GEOTHERMAL ENERGY FOR POWER GENERATION (GEPG)

By

MOHD.SAIFFUL IZZUAN BIN ISHAK

FINAL PROJECT REPORT

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

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CERTIFICATION OF APPROVAL

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Approved:

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(Dr. Mumtaj Begam)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

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

Mohd.Saifful Izzuan Bin Ishak

ABSTRACT

Since the dawn of civilization, world has become increasingly addicted to electricity due to its utmost necessity for human life. In order to cater to the needs of electricity, many sources have been explored, amongst which, this project addresses the usage of geothermal energy where heat from underground is considered for the production of electricity. This is basically inter-conversion of energy from thermal to electrical. Besides the basic need for electricity, stock for oil, gases and coil will decrease and the nuclear energy is not very safe and hard to handle. So, the alternative renewable energy must be explored and implemented to the society. This project will cover from the geographical aspect to steam turbine and finally generator set. For geographical aspect, the author learns about hot spot on the earth such as volcanoes, magma flow and also source for hot steam. Next, the simulation to get minimum amount for heat that includes the pressure and temperature to move the turbine blade and become as a prime mover. The design for the turbine and other equipment are included in this project to increase the efficiency for the systems. Steam turbine is the most efficient turbine compared to gas and internal combustion engine. The author chooses heat source from underground because of the clean and unlimited renewable energy for future.

ACKNOWLEDGEMENT

First of all, I would like to express my gratitude to my final year project supervisor, Dr. Mumtaj Begam for giving me advices and support for this one year project. Her encouragement has given me the strength to overcome the problems that I have encountered when the project is in progress.

Thanks to all the people that have helped me in achieving the objectives of the project especially the lecturers. The lecturers whom I consult have explained to me the basic theory to make this project works. I would like to thank to the mechanical and electrical technician for assisting me in finishing the project. Not forgetting Mrs Siti Hawa for helping me preparing the necessary document in order to make sure the project is running smoothly.

Most importantly, I would like to express my gratitude to my parent and sibling who had support me form the back. Their sacrifices and support has helped me a lot in this project.

Last but not least, I would like to extend my appreciation to my friends in University Technology PETRONAS (UTP) who has helped me and gave me some advices so that my project works and has successfully achieved the objectives.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Thermal energy is a heat source that can be found in underground and at any hot spot around the world such as hot springs, geysers, hot rock and also volcanoes. About 23 countries in the world used the thermal energy as an alternative energy source for electricity. According to Table 1.1 below, total installed thermal power in year 2000 was about 15 145 MW and for energy used was about 190,600 TJ/Yr. In 2001, the total for installed thermal power and energy used were found to increase by 27% [1].

Table 1 Installed geothermal generating capacities world-wide from 1005 to 2000 and in 2004 [1]

Country	1995 (MW_e)	2000 (MW_e)	1995–2000 (increase in MW_e)	% increase (1995–2000)	2004 (MW_e)
Australia	0.17	0.17	0	0	0.17
Austria	—	—	—	—	1.25
China	28.78	29.17	0.39	1.35	32
Costa Rica	55	142.5	87.5	159	162.5
El Salvador	105	161	56	53.3	162
Ethiopia	0	8.52	8.52		7
France (Guadeloupe)	4.2	4.2	0	0	15
Guatemala	0	33.4	33.4		29
Iceland	50	170	120	240	202
Indonesia	309.75	589.5	279.75	90.3	807
Italy	631.7	785	153.3	24.3	790.5
Japan	413.705	546.9	133.195	32.2	537
Kenya	45	45	0	0	127
Mexico	753	755	2	0.3	953
New Zealand	286	437	151	52.8	453
Nicaragua	70	70	0	0	77.5
Papua New Guinea	—	—	—	—	6
Philippines	1 227	1 909	682	55.8	1 931
Portugal (Azores)	5	16	11	220	16
Russia	11	23	12	109	81.6
Thailand	0.3	0.3	0	0	0.3
Turkey	20.4	20.4	0	0	20.4
USA	2 816.7	2 228	−588	n/a	2 395
Total	6 833	7 974	1 141	16.7	8806.45

1.2 Problem Statement

This project utilizes the latest technology for power generation by combining the electrical power engineering knowledge and geographical aspect. Thus, the author must know all aspect for generator part until the geography for earth to find the suitable place to implement this technology.

Geothermal energy is come from the hot spot around the world such as geysers, hot springs, hot rocks and volcanoes. The first problem that occurs is a way to ‘bring out’ the geothermal energy from underground. The basic step is to ‘take’ the heat from the ground is to use the well like petroleum well. Geothermal plant is look like the oil and gas plant and also construction of the steam well will need proper tool and it is very costly. The effect for the environmental like’s noise, surface damage and local disruption will occur while implement the plant for power generation.

Basically for non-volcanic area, such as in Malaysia, the temperature for ground just increases 17 to30 degree Celsius per kilometers or 50 to 87 Fahrenheit per miles. This condition will make the project very difficult to implement because of the lower temperature. The main problem is unavailability for geothermal energy itself. If the geothermal energy is available, it can contribute 20 to 50 % energy that needs of the industrial countries. Northern Europe and the Eastern parts of Americas is not a suitable part to develop the technology because of unavailability of geothermal source.

1.3 Objective and Scope of Studies

To determine the most efficient steam turbine and applicable to this project. Besides to know the right formula for heat-to-electric power conversion and derive the formula to get the minimum temperature of steam that can generate the electric power. For this Final Year Project, the author has done some simulation using Matlab to determine the minimum pressure and temperature that can run the steam turbine and move the generator.

1.3.1 Scope of Study

In this chapter, the author will discuss about the types of steam turbine used now days. For this report, many research from the websites and books helped the author to understand the types of the steam turbines and the specification for each type of steam turbine.

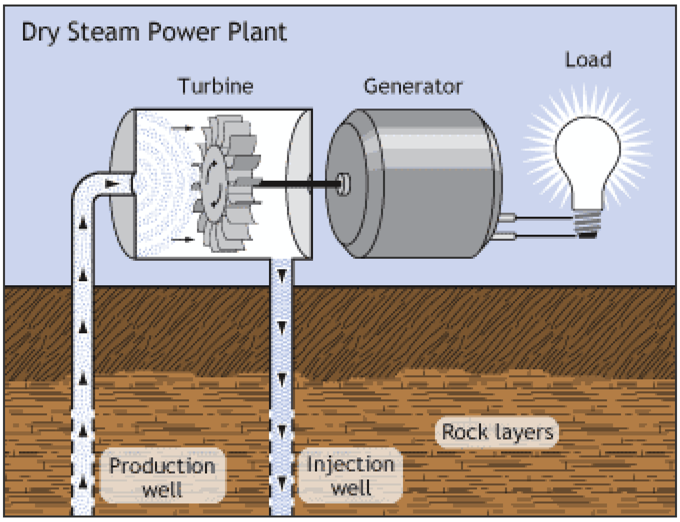

Figure 1 Type of dry steam power plants [3]

Dry steam plant can produce more steam but used less water. The operation of this type is to build a well to underground and shoots the water directly through a hot rock and transfers it into the turbine. This type used very old technology since 1904 that used at Lardarello in Italy but until now it is efficient [3].

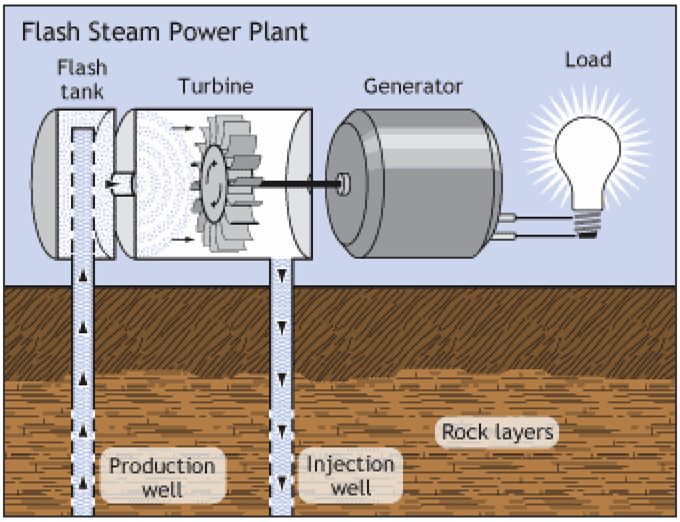

Figure 2 Type of the flash steam power plant [3]

The next type is a flash steam plant that used for hydrothermal fluid above 182 degree Celsius. This turbine's concept is same like the dry steam plant but used high temperature. The steam from the well will be pumped to the flash tank that has low pressure than the fluid. This condition will make the fluid to vaporize rapidly and the vapor will move the turbine and generate the electricity. The 'flash steam plant' named came because of the vapor or 'flash' of steam that happened in this operation [3].

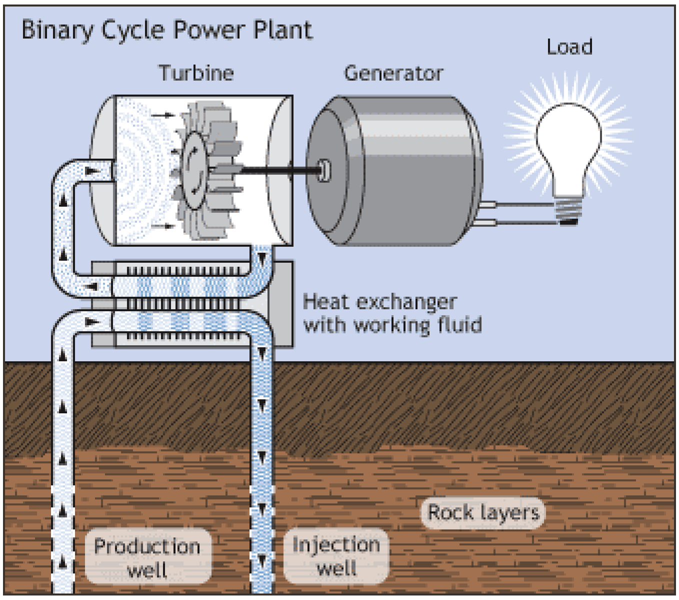

Figure 3 Type of the binary steam power plant [3]

The binary steam power plant is a future technology that can be implemented to increase the efficiency of the turbine and cost-effective. This is because of the binary steam power plant needs less temperature than the flash steam power plant; about 85 to 170 degree Celsius [3]. If the fluid temperature is less than that, it becomes an uneconomical turbine. This type of turbine can produce a hundred of KW to few MW and costs about 1,500 to 2,550 US$/ KW excluding drilling cost. The overall cost to operate this plant included the temperature of the fluid, size of the turbine and the heat exchange and cooling systems that used in the system.

The advantages of this type are its working by fluid. By using this element, the generator still can produce the electricity although the temperature is lower. This steam system also is most effective and efficient because of the closed-loop system. The heat loss can be minimize and no water loss by using this system.

A new binary-fluid cycle has been developed now, called Kalina. This type used the mixture of the water and ammonia as a working fluid. It can reduce the temperature requirement for the steam turbine and 40 % more efficiency than the existing binary system [3].

CHAPTER 2
LITERATURE REVIEW

2.1 Geological Structure of the Earth

The earth has 5 concentric spheres which are the atmosphere, crust, mantel, liquid outer core (magma) and liquid inner core. The earth's crust is a composed of basalt and silicate rock but the thickness is depending on the other geographical aspects. For example, the thickness of the crust at the land is about 35 km but for the ocean just around 15 km under the sea [2].

There is one layer between the crust and the mantel called Mohorivicic. This boundary is made of vicious and molten rock and the temperature for this layer around 650 to 1250 degree Celsius. It also contains mixtures of magnesium and iron silicates [4].

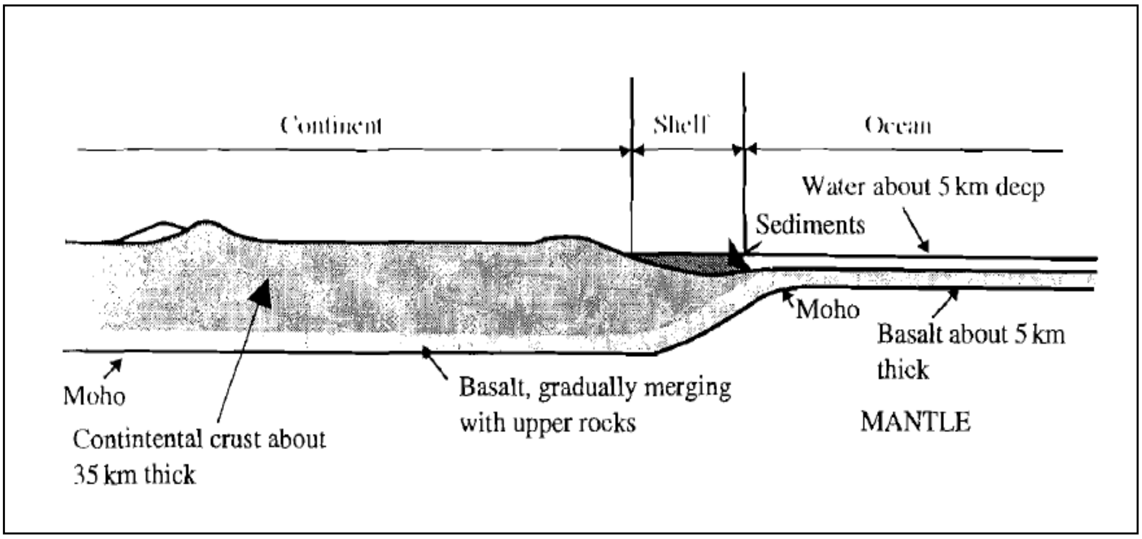

Figure 4 Schematic section of earth's crust [4]

2.2 Thermodynamics of Flash Process

The flashed-steam system is simple and very efficient for steam power plant. For instance, a temperature for entropy diagram for a typical flash process is considered for reservoir liquid at 281 degree Celsius and the corresponding enthalpy is 1241 kJ/kg.

The process involves the reservoir liquid from underground that flashes during its passage up the well to the separation pressure around 7 bars. This pressure will decrease to 0.12 bars when passed through a condensing turbine [4]. The isentropic process is a process where the theoretical maximum power is extracted by a heat engine between an initial and final temperature.

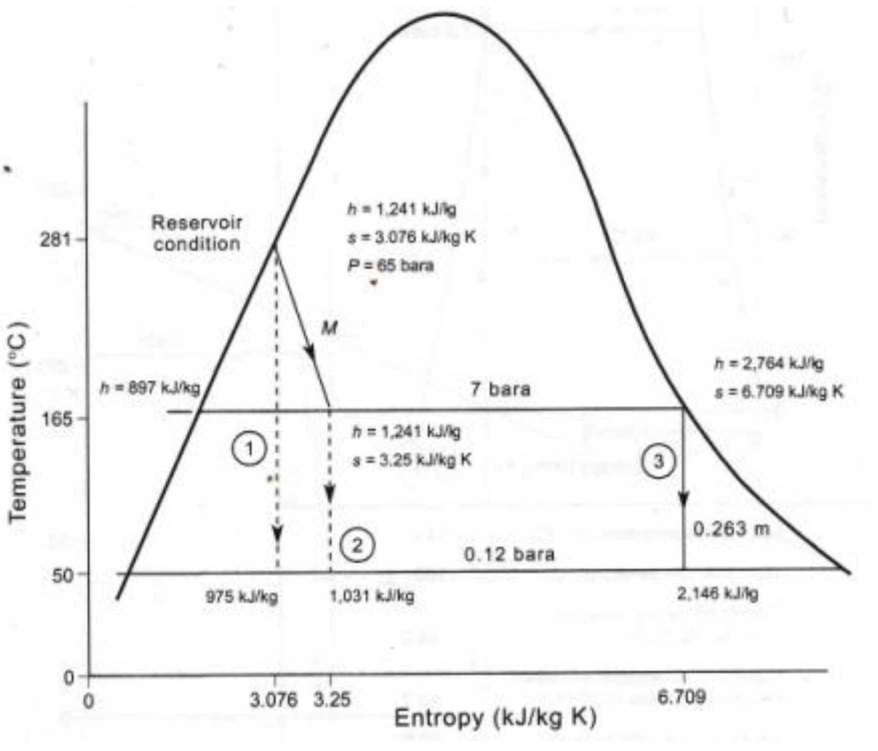

Figure 5 Temperature-entropy diagrams of typical geothermal flashed-steam process and available isentropic heat drop [4]

The first is the maximum power that could be produced using the reservoir fluid at reservoir condition. In practical situation, this condition is impossible without the down-hole pumps; as the well will not flow unless the surface pressure is lower that reservoir pressure. However, assuming the ideal case as the maximum power output had been taken which is 100 per cent. The second case involves the total water and steam that flow from the separator condition. The result will be 79 per cent of case one. Finally, for the third case that using only the separate steam and the result for maximum extractable power output is about 61 per cent from case one.

Case (1) Total flow from reservoir condition

M (1241 – 975) = 266 M kW, $\frac{266}{266}\ x\ 100\ \% = 100\%$

Case (2) Total flow from the optimized separation condition

M (1241 – 1031) = 210 M kW, $\frac{210}{266}\ x\ 100\ \% = 79\%$

Case (3) Optimized separated steam flow through the condensing turbine

0.263 M (1241 – 2146) = 163 M kW, $\frac{163}{266}\ x\ 100\ \% = 61\%$

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

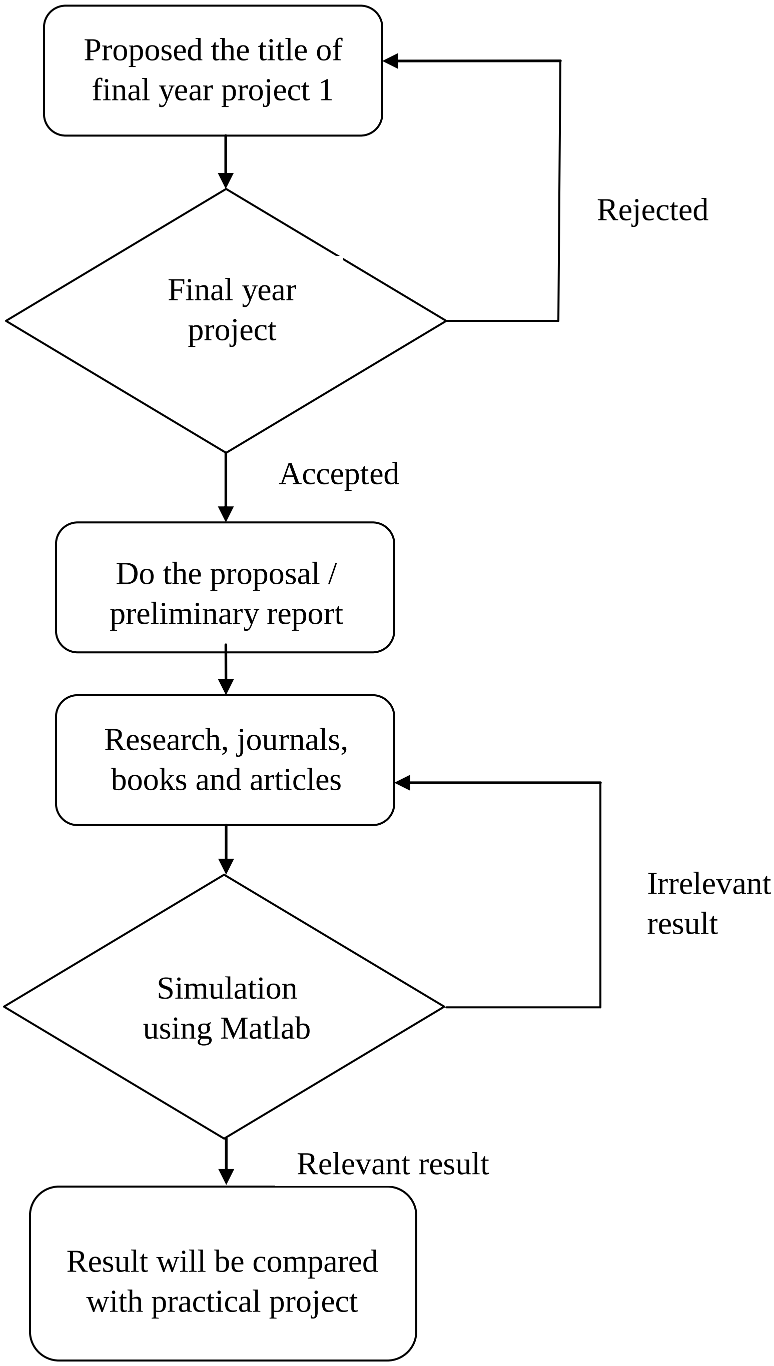

Figure 6 Flow chart for Final Year Project

This project will begin with some research and discuss with supervisor. The topic was selected after doing a proposal to final year project committee and they approve this project without any problem. The main sources for references are the book that related to the geothermal energy, steam turbine and generator. These entire books can easily get from the information research centre (IRC) and some journals at internet.

After review some books, notes and journals, the next step is to do simulations refer to formula and some theoretical note and journal. If the result for the simulation part is totally different from the actual value, the result must be rejecting and find other result or solution. After get the exact value, then the result can be proceed to next step and compare it with prototype or during future work

Main objective for this final year project is to simulate the steam turbine generator by using some formula in Matlab stimulation. This simulation was done by using formula related to minimum heat required generating electricity by using steam turbine. By this stimulation, the efficiency and cost-effectiveness can be calculated

3.2 Prototype for Steam Turbine Systems

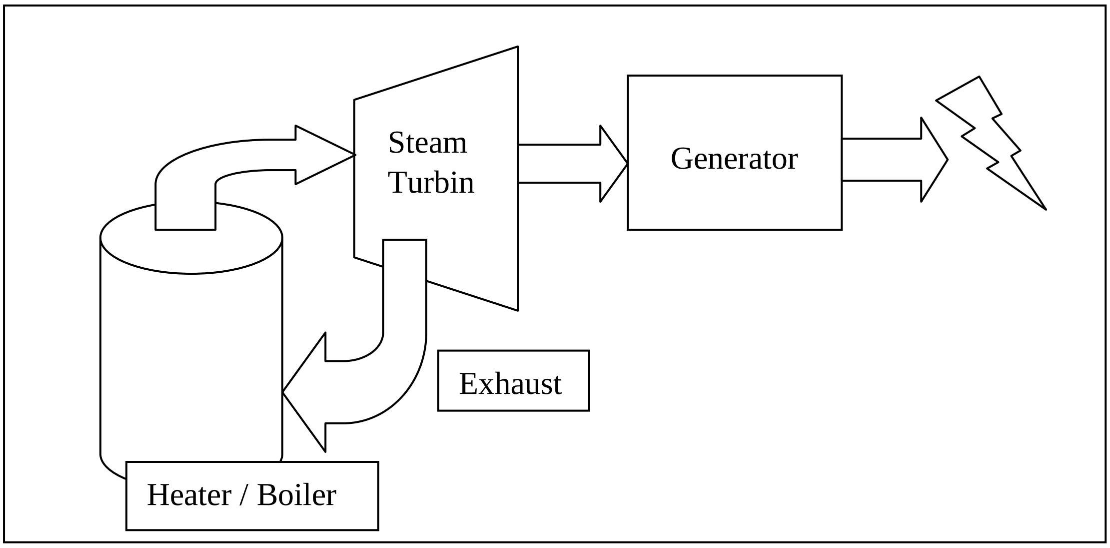

Figure 7 the operation for the steam turbine generation process

Figure 7 showed the operation of steam turbine in this project. The prototype is a practical part to prove the theoretical concept. Thus, the result obtained from this part can be compared to table 3 which will be shown in Chapter 4 (Result & Discussion). There is a close agreement; prototype must be considered for implementation and assuming minimal error such as human error or mechanical error.

For the generator part, there are some errors in theory. The errors such as the core losses, iron losses, stray losses and also mechanical losses. These losses depend on the generator's design itself, better design for the generator will result in better performance. Copper losses depend on the resistive heating that occurs at the stator and the rotor winding machine. The material used for the motor itself will cause the iron losses. If the material for motor can allow more flux density through the material, the iron losses will also increase.

The steam turbine may have other power losses when the operation is in progress. The steam flow from the boiler /heater to the turbine may leak in some place along the pipeline. Inside the turbine, when the heat is converted to kinetic energy there are losses for heat transfer. The environment temperature may affect the total heat transfer progress. The prototype will be divided into 3 sections; input, process and output section.

Input section

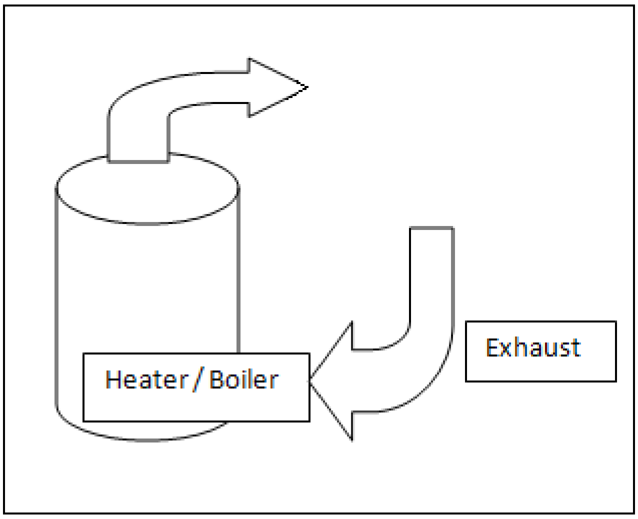

Figure 8 the input section for steam turbine generation process

The beginning of this system is to generate the steam by using a boiler/heater. For this prototype, the heater is used to generate the steam. The steam will flow in a pipeline to steam turbine and move the turbine. The main process in the input section is to produce some amount of steam that having energy including heat and pressure to move the turbine continuously.

The exhaust can be function as a release gauge for the pressure that enters the turbine. This exhaust can be designed as a path for steam to flow back to the boiler / heater so this system is a closed-loop system [5]. By designing the steam flow with recycle or closed-loop system, the efficiency of the boiler /heater can be maximized and the turbine has enough energy to move.

Process Section

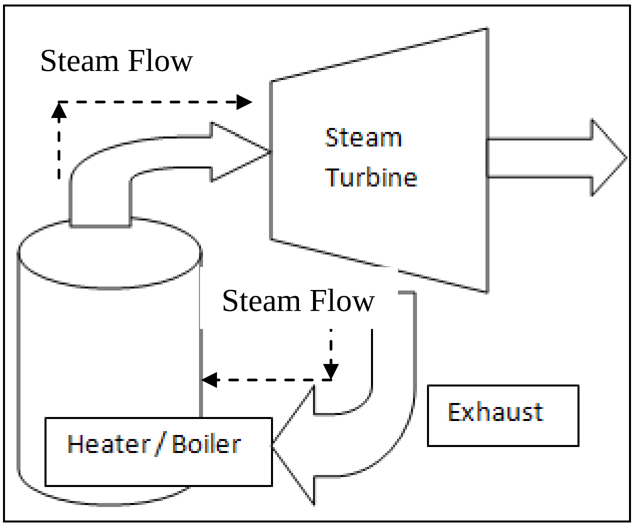

Figure 9 The steam flow at the process section

In this section, the main function of the system takes place, the energy conversion from mechanical to electrical. The steam from the boiler / heater move the blades that make the turbine blade rotate. This rotating motion is a mechanical energy that produces from the turbine and as a prime mover for the generator to generate the electrical energy.

Steam turbine also has some conditions to move the blade. The steam must have enough energy including the temperature and pressure to push and move the blade. If the produced steam can't move the blade, the flow rate for the steam must be increased. The pump must be installed to control the flow rate of the steam.

Output Section

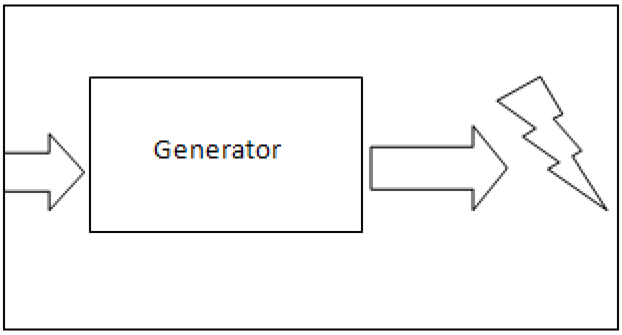

Figure 10 the output at the end of the system

This is the final section of the system; the electricity is produced at the end of the system. The generator can generate the electricity by convert the mechanical energy (blade rotating motion) to the electrical energy. From the rotating blade becomes a prime mover, it rotates the rotor inside the generator and cuts the flux and produces the electrical energy.

For this prototype, the car alternator functions as a generator because the generator set is very expensive and hard to find. The alternator works like a small generator; it must be coupled with prime mover to move the rotor and also has an outlet that produces ac current. The power produced depends on the speed of the turbine (energy of steam) and also the efficiency of the generator itself.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Analysis and Calculation

Net generated electric power

Two main factors that can optimize the application of the steam turbine are the size of exchange heat and the organic fluid used for the system. The operation temperature and the value electric power also must be considered under this condition [8]. The net electric power (NEP) can be calculate by using this formula below:

$$NEP = \frac{[(0.18T-10)ATP]}{278} \qquad \text{..... (1)}$$

where the T is inlet temperature of primary fluid (degree Celsius), and ATP is available thermal power (kW).

The ATP is the heat that available from the geothermal flow and basically the bottom-cycle temperature is less 10 degree Celsius than the conventional value. The bottom-cycle temperature normally can be assuming about 40 degree Celsius.

By using the NEP equation (1), the efficiency of the system can be calculated by rearrange the formula. The efficiency of the system is the ratio of the net electric power to the available thermal power [8].

$$\frac{NEP}{ATP} = \frac{(0.18T-10)}{278} \qquad \text{...... (2)}$$

For example, the efficient of the system can be achieved to 5.0 per cent when the temperature is around 138.97 degree Celsius and for temperature of 100 degree Celsius just around 2.8 per cent. When the temperature of 55.5 degree Celsius or below applied to the system the efficiency is become zero, which means the minimum requirement of the temperature for effective and efficient steam turbine is more that 55.5 degree Celsius.

Table 2 The relation between the temperatures applied (In Celsius) and the efficiency of the system

Temperature applied (Degree Celsius)	Efficiency of the system (in per cent)
55.5	0.00
100.0	2.93
150.0	6.23
250.0	9.52
500.0	29.30
1000.0	62.27
1500.0	95.24

4.2 Steam Turbine Calculation

In an ideal thermodynamic steam turbine, we assume that the turbine as isentropic devices. An isentropic device means that the device has unchanging entropy, same entropy. Calculation for steam turbine can be done by 3 method; using an isentropic assumption, using a specified adiabatic or isentropic efficiency, and using actual manufacture operating data.

For this Final Year Project 1, the author using Adiabatic Turbine Calculation to calculate the power produce for some input pressure that entered the steam turbine. The specified work is calculated with:

$$W = \eta s \times W_{ideal}$$

ηs = Isentropic efficient of turbine

W_{ideal} = Work produced if turbine behaved isentropically

To complete this calculation, some data must be known, such as;

- Input Pressure, P1
- Input temperature , T1
- Output pressure, P2
- Flow rate for steam, m
- Efficiency of turbine, eff
- Actual power output, W_{act}
- Saturated Temperature, T2
- Actual Outlet Fluid Phase, X2a

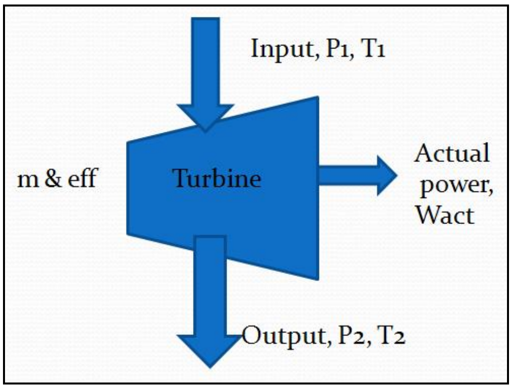

Figure 11 Parameters involved in the calculation using adiabatic method for a steam turbine

Adiabatic Turbine calculation example:

Steam enters a turbine with isentropic efficiency of 0.78 at 12Mpa, at 400 ºC and 0. 3kg/s and exits at 0.15 Mpa.

For input parameters, we can analysis that for P1 =12Mpa and T1 = 400 ºC. By referring to

- saturation pressure table (refer appendix 1) when P1 =12.5Mpa and temperature at 400 ºC , saturation or boiling temperature = 324.75 ºC
- superheated table (refer appendix 2)when P1 =12.5Mpa and temperature at 400 ºC,

h1 = 3051.3 kJ/kg

s1 = 6.0747 kJ/(kg.K)

For output pressure, the output pressure, P2 is 0.15Mpa.The value for sf and sg at saturation pressure table when the pressure is 0.15Mpa is,

sf = 1.4336 (kJ/kg.K)

sg= 7.2233 kJ/(kg.K)

S_{2s} is between 2 values, have two phase mixture

$$X2s = \frac{(S2s - sf)}{(sg - sf)} = \frac{6.0747 - 1.4336}{7.2233 - 1.4336} = 0.802$$

Temperature for output can be found by refer to Mollier graph (refer appendix 3),

T2 = 111.37 ºC

To calculate enthalpy for h_{2s}, the formula shown below

$$h_{2s} = hf\ at\ 0.15Mpa + x2s \times hfg\ at\ 0.15MPa$$

$$= 467.11 + (0.802 \times 2226.5) = 2251.9 \text{ kJ/kg}$$

Work for ideal case W_{ideal} , actual work W_{act}, actual exit enthalpy, h_{2a} and X_{2a} can be calculate as shown below

$$W_{ideal} = m \times [h1 - h2s] = 0.3 \times [3051.3 - 2225.9] = 239.8\ kW$$

$$\text{Wact} = \eta s \times \text{Wideal} = 0.78 \times 239.8 = 187.1 \text{ kW}$$

$$h_{2a} = h1 - \frac{\text{Wact}}{m} = 3051.3 - \frac{187.1}{0.3} = 2427.6\ kJ/kg$$

$$X_{2a} = \frac{h2a - hf}{hg - hf} = \frac{2427.6 - 467.11}{2693.6 - 467.11} = 0.881$$

4.3 Matlab Calculation

All calculation in **4.2 Steam Turbine Calculation** above has been done during Final Year Project 1. Usage of Matlab in this FYP 1 can reduced the time to calculate, avoid the human error and also high accuracy in final answer.

For this FYP 1, Matlab coding was divided by two parts; first part is a coding for saturation pressure table, superheated table and Mollier chart (Refer appendix 3). This part is a reference part because of the input parameters will referred to these table/chart while calculate the output. Second part is a calculation steps for adiabatic method (Refer appendix 4). This part was generated by author itself and these coding are free-error coding.

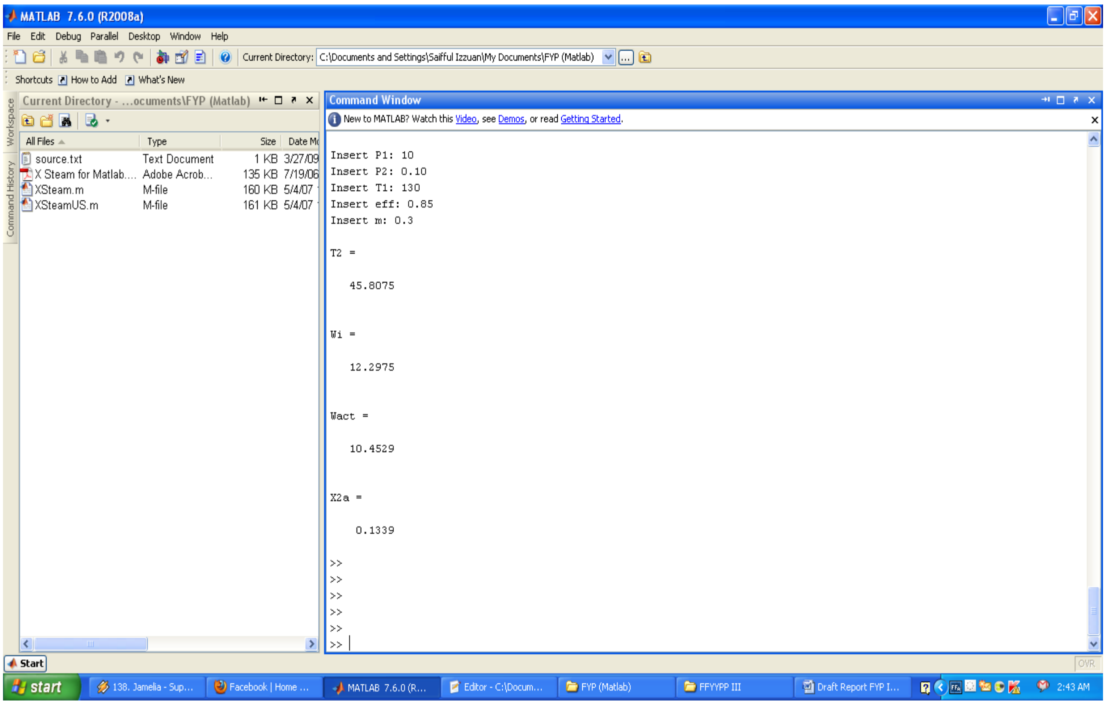

Figure 12 the adiabatic calculation done by using matlab

By using matlab, we can find the minimum requirement for input pressure and temperature to produce electricity that we need. Table 4.2 shown the variable of input pressure with a temperature and we assume the value for mass flow rate and turbine efficiency is constant.

Table 3 the parameters for ground heat generator by using matlab

Input Pressure P1 (Bar)	Input Temperature, T1 (ºC)	Output Pressure, P2 (Bar)	Output Temperature, T2, (ºC)	Work Produce, electricity (KW)	Exit enthalpy, (kJ/kg)	Mass Flow Rate, (kg/s)	Turbine efficiency, 100%
1.0	50	0.5	81.32	1.58	0.0592	0.3	0.85
2.0	60	1.0	99.61	2.45	0.0772	0.3	0.85
5.0	75	2.5	127.41	4.10	0.1076	0.3	0.85
7.5	80	3.75	141.30	5.52	0.1297	0.3	0.85
10.0	**130**	**0.10**	**45.81**	**10.45**	**0.1339**	**0.3**	**0.85**
12.0	150	0.20	60.06	11.48	0.1455	0.3	0.85

According to result above, we can determine the minimum requirement for generator to generate 10 kW is when the input pressure is above 10 Bar with input temperature more than 130 ºC. The greater temperature value for input, more electricity can be produce from the generator. These data can be compared to practical work and the calculation will be proving by result from future work.

4.4 Systems Design

For initial systems, there is a pipeline for an inlet and outlet to flow the steam from the reservoir underground and supply to the plant. Basically the pipelines just have 2 elements; first one for the input known as injection well and the second one are for output part known as production well as shown at figure 13 below. The flow rate for steam inside pipeline can be controlled by adding the pump at the injection well so the speed of the pump can vary the flow rate for the steam.

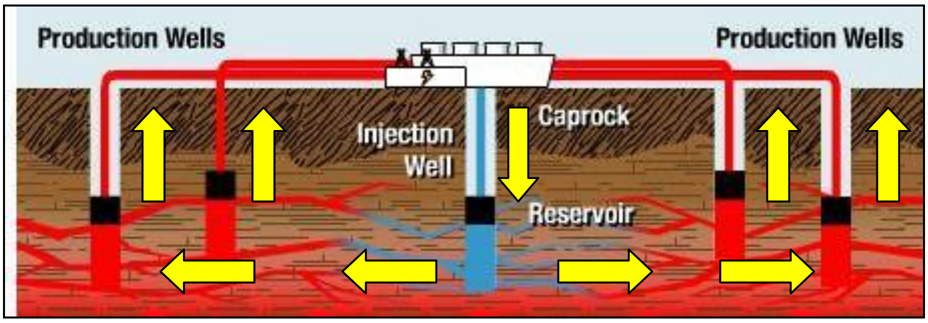

Figure 13 The flow of the steam for the systems

In theory, the steam that flow into the steam turbine is discharge into the turbine in the form of a high-velocity jet from a nozzle that impinges or accurately strikes upon rows of blades mounted on a wheel, whereby the blade is then caused to rotate.

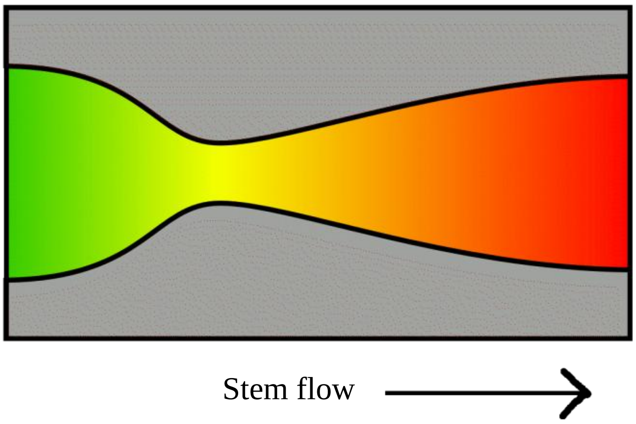

Figure 14 The Laval Nozzle

In order to convert the 'force' energy (pressure) of the steam as efficiently as possible into 'dynamic' energy (kinetic), a so called 'Laval nozzle' (refer to figure 14) are employed - comprising of an inlet portion, a constrict or narrow throat that gradually widens as it gets towards the outlet [11]. As a result of the constriction of the passage followed by a widened outlet portion called diffuser, the pressure of the steam flowing through this nozzle is converted from pressure into velocity.

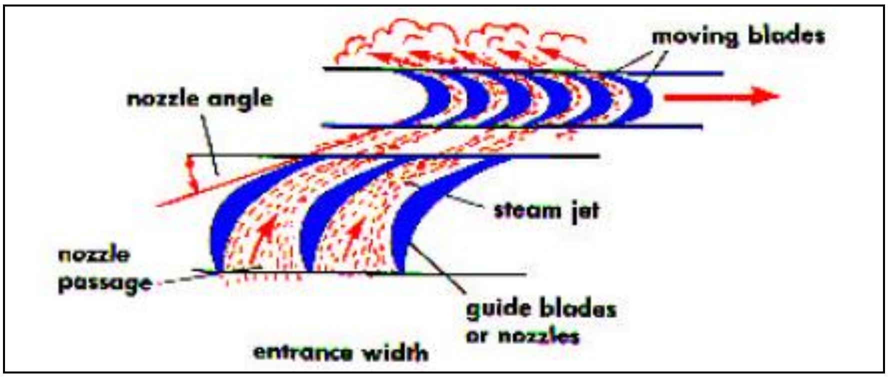

Figure 15 Deflection of the steam jet [11]

The higher the velocity of the steam, the larger is the force that the jet stream is able to exert upon any obstacle or obstruction it encounters. Also, it very much depends upon how much the steam is thereby deflected from its original path. If a wheel is provided with a set of blades which deflect and reroute the steam into very nearly the circumferential direction (at the boundary of its circle, figure 15), then the steam will exert upon the wheel a force in the circumferential direction, causing it to rotate (fig.16).

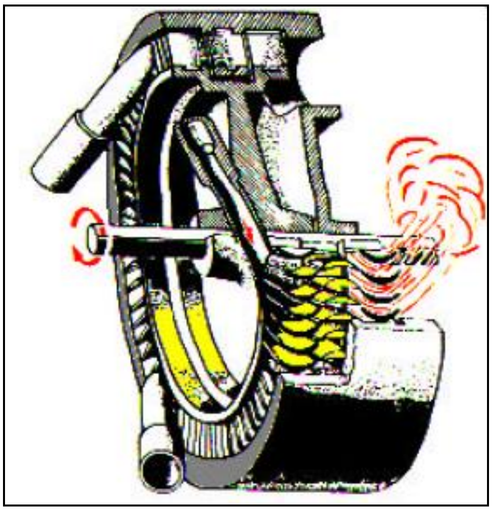

Figure 16 Drive of a wheel with rotor blades [11]

There are 3 conditions for generator to generate voltage; magnetic field, conductor and prime mover. The prime mover in this project is the rotor for the turbine that coupled with the generator's rotor. The magnetic field in generator can be produces by temporary or permanent magnet. This magnetic field is cut by the conductor to induce the current and the voltage will be produce. By refer to the Fehling right-hand rules; once the rotor that contains the coil perpendicularly cut the magnetic field, the current will be induce.

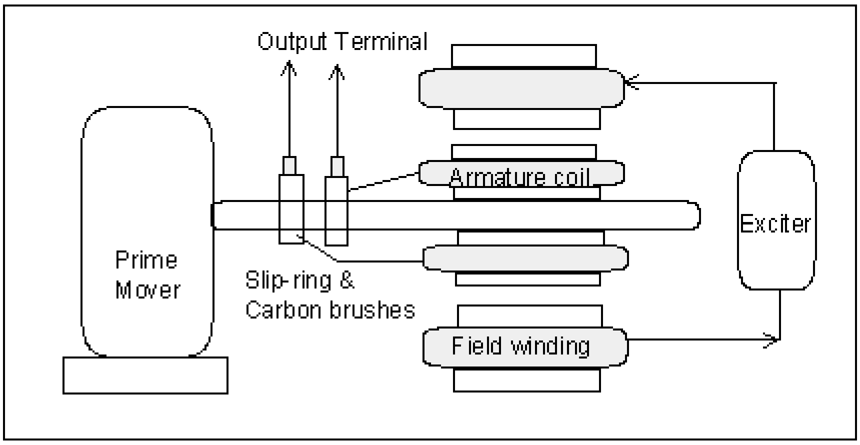

Figure 17 Diagram of single phase generator

Refer to the figure 17, when a prime mover is operating, it will rotate the generator shaft together with the armature coil. An armature coil will cut a magnetic field produced by a field winding when it receives a DC supply (exciting current) from an exciter. Results of this cutting process, an armature coil will induce or generate current

CHAPTER 5
CONCLUSION

5.1 Conclusion

The renewable energy is very important these days due to the existing conditions. Many countries try to reduce pollution by controlling and enforcing the law to factories and houses. This project will bring new idea as to introduce new clean renewable energy, geothermal energy and at the same time reducing pollution and save the world for the next generation.

By done some analysis and calculation, there was proving that the geothermal can provide clean and unlimited energy. Matlab software is used to make the calculation simple and easy to analyze. Besides, to increase the efficiency of the systems, the proper design for whole system had been studied and can be applied.

This project has highlighted various benefits from utilizing geothermal energy. The main objective is no to discourage potential users of geothermal energy but wish to promote this energy as much as possible

5.2 Recommendations

According to the plan, the prototype can be complete during Final Year Project II but in some condition and problems occurs this project will be done later. The actual design for the prototype can be refer in Chapter 3 below the Prototype for Steam Turbine System section. There are some problems occur while completing the prototype for this project.

The problems are not involved in designing part but in the devices or hardware part. For the boiler part, heater is used to be function as a boiler and must produce steam that can have enough temperature and pressure to move the blade for turbine. Although the heater can boil the water until 100 Degree Celsius, but the pressure don’t have enough energy to move the blade for turbine. The steam must achieve certain condition (pressure and temperature) depend on the size or capacity of the turbine so it can move the turbine.

For this project, the home electrical heater was used to become a boiler. Thus, the steam produced didn’t have enough pressure to make the blade for turbine moving. Recommendation for this part is to find suitable boiler that can produce enough pressure rather than using home electric heater.

Moving to steam turbine part, there also have other problems and need more action to solve it. The first problems occur was when to find suitable steam turbine for prototype application. Green Steam Engine was a company that found as a supplier for many type of turbine. Mini steam turbine that require to complete this project is a rare item and difficult to find.

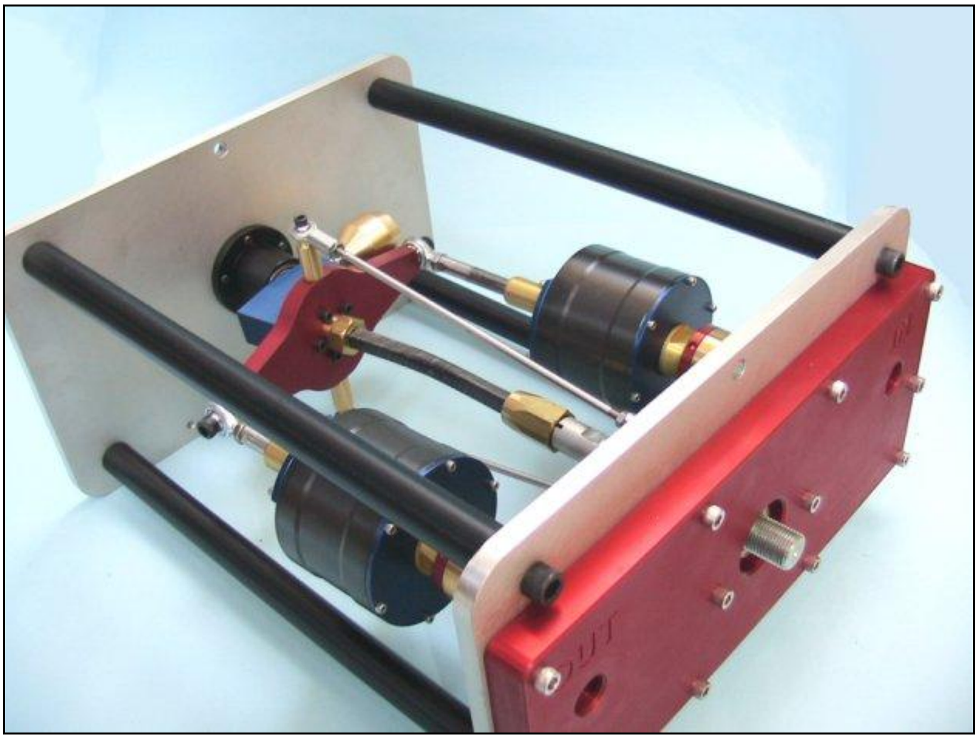

Figure 18 Mini Steam Turbine

The invoice that send by the Green Steam Engine Company shown that the cost for steam turbine and shipping to Malaysia is near to USD 2,000. It is because the company headquarters located at the United State of America and it need a period and more cost for shipping. Thus, after had some discussion with the company, they suggested their other product which was other mini steam turbine. The suggested product was a blueprint for mini steam turbine and must be done by refer to the blueprint given.

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APPENDICES

APPENDIX A

SATURATION PRESSURE TABLE

		Density, kg/m^3		Enthalpy, kJ/kg			Entropy, kJ/(kg·K)			Volume, cm^3/g	
p, MPa	t, °C	ρ_L	ρ_V	h_L	h_V	Δh	s_L	s_V	Δs	v_L	v_V
611.657 Pa	0.01	999.79	0.004 855	0.00	2500.9	2500.9	0.000 00	9.1555	9.1555	1.000 21	205 991.
0.0007	1.881	999.89	0.005 518	7.89	2504.3	2496.5	0.028 78	9.1058	9.0770	1.000 11	181 217.
0.0008	3.761	999.92	0.006 264	15.81	2507.8	2492.0	0.057 48	9.0567	8.9992	1.000 08	159 640.
0.0009	5.444	999.91	0.007 005	22.89	2510.9	2488.0	0.082 97	9.0135	8.9305	1.000 09	142 757.
0.0010	6.970	999.86	0.007 741	29.30	2513.7	2484.4	0.105 91	8.9749	8.8690	1.000 14	129 178.
0.0012	9.654	999.68	0.009 202	40.57	2518.6	2478.0	0.145 95	8.9082	8.7623	1.000 32	108 670.
0.0014	11.969	999.46	0.010 650	50.28	2522.8	2472.5	0.180 15	8.8521	8.6719	1.000 54	93 899.
0.0016	14.010	999.20	0.012 086	58.83	2526.5	2467.7	0.210 04	8.8035	8.5935	1.000 80	82 743.
0.0018	15.837	998.93	0.013 511	66.49	2529.9	2463.4	0.236 62	8.7608	8.5241	1.001 08	74 011.
0.0020	17.495	998.64	0.014 928	73.43	2532.9	2459.4	0.260 56	8.7226	8.4620	1.001 36	66 987.
0.0024	20.414	998.08	0.017 738	85.65	2538.2	2452.5	0.302 39	8.6567	8.3544	1.001 93	56 375.
0.0028	22.935	997.51	0.020 522	96.19	2542.8	2446.6	0.338 16	8.6012	8.2631	1.002 49	48 729.
0.0032	25.158	996.96	0.023 282	105.49	2546.8	2441.3	0.369 45	8.5533	8.1838	1.003 05	42 952.
0.0036	27.152	996.43	0.026 021	113.83	2550.4	2436.6	0.397 29	8.5110	8.1138	1.003 58	38 430.
0.0040	28.960	995.92	0.028 743	121.39	2553.7	2432.3	0.422 39	8.4734	8.0510	1.004 10	34 791.
0.0045	31.012	995.30	0.032 122	129.96	2557.4	2427.4	0.450 69	8.4313	7.9806	1.004 73	31 131.
0.0050	32.874	994.70	0.035 480	137.75	2560.7	2423.0	0.476 20	8.3938	7.9176	1.005 33	28 185.
0.0055	34.581	994.13	0.038 816	144.88	2563.8	2418.9	0.499 45	8.3599	7.8605	1.005 90	25 762.
0.0060	36.159	993.59	0.042 135	151.48	2566.6	2415.2	0.520 82	8.3290	7.8082	1.006 45	23 733.
0.0065	37.627	993.06	0.045 436	157.61	2569.3	2411.6	0.540 60	8.3007	7.7601	1.006 99	22 009.
0.0070	39.000	992.55	0.048 722	163.35	2571.7	2408.4	0.559 03	8.2745	7.7154	1.007 50	20 524.
0.0075	40.290	992.06	0.051 994	168.75	2574.0	2405.3	0.576 27	8.2501	7.6738	1.008 00	19 233.
0.0080	41.509	991.59	0.055 252	173.84	2576.2	2402.4	0.592 49	8.2273	7.6348	1.008 48	18 099.
0.0085	42.663	991.13	0.058 498	178.67	2578.3	2399.6	0.607 80	8.2060	7.5982	1.008 95	17 095.
0.0090	43.761	990.69	0.061 731	183.25	2580.2	2397.0	0.622 30	8.1858	7.5635	1.009 40	16 199.
0.0095	44.807	990.25	0.064 954	187.63	2582.1	2394.5	0.636 07	8.1668	7.5308	1.009 84	15 396.
0.010	45.806	989.83	0.068 166	191.81	2583.9	2392.1	0.649 20	8.1488	7.4996	1.010 27	14 670.
0.011	47.683	989.03	0.074 560	199.65	2587.2	2387.5	0.673 72	8.1154	7.4417	1.011 10	13 412.
0.012	49.419	988.26	0.080 917	206.91	2590.3	2383.4	0.696 28	8.0849	7.3887	1.011 88	12 358.
0.013	51.034	987.53	0.087 242	213.67	2593.1	2379.4	0.717 17	8.0570	7.3398	1.012 63	11 462.
0.014	52.547	986.82	0.093 535	219.99	2595.8	2375.8	0.736 64	8.0311	7.2945	1.013 35	10 691.
0.016	55.313	985.50	0.106 04	231.57	2600.6	2369.1	0.772 01	7.9846	7.2126	1.014 71	9430.6
0.018	57.798	984.28	0.118 44	241.96	2605.0	2363.0	0.803 55	7.9437	7.1402	1.015 97	8443.1
0.020	60.058	983.13	0.130 75	251.42	2608.9	2357.5	0.832 02	7.9072	7.0752	1.017 16	7648.0
0.024	64.053	981.03	0.155 15	268.15	2615.9	2347.7	0.881 91	7.8442	6.9623	1.019 34	6445.3
0.028	67.518	979.13	0.179 28	282.66	2621.8	2339.2	0.924 72	7.7912	6.8664	1.021 31	5577.8
0.032	70.586	977.40	0.203 19	295.52	2627.1	2331.6	0.962 28	7.7453	6.7830	1.023 12	4921.5
0.036	73.345	975.80	0.226 90	307.09	2631.8	2324.7	0.995 79	7.7050	6.7092	1.024 80	4407.2
0.040	75.857	974.30	0.250 44	317.62	2636.1	2318.4	1.0261	7.6690	6.6429	1.026 38	3993.0
0.045	78.715	972.56	0.279 65	329.62	2640.9	2311.2	1.0603	7.6288	6.5686	1.028 21	3575.9
0.050	81.317	970.94	0.308 64	340.54	2645.2	2304.7	1.0912	7.5930	6.5018	1.029 93	3240.0
0.055	83.709	969.42	0.337 44	350.59	2649.2	2298.6	1.1194	7.5606	6.4412	1.031 54	2963.5
0.060	85.926	967.99	0.366 07	359.91	2652.9	2292.9	1.1454	7.5311	6.3857	1.033 07	2731.7
0.065	87.993	966.63	0.394 54	368.60	2656.3	2287.7	1.1696	7.5040	6.3345	1.034 52	2534.6
0.070	89.932	965.34	0.422 87	376.75	2659.4	2282.7	1.1921	7.4790	6.2869	1.035 90	2364.8
0.075	91.758	964.11	0.451 07	384.44	2662.4	2277.9	1.2132	7.4557	6.2425	1.037 23	2217.0
0.080	93.486	962.93	0.479 14	391.71	2665.2	2273.5	1.2330	7.4339	6.2009	1.038 50	2087.1
0.085	95.125	961.79	0.507 09	398.62	2667.8	2269.2	1.2518	7.4135	6.1617	1.039 72	1972.0
0.090	96.687	960.70	0.534 94	405.20	2670.3	2265.1	1.2696	7.3943	6.1246	1.040 91	1869.4
0.095	98.178	959.65	0.562 69	411.48	2672.7	2261.2	1.2866	7.3761	6.0895	1.042 05	1777.2
0.10	99.606	958.63	0.590 34	417.50	2674.9	2257.4	1.3028	7.3588	6.0561	1.043 15	1693.9
0.11	102.292	956.69	0.645 39	428.84	2679.2	2250.3	1.3330	7.3269	5.9938	1.045 27	1549.5
0.12	104.784	954.86	0.700 10	439.36	2683.1	2243.7	1.3609	7.2977	5.9367	1.047 27	1428.4
0.13	107.109	953.13	0.754 53	449.19	2686.6	2237.5	1.3868	7.2709	5.8840	1.049 17	1325.3
0.14	109.292	951.49	0.808 69	458.42	2690.0	2231.6	1.4110	7.2461	5.8351	1.050 99	1236.6

p, MPa	t, °C	Density, kg/m^3		Enthalpy, kJ/kg			Entropy, kJ/(kg·K)			Volume, cm^3/g	
		ρ_L	ρ_V	h_L	h_V	Δh	s_L	s_V	Δs	v_L	v_V
0.15	111.349	949.92	0.862 60	467.13	2693.1	2226.0	1.4337	7.2230	5.7893	1.052 73	1159.3
0.16	113.297	948.41	0.916 29	475.38	2696.0	2220.7	1.4551	7.2014	5.7463	1.054 40	1091.4
0.17	115.148	946.97	0.969 76	483.22	2698.8	2215.6	1.4753	7.1812	5.7059	1.056 00	1031.2
0.18	116.911	945.57	1.0230	490.70	2701.4	2210.7	1.4945	7.1621	5.6676	1.057 56	977.47
0.19	118.596	944.23	1.0761	497.85	2703.9	2206.0	1.5127	7.1440	5.6313	1.059 06	929.24
0.20	120.210	942.94	1.1291	504.70	2706.2	2201.5	1.5302	7.1269	5.5967	1.060 52	885.68
0.21	121.759	941.68	1.1818	511.29	2708.5	2197.2	1.5469	7.1106	5.5638	1.061 93	846.14
0.22	123.250	940.47	1.2345	517.63	2710.6	2193.0	1.5628	7.0951	5.5323	1.063 30	810.07
0.23	124.686	939.28	1.2869	523.74	2712.7	2188.9	1.5782	7.0803	5.5021	1.064 64	777.04
0.24	126.072	938.13	1.3393	529.64	2714.6	2185.0	1.5930	7.0661	5.4731	1.065 94	746.68
0.25	127.411	937.02	1.3915	535.34	2716.5	2181.1	1.6072	7.0524	5.4452	1.067 22	718.66
0.26	128.708	935.93	1.4436	540.87	2718.3	2177.4	1.6210	7.0394	5.4184	1.068 46	692.73
0.27	129.965	934.86	1.4955	546.24	2720.0	2173.8	1.6343	7.0268	5.3925	1.069 68	668.65
0.28	131.185	933.83	1.5474	551.44	2721.7	2170.3	1.6471	7.0146	5.3675	1.070 86	646.24
0.29	132.370	932.81	1.5992	556.50	2723.3	2166.8	1.6596	7.0029	5.3433	1.072 03	625.33
0.30	133.522	931.82	1.6508	561.43	2724.9	2163.5	1.6717	6.9916	5.3199	1.073 17	605.76
0.31	134.644	930.85	1.7024	566.22	2726.4	2160.2	1.6835	6.9807	5.2972	1.074 29	587.41
0.32	135.737	929.90	1.7539	570.90	2727.8	2157.0	1.6949	6.9701	5.2752	1.075 39	570.17
0.33	136.802	928.96	1.8052	575.46	2729.3	2153.8	1.7060	6.9598	5.2538	1.076 47	553.95
0.34	137.842	928.05	1.8565	579.91	2730.6	2150.7	1.7168	6.9498	5.2330	1.077 53	538.64
0.35	138.857	927.15	1.9077	584.26	2732.0	2147.7	1.7274	6.9401	5.2128	1.078 57	524.18
0.36	139.849	926.27	1.9589	588.52	2733.2	2144.7	1.7377	6.9307	5.1931	1.079 60	510.50
0.37	140.819	925.40	2.0099	592.68	2734.5	2141.8	1.7477	6.9216	5.1739	1.080 61	497.53
0.38	141.769	924.55	2.0609	596.75	2735.7	2139.0	1.7575	6.9126	5.1551	1.081 61	485.22
0.39	142.698	923.71	2.1119	600.74	2736.9	2136.2	1.7671	6.9040	5.1369	1.082 59	473.52
0.40	143.608	922.89	2.1627	604.65	2738.1	2133.4	1.7765	6.8955	5.1190	1.083 55	462.38
0.42	145.375	921.28	2.2642	612.25	2740.3	2128.0	1.7946	6.8791	5.0846	1.085 44	441.65
0.44	147.076	919.72	2.3655	619.58	2742.4	2122.8	1.8120	6.8636	5.0516	1.087 29	422.74
0.46	148.716	918.20	2.4666	626.64	2744.4	2117.7	1.8287	6.8487	5.0199	1.089 08	405.42
0.48	150.300	916.73	2.5674	633.47	2746.3	2112.8	1.8448	6.8344	4.9895	1.090 84	389.50
0.50	151.831	915.29	2.6680	640.09	2748.1	2108.0	1.8604	6.8207	4.9603	1.092 55	374.81
0.52	153.314	913.89	2.7685	646.50	2749.9	2103.4	1.8754	6.8075	4.9321	1.094 23	361.20
0.54	154.753	912.52	2.8688	652.72	2751.5	2098.8	1.8899	6.7948	4.9049	1.095 87	348.58
0.56	156.149	911.18	2.9689	658.77	2753.1	2094.4	1.9040	6.7825	4.8786	1.097 48	336.82
0.58	157.506	909.87	3.0689	664.65	2754.7	2090.0	1.9176	6.7707	4.8531	1.099 05	325.85
0.60	158.826	908.59	3.1687	670.38	2756.1	2085.8	1.9308	6.7592	4.8284	1.100 60	315.58
0.62	160.112	907.34	3.2684	675.96	2757.6	2081.6	1.9437	6.7482	4.8045	1.102 12	305.96
0.64	161.365	906.11	3.3680	681.41	2758.9	2077.5	1.9562	6.7374	4.7813	1.103 62	296.91
0.66	162.587	904.91	3.4675	686.73	2760.3	2073.5	1.9684	6.7270	4.7587	1.105 09	288.40
0.68	163.781	903.72	3.5668	691.92	2761.5	2069.6	1.9802	6.7169	4.7367	1.106 54	280.36
0.70	164.946	902.56	3.6660	697.00	2762.8	2065.8	1.9918	6.7071	4.7153	1.107 96	272.77
0.72	166.086	901.42	3.7652	701.97	2763.9	2062.0	2.0031	6.6975	4.6944	1.109 36	265.59
0.74	167.200	900.30	3.8642	706.84	2765.1	2058.2	2.0141	6.6882	4.6741	1.110 75	258.79
0.76	168.291	899.19	3.9631	711.61	2766.2	2054.6	2.0248	6.6791	4.6543	1.112 11	252.33
0.78	169.360	898.10	4.0620	716.28	2767.3	2051.0	2.0354	6.6703	4.6349	1.113 46	246.18
0.80	170.406	897.04	4.1608	720.86	2768.3	2047.4	2.0457	6.6616	4.6160	1.114 78	240.34
0.82	171.433	895.98	4.2595	725.36	2769.3	2043.9	2.0557	6.6532	4.5975	1.116 09	234.77
0.84	172.440	894.94	4.3581	729.78	2770.3	2040.5	2.0656	6.6449	4.5793	1.117 39	229.46
0.86	173.428	893.92	4.4567	734.11	2771.2	2037.1	2.0753	6.6369	4.5616	1.118 67	224.38
0.88	174.398	892.91	4.5552	738.37	2772.1	2033.8	2.0847	6.6290	4.5443	1.119 93	219.53
0.90	175.350	891.92	4.6536	742.56	2773.0	2030.5	2.0940	6.6213	4.5272	1.121 18	214.89
0.92	176.287	890.93	4.7520	746.68	2773.9	2027.2	2.1032	6.6137	4.5106	1.122 42	210.44
0.94	177.207	889.96	4.8503	750.73	2774.7	2024.0	2.1121	6.6063	4.4942	1.123 64	206.17
0.96	178.112	889.01	4.9486	754.72	2775.5	2020.8	2.1209	6.5991	4.4782	1.124 85	202.08
0.98	179.002	888.06	5.0468	758.65	2776.3	2017.7	2.1296	6.5920	4.4624	1.126 05	198.14

p, MPa	t, °C	Density, kg/m³ ρ_L	ρ_V	Enthalpy, kJ/kg h_L	h_V	Δh	Entropy, kJ/(kg·K) s_L	s_V	Δs	Volume, cm³/g v_L	v_V
1.00	179.878	887.13	5.1450	762.52	2777.1	2014.6	2.1381	6.5850	4.4470	1.127 23	194.36
1.05	182.009	884.84	5.3903	771.94	2778.9	2007.0	2.1587	6.5681	4.4095	1.130 14	185.52
1.10	184.062	882.62	5.6354	781.03	2780.6	1999.6	2.1785	6.5520	4.3735	1.132 99	177.45
1.15	186.043	880.46	5.8804	789.82	2782.2	1992.4	2.1976	6.5365	4.3390	1.135 77	170.06
1.20	187.957	878.35	6.1251	798.33	2783.7	1985.4	2.2159	6.5217	4.3058	1.138 50	163.26
1.25	189.809	876.29	6.3698	806.58	2785.1	1978.6	2.2337	6.5074	4.2737	1.141 18	156.99
1.30	191.605	874.28	6.6144	814.60	2786.5	1971.9	2.2508	6.4936	4.2428	1.143 80	151.19
1.35	193.347	872.31	6.8589	822.39	2787.7	1965.3	2.2674	6.4803	4.2129	1.146 38	145.80
1.40	195.039	870.39	7.1034	829.97	2788.8	1958.9	2.2835	6.4675	4.1839	1.148 92	140.78
1.45	196.685	868.50	7.3479	837.35	2789.9	1952.6	2.2992	6.4550	4.1559	1.151 41	136.09
1.50	198.287	866.65	7.5924	844.56	2791.0	1946.4	2.3143	6.4430	4.1286	1.153 87	131.71
1.55	199.848	864.84	7.8369	851.59	2791.9	1940.3	2.3291	6.4313	4.1022	1.156 29	127.60
1.60	201.370	863.05	8.0815	858.46	2792.8	1934.4	2.3435	6.4199	4.0765	1.158 68	123.74
1.65	202.856	861.30	8.3261	865.17	2793.7	1928.5	2.3575	6.4089	4.0514	1.161 03	120.10
1.70	204.307	859.58	8.5708	871.74	2794.5	1922.7	2.3711	6.3981	4.0270	1.163 36	116.67
1.75	205.725	857.89	8.8156	878.17	2795.2	1917.0	2.3845	6.3877	4.0032	1.165 65	113.43
1.80	207.112	856.22	9.0606	884.47	2795.9	1911.4	2.3975	6.3775	3.9800	1.167 92	110.37
1.85	208.469	854.58	9.3056	890.65	2796.6	1905.9	2.4102	6.3675	3.9573	1.170 16	107.46
1.90	209.798	852.96	9.5508	896.71	2797.2	1900.5	2.4227	6.3578	3.9351	1.172 38	104.70
1.95	211.101	851.37	9.7962	902.66	2797.8	1895.1	2.4348	6.3483	3.9135	1.174 58	102.08
2.0	212.377	849.80	10.042	908.50	2798.3	1889.8	2.4468	6.3390	3.8923	1.176 75	99.585
2.1	214.858	846.72	10.533	919.87	2799.3	1879.4	2.4699	6.3210	3.8511	1.181 03	94.938
2.2	217.249	843.72	11.026	930.87	2800.1	1869.2	2.4921	6.3038	3.8116	1.185 23	90.698
2.3	219.557	840.79	11.519	941.53	2800.8	1859.3	2.5136	6.2872	3.7736	1.189 36	86.815
2.4	221.789	837.92	12.013	951.87	2801.4	1849.6	2.5343	6.2712	3.7369	1.193 43	83.244
2.5	223.950	835.12	12.508	961.91	2801.9	1840.0	2.5543	6.2558	3.7015	1.197 43	79.949
2.6	226.046	832.37	13.004	971.67	2802.3	1830.7	2.5736	6.2409	3.6672	1.201 38	76.899
2.7	228.080	829.68	13.501	981.18	2802.7	1821.5	2.5924	6.2264	3.6340	1.205 28	74.066
2.8	230.057	827.04	14.000	990.46	2802.9	1812.4	2.6106	6.2124	3.6018	1.209 13	71.429
2.9	231.980	824.45	14.500	999.51	2803.1	1803.6	2.6283	6.1988	3.5705	1.212 93	68.968
3.0	233.853	821.90	15.001	1008.3	2803.2	1794.8	2.6455	6.1856	3.5400	1.216 69	66.664
3.1	235.679	819.39	15.503	1017.0	2803.2	1786.2	2.6623	6.1727	3.5104	1.220 42	64.504
3.2	237.459	816.92	16.006	1025.4	2803.1	1777.7	2.6787	6.1602	3.4815	1.224 10	62.475
3.3	239.198	814.49	16.512	1033.7	2803.0	1769.3	2.6946	6.1479	3.4533	1.227 76	60.564
3.4	240.897	812.10	17.018	1041.8	2802.9	1761.0	2.7102	6.1360	3.4258	1.231 38	58.761
3.5	242.557	809.74	17.526	1049.8	2802.6	1752.8	2.7254	6.1243	3.3989	1.234 97	57.058
3.6	244.182	807.41	18.036	1057.6	2802.4	1744.8	2.7403	6.1129	3.3726	1.238 54	55.446
3.7	245.772	805.10	18.547	1065.3	2802.1	1736.8	2.7549	6.1018	3.3469	1.242 08	53.918
3.8	247.330	802.83	19.059	1072.8	2801.7	1728.9	2.7691	6.0908	3.3217	1.245 59	52.467
3.9	248.857	800.59	19.574	1080.2	2801.3	1721.1	2.7831	6.0801	3.2970	1.249 08	51.089
4.0	250.354	798.37	20.090	1087.5	2800.8	1713.3	2.7968	6.0696	3.2728	1.252 56	49.776
4.1	251.823	796.17	20.608	1094.7	2800.3	1705.7	2.8102	6.0592	3.2491	1.256 01	48.525
4.2	253.264	794.00	21.127	1101.7	2799.8	1698.1	2.8234	6.0491	3.2257	1.259 44	47.332
4.3	254.680	791.85	21.649	1108.7	2799.2	1690.6	2.8363	6.0391	3.2028	1.262 86	46.192
4.4	256.070	789.73	22.172	1115.5	2798.6	1683.1	2.8490	6.0293	3.1803	1.266 26	45.102
4.5	257.437	787.62	22.697	1122.2	2797.9	1675.7	2.8615	6.0197	3.1582	1.269 65	44.059
4.6	258.780	785.53	23.224	1128.9	2797.3	1668.4	2.8738	6.0102	3.1364	1.273 02	43.059
4.7	260.101	783.47	23.753	1135.5	2796.5	1661.1	2.8859	6.0009	3.1150	1.276 38	42.100
4.8	261.402	781.42	24.284	1141.9	2795.8	1653.9	2.8978	5.9917	3.0939	1.279 73	41.180
4.9	262.681	779.38	24.816	1148.3	2795.0	1646.7	2.9095	5.9826	3.0731	1.283 06	40.296
5.0	263.941	777.37	25.351	1154.6	2794.2	1639.6	2.9210	5.9737	3.0527	1.286 39	39.446
5.1	265.181	775.37	25.888	1160.9	2793.4	1632.5	2.9323	5.9648	3.0325	1.289 71	38.628
5.2	266.403	773.39	26.427	1167.0	2792.5	1625.5	2.9435	5.9561	3.0126	1.293 02	37.840
5.3	267.608	771.42	26.968	1173.1	2791.6	1618.5	2.9546	5.9475	2.9930	1.296 32	37.081
5.4	268.795	769.46	27.512	1179.1	2790.7	1611.5	2.9654	5.9391	2.9736	1.299 61	36.348

p, MPa	t, °C	Density, kg/m^3		Enthalpy, kJ/kg			Entropy, kJ/(kg·K)			Volume, cm^3/g	
		ρ_L	ρ_V	h_L	h_V	Δh	s_L	s_V	Δs	v_L	v_V
5.5	269.965	767.52	28.057	1185.1	2789.7	1604.6	2.9762	5.9307	2.9545	1.302 90	35.642
5.6	271.120	765.59	28.605	1191.0	2788.7	1597.8	2.9868	5.9224	2.9356	1.306 18	34.959
5.7	272.258	763.67	29.155	1196.8	2787.7	1590.9	2.9972	5.9142	2.9170	1.309 46	34.300
5.8	273.382	761.77	29.707	1202.6	2786.7	1584.1	3.0075	5.9061	2.8985	1.312 73	33.662
5.9	274.490	759.88	30.262	1208.3	2785.7	1577.4	3.0177	5.8981	2.8803	1.316 00	33.045
6.0	275.585	758.00	30.818	1213.9	2784.6	1570.7	3.0278	5.8901	2.8623	1.319 26	32.448
6.1	276.666	756.13	31.378	1219.5	2783.5	1564.0	3.0377	5.8823	2.8445	1.322 53	31.870
6.2	277.733	754.27	31.940	1225.1	2782.4	1557.3	3.0476	5.8745	2.8269	1.325 79	31.309
6.3	278.787	752.42	32.504	1230.5	2781.2	1550.7	3.0573	5.8668	2.8095	1.329 05	30.766
6.4	279.829	750.58	33.070	1236.0	2780.1	1544.1	3.0669	5.8592	2.7923	1.332 30	30.238
6.5	280.858	748.75	33.640	1241.4	2778.9	1537.5	3.0764	5.8516	2.7752	1.335 56	29.727
6.6	281.875	746.93	34.211	1246.7	2777.7	1530.9	3.0858	5.8441	2.7583	1.338 82	29.230
6.7	282.880	745.11	34.786	1252.0	2776.4	1524.4	3.0951	5.8367	2.7416	1.342 08	28.747
6.8	283.874	743.31	35.363	1257.3	2775.2	1517.9	3.1043	5.8293	2.7250	1.345 33	28.278
6.9	284.857	741.51	35.943	1262.5	2773.9	1511.4	3.1134	5.8220	2.7086	1.348 59	27.822
7.0	285.829	739.72	36.525	1267.7	2772.6	1505.0	3.1224	5.8148	2.6924	1.351 86	27.378
7.1	286.790	737.94	37.110	1272.8	2771.3	1498.5	3.1313	5.8076	2.6762	1.355 12	26.947
7.2	287.741	736.17	37.698	1277.9	2770.0	1492.1	3.1402	5.8004	2.6603	1.358 39	26.526
7.3	288.682	734.40	38.289	1282.9	2768.6	1485.7	3.1489	5.7933	2.6444	1.361 66	26.117
7.4	289.614	732.64	38.883	1287.9	2767.3	1479.3	3.1576	5.7863	2.6287	1.364 93	25.718
7.5	290.535	730.88	39.479	1292.9	2765.9	1473.0	3.1662	5.7793	2.6131	1.368 21	25.330
7.6	291.448	729.14	40.079	1297.9	2764.5	1466.6	3.1747	5.7723	2.5976	1.371 49	24.951
7.7	292.351	727.39	40.681	1302.8	2763.1	1460.3	3.1832	5.7654	2.5823	1.374 77	24.581
7.8	293.245	725.66	41.287	1307.7	2761.6	1454.0	3.1915	5.7586	2.5671	1.378 06	24.221
7.9	294.131	723.92	41.895	1312.5	2760.2	1447.7	3.1998	5.7518	2.5519	1.381 36	23.869
8.0	295.008	722.20	42.507	1317.3	2758.7	1441.4	3.2081	5.7450	2.5369	1.384 67	23.526
8.1	295.876	720.47	43.122	1322.1	2757.2	1435.1	3.2162	5.7383	2.5220	1.387 97	23.190
8.2	296.737	718.76	43.740	1326.8	2755.7	1428.8	3.2243	5.7316	2.5072	1.391 29	22.863
8.3	297.589	717.04	44.361	1331.6	2754.1	1422.6	3.2324	5.7249	2.4925	1.394 61	22.542
8.4	298.434	715.34	44.985	1336.3	2752.6	1416.3	3.2403	5.7183	2.4779	1.397 95	22.229
8.5	299.271	713.63	45.613	1340.9	2751.0	1410.1	3.2483	5.7117	2.4634	1.401 28	21.923
8.6	300.100	711.93	46.244	1345.6	2749.4	1403.9	3.2561	5.7051	2.4490	1.404 63	21.624
8.7	300.922	710.23	46.879	1350.2	2747.8	1397.7	3.2639	5.6986	2.4347	1.407 99	21.332
8.8	301.737	708.54	47.517	1354.8	2746.2	1391.5	3.2717	5.6921	2.4204	1.411 35	21.045
8.9	302.544	706.85	48.159	1359.3	2744.6	1385.3	3.2793	5.6856	2.4062	1.414 73	20.765
9.0	303.345	705.16	48.804	1363.9	2742.9	1379.1	3.2870	5.6791	2.3922	1.418 11	20.490
9.1	304.139	703.48	49.453	1368.4	2741.3	1372.9	3.2946	5.6727	2.3782	1.421 51	20.221
9.2	304.926	701.80	50.105	1372.9	2739.6	1366.7	3.3021	5.6663	2.3642	1.424 91	19.958
9.3	305.707	700.12	50.761	1377.4	2737.9	1360.5	3.3096	5.6599	2.3504	1.428 33	19.700
9.4	306.481	698.44	51.421	1381.8	2736.2	1354.4	3.3170	5.6536	2.3366	1.431 76	19.447
9.5	307.249	696.77	52.085	1386.2	2734.4	1348.2	3.3244	5.6473	2.3229	1.435 20	19.199
9.6	308.010	695.09	52.753	1390.6	2732.7	1342.0	3.3317	5.6410	2.3092	1.438 65	18.956
9.7	308.766	693.42	53.424	1395.0	2730.9	1335.9	3.3390	5.6347	2.2957	1.442 12	18.718
9.8	309.516	691.76	54.100	1399.4	2729.1	1329.7	3.3463	5.6284	2.2822	1.445 60	18.484
9.9	310.259	690.09	54.779	1403.7	2727.3	1323.6	3.3535	5.6222	2.2687	1.449 09	18.255
10.0	310.997	688.42	55.463	1408.1	2725.5	1317.4	3.3606	5.6160	2.2553	1.452 59	18.030
10.2	312.456	685.10	56.843	1416.7	2721.8	1305.1	3.3749	5.6035	2.2287	1.459 65	17.592
10.4	313.893	681.77	58.240	1425.2	2718.0	1292.8	3.3889	5.5912	2.2023	1.466 76	17.170
10.6	315.308	678.45	59.655	1433.7	2714.2	1280.5	3.4028	5.5789	2.1761	1.473 94	16.763
10.8	316.703	675.13	61.089	1442.1	2710.3	1268.2	3.4166	5.5667	2.1501	1.481 19	16.370
11.0	318.079	671.81	62.541	1450.4	2706.3	1255.9	3.4303	5.5545	2.1242	1.488 51	15.990
11.2	319.434	668.49	64.012	1458.7	2702.3	1243.6	3.4438	5.5423	2.0985	1.495 90	15.622
11.4	320.771	665.17	65.504	1467.0	2698.2	1231.2	3.4572	5.5302	2.0730	1.503 37	15.266
11.6	322.090	661.85	67.016	1475.2	2694.0	1218.8	3.4705	5.5181	2.0476	1.510 93	14.922
11.8	323.391	658.52	68.550	1483.3	2689.8	1206.4	3.4836	5.5060	2.0224	1.518 57	14.588

		Density, kg/m^3		Enthalpy, kJ/kg			Entropy, kJ/(kg·K)			Volume, cm^3/g	
p, MPa	t, °C	ρ_L	ρ_V	h_L	h_V	Δh	s_L	s_V	Δs	v_L	v_V
12.0	324.675	655.18	70.106	1491.5	2685.4	1194.0	3.4967	5.4939	1.9972	1.526 30	14.264
12.2	325.942	651.84	71.684	1499.5	2681.0	1181.5	3.5097	5.4819	1.9722	1.534 13	13.950
12.4	327.194	648.49	73.287	1507.6	2676.6	1169.0	3.5226	5.4698	1.9472	1.542 05	13.645
12.6	328.429	645.13	74.914	1515.6	2672.0	1156.4	3.5354	5.4577	1.9223	1.550 09	13.349
12.8	329.649	641.75	76.566	1523.6	2667.4	1143.8	3.5481	5.4457	1.8975	1.558 23	13.061
13.0	330.854	638.37	78.245	1531.5	2662.7	1131.2	3.5608	5.4336	1.8728	1.566 49	12.780
13.2	332.044	634.97	79.950	1539.4	2657.9	1118.5	3.5734	5.4215	1.8481	1.574 87	12.508
13.4	333.220	631.56	81.685	1547.3	2653.0	1105.7	3.5859	5.4093	1.8234	1.583 38	12.242
13.6	334.382	628.13	83.448	1555.2	2648.0	1092.8	3.5984	5.3972	1.7988	1.592 02	11.983
13.8	335.531	624.69	85.243	1563.1	2643.0	1079.9	3.6108	5.3850	1.7742	1.600 81	11.731
14.0	336.666	621.22	87.069	1571.0	2637.9	1066.9	3.6232	5.3727	1.7495	1.609 74	11.485
14.2	337.789	617.73	88.928	1578.8	2632.6	1053.8	3.6355	5.3604	1.7249	1.618 83	11.245
14.4	338.899	614.22	90.822	1586.7	2627.3	1040.6	3.6478	5.3481	1.7002	1.628 09	11.011
14.6	339.996	610.68	92.752	1594.5	2621.9	1027.4	3.6601	5.3356	1.6756	1.637 52	10.781
14.8	341.082	607.11	94.720	1602.3	2616.3	1014.0	3.6723	5.3231	1.6508	1.647 14	10.557
15.0	342.155	603.52	96.727	1610.2	2610.7	1000.5	3.6846	5.3106	1.6260	1.656 95	10.338
15.2	343.217	599.89	98.776	1618.1	2605.0	986.9	3.6968	5.2979	1.6011	1.666 97	10.124
15.4	344.268	596.23	100.87	1625.9	2599.1	973.2	3.7090	5.2852	1.5762	1.677 22	9.9140
15.6	345.308	592.52	103.00	1633.8	2593.1	959.3	3.7212	5.2723	1.5511	1.687 70	9.7083
15.8	346.337	588.78	105.19	1641.7	2587.0	945.3	3.7335	5.2594	1.5259	1.698 43	9.5067
16.0	347.355	584.99	107.42	1649.7	2580.8	931.1	3.7457	5.2463	1.5006	1.709 44	9.3088
16.2	348.362	581.15	109.71	1657.7	2574.4	916.8	3.7580	5.2331	1.4750	1.720 73	9.1147
16.4	349.360	577.26	112.06	1665.7	2567.9	902.2	3.7704	5.2197	1.4494	1.732 33	8.9240
16.6	350.347	573.31	114.46	1673.7	2561.3	887.5	3.7827	5.2062	1.4235	1.744 27	8.7366
16.8	351.325	569.29	116.93	1681.9	2554.5	872.6	3.7952	5.1925	1.3974	1.756 57	8.5523
17.0	352.293	565.21	119.46	1690.0	2547.5	857.5	3.8077	5.1787	1.3710	1.769 26	8.3709
17.2	353.251	561.05	122.07	1698.3	2540.4	842.1	3.8203	5.1646	1.3443	1.782 37	8.1923
17.4	354.200	556.81	124.75	1706.6	2533.0	826.5	3.8330	5.1504	1.3174	1.795 93	8.0163
17.6	355.140	552.49	127.51	1715.0	2525.5	810.5	3.8458	5.1359	1.2901	1.810 00	7.8426
17.8	356.071	548.06	130.36	1723.5	2517.8	794.3	3.8587	5.1211	1.2624	1.824 60	7.6712
18.0	356.992	543.54	133.30	1732.1	2509.8	777.7	3.8718	5.1061	1.2342	1.839 80	7.5017
18.2	357.906	538.90	136.35	1740.8	2501.6	760.8	3.8851	5.0907	1.2056	1.855 64	7.3341
18.4	358.810	534.13	139.51	1749.7	2493.2	743.5	3.8985	5.0750	1.1765	1.872 19	7.1681
18.6	359.706	529.24	142.79	1758.7	2484.4	725.8	3.9121	5.0590	1.1468	1.889 51	7.0034
18.8	360.594	524.20	146.20	1767.8	2475.4	707.6	3.9260	5.0425	1.1165	1.907 67	6.8399
19.0	361.473	519.00	149.76	1777.2	2466.0	688.9	3.9401	5.0256	1.0855	1.926 77	6.6773
19.2	362.344	513.64	153.49	1786.7	2456.2	669.6	3.9545	5.0081	1.0536	1.946 89	6.5153
19.4	363.208	508.09	157.39	1796.4	2446.1	649.6	3.9692	4.9901	1.0208	1.968 14	6.3535
19.6	364.063	502.35	161.51	1806.4	2435.4	629.0	3.9843	4.9713	0.9871	1.990 64	6.1915
19.8	364.910	496.39	165.87	1816.7	2424.2	607.5	3.9997	4.9518	0.9521	2.0145	6.0290
20.0	365.749	490.19	170.50	1827.2	2412.3	585.1	4.0156	4.9314	0.9158	2.0400	5.8652
20.2	366.581	483.71	175.45	1838.1	2399.8	561.7	4.0320	4.9100	0.8780	2.0674	5.6996
20.4	367.404	476.90	180.79	1849.5	2386.3	536.9	4.0491	4.8872	0.8381	2.0969	5.5313
20.6	368.220	469.67	186.60	1861.4	2371.9	510.5	4.0670	4.8629	0.7959	2.1291	5.3590
20.8	369.027	461.91	193.00	1874.0	2356.1	482.1	4.0860	4.8367	0.7507	2.1649	5.1814
21.0	369.827	453.41	200.16	1887.6	2338.6	451.0	4.1064	4.8079	0.7015	2.2055	4.9961
21.2	370.619	443.83	208.33	1902.6	2318.9	416.3	4.1291	4.7758	0.6467	2.2531	4.8000
21.4	371.402	432.62	217.96	1919.7	2296.1	376.4	4.1550	4.7390	0.5839	2.3115	4.5880
21.6	372.178	418.75	229.84	1940.4	2268.6	328.2	4.1864	4.6950	0.5086	2.3880	4.3508
21.8	372.946	400.26	245.82	1967.4	2232.9	265.5	4.2274	4.6383	0.4109	2.4983	4.0680
22.0	373.705	369.77	274.16	2011.3	2173.1	161.7	4.2945	4.5446	0.2501	2.7044	3.6475
22.064	373.946	322.00	322.00	2084.3	2084.3	0.	4.4070	4.4070	0.	3.1056	3.1056

APPENDIX B

SUPERHEATED VAPOR TABLE

deg-C	m^3/kg	kJ/kg	kJ/kg	kJ/kg K	m^3/kg	kJ/kg	kJ/kg	kJ/kg K	m^3/kg	kJ/kg	kJ/kg	kJ/kg K
T	*p* = 0.01 MPa (45.81 C)				*p* = 0.05 MPa (81.33 C)				*p* = 0.10 MPa (99.63 C)			
	v	*u*	*h*	*s*	*v*	*u*	*h*	*s*	*v*	*u*	*h*	*s*
Sat.	14.674	2437.9	2584.7	8.1502	3.24	2483.9	2645.9	7.5939	1.694	2506.1	2675.5	7.3594
50	14.869	2443.9	2592.6	8.1749								
100	17.196	2515.5	2687.5	8.4479	3.418	2511.6	2682.5	7.6947	1.6958	2506.7	2676.2	7.3614
150	19.512	2587.9	2783.0	8.6882	3.889	2585.6	2780.1	7.9401	1.9364	2582.8	2776.4	7.6143
200	21.825	2661.3	2879.5	8.9038	4.356	2659.9	2877.7	8.1580	2.172	2658.1	2875.3	7.8343
250	24.136	2736.0	2977.3	9.1002	4.82	2735.0	2976.0	8.3556	2.406	2733.7	2974.3	8.0333
300	26.445	2812.1	3076.5	9.2813	5.284	2811.3	3075.5	8.5373	2.639	2810.4	3074.3	8.2158
400	31.063	2968.9	3279.6	9.6077	6.209	2968.5	3278.9	8.8642	3.103	2967.9	3278.2	8.5435
500	35.679	3132.3	3489.1	9.8978	7.134	3132.0	3488.7	9.1546	3.565	3131.6	3488.1	8.8342
600	40.295	3302.5	3705.4	10.1608	8.057	3302.2	3705.1	9.4178	4.028	3301.9	3704.4	9.0976
700	44.911	3479.6	3928.7	10.4028	8.981	3479.4	3928.5	9.6599	4.49	3479.2	3928.2	9.3398
800	49.526	3663.8	4159.0	10.6281	9.904	3663.6	4158.9	9.8852	4.952	3663.5	4158.6	9.5652
900	54.141	3855.0	4396.4	10.8396	10.828	3854.9	4396.3	10.0967	5.414	3854.8	4396.1	9.7767
1000	58.757	4053.0	4640.6	11.0393	11.751	4052.9	4640.5	10.2964	5.875	4052.8	4640.3	9.9764
1100	63.372	4257.5	4891.2	11.2287	12.674	4257.4	4891.1	10.4859	6.337	4257.3	4891.0	10.1659
1200	67.987	4467.9	5147.8	11.4091	13.597	4467.8	5147.7	10.6662	6.799	4467.7	5147.6	10.3463
1300	72.602	4683.7	5409.7	11.5811	14.521	4683.6	5409.6	10.8382	7.26	4683.5	5409.5	10.5183
T	*p* = 0.2 MPa (120.23 C)				*p* = 0.30 MPa (133.55 C)				*p* = 0.40 MPa (143.63 C)			
	v	*u*	*h*	*s*	*v*	*u*	*h*	*s*	*v*	*u*	*h*	*s*
Sat.	0.8857	2529.5	2706.7	7.1272	0.6058	2543.6	2725.3	6.9919	0.4625	2553.6	2738.6	6.8959
150	0.9596	2576.9	2768.8	7.2795	0.6339	2570.8	2761.0	7.0778	0.4708	2564.5	2752.8	6.9299
200	1.0803	2654.4	2870.5	7.5066	0.7163	2650.7	2865.6	7.3115	0.5342	2646.8	2860.5	7.1706
250	1.1988	2731.2	2971.0	7.7086	0.7964	2728.7	2967.6	7.5166	0.5951	2726.1	2964.2	7.3789
300	1.3162	2808.6	3071.8	7.8926	0.8753	2806.7	3069.3	7.7022	0.6548	2804.8	3066.8	7.5662
400	1.5493	2966.7	3276.6	8.2218	1.0315	2965.6	3275.0	8.0330	0.7726	2964.4	3273.4	7.8985
500	1.7814	3130.8	3487.1	8.5133	1.1867	3130.0	3486.0	8.3251	0.8893	3129.2	3484.9	8.1913
600	2.013	3301.4	3704.0	8.7770	1.3414	3300.8	3703.2	8.5892	1.0055	3300.2	3702.4	8.4558
700	2.244	3478.8	3927.6	9.0194	1.4957	3478.4	3927.1	8.8319	1.1215	3477.9	3926.5	8.6987
800	2.475	3663.1	4158.2	9.2449	1.6499	3662.9	4157.8	9.0576	1.2372	3662.4	4157.3	8.9244
900	2.705	3854.5	4395.8	9.4566	1.8041	3854.2	4395.4	9.2692	1.3529	3853.9	4395.1	9.1362
1000	2.937	4052.5	4640.0	9.6563	1.9581	4052.3	4639.7	9.4690	1.4685	4052.0	4639.4	9.3360
1100	3.168	4257.0	4890.7	9.8458	2.1121	4256.8	4890.4	9.6585	1.584	4256.5	4890.2	9.5256
1200	3.399	4467.5	5147.5	10.0262	2.2661	4467.2	5147.1	9.8389	1.6996	4467.0	5146.8	9.7060
1300	3.63	4683.2	5409.3	10.1982	2.4201	4683.0	5409.0	10.0110	1.8151	4682.8	5408.8	9.8780
T	*p* = 0.50 MPa (151.86 C)				*p* = 0.60 MPa (158.85 C)				*p* = 0.80 MPa (170.43 C)			
	v	*u*	*h*	*s*	*v*	*u*	*h*	*s*	*v*	*u*	*h*	*s*
Sat.	0.3749	2561.2	2748.7	6.8213	0.3175	2567.4	2756.8	6.7600	0.2404	2576.8	2769.1	6.6628
200	0.4249	2642.9	2855.4	7.0592	0.352	2638.9	2850.1	6.9665	0.2608	2630.6	2839.3	6.8158
250	0.4744	2723.5	2960.7	7.2709	0.3938	2720.9	2957.2	7.1816	0.2931	2715.5	2950.0	7.0384

300	0.5226	2802.9	3064.2	7.4599	0.4344	2801.0	3061.6	7.3724	0.3241	2797.2	3056.5	7.2328
350	0.5701	2882.6	3167.7	7.6329	0.4742	2881.2	3165.7	7.5464	0.3544	2878.2	3161.7	7.4089
400	0.6173	2963.2	3271.9	7.7938	0.5137	2962.1	3270.3	7.7079	0.3843	2959.7	3267.1	7.5716
500	0.7109	3128.4	3483.9	8.0873	0.592	3127.6	3482.8	8.0021	0.4433	3126.0	3480.6	7.8673
600	0.8041	3299.6	3701.7	8.3522	0.6697	3299.1	3700.9	8.2674	0.5018	3297.9	3699.4	8.1333
700	0.8969	3477.5	3925.9	8.5952	0.7472	3477.0	3925.3	8.5107	0.5601	3476.2	3924.2	8.3770
800	0.9896	3662.1	4156.9	8.8211	0.8245	3661.8	4156.6	8.7367	0.6181	3661.1	4155.6	8.6033
900	1.0822	3853.6	4394.7	9.0329	0.9017	3853.4	4394.4	8.9486	0.6761	3852.8	4393.7	8.8153
1000	1.1747	4051.8	4639.1	9.2328	0.9788	4051.5	4638.8	9.1485	0.734	4051.0	4638.2	9.0153
1100	1.2672	4256.3	4889.9	9.4224	1.0559	4256.1	4889.6	9.3381	0.7919	4255.6	4889.1	9.2050
1200	1.3956	4466.8	5146.6	9.6029	1.133	4466.5	5146.3	9.5185	0.8497	4466.1	5145.9	9.3855
1300	1.4521	4682.5	5408.6	9.7749	1.2101	4682.3	5408.3	9.6906	0.9076	4681.8	5407.9	9.5575
T	p = 1.00 MPa (179.91 C)				*p* = 1.20 MPa (187.99 C)				*p* = 1.40 MPa (195.07*C)			
	v	***u***	***h***	***s***	***v***	***u***	***h***	***s***	***v***	***u***	***h***	***s***
Sat.	0.19444	2583.6	2778.1	6.5865	0.16333	2588.8	2784.4	6.5233	0.14084	2592.8	2790.0	6.4693
200	0.2060	2621.9	2827.9	6.6940	0.16930	2612.8	2815.9	6.5898	0.14302	2603.1	2803.3	6.4975
250	0.2327	2709.9	2942.6	6.9247	0.19234	2704.2	2935.0	6.8294	0.16350	2698.3	2927.2	6.7467
300	0.2579	2793.2	3051.2	7.1229	0.2138	2789.2	3045.8	7.0317	0.18228	2785.2	3040.4	6.9534
350	0.2825	2875.2	3157.7	7.3011	0.2345	2872.2	3153.6	7.2121	0.2003	2869.2	3149.5	7.1360
400	0.3066	2957.3	3263.9	7.4651	0.2548	2954.9	3260.7	7.3774	0.2178	2952.5	3257.5	7.3026
500	0.3541	3124.4	3478.5	7.7622	0.2946	3122.8	3476.3	7.6759	0.2521	3121.1	3474.1	7.6027
600	0.4011	3296.8	3697.9	8.0290	0.3339	3295.6	3696.3	7.9435	0.2860	3294.4	3694.8	7.8710
700	0.4478	3475.3	3923.1	8.2731	0.3729	3474.4	3922.0	8.1881	0.3195	3473.6	3920.8	8.1160
800	0.4943	3660.4	4154.7	8.4996	0.4118	3659.7	4153.8	8.4148	0.3528	3659.0	4153.0	8.3431
900	0.5407	3852.2	4392.9	8.7118	0.4505	3851.6	4392.2	8.6272	0.3861	3851.1	4391.5	8.5556
1000	0.5871	4050.5	4637.6	8.9119	0.4892	4050.0	4637.0	8.8274	0.4192	4049.5	4636.4	8.7559
1100	0.6335	4255.1	4888.6	9.1017	0.5278	4254.6	4888.0	9.0172	0.4524	4254.1	4887.5	8.9457
1200	0.6798	4465.6	5145.4	9.2822	0.5665	4465.1	5144.9	9.1977	0.4855	4464.7	5144.4	9.1262
1300	0.7261	4681.3	5407.4	9.4543	0.6051	4680.9	5407.0	9.3698	0.5186	4680.4	5406.5	9.2984
T	p = 1.60 MPa (201.41 C)				*p* = 1.80 MPa (207.15 C)				*p* = 2.00 MPa (212.42 C)			
	v	***u***	***h***	***s***	***v***	***u***	***h***	***s***	***v***	***u***	***h***	***s***
Sat.	0.12380	2596.0	2794.0	6.4218	0.11042	2598.4	2797.1	6.3794	0.09963	2600.3	2799.5	6.3409
225	0.13287	2644.7	2857.3	6.5518	0.11673	2636.6	2846.7	6.4808	0.10377	2628.3	2835.8	6.4147
250	0.14184	2692.3	2919.2	6.6732	0.12497	2686.0	2911.0	6.6066	0.11144	2679.6	2902.5	6.5453
300	0.15862	2781.1	3034.8	6.8844	0.14021	2776.9	3029.2	6.8226	0.12547	2772.6	3023.5	6.7664
350	0.17456	2866.1	3145.4	7.0694	0.15457	2863.0	3141.2	7.0100	0.13857	2859.8	3137.0	6.9563
400	0.19005	2950.1	3254.2	7.2374	0.16847	2947.7	3250.9	7.1794	0.15120	2945.2	3247.6	7.1271
500	0.2203	3119.5	3472.0	7.5390	0.19550	3117.9	3469.8	7.4825	0.17568	3116.2	3467.6	7.4317
600	0.2500	3293.3	3693.2	7.8080	0.2220	3292.1	3691.7	7.7523	0.19960	3290.9	3690.1	7.7024
700	0.2794	3472.7	3919.7	8.0535	0.2482	3471.8	3918.5	7.9983	0.2232	3470.9	3917.4	7.9487
800	0.3086	3658.3	4152.1	8.2808	0.2742	3657.6	4151.2	8.2258	0.2467	3657.0	4150.3	8.1765
900	0.3377	3850.5	4390.8	8.4935	0.3001	3849.9	4390.1	8.4386	0.2700	3849.3	4389.4	8.3895
1000	0.3668	4049.0	4635.8	8.6938	0.3260	4048.5	4635.2	8.6391	0.2933	4048.0	4634.6	8.5901
1100	0.3958	4253.7	4887.0	8.8837	0.3518	4253.2	4886.4	8.8290	0.3166	4252.7	4885.9	8.7800
1200	0.4248	4464.2	5143.9	9.0643	0.3776	4463.7	5143.4	9.0096	0.3398	4463.3	5142.9	8.9607
1300	0.4538	4679.9	5406.0	9.2364	0.4034	4679.5	5405.6	9.1818	0.3631	4679.0	5405.1	9.1329
T	p = 2.50 MPa (223.99 C)				*p* = 3.00 MPa (233.90 C)				*p* = 3.50 MPa (242.60 C)			
	v	***u***	***h***	***s***	***v***	***u***	***h***	***s***	***v***	***u***	***h***	***s***
Sat.	0.07998	2603.1	2803.1	6.2575	0.06668	2604.1	2804.2	6.1869	0.0507	2603.7	2803.4	6.1253
225	0.08027	2605.6	2806.3	6.2639								
250	0.08700	2662.6	2880.1	6.4085	0.07058	2644.0	2855.8	6.2872	0.05872	2623.7	2829.2	6.1749
300	0.09890	2761.6	3008.8	6.6438	0.08114	2750.1	2993.5	6.5390	0.06842	2738	2977.5	6.4461
350	0.10976	2851.9	3126.3	6.8403	0.09053	2843.7	3115.3	6.7428	0.07678	2835.3	3104.0	6.6579
400	0.12010	2939.1	3239.3	7.0148	0.09936	2932.8	3230.9	6.9212	0.08453	2926.4	3222.3	6.8405
450	0.13014	3025.5	3350.8	7.1746	0.10787	3020.4	3344.0	7.0834	0.09196	3015.3	3337.2	7.0052

500	0.13993	3112.1	3462.1	7.3234	0.11619	3108.0	3456.5	7.2338	0.09918	3103.0	3450.9	7.1572
600	0.15930	3288.0	3686.3	7.5960	0.13243	3285.0	3682.3	7.5085	0.11324	3282.1	3678.4	7.4339
700	0.17832	3468.7	3914.5	7.8435	0.14838	3466.5	3911.7	7.7571	0.12699	3464.3	3908.8	7.6837
800	0.19716	3655.3	4148.2	8.0720	0.16414	3653.5	4145.9	7.9862	0.14056	3651.8	4143.7	7.9134
900	0.21590	3847.9	4387.6	8.2853	0.17980	3846.5	4385.9	8.1999	0.15402	3845.0	4384.1	8.1276
1000	0.2346	4046.7	4633.1	8.4861	0.19541	4045.4	4631.6	8.4009	0.16743	4044.1	4630.1	8.3288
1100	0.2532	4251.5	4884.6	8.6762	0.21098	4250.3	4883.3	8.5912	0.18080	4249.2	4881.9	8.5192
1200	0.2718	4462.1	5141.7	8.8569	0.22652	4460.9	5140.5	8.7720	0.19415	4459.8	5139.3	8.7000
1300	0.2905	4677.8	5404.0	9.0291	0.24206	4676.6	5402.8	8.9442	0.20749	4675.5	5401.7	8.8723

T	p = 4.0 MPa (250.4 deg C)				p = 4.5 MPa (257.49 deg C)				p = 5.0 MPa (263.99 deg C)			
	v	u	h	s	v	u	h	s	v	u	h	s
Sat.	0.04978	2602.3	2801.4	6.0701	0.04406	2600.1	2798.3	6.0198	0.03944	2597.1	2794.3	5.9734
275	0.05457	2667.9	2886.2	6.2285	0.0473	2650.3	2863.2	6.1401	0.04141	2631.3	2838.3	6.0544
300	0.05884	2725.3	2960.7	6.3615	0.05135	2712.0	2943.1	6.2828	0.04532	2698.0	2924.5	6.2084
350	0.06645	2826.7	3092.5	6.5821	0.0584	2817.8	3080.6	6.5131	0.05194	2808.7	3068.4	6.4493
400	0.07341	2919.9	3213.6	6.7690	0.06475	2913.3	3204.7	6.7047	0.05781	2906.6	3195.7	6.6459
450	0.08002	3010.2	3330.3	6.9363	0.07074	3005.0	3323.3	6.8746	0.06330	2999.7	3316.2	6.8186
500	0.08643	3099.5	3445.3	7.0901	0.07651	3095.3	3439.6	7.0301	0.06857	3091.0	3433.8	6.9759
600	0.09885	3279.1	3674.4	7.3688	0.08765	3276.0	3670.5	7.3110	0.07869	3273.0	3666.5	7.2589
700	0.11095	3462.1	3905.9	7.6198	0.09847	3459.9	3903.0	7.5631	0.08849	3457.6	3900.1	7.5122
800	0.12287	3650.0	4141.5	7.8502	0.10911	3648.3	4139.3	7.7942	0.09811	3646.6	4137.1	7.7440
900	0.13469	3843.6	4382.3	8.0647	0.11965	3842.2	4380.6	8.0091	0.10762	3840.7	4378.8	7.9593
1000	0.14645	4042.9	4628.7	8.2662	0.13013	4041.6	4627.2	8.2108	0.11707	4040.4	4625.7	8.1612
1100	0.15817	4248.0	4880.6	8.4567	0.14056	4246.8	4879.3	8.4015	0.12648	4245.6	4878.0	8.3520
1200	0.16987	4458.6	5138.1	8.6376	0.15098	4457.5	5136.9	8.5825	0.13587	4456.3	5135.7	8.5331
1300	0.18156	4674.3	5400.5	8.8100	0.16139	4673.1	5399.4	8.7549	0.14526	4672.0	5398.2	8.7055

T	p = 6.0 MPa (257.64 deg-C)				p = 7.0 MPa (285.88 deg-C)				p = 8.0 MPa (295.06 deg-C)			
	v	u	h	s	v	u	h	s	v	u	h	s
Sat.	0.03244	2589.7	2784.3	5.8892	0.02737	2580.5	2772.1	5.8133	0.02352	2569.8	2758.0	5.7432
300	0.03616	2667.2	2884.2	6.0674	0.02947	2632.2	2838.4	5.9305	0.02426	2590.9	2785.0	5.7906
350	0.04223	2789.6	3043.0	6.3335	0.03524	2769.4	3016.0	6.2283	0.02995	2747.7	2987.3	6.1301
400	0.04739	2892.9	3177.2	6.5408	0.03993	2878.6	3158.1	6.4478	0.03432	2863.8	3138.3	6.3634
450	0.05214	2988.9	3301.8	6.7193	0.04416	2978.0	3287.1	6.6327	0.03817	2966.7	3272.0	6.5551
500	0.05665	3082.2	3422.2	6.8803	0.04814	3073.4	3410.3	6.7975	0.04175	3064.3	3398.3	6.7240
550	0.06101	3174.6	3540.6	7.0288	0.05195	3167.2	3530.9	6.9486	0.04516	3159.8	3521.0	6.8778
600	0.06525	3266.9	3658.4	7.1677	0.05565	3260.7	3650.3	7.0894	0.04845	3254.4	3642.0	7.0206
700	0.07352	3453.1	3894.2	7.4234	0.06283	3448.5	3888.3	7.3476	0.05481	3443.9	3882.4	7.2812
800	0.0816	3643.1	4132.7	7.6566	0.06981	3639.5	4128.2	7.5822	0.06097	3636.0	4123.8	7.5173
900	0.08958	3837.8	4375.3	7.8727	0.07669	3835.0	4371.8	7.7991	0.06702	3832.1	4368.3	7.7351
1000	0.09749	4037.8	4622.7	8.0751	0.08350	4035.3	4619.8	8.0020	0.07301	4032.8	4616.9	7.9384
1100	0.10536	4243.3	4875.4	8.2661	0.09027	4240.9	4872.8	8.1933	0.07896	4238.6	4870.3	8.1300
1200	0.11321	4454.0	5133.3	8.4474	0.09703	4451.7	5130.9	8.3747	0.08489	4449.5	5128.5	8.3115
1300	0.12106	4669.6	5396.0	8.6199	0.10377	4667.3	5393.7	8.5475	0.09080	4665.0	5391.5	8.4842

T	p = 9.0 MPa (303.4 deg-C)				p = 10.0 MPa (311.06 deg-C)				p = 12.5 MPa (327.89 deg-C)			
	v	u	h	s	v	u	h	s	v	u	h	s
Sat.	0.02048	2557.8	2742.1	5.6772	0.018026	2544.4	2724.7	5.6141	0.013495	2505.1	2673.8	5.4624
325	0.02327	2646.6	2856.0	5.8712	0.019861	2610.4	2809.1	5.7568				
350	0.02580	2724.4	2956.6	6.0361	0.02242	2699.2	2923.4	5.9443	0.016126	2624.6	2826.2	5.7118
400	0.02993	2848.4	3117.8	6.2854	0.02641	2832.4	3096.5	6.2120	0.02000	2789.3	3039.3	6.0417
450	0.03350	2955.2	3256.6	6.4844	0.02975	2943.4	3240.9	6.4190	0.02299	2912.5	3199.8	6.2719
500	0.03677	3055.2	3386.1	6.6576	0.03279	3045.8	3373.7	6.5966	0.02560	3021.7	3341.8	6.4618
550	0.03987	3152.2	3511.0	6.8142	0.03564	3144.6	3500.9	6.7561	0.02801	3125.0	3475.2	6.6290
600	0.04285	3248.1	3633.7	6.9589	0.03837	3241.7	3625.3	6.9029	0.03029	3225.4	3604.0	6.7810
650	0.04574	3343.6	3755.3	7.0943	0.04101	3338.2	3748.2	7.0398	0.03248	3324.4	3730.4	6.9218
700	0.04857	3439.3	3876.5	7.2221	0.04358	3434.7	3870.5	7.1687	0.03460	3422.9	3855.3	7.0536
800	0.05409	3632.5	4119.3	7.4596	0.04859	3628.9	4114.8	7.4077	0.03869	3620.0	4103.6	7.2965
900	0.05950	3829.2	4364.8	7.6783	0.05349	3826.3	4361.2	7.6272	0.04267	3819.1	4352.5	7.5182
1000	0.06485	4030.3	4614.0	7.8821	0.05832	4027.8	4611.0	7.8315	0.04658	4021.6	4603.8	7.7237
1100	0.07016	4236.3	4867.7	8.0740	0.06312	4234.0	4865.1	8.0237	0.05045	4228.2	4858.8	7.9165
1200	0.07544	4447.2	5126.2	8.2556	0.06789	4444.9	5123.8	8.2055	0.05430	4439.3	5118.0	8.0937
1300	0.08072	4662.7	5389.2	8.4284	0.07265	4460.5	5387.0	8.3783	0.05813	4654.8	5381.4	8.2717

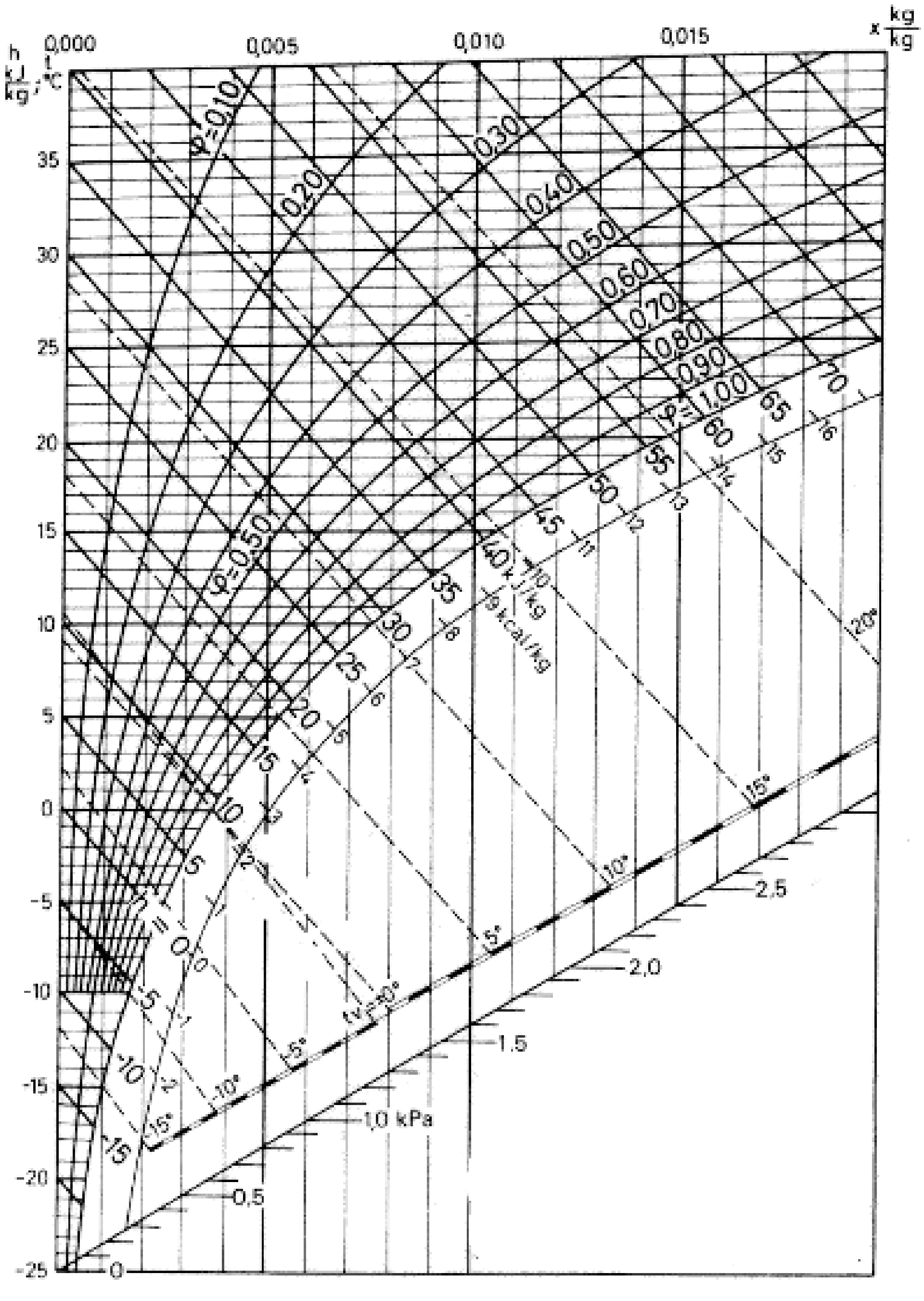
T	*p* = 15.0 MPa (342.24 °C)				*p* = 17.5 MPa (354.75 °C)				*p* = 20.0 MPa (365.81 °C)			
	v	*u*	*h*	*s*	*v*	*u*	*h*	*s*	*v*	*u*	*h*	*s*
Sat.	0.010337	2455.5	2610.5	5.3098	0.007920	2390.2	2528.8	5.1419	0.005834	2293.0	2409.7	4.9269
350	0.011470	2520.4	2692.4	5.4421								
400	0.015649	2740.7	2975.5	5.8811	0.012447	2685.0	2902.9	5.7213	0.009942	2619.3	2818.1	5.5540
450	0.018445	2879.5	3156.2	6.1404	0.015174	2844.2	3109.7	6.0184	0.012695	2806.2	3060.1	5.9017
500	0.02080	2996.6	3308.6	6.3443	0.017358	2970.3	3274.1	6.2383	0.014768	2942.9	3238.2	6.1401
550	0.02293	3104.7	3448.6	6.5199	0.019288	3083.9	3421.4	6.4230	0.016555	3062.4	3393.5	6.3348
600	0.02491	3208.6	3582.3	6.6776	0.02106	3191.5	3560.1	6.5866	0.018178	3174.0	3537.6	6.5048
650	0.02680	3310.3	3712.3	6.8224	0.02274	3296.0	3693.9	6.7357	0.019693	3281.4	3675.3	6.6582
700	0.02861	3410.9	3840.1	6.9572	0.02434	3398.7	3824.6	6.8736	0.02113	3386.4	3809.0	6.7993
800	0.03210	3610.9	4092.4	7.2040	0.02738	3601.8	4081.1	7.1244	0.02385	3592.7	4069.7	7.0544
900	0.03546	3811.9	4343.8	7.4279	0.03031	3804.7	4335.1	7.3507	0.02645	3797.5	4326.4	7.2830
1000	0.03875	4015.4	4596.6	7.6348	0.03316	4009.3	4589.5	7.5589	0.02897	4003.1	4582.5	7.4925
1100	0.04200	4222.6	4852.6	7.8283	0.03597	4216.9	4846.4	7.7531	0.03145	4211.3	4840.2	7.6874
1200	0.04523	4433.8	5112.3	8.0108	0.03876	4428.3	5106.6	7.9360	0.03391	4422.8	5101.0	7.8707
1300	0.04845	4649.1	5376.0	8.1840	0.04154	4643.5	5370.5	8.1093	0.03636	4638.0	5365.1	8.0442

T	*p* = 25.0 MPa				*p* = 30.0 MPa				*p* = 35.0MPa			
	v	*u*	*h*	*s*	*v*	*u*	*h*	*s*	*v*	*u*	*h*	*s*
375	0.0019731	1798.7	1848.0	4.0320	0.0017892	1737.8	1791.5	3.9305	0.0017003	1702.9	1762.4	3.8722
400	0.006004	2430.1	2580.2	5.1418	0.002790	2067.4	2151.1	4.4728	0.002100	1914.1	1987.6	4.2126
425	0.007881	2609.2	2806.3	5.4723	0.005303	2455.1	2614.2	5.1504	0.003428	2253.4	2373.4	4.7747
450	0.009162	2720.7	2949.7	5.6744	0.006735	2619.3	2821.4	5.4424	0.004961	2498.7	2672.4	5.1962
500	0.011123	2884.3	3162.4	5.9592	0.008678	2820.7	3081.1	5.7905	0.006927	2751.9	2994.4	5.6282
550	0.012724	3017.5	3335.6	6.1765	0.010168	2970.3	3275.4	6.0342	0.008345	2921.0	3213.0	5.9026
600	0.014137	3137.9	3491.4	6.3602	0.011446	3100.5	3443.9	6.2331	0.009527	3062.0	3395.5	6.1179
650	0.015433	3251.6	3637.4	6.5229	0.012596	3221.0	3598.9	6.4058	0.010575	3189.8	3559.9	6.3010
700	0.016646	3361.3	3777.5	6.6707	0.013661	3335.8	3745.6	6.5606	0.011533	3309.8	3713.5	6.4631
800	0.018912	3574.3	4047.1	6.9345	0.015623	3555.5	4024.2	6.8332	0.013278	3536.7	4001.5	6.7450
900	0.021045	3783.0	4309.1	7.1680	0.017448	3768.5	4291.9	7.0718	0.014883	3754.0	4274.9	6.9386
1000	0.02310	3990.9	4568.5	7.3802	0.019196	3978.8	4554.7	7.2867	0.016410	3966.7	4541.1	7.2064
1100	0.02512	4200.2	4828.2	7.5765	0.020903	4189.2	4816.3	7.4845	0.017895	4178.3	4804.6	7.4037
1200	0.02711	4412.0	5089.9	7.7605	0.022589	4401.3	5079.0	7.6692	0.019360	4390.7	5068.3	7.5910
1300	0.02910	4626.9	5354.4	7.9342	0.024266	4616.0	5344.0	7.8432	0.020815	4605.1	5333.6	7.7653

T	*p* = 40.0 MPa				*p* = 50.0 MPa				*p* = 60.0 MPa			
	v	*u*	*h*	*s*	*v*	*u*	*h*	*s*	*v*	*u*	*h*	*s*
375	0.0016407	1677.1	1742.8	3.8290	0.0015594	1638.6	1716.6	3.7639	0.0015028	1609.4	1699.5	3.7141
400	0.0019077	1854.6	1930.9	4.1135	0.0017309	1788.1	1874.6	4.0031	0.0016335	1745.4	1843.4	3.9318
425	0.002532	2096.9	2198.1	4.5029	0.002007	1959.7	2060.0	4.2734	0.0018165	1892.7	2001.7	4.1626
450	0.003693	2365.1	2512.8	4.9459	0.002486	2159.6	2284.0	4.5884	0.002085	2053.9	2179.0	4.4121
500	0.005622	2678.4	2903.3	5.4700	0.003892	2525.5	2720.1	5.1726	0.002956	2390.6	2567.9	4.9321
550	0.006984	2869.7	3149.1	5.7785	0.005118	2763.6	3019.5	5.5485	0.003956	2658.8	2896.2	5.3441
600	0.008094	3022.6	3346.4	6.0144	0.006112	2942.0	3247.6	5.8178	0.004834	2861.1	3151.2	5.6452
650	0.009063	3158.0	3520.6	6.2054	0.006966	3093.5	3441.8	6.0342	0.005595	3028.8	3364.5	5.8829
700	0.009941	3283.6	3681.2	6.3750	0.007727	3230.5	3616.8	6.2189	0.006272	3177.2	3553.5	6.0824
800	0.011523	3517.8	3978.7	6.6662	0.009076	3479.8	3933.6	6.5290	0.007459	3441.5	3889.1	6.4109
900	0.012962	3739.4	4257.9	6.9150	0.010283	3710.3	4224.4	6.7882	0.008505	3681.0	4191.5	6.6805
1000	0.014324	3954.6	4527.6	7.1356	0.011411	3930.5	4501.1	7.0146	0.009480	3906.4	4475.2	6.9127
1100	0.015642	4167.4	4793.1	7.3364	0.012496	4145.7	4770.5	7.2184	0.010409	4124.1	4748.6	7.1195
1200	0.016940	4380.1	5057.7	7.5224	0.013561	4359.1	5037.2	7.4058	0.011317	4338.2	5017.2	7.3083
1300	0.018229	4594.3	5323.5	7.6969	0.014616	4572.8	5303.6	7.5808	0.012215	4551.4	5284.3	7.4837

APPENDIX C

MOILLER CHART



APPENDIX DATLAB CODING FOR ADIABATIC CALCULATION

```
%Input P1,P2, T1 , eff,and m
%Output Wi , Wact, X2a

P1 = input('Insert P1: ');
P2=input('Insert P2: ');
T1=input('Insert T1: ');
eff=input('Insert eff: ');
m=input('Insert m: ');

h1 = XSteam ('h_pT', P1, T1);
S1 = XSteam ('s_pT', P1, T1);
S2s = S1;
Sf = XSteam ('sL_p',P2);
Sg = XSteam ('sV_p', P2);
X2s = (S2s - Sf)/(Sg-Sf);
T2 = XSteam ('Tsat_p',P2)
hf = XSteam ('hL_p',P2);
ha = XSteam ('hV_p',P2);
hd = ha - hf;
h2s = hf + X2s*hd;
Wi = m*(h1-h2s)
Wact = eff*Wi
h2a = h1 -(Wact/m);
hg = XSteam ('hV_p',P2);
X2a = (h2a -hf)/(hg - hf)
```