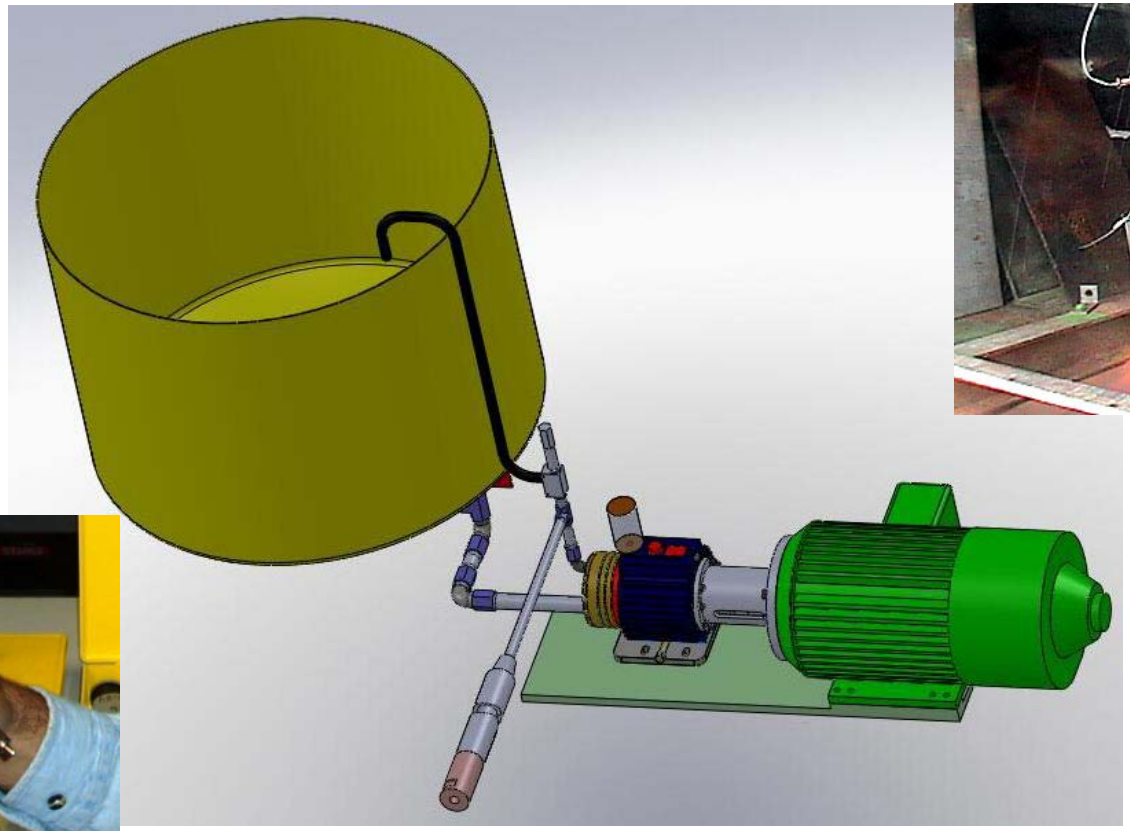
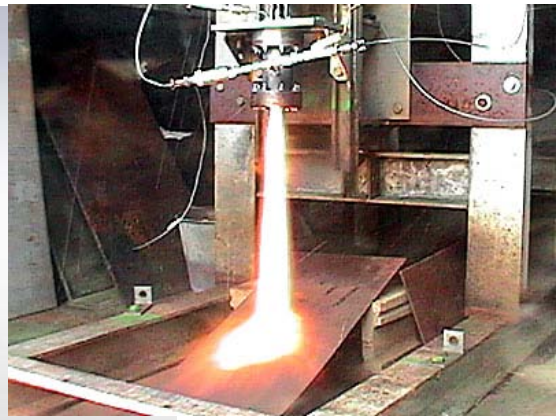




Controlled Rapid Pressurization Using Liquid Propellants for EGS Well Stimulation

May 18, 2010

Mark C. Grubelich

Sandia National Laboratories

Chemistry, Reservoir and Integrated Models

Overview

- Project Overview
  - Timeline
    - Project start date FY 2010, Project end date FY 2011
      - Currently 5% complete
  - Budget
    - Non ARRA project funded by DOE Geothermal total budget , FY10-11 $250k
  - Barriers
    - None Identified
  - Partners
    - None Identified

Why Use liquid propellants for well stimulation?

- Propellants can provide another option for reservoir stimulation
  - Injection and subsequent reaction of liquid propellants provides another potential method for enhancing formation permability
    - Surface control of reaction rates
    - Alternative load paths
    - Possible propellant reactions *within* reservoir
    - Conceptually suitable for initial and subsequent stimulations
- No liquid propellant injection system exists

Project objective

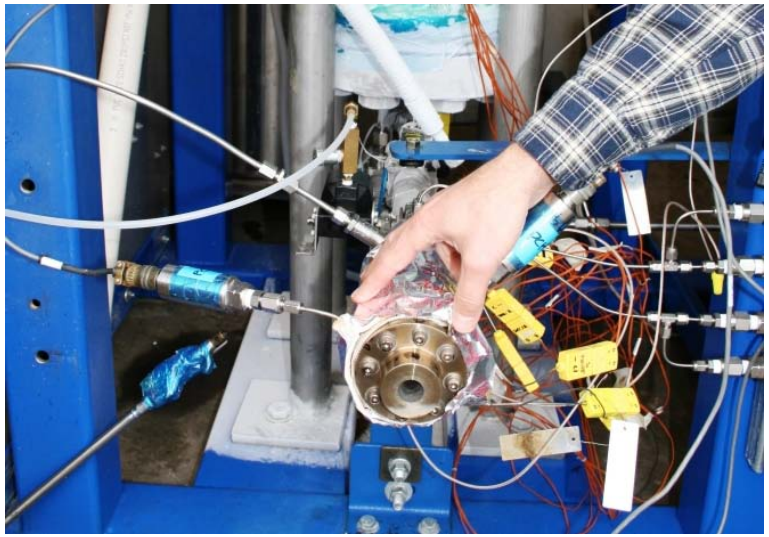
- Investigate the use of “non-toxic” or negligible environmental impact liquid propellants for the stimulation of geothermal fields.

Scientific/Technical Approach

- Approach
  - Review past efforts
  - Develop feasible stimulation scenarios where controlled propellant could have an advantage
  - Evaluate possible liquid propellants
  - Design a conceptual system (flow rates, equipment needs)
  - Determine feasibility today and in the future
- Milestones
  - Literature search on tailored pulse loading (June,10, complete)
  - Stimulation scenarios / discussions with industry (Aug, 10)
  - Determine pressurization rate requirements, (Nov, 10)
  - Conceptual system design (Feb, 11)
  - Feasibility assessment (Mar, 11)

Project Subtopics Include:

- Identify propellants
  - Monopropellants & possible bi-propellants
- Leverage commercial components if possible
  - Pumps- Positive displacement high pressure diaphr
  - Gas generators- catalytic or thermal



Project Management/Coordination

- Schedule
  - Schedule based on previously discussed milestones
  - Currently 5% complete, (starting)
- Application of resources
  - Sandia Geothermal Department –
  - External explosives/propellant consultant- P.W. Cooper
- Coordination with industry
  - Industrial partner possibilities

Future Directions

- Propellants have been used by others, critical to determine if controlled propellant deflagration system is feasible, if so:
  - Move beyond the conceptual design phase
  - Component level testing (leveraging from other development programs)
  - Identify potential partners (operators, service companies, labs)
  - Design test plan
  - Perform field testing

Summary

- Controlled Rapid Pressurization Using Liquid Propellants for EGS Well project funded
- Explosive/propellant consultant identified
- Preliminary SNL literature search completed
- Remaining tasks:
  - Estimate the pressure pulse requirements for stimulating a typical reservoir.
  - Identify candidate liquid propellants that could be used in a gas generator to produce hot high pressure gas.
  - Determine liquid propellants flow rates in order to size the overall system (pumps, tanks, feed lines, gas generator injectors, etc).
  - Develop a conceptual design of down-hole gas generator system and make recommendations as to the viability of producing the overall system.