Boring for domestic scale geothermal

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1 Introduction

Geothermal energy is both an environmentally and economically friendly method for heating and cooling. This report is to investigate methods of drilling the bore hole for geothermal.

Geothermal energy can be extracted in a variety of configurations. For instance, the heated water could be directly used for heating or through a closed loop pump. Another axis of differences is the depth of heat extraction.

Horizontal: A web of coils is laid just below the frost line, since the ground temperature does not vary much below a certain point. This is generally cheapter if land is available.

Vertical: If land is not easily available, or if higher temperatures are needed, a hole can be bored in vertically. This can go down to anywhere from a few tens of meters to hundreds.

In this report we discuss how to bore for the vertical method. Furthermore, we concentrate on depths of about 200m.

2 Issues and considerations for boring

Boring can be done manually or by a drilling rig. Manual methods are slow and limited to about 40m [8]. Hence, we will concentrate on powered rigs.

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We will discuss the different methods these rigs employ to drill below. Here the factors that determine how deep a rig can drill and how fast in a certain area.

Rig power: A rig can only provide so much torque (if it is rotatory type) or hammering force (if it is a hammer type). This force is negated by the frictional force between the circumference of the drill pipe and the earth. At a certain depth this frictional force will equate the rig's driving force.

Diameter of bore: The larger the diameter, the more the friction with the sides of the bore. Moreover, more area has to dug at the bottom of the bore. This can limit the speed, especially in rock formations.

The diameter of the drill-pipe and bore are typically greater than the needed amount. This is because the water-pipe is inserted through the drill-pipe all the way to the bottom. Then the drill-pipe is extracted out. If the drill-pipe is removed before, there is a danger of the bore hole collapsing before the water-pipe can be inserted [2]. To counter this, casings are often used.

Weight of the drill-pipe: The weight of the drill pipe increases with the depth of drilling. The rig structure is designed to support a given amount of weight. This limits the depth of the bore.

Rock formation: Depending on the sub-surface lithologies in an area, the drilling speed will vary. For instance, rocks are hard to drill through. On the other hand, if sandy layers are present, casing have to be put in [1].

Drill pipe segments: The drill-pipe comes in segments eg. 10 m. After one segment has been dug in, a new segment is attached to the top and the process continued. If the drill-pipe needs to be extracted, say to change the drill-bit, it has to be done segment by segment. This slows down the drilling process and adds significant manual labour to the process.

Besides the above limitations, there are other factors that increase the difficulty and cost of drilling.

Casing: In sandy soil, the bore hole will tend to collapse around the drilling pipe. The massive friction generated is often above the power ratings of rigs, and goes up with distance. To counteract this, the sides of the

bore hole are typically cased with a pipe of diameter equal to the bore hole and slightly greater than the diameter of the drill pipe. This is clearly a cost increase as well as a technological challenge.

Drilling-pump: The drilling material is brought up to the surface using liquid that is pumped down the drill-pipe and then brought up from the annular region between the drill pipe and bore hole. This liquid also cools the drill bit and supports the walls of the bore hole. As depth increases, the pumping power has to increase.

Drilling-fluid: The drilling fluid is not always water. Not all fluids are equally effective at bringing up the cuttings or equally easy to pump.

3 Some Calculations

3.1 Mass of the pipe

Length of pipe (L) = 100 m
Diameter of the pipe (d) = 50 mm
Thickness of pipe (t) = 2 mm
Density (ρ) = 8030 kg/m^3

Mass of pipe = Cross-sectional Area x Length = $\frac{\pi(d^2-(d-2t)^2)}{4}L\rho$

Mass of pipe/meter = 2.422 kg/m

Mass of 100 m pipe = 242 kg.

Notice, this does not take into account the mass of the connectors between pieces of the drill pipe or the drill bit.

4 Costs

Commercially, boreholes are drilled for around 55-160 US dollars/meter [1, 3]. This is just the drilling cost. If casing needs to be put in, extra charges have to be paid per meter which can be about 35 US dollars/meter [1]. Moreover, there are typically some fixed cost for transporting the drilling rig to the location.

By these rates, the cost of just drilling 200 meters ranges from 11,000 to 32,000 US dollars. Adding the fixed cost and casing cost, the cost of a commerically drilled 200m borehole is at least about 20,000 US dollars.

To setup our system, we will need some analysis of prices.

4.1 Drill pipe

According to an online retailer [12], the pipe price per meter = US$11.23/m for 2 inches (50mm).

Price of 200 m pipe = US$2,246

4.2 Casing

According to an online retailer [11] the price of pvc pipes of 1.5 inches is US$1.22/foot. This is equal to US$4.00/meter.

Based on this rate, 200m casing will cost = US$800.

5 Drilling Methods

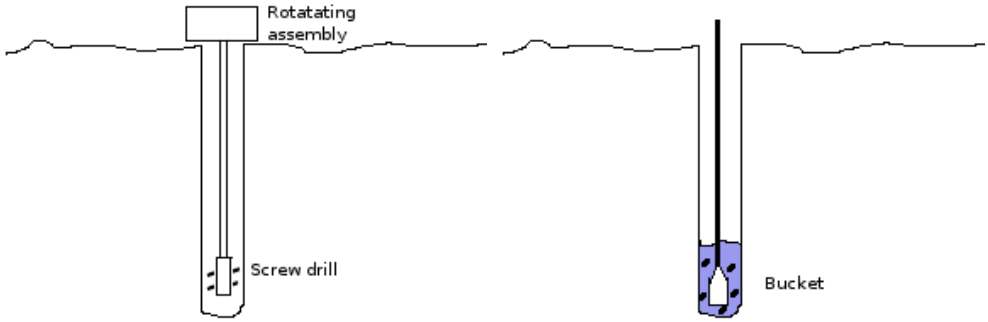
There are various types of drilling methods. We discuss here the main types suitable for well type applications. There are many other methods which are suited for geological study. These methods are designed to improve the quality of cuttings brought up as well as prevent them from contanimation. These extra design features add to the cost. We are only interested in drilling a bore hole so we will ignore these drilling methods.

5.1 Auger drilling

This is one of the simpler methods of drilling. The drilling is done by rotating a screw type drill bit. Once a sufficient length has been drilled, the drill bit is pulled out and a bucket is lowered into the bore hole. This bucket is used to pull up the cuttings. Then the drill bit is inserted again and drilling is continued.

5.2 Cable tool drilling

This is the simplest type of drilling method, and similar to auger drilling. Instead of using a rotating screw, a strong and heavy drill bit is lowered and dropped repeatedly into the bore hole. This breaks up the rock. Similar



(a) (b)

Figure 1: Auger method consists of alternatively drilling with a screw and removing cuttings with a bucket. The bucket has a flap on the bottom that opens up when it hits the water. As the bucket is filled, the flap closes and the bucket can be pulled out.

to auger drilling, a bucket is used to pull out the cuttings. This method is however very slow (10-20 m per day). It is also not suitable for soft formations.

Down-the-hole-hammering method is an advanced form of this method and discussed in the the air flow subsection of rotatory drilling below.

5.3 Rotatory drilling

Rotatary drilling is more complicated than other forms of drilling but is typically faster. The drilling process involves rotating the drill bit at the end of the drill pipe, by rotating the whole drill pipe. The cuttings are brought up to the surface by air or water.

5.3.1 Air flow

Drilling with air can be cheaper than with water, especially if water is not freely available. However, air pressure and flow rate rate need to be much more than water flowrate for the same diameter and depth hole because air is much less viscious than water.

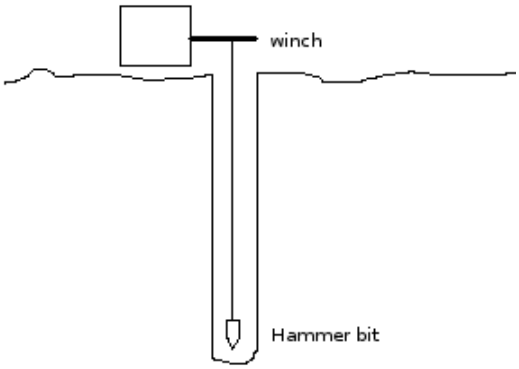


Figure 2: Cable tool drilling. The cable tool has a hammer type bit. This is raised with the winch and then allowed to fall and pulverize the rock. The cuttings are removed in a method similar to in auger drilling.

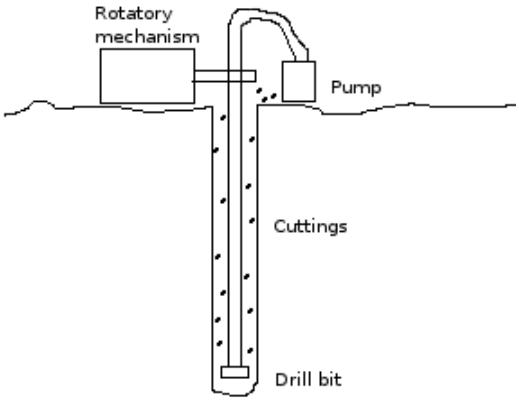


Figure 3: The whole drill pipe is rotated to drill through the rock. A fluid is pumped down the drill pipe and back up outside the drill pipe. The cuttigns are carried up by this flow.

Depending on soil formation, different types of bits might be needed. Each type requires it's own drilling method.

Drag bits are rotatory type bits that are suitable for soft material such as sand or clay. The purpose of air is only to cool the bit and to carry the cuttings to the surface. The cutting power is provided by the rotation of the drill pipe and bit.

However, in the case of hardrock down-the-hole-hammers are needed. These need only low rotation speeds (20-30 revs/min). The primary means of drilling is hammering through the use of compressed air. The bit is made so that pushing against hard rock automatically starts the hammering, while raising the bit allows the air to carry up the cuttings. This method also requires a much more stable rig, able to withstand shocks from the hammering which are carried up the drill pipe.

5.3.2 Water flow

Drilling with water is more complicated than with air. Pumping fluid properties become important. It is recommended for deep well's to use mud pumps. These are in general 'fixed displacement type' pumps. These should be used with water mixed with benotite. This is a type of clay that adds viscosity to the water, helping to bring up the cuttings. This clay also helps line the walls of the bore for strength, till casings can be put in place.

6 Analysis

Auger drilling is suitable for small depths. To alternate between the the drill bit and bucket requires a considerable amount of time. Each drill pipe piece has unscrewed and removed when the drill pipe is being pulled out and has to screwed on when it is being put back in. For a depth of 200m, this is not very practical. This method also not very suitable for hard rocks.

This problem also exists for the cable tool drilling method. However, cables can be pulled out in one piece, hence this method can be used for greater depths than auger drilling. On the other hand, it is only suitable for hard rock system. A continous rock system is not expected to exist for depths upto 200m.

One can then consider the more complicated and correspondingly expensive methods of rotatory style drilling. These methods are effective for different rock formations as well as for depths greater than 200m. However, they are

much more complicated and require much more equipment - pumps, water supply - than the simpler methods discussed above.

7 Conclusion and Proposal

Since, auger drilling and cable drilling method won't work for deeper wells, it is recommended that the rotatory style drilling be employed. Compressed air is simpler to deal with than fluids, so it is recommended that the compressed air method be used. This has the added advantage that the drill bit can be changed and rotation speed and drill bit be changed to down-the-hole-hammering method if hard rocks are encountered.

Casing for the bore hole will be essential. PVC pipes are typically cheap and have all the required properties. This need not be permanent. Once boring is complete, and the final water pipes have been installed, the casing can be removed. However, it might be cheaper to buy new casing then to pull out 200m of PVC pipe.

One interesting technique that is often used is the following. Drilling is started with a large diameter, since near the surface drilling is easy. When drilling speed slows down because of depth, a smaller diameter pipe can be employed. This can be done two or three times, till the last diameter is sufficient for our water pipe to go through. This speeds up the drilling and reduces the weight of the drill pipe.

For further information many of the links in the bibliography will be useful.

References

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