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

The UNIVERSITY of OKLAHOMA

Mewbourne School of Petroleum and Geological Engineering

leidos

Laboratory-Scale Characterization of EGS Reservoirs

Project Officer: Elisabet Metcalfe
Total Project Funding: $880k
10-01-2014; 09-3-2016

Ahmad Ghassemi
The University of Oklahoma
J. Pritchett
Leido, Inc

This presentation does not contain any proprietary confidential, or otherwise restricted information.

Laboratory-Scale Characterization of EGS Reservoirs

Organization: The University of Oklahoma
Principal Investigator: Ahmad Ghassemi
Contact information: email: ahmad.ghassemi@ou.edu
Project Team: John Pritchett, Sabodh Garg: Leidos Inc.

Objectives: Laboratory investigation of EGS reservoir creation and production processes to understand the role of rock and deformation regime on the nature and extent of induced fractures, to develop a better understanding of the fractures using AE, to characterize the induced fracture permeability and fluid/heat flow using SP and tracer analyses, to use numerical simulation techniques to provide a unified interpretation of the various laboratory determinations.

Relevance/Impact of Research

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

- **Improve the state- of- the- art in estimating EGS stimulated volume, its permeability structure, and the surface area created**
- **Improve the current state of knowledge regarding reservoir performance and expected heat recovery**
- **Improve use of injection induced seismicity in reservoir characterization**

This state-of-the-art laboratory effort will benefit the design of large-scale field test sites such as FORGE, as well as providing results suitable for benchmarking theoretical studies and numerical modeling efforts that have been carried out in the past under DOE sponsorship

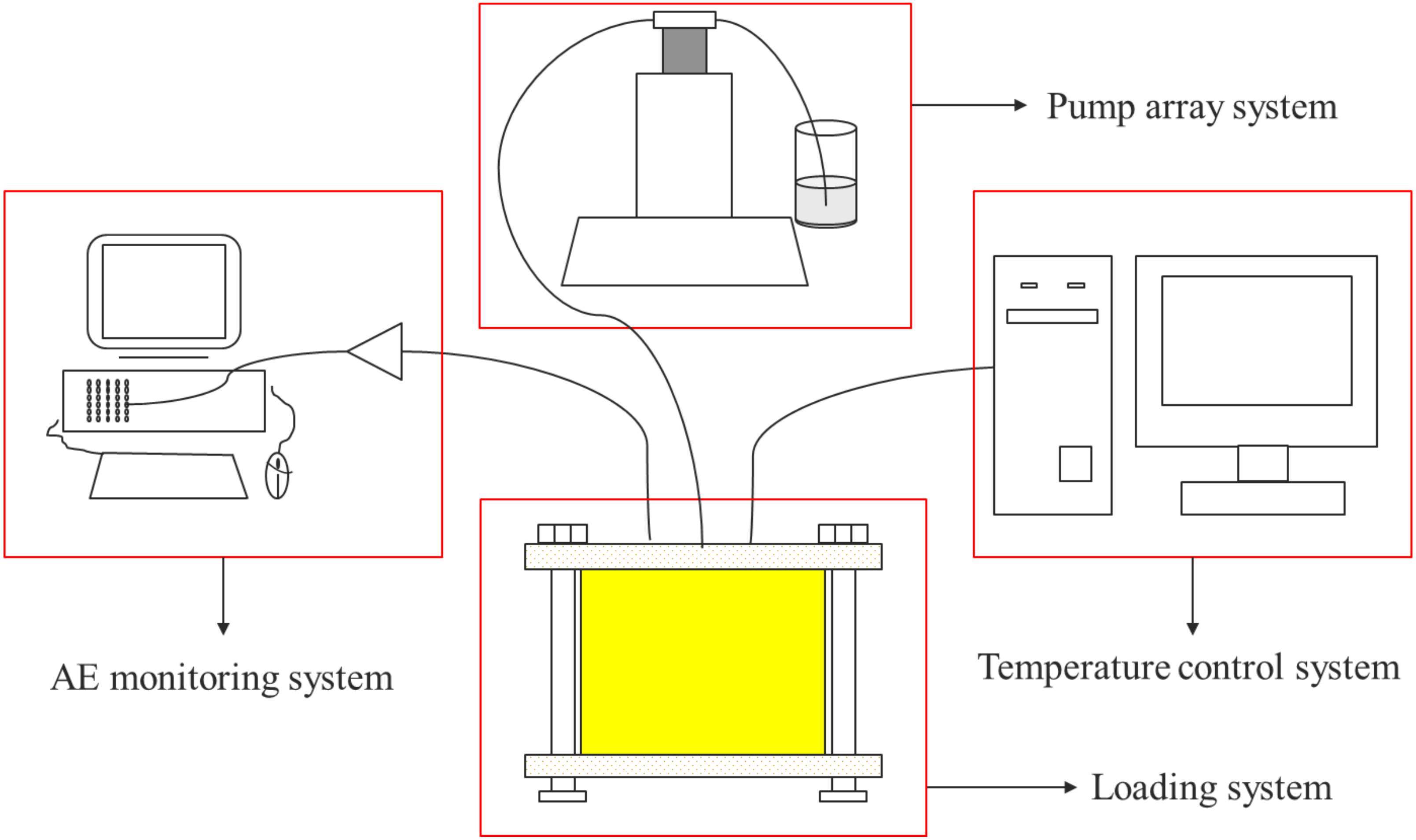
Scientific/Technical Approach

- **Lab-scale testing of cubical reservoirs under non-isothermal conditions and at representative stress regimes**
- **Reservoir stimulation via miniature well(s) to induce fracturing and initiate fluid and heat flow**
- **Integrate a number of technologies to better describe and assess reservoir stimulation and production**
- **Tracer injection and collection from one or more nearby miniature production wells; AE monitoring to characterize and locate fractures**
- **Monitor local changes in fluid pressure, temperature and electrical self-potential (SP)**
- **Use high-resolution X-ray techniques to map fractures within the sample both before and after the stimulation**

Scientific/Technical Approach

- The first few experiments will test a synthetic cement block to verify and refine the experimental techniques, but subsequent experiments will involve actual geological materials (granite). In subsequent years, we plan to consider other rocks of geothermal interest.

Methodology: Experimental Set-up

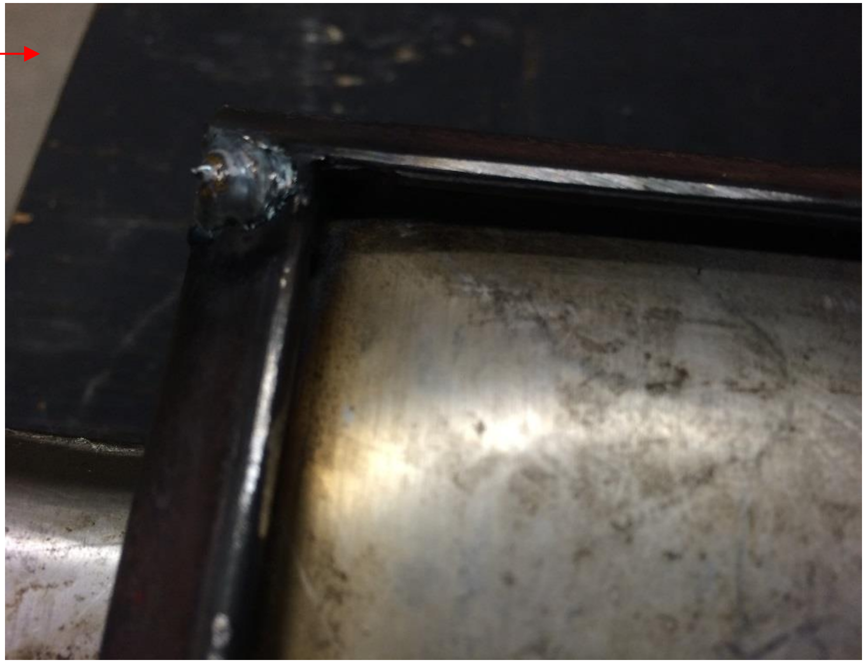


Methodology: Experimental Set-up

- **The loading cell has a working pressure of 3000psi and dimensions of 18.75 in (w) ×18.75in (L)×18in (h)**

- **Two different designs are considered to carry out the tests at high temperature and with pore pressure**

Methodology-flat-jack

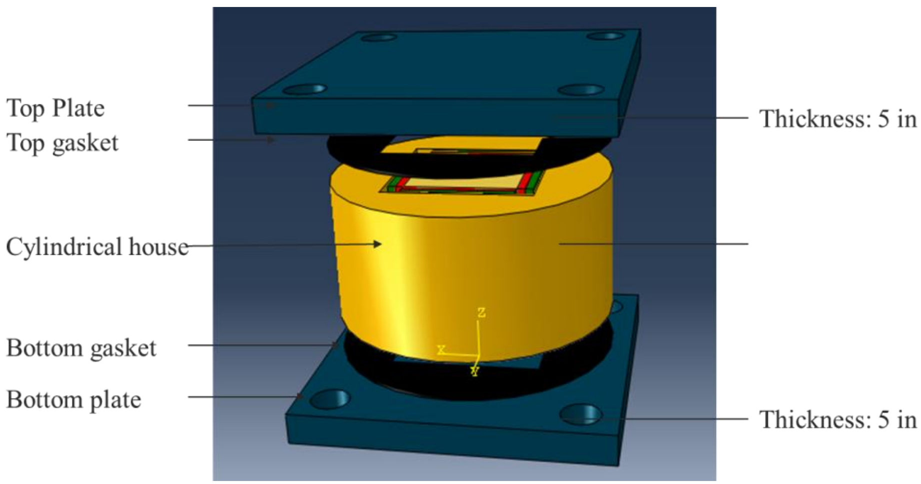


- Each flat jack is made by soldering two stainless steel sheets together; the sides of the jack are protected by a V-shaped steel strip. In this way, the flat jack can withstand high internal pressure without leakage through the four soldered sides.

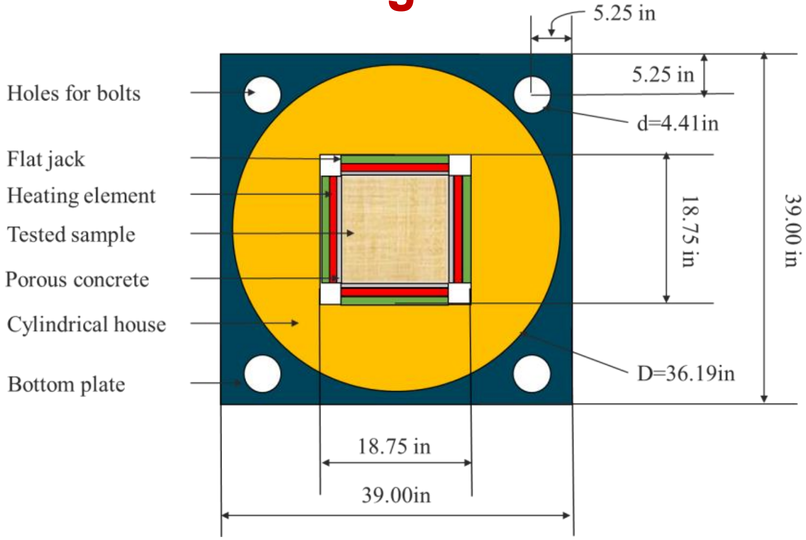
Accomplishments, Results and Progress

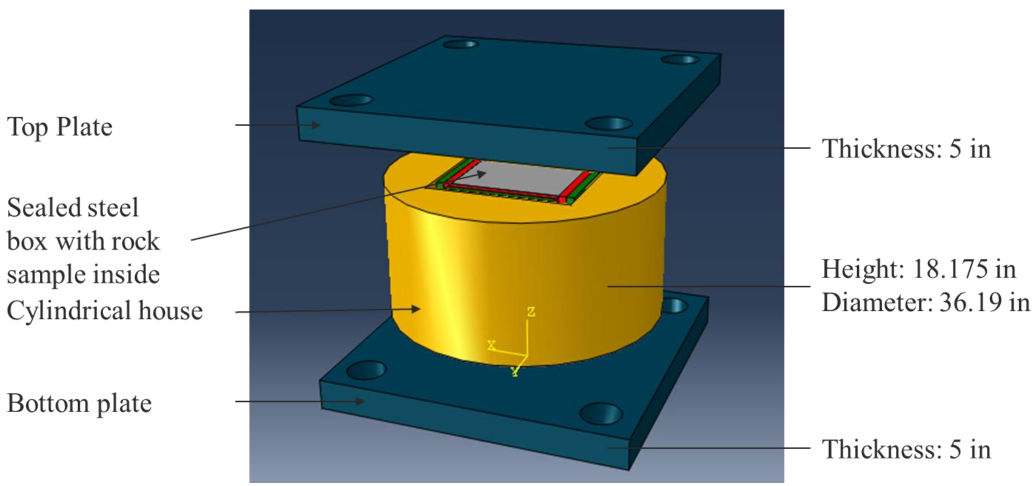
Accomplishments, Results and Progress

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

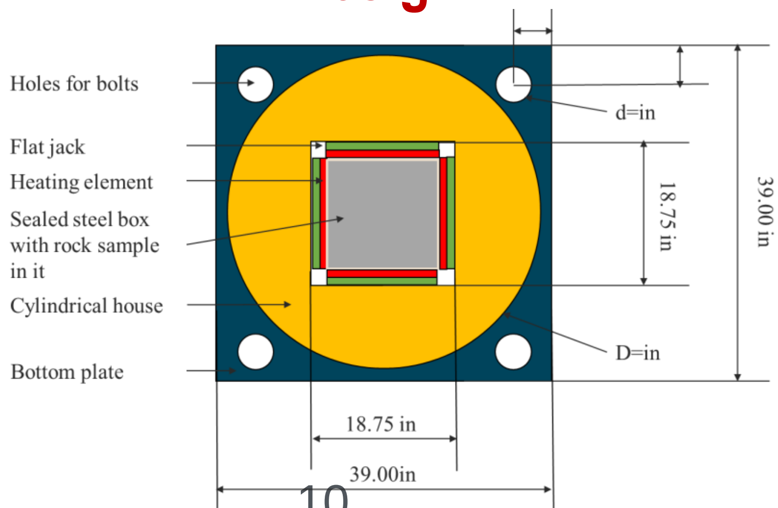


Design A





Design B

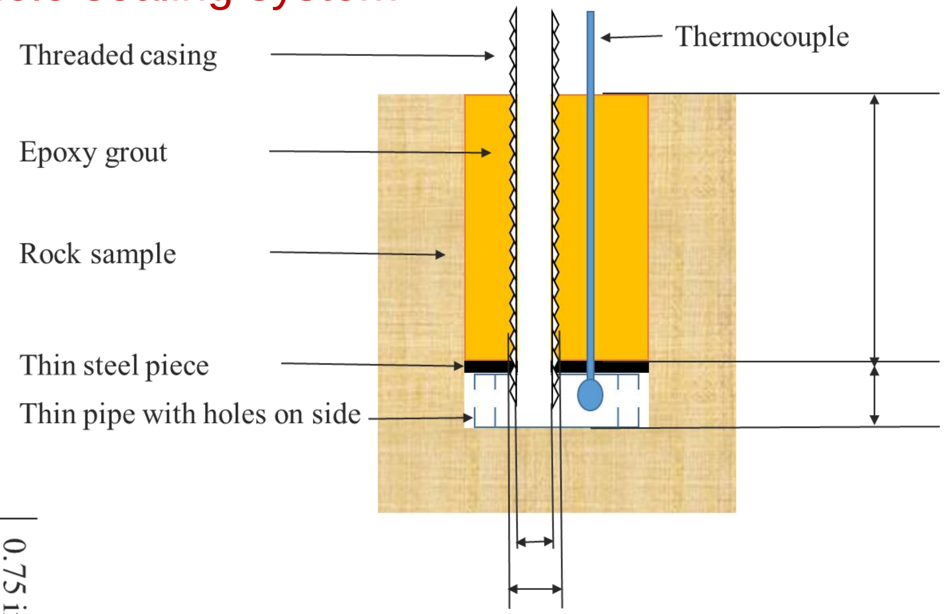


- A novel but simple heating element has been designed which can transmit the mechanical loading while at the same time heating the rock in a controlled manner to assure a uniform sample surface temperature.

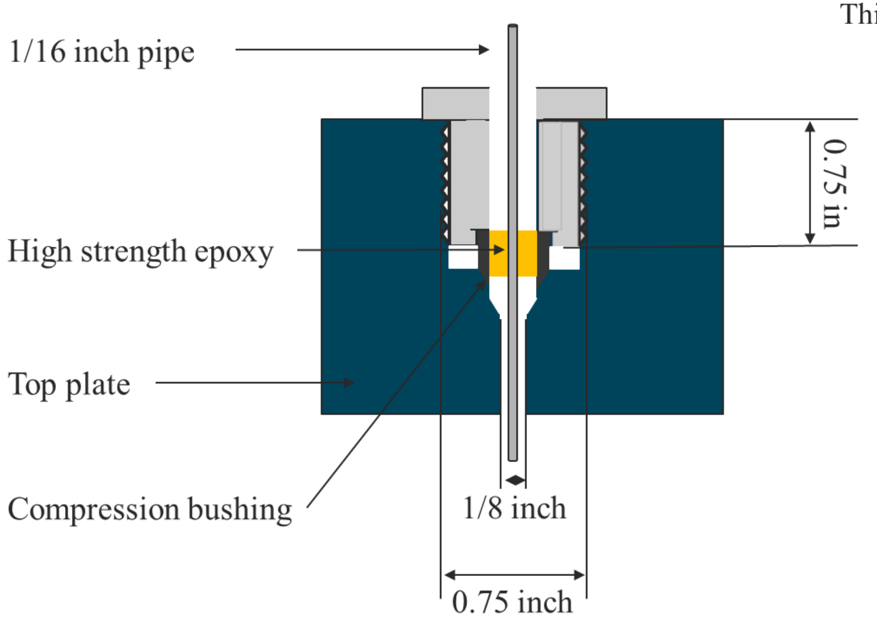
Accomplishments, Results and Progress

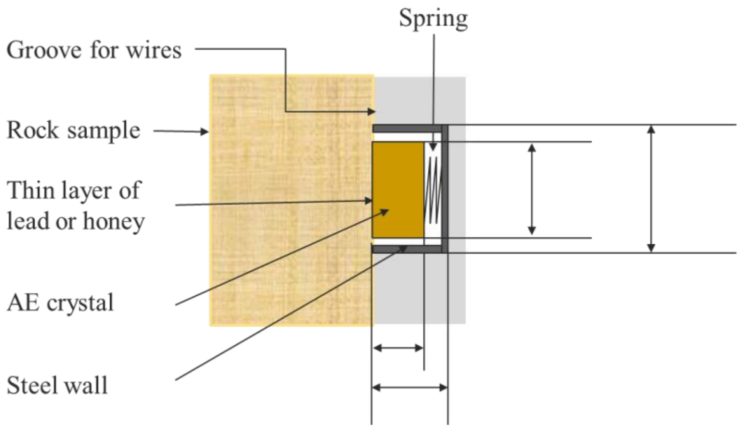
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Borehole sealing system



Sealing method for pipes/wires (Plan A):





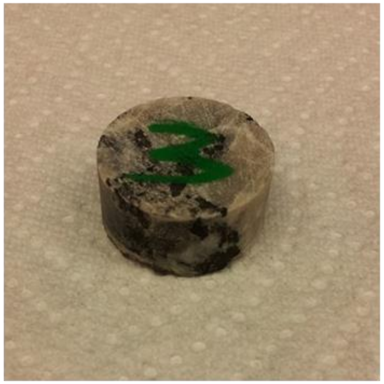
AE sensor mounting method

Rock Characterization

Dunnville sandstone

Sierra White Granite

Kasota Valley Limestone



Rockville White Granite

Iridian Granite

Rock characterization

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

Sierra White Granite

Minerals	Content (%)
Quartz	30.1
Albite	25.2
Albite, calcian, ordered	22.3
Clinochlore-1MIIb, ferroan	4.7
Biotite	1.7
Magnetite	0.9
Cummingtonite	0.3
Chlorapatite,	0.8
Muscovite-2M1	8.2
Microcline,	5.6

From vendor

Axial stress (MPa)		5	40	125
P-wave Velocity (m/sec)		5486	5934	6081
S-wave Velocity (m/sec)		3076	3398	3540
Bulk Modulus (GPa)	Static	18	44.1	55.9
	Dynamic	46.3	52.5	53.7
Young's Modulus (GPa)	Static	35.8	72.4	79.7
	Dynamic	63.6	76.8	82.5
Shear Modulus (GPa)	Static	15.3	29.5	31.5
	Dynamic	25	30.6	33.1
Poisson's Ratio	Static	0.17	0.23	0.26
	Dynamic	0.27	0.26	0.24

ingredient	Weight ratio	Mount for 13.5'' cubic block, kg
Class H Cement	100	54.8%
Silicone	39	21.4%
water	43.2	23.7%
deformer	0.1	0.05%
dispersant	0.1	0.05%

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Milestone Name/Description	End Date	Type
Acquisition of rock samples and their characterization, including blanks and real rock samples (igneous and/or metamorphic); Work out details of experimental procedures to be used; procure and prepare rock samples for testing; procure, assemble and test instrumentation and recording/control/monitoring systems.	A number of candidate rocks have been identified and their properties measured to identify those most suitable for our work. We have identified two final candidates, Sierra granite and Westerly granite, and have acquired the former. We have established the procedures for making the cement blocks for use in equipment testing and calibration. The compression frame has been refurbished and two experimental designs have been identified. The frame top has been modified to accept the	1/30/2015 (target) Mostly completed Jan 15, 2015

late

ation

Future Directions

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

- Plans include finalizing sample acquisition, characterization, preparation of proxy blocks (concrete, sandstone)
- Integration of testing equipment and initial testing of proxy samples using the most effective testing methodology
- Carry out stimulation/production experiments at room temperature. These tests will involve injecting traced water into distilled-water-saturated test blocks.

Milestone or Go/No-Go			Status & Expected Completion Date
Successful completion of tasks I,II	Go/No-Go decision point will be reached near the end of the first year. If Tasks 1, 2 and 3 have been successfully completed by that time, work on Task 4 will be undertaken and the project will be carried forward into a second year.		04-1-2016

Mandatory Summary Slide

- Testing system components have been collected
- Integration of system components has begun
- Rock and proxy material selection and characterization has been performed
- Testing methodologies have been developed and are being tested
- Technical barriers have been identified and are being mitigated