STUDY OF GROUND SOURCE HEAT PUMP AS COOLING SYSTEM FOR LOCAL APPLICATIONS

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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.

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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.

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In the name of Allah S.W.T the Most Beneficent and the Most Merciful. The deepest sense of gratitude to the Almighty for the strength and ability to complete this project. Infinite thanks I brace upon Him.

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ABSTRACT

This report describes in detail includes a brief description of the Ground Source Heat Pump as cooling system, concentrating on hole depth and coils length. Besides, the descriptive drawings make this report very easy to understand. The main objective of this report is to determine the suitable hole depth and coils length during Ground Source Heat Pump installation. The hole depth and coils length are determined according to the different type of soil moisture. Every type of soil moisture will give different hole depth and coils length. The parameter of hole depth and coils length are determined through the equation in chapter 3. In chapter 4, there are the result of hole depth and coils length parameter that can be used according to the flow rate of R-134 A and soil moisture. Higher soil moisture will decreasing hole depth and coils length. In addition to these, this report also contains the details regarding the different type of other Ground Source Heat Pump which are used these days. Above all, this report gives a detailed description of closed looped Ground Source Heat Pump. This report 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 system.

ABSTRAK

Laporan ini menjelaskan secara terperinci merangkumi huraian ringkas tentang Pam Haba Sumber Tanah sebagai sistem penyejukan, menumpukan pada kedalaman lubang dan panjang lingkaran. Selain itu, gambar-gambar deskriptif membuat laporan ini sangat mudah untuk difahami. Tujuan utama dari laporan ini adalah untuk menentukan kedalaman lubang yang sesuai dan panjang lingkaran semasa pemasangan Pam Haba Sumber Tanah. Kedalaman tanah dan panjang lingkaran ditemui berdasarkan kepada jenis kelembapan tanah yang berbeza. Setiap jenis kelembapan tanah akan memberi kedalaman tanah dan panjang lingkaran yang berbeza. Nilai kedalaman tanah dan panjang lingkaran ditemui menerusi persamaan di bab 3. Dalam bab 4, terdapat keputusan parameter kedalaman tanah dan panjang lingkaran yang boleh diguna berdasarkan kadar aliran R-134A dan kelembapan tanah. Tingginya kelembapan tanah, akan mengurangkan kedalaman tanah dan panjang linkaran. Sebagai tambahan, laporan ini juga mengandungi keperincian berkaitan jenis lain Pam Haba Sumber Tanah yang berbeza dimana telah digunakan pada hari ini. Di bawah ini, laporan ini memberi keperincian akan Pam Haba Sumber Tanah pusingan tertutup. Laporan 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 penyejukan.

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LIST OF SYMBOLS

A_s	Soil temperature amplitude , K
α	Soil thermal diffusivity , W/m.k
Cp	Specific heat , J/kg.k
h	Enthalpy , KJ/kg
K	Thermal conductivity , W/m.k
L	Coils length , m
p	Preassure , Pa
$\dot{Q}_{cond}$	Heat conduction , kW
s	Enthropy , kJ/kg
T	Temperature , K
$T_{in}–T_{out}$	Temperature difference between temperature inlet and temperature outlet , K
$T_{g\ max}$	Maximum soil temperature , K
X_s	Soil depth , m

LIST OF ABBREAVIATIONS

A/C	Air conditioning
ASHP	Air source heat pump
ASHRAE	American Society of Heating, Refrigerating and Air- conditioning
ASME	American Society of Mechanical Engineering
CF_3CH_2F	Tetrafluoroethane
CFCs	Chlorofluorocarbon
COP	Coefficient of performance
EESs	Earth –energy systems
GCHP	Ground-coupled heat pump
GSHP	Ground source heat pump
GWHP	Ground water heat pump
HDPE	High-density polyethylene
SDR	Standard Dimension Ratio
SWHP	Surface water heat pump
USA	United States Of America

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Ground Source Heat Pump (GSHP) system uses the ground temperature as a heat source in a heating mode and a heat sink in a cooling mode, respectively. In the cooling mode, GSHP system absorbs heat from the conditioned space and discharges it to the ground through a ground heat exchanger while air source heat pump (ASHP) system discharges heat to outdoor air. Therefore, the coefficient of performance (COP) of ASHP system is generally confined to the limited value strongly dependent to the outdoor temperature.

However, the water circulated through the ground heat exchanger is used as the heat sink of the condenser, in which the temperature is lower than outdoor air, in spite of that it can be possible for GSHP system to have higher COP than ASHP system. In this study, the coils length and hole depth during GSHP installation process will be focus. Besides, the effect of soil moisture to the coils length and hole depth will be discuss. This system mainly consists of three separate circuits: (a) the ground heat exchanger circuit, (b) the refrigerant circuit and (c) the fan-coil circuit or air circuit.

1.2 STATEMENT OF THE PROBLEMS

Nowadays, the temperature in Malaysia is increasing day by day. Many of the owners use air-conditioners in order to decrease the temperature in their houses. But, the usage of the air-conditioners may increase their electricity bill. So, the cooling systems that user friendly and cheaper must be created. In this project, the Ground Source Heat

Pump systems that can replace the conventional systems will be discovering. Since Ground Source Heat Pump are the one of the fastest growing applications of renewable energy in USA and Europe, so it’s would possible to apply these systems in Malaysia and see whether it is suitable for use in hot country like Malaysia and Asia region. The usage of Ground Source Heat Pump systems as cooling systems will help people to decrease their monthly electric’s bill and to avoid global warming become more serious.

1.3 OBJECTIVES OF THE STUDY

i. To study and analysis of vapor compression heat pump to be used as heat sink.
ii. To study about vapor compression heat pump in order to build a circuit that suitable for cooling system.
iii. Finding the best type of Ground Source Heat Pump to be used as a cooling system.
iv. Finding the suitable coils length and hole depth according to the soil moisture.

1.4 SCOPE OF STUDY

i. Research appropriate heat pump circuit that suitable for cooling system with ground as heat sink.
ii. The types of Ground Source Heat Pump that will be discuss are open loop systems and close loop systems. The closed loop can be dividing into four types, which are horizontal loop, vertical loop, slinky loop and pond loop. The capability of the each system is determine base on their advantages and disadvantages. The best system will picking as the cooling system in this study.
iii. The soils that are use in this project are sand soil, which is a main soil in Pekan. The side effects that can cause by soil are neglect.
iv. The coils length and hole depth base on the soil moisture (5%, 10% and 15% soil moisture) will be determined by the equation that will be discuss in chapter 3.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A Ground Source Heat Pump is a central heating or cooling system that pumps heat to or from the ground. It uses the ground as a heat source (in the winter) or a heat sink (in the summer). This design takes advantage of the reasonable temperatures in the ground to increase efficiency and reduce the operational costs of heating and cooling systems, and may be combined with solar heating to form a geosolar system with even greater efficiency. Ground Source Heat Pumps are also known by a variety of other names, including geoexchange, earth-coupled, earth energy or water-source heat pumps. The engineering and scientific communities prefer the terms “geoexchange” or “Ground Source Heat Pump" because ground source power traditionally refers to heat originating from deep in the Earth's mantle. Ground source heat pumps crop a combination of geothermal power and heat from the sun when heating, but work against these heat sources when used for air conditioning (Milenic, 2003).

Heat pumps can transfer heat from a cool space to a warm space, against the natural direction of flow, or they can improve the natural flow of heat from a warm area to a cool one. The center of the heat pump is a loop of refrigerant pumped through a vapor-compression refrigeration cycle that moves heat. Heat pumps are always more efficient at heating than pure electric heaters, even when extracting heat from cold winter air. But unlike an air-source heat pump, which transfers heat to or from the outside air, a Ground Source Heat Pump exchanges heat with the ground. This is much more energy-efficient because underground temperatures are more stable than air temperatures through the year (Kuzniak, 1990). Seasonal variations drop off with depth and disappear below seven meters due to thermal inertia. Like a cave, the shallow ground temperature is warmer than the air above during the winter and cooler than the air in the summer. A Ground Source Heat Pump extracts ground heat in the winter (for heating) and transfers heat back into the ground in the summer (for cooling). Some systems are designed to operate in one mode only, heating or cooling, depending on climate.

The use of Ground Source Heat Pumps (GSHP) in commercial and residential facilities is a tremendous example. GSHP systems have a number of desirable characteristics, including high efficiency, low maintenance costs, and low life-cycle cost. However, the high initial costs of GSHP systems sometimes cause a building owner to reject the GSHP system as an alternative method.

A Ground Source Heat Pumps includes three principle components, which are an earth connection subsystem, heat pump subsystem, and heat distribution subsystem. The earth connection subsystem usually includes a closed loop of pipes that is buried with horizontally or vertically (Omer, 2006). A fluid is circulated through these pipes, allowing heat but not fluid to be transferred from the building to the ground. The circulating fluid is generally water or a water and antifreeze mixture. Less commonly, the earth connection system includes an open loop of pipes linked to a surface water body or an aquifer, that directly transfers water between the heat exchanger and water source (pond or aquifer).

Ground Source Heat Pumps work with the environment to supply the clean, efficient, and energy saving heating and cooling year round. Ground Source Heat Pumps uses less energy than alternative heating and cooling systems, in order to conserve the natural resources. Ground Source Heat Pumps are housed entirely within the building and underground. Plus, the GSHP usages are pollution free and do not detract from the surrounding landscape.

2.2 HISTORY OF GROUND SOURCE HEAT PUMP

The heat pump was discovered by Lord Kelvin in 1852 and developed by Peter Ritter Von Rittinger in 1855. Robert C. Webber was built the first direct exchange Ground Source Heat Pump in the late 1940s after experimenting it with a freezer. The first successful commercial project was installed in the Commonwealth Building (Portland, Oregen) in 1946, and has been designated a National Historic Mechanical Engineering Landmark by ASME. The GSHP became popular in Sweden in the 1970s, and has been growing slowly in worldwide acceptance since then. Open loop systems dominated the market until the development of polybutylene pipe in 1979 made closed loop systems economically feasible. As of 2004, there are over a million units installed worldwide providing 12 GW of thermal capacity. Each year about 80 000 units are installed in the USA and 27 000 in Sweden (Omer, 2006).

Fossil fuels and low-efficiency electrical equipment are still being used for heating during the winter season. However, efficient energy utilization is getting very important due to environmental and energy problems such as global warming and the reduction of fossil fuels. In this context, a high thermal efficiency heat pump has been proposed as a new heating apparatus. In the early 1970s, especially after the oil shock, there has been more research and technical development for smaller, quieter, and higher efficiency heat pump systems.

In a comprehensive study, it is reported that GSHP have the largest energy use and installed capacity according to the 2005 data. The distribution of thermal energy used by category is approximately 32% for GSHP, 30% for bathing and swimming (including balneology), 20% for space heating (of which 83% is for district heating), 7.5% for greenhouse and open-ground heating, 4% for industrial process heat, 4% for aquaculture pond and raceway heating, <1% for agricultural drying, and <1.5% for other uses. The equivalent annual savings in fuel oil amounts to 25.4 and 24 million tones in carbon emissions to the atmosphere. The equivalent number of installed 12-kW GSHP units (typical of US and Western European homes) is approximately 1.3 million, over double the number of units reported for 2000. The size of individual units, however, ranges from 5.5kW for residential use to large units of over 150kW for commercial and institutional installations (Al, 2005). Ground Source Heat Pumps systems use the ground as a heat source or sink to provide space heating and cooling as well as domestic hot water. The GSHP technology can offer higher energy efficiency for air-conditioning compared to conventional air conditioning (A/C) systems because the underground environment provides lower temperature for cooling and higher temperature for heating and experiences less temperature fluctuation than ambient air temperature change.

Today, GSHP systems are one of the fastest growing applications of renewable energy in the world. This growth not just happening in USA and Europe, but also in other countries such as Japan and Turkey. By the end of 2004, the worldwide installed capacity was estimated at almost 12 GWth with an annual energy use of 20 TWh. Today, around one million GSHP system units have been installed worldwide and annual increases of 10% have occurred in about 30 countries over the past 10 years.

In the USA, over 50,000 GSHP units were sold each year, with a majority of these for residential applications. It is estimated that a half million units are installed, with 85% closed-loop earth connections (46% vertical, 38% horizontal) and 15% open loop systems (groundwater).

At mid 2005, the world's largest GSHP system is for a building cluster in Louisville (KY), USA, which provides heating and cooling for 600 rooms, 100 apartments, and 89,000 m^2 of office space, representing a total area of 161,650 m^2. It makes use of groundwater to supply 15.8 MW of cooling and 19.6 MW of heating capacity, demonstrating that GSHP are not limited to small-scale applications. Running for 15 years with no system problems, it has reduced the overall energy consumption by 47% and provides monthly savings of CDN$30,000 compared to an adjacent, similar building (NASA, 2001-2005).

The first known record of the concept of using the ground as heat source for a heat pump was found in a Swiss patent issued in 1912. Thus, the research associated with the GSHP systems has been undertaken for nearly a century. The first surge of interest in the GSHP technology began in both North America and Europe after World War Two and lasted until the early 1950s when gas and oil became widely used as heating fuels. At that time, the basic analytical theory for the heat conduction of the GSHP system was proposed by Ingersoll and Plass, which served as a basis for development of some of the later design programs. The next period of intense activity on the GSHP started in North America and Europe in 1970s after the first oil crisis, with an emphasis on experimental investigation. During this time period, the research was focused on the development of the vertical borehole system due to the advantage of less land area requirement for borehole installation. In the ensuing two decades, considerable efforts were made to establish the installation standard and develop design methods. Today, the GSHP systems have been widely used in both residential and commercial buildings. It is estimated that the GSHP system installations have grown continuously on a global basis with the range from 10% to 30% annually in recent years. The GSHP comprise a wide variety of systems that may use ground water, ground, or surface water as heat sources or sinks. These systems have been basically grouped into three categories by ASHRAE, i.e. (1) ground water heat pump (GWHP) systems, (2) surface water heat pump (SWHP) systems and (3) ground-coupled heat pump (GCHP) systems. The schematics of these different systems are shown in Figure 2.1 (D.A. Ball, 1983).

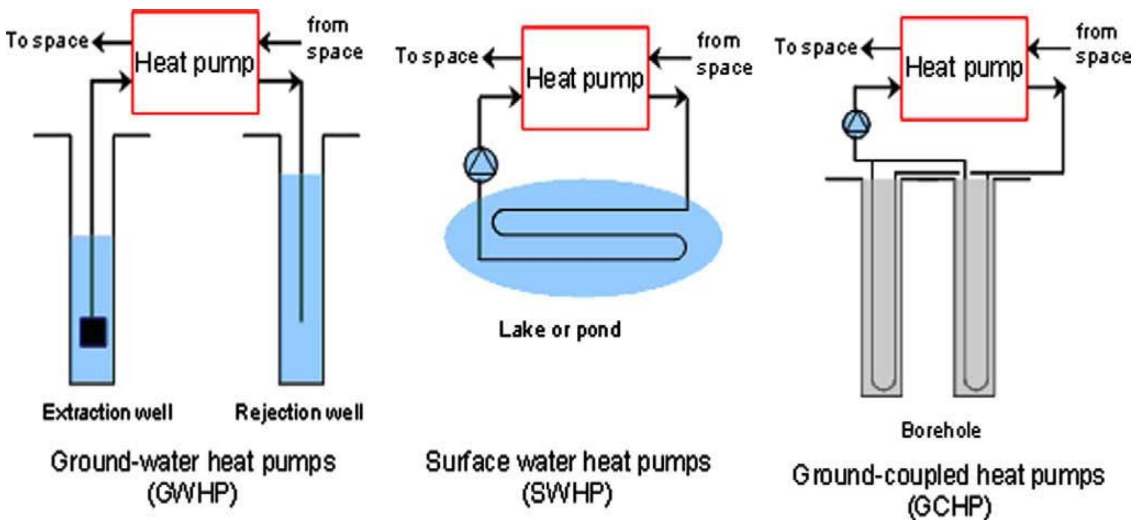

Figure 2.1: Schematics of different ground source heat pumps.

Source: D.A Ball (1983)

From Figure 2.1, the GWHP system, which utilizes ground water as heat source or heat sink, has some marked advantages including low initial cost and minimal requirement for ground surface area over other GSHP systems. However, a number of factors seriously control the wide application of the GWHP systems, such as the limited availability of ground water and the high maintenance cost due to fouling corrosion in pipelines and equipment. In addition, many legal issues have arisen over ground water withdrawal and re-injection in some regions, which also restrict the GWHP applications to a large extent. In a SWHP system, heat rejection extraction is accomplished by the circulating working fluid through high-density polyethylene (HDPE) pipes positioned at an adequate depth within a lake, pond, reservoir, or other suitable open channels. Natural convection becomes the primary role in the heat exchangers of the SWHP system rather than heat conduction in the heat transfer process in a GCHP system, which tends to have higher heat exchange capability than a GCHP system (D.A. Ball, 1983).

2.3 TYPES OF GROUND SOURCE HEAT PUMP

A significant portion of world energy consumption is attributable to domestic heating and cooling. Ground Source Heat Pumps (GSHPs) are preferred and widely used in many applications due to their high utilization .There are two types systems of GSHPs:

2.3.1 Opened loop system

In an open loop system, groundwater is usually supplied to the heat pump by a drilled well with a submersible pump system. If a recharge well is to be used, it should be drilled at the same time as the primary well. The groundwater should be tested for acidity, dissolved solids and mineral content. The open loop system is shown in Figure 2.2.

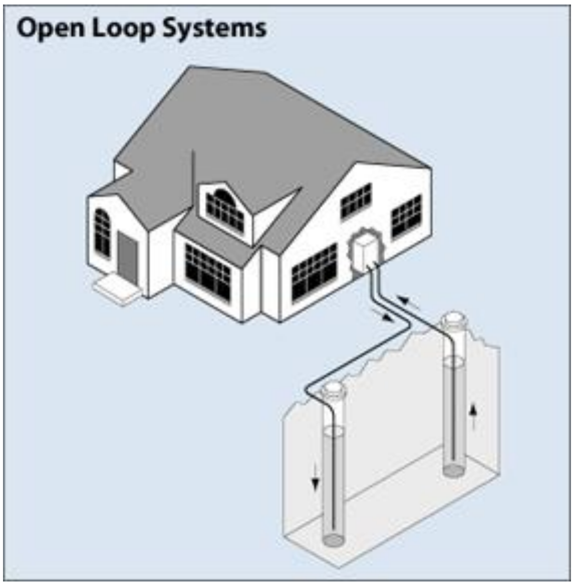

Figure 2.2: Open loop system.

Source: Singh (2005)

2.3.2 Closed loop system

The most typical Ground Source Heat Pump installation utilizes a closed loop system. In a closed loop system, a loop of piping is buried underground and filled with water or antifreeze that continuously circulates through the system. There are four major types of closed loop geothermal systems, which are vertical loops, horizontal loops, slinky coils and pond loops.

2.3.2.1 Vertical loop

This is the most common type of closed loop, as it requires the least amount of ground to contain it. However it is the most expensive but most efficient as the earth's temperature is more consistent with depth. To install a loop system firstly a vertical bore holes are drilled 50 to 100 m deep and at least 5 m apart, this gap ensures that the individual loops do not encroach on the available heat energy in the soil. When the required number of boreholes has been drilled (the contractor will have calculated the number required to suit the buildings heating requisite) the U shaped pipe typically between ¾" and $1^{1/4"}$ diameter, are then inserted down into the borehole. An efficient heat-transferring sealing compound or grout is poured into the gap between the pipe and the soil. This is not only to ensure a good contact between the pipe and the ground, but also to prevent rainwater from penetrating into the borehole. When all the pipes have been inserted and grouted, they are connected up to an inlet and outlet manifold which supply and return the loop circulating fluid, a mixture of water and antifreeze to and from the heat pump via the circulating pump. The vertical loop system is shown in Figure 2.3.

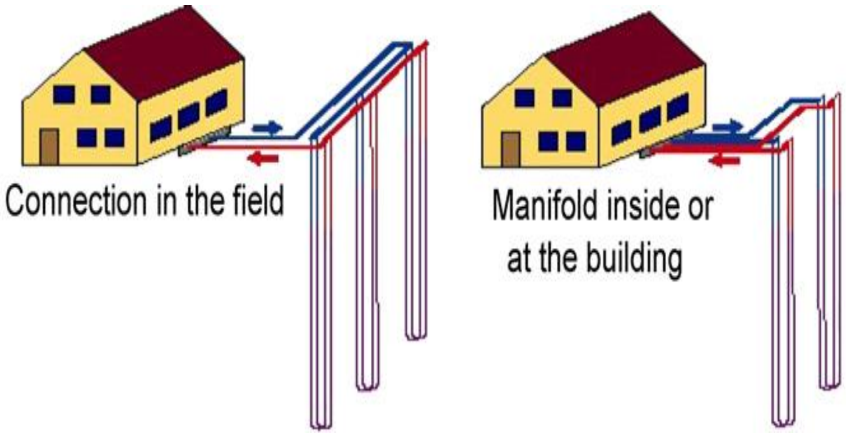

Figure 2.3: Vertical loop.

Source: Omer (2006)

2.3.2.2 Horizontal loop

Provided there is plenty of ground available, this design of ground loop is very economical, as it only requires a digger with a backhoe to excavate the required number of 2 m deep trenches, over an area of ¼ to ¾ acre for a typical dwelling house which is a much cheaper option than a vertical loop. When the required number of trenches is dug, the prefabricated U shaped pipes are laid horizontally at the bottom of the trenches and the whole area backfilled leaving the pipe tails exposed. These tails are connected to inlet and outlet manifolds, supplying the fluid to and from the heat pump via the circulating pump. The one disadvantage of horizontal ground source heat pumps loops has is that it cannot be used in any location subject to thermo frost. The horizontal loop system in European style and American style are shown in Figure 2.4 and Figure 2.5.

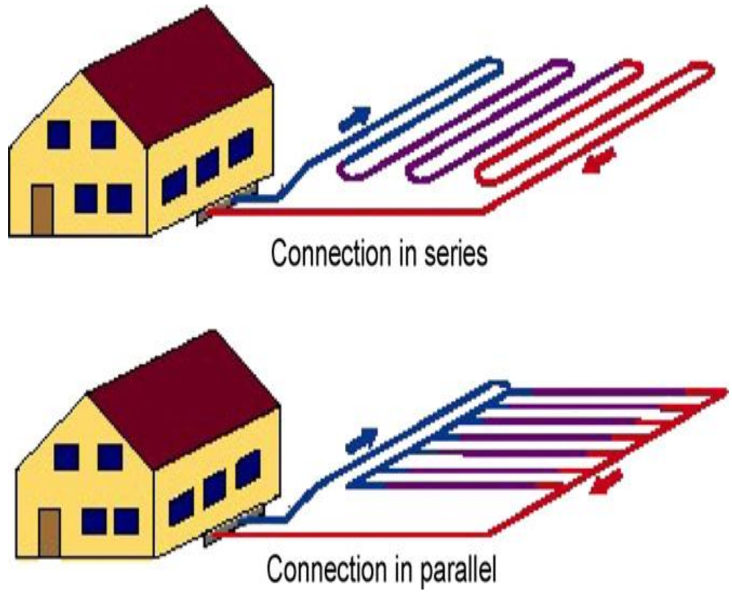

Figure 2.4: Horizontal loop (European style).

Source: Omer (2006)

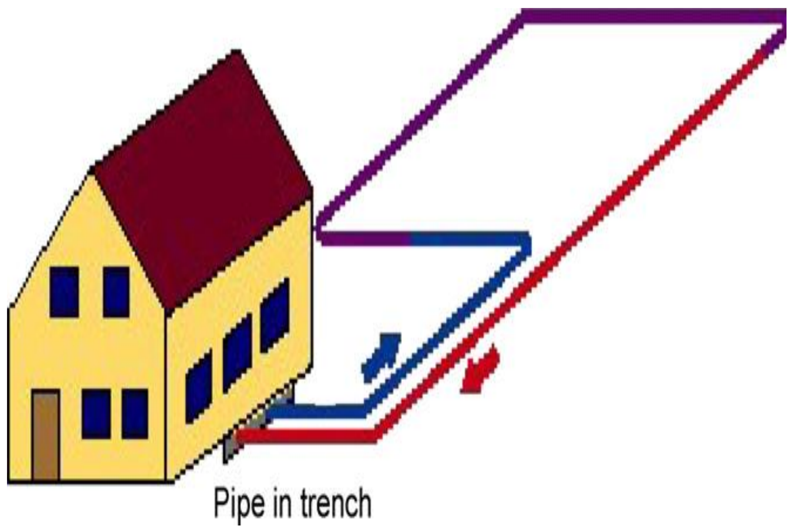

Figure 2.5: Horizontal loop (North European and American style).

Source: Omer (2006)