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HYDRAULIC FRACTURING IN THE BOHUS GRANITE, SW-SWEDEN. TESTS FOR HEAT STORAGE AND HEAT EXTRACTION.

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Abstract

The HDR-concept initially invented and tested at Los Alamos Scientific Laboratories has been considered as interesting for domestic heating in Sweden. The technic to produce large heat exchanger surfaces, by hydraulic fracturing, within the bedrock has in Sweden been tried at shallow depth, in order to create a subsurface energy storage. The initial tests have been very promising and it is concluded that it is possible to produce a competitive low cost energy storage in this way. Experiences from the hydraulic fracturing experiments at shallow depths (<50 m) will be considered when planning a program for the new test site at Fjällbacka, SW Sweden. Here fracturing experiments will be carried out in 500 metres boreholes.

Introduction

In step with increasing prices of energy the need for saving of energy has been even more essential. In Sweden 40% of the total energy consumption is used for domestic heating - ventilation - and tapwater. About 90% of this energy is supplied from oil. The Swedish parliament has decided to decrease the oil based energy consumption from 70% to a level of 40% which is intended to be reached during 1990.

Heat extraction and heat storage

Sweden constitutes a part of the Baltic shield. Except for the southernmost and westernmost Sweden most areas exhibit Precambrian, metamorphic rocks. Some Precambrian alkalirich granites contain U and Th to a level higher than normal resulting in an anomalous heat production. Temperature measurements in shallow boreholes (mostly 100 - 700 m) show that the highest gradients are approximately 25°C/km (Ahlbom et al., 1978, Landström et al., 1980; Malmqvist et al., 1983). However, most gradients recorded are only 10 - 20°C/km. Airborne gammaray investigations indicate a few interesting targets in respect of the HDR-concept (Lindén et al., 1983). It has been advocated that due to the relatively low temperature gradients the only potential use for geothermal heat is for domestic heating. As most densely populated areas already have got district heating systems the distribution heat from HDR-plants will be facilitated.

In Sweden as well as in many other countries a lot of different energy R & D projects have been carried out concerning solar heat and waste heat. This is due to the fact that both solar and waste energy are examples of energy resources exploited to a degree far less than what could be possible. As Supply and demand of solar energy, waste energy etc. does not go hand in hand, the problem is to find a method of storing energy in an inexpensive way. Heat storage for shorter periods is a well established technology, especially with water as storage medium. For large scale seasonal storage there are a number of methods under development. These methods can be arranged into two main groups — heat storage in water and in rock. A problem for most methods is the high cost.

This paper presents field experiments on hydraulic fracturing at shallow depth within the Bohus granite in order to create a low cost, heat storage within the rock. Experiences from these experiments have been useful in planning the work for a HDR-test site at Fjällbacka, SW-Sweden.

Hydrock

At shallow depth (<500 metres) most shield areas will exhibit a rock stress pattern, so conditioned, that the least principal stress is approximately vertical (Hoek & Brown, 1977). This means that hydraulic fracturing of the rock will give fractures propagating in a subhorizontal plane. If several parallel fractures are arranged, they can be connected to each other through drillholes allowing water to be circulated through the system (figure 1). Thus large heat exchanger surfaces between the rock, as storage medium, and the water, as heat carrier, can be obtained. In summertime, when there is an excess of energy and also a need for airconditioning, warm water is cooled down by circulating the water through the system. In winter time when there is a shortage of energy and a need for domestic heating cold water is heated by circulating the water through the system. To reduce the impedance within the system, propants can be introduced into the fractures.

At Rixö, SW-Sweden, fracture experiments have been carried out in four vertical 70 metres deep boreholes drilled within the Bohusgranite. A central borehole has been used as a fracturing hole, whereas the three other holes were used as obser-

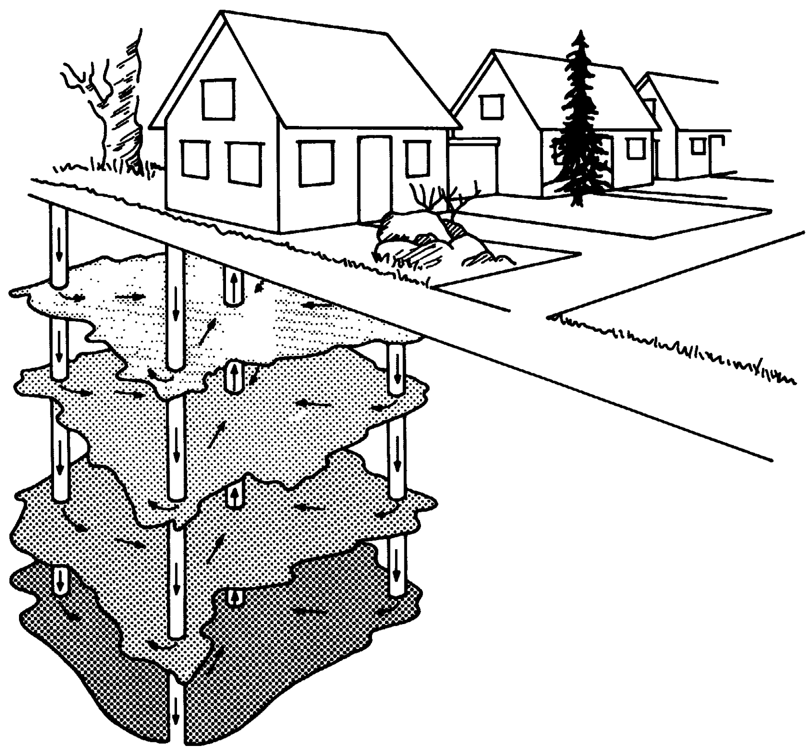

FIGURE 1
PRINCIPLE OUTLINE OF A HYDROCK SYSTEM

vation holes, 6-10 metres away from the central hole. Two sections were fractured. The first attempt was made on a depth of 32 m below the surface. A break down pressure of 21 MPa was registrated and a response was recorded in the nearest borehole after 40 seconds as a water inflow. The other observation holes responded after 5 and 20 minutes respectively. The flow rate was then equal to the maximum pump rate (55 l/minute). At refracturing a maximum flow was attained at a pressure of less than 4 MPa.

Another section (44 m below surface) was then selected. There a reaming of the borehole wall was made by using a casing cutter. The pressure needed for break down was then reduced to 10.5 MPa. The nearest observation hole responded after a few seconds. Refracturing allowed a flow of 55 l/minute at a pump pressure of 2.5 MPa. A shut in pressure of 1.3 MPa was recorded (i.e. close to the theoretical value considering the weight of overburden). Impression packers as well as TV-logging documented the new horizontal fractures within the observation holes.

Future

Both heat extraction from rocks (HDR) as well as heat storage within rocks will be considered in a future Swedish R & D program. In May 1984 drilling operations will start for an HDR-test site at Fjällbacka, SW-Sweden. Three holes will be drilled down to at least 500 metres below surface, to be used for fracturing experiments as well as circulation tests. The first phase ended in August 1984 includes establishment and geological documentation of the drill site, drilling program and geological as well as geophysical documentation of the drillholes.

At Rixö the next phase will include pumping and circulation test as well as tests with propants. The experiences from the Rixö test will be used for the planning of the phase 2 program at Fjällbacka which will include fracturing as well as circulation tests. The Rixö and Fjällbacka experiments will be run parallel.

Conclusions

The Rixö test shows that subhorizontal, parallel fractures can be created at shallow depth allowing water to be circulated. It is concluded that in order to decrease the impedance and to get a controlled flow through the fractures, propants will be necessary. The reaming of the borehole wall at the fracture inlet/outlet is a complementary way to reduce the impedance.

The Hydrock method seems to be the solution both technically and economically in many cases of energy storage. The large heat exchanger surfaces result in a possibility to use Hydrock both for seasonal storage and for shorter periods. Another advantage is that the storage can be built both for existing and new buildings as no space consuming surface construction has to be carried out. The method gives the future possibility of forming a competitive heat storage in different energy systems, especially for large scale/low temperature heat storage.

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