### Development of an Improved Cement for Geothermal Wells

<table>
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<tr>
<th><strong>Project Technology Type</strong></th>
<th>EGS Component R&amp;D &gt; High-Temperature Cements</th>
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<tr>
<td><strong>Awardee</strong></td>
<td>Trabits Group, LLC</td>
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<tr>
<td><strong>Partners</strong></td>
<td>University of Alaska Fairbanks, ThermaSource Cementing, Inc.</td>
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<td><strong>Location</strong></td>
<td>Wasilla, AK; Fairbanks, AK; Arbuckle, CA; Reno, NV; Chena Hot Springs, AK</td>
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<td><strong>Objectives</strong></td>
<td>Develop a novel, zeolite-containing lightweight, high temperature, high pressure geothermal cement, which will provide operators with an easy to use, flexible cementing system that saves time and simplifies logistics. The cement to be developed would have the following characteristics:</td>
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  1) Thermal stability with little strength retrogression to 300° C.
  2) Tensile strength to withstand temperature and pressure changes.
  3) Low-density, low-viscosity slurries with low equivalent circulating densities (ECD) without the need for air or nitrogen foaming.
  4) A single cement blend allowing density adjustments without adversely affecting slurry properties to eliminate the need for separate blends for lead and tail slurries.
  5) Resistance to carbonation.
  6) Accurate downhole densities throughout cement placement without significant changes in viscosity.
  7) Water absorption capacity without retaining free water.
  8) Good bonding to casing and formation.
  9) Adequate compressive strength. |
<table>
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<tr>
<th><strong>Funding Opportunity Announcement</strong></th>
<th>DE-FOA-0000075: <a href="#">Recovery Act: Enhanced Geothermal Systems Component Research and Development/Analysis</a></th>
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<tr>
<td><strong>Funding Source</strong></td>
<td>American Recovery and Reinvestment Act of 2009</td>
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<tr>
<td><strong>DOE Funding Level</strong></td>
<td>Total Award: $2,154,238</td>
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<td><strong>Total Project Cost</strong></td>
<td>$2,692,795</td>
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<td><strong>Principal Investigator(s)</strong></td>
<td>George Trabits</td>
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| **Description of Technical Approach** | The project is based on technology developed for low temperature, weak formation applications that has had limited commercialization. There exists a sound scientific knowledge base using the technology in actual well completions but not the harsh high temperature, high pressure, corrosive environments posed in geothermal well completions. Performance characteristics of the technology however, indicate that the technology can be amended or modified to be effective in harsh geothermal environments.  

Previous work identified a number of variables that affect the cement characteristics. Among these are; particle size of zeolite, percent of zeolite by weight of cement, the API Class of cement used and the zeolite type. No work has been completed on using multiple types of zeolite in the same blend.

The research and development will be conducted in five overlapping Tasks. These are:

**TASK 1 – RESEARCH**

**Literature Search**

A comprehensive literature search will be performed to fully review the current technology in cementing of HTHP oil, gas, and geothermal wells. The literature search will involve reviewing information in the public domain as well as acquiring documents with fee payments.

**Geothermal Cementing Practices and Constraints**

A comprehensive review of current cementing materials and placement methods will be performed to identify operational constraints that could be reduced or eliminated with the development of improved geothermal cement. This review will include U.S. geothermal development and information requests to the International Partnership for Geothermal Technology member countries Australia and Iceland.
Mechanisms of Geothermal Well Failure

A review will be completed to understand the processes of geothermal well failure resulting from cement breakdown. The unique EGS well conditions of long casing strings, temperature drops during stimulation and the mechanical stresses of through-casing stimulation will be examined for cement design.

TASK 2 – DESIGN

Compile Research Findings

The knowledge base gained during the completion of Task 1 will be compiled noting existing technology, current practices as well as cost and logistical constraints that influence cement development.

Modification of Project Tasks 3 and 4

It is anticipated that the completion of research under Task 1 will provide information that will serve to refine the development and testing of a cement to meet the Project Objectives. Under this Task, Tasks 3 and 4 will be modified to take advantage of any improvements in additives, methods and testing procedures. Additionally, it is anticipated that refinement of the Development and Testing Tasks will continue as research results are factored into cement formulations.

TASK 3 – DEVELOP

Zeolite Sample Acquisition

For this project four zeolite types will be used. These are, Clinoptilolite, Chabazite, Ferrierite and Analcime. Approximately 1,000 pounds of each zeolite type will be required for the project. For each sample type the material will be crushed and sized to a uniform minus US 8 Mesh product.

Zeolite Type Confirmation

Representative samples will be taken from each of the four zeolite type bulk 8 Mesh samples. These representative samples will be submitted for X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM) studies to confirm zeolite percentage and type.

Zeolite Particle Size Preparation

For this project each zeolite type will be prepared to three different particle sizes. These particle sizes are: 5 micron, 10 micron and 44 micron. Milling requirements are for 80% particle distribution in the target size. Particle size distribution will be confirmed by Coulter Multisizer or similar tests.

Initial Screening of Cement Formulations

A large number of cement samples will be prepared for initial screening using permutations of zeolite species, particle size, percent zeolite by weight of cement and certain additives. Cement samples may contain more
than one zeolite species and particle size in a test blend to take advantage of the properties of each. Sample preparation will be a heuristic process as the sample composition will need to be fine tuned based on the feedback from sample testing. API Class G and Class H cements will be used as the base for making the zeolite test samples. The following properties are expected to be the primary criteria for initial screening:

- Zero percent free water
- Rheological properties of less than 200 reading at 300 rpm
- 24 Hour compressive strength greater than 500 psi
- Thickening time and consistency, end thickening under 70 Bc
- Slurry density less than 13.5 lbs/gal

**TASK 4 – TEST**

**Second Stage Cement Development**

In the second stage of development, comprehensive testing of cement samples that meet the minimum criteria of the initial screening will be performed. However, in view of multiple variables presented in initial screening a blend that failed to meet minimums in one variable would not necessarily be eliminated from second stage development. Cement property trends will be established as a function of cement composition. This will provide the necessary feedback to adjust cement compositions. During the second stage of development the following tests will be performed:

- Rheological properties of cement slurry (shear stress versus shear rate)
- Slurry density measurement
- Slurry consistency and thickening time
- Compressive strength at 12 hour and 24 hour
- Tensile strength of set cement
- Percent free water measurement
- Response to retarders at high pressure and high temperature
- Quality of cement to casing bond
- Resistance to geothermal brines (long term stability)
- Compressive strength retrogression over a three to six month period
- Determination of the optimum blend ratio of silica flour and other additives to zeolite for thermal stability
- Permeability of set cement
- Poisson’s ratio and Young’s modulus of set cement
- Thermal conductivity of set cement
**Final Stage Cement Development**

It is anticipated that two cement blends will be presented for final stage development. One of the primary objectives of the project is the development of geothermal cement with qualities that resist destruction due to the effects of carbonation. During Final Stage Cement Development samples will be subjected to a test cell bath of steam and formation fluid from Ormat’s Brawley, California field or a similar field which has high CO₂ and minerals content. Samples will be tested at 1 week and 3 week time periods.

**TASK 5 – DEMONSTRATE**

**Laboratory Scale Demonstration**

Cement samples for laboratory scale demonstration will be subjected to conditions of heat and brine for 3 month and 6 month exposures. It is anticipated that curing will be done at 300°C at high pressure and then tested for Young’s modules and Poisson’s ratio for ultimate strength and retrogression from high temperature. Each test cylinder will be examined by SEM for the occurrence of microscopic degradation.

**Logistics and Ease of Use Field Demonstration – Chena Hot Springs Resort**

One of the intended qualities of the developed cement is to “provide operators with an easy to use, flexible cementing system that saves time and simplifies logistics”. It is the intent of this task to place the cement using Chena Hot Springs’ local contractor with their normal and customary methods and equipment. Pre-blended cement will be delivered to the local contractor at the Chena Hot Springs location. The contractor will be given instruction on how to use the cement and the effect of adding water to vary the density. The cementing operation will be observed noting any handling, mixing or pumping problems. The contractor / operator will be asked to comment on the cementing operation particularly as to whether or not the cement appears to have functioned as designed.

**High Temperature EGS Well Demonstration – Ormat Technologies**

It is the intent of this demonstration to test the cement in one of Ormat’s wells under development in a “real world” situation. Ormat has agreed to provide data from their geothermal wells, both hydrothermal and EGS, to guide the development of the cement.

**Project Management, Targets/Milestones**

The Project Objectives (Targets) have been formulated as specific performance characteristics that are necessary for a high temperature cement. As such, each of the Project Objectives requires measurable data that can be evaluated to determine the success or failure of a particular cement blend. These clear and concise performance characteristics provide a systematic method for initial screening, second stage development and ultimately for the final stage of cement development. This logical progression of scientific study results in five Tasks that lead to realistic project milestones and go / no-go decisions points.
### Task Timeline

![Task Timeline Diagram](image)

In view of the fact that the tasks overlap, the go / no-go decision points have been established at the completion of Project Years 1 and 2.

**GO / NO GO DECISION POINTS**

1) The Project will continue into the second year if at the end of Year 1, at least 3 cement samples pass the initial screening. If at least 3 samples pass the initial screen that will give enough confidence that the project objective is viable and the development is heading in the right direction.

2) The Project will continue into the third year if at the end of Year 2 at least 2 cement samples are determined to be potential candidates for field testing.

### Future Directions

Successful completion of the project will result in the development of a cementing solution for geothermal wells that is cost effective as well as logistically simple. This should greatly enhance rapid deployment of geothermal energy as a renewable energy source in USA, thereby reducing the flow of US dollars to petroleum exporting countries.

Additionally, an improved cement for geothermal applications would be directly suitable for use in heavy oil recovery by steam cycle methods. The low cost aspect of the proposed zeolite-containing cement would make marginal heavy oil deposits economic and create new jobs.