UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS◆

JUDUL: **EXPERIMENTAL STUDY HEAT TRANSFER OF NATURAL CONVECTION IN HORIZONTAL INTERNALLY FINNED TUBE**

SESI PENGAJIAN: 2009/2010

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FACULTY OF MECHANICAL ENGINEERING

We certify that the project entitled "***Experimental Study Heat Transfer of Natural Convection in Horizontal Internally Finned Tube***" is written by Mohd Waqiuddin Bin Nordin. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering *with Automotive Engineering.

AZIZUDDIN ABD AZIZ

(Name of panel member)

Examiner 24/11/09

Signature

EXPERIMENTAL STUDY OF HEAT TRANSFER NATURAL CONVECTION IN HORIZONTAL INTERNALLY FINNED TUBE

MOHD WAQIUDDIN BIN NORDIN

Thesis submitted in fulfilment of the requirements
For the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2009

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with specialization.

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STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Name : MOHD WAQIUDDIN BIN NORDIN

I.D Number : 870324055083

Date : 1 DECEMBER 2009.

DEDICATED TO MY BELOVED PARENTS, FAMILY AND FRIENDS.

THANK YOU FOR ALL YOUR SUPPORT, IDEAS AND COOPERATION.

ALL OF YOU ALWAYS IN MY HEART FOREVER

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ABSTRACT

A simplified model of the tube heat exchanger is used to experimentally study the thermal impact of using four internal fins fixed to the diameter inside tube heat exchanger. This model consists of a heated horizontal cylinder with a constant heat flux placed around the cylinder. The project also using the laminar air flow as the medium in the tube. Correlations for the averaged Nusselt number for different configuration are presented. These correlations relate the averaged Nusselt number with the variation of tube with fins and without fins (smooth), and different Raleigh numbers. The fins are used to increase the area inside the tube to relate with heat transfer area. It is found that, unlike expected, the value of Nu for horizontal cylinder under constant heat flux conditions varies with the variation of the heat flux. Also it is found that the value of Nu increases as the area inside cylinder increases. To be conclusive on this result a further experimentations are needed. The experimental result are expected to be very useful for the design of pipelines and heat exchanger tube for more efficient.

ABSTRAK

Satu model mudah untuk penukar ganti haba digunakan untuk menjalankan pembelajaran melalui experiment untuk mengetahui impak haba menggunakan empat sirip yg dilekatkan pada diameter dalam penukar ganti haba. Model ini menunjukkan pemanasan silinder secara melintang dengan fluks haba yang serata di sekeliling batang silinder. Projek ini menggunakan pengaliran udara secara lamina sebagai bahan di dalam tiub silinder. Perbandingan untuk setara nombor Nusselt untuk perbezaan bilangan sirip di ketengahkan. Perbandingan ini berkaitan dengan nombor Nusselt yang setara dengan variasi tiub dengan sirip, tiub tanpa sirip dan perbezaan nombor Nusselt. Sirip biasanya digunakan untuk meningkatkan luas permukaan didalam tiub yang berkaitan dengan luas permukaan pertukaran haba. Nilai nombor Nusselt meningkat apabila luas permukaan didalam silinder meningkat. Untuk membuktikan keputusan ini, beberapa lg experimen perlu dijalankan. Semua keputusan experimen ini dapat membantu untuk mereka bentuk sistem paip dan tiub penukar ganti haba yg lebih effektif.

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LIST OF SYMBOLS

Ra	Rayleigh Number
$\dot{Q}$	Rate of net heat transfer
L	Length of the specimen
A	Surface area inside the tube
h	Heat transfer coefficient
Nu	Nusselt Number
$°C$	Degree Celsius
o	Degree
D	Inner diameter in the tube
d	Diameter of the nozzle
A_x	Surface area without fins
A_f	Surface area with fins
υ	Kinematic viscosity
T_s	Temperature surface
T_∞	Ambient temperature
ΔT	Temperature Different
k	Thermal conductivity
Pr	Prandtl number

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Heat transfer is thermal energy in transit due to a temperature difference. The convection heat transfer mode is comprised of two mechanism, in which energy transfer due to random molecular motion (diffusion) and bulk, or macroscopic, motion of fluid. Technically, convection denotes the non-radiant heat exchange between a surface and a fluid flowing over it when the two are at different temperatures. Although heat flow by conduction also occurs in this process, the controlling feature is the energy transfers by flow of the fluid hence the name convection. Convection is one of the three basic methods of heat transfer, the other two being conduction and radiation. Natural convection is a mechanism of transport in which fluid motion is not generated by any external source but only by density differences in fluid occurring due to temperature gradients and buoyancy forces within the fluids. Buoyancy is due to the combined presence of a fluid density gradient and a body force that is proportional to density. The presence of gravitation or an equivalent force (arising from the equivalence principle, such as acceleration or centrifugal force or Coriolis forces) is essential for natural convection.

Finned tube has been used in many applications in the industries in the world especially in heat transfer process. Major application of finned tube occurs in the automotive, aerospace, petroleum, chemical and food processing industries. Nowadays, many of the researcher design a better solution for the cylindrical tube such added the internally finned to the tube. As a result, fins are employed to increase the heat transfer between the cylinders. So the internally finned tube has found extensive use in heat exchanger. Several of the study and researched have been conducted to investigate the effect of the fin characteristic on heat transfer. The internal fining tube was found to extend the effect of the natural convective and to support the enhancement of friction factors and Nusselt number compared to the smooth tubes. Some of the researcher conclude that the Nusselt number based on the inside diameter was higher than for the smooth tube without fins. They also found that the fins could reduce the cost and size of the tube to get the better efficiency of the heat exchanger. Efficient design of the heat exchanger equipment can improve the system performance considerably. Hence, this will lead to a better design of heat exchangers.

Due to the important of using finned tube, several study has consider the internal finned tube with different angle but it not classified. So the different position of the tube could effect the convection of the heat and the Nusselt number. Then to ensure the effect of the tube position, there will be different in horizontal position. The comparison could be with the smooth tube that is without internal fins. In the theory, the most effective tube is the larger surface area in the tube. So theoretically, the finned tube will transfer more heat than without fin tube. In this project, we run an experiment to justify the theory using natural convection for the heat transfer method and the tube without fins and with 4 internal fins. Then the position of the tube will be fixed in horizontal @ 180^0. The experiment used the electrical circuit as the heat supplier.

1.2 PROBLEM STATEMENT

Some of the industries have to expend their budget to perform the heat exchanger process. Using bigger diameter of the tube or use many of the tube in the process. There are some weaknesses in the past project in understanding the real ability of the internal finned tube compare to the smooth tube that is without the fins. The project result should briefly state that the better tube that can produce the better performance as heat exchanger. The same position and the same steady state should be the main characteristic. Then the Nusselt number should be the main objective to be compared. The heat should be continuously and should be the same for the both tubes. Then the better procedures must be following in order to get the prescient result.

1.3 OBJECTIVES OF THE PROJECT

In order to make the experiment run smoothly, the objective must be stated and need to be fulfilled. The main objective is to determine the effect of the horizontal tube with internal fins in heat transfer. This could be done with the variable of the fin exist in the tube. Then it must be completed with determine and differentiate using the Nusselt number.

1.4 SCOPES OF STUDY

In order to improve the performance of heat exchanger, many studies has been done about the heat exchanger. The scopes of this project can make the previous study as boundaries to fulfil the objective. Firstly, air has been selected as a medium through the tube to get the laminar flow. The tube is made from aluminium as among the material with high thermal conductivity. Then this study considers the position of the tube and the different length of the fins due to effect the heat transfer. The inner area inside the tube has been measured.

For the heat source, this project used AC power to supply the electricity around the tube to supply the heat around the tube. The electrical measurement also include in this project such ammeter and voltmeter to collect the data. Then, the thermocouple used as a sensor to measure the heat. This project also used some insulator to provide from heat loss and current waste. Furthermore, this study used Nusselt Number formula as the main formula to be more understanding and clearer. Assume the system runs in steady state condition, which room temperature at 30^0C.

1.5 FLOW CHART OF THE PROJECT

From the flow chart project in Figure 1.1 below, show the rough step to complete this project. This flow chart is to make sure the project runs smoothly. By following this step, the experiment can be done just in time and successfully.

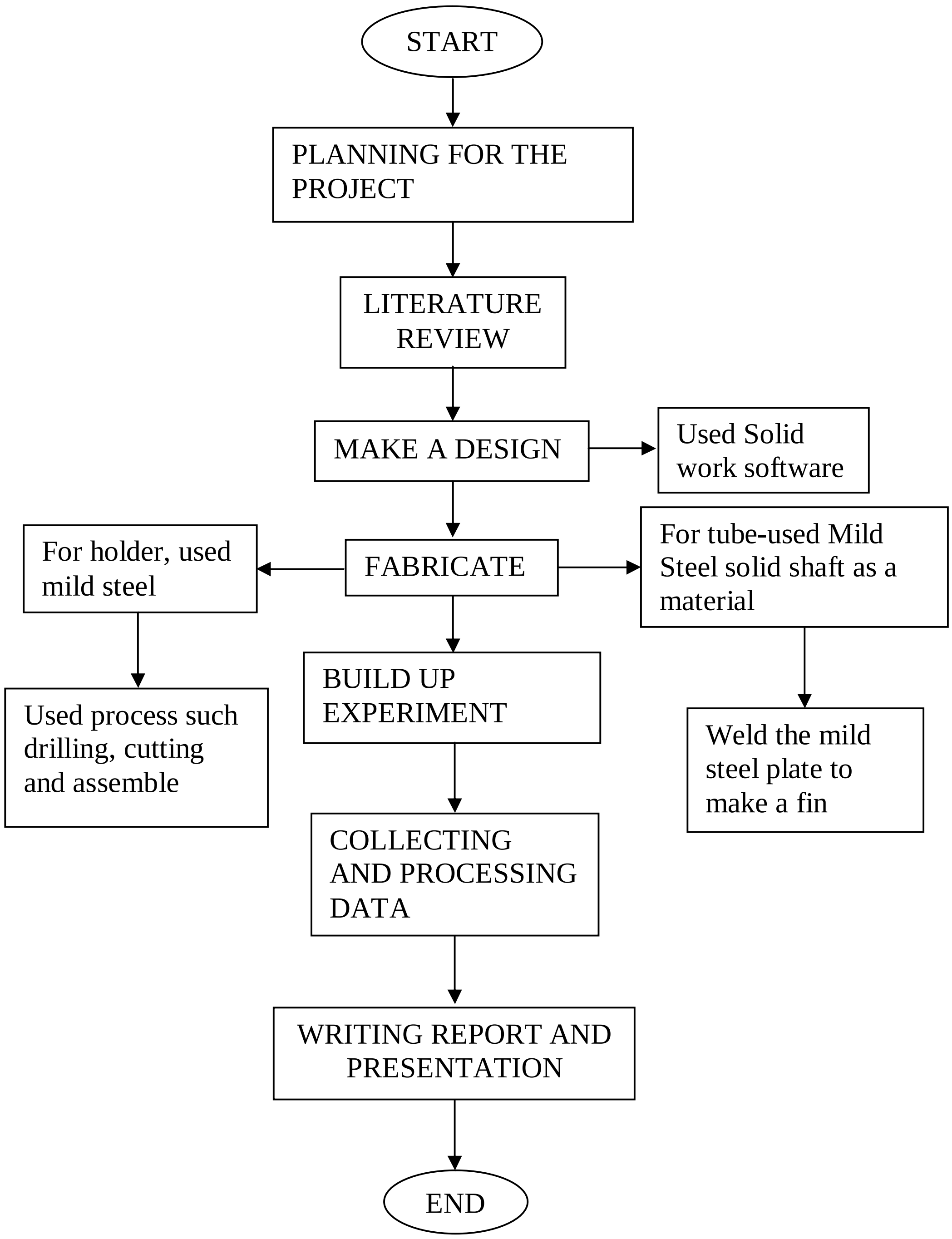

Figure 1.1: Shows the flow chart of the project

1.6 RESULT FROM SOLID WORK SOFTWARE

Refer from Figure 1.2 and 1.3; this process is done by using Solid Work software. It shows the top view and the side view for the specimen. The length of the tube is 100mm and the outside diameter is 90mm. As in this experiment required hollow cylinder, then the thickness of the tube fixed to 10mm so the inner diameter will be 80mm. For the tube with fins, the length of fins is 24mm and the thickness is 3mm.

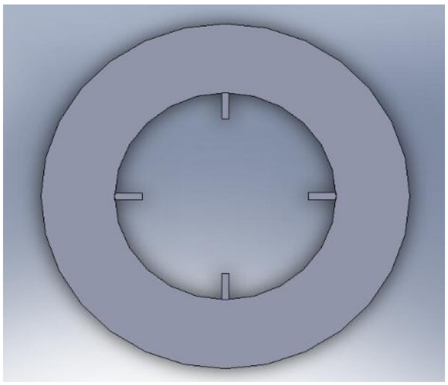

Figure 1.2: Top view of the tube with fin

Figure 1.3: Side view of the tube with fins

CHAPTER 2

LITERITURE REVIEW

2.1 INTRODUCTION

Tube cylinder is the most important part in heat exchanger process. Before fins was invented, the cost of the heat exchanger is high because of the performance of the heat transfer in heat exchanger are low. This is cause by the low surface area in the tube. But nowadays, they have found the better way to increase the performance of heat exchanger and decrease the cost of making heat exchanger. They have done the work consider in many ways to increase the surface area in the tube.

2.2 CONVECTION OF HEAT TRANSFER

Mechanism that involve in heat transfer is convection. Convection is classified as natural (or free) and forced convection, depending on how the fluid motion is initiated. To simplify the explanation, refer Figure 2.1 to give slight understanding. In forced convection, the fluid is forced to flow over a surface or in a pipe by external means such as a pump or a fan. In natural convection, any fluid motion is caused by natural means such as the buoyancy effect, which manifests itself as the rise of warmer fluid and fall of the cooler fluid. Convection involves fluid motion as well as conduction. The fluids motion enhances heat transfer, since it brings warmer and cooler chunks of fluids into contact, initiating higher rates of conduction at greater number of sites in a fluid. Convection heat transfer strongly depends on the fluid properties dynamic viscosity, μ, thermal conductivity, k, density and specific heat c_p as well as the fluids velocity V.

It also depends on the geometry and the roughness of the solid surface, in addition to the type of fluid flow (such as being streamlined or turbulent).Thus, convection heat transfer relations to be rather complex because of the dependence of convection on so many variable

The rate of convection heat transfer is observed to be proportional to the temperature difference and is conveniently expressed by Newton's Law of cooling, refer Equation 2.1:

$$\dot{Q}_{conv} = hA_s(T_s - T_\infty) \quad (2.1)$$

Important factor that effecting heat transfer is due to h, convection heat transfer coefficient, W/m^2.^{o}C Heat transfer will increase by increasing h. Value h also define as the rate of heat transfer between a solid surface and a fluid per unit surface area per unit temperature difference. Newton's Law of Cooling states that the rate of change of the temperature of an object is proportional to the difference between its own temperature and the ambient temperature (i.e. the temperature of its surroundings). Newton's Law makes a statement about an instantaneous rate of change of the temperature.

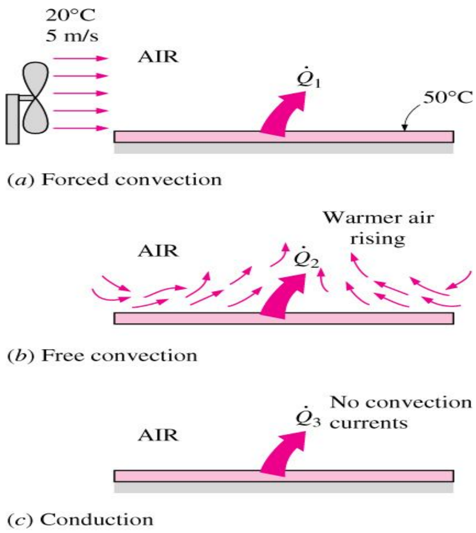

Figure 2.1: Comparison on Forced convection, natural convection and conduction

Source: Lienhard J.H. (2001)

2.3 LAMINAR FLOW

Some flows are smooth and orderly while other are rather chaotic. The highly ordered fluid motion characterized by smooth layers of fluid is called laminar. The word laminar comes from the movement of adjacent fluids particles together in laminates. The flow of high viscosity fluids such as oils at low velocities is typical laminar. The highly disordered fluid motion that typically occurs at high velocities and is characterized by velocity fluctuations is called turbulent. The flow of low viscosity fluids such as air at high velocities is typically turbulent. The flow regime greatly influences the required power for pumping .A flow that alternates between being laminar and turbulent is called transitional.

The flow regime for laminar characterized by smooth streamlines and highly-ordered motion. Turbulent flow characterized by velocity fluctuations and highly-disordered motion. Laminar flow is encountered when highly viscous fluids such as oil flow in a small pipes or narrow passages.

2.4 FINNED TUBE IN HEAT EXCHANGER

Finned tube has been used in many applications in the industries in the world especially in heat transfer process. Major application of finned tube occurs in the automotive, aerospace, petroleum, chemical and food processing industries. Nowadays, many of the researcher design a better solution for the cylindrical tube such added the internally finned to the tube. As a result, fins are employed to increase the heat transfer between the cylinders. So the internally finned tube has found extensive use in heat exchanger for schematic example in Figure 2.2.

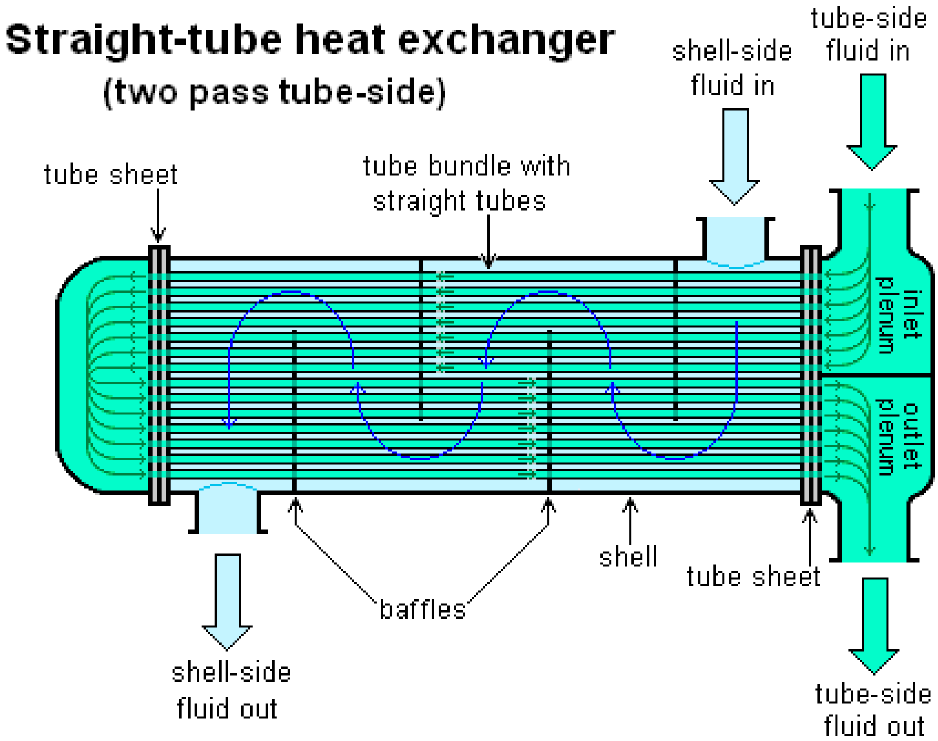

Figure 2.2: Schematic diagram for heat exchanger

Several of the study and researched have been conducted to investigate the effect of the fin characteristic on heat transfer. The internal fining tube was found to extend the effect of the natural convective and to support the enhancement of friction factors and Nusselt number compared to the smooth tubes.

Some of the researcher conclude that the Nusselt number based on the inside diameter was higher than for the smooth tube without fins. They also found that the fins could reduce the cost and size of the tube to get the better efficiency of the heat exchanger. Efficient design of the heat exchanger equipment can improve the system performance considerably. Hence, this will lead to a better design of heat exchangers.

2.5 PREVIOUS RESEARCH

Considerable from the work has done in the influence of internal fins on mixed convection in the fully developed region of horizontal tubes was investigated by Soliman and co-workers [1]. Results were presented for tubes with 2, 4 and 16 fins, and for a variety of modified Grashof numbers. Internal fining was found to retard the onset of significant free convective effects and to suppress the enhancements in friction factor and Nusselt number, as compared with smooth tubes. Then, the other author considers the natural convection between horizontal concentric and eccentric cylinders with isothermal boundaries. Kuehn and Goldstein [9] presented numerical and experimental results for these configurations over a wide range of Rayleigh numbers, Prandtl numbers, and diameter and eccentricity ratios. An experimental for turbulence fluid flow and heat transfer in a tube having internal fins done by Mafizul Huq and Mustafizur [2]. The result from the experiment as shown in Figure 2.3.

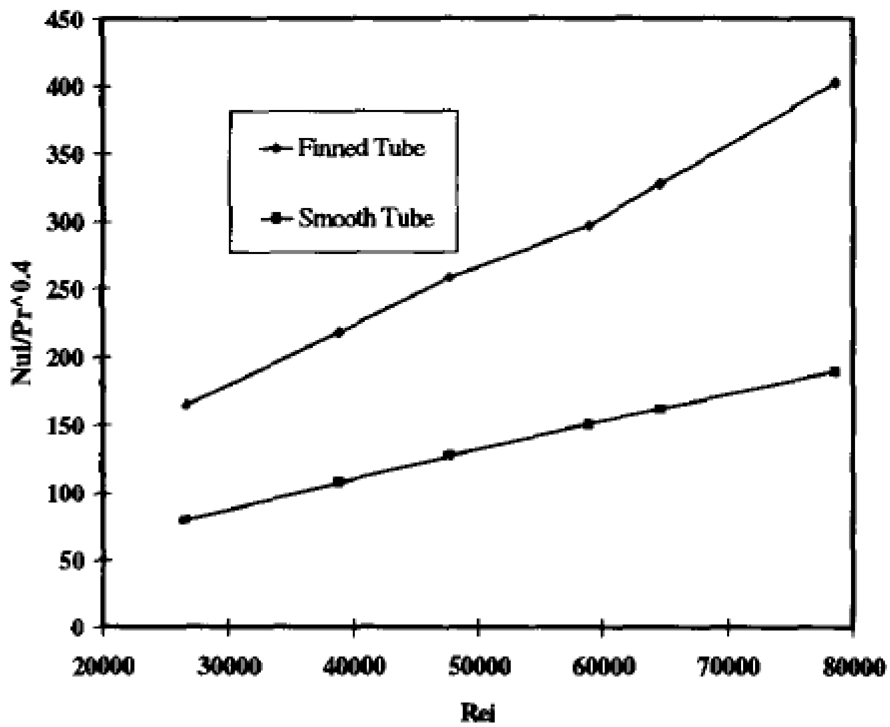

Figure 2.3: Variation of Nusselt Number based on inside diameter and nominal area.

Then Churchill and Chu [2] create the equation for the natural convection with laminar flow in horizontal position. Refer to the Equation 2.2.

$$\mathrm{Nu} = [0.6 + \frac{0.387Ra^{1/6}}{\left\{\left([1+\left(\frac{0.559}{Pr}\right)]^{9/16}\right)^{8/27}\right\}}]^2 \qquad (2.2)$$

Other investigators reported a number of experimental and numerical studies for a variety of configurations – positive and negative vertical eccentricities, and diameter ratios – [6], [7], boundary conditions - isothermal [8], constant heat flux [10] and mixed boundary conditions - Prandtl number and variable properties [11], [12], [13]. Other authors have studied the internal fin configuration. [16] gave results for the optimal fin number for the best heat transfer, [17] studied the importance of the fin geometry over the Nusselt number.

More recently, a numerical analysis was conducted for the laminar natural convection for air in two internally finned horizontal annuli [5]. A control-volume-based finite difference method was employed to examine the effects of the Rayleigh number and of the fin height and orientation on the Nusselt number. Results showed that the orientation of the fins has an insignificant effect on the heat transfer between the cylinders. Kiwan and Al-Nimr [18] introduced the concept of using porous fins to enhance the heat transfer from a given porous surface. The basic philosophy behind using porous fins is to increase the effective area through which heat converted to ambient fluid.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this project, the experiment will be conduct by the several of time, existing the fins in the tube (with fins and without fins), and the Nusselt number (due to inner area different). The time will be in 0s, 30s, 60s, 90s and 120s. The tube with fins configuration will be fixed to 4 fins. Then the difference of the Nusselt number will be determined after the experiment by using formula. This experiment used the hair dryer as the heat source to supply the heat to the tube. Research design and approach will be described clearly in the flow chart, apparatus, experiment setup and procedures. Flow chart will show the overall flow of the experiment. In other hands, the exact experimental procedures can be achieved when the improvement is made at the recommendation in further of the report.

3.2 FLOW CHART OF THE EXPERIMENT

The figure 3.1 shows the flow chart of the whole experiment. This flow chart can brief about the entire step during the experiment. This figure also can give a rough explanation about the procedures of the experiment.

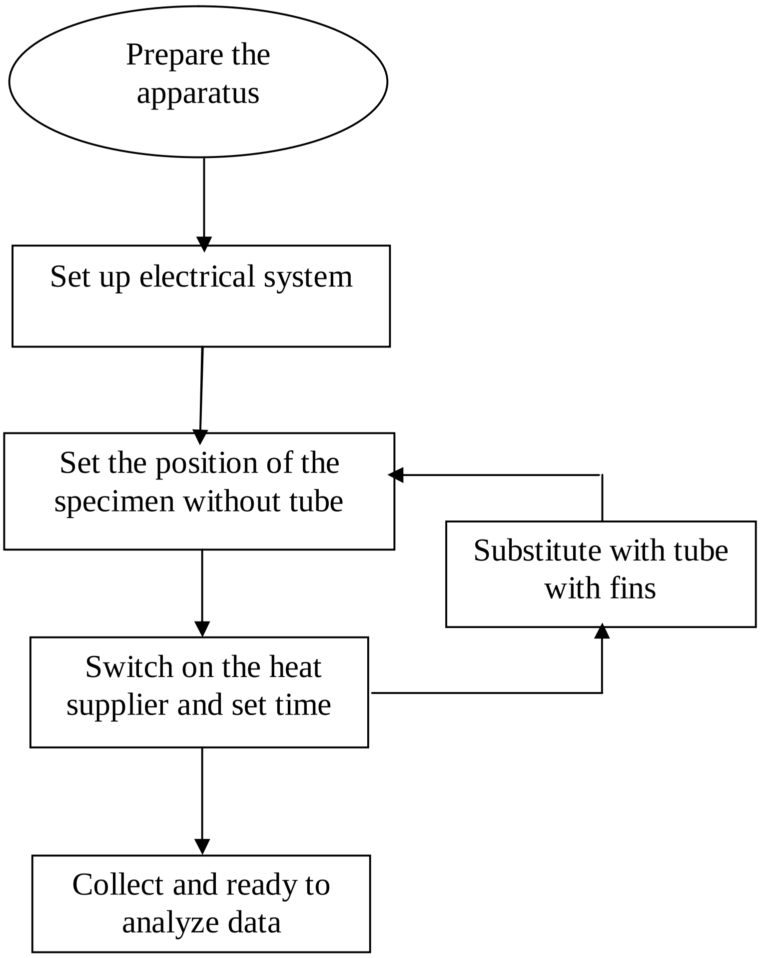

Figure 3.1: The Flow Chart of the Experiment

3.3 MEASUREMENT DEVICES AND SPECIMEN

In the experiment, the specimens are made from the Mild Steel. It is one of the materials that have high thermal conductivity. There will be 2 specimens that are the tube without fin (Figure 3.4) and tube with fins. Then the tubes will conduct the heat from outer side to the inner side of the tubes to neglect the natural conduction of Heat Transfer Rate. The specification of the specimens has been stated before. Then for the tube with fin, the Mild Steel plate used as the inner fins is welded to the inner surface of the tube. The fin must be fully fixed along the tube. The fin configuration is fixed to 4 fins. Refer Figure 3.2 and 3.3.

Figure 3.2: Side view specimen

Figure 3.3: Top view specimen

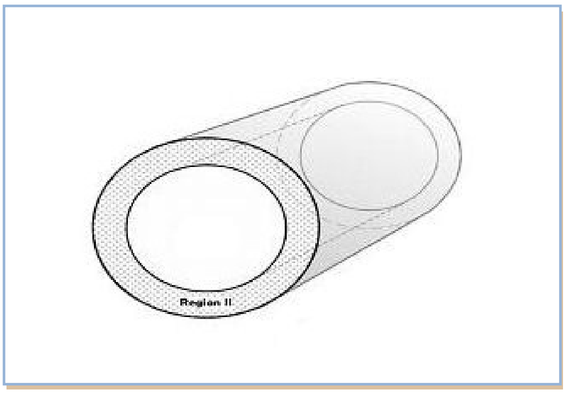

Figure 3.4: The tube without fin

Hair dryer is used as the heat supplier from the outer side. The heat must be supplied continuously and constantly around the tube. The number of the heat supplier can be more than one but remember to consider when analyze the data. The power used in each hair dryer is 110W. As known the hair dryer will produce the heat using turbulence flow, then the Aluminium foil is used to allow the heat through the foil by convection (Figure 3.5). To make sure the heat is transferred by convection, the foil is wrapped slightly and gives the air in between the foil and outer surface of the tube.

Figure 3.5: Tube wrap by Aluminium foil

As the experiment measure the heat, so the Laser thermocouple and Thermocouple digital required. The Laser Thermocouple is used to measure the surface temperature. During the experiment, this device used to measure the temperature at inner surface for tube without fin (smooth) and at the fin for the tube with fins. This thermocouple has laser beam make it easier to project in the narrow surface. Also can read precisely within vary point. Refer Figure 3.6.

Figure 3.6: Thermocouple Laser

Figure 3.7 shows how to measure the temperature at the fins. The same method also used to measure the inner surface of tube without fin.

Figure 3.7: Taking the temperature at fins

Then for the Thermocouple Digital (Figure 3.8), it used to measure the temperature at the certain ambient. It has a beam that is sensitive to heat. The reader is connected by wire. Along the beam, it gives the same temperature reading. Then, due to measure the temperature inside the tube, it can be very useful. The ambient inside the tube will carry the heat transferred from the tube. Then it will be neutralize by the air flow.

Figure 3.8: Thermocouple digital

Figure 3.9 show how to measure the ambient temperature of the tube. This method also can be used to the tube without fins. Take the temperature when it shows constant temperature.

Figure 3.9: Measure the ambient temperature

3.4 EXPERIMENT SETUP

The Figure 3.9 below shows the experiment setup. Remember that the natural convection only occur at the closed room with no air flow. So this experiment must be done in closed room. The specimen placed horizontally. The heat is supplied around the tube but on the half of the tube length. Then, the result expected to be the hot air flow will flow out from the tube and replaced by the cold air. Then the hot air will transfer the air to the ambient outside the tube and rotate again as the cold air flow.

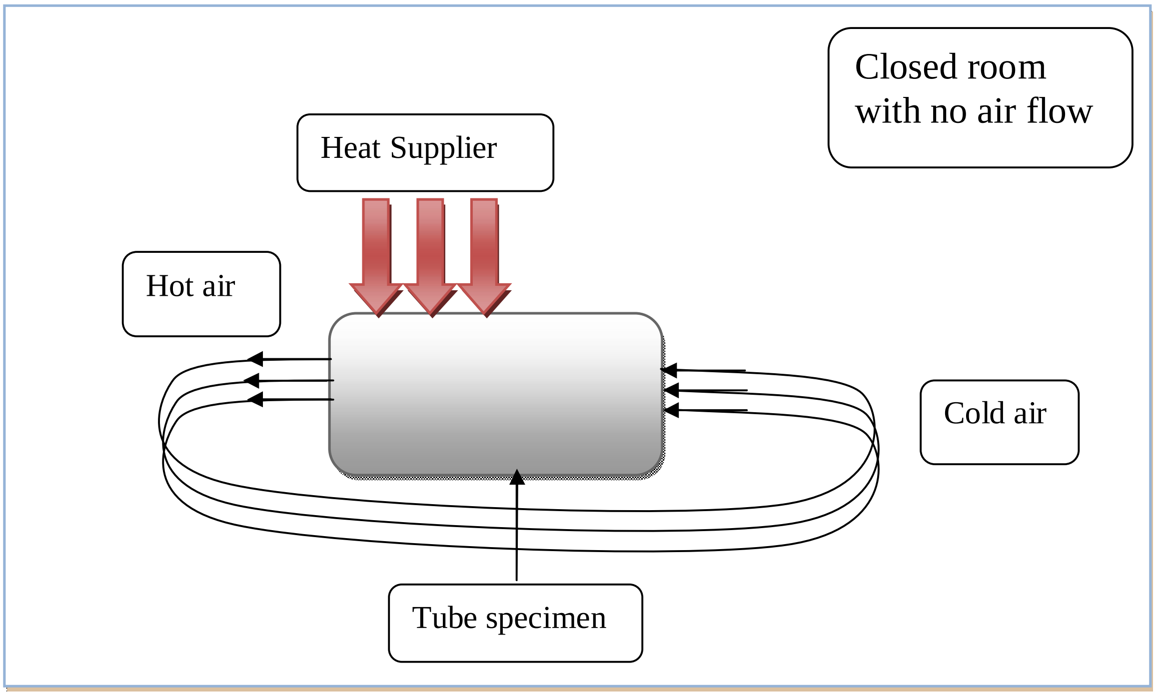

Figure 3.9: Experiment Setup

Before run the experiment, tick 10 point with different position at the fins plate as shown in Figure 3.11 below. During the experiment, measure the temperature for each point to get the average temperature of the fins and the inner surface for the tube without fins. With this method, the result can be more precisely than taking just in one point.

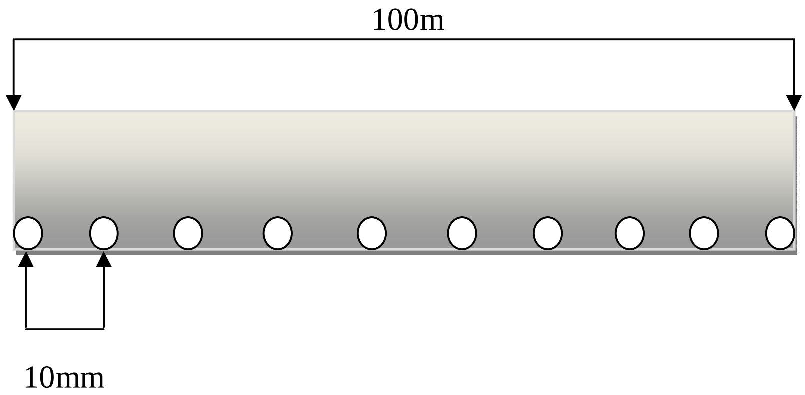

Figure 3.11: Shows the 10 point position to measure temperature

3.5 PROCEDURES

The procedures below used to guide during the experiment. The procedures must be following carefully to avoid huge uncertainty during collecting data.

I. Prepare all the apparatus needed and make sure the experiment setup is done. This experiment must be run inside closed place with no air flow. Then the specimen must be higher from the ground 500mm to make sure the laminar flow is in steady state condition.

II. Wrap the tube with the aluminium foil to avoid the air from hair dryer touch the tube outer surface and only the heat from hair dryer is past through the foil and tube.

III. Set the time range between 0s to 150s with difference 30s. Make sure the position from the supplier to the specimen is correct and safe to use.

IV. Start with tube without fins (smooth). Turn on the heat supplier. Set the time. When reach the time range, take a reading from 10 point at the inner surface using the laser thermocouple and the temperature inside the tube with digital thermocouple.

V. Collect all the data and fill into Table 3.2. Repeat procedure 2, 3, 4 using tube with fins. During measure the surface, take the reading at the fins.

VI. Assume the power used to produce the heat is constant. The heat is surrounding the tube constantly.

3.6 DATA DISTRIBUTION

From the experiment, the temperature is varying with the time in second. Then the collected data need to analyze to fulfil the objective of the project. All the data rearrange in Table 3.2 below.

Then the inner surface area of the tube can be calculated using formula below;

$$A = \pi DL + A_{fins}$$

Then from the formula, the inner surface for smooth tube and tube with fins are;

$$A_{smooth} = 0.0251m^2$$

$$A_{fins} = 0.1163m^2$$

Table 3.2: The sample of table for the data gets from experiment

Time (second)	Temperature ambient (^{0}C)	Temperature at inner surface without fins (^{0}C)	Temperature at inner surface with fins (^{0}C)
30			
60			
90			
120			
150			

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

The data get from the experiment must be analyzed using the formula below to determine the heat transfer rate and the Nusselt number. All the raw result will be arranged and the selected value finding will be describe briefly to give the proper explanation about analysis and the important point of the result. All the evaluated data calculated in order to get the value of heat transfer coefficient and Nusselt number for each case. For expected result, inner surface area will directly proportional to the Rayleigh number. Then the Nusselt Number also increase when Rayleigh Number increase.

4.2 CALCULATION

After the experiment is done, all the collected data must be analyze. The main objective of this project is to determine the effect of heat transfer rate between tube without fins and tube with fins. Then, to fulfil the objective used the general equation (Equation 4.1) of the heat transfer rate for natural convection.

Conservation energy for convection:

$$\dot{Q}_{conv} = hA_s\,(T_s - T_\infty) \tag{4.1}$$

Known that h is the heat transfer coefficient, A_s is the inner surface area in the tube, Ts is the temperature surface that can get from the experiment, and the T_∞ is the temperature at the ambient.

Since the experiment used the electrical component (hair dryer), the Work done by the heat supplier need to be considered. Refer Equation 4.2.

Equation for work (W),

$$W = VI \tag{4.2}$$

Then, in this project the heat transfer that transferred to the air need to be determine with the Heat Transfer coefficient, h. Combine the Equation 4.1 and Equation 4.2.

Know that the $\dot{\boldsymbol{W}}=\dot{\boldsymbol{Q}}$, so

$$w = I^2 R \quad (4.3)$$

$$= V^2/_R \quad (J)$$

$$\dot{W} = \int_{t_1}^{t_2} VI \; dt \quad (4.4)$$

$$\dot{W} = VI\Delta t \quad \text{(W)} \quad (4.5)$$

$$hA_s\,(T_s - T_\infty) = VI\Delta t \quad (4.6)$$

Then the equation of h is finalize with,

$$h = \frac{VI\Delta t}{A_s\,(T_s - T_\infty)} \quad (W/_{m^2} \cdot °K) \quad (4.7)$$

Noted that the Δt is the time difference.

Then to calculate the heat flux along the cylinder, refer to Equation 4.8. The heat flux equation used because of the heat transferred from the outer to the outer surface of the cylinder.

$$q_c'' = \frac{P_{elec} - A_c q_{insul}''}{A_s} - q_r'' \quad (4.8)$$

The Rayleigh Number, Ra used only for Natural Convection. To determine the Rayleigh Number used the Equation 4.9. Noted that Gr is the Grashof Number and the Pr is the Prandtl Number.

$$\text{Ra} = \text{Gr X Pr} \quad (4.9)$$

Note that,

$$Gr = \frac{g\beta(Ts - T\infty)D3}{\upsilon 2} Pr \qquad (4.10)$$

$$\beta = \frac{1}{T_f} \qquad T_f = \frac{T_S + T_\propto}{2} \qquad (4.11)$$

Properties that can get for the experiment:

Where: g = gravity acceleration $\left({m^2}/{s}\right)$

β = thermal expansion coefficient

α = thermal diffusivity $\left({m^2}/{s}\right)$

υ = kinematic viscosity

Where: α_{Al} = $8.418 \times 10^{-5}\ {m^2}/{s}$

$\upsilon_{\infty_{air}}$ = $1.78 \times 10^{-5}\ {kg}/{m.s}$

Where: k_f = thermal conductivity of the air

$k_{f_{air}}$ = $0.025\ {W}/{m.K}$

The fin efficiency is defined as the actual rate of heat transfer from fin to the maximum possible heat transfer rate from the fin:

$$\eta = \frac{q_{fin}}{q_{\max}} = \frac{\overline{h}A\left(\overline{T_w} - T_\infty\right)}{\overline{h}_{\max}A\left(\overline{T_w} - T_\infty\right)} = \frac{\overline{h}}{\overline{h}_{\max}} \qquad (4.12)$$

As this experiment in same condition as experiment done by Churchill and Chu, the Equation 4.13 can be used. This equation determine from the experimental and from the numerical research.

$$\mathrm{Nu} = [0.6 + \frac{0.387Ra^{1/6}}{\left\{\left([1+\left(\frac{0.559}{Pr}\right)]^{9/16}\right)^{8/27}\right\}}]^2 \qquad (4.13)$$

For Prandtl Number, kinematic viscosity and thermal conductivity refers to table A-15 due to the temperature calculated as above. All the calculated data can be rearranged into the table.

4.3 RESULT

After the data been analyzed, all the data is rearrange into the table to make it easy to compare and plot graph**.**

Table 4.1: Data for tube with fins

Time (second)	**Temperature ambient (°C)**	**Temperature surface (with fins)(°C)**	**Heat Transfer (W)**
30	***36.0***	***40.3***	***2.0812***
60	***38.0***	***43.9***	***2.5564***
90	***38.6***	***44.5***	***3.1837***
120	***39.3***	***45.0***	***7.7549***
150	***39.6***	***48.3***	***9.0212***

Table 4.2: Data for tube without fins

Time (second)	***Temperature ambient (°C)***	***Temperature surface (without fins)(°C)***	***Heat Transfer, (W)***
30	***36.0***	***44.1***	***1.1446***
60	***38.0***	***50.4***	***1. 7336***
90	***38.6***	***50.7***	***1.8240***
120	***39.3***	***50.8***	***1.9083***
150	***39.7***	***51.4***	***2.0561***

Table 4.3: The Nusselt number for each case

Time	***With fins***	***Without fins***
30	***19.0070***	***12.253***
60	***20.0000***	***13.313***
90	***20.0170***	***13.980***
120	***20.6800***	***16.124***
150	***21.0495***	***17.533***

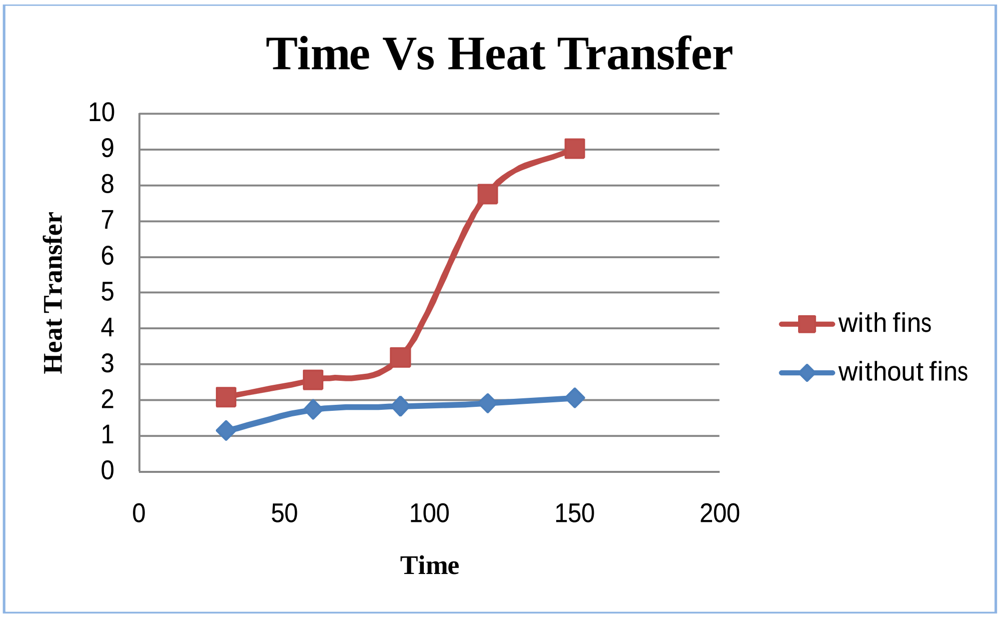

Figure 4.1: Graph Time versus Heat Transfer

From the graph, the heat transfer rate of the tube with fin is higher than the tube without fin. It happens due to the higher inner area than the tube without fin. The tube without fin just has the inner surface but for the tube with fins, the area includes the area of the fins.

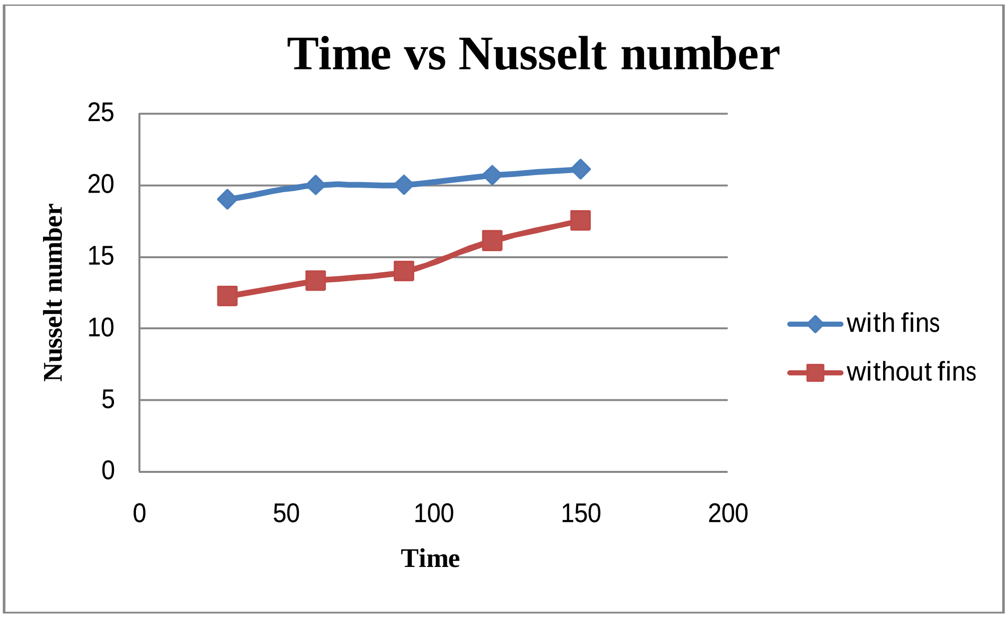

Figure 4.2: Graph Time versus Nusselt for each case

From the graph, the nusselt number increase due to time. This is because the heat is fully transferred to the ambient of the inner cylinder. It can be concluding that the higher heat transferred to the ambient, so the higher Nusselt number.

Table 4.4: The table for Nusselt number and Rayleigh number for each case

Nusselt Number at tube with fins	**Nusselt Number at tube without fins**	**Rayleigh Number(with fins)**	**Rayleigh Number (without fins)**
19.0070	12.253	2.5428×10^6	0.9773×10^6
20.0000	13.313	3.1745×10^6	1.0688×10^6
20.0170	13.980	3.2566×10^6	1.1287×10^6
20.6800	16.124	4.0253×10^6	1.9243×10^6
21.0495	17.533	4.3971×10^6	2.3558×10^6

Theoretically the Nusselt number and the Rayleigh number are directly proportional to each other. The higher Nusselt number then the Rayleigh number also increases due to the Equation 4.15 above. Compare to this experiment, the Nusselt number also increase when the Rayleigh number increase. Then it proved that this experiment is valid due to the theory based on the Figure 4.3 below.

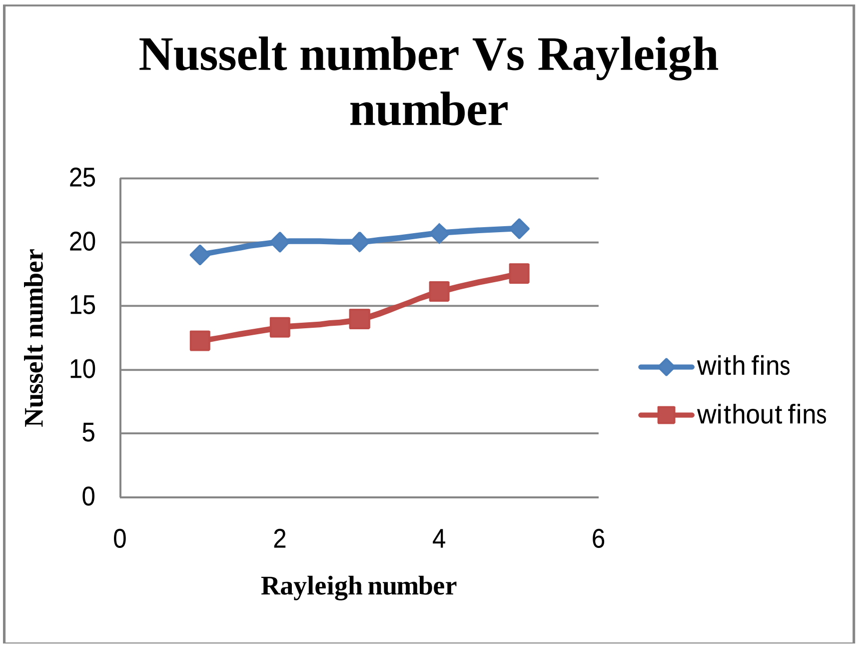

Figure 4.3: The relation between Nusselt number and Rayleigh number

From the graph above, the Nusselt Number at the fin tube is higher than the tube without fin. The Rayleigh number increased when the Nusselt number increased. From that, it can be conclude the tube with fins can give higher efficiency to the heat transfer.

4.4 VALIDATION FROM THE OTHER RESEARCH

For the other research that considers the same objective but different in the position of the specimen this writer used the vertical position as the new method. With this research, it can determine the effect of the heat transfer due to it position. The experiment used the same method and the same character of the specimen but with different analyze method. The result is shown in Table 4.5 below.

Nusselt Number at tube with fins	**Nusselt Number at tube without fins**	**Rayleigh Number(with fins)**	**Rayleigh Number (without fins)**
15.0637	12.2537	$1.9498x10^6$	$0.9773x10^6$
16.8443	12.5975	$2.1711x10^6$	$1.0688x10^6$
17.2411	13.1101	$2.7814x10^6$	$1.1287x10^6$
17.5563	13.2247	$2.9513x10^6$	$1.3833x10^6$
17.7902	13.5339	$3.2851x10^6$	$1.5145x10^6$

Figure 4.5: The table for the vertical tube

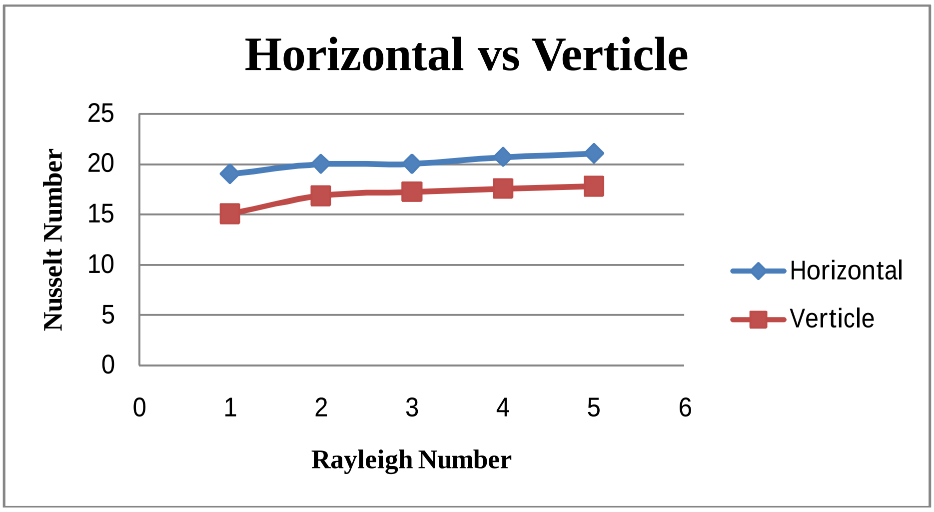

Figure 4.4: Show the different between horizontal position and vertical position

From the Figure 4.4, the graph shows the different of the Nusselt Number for each position by the tube with fins. From the graph shows the horizontal position has the higher Nusselt number compare to the specimen in vertical position. It effected by the own characteristic of the air. The hot air will automatically leave the tube as the tube in vertical position. For the horizontal position, there is high friction flow as the flow have been forced moving horizontally out from the inner tube. it is the same as the Figure 4.5, as it for the smooth tube (without fins).

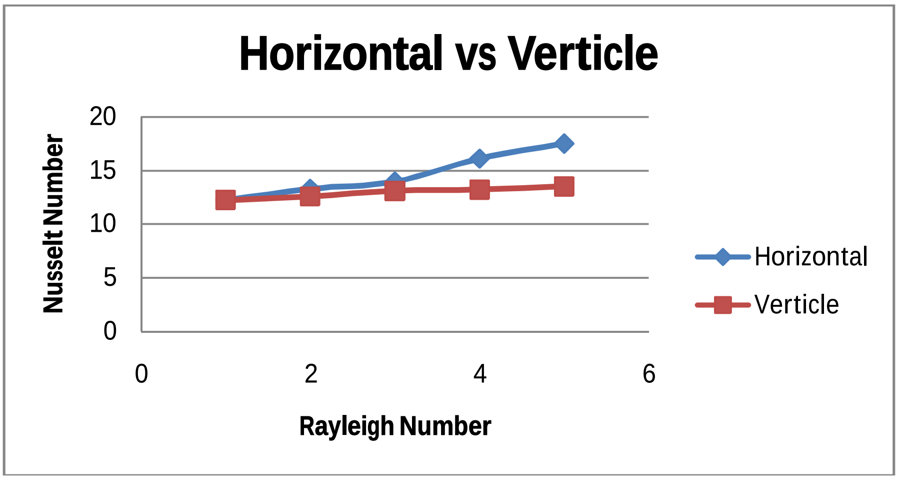

Figure 4.5: Comparison between horizontal and vertical position.

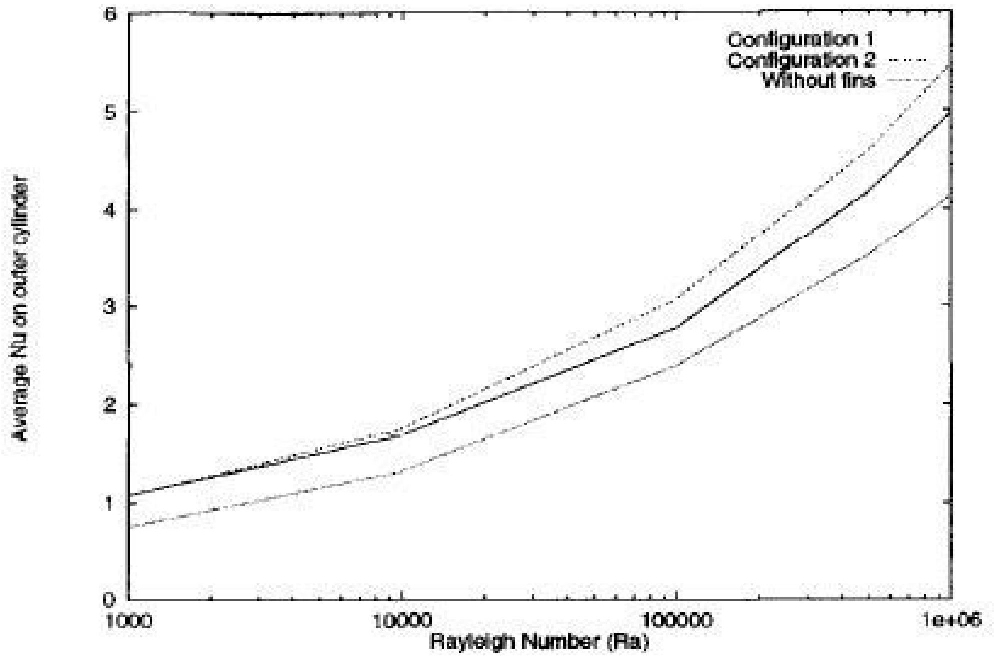

Figure 4.6: Graph validation from previous research

This Figure 4.6, it get from the previous research, [19]. It shows the relation between Rayleigh number and Nusselt number. Then it also shows the differences between Nusselt number at tube with fins and tube without fins. From this figure can approved the result from this project is valid and can be used. For every experiment refer to their own objective, so there is some different between the results.

4.5 DISCUSSION

This report can be improved with the correct procedures below with a new method consider using the electrical system as the heat supplier. This procedures is taken from the previous research [18].

EXPERIMENTAL SETUP AND PROCEDURE

Tests were carried out using a rig composed of three Aluminum cylinders of length 300 mm and diameters of 30, 50, and 80 mm. Each cylinder is heated internally over its entire length with a uniform heat flux generated by a flexible Kapton heater (33.4Ω), and thermally insulated from both ends with Bakelite insulating material of thickness 20 mm each end. The magnitude of the heat flux was adjusted by varying the intensity of the current measured with the ammeter and supplied by the direct current power supply. Temperatures of the surface at different axial positions were recorded using twelve K-type omega thermocouples. The resulting analog signals were further converted into digital signals by a DAQ card installed into a PC and recorded with an application Omega pDaqView 56.

The procedure followed during each experiment is as follows. An initial power input was supplied and then adjusted such that the heat flux gives Ra*L in the required range. The temperatures along the cylinder were continuously measured and monitored with a scanning each 0.617 sec. Usually an initial period of approximately 2–3 hrs was required before reaching steady-state conditions (considered to be attained, when the temperatures indicated by the thermocouples did not vary with more than ±1 C within a period of about 2 min). To reduce the noise specific to each sensor as well as the noise induced in the electric wires by the surrounding electromagnetic fields, each data point was obtained by averaging 40 discrete values acquired with the above mentioned rate.

After collecting a set of data at steady-state conditions, the supplied mass current to the heater was increased so that the next value of q" is obtained. A new set of data was collected when steady-state conditions were reached again, usually within a period of approximately 30-45 minutes. Heat losses from the heated section from cylinder ends through the insulation material by conduction, to the atmosphere by radiation and natural convection were accounted.

Then, the result as in the Figure 4.7 and Figure 4.8 below:

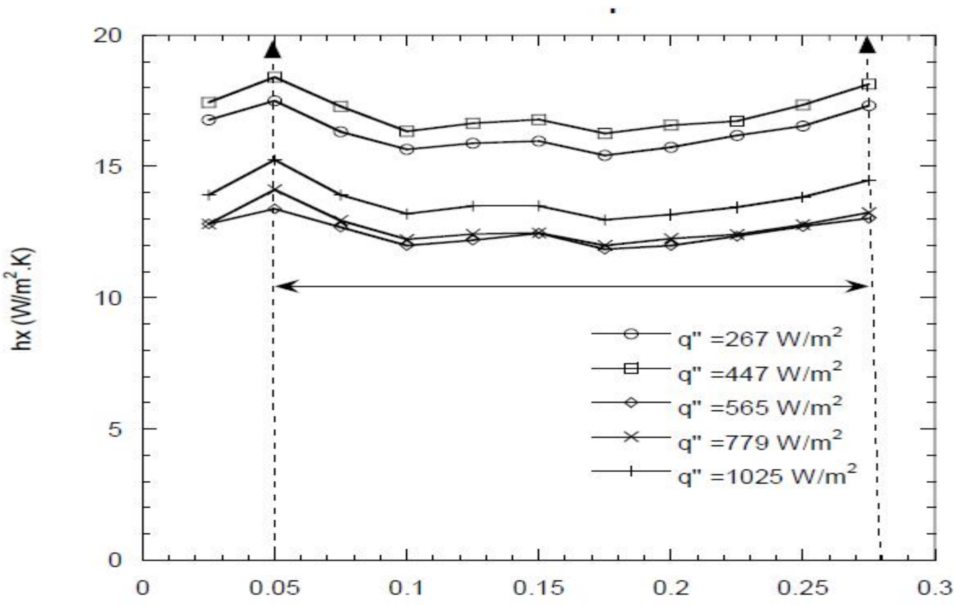

Figure 4.7: The variation of local heat transfer coefficient along the cylinder for selected heat fluxes.

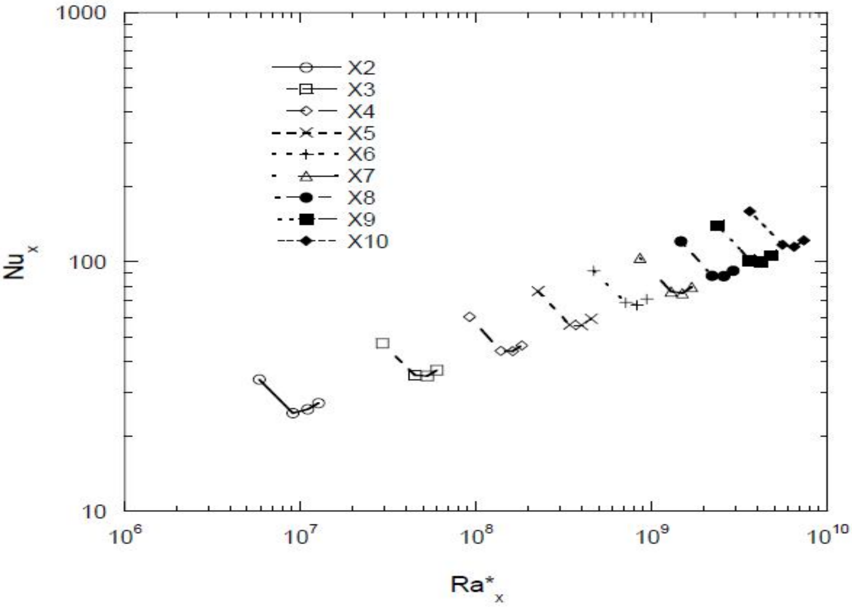

Figure 4.8: The variation of Nusselt number along the cylinder with the variation of the modified Ra at different locations

CHAPTER 5

CONCLUSION AND RECOMMANDATIONS

5.1 CONCLUSION

For this project, the effects of internally finned tube in heat exchanger are determined after experiment and data analyze. From the graph and discussion, it can be conclude that the heat transfer are more effective when there are fins in the tube compare to the tube without fins and the horizontal position will slow the air flow through the middle of the tube. It happens because the surface area inside the tube is bigger.

Besides that, there are other properties that can affect the heat transfer in the tube exchanger. One of the properties are the higher Rayleigh number than the higher heat transfer from the tube. The enhancement of heat transfer rate due to integral fins was found to be very significant over the entire range of flow rates studied in this experiment. Proved that the Rayleigh number increase as increased the Nusselt number. All this design can save all the budget of the company that used the heat transfer process.

5.2 RECOMMANDATIONS

There are some correction must be made from this project. This required getting more efficient in the result and improvement to make the project tough. Firstly, the material of the tube must be a material that has high thermal conductivity such as aluminium. Then use the solid material and machining with wire cut process at CNC machine. This is to make sure the fins in directly touch the entire surface inside the tube. So there will be no heat loss during the heat conduction inside the tube. The length of the tube must be higher than 100mm to produce more constant air flow through inside the tube. It can give more persistence data.

Then for the heat supplier, the better method is to use the electrical system. Make the coil around the tube. The coil can produce heat from electricity. For example, the coil is made from Nickel-Chromium (NiCr). Then the power supply can vary the voltage and current to make it variable with time. Then the power can be calculated using the formula in appendix. Beside that, the variable can be the position of the specimen such create angle at 45^0, 60^0 and so on. This can give different from the result in this project. Then, the other improvement due to this project is using turbulence flow and makes the variable of the fins length.

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APPENDIX

Table A-15

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APPENDIX 1

TABLE A–15

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m³	Specific Heat c_p, J/kg · K	Thermal Conductivity k, W/m · K	Thermal Diffusivity α, m²/s²	Dynamic Viscosity μ, kg/m · s	Kinematic Viscosity ν, m²/s	Prandtl Number Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	0.7263
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	0.7132
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	0.7111
120	0.8977	1011	0.03235	3.565×10^{-5}	2.264×10^{-5}	2.522×10^{-5}	0.7073
140	0.8542	1013	0.03374	3.898×10^{-5}	2.345×10^{-5}	2.745×10^{-5}	0.7041
160	0.8148	1016	0.03511	4.241×10^{-5}	2.420×10^{-5}	2.975×10^{-5}	0.7014
180	0.7788	1019	0.03646	4.593×10^{-5}	2.504×10^{-5}	3.212×10^{-5}	0.6992
200	0.7459	1023	0.03779	4.954×10^{-5}	2.577×10^{-5}	3.455×10^{-5}	0.6974
250	0.6746	1033	0.04104	5.890×10^{-5}	2.760×10^{-5}	4.091×10^{-5}	0.6946
300	0.6158	1044	0.04418	6.871×10^{-5}	2.934×10^{-5}	4.765×10^{-5}	0.6935
350	0.5664	1056	0.04721	7.892×10^{-5}	3.101×10^{-5}	5.475×10^{-5}	0.6937
400	0.5243	1069	0.05015	8.951×10^{-5}	3.261×10^{-5}	6.219×10^{-5}	0.6948
450	0.4880	1081	0.05298	1.004×10^{-4}	3.415×10^{-5}	6.997×10^{-5}	0.6965
500	0.4565	1093	0.05572	1.117×10^{-4}	3.563×10^{-5}	7.806×10^{-5}	0.6986
600	0.4042	1115	0.06093	1.352×10^{-4}	3.846×10^{-5}	9.515×10^{-5}	0.7037
700	0.3627	1135	0.06581	1.598×10^{-4}	4.111×10^{-5}	1.133×10^{-4}	0.7092
800	0.3289	1153	0.07037	1.855×10^{-4}	4.362×10^{-5}	1.326×10^{-4}	0.7149
900	0.3008	1169	0.07465	2.122×10^{-4}	4.600×10^{-5}	1.529×10^{-4}	0.7206
1000	0.2772	1184	0.07868	2.398×10^{-4}	4.826×10^{-5}	1.741×10^{-4}	0.7260
1500	0.1990	1234	0.09599	3.908×10^{-4}	5.817×10^{-5}	2.922×10^{-4}	0.7478
2000	0.1553	1264	0.11113	5.664×10^{-4}	6.630×10^{-5}	4.270×10^{-4}	0.7539

Note: For ideal gases, the properties c_p, k, μ, and Pr are independent of pressure. The properties ρ, ν, and α at a pressure P (in atm) other than 1 atm are determined by multiplying the values of ρ at the given temperature by P and by dividing ν and α by P.

Source: Data generated from the EES software developed by S. A. Klein and F. L. Alvarado. Original sources: Keenan, Chao, Keyes, Gas Tables, Wiley, 198; and Thermophysical Properties of Matter. Vol. 3: Thermal Conductivity, Y. S. Touloukian, P. E. Liley, S. C. Saxena, Vol. 11: Viscosity, Y. S. Touloukian, S. C. Saxena, and P. Hestermans, IFI/Plenun, NY, 1970, ISBN 0-306067020-8.

Formula for voltage and current

$$P_{elec} = A_s\left(q''_c + q''_r\right) + A_{insul}\, q''_{insul}$$

Where the value of P_{elec} is calculated from the measured values of the voltage drop and the current passing in the electrical heater.

Time schedule

Activities\ month	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**
Draft for outline and design project	→	→										
Literature review			→	→								
Setup material and fabricate					→	→						
Experiment setup							→	→				
Data analysis									→	→		
Report writing and presentation											→	→