CHAPTER 1
INTRODUCTION

This chapter is dedicated to introduction and explanation of the Final Year Project (FYP) topic, ***"Experimental & Numerical Investigation on the effect of inlet shape of inclined heated channel"***. A background study, problem statement, the objectives and lastly scope of the work are pointed out in this chapter.

1.1 Background Study

FYP will concentrate on experimental and numerical investigation on the inlet shape of inclined heated channel of Roof Top Solar Chimney (RTSC). Basically, FYP is based on the Solar Chimney application which idea to generate electricity for a home usage. In conjunction with previous task done by Khor Yin Yin (2009) and Jothirmay (2005), both projects beneficial for FYP references. Khor Yin Yin (2009) had mentioned that the flow and temperature distributions in Solar Chimney are influenced by the collector length and inlet air gap [10]. Meanwhile, Jothirmay (2005) had carried out a study of heat transfer through natural convection and reported that the process analysis includes some parameters such as ambient temperature, air flow velocity and area inlet and outlet opening [12]. Inlet air gap and area inlet/outlet opening are described as the specified cross sectional area of the inlet configuration. Different inlet configuration has different cross sectional area. There are still setbacks in the effect of inlet shape on the thermal process efficiency. The most related project in this topic goes to define the efficiency of the process of heat transfer with different height. FYP is not focus on designing of Wind turbine due to time constraint. Therefore, it is very essential to take into consideration of the inlet configuration on analyzing the performance of the solar chimney. Does the inlet configuration affect the overall performance of the system? What happens if the inlet configuration varies? These are questions that consider for FYP.

1.2 Problem Identification

1.2.1 Problem Statement

Solar chimney has widely used for power generation purposes. However, there are still setbacks in the effect of inlet configuration on the thermal process efficiency. The performance of solar chimney in terms of inlet configuration is still doubtful. The literature lacks a data on the effect of various inlet configuration analyses in solar chimney. Does the inlet configuration affect the overall performance of the system? What happens if the inlet configuration varies? Those are two questions had been arisen while conducting these experiments.

1.2.2 Significance of the Project

Energy demand in the world is increasing rapidly due to the increasing number of developing countries and further growth of energy consumption in developed countries. Renewable energy technologies are essential contributors to the future energy supply portfolio, as they contribute to reduce dependency on main energy and provide opportunities for mitigating green house gases.

The International Energy Agency (IEA) estimated that nearly 50% of global electricity supplies will need to come from renewable energy sources in order to half CO^2 emissions by 2050 and minimized significant, irreversible climate change impacts. One of the renewable energy is solar energy. It has estimated that solar energy expenses will growth three times from $77.3 US billions at year 2007 to $254.4 US billions at year 2017. [4].

The following figure show the Clean energy Projected growth 2007-2017:

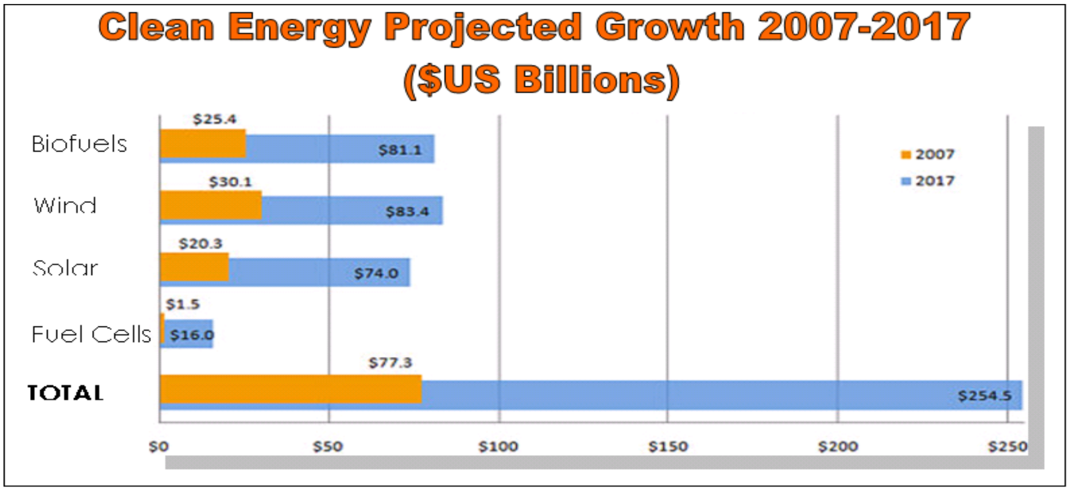


Figure 1: Clean Energy Projected Growth 2007-2017 [3]

One of the solar energy application is the Solar Chimney which utilizes the outside surface of house roof by accumulates solar radiation which rotate wind turbine to generate electricity for home usage. [3]

Solar Chimney is useful and effective in place with less accessible and remote such as rural area, public buildings such as hospital, and undeveloped countries such as African region. Moreover, it is used minimum cost to operate and very green technology to generate electricity.

1.3 Objectives

Objectives of FYP are:

- To fabricate various air inlets of the RTSC model.
- To carry out experimental measurements.
- To model and simulate the variation air inlets of the RTSC.

1.4 Scope of work

Follows are the scope of works to be accomplished for FYP 1:

1. Researched related data/ information on the project
2. Produce various inlets of the RTSC configurations for suitability studies.

Follows are the continued scope of works for FYP 2:

3. Conducting experimental measurements program to investigate the RTSC at various air inlets.
4. To model each inlet configuration and simulate using the same metrological data of the experiments to predict the RTSC performance. The basic parameters to be predicted are same of the measured in the experiments, air velocity at inlet and at chimney base, the collector temperature, and the glass temperature.
5. To compare the experimental measurement with the simulation prediction for validation for a simulation.

CHAPTER 2
LITERATURE REVIEW

In conjunction with solar energy application which called Solar Chimney, reviewed from previous similar and related works had been required in order to enhance understanding of the concept especially on inlet shape of the inclined heated channel. The focus of the analysis is more towards the roof part (the circle mark) rather than on the chimney. The fact is that the main mechanism which is the heat transfer is happening within the roof region instead of the chimney. The roof area which FYP will focus is called the Roof Top Solar Chimney (RTSC). The main elements of RTSC are roof collector, absorber, and chimney.

The following shows the schematic diagram of RTSC:

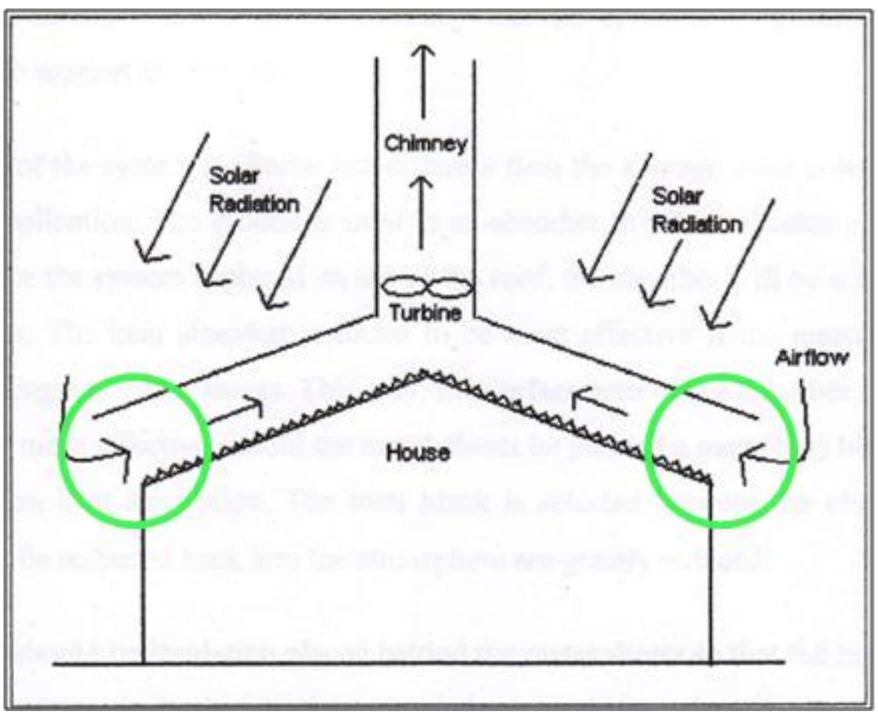


Figure 2: Schematic diagram of RTSC

In order to clarify misunderstanding regarding on each element of RTSC, the importance of studies for those elements are necessary. Following is a summary of studies related to those elements:

Solar Chimney

Solar chimneys are constructed to actively promote ventilation of unwanted heated or stale air by drawing fresh cooler air from vents at lower levels. The concept of Solar Chimney to generate electricity is based on the roof part of the system and less on the chimney. The process by which this movement of air occurs is called natural convection [1]. Natural convection is created by solar energy heating air within the chimney. The heated air escapes out the top of the chimney and is replaced by air from the outside (through windows or vents elsewhere in the building). In winter the chimney vents to the outside can be closed and heated air in the chimney forced (using fans or other air handling system) into the building for heating purposes [2].

Analysis on inlet shape

Ref. [6] had studied on Space cooling between collector and roof can be achieved by improving the performance of roofs. This is because the roofs are the surfaces most exposed to direct solar radiation and can cause excessive heat gain in hot periods. Some efforts were made by investigators to improve roof thermal performance.

Ref. [3] had studied and carried out the analysis on mathematical model in order to examine the effects of various parameters that may influence the efficiency of the power plant. The mathematical model includes the geometries of a solar collector and the ground type as absorbing surface. Researcher had described seven principle factors which strongly affect the amount of solar radiation incident on a collector which are geographical location, site location of the collector, collector orientation, time of the day, time of the year, atmospheric condition, and collector design (referred to inlet shape design). Inlet shape is referred to the design roof between corrugated plate and Acrylic

Perspex. This shape is critical in order to cater the best medium for heat transfer process to takes place.

Effect of inlet shape

The effect of inlet shape is based on the experiment on variable inlet configurations of RTSC. Experiment will be conducted in such a way to acquire some parameters which technically appropriate to describe the performance of RTSC. This is the main scope of study for this project.

Analysis on inclined heated channel

Since the natural convection from collector surface is bounded by the cover, it will form a channel for the air to flow and hence it can suitable be modeled as inclined heated channel. For inclined heated channel, analysis focused more on optimum angle for collector and glazing (cover part). It is expected to give the best result for modeling of the heat transfer in the Solar Chimney under the roof. FYP will consider constant angle at 30° from the horizontal line in order to focus more on the inlet shape only.

The chimney giving the best performance (0.25 m, single glazing, and low-emissivity) was studied in more detail regarding the angle [5]. Because of the changes in the position of the sun, the performance varies throughout the day for the differing chimney angles. Fig. 3 shows some typical results at 12.00 and 16.00 h with single glazing and high emissivity. The change in mean cavity-temperature with angle of inclination from the horizontal is shown in Fig. 4. The flow rate increases for up to 67.5˚, and for angles lower then 45˚ the flow reduces. At 22˚ from the vertical, the availability of solar radiation is at a maximum (at this latitude): however the flow rate is still lower than at 67.5˚, due to greater heat- losses.

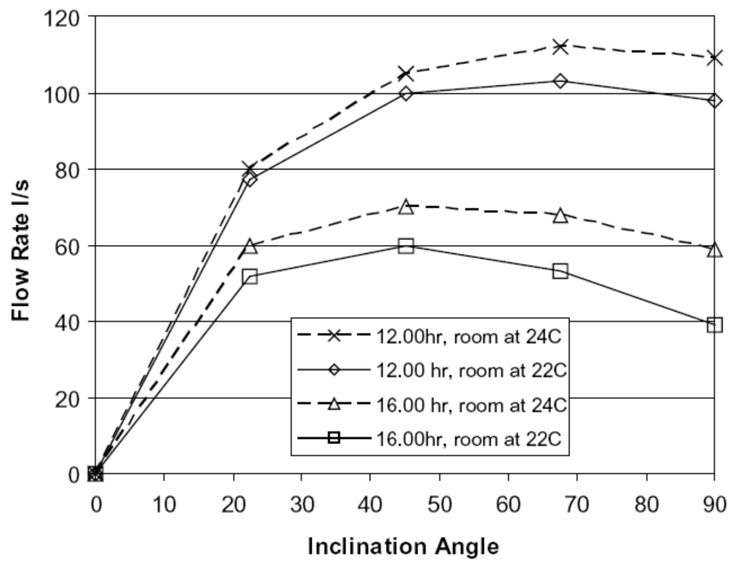


Figure 3: Single glazing, low-emissivity at 12.00 and 16.00 h [5]

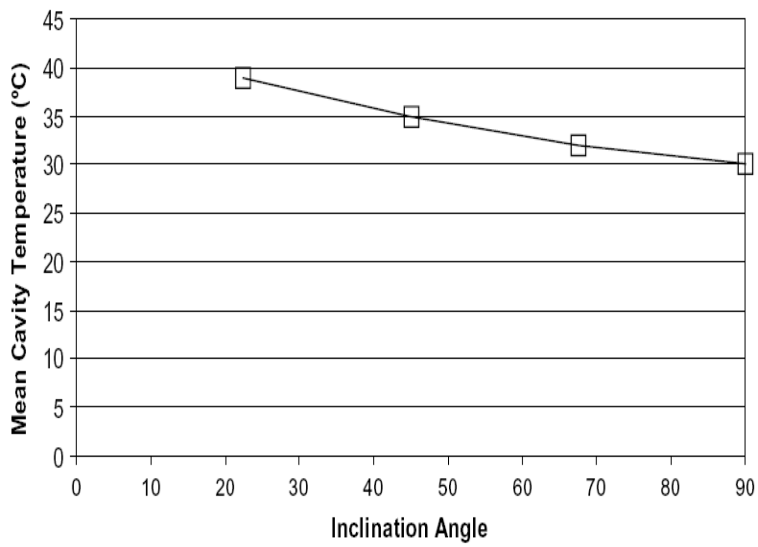


Figure 4: Effect of inclination angle on cavity temperature [5]

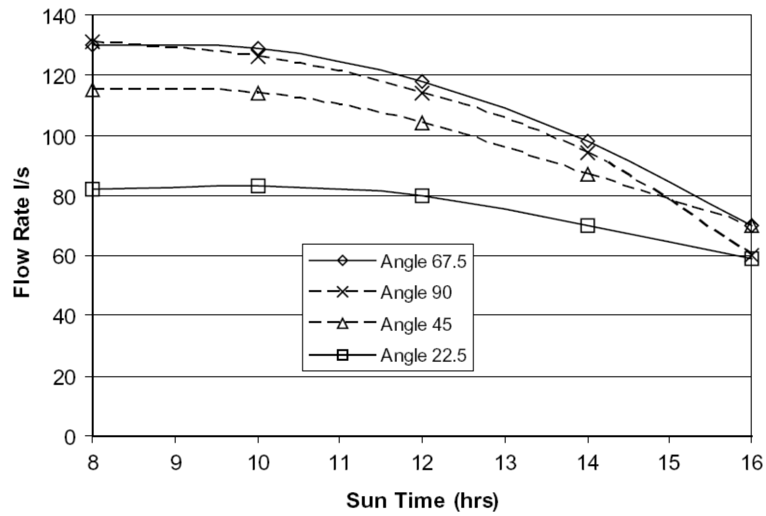


Figure 5: Twenty-four hour performance [5]

Twenty-four hour performance is shown in Figure 5. The slope of roofs on houses in the location studied is either 45˚ (older houses) or 60˚ from the vertical (more modern houses) which means that sloping of the solar chimney along the roof line gives less than optimum conditions. On average, the performance at 45˚ is approximately the same as at 90˚, but 10% lower than at 67.5˚. At 60˚, the flow is 25% lower than at 90˚ and 30% lower than at 67.5˚. The increase in heat loss from the surface more than counterbalances the increase in solar radiation received, (at least during the summer months, when ventilation cooling is required most). Therefore, for this project, constant angle of 30° is considered the best angle based on the result of experiment given. [5]

CHAPTER 3
METHODOLOGY

This chapter explain the methods used in FYP. Some methods are useful for FYP1 meanwhile others for FYP2. The inlet configurations required for each experiment are presented in this chapter.

For this project, some data about solar intensity that can be used to compare with the profile obtained from the previous related projects will be referred. Another factor that consider is analyze the heat transfer coefficient (convection) acquired from the data collected during the experimental part. Then, it is necessary to conduct graph analysis in order to define the performance of the chimney. There is also attempted to conduct the CFD modeling simulation to define the characteristics of the flow in the roof chimney.

It is very important to take into consideration the inlet shape roof in analyzing the performance of the solar chimney system. Does the inlet shape affect the overall performance of the system? What happens if the inlet shape varies? These are questions that consider for this project.

3.1 Analysis Method:

The analysis will be carried out numerically and experimentally.

3.1.1 Numerical analysis

A CFD simulation will be carried out using the GAMBIT 2.2.30 & FLUENT 6.3.26 soft wares.

3.1.1.1 GAMBIT 2.2.30 (Design Software):

- A state-of-the-art preprocessor for engineering analysis.
- With advanced geometry and meshing tools in a powerful, flexible, tightly-integrated with any major CAD/CAE system, and easy-to-use interface.

3.1.1.2 FLUENT 6.3.26 (Modeling Software):

- Broad physical modeling capabilities needed to model flow, turbulence, and heat transfer.
- Advanced solver technology provides fast, accurate CFD results, flexible moving and deforming meshes, and superior parallel scalability. [3]

3.1.2. Experimental investigation

For design analysis, four configurations for inlet shape are proposed to be investigated as follows:

Those four configurations are considered because:

- The simple and possible roof designs
- The widest area possible for air flow in
- Configuration 4 is consider based on the related project that applied half pipe

The four inlet shapes are shown in figure 6:

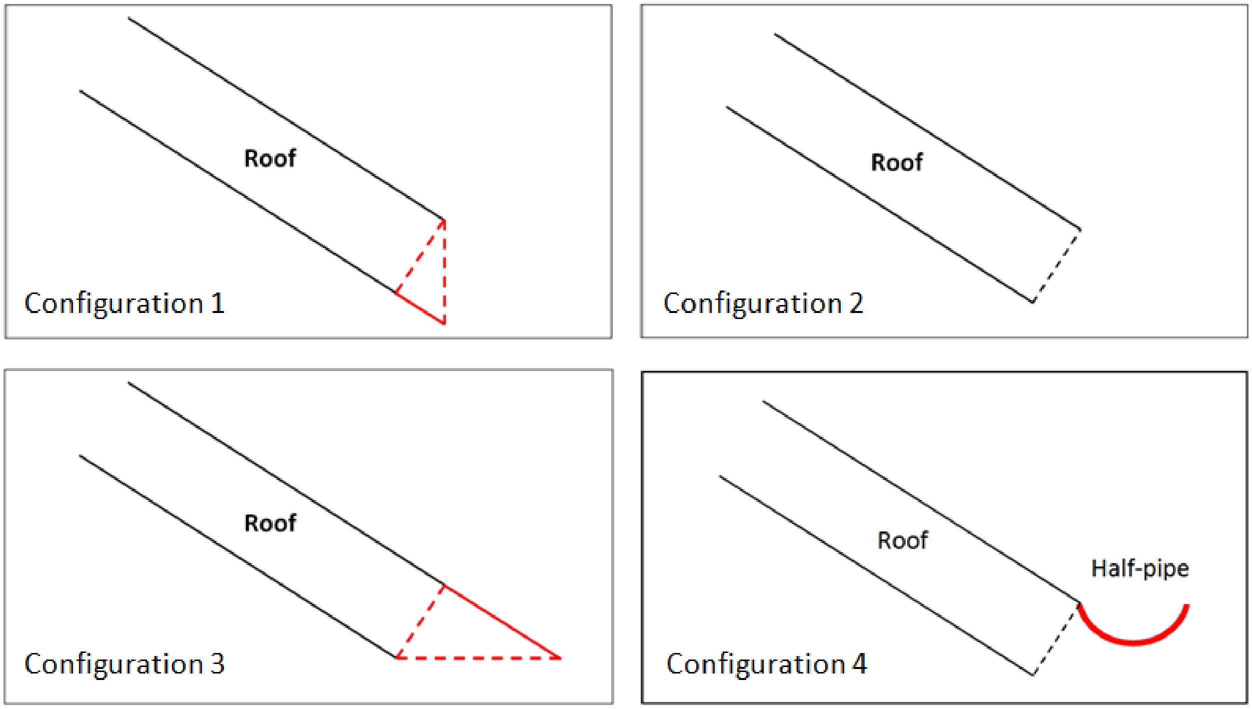
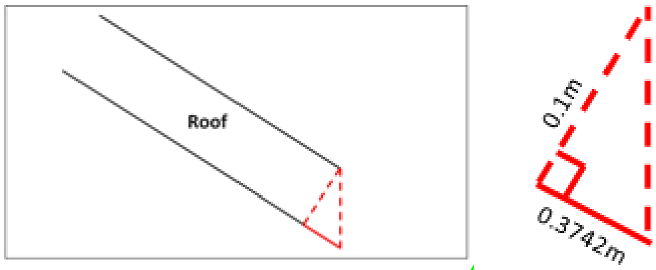


Figure 6: Four roof configurations for inlet shape

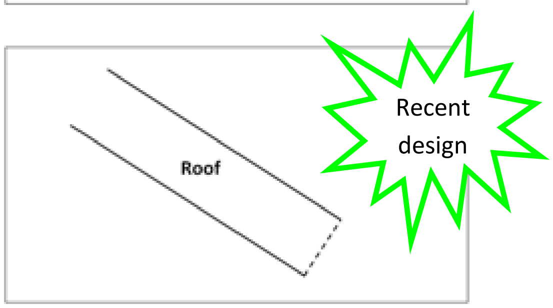
Calculation for each configuration area

To proof the area covered in the RTSC, the area for each configuration is calculated as follow:



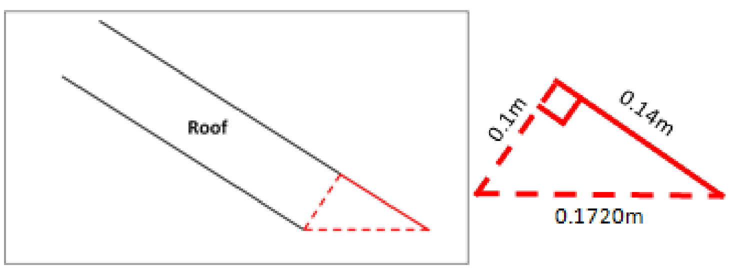
Area (A_1) for Configuration 1:

$A_1 = \frac{1}{2}(0.3742)(0.1) = \mathbf{0.01871m^2}$



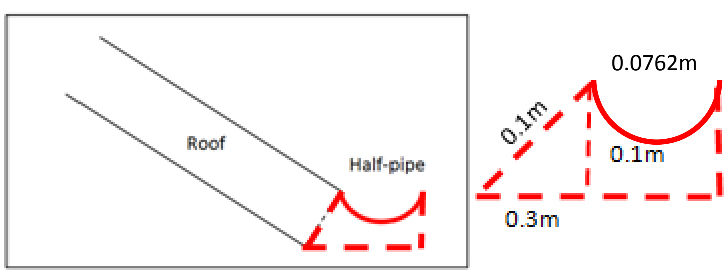
Area (A_2) for Configuration 2:

$A_2 =$ **0 (no changes)**



Area (A_3) for Configuration 3:

$A_3 = \frac{1}{2}(0.14)(0.1) = \mathbf{0.0070m^2}$



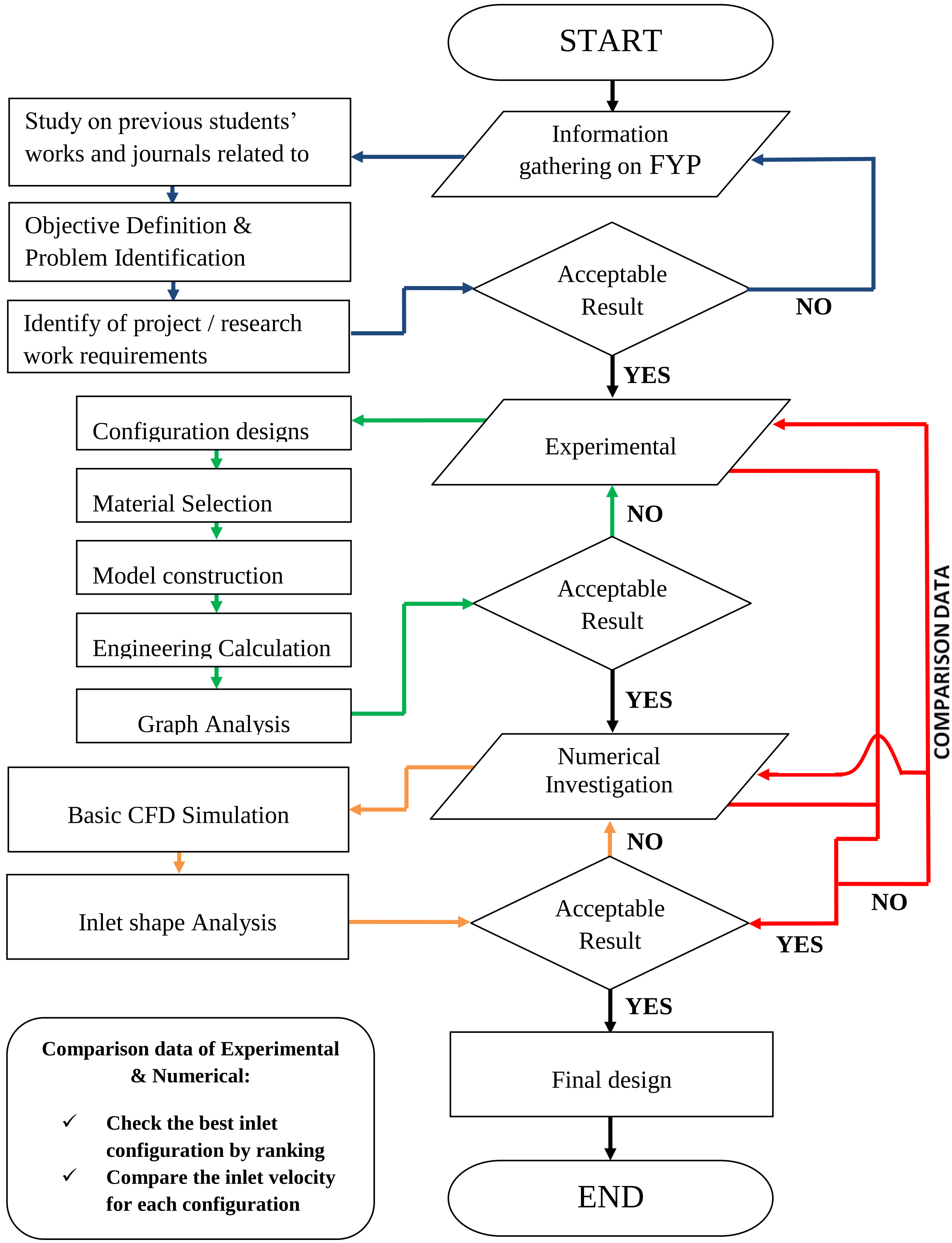
Area (A_4) for Configuration 4:

$A_4 = [(\frac{1}{2}(0.0762)(0.1)) - \frac{1}{2}(\pi(0.0381)^2)] + [\frac{1}{2}(0.3)(0.1)]$

$= [0.00381 - 0.00280] + [0.015]$

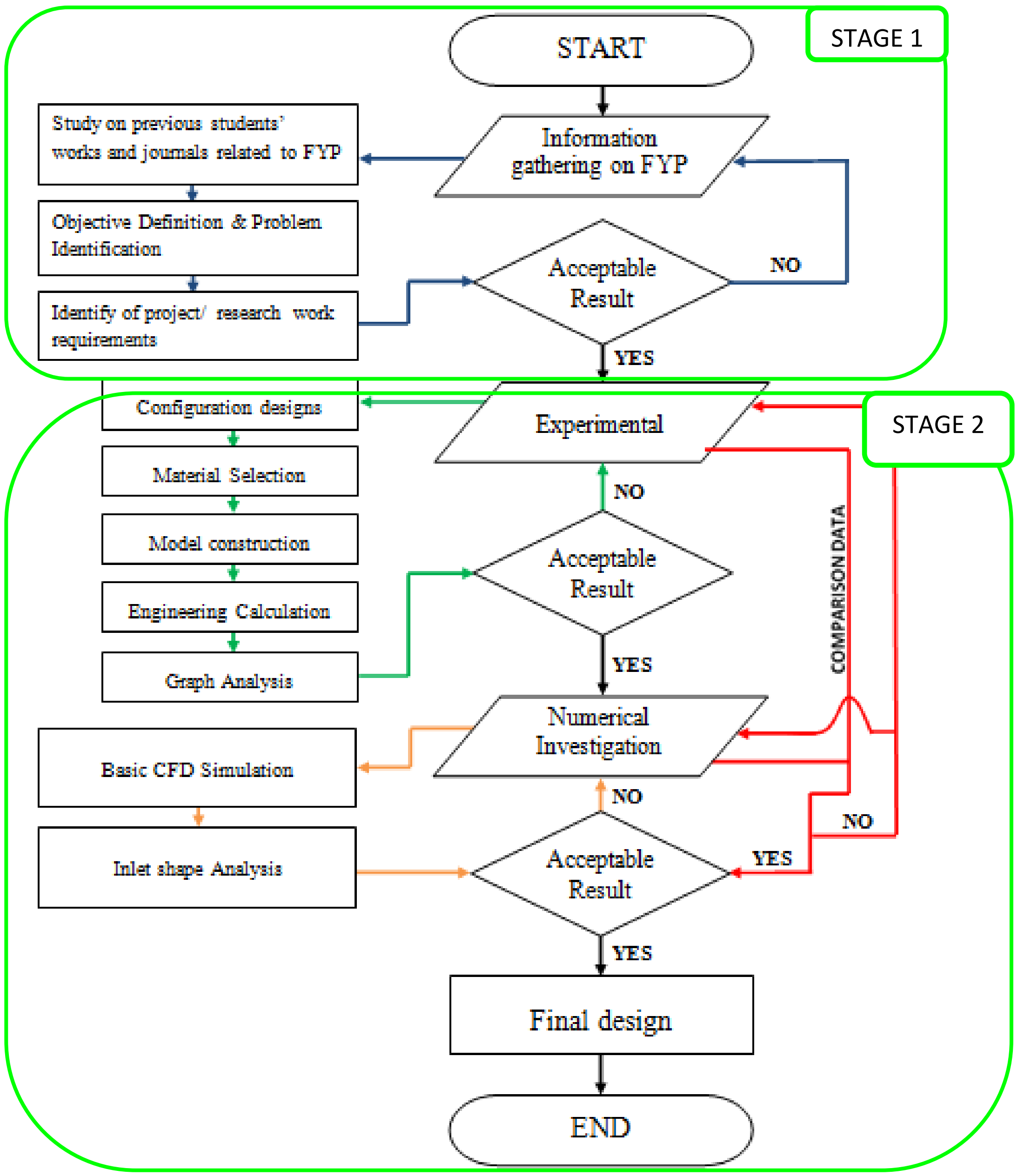
$= \mathbf{0.01653m^2}$

3.2 Execution Flow Chart



3.3 Key Milestone

Progress activity for FYP 1 and FYP 2 are allocated in the following figure. STAGE 1 is the stage where research is conducted. Research part deals with gaining the information from previous journals, project papers or thesis that related to FYP's topic.



Meanwhile, STAGE 2 is for Experiment and Numerical analysis. Experimental is more on conducting experiment to define performance of the RTSC. Numerical analysis is about conducting simulation using GAMBIT and FLUENT soft wares.

Gantt chart for FYP 1

Task	Date/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Selection of Project Topic	-															
Preliminary Research work	-															
Preliminary Report Submission	21Aug 09															
Experimental and Analysis for inlet shape																
Numerical investigation using Fluent																
Progress Report Submission	9 Sept. 09															
Seminar	10 Sept. 09															
Interim Report Submission	27 Oct. 09															
Oral Presentation	1 Dec. 09															

Gantt chart for FYP 2

Task	Date/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Experiment	-															
Progress Report 1 Submisson	22 Feb.10															
Analysis at measurements																
Numerical investigation using Fluent	-															
Progress Report 2 Submisson	30 Mac 10															
Seminar	29 Mac 10															
Verification of simulation																
Poster Exhibition	12 April 10															
Dissertation Final Draft Submission	7 May 10															
Oral Presentation	10 May 10															
Submission of Dissertation (hard bound)	31 May 10															

CHAPTER 4

EXPERIMENTAL PROCEDURE & RESULTS

For this chapter, the procedure and process taken during experiments are discussed in detail. The graph is produced for each configuration and followed by analysis for each graph.

4.1 Fabrication Process

Before proceed to the experimental part, there are importance to design the four various inlet configurations in order to provide real inlet design of RTSC. By having real inlet design of RTSC, more accurate and reliable data could be obtained from experiment analysis. Refer to the figure 8; there are the description mentioning the method of installation for the corrugated plate (absorber) and glass called the Acrylic Perspex (collector) with dimension for each configuration. Plus the dimension for the Acrylic Perspex that required to structure each configuration (figure 7 and 9). The equipments that used during fabrication process are portable jigsaw, portable drill, scissor, and measuring tape. Follow are the function of equipments:

Table 1: List of fabrication's equipments and functions

No.	Equipment	Function
1.	Portable jigsaw	To cut the Perspex and pipe
2.	Portable drill	To make hole for bolt and nut
3.	Scissor	To cut the zinc (corrugated plate)
4.	Measuring tape	To measure the dimension of each configuration

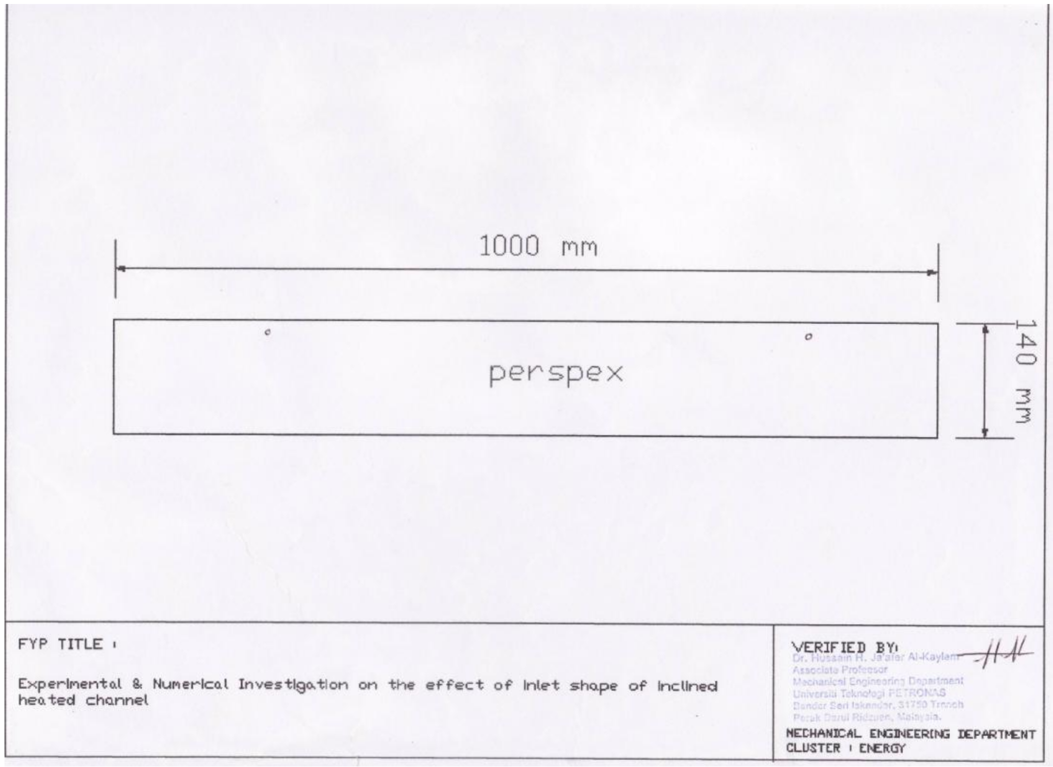


Figure 7: Dimension for Acrylic Perspex

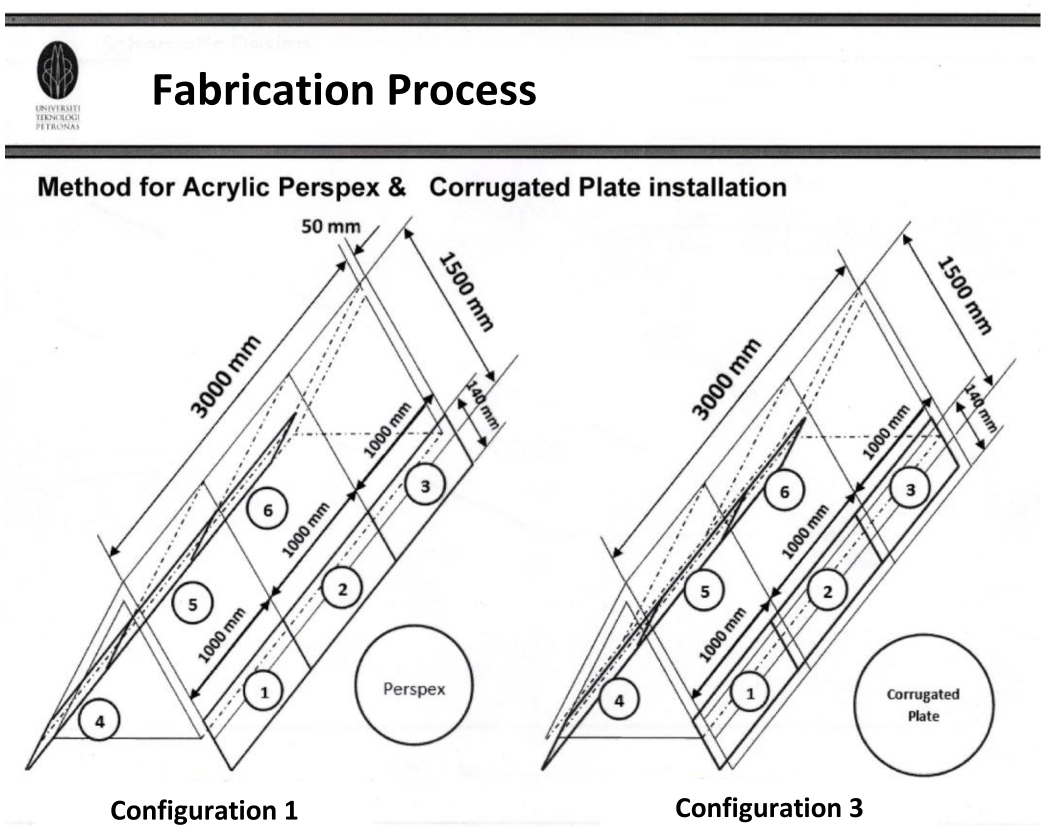


Figure 8: Method installation for Acrylic Perspex and Corrugated plate

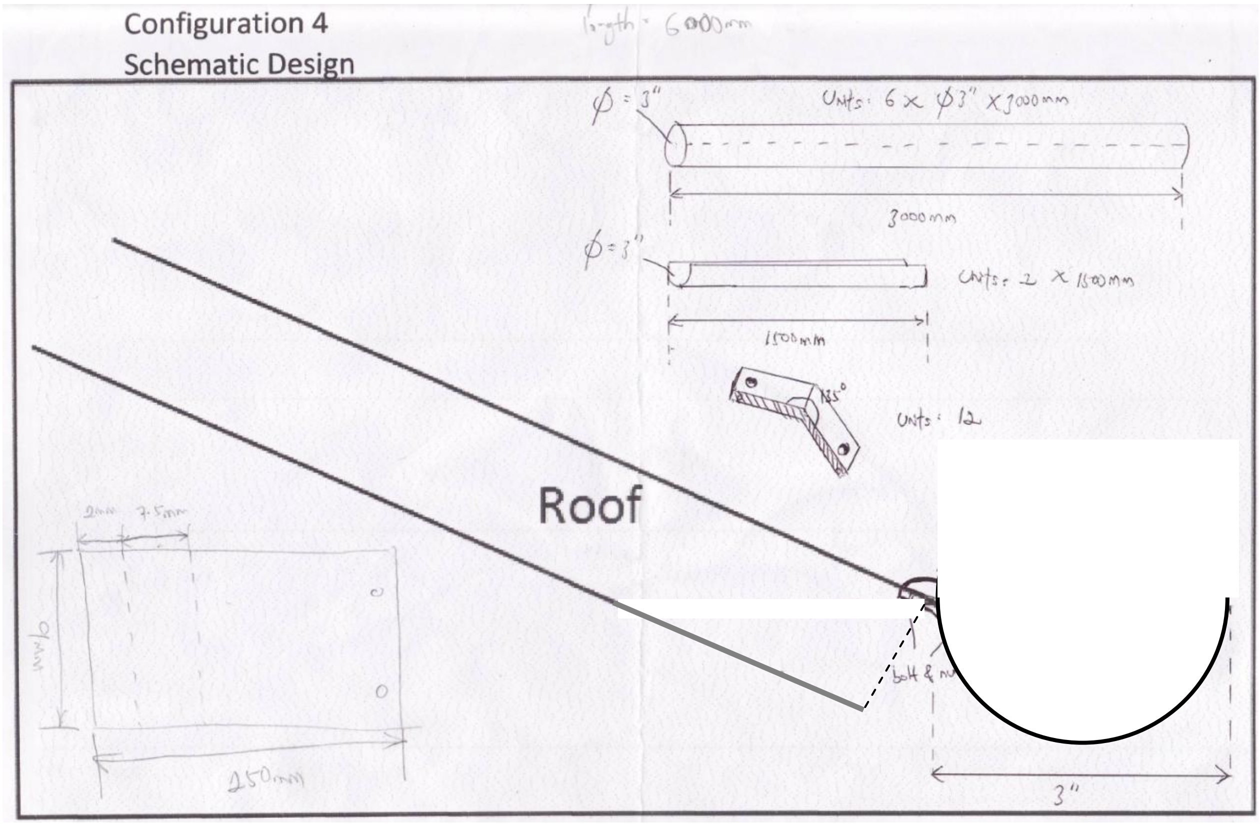


Figure 9: Method installation for Configuration 4

4.2 Experimental Procedure

Experiment is conducted to acquire some useful data in order to define the effect of the various inlet configurations toward the RTSC performance. There are some parameters that must to consider before conduct the experiments. The parameters are the temperature (°C), air velocity (m/s), and solar intensity (W/m^2). Temperature and air velocity are the main parameters studied of FYP. Those parameters are important to analyze the effect of the inlet configurations toward the RTSC performance. The effect of the inlet configurations can be identified from the temperature different of each experiment. As mentioned before, the performance of the RTSC is based on the current of air in a passage. The different in temperature created by the solar intensity on a collector will increase the current of air in the passage. The velocity parameter also is important to analyze the effect of the inlet configurations toward RTSC. The increase of the current of air in the passage will increase the air flow along the passage. The different in the air flow will caused the rate of change of air position. In physics, the rate of change of position is called the velocity. Meanwhile, solar intensity parameter is useful to analyze the weather condition throughout the experiments. Solar intensity is high on the day when the clouds is less than 50% and lower when 90% of the clouds covered the area experiment being conducted. Each parameter must be measured and recorded in the proper table for experimental analysis. Those parameters are called the reading data when the measurements are recorded in the table. The following shows the schematic diagram of RTSC with location of reading data.

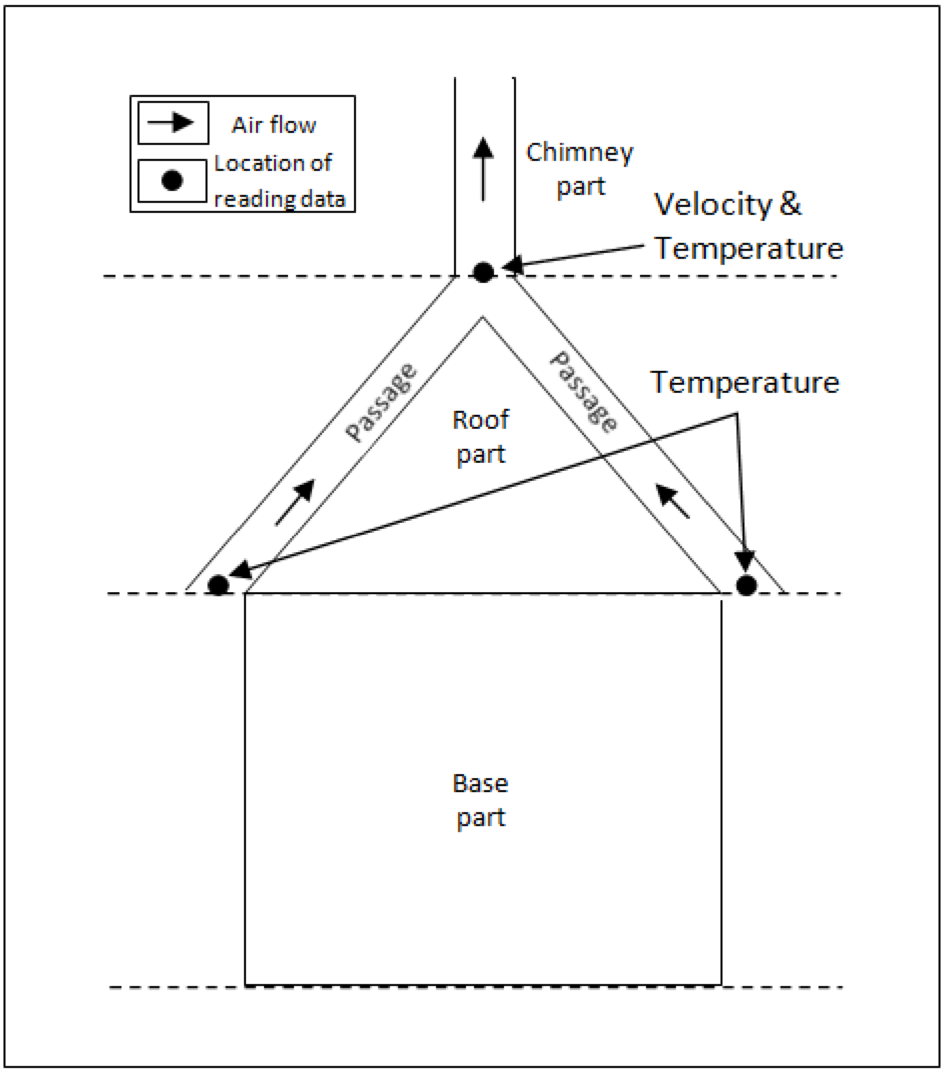


Figure 10: The schematic diagram of RTSC with location of reading data

The following is the table used to record the data for each configuration:

Table 2: Sample of Experiment's data

Time	Intensity (horizontal) **W/m²**	Intensity (vertical) **W/m²**	Ambient temperature **˚C**	Collector temperature **˚C**						
				1	2	3	7	8	9	Mean

Glass temperature **˚C**							Temperature air inlet (right) **˚C**			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean

Temperature air inlet (left) **˚C**				Temperature air outlet **˚C**	Velocity air at top **m/s**
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0

Configuration X	
Date	XX/X/XXXX
Day	X
Duration	X hours

The data is collected by using the sophisticated experimental equipments borrowed from the UTP's laboratory. Follow are the list and function of equipments:

Table 3: List of experiment's equipments and functions

No.	List of equipment	Function
1.	Thermocouples	To measure surface temperature
2.	Data logger	To measure surface temperature (preferred for high location)
3.	Solarimeter	To measure solar intensity
4.	Anemometer	To measure wind speed

Basically, the experiments consist of four inlet configurations of RTSC. Each experiment is conducted in 3 days with at least 6 hours of experiment per day. The reason of the 3 days of experiment is due to the take average of the data readings. Meanwhile for 6 hours of the data readings because the minimal requirement to obtain valid data for each configuration. Next step is to produce related graph and conduct the graph's analysis.

4.3 Experimental Analysis

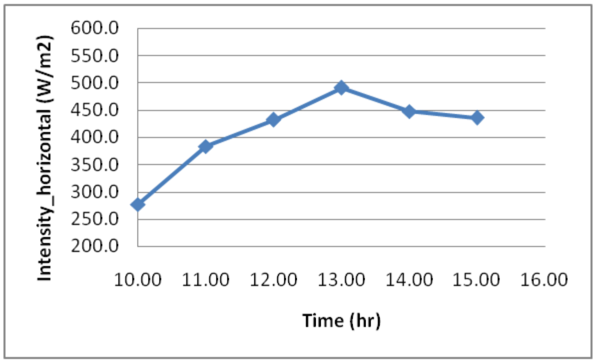
Experimental analysis is focused on two parts which are the experiment data for each inlet configuration and the chimney performance's graphs. The graphs will consist of the data in term of the solar intensity, the collector and glass's temperature, temperature air inlet and outlet and lastly the velocity at the chimney. Each data will represent the effect of inlet configuration toward the RTSC's performance. Later, the graph analysis will be explained in details.

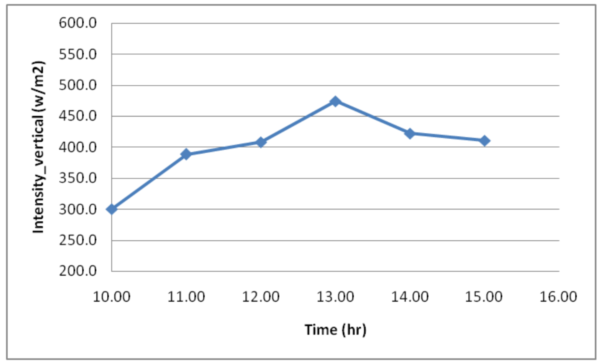
4.3.1 Inlet configurations

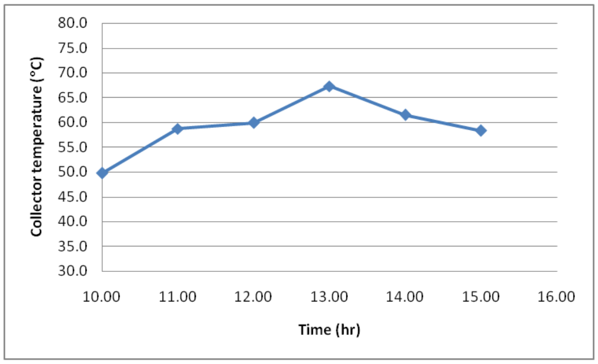
There are 8 data represented for each configuration for each day of working experiment. As mentioned, there are 3 days of experiment for each configuration. To make simple, the result will conduct only on the average data for each configuration. Later, details of each configuration will be explained and list out the ranking of the best air flow.

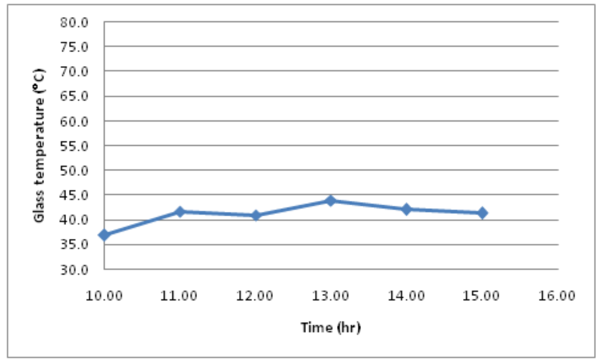
Follow are the graph represent the average data for each configuration:

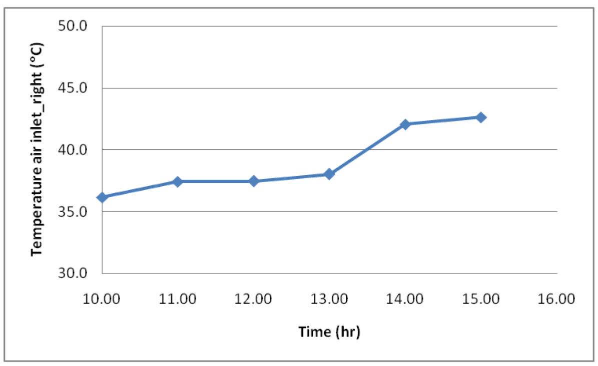
Graph of Configuration 1 (Average)

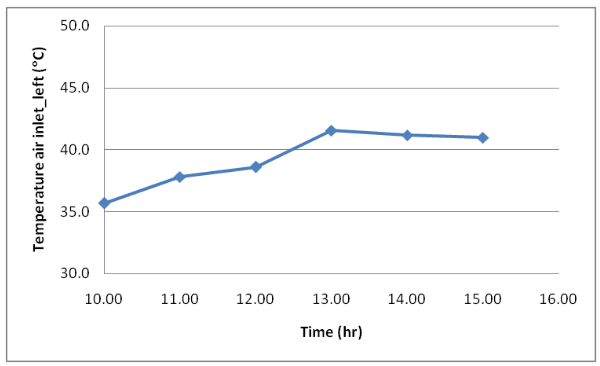


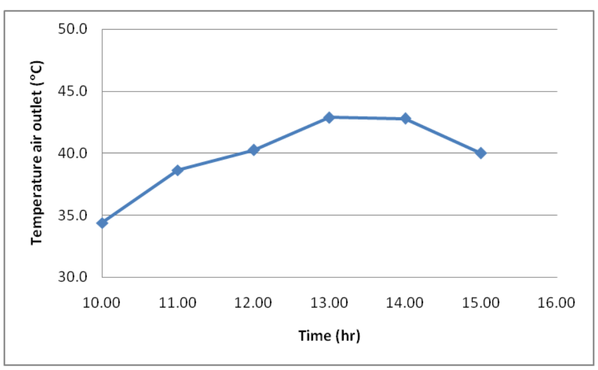


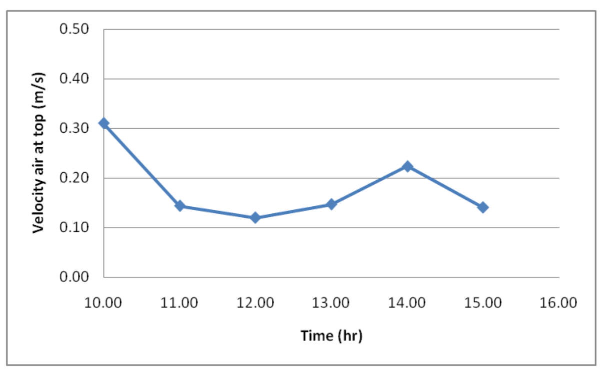




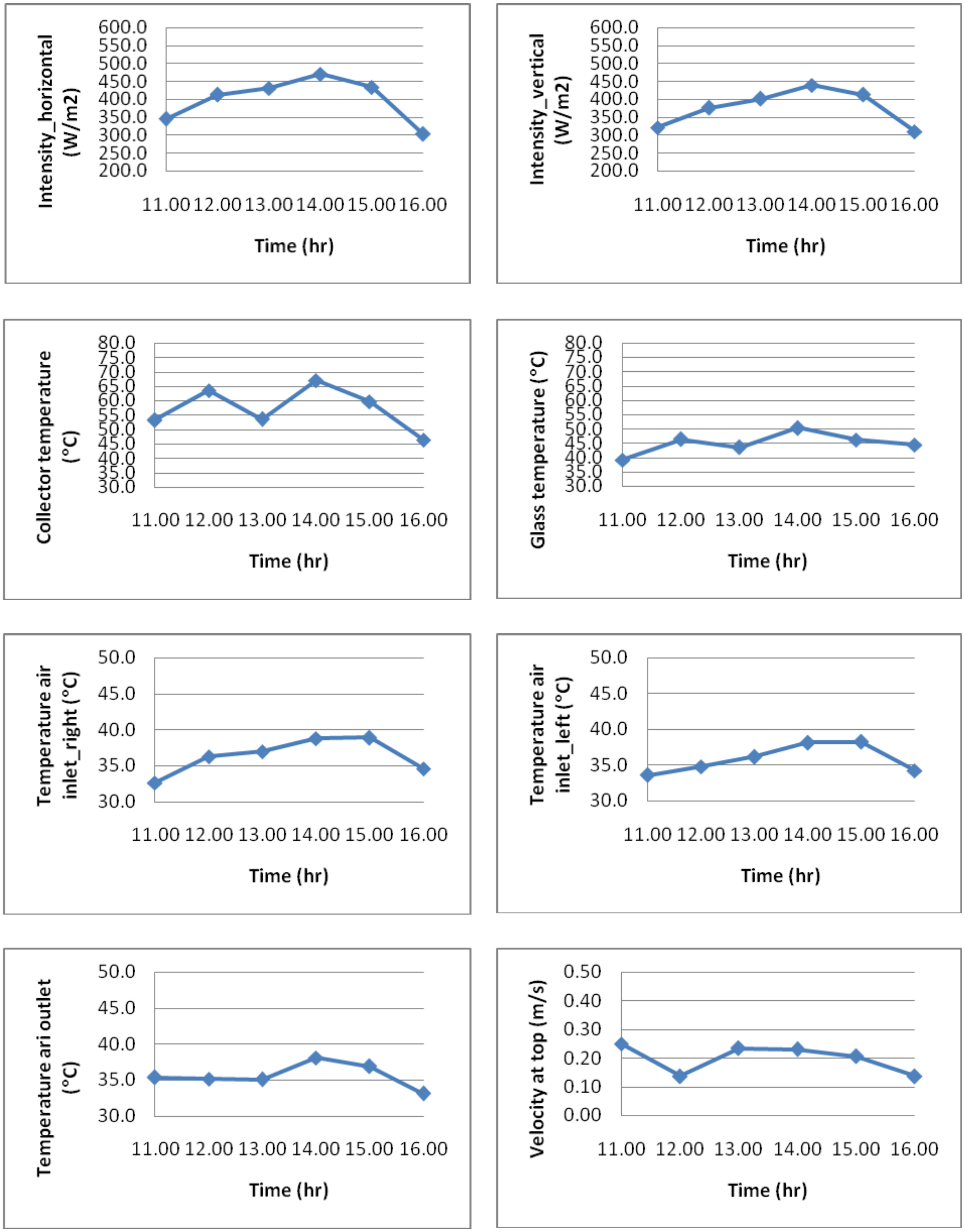




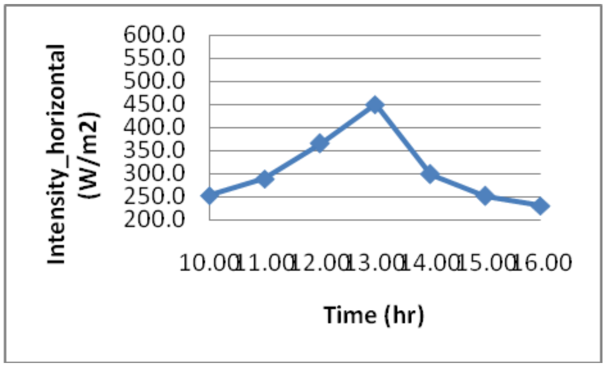


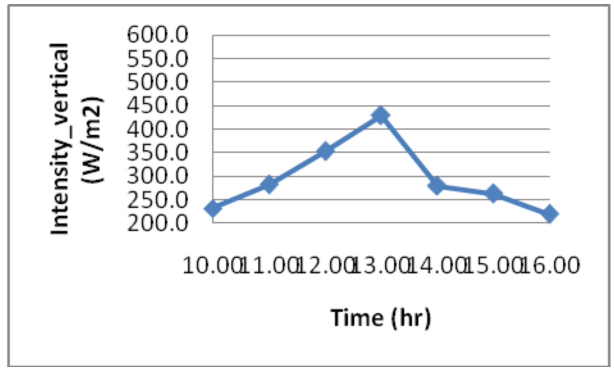


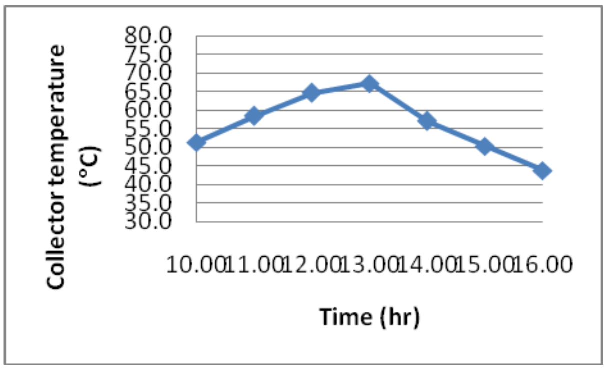
Graph of Configuration 2 (Average)

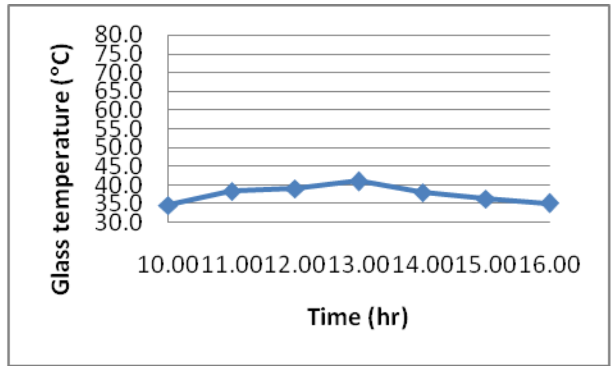


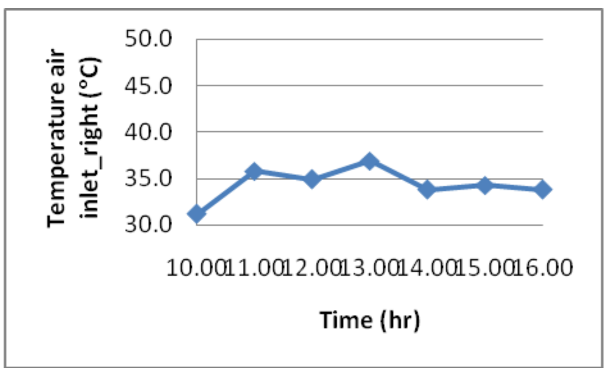
Graph of Configuration 3 (Average)

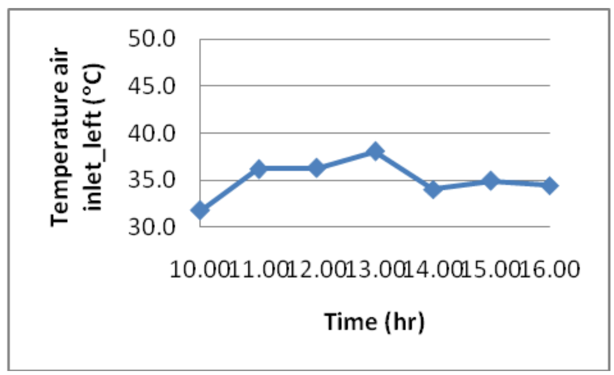


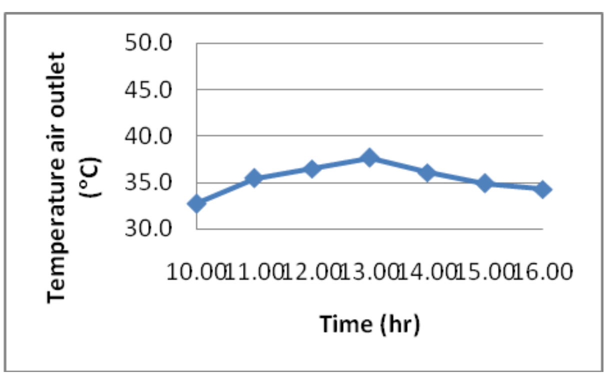


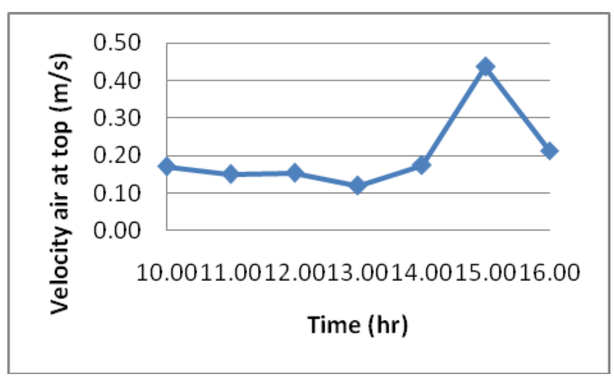




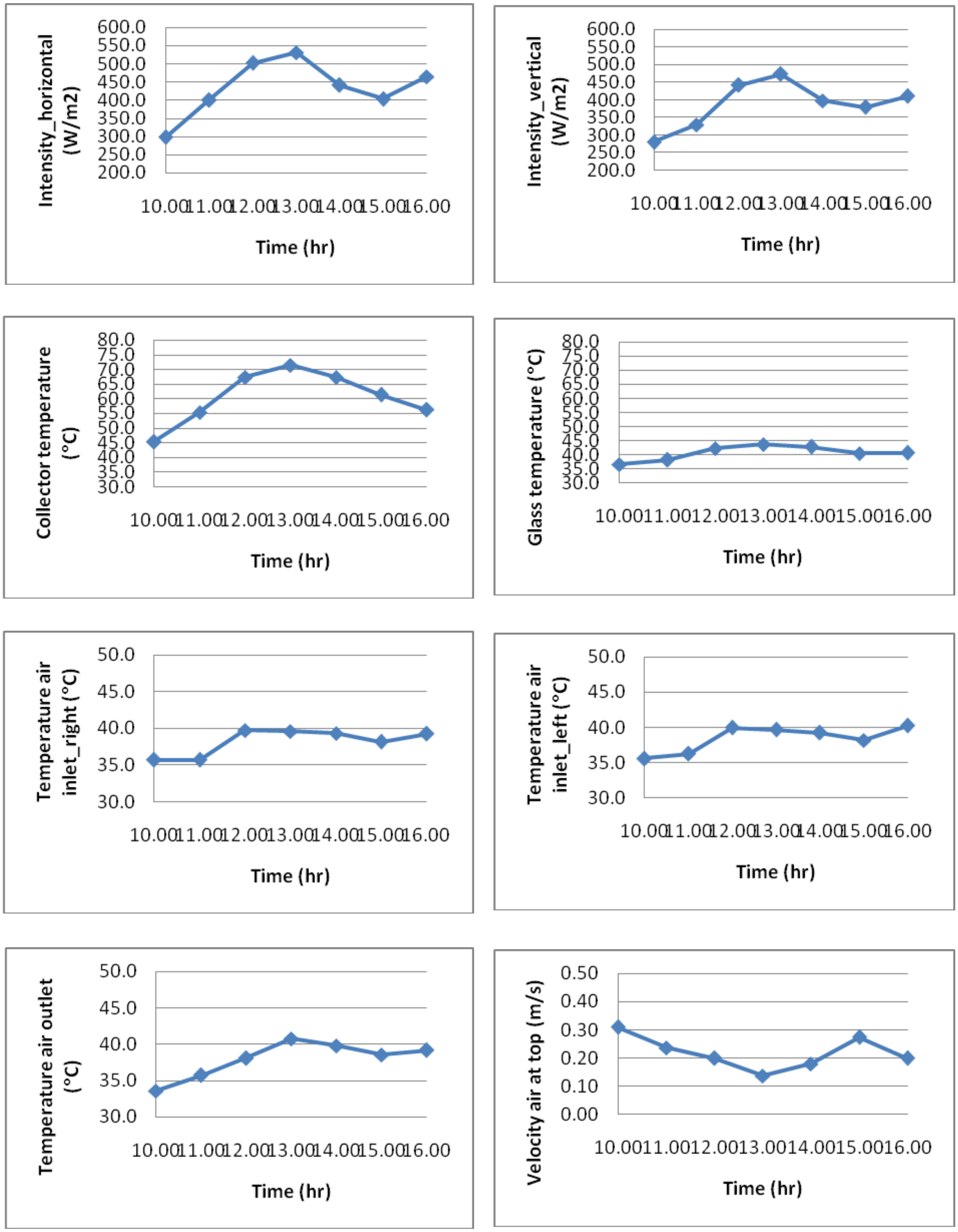








Graph of Configuration 4 (Average)



4.3.1.1 Analysis on inlet configuration

The data is about comparison on the temperature for each configuration. Generally, the graph is produced between temperatures vs. time. As mentioned, the data taken from location indicated at the inlet and the chimney's parts. Generally, the collector temperature is higher than glass temperature due to the material used is different. For this experiment, the collector is used due to property of zinc material which has high thermal energy. In addition, the surface of the zinc is covered with black surface in order to increase the efficiency to absorb heat produce by solar radiation. Glass is fabricated from Acrylic Perspex which property has less thermal energy but better insulation. Good insulation is useful to reduce percentage of heat loss at the roof top part.

The graphs consist of intensity (horizontal & vertical) vs. time; collector temperature vs. time; glass temperature vs. time, temperature air inlet (right & left) vs. time; temperature air outlet vs. time and velocity air outlet vs. time.

Based on the graph of intensity (horizontal & vertical) vs temperature, the data ranges are between 250°C and 500°C.

Based on the graph of collector temperature vs time, the data ranges are between 30°C and 70°C. Average collector temperature is around 58°C.

Based on the graph of glass temperature vs time, the data ranges are between 30°C and 45°C. Average glass temperature is 40°C.

Based on the graph of temperature air inlet (right & left) vs time, the data ranges are between 30°C and 45°C. Average temperature air inlet (right & left) is 40°C.

Based on the graph of temperature air outlet vs time, the data ranges are between 30°C and 45°C. Average temperature air outlet is 40°C.

Based on the graph of velocity air outlet vs time, the data ranges are between 0.1m/s and 0.5m/s. Average velocity air outlet is 0.3m/s.

4.3.2 The Chimney Performance

The chimney performance is defined based on the Continuity equation. The Continuity equation in physics is a differential equation that describes the transport of some kind of conserved quantity. Since mass, energy, momentum, electric charge and other natural quantities are conserved; a vast variety of physics may be described with the continuity equations. [1]

Continuity equations are the stronger local form of conservation laws. All the examples of continuity equations below express the same idea, which is roughly that: the total amount (of the conserved quantity) inside any region can only change by the amount that passes in or out of the region through the boundary. A conserved quantity cannot increase or decrease, it can only move from place to place. [2]

Based on the Continuity equation:

$\dot{m}\ \Delta T = \rho VA\ (T_{air,\ out} - T_{amb.})$ ………………………….. (1)

Solve for ρ:

$PV = mRT_{air,\ out}$

$P\gamma\ = RT_{air,\ out}$

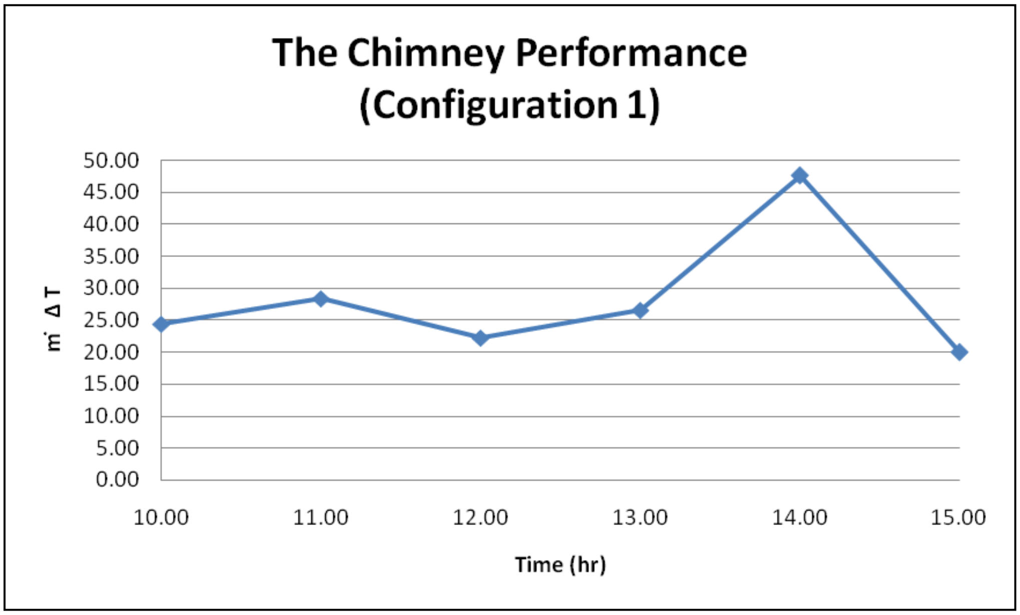
$P*\frac{1}{\rho} = RT_{air,\ out}$

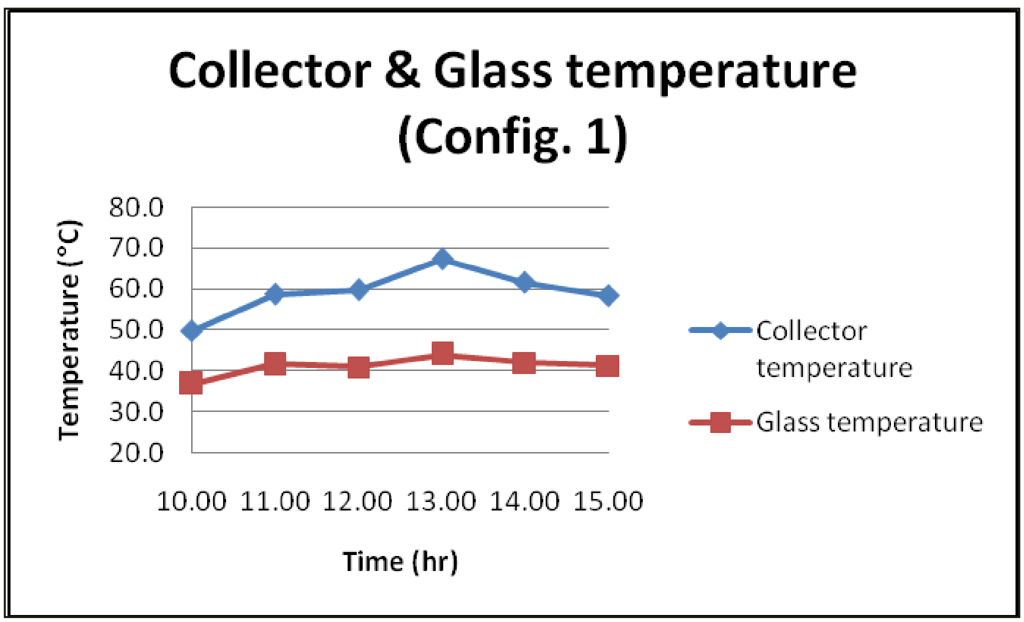
$\rho = \frac{P}{RT_{air,out}}$ …………………………………………..… (2)

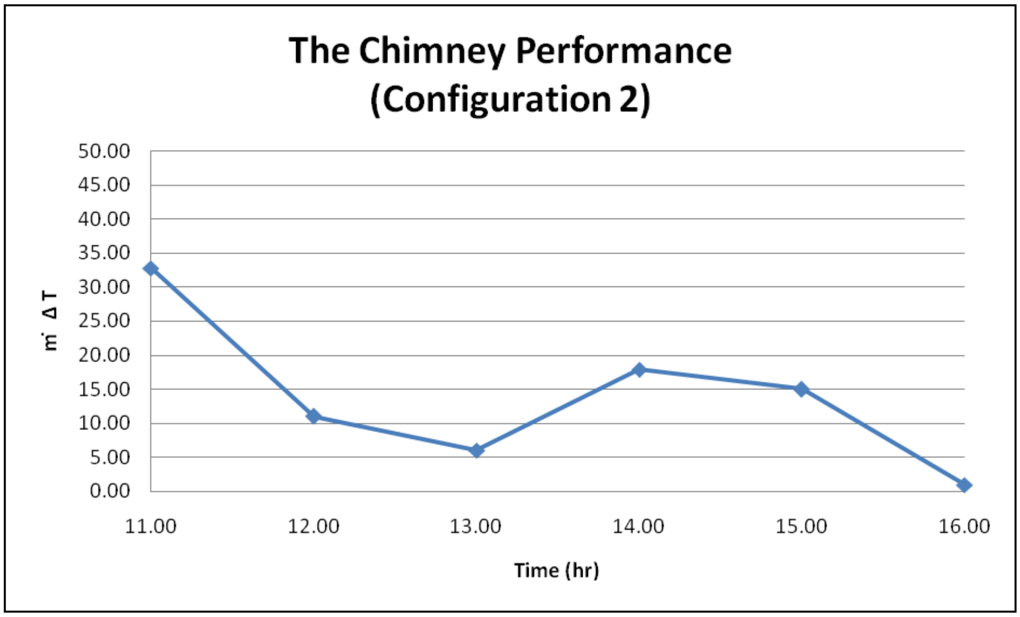
(2) into (1)

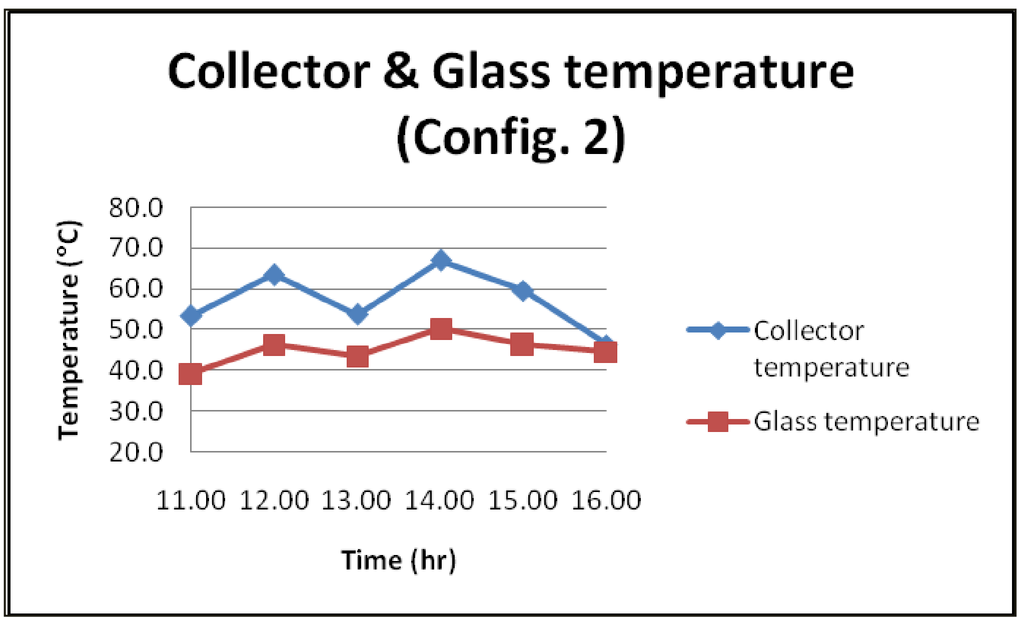
$\dot{m}\ \Delta T = \frac{P}{RT_{air,out}} VA\ (T_{air,\ out} - T_{amb.})$ ………………….. (3)

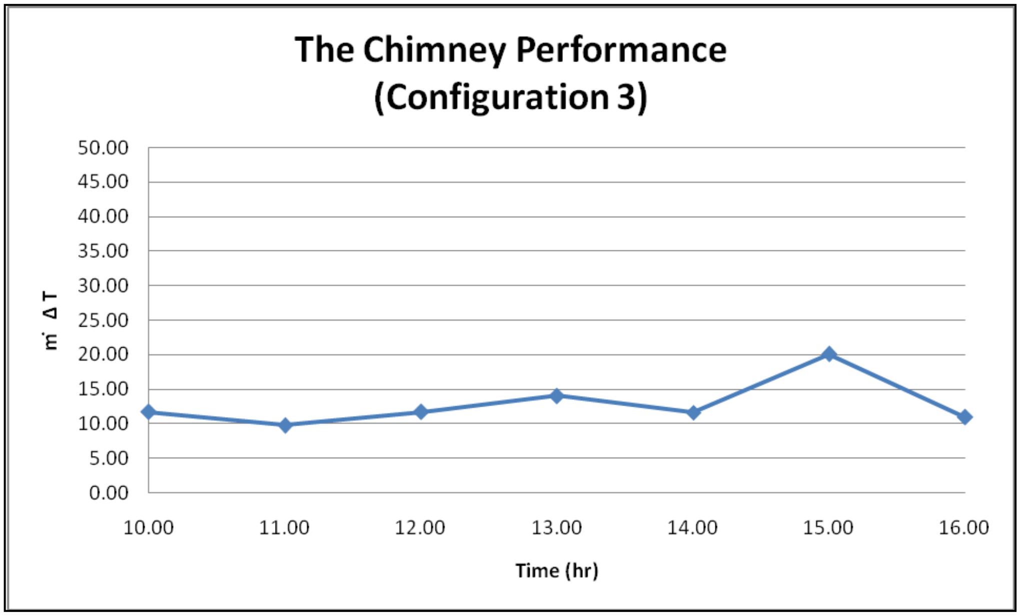
Calculation for the Chimney performance has calculated based on equation (3). From experiment, the data in term of air velocity (V); cross sectional area (A); ambient temperature and air outlet temperature have been considered. The detail of the calculation represent in the table of average for chimney performance stated in the appendices. Follows are the chimney performance's graph for those four configurations:


The Chimney Performance
(Configuration 1)
m ΔT
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
10.00
11.00
12.00
13.00
14.00
15.00
Time (hr)

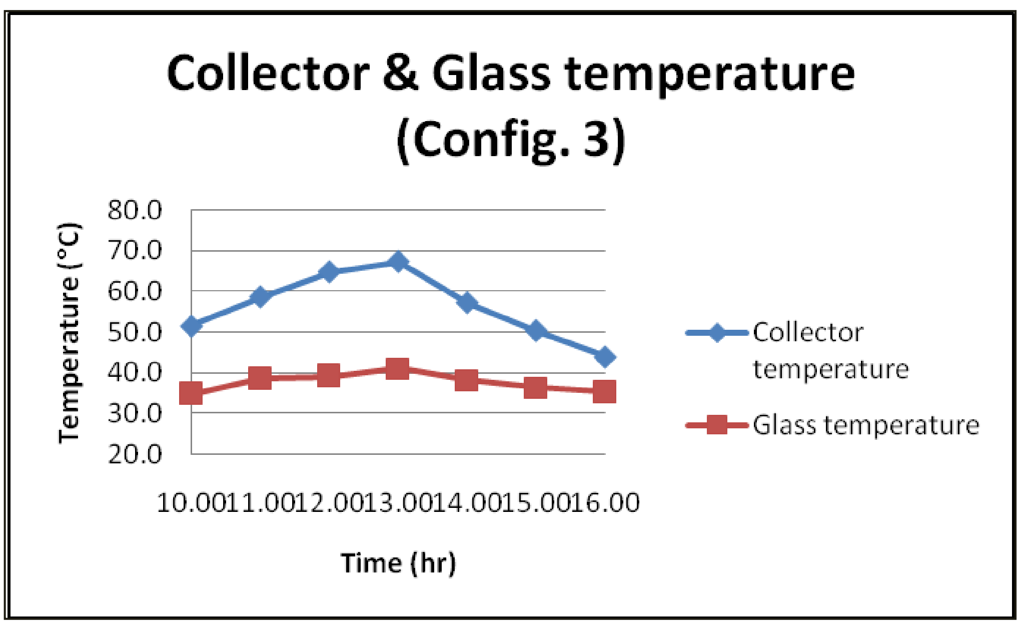

Collector & Glass temperature
(Config. 1)
Temperature (°C)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.00 11.00 12.00 13.00 14.00 15.00
Time (hr)
Collector temperature
Glass temperature


The Chimney Performance
(Configuration 2)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
m ΔT
11.00
12.00
13.00
14.00
15.00
16.00
Time (hr)

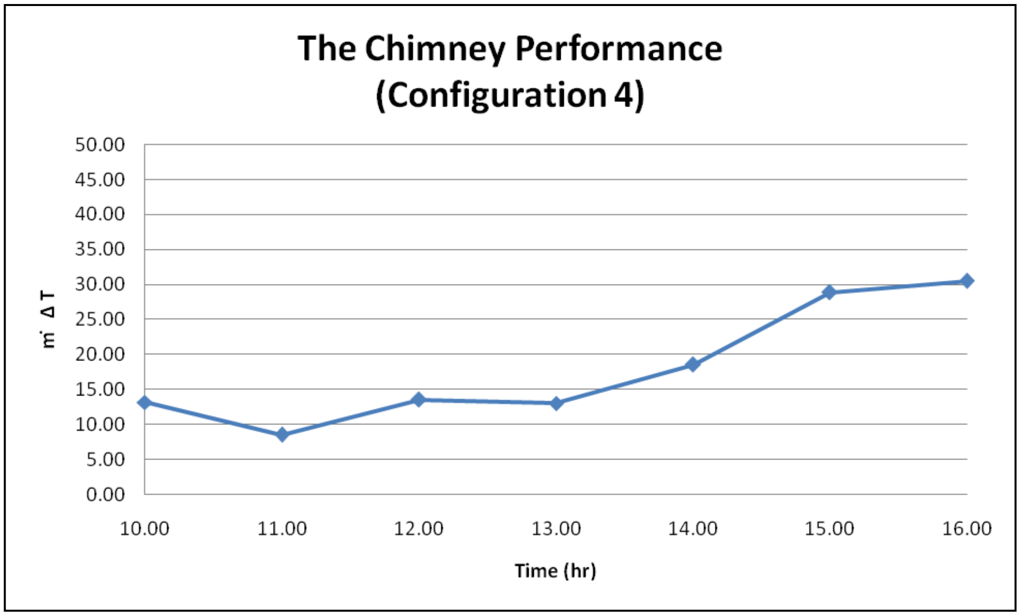

Collector & Glass temperature
(Config. 2)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
Temperature (°C)
11.00 12.00 13.00 14.00 15.00 16.00
Time (hr)
Collector temperature
Glass temperature

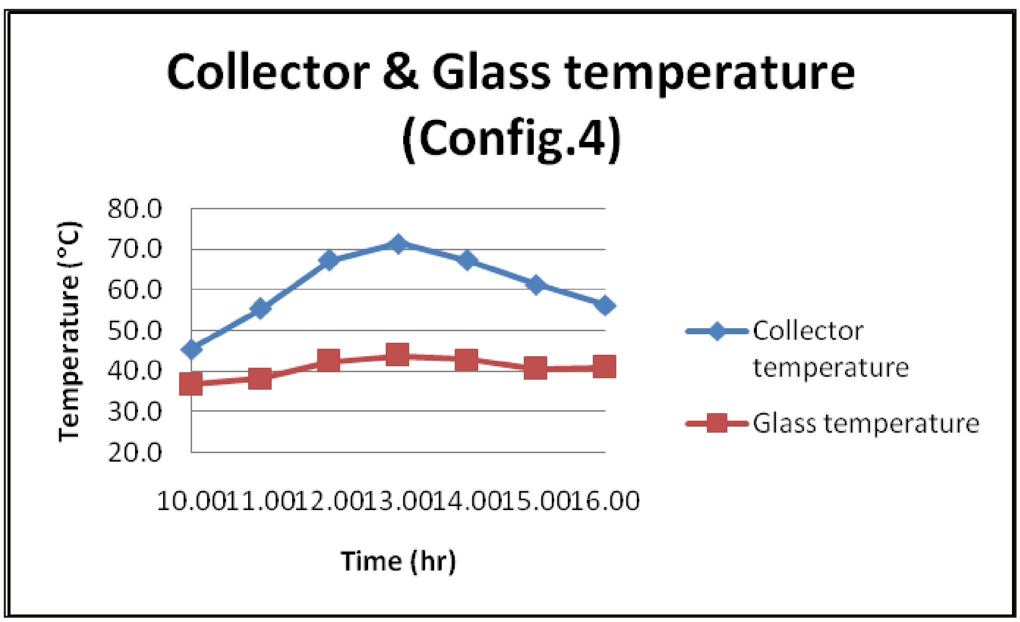


The Chimney Performance
(Configuration 3)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
m ΔT
10.00
11.00
12.00
13.00
14.00
15.00
16.00
Time (hr)



Collector & Glass temperature
(Config. 3)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
Temperature (°C)
10.0011.0012.0013.0014.0015.0016.00
Time (hr)
Collector temperature
Glass temperature


The Chimney Performance
(Configuration 4)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
m ΔT
10.00
11.00
12.00
13.00
14.00
15.00
16.00
Time (hr)


Collector & Glass temperature
(Config.4)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
Temperature (°C)
10.0011.0012.0013.0014.0015.0016.00
Time (hr)
Collector temperature
Glass temperature

4.3.2.1 Analysis on the Chimney Performance

The performance of chimney is defined by the temperature different between the temperature of the collector and the glass for each hours of experiment. The high difference in temperature created by the sun on a collector will cause a current of air in a passage which strong enough to rotate wind turbine. As mentioned, increasing the air flow along the passage represents increasing of temperature different. Increasing the air flow along the passage indicate better air flow. The better air flow represents good air velocity in the passage. Based on the chimney performance's graphs, the average temperature different is calculated to define the highest percentage different for overall RTSC's performance.

The following table shows the temperature different for each configuration:

Table 4: Temperature different for Configuration 1

Time (hr)	**Temperature different (Collector – Glass) (°C)**	**Temperature different (∆T) (°C)**
10.00	50.0-35.0	15.0
11.00	50.0-42.0	18.0
12.00	60.0-40.0	20.0
13.00	68.0-44.0	24.0
14.00	62.0-40.0	22.0
15.00	58.0-39.0	19.0
TOTAL		**118.0**
AVERAGE		**118.0/6 = 19.66**

Table 5: Temperature different for Configuration 2

Time (hr)	Temperature different (Collector – Glass) (°C)	Temperature different (ΔT) (°C)
11.00	54.0-40.0	14.0
12.00	64.0-46.0	18.0
13.00	54.0-45.0	9.0
14.00	65.0-50.0	15.0
15.00	60.0-46.0	14.0
16.00	46.0-45.0	1.0
TOTAL		**71.0**
AVERAGE		**71.0/6 = 11.83**

Table 6: Temperature different for Configuration 3

Time (hr)	Temperature different (Collector – Glass) (°C)	Temperature different (ΔT) (°C)
10.00	51.0-35.0	16.0
11.00	59.0-39.0	20.0
12.00	65.0-39.0	26.0
13.00	67.0-40.0	27.0
14.00	57.0-39.0	18.0
15.00	50.0-37.0	13.0
16.00	44.0-35.0	9.0
TOTAL		**129.0**
AVERAGE		**129.0/7 = 18.43**

Table 7: Temperature different for Configuration 4

Time (hr)	Temperature different (Collector – Glass) (°C)	Temperature different (∆T) (°C)
10.00	45.0-36.0	9.0
11.00	55.0-39.0	16.0
12.00	68.0-43.0	25.0
13.00	70.0-44.0	26.0
14.00	67.0-44.0	23.0
15.00	61.0-40.0	21.0
16.00	56.0-40.0	16.0
TOTAL		**136.0**
AVERAGE		**136.0/7 = 19.43**

It stated that the Configuration 1 is the best performance because the percentage different with 19.66% between the collector and glass temperature is the highest. Then, referred to the Equation (3) - Modified Continuity Equation, the ambient temperature at the top chimney, the ambient temperature and the temperature air outlet are high. Referred to the temperature vs. time's graph, we can define that the collector temperature and glass temperature are increasing. It shows the consistent increasing and stable condition.

The least preferred configuration is the Configuration 2 since its fewer values in term of the temperature air outlet. The temperature different between the collector and glass temperature indicate the changes around 12% as mentioned in the table 5. This configuration is the recent design used in the solar chimney model. None improvement in term of Chimney performance indicate along the graph. As we can see, the collector temperature and the glass temperature are not consistent along the experiment workdays. There are some greater increasing at the beginning and steep slope after the hour at the temperature vs. time's graph. It shows unstable graph with inconsistency data.

For the Configuration 3, the collector temperature is increase at the first four hours of experiment and keeps decreasing at the last three hours of experiment. The glass temperature show constant values along the experiment. For the first four hours of experiment, the chimney performance is very good with around 25% temperature different however for the last three hours of experiment, the chimney performance decrease until 10%. Overall percentage different is calculated around 18% as mentioned in the table 6.

For the Configuration 4, the temperature different between the collector and glass is stated around 15%. The first four hours of experiment show very good response with 25% temperature different between the collector and glass. However, the last three hours of experiment clearly effect toward declining until the last hour of experiment. Final outcome for the temperature different between the collector and glass is around 19% as mentioned in the table 7.

As conclusion, the best inlet configurations to provide the highest air flow rate by ranking are the Configuration 1, Configuration 4, Configuration 3 and lastly the Configuration 2. The following table summarizes each configuration:

Table 8: Configuration ranking by experimental analysis

Ranking	**Details**	**Percentage different (%)**
1	Configuration 1	**19.66**
4	Configuration 2	**11.83**
3	Configuration 3	**18.43**
2	Configuration 4	**19.43**

CHAPTER 5
SIMULATION PROCEDURE & RESULTS

5.1 Simulation Procedure

The simulation has been conducted via the engineering soft wares called GAMBIT 2.2.30 and FLUENT 6.3.26. As mentioned in the methodology, those simulation soft wares are important in the engineering problem's solution. A CFD simulation is applied as a method of analysis. Simulation is useful to validate data obtained from the experimental part. Simulation analysis is use to clarify the data obtained from experiment by comparing the results based on the best air flow in the inlet configuration by ranking. The data required for the FLUENT simulation are in term of the Static Temperature and Magnitude Velocity graphs. Those graphs will need to compare with the graph analysis obtained from the experimental part.

5.1.1 Model by GAMBIT

For the simulation part, the model is designed by using GAMBIT 2.2.30 for those four configurations. This software is provided with the advanced geometry and meshing tools. The following are the functions of GAMBIT:

- To design the 2 dimensional (2D) model of four configurations
- To setup the boundary condition for each edge and faces of configurations
- To provide the meshing analysis for each configuration

Design model is conducted with the real dimension in order to simulate with the real design. Setup the boundary condition is to define the situation occur at the surface condition in term of friction, static or moving part for each configuration. Meanwhile, defining the meshing is vital in order to discrete each part to certain section for more accuracy FLUENT's analysis. It is important to define model, meshing, and boundary condition before runs into FLUENT. The figure for the GAMBIT analysis is attached in the Appendices for references.

5.1.2 Simulation with FLUENT

After completed the model by using GAMBIT, the simulation proceed with the CFD analysis via FLUENT. This software is the CFD advanced solver technology with accurate results. The following are the functions of FLUENT:

- To obtain data in term of Static Temperature and Velocity Magnitude for each configuration
- To model the contour of Static Temperature and Velocity Magnitude for each configuration
- To verify the velocity contour, velocity contour mesh, and velocity vector for each configuration
- To verify data obtained from the experimental results

Each configuration will focus on the inlet and outlet for each configuration. Inlet part is located at the inlet design. There are four inlet configurations that need to simulate. Meanwhile, outlet part is located at the outlet design in the chimney area. Parameters required for simulation are the temperature and velocity. As mentioned, the relationship between temperature and velocity will performed better air flow in the passage. The data in term of Static Temperature and Velocity Magnitude are useful to define the result for parameters of temperature and velocity at inlet and outlet parts. To represent those results, it is necessary to produce graph in term of the velocity contour, velocity mesh, and velocity vector for each configuration. It is important to verify data obtained from the experimental results and produced the best air flow for inlet configurations by ranking. The ranking analysis will be compared with the experimental part. FYP is considered successful if the result from simulation similar with the experimental part.

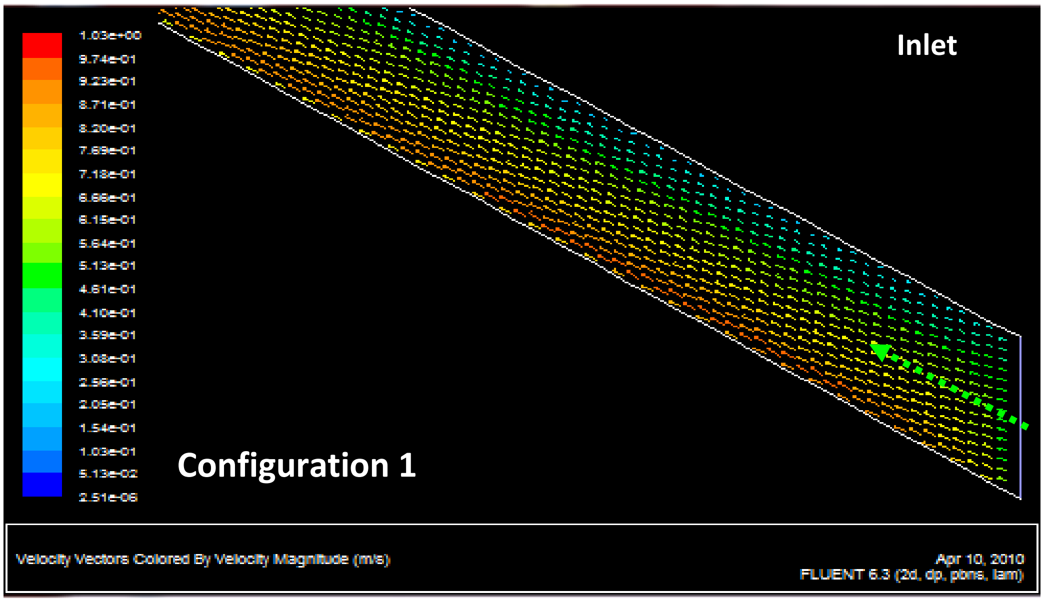


Figure 11: Simulation for inlet of Configuration 1

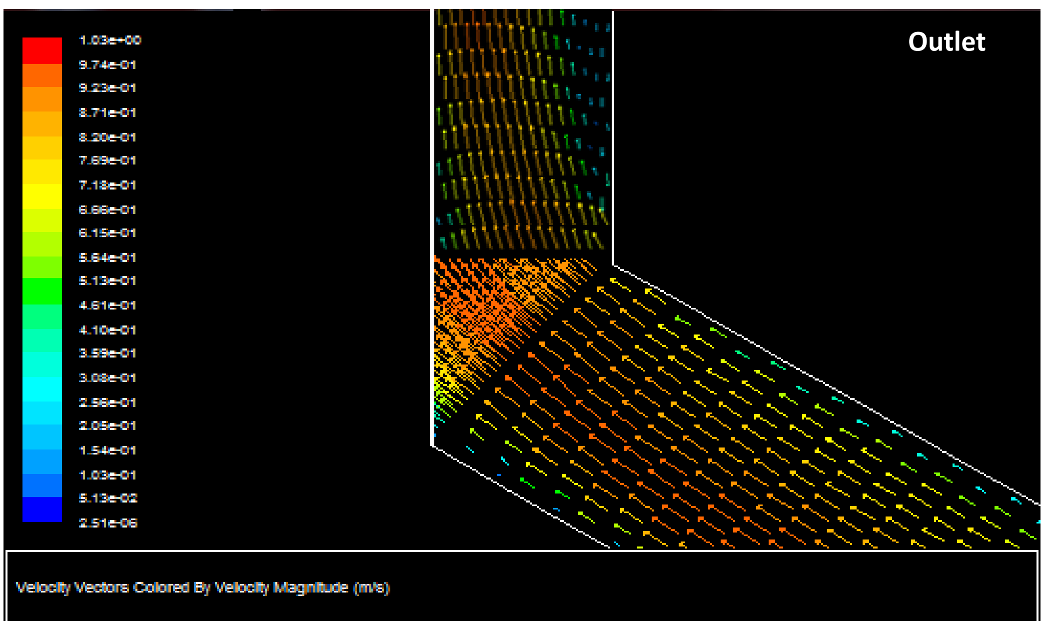


Figure 12: Simulation for outlet of Configuration 1

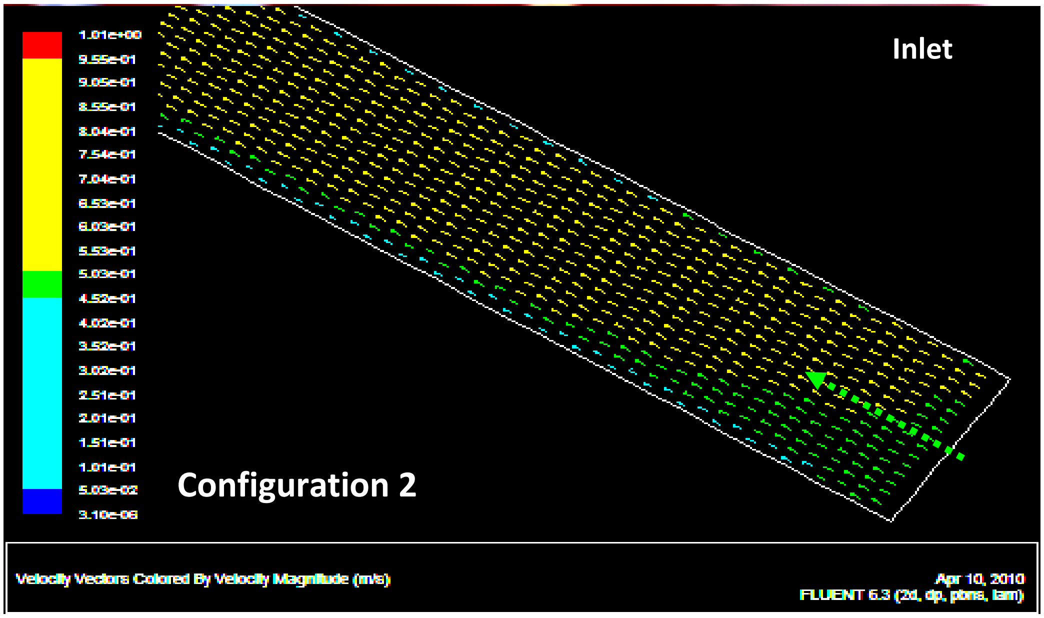


Figure 13: Simulation for inlet of Configuration 2

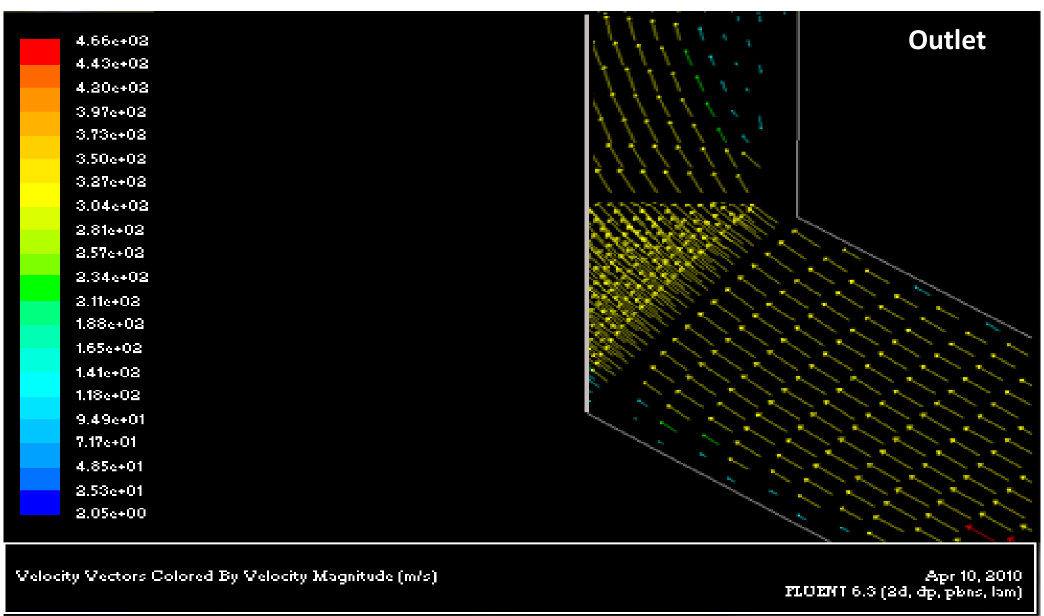


Figure 14: Simulation for outlet of Configuration 2

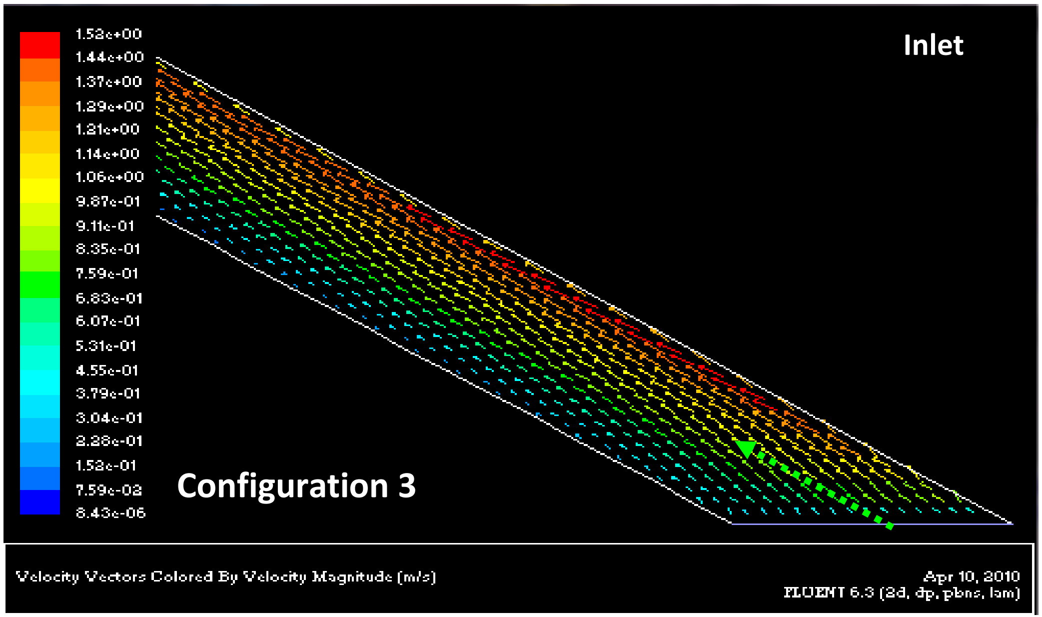


Figure 15: Simulation for inlet of Configuration 3

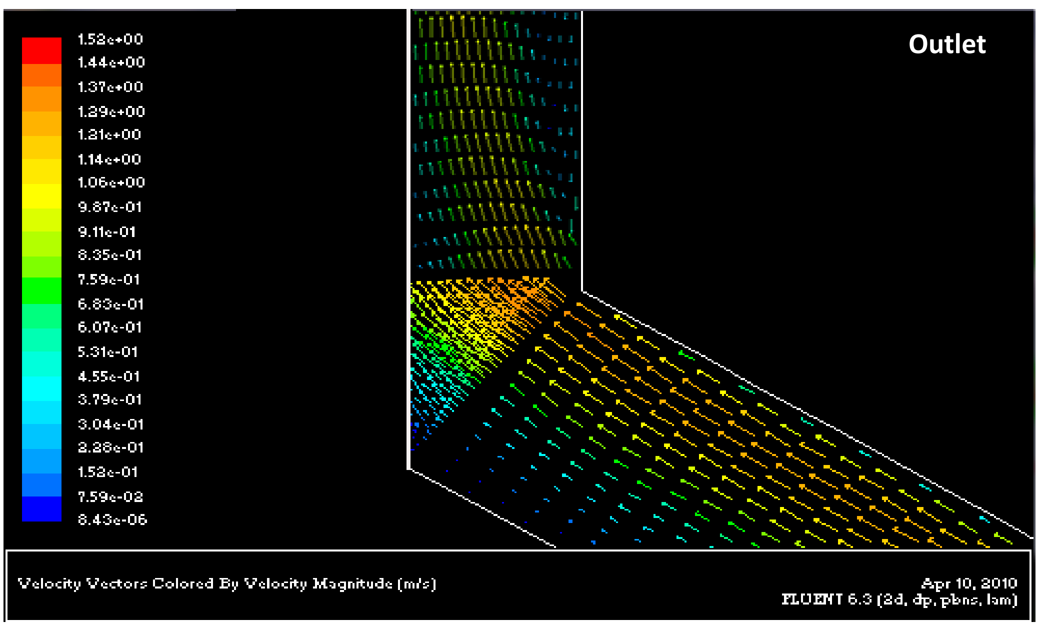


Figure 16: Simulation for outlet of Configuration 3

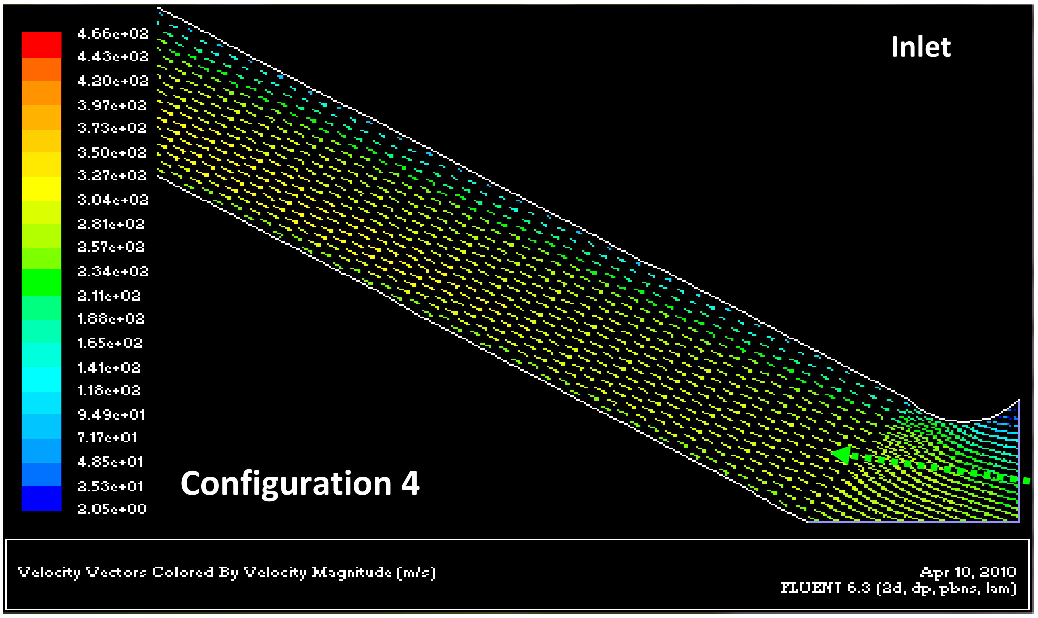


Figure 17: Simulation for inlet of Configuration 4

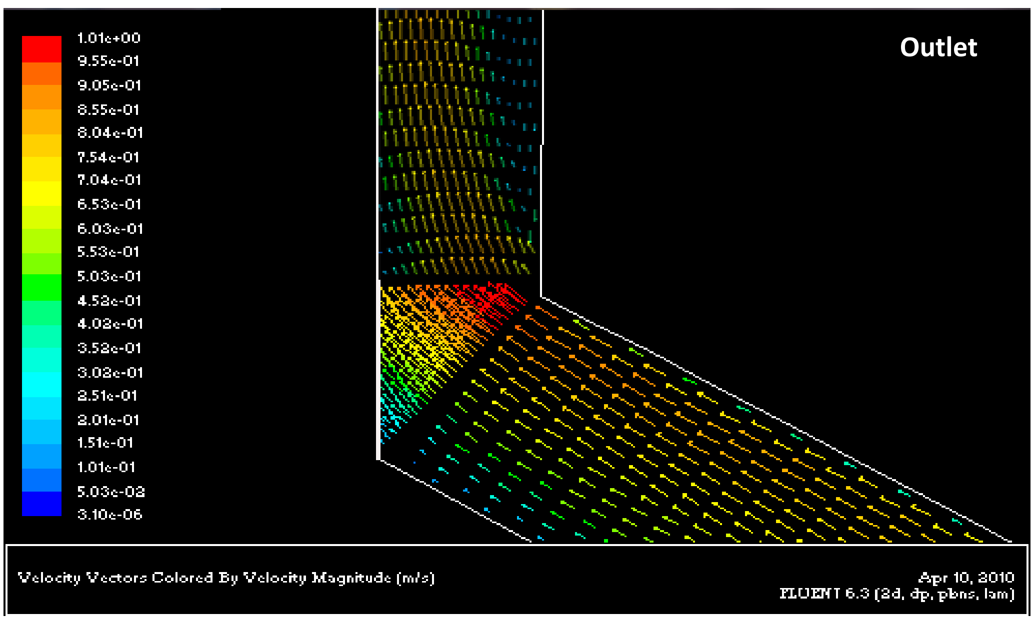


Figure 18: Simulation for outlet of Configuration 4

5.2 Analysis on simulation results

Based on the graph Velocity Magnitude vs. Position, the characteristic of air velocity can be defined from the position along the passage between the collector and glass. It is useful to understand the air velocity to define the variation of speed at certain position.

For Configuration 1, the range of velocity magnitude at the inlet is between 0.564m/s and 1.03m/s. At the outlet, the range is between 0.513m/s until 1.03m/s. The Configuration 1 is the best configuration since the outlet velocity is high. The range between yellow until red indicate at the side bar is placed at the top level.

For Configuration 2, the range of velocity magnitude at the inlet is between 0.503m/s until 0.603m/s. At the outlet, the range of velocity magnitude at the outlet is between 0.211m/s until 0.34m/s. The Configuration 2 is the least preferred because the outlet velocity is not high. The range between dark blue until dark yellow indicate at the side bar is located at the bottom level.

For Configuration 3, the range of velocity magnitude at the inlet is between 0.512 until 1.52m/s. At the outlet, the range of velocity magnitude is between 0.223m/s until 0.663m/s. The Configuration 3 is not preferred because the outlet velocity is not high. The side bar shows the range between dark blue until light yellow which at the bottom level.

For Configuration 4, the range of velocity magnitude at the inlet is between 0.66m/s until 1.03m/s. At the outlet velocity, the range of velocity magnitude is between 0.663m/s until 0.987m/s. The Configuration 4 is good because the outlet velocity is high compare with Configuration 2 and 3. The side bar shows the range between dark green until dark yellow is located at the upper level.

As conclusion, , the best inlet configuration to provide the highest air flow rate by ranking are the Configuration 1, Configuration 4, Configuration 3 and lastly the Configuration 2. The following table summarizes each configuration:

Table 9: Configuration ranking by simulation analysis

Ranking	Details	Range of velocity (m/s)	
		Inlet	Outlet
1	Configuration 1	0.564 - 1.03	0.513 - 1.03
4	Configuration 2	0.503 - 0.603	0.211 - 0.34
3	Configuration 3	0.512 - 1.52	0.223 - 0.663
2	Configuration 4	0.660 - 1.03	0.663 - 0.987

CHAPTER 6
CONCLUSION & RECOMMENDATION

6.1 Conclusion

The solar roof chimney is a slightly modified version of the solar chimney power plants. Experimental modeling of the system is very important to obtain the vital data that can be interpreted into characteristics of the flow. There are attempted to analyze four inlet configurations in order to define the best inlet configurations which increase the performance of RTSC. The data obtained from experimental analysis indicate that the potential utilizing of the solar system can be effective in providing power for home usage. Simulation analysis is conducted to predict the air velocity and temperature along the configuration. Those results from experimental and simulation will be analyzed and compared. By experimental and simulation analysis, the best air flow in the inlet configuration is the Configuration 1, 4, 3 and lastly 2 by ranking. FYP analysis is considered successful and achieved objectives. Overall, more improvement can be done to further increase the efficiency of the system.

6.2 Recommendation:

Throughout the whole semester working on FYP, more improvement can be done to further increase the efficiency of the RTSC. Follow are some suggestions for FYP:

1. CFD Simulation of the flow between the canopy and the collector in 3D

- Since the flow of the simulation is free natural convection, this requires a solid knowledge of the usage of FLUENT because the free natural convection is very difficult to simulate. 3D analysis is better in term of accuracy and verification result.
- Further analysis in term of change some parameters can be conduct to predict effect to the prototype.

2. Analysis and experimental studies on the inlet shape (roof configurations):

- It is important to take into consideration the inlet shape in order to analyze the performance of the solar chimney system.
- As mentioned, the four inlet configurations give various result of the chimney performance. What happens if the inlet shape varies? These are the basic question for FYP2 analysis.

3. Conduct research on wind turbine design to generate electricity

- FYP is not covered the design of wind turbine, need to consider for the power generation system
- What type of wind turbine, the specification and the dimension is suitable for Solar Chimney?

REFERENCES

The reference for the respective sources is as follows:

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APPENDICES

Data Experiment: Configuration 1 (Day 1)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature ˚C	Collector temperature ˚C						
				1	2	3	7	8	9	Mean
10.00	147.0	183.0	27.3	53.1	49.7	48.2	32.4	34.7	34.8	42.2
11.00	319.0	325.0	30.6	73.0	56.4	64.9	39.8	41.1	37.7	52.2
12.00	313.0	280.0	30.7	65.6	58.5	60.4	42.5	44.4	42.5	52.3
13.00	476.0	465.0	38.8	91.6	87.3	90.5	55.7	56.4	55.4	72.8
14.00	428.0	389.0	37.1	80.6	79.4	79.3	47.8	51.9	47.7	64.5
15.00	461.0	434.0	39.3	81.6	77.4	75.2	43.2	49.7	49.2	62.7

Glass temperature ˚C							Temperature air inlet (right) ˚C			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
37.4	33.7	36.5	29.1	28.3	32.8	33.0	34.8	35.1	35.5	35.1
41.9	40.5	45.3	33.2	32.8	41.1	39.1	35.4	35.1	35.8	35.4
40.5	39.6	41.5	34.6	35.3	36.8	38.1	33.7	34.2	34.9	34.3
48.3	50.5	50.4	40.6	42.7	37.8	45.1	39.4	40.0	40.3	39.9
43.4	44.6	45.8	39.1	39.8	34.9	41.3	39.1	39.7	39.3	39.4
46.0	46.4	48.2	39.4	43.2	35.2	43.1	42.1	42.3	43.2	42.5

Temperature air inlet (left) ˚C				Temperature air outlet ˚C	Velocity air at top m/s
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
34.9	34.9	34.8	34.9	24.3	0.33
35.4	35.8	36.2	35.8	35.1	0.13
35.5	35.7	36.1	35.8	37.1	0.18
40.3	40.2	40.3	40.3	44.3	0.01
37.6	37.6	37.5	37.6	45.1	0.21
42.1	41.7	41.4	41.7	41.5	0.20

Configuration 1	
Date	14/1/2010
Day	1
Duration	6 hours

Data Experiment: Configuration 1 (Day 2)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
10.00	316.0	337.0	38.3	70.1	69.9	65.2	38.5	35.3	36.0	52.5
11.00	382.0	410.0	33.8	76.3	77.6	73.4	46.3	43.6	45.8	60.5
12.00	473.0	460.0	35.0	92.0	87.9	79.8	51.0	47.6	51.7	68.3
13.00	488.0	471.0	35.3	75.9	74.3	69.4	41.1	43.2	49.2	58.9
14.00	417.0	398.0	34.3	88.5	80.2	73.9	48.6	49.0	51.5	65.3
15.00	366.0	342.0	36.3	86.2	77.1	70.3	47.1	43.5	48.4	62.1
16.00	376.0	383.0	37.4	84.0	76.5	70.4	49.6	47.7	51.3	63.3

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
42.9	45.5	41.7	33.9	36.8	42.1	40.5	37.8	37.5	38.1	37.8
43.0	47.6	43.5	36.9	39.9	46.9	42.9	35.8	36.1	36.7	36.2
49.0	52.7	43.3	38.6	41.0	35.2	43.3	37.9	38.5	39.4	38.6
46.2	49.9	41.6	38.9	41.9	35.8	42.4	33.9	34.2	34.5	34.2
48.4	50.9	42.5	38.2	40.6	35.5	42.7	45.9	45.8	46.0	45.9
45.6	48.2	41.4	40.3	38.9	36.6	41.8	48.9	49.0	49.1	49.0
45.6	47.2	40.2	41.8	36.9	39.4	41.9	37.9	38.1	39.1	38.4

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
35.9	36.1	36.3	36.1	48.9	0.10
36.8	36.8	37.0	36.9	41.2	0.20
39.0	39.2	39.8	39.3	38.9	0.08
35.6	36.0	36.2	35.9	40.2	0.03
45.0	45.6	45.1	45.2	39.8	0.16
43.7	43.6	43.8	43.7	40.5	0.12
38.9	38.8	38.7	38.8	38.1	0.11

Configuration 1	
Date	18/1/2010
Day	2
Duration	7 hours

Data Experiment: Configuration 1 (Day 3)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature ˚C	Collector temperature ˚C						
				1	2	3	7	8	9	Mean
11.00	193	138	29.8	30.2	30.2	29.8	30.6	30.2	29.5	30.1
12.00	290	225	31.9	53.5	51.6	50.1	56.6	55.1	41.4	51.4
13.00	317	290	32.1	57.1	58.1	59.4	56.1	53.8	47.9	45.9
14.00	450	423	34.6	79.1	72.2	75.7	64.3	60.1	48.4	66.6
15.00	430	399	33.5	68.3	68.0	64.7	55.4	53.4	53.3	60.5
16.00	288	270	30.4	43.2	43.0	42.1	42.9	41.0	36.5	41.5

Glass temperature ˚C							Temperature air inlet (right) ˚C			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
37.4	33.7	36.5	29.1	28.3	32.8	33.0	34.8	35.1	35.5	35.1
41.9	40.5	45.3	33.2	32.8	41.1	39.1	35.4	35.1	35.8	35.4
40.5	39.6	41.5	34.6	35.3	36.8	38.1	33.7	34.2	34.9	34.3
48.3	50.5	50.4	40.6	42.7	37.8	45.1	39.4	40.0	40.3	39.9
43.4	44.6	45.8	39.1	39.8	34.9	41.3	39.1	39.7	39.3	39.4
46.0	46.4	48.2	39.4	43.2	35.2	43.1	42.1	42.3	43.2	42.5

Temperature air inlet (left) ˚C				Temperature air outlet ˚C	Velocity air at top m/s
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
34.9	34.9	34.8	34.9	24.3	0.33
35.4	35.8	36.2	35.8	35.1	0.13
35.5	35.7	36.1	35.8	37.1	0.18
40.3	40.2	40.3	40.3	44.3	0.01
37.6	37.6	37.5	37.6	45.1	0.21
42.1	41.7	41.4	41.7	41.5	0.20

Configuration 1	
Date	19/1/2010
Day	3
Duration	6 hours

Data Experiment: Configuration 2 (Day 1)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
11.00	438.0	432.0	31.6	83.0	74.3	74.7	40.9	44.0	45.6	60.4
12.00	459.0	441.0	32.6	79.1	74.3	80.0	48.0	56.6	55.6	65.6
13.00	493.0	460.0	37.8	83.9	81.7	80.6	42.9	55.5	52.2	66.1
14.00	479.0	442.7	37.2	84.9	83.5	76.4	49.5	53.7	57.2	67.5
15.00	430.0	401.0	35.5	63.2	61.0	56.4	39.2	40.6	40.2	50.1
16.00	239.0	295.0	34.2	56.6	61.5	60.0	44.6	43.1	42.9	46.5

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
52.8	43.3	51.8	38.5	37.9	32.5	42.8	32.8	32.7	32.6	32.7
56.4	46.1	54.5	41.3	40.7	33.2	45.4	36.6	36.5	36.4	36.5
51.8	42.7	51.9	36.2	39.4	33.7	42.6	36.0	35.9	35.7	35.9
53.3	42.8	50.7	39.1	44.1	35.3	44.3	35.9	35.3	35.0	35.4
46.6	39.6	45.4	36.4	35.5	33.9	39.6	37.5	37.2	37.0	37.2
39.9	40.2	43.5	41.6	35.3	34.5	46.5	34.1	33.9	33.8	33.9

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
34.7	36.0	35.8	35.5	39.3	0.37
35.9	36.0	36.2	36.0	35.0	0.08
35.4	35.5	35.7	35.5	35.9	0.11
36.0	36.3	36.4	36.2	36.3	0.19
36.9	36.6	36.6	36.7	35.3	0.18
34.1	34.0	34.1	34.1	30.0	0.06

Configuration 2	
Date	07/12/2010
Day	1
Duration	6 hours

Data Experiment: Configuration 2 (Day 2)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
10.00	326.0	348.0	29.4	75.3	73.8	78.8	38.2	37.9	43.1	57.9
11.00	406.0	395.0	32.6	80.6	70.9	85.5	54.4	57.6	60.1	69.4
12.00	490.0	462.0	33.5	85.9	85.7	87.1	59.5	61.9	60.9	73.5
13.00	93.7	92.1	32.9	54.9	49.4	53.2	44.4	45.9	45.6	48.9
14.00	482.0	474.0	35.2	89.4	79.0	84.2	47.5	47.8	53.7	66.9
15.00	440.0	437.0	35.1	87.3	81.0	81.3	53.7	54.0	52.2	68.3
16.00	380.0	367.0	34.0	72.2	70.1	70.1	56.9	53.8	54.7	51.3

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
49.2	47.1	51.2	34.8	35.9	36.8	42.5	32.6	32.6	33.5	32.9
50.9	51.4	53.3	40.9	42.0	38.1	46.1	33.9	34.2	34.6	34.2
58.0	56.2	57.2	43.3	44.0	41.9	50.1	36.6	36.4	37.1	36.7
40.9	40.4	41.3	36.6	36.7	36.4	38.7	32.8	33.0	33.2	33.0
52.5	52.5	54.2	37.5	41.5	37.8	46.0	36.6	36.9	37.2	36.9
49.0	52.5	54.6	45.9	43.1	40.7	47.6	36.7	36.8	37.0	36.8
49.4	52.1	53.1	47.9	46.5	45.7	49.1	36.2	36.3	36.4	36.3

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
32.9	32.9	32.9	32.9	33.8	0.08
34.7	35.2	35.7	35.2	34.8	0.20
36.3	36.7	36.9	36.6	37.1	0.07
33.1	33.1	33.1	33.1	33.5	0.26
36.2	36.3	36.3	36.3	37.6	0.18
36.9	37.1	37.1	37.1	37.9	0.23
36.3	36.3	36.3	36.3	36.6	0.19

Configuration 2	
Date	10/12/2010
Day	2
Duration	6 hours

Data Experiment: Configuration 2 (Day 3)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
11.00	193	138	29.8	30.2	30.2	29.8	30.6	30.2	29.5	30.1
12.00	290	225	31.9	53.5	51.6	50.1	56.6	55.1	41.4	51.4
13.00	317	290	32.1	57.1	58.1	59.4	56.1	53.8	47.9	45.9
14.00	450	423	34.6	79.1	72.2	75.7	64.3	60.1	48.4	66.6
15.00	430	399	33.5	68.3	68.0	64.7	55.4	53.4	53.3	60.5
16.00	288	270	30.4	43.2	43.0	42.1	42.9	41.0	36.5	41.5

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
28.9	28.5	28.7	28.2	28.8	28.2	28.6	31.1	33.3	30.0	31.1
43.5	49.5	45.5	43.2	37.1	43.9	43.7	35.7	35.6	35.5	35.6
50.2	51.5	50.7	48.2	46.0	48.4	49.2	42.0	42.0	42.0	42.0
64.7	69.3	65.9	55.9	53.9	55.0	60.8	44.1	44.2	44.1	44.1
54.6	56.1	54.0	48.5	47.6	49.0	51.6	43.3	42.8	41.9	42.7
39.6	40.4	38.9	35.4	36.2	37.2	38.0	33.9	33.7	32.8	33.5

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
29.9	29.7	29.8	29.8	31.9	0.18
31.8	31.5	31.7	31.7	33.3	0.26
39.9	39.9	39.9	39.9	35.8	0.33
41.9	41.9	41.9	41.9	40.4	0.32
40.7	40.9	41.2	40.9	37.5	0.21
32.3	32.3	32.3	32.3	32.8	0.16

Configuration 2	
Date	16/02/2010
Day	3
Duration	6 hours

Data Experiment: Configuration 3 (Day 1)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
10.00	285.0	226.0	31.8	58.6	60.0	62.6	39.0	40.4	42.9	50.6
11.00	358.0	361.0	34.1	83.9	81.9	84.7	49.3	52.7	52.3	67.5
12.00	454.0	460.0	34.3	88.9	88.3	89.8	51.5	59.3	64.4	73.7
13.00	433.0	453.0	36.3	78.8	79.0	80.6	56.3	54.7	59.1	68.1
14.00	275.0	225.0	32.3	57.7	59.6	61.9	43.7	46.3	49.5	53.1
15.00	282.0	315.0	34.8	60.3	61.6	64.1	45.4	48.3	54.3	55.7
16.00	177.4	180.0	32.5	59.4	59.0	58.9	43.8	33.3	41.1	49.3

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
35.0	38.5	35.4	32.7	35.2	32.1	34.8	31.5	31.8	32.1	31.8
45.2	53.5	44.7	38.8	42.4	32.6	42.9	37.1	37.2	37.5	37.3
42.9	54.4	44.8	38.5	41.0	32.3	42.3	34.2	34.6	35.2	34.7
43.2	51.9	42.6	40.8	44.4	36.2	43.2	37.3	37.5	37.9	37.6
37.5	43.7	39.8	36.4	37.8	32.8	38.0	33.8	34.1	34.7	34.2
38.4	43.4	41.5	36.9	39.2	33.1	38.8	35.8	36.2	36.5	36.2
36.0	40.3	38.5	34.4	33.9	32.5	35.9	33.6	33.7	33.9	33.7

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
32.2	32.3	32.0	32.2	33.8	0.23
38.2	38.3	37.9	38.1	37.8	0.08
35.6	36.2	36.6	36.1	37.5	0.18
37.7	38.0	38.2	37.9	39.2	0.05
35.2	35.4	35.6	35.4	35.6	0.14
36.4	36.8	37.0	36.7	36.1	0.15
34.0	33.9	34.1	34.0	34.7	0.21

Configuration 3	
Date	20/01/2010
Day	1
Duration	7 hours

Data Experiment: Configuration 3 (Day 2)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
10.00	222.0	219.0	29.8	66.9	61.5	55.9	41.3	43.9	43.4	52.2
11.00	110.0	85.0	29.6	48.2	45.6	42.4	41.2	40.6	38.9	42.8
12.00	178.0	152.0	31.1	56.7	55.2	49.5	44.4	44.5	44.4	49.1
13.00	419.0	350.0	33.9	78.1	74.0	66.2	56.6	60.5	62.5	66.3
14.00	123.0	110.0	31.6	53.4	50.3	46.6	43.6	42.9	41.4	46.4
15.00	125.0	96.0	32.5	48.9	47.2	43.7	41.1	42.0	41.8	44.1
16.00	89.4	66.1	31.2	42.2	41.1	39.4	38.3	40.9	41.9	40.6

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
37.9	36.2	37.6	31.2	34.4	31.1	34.7	30.6	30.9	31.3	30.9
32.2	33.1	33.3	32.3	33.0	30.1	32.3	29.8	30.1	30.3	30.1
35.0	34.8	34.5	33.7	35.6	31.0	34.1	30.3	30.8	31.7	30.9
41.2	40.9	41.9	39.8	41.9	33.0	39.8	34.4	34.3	34.7	34.5
35.3	36.7	36.9	34.2	35.1	32.1	35.1	32.3	32.0	32.6	32.3
34.3	35.1	34.9	34.0	34.6	32.0	34.2	32.8	32.8	32.9	32.8
31.6	32.3	32.5	32.6	33.5	30.7	32.3	31.4	31.6	31.7	31.6

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
31.5	31.7	31.6	31.6	32.7	0.17
30.1	30.3	30.2	30.2	31.5	0.23
32.3	32.5	32.4	32.4	32.9	0.20
35.7	35.9	36.4	36.0	38.5	0.15
32.4	32.5	32.5	32.5	33.2	0.23
32.9	33.1	33.0	33.0	33.1	0.49
31.9	32.2	32.2	32.1	32.4	0.19

Configuration 3	
Date	21/01/2010
Day	2
Duration	7 hours

Data Experiment: Configuration 3 (Day 3)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
10.00	252.0	250.0	30.2	65.3	60.7	54.9	40.5	44.0	43.9	51.6
11.00	397.0	401.0	36.8	83.0	82.6	76.1	48.1	50.0	51.0	65.1
12.00	465.0	448.0	37.0	96.9	91.3	78.3	50.9	53.5	56.9	71.3
13.00	497.0	483.0	32.2	85.4	78.1	68.5	50.0	59.3	61.4	67.2
14.00	499.0	501.0	38.0	96.0	80.3	77.6	57.0	57.0	61.8	71.6
15.00	346.0	377.0	33.3	61.3	58.0	53.4	47.5	42.3	43.8	51.1
16.00	425.0	411.0	34.5	72.0	72.8	63.4	47.5	41.6	41.6	41.6

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
38.0	36.0	36.9	31.2	33.3	30.9	34.4	30.3	30.5	31.3	30.7
45.5	41.0	42.1	38.3	39.0	34.1	40.0	39.7	40.1	40.5	40.1
46.6	43.3	43.5	38.9	39.6	33.2	40.9	38.5	39.0	39.5	39.0
44.4	42.0	42.8	36.8	41.4	33.3	40.2	38.0	39.1	38.9	38.7
47.5	44.6	44.5	36.2	40.9	33.7	41.2	34.9	34.9	35.0	34.9
36.3	36.5	37.0	37.0	37.4	32.7	36.2	33.7	33.9	34.0	33.9
38.1	38.5	39.2	36.2	34.8	36.5	37.2	35.8	35.9	36.3	36.0

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
31.4	31.6	31.5	31.5	31.7	0.11
39.7	40.5	40.6	40.3	37.1	0.14
40.3	40.4	40.3	40.3	39.0	0.08
39.8	40.4	40.3	40.2	35.3	0.16
34.3	34.2	34.1	34.2	39.4	0.15
35.0	35.1	35.2	35.1	35.5	0.67
37.2	37.1	37.2	37.2	35.8	0.24

Configuration 3	
Date	22/01/2010
Day	3
Duration	7 hours

Data Experiment: Configuration 4 (Day 1)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
10.00	285.0	286.0	31.3	53.2	48.8	49.8	38.7	34.8	36.0	43.6
11.00	317.0	260.0	32.5	56.3	51.7	54.4	46.0	45.6	43.0	49.5
12.00	341.0	301.0	34.2	68.0	59.1	56.4	52.8	49.0	47.3	55.4
13.00	387.0	339.0	34.1	74.6	65.3	63.9	53.9	49.0	48.4	59.2
14.00	201.0	156.0	33.3	57.2	49.2	49.6	53.4	51.1	45.0	50.9
15.00	144.0	129.0	30.2	54.0	52.7	54.2	49.9	48.6	41.5	50.2
16.00	412.0	393.0	34.5	54.9	48.5	51.4	53.4	48.5	50.7	51.2

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
39.1	38.4	34.4	30.3	31.3	30.4	34.0	37.8	37.8	37.9	37.8
40.6	40.0	36.2	33.6	34.5	34.3	36.5	34.2	34.4	34.6	34.4
43.4	42.4	39.7	37.5	39.7	39.1	40.3	36.0	36.2	36.7	36.3
44.7	46.7	42.2	38.5	40.7	38.9	41.5	36.3	36.9	37.3	36.8
39.2	41.1	38.2	37.3	40.2	38.5	39.1	35.5	36.1	36.0	35.9
38.5	40.5	38.9	36.2	38.7	37.3	38.4	35.0	35.3	35.3	35.2
38.3	44.1	40.0	42.7	38.5	40.1	40.6	38.3	38.4	38.6	38.4

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
37.5	37.3	37.3	37.4	33.7	0.24
34.7	34.7	34.6	34.7	34.1	0.26
36.4	36.5	36.4	36.4	36.0	0.29
36.7	36.8	36.9	36.8	38.0	0.12
36.9	37.0	37.0	37.0	37.9	0.17
35.8	35.7	35.5	35.7	35.3	0.28
39.1	39.3	39.5	39.3	40.1	0.16

Configuration 4	
Date	13/02/2010
Day	1
Duration	7 hours

Data Experiment: Configuration 4 (Day 2)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
10.00	312.0	280.0	33.1	60.8	52.2	47.8	39.3	33.2	33.6	44.5
11.00	395.0	303.0	36.7	70.2	69.9	64.3	54.4	49.6	47.3	59.3
12.00	557.0	488.0	36.5	82.2	77.9	81.0	56.7	55.2	51.3	67.4
13.00	594.0	537.0	39.6	93.4	93.7	88.2	68.0	66.1	59.4	78.1
14.00	584.0	540.0	40.9	94.6	95.0	82.9	65.4	65.3	59.8	77.2
15.00	556.0	524.0	40.6	85.5	83.4	74.6	51.2	57.6	56.1	64.7
16.00	491.0	419.0	35.0	73.2	64.5	61.7	57.4	55.8	54.7	61.2

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
41.7	38.8	33.0	28.4	32.0	31.3	39.9	35.1	35.4	35.9	35.5
38.8	42.8	41.7	38.8	37.0	37.7	39.5	37.3	37.3	37.4	37.3
49.6	49.9	48.8	36.8	39.3	39.4	44.0	40.1	41.4	42.6	41.4
50.1	51.9	52.0	38.7	43.3	43.3	46.6	40.7	41.3	41.6	41.2
50.6	54.3	47.2	39.3	45.7	45.1	47.0	45.5	45.9	46.2	45.9
46.0	47.4	43.8	39.2	42.6	42.1	43.5	42.9	43.2	43.8	43.3
45.3	46.4	41.1	36.1	38.3	39.8	41.2	37.1	37.6	38.1	37.6

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
36.1	36.1	35.6	35.9	33.9	0.24
37.6	37.7	37.9	37.7	37.3	0.28
40.1	40.6	41.4	40.7	39.1	0.16
41.1	41.3	42.4	41.6	42.7	0.23
44.0	44.1	43.9	44.0	43.9	0.18
42.9	42.7	42.5	42.7	42.0	0.31
38.1	38.3	38.6	38.3	37.1	0.14

Configuration 4	
Date	14/02/2010
Day	2
Duration	7 hours

Data Experiment: Configuration 4 (Day 3)

Time	Intensity (horizontal) W/m²	Intensity (vertical) W/m²	Ambient temperature °C	Collector temperature						
				1	2	3	7	8	9	Mean
10.00	298.0	276.0	32.6	61.2	57.3	47.5	41.4	41.6	39.4	48.1
11.00	490.0	427.0	34.6	72.8	65.0	56.7	51.5	50.6	46.6	57.2
12.00	606.0	537.0	37.3	96.4	91.0	91.0	68.3	64.2	63.2	79.0
13.00	610.0	544.0	40.0	95.2	90.0	81.8	68.4	58.6	67.1	76.9
14.00	539.0	498.0	35.7	90.0	88.5	86.5	64.8	58.4	54.6	73.8
15.00	510.0	486.0	34.9	81.5	81.9	69.1	67.3	59.4	55.0	69.0
16.00	490.0	419.0	33.9	68.2	69.2	57.9	50.2	48.5	42.1	56.0

Glass temperature							Temperature air inlet (right)			
4	5	6	10	11	12	Mean	T_{i1}	T_{i2}	T_{i3}	Mean
39.3	37.4	38.4	29.5	37.2	33.6	35.9	33.6	33.8	34.2	33.9
42.5	42.9	39.5	31.7	38.2	36.7	38.6	35.2	35.4	35.7	35.4
44.7	47.4	47.3	33.1	45.3	38.5	42.7	40.8	41.5	42.2	41.5
46.5	47.1	46.1	34.9	43.2	39.8	42.9	40.2	40.8	41.2	40.7
48.4	47.4	40.7	35.2	42.3	39.5	42.3	36.2	36.1	36.6	36.3
37.7	45.2	40.1	37.0	39.0	39.7	39.8	35.7	35.9	36.1	35.9
38.7	45.5	41.7	36.2	41.1	39.7	40.5	41.2	41.9	42.0	41.7

Temperature air inlet (left)				Temperature air outlet	Velocity air at top
T_{i4}	T_{i5}	T_{i6}	Mean	T_o	V_0
33.6	33.5	33.3	33.5	33.2	0.45
36.2	36.4	36.6	36.4	35.8	0.17
42.7	42.7	42.8	42.7	39.2	0.15
40.7	40.5	40.6	40.6	41.6	0.06
36.6	36.8	36.6	36.7	37.5	0.19
36.1	36.2	36.2	36.2	38.3	0.23
43.1	43.0	42.9	43.0	40.4	0.30

Configuration 4	
Date	15/02/2010
Day	3
Duration	7 hours

Configuration 1: The Chimney Performance

Time	Intensity (Mean) W/m²	Ambient temperature ˚C	Collector temperature ˚C	Glass temperature ˚C	Temperature air outlet ˚C	Velocity air at top m/s
			Mean	Mean	T_o	V_0
10.00	288.3	32.0	49.7	36.9	34.4	0.31
11.00	386.0	32.4	58.7	41.6	38.6	0.14
12.00	420.2	34.5	59.9	41.0	40.2	0.12
13.00	482.5	37.4	67.3	43.9	42.9	0.15
14.00	434.8	36.1	61.5	42.1	42.8	0.22
15.00	423.2	35.6	58.3	41.3	40.0	0.14

Time	Density of Air kg/m³	Velocity air at top m/s	Cross sectional area of Solar Chimney	Ambient temperature	Temperature air outlet ˚C	$\dot{m}\ \Delta T$
		V_0	inch²	˚C	T_o	
10.00	1.157	0.31	28.278	32.0	34.4	24.349
11.00	1.156	0.14	28.278	32.4	38.6	28.370
12.00	1.148	0.12	28.278	34.5	40.2	22.203
13.00	1.137	0.15	28.278	37.4	42.9	26.530
14.00	1.142	0.22	28.278	36.1	42.8	47.600
15.00	1.144	0.14	28.278	35.6	40.0	19.925

Configuration 2: The Chimney Performance

Time	Intensity (Mean) W/m²	Ambient temperature ˚c	Collector temperature ˚c	Glass temperature ˚c	Temperature air outlet ˚c	Velocity air at top m/s
			Mean	Mean	T_o	V_0
11.00	333.6	31.3	53.3	39.2	35.3	0.25
12.00	394.5	32.7	63.5	46.4	35.1	0.14
13.00	416.0	34.3	53.6	43.5	35.1	0.23
14.00	455.1	35.7	67.0	50.4	38.1	0.23
15.00	422.8	34.7	59.6	46.3	36.9	0.21
16.00	306.5	32.9	46.4	44.5	33.1	0.14

Time	Density of Air kg/m³	Velocity air at top m/s	Cross sectional area of Solar Chimney	Ambient temperature	Temperature air outlet ˚C	ṁ ΔT
		V_0	inch²	˚C	T_o	
11.00	1.160	0.25	28.278	31.3	35.3	32.802
12.00	1.155	0.14	28.278	32.7	35.1	10.971
13.00	1.149	0.23	28.278	34.3	35.1	5.977
14.00	1.143	0.23	28.278	35.7	38.1	17.849
15.00	1.147	0.21	28.278	34.7	36.9	14.987
16.00	1.154	0.14	28.278	32.9	33.1	0.914

Configuration 3: The Chimney Performance

Time	Intensity (Mean) W/m²	Ambient temperature °c	Collector temperature °c	Glass temperature °c	Temperature air outlet °c	Velocity air at top m/s
			Mean	Mean	T_o	V_0
10.00	242.3	30.6	51.4	34.6	32.7	0.17
11.00	285.3	33.5	58.5	38.4	35.5	0.15
12.00	359.5	34.1	64.7	39.1	36.5	0.15
13.00	439.2	34.1	67.2	41.0	37.7	0.12
14.00	288.8	34.0	57.0	38.1	36.1	0.17
15.00	256.8	33.5	50.3	36.4	34.9	0.44
16.00	224.8	32.7	43.8	35.2	34.3	0.21

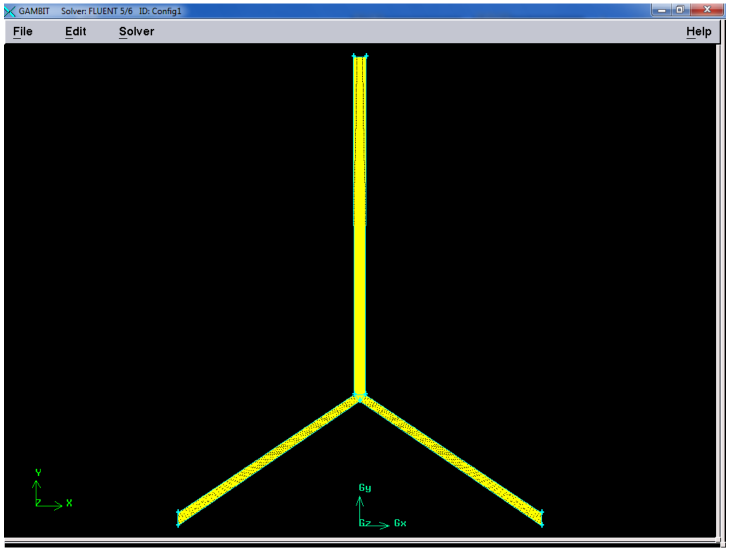
Time	Density of Air kg/m³	Velocity air at top m/s	Cross sectional area of Solar Chimney	Ambient temperature	Temperature air outlet °c	$\dot{m}\ \Delta T$
		V_0	inch²	°C	T_o	
10.00	1.163	0.17	28.278	30.6	32.7	11.737
11.00	1.152	0.15	28.278	33.5	35.5	9.770
12.00	1.149	0.15	28.278	34.1	36.5	11.701
13.00	1.149	0.12	28.278	34.1	37.7	14.041
14.00	1.150	0.17	28.278	34.0	36.1	11.607
15.00	1.152	0.44	28.278	33.5	34.9	20.061
16.00	1.155	0.21	28.278	32.7	34.3	10.971

Configuration 4: The Chimney Performance

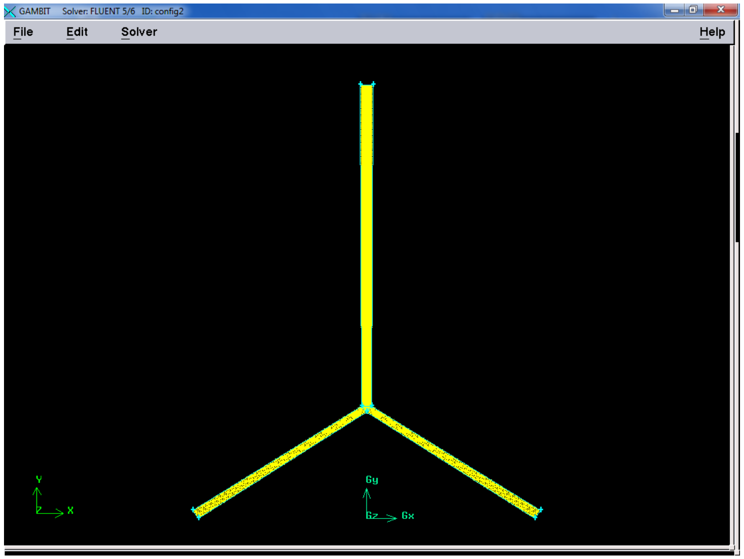
Time	Intensity (Mean) W/m²	Ambient temperature °c	Collector temperature °c	Glass temperature °c	Temperature air outlet °c	Velocity air at top m/s
			Mean	Mean	T_o	V_0
10.00	289.5	32.3	45.4	36.6	33.6	0.31
11.00	365.3	34.6	55.3	38.2	35.7	0.24
12.00	471.7	36.0	67.3	42.3	38.1	0.20
13.00	501.8	37.9	71.4	43.6	40.8	0.14
14.00	419.7	36.6	67.3	42.8	39.8	0.18
15.00	391.5	35.2	61.3	40.6	38.5	0.27
16.00	437.3	34.5	56.2	40.8	39.2	0.20

Time	Density of Air **kg/m³**	Velocity air at top **m/s**	Cross sectional area of Solar Chimney	Ambient temperature	Temperature air outlet °c	$\dot{m}$ Δ T
		V_0	**inch²**	**°C**	T_o	
10.00	1.156	0.31	28.278	32.3	33.6	13.176
11.00	1.148	0.24	28.278	34.6	35.7	8.567
12.00	1.142	0.20	28.278	36.0	38.1	13.567
13.00	1.135	0.14	28.278	37.9	40.8	13.035
14.00	1.140	0.18	28.278	36.6	39.8	18.571
15.00	1.145	0.27	28.278	35.2	38.5	28.857
16.00	1.148	0.20	28.278	34.5	39.2	30.513

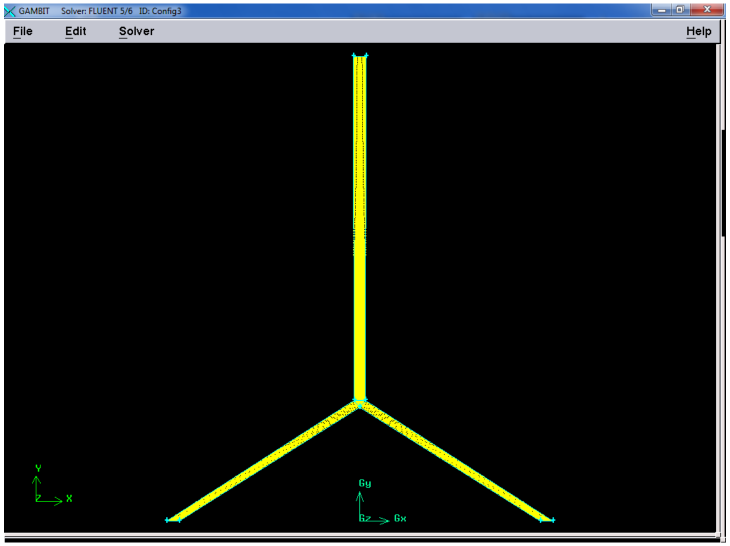
Sample of GAMBIT for each configuration:



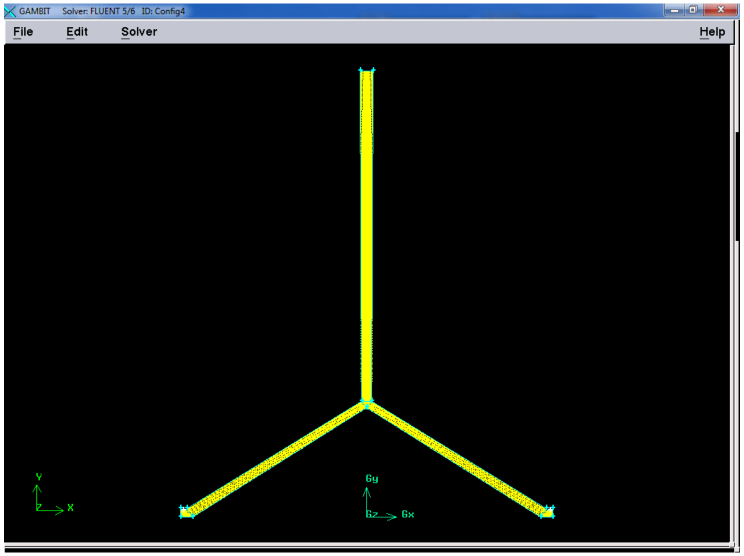
GAMBIT: Configuration 1



GAMBIT: Configuration 2



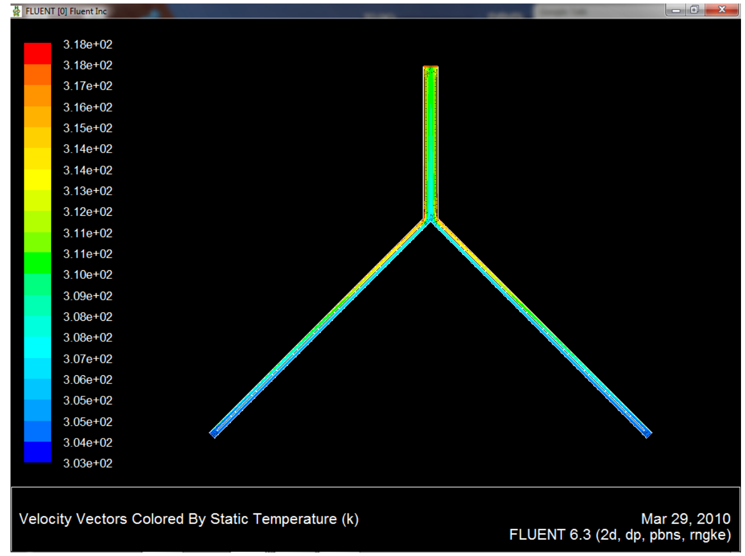
GAMBIT: Configuration 3



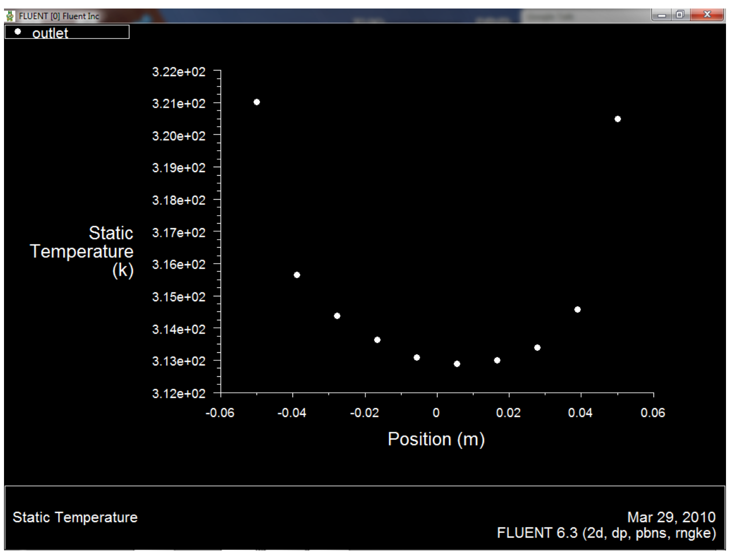
GAMBIT: Configuration 4

Sample of FLUENT for Configuration 2:

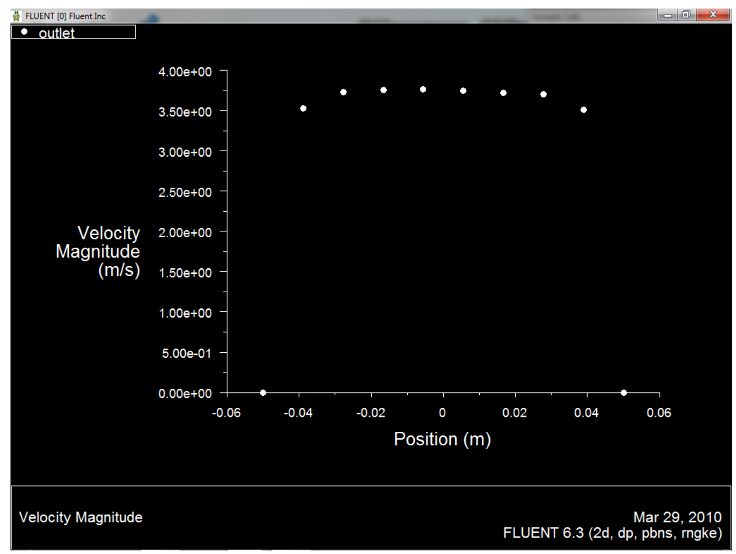
FLUENT: Configuration 2 for Velocity Magnitude



FLUENT: Configuration 2 for Static Temperature



FLUENT Configuration 2: Static Temperature vs. Position Graph



FLUENT Configuration 2: Velocity Magnitude vs. Position Graph