2017 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
GEOTHERMAL TECHNOLOGIES OFFICE

SAND2017-10431C

Summary: Microhole Drilling

1. Microhole Drilling – Application of Low Weight-on-Bit Technologies

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- Subcontractors: Foro Energy, Littleton, CO; Atlas Copco, Roanoke, VA (Vendor); Geothermal Research Group, Palm Desert, CA

- Project Start and End Date: 10/2016 – 09/2018

2. Project Objectives and Purpose

Drilling costs remain one of the most significant economic barriers to geothermal development. Albright and Dreesen [1] estimate that cost savings of up to 70% can be achieved when routinely drilling microholes instead of conventional boreholes. However, the well documented promise of microholes has not yet matched expectations. A fundamental issue is that delivering high weight-on-bit (WOB), high torque rotational horsepower to a conventional drill bit does not scale down to the hole sizes necessary to realize the envisioned cost savings. The proposed work seeks to build upon previous efforts by tackling past limitations through transitioning to a low WOB drilling technique using newly available technologies. This project will:

- Investigate low WOB drilling technologies like percussive hammers and high power laser-mechanical drilling systems.
- Develop and test downhole rotation mechanisms compatible with coiled tubing drilling (CTD) technology
- Develop WOB control systems compatible with CTD technology

Once realized, these small diameter systems will form the foundational technology platform for economical microhole drilling. Sandia and its partners see an opportunity to develop realizable low weight-on-bit drilling technologies needed to allow microholes to become a viable and most importantly a cost-effective method for geothermal exploration, assessment, and monitoring.

3. Project Timeline (with milestones and/or decision points, as applicable)

The project timeline is shown in the table below. A go/no-go review was conducted at 18 months (April 2017). The SMART milestones listed in the table continue to track overall progress.

Milestone	Description	Completion Date
FY16	**Specify requirements for low WOB drilling bottom hole assembly (BHA) and identify and demonstrate technologies capable of meeting system level performance targets** Verification Method: Analysis	Q4 FY16
	Quarterly Progress Measures *- Complete literature review of microhole drilling cost drivers* *- Complete necessary partnership agreements to perform work* *- Complete microhole resource assessment modeling* *- Identify downhole rotation and WOB control options*	 Q1 FY16 Q2 FY16 Q3 FY16 Q4 FY16
FY17	**Design and complete build of small diameter, low WOB drilling tools. (2" diameter percussive hammer, 2" laser-mechanical optics package and drill)**	Q4 FY17

[1] Albright, J.N. and D.S. Dreesen, Microhole technology lowers reservoir exploration, characterization costs. Oil & Gas Journal, 2000. 98(2).

	Verification Method: Inspection, analysis, limited lab tests	
Go/No-Go	*Quarterly Progress Measures* *- Complete requirements definition for downhole tools* *- Preliminary designs for downhole tools are complete and ready for fab* *- Designs for low WOB tools are in production* *- Low WOB tools production is complete*	 Q1 FY17 Q2 FY17 Q3 FY17 Q4 FY17
FY18	**Build, integrate, and conduct initial prototype lab test bottom hole assembly (BHA) (drill, rotation, WOB control)** Verification Method: Demonstrate rapid ROP and path towards compelling commercial economics in a laboratory test frame.	Q4 FY18
	Quarterly Progress Measures *- Select and acquire rotation option for BHA* *- Implement WOB control* *- Successfully integrate BHA components* *- Test integrated low WOB BHA*	 Q1 FY18 Q2 FY18 Q3 FY18 Q4 FY18
FY18	**Submit final report to DOE**	Q4 FY18

4. Technical Barriers and Targets

The current microhole work is a departure from the previous paradigm of miniaturizing high WOB conventional rotating drilling operations by focusing on low WOB drilling technologies applied now to microholes. As smaller diameters are targeted for these low WOB drilling technologies, several associated sets of challenges arise. For example, energy transfer efficiency in small diameter percussive hammers is different than conventional hammers. Finding adequate methods of producing downhole rotation may also prove to be difficult. Furthermore, the rotation requirements for percussive drilling are different than the requirements for laser-mechanical drilling. The variability of rock in the natural environment may also introduce additional complications compared to lab testing.

At the start of the project, there was no formal definition of microhole. Simply drilling a smaller diameter hole does not necessarily lead to meaningful cost savings. We worked with Geothermal Resource Group to help define what sized boreholes and at what depths would provide meaningful information with respect to resource assessment and monitoring. Their work helped to bound the range of boreholes and provided insight into the utility of microholes for characterizing geothermal resources.

5. Technical Approach

The idealized, long-term microhole drilling solution would be compact, easily deployable, (e.g. on a wireline truck), and operate with a minimal amount of surface equipment. The user would simply define the location at which to drill, and let the system go. The more realistic near-term solution would likely be a drilling system deployed on a coiled tubing rig. To help achieve the long-term vision, several aspects of the drilling system need to be developed or refined to a higher TRL. For this project, we are addressing rock reduction, weight-on-bit (WOB) control and downhole rotation.

Two complementary approaches to rock reduction are being pursued: a high TRL conventional percussive hammer modified for high-temperature environments and a more experimental approach using laser-assisted mechanical drilling. These two approaches enable us to have a near-term solution that can demonstrate the feasibility of deep, microhole drilling while also developing a tool that may be capable of drilling handling in the future.

Other aspects of the drilling process are also being addressed including techniques to optimize the drilling process. Sandia is leveraging internal lab directed research and development (LDRD) funding related to drilling automation to

improve WOB control and other drilling parameters. Internal testing has shown that optimizing WOB in real-time can lead to up to 20% improvement in ROP with all other conditions being the same.

Another aspect of drilling that is being addressed is the ability to generate rotation downhole. Previous efforts at microhole drilling utilized turbines and small diameter positive displacement motors (PDM). Sandia has been developing alternative downhole motors which could be used for low weight on bit drilling applications and is developing an integrated downhole rotary tool for use with percussive hammers.

6. Technical Accomplishments

- Conducted resource assessment modeling with Geothermal Resources Group to "define" useful microholes
- Implemented weight-on-bit control optimization algorithm leveraging Sandia LDRD
- Designed and tested prototype WOB control/anti-rotation hardware (lead to patent application)
- Designing and building integral downhole rotation for percussive hammers (lead to CRADA with CMW)
- Tested small-diameter percussive hammers without lubrication
- Completed small-diameter laser-assisted mechanical drilling design utilizing DHC-3 connector for high-pressure/temperature seal

7. Challenges to Date

Early on, the ambiguity in the formal definition for microhole was a challenge for setting direction in the project. However, the results from Geothermal Resources Group helped to bound the problem and guide the project in terms of design and performance targets. The project has mostly followed the proposed schedule. It is currently on track to meet the milestones and targets. There have been a few delays in designing and building the hardware. However, there are no obvious deal-breakers.

8. Conclusion and Plans for the Future

Future work will continue to integrate the various drilling components along with conducting lab tests. We have set up limited field testing opportunities at Blue Canyon Dome in Socorro, NM to enable drilling deeper boreholes.

9. DOE Geothermal Data Repository

Percussive hammer tests results were submitted to the Geothermal Data Repository. Additional test data that will be collected includes the integral rotary tool performance and drilling results Additional data to be collected include

10. Other Dissemination of Research

- CRADA with Charles Machine Works to co-develop integral downhole rotation tool for use with percussive hammers

11. Publications and Presentations, Intellectual Property (IP), Licenses, etc.

- DOE Technology Commercialization Fund (TCF) award to develop downhole rotation with Charles Machine Works (aka Ditch Witch)
- Patent Application for the weight-on-bit (WOB) control mechanism

12. Supplemental Information- Optional

- N/A