2017 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
GEOTHERMAL TECHNOLOGIES OFFICE

SAND2017-12512C

Summary: Gas Generator Development and Testing for Controlled Rapid Pressurization Using Liquid Propellants for EGS Well Stimulation

- **Gas Generator Development and Testing for Controlled Rapid Pressurization Using Liquid Propellants for EGS Well Stimulation**
- Organization or Affiliation: Sandia National Laboratories, Albuquerque, NM
- Principal Investigator: Mark Grubelich
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- Subcontractors: EMRTC, Socorro NM
- Project Start and End Date: 10/2014 – 09/2018

1. Project Objectives and Purpose

The objective of this research project is to provide proof-of-concept of an energetic material system for wellbore/formation stimulation down hole. As a result of testing, a novel energetic materials system has been developed. This system has been further developed into a high temperature resistant molding powder and pressed into cylinders for down hole experiments. These experiments have generated fractures that have been documented via wellbore imaging and have shown an increase in wellbore permeability. The results indicate that energetic system not only generates pressure at the requisite high rate but also produces secondary products that will maintain a sustained high pressure in order to continue to propagate fractures after the initial initiation of the fractures occurs. A high pressure detonation bomb calorimeter was used to test combustion efficiency of the system (heterogenous explosive). Thermochemical modeling was employed to better understand the behavior of the energetic material fluid (water) interaction. Detonation bomb calorimetry measurements were employed to better understand the rapid pressure generation followed by a secondary reaction to maintain pressure. The main phase of project demonstrated this technique in shallow well bore tests at a site in Socorro NM. Water filled tank testing was conducted to verify system functionality and to demonstrate pressure propagation through a perforated liner to a simulated formation; a key requirement for "lined" geothermal systems. Pressure was measured, a video inspection and seismic imaging was conduct to determine the performance of the system. Hydro-pressurization tests were conducted to measure the increase in well bore permeability. Field test results were analyzed for fracture nucleation and propagation characteristics. Stimulation tests will continue to determine the efficiency of multiple well bore stimulations. This project will:

- Develop a high temperature energetic systems suitable for down hole geothermal stimulation
- Demonstrate an increase in permeability at the test site in Socorro NM
- Deploy and demonstrate and energetic stimulation tool in a 5000-foot deep geothermal injection well

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

The project timeline is shown in the table below.

Milestone	Description	Completion Date
FY16	**Preliminary development of novel energetic material for stimulation** Verification Method: Demonstration	Q4 FY16
FY17	**Develop/design/produce a high temperature down hole energetic stimulation tool for deployment in a deep (~5000 foot) geothermal injection well** Verification Method: Demonstration	Q4 FY17
	Quarterly Progress Measures	

	- Thermochemical/calorimeter testing	Q1 FY17
	- Plastic bonded energetic material evaluation	Q2 FY17
	- Detonation properties testing, Liner testing	Q3 FY17
	-Energetic tool fabrication	Q4 FY17
FY18	**Deploy and fire energetic stimulation in a 5000 feet injection well.** Verification Method: Demonstrate	Q4 FY18
	Quarterly Progress Measures	
	- Assemble and test energetic tool above ground	Q1 FY18
	- Deploy energetic stimulation tool in deep injection well	Q2 FY18
	- Additional testing and formulation development as needed	Q3 FY18
		Q4 FY18
FY18	**Alta Rock test site experiment report**	Q4 FY18

3. Technical Barriers and Targets

Controlling detonation velocity and shock pressure is non-trivial. Typical propellants deflagrate in the fractional inch per second rate and high explosive detonate at ~25000 feet per second. The propellants are too slow for effective stimulation and the high explosives are too fast. We have demonstrated the ability to generate low shock pressure at moderate velocity with new energetic formulations. This minimizes well bore or linear damage and maximizes fracture formation. We have developed techniques to manufacture and deploy these materials in geothermal wells

4. Technical Approach

The technical approach examined three distinct methods of rapidly generating down hole pressure while limiting the maximum peak pressure and extending the pressure duration. The first employed a pump fed liquid propellant, the second employed the injection and ignition of a bi-propellant gas mixture and the third required the development of a novel high temperature low shock velocity/detonation-pressure energetic material.

5. Technical Accomplishments

- Demonstrate a liquid phase pump fed liquid energetic system
- Demonstrate a high pressure bi-propellant gas phase system over a pressure range from 300-80,000 psi
- Develop a solid energetic material with tailored reaction properties suitable for well bore stimulation
- Demonstrate increased well bore permeability after test firing without excessive well bore damage
- Conduct perforated liner testing to show significant pressurization between liner and formation
- Develop hydraulic pressing system for energetic material prototype run
- Develop energetic stimulation tool

6. Challenges to Date

A significant effort has been made in developing a suitable energetic formation that now includes an “industry standard” energetic material that can be transported in interstate commerce. Fabrication of the material has proved challenging and improvements have been made to the process to manufacture energetic items.

7. Conclusion and Plans for the Future

Future work will focus on dissemination and potential licensing of the technology

8. DOE Geothermal Data Repository

3-D images of fracture network, fracture images, pressure data, test site documentation

9. Other Dissemination of Research

- N/A

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

- Patent Applications for Energetic Stimulation employing gas phase bi-propellants and metalized solid explosives
- SPE Fracturing Committee Member
- “Bipropellant High Energy Stimulation for Geothermal Applications”
    - Purdue University: Prashanth Bangalore Venkatesh, James H. D’Entremont, Scott E. Meyer, Sally P.M. Bane
    - Sandia National Laboratories Mark C. Grubelich, Dennis King, Steve Knudsen, Douglas Blankenship
        - Journal of Petroleum Science and Engineering (Submitted)
- An Overview of a High Energy Stimulation Technique for Geothermal Applications
    - Mark C. Grubelich, Dennis King, Steve Knudsen, Douglas Blankenship
    - Prashanth Bangalore Venkatesh, Sally P.M. Bane
        - World Geothermal Congress Melbourne Australia 2015
- "Imaging Fracture Networks Using Angled Cross-hole Seismic Logging and Change Detection Techniques"
    - Hunter Knox, M. Grubelich, L. Preston, J. Knox, D. King
        - AGU Fall Meeting DEC, 14-18 2015, San Francisco, CA 2015.
- "Imaging Fracture Networks Using Joint Seismic and Electrical Change Detection Techniques",
    - Hunter Knox, J. Ajo-Franklin, T. Johnson, J. Morris, M. Grubelich, L. Preston, J. Knox, D. King,
- CoDA Conference, MAR 2 2016, Santa Fe, NM. (Invited presentation, conference).
- “Imaging Fracture Networks Using Joint Seismic and Electrical Change Detection Techniques”,
    - Knox, H., Ajo-Franklin, J., Johnson, T., Morris, J., Grubelich, M., Preston, L., Knox, J., and D. King,
        - The 50th US Symposium on Rock Mechanics (USRMS). American Rock Mechanics Association, JUN 26-29 2016, Houston TX.
- "Imaging Fracture Networks Using Joint Seismic and Electrical Change Detection Technique"
    - Hunter Knox, J. Ajo-Franklin, T. Johnson, J. Morris, M. Grubelich, D. King, L, Preston, J. Knox, V. Vermeul, S. James, C. Strickland.
        - Mastering the Subsurface through Technology Innovation & Collaboration: Carbon Storage & Oil & Natural Gas Technologies Review Meeting, AUG 16-18 2016, Pittsburgh, PA.

11. Supplemental Information- Optional

- N/A