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DIRECT UTILISATION OF GEOTHERMAL ENERGY

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ABSTRACT

Direct use of geothermal energy is gaining popularity and the past decade has witnessed a tremendous growth in this technology. The biggest use of geothermal energy has been space heating especially in countries with cold climates. However, other direct uses such as drying, greenhouse heating and fish farming are also being practiced. Each of these direct use applications has its requirements in terms of the geothermal fluid temperature. The utilisation of geothermal energy requires the use of specific equipment which are discussed in this paper.

1. INTRODUCTION

The centre of the earth is made up of high temperature molten material called magma which is estimated to be between 5000 and 7000°C (Kubala et al., 1996). The magma sometimes gets trapped in chambers close to the surface of the earth, especially in tectonically active areas as it tries to find its way to the surface of the earth. The heat in the magma is transmitted to the surrounding rocks and conducted all the way to the surface of the earth.

The fractures in these rocks contain water, mainly of meteoric origin, which gets heated by the magma to very high temperatures. When the material overlying the hot subsurface rocks is a cap rock, the hot water gets pressurized and can sometimes find its way to the surface through cracks as hot springs, fumaroles or geysers. However with the advancement in technology, wells can now be drilled to more than 3 km to tap into the geothermal reservoirs and transport the energy in the water to the surface for utilisation. The energy in the hot fluid is referred to as geothermal energy since it is energy from the earth. This is shown in Figure 1 below.

Geothermal is a clean and renewable energy resource which can be found in many places in the world and especially in the tectonically active areas. This energy has been harnessed for both electricity generation and direct uses.

The worldwide direct use of geothermal as at 2010 according to IGA stood at 50583 MWt which is equivalent to 438071 TJ/yr. This was in 79 countries. The biggest users were China, USA, Iceland, Japan, Turkey, Norway, France and Germany.

Direct use refers to the utilisation of geothermal energy for any other application apart from electricity generation. The major direct use applications are in agriculture, aquaculture, swimming, bathing and balneology, space conditioning, industrial processes and heat pumps as shown in the Lindal diagram below (Figure 2).

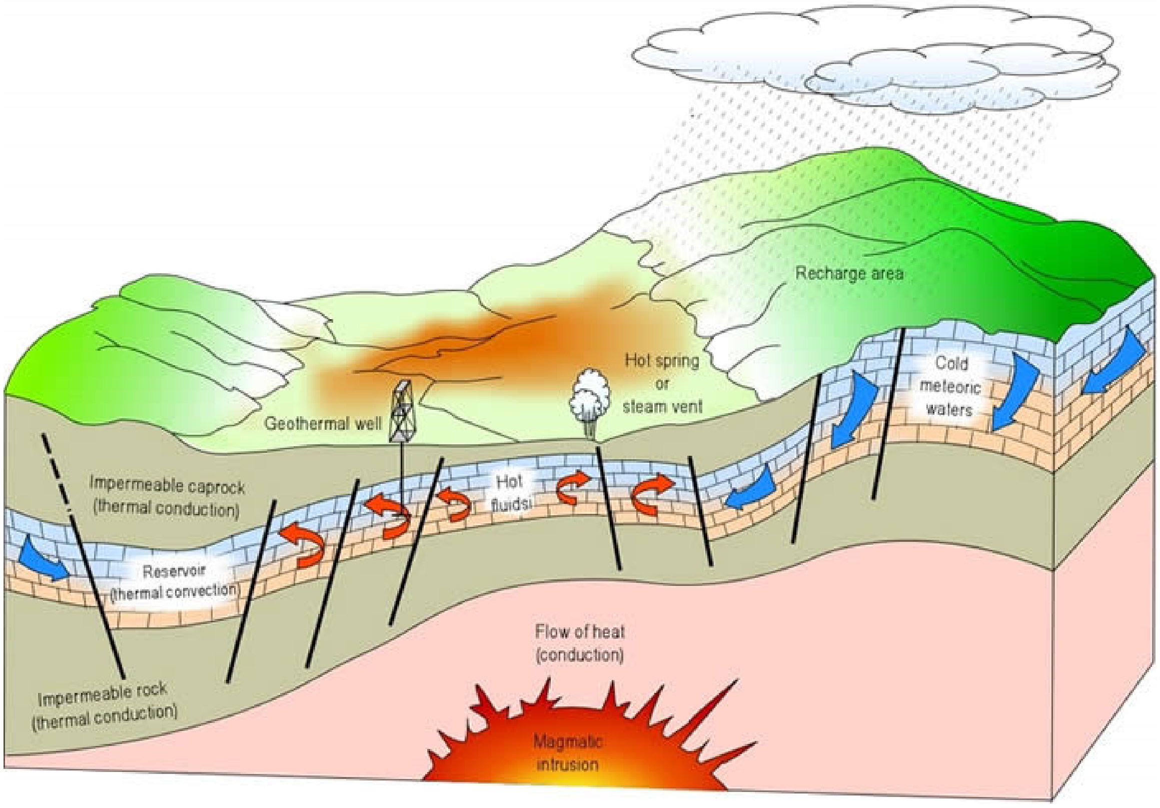

FIGURE 1: A geothermal conceptual model

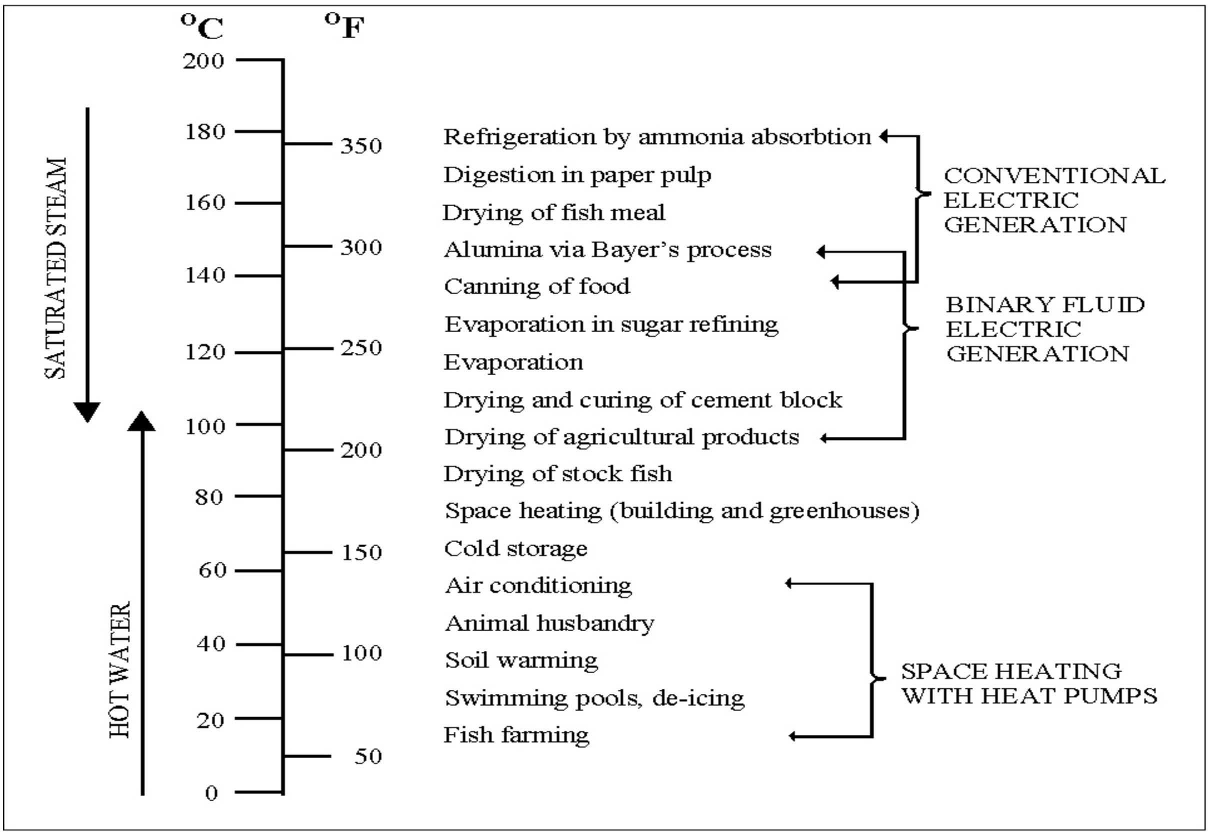

FIGURE 2: Lindal diagram

2. DIRECT USES OF GEOTHERMAL ENERGY

It can be observed from the Lindal diagram that fluids with temperature below 100°C are utilized mainly for space heating and agricultural applications while those above 100°C are for industrial applications.

2.1 Bathing, swimming and balneology

Bathing is one of the earliest known uses of geothermal energy. Ancient Romans, Turks and Japanese have bathed in geothermal water for over 1000 years. Not only is bathing in geothermal water a recreational activity even today, but also believed to have therapeutical effect on the human body. Some of the health benefits derived from bathing in geothermal water include treatment of high blood pressure, skin diseases, diseases of the nervous system and relieving the symptoms of rheumatism.

The use of geothermal energy to heat swimming pools is a common practice especially in the cold countries such as Iceland where almost all outdoor swimming pools are geothermally heated all year round. Lake Bogoria spa and hotel in Kenya is also using water from a nearby warm spring to heat its swimming pool.

Steam baths and saunas have also been designed to utilize geothermal fluids to provide steam and heat. Relaxing in these facilities is also associated with some health benefits such as

- improving blood circulation
- cleaning and rejuvenating the skin
- easing muscle tension
- promoting feelings of relaxation and well-being
- enhancing detoxification processes

2.2 Space conditioning

Space condition refers to the alteration of the climate in an enclosed space by either heating or cooling. The use of geothermal energy for space conditioning is popular in cold climates like Iceland where about 90% of the houses are heated using geothermal water (Lund et al., 2004). The heating of buildings is accompanied by the supply of hot water for domestic uses such as washing. In tropical climates, geothermal energy could be used to cool building for the comfort of the occupants. This is done by the use of vapour absorption machines, which use hot water as the source of energy in order to circulate a refrigerant medium within the system as shown in Figure 3.

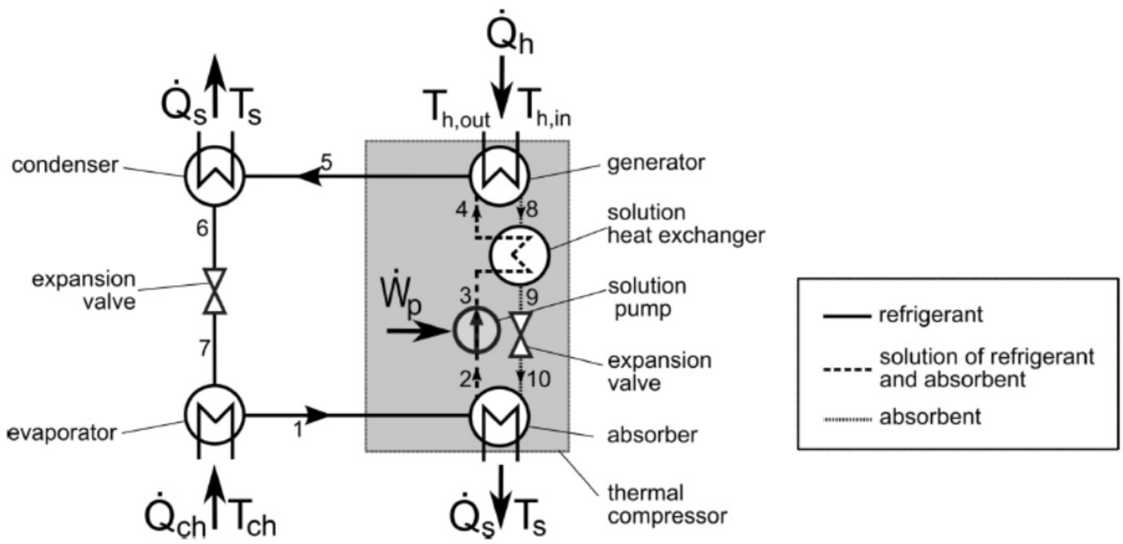

FIGURE 3: Vapour absorption system for space cooling

Vapour absorption systems are of two types: Lithium Bromide/water cycle, where water is the refrigerant while lithium bromide is the absorbent. This configuration is used mainly for air conditioning where temperatures do not go below 0°C as this would result in freezing of the refrigerant. The second configuration is the water/ammonia cycle where ammonia is the refrigerant. This is mainly used for refrigeration since it achieves temperatures below 0°C (Herold et al., 1996).

2.3 Agriculture

The major application of geothermal energy in agriculture is the heating of greenhouses in order to control the climate, mainly temperature and relative humidity. The temperature of the water supplied to the greenhouse depends on the heating demand and ranges from 40-100°C (Vasilevska, 2007). The water is distributed in steel pipes which could be placed under the soil, on the soil or on benches, between rows of plants or suspended in the greenhouse space (Panagiotou, 1996).

In order to produce fast maturing and high quality plants, certain growing conditions must be maintained as close as possible to the optimum. These include nutrients and climatic conditions such as temperature and humidity. It is for this reason that Oserian flower farm in Kenya utilizes thermal energy from one of its geothermal wells leased from KenGen to heat its greenhouses. Kenya is a tropical country in which annual temperatures remain relatively constant throughout the year. However during the cold months and at night, the temperatures could drop considerably. These temperatures may drop below the optimal value for growing flowers and result in formation of dew on the flowers and the leaves, a situation that could encourage the growth of fungi which destroy the quality of flowers.

Oserain has therefore put 50 hectares of rose flowers under the greenhouse heating project mainly to control the moisture content in the greenhouses especially at night and to maintain almost constant temperature throughout the growing life of the flowers. CO_2 gas from the geothermal wells is also separated from the geothermal fluids and used in the greenhouses to enhance photosynthesis in the flower. Irrigation water is also sterilized using the hot water to avoid infecting the flowers with diseases.

2.4 Industrial uses

The industrial uses of geothermal energy are numerous and involve mainly heating and cooling. They depend to a large extent on the economic activities around the geothermal resource. Drying or dehydration of agricultural produce is one of the major industrial applications of geothermal energy. The products that can be dried include grains, fruits, vegetables and pyrethrum as is the case at Eburru in Kenya where the local community uses steam from a shallow borehole for drying.

Dairy processing is yet another application of geothermal energy where fresh milk from the farmers can be pasteurised using hot geothermal water. A series of plate heat exchangers are used to keep the milk and heating water separated during pasteurisation. Concentration of milk, one of the stages in milk powder production, requires temperatures below 100°C. This is done in a falling film evaporator and the evaporation temperature can easily be obtained from geothermal water.

Animal products need to be processed immediately after production in order to preserve them for later use. Bee honey, which is a common product in Kenya, is heat treated after harvesting at about 60°C to prevent crystallisation. Skins and hides from goats and cows are treated by tawing and tanning at temperatures of about 40°C in order to produce high quality leather. Meat from livestock is preserved by refrigeration or canning. The use of a vapour absorption machine running on water/ammonia mixture as the working fluid, can provide the necessary refrigeration at about 0°C, which is sufficient for meat preservation. On the other hand, canning of beef entails precooking it and packing it in sterilised containers using hot water or steam at about 140°C. These processes require temperatures which can be supplied from a geothermal resource.

3. GEOTHERMAL FLUID

The utilisation of geothermal fluids for any purpose depends on the chemistry of the fluid and its thermodynamic properties. The most important of the thermodynamic properties is the enthalpy of the fluid. A fluid is classified as being low enthalpy (<90°C), medium enthalpy (90°C-150°C) or high enthalpy (>150°) depending on the nature of the geothermal system from which it originates (Muffler and Cataldi, 1978). Most direct uses utilize geothermal fluids in the low and medium enthalpy resource while fluids from high enthalpy resource are suitable for electricity generation. However, the waste brine from a high enthalpy resource is ideal for certain direct uses such as absorption cooling.

The common practice in many geothermal power stations including Olkaria in Kenya has been to re-inject the hot brine back into the ground immediately after separation from the steam. This is an inefficient way of utilizing geothermal energy because the brine is usually at a high temperature. At such a temperature, the brine has a lot of thermal energy which can be utilized for other applications such as hot water supply, greenhouse heating or space cooling.

It is clear that direct use is a way of diversifying utilization of geothermal resource.
The major problem associated with the use of brine is the presence of many dissolved solids such as silica, quartz and calcite. The solutes are usually in equilibrium with each other at high temperature and pressure in the reservoir. Upon change of these thermodynamic properties, deposition of amorphous silica in the pipeline and other equipment e.g. heat exchangers and valves normally occurs. To arrest silica deposition, heat exchange should be done at a temperature above the super saturation point of silica. Other factors such as pH and ion concentration also determine the rate of deposition. Therefore, pH reduction and dilution of the brine before utilization are options which can be used to inhibit deposition (Gudmundsson, 1983). Figure 3 and Figure 4 below shows the effect of pH alteration on the deposition rate of amorphous silica. It is also desirable that the level of reactive gases such as CO_2, H_2S, H_2, CH_4 and N_2 should be low so that corrosion is kept to a minimum.

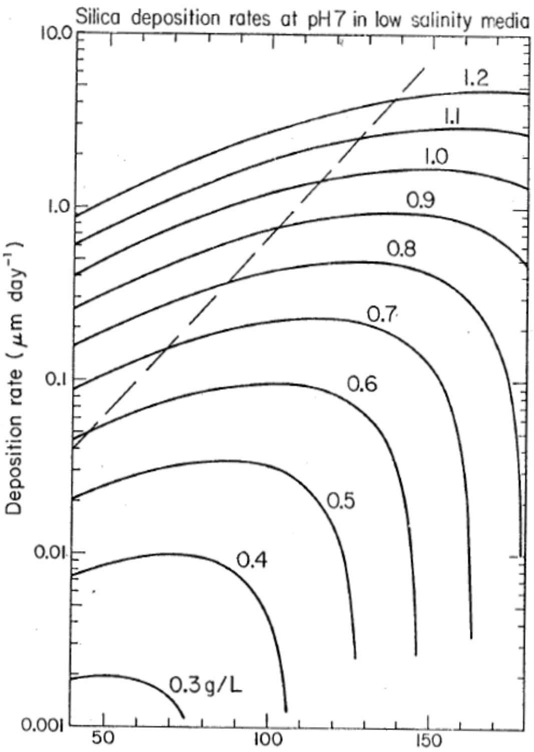

FIGURE 3: Rate of Silica deposition at varying concentrations and pH = 7 (Kruger and Ramey, 1978)

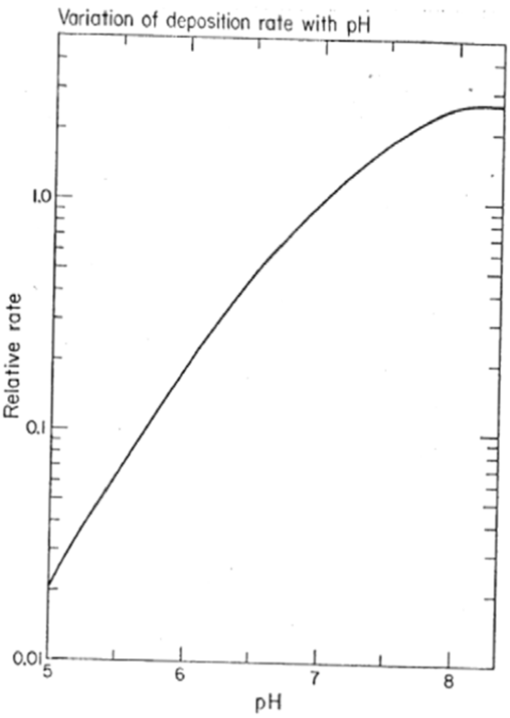

FIGURE 4: Rate of Silica deposition at pH = x relative to rate of deposition at pH = 7, where x = 5, 6, 7, 8 (Kruger and Ramey, 1978)

A reduction in pH from 7 to 6 results in an 80% decrease in the rate of deposition (Figure 4). At such a rate, the deposition is likely not to be a major concern. In addition, heat exchange can be done at a much lower temperature and this will result in more energy being availed for utilization.

4. BENEFITS OF USING GEOTHERMAL ENERGY

Geothermal is a clean and renewable energy resource. It is classified as one of the green energy resources because it is friendly to the environment. Production of energy from geothermal is associated with the release of very little or no CO_2 to the atmosphere unlike the burning of fossil fuels. This means that industrial processes requiring temperatures in the range that geothermal fluids can provide such as milk pasteurization and food canning can replace the fossil fuel fired boilers with geothermal energy.

Over the past few years, the world has been experiencing ever rising fuel prices. This has placed a heavy financial burden on industries which rely on fossil fuels to run their daily operations. On the other hand, the prices of geothermal energy remains relatively unaltered for long periods of time once drilling has been completed. In some cases, savings of up to 80% on fossil fuels have been recorded with the use of geothermal energy directly (Lund, 2004). In addition, the maintenance of systems running on geothermal energy is very little as compared to other systems.

Direct use of geothermal energy is more efficient in the utilisation of energy as compared to other forms energy utilisation. At 50-70% efficiency, it stands much higher above geothermal electricity generation (12%) and internal combustion engines (54%) (EPA, 2006). In addition, with cascaded systems, the energy in geothermal fluids can be utilized down to very low values. Cascading is where a process which requires higher temperatures utilizes the energy in the geothermal fluids first, and then the fluid is utilized by yet another process requiring lower temperatures.

Finally, direct use of geothermal energy is a reliable source of energy. As longs as the associated equipment such as heat exchangers, valves and pumps are working well and the resource is utilized sustainably, a constant source of energy is assured. This is unlike other sources of energy such as hydro-power which rely heavily on the rainfall.

Before direct use of geothermal energy can be made a reality, there are a few requirements that should be in place. Firstly, there must be a geothermal resource which can be economically exploited. The thermodynamic properties of the geothermal fluid and its chemistry should be appropriate for direct utilisation.

Secondly, it is important that a market for the direct use application is within the locality of the geothermal resource. In most cases, the market is determined by the economic activities of the communities living close to the resource. For example, if the population living around the geothermal resource is made up of farmers, then the most appropriate direct uses should be geared towards the processing of agricultural produce. It is also worth noting that transporting the fluid over long distances is a costly affair because of the high cost of the equipment involved such as the transmission pipelines, valves and pumps. Fluid transportation is also associated with both temperature and pressure losses along the length of the pipeline which are not desirable.

5. COMPONENTS NECESSARY FOR GEOTHERMAL DIRECT UTILISATION

The geothermal fluid for utilisation in direct use applications should be transported from the geothermal reservoir to the surface. In some cases, this reservoir may not have outflow areas and therefore, a production well must be drilled to tap into the reservoir and bring the hot fluid to the surface for utilisation. The depth of the production well varies widely but can range from about 1000 m to 3000 m.

In the medium and high temperature reservoirs, the geothermal fluid will in most cases flow to the surface under pressure but in the low temperature fields, the fluid must be pumped unless in situations where artesian flow is possible. Downhole pumps are used to pump the geothermal water to the surface especially where large scale applications are involved. The pumps used with geothermal fluids are the line shaft and submersible pumps. Line shaft pump is the preferred choice because of its longer mean time between failure and lower price (Lund, 1996).

5.1 Pump

The line shaft pump consists of a multi-stage downhole centrifugal pump, a surface mounted motor, a drive shaft connecting the pump and the motor, an enclosing tubing with water lubricated bearing and an outer column as shown in Figure 5

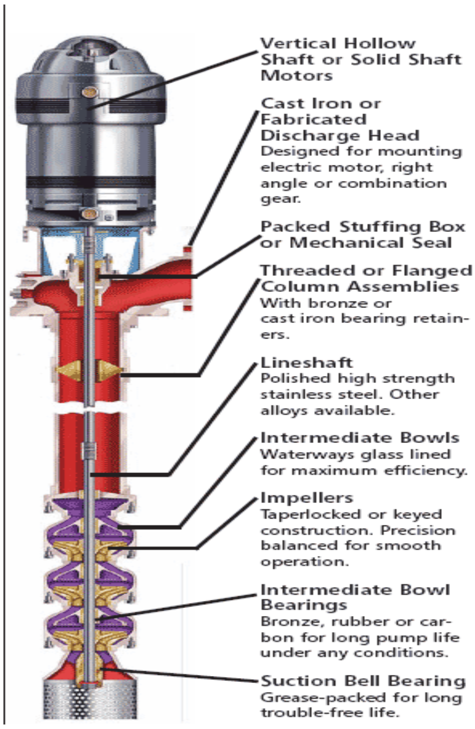

FIGURE 5: Line shaft pump

This pump has the following benefits:

- Proven pump reliability in diverse geothermal fluids.
- Mean time between failure is 7-15 years, depending mainly on water quality
- Water lubricated line shaft bearings which ensures there is no down-hole pollution of oil in water
- Depth range 0 to 300 m
- Fluid temperature range 4°C to 200°C

5.2 Heat exchangers

A heat exchanger is a partition that keeps the hot and the cold fluid separated during heat exchange. The heat exchangers used with geothermal fluids are made of stainless steel which has a good overall heat transfer coefficient and is relatively corrosion resistant. However, where highly corrosive fluids are involved, titanium could be used though it is expensive.

The driving force for heat transfer in a heat exchanger is the temperature difference between the heating medium and the product being heated. The bigger the temperature difference the bigger the quantity of heat transferred. Since this temperature difference varies within the heat exchanger, a logarithmic mean value is normally used and it is called Logarithmic mean temperature difference (LMTD).

In order to achieve efficient utilisation of energy during heat transfer, the two fluids should flow in opposite directions i.e. counter current flow, where the cold incoming fluid meets the cooled outgoing heating medium at the inlet, and a progressively warmer medium as it passes through the heat exchanger. During the passage the cold fluid is gradually heated so that the temperature is always only a few degrees below that of the heating medium at the corresponding point as shown in Figure 6.

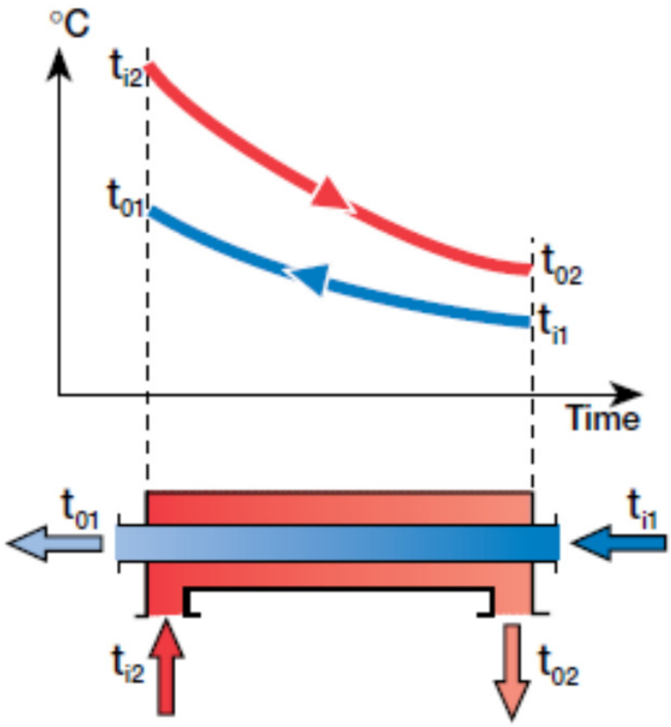

FIGURE 6: Counter current flow of fluids in a heat exchanger (Bylund, 1995)

There are three types of heat exchangers that are commonly used with geothermal fluids. These are plate, shell and tube and downhole heat exchanger. The most common of these is the plate heat exchanger.

In plate heat exchangers, the good overall heat transfer coefficient is made possible not only by the thinness and good thermal conductivity of stainless steel plates, but also by the design of the plates. The plates are corrugated to create turbulence in the flow of cold and hot media. Furthermore, the two fluids flow in opposite directions to enhance heat transfer as shown in Figure 7.

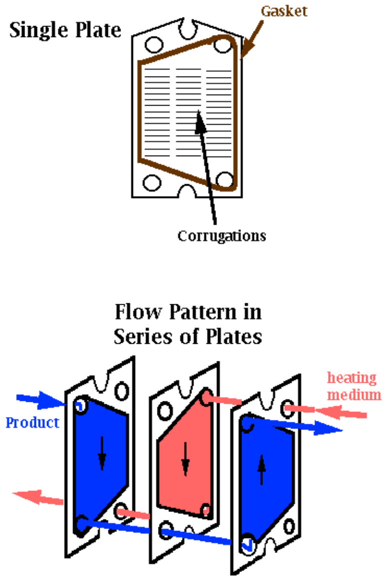

FIGURE 7: plate heat exchangers

As its name implies, shell and tube heat exchanger consists of a shell, which is a large pressure vessel, with a bundle of tubes inside it (Figure 8). One fluid runs through the tubes while the other fluid flows over the tubes to facilitate heat transfer between the two. The set of tubes is called a tube bundle. However, this heat exchanger is less commonly used with geothermal fluids because of fouling, big volume and high price of the device.

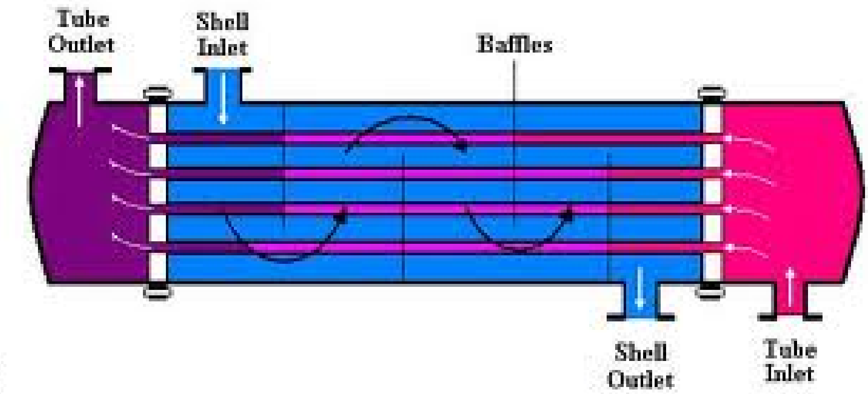

FIGURE 8: Shell and tube heat exchanger

5.3 Pipeline

Hot geothermal water should be transported from the source to the location where it is required for utilisation. A transmission pipeline is laid for this purpose, with provisions made to allow for thermal expansion when the pipe gets heated, with either expansion bellows or loops. The most common material for the transmission pipeline is carbon steel especially when the water temperature is above 100°C. Polyvinyl Chloride pipes (PVC) are used for water temperatures below 100°C. The pipes can be buried in the soil or installed above the ground (Lund, 1996).

In order to avoid heat loss in transmission pipelines, insulation with a watertight and waterproof material should be made. This is because moisture will conduct heat away and render the insulation ineffective. The most common insulation materials are rock wool, polyurethane foam and fiberglass. Burying the pipeline under the soil is also an insulation method though not as effective as with the use of insulation material. Apart from insulation, the other factors that affect heat loss are the pipe diameter and the flow rate (Ryan, 1981). Bigger diameters and higher flow rates lead to lower heat losses.

6. CONCLUSION

Geothermal direct use promises a wide range of applications such as space heating and refrigeration, drying and process heating. Though the installation of direct use systems is high, the running costs are very low and this makes the technology attractive in the long run. Apart from cost, the other important factor to consider before setting up a direct use system is to ensure reliability of the system. The major challenges associated with the utilisation of geothermal energy are scaling and corrosion. Scaling occurs due to the chemicals in the water such as silica and calcite. Corrosion is caused by the acidity of the water which wears out the equipment, especially the pipeline.

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