	39	42	42	45
Horizontal skylight	156	156	161	166	167	171	137	138	140	143	144	147	90	91	93	95	96	98	124	125	127
Draperies, venetian blinds, translucent roller shades fully drawn																					
North	18	19	23	27	29	33	16	16	19	22	23	26	13	14	16	18	19	21	15	16	18
NE and NW	32	33	38	42	43	47	29	30	32	35	36	39	24	24	27	29	29	32	28	28	30
E and W	45	46	50	54	55	59	40	41	44	46	47	50	33	33	36	38	38	41	39	39	41
SE and SW[b]	40	41	46	49	51	55	36	37	39	42	43	46	29	30	32	34	35	37	35	36	38
South[b]	27	28	33	37	38	42	24	25	28	31	31	34	20	21	23	25	26	28	23	24	26
Horizontal skylight	78	79	83	86	87	90	71	71	74	76	77	79	58	59	61	63	63	65	69	69	71
Opaque roller shades fully drawn																					
North	14	15	20	23	25	29	13	14	17	19	20	23	12	12	15	17	17	20	13	13	15
NE and NW	25	26	31	34	36	40	23	24	27	30	30	33	21	22	24	26	27	29	23	23	26
E and W	34	36	40	44	45	49	32	33	36	38	39	42	29	30	32	34	35	37	32	32	35
SE and SW[b]	31	32	36	40	42	46	29	30	33	35	36	39	26	27	29	31	32	34	29	29	31
South[b]	21	22	27	30	32	36	20	20	23	26	27	30	18	19	21	23	24	26	19	20	22
Horizontal skylight	60	61	64	68	69	72	57	57	60	62	63	65	52	52	55	57	57	59	56	57	59

[a]Glass load factors (GLFs) for single-family detached houses, duplexes, or multifamily, with both east and west exposed walls or only north and south exposed walls, Btu/h • ft².

[b]Correct by +30% for latitude of 48° and by −30% for latitude of 32°. Use linear interpolation for latitude from 40 to 48° and from 40 to 32°.

To obtain GLF for other combinations of glass and/or inside shading: $GLF_a = (SC_a/SC_t)(GLF_t - U_tD_t) + U_aD_t$, where the subscripts a and t refer to the alternate and table values, respectively. SC_t and U_t are given in Table 5. $D_t = (t_a - 75)$, where $t_a = t_o - (DR/2)$; t_o is the outdoor design temperature and DR is the daily range.

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TABLE 6.21 SHADE LINE FACTORS (SLF)

Direction Window Faces	Latitude, Degrees N						
	24	32	36	40	44	48	52
East	0.8	0.8	0.8	0.8	0.8	0.8	0.8
SE	1.8	1.6	1.4	1.3	1.1	1.0	0.9
South	9.2	5.0	3.4	2.6	2.1	1.8	1.5
SW	1.8	1.6	1.4	1.3	1.1	1.0	0.9
West	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Shadow length below the overhang equals the shade line factor times the overhang width. Values are averages for the 5 h of greatest solar intensity on August 1. Reprinted with permission from the *1997 ASHRAE Handbook—Fundamentals.*

TABLE 6.22 AIR CHANGE RATES AS A FUNCTION OF OUTDOOR DESIGN TEMPERATURES

Class	Outdoor Design Temperature, °F					
	85	90	95	100	105	110
Tight	0.33	0.34	0.35	0.36	0.37	0.38
Medium	0.46	0.48	0.50	0.52	0.54	0.56
Loose	0.68	0.70	0.72	0.74	0.76	0.78

Values for 7.5 mph wind and indoor temperature of 75°F.
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TABLE A.7 OVERALL HEAT TRANSFER COEFFICIENT *U* FOR BUILDING CONSTRUCTION COMPONENTS, BTU/HR-FT^2-F

Construction	*U*-Value in BTU/hr-ft^2-F	
	Summer	**Winter**
WALLS		
Frame with wood siding, sheathing, and inside finish:		
No insulation	.22	.23
R-7 insulation (2 in.–2½ in.)	.09	.09
R-11 insulation (3 in.–3½ in.)	.07	.07
Frame with 4 in. brick or stone veneer, sheathing, and inside finish:		
No insulation	.24	.24
R-7 insulation	.09	.09
R-11 insulation	.07	.07
Frame with 1 in. stucco, sheathing, and inside finish:		
No insulation	.29	.29
R-7 insulation	.10	.10
R-11 insulation	.07	.07
Masonry:		
8 in. concrete block, no finish	.49	.51
12 in. concrete block, no finish	.45	.47
Masonry (8 in. concrete block):		
Inside finish:		
furred gypsum wallboard (½ in.); no insulation	.29	.30
furred, foil-backed gypsum wallboard (½ in.); no insulation	.29	.30
1 in. polystyrene insulation board (*R*-5), and ½ in. gypsum wallboard	.13	.13
Masonry (8 in. cinder block or hollow clay tile):		
Inside finish:		
furred gypsum wallboard (½ in.); no insulation	.25	.25
furred, foil-backed gypsum wallboard (½ in.); no insulation	.17	.17
1 in. polystyrene insulation board (*R*-5), and ½ in. gypsum wallboard	.12	.12
Masonry (4 in. face brick and 8 in. cinder block or 8 in. hollow clay tile):		
Inside finish:		
furred gypsum wallboard (½ in.); no insulation	.22	.22
furred, foil-backed gypsum wallboard (½ in.); no insulation	.15	.16
1 in. polystyrene insulation board (*R*-5), and ½ in. gypsum wallboard	.12	.12
Masonry (12 in. hollow clay tile or 12 in. cinder block):		
Inside finish:		
furred gypsum wallboard (½ in.); no insulation	.24	.24
furred, foil-backed gypsum wallboard (½ in.); no insulation	.16	.17
1 in. polystyrene insulation board (*R*-5), and ½ in. gypsum wallboard	.12	.12
Masonry (4 in. face brick, 4 in. common brick):		
Inside finish:		
furred gypsum wallboard (½ in.); no insulation	.28	.28
furred, foil-backed gypsum wallboard (½ in.); no insulation	.18	.19
1 in. polystyrene insulation board (*R*-5), and ½ in. gypsum wallboard	.13	.13
Masonry (8 in. concrete or 8 in. stone):		
Inside finish:		
furred gypsum wallboard (½ in.); no insulation	.33	.34
furred, foil-backed gypsum wallboard (½ in.); no insulation	.21	.21
1 in. polystyrene insulation board (*R*-5), and ½ in. gypsum wallboard	.14	.14
Metal with vinyl inside finish, *R*-7 (3 in. glass fiber batt)	.14	.14
PARTITIONS		
Frame (½ in. gypsum wallboard one side only): No insulation	.55	.55
Frame (½ in. gypsum wallboard each side):		
No insulation	.31	.31
R-11 insulation	.08	.08
Masonry (4 in. cinder block):		
No insulation, no finish	.40	.40
No insulation, one side furred gypsum wallboard (½ in.)	.26	.26
No insulation, both sides furred gypsum wallboard (½ in.)	.19	.19
One side 1 in. polystyrene insulation board (*R*-5), and ½ in. gypsum wallboard	.13	.13

TABLE A.7 (Continued)

Construction	*U*-Value in BTU/hr-ft²-F	
	Summer	Winter
CEILING–FLOOR		
Frame (asphalt tile floor, ⅝ in. plywood, 25/32 in. wood subfloor, finished ceiling):		
Heat flow up	.23	.23
Heat flow down	.20	.19
Concrete (asphalt tile floor, 4 in. concrete deck, air space, finished ceiling):		
Heat flow up	.34	.33
Heat flow down	.26	.25
ROOF (flat roof, no finished ceiling)		
Steel deck:		
No insulation	.64	.86
1 in. insulation (*R*-2.78)	.23	.25
2 in. insulation (*R*-5.56)	.15	.16
1 in. Wood deck:		
No insulation	.40	.48
1 in. insulation (*R*-2.78)	.19	.21
2 in. insulation (*R*-5.56)	.12	.13
2.5 in. Wood deck:		
No insulation	.25	.26
1 in. insulation (*R*-2.78)	.15	.16
2 in. insulation (*R*-5.56)	.10	.11
4 in. Wood deck:		
No insulation	.17	.18
1 in. insulation (*R*-2.78)	.12	.12
2 in. insulation (*R*-5.56)	.09	.09
ROOF–CEILING (flat roof, finished ceiling)		
Steel deck:		
No insulation	.33	.40
1 in. insulation (*R*-2.78)	.17	.19
2 in. insulation (*R*-5.56)	.12	.13
1 in. Wood deck:		
No insulation	.26	.29
1 in. insulation (*R*-2.78)	.15	.16
2 in. insulation (*R*-5.56)	.11	.11
2.5 in. Wood deck:		
No insulation	.18	.20
1 in. insulation (*R*-2.78)	.12	.13
2 in. insulation (*R*-5.56)	.09	.10
4 in. Wood deck:		
No insulation	.14	.15
1 in. insulation (*R*-2.78)	.10	.10
2 in. insulation (*R*-5.56)	.08	.08
4 in. Lightweight concrete deck:		
No insulation	.14	.15
6 in. Lightweight concrete deck:		
No insulation	.10	.11
8 in. Lightweight concrete deck:		
No insulation	.08	.09
2 in. Heavyweight concrete deck:		
No insulation	.32	.38
1 in. insulation (*R*-2.78)	.17	.19
2 in. insulation (*R*-5.56)	.11	.12
4 in. Heavyweight concrete deck:		
No insulation	.30	.36
1 in. insulation (*R*-2.78)	.16	.18
2 in. insulation (*R*-5.56)	.11	.12
6 in. Heavyweight concrete deck:		
No insulation	.28	.33
1 in. insulation (*R*-2.78)	.16	.17
[illegible]	.11	.12

TABLE A.7 (Continued)

Construction	*U*-Value in BTU/hr-ft²-F	
	Summer	Winter
ROOF–CEILING (wood frame pitched roof, finished ceiling on rafters)		
No insulation	.28	.29
R-19 insulation (5½ in.–6½ in.)	.05	.05
ROOF–ATTIC–CEILING (attic with natural ventilation)		
No insulation	.15	.29
R-19 insulation (5½ in.–6½ in.)	.04	.05
FLOORS		
Floor over unconditioned space, no ceiling:		
Wood frame:		
No insulation	.33	.27
R-7 insulation (2 in.–2½ in.)	.09	.08
Concrete deck:		
No insulation	.59	.43
R-7 insulation	.10	.09
DOORS		
Solid wood:		
1 in. thick	.61	.64
1½ in. thick	.47	.49
2 in. thick	.42	.43
Steel:		
1½ in. thick, mineral fiber core	.58	.59
1½ in. thick, polystyrene core	.46	.47
1½ in. thick, urethane foam core	.39	.40

TABLE A.8 OVERALL HEAT TRANSFER COEFFICIENT *U* FOR GLASS (BTU/HR-FT²-F) (For glass installed vertically)

Type of Glazing	Type of Frame (Sash)			
	Aluminum (with thermal break)		Wood or Vinyl	
	Winter	Summer	Winter	Summer
Single glass	1.10	1.01	0.98	0.90
Double glass				
⅜ in. air space	0.60	0.56	0.51	0.47
⅜ in. air space E-film	0.48	0.45	0.39	0.37
Triple Glass				
⅜ in. air space	0.46	0.43	0.38	0.36
⅜ in. argon space	0.34	0.33	0.25	0.24

Note: E-film is a reflective coating (E = 0.15).
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TABLE A.9 OUTDOOR HEATING AND COOLING DESIGN CONDITIONS—WORLD LOCATIONS—(CONCLUDED)

		Heating		Cooling				
Location	LAT	Degree Days	DB	DB	MWB	WB	MDB	DR
SAUDI ARABIA								
Riyadh	25N		41	111	64	69	96	25
SINGAPORE								
Singapore	1N		73	91	79	81	88	11
SOUTH AFRICA								
Johannesburg	26S		34	84	60	65	77	19
SPAIN								
Barcelona	41N		32	85	74	77	83	15
Madrid	41N		24	97	69	71	94	29
SWEDEN								
Stockholm	59N		-1	79	63	66	74	16
SWITZERLAND								
Geneva	46N		18	86	66	68	82	22
TAIWAN								
Taipei	25N		48	94	80	82	91	13
THAILAND								
Bangkok	14N		65	99	80	84	94	17
TURKEY								
Istanbul	41N		26	86	70	74	82	15
UNITED KINGDOM								
Birmingham	52N		21	78	64	65	75	17
London	51N		22	80	65	67	77	18
UKRAINE								
Kiev	50N		-2	83	67	69	79	17
URUGUAY								
Montevideo	35S		35	89	72	76	83	17
VENEZUELA								
Caracas	11N		70	92	84	86	90	13
VIETNAM								
Ho Chi Minh City (Saigon)	11N		68	95	77	81	90	15
YUGOSLAVIA								
Belgrade	45N		11	92	71	73	87	22
ZIMBABWE								
Harare	18S		45	86	62	68	76	21

Lat. = latitude
DB = dry bulb temperature, F
MWB = mean coincident wet bulb temperature, F
MDB = mean coincident dry bulb temperature, F
DR = mean daily range of DB temperature, F
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