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GEOTHERMAL DRILLING AND COMPLETION TECHNOLOGY DEVELOPMENT

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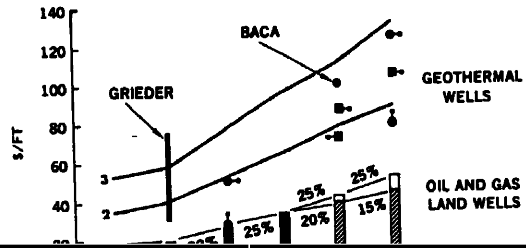
Abstract

The high cost of drilling and completing geothermal wells is an impediment to the development of geothermal energy resources. Technological deficiencies in rotary drilling techniques are evidenced when drilling geothermal wells. The Division of Geothermal Energy (DGE) of the U. S. Department of Energy has



cost of $500,000 per well, a 40% reduction in well cost, for example, would result in a decrease in busbar energy cost of from 15 to 23%, depending on reservoir temperature. Since geothermal power-on-line is sensitive to busbar energy cost, reductions in well cost have the potential for significantly accelerating the utilization of geothermal energy. Therefore, it is important to consider the role of technology development in reducing well cost.

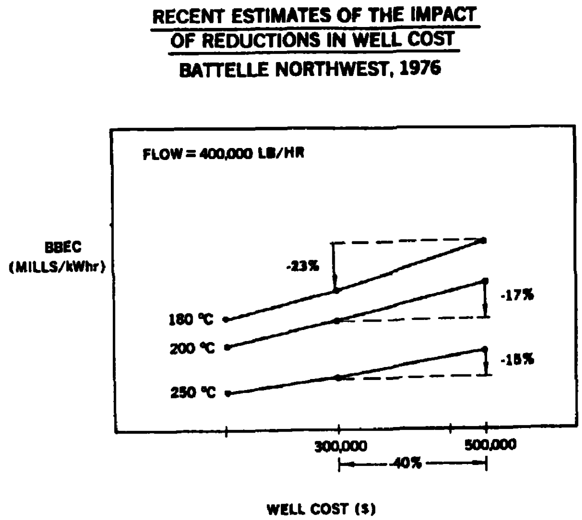


Fig. 2 Recent estimates of the impact of reductions in well cost

Present Difficulties in Drilling

The high cost associated with geothermal wells is due in part to a number of deficiencies in geothermal drilling and completion technology. These deficiencies are attributable to temperature, formation, and corrosion and erosion effects which are found uniquely or primarily in geothermal environments.

Temperature Effects

The high temperature environment encountered in geothermal wells produces adverse effects on drilling fluids, casing and cement, bits, and elastomeric materials.

Drilling-fluid-related difficulties form the single most frequently cited category of geothermal drilling problems. Lost circulation is a pervasive difficulty in the geothermal field because of the highly fractured formations in which geothermal resources are found. Fluids which remain stable at high temperature often do not have adequate filtration characteristics for control of lost circulation. Furthermore, conventional muds tend to gel when circulation is stopped for tripping, logging, and running casing. This can lead to induced problems such as stuck tools and failures of the drill string from differential sticking. Expensive procedures are required to correct these fluid-related failures.

Drilling fluids can also affect the quality of the cementing job, since they tend to contaminate the cement, and muds that have gelled and thickened leave excessive filter cake on the casing and formation. This filter cake inhibits good cement bonding. Also, a thickened mud can cause the cement to channel behind the casing and can result in large uncemented regions. These regions can fill with water which can vaporize at geothermal temperatures. The pressures which build up have the potential for causing collapse of the casing.

A further problem results from uncertainty in determining the temperature profile of the well. Geothermal cements must be formulated with the proper amount of retardants. Incorrect mixtures will fail to set up properly and may lead to expensive remedial cementing ("perf and squeeze"). Such operations are expensive in themselves and also increase non-rotating rig costs.

The predominant mode of bit failure in geothermal wells is through bearing failure. Unsealed bearings are normally used because elastomeric seals will not survive the high temperatures encountered. The bearings and races are lubricated only by the drilling fluid. High downhole temperature and increased friction cause these critical parts to experience much higher temperatures than the main bit body. Research at the Geysers,[6] where formation temperatures are about 240°C, has shown that temperatures up to 540°C are experienced at the friction pin, and that significant softening of the steel occurs at 260-316°C. The high temperature and resultant softening of the bearing surfaces reduces bit life at the Geysers to 1/4-1/5 normal. Costs are increased by the need for more bits, the greater number of round trips required, and reduced penetration rates while drilling.

Currently the best available elastomers fail at temperatures of 175-225°C depending upon use and environment. These materials cease to be elastomeric when subjected to high temperatures and pressures, and thus their value in geothermal applications is limited. Unfortunately, elastomers are important to virtually every aspect of drilling. The best current designs of rock bits, downhole motors, blowout preventers, packers, and logging tools all contain elastomers. Most of this equipment either cannot be used or can be used only with frequent, costly inspection, repair, and special procedures.

Formation Effects

In addition to the extra costs due to high temperature, additional costs are often incurred in geothermal drilling because of the type and condition of the formations which must be penetrated. The fractured formations that predominate in most geothermal reservoirs (except the geopressured Gulf Coast) cause severe stresses on drilling equipment. Furthermore, many reservoirs exist in hard or medium-hard formations where penetration is slow and equipment wear is high.

Erosion and Corrosion Effects

Air is an attractive fluid for drilling into competent reservoirs because it will not damage the formations and generally improves rate of penetration. However, air drilling causes rapid erosion of downhole equipment.[7] At the Geysers, where the drill string is frequently inspected and hardbanded and where a special anti-erosion additive is used in the air stream, it is still necessary to junk one foot of drill pipe for each seven feet of hole.[8] These procedures require extra services and additional training for the rig crew, and the high discard rate for pipe requires advance planning to insure adequate supplies of replacements.

Completion problems can arise for those wells which produce wet stream because it can erode casing as the high speed fluid strips water film from the casing surface. Higher quality casing with flush joints must be used to reduce the problem.

When hot, acidic brines or H_2S are present, downhole equipment is subject to embrittlement and corrosion. These conditions also require special procedures and training for the crews. Also, more expensive, corrosion resistant materials are used, and additives may be required in the drilling fluid to help control corrosion.

Geothermal Well Technology Development Program

In view of the existing technological difficulties associated with drilling and completing geothermal wells, DOE/DGE has initiated a program directed at developing and commercializing the technology required to reduce the cost of geothermal wells. An analysis of existing geothermal well cost data indicates that technological developments such as higher penetration rate, longer life rock bits; high temperature drilling fluids; improved completion techniques; and improved directional drilling techniques have the potential for reducing the cost of geothermal wells drilled with conventional rotary technology by approximately 25%. Cost reductions in excess of 25% will require the use of new drilling techniques. Research in novel drilling techniques is presently underway, and the successful implementation of these new techniques could possibly reduce well costs by as much as 50%. Based on these facts, cost reduction goals of 25% by 1982 and 50% by 1986 have been set for the DOE/DGE Geothermal Well Technology Program.

In October of 1977, Sandia Laboratories was selected by DOE/DGE to manage the well technology development program. Since that time a detailed, ten-year program plan has been prepared, and technical management of contracted R&D activities has begun. In addition, in-house research is being conducted on novel bit designs, high temperature elastomers, and novel drilling systems. Drilling technology R&D efforts during 1978 are centered on three major areas: high temperature drilling fluids, high temperature downhole motors, and high performance rock bits. Completion technology efforts emphasize sand control methods in geopressured formations and analyses of reinjection well plugging problems in all reservoirs.

Research in high temperature drilling fluids is underway at Maurer Engineering, Baroid, and the University of Oklahoma. Maurer has performed high temperature laboratory tests of commercially available muds, and is presently involved in a study of high temperature drilling foams. Baroid has entered a cost sharing contract with DOE/DGE to design, fabricate, and test a 700°F, 20,000 psi mud flow loop to test rheology, filtration, density, and corrosion characteristics of muds at temperature and pressure. The University of Oklahoma is using a modified Magcobar mud flow loop for testing muds to 400°F.

Sandia is presently funding work at Terra Tek directed at the development of high temperature bearings, seals, and lubricants for use in bits and downhole motors. Under previous DOE funding, a seal tester has been developed and is available for general use. Temperatures and pressures representative of geothermal well borehole conditions can be simulated in this tester. In addition, a twenty-five-foot-long borehole simulator suitable for testing the bearing and seal package for a geothermal downhole motor has been constructed. Extension of this simulator to allow full scale motor testing is underway.

Bit development includes investigation of sealed and unsealed bits at Terra Tek, of water jet erosion drilling at the University of Missouri, of cavitation assisted diamond bits at Hydronautics, of Stratapax[R] bits at General Electric, and of the continuous chain, downhole replaceable bit at Sandia. These efforts are directed at increasing penetration rate and bit life in the geothermal environment. Performance of these bits will be described in detail.

[R]Registered trademark for the General Electric synthetic diamond cutters

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