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2011 Geothermal Technologies Peer Review Summary: EGS Drilling Systems

1. Technology Development and Field Trials of EGS Drilling Systems

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Subcontractors and Participating Organizations:
United States Navy Geothermal Program Office; China Lake, CA
Barbour Well, Inc; Henderson, NV
Atlas Copco Secoroc, LLC; Ft Loudon, PA
NOV Reed Hycalog; Conroe, TX

2. Project Objectives and Purpose

The primary objective of this project is to develop and demonstrate Enhanced Geothermal Systems (EGS) drilling solutions based upon mature, proven rock penetration systems that have been used in the oil and gas/mineral drilling industries for well construction to penetrate hard rock formations. Conventional geothermal drilling is hampered by the challenges of hard/abrasive/fractured rock, high temperatures, and the frequent loss of circulated drilling fluids to the formation. In the past, this drilling difficulty has been a point of distinction between geothermal and oil and gas applications. Recently this difference is less pronounced as the oil and gas industry encounters more difficult drilling conditions. This synergy can benefit the geothermal industry as technology developed for oil and gas, backed by significant research and testing, can be adapted for use in geothermal drilling. This project proposes to introduce two mature oil and gas/minerals drilling technologies for use in geothermal well construction: Percussive Hammers and PDC Bits. Pneumatic down the hole hammers (DTHH) are routinely used in the mining industry and the oil and gas industries for penetrating hard formations. Polycrystalline diamond compact (PDC) bits are another rock drilling technology that has not been adopted for geothermal drilling, largely due to past reliability issues and higher purchase costs. These technologies will be specifically tailored for use in geothermal drilling and demonstrated on a production geothermal drilling project. Ultimately, the objective is to achieve development of fit-for-purpose EGS drilling solutions (hard/abrasive/fractured rock, high temperature, deep drilling) for geothermal exploration and production drilling.

The outcome of this work (i.e., the purpose) will be improved drilling technologies to reduce geothermal well construction costs by drilling faster with improved tool life, capabilities for improved hard stringer

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penetration, and suitability for deep drilling applications. To the DOE Geothermal Technologies Program, this anticipated outcome will mean improved rates of penetration (ROP), bit life, and viable access to deep EGS reservoirs resulting in a reduction in well construction costs supporting economic development of geothermal resources. To the geothermal industry/market, this will result in specialized product support from the drilling services industry specifically for geothermal drilling. Ultimately this will result in: 1) an increase in the number of tools / options available for geothermal well construction, 2) service companies being more engaged in the geothermal market, and 3) an enhanced drilling experience base to help de-risk and support continued geothermal well construction.

3. Technical Barriers and Targets

This work seeks to address the following technical challenges and barriers that inhibit new geothermal well drilling technologies from being adopted for routine application in geothermal well construction:

Risk Reduction

Like other drilling sectors, the geothermal drilling industry is very risk adverse. This is not surprising given the small number of geothermal wells annually drilled within the US. This project seeks to reduce the risk borne by a geothermal driller/operator in attempting new technologies by bearing the testing burden within the US Government/DOE funding framework as opposed to the risk of private investment. This project will bear the cost of these technologies and offer them to the drilling contractor for companion testing in a geothermal exploration and/or production well construction project for in situ evaluation.

Limitations of Laboratory Testing

Rock reduction technologies have long been demonstrated in the laboratory. Yet the laboratory does not address all situations or failure scenarios that may be encountered. Field testing in an actual geothermal well construction environment is needed to prove out these technologies. PDC bits have been demonstrated to be abrasion resistant in the laboratory and have also been used in controlled field trials to drill hard rock. What is needed now is a test that demonstrates that they can drill in a geothermal exploration and production type environment. Likewise, percussive hammers have been used to drill hard rock. However, their use in high temperature drilling has been limited. This project will allow a representative evaluation of both technologies.

Service Company Investment

A significant barrier with geothermal drilling is the drilling products developed are largely intended for O&G/minerals drilling and this standard product line is subsequently offered to the geothermal drilling industry. The intent with this project is to engage the service companies collaboratively in the problems faced by the geothermal drilling industry. This engagement will forge a participation that will develop fit-for-purpose solutions specifically for the geothermal drilling industry.

Drilling Industry Acceptance

By reducing the risk, demonstrating applicability, engaging the service companies, the outcome is acceptance by the entire drilling industry. Industry sees first-hand that these technologies are available and considers using them on future drilling projects resulting in concomitant reductions in drilling costs through the improved application of technology within the open market.

The technical targets, performance metrics, pertaining to this development are addressed at improvements in rock reduction performance. Reduced drilling costs can be realized by a balance of improved rate of penetration and bit life. It is important to realize that the choice to improve ROP or bit

life depends upon the economics of the existing technology. Sometimes a greater reduction in drilling costs is realized by an improvement in ROP; other times an improvement in bit life is necessary. The relative improvements in these metrics depend upon present economic performance to realize cost reductions. A baseline performance standard for geothermal drilling is the sealed roller cone bit. Widely used in the geothermal industry, it typically drills at 10-20 ft/hr with a nominal life of 40 hours in hard abrasive geothermal conditions. The performance of the present technology will be compared to this nominal baseline performance.

More importantly, what is needed are rock reduction technologies that allow economic drilling to increased depths. The technical performance metric of this work is to catalyze the drilling industry via improved deep hole access to EGS reservoirs.

4. Technical Approach

From a scientific perspective, drilling cost reductions will be realized through: 1) Improved deep hole access through alternate technologies that rely upon energy augmentation, and/or 2) Advanced materials applied to rock reduction to increase rock/bit interfacial stress concentrations and reduce abrasion induced wear mechanisms.

The overall approach consists of a three-year work plan to address each of the respective phases. In year one, field trials of candidate drilling systems will be conducted with preliminary modifications deemed necessary for their applicability to geothermal drilling. The objective of the early field trial is two-fold: 1) demonstrate the drilling performance that can be realized with these technologies and 2) identify their existing shortfalls for geothermal drilling. An industry partner will be identified among geothermal operators and drillers and a well of opportunity will be identified. Drilling and support equipment will be provided and operated by the industry partner. Major service companies will be contracted to provide current technology product offerings to drill the subject well. Sandia will oversee operations and provide data collection, analysis, and reporting while candidate drilling systems are being deployed. Identification of limitations is key to providing input to correcting design deficiencies in the second and third year of the project to improve the performance of these technologies to support EGS drilling.

Year two will address design improvements to make these drilling systems more relevant for EGS environments. This will include an assessment of failure criteria to be corrected, custom development for application, and qualification testing in laboratory test fixtures to validate the design improvements.

Finally, year three will address development and demonstration of the improved EGS Drilling Systems based upon these design improvements. Follow-on testing will be conducted in a comparable geothermal exploration and production drilling project for verification and validation. The objective of the second field trial is to demonstrate technology readiness for geothermal drilling and verify the design improvements realized in year two.

The following key issues pertaining to the phase 1 drilling activity coordination are currently being addressed:

Formation assessment

Specific characteristics must be included in the rock reduction hardware based upon the formations that are anticipated. Sandia has recently received this information from the operator/driller and is working closely with the service companies to develop solutions appropriate for these rock types. One would

like to have a detailed formation assessment performed by a geologist that predicts the expected lithology and resource characteristics (e.g., known fractures, temperatures, etc) within the well field. Since the target well is an exploratory well this type of information will not be specifically available.

Well Profile and Drilling Plan

The drilling solutions must be specific to the particular well profile and drilling plan being executed by the host operator/driller. Candidate drilling systems are being reviewed relative to these criteria which includes: (i) the location, number and types of wells (production, injection) to be drilled during the drilling program; (ii) Rig Specifications and Performance; (iii) Drilling configuration; (iv) Hole diameters; (v) BHA configuration; (vi) well depths; (vii) Casing schedules; (viii) Lost circulation treatments; (ix) mud program; and (x) any other considerations relevant to the work scope. The drilling plan should specify the approach to the drilling activity including primary equipment and procedures to be used. Additionally, the drilling plan is being reviewed relative to the overall drilling project schedule, environmental plan, safety plan, and approach to well control.

Test Plan Development

Sandia is currently working closely with the drilling contractor and the service companies to identify an acceptable interval during the proposed well construction to evaluate the candidate drilling technologies. Sandia will write the test plan and submit it to the drilling contractor for concurrence prior to the testing activities.

Review Current Product Line Offering

Once the former issues are resolved, the service companies will prepare fit-for-purpose hardware based upon slight modifications to current product line offerings. This hardware will be tested with the project team. A leading manufacturer of pneumatic hammer systems, Atlas Copco, has been engaged as an industry partner. They are currently reviewing the temperature suitability of their standard product line relative to this application. Improvements will be made where possible prior to the preliminary field trials. Sandia will work with Atlas Copco to review product designs and collaboratively identify slight modifications for the first generation version of a high temperature system. These first-generation high temperature hammers will be field-tested and performance data and any failure mechanisms will be investigated. In the second year, critical technologies such as high temperature seals and material coatings will be pursued that will allow this technology to be applied in high-temperature EGS well drilling applications. Based upon success realized, a second-generation DTHH will be designed, developed, and field tested in the third year of the project.

Like the approach above, an industry partner will be identified with an established presence providing PDC bit technology in the drilling industry. A leading manufacturer of fixed cutter bits, Reed Hycalog, has been engaged as an industry partner in this role. They are currently recommending standard product line offerings that can be considered for test and evaluation. This will include design features on the bit including PDC cutter parameters, bit cutting structure, and aggressivity limiters on the bit face. Use of dampers or other BHA tools will also be considered to facilitate success of the initial field trial. The PDC bits will then be fabricated and tested in year one. The test results will be reviewed with the industry partner. Key technologies that are necessary to enable the use of PDC bits in these operating conditions will be identified. These technologies, or design improvements will be addressed in year two. Eventually, this may include an evaluation of the rig/drillstring selected for the field trials to address the compliance and possible vibration modes that could be introduced at the bit – inhibiting its performance and contributing to failure. Sandia will work with the industry partner to specify the

preferred bottom-hole assembly (BHA) that should be used for the field trials. Once these technologies are available, system-engineered EGS PDC Bits will be developed and tested in year three of the project.

A unique aspect of the approach in this area is that Reed Hycalog offers down hole dynamics analysis recorders. Plans are underway to field one of these recorders during the field drilling demonstrations to gain a better understanding of conditions when using these types of bits in geothermal drilling.

Data Acquisition System development

In an effort to collect meaningful data for objective evaluation, Sandia is currently working to deploy a measurement sensor system suite and connect data acquisition system equipment on the drill rig prior to commencement of drilling activities.

Drilling activity coordination

Sandia will work closely with the drilling contractor and the service companies throughout the drilling campaign to conduct the testing. This includes a) daily communication to communicate the daily drilling plan, b) daily pre job briefings (i.e., tailgater meetings), and c) and coordination with the Tool Pusher regarding preferred drilling parameters to be targeted during drilling the test interval.

Well logging activities

Once the drilling activity is complete, 1) a deviation log and 2) a caliper log for the completed test interval sections will be completed to facilitate evaluation of drilling system performance.

5. Technical Accomplishments

Accomplishments to date are briefly summarized below:

Geothermal Developer/Drilling company Identification

The US Navy GPO has agreed to collaborate with Sandia to provide “wells of opportunity” for evaluation of drilling technologies in geothermal exploration and production drilling environments. The US Navy Geothermal Program Office (GPO) is the lead office within the Department of Defense (DOD) for the exploration, development and management of geothermal energy resources on all DOD installations. The USN GPO has an aggressive exploration and production program to characterize and develop geothermal energy resources on military installations in response to Presidential and DOD mandates. The USN GPO is also the beneficiary of ARRA-funding to pursue this mission. Fortuitously, a Memorandum of Understanding (MOU) is in place between the DOE and DOD. This agreement will be the supervisory agreement in guiding a collaborative relationship between Sandia and the US Navy. Furthermore, along with the Navy collaboration, their drilling contractor, Barbour Well Inc., has agreed to partner with Sandia in the drilling tests. This will allow integration of a test plan for the subject technologies integrated with the overall drilling plan.

Test Site/ Well of Opportunity Identified

As a component of its evaluation of the geothermal energy potential of the Chocolate Mountains Aerial Gunnery Range, CA, the USN GPO proposes to drill two deep geophysical test holes to further investigate the temperature field and potential hydrothermal alteration in the Camp Billy Machen/Hot Mineral Spa region. This is an area of apparent geothermal significance and these test holes will identify and document geothermal manifestations otherwise undetectable at the surface. The geologic and geophysical data collected from the resulting holes will be compiled and analyzed to provide necessary insight into potential geothermal resources. The sitting (targeting) for these holes is based on a variety of geological and geophysical data combined with the results of shallow (500-ft) temperature gradient

drilling conducted from January to March 2010. Drilling the exploratory well is currently planned for the summer of 2011.

Contracting operations with service companies

The solicitations for the service company contracts have been openly posted and bid. Sandia has down-selected to work with Atlas Copco and Reed Hycalog. Finalization of contract placement is currently underway.

Drilling Plan Coordination

A technical interchange meeting has been held with all collaborating organizations to address integration of the subject project testing with the current drilling plan being pursued by the USN GPO and Barbour Well, Inc. Project personnel from Sandia National Laboratories, and personnel from the participating service companies, Atlas Copco and NOV Reed Hycalog, attended this meeting; alignment of the test plan with the drilling plan is converging.

6. Challenges to Date

Significant difficulty was encountered in identifying a geothermal operator and/or driller to support field testing on this activity. This is not surprising given the barriers identified above. Various means were used to identify wells of opportunity and partnership opportunities; methods pursued included attendance at the Geothermal Resources Council annual meeting, web/literature surveys; broad solicitation announcements; and mass emailing. Ultimately, the USN GPO was identified as a premier partner for this work since they have a geothermal development program, a drilling program, and comparable ARRA-related funding.

7. Conclusion and Plans for the future

Based upon the work accomplished to date, the service companies recognize significant market potential for EGS development. Accordingly, they are willing to offer cost share to develop specific product line for this market.

Future work on this project will include the completion of activities associated with the Phase 1 field drilling demonstration. Phase 2 work will be subsequently initiated to identify deficiencies and engineer improvements into these rock reduction systems. Performance verification and validation testing to be completed in year 3, in accordance with the original project plan, will be proposed to DOE outside of the existing ARRA project framework.

8. Publications and Presentations

Results and findings will be published as a technical publication in the Geothermal Resources Council Transactions.