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by R.E. Williams

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GEOTHERMAL DRILLING IN HOT GRANITIC ROCK

R. E. Williams

UNIVERSITY OF CALIFORNIA
LOS ALAMOS SCIENTIFIC LABORATORY
LOS ALAMOS, NEW MEXICO 87545

Geothermal drilling has largely followed the methods of the oil well drilling industry. It has used the techniques, tools, and indeed the personnel and equipment used by this older industry. This is natural and certainly justified as the most cost effective method.

Some extension of the methods used in oil well drilling is now being required in order to penetrate the hotter zones and the harder rocks from which geothermal energy can be obtained. Fortunately, some of the established producers of oil field equipment see the possibilities of an expanding, though presently small, market for their equipment in the geothermal area. They also see that many of the developments of equipment for geothermal use also have an application in the drilling of deeper and hotter holes for hydrocarbons. Therefore, while we in the geothermal field are continuing to learn and obtain valuable information from the older drillers, we are now in a position to share in the advancement of some techniques and equipment development which will be of use in the drilling for hydrocarbons.

In the hot dry rock program, we see the most urgent techniques and equipment problems as those shown in Tables I and II which list the problems and their present status.

An elaboration of the status of each of these various problem areas is as follows:

Mud Motors. Because of the temperature limitations of presently available mud motors, a new turbodrill has been designed for our needs by Maurer Engineering, Inc. of Houston, Texas. The first unit is now being manufactured. This unit is required to meet the high temperatures we will encounter and is designed with special blades which will cause it to rotate more slowly than presently-available downhole motors. Characteristics are as follows for the version of this motor which is especially designed for use in directional drilling with button-type roller bits: rotary speed 150 rpm; diameter 7-3/4-in.; length 21 ft; power output 36 hp; flow rates 400 gpm; temperature limit 350°C (662°F); and bearing life 50 h at 275°C (527°F). Unfortunately, we will have only one of these units, plus replacement parts, for our next drilling program. The only backup is the Dyna-Drill or similar mud motors which have temperature limitations of

TABLE I

HEAT-RELATED PROBLEMS

Item	Problem	Solution or Status
Mud Motors	Temperature limitations of elastomers used in these units.	A new all-metal turbodrill with a slower speed has been designed and is being fabricated.
	Inability to run at slow speeds for efficient use of button-type bits.	
Steering Tools	Heat limit of internal components.	Suppliers are providing heat shields to protect equipment for limited time down hole.
Open-Hole Packers	Temperature limitations of elastomers used extensively in these units.	Suppliers are experimenting with higher temperature elastomers and asbestos-type compression packers.
Cementing	Emplacement difficulties.	Testing closely controlled samples at downhole temperatures.
	Deterioration of cement at high temperatures and under cyclic conditions.	Possible use of polymeric cements or viscous epoxy fluids. No good solution now appears evident.

TABLE II

HARD ROCK-RELATED PROBLEMS

Item	Problem	Solution or Status
Sidetracking in Granitic Rock	Neither special diamond bits or standard button-type bits cut satisfactorily into hard walls.	Use of special button-type bits with extremely hard "gage" buttons.
Coring	Sub-marginal cutting of diamond coring bits in fractured granitic formation.	Use of hybrid button-stratapax bits.
Standard	Low bearing and button life.	Use of hard-rock type mining bits altered for use with water.

about 196°C (385°F) but which may be utilized at somewhat higher temperatures by hole cooling and cutting back on bit loading.

Steering Tools. Two companies, Eastman Whipstock and Sperry-Sun, have agreed to improve the temperature capabilities of their directional steering tools to meet our needs in the 250 to 275°C (482 to 527°F) temperature range. It is expected that these tools will be required for much of the directional drilling that is performed below a depth of 8000 ft or at temperatures greater than 166°C (330°F). Heat shielding will increase the tool diameters to about 3 in., which will necessitate a limitation on the minimum inside diameter of the drill string and particularly on the non-magnetic drill collar. The expected limit on the time the tools can spend downhole in a 250°C (482°F) environment is 6 h. In order to cut down on the cost of steering tool services, the old method of directional drilling using single-shot orientation tools will be used when it is practical.

Open-Hole Packers. In the early fracturing work at the Fenton Hill site, many commercial packers were tried and found to be inadequate for our temperature requirements. However, for the last redrilling program, Lynes Services, Inc. provided inflatable packers which had been designed for temperatures of 195°C (383°F) and pressures of 2000 psi. These packers were used successfully downhole at 187°C (368°F) and 1830 psi. At these conditions, the elastomer coatings of the packers became bonded to the walls of the formation and were stripped from the packer as it was removed from the holes. The packers were not reusable. They performed adequately in packing off the formation and continued to function during inflations of as long as 20 h.

The 195°C rated packers used previously will not be adequate for our next fracturing job. Therefore, we have interested Guiberson and Brown Oil Tools, as well as Lynes, in providing us with high-temperature packers for this work. Lynes and Brown Oil Tools are planning, as far as we now know, to propose their standard products modified by the use of high-temperature elastomeric compounds for this work. Guiberson is proposing an asbestos compression-type packer modeled after a unit which they have not marketed since the 1940's. These packers are all being tested at high-temperatures.

Our requirement for these packers is perhaps unique since they will not be subjected to any petroleum products. This undoubtedly will ease the problem of locating materials which will withstand the 250°C (482°F) or greater temperatures we expect to encounter.

Cementing. Pumping and emplacement problems have been eliminated by closely monitoring the cement batching and by testing samples of each batch prior to pumping. Samples, mixed with water from our local well, are tested at temperature by the cementing service company prior to pumping the cement into the hole.

Standard cements which are available are not able to withstand the high temperature now encountered (200°C) and the temperature cycling which is the result of intermittent flow thru the system. With the higher temperatures we expect to obtain at greater depths (250°C), this problem will be more severe. It is suspected that these standard cements crack and do not satisfactorily seal off the water flow in the annulus around the casings. Polymeric cements have been suggested as solutions to this problem and we are now beginning to investigate the possibilities of using these cements. Also the use of very viscous epoxy fluids to seal cracks in the standard cements is another possibility. Hopefully, one of these methods will appear sufficiently promising by the time we conduct our next casing cementing operation.

Drill Bits. For drilling holes in hot, hard granitic rock we have found that tungsten carbide insert bits are doing an excellent job. The bits we have used are mining-type bits (Security Type H-100 and Smith Tool Type 9JA). When using unsealed air-type bits, the air passages were sealed off to prevent the drilling mud from fouling the bearings. These bits are used in rotary drilling at 40 rpm and 40,000-lb load; they are also used in directional drilling with the Dyna-Drill at speeds of 400 rpm but with reduced life. No problems are expected in using these bits at temperatures up to 250°C (482°F). Hopefully they will continue to function well at even higher temperatures.

Sidetracking Bits. During our last drilling operation, a 9-5/8-in. hole was sidetracked twice. The first of these operations required 2-1/2 weeks and was performed with both specially-designed diamond bits and standard-type tungsten-carbide button bits. These bits were used with a Dyna-Drill and a kick sub or with a Dyna-Drill with a bent housing. The diamond bits were successful in cutting only a few feet of hole at best and often the side-cutting surfaces appeared to have been badly worn by scraping the side of the hole before the bits reached bottom. Diamond bits were preferred at the beginning of this operation as specially-designed bits could be procured in about 36 h, whereas the procurement time of specially-designed button bits was prohibitative. The second sidetracking operation was performed using only the standard button bits and was accomplished in 2-1/2 days. This improvement in time was probably due to improvement in the drilling techniques, but as it was performed inexpensively with button bits, we plan to use this general type of bit for any future sidetracking attempts. For this purpose, we have ordered two special bits from Smith Tool with extra hard buttons on the "gage" surfaces. We are also looking for any other bit which appears to have the capability of side cutting into granitic formations.

Coring Bits. Our coring bit experience has been quite similar to the sidetracking bit experience. In our last drilling operation, five attempts were made with diamond bits to obtain granitic cores. From these attempts, only one core about 2 ft long was obtained. One coring run was made using a Smith hybrid-type bit with both tungsten-carbide roller cones and stratapax snythetic diamonds. This run produced 4 ft of core. We are ordering an improved version of these hybrid bits for use in the next drilling program.