RESEARCH AND DEVELOPMENT ACTIVITIES IN GEOTHERMAL DRILLING,
COMPLETION, AND LOGGING

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Sandia National Laboratories manages the Geothermal Drilling and Completion Program for the US Department of Energy. The primary purpose of this program is to expand access to the geothermal resource by reducing the cost of drilling and completing geothermal wells. This cost is typically two to five times that for an oil well of comparable depth, and well cost is usually about half the total capital investment for a geothermally-powered plant to generate electricity.

Geothermal drilling is plagued by a combination of problems not shared by the rest of the drilling industry. Formations are hard, abrasive, fractured, and frequently underpressured, which results in slow drilling and lost circulation. The fluids produced are often corrosive and high in dissolved solids. Completions are difficult, with casing failure a major cost in many geothermal wells. Aggravating this catalog of complications is the fact that the geothermal industry is so small compared to the oil and gas industry that oil tool manufacturers and service companies have little incentive to do research on geothermal problems. Thus, if we accept the premise that development of this alternative energy source is in the national interest, reduction of geothermal well cost is a legitimate expenditure of taxpayer's money.

Our principal goal in this program is the development of an advanced drilling system that can drastically reduce well costs. Since this is a large task, and we do not have the resources to attack the whole problem, we have chosen projects that would be part of an advanced system but would also have stand-alone value as successful research and development. Since a great variety of projects is available, we have conducted systems analyses to select work that is appropriate to the goal, scaled to our resources, and likely to have a high payoff.

Our program is defined in five basic elements:

- Rock Penetration Mechanics
- Fluid Technology
- Borehole Mechanics
- Diagnostics
- Permeability Enhancement

Each of these elements will be briefly summarized with examples of typical projects in each area.

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Rock Penetration Mechanics

This element includes all the aspects of actually making a hole in the rock. In general, the work has been directed toward analytical and experimental investigation of rock breakage mechanisms and drill bit behavior. Some examples are:

-Erosion drilling - A series of contracts with Hydronautics, Inc has led to the analytic description and experimental verification of cavitating and pulsating water jets. These jets produce a periodic train of ring vortices which can impinge on a wellbore surface. Jets of this type are interesting for several potential uses - direct rock breakage, augmentation of mechanical rock breakage, and improved bottom hole cleaning. A roller cone bit with pulsating jet nozzles has been commercially produced and shown to have performance superior to the same bit with conventional nozzles.

-Rock/cutter interaction - A finite element model of a drag bit cutter moving through rock has been developed and compared to laboratory experiment. The model gives forces on the cutter, stresses in the cutter, and fracture patterns in the rock. Qualitatively, the agreement with experiment has been good, although the calculated loads are lower than actual loads. All cutting tests have been done at atmospheric pressure, but model predictions should be better when there is borehole or confining pressure to suppress tensile cracks. A series of pressurized cutting tests to investigate cutter forces and rock damage patterns is imminent.

-Drill String Dynamics - A finite element model of a drill string - from the bit/rock interface to the surface - is under construction. This model incorporates user-definable formation, bit geometry, and drill string configuration. Knowledge of the dynamic behavior of the drill string is important when considering hole deviation, bit performance, and the environment to be imposed on potentially delicate downhole equipment. The elements of this model will be validated by lab experiment; parts of this have already been done. This project is being supported jointly by Sandia plus four oil and service companies.

Fluid Technology

This element deals primarily with drilling fluid; its properties and its flow in the borehole.

-Aqueous Foam - Because many geothermal formations are underpressured, the use of low density drilling fluids is either advantageous or necessary. Compared to air, aqueous foam has higher carrying capacity and lower air flow rate requirements. Early foam work investigated drainage times of various surfactants at high temperature; current work is focussed on heat transfer properties and rheology of flowing foam.

-Clay-Based Drilling Fluids - Because some wells will be drilled with mud, we have measured properties of clay-based drilling fluids at high temperature, including the effects of several salts and hydroxides on viscosity. Current work includes a look at in-situ clay-to-cement conversion and the formulation of a high temperature bentonite mud.