Monitoring Solar Data near Equator

by

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CERTIFICATE OF ORIGINALITY

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

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ABSTRACT

In this project, the purpose of solar monitoring data at UTP is to act as a stepping stone for other related projects in utilizing the energy from the sun (solar energy). Although the original intention of this project is to monitor the solar data at UTP, equipment setups at USM and UKM (auto-monitoring system) were used since it uses more accurate equipments. Besides that, experimental data from Metrological Department were also analyzed for verification and comparison purposes.The scope of study includes literature review, data collecting process (using equipments setup) and data analysis. For the methodology section, the procedures involved are data collection process (using three equipment setups); and data analysis. There are tables regarding values of solar radiation and other parameters such as temperature, relative humidity and wind speed in the result section, followed by discussion to analyze the readings taken. In the last section, the readings from all the sources are compared and the solar radiation patterns are also concluded. Recommendation was made based on the conclusion. Upon completing this Final Year Project, the student able to appreciate the importance of solar data monitoring in utilizing solar energy as an alternative energy source.

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In the name of Allah the Almighty, the most Merciful and the most Graceful

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS / NOMENCLATURES

d	solar declination angle
Et	equation of time
I_b	direct / beam radiation
I_d	diffuse radiation
I_G	global radiation
j	day of the year / 100
l	latitude of the site
Lc	longitude correction
S_0	potential solar radiation
t	clock time
t_0	time of solar noon
UKM	Universiti Kebangsaan Malaysia
USM	Universiti Sains Malaysia
UTP	Universiti Teknologi Petronas
Φ	elevation angle of the sun

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Solar energy plays an important role in meeting the world's energy demand. The use of non-renewable energy such as fuels has many side effects. Their combustion products produce pollution, acid rain and global warming. Furthermore, solar energy sources are more environment friendly which improve the living quality in the world; not only for humans but also for its flora and fauna as well.

Realizing the need of solar energy, methods of solar energy conversion system have to be developed and used to substitute the non-renewable energy. Therefore, extensive research and development in solar energy utilization technologies have to be carried out. But, in order to achieve these, the initial step which is monitoring solar data has to be done first to study the characteristics and patterns of solar energy.

The purpose of solar monitoring data at UTP is to utilize the energy from the sun (solar energy) and use it as an alternative energy. This project will also enhance the understanding of solar concept. In the past, there was no attempt to monitor the solar radiation in UTP. The solar radiation data gathered will then be available for further work analysis. One of the examples is utilizing the solar energy using solar pond.

In this project, the study emphasizes on the relationship between solar radiation and other related parameters. These parameters are ambient temperature, relative humidity and wind speed. Based on the relationship, the pattern of solar radiation can be predicted through plotted graphs.

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

Since the launching of UTP in 1997, there has been no attempt to gather any information on the solar radiation. This is unfortunate since there are enormous exposures of sun in Tronoh, Perak. By monitoring solar data near equator, analysis can be done to implement it as a clean energy sources.

For this project, solarimeter is the main equipment used to collect the solar radiation. In UTP, there is only photo radiometer available. Because of this limitation, the equipment setup was done at USM using more accurate equipment. Both of the equipment setups in UTP and USM require manual monitoring and this cause a problem to obtain a continuous day-to-day data.

Due to this problem, visits have been made to UKM to learn the auto-monitoring system. Regarding the solar data from the UKM, they only permit one sample of solar radiation data since the data has not yet been publicized. Using these data, only limited analysis can be done. They also did not unveil the full setup of the patterned solar monitoring system.

Besides that, only global solar radiation is measured in UTP, UKM and USM due to limited equipments. This is inopportune because with the addition of direct or diffuse solar radiation, comparison can be made using theoretical calculations to the experimental values.

1.3 OBJECTIVE AND SCOPE OF STUDY

1.3.1 Objective

The main objectives of this project are to monitor the solar data at UTP (4° 25'N, 100°59'E) and compare it with the data sets from various sources. There are five (5) parameters being considered; which are:

a. Direct solar radiation
b. Diffuse solar radiation
c. Ambient temperature
d. Wind velocity
e. Relative humidity

Other objectives include data analysis for recommendations and to act as a stepping stone for other related solar projects.

1.3.2 Scope of study

The scope of project is divided into three stages. The first stage is the literature review of all elements that are related to the project which more towards the planning of the project. This includes books, journals and websites regarding other solar monitoring project and the equipment used. All of the findings will be discussed with supervisors. In the beginning, the study focuses on the examples of solar radiation data from other sources. This is important for reference, comparison and verification purposes. Besides that, various of equipment setups for solar monitoring project were also reviewed. This includes types of solarimeter with different accuracy and functions.

For the second stage, equipments used will be set up and all the relevant information/ data will be gathered. The first step in this stage is to take sample readings in UTP using photo radiometer (to measure solar radiation) and thermometer (to measure ambient temperature). Readings are also taken at USM using two different setups; and at UKM using auto-monitoring system. All the methods learned during the first stage are applied during the second stage of the project.

Finally, the solar data gathered will be analyzed using graphs to see the patterns of various parameters. Experimental data from Metrological Department were also analyzed for verification and comparison purposes. Further recommendations will be made for future work using solar energy.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 LITERATURE REVIEW

2.1.1 Components of solar radiation

Basically, there are two components of solar radiation which are direct and diffuse solar radiation. Global solar radiation (I_G) is the sum of both direct and diffuse solar radiation.

a. **Direct / beam radiation** - Solar radiation received from the sun without being scattered by the atmosphere, I_b

b. **Diffuse radiation** - Solar radiation received from the sun after its direction has been changed (scattered) by the atmosphere, I_d

2.1.2 Basic types of instruments measuring solar radiation

a. **Pyranometer / Solarimeter**

Pyranometers are used for measuring global solar (beam plus diffuse) radiation, and it is from these instruments that most of the available data on solar radiation are obtained. The detectors for these instruments must have a response independent of wavelength of radiation over the solar energy spectrum. In addition, they should have a response independent of the angle of the incidence of the solar radiation. The detectors of most pyranometers are covered with one or two hemispherical glass covers to protect them from wind and other extraneous effects; the covers must be very uniform in thickness so as not to cause uneven distribution of radiation on the detectors.

There are many types of pyranometers. One of them is the Eppley Black and White pyranometer which utilizes Parson's black and barium sulfate coated hot and cold thermopile juctions. It has a good angular (cosine) response, uses an optically ground glass envelope and temperature compensation too maintain calibration within ± 1.5% over a temperature range of -20 to 40°C. The Eppley Precision Spectral Pyranometer (PSP) (refer figure 2.1) is another type of pyranometer which utilizes a thermopile detector, two concentric hemispherical optically ground covers, and temperature compensation that results in temperature dependence of 0.5% from -20 to 40°C. There is also type of pyranometer which is based on photovoltaic (solar cell) detectors such as the Yellott Solarimeter. They are less precise instruments than the thermopile instruments but also less expensive and are easy to use.

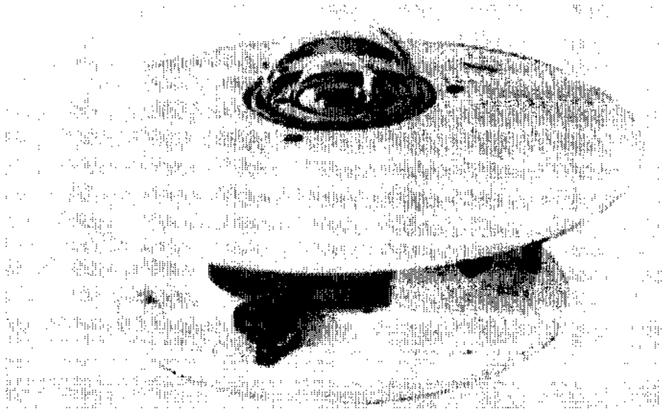


Figure 2.1: Eppley Precision Spectral Pyranometer

Measurements of solar radiation on inclined planes are important in determining the input to solar collectors. There is evidence that the calibration of pyranometers changes if the instrument is inclined to horizontal. The reason for this appears to be changes in the convection patterns inside the glass dome, which changes the manner in which heat is transferred from the hot junction of the thermopiles to the cover and other parts of the instrument. From figure 2.2, it is evident that the calibration of pyranometers is to some degree dependent on inclination and that experimental information is needed on particular pyranometer in any orientation to adequately interpret information from it.

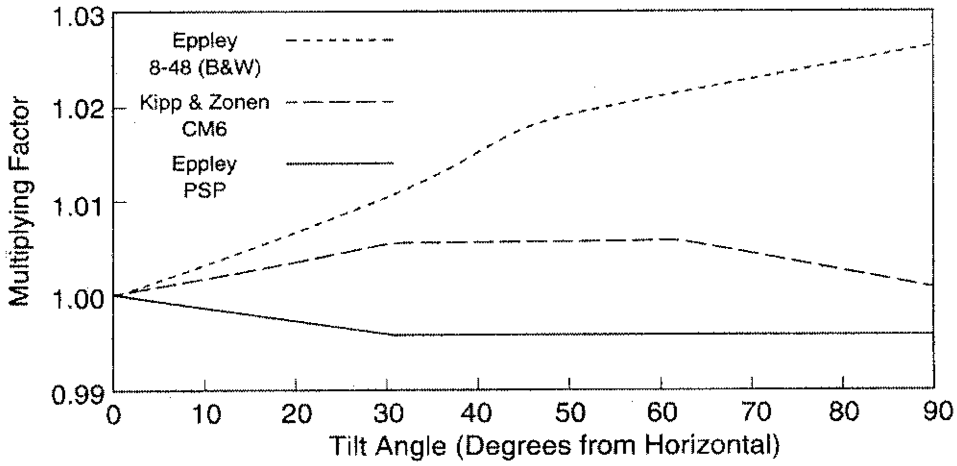


Figure 2.2: Effects of inclination of pyranometers on calibration

Pyranometers are usually calibrated against standard pyrheliometers. A standard method has been set forth in the Annals of the International Geophysical Year, which requires that readings be taken at times of clear skies, with the pyranometer shaded and unshaded at the same time as readings are taken with the pyrheliometer. Shading is recommended to be accomplished by means of a disc held one meter from the pyranometer with the disc just large enough to shade the glass envelope. The calibration constant is then the ratio of the difference in the output of the shaded and unshaded pyranometer to the output of the pyrheliometer multiplied by the calibration constant of the pyrheliometer and the angle of incidence of beam radiation on the horizontal pyranometer.

b. Pyrheliometer

Pyrheliometers are instruments which can only reads the direct beam radiations. The water flow pyrheliometer, designed by Abbot in 1905, was an early standard instrument. This instrument uses a cylindrical blackbody cavity to absorb radiation which is admitted through a collimating tube. Water flows around and over the absorbing cavity. The measurement of its temperature and flow rate provides the means for determining the absorbed energy.

Standard pyrheliometers are not easy to use, and secondary standard instruments have been devised that are calibrated against the standard instruments. One of the secondary standard pyrheliometer is the Abbot silver disc pyrheliometer, which uses a silver disc 38 mm in diameter and 7 mm thick as the radiation receiver. The side exposed to the radiation is blackened and the bulb of a precision mercury thermometer is inserted in a hole in the side of the disc to enhance good thermal contact. A shutter alternately admits radiation and shades the detector at regular intervals; the corresponding changes in disc temperature are measured and provide the means to calculate the absorbed radiation.

Operational and field instruments are calibrated against secondary standards. These are instruments which the source of most of the data on which solar process engineering designs must be based. The Eppley Normal Incidence Pyrheliometer (NIP) is the instrument in most common use in the United States for measuring beam solar radiation and the Kipp & Zonen instrument is in wide use in Europe. For the Normal Incidence Pyrheliometer (refer figure 2.3 and 2.4), the detector is at the end of the collimating tube, which contains several diaphragms and blackened on the inside. The detector is a multijunction thermopile coated with Parsons optical black. Temperature compensation is provided to minimize sensitivity to variations of ambient temperature. The aperture angle of the instrument is 5.7°.

In pyrheliometers, the dimensions of the collimating systems are such that the detectors are exposed to the radiation from the sun and from a portion of the sky around the sun. Since the detectors do not distinguish between forward-scattered radiation, which comes from the circumsolar sky, and beam radiation, the instruments are in effect defining beam radiation. An experimental study which utilized several length of collimating tubes so that the aperture angles were reduced in step from 5.72° to 2.02°, indicated that for cloudless conditions this reduction resulted in insignificant changes in the measurement of beam radiation. On a day of thin uniform cloud cover, however, with solar altitude angle of less than 32°, as much as 11% of the measured intensity was received from the circumsolar sky between aperture angles of 5.72° and 2.02°. It appears that thin clouds or haze can affect angular distribution of radiation within the field of standard pyrheliometers.

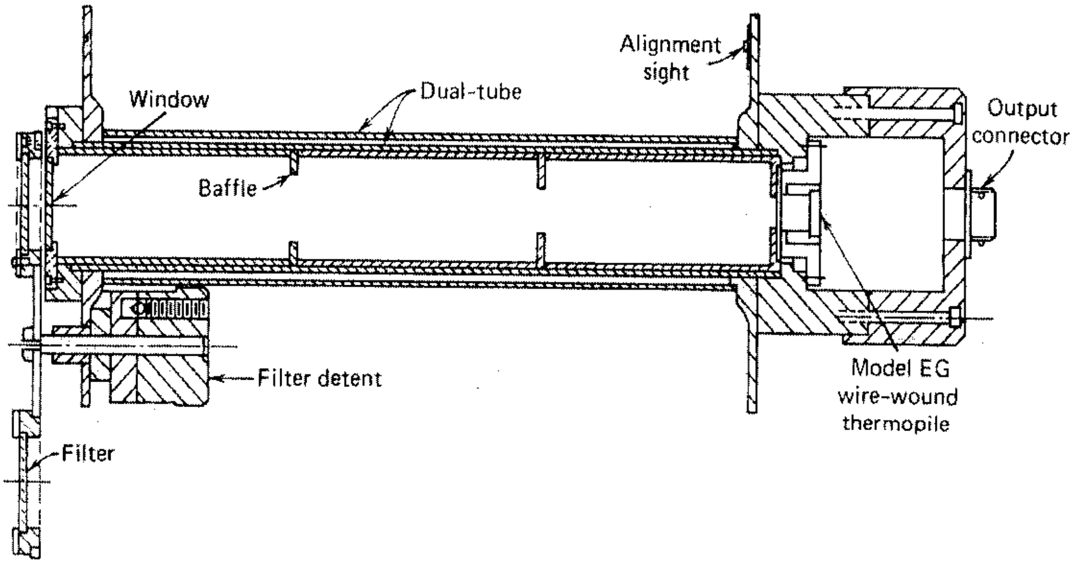


Figure 2.3: Cross section of the Eppley Normal Incidence Pyrheliometer

Figure 2.4: Eppley Normal Incidence Pyrheliometer (NIP) on a tracking mount

2.1.3 Methods used to record the solar radiation data

There are many methods used to record the solar radiation data. For many years, it has been recorded using manually operated metrological stations. This measurement was originally developed as a means of recording integrated global solar radiation, before the advent of electronics. Now, there are more appropriate ways of recording solar radiation for scientific purpose, using modern instruments and datalogging systems. One of the modern instruments used is a tracking pyrheliometer, where a collimated sensor automatically moves to track the movement of the sun. The disadvantage of using this instrument is that it can only sense the direct beam radiations.

An alternative technique which does not involve any moving parts is the combination of two pyranometers, one with shadow ring and one which is normally exposed to record total global radiation. The ring is used to allow continuous recording of diffuse radiation without the necessity of continuous positioning of smaller shading devices; adjustments need to be made for changing declination only and can be made every few days. The ring shades the pyranometer from part of the diffuse radiation, and a correction for this shading must be estimated and applied to the observed diffuse radiation. The corrections are based on assumptions of the distribution of diffuse radiation over the sky and typically are factors of 1.05 and 1.2. The difference between the global radiation and diffuse radiation measurements is the direct beam component.

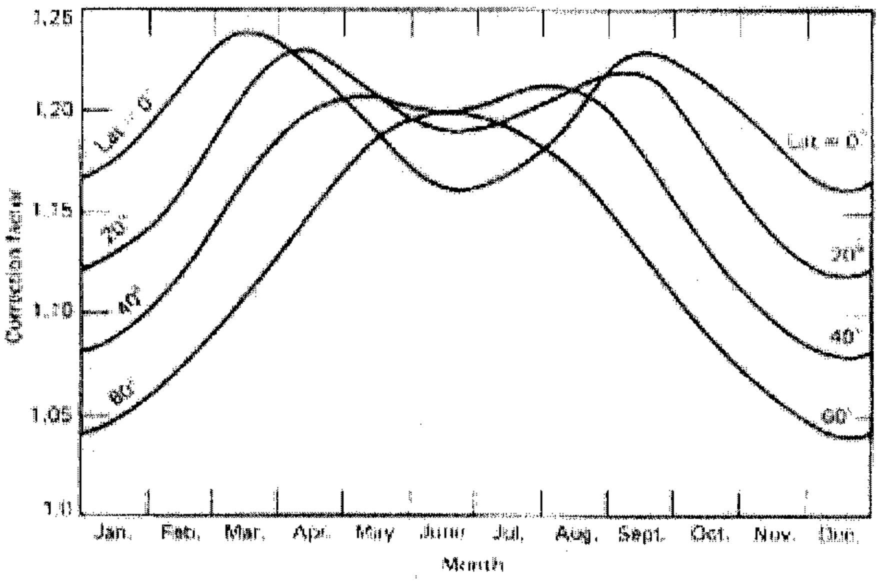


Figure 2.5: Typical shade ring correction factors

2.1.4 Solar radiation data

Solar radiation data are available in several forms. The information about radiation data such as whether they are instantaneous measurements (irradiance) or values integrated over some period of time (irradiation); the time or time period of the measurements; whether the measurements are of beam, diffuse or total radiation; the instruments used; the period over which the data are averaged (for averaged data) and the receiving surface orientation (horizontal or inclined) are important in their understanding and use. Most radiation data available are for horizontal surfaces, include both direct and diffuse radiation, and were measured with thermopile pyranometers. Most of these instruments provide radiation records as a function of time and do not provide a means of integrating the records.

There are two types of solar radiation data which are widely available. The first type is monthly average daily total radiation on a horizontal surface. These data are widely available and can be obtained from many weather stations. The second type is hourly total radiation on a horizontal surface for each hour, taken for extended periods such as one or more years. Recent laboratory measurements and the averages base thereon are probably accurate to ± 5%. Errors in readings are commonly caused by inadequate calibration and care in using the instruments.

2.2 THEORY

The potential solar radiation (S_0) on a horizontal surface outside the earth's atmosphere is calculated in Wm^{-2} from:

$$(S_0) = 1373 \sin \Phi$$

where Φ is the elevation angle of the sun. Sin Φ is computed from :

$$\sin \Phi = \sin d \sin l + \cos d \cos l \cos [15(t-t_0)]$$

where d is the solar declination angle, l is the latitude of the site, t is clock time and t_0 is the time of solar noon.

In order to measure the solar decimation angle of the device, it is advisable to approximate the sin d using a polynomial.

$\text{Sin } d = -0.37726 - 0.10564j + 1.2458\, j^2 - 0.757478\, j^3 + 0.13627\, j^4 - 0.0572\, j^5$

j = Day of the year / 100

The time of solar noon is given by:

$t_0 = 12 - Lc - Et$ (hr)

Lc = Longitude correction

Et = Equation of time

Longitude correction also can be calculated by using the formula:

$Lc = (Ls - L)/15$

Solar constant, the mean radiation flux density outside of the earth's atmosphere is 1367 Wm^2.

CHAPTER 3

METHODOLOGY

In order to proceed with the project, a clear and concise methodology is important to ensure that the flow of the project would be smooth and organized. In this project, there are three main setups used in various locations to provide sufficient data.

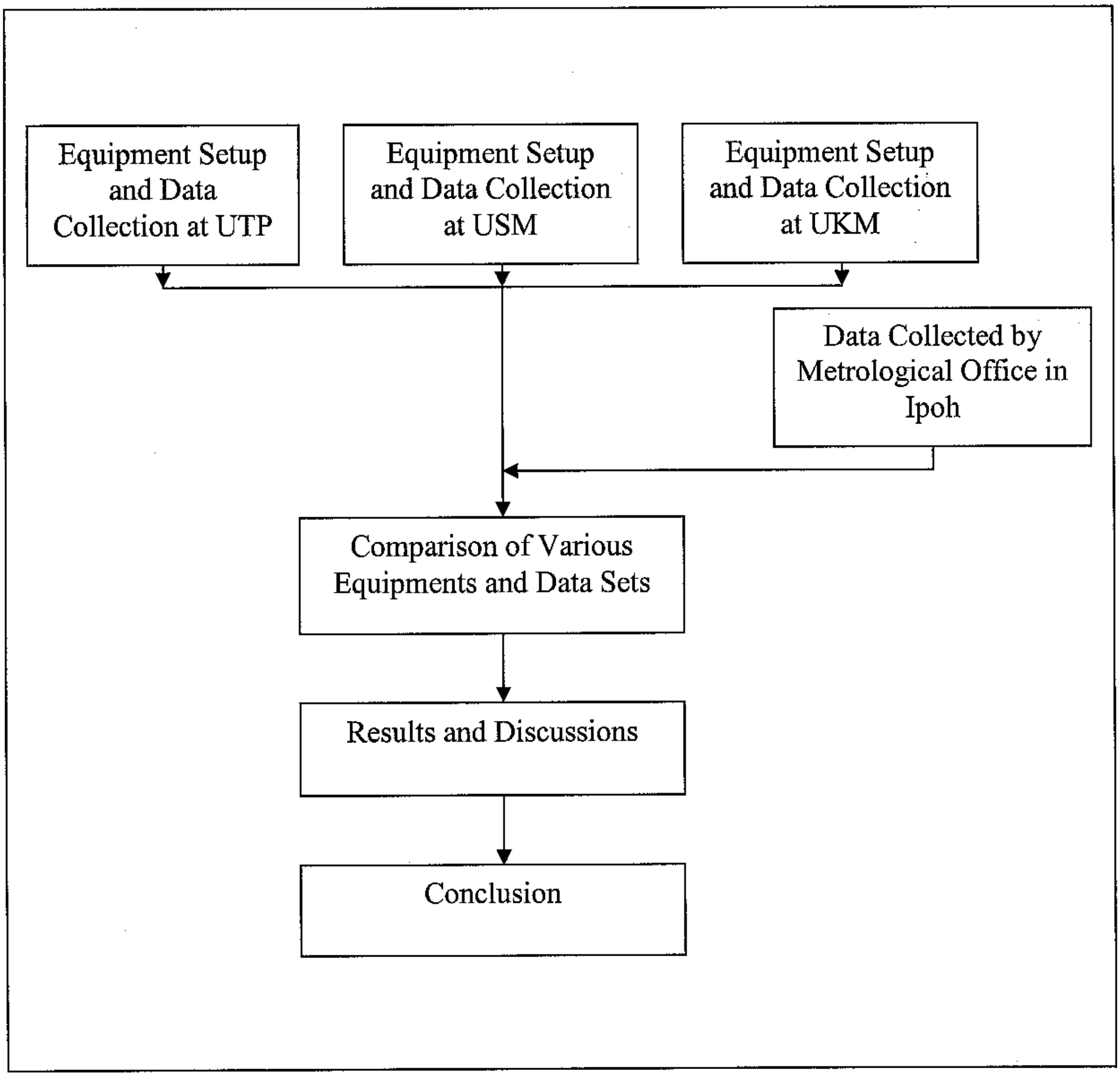


Figure 3.1: Flowchart of project methodology

3.1 EQUIPMENT SETUP AT UTP

3.1.1 Solarimeter / Photo Radiometer

Photo radiometer is the only type of solar radiation measuring instrument available in UTP. The instrument may be fitted with interchangeable probes for measuring illuminance, irradiance and luminance. In the case of solar radiation, the radiometric probe (irradiance meter cosine corrector) is connected to the instrument and the unit used is Watt/m^2. It can only be used to measure the direct solar radiation. The radiometer has measuring ranges from 10 microWatt/cm2 to 200miliWatt/cm2 and precision of ± 4%.

In term of application, there is only ON/OFF switch on the instrument. In order to obtain reliable measurements, sudden variations of lights, or any influence of the undesired reflections and shadows has to be avoided. Nearby high frequency sources, microwaves or large magnetic fields may also create electromagnetic disturbance in the sensor of the instrument.

The photo radiometer is calibrated yearly. The calibration is done on two parts: the instrument itself and the probe. For calibration of the instrument, the photometric simulator (instead of the probe) is inserted into the connector. Button P1 is pressed so that the display shows the value of simulator. For the probe, it is fitted into the photometric bench. Trimmer T1 of the amplification and calibration circuit is turned on until the value shown on the display coincides with the reference value.

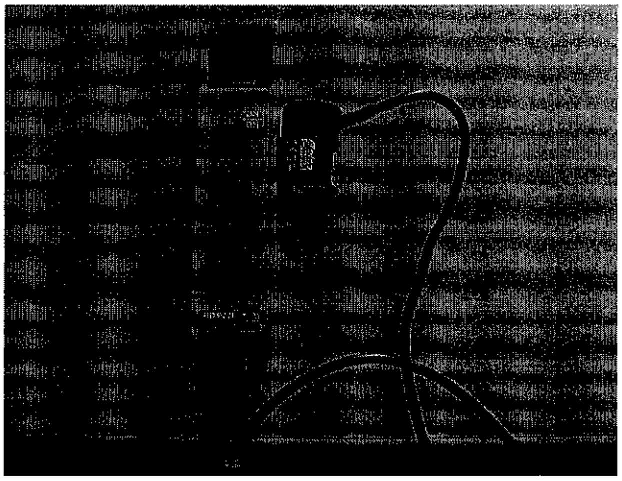


Figure 3.2: Photo Radiometer

3.1.2 K Thermocouple Thermometer

This instrument allows temperature measurements using K-type thermocouple probe. The non linearity of the temperature probe is linearized by the build-in compressor, in order to achieve high degree accuracy and resolution. Measurement can be performed on either Centigrade or the Fahrenheit scale with range from -50°C to 950°C (-58°F to 1742°F). The instrument has an accuracy of ± 0.2% and calibrated yearly. In this project, the thermometer is particularly used for measuring ambient temperature of the surrounding.

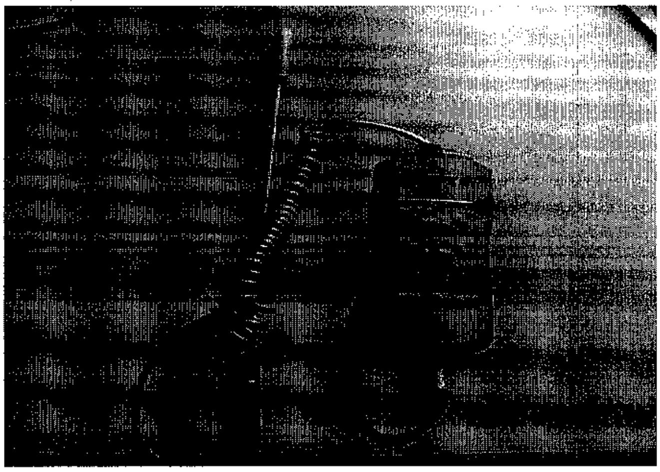


Figure 3.3: K Thermocouple Thermometer

3.2 EQUIPMENT SETUP AT USM

3.2.1 Setup A

a. Solarimeter / Pyranometer

Pyranometers are radiometers designed for measuring the irradiance on a plane surface, resulting from radiant fluxes in the wavelength range from 0.3 to 3 micrometers. It is used to measure solar radiation, in this case global solar radiation. Inside the pyranometer, there is photodiode which transform the intensity of the sun and convert it to electrical signal. It has accuracy of + 5% and sensitivity ranging from 9 to 15 $\mu V/Wm^2$. In term of application, the pyranometer is placed on the roof of the Physics building to get uninterrupted solar radiation. Since it requires no power supply, it is directly connected to the solarimeter integrator via wiring. In order to obtain reliable measurements, sudden variations of light sources, or any influence of the undesired reflections and shadows has to be avoided during the experiment.

b. Solarimeter Integrator

In this setup, the inputs from the equipment are connected to the solarimeter integrator to obtain the solar radiation readings. The solarimeter integrator has been developed for the integration of low voltages. It has accuracy better than 0.5%. For obtaining a stable operation of the instrument, the small input signals are amplified by means of chopper stabilized amplifier. The output signal of the amplifier is fed to the integrator. This integrator gives for a constant Voltage time product a pulse to the printer unit thus increasing the value of integral counter with 1. One count at the integral counter is equal to energy of 0.1 $J.cm^2$ if the proper calibration constants are set at the instrument. Originally, the measurements can be printed out on a paper strip, but due to malfunction of the printer, the readings have to be recorded manually.

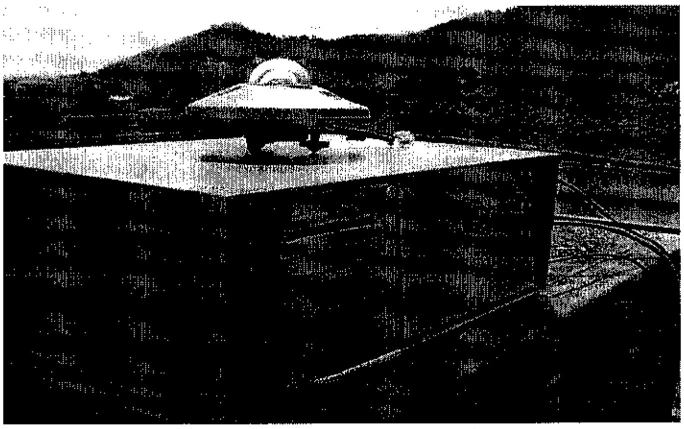


Figure 3.4: Setup A (Solarimeter with Integrator)

3.2.2 Setup B

a. Standard Solar Cell

This equipment is more or less similar to the photo radiometer used in UTP. It was made by En. Jamil Kassim (technician in-charge of physics department), and calibrated under control lightings. This equipment is a cheap alternative to the solarimeter. It is used mainly as a verification and comparison purpose to Setup A.

In term of operation, it is connected to a multimeter to get the solar radiation readings.

b. Multimeter

For this setup, multimeter is used together with the standard solar cell. It is set to miliAmpere (mA) mode to obtain the readings. It is then converted to Wattjoule/meter square (Wj/m2) using conversion graph. Since there is no datalogger, all the readings of the solar radiation have to be recorded manually.

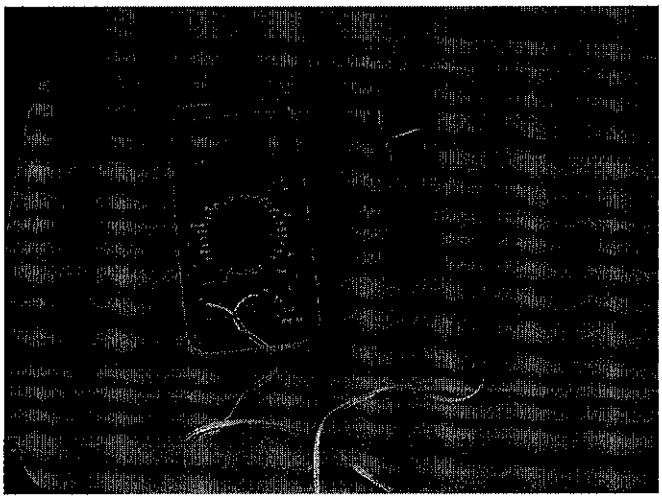


Figure 3.5: Setup B (Standard Solar Cell and Multimeter)

c. Thermometer

This instrument allows temperature measurements in the Centigrade scale. In this project, the thermometer is particularly used for measuring ambient temperature of the surrounding. It can measure up to 0.5^0C intervals.

3.3 EQUIPMENT SETUP AT UKM

3.3.1 Solarimeter / Pyranometer

Pyranometers are radiometers designed for measuring the irradiance on a plane surface, resulting from radiant fluxes in the wavelength range from 0.3 to 3 micrometers. It is used to measure solar radiation, in this case global solar radiation. Inside the pyranometer, there is photodiode which transform the intensity of the sun and convert it to electrical signal. It has accuracy of + 5% and sensitivity ranging from 9 to 15 $\mu V/Wm^2$. In term of application, the pyranometer is connected to the thermocouple input module. It is placed on a surfaced area under the sun, and in order to obtain reliable measurements, sudden variations of light sources, or any influence of the undesired reflections and shadows has to be avoided.

3.3.2 Thermocouple Input Module

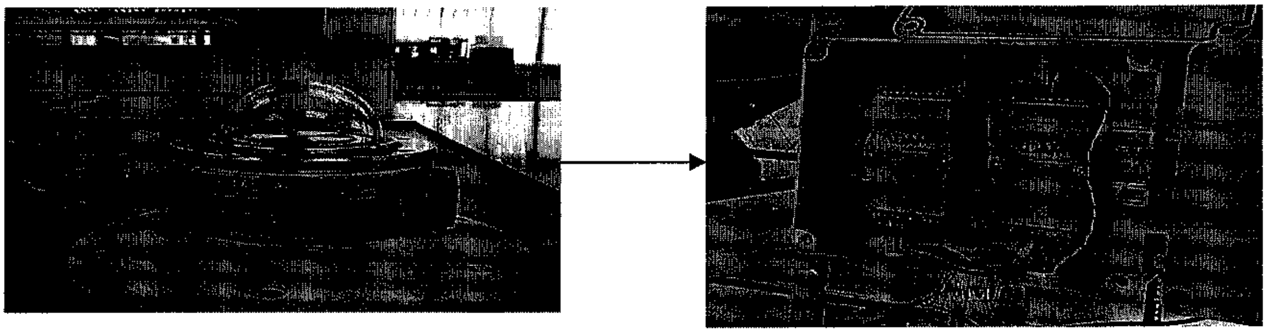
In the auto monitoring setup, the inputs from the equipment are connected to an 8-channel Thermocouple Input Module. The ADAM-4017/4018 is used as a 16-bit,8-channel analog input module that provides programmable input ranges on all channels. This module is an extremely cost-effective solution for industrial measurement and monitoring applications. Its opto-isolated inputs provide 3000 V DC of isolation between the analog input and the module, protecting the module and peripherals from damage due to high input-line voltages. It is then connected to ADAM-4520/4522 which is the signal converter.

3.3.3 Signal Converter

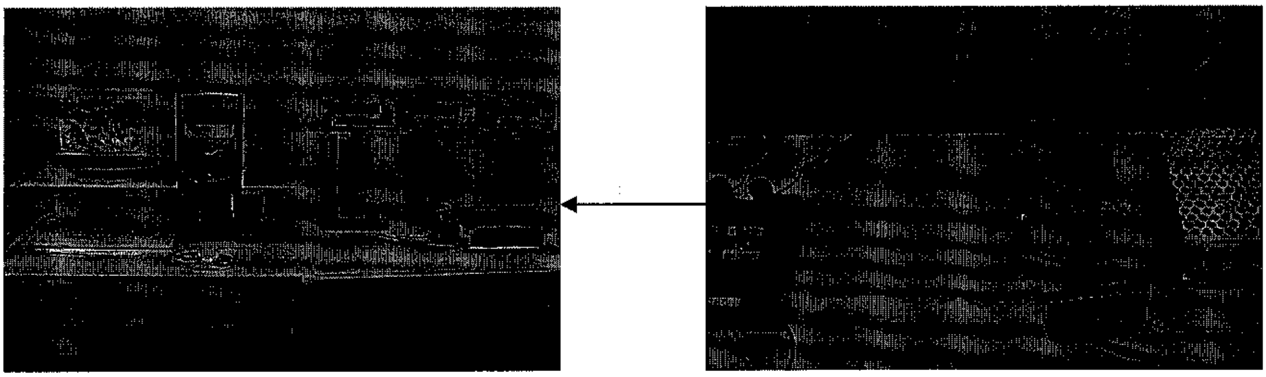
Since there is a distance (around 20 metres) between the equipment setup and the computer, ADAM-4520/4522 is used as a long distance communication system with standard PC hardware. The ADAM-4520/4522 converter takes the advantage of RS-422 and RS-485 on systems originally equipped with RS-232. It transparently converts RS-232 signals into RS-422 or RS-485 signals. By doing that, there is no change needed in the PC's hardware or software. The system requires two units; one at the equipment setup as the output unit and the other near the computer as the input unit (connected via wiring).

3.3.4 Computer with Data Acquisition System (DASyLAB) software

From the signal converter, it is connected straight away to the computer. Data Acquisition System (DASyLAB) software is used to record all the data automatically; and it can be run 24 hours with required intervals. The intervals can be set as small as ten seconds. (refer appendix D for more details)



Pyranometer Input Module



Computer Signal Converter

Figure 3.6: Equipment Setup in UKM

CHAPTER 4

RESULT AND DISCUSSION

From the experiment conducted, the readings are recorded into tables. Graphs are plotted from the tables to see the patterns of the data and the relationship between certain parameters. The analyzed data will then be verified and discussed.

4.1 EXPERIMENT AT UTP

Hour	Solar radiation (W / m^2)				Temperature (°C)			
	1	2	3	Avearge	1	2	3	Average
(MON 29/9)								
1100	223	225	233	227.00	31.9	31.9	31.8	31.87
1200	245	253	248	248.67	32.2	32.3	32.3	32.27
1300	261	262	255	259.33	32.4	32.4	32.3	32.37
1400	312	330	323	321.67	35.6	35.7	36.7	36.00
1500	235	234	242	237.00	34.2	34.3	34.3	34.27
1600	240	244	245	243.00	34.1	34.1	34	34.07
1700	264	255	274	264.33	33.5	33.5	33.6	33.53
(WED 1/10)								
1100	272	284	254	270	31.5	31.6	31.6	31.57
1200	380	398	409	395.67	32.1	32.1	32.2	32.13
1300	423	447	438	436.00	32.7	32.8	32.8	32.77
1400	396	399	431	408.67	32.9	33	33.1	33.00
1500	105.8	114.3	114.1	111.40	32.1	32.2	32.1	32.13
1600	293	324	295	304.00	33.1	33.1	33	33.07
1700	102.3	119.6	105.8	109.23	32.2	32.3	32.2	32.23
(THURS2/10)								
1100	232	248	222	234.00	27.4	27.5	27.5	27.47
1200	253	254	258	255.00	27.5	27.5	27.6	27.53
1300	169.9	169.3	164.6	167.93	29	28.9	28.9	28.93
1400	127.3	135.6	125.3	129.40	28.1	28.2	28.1	28.13
1500	108.3	108.6	106.2	107.70	30.1	30.1	30.2	30.13
1600	80.9	61.5	80.7	74.37	27.7	27.8	27.7	27.73
1700	NA	NA	NA	NA	26.1	26.1	26.2	26.13

Table 4.1: Readings of solar radiation and temperature on Monday (29/9/03), Wednesday (1/10/03) and Thursday (2/10/03)

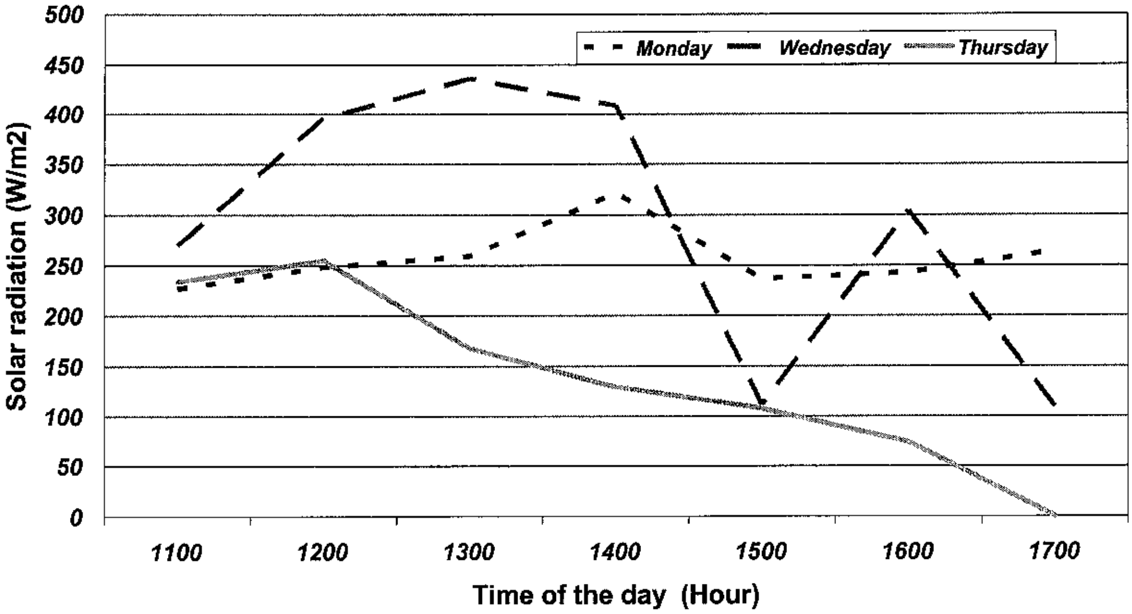


Figure 4.1: Patterns of solar radiation versus time on Monday (29/9/03), Wednesday (1/10/03) and Thursday (2/10/03)

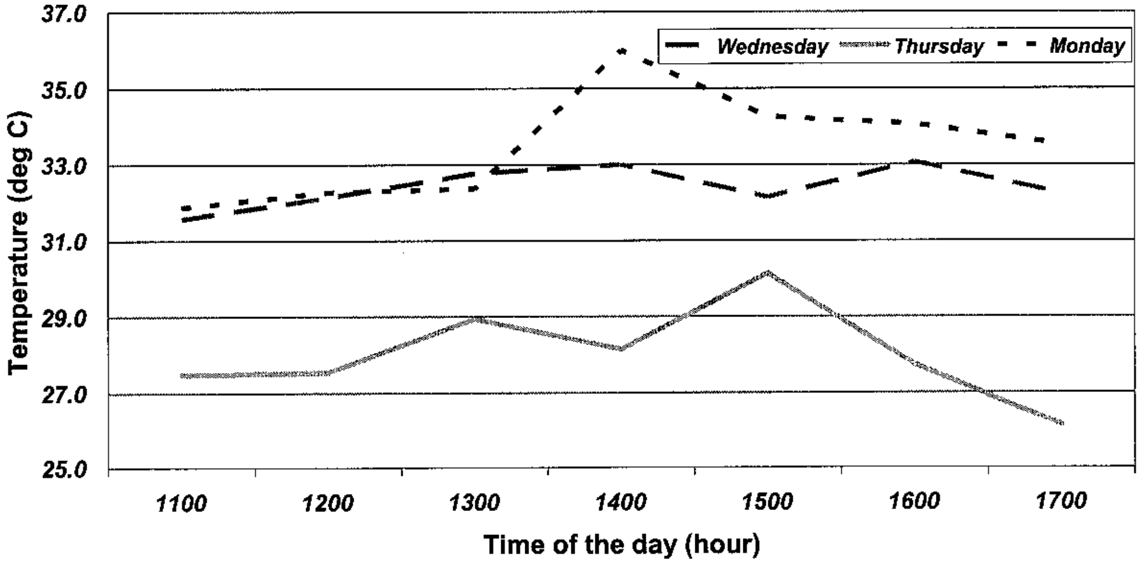


Figure 4.2: Patterns of temperature versus time on Monday (29/9/03), Wednesday (1/10/03) and Thursday (2/10/03)

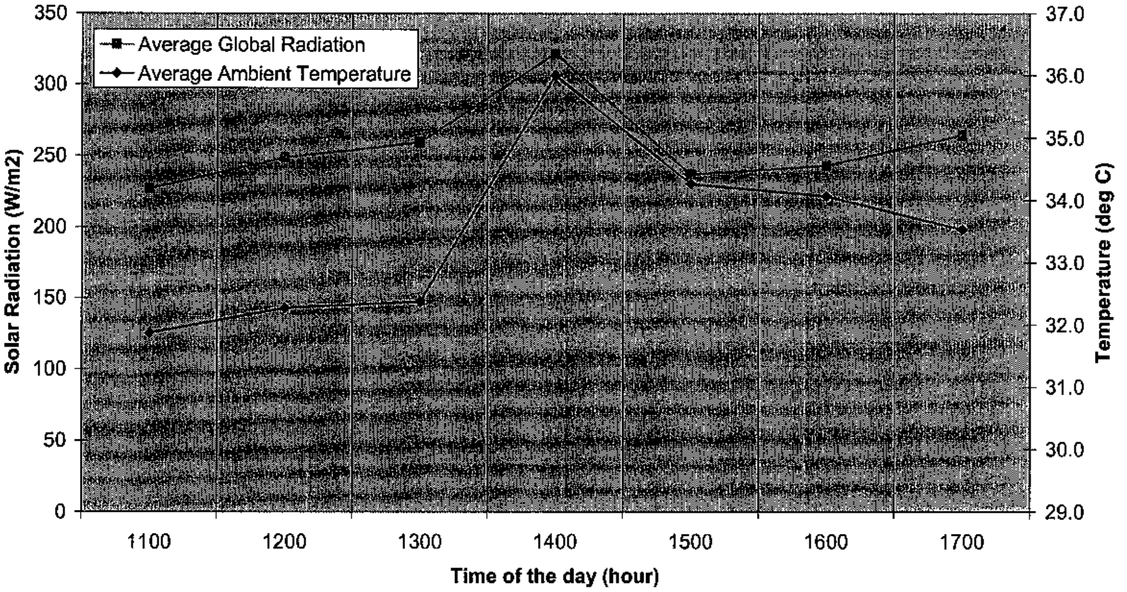


Figure 4.3: Relationship between Solar Radiation and Temperature on a Sunny Day (29/9/03)

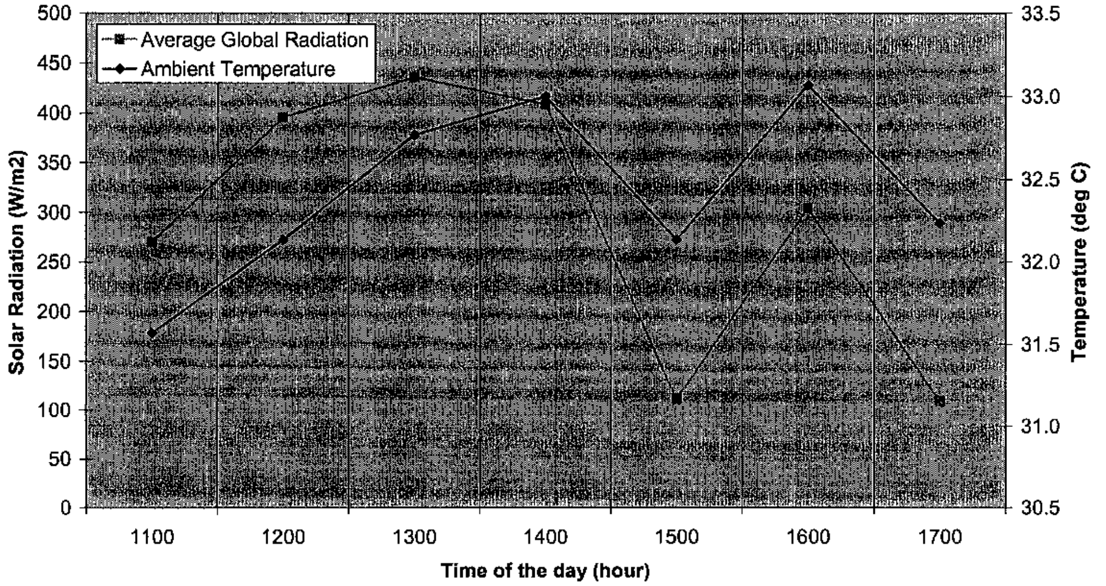


Figure 4.4: Relationship between Solar Radiation and Temperature on a Mixed Pattern Day (1/10/03)

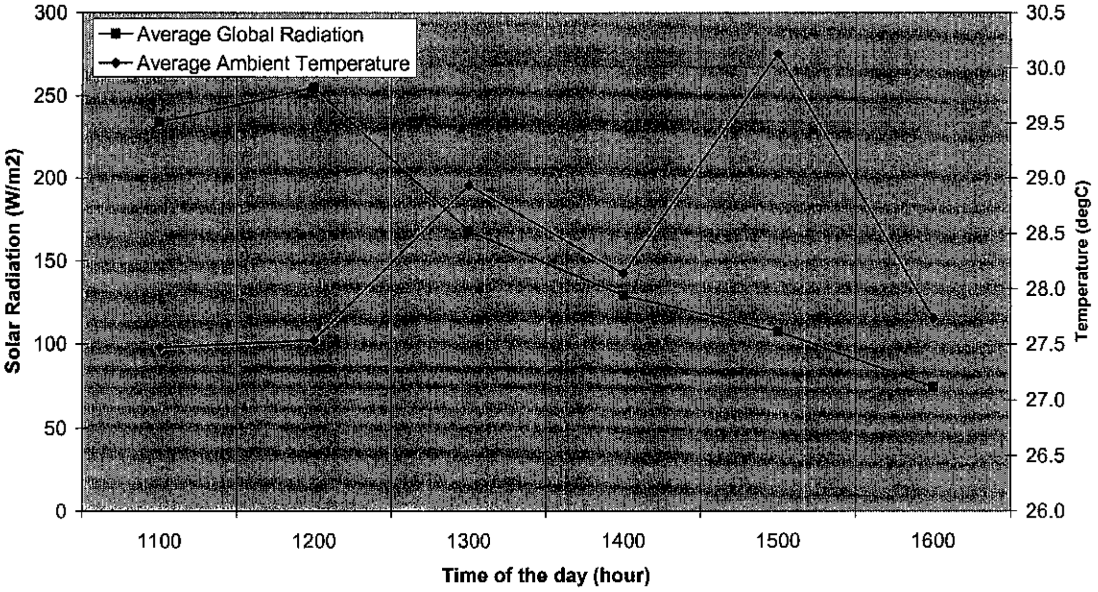


Figure 4.5: Relationship between Solar Radiation and Temperature on a Rainy Day (2/10/03)

As shown above, there are five plotted graphs from the readings taken at UTP. Graph 4.1 shows the pattern of solar radiation versus time on Monday (29/9/03), Wednesday (1/10/03) and Thursday (2/10/03) while graph 4.2 shows the pattern of ambient temperature versus time. From the graphs, we can see that the highest solar radiation reading (436 W/m^2) was taken on Wednesday and the highest ambient temperature reading (36°C) was taken on Monday.

Graphs 4.3, 4.4 and 4.5 show the relationship between solar radiation and ambient temperature for Monday (29/9/03), Wednesday (1/10/03) and Thursday (2/10/03) respectively. On Monday, we can see that the patterns of solar radiation and ambient temperature are the same except from 4.00 to 5.00 pm. At this period, the ambient temperature decreases while the solar radiation increases.

On Wednesday, the pattern of the graph also shows that the temperature is dependent on the solar radiation except at 2.00 pm; where the solar radiation increases while the ambient temperature decreases. The reason behind this is because the temperature needs a longer time to increase compared to solar radiation. Since the readings were taken hourly, there are also other possibilities such shading occurs during that period.

On Thursday, the graph shows that there is no correlation between solar radiation and ambient temperature. This shows that temperature is not only dependent on solar radiation, but also on other parameters as well such as relative humidity and wind speed.

4.2 EXPERIMENT AT USM

Time(min)	Solar radiation (count/sec)	Solar radiation (W/m²)	Solar radiation (mA)	Solar radiation (W/m2)	Ambient Temp. (°C)
0	40	66.67	13	50	28
10	45	75.00	14	55	28.5
20	51	85.00	16	70	29
30	85	141.67	19	85	30
40	61	101.67	17	75	29
50	58	96.67	10	40	29
60	62	103.33	13	52	29.5
70	64	106.67	15	60	29.5
80	66	110.00	11	42	29.5
90	90	150.00	14	55	29.5
100	115	191.67	14	55	29.5
110	154	256.67	17	75	30.5
120	177	295.00	20	90	31.5
130	180	300.00	21	95	32
140	184	306.67	21	95	32.5
150	223	371.67	23	110	32.5
160	242	403.33	27	140	32.5
170	252	420.00	32	175	32.5
180	288	480.00	32	175	32.5

190	260	433.33	33	180	32.5
200	266	443.33	33	180	32
210	247	411.67	30	160	32.5
220	293	488.33	35	200	33.5
230	281	468.33	35	200	34
240	292	486.67	35	200	34.5
250	293	488.33	36	207	34.5
260	304	506.67	34	195	35
270	283	471.67	34	195	35
280	287	478.33	34	195	34
290	281	468.33	34	195	35
300	289	481.67	34	195	34.5
310	281	468.33	34	195	34.5
320	266	443.33	34	195	34
330	275	458.33	34	195	35
340	282	470.00	34	195	35.5
350	128	213.33	33	187	35
360	82	136.67	7	30	35
370	112	186.67	22	102	34
380	39	65.00	9	45	35
390	113	188.33	8	37	34.5
400	178	296.67	17	70	35
410	147	245.00	29	155	33.5
420	118	196.67	14	55	34
430	82	136.67	14	55	33
440	83	138.33	11	42	33
450	57	95.00	11	42	33.5
460	54	90.00	11	42	33
470	23	38.33	8	37	33
480	21	35.00	7	30	33

Table 4.2 : Data taken at USM between 9am to 5pm on Saturday (21/2/2004)

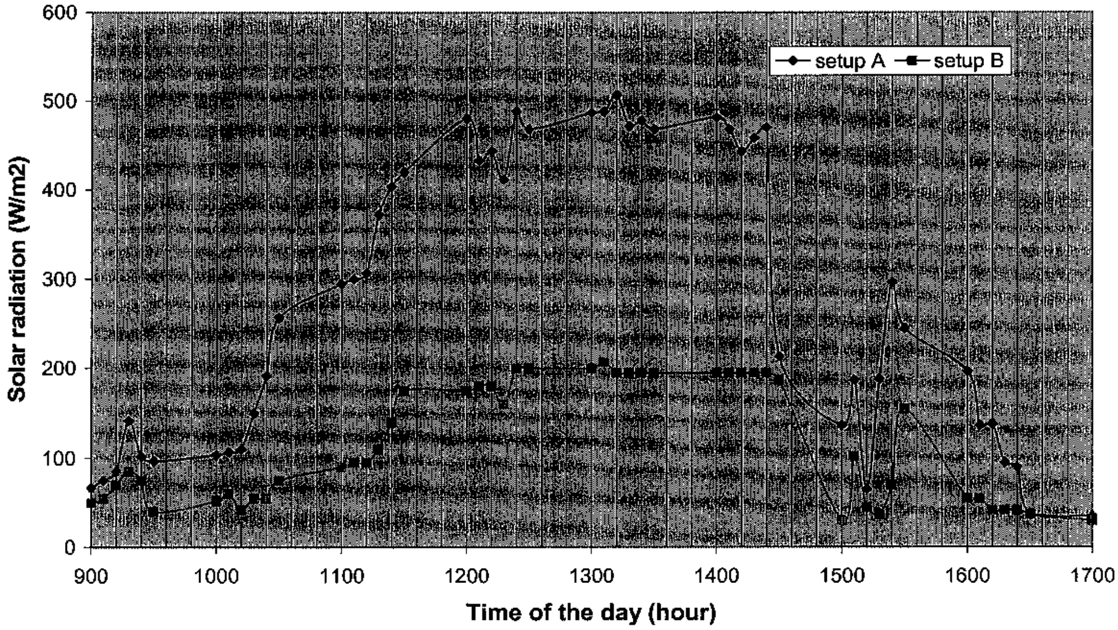


Figure 4.6: Pattern of global solar radiation versus time on 21/2/04

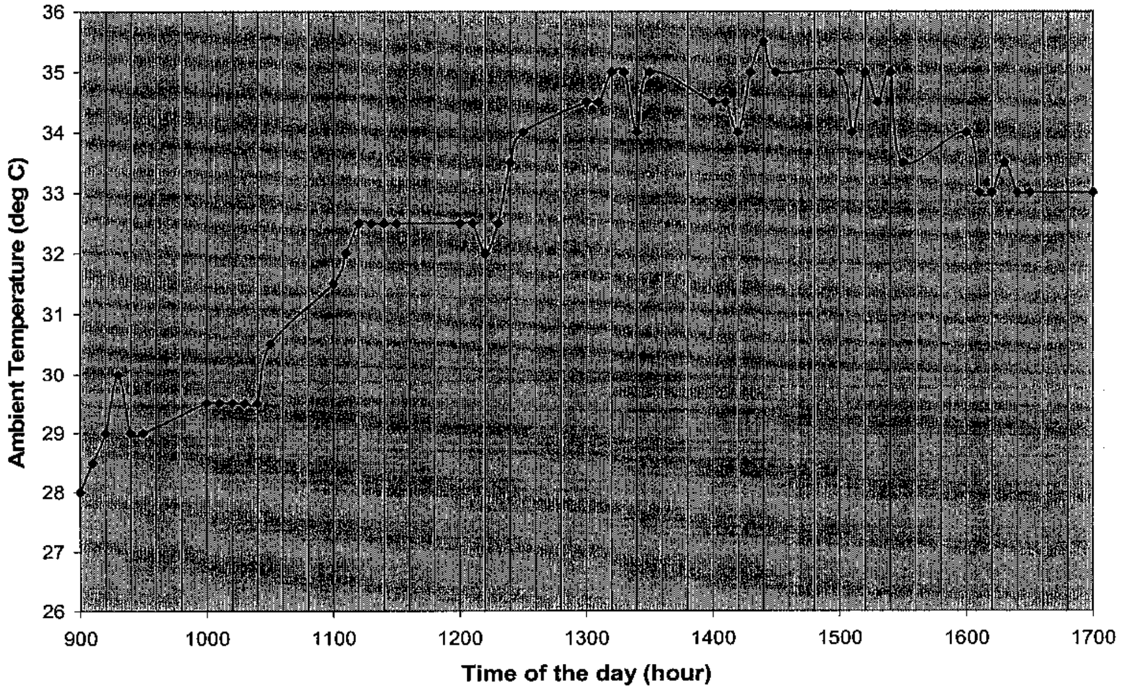


Figure 4.7: Pattern of ambient temperature versus time on 21/2/04

As shown in the section 4.2, there are three main tables. The first table is the readings (solar radiations and ambient temperatures) taken at USM from 9.00 am to 5.00 pm. Regarding the experiment, the solar data monitoring has been done using two setups of equipments. The first setup is a combination of solarimeter and solarimeter integrator (setup A), while the second setup consists of standard solar cell and multimeter (setup B). From the first graph, we can see that there is a big difference in readings between these two setups. The errors might be caused by insensitivity of setup B (mostly used for verification only) or inaccurate conversion graph from miliAmpere (mA) to Watt joule/meter square (Wj/m2). Comparing it directly to the data taken at UTP last semester, the readings obtained from setup A have a closer values.

Referring to the Figure 4.6 (setup A), the global solar radiation varies from 45 W/m2 (at 5.00 pm) to maximum 506.67 W/m2 (at 1.20 pm). On the other side, the ambient temperatures vary from 28 ^{0}C (at 9.00 am) to maximum 35.5 ^{0}C (at 2.40 pm). Comparing the solar radiation and temperature graphs together, we can see that between 9.00 am and 2.40 pm, the pattern of both parameters is same and proportional. After 2.40 pm, the solar radiation readings seem to drop dramatically while the ambient temperatures only decrease slightly. This was caused by the cloudy sky at that particular time.

4.3 EXPERIMENT AT UKM

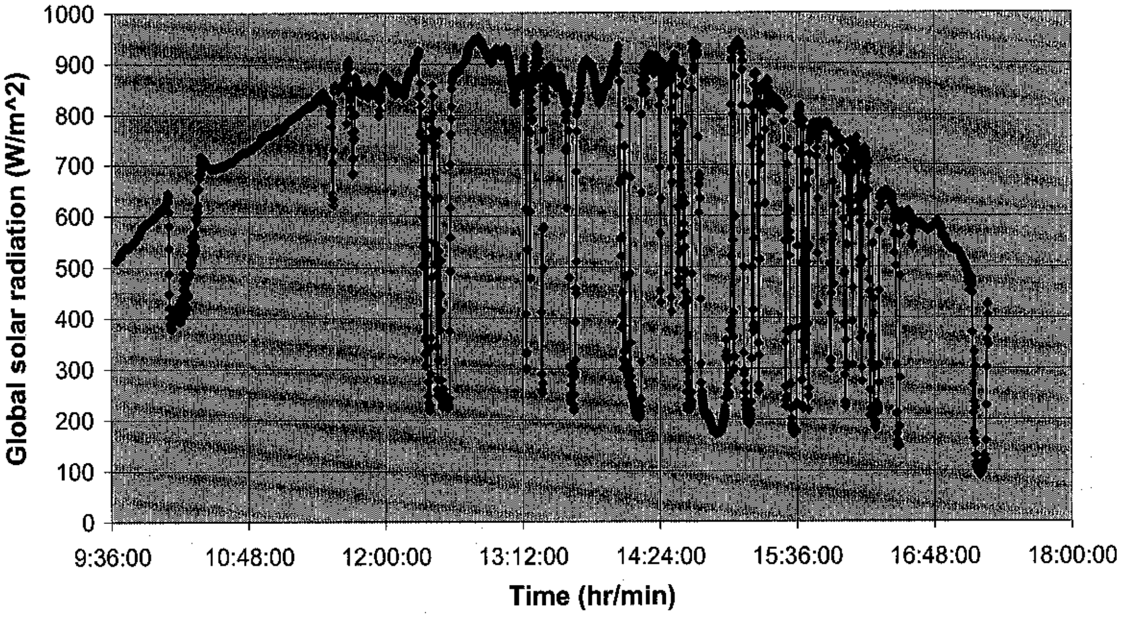


Figure 4.8: Pattern of global solar radiation versus time on 21/1/04

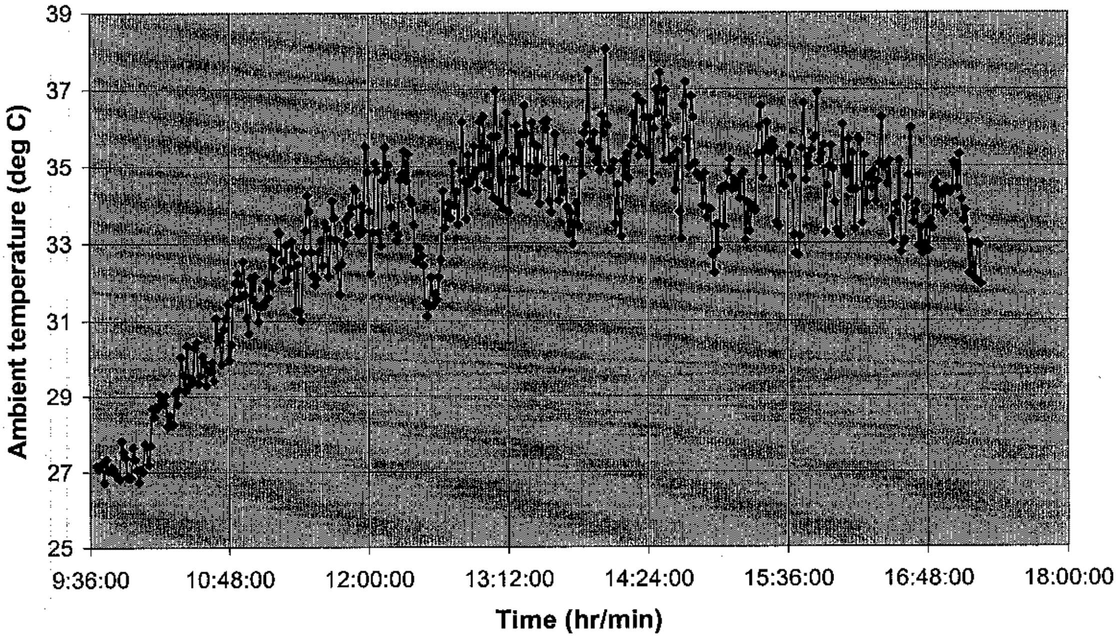


Figure 4.9: Pattern of temperature versus time on 21/1/04

As shown in the figures 4.8 and 4.9, there are two main graphs. The first graph shows the pattern of solar radiations (taken with 10 seconds interval); while the second graph shows the pattern of temperatures (taken with 1 minute interval). The readings were taken on 21/1/04 at UKM from 9.30 am to 5.15 pm. These small intervals can only be obtained with auto-monitoring system. Besides that, it is more accurate compare to manual monitoring system.

Referring to the Figure 4.8, the global solar radiation varies from 94.12 W/m2 (at 5:12:10 pm) to maximum 950.11 W/m2 (at 12:49:10 pm). On the other side, the ambient temperatures vary from 27.8 ^{0}C (at 9:39:21 am) to maximum 34.9 ^{0}C (at 2:18:21 pm). Comparing the solar radiation and temperature graphs together, we can see that the patterns differ slightly. For the first graph, generally the solar radiation increase constantly from 9.30 am to 11.50 am at a high rate and increase slowly to 12.50 pm. There were huge amount of solar radiation from 12.17 pm to 3.07 pm. After that, the solar radiation decrease at a constant rate. For the second graph, the ambient temperature readings increase constantly from 9.30 am to 2.00 pm. From there, the temperature decrease slightly from 2.00 pm to 2.30 pm and more or less remains the same. This shows that on the afternoon, the solar radiation readings seem to drop dramatically while the ambient temperatures only decrease slightly. This may be caused by the cloudy sky on the afternoon.

Since the data were taken using small intervals, changes of solar radiation and ambient temperature were captured more frequently. In Malaysia, these two parameters (solar radiation and ambient temperature) are very much affected by the clouds. The clouds move along with the wind in the sky; and resulted to high and low points in both graphs.

4.4 EXPERIMENT DATA FROM METROLOGICAL DEPARTMENT

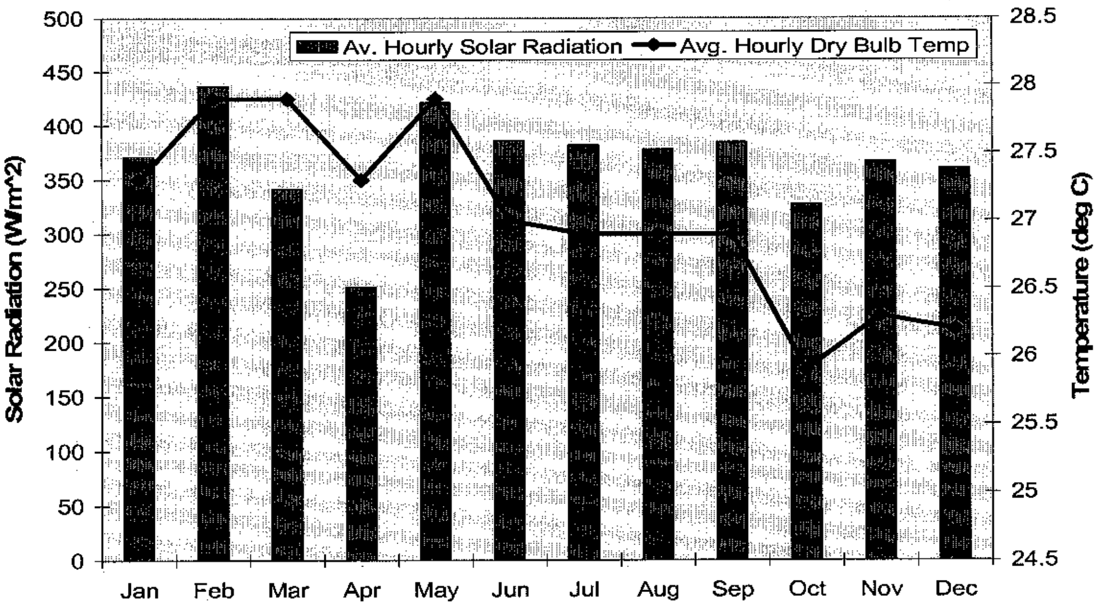


Figure 4.10: Relationship between hourly average monthly solar radiation and temperature in Ipoh for 2003

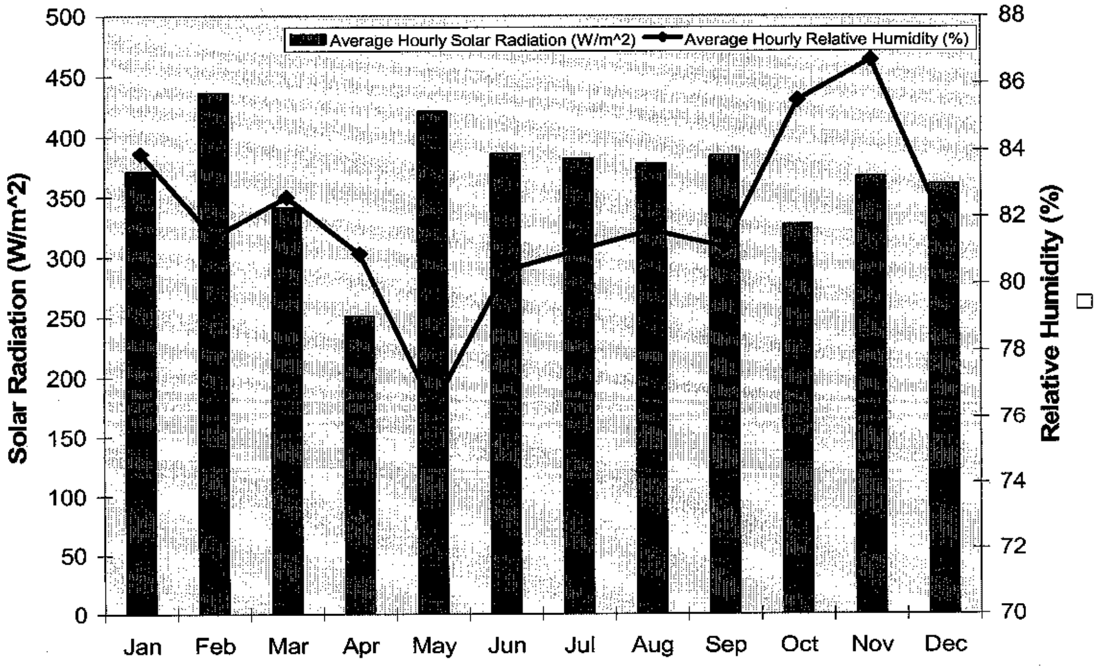


Figure 4.11: Relationship between hourly average monthly solar radiation and relative humidity in Ipoh for 2003

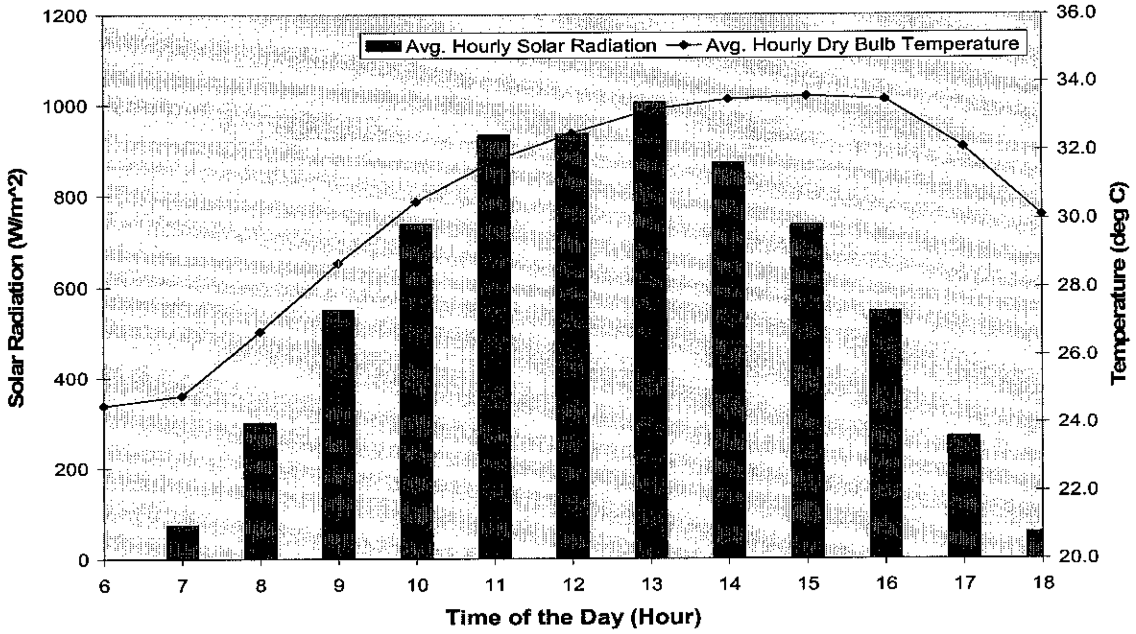


Figure 4.12: Relationship between average hourly solar radiation and temperature on a sunny day (15/4/2003)

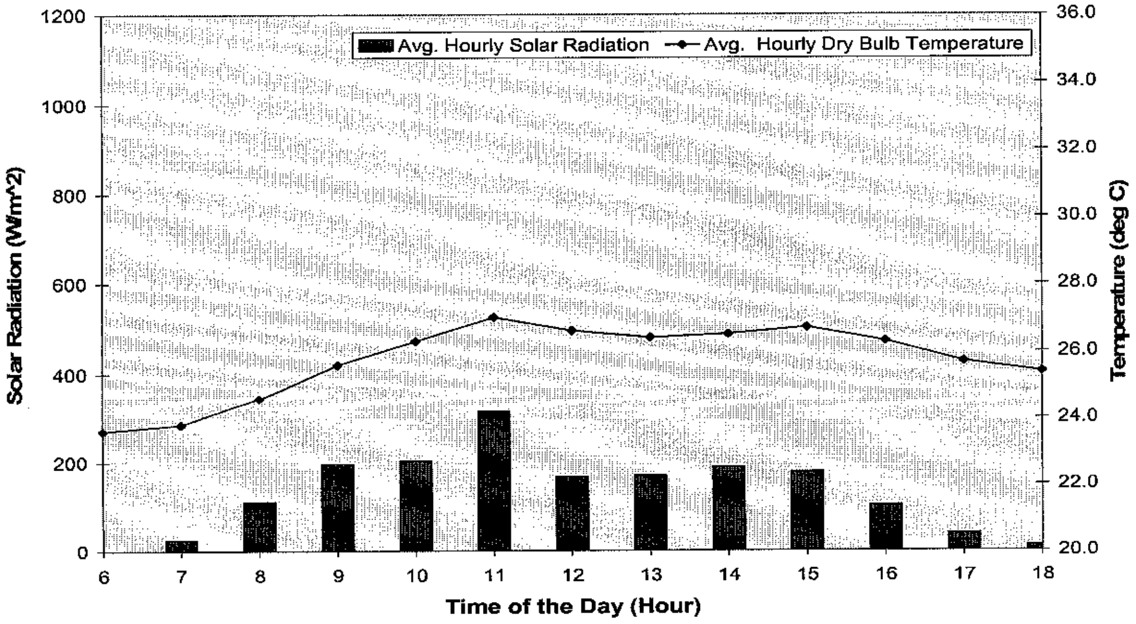


Figure 4.13: Relationship between average hourly solar radiation and temperature on a rainy day (9/12/2003)

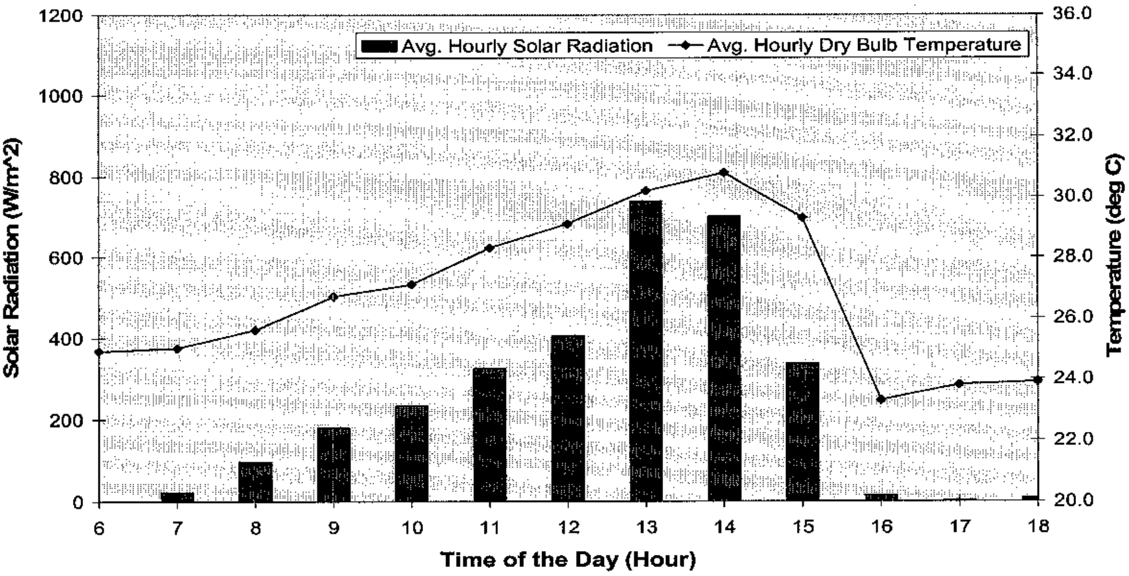


Figure 4.14: Relationship between average hourly solar radiation and temperature on a mix pattern day (12/12/2003)

The highest monthly average solar radiation is recorded on February (436.48 W/m^2) ; while the highest monthly average dry bulb temperature is 27.9 °C (on February, March and May). From my observation, the solar radiation is quite proportional to the dry bulb temperature. In this case, high dry bulb temperature will resulted high solar radiation.

Secondly, the monthly average solar radiation with the relative humidity was compared. The highest monthly average relative humidity is 86.7% (on November). For this analysis, the pattern of solar radiation versus relative humidity cannot be summarized as proportional or inversely proportional; since there are other factors as well that influence the solar radiation.

Next, three different days with various pattern of weather; sunny/clear day (15/4/03), rainy/cloudy day (9/12/03) and mix patterns (12/12/03) were analyzed. Overall, the solar radiation is quite proportional to the dry bulb temperature; although there is a case where the temperature remains high while the solar radiation decreases (from 2.00 – 3.00 pm on 15/4/03).

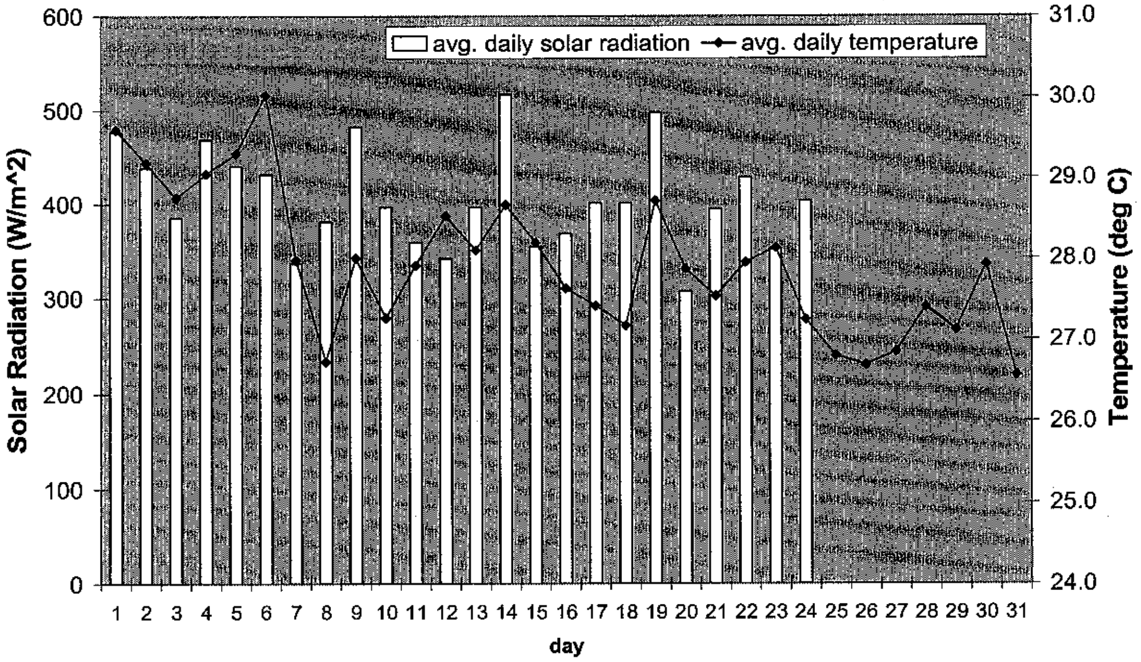


Figure 4.15: Relationship between solar radiation and temperature on March 2003

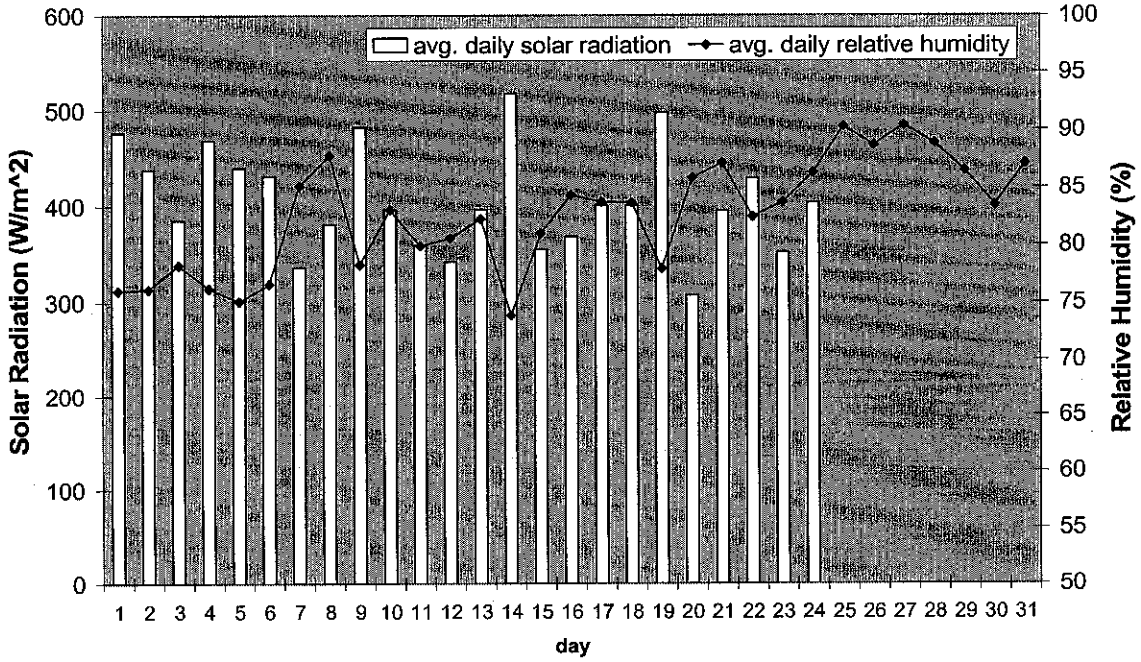


Figure 4.16: Relationship between solar radiation and relative humidity on March 2003

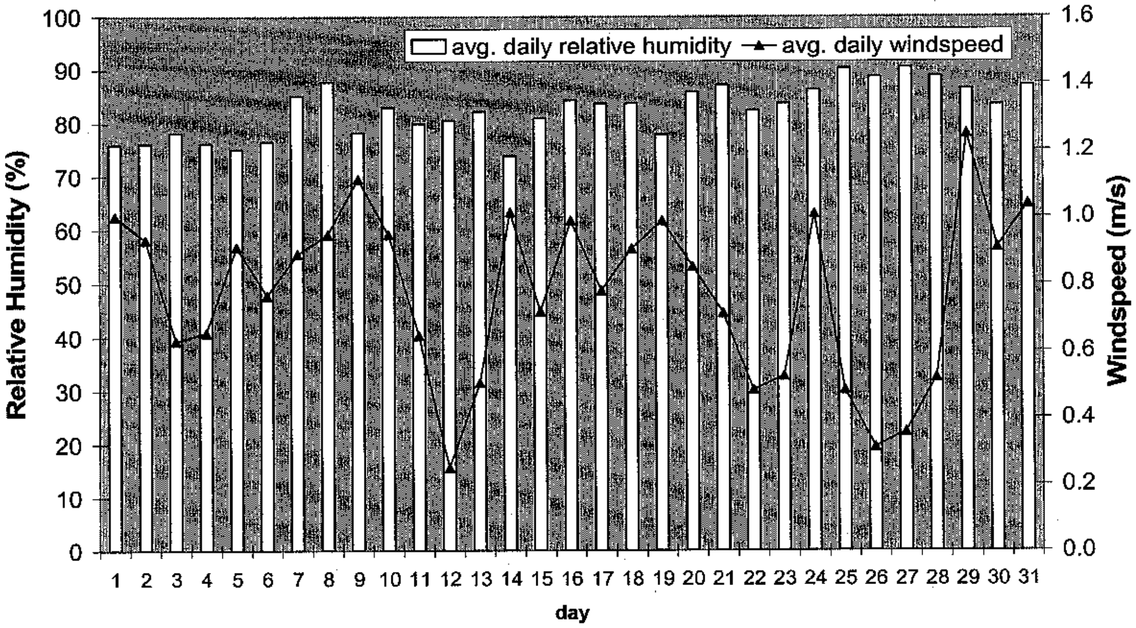


Figure 4.17: Relationship between relative humidity and wind speed on March 2003

Out of the 12 months, March 2003 is chosen as a case study. On that month, the highest average daily dry bulb temperature (30°C) falls on 6/3/2004 while the lowest (26.7°C) falls on 8/3/2004. The highest average daily solar radiation (517.31W/m^2) was recorded on 14/3/2004.On 6/3/2004, although the average daily temperature is the highest, the average daily solar radiation is only at moderate value (431.62 W/m^2). This might be caused by the shading from the clouds. Meanwhile the average relative humidity is quite low (76.6%) and the wind speed is moderate (0.8 m/s).

On 8/3/2004, although the temperature is low, there are plenty of solar radiations (381.41 W/m^2). The low temperature might be caused by the high wind speed (0.9 m/s).

On 14/3/2004, the average daily solar radiation is the highest in March (517.31W/m^2). Meanwhile the average daily temperature is only at moderate value (28.7°C). This is caused by high average daily windspeed (1.0m/s). The windspeed factor also causes the low average daily relative humidity (73.9%).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the experiment done at UTP, it can be concluded that the readings of the average hourly solar radiation is quite low compared to experimental data obtained in Ipoh. On a clear sunny day, the highest solar radiation recorded in UTP is 436 W/m² while the experimental data shows that the reading can exceed 1000 W/m². This may be caused by the inaccuracy of the photo radiometer.

Referring to the experiment done at USM, monitoring solar radiation using solarimeter with integrator (setup A) is more accurate than using standard solar cell with multimeter (setup B). This is proved by comparing the data with other data obtained in UTP and UKM as well as the experimental data from Metrological Department. (Refer Figure 4.6 and Figure 4.8)

Out of three equipment setups in UTP, USM and UKM, the auto-monitoring system in UKM proved to be the best. It can measure data continuously with high accuracy since it uses small intervals up to ten seconds. Besides that, the readings obtained in UKM are the closest to the experimental data from the Metrological Department.

Based on the experiments done at various locations, it can be concluded that the temperature is dependent on the solar radiation. Most of the time, the temperature increases as the solar radiation increases. There are also cases when there is no correlation between the solar radiation and the temperature. This shows that temperature is not the only parameter dependent on solar radiation, but also other parameters as well such as relative humidity and wind speed. Besides that, shading from the clouds does play a major role in influencing the solar radiation.

Using the experimental data from Metrological Department (taken at Ipoh for year 2003) as reference, we can conclude that the average solar radiation values are quite high except in March, April and October. These are the months where rainy season occurs. On a sunny day, the solar radiation can exceed 1000 W/m^2 according to data taken in Ipoh. Since Universiti Teknologi Petronas (UTP) is located in Bandar Seri Iskandar (4° 25'N, 100°59'E), which is about 35 kilometres away from Ipoh (4°34'N, 101°06'E), the experimental data can be used as a valid guidance although it does not mean that both places (Ipoh and Bandar Seri Iskandar) have identical weather at all time. This is supported by the fact that the average solar radiation are taken for a long period (one year) and not based only on hourly or daily data which can be misleading. Besides that, Bandar Seri Iskandar was also renowned as a mining town in the fifties and sixties. Naturally, there are a lot of sands and this can increase the value of diffuse solar radiation.

5.2 RECOMMENDATION

Since the sun intensity is quite high in Bandar Seri Iskandar, the energy from the sun (solar energy) should be utilized and used as an alternative energy. In order to do that, the pattern of the solar radiation should be studied for at least 10 years to fully understand it. Based on the various experimental setups, the auto-monitoring system gives the most accurate readings compared to other setups. As a recommendation, UTP should have its own auto-monitoring system as in UKM to monitor the pattern of the solar radiation. The system should consist of two pyranometers (one with shadow ring), thermometer and anemometer. With the constant effort from the university, this project can become a stepping stone for other related projects regarding solar energy.

REFERENCES

1. John A Duffie and William A. Beckman, Second Edition (1991), Solar Engineering of Thermal Processes, Wiley Interscience
2. CG Granqvist, First Edition (1999), Materials Science for Solar Energy Conversion System, Pergamon Press
3. Mohd Yusof Hj. Othman, Kamaruzzaman Sopian, Baharudin Yatim and Mohd. Noh Dalimin, Diurnal pattern of global solar radiation in the Tropics : a case study in Malaysia, Pergamon Press (1992)
4. Muhammad Iqbal, An Introduction to Solar Radiation, Academic Press (1983)
5. Kipp & Zonen catalogues
6. www.advantech.com
7. www.dasytec-dasylab.com
8. www.campbellsci.co.uk

APPENDICES

APPENDIX A : PYRANOMETER CM 6B

SPECIFICATIONS:

Spectral range	305-2800 nm (50% points)
Sensitivity	9-15 μV/Wm^2
Impedance	70-100Ω
Response Time	1/e 5s, 99% 55s
Non linearity	<1.5% (<1000 W/m^2)
Tilt error	<1.5% at 1000 W/m^2
Operating temperature	-40 to 80°C
Temperature dependence on sensitivity	± 2% (-10 to +40°C)
Maximum irradiance	2000 W/m^2
Directional error	<± 20 W/m^2 at 1000 W/m^2
Weight	0.85 kg
Cable length	10 m

APENDIX B : SOLARIMETER INTEGRATOR CC2

SPECIFICATIONS:

Input voltage	0-18 mV
Range selector	For solarimeters CM5/6 with a calibration constant of 100-130 mV/W.cm-^{2} choseable in steps of 1 mV
Count rate	10 counts/J.cm-^{2}
Accuracy	Better than 0.5%
Temperature coefficient	< 0.03%/°C
Linearity	Better than 0.1% if correctly zeroed
Zero stability	< 0.02%/°C
Input impedance	> 5 kOhms

APPENDIX C: EXPERIMENTAL DATA FOR MARCH 2003 (SAMPLE)

Month	Day	Hour (ST)	Dry Bulb Temp. (° C)	Relative Humidity (%)	Mean Surface Wind Direction (°)	Speed (m/s)	Solar Radiation (MJm-2)	Solar Radiation (Whrm-2)
3	1	1	27.0	92	0	0.0		0.00
3	1	2	27.0	90	0	0.0		0.00
3	1	3	27.1	90	0	0.0		0.00
3	1	4	26.8	90	0	0.0		0.00
3	1	5	26.5	92	50	1.0		0.00
3	1	6	26.3	91	40	1.0	0.00	0.00
3	1	7	25.9	90	30	0.5	0.14	38.89
3	1	8	27.1	80	30	2.6	0.91	252.78
3	1	9	28.7	73	30	3.1	1.56	433.33
3	1	10	29.8	70	20	3.1	2.39	663.89
3	1	11	31.5	61	350	0.5	3.09	858.33
3	1	12	33.2	59	0	0.0	3.31	919.45
3	1	13	33.9	52	220	1.5	3.33	925.00
3	1	14	34.2	51	240	1.0	2.95	819.45
3	1	15	34.4	54	190	0.5	2.07	575.00
3	1	16	33.8	57	140	0.5	1.34	372.22
3	1	17	33.4	61	190	1.0	1.01	280.56
3	1	18	31.7	71	220	3.1	0.20	55.56
3	1	19	30.2	76	230	3.1	0.00	0.00
3	1	20	29.4	80	160	0.5		0.00
3	1	21	28.7	83	160	0.5		0.00
3	1	22	28.2	84	150	0.5		0.00
3	1	23	28.0	86	0	0.0		0.00
3	1	24	27.4	91	0	0.0		0.00
3	2	1	26.9	93	0	0.0		0.00
3	2	2	26.8	95	0	0.0		0.00
3	2	3	26.8	90	40	0.5		0.00
3	2	4	26.6	90	0	0.0		0.00
3	2	5	26.1	90	0	0.0		0.00
3	2	6	26.0	90	30	1.0	0.00	0.00
3	2	7	25.7	93	30	0.5	0.12	33.33
3	2	8	26.4	90	30	1.5	0.51	141.67
3	2	9	28.3	78	10	1.5	1.55	430.56
3	2	10	30.1	72	360	0.5	2.27	630.56
3	2	11	31.7	60	0	0.0	2.93	813.89
3	2	12	32.8	50	220	0.5	3.21	891.67
3	2	13	33.7	51	200	1.0	3.05	847.22
3	2	14	34.1	49	220	1.5	2.87	797.22
3	2	15	34.5	51	220	2.0	2.21	613.89
3	2	16	33.3	57	230	3.6	1.27	352.78
3	2	17	32.2	61	240	4.1	0.40	111.11

3	2	18	31.1	60	250	3.1	0.12	33.33
3	2	19	29.1	80	160	1.0	0.00	0.00
3	2	20	28.8	80	0	0.0		0.00
3	2	21	28.3	86	0	0.0		0.00
3	2	22	27.6	82	0	0.0		0.00
3	2	23	26.9	87	0	0.0		0.00
3	2	24	26.5	92	0	0.0		0.00
3	3	1	26.0	89	0	0.0		0.00
3	3	2	25.4	90	0	0.0		0.00
3	3	3	25.1	94	0	0.0		0.00
3	3	4	24.8	95	0	0.0		0.00
3	3	5	25.0	88	50	0.5		0.00
3	3	6	24.8	91	0	0.0	0.00	0.00
3	3	7	24.9	92	50	1.0	0.16	44.44
3	3	8	26.4	89	30	1.5	0.80	222.22
3	3	9	28.1	81	30	1.5	1.56	433.33
3	3	10	30.1	70	50	0.5	2.29	636.11
3	3	11	31.5	66	170	0.5	2.65	736.11
3	3	12	32.8	58	180	0.5	3.09	858.33
3	3	13	33.5	53	0	0.0	2.64	733.33
3	3	14	32.5	66	220	0.5	0.94	261.11
3	3	15	32.2	50	310	2.0	0.97	269.44
3	3	16	33.4	58	230	2.0	1.72	477.78
3	3	17	32.4	63	230	2.6	0.92	255.56
3	3	18	31.5	66	230	1.5	0.30	83.33
3	3	19	29.9	75	0	0.0	0.01	2.78
3	3	20	29.0	80	170	0.5		0.00
3	3	21	28.4	86	0	0.0		0.00
3	3	22	27.9	89	0	0.0		0.00
3	3	23	27.3	94	0	0.0		0.00
3	3	24	26.9	94	0	0.0		0.00
3	4	1	26.4	97	0	0.0		0.00
3	4	2	25.8	95	0	0.0		0.00
3	4	3	25.5	95	0	0.0		0.00
3	4	4	25.4	93	0	0.0		0.00
3	4	5	25.2	93	0	0.0		0.00
3	4	6	24.9	92	0	0.0	0.00	0.00
3	4	7	24.9	92	0	0.0	0.18	50.00
3	4	8	26.8	86	0	0.0	0.79	219.44
3	4	9	27.4	83	70	0.5	1.19	330.56
3	4	10	28.8	73	20	1.5	1.20	333.33
3	4	11	31.0	63	340	1.0	2.95	819.45
3	4	12	32.9	52	0	0.0	3.32	922.22
3	4	13	33.8	51	210	1.0	3.35	930.56
3	4	14	34.3	46	230	2.6	3.09	858.33
3	4	15	35.0	46	240	2.0	2.62	727.78
3	4	16	34.4	49	200	1.5	1.70	472.22
3	4	17	33.7	54	210	1.5	1.12	311.11

3	4	18	31.7	66	220	2.6	0.43	119.44
3	4	19	29.9	75	210	1.0	0.02	5.56
3	4	20	29.1	80	150	0.5		0.00
3	4	21	28.5	83	0	0.0		0.00
3	4	22	28.0	85	0	0.0		0.00
3	4	23	27.1	90	0	0.0		0.00
3	4	24	26.5	90	0	0.0		0.00
3	5	1	26.1	87	0	0.0		0.00
3	5	2	25.7	86	70	1.0		0.00
3	5	3	25.3	89	0	0.0		0.00
3	5	4	25.0	90	0	0.0		0.00
3	5	5	24.8	92	0	0.0		0.00
3	5	6	24.4	92	0	0.0	0.00	0.00
3	5	7	24.4	96	0	0.0	0.09	25.00
3	5	8	25.3	92	30	1.5	1.09	302.78
3	5	9	28.0	76	10	1.5	1.83	508.33
3	5	10	30.5	68	50	0.5	2.56	711.11
3	5	11	32.6	49	30	1.0	3.10	861.11
3	5	12	33.9	47	330	3.1	3.37	936.11
3	5	13	35.1	48	200	1.5	3.53	980.56
3	5	14	34.8	52	0	0.0	2.14	594.44
3	5	15	34.1	52	220	2.0	1.05	291.67
3	5	16	33.7	59	210	3.1	1.01	280.56
3	5	17	32.8	64	210	3.6	0.68	188.89
3	5	18	31.5	68	200	2.0	0.16	44.44
3	5	19	30.3	75	140	0.5	0.00	0.00
3	5	20	29.7	81	140	0.5		0.00
3	5	21	29.3	81	0	0.0		0.00
3	5	22	28.9	84	0	0.0		0.00
3	5	23	28.7	87	0	0.0		0.00
3	5	24	28.2	87	0	0.0		0.00
3	6	1	28.0	88	0	0.0		0.00
3	6	2	27.9	87	280	0.5		0.00
3	6	3	27.3	90	40	1.0		0.00
3	6	4	27.2	91	40	1.0		0.00
3	6	5	26.8	92	0	0.0		0.00
3	6	6	26.4	94	0	0.0	0.00	0.00
3	6	7	26.2	93	0	0.0	0.19	52.78
3	6	8	27.6	89	10	2.6	0.96	266.67
3	6	9	29.7	77	20	2.0	1.80	500.00
3	6	10	31.2	70	10	1.0	2.45	680.56
3	6	11	32.9	57	0	0.0	2.98	827.78
3	6	12	34.2	53	40	0.5	2.29	636.11
3	6	13	33.9	58	210	1.5	2.78	772.22
3	6	14	34.8	51	230	1.5	2.44	677.78
3	6	15	34.5	51	170	0.5	1.98	550.00
3	6	16	34.6	56	200	1.5	1.77	491.67
3	6	17	32.8	65	210	3.1	0.47	130.56

3	6	18	31.1	71	210	2.6	0.09	25.00
3	6	19	30.0	77	140	0.5	0.00	0.00
3	6	20	29.2	82	140	0.5		0.00
3	6	21	29.0	84	0	0.0		0.00
3	6	22	28.8	85	0	0.0		0.00
3	6	23	28.4	88	0	0.0		0.00
3	6	24	28.0	89	0	0.0		0.00
3	7	1	27.6	90	0	0.0		0.00
3	7	2	27.3	91	0	0.0		0.00
3	7	3	27.3	91	0	0.0		0.00
3	7	4	27.1	89	40	1.0		0.00
3	7	5	27.1	92	0	0.0		0.00
3	7	6	27.0	91	0	0.0	0.00	0.00
3	7	7	27.0	91	0	0.0	0.14	38.89
3	7	8	27.8	85	20	1.0	0.64	177.78
3	7	9	29.3	73	40	1.5	1.66	461.11
3	7	10	31.6	67	70	0.5	2.57	713.89
3	7	11	32.9	64	0	0.0	3.04	844.45
3	7	12	34.2	59	0	0.0	2.91	808.33
3	7	13	33.2	64	180	0.5	1.12	311.11
3	7	14	31.9	67	200	4.1	1.95	541.67
3	7	15	30.7	73	190	2.6	1.09	302.78
3	7	16	26.6	85	360	6.6	0.25	69.44
3	7	17	24.8	97	0	0.0	0.23	63.89
3	7	18	25.4	94	0	0.0	0.16	44.44
3	7	19	25.5	95	60	1.0	0.00	0.00
3	7	20	25.9	96	0	0.0		0.00
3	7	21	25.4	93	50	1.0		0.00
3	7	22	25.3	100	0	0.0		0.00
3	7	23	25.4	98	30	1.0		0.00
3	7	24	25.0	98	30	0.5		0.00

APPENDIX D: DATA ACQUISITION LAB (DASyLAB)

Data Acquisition and Analysis under Windows

DASYLab is a data acquisition, process control, and analysis system which takes full advantage of the features and the graphical interface provided by Microsoft® Windows™.The most important design requirements for DASYLab were the integration of the important measuring and control devices on the market, a truly intuitive operating environment which offers extensive help functions, a maximum signal processing speed, and the most effective graphical display of results.

Intuitive Operation

Using DASYLab, a measuring, process control, or simulation task can be set up directly on your screen by selecting and connecting modular elements that can then be freely arranged. Even highly specialized tasks can be solved immediately on the screen, interactively and without difficulty. It is no longer necessary to find your way through lengthy and rigid menu structures.

Large Variety of Measuring, Control, and Analysis Functions

Among the module functions provided are A/D and D/A converters, Pre/Post and Start/Stop Triggers, digital I/O, mathematical functions from fundamental arithmetic to integral and differential calculus, statistics, digital filters of several types, frequency analysis including various evaluation windows, signal generators for simulation purposes, scopes for the graphic display of results, logical connectors like AND, OR, NOR, etc., counters, a chart recorder, file I/O, timer, digital display, bar graph, analog meter and more.

Measuring Technology under Windows

With DASYLab it is now possible to achieve high signal input/output rates using the full power of the PC. Special buffers with large, selectable, memory address ranges enable continuous data transfer from the data acquisition device through to the software. DASYLab uses extremely sophisticated drivers to obtain realtime logging at a rate of up to 800 kHz and real-time on-screen signal display at a rate of up to 70 kHz (depending on the type of data acquisition device and graphics board installed).

Flexible Worksheet Setup

In spite of its complexity and high performance, DASYLab can be used easily. The worksheet displayed on screen can be edited at any time. New modules can be inserted; others can be moved to a different position or deleted altogether. Dialog boxes prompt for all the necessary parameters to be set for an experiment. Use the Black Box module to take combinations of worksheet elements repeatedly required in your experiments, and integrate them into a Black Box module, which you can then insert into worksheets as ready-to-use units. This will save you time and simplify your worksheets.

Integrated Autorouter Utility

While you are connecting the module inputs and outputs using the mouse, these connections are displayed as direct lines, but as soon as the mouse button is released the integrated Autorouter optimizes all these connections. This prevents data channel lines being drawn through or behind existing module symbols or too close to other lines. In the same way, the integrated Autorouter rearranges the display whenever a module symbol has been moved. It thus creates a readable worksheet diagram ready for documentation purposes.

Ample Resources

The maximum worksheet size is 2000 by 2000 pixels, and a worksheet can contain up to 256 modules. For most modules up to 16 inputs and/or outputs can be configured. The virtual working area at the user's disposal is much larger than what can actually be presented in the active window on screen. When dealing with more extensive applications, where the complete arrangement of module symbols will not fit on the screen, you can scroll through the screen window vertically and horizontally. In addition, an overview command, several tagging functions, and the ability to hide the worksheet diagram help you to keep track of the setup and experiment.

Function Bar and Module Bar

Icon bars that provide commands and functions that might be repeatedly required when experiments are set up and carried out enhance DASYLab's userfriendliness considerably. You can define the Module Bar on the left of the screen to reflect your preferences. You can assign module functions that you need most often in your individual tasks to the buttons on the Module Bar. Once configured, these settings can be saved and reused for other worksheets or experiments. Various configurations adapted to the individual requirements of different tasks are easily reused.

Display of Results

Readings can be displayed graphically or numerically using specially assigned modules. This can be done effectively by making use of scope modules. Each one provides a resizable window in which data from several channels can be displayed; a system of suitable coordinates (linear, logarithmic, polar, waterfall), and different color codes (for multiple signals) can be selected. Scaleable analog instruments, bar graphs and LED indicators are especially helpful when it comes to process control and testing. As these elements can be freely placed and combined, all the instruments necessary for any process can be integrated completely.

Storing the Setup

The complete experiment setup, including all the currently selected parameters, window positions, and additional information can be saved to a file and opened again later. Multiple ready-to-use standard setups for different tasks can be developed. The corresponding data acquisition process itself can even be started automatically at a specified time, when your computer restarts or when Windows starts.

Storing Data and Data Exchange

The acquired data and process results can also be saved to files so that they can be retrieved for further processing at a later time. They can be analyzed in detail, or used for simulation and training. Use DDE (Dynamic Data Exchange) to transfer data directly to other Windows applications supporting the DDE protocol. For example: Excel and applications with DDE capabilities may be used to start DASYLab and control it while running an experiment.

Process Control Applications

External systems can be controlled by employing appropriate modules for digital I/O or D/A conversion. DASYLab provides a wide range of powerful modules for binary operations (AND / OR / NOT etc.), counters, and PID control functions. Precise time-related process control operations depending on complex signals can be realized with DASYLab. Output frequencies, slopes, duration, dependencies on certain input source conditions, etc., can be determined for several channels by the user.

Simulation – for Testing and Training Purposes

Pure simulations, even without a data acquisition device, offer excellent opportunities to test measuring or process control experiments that have been developed on the PC. In these cases, a signal generator module, or several of them, is substituted for the measuring device. By combining signal generator modules with mathematical modules, complex stimuli can be generated. For example, a sine or rectangle signal might be overlaid by a noise signal or by further sine, rectangle, or saw tooth signals. Even signals that have previously been saved to files may be retrieved and used again as stimuli using the file I/O module. You can use DASYLab in training courses, as trainees can directly observe the effects and results of data acquisition and process control systems.

Custom Functions

As a service to customers who have to cope with highly specialized tasks, MeasX will develop custom function modules and other software modifications on request to meet individual demands. For instance, specified mathematical operations or options concerning the graphic presentation can be implemented or modified as required, and further data exchange interfaces can also be supplied. An Extensions Tool Kit is available for experienced C programmers who wish to design their own modules. Contact your dealer for more information.

Integrated Help System

In most situations, it is not necessary to refer to the complete manual, since almost any problem can be solved using the online help system. The context-sensitive help system provides the user with detailed instruction on hardware settings and software options, and it also supplies background information on measuring technology topics like FFT/spectral analysis.

Conclusions

In combination with one of the established PC measuring and process control devices, the DASYLab system is a powerful tool for data acquisition, process control and simulation.