THERMODYNAMIC ANALYSIS OF GROUND SOURCE HEAT PUMP

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FACULTY OF MECHANICAL ENGINEERING

We certify that the project entitled "Thermodynamic analysis of Ground Source Heat Pump" is written by Khairul Ridhwan Zainudin. 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 here recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

Dr. Maisara Mohyeldin Gassim …….....

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature:

Name of Supervisor: EN AMIR ABDUL RAZAK

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Date: 6th DECEMBER 2010

STUDENT'S DECLARATION

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

Signature:

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ABSTRACT

This thesis describes in detail includes a brief description of the Ground Source Heat Pump as cooling and heating system, concentrating on thermodynamic analysis. Besides, the descriptive drawings make this thesis very easy to understand. The main objective of this thesis is to do thermodynamic analysis on performance of the heat pump system. The changes in cooling water flow will affect the performance of the heat pump system. The value of hole depth and coils length are determine through the equation in chapter 3. In addition to these, this thesis also contains the details regarding the different type of other Ground Source Heat Pump which are used these days. Above all, this thesis gives a detailed description of closed looped Ground Source Heat Pump. This thesis will be help for those who wish to understand about the basic working of different Ground Source Heat Pump especially those who wish to study Ground Source Heat Pump as cooling and heating system.

ABSTRAK

Tesis ini menjelaskan secara terperinci merangkumi huraian ringkas tentang Pam Haba Sumber Tanah sebagai sistem penyejukan dan pemanasan, menumpukan pada analisis termodinamik. Selain itu, gambar-gambar deskriptif membuat tesis ini sangat mudah untuk difahami. Tujuan utama dari tesis ini adalah untuk membuat analisis termodidnamik terhadap dayaguna Pam Haba Sumber Tanah. Perubahan terhadap kadar arus jisim air penyejukan akan merubah dayaguna system Pam Haba Sumber Tanah ini. Panjang lingkaran ditemui menerusi persamaan di bab 3. Sebagai tambahan, tesis ini juga mengandungi keperincian berkaitan jenis lain Pam Haba Sumber Tanah yang berbeza dimana telah digunakan pada hari ini. Di bawah ini, tesis ini memberi keperincian akan Pam Haba Sumber Tanah pusingan tertutup. Tesis ini akan membantu kepada sesiapa berhasrat untuk memahami tentang asas pekerjaan kepada perbezaan Pam Haba Sumber Tanah terutamanya kepada sesiapa yang berhasrat mempelajari tentang Pam Haba Sumber Tanah sebagai sistem pemanasan.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Nowadays, there are many systems built to make human life more easier and comfortable. According to nowadays lifestyle, there are many things that they have to think about to make life easier. As an example is their electricity. The using of electricity is high because of refrigerator, radio, television, lamp and other thing uses. It is possible to stop from using those because of their own purpose. So, if exploring the heating and cooling options for your house or looking for ways to reduce our energy bills, we may be considering a heat pump. A heat pump can provide year-round climate control for our home by supplying heat to it in the winter and cooling it in the summer. Some types can also heat water. Actually, heat is a form of energy. The geothermal energy is literally the heat contained within the earth that generates geological phenomena on a planetary scale. The system that can manipulate the heat Ground Source Heat Pump. The geothermal heat pump, also known as the ground source heat pump, is a highly efficient renewable energy technology that is gaining wide acceptance for both residential and commercial buildings. Ground source heat pumps are used for space heating and cooling, as well as water heating. Its great advantage is that it works by concentrating naturally existing heat, rather than by producing heat through combustion of fossil fuels. Ground source heat pump doesn't create heat by burning fuel, like a furnace does. Instead, in winter it collects the Earth's natural heat through a series of pipes, called a loop, installed below the surface of the ground. Fluid circulates through the loop and carries the heat to the house. There, an electrically driven compressor and a heat exchanger concentrate the Earth's energy and release it inside the

home at a higher temperature. Ductwork distributes the heat to different rooms. The technology relies on the fact that the Earth (beneath the surface) remains at a relatively constant temperature throughout the year, warmer than the air above it during the winter and cooler in the summer, very much like a cave. The Ground source heat pump takes advantage of this by transferring heat stored in the Earth or in ground water into a building during the winter, and transferring it out of the building and back into the ground during the summer. The ground, in other words, acts as a heat source in winter and a heat sink in summer.

1.2 PROBLEM STATEMENT

1. Actually, it is hard to get software that can do an analysis or thermodynamic analysis on ground Source Heat Pump.
2. Moreover, certain equations from books are made by doing a lot of assumptions. Some of important thing that can influence the result had been neglect. So, it is not suitable to get practical result.
3. Furthermore, there are lacks of sources based on Ground Source Heat Pump thermodynamic analysis. Even we can get some information, journals or report on Ground Source Heat Pump from internet, but it is hard to get information about thermodynamic analysis of Ground Sourcel Heat Pump. There are still quit people doing research on this topic. So, by doing this research, it will help other researcher for further study in the future.

1.3 SCOPE

The project will focus on following matter;

1. Analysis on evaporator, condenser, expansion valve, compressor in Excel 2007
2. Discuss the relation between varies water flow rate, length of Ground Heat Exchanger and heat output by the condenser.
3. Discuss and produce the performance of heat pump over a range of source and delivery temperatures

4. Discuss and produce the performance of heat pump over a range of evaporating and condensation temperatures which is the saturation temperature at condensing pressure
5. Analysis on mathematical designing of Ground Heat Exchanger.

1.4 OBJECTIVES

The main objective of this study is to develop mathematical model of components of Ground Source Heat Pump based on thermal analysis on each corresponding components by using Excel 2007.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A significant of this topic is based on model of components of Ground source heat pump based on mathematical analysis on each corresponding components and behavior of the circuits. Basic understanding in the study must be recognizable before mathematical modeling of the Ground Source Heat Pump.

The review of this study is based on developing Ground Source Heat Pump Excel 2007 by using real equation. The equation to be put in should be practical without neglecting any important factor.

2.2 COMPONENT INFORMATION

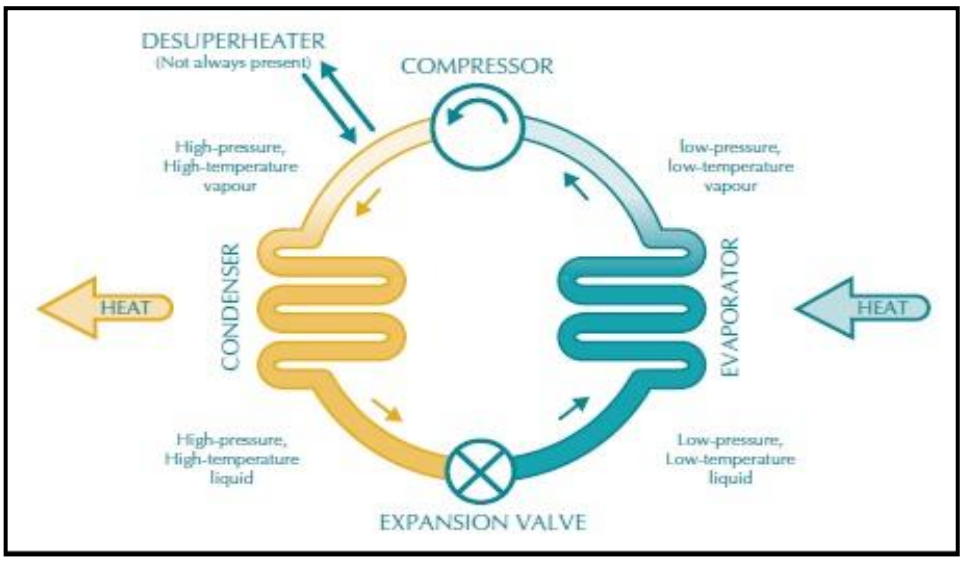

Figure 2.1: Circulation of refrigerant

Source: Natural Resources of Canada, 2004

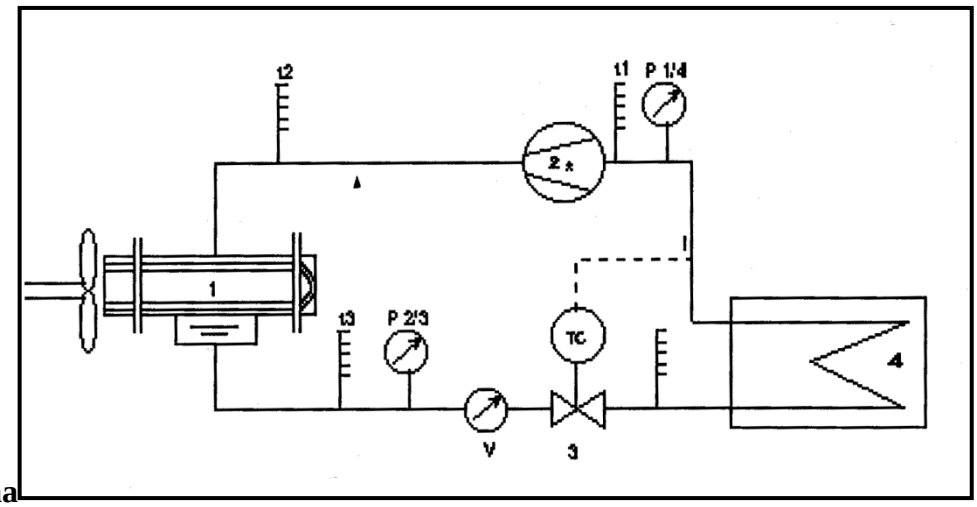

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Figure 2.2: Heat pump component with meter temperature and gauge pressure

Sources : Solution Engineering Sdn. Bhd.

2.2.1 Compressor

The compressor squeezes the molecules of the refrigerant gas together, increasing the temperature of the refrigerant. A compressor pumps the refrigerant between two heat exchanger coils such as condenser and evaporator. It circulates the refrigerant (R134) from condenser to expansion valve and evaporator lastly before come back to compressor. It had some analysis of Energy Balance on the Compressor.

Figure 2.3: Compressor

$$\text{Compressor pressure ratio} = \frac{P_2}{P_1} \tag{2.1}$$

Where P_1 is represent the pressure values before the compressor suction and P_2 represent the pressure after the compressor. The P_2 will show the higher number than P_1 because the refrigerant at the pump suction is in low temperature and low pressure in able to it to achieve the heat pump effect continuously, it must be brought to the liquid form at high pressure.

$$\text{Volumetric flow rate of refrigrant at the compressor suction} = m \times v \tag{2.2}$$

Where m represents the refrigerant mass flow rate and v is represent the specific volume of refrigerant at compressor suction. Volumetric flow rate of refrigerant at the compressor suction is equal to refrigerant mass flow rate times specific volume of refrigerant at compressor suction. This equation will use later to define the volumetric efficiency.

$$\text{Compressor swept volume} = \text{Compression speed} \times 1 \frac{\text{min}}{60\text{s}} \times \text{swept volume} \quad (2.3)$$

$$\text{Volumetric effeciency} = \frac{\text{Volumetric}}{\text{Compressor swept volume}} \times 100\% \quad (2.4)$$

Where volumetric efficiency describes how efficient a compressor compresses a volume flow compared to the displacement of the compressor. The displacement is calculated from the stroke volume and the number of revolutions.

2.2.2 Condenser

The condenser is a coil in which the refrigerant gives off heat to its surroundings and becomes a liquid. The refrigerant leaves the compressor as a gas at high temperature and pressure. In order to change it to a liquid, heat must be removed from it. This is accomplished in a heat exchanger called the condenser. The refrigerant flow one circuit in the condenser. In other circuit, a water flows as a cooling fluid, at a temperature lower than the refrigerant.

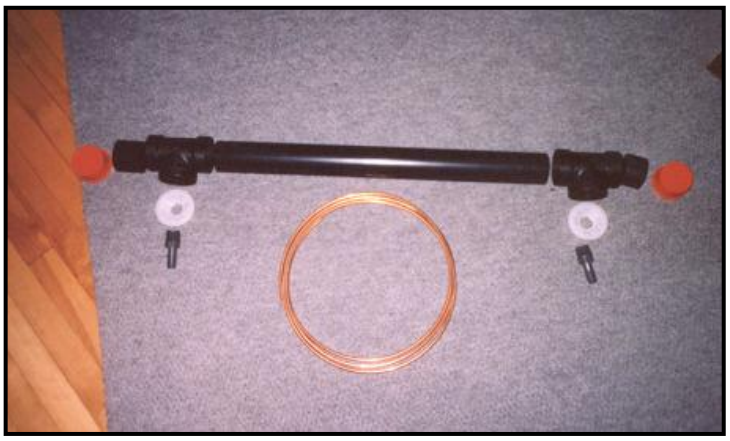

Figure 2.4: Condenser

$$\text{Heat transfer from refrigerant} = M_{R134} \times (h_2 - h_3) \times 100 \frac{J}{kg} \quad (2.5)$$

Where MR134 is represent the Refrigerant mass flow rate, h2 is represent the enthalpy of refrigerant before enter the condenser and which is the point where compression process ends while h3 is enthalpy of refrigerant after come out from condenser which is the point where condensation is complete. Heat transfer from refrigerant is heat that had been transferred by refrigerant due to enthalpy changes.

$$Q = M_{water} \frac{L}{m} \times 1 \frac{L}{kg} \times 1 \frac{min}{60s} \times C_p \times (T_6 - T_5) \quad (2.6)$$

From the equation above, Q is represent the heat had been released at the condenser, where M is represent water mass flow rate while cp is represent specific heat of water and T6 is represent cooling water temperature after come out from condenser and T5 is represent cooling water temperature before entering the condenser. The heat that had been released here is heat that will be used such as room heating. It is also called as heat output.

2.2.3 Expansion Valve

A thermal expansion valve (often abbreviated as TXV or TX valve) is a component that controls the amount of refrigerant flow into the evaporator thereby controlling the superheat at the outlet of the evaporator. Thermal expansion valves are often referred to generically as "metering devices". Flow control, or metering, of the refrigerant is accomplished by use of a temperature sensing bulb filled with a similar gas as in the system that causes the valve to close against the spring pressure in the valve body as the temperature on the bulb increases. As temperatures in the evaporator decrease, so does the pressure in the bulb and therefore on the spring causing the valve to open. [3]

Figure 2.5: Expansion Valve

2.2.4 Evaporator

The evaporator is a coil in which the refrigerant absorbs heat from its surroundings and boils to become a low-temperature vapor. As the refrigerant passes from the reversing valve to the compressor, the accumulator collects any excess liquid that didn’t vaporize into a gas. Not all heat pumps, however, have an accumulator.

Figure 2.6: Evaporator

$$Q_{extracted} = M \times (h_1 - h_2) \quad (2.7)$$

The Qextracted as we can see above is represent heat that had been extracted from ambient that will be use to vaporized the refrigerant at evaporator, where m is represent the refrigerant mass flow rate while h1 is enthalpy at t1p1 where it means temperature at point 1 and pressure at point 1, while h4 is enthalpy at t4p1 where it meant temperature at point 4 and pressure at point 1.

2.2.5 Ground Heat Exchanger

The earth connection is where heat transfer between the Heat Pump system and the soil occurs. Refrigerant as a heat-transfer fluid is circulated from the pump, around the tubing, and back to the pump in a closed loop. High density Polyethylene (HDPE) pipe material is use as the coil for the Ground Heat Exchanger. It used to extract heat from soil.

Figure 2.7: Ground Heat Exchanger

$$L = \frac{Q}{2} \times \pi k \times \left(\frac{T_s - T_{bulk}}{\ln\left(\frac{r_2}{r_1}\right)} \right) \quad (2.8)$$

For the equation above, L is represent the length of ground heat exchanger, while Q is represent heat extracted from the ground, actually k is represent the conductivity of Ground Heat Exchanger and the material that will be use in this analysis is HDPE where the conductivity values is around 4.8 to 5.2. Ts are representing the soil temperature while r_2 and r_1 in outside and inside diameter of Ground heat exchanger.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The main objective of this project is to define the relations between water flow rate, Ground Heat Exchanger and heat output produce by condenser, by doing experiment of Heat Pump. It is also need to design a Ground source Heat Pump that produce 1 kw of heat output. In this section, it will tell about the experiment that had been done from the research up to the analysis to fulfill the objectives of the project. By making the literatures review, it helps in order to further understand the parameter and building up the flow of the project. For this project, the experiment need to be done first to get the parameter that will be relate and use to do analysis on Ground Source Heat Pump. With this, the data and result that come out from the experiment is reliable and trusted.