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ADVANCED TURBODRILLS FOR GEOTHERMAL WELLS

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ABSTRACT

Maurer Engineering Inc. is continuing the development of a new high-temperature, 350°C advanced turbodrill for use in drilling geothermal wells. Existing downhole drilling motors are temperature limited because of elastomeric degradation at elevated temperature. The new turbodrill contains high-torque turbine blades and improved seals which allow higher bit pressure drops. This new geothermal turbodrill which is designed for improved directional drilling offers economic alternatives for completing geothermal wells. The advanced turbodrill will be tested in the Los Alamos Scientific Laboratory's hot dry rock geothermal wells.

INTRODUCTION

The purpose of downhole drill motors is to provide the power needed to rotate drill bits at the bottom of the boreholes. Drill motors are especially advantageous for 1) wells where drill pipe wear, fatigue, and twist-offs occur, 2) directional drilling in wells where direction and trajectory control are required to attain a preselected target, and 3) starting wells that are spudded in volcanic rock or alluvium containing large boulders.

BACKGROUND

First tested in the 1920's, drilling motors did not find widespread application until the 1950's, when turbodrill use began in the Soviet Union, [1, 2]. By the early 1960's, about 85% of the Soviet's oil and gas wells were drilled with turbodrills. Their usage has decreased to approximately 70 percent since rotary drilling is now being used in most Soviet wells deeper than 12,000 feet.

Drill motors are currently used in the United States primarily for directional drilling. Current motor seals typically limit bit pressure drops to less than 300 psi, which is inadequate for good bottomhole cleaning of cuttings. Commercial downhole motors operate at speeds of 300 to 1000 rpm, whereas roller-cone bits operate most effectively at speeds of 50 to 150 rpm. The bit bearings tend to fail in 5 to 15 hours at these high motor speeds thereby seriously limiting the application of drilling motors.

A review of the various types of downhole motors, i.e., turbines [3, 4], positive displacement [5, 6], and electric drills [7, 8], indicated that a turbodrill would be the most practical to upgrade for high-temperature because of the all-metal turbine blades.

GEOTHERMAL APPLICATIONS

Soviet geothermal drilling has not been reported in detail [9], but it is likely that turbodrills have been utilized in the geothermal drilling program in the Soviet Union since that is their principal mode of drilling. Directional geothermal wells have been drilled with turbodrills in the extensions of the Hachimantai field in Japan [10]. The Philippine geothermal development by Union Oil of California has also indicated [11] a program of multiple wells from individual locations.

Directional drilling with downhole motors has been used to control geothermal well blowouts in the extensively developed Lardarello, Italy [12] and Wairakei, New Zealand [13] fields.

Directional drilling has been used in The Geysers, CA geothermal field to drill multiple wells from a single pad. One drilling contractor [14] indicated that about 15 wells have been successfully completed at The Geysers by that technique. It was also indicated that several essentically vertical wells have been provided with multiple side-tracked completions at The Geysers.

The DOE-funded Raft River, ID geothermal project [15], conducted by the Idaho National Engineering Laboratory, has effectively utilized a downhole motor to drill two directional holes from the bottom of a vertical geothermal well, Figure 1. This three-legged completion enhanced the productively of the well three to five fold in this fracture-controlled formation. This technique, which increased the total well cost by only 20 to 30 percent, will undoubtedly be more widely applied in future geothermal drilling programs. Consideration is being given to using the new geothermal turbodrills in future Raft River wells.

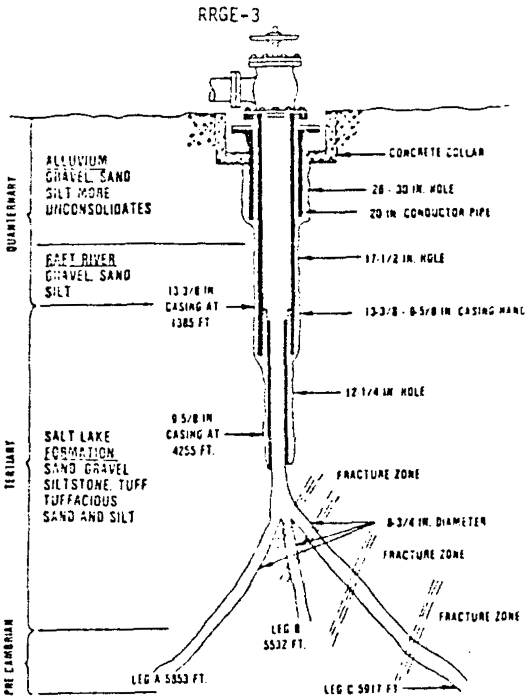

Figure 1 RAFT RIVER GEOTHERMAL WELL

The initial experimental approach to a hot dry rock geothermal project [16, 17] funded by DOE and conducted by the Los Alamos Scientific Laboratory (LASL), is based on the concept shown in Figure 2. The first borehole drilled into hot 200 to 300°C rock was hydraulically fractured and the second well was then directionally drilled to intersect the fracture.

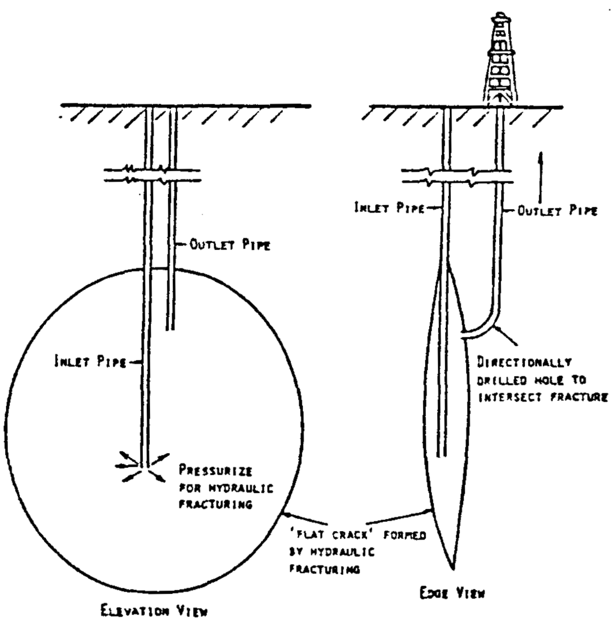

Figure 2 LASL HOT DRY ROCK WELLS

Directional drilling hard, hot granite has proven to be slow and expensive. Several approaches have been taken to improve the situation. The Dyna-Drill Division of Sii has provided an experimental unit, Figure 3, with a coolant flow hole in the rotor. This modification should provide better cooling by the drilling fluid and enhance the life of this drill motor at 200°C. For higher temperature service, the design of the turbodrill discussed in this report was initiated.

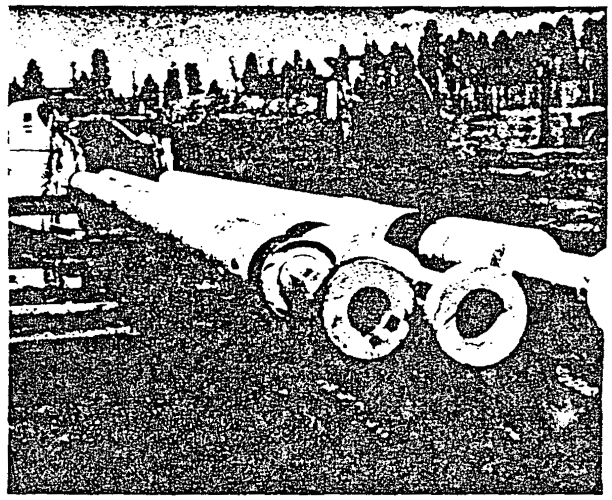

Figure 3 DYNA-DRILLS WITH HOLLOW ROTORS

HYDRAULIC DRILL MOTORS

There are two basic types of downhole hydraulic powered drill motors; positive-displacement and turbines. Positive-displacement motors have the distinct operational advantage that the rotary speed is directly proportional to the pump flow rate and flow rate gives a direct measure of the rotary speed. Volumetric efficiency decreases as motor torque increases because the increased pressure drop across the motor increases the leakage.

The torque delivered by a positive-displacement motor is directly proportional to the pressure drop across the motor. The rig mud pressure guage can therefore be used to monitor the bit torque.

Four types of positive-displacement motor concepts (Moineau, vane, piston, and gear) have been proposed for drill motors; but of these, only the Moineau type (Dyna-Drill) has been widely used for geothermal drilling. The Dyna-Drill is powered by an eccentric steel shaft rotating in a rubber stator. Dyna-Drill motors are limited to maximum operating temperatures of about 180°C primarily by the rubber stator. Attempts to increase the temperature capabilities using higher temperature elastomers have been of limited success because of their unfavorable fabrication properties and high costs.

TURBODRILLS

Turbodrills utilize axial flow turbine blade sections to apply torque to the drill bit. The torque developed by a turbodrill is maximum when the turbodrill stalls and decreases to zero as the rotary speed is increased to the runaway speed. Turbine torque can be increased by increasing the number of turbine stages, the fluid flow rate, or the exit angle of the turbine blades. Existing turbodrills deliver maximum power output at speeds of 500 to 1000 rpm. This high speed is excessive for roller bits and results in short bit bearing life.

ADVANCED GEOTHERMAL TURBODRILL DESIGN AND DEVELOPMENT

Existing turbodrills are limited to maximum operating temperatures of about 180°C due to the use of elastomeric thrust and radial bearings. Because of bearing limitations, these turbodrills are usually operated at bit loads of only 20,000 to 25,000 pounds, whereas many bits drill most effectively at bit loads of 40,000 to 60,000 pounds. This reduced bit load greatly reduces drilling rate, especially in the hard rocks encountered in many geothermal wells. These turbodrills do not deliver sufficient torque for optimum use of tricone drill bits; consequently, the bits drill at reduced speeds. Inadequate seals in existing drill motors, result in reduced bit hydraulics and reduced drilling rates.

Due to the temperature limitations of existing downhole motors, two advanced turbodrills are being designed for use in higher temperature wells:

- Directional Turbodrill - This turbodrill utilizes water to cool and lubricate the bearings and is designed to operate in hot geothermal wells at temperatures up to 350°C.
- Straight Hole Turbodrill - This turbodrill contains a sealed lubrication system which allows the bearings to operate in lubricant. The unit is applicable to both oil field and geothermal drilling.

The design specifications for these two turbodrills are given below:

GEOTHERMAL TURBODRILLS - SUMMARY SPECIFICATIONS

Parameter	Directional	Straight Hole
Rotary Speed:		
With Roller Bits	100-200 rpm	100-200 rpm
With Diamond Bits	400-800 rpm	400-800 rpm
Diameter:	7-3/4 inch	7-3/4 inch
Length:	21 feet	25 feet
Power Output:		
At 150 rpm	36 hp	65 hp
At 600 rpm	123 hp	222 hp
Flow Rate:	400 gal/min	400 gal/min
Temperature Limitations:	350°C	200°C
Bearing Life:	50 hours	100-200 hours

DIRECTIONAL TURBODRILL

A flow constrictor at the bottom of the high temperature directional turbodrill, Figure 4, allows approximately 10 percent of the drilling fluid to flow through the roller bearings to cool and lubricate them. The remaining fluid flows through the bit nozzles to remove the rock cuttings from the hole bottom.

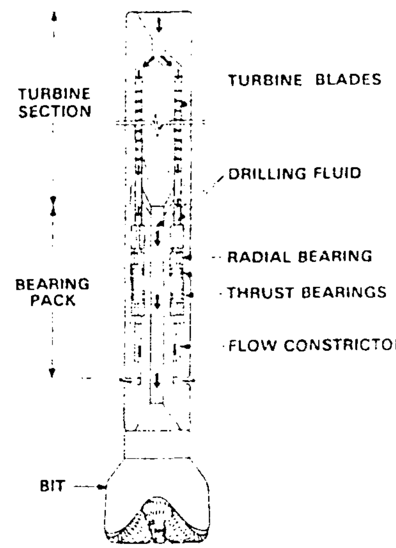

Figure 4 ADVANCED DIRECTIONAL TURBODRILL

The new turbodrills utilize advanced turbine blades which deliver 4 to 5 times more torque than the blades used in existing turbodrills. This allows the new turbodrills to be shorter and to deliver 100 percent more power than existing motors of comparable diameter. These turbodrills can be operated at rotary speeds of 100 to 200 rpm with high-torque roller bits and at 400 to 800 rpm with low-torque diamond bits.

A separate bearing pack is used to facilite turbodrill maintenance in the field. The bearing pack utilizes high-thrust roller bearings made of M50 tool steel. These bearings operate effectively at temperatures up to 600°C thereby overcoming a major temperature limitation of existing motors. These roller bearings have 10 to 80 times the life of the ball and rubber friction bearings used in existing motors.

Roller bearings are also used to accommodate the high radial loads in the turbodrills. These high loads are produced as the turbodrills are deflected in directional holes.

STRAIGHT HOLE TURBODRILL

The straight hole turbodrill, Figure 5, is designed to operate in abrasive drilling mud. The bearings are sealed in lubricant which is pressurized by the mud acting on top of a floating piston. Improved high-pressure rotary seals allow bit pressure drops of 300 to 800 psi across diamond bits and 500 to 1000 psi across roller bits. This compares to only 200 to 500 psi with existing motors. These higher pressure drops should significantly increase drilling rates.

Although this turbodrill is currently designed for moderate temperature drilling (200°C), it is suited for drilling the shallower portions of geothermal wells, where drilling muds are required to prevent lost circulation into porous or fractured formations.

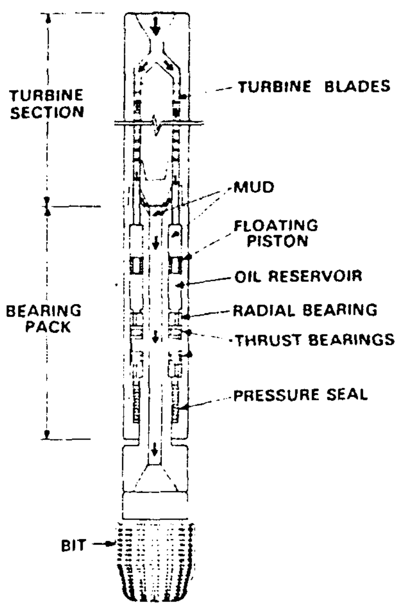

Figure 5 ADVANCED STRAIGHT-HOLE TURBODRILL

The temperature gradient in geothermal wells varies with hole depth; consequently, only the bottom portions of most geothermal wells are hot enough to necessitate the use of the directional geothermal turbodrill. When drilling with abrasive drilling mud, the straight hole turbodrill is preferred and should be used as long as possible before switching to the geothermal turbodrill.

CONCLUSIONS

Drilling motors have found rather widespread application for directional drilling of geothermal wells. An advanced high temperature turbodrill is being developed which will allow the drilling of several wells from a single location. The motivation for development of the advanced turbodrill was the directional drilling requirements in hot, hard granite for the LASL hot dry rock geothermal project. However, additional applications to other geothermal energy development projects can be expected.

ACKNOWLEDGEMENTS

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