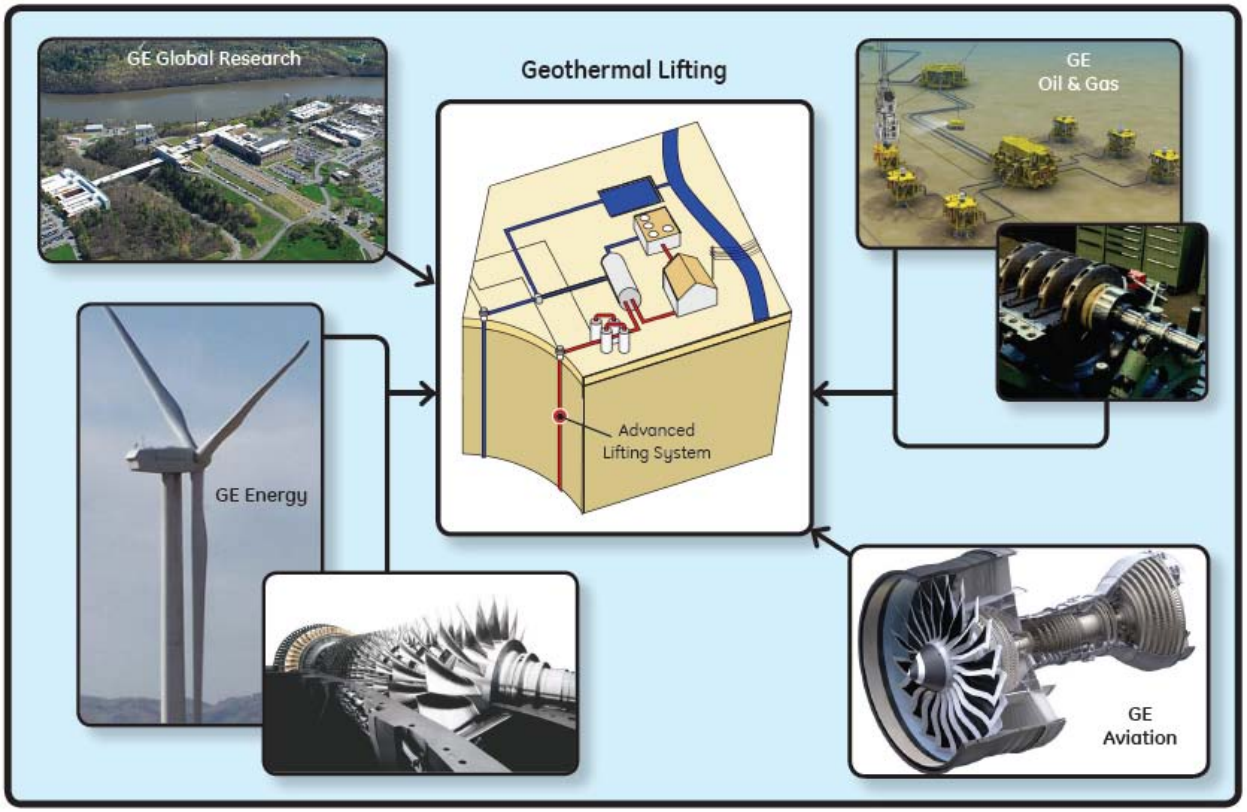

High-Temperature-High-Volume Lifting for Enhanced Geothermal Systems

May 19, 2010

Norman Turnquist
GE Global Research

High Temperature Tools and Sensors, Down-hole Pumps and Drilling

Overview

High-Temperature-High-Volume Lifting for Enhanced Geothermal Systems

Phase	Task	Description of Task	2010												2011												2012												2013											
			1Q			2Q			3Q			4Q			1Q			2Q			3Q			4Q			1Q			2Q			3Q			4Q			1Q			2Q			3Q			4Q		
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
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- Timeline
  - Project start date – April 01, 2010
  - Project end date – March 31, 2013
  - Percent complete – 2.5%
- Budget
  - Total project funding = $3M, DOE share = $2.4M, Awardee share = $0.6M, Funding for FY10 = $0.5M ($0.4M DOE)
- Barriers – K: Downhole Pumps
- Partners – None

Relevance/Impact of Research

Overall objective: Advance the technology for well fluids lifting systems to meet the foreseeable pressure, temperature, and longevity needs of the Enhanced Geothermal Systems (EGS) industry.

Benefits include:

- Definition of the temperature, pressure, and flow rate requirements for geothermal fluid lifting systems for the next 10 years
- High-temperature (>300ºC) lifting system component technology
- Extension of geothermal technology to geographic areas that are not candidates for conventional geothermal power production (by going to depths up to 10 km)
- Reduced dependence on fossil fuels and accompanying reduction in carbon emissions

Scientific/Technical Approach

Three-phased Approach:

1. Define requirements including combinations of well depths, temperatures, boost pressures, flow rates, and environmental threats beyond the capability of current state-of-the-art lifting systems. (GO/NO GO - Sept. 2010)

2. Develop materials, components, and other technologies that will meet the lifting system requirements. (For example, motors, pumps, bearings, and seals.) (GO/NO GO - March 2012)

3. Demonstrate a subscale prototype Advanced Lifting System integrating the technologies under simulated fluid conditions, temperatures, and pressure boost in a flow loop at GE's Research Center. (Complete - March 2013)

Scientific/Technical Approach

Establishing Lifting System Requirements:

- Leverage GE's relationship with AltaRock Energy, Inc. (site visit May, 2010)
- Establish contact with other EGS sites to learn operating conditions
- Acquire / study site data from geothermal projects within GE Energy and GE Oil & Gas businesses

Get broad picture of site requirements for lifting system design criteria.

Scientific/Technical Approach

Lifting Technologies being considered (others may be added):

- Pneumatic driven lifting systems
  - Gas Lift
- Hydraulic driven lifting systems
  - Hydraulic Pump
- Electric driven lifting systems
  - Rotodynamic pumps
    - » Electric submersible pumps
  - Positive displacement pumps
    - » Progressing Cavity Pumps
    - » Diaphragm Pumps
- Mechanical drive lifting systems
  - Suction Rod Pumps
- Miscellaneous
  - Jet Pumps
  - Other…

Each of the lifting technologies will be analyzed for its ability to meet the target specifications:

- **300 bar boost**
- **80 kg/s flow rate**
- **6.625” to 10.625” bore size**

Scientific/Technical Approach

Lifting System Evaluation Criteria:

- Flow rate capability
- Pressure boost delivered
- Working temperature
- Working pressure
- Operating depth
- Bore size requirement
- Size of the lifting system
- Ability to handle erosion, corrosion, scale, brine concentration etc.
- Capital costs
- Running costs
- Maintenance costs
- Reliability
- Availability
- Operational life
- Ability to meet future needs

Accomplishments, Expected Outcomes and Progress

- Project commenced on April 01, 2010
- For period from April 01 – Sept. 30, 2010:
  - Define lifting system requirements
  - Identify alternative lifting systems and their development potential / technology gaps
  - Establish conceptual ALS design

Wherever possible, GE will use its expertise and technology in relevant areas including gas/steam turbines, aircraft engines, oil and gas pumps and compressors, generators, and motors. Use will be made of the GE Global Research Center's extensive facilities for testing materials and equipment as well as computational modeling resources.

Project Management/Coordination

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

3-Phase, 3-Year Effort - $3M total, including 20% cost share by GE

- **Timeline**
  - **Project start date – April 01, 2010**
  - **Project end date – March 31, 2013**
  - **Percent complete – 2.5%**
- **Budget**
  - **Total project funding = $3M, DOE share = $2.4M, Awardee share = $0.6M, Funding for FY10 = $0.5M ($0.4M DOE)**

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Future Directions

Demonstrate the laboratory-scale Advanced Lifting System in March, 2013.

Planned activities in remainder of 2010 and 2011:

- Complete Phase 1
  - Establish system requirements
  - Review concept options and their potential for development
  - Establish conceptual system design and development plan
- Begin Phase 2
  - Execute component-level technology development
  - Scale conceptual design for laboratory demonstration
  - Establish demonstration plan and flow loop design

Summary

- Objective is to advance well fluids lifting system technology to meet the foreseeable pressure, temperature, and longevity needs of the EGS industry.
- 3-Year, $3M effort
- Project commenced on April 01, 2010.
- Phase 1 to be complete Sept. 30, 2010
  - Well fluid lifting system requirements defined
  - System concepts and their development potential identified
  - Conceptual lifting system and development plan established