Analytical and Experimental Investigation of Convective Heat Transfer in Solar Collector

by

Toh Seng Peow

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

MAY 2011

Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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Approved by,

(Assoc. Prof. Dr. Hussain H. Al-Kayiem)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May, 2011

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 the original work contained herein have not been undertaken or done by unspecified sources or persons.

TOH SENG PEOW

ABSTRACT

The evaluation of the outlet temperature of flow in solar collector is still of interest for the convection heat transfer investigator. The aim of this project is to correlate the air outlet temperature to inlet of the solar thermal channel, wall temperature, radiation intensity and air flow rate, at different tilt angle and channel length. This project is involved both the analytical and experimental works. For analytical analysis, the physical model of the solar thermal channel is developed together with the mathematical model for the system. Solution is proposed by using iteration in the MATLAB program to find the unknowns. A test rig based on the physical model is designed and fabricated for experimental validation. Experiments were run at 10^0, 30^0, 50^0, 70^0, 90^0 tilt angles, for 1m, 1.5m, and 2m channel length respectively. In addition, readings were taken every 2 hours interval to investigate the transient behavior of the system. Finally, results from analytical analysis is compared and validated with the experimental result. The percentage error of the validation results is within the margin of 6% to 13%, effectively. In addition, recommendations were provided for future work, to improve both the analytical and experimental aspects.

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to Assoc. Prof. Dr. Hussain H. Al-Kayiem, from Mechanical Engineering Department, Universiti Teknologi PETRONAS for providing me an opportunity to do my project work on "Analytical And Experimental Investigation of Convective Heat Transfer in Solar Collector", and also for willing to supervise, guide, and support me throughout the completion of this project despite his hectic schedule.

Besides that, I sincerely thank to Mr. Aja Ogboo Chikere and Mr. Saw Chun Lin, PhD. Research Students, from Mechanical Engineering Department, Universiti Teknologi PETRONAS, without whom this project would have been a distant reality. I would like to thank them for their encouragements and willingness to guide and assist, which help me in completion of this project.

In addition, I would also thank my Institution and my faculty members who had been directly and indirectly involved in this project. Last but not least, I wish to avail myself of this opportunity, express a sense of gratitude and love to my friends and my beloved parents for their manual support strength, motivation, advices, helps and for everything else.

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NOMENCLATURE

h_g	convective heat transfer between glass and air channel (W/m^2.K)
h_{rs}	radiative heat transfer coefficient between glazing 1 and sky (W/m^2.K)
h_{rag}	radiative heat transfer coefficient between absorber plate and glazing 2 (W/m^2.K)
h_w	wind convective heat transfer coefficient (W/m^2.K)
H	incident solar radiation on inclined surface (W/m^2)
K_f	thermal conductivity of air (W/m.K)
K_{ins}	thermal conductivity of wall insulator (W/m.K)
q''	heat transfer to the air stream (W/m^2)
S_1	solar radiation heat flux absorbed by glazing 1 (W/m^2)
S_2	solar radiation heat flux absorbed by glazing 2 (W/m^2)
S_3	solar radiation heat flux absorbed by absorber (W/m^2)
T_A	temperature of the absorber (K)
T_{amb}	ambient temperature (K)
T_f	mean temperature of air in channel (K)
T_{fi}	air temperature at inlet of channel (K)
T_{fo}	air temperature at outlet of channel (K)
T_{G1}	temperature of the glazing 1 (K)
T_{G2}	temperature of the glazing 2 (K)
T_s	sky temperature (K)
V	wind velocity (m/s)

θ	angle of inclination with the horizontal surface
υ_f	kinematic viscosity of air
μ_f	dynamic viscosity of air
ρ_f	density of air
C_f	Specific heat of air
β	Coefficient of volumetric expansion
Nu	Nusselt number
Pr	Prandtl number
Gr	Grashof number

Constants

Δw_{ins}	thickness of insulation behind absorber (0.01m)
α_1	absorptivity of glazing 1 (0.6)
α_2	absorptivity of glazing 2 (0.6)
α_3	absorptivity of absorber (0.95)
ε_{G1}	emissivity of glazing 2 (0.9)
ε_A	emissivity of absorber (0.95)
γ	constant for mean air temperature approximation (0.7)
g	gravitational force (0.98)
σ	Steffan-Boltzmann constant (5.67×10^{-8} W/m^{2}K^4)
τ_1	transmissivity of glazing 1 (0.9)
τ_2	transmissivity of glazing 2 (0.9)

CHAPTER 1

INTRODUCTION

1.1 Background Study

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major components of any solar system are the solar collector, a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water or oil) flowing through the collector. The solar energy collected thus is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days.

Solar collectors consist of two major categories: stationary and sun-tracking. Stationary solar collectors are usually flat-plate collector which is the most common type. On the other hand, sun-tracking solar collector usually has concave reflecting surfaces to intercept and focus the sun's beam radiation to a smaller receiving area, thereby increasing the radiation flux. It is mainly used in the power generation industries. Air heating flat-plat solar collectors are usually rectangular passages with two openings at both of their ends. The main engineering concept behind a air heating solar collector is natural convection.

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by density differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density. [1]

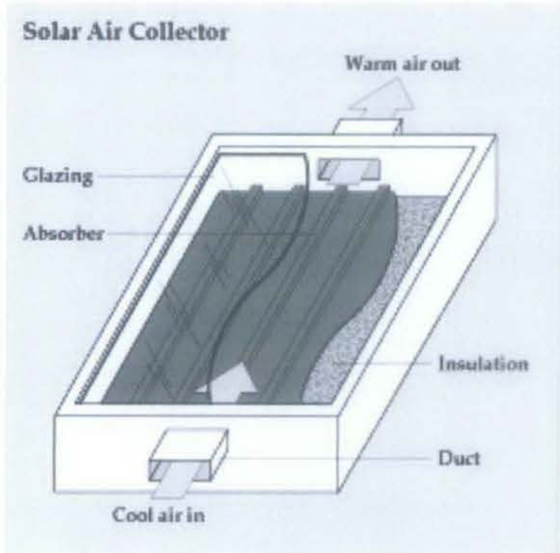


Figure 1.1 Air heating flat-plate solar collector [2]

A typical air heating flat-plate solar collector is shown in the following figure. When solar radiation passes through a transparent cover and impinges on the blackened absorber surface of high absorptivity, a large portion of this energy is absorbed by the plate and then is transferred to the air in the channel. Cool air enters from the bottom opening and as the air is heated, it moved upwards due to natural convection of the air inside the channel. Then the warm air that exits from the solar collector can be utilized for various applications. Transparent cover or glazing is used to reduce the convective losses from the absorber plate to the atmosphere. It also reduces radiation losses from the collector as the glass is transparent to the short wave radiation received by from the sun but it is nearly opaque to long wave thermal radiation emitted by the absorber plate (greenhouse effect). [3]

The most common applications of air heating solar collector are solar chimney and Trombe Wall. A solar chimney uses the natural convection of air heated by the passive solar energy to improve the ventilation of buildings. Some modern solar chimney with high ventilation rate even incorporates a small wind turbine to generate electricity for household supplies purposes. Natural ventilation can be created by providing vents in the upper level of a building to allow warm air to rise by convection and escape to the outside. At the same time cooler air can be drawn in through vents at the lower level.

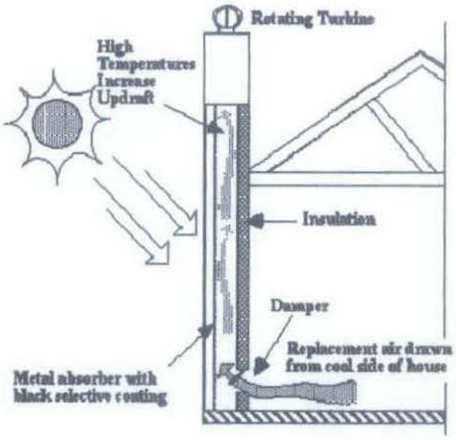


Figure 1.2: Solar chimney for building ventilation [4]

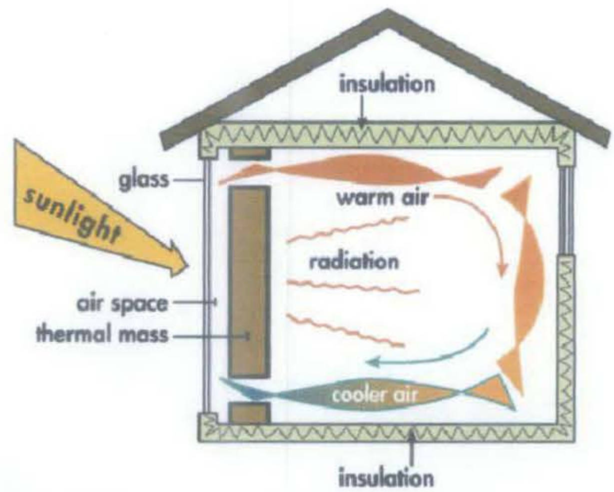


Figure 1.3: Trombe wall to warm up living space. [5]

Figure 1.2 shows an example of a modern solar chimney incorporating a rotating turbine. On the other hand, Trombe wall is used to trap the passive solar energy to warm up the living room. However, the working principle is similar to the solar chimney. During the day, sunlight shines through the glazing and hits the surface of the thermal mass, warming it by absorption. The air between the glazing and the thermal mass warms (via heat conduction) and rises, taking heat with it (convection). The warmer air moves through vents at the top of the wall and into the living area while cool air from the living area enters at vents near the bottom of the wall. At night, a one-way flap on the bottom vent prevents backflow, which could give undesired reverse cooling effect. In addition, the heat stored in the thermal mass radiates into the living area to continuously warming the living space. **Figure 1.3** shows the basic design and heat transfer principles of a Trombe wall.

Other than that, air heating solar collector can also be used in process applications such as drying laundry, crops and other drying applications. Air heated through a solar collector and then passed over a medium to be dried can provide an efficient means by which to reduce the moisture content of the material. [6]

1.2 Problem Statement

The evaluation of the outlet temperature of flow in solar collector is still of interest for the convective heat transfer investigators. Many parameters are involved in such case, for example the passage length and gap size, inclination angle, walls temperature, ambient temperature, insolation, etc. Accordingly, correlating the outlet temperature to the inlet at different conditions will simplify the mathematical modeling of the phenomena.

1.3 Objectives

The objective of this project is to investigate the heat transfer in solar collector to correlate the outlet to the inlet air temperatures at various passage lengths and inclination angles.

1.4 Scope of Work

1. To do analytical analysis on the physical model of a solar collector to correlate the outlet air temperature to inlet air temperature, wall temperature, insolation, etc. at various passage lengths and inclination angles.

2. To conduct series of experiments based on the physical model in analytical analysis to investigate the relationship between the parameters involved and observe the transient behavior of the system.

3. To validate the results from analytical analysis with the experimental results.

1.5 Significance of the Project

The actual mathematical modeling for a solar collector of a rectangular passage is very complicated as there are too many unknown parameters to be taken into consideration, such as the inlet air and outlet air temperature, the passage wall and glass temperature, solar irradiation, outlet air velocity, length and inclination angle of the passage, etc.

Yet, if the correlation of the outlet air temperature to the inlet air temperature at the various conditions were found, the mathematical modeling of such particular phenomena could be simplified significantly.

For instance, with a given inlet air temperature, the outlet air temperature can be easily predicted at different passage lengths and inclination angles, using the same established correlation. This information would be very useful for engineers to improve or design new solar collectors up to their desired standards and specifications.

CHAPTER 2

LITERATURE REVIEW

Many researches, studies, experiments, and modeling had been done related to the topic of this project. Most of them involved with the chimney and the Trombe wall. Evaluation of the performance of special chimney configuration, such as solar roof collectors and Trombe walls had been made to achieve optimum and energy conservation in buildings. (e.g. Gan 1998; Sànchez et al., 2003; Ong and Chow 2003; Khedari et al., 2000, 2003; Heras et al., 2005).

Bouchair [7] showed that there is an optimum chimney length/gap width ratio for maximum air flow rate for his 1.95 m high and variable width chimney which was electrically heated. However, if the chimney was too big reverse circulation occurred whereby the air flows downward via the center of the duct. Hocevar and Casperson [8] had proven experimentally that the velocity and temperature magnitudes in width size varying from 2.5 to 20 cm of a vented 2.2 m high Trombe wall are functions of the gap width, ambient air temperature, insolation rate, wall temperature and the elevation above the Trombe wall inlet duct. They also pointed out that changes in ambient conditions at different measurement times would not change the temperature profile significantly.

Bansal et al. (1993) [9] developed a steady state analytical model for uniform wall temperature applied to a solar system consisting of a solar air heater connected to a conventional chimney. Combining the air flow rate equations and for the chimney and the energy balance equation for a conventional irradiation heat absorber, they managed to derive a temperature distribution equation for the air. Andersen (1995) [10] derived a set of equations to predict the natural ventilation in a room with small openings based on the pressure model. He mentioned that the channel width for solar chimneys should be at least 4.7cm. Gan (1998) [11] used 3D CFD techniques to study the parameters that influence the performance of a Trombe wall. He concluded that the ventilation rate increased with wall temperature, solar heat gain, wall height, channel gap, double-glazing, and thickness of wall. In the studies, he highly recommended increasing the thickness of the interior surface of the wall to increase its performance.

Using the concept of a thermal resistance network, Ong and Chow (2003) [12] developed an analytical model to examine the effects of air gap and solar irradiation intensity on the performance of different chimneys assuming uniform heat flux on the heated wall, solved using matrix inversion. Existing correlations of heat transfer coefficients were utilized. Property values for the air flow in the duct were based on mean bulk or film temperatures. The performance of the chimney was evaluated by predicting the temperatures of the glass glazing and the heat-absorbing wall and also the temperature and velocity of the induced air flow in the chimney. The effects of air gap and solar radiation intensity on the performance of different chimneys were investigated. In order to verify the theoretical model, experiments were conducted on a 2 m high x 0.45 m wide physical model with air gaps of 0.1, 0.2 and 0.3 m. Experiments were carried out outdoors on the roof and the experimental model exposed to both direct and diffuse solar radiation. Air velocities between 0.25 m/s and 0.39 m/s for radiation intensity up to 650 W/m^2 were obtained. No reverse air flow circulation was observed even at the large gap of 0.3 m. **Figure 2.1** below shows the description of the physical model of chimney used.

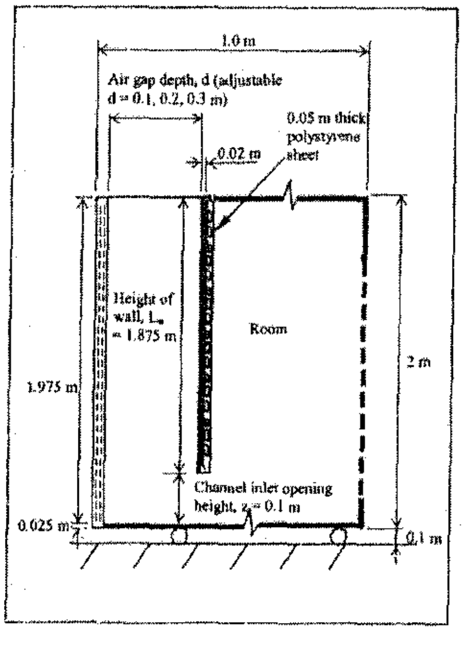


Figure 1.1 Cross sectional view for physical model of chimney

Most published works deal with solar chimneys fixed at a specific inclination, usually vertical, mostly because these are easier to construct and operate. In fact, E.P. Sakonidou et al. (2008) [13] mentioned that solar chimneys employing inclined collectors can evidently exploit more the incident irradiation to enhance air flow in the chimney. As the inclination of the chimney varies, two things occur that work in opposite directions with respect to the air flow rate. A lower inclination results in a higher exposure of the wall to solar irradiation and hence yield higher heat utilization and more intense buoyant air flow. However, tilting the chimney reduces the effective pressure head of the chimney and so diminishes air flow. Therefore, it is apparent that there must be an optimum tilt to the highest flow rate, compromising these two effects. Through CFD modeling and experimental results, they found that the optimum tilt of a solar chimney for maximizing air flow varies from 65^0 to 76^0. Besides velocity, the output of the model includes the temperature of the air inside the chimney and the temperatures of the glazing and the black painted absorber, as a function of tilt and height. Besides that, they also considered chronological, geographical, meteorological, geometrical aspects and the optical irradiation properties of construction materials in their study. A related research of solar irradiation and glazing optical properties was employed by Hamdy and Fikry (1998) [14] for Alexandria (Egypt) in the summer months. They examined the optimum tilt angle of a solar collector connected to a conventional chimney at 32° N latitude. For these particular conditions, an optimum tilt around 60^o was estimated for maximum air flow.

Similar works has already been carried out by Moshfegh and Sandberg (1998); and Chen et al. (2001), however, they involved heating means other than solar irradiance to achieve uniform wall heat flux. Chen et al. [15] carried out indoor experiments on a one-side electrically heated 1.5 m high solar chimney with variable gaps from 0.1 to 0.6 m and at different chimney inclinations. Their results show maximum air flow rate at an inclination angle around 45° for a 0.2 m gap and 1.5 m height of chimney. The air flow rate was about 45% higher than a vertical chimney at otherwise identical conditions. They concluded that prediction methods currently available over-predicted the air flow the air flow rate because of the uniform temperature air velocity across the same height assumption, especially for chimneys with large gaps.

D.J Harris, N. Helwig (2006) [16] had also performed an assessment of the impacts of the inclination angle on the induced ventilation rate by CFD modeling technique. Besides that, his studies involved the effects of double glazing and low emissivity finishes of the solar chimney. It was found that for a south-facing chimney, an inclination angle of 67.5^0 from the horizontal was optimum for the location chosen, giving 11% greater efficiency than the vertical chimney, and that a 10% higher efficiency was obtained by using a low-emissivity wall surface. Low-emissivity coatings allow radiation to be absorbed but limit the emission of long wave infrared radiation back to the surroundings. The addition of double glazing gave a slight improvement in performance, but it was not significant enough to be cost effective. Some of the graphical results of analysis are shown in following figures. **Figure 2.2** shows the effects of double glazing and low-emissivity on air flow rate at different inclination angle and cavity width. The result indicates that the maximum air flow is given with the cavity width of 0.25 m. Meanwhile, **Figure 2.3** indicates the 24 hours performance of different tilt angle configuration.

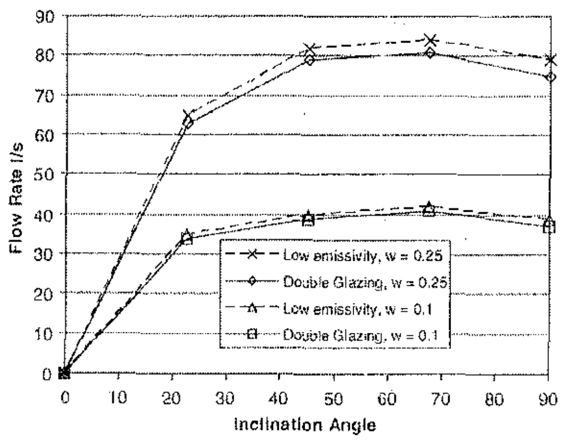


Figure 2.2 Effects of double glazing, low emissivity on performance

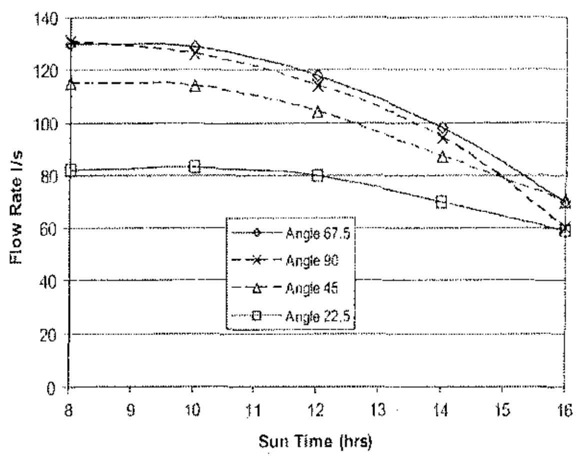


Figure 2.3 Twenty four hour performance at different inclination angle

Jyotirmay et al. [17] (2006) had also proposed solution to obtained mass flow rate through inclined solar chimney for given latitude, day, time, inclination and chimney dimensions. The theoretically determined results with the presented solution are found to be in good agreement with experimental results. Their study shows that optimum inclination at any place varies from 40^0 to 60^0 depending upon latitude. The maximum mass flow rate through an inclined solar chimney at Jaipur (India) 27°N latitude can be obtained at an absorber inclination of 45°. Flow rate at 45° inclinations is about 10% more than the flow rate at 30° and 60° inclinations. It can also be concluded that with increase in *air gap*, rate of air flow increases. Similarly, it has also been established that with increase in *inlet height*, flow rate increases. The obtained flow rates are sufficient for using roof solar chimneys for inducing ventilation in real buildings.

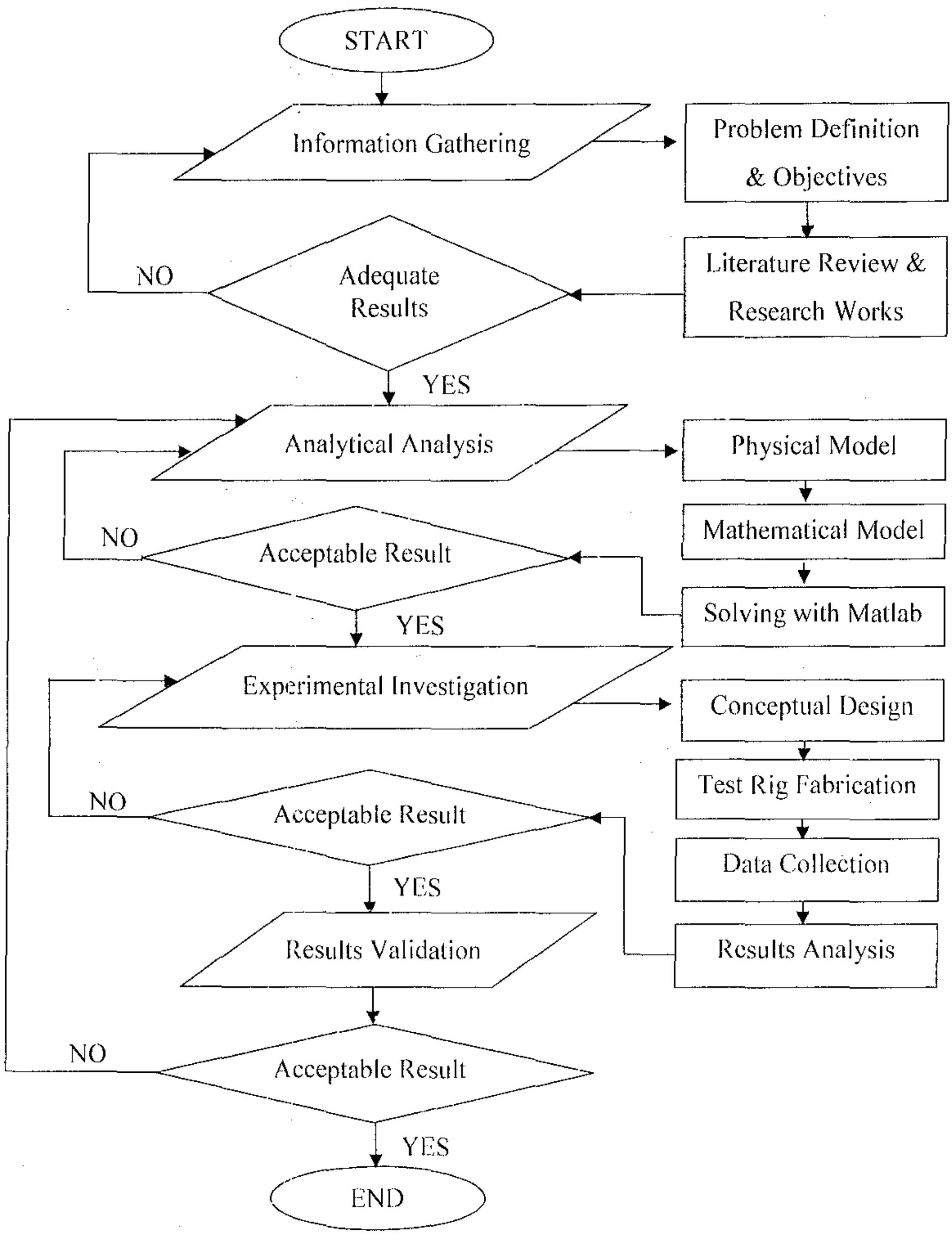
The more current related study has been done by Azrul (2010) [18] to investigate the effects of four different inlet configurations of inclined heated channel of Roof Top Solar Chimney (RTSC). His experiments and simulations analysis showed that the air flow rate varies with the type of inlet configurations, thus recommended taking into the consideration of inlet shape when analyzing performance of solar chimney system. On the other hand, J. Arce et al. (2010) [19] carried out an experimental analysis on the thermal performance on a full scale solar chimney. An experiment model was built and operated at outdoor, facing south in vertical position, located at Desert of Tabernas, Almeria. It was observed that the air flow rate through the solar chimney was influenced by a pressure difference between input and output caused by *thermal gradients* and by *wind velocity*, mainly. A maximum air temperature increment of 70°C was obtained was obtained through the system for a maximum irradiance of 604W/m^2 occurring around 13:00h. Values of air flow rate 50–374 m^3/h were obtained for a typical day of September 15th 2007. An average air flow rate of 177 m^3/h was obtained from 0:00 h to 24:00 h. A discharge coefficient C_d of 0.52 was experimentally obtained and it may be used to determine the mass flow rate on theoretical models of solar chimneys.

From the literature review, it is observed that most of the research was focusing more on the outlet velocity but less on the outlet temperature of the air. Thus, in order to correlate the outlet air temperature to the inlet, the convection heat transfer in open solar collectors is still requiring further investigation. Since many parameters are affecting the system, experimental and analytical analyses will be carried out in this study in order to obtain the solution.

CHAPTER 3

METHODOLOGY

3.1Project Execution Flow Chart



3.2 Gantt Chart

Final Year Project 1

No	Detail / Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Selection of Project Topic							Mid Semester Break								
2	Preliminary Research Work															
3	Literature Review															
3	Submission of Preliminary Report															
4	Conceptual Design & Material Selection															
5	Detailed Design															
6	Fabrication															
7	Submission of Progress Report															
8	Seminar															
9	Start Experiments															
10	Data & Results Analysis															
11	Submission of Interim Report Final Draft															
12	Oral Presentation								During Study Week							

Final Year Project 2

No	Detail / Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Continue Experiment							Mid Semester Break								
2	Analytical Analysis															
3	Results Analysis															
4	Submission of Progress Report															
5	Pre-EDX															
6	Submission of Draft Report															
7	Submission of Dissertation (Soft Bound)															
8	Submission of Technical Paper															
9	Oral Presentation															
10	Submission of Dissertation (Hard Bound)								Week 15							

3.3 Analytical Analysis

A physical model of a solar collector was established in order to define the control volume and boundaries of the system. **Figure 3.1** shows the physical model of a double glazing solar collector which will be used in this particular study. Following assumptions were taken in this case:

1. The entire system is in steady state condition.
2. Friction losses is neglected due to the very low order of air flow velocity.
3. The flow of air in the channel is in laminar.
4. The inlet air temperature is the same as the ambient temperature.
5. All energy transfer processes through the glass cover, absorber plate and air channel are in one dimensional in nature.

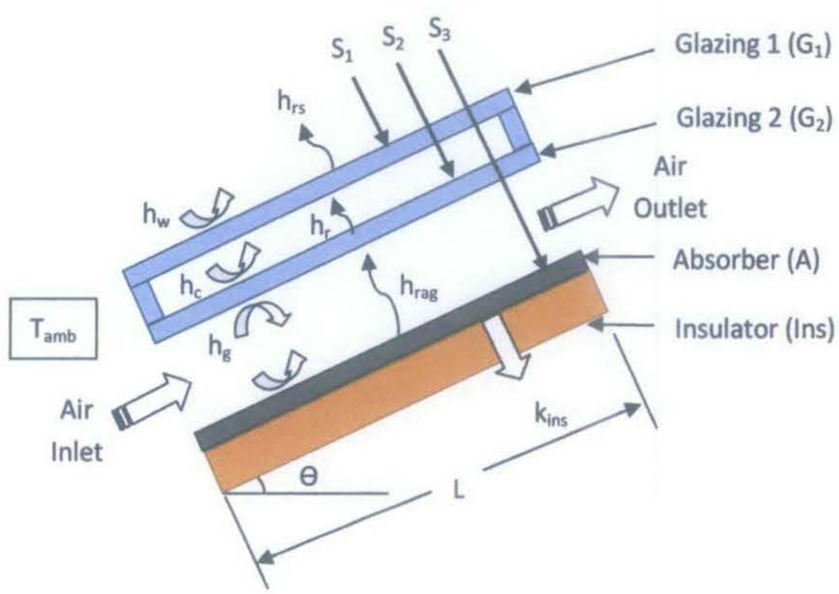


Figure 3.2 Physical model of a double glazing solar collector

Subsequently, mathematical model was then developed based on the physical model above. The mathematical model is mainly used to predict the outlet air temperature of the system to the inlet air temperature at an inclined angle and varied passage length. In order to perform this, study of natural convection of heat transfer was conducted. The major parameters included in this study are: temperature of absorber (T_A) and glazing surface (T_{G1}, T_{G2}), ambient air temperature (T_{amb}), temperatures of air inlet (T_{fi}) and outlet (T_{fo}), mean air temperature (T_f), inclination angle from horizontal plane (θ) and length of passage (L).

The following energy equations for the glazing surfaces, air passage, and absorber surfaces were established to find the desired correlation.

At Glazing 1,

$$S_1 + h_c(T_{G2} - T_{G1}) + h_r(T_{G2} - T_{G1}) = h_{rs}(T_{G1} - T_{amb}) + h_w(T_{G1} - T_{amb}) \quad (1)$$

At Glazing 2,

$$S_2 + h_g(T_f - T_{G2}) + h_{rag}(T_A - T_{G2}) = h_c(T_{G2} - T_{G1}) + h_r(T_{G2} - T_{G1}) \quad (2)$$

Substituting (2) into (1),

$$S_1 + S_2 + h_g(T_f - T_{G2}) + h_{rag}(T_A - T_{G2}) = h_{rs}(T_{G1} - T_{amb}) + h_w(T_{G1} - T_{amb}) \quad (3)$$

At Air Passage,

$$h_a(T_A - T_f) = h_g(T_f - T_{G2}) + q'' \quad (4)$$

At Absorber,

$$S_3 = h_a(T_A - T_f) + h_{rag}(T_A - T_{G2}) + \left(\frac{k_{ins}}{\Delta w_{ins}}\right)(T_A - T_{amb}) \quad (5)$$

The useful heat gain by air in the equation (4) can be found through following equation

$$q'' = \dot{m} C_f (T_{fo} - T_{fi}) \quad (6)$$

Where

$$\dot{m} = C_d \rho_f A_0 \sqrt{\frac{2gL\sin\theta\,(T_f - T_{amb})}{(1 + A_r^{\,2})T_{amb}}}$$

Where $A_r = A_0/A_i$; ρ_f of (8) & (9); $C_d = 0.57$ [20]

The mean air temperature is given as

$$T_f = \gamma T_{fo} + (1 - \gamma)T_{fi} \tag{7}$$

Where γ is constant for mean temperature approximation (0.74) [21]

The solar radiation heat flux absorbed by glazing 1 (S_1), glazing 2 (S_2) and absorber (S_3) are given as

$$S_1 = \alpha_1 \qquad S_2 = \tau\alpha_1 \qquad S_3 = \tau^2\alpha_1$$

Radiative heat transfer coefficient between glazing 1 and sky is given as

$$h_{rs} = \frac{\sigma\varepsilon_{G1}(T_{G1} + T_s)\left(T_{G1}{}^2 + T_s{}^2\right)(T_{G1} - T_s)}{T_{G1} + T_{amb}}$$

Where sky temperature, $T_s = 0.0552(T_{amb})^{1.5}$ [22]

Convective wind heat loss coefficient is given as

$h_w = 5.7 + 3.8\,V$ [23]

Where V = wind velocity

Radiative heat transfer coefficient between absorber and glazing 2 is given as

$$h_{rag} = \frac{\sigma\left(T_{G2}{}^2 + T_A{}^2\right)(T_{G2} + T_A)}{\left(\frac{1}{\varepsilon_{G2}} + \frac{1}{\varepsilon_A} - 1\right)}$$

Convective heat transfer coefficient between glazing 2 and air channel is given as

$$h_g = \frac{Nuk_f}{L}$$

Where, $Nu = 0.6(Gr.cos\theta.\mathrm{Pr})^{0.2}$

$$Pr = \frac{\mu_f C_f}{k_f}$$

$$Gr = \frac{g\beta S_2 L^4}{k_f v_f{}^2}$$

* $\mu_f, C_f, k_f, \beta, v_f$ can be found from the empirical relationships proposed based on tabulated data from handbooks for air properties by using the mean temperature value of

$$T_m = \frac{T_{G1} + T_f}{2}$$

Convective heat transfer coefficient between absorber and air channel,

$$h_a = \frac{NuK_f}{L}$$

Where, $$Nu = 0.6(Gr.\cos\theta.\text{Pr})^{0.2}$$

$$Pr = \frac{\mu_f C_f}{k_f}$$

$$Gr = \frac{g\beta S_2 L^4}{k_f {v_f}^2}$$

* $\mu_f, C_f, k_f, \beta, v_f$ can be found from the empirical relationships proposed based on tabulated data from handbooks for air properties by using the mean temperature value of

$$T_m = \frac{T_A + T_f}{2} \quad (8)$$

The empirical relationships proposed based on tabulated data from handbooks for air properties

$$\mu_f = [1.846 + 0.00472\ (T_m - 300) \times 10^{-5}]$$

$$C_f = [1.007 + 0.00004\ (T_m - 300) \times 10^{3}]$$

$$k_f = [0.0263 + 0.000074\ (T_m - 300)]$$

$$\rho_f = [1.1614 + 0.00353\ (T_m - 300)] \quad (9)$$

$$v_f = \frac{\mu_f}{\rho_f} \qquad \beta = \frac{1}{T_m}$$

From the equations above, T_A, T_{G1}, T_{G2}, T_f, T_m and T_{fo} are the four unknowns that are to be solved. However, in order to find the empirical relationship of air properties (where the calculation should be started), T_A, T_{G2} and T_f are first required to be known in order to calculate the mean air temperatures, T_m. In other words, T_A, T_{G2} and T_f are first needed to be guessed in order to find their real value through the method of iterations. However, the calculation can be very complex due to the many unknowns involved. Thus, in order to simplify this problem, T_A, T_{G1}, T_{G2} were assumed to be known. As a matter of fact, the values will be obtained from the experimental data. Now that with only Tm, Tf, and Tfo left to be unknowns, the problem can be solved by

Substituting (7) into (5),

$$S_3 = h_a\{T_A - [\gamma T_{fo} + (1-\gamma)T_{fi}]\} + h_{rag}(T_A - T_{G2}) + (\frac{k_{ins}}{\Delta w_{ins}})(T_A - T_{amb})$$

Rearranging,

$$T_{fo} = T_{fi} + \frac{T_A - T_{fi}}{\gamma} + \frac{h_{rag}(T_A - T_{G2}) - S_3}{h_a \gamma} - \frac{k_{ins}(T_A - T_{amb})}{h_a \gamma (\Delta w_{ins})} \qquad (10)$$

Due to the lengthy calculation, it is rather difficult to solve the simultaneous equations for T_{fo} and T_f through traditional method. Therefore, it is proposed that this problem is to be solved through mathematical computer program. For this study, **MATLAB v7.1** was used to write the program required to solve the problem. An initial guess was given to T_{fo} in order to find T_f from equation (7). Meanwhile, equation (10) is used to calculate for T_{fo}. Then, the computed T_{fo} is compared with the initial guessed value. If the error of guessing were too big (more than 0.1%), the program will use the computed T_{fo} as a new guessed T_{fo} and repeat the calculation. Each of this loop is called iteration where the values of Tfo will continue to converge with each iteration. The loop will be repeated until the condition is met (error is less or equal to 0.1%). A more detailed execution flow chart of the written MATLAB program is showed in the following **Figure 3.3**. Meanwhile, the MATLAB program codes are attached in the **APPENDIX I**.

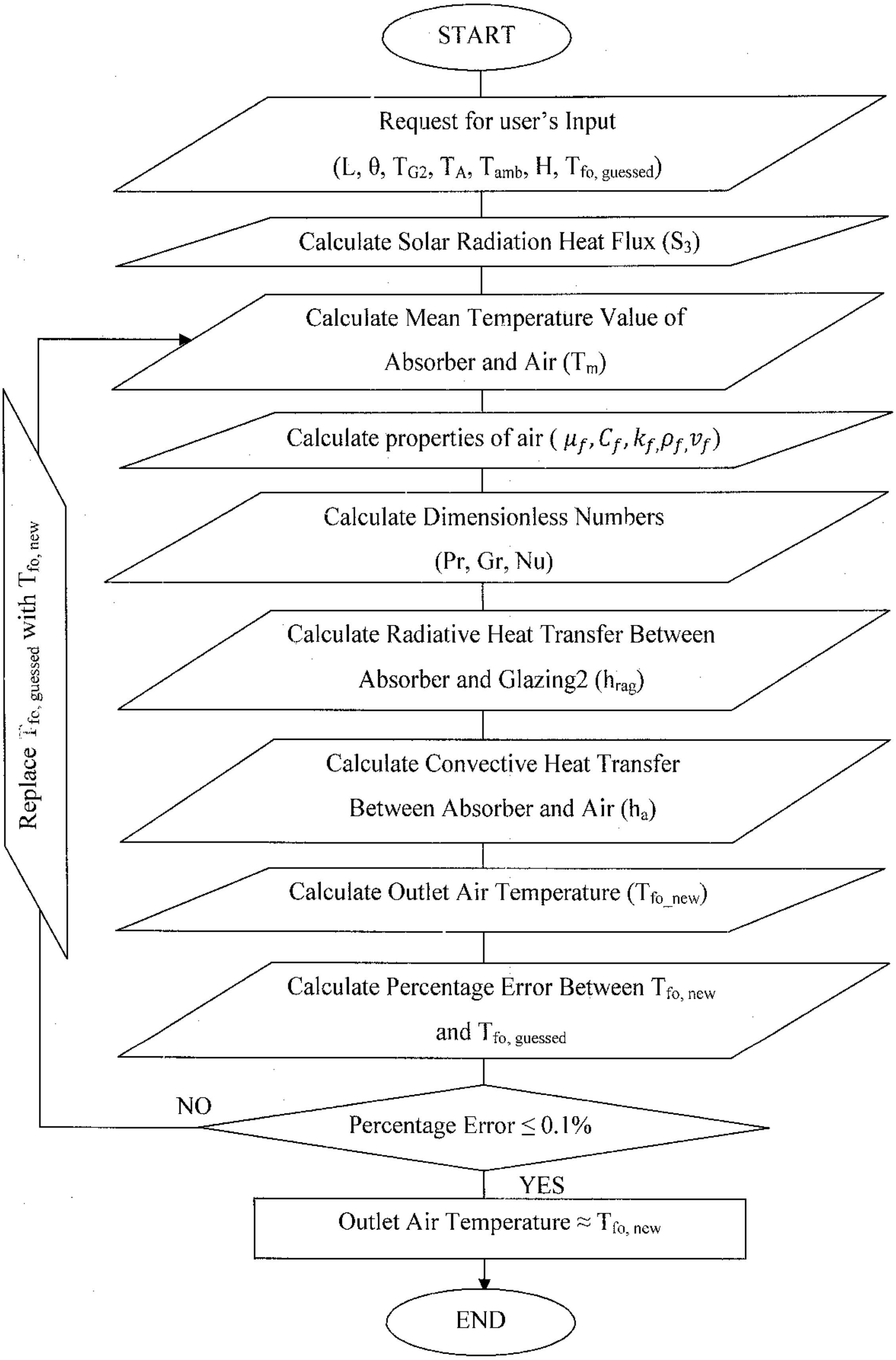


Figure 3.3 MATLAB Program Execution Flow Chart

3.5 Experimental Investigation

3.5.1 Conceptual Design

The design of the experimental model for this project is fairly simple. Figure 4.1 shows the dimensions of the models which have 0.5 m x 0.13 m cross sectional area with three different lengths which are 1 m, 1.5 m and 2 m respectively. In order to reduce the cost of production, at the same time increasing the ease of transportation, fabrication and configuration, the model is designed to be attachable and detachable to fulfill the different length requirement. Figure 4.2 shows the isometric view hand-sketch of the initial stage model design. Two supporters are used to support the rectangular passage with adjustable lock to ensure that the rectangular passage could be tilt to the desired angle (10°, 30°, 50°, 70°, and 90° measured from horizontal plane). Supporter will be directly attached to the 1 m rectangular passage; meanwhile of the 0.5m section(s) can be attached to the 1m section by clipper or hinge to achieve 1.5m and 2m respectively.

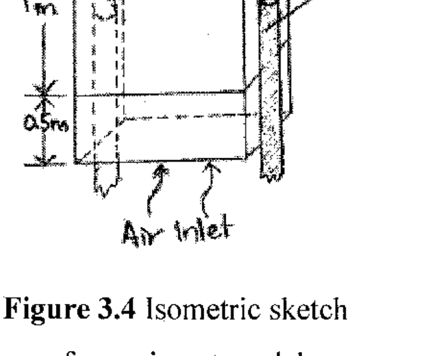


Figure 3.4 Isometric sketch of experiment model

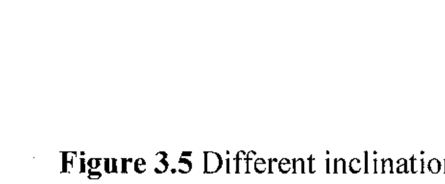


Figure 3.5 Different inclination angle configurations

3.5.2 Detailed Drawings

The detailed drawings of the test rig have been completed using **AutoCAD 2007**. The drawings are including the four different view angles of the test model, which are the plan, front, side and isometric view respectively. Please refer to **APPENDIX II** for the detail drawings.

3.5.3 Material Selection

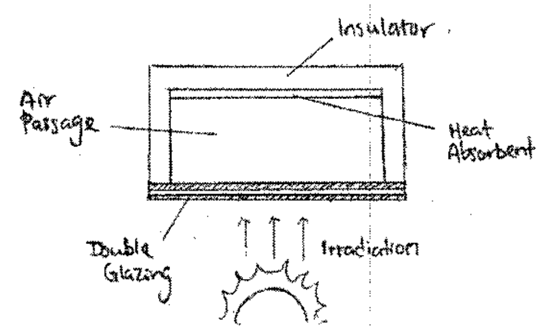


Figure 3.6 Cross sectional view of the solar collector

Based on **Figure 3.6**, three different characteristic of the materials that work in a typical solar collector are used to construct the passage. The three types of materials are glazing, heat absorbent and insulator.

Glazing is the transparent part of the wall where the solar irradiation will transmit through and hit directly at the heat absorbent.

Absorber will transfer heat as radiation to the glazing then back to the sky; at the same time, transfer heat as convection to the air inside the passage.

Insulator will trap heat and prevent unnecessary heat loss through conduction and convection at the other surface of the absorber.

The type of material selected with justification of selection is shown in the following **Table 3.3**.

Table 3.3 Materials selections for test model's components

Components	Materials	Justification
Double Glazing	Perspex	• Ease of fabrication, • Sheer clarity • Lighter weight and better insulation than glass
Absorber	Aluminum	• Ease of fabrication • High thermal conductivity • Lighter weight and more economical than copper
Insulator	Plywood	• Low thermal conductivity • Cost-effective

3.5.4 Experiment Settings and Procedures

The data collected from the experiment are insolation, ambient, outlet and mean air temperature, inner and outer glazing temperature, absorber plate temperature. Meanwhile, the tools and equipments used for the data collection purpose include:

1. Test rig
2. Two channels data logger – to display temperatures value
3. Thermocouple wires – to measure wall surfaces temperatures
4. Thermocouple probes – to measure air temperatures
5. Solar meter – to measure insolation

First of all, thermocouples are placed along the length of the surface of the inner and outer glazing and absorber in order to take their mean temperature. Four thermocouples are placed along the wall surfaces of 2m length; three thermocouples are placed for 1.5m length; 2 thermocouples for 1m length. Measurements are taken every 2 hours interval, at 8am, 10am, 12pm, 2pm, 4pm, and 6pm to observe the transient behavior of the system.

The experiment is started with 2m wall length at 90° inclination angle, followed by 70°, 50°, 30°, and 10° from the horizontal axis. For each set of tilt angle at 2m, the readings are taken for 3 consecutive days in order to find the average result. After 2m configuration is completed, the same procedure is repeated for each 1.5m and 1m wall length. The sample data sheet used for experiment is attached the **APPENDIX III**.

Figure 3.7 1m wall channel at 30°

Figure 3.8 1.5m wall channel at 70°

Figure 3.9 2m wall channel at 30°

From **Figure 3.7**, it is observed that 1m section is fixed at the center of the support with a bearing for tilting. The four hinges at the top and bottom of the insulator are used to extend the wall length to 1.5 and 2m. **Figure 3.8** shows that the wall is extended at the top hinges to 1.5m. Meanwhile, **Figure 3.9** shows the 2m configuration, extended both from the top and bottom hinges. Like insulator, the double glazing is also extended. On the other hand, absorber plate is not extended. Three different absorber plates will be manually fixed onto the insulator based on the configuration length of 2m, 1.5m and 1m, respectively. All four sides and edges of the double glazing are sealed using silicon tape to reduce losses. In addition, every time when the insulator and glazing are extended, silicon tape will again be applied to seal the tiny gap in between to minimize the losses.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Experimental Data Analysis

Microsoft Excel 2007 was used to store and summarize raw data, and also to plot all the graphs for analysis purposes. As mentioned previously, each of the configurations (varied length and inclination angle) are repeated for 3 consecutive days to consider the average reading. This is because the weather is changing too frequently, thus average result is taken to improve the reliability of the data. As a result, the experiment was conducted for a total of 45 days until all data are successfully collected. Both the data summary and raw data are presented in the **APPENDIX IV**.

Despite that average readings have considered, it is necessary to clarify that the data collected are sometime inconsistent, due to the inevitable sudden change of weather (cloudy and windy). Therefore, the following discussions are made based on the overall observation, rather by individual configuration. In addition, the following graphs are plotted against time to observe the transient behavior of the system.

The following figure is showing the variation of mean air temperature (left y-axis) and

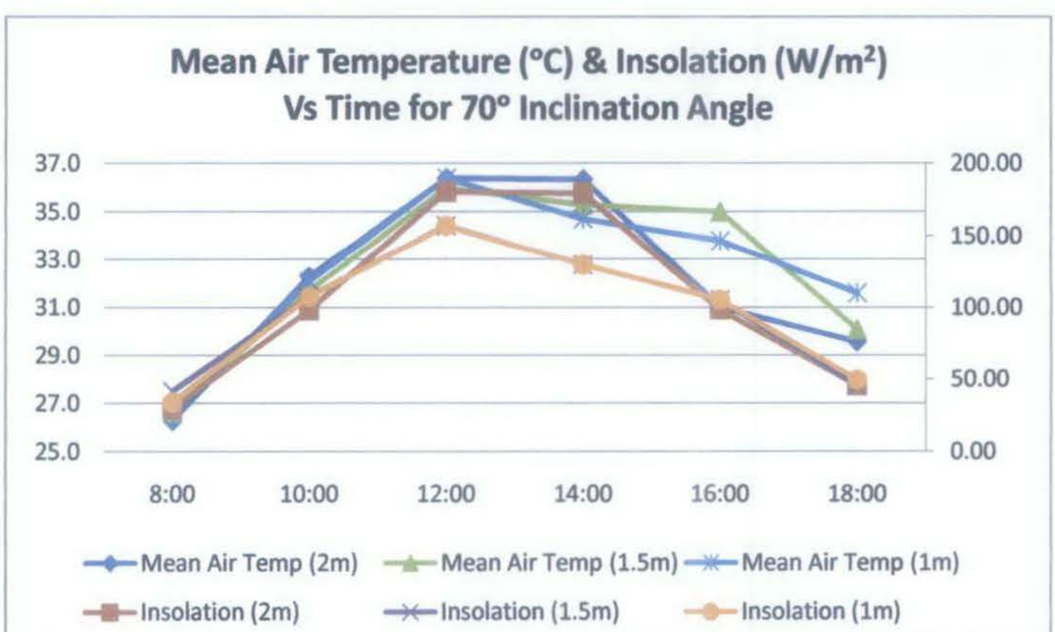


Figure 4.1 Mean air temperature & insolation profile for 70° inclination angle

insolation (right y-axis) at 70° inclination for 2m, 1.5m and 1m passage lengths. This angle was randomly selected simply as an example to compare the relationship between the mean air temperature and insolation. It is observed that the mean air temperature profile is closely matching the insolation profile for each individual passage length. Both of the readings are gradually increasing from 8am, reaching its peak around 12pm to 2pm, and then gradually reducing afterwards.

To observe the influence of inclination angle on both insolation and mean air temperature, the following graphs are presented. Passage length of 2m was randomly selected solely as an example to be presented. The graphs are showing the variation of insolation and mean air temperature profile at all inclination angles.

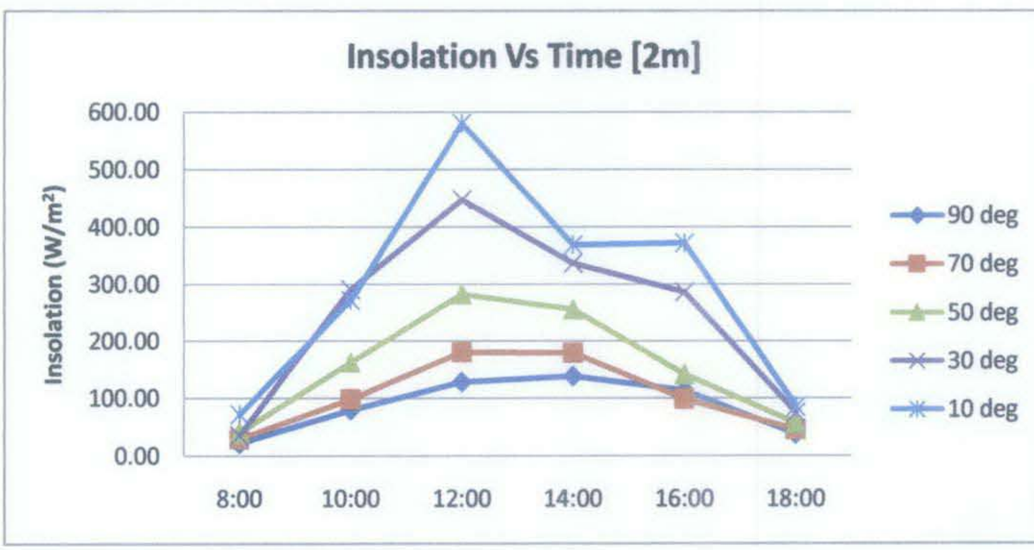


Figure 4.2 Insolation profile for passage length of 2m

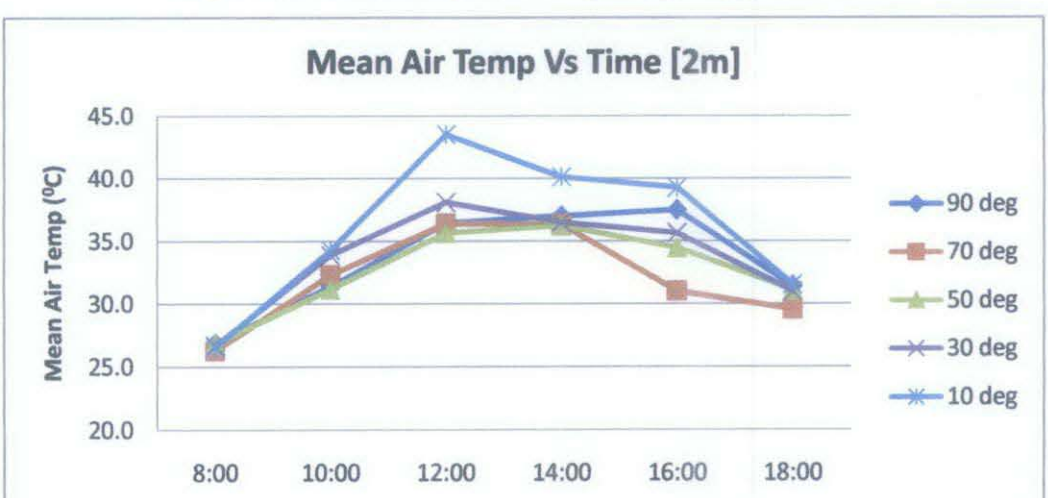


Figure 4.3 Mean air temperature profile for channel length of 2m

From **Figure 4.2** above, it is observed that the intensity of insolation is significantly affected by the tilt angle. The system is gaining higher incident solar radiation at lower tilt angle, thus providing higher value of insolation. The difference is most significant around 12pm where the insolation is the most intense throughout the day. Nevertheless, **Figure 4.3** shows that inclination angle does not significantly affecting the variation of mean air temperature in the air passage. Yet, lower inclination angle still noticeably produces higher mean air temperature for all passage lengths. The inconsistent behavior of mean air temperature at different inclination angles could be due to the wind running through the channel – replacing the warm air in the channel with ambient air, thus, lowering the air temperature at that particular day and time. In addition to **Figure 4.1**, the fact that the mean air temperature profile closely matches the insolation profile at other inclination angles (10°, 30°, 50°, and 90°) can be observed by comparing **Figure 4.2** and **Figure 4.3**.

Finally, the following graphs are plotted to analyze the impact of different passage length is having on its mean air temperature profile. The graphs are showing the mean air temperature profile at 2m, 1.5m and 1m passage lengths for all tested inclination angles.

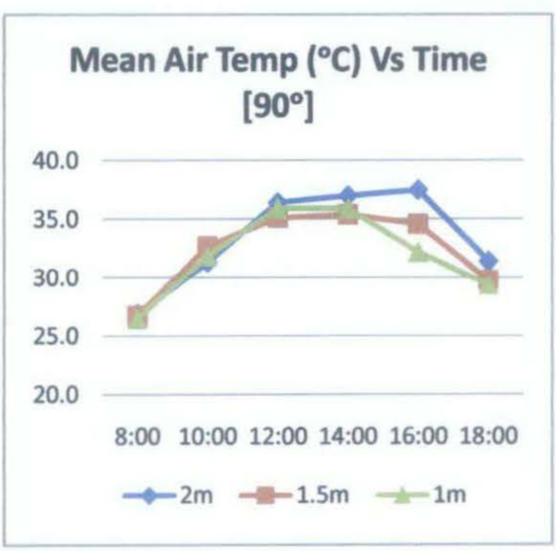


Figure 4.4 Mean air temperature profile for 90° inclination angle

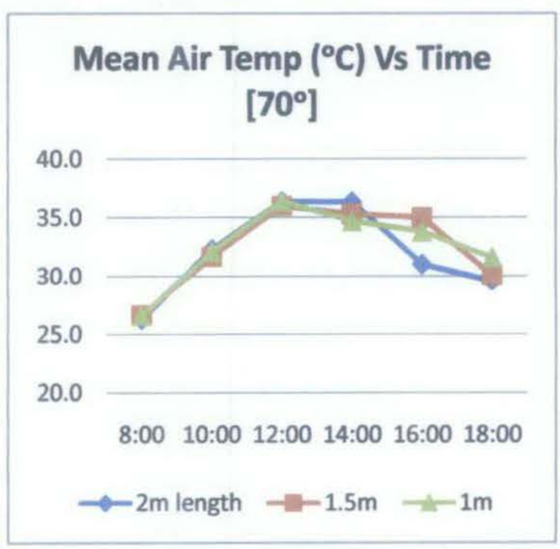


Figure 4.5 Mean air temperature profile for 70° inclination angle

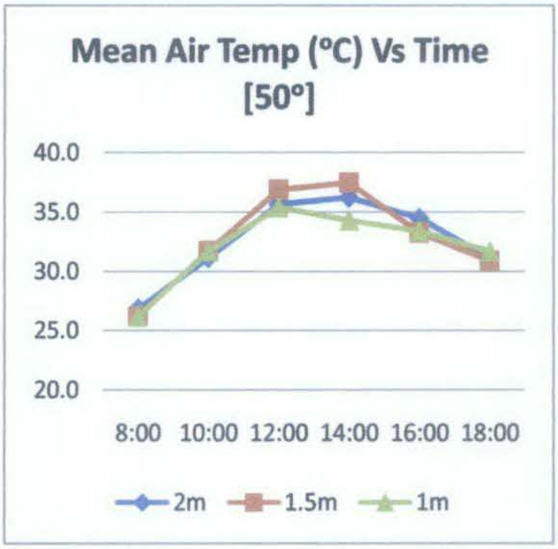


Figure 4.6 Mean air temperature profile for 50° inclination angle

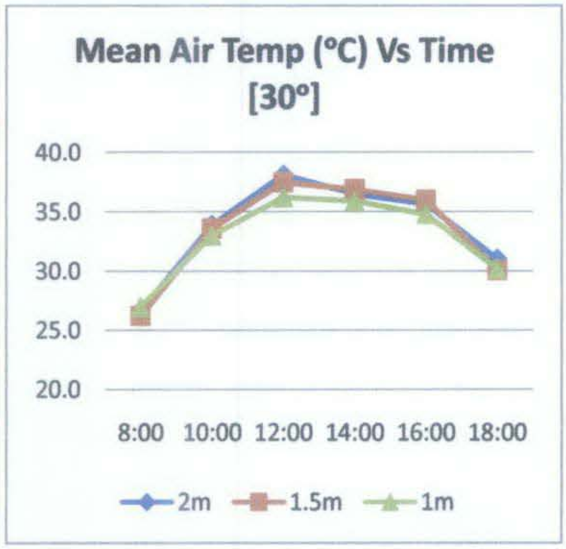


Figure 4.7 Mean air temperature profile for 30° inclination angle

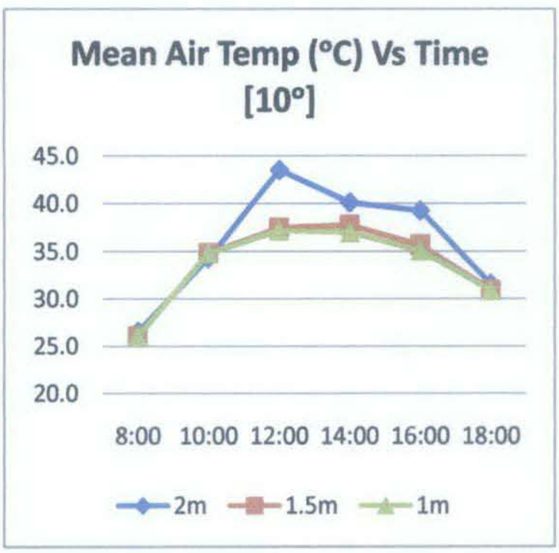


Figure 4.8 Mean air temperature profile for 50° inclination angle

From all the figures above, it can be seen that the length of the wall does not significantly affecting the variation of mean air temperature in the air passage. Similar to previous analysis, changes in weather condition (insolation and wind velocity) when the readings are taken could be the main contributor to this behavior. However, generally 2m passage length has slightly higher peak mean air temperature compared to 1.5m, followed by 1m passage length.

4.3 Analytical And Experimental Validation

The computation results from the mathematical model and MATLAB program written earlier are validated with the experimental data collected. To perform the validation, inputs (L 0, T_{G2}, T_A, and T_{amb}) were obtained from the experimental data, then the computed output (T_{fo}) is compared with the real outlet air temperature from the experimental data.

The following **Table 4.1, 4.2, 4.3, 4.4, 4.5,** and **4.6** are showing the comparison between the computed (theoretical) results and experimental results for all configurations at 08:00, 10:00, 12:00, 14:00, 16:00, and 18:00, respectively. In addition, the individual percentage of error between both results $\{ \frac{Theoretical-Experimental}{Theoretical} \times 100 \}$ is calculated and the mean percentage error for the respective time is found. The mean percentage of error calculated varied from 6.21% (at 08:00) to 12.20% (at 12:00).

In addition, the variation of outlet air temperature against the inclination angles at different length for both theoretical and experimental results were plotted. It is displayed as **Figure 4.9, 4.10, 4.11, 4.12,** and **4.13** at 08:00, 10:00, 12:00, 14:00, 16:00, and 18:00, respectively. Based on these tables and figures, it can be seen that theoretical results of each configuration is noticeably higher than experimental results. This is most probably because the wind is displacing the hot air with cooler ambient air in the channel, thus making it lower than the theoretical results.

Besides that, it is also observed that configuration of lower inclination angles is generally producing higher percentage of error compared to configuration with lower inclination angles. Similarly, the fluctuation of percentage error is again caused by wind traveling through the air passage. In most cases, the wind has greater impact on lower inclination angle configuration. This is because when the air passage is more parallel to the direction of the wind itself, the wind is able to travel through the passage more freely, thus displacing more hot air with cooler ambient air. Therefore, when the inclination angle of the system is decreasing, the percentage of error is naturally increasing.

Table 4.1 Comparison of theoretical and experimental results for 08:00

L	θ	TG2	TA	Tfi	H	Tfout		
						Theo	Exp	% Error
2m	90.0	26.3	27.5	26.6	21.96	27.5	27.1	1.45
	70.0	24.7	27.2	26.2	29.97	28.8	26.4	8.33
	50.0	25.6	28.0	26.3	40.32	29.4	27.1	7.82
	30.0	26.1	27.8	26.1	35.72	29.1	28.0	3.78
	10.0	23.8	28.9	26.2	72.12	31.1	26.7	14.15
1.5m	90.0	26.0	27.7	26.6	28.91	27.2	26.8	1.47
	70.0	24.9	27.9	26.5	41.91	28.1	26.7	4.98
	50.0	24.5	27.0	26.1	29.67	27.7	26.2	5.42
	30.0	25.3	28.1	26.2	46.25	29.4	26.3	10.54
	10.0	26.7	28.7	26.0	52.90	30.6	26.1	14.71
1m	90.0	26.4	27.4	26.2	25.89	26.8	26.8	0.00
	70.0	24.9	27.5	26.5	33.90	27.2	26.7	1.84
	50.0	25.3	27.4	26.1	33.41	28.0	26.3	6.14
	30.0	26.1	27.8	26.3	33.60	28.6	27.9	2.28
	10.0	26.7	28.9	26.0	60.90	29.1	26.1	10.31
						Mean % Error =		6.21

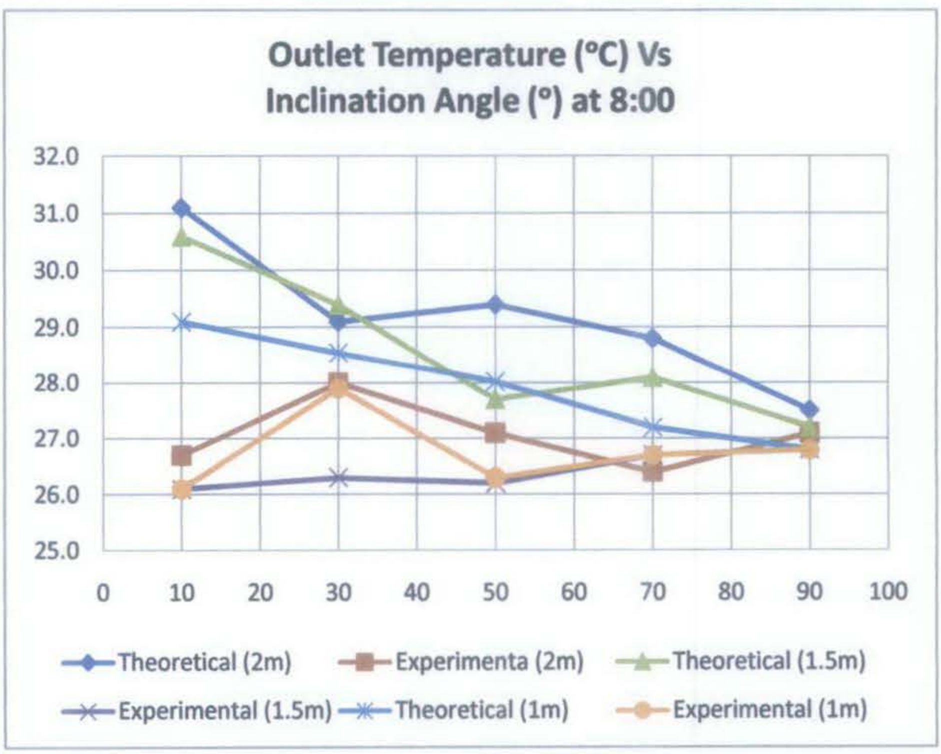


Figure 4.9 Outlet air temperatures versus inclination angles at 08:00

Table 4.2 Comparison of theoretical and experimental results for 10:00

L	θ	TG2	TA	Tfi	H	Tfout		
						Theo	Exp	% Error
2m	90.0	29.0	33.9	31.0	79.61	33.9	31.9	5.90
	70.0	28.3	34.7	31.3	98.12	35.2	34.1	3.18
	50.0	28.5	36.2	29.4	162.45	36.7	33.3	9.26
	30.0	28.9	42.8	31.8	290.80	39.4	35.9	8.88
	10.0	31.8	43.4	32.3	272.00	41.6	38.9	6.49
1.5m	90.0	29.3	35.0	32.5	81.29	33.5	32.9	1.79
	70.0	27.7	34.1	30.0	107.62	35.3	33.0	6.52
	50.0	29.7	38.2	31.5	173.98	36.4	32.0	12.09
	30.0	28.6	42.6	33.3	268.15	38.2	33.9	11.26
	10.0	41.4	48.6	34.2	316.31	41.9	35.6	15.04
1m	90.0	29.3	34.3	31.5	80.20	33.4	32.1	3.89
	70.0	28.9	34.2	31.3	107.62	35.0	33.3	4.86
	50.0	29.1	37.8	31.5	164.35	37.8	32.0	15.34
	30.0	29.3	38.9	31.8	186.32	38.5	34.8	9.61
	10.0	38.9	47.4	34.0	304.68	42.2	35.6	15.64
						Mean % Error =		8.65

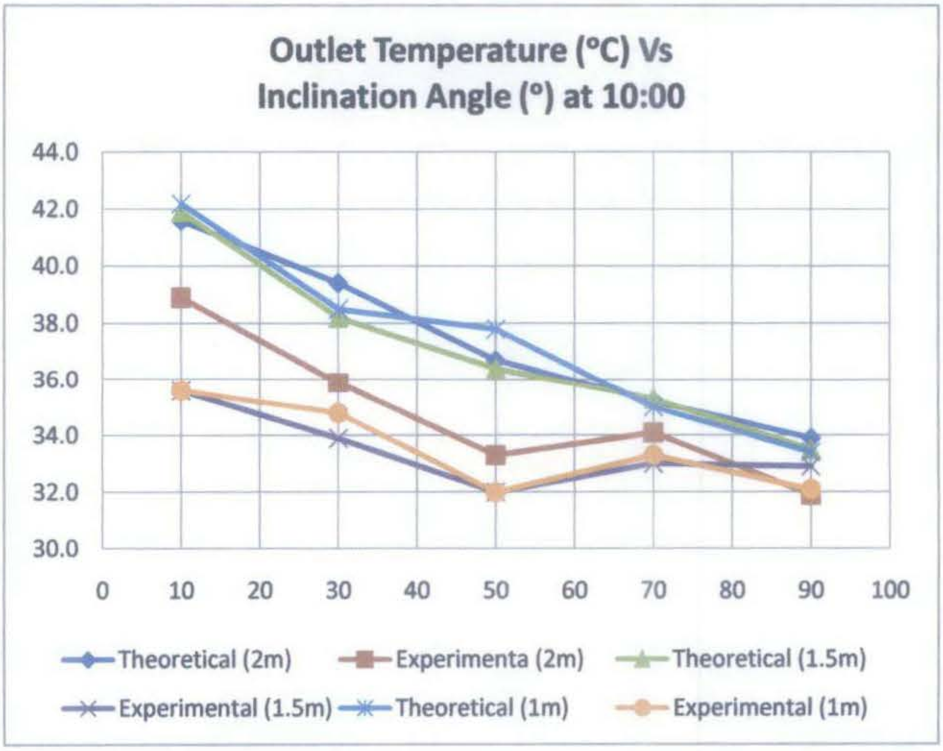


Figure 4.10 Outlet air temperatures versus inclination angles at 10:00

Table 4.3 Comparison of theoretical and experimental results for 12:00

L	θ	T_{G2}	T_A	T_{fi}	H	T_{fo}		
						Theo	Exp	% Error
2m	90.0	35.1	41.1	35.8	127.71	40.9	38.0	7.09
	70.0	35.7	43.1	35.3	180.60	43.1	37.9	12.06
	50.0	34.3	45.5	33.5	282.70	44.2	38.5	12.90
	30.0	36.3	53.5	36.1	447.10	45.6	40.5	11.18
	10.0	42.7	62.0	38.0	580.20	55.8	47.0	15.77
1.5m	90.0	34.2	38.3	34.0	96.51	39.1	36.0	7.93
	70.0	31.5	40.8	35.2	157.18	42.5	37.4	12.00
	50.0	36.0	43.8	35.1	202.71	42.7	38.1	10.77
	30.0	37.0	51.9	35.0	413.60	45.7	38.5	15.75
	10.0	39.2	56.4	34.9	517.93	49.1	40.5	17.52
1m	90.0	35.3	40.0	35.4	110.64	39.1	36.6	6.39
	70.0	32.1	40.8	35.2	157.18	39.7	37.5	5.54
	50.0	35.7	44.4	33.4	250.13	42.8	37.1	13.32
	30.0	36.5	52.3	35.2	435.60	44.8	37.2	16.96
	10.0	40.9	56.1	34.8	511.23	47.6	39.1	17.86
						Mean % Error =		12.20

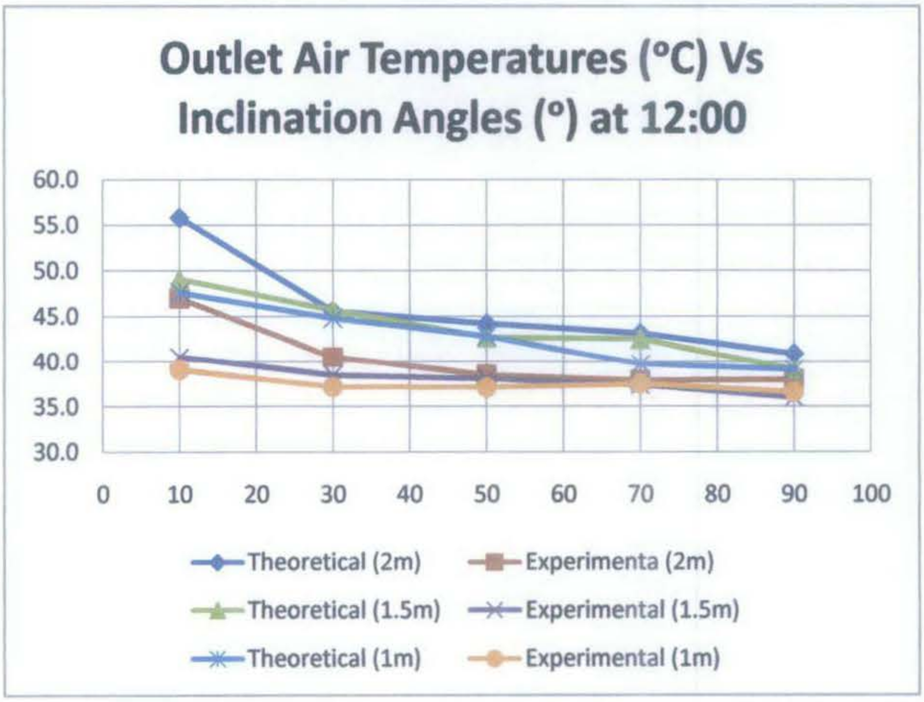


Figure 4.11 Outlet air temperatures versus inclination angles at 12:00

Table 4.4 Comparison of theoretical and experimental results for 14:00

L	θ	TG2	TA	Tfi	H	Tfout		
						Theo	Exp	% Error
2m	90.0	36.0	41.9	36.0	138.31	40.3	38.4	4.71
	70.0	34.7	42.0	34.2	179.49	41.8	38.9	6.94
	50.0	36.3	45.3	34.1	255.89	43.0	39.0	9.30
	30.0	38.9	49.6	35.0	336.63	44.8	38.7	13.62
	10.0	43.3	54.3	38.1	369.00	49.8	42.5	14.61
1.5m	90.0	32.7	39.1	34.7	115.85	39.0	36.1	7.44
	70.0	33.0	39.9	34.9	130.05	40.2	36.5	9.20
	50.0	34.7	45.4	35.0	257.60	42.8	39.1	8.64
	30.0	37.1	49.5	35.7	339.20	44.4	39.8	10.40
	10.0	39.7	55.8	36.2	484.53	47.3	39.5	16.49
1m	90.0	32.7	38.7	35.2	100.85	37.1	36.2	2.45
	70.0	34.1	39.7	34.2	130.05	39.5	35.1	11.14
	50.0	34.2	41.9	33.1	201.35	41.5	35.8	13.73
	30.0	37.6	47.8	35.0	305.46	43.2	36.8	14.81
	10.0	39.4	55.2	36.3	478.63	45.7	37.6	17.69
						Mean % Error =		10.75

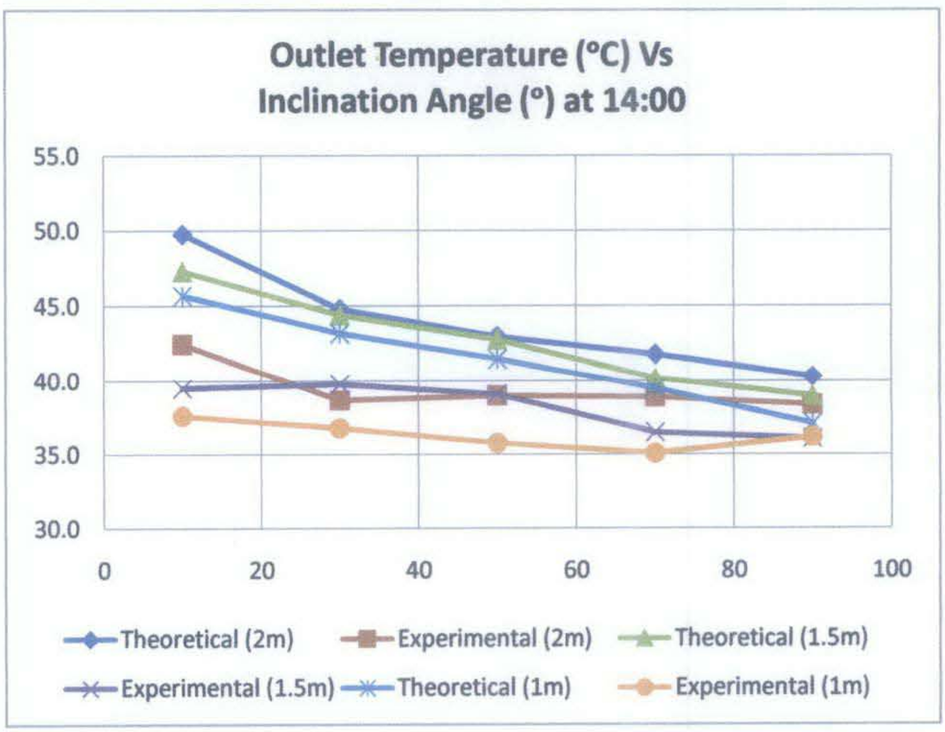


Figure 4.12 Outlet air temperatures versus inclination angles at 14:00

Table 4.5 Comparison of theoretical and experimental results for 16:00

L	θ	TG2	TA	Tfi	H	Tfout		
						Theo	Exp	% Error
2m	90.0	35.1	41.3	37.0	1113.54	41.3	38.0	8.03
	70.0	30.7	34.4	29.9	98.59	33.8	31.5	6.80
	50.0	32.6	39.3	33.2	141.37	42.9	36.2	15.62
	30.0	36.9	46.5	33.7	286.43	44.8	38.0	15.18
	10.0	41.9	52.8	36.7	371.90	46.3	41.2	11.02
1.5m	90.0	31.8	36.5	33.1	78.39	37.6	34.7	7.71
	70.0	32.2	38.3	34.5	105.56	38.1	35.7	6.30
	50.0	32.3	39.0	31.5	168.45	39.7	34.5	13.10
	30.0	35.9	45.1	35.6	238.60	40.6	36.6	9.85
	10.0	35.9	50.2	34.8	391.13	42.5	37.1	12.71
1m	90.0	32.1	36.0	31.2	79.91	36.2	34.7	4.14
	70.0	33.1	37.0	32.1	105.56	37.4	34.7	7.22
	50.0	31.8	39.2	32.8	159.84	38.4	34.5	10.16
	30.0	37.2	45.7	33.7	279.50	40.5	35.9	11.36
	10.0	38.7	49.5	33.6	376.24	41.6	36.9	11.30
						Mean % Error =		10.03

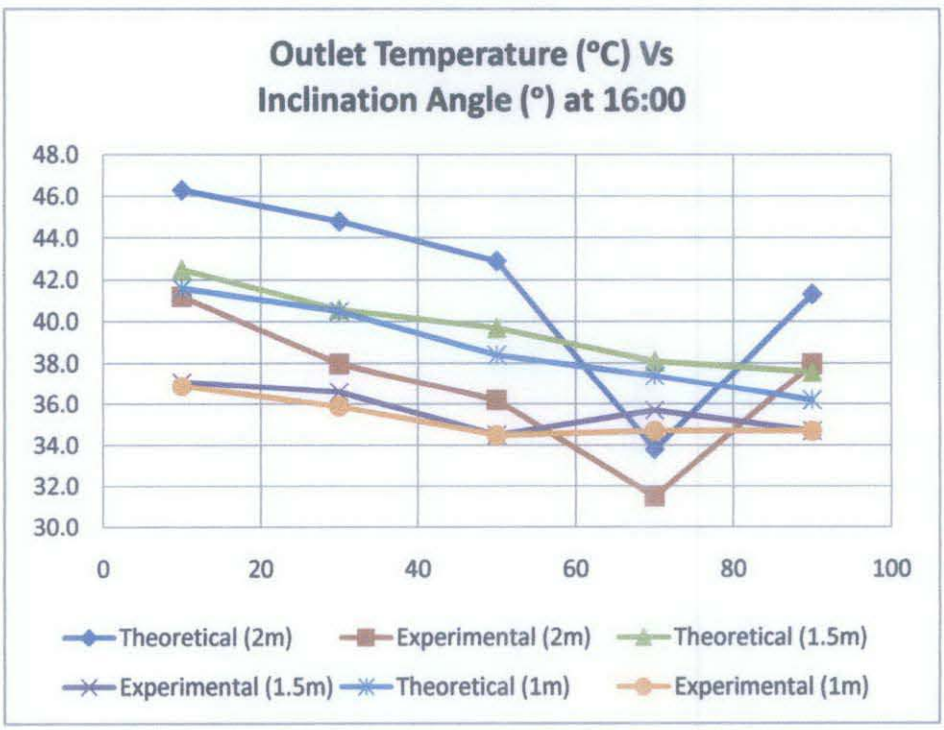


Figure 4.13 Outlet air temperatures versus inclination angles at 16:00

Table 4.6 Comparison of theoretical and experimental results for 18:00

L	θ	TG2	TA	Tfi	H	Tfout		
						Theo	Exp	% Error
2m	90.0	31.8	32.1	29.7	37.56	33.6	30.4	9.52
	70.0	28.2	31.3	29.1	45.68	34.4	31.0	9.88
	50.0	28.4	31.6	28.9	57.15	35.4	32.5	8.19
	30.0	29.6	33.7	30.3	75.04	37.2	31.9	14.25
	10.0	31.2	34.5	29.8	85.55	39.8	32.7	17.84
1.5m	90.0	28.7	30.8	29.6	31.19	32.8	30.0	8.54
	70.0	27.4	30.5	28.6	45.23	33.8	31.9	5.62
	50.0	29.0	33.0	30.7	62.32	34.1	31.3	8.21
	30.0	30.7	34.1	29.7	87.76	36.7	30.5	16.89
	10.0	33.4	34.8	28.4	103.30	38.1	32.6	14.44
1m	90.0	28.6	29.9	28.0	36.20	31.9	30.0	5.96
	70.0	29.4	32.8	31.2	49.67	32.7	32.0	2.14
	50.0	29.4	33.1	31.1	56.89	33.6	32.3	3.87
	30.0	29.8	33.6	30.1	78.80	35.2	30.3	13.92
	10.0	33.6	34.5	28.8	91.10	36.8	32.1	12.77
						Mean % Error =		10.14

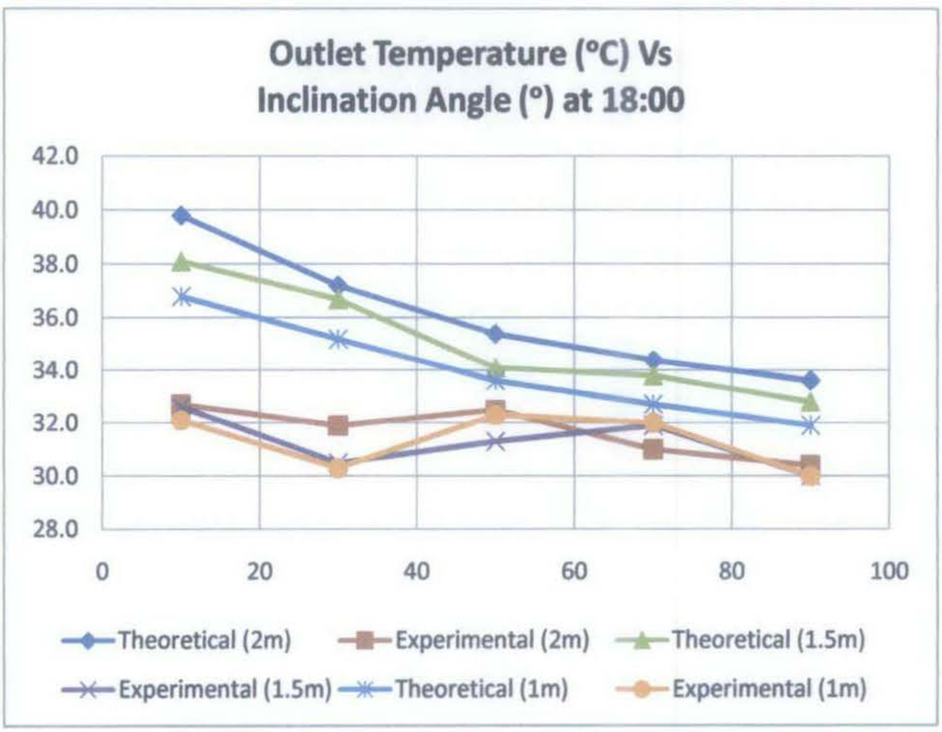


Figure 4.14 Outlet air temperatures versus inclination angles at 18:00

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The objective of this project has been met. A MATLAB program was written based on the physical and mathematical model developed to correlate the outlet to inlet air solar collector for different lengths and inclination angles. Besides that, an experiment based on the same model was conducted in order to validate the computation results from the MATLAB program. From the results validation performed, it is concluded that the mean percentage error of the results are within the margin of 6% to 13%, effectively. These errors are believed to be caused by the wind. In addition, the experimental data was also analyzed to discover the transient behavior and relationships, between the inclination angles and passage lengths, with the insolation and mean air temperatures of the system. Generally, lower inclination angles and higher passage lengths are producing higher mean air temperature. Meanwhile, the mean air temperature profile closely matches with the insolation profile.

5.2 Recommendation

Recommendation for future works will be given on both experimental and analytical models. Firstly, the major problems identified in the experimental work in this project are the ineffective methods of data collection which will affect the accuracy and precision of the readings. Ideally, the experiment should be conducted as the following suggestions in order to obtain more consistent readings:

1. Run three different types of passage length with the same inclination angle, all at the same time (requires three test rigs with different lengths).

2. Use a multichannel data logger with automatic recording capability to take measurements simultaneously, in order to reduce the time lag.

3. If the data logger above is available, decrease the intervals between measurements for the best results

Besides that, it is also mentioned that wind is greatly affecting the data measurement. Therefore, the test rig should be improved with special inlet and outlet designs in order to reduce the impact of wind onto the system. Alternatively, the mathematical model and MATLAB program should be improved by considering the effects of wind, in order to simulate the real environment.

On top of that, it is important to be reminded that the analytical model proposed in this project has its problem simplified. Thus, for it to be of practical use, it should be continuously improved in order to simulate the real problems. For instance, an engineer who is designing a new solar collector does not know the temperatures of double glazing (T_{G1}, T_{G2}) and absorber plate (T_A) in reality. In fact, these values were to be found for designing purposes. Therefore, for this model to be useful for him, it should be able to also predict these values as one of the outputs.

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APPENDIX I

MATLAB PROGRAM CODES

RUNSCRIPT

Typing "runscript" in the MATLAB command window will call upon this script. This script is written with the "While" loop for iteration purpose. In addition, "runscript" will automatically call upon "script1" and "script2", where the codes are also attached in the following sections. Notice that, script1 is only being called upon once; while script2 is being called upon twice and also repeated in the "While" loop until the condition set has been met.

```
%% Iteration for Outlet Air Temperature (Tfo)

script1;
script2;

% Defining error tolerance

tol = 0.001;

% Iterating mean air temperature using "While" loop

while abs(error) > tol

    Tfo = Tfo_new;

    script2;

    count = count+1;
end

% Unit conversions

Tf = Tf - 273;          % Theoretical result

Tfo = Tfo-273;          % Theoretical result

%Percentage difference between theoretical and experimental results

diff = abs(Tfo - Tfo_exp)/Tfo*100;

% Displaying the results

fprintf('\n Mean air temperature is %.1f deg Celsius.\n',Tf);

fprintf('\n Outlet air temperature is %.1f deg Celsius.\n',Tfo);
```

SCRIPT1

"script1" will first load the "constants" into the workspace. These "constants" are known as *variables* in MATLAB. Please refer to the **Constants** under the **NOMENCLATURE** for the values of the *variables* or "constants". Then, it will request for user's input and subsequently make the necessary unit conversion. Finally, it will calculate the solar radiation of heat flux.

```
%% Workspace Preparation

% Loading preset constants into workspace

load constants


%% Inputs Assignment

% Insert the following variables (theta in degree; L in meter)

L = input('Enter length of wall, L: ');
theta = input('Enter tilt angle, theta: ');

% Insert the following available data (TG1,TG2,TA, and Tamb in degree
Celcius; H in W/m2)

TG2 = input('Enter glazing2 temperature, TG2: ');
TA = input('Enter absorber temperature, TA: ');
Tamb = input('Enter ambient temperature, Tamb: ');
H = input('Enter solar radiation, H: ');

% Insert initial guess for the outlet air temperature (in degree
Celcius)

Tfo = input('Enter initial guess of outlet air temperature, Tfo: ');

Tfo_exp = Tfo;      % mean air temperature measured through experiment

% Assuming inlet air temperature is the same as ambient temperature

Tfi = Tamb;

%% Units Conversion

% Converting all temperatures from degree Celcius into Kelvin

Tamb = Tamb + 273;
TA = TA + 273;
TG2 = TG2 + 273;
Tfo = Tfo + 273;
```

```
Tfi = Tfi + 273;

% Converting theta from degree into radiance (required in MATLAB
Trigonometry operation)

theta = theta*pi/180;

%% Calculation of Solar Radiation Heat Flux

% Solar radiation heat flux absorbed by glazing1

S1 = alpha1*H;

% Solar radiation heat flux absorbed by glazing2

S2 = tao1*alpha2*H;

% Solar radiation heat flux absorbed by absorber

S3 = tao1*tao2*alpha3*H;
```

SCRIPT2

"script2" will be automatically called upon right after "script1" is completed. It will calculate the convective and heat transfer between absorber and air, radiative heat transfer between absorber and glazing 2, and finally outlet air temperature. Also, notice that the percentage of error is being calculated here.

```
%% Calculation of Convective Heat Transfer Between Absorber and Air
(hag)

% Mean air temperature of air in channel

Tf = sigma*Tfo + (1-sigma)*Tfi;

% Mean temperature value of absorber and air

Tm1 = (Tf + TA)/2;

% Calculating properties of air

rho1 = 1.1614-0.00353*(Tm1-300);             %Density of air
dyn_vis1 = (1.846+0.00472*(Tm1-300))*10^-5; %Dynamic viscosity of air
kin_vis1 = dyn_vis1/rho1;                    %Kinematic viscosity of air
K1 = 0.0263+0.000074*(Tm1-300);              %Thermal conductivity of
                                              air
C1 = (1.007+0.00004*(Tm1-300))*10^3;         %Specific heat of air
beta1 = 1/Tm1;                               %Coefficient of volumetric
                                              expansion

% Calculating Prandt number

Pr1 = dyn_vis1*C1/K1;

% Calculating Grashof number

Gr1 = (g*beta1*S3*(L^4))/(K1*kin_vis1^2);

% Calculating Nusselt number

Nu1 = 0.6*(Gr1*cos(theta)*Pr1)^0.2;

% Calculating convective heat transfer

ha = Nu1*K1/L;
```

```
%% Calculation of Radiative Heat Transfer Between Absorber and
Glazing2(hrag)

% Calculating radiative heat transfer

hrag = SB*(TG2^2+TA^2)*(TG2+TA)/(1/epsG2+1/epsA-1);


%% Calculation of Outlet Air Temperature (Tfo_new)

% Calculating outlet air temperature

Tfo_new = Tfi + (TA-Tfi)/sigma +(hrag/(ha*sigma))*(TA-TG2)+(Kins*(TA-
Tamb)/(Wins*ha*sigma))-(S3/(ha*sigma));

% Calculating percentage of error

error = (Tfo_new-Tfo)/Tfo;

% Number of iteration

count = 0;
```

APPENDIX II

DETAILED DRAWINGS

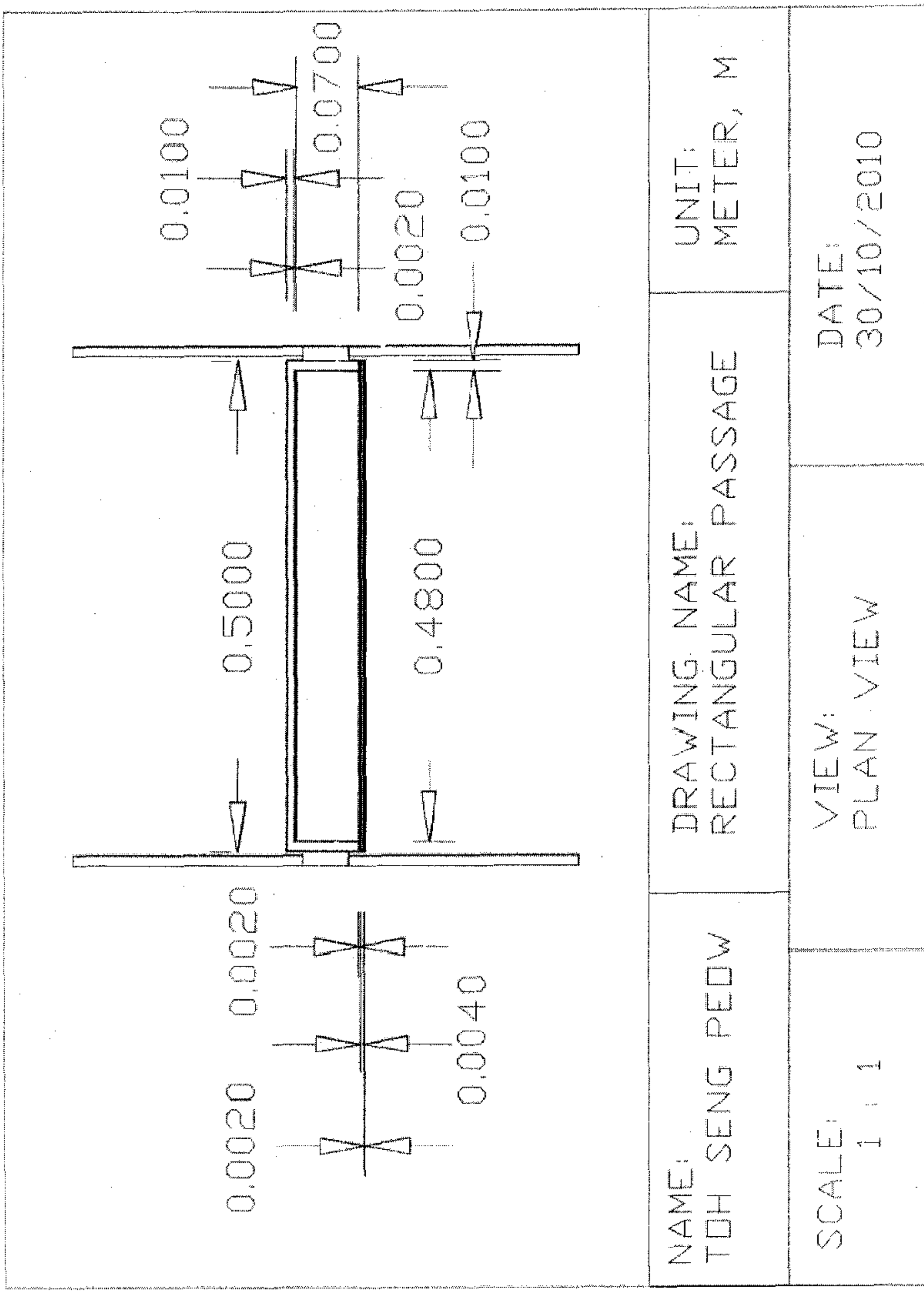

Figure 1: Detailed drawing plan view

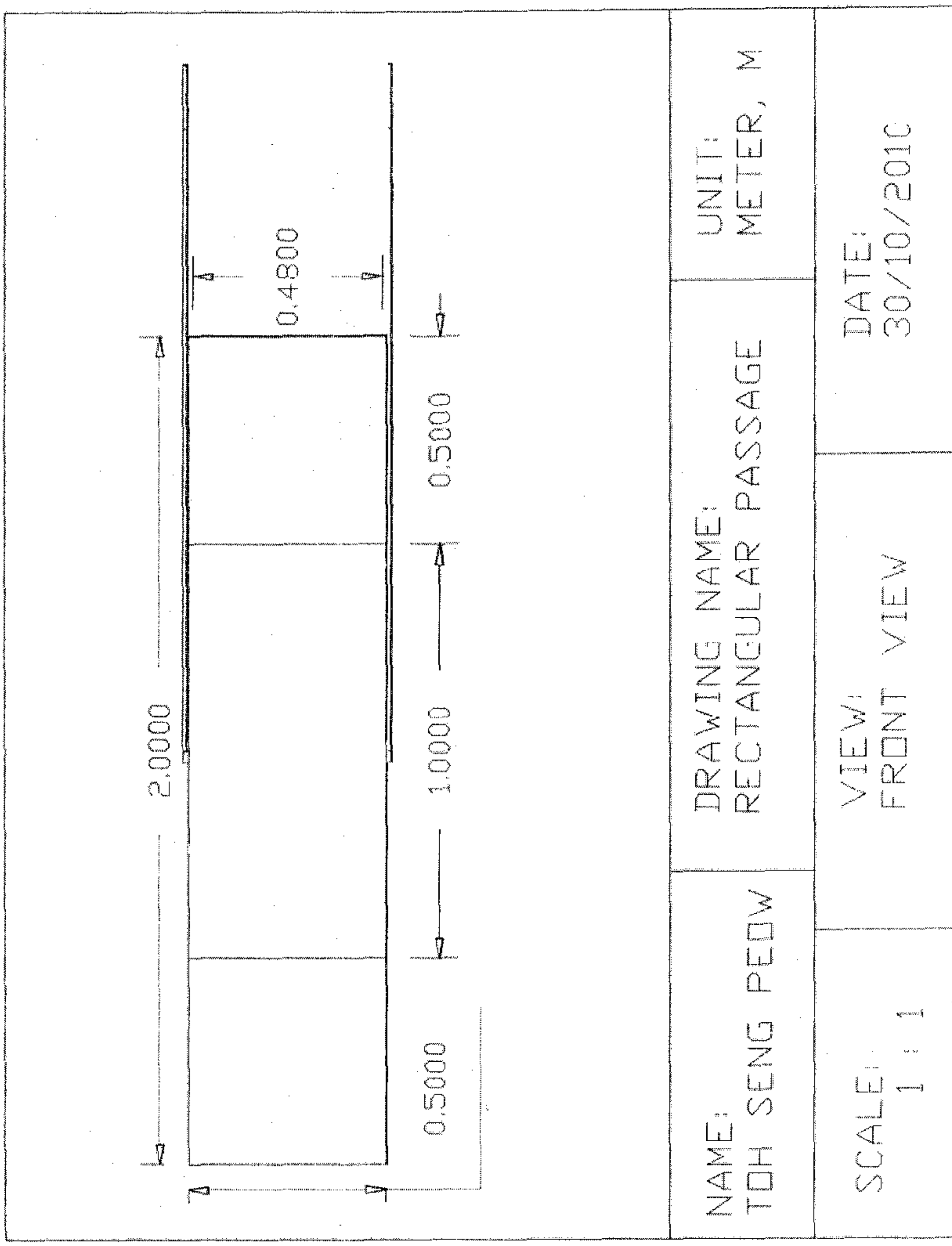

Figure 4.7 Detailed drawing front view

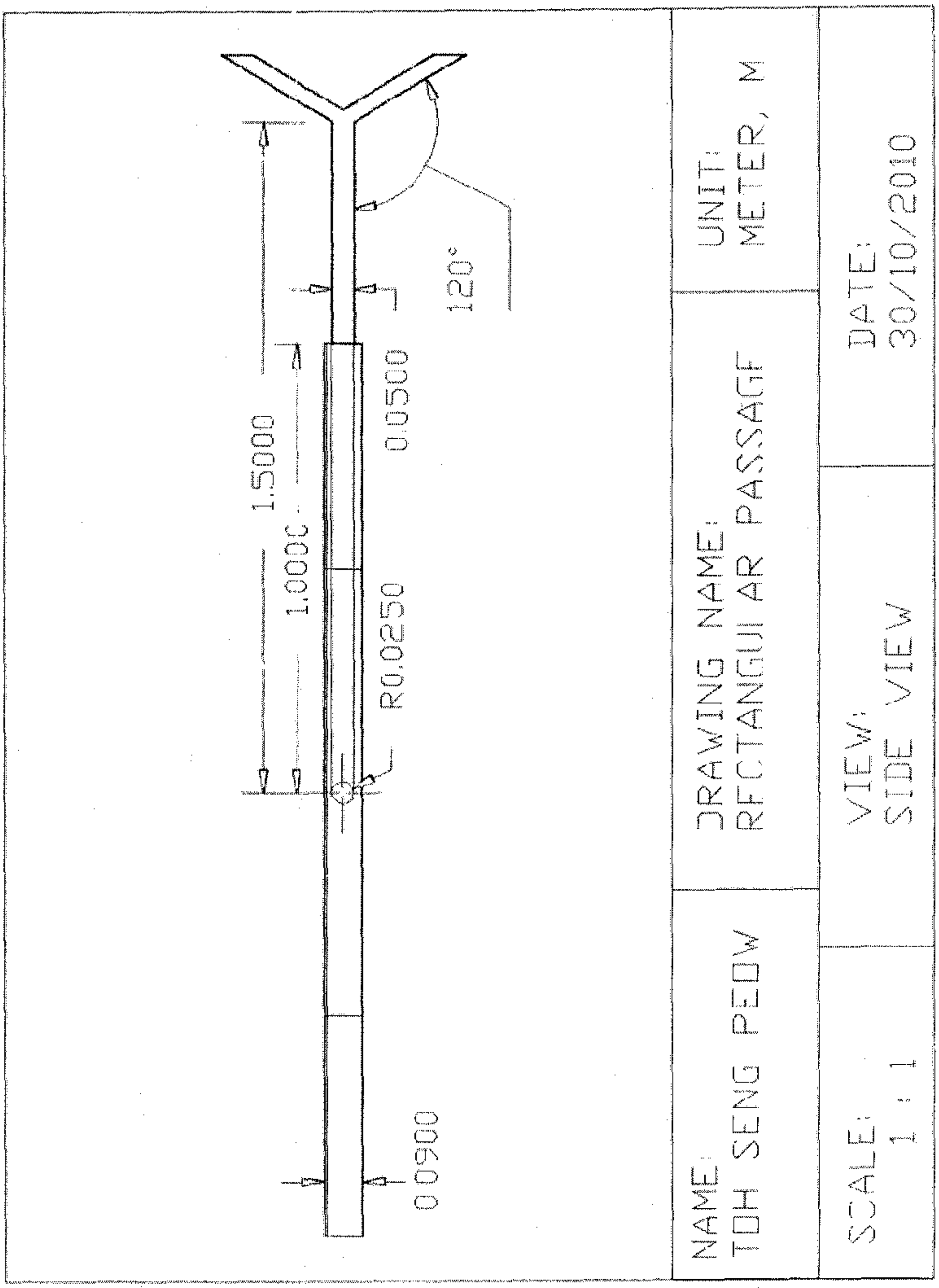

Figure 4.8 Detailed drawing side view

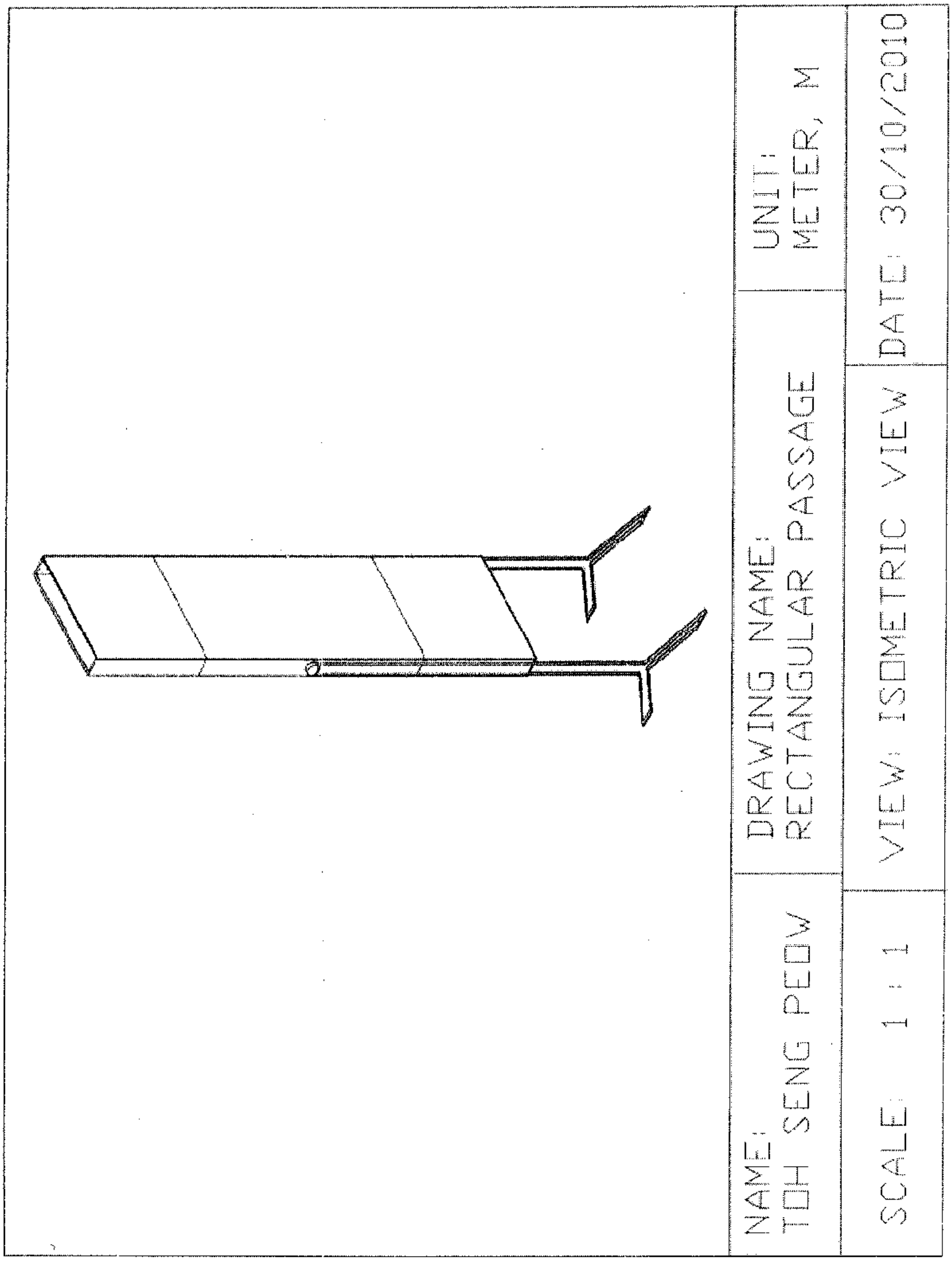

Figure 4.9 Detailed drawing isometric view

APPENDIX III

SAMPLE DATA SHEET

LENGTH: ______ ANGLE: ______ DAY: ______ DATE: ______

TIME	TGO (°C)				TGI (°C)				TA (°C)				AIR TEMP (°C)				INSOLATION (W/m^2)	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	ANG.	HOR.
0800																		
1000																		
1200																		
1400																		
1600																		
1800																		

REMARKS:

LENGTH: ______ ANGLE: ______ DAY: ______ DATE: ______

TIME	TGO (°C)				TGI (°C)				TA (°C)				AIR TEMP (°C)				INSOLATION (W/m^2)	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	ANG.	HOR.
0800																		
1000																		
1200																		
1400																		
1600																		
1800																		

REMARKS:

APPENDIX IV

EXPERIMENTAL DATA

DATA SUMMARY

Average readings for **2m length** at different tilt angles

90° configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	25.3	26.3	27.5	26.6	27.1	26.9	21.96
10:00	29.6	29.0	33.9	31.0	31.9	31.4	79.61
12:00	35.0	35.1	41.1	35.8	38.0	36.4	127.71
14:00	36.7	36.0	44.2	36.0	38.4	37.0	138.31
16:00	36.8	35.1	41.3	37.0	38.0	37.5	113.54
18:00	32.7	31.8	32.1	29.7	33.1	31.4	37.56

70° configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	24.2	24.7	27.2	26.2	26.4	26.3	29.97
10:00	28.6	28.3	34.7	31.3	34.1	32.3	98.12
12:00	35.8	35.7	43.1	35.3	37.9	36.4	180.60
14:00	36.6	34.7	42.0	34.2	38.9	36.3	179.49
16:00	31.1	30.7	34.4	29.9	31.5	31.0	98.59
18:00	28.9	28.2	31.1	29.1	30.4	29.6	45.68

50° configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	25.1	25.6	28.0	26.3	27.1	26.9	40.32
10:00	30.3	28.5	36.2	29.4	33.3	31.2	162.45
12:00	37.4	34.3	45.5	33.5	38.5	35.7	282.70
14:00	38.8	36.3	45.3	34.1	39.0	36.2	255.89
16:00	35.7	32.6	39.3	33.2	36.2	34.5	141.37
18:00	31.8	28.4	31.6	28.9	32.5	31.1	57.15

30° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	25.1	26.1	27.8	26.1	28.0	26.7	35.72
10:00	30.7	28.9	42.8	31.8	35.9	33.9	290.80
12:00	34.0	36.3	53.5	36.1	40.5	38.1	447.10
14:00	36.2	38.9	49.6	35.0	38.7	36.5	336.63
16:00	35.5	36.9	46.5	33.7	38.0	35.7	286.43
18:00	30.8	29.6	33.7	30.3	31.9	31.0	75.04

10° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	25.0	23.8	28.9	26.2	26.7	26.6	72.12
10:00	30.4	31.8	43.4	32.3	38.9	34.3	272.00
12:00	41.3	42.7	62.0	40.3	47.0	43.5	580.20
14:00	41.8	43.3	54.3	38.1	42.5	40.1	369.00
16:00	40.1	41.9	52.8	36.7	41.2	39.3	371.90
18:00	32.9	31.2	34.5	29.8	32.7	31.6	85.55

Average readings for 1.5m length at different tilt angles

90° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	25.4	26.0	27.7	26.6	26.8	26.7	28.91
10:00	30.8	29.3	35.0	32.5	32.9	32.7	81.29
12:00	35.9	34.2	38.3	34.0	36.0	35.1	96.51
14:00	37.0	32.7	39.1	34.7	36.1	35.4	115.85
16:00	34.6	31.8	38.3	34.5	34.7	34.6	78.39
18:00	29.3	28.7	30.8	29.6	30.0	29.8	31.19

70° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	25.2	24.9	27.9	26.5	26.7	26.6	41.94
10:00	30.4	27.7	34.1	30.0	33.0	31.7	107.62
12:00	35.0	31.5	40.8	35.2	37.4	36.0	157.18
14:00	36.4	33.0	39.9	34.9	36.5	35.3	130.05
16:00	35.9	32.2	39.0	34.5	35.7	35.0	105.56
18:00	32.2	27.4	30.5	28.6	31.9	30.1	45.23

50° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	24.5	25.5	27.0	26.1	26.3	26.2	29.67
10:00	29.6	29.7	38.2	31.5	32.0	31.7	173.98
12:00	35.9	36.0	43.8	35.1	38.1	36.9	202.71
14:00	36.0	34.7	45.4	35.0	39.1	37.5	257.60
16:00	32.7	32.3	39.0	31.5	34.5	33.3	168.45
18:00	30.5	29.0	33.0	30.7	31.3	30.9	62.32

30° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	24.3	25.3	28.1	26.2	26.3	26.2	46.25
10:00	28.9	28.6	42.6	33.3	33.9	33.6	268.15
12:00	38.6	37.0	51.9	35.0	38.5	37.5	413.60
14:00	39.2	37.1	49.5	35.7	39.8	36.9	339.20
16:00	36.7	35.9	50.2	35.6	36.6	36.0	238.60
18:00	31.9	30.7	34.1	29.7	30.5	30.1	87.76

10° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	24.0	26.7	28.7	26.0	26.1	26.1	52.90
10:00	33.8	41.1	48.6	34.2	35.6	34.8	316.31
12:00	39.7	39.2	56.4	34.9	40.5	37.5	517.93
14:00	40.7	39.7	55.8	36.2	39.5	37.8	484.53
16:00	39.2	35.9	50.2	34.8	37.1	35.7	391.13
18:00	33.4	28.4	34.8	28.4	32.6	30.9	103.30

Average readings for 1m length at different tilt angles

90° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	25.3	26.4	27.4	26.2	26.8	26.5	25.89
10:00	30.8	29.3	34.3	31.5	32.1	31.9	80.20
12:00	35.0	35.3	40.0	35.4	36.3	35.9	110.64
14:00	37.0	32.7	38.7	35.2	36.2	35.9	100.85
16:00	34.6	32.1	36.0	31.2	34.7	32.2	79.91
18:00	29.3	28.6	29.9	28.0	30.0	29.4	36.20

70° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	24.2	24.9	27.5	26.5	26.7	26.6	33.90
10:00	30.6	28.9	35.2	31.3	33.3	32.1	107.62
12:00	34.6	32.1	40.8	35.2	37.5	36.4	157.18
14:00	36.4	34.1	39.7	34.2	35.1	34.7	130.05
16:00	35.4	33.1	37.0	32.1	34.7	33.8	105.56
18:00	32.9	29.4	32.8	31.2	32.0	31.6	49.67

50° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	23.6	25.9	27.4	26.1	26.3	26.2	33.41
10:00	29.6	29.1	37.8	31.5	32.0	31.7	164.35
12:00	34.5	35.7	44.4	33.4	37.1	35.4	250.13
14:00	35.1	34.2	41.9	33.1	35.8	34.3	201.35
16:00	31.9	31.8	39.2	32.8	34.5	33.4	159.84
18:00	29.5	29.4	33.1	31.1	32.3	31.7	56.89

30° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	24.3	26.2	27.8	26.3	27.9	27.0	33.60
10:00	31.9	29.3	38.9	31.8	34.8	33.0	186.32
12:00	35.4	36.5	52.3	35.2	37.2	36.2	435.60
14:00	37.6	39.1	47.9	35.0	36.8	35.9	305.46
16:00	36.5	37.3	45.7	33.7	35.9	34.8	279.50
18:00	31.2	29.8	33.6	30.1	30.3	30.2	78.80

10° Configuration

TIME	GLAZING		ABSORBER	AIR TEMPERATURE			INSOLATION
	OUTER	INNER		INLET	OUTLET	MEAN	ANG
8:00	24.6	26.6	29.0	26.0	26.1	26.1	60.90
10:00	31.6	38.9	47.4	34.0	35.6	34.8	304.68
12:00	38.6	40.9	56.1	34.8	39.1	37.2	511.23
14:00	39.5	39.4	55.2	36.3	37.6	37.0	478.63
16:00	39.4	38.8	49.6	33.6	36.9	35.1	376.24
18:00	32.4	33.6	34.5	28.8	32.1	30.9	91.10

RAW DATA

LENGTH: 2m ANGLE: 90° DAY: 1 DATE: 11-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	25	25.1	25	25.5	26.1	26	25.9	25.4	26.9	27.1	27	26.4	25.5	25.5	25.6	25.7	25.8	25.8	20.68
10:00	28	28.3	28.6	28.5	28.3	28.8	29	29.7	32.3	32.5	33.9	33	29.5	30.4	29.8	29.7	29.5	30.4	81
12:00	34.6	35.1	34.8	32.9	38	38.5	39.1	35.7	45.9	44.7	44.5	40.2	32.9	32.9	32.9	33.2	32.8	33.2	122.19
14:00	39.4	38	38.3	37.5	41	39.7	41.2	38.9	50.6	51.3	51.3	51.2	35.4	35.4	36	36.4	36.3	36.3	123
16:00	38.6	38.8	39	38	38.6	39.5	39.2	39.8	45.8	45.5	46.41	44.8	38	38	38	38.1	38.4	38.4	121.53
18:00	34	34.9	34.7	34.1	34.8	35.6	36.2	35.5	38.8	39.2	39.2	37.7	33.1	34.9	34.6	34.4	34.2	34.9	35.4

LENGTH: 2m ANGLE: 90° DAY: 2 DATE: 12-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.8	24.9	25.4	25.5	25.6	25.6	27	26	26.4	26.8	27.4	26.9	26.3	26.8	26.6	26.4	26.3	26.8	19.4
10:00	29.2	29.4	29.5	29.5	27.5	28.4	30.2	30.9	32.6	32.1	35.3	34.4	31	30.9	30.6	30.9	31	30.9	76.55
12:00	33.7	34.1	34.8	34	31	31.2	34.1	35.7	41.4	40.5	43	42.6	37	38.1	36.3	36.2	37	38.1	152.58
14:00	34.6	34.7	34.7	33.6	30.4	31.4	33.6	35.4	33.3	37.9	39.2	39.6	34.3	34.1	34.1	34.4	34.3	34.1	105.86
16:00	36.2	36.4	36.5	35.1	29.3	31.5	34.1	37.4	40.7	40.1	40.6	41.7	36.7	38.5	37.5	37.5	37.6	38.5	119.67
18:00	30.6	30.7	30.9	30.7	26.2	27.5	27.5	31.7	29.2	28.9	30.9	33.5	29.1	31.2	31.7	31.9	32	31.2	39.4

LENGTH: 2m ANGLE: 90° DAY: 3 DATE: 13-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	25.5	25.6	25.9	25.8	26.5	26.4	28	27	29.2	29.5	27.2	29.5	28	28.4	28.5	28.6	28.9	28.7	25.8
10:00	30.9	30.8	31.2	30.9	25.6	27.1	30	32.8	34.2	34.7	34.9	36.9	32.5	33.2	33.8	33	32.9	34.4	81.28
12:00	35.9	36	37	36.5	33	32.6	33.7	38.7	36.3	38.4	35.8	39.9	37.5	37.6	39.4	39.5	38.5	42.7	108.37
14:00	37.9	37.9	37.4	36.3	33.6	33.4	35	38.2	45.4	43.8	41.7	45.1	38.3	41.5	40.6	39.9	39.8	44.8	186.07
16:00	35.7	35.9	35.7	35.1	30.1	31.1	34.1	36.8	37.7	38.6	36.89	36.8	36.3	36	36.9	36.5	36.5	37.1	99.43
18:00	33	33.3	32.9	32.2	29.8	31.3	31.3	33.6	28.3	27.6	26.2	25.7	26.9	28.1	27.6	27.9	28.3	33.2	37.88

LENGTH: 2m ANGLE: 90° DAY: AVG

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	25.1	25.2	25.4	25.6	26.1	26.0	27.0	26.1	27.5	27.8	27.2	27.6	26.6	26.9	26.9	26.9	27.0	27.1	21.96
10:00	29.4	29.5	29.8	29.6	27.1	28.1	29.7	31.1	33.0	33.1	34.7	34.8	31.0	31.5	31.4	31.2	31.1	31.9	79.61
12:00	34.7	35.1	35.5	34.5	34.0	34.1	35.6	36.7	41.2	41.2	41.1	40.9	35.8	36.2	36.2	36.3	36.1	38.0	127.71
14:00	37.3	36.9	36.8	35.8	35.0	34.8	36.6	37.5	43.1	44.3	44.1	45.3	36.0	37.0	36.9	36.9	36.8	38.4	138.31
16:00	36.8	37.0	37.1	36.1	32.7	34.0	35.8	38.0	41.4	41.4	41.3	41.1	37.0	37.5	37.5	37.5	37.5	38.0	113.54
18:00	32.5	33.0	32.8	32.3	30.3	31.5	31.7	33.6	32.1	31.9	32.1	32.3	29.7	31.4	31.3	31.4	31.5	33.1	37.56

LENGTH: 2m ANGLE: 70Ī DAY: 1 DATE: 14-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.5	24.2	25.1	25.8	24	23.8	26.7	26	25.5	26.1	27	27	27	27.2	27.1	27.1	27	27.2	29.1
10:00	28	27.7	28.1	28	26	26.3	28.8	29.6	35.6	35.1	34.8	34.7	31.6	32	31.7	31.7	31.6	32	119.48
12:00	35.4	35.9	35.9	34.6	38.2	39.3	39.4	37.2	46.1	47.4	46.8	43.5	35	35	35.4	35.7	36	36	188.49
14:00	35.4	35.7	35.3	33.9	35.4	32.3	33.6	36	42.4	41.1	41.6	42	33	35.3	34.5	33.7	33	35.3	178.71
16:00	33.8	33.6	33.4	32.2	29.9	33.7	32.2	32.1	36.2	36.3	35.4	38.2	33.6	34.9	34.5	34.1	34.8	35	121.43
18:00	31.5	31.7	31.6	30.6	29.7	29.5	28.6	32.3	33.4	34.2	32.5	35.1	32.3	33.2	33	32.5	32.3	33.2	47.57

LENGTH: 2m ANGLE: 70Ī DAY: 2 DATE: 15-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.3	24.3	24.6	[illegible]	24.1	24.6	25.6	25.5	26.6	26.7	[illegible]	27.3	26.7	26.9	26.9	26.8	26.7	26.9	34.91
10:00	30.6	30.4	30.6	28.8	29	27.6	29.9	32.1	32.6	33.8	34.7	36.5	31.2	33.6	31.7	31	31.2	33.6	86.44
12:00	36	36.5	36	36	33.6	31.9	33.1	37.1	40.1	40.8	41.8	43.6	35.1	38.7	37.4	35.6	35.1	38.7	156.7
14:00	37.9	38.1	36.9	36.7	33.6	32.6	33.4	37.7	42.8	40.9	40.9	44	35	40.5	37.1	36.4	35	40.5	193.19
16:00	23.2	23.7	23.8	23.9	26.8	26.2	26.7	24.1	26.3	25.3	27.5	24.9	24.1	24.4	24.3	24.4	24.4	24.6	20.84
18:00	23.2	23.4	23.4	23.4	25.6	25.7	26	24.7	25.8	25.4	26.7	24.4	24	24.3	24.4	24	24.5	24.5	12.25

LENGTH: 2m ANGLE: 70Ī DAY: 3 DATE: 16-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	23	23.1	23.2	23.4	24	23.9	24.3	23.8	29.2	29.1	28.6	27	24.9	24.9	24.8	24.9	25	25.1	25.9
10:00	28.3	27.5	26.7	28.5	28.4	26.5	26.2	29.5	35.9	35.5	34.6	32.6	31.1	33.5	33.1	32.6	31.7	36.7	88.44
12:00	36.4	36.4	36.3	34.7	33.9	32.8	37	34.7	40.5	41.7	41.5	43.4	35.8	37.5	37	36.4	35.7	39	196.6
14:00	38	37.6	37	36.1	34.9	35.2	34.4	37.2	41.7	43.7	42.9	40	34.6	39.7	37.8	36.9	35	40.9	166.57
16:00	37.4	36.6	36.4	35.4	33.8	33.8	32.9	36.4	40.1	41	40	41.6	32	34.7	34.7	34.9	34.2	34.9	153.51
18:00	32	31.7	32.6	31.4	28.5	27.5	28	32.3	34.4	32.7	33.8	33.8	31	32.2	31.4	31.1	30.9	33.5	77.22

LENGTH: 2m ANGLE: 70Ī DAY: AVG

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	23.9	23.9	24.3	24.6	24.0	24.1	25.5	25.1	27.1	27.3	27.3	27.1	26.2	26.3	26.3	26.3	26.2	26.4	29.97
10:00	29.0	28.5	28.5	28.4	27.8	26.8	28.3	30.4	34.7	34.8	34.7	34.6	31.3	33.0	32.2	31.8	31.5	34.1	98.12
12:00	35.9	36.3	36.1	35.1	35.2	34.7	36.5	36.3	42.2	43.3	43.4	43.5	35.3	37.1	36.6	35.9	35.6	37.9	180.60
14:00	37.1	37.1	36.4	35.6	34.6	33.4	33.8	37.0	42.3	41.9	41.8	42.0	34.2	38.5	36.5	35.7	34.3	38.9	179.49
16:00	31.5	31.3	31.2	30.5	30.2	31.2	30.6	30.9	34.2	34.2	34.3	34.9	29.9	31.3	31.2	31.1	31.1	31.5	98.59
18:00	28.9	28.9	29.2	28.5	27.9	27.6	27.5	29.8	31.2	31.1	31.0	31.1	29.1	29.9	29.6	29.2	29.2	30.4	45.68

LENGTH: 2m ANGLE: 50□ DAY: 1 DATE: 17-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.9	25.2	25.1	24.9	24.6	24.5	24.8	25.8	26.6	26.7	26.7	27.8	26.5	26.6	26.7	26.6	26.5	26.6	40.83
10:00	31.8	32.2	32	31.3	26.9	25.2	26	31.2	34.3	32.4	31.3	34	31.1	33.5	32.4	31.8	31.1	33.5	155.8
12:00	39.1	39.7	39.3	38.3	37.4	37.1	35.6	38.1	48.1	46.2	45.3	41.2	34.9	39.5	37.1	35.7	34.9	39.5	280.1
14:00	38.8	38.4	38.1	37.1	36.4	35.8	34.5	37.2	45.7	44.1	44.6	43.8	33.6	36.9	35.4	34.5	33.6	36.9	156.28
16:00	38.5	37.4	37.3	36.1	33.5	31.5	32.6	37.3	38.7	39.4	38.6	41.9	35.3	36.5	36	35.6	35.3	36.5	190.56
18:00	32.3	31.8	31.8	31.4	28.1	27.7	28.5	32.7	32.4	31.5	31.3	30	28.6	33.43333	33.16667	32.5	32.13333	32.5	56.24

LENGTH: 2m ANGLE: 50□ DAY: 2 DATE: 18-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	2[illegible]	25.4	25.3	25.4	25.4	25.4	25.3	25.9	27.6	27.6	27.4	27.9	27.1	27.4	27.3	27.2	27.1	27.4	42.5
10:00	28.8	29.6	29.4	29.2	28.4	27	27	29.8	34.9	35.5	34.3	34.2	29.3	32	30.9	29.9	29.3	32	157.31
12:00	37.4	37.5	36.8	36.1	33.7	32.7	31.4	36	44.8	42.4	41.5	44	34.3	36.4	35.4	35	34.3	36.4	287
14:00	40.5	40.4	39.9	38.9	37.2	37.6	36.1	39.4	47.3	48.1	47.9	47.3	35.6	38.3	37.3	36.2	35.6	38.3	310.2
16:00	35.4	34.8	34.4	33.7	32	31.4	31	34.7	38	37.7	36.4	38.7	32.8	34.5	33.7	33.2	32.8	34.5	120.14
18:00	32	32	31.9	31.5	28.9	28.2	28	32.5	31	31.8	33	32	28.9	33.43333	33.16667	32.5	32.13333	32.5	54.85

LENGTH: 2m ANGLE: 50□ DAY: 3 DATE: 19-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	25.1	25.5	25.6	25.3	26.5	26.7	26.9	25.8	29.8	29.7	29.6	28.6	25.3	27	27	27	27	27.3	37.64
10:00	29.2	30.4	29.9	29.9	27.6	26.9	30.4	35.6	39.4	40.7	42.7	40.7	27.8	31.3	30.7	30.4	29.5	34.4	174.25
12:00	36.5	36.4	36.2	35.5	32.2	31	31.1	35.7	43.6	48.2	49.4	51.3	31.3	36.3	35.3	33.3	32.6	39.6	281
14:00	39.2	39.1	38.5	36.8	35.1	35	33.6	37.9	42.9	43.4	44.3	44.2	33.1	38.2	37.3	35.2	34.3	41.8	301.2
16:00	36.1	35.5	35	34.2	31.2	31	29.8	35	40.9	41.7	42.3	37.3	31.5	35.3	34	33.2	32.5	37.6	113.41
18:00	32.1	31.5	31.6	31.3	24.8	24.2	25.4	32.1	31.2	32.1	30.5	32.2	29.2	23.13333	29.96667	29.5	30.53333	32.5	60.35

LENGTH: 2m ANGLE: 50□ DAY: AVG

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.7	25.4	25.3	25.2	25.5	25.5	25.7	25.8	28.0	28.0	27.9	28.1	26.3	27.0	27.0	26.9	26.9	27.1	40.32
10:00	29.9	30.7	30.4	30.1	27.6	26.4	27.8	32.2	36.2	36.2	36.1	36.3	29.4	32.3	31.3	30.7	30.0	33.3	162.45
12:00	37.7	37.9	37.4	36.6	34.4	33.6	32.7	36.6	45.5	45.6	45.4	45.5	33.5	37.4	35.9	34.7	33.9	38.5	282.70
14:00	39.5	39.3	38.8	37.6	36.2	36.1	34.7	38.2	45.3	45.2	45.6	45.1	34.1	37.8	36.7	35.3	34.5	39.0	255.89
16:00	36.7	35.9	35.6	34.7	32.2	31.3	31.1	35.7	39.2	39.6	39.1	39.3	33.2	35.4	34.6	34.0	33.5	36.2	141.37
18:00	32.1	31.8	31.8	31.4	27.3	26.7	27.3	32.4	31.5	31.8	31.6	31.4	28.9	30.0	32.1	31.5	31.6	32.5	57.15

LENGTH: 2m ANGLE: 30Σ DAY: 1 DATE: 20-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.5	24.9	25	25	25.8	25.8	26	25.7	28.1	28.3	28.3	28.1	27.3	27.5	27.4	27.3	27.3	28.6	47.8
10:00	33.6	33.9	33.8	33.4	30.5	29.1	27.9	28.5	40.1	39.2	38.3	41.8	32.2	34.4	33.2	32.3	32.2	34.4	327.5
12:00	38.4	37.7	36.9	35.3	35.8	35.6	33.9	36.9	48.3	47.8	45.3	45.9	34.3	35.6	34.9	34.5	34.3	35.6	441.2
14:00	35.7	35.3	34.7	33.7	31.1	30.8	30.4	34.6	41.3	40.5	39.6	41.9	31.6	34.2	33	32.5	31.6	34.2	201.5
16:00	38.5	37.9	37.9	35.4	33.2	33.4	31.5	36	42.3	44.2	41.2	43.8	32.6	36	34.8	34	32.6	36	288.5
18:00	33.3	32.9	32.6	32.2	28	28	27.2	33.8	33.8	33.1	32.6	33.8	31.9	33.8	33.1	32.6	31.9	33.8	104.93

LENGTH: 2m ANGLE: 30Σ DAY: 2 DATE: 21-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.8	25	24.9	25	25.9	25.7	25.9	25.3	27.1	27.8	28	27.5	26.8	26.9	26.9	26.5	26.9	28	50.11
10:00	29.5	30	30.5	32.1	24.6	26	28.4	25.7	34	34.8	36.3	35.6	32	33.5	33	32.5	32	33.5	254.1
12:00	42	42.2	41.1	39.6	40.2	39	36.6	40.3	54	55	52.9	53.8	38.1	42	40.7	39	38.1	42	449.8
14:00	42	41.5	40.6	39.2	40	39.5	38.5	40.1	50.3	51.6	50.4	49.4	35.3	37.3	36.7	36	35.3	37.3	258.4
16:00	38.8	38.7	38.5	37.7	38.7	40	40	38.9	46.5	47.7	48.9	46.3	35.6	38	37	36.5	35.6	38	248.8
18:00	29.4	29.5	29.5	29.6	28	28.3	28.5	30.4	30.8	31.3	31.8	33.6	29.7	30	29.9	29.8	29.7	30	51.26

LENGTH: 2m ANGLE: 30Σ DAY: 3 DATE: 22-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	25.5	25.6	25.5	25.6	27.1	26.7	26.8	26	28.5	27.3	27.4	27.2	24.2	24.2	25.8	26.9	24.7	27.4	9.26
10:00	31.55	31.95	32.15	32.75	31.6	31.6	31	31.9	54.3	54.7	53.5	51	31.2	32.9	36.4	37.2	37.5	39.8	290.8
12:00	33	30	32.6	32	36.5	33.2	31.9	35.5	58.8	57.7	61.4	61.1	35.9	40.9	39.9	38.9	37.1	43.9	450.3
14:00	42.6	42.9	42.2	40.9	45.6	46.9	46.5	42.3	57.4	57.3	58.5	57	38.1	41	40.3	39.2	38.8	44.6	550
16:00	38.6	38.6	37.9	36.6	38.1	38.7	37.4	37.4	50.4	47.6	49.1	50	32.9	37	36.2	35	33.9	40	322
18:00	31.9	31.5	31.3	30.6	30.6	30.8	30	31.5	36.2	36.7	36.4	34.3	29.3	30.6	30.4	30.1	29.8	31.9	68.94

LENGTH: 2m ANGLE: 30Σ DAY: AVG

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.9	25.2	25.1	25.2	26.3	26.1	26.2	25.7	27.9	27.8	27.9	27.6	26.1	26.2	26.7	26.9	26.3	28.0	35.72
10:00	25.9	32.0	32.2	32.8	28.9	28.9	29.1	28.7	42.8	42.9	42.7	42.8	31.8	33.6	34.2	34.0	33.9	35.9	290.80
12:00	26.9	36.6	36.9	35.6	37.5	35.9	34.1	37.6	53.7	53.5	53.2	53.6	36.1	39.5	38.5	37.5	36.5	40.5	447.10
14:00	27.9	39.9	39.2	37.9	38.9	39.1	38.5	39.0	49.7	49.8	49.5	49.4	35.0	37.5	36.7	35.9	35.2	38.7	336.63
16:00	28.9	38.4	38.1	36.6	36.7	37.4	36.3	37.4	46.4	46.5	46.4	46.7	33.7	37.0	36.0	35.2	34.0	38.0	286.43
18:00	29.9	31.3	31.1	30.8	28.9	29.0	28.6	31.9	33.6	33.7	33.6	33.9	30.3	31.5	31.1	30.8	30.5	31.9	75.04

LENGTH: 2m ANGLE: 10° DAY: 1 DATE: 23-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.3	24.9	24.8	25	24.2	24.9	25.2	25.3	27.3	27.1	27.8	28.4	26.8	26.8	26.9	26.9	26.8	26.8	95.11
10:00	28.7	29.7	30.1	30.8	31.6	32.4	32.7	35	46.9	44.9	46.5	49.1	31.4	34	33.8	33	31.4	34	292.7
12:00	39.3	40.8	41.8	41.5	40.5	39.9	42.5	45.4	57.1	57.2	59.3	61.8	41	49	46.3	43	41	49	455.6
14:00	44	44.8	44.2	43.7	47.1	48.8	48.5	45.5	66.4	67	67.7	64.2	41.5	44.4	43.5	42.3	41.5	44.4	400.6
16:00	39.9	41.3	41.9	41.6	39.3	42.2	42.8	45.6	50.4	54.2	54.5	56.9	40.6	42.2	44.1	42.6	40.6	42.2	484.7
18:00	32.8	32.8	32.5	32.6	30.3	31	31.2	33.9	34.6	35.3	35.3	37.4	30.3	31.4	31	30.8	30.3	31.4	64.5

LENGTH: 2m ANGLE: 10° DAY: 2 DATE: 24-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.5	25	25	25.1	26.9	26.7	25.9	25.5	28.9	28.9	29.2	28.3	26	26.7	26.7	26.6	26	26.7	65.51
10:00	28.5	29.4	29.3	29.4	32.1	30.2	30.6	32.4	44	42.1	43.5	43.7	34.8	35.4	35.2	35	34.8	35.4	287.2
12:00	45	45.8	41.7	42.7	46.6	46.9	43.7	45.6	69.3	67.3	68.3	64.5	44	47.2	47.1	46	44	47.2	671.5
14:00	40.9	40.1	39.3	38.4	40.3	39.5	38.1	39.4	51.3	50.1	48.8	49.3	36.6	39	37.7	37.2	36.6	39	243.3
16:00	41.3	40.8	40.2	38.8	44.2	44.3	43.1	40.6	54.6	53.6	53.1	48.2	37.8	39.9	39.2	38.5	37.8	39.9	331.3
18:00	32.4	32.1	31.6	31.4	27.2	27.3	27.5	32.2	32	32.1	31.4	32.1	30.7	31.8	31.5	31.1	30.7	31.8	59.82

LENGTH: 2m ANGLE: 10° DAY: 3 DATE: 25-Jun

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	25.2	25.4	25.5	25.5	20.3	19.8	20	20.9	30.4	31	29.5	30	25.8	26.5	26.5	26.4	26.4	26.6	55.73
10:00	31.5	32.9	32	32	31.4	30.4	29.5	33.4	39.9	40.9	41.4	38	30.7	34	34	31.6	31.2	47.3	236.1
12:00	41.9	41.5	40.2	32.8	41.4	40.6	37.7	41	59.9	61.2	59	59.1	35.9	41	41	38.5	37.5	44.8	613.5
14:00	42.6	42	41.7	40.2	43.1	43.7	43.4	42.4	45.2	44.9	47.3	49.4	36.2	41.2	41.2	38.7	37.3	44.1	463.1
16:00	39	39.2	39	37.9	40	40.9	40	40.1	52.7	50.9	50.5	53.9	31.7	38.2	38.1	36.5	35.4	41.5	299.7
18:00	34.8	34.2	34.2	33.5	32.8	33	32.8	34.9	36.9	37.6	36.5	32.8	28.4	33.6	33.6	32.6	32	34.9	132.33

LENGTH: 2m ANGLE: 10° DAY: AVG

TIME	TGO				TGI				TA				Air Temp						Insolation
	1	2	3	4	1	2	3	4	1	2	3	4	Inlet	1	2	3	4	Outlet	Ang.
8:00	24.7	25.1	25.1	25.2	23.8	23.8	23.7	23.9	28.9	29.0	28.8	28.9	26.2	26.7	26.7	26.6	26.4	26.7	72.12
10:00	29.6	30.7	30.5	30.7	31.7	31.0	30.9	33.6	43.6	42.6	43.8	43.6	32.3	34.5	34.3	33.2	32.5	38.9	272.00
12:00	42.1	42.7	41.2	39.0	42.8	42.5	41.3	44.0	62.1	61.9	62.2	61.8	40.3	45.7	44.8	42.5	40.8	47.0	580.20
14:00	42.5	42.3	41.7	40.8	43.5	44.0	43.3	42.4	54.3	54.0	54.6	54.3	38.1	41.5	40.8	39.4	38.5	42.5	369.00
16:00	40.1	40.4	40.4	39.4	41.2	42.5	42.0	42.1	52.6	52.9	52.7	53.0	36.7	40.1	40.5	39.2	37.9	41.2	371.90
18:00	33.3	33.0	32.8	32.5	30.1	30.4	30.5	33.7	34.5	35.0	34.4	34.1	29.8	32.3	32.0	31.5	31.0	32.7	85.55

LENGTH: 1.5m ANGLE: 90° DAY: 1 DATE: 26-Jun

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	25.9	26.2	24.9	25.8	26.2	26.5	27.5	28	28	27.1	27.2	27.2	27.1	27.2	26.07
10:00	33	33	32.9	31.1	29.4	30.6	36.4	36.7	35.6	32	32.1	32.2	32.3	32.4	79.49
12:00	39	38.6	38.2	40.4	39	39.7	46.3	45.6	44	37.1	38	37.5	37.1	38	69.1
14:00	37.6	37.4	37	32.9	32.5	32.6	39.9	40.1	38.6	36.5	37.8	36.8	36.9	38.3	107.17
16:00	31.6	31.5	31.6	29.3	28.8	29.2	32.3	32.3	32	31.5	31.7	31.6	31.5	31.7	51.86
18:00	26.9	27.1	27.7	26	26.1	26.9	26.7	27.4	27.4	27.3	27.3	27.6	27.5	27.7	3.79

LENGTH: 1.5m ANGLE: 90° DAY: 2 DATE: 27-Jun

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	25.45	25.6	25.05	25.5	26.2	26.2	28.35	28.7	27.65	26.65	26.7	26.75	26.65	26.7	28.91
10:00	27.4	29.2	28	28.4	27.5	28.4	35.5	36.6	35.6	30.4	30.5	30.5	30.4	30.5	74.35
12:00	34	33.8	32.9	31.7	30.1	28.4	37.4	37	37.2	30.6	31.5	31	30.6	31.5	102.64
14:00	36.7	35.8	35.6	31.3	31	30.7	35.9	36.5	34.7	35.6	35.7	36.9	37.1	37.2	113.82
16:00	36.4	35.9	35.6	34.4	34.2	33.7	40.3	40.3	38.3	34.2	34.3	34.2	34.5	34.8	85.95
18:00	27.1	27.2	27.4	27.6	28.2	29.1	29.5	29.3	29.6	28	28	28	28	28.1	37

LENGTH: 1.5m ANGLE: 90° DAY: 3 DATE: 28-Jun

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	25	25	25.2	25.2	26.2	25.9	26.8	27	27.3	26.05	25.975	26.45	26.65	26.5	31.75
10:00	31	31.2	31.2	29.4	29.5	29.6	32.5	32.3	33.8	35.1	35.2	35.4	35.7	35.8	90.03
12:00	35.5	35.3	35.4	33.3	32.1	32.8	32.1	32.3	32.8	34.3	36.475	37.1	37.6	38.5	117.79
14:00	38	37.4	37.1	34.1	34.8	34.6	41.5	41	43.7	32	32.4	32.5	32.5	32.8	126.55
16:00	36.2	36.2	36	31.5	32.1	32.6	42.6	42.6	44	37.8	37.8	38	37.8	37.6	97.37
18:00	33.6	33.6	33.2	31.6	31.7	31.1	36.2	35.4	35.7	33.5	33.55	33.8	34.2	34.2	52.77

LENGTH: 1.5m ANGLE: 90° DAY: AVG

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	25.5	25.6	25.1	25.5	26.2	26.2	27.6	27.9	27.7	26.6	26.6	26.8	26.8	26.8	28.91
10:00	30.5	31.1	30.7	29.6	28.8	29.5	34.8	35.2	35.0	32.5	32.6	32.7	32.8	32.9	81.29
12:00	36.2	35.9	35.5	35.1	33.7	33.6	38.6	38.3	38.0	34.0	35.3	35.2	35.1	36.0	96.51
14:00	37.4	36.9	36.6	32.8	32.8	32.6	39.1	39.2	39.0	34.7	35.3	35.4	35.5	36.1	115.85
16:00	34.7	34.5	34.4	31.7	31.7	31.8	38.4	38.4	38.1	34.5	34.6	34.6	34.6	34.7	78.39
18:00	29.2	29.3	29.4	28.4	28.7	29.0	30.8	30.7	30.9	29.6	29.6	29.8	29.9	30.0	31.19

LENGTH: 1.5m ANGLE: 70° DAY: 1 DATE: 29-Jun

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	26.3	26.5	26.6	26.3	26.7	27	28.6	28.9	28.8	27.4	27.6	27.5	27.4	27.6	42.15
10:00	31.2	31	31.1	30.1	28.1	26.4	34.3	34.1	33.9	32.1	33	32.6	32.1	33	101.57
12:00	34.5	35.4	34.8	34.7	33.7	30.6	40.4	40	39.8	35.3	37.1	36.5	35.3	37.1	156.81
14:00	35.5	35.3	35.2	34	34.3	32.1	37.5	38.5	38.1	36.1	37.5	36.8	36.1	37.5	106.02
16:00	35.3	34.5	34.4	31.7	30.5	29.7	35.6	37.9	36.1	35.4	35.5	35.6	35.4	36.4	82.89
18:00	32.4	31.8	32.1	26.6	26.8	27.8	32.6	32.6	31.8	33.2	33.7	33.4	33.2	33.7	56.89

LENGTH: 1.5m ANGLE: 70° DAY: 2 DATE: 30-Jun

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24.2	24.4	24.4	24.3	24.6	24.6	26.6	25.9	26.4	26.1	26.4	26.3	26.1	26.4	45.67
10:00	29	30	29.7	26.6	24.2	24.4	30.6	30.1	30.6	31.9	32.9	32.4	31.9	32.9	100.59
12:00	34.5	34.7	33.9	32.8	31.9	29.5	37.4	37.4	37.6	36	37.2	36.4	36	37.2	132.35
14:00	37.3	37	36.9	33.9	34.6	32.1	39.8	37.9	37.6	37.5	39	38.5	37.5	39	120.99
16:00	37.4	36.5	35.9	32.2	31.8	30.3	38	38	37.9	35.9	35.9	35.9	35.9	37	111.48
18:00	32.3	32.1	31	27.6	27.6	31	30.7	30.9	31	31.2	32	31.6	31.2	32	35.38

LENGTH: 1.5m ANGLE: 70° DAY: 3 DATE: 01-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24.6	24.7	25.1	22.9	23.7	23.9	28.5	28.6	28.8	26	25.9	26.3	26.6	26.1	38
10:00	30.7	30.4	30.2	27.8	26.3	35.6	37.1	38.7	37.5	26	28	30.6	33.2	33.1	120.7
12:00	36.3	35.8	35.2	31.3	30.2	28.7	44.3	45	45.3	34.3	31.3	34.2	38.2	37.9	182.39
14:00	37.1	36.8	36.6	32.6	32.5	31.3	43.3	43	43.4	31.1	24.3	31.2	34.4	33	163.13
16:00	36.7	36.2	35.9	35.1	34.5	34	42.8	41.1	43.6	32.2	32.4	32.9	34.9	33.7	122.31
18:00	36.9	30.7	30.6	26.5	26.4	26.3	27.9	28	29	21.4	22.8	25.3	26.8	30	43.42

LENGTH: 1.5m ANGLE: 70° DAY: AVG

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	25.0	25.2	25.4	24.5	25.0	25.2	27.9	27.8	28.0	26.5	26.6	26.7	26.7	26.7	41.94
10:00	30.3	30.5	30.3	28.2	26.2	28.8	34.0	34.3	34.0	30.0	31.3	31.9	32.4	33.0	107.62
12:00	35.1	35.3	34.6	32.9	31.9	29.6	40.7	40.8	40.9	35.2	35.2	35.7	36.5	37.4	157.18
14:00	36.6	36.4	36.2	33.5	33.8	31.8	40.2	39.8	39.7	34.9	33.6	35.5	36.0	36.5	130.05
16:00	36.5	35.7	35.4	33.0	32.3	31.3	38.8	39.0	39.2	34.5	34.6	34.8	35.4	35.7	105.56
18:00	33.9	31.5	31.2	26.9	26.9	28.4	30.4	30.5	30.6	28.6	29.5	30.1	30.4	31.9	45.23

LENGTH: 1.5m ANGLE: 50□ DAY: 1 DATE: 02-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	25.2	25.3	25.2	26	26	25.2	27.8	28.2	27	26.6	26.5	26.8	27.2	27.1	49.9
10:00	31.9	31.9	32.2	29.1	29.1	27.5	37.3	35.6	34.7	33.8	33.7	34.2	33.8	34.1	189
12:00	38.7	38.9	38.1	38.4	37.6	35.4	48.1	46.8	47.2	38.3	40.4	42.3	43.2	42.6	298.5
14:00	29.5	30.3	30.6	30.2	30.9	30.5	41	41.4	41.9	35.8	40.4	39.4	38.5	39.9	304.9
16:00	29.1	28.9	29.4	31.2	30.6	28.5	39.4	38.7	38.1	30.8	35	34.1	34.7	35.8	159.3
18:00	28	28.2	28	28.3	28.1	27.7	30.1	30.1	29.5	30.3	29.5	29.95	30.6	30.4	24.93

LENGTH: 1.5m ANGLE: 50□ DAY: 2 DATE: 03-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24.2	24.2	24.2	25.5	25.6	25.6	26.3	26.4	26.5	25.7	25.8	25.8	25.7	25.8	6.31
10:00	26.6	26.4	20.7	30.6	30.8	30.1	35.4	35.7	34.2	28.2	28.5	28.4	28.2	28.5	96.85
12:00	31.2	31.1	32.7	37.7	37.4	35.7	46.2	45.9	47.1	31	33.4	32.6	31.9	34.3	21.54
14:00	38.8	39	37.6	40.3	40.5	38.6	51.2	50.6	50.3	32.4	36.9	35.8	34.4	37.8	334
16:00	36.5	36.5	35.6	34.8	35.2	33.5	40	42	42.6	32	33.3	33.7	33.4	33.8	177.6
18:00	33.3	33.2	32.3	29.8	30.3	29.6	36.5	36.7	36.3	32.1	32.7	32.4	32.1	33	99.7

LENGTH: 1.5m ANGLE: 50□ DAY: 3 DATE: 04-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24	23.9	24	25.5	25.1	25.2	27.2	26.4	27.2	26	26.1	26.1	26	26	32.81
10:00	32.3	32.2	32.1	30	29.8	29.9	41.9	43	46	32.5	32.9	32.5	33.4	33.4	236.1
12:00	38	37.7	36.9	35.7	33.6	32.3	37.1	38.4	37.4	36	36.6	36.1	37.4	37.4	288.1
14:00	39.8	39.7	38.7	34.4	34.4	32.4	44	44.8	43.4	36.8	38.2	37	39.6	39.6	334.1
16:00	32.8	32.7	32.5	33	32.9	31	37.9	35.7	36.6	31.7	31.9	32.4	33	33.9	168.45
18:00	30.65	30.7	30.15	29.05	29.2	28.65	32.1	32.8	32.9	29.7	29.9	30.05	30.3	30.5	62.315

LENGTH: 1.5m ANGLE: 50□ DAY: AVG

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24.5	24.5	24.5	25.7	25.6	25.3	27.1	27.0	26.9	26.1	26.1	26.2	26.3	26.3	29.67
10:00	30.3	30.2	28.3	29.9	29.9	29.2	38.2	38.1	38.3	31.5	31.7	31.7	31.8	32.0	173.98
12:00	36.0	35.9	35.9	37.3	36.2	34.5	43.8	43.7	43.9	35.1	36.8	37.0	37.5	38.1	202.71
14:00	36.0	36.3	35.6	35.0	35.3	33.9	45.4	45.6	45.2	35.0	38.5	37.4	37.5	39.1	324.33
16:00	32.8	32.7	32.5	33.0	32.9	31.0	39.1	38.8	39.1	31.5	33.4	33.4	33.7	34.5	168.45
18:00	30.7	30.7	30.2	29.1	29.2	28.7	32.9	33.2	32.9	30.7	30.7	30.8	31.0	31.3	62.32

LENGTH: 1.5m ANGLE: 30° DAY: 1 DATE: 05-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24.3	24.4	24.5	25	25	25	26.5	26.6	26.6	26.1	26.1	26.1	26.1	26.2	31.63
10:00	28.95	29.15	28.6	27.55	28.4	29.95	54.4	52.3	51.7	33.55	34.2	33.95	33.55	33.9	268.15
12:00	35.8	36.2	35.2	35.4	33.5	31	47.7	46.6	48.3	33.2	34.7	34	33.2	35.6	341.5
14:00	39.5	39.6	37.9	38	37.1	34	52.6	52.4	47.2	34.7	34.7	36.2	34.7	38.9	435.4
16:00	36.9	36.7	36.5	37.2	36.5	33.9	46.7	46.2	46.9	34.1	34.1	34.4	34.5	35.1	238.6
18:00	32.1	32	31.7	30.8	30.7	30.45	31.8	32.4	32.1	31.1	31.55	31.35	31.1	27.5	87.755

LENGTH: 1.5m ANGLE: 30° DAY: 2 DATE: 06-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	23.7	23.5	23.7	24.8	24.7	24.9	26.4	26.6	26.7	25.6	25.6	25.5	25.6	25.7	42.41
10:00	28.6	29.1	29.2	27.8	28.7	30.1	36.8	38.6	39.4	33.3	34.3	33.8	33.3	33.4	279.9
12:00	39.4	40.9	40.1	39.8	38	35.8	53.7	53.1	54.7	36.2	38.3	36.7	36.2	39.5	437.1
14:00	43	40.4	39.6	36.5	37.2	35.3	48.9	51.8	49.2	38.6	38.9	40	41.2	42.4	452.6
16:00	36.9	36.7	36.5	37.2	36.5	33.9	46.7	46.2	45.5	36	36.2	36.5	36.9	37.2	238.6
18:00	31.8	31.3	31.5	31.3	31.2	30.8	34.8	34.9	34	31.8	32.1	31.9	31.8	32.3	53.19

LENGTH: 1.5m ANGLE: 30° DAY: 3 DATE: 07-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24.9	24.9	24.9	26.2	26	25.9	31.4	30.8	31.3	26.9	27	26.9	27.1	27	64.72
10:00	29.3	29.2	28	27.3	28.1	29.8	36	37.2	37	33.05	31.7	33.05	34.55	34.4	256.4
12:00	39.4	40.4	40	40.4	40.4	38.4	54	56	53	35.6	40.8	43.3	44.9	40.3	462.2
14:00	38.6	39.1	37.8	40.3	39.5	36.4	46.4	44.6	52.4	33.8	34	32.7	34.5	38.2	129.6
16:00	36.9	36.7	36.5	37.2	36.5	33.9	56.6	58.5	57.5	36.7	36.8	36.8	37.2	37.5	238.6
18:00	32.4	32.2	31.9	30.3	30.2	30.1	35.7	35.3	35.9	26.2	25.75	27.05	28.3	31.7	122.32

LENGTH: 1.5m ANGLE: 30° DAY: AVG

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24.3	24.3	24.4	25.3	25.2	25.3	28.1	28.0	28.2	26.2	26.2	26.2	26.3	26.3	46.25
10:00	29.0	29.2	28.6	27.6	28.4	30.0	42.4	42.7	42.7	33.3	33.4	33.6	33.8	33.9	268.15
12:00	38.2	39.2	38.4	38.5	37.3	35.1	51.8	51.9	52.0	35.0	37.9	38.0	38.1	38.5	413.60
14:00	39.4	39.7	38.4	38.3	37.9	35.2	49.3	49.6	49.6	35.7	35.9	36.3	36.8	39.8	339.20
16:00	36.9	36.7	36.5	37.2	36.5	33.9	50.0	50.3	50.3	35.6	35.7	35.9	36.2	36.6	238.60
18:00	32.1	32.0	31.7	30.8	30.7	30.5	34.1	34.2	34.0	29.7	29.8	30.1	30.4	30.5	87.76

LENGTH: 1.5m ANGLE: 10° DAY: 1 DATE: 08-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	23.7	24.1	24	25.5	25.8	25.8	27.2	27.5	27.9	25.7	25.9	25.8	25.7	25.8	51.12
10:00	33.6	43.7	34.4	45.1	49.7	52.2	62.3	64.7	63.3	38.1	38	37.5	38.1	39	395.1
12:00	40.6	41.4	40.6	41.1	43.5	39.8	55.2	57.2	57.1	38	38.9	38.9	38	41.2	468.9
14:00	40.7	42	43	40	43.2	42.6	58	62	61.5	39.1	39.2	39.7	40.8	41.9	584.8
16:00	37.7	38.7	39.4	31.1	36.4	36	51	50.5	49.6	35.3	35.5	36	35.3	37.5	420.1
18:00	32.4	32.7	32.2	29.1	27.3	29.6	33.2	34	34	32.1	32.3	32.3	32.1	32.4	85

LENGTH: 1.5m ANGLE: 10° DAY: 2 DATE: 09-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	23.4	23.4	23.5	25.2	25.3	25.3	27.1	27.5	27.5	25.3	25.3	25.4	25.3	25.4	52.72
10:00	29.4	29.5	31	37.8	38.1	38	51	50.6	49.9	33.8	34.3	34.1	33.8	34.5	373.5
12:00	36.7	40.1	39	40.5	39	33.5	59.6	57.8	56.9	34.5	34.6	35.1	38.2	39	581
14:00	42.4	42.3	40.7	43.2	41.7	37.6	61.2	61.7	57.6	36	36.7	36.8	37.9	38.9	553.1
16:00	38.8	38.8	37.3	32.9	33.8	31	43.8	43.7	42.8	32.9	33	33.7	35.1	35.8	369.8
18:00	34	33	38.4	26.5	27	24.1	32.4	31.9	31	31.9	32.8	32.1	31.9	32.9	115.7

LENGTH: 1.5m ANGLE: [illegible] DAY: 3 DATE: 10-Jul

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	24.7	24.7	24.8	25.9	36.1	25.8	31.5	30.8	31.3	27	27.2	27.1	27.1	27.1	54.86
10:00	34	34	34.7	37.6	37.2	34.6	32.8	30.2	32.6	30.7	30.8	33.1	33.1	33.3	180.32
12:00	39.5	39.7	39.4	39.9	40.1	35.4	54.7	54.2	54.9	32.2	33.6	38.5	40.5	41.3	503.9
14:00	37.3	39.6	38.5	39.5	36.6	32.8	47.9	44	48.3	33.5	34.3	37.5	36.8	37.6	315.7
16:00	42.4	40.4	39.4	40.7	42.4	38.8	55.5	56.7	58.2	36.2	36.3	37	37.6	38	383.5
18:00	33.1	32.8	32.4	31.5	31.4	29.5	39.4	38.2	39.1	21.2	23.3	32	31.7	32.5	109.19

LENGTH: 1.5m ANGLE: 10° DAY: AVG

TIME	TGO			TGI			TA			Air Temp					Insolation
	1	2	3	1	2	3	1	2	3	Inlet	1	2	3	Outlet	Ang.
8:00	23.9	24.1	24.1	25.5	29.1	25.6	28.6	28.6	28.9	26.0	26.1	26.1	26.0	26.1	52.90
10:00	32.3	35.7	33.4	40.2	41.7	41.6	48.7	48.5	48.6	34.2	34.4	34.9	35.0	35.6	316.31
12:00	38.9	40.4	39.7	40.5	40.9	36.2	56.5	56.4	56.3	34.9	35.7	37.5	38.9	40.5	517.93
14:00	40.1	41.3	40.7	40.9	40.5	37.7	55.7	55.9	55.8	36.2	36.7	38.0	38.5	39.5	484.53
16:00	39.6	39.3	38.7	34.9	37.5	35.3	50.1	50.3	50.2	34.8	34.9	35.6	36.0	37.1	391.13
18:00	33.2	32.8	34.3	29.0	28.6	27.7	35.0	34.7	34.7	28.4	29.5	32.1	31.9	32.6	103.30

LENGTH: 1m ANGLE: 90° DAY: 1 DATE: 11-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	25	25.1	26.1	26	26.9	27.1	25.5	25.5	25.6	25.8	20.68
10:00	28	28.3	28.3	28.8	32.3	32.5	29.5	30.4	29.8	30.4	81
12:00	34.6	35.1	38	38.5	45.9	44.7	32.9	32.9	33.2	33.2	122.19
14:00	39.4	38	41	39.7	50.6	51.3	35.4	35.4	36	36.3	123
16:00	38.6	38.8	38.6	39.5	45.8	45.5	38	38	38	38.4	113
18:00	34	34.9	34.8	35.6	38.8	39.2	32.6	34.9	34.6	34.9	35.4

LENGTH: 1m ANGLE: 90° DAY: 2 DATE: 12-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.8	24.9	25.6	25.6	26.4	26.8	26.3	26.8	26.6	26.8	19.4
10:00	29.2	29.4	27.5	28.4	32.6	32.1	30.9	30.9	30.6	31	76.55
12:00	33.7	34.1	31	31.2	41.4	40.5	36.3	36.3	37.2	37.2	102.58
14:00	34.6	34.7	30.4	31.4	33.3	37.9	34.1	34.3	34.1	34.3	85.86
16:00	36.2	36.4	29.3	31.5	40.7	40.1	34.2	34.2	34.4	38.5	79
18:00	30.6	30.7	26.2	27.5	29.2	28.9	29.1	31.2	31.7	31.2	39.4

LENGTH: 1m ANGLE: 90° DAY: 3 DATE: 13-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	25.8	25.9	27.5	27.6	28.3	28.6	26.8	26.9	27.6	27.8	37.59
10:00	35.2	34.7	30.6	32.2	37.7	38.3	34.1	34.7	35.6	34.9	83.05
12:00	36.1	36.4	36.6	36.2	32.7	34.8	37	37.6	38.5	38.5	107.15
14:00	37.6	37.7	27	26.7	30.4	28.7	36.1	38.3	38.5	38	93.69
16:00	28.7	28.9	26.3	27.1	21.5	22.4	21.4	21.4	22.7	27.2	47.73
18:00	22.4	22.9	23	24.5	22	21.3	22.3	23.3	23.1	23.9	33.8

LENGTH: 1m ANGLE: 90° DAY: AVG

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	25.2	25.3	26.4	26.4	27.2	27.5	26.2	26.4	26.6	26.8	25.89
10:00	30.8	30.8	28.8	29.8	34.2	34.3	31.5	32	32	32.1	80.2
12:00	34.8	35.2	35.2	35.3	40	40	35.4	35.6	36.3	36.3	110.64
14:00	37.2	36.8	32.8	32.6	38.1	39.3	35.2	36	36.2	36.2	100.85
16:00	34.5	34.7	31.4	32.7	36	36	31.2	31.2	31.7	34.7	79.91
18:00	29	29.5	28	29.2	30	29.8	28	29.8	29.8	30	36.2

LENGTH: 1m ANGLE: 70° DAY: 1 DATE: 14-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.5	24.2	24	23.8	25.5	26.1	27	27.2	27.1	27.2	29.1
10:00	28	27.7	26	26.3	35.6	35.1	31.6	32	31.7	32	109.48
12:00	35.4	35.9	38.2	39.3	46.1	47.4	35	35	35.4	36	158.49
14:00	35.4	35.7	35.4	32.3	42.4	41.1	33	34	34.5	35.3	158.71
16:00	33.8	33.6	29.9	33.7	36.2	36.3	33.6	34.9	34.5	35	121.43
18:00	31.5	31.7	29.7	29.5	33.4	34.2	32.3	32.8	33	33.2	47.57

LENGTH: 1m ANGLE: 70° DAY: 2 DATE: 15-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.3	24.3	24.1	24.6	26.6	26.7	26.7	26.8	26.9	26.9	34.91
10:00	30.6	30.4	29	27.6	32.6	33.8	31.2	31.5	31.7	33.6	96.44
12:00	36	36.5	33.6	31.9	40.1	40.8	35.1	34.3	37.4	38.7	156.7
14:00	37.9	38.1	33.6	32.6	42.8	40.9	36.7	36.8	37.1	40.5	143.19
16:00	23.2	23.7	26.8	26.2	26.3	25.3	24.1	24.4	24.3	24.6	60.84
18:00	23.2	23.4	25.6	25.7	25.8	26.4	24	24.3	24.4	24.5	12.25

LENGTH: 1m ANGLE: 70 DAY: 3 DATE: 16-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	23.8	24.1	26.3	26.6	30.1	30	25.8	25.8	25.8	26	37.69
10:00	32.6	34.3	33.2	31.3	37.1	36.7	31.1	31.9	32.6	34.3	116.94
12:00	31.8	32	25.1	24.2	34.4	35.7	35.5	36.9	39.7	37.8	156.35
14:00	35.9	35.4	35.1	35.6	34.5	36.5	32.9	32.7	33.4	29.5	88.25
16:00	49.5	48.6	41.1	40.9	48.5	49.4	38.6	42.7	44.4	44.5	134.15
18:00	44	43.6	33.2	32.4	39.2	37.5	37.3	37.4	37.7	38.3	89.19

LENGTH: 1m ANGLE: 70° DAY: AVG

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.2	24.2	24.8	25	27.4	27.6	26.5	26.6	26.6	26.7	33.9
10:00	30.4	30.8	29.4	28.4	35.1	35.2	31.3	31.8	32	33.3	107.62
12:00	34.4	34.8	32.3	31.8	40.2	41.3	35.2	35.4	37.5	37.5	157.18
14:00	36.4	36.4	34.7	33.5	39.9	39.5	34.2	34.5	35	35.1	130.05
16:00	35.5	35.3	32.6	33.6	37	37	32.1	34	34.4	34.7	105.4733
18:00	32.9	32.9	29.5	29.2	32.8	32.7	31.2	31.5	31.7	32	49.67

LENGTH: 1m ANGLE: 50° DAY: 1 DATE: 17-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.9	25.2	24.6	24.5	26.6	26.7	26.5	26.5	26.6	26.6	40.83
10:00	31.8	32.2	26.9	25.2	34.3	32.4	31.5	31.6	31.7	32	155.8
12:00	39.1	39.7	37.4	37.1	48.1	46.2	34.9	34.9	36.9	37.6	280.1
14:00	38.8	38.4	36.4	35.8	45.7	44.1	33.6	33.6	34.5	36.9	156.28
16:00	38.5	37.4	33.5	31.5	38.7	39.4	35.3	35.3	35.6	36.5	190.56
18:00	32.3	31.8	28.1	27.7	32.4	31.5	31.6	32.13333	32.5	32.5	56.24

LENGTH: 1m ANGLE: 50° DAY: 2 DATE: 18-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24	25.4	25.4	25.4	27.6	27.6	27.1	27.1	27.2	27.4	42.5
10:00	28.8	29.6	28.4	27	34.9	35.5	31.5	31.6	31.7	32.1	157.31
12:00	37.4	37.5	33.7	32.7	44.8	42.4	34.3	34.3	36.1	36.4	287
14:00	40.5	40.4	37.2	37.6	47.3	48.1	35.6	36	36.2	38.3	310.2
16:00	35.4	34.5	32	31.4	38	37.7	32.8	32.8	33.2	34.5	120.14
18:00	32	32	28.9	28.2	31	31.8	31.9	32.13333	32.5	32.5	54.85

LENGTH: 1m ANGLE: 50° DAY: 3 DATE: 19-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	20.7	21.1	29.2	26	28	27.9	24.7	25	24.8	24.9	16.9
10:00	24.3	30.6	33.8	33.3	44.2	45.5	31.5	31.6	31.7	31.9	179.94
12:00	26.7	26.6	37.2	36.1	40	44.6	31	34.3	37.16	37.3	183.29
14:00	26.3	26.2	29	28.9	32.7	33.2	30.1	32.4	32.2	32.2	137.57
16:00	23	22.3	31.1	31	40.3	41.1	30.3	30.9	31.1	32.5	168.82
18:00	24.5	24.1	32.1	31.4	35.3	36.3	29.8	30.83333	30.1	31.9	59.58

LENGTH: 1m ANGLE: 50° DAY: AVG

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	23.2	23.9	26.4	25.3	27.4	27.4	26.1	26.2	26.2	26.3	33.41
10:00	28.3	30.8	29.7	28.5	37.8	37.8	31.5	31.6	31.7	32	164.35
12:00	34.4	34.6	36.1	35.3	44.3	44.4	33.4	34.5	36.72	37.1	250.13
14:00	35.2	35	34.2	34.1	41.9	41.8	33.1	34	34.3	35.8	201.35
16:00	32.3	31.5	32.2	31.3	39	39.4	32.8	33	33.3	34.5	159.84
18:00	29.6	29.3	29.7	29.1	32.9	33.2	31.1	31.7	31.7	32.3	56.89

LENGTH: 1m ANGLE: 30° DAY: 1 DATE: 20-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.5	24.9	25.8	25.8	28.1	28.3	27.3	27.5	27.4	28.6	32.6
10:00	33.6	33.9	30.5	29.1	40.1	39.2	32.2	32.9	33.2	34.4	189.6
12:00	35.4	35.4	35.8	35.6	48.3	47.8	34.3	35.6	34.9	35.6	441.2
14:00	38.1	37.1	31.1	30.8	41.3	40.5	31.6	32.1	33	34.2	201.5
16:00	36.8	36.2	33.2	33.4	42.3	44.2	32.6	33.1	34.8	36	288.5
18:00	33.3	32.9	28	28	33.8	33.1	31.9	31.9	33.1	33.8	104.93

LENGTH: 1m ANGLE: 30° DAY: 2 DATE: 21-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.8	25	25.9	25.7	27.1	27.8	26.8	26.8	27.6	28	35.9
10:00	29.5	30	24.6	26	34	34.8	32	32.4	33	33.5	175.6
12:00	35.4	35.4	40.2	39	54	55	38.1	40.2	40.7	42	449.8
14:00	38.1	37.1	40	39.5	50.3	51.6	35.3	35.8	36.7	37.3	258.4
16:00	36.8	36.2	38.7	40	46.5	47.7	35.6	35.9	37	38	248.8
18:00	29.4	29.5	28	28.3	30.8	31.3	29.7	29.7	29.9	30	51.26

LENGTH: 1m ANGLE: 30° DAY: 3 DATE: 22-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	23.3	23.3	27.5	26.5	28.2	27	24.8	25.2	26.9	27.1	32.3
10:00	33.8	30.6	32.8	32.8	42.3	42.7	31.2	31.9	32.8	36.5	193.76
12:00	35.4	35.4	35.9	32.5	54.9	53.8	33.2	32.2	33.6	34	415.8
14:00	38.1	37.1	45.9	47.3	51.8	51.6	38.1	39.2	38.6	38.9	456.48
16:00	36.8	36.2	38.8	39.4	48	45.2	32.9	33.6	34.4	33.7	301.2
18:00	28.8	33.3	33.1	33.1	35.9	36.4	28.7	28.7	27.9	27.1	80.21

LENGTH: 1m ANGLE: 30° DAY: AVG

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.2	24.4	26.4	26	27.8	27.7	26.3	26.5	27.3	27.9	33.6
10:00	32.3	31.5	29.3	29.3	38.8	38.9	31.8	32.4	33	34.8	186.32
12:00	35.4	35.4	37.3	35.7	52.4	52.2	35.2	36	36.4	37.2	435.6
14:00	38.1	37.1	39	39.2	47.8	47.9	35	35.7	36.1	36.8	305.46
16:00	36.8	36.2	36.9	37.6	45.6	45.7	33.7	34.2	35.4	35.9	279.5
18:00	30.5	31.9	29.7	29.8	33.5	33.6	30.1	30.1	30.3	30.3	78.8

LENGTH: 1m ANGLE: 10° DAY: 1 DATE: 23-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.3	24.9	24.2	24.9	27.3	27.1	27	27	27	27.1	60.5
10:00	28.7	29.7	31.6	32.4	46.9	44.9	31.4	31.4	33	34	292.7
12:00	39.3	40.8	40.5	39.9	57.1	57.2	41	41	43	45.1	455.6
14:00	44	44.8	47.1	48.8	66.4	67	41.5	41.5	42.3	44.4	400.6
16:00	39.9	41.3	39.3	42.2	50.4	54.2	40.6	40.6	42.6	42.2	484.7
18:00	32.8	32.8	30.3	31	34.6	35.3	30.3	30.3	30.8	31.4	81.69

LENGTH: 1m ANGLE: 10° DAY: 2 DATE: 24-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.5	25	26.9	26.7	28.9	28.9	24	24.2	24.1	24	65.51
10:00	28.5	29.4	32.1	30.2	44	42.1	34.8	35.2	35	35.4	287.2
12:00	45	45.8	46.6	46.9	69.3	67.3	36.4	41.5	41.5	42.7	671.5
14:00	40.9	40.1	40.3	39.5	51.3	50.1	36.6	36.6	37.2	39	431.2
16:00	41.3	40.8	44.2	44.3	54.6	53.6	37.8	37.8	38.5	39.9	331.3
18:00	32.4	32.1	27.2	27.3	32	32.1	30.7	30.7	31.1	31.8	89.23

LENGTH: 1m ANGLE: 10° DAY: 3 DATE: 25-Jul

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.4	24.5	28.1	28.5	30.5	31	27	27.4	27.2	27.2	56.69
10:00	39.7	33.3	53.9	52.9	52.8	53.7	35.8	37.2	37	37.4	324.14
12:00	30.6	30.1	35.9	35.3	42.2	43.5	27	28.8	28.9	29.5	406.59
14:00	33.9	33.3	29.9	30.5	48.2	47.9	30.8	32.6	32.1	29.4	604.09
16:00	36.4	36.4	30.8	31.7	43.2	41.3	22.4	24.8	25.4	28.6	312.72
18:00	32.3	31.7	42.7	42.8	36	36.7	25.4	31.7	33.5	33.1	102.38

LENGTH: 1m ANGLE: 10° DAY: AVG

TIME	TGO		TGI		TA		Air Temp				Insolation
	1	2	1	2	1	2	Inlet	1	2	Outlet	Ang.
8:00	24.4	24.8	26.4	26.7	28.9	29	26	26.2	26.1	26.1	60.9
10:00	32.3	30.8	39.2	38.5	47.9	46.9	34	34.6	35	35.6	304.68
12:00	38.3	38.9	41	40.7	56.2	56	34.8	37.1	37.8	39.1	511.23
14:00	39.6	39.4	39.1	39.6	55.3	55	36.3	36.9	37.2	37.6	478.63
16:00	39.2	39.5	38.1	39.4	49.4	49.7	33.6	34.4	35.5	36.9	376.24
18:00	32.5	32.2	33.4	33.7	34.2	34.7	28.8	30.9	31.8	32.1	91.1