

Annual Report for 2012

Annex VII Advanced Geothermal Drilling and Logging Technologies

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Bit 1 before drilling.



Bit 1 after removal at 2070 ft.

PDC Bits Outperform Conventional Bit in Geothermal Drilling Project*

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1. Introduction

a. The objective of advanced drilling and logging technologies is to promote ways and means to reduce the cost of geothermal drilling through an integrated effort which involves developing an understanding of geothermal drilling and logging needs, elucidating best practices, and fostering an environment and mechanisms to share methods and means to advance the state of the art. Drilling is an essential and expensive part of geothermal exploration, development, and utilization. Drilling, logging, and completing geothermal wells are expensive because of high temperatures and hard, fractured formations. The consequences of reducing cost are often impressive, because drilling and well completion can account for more than half of the capital cost for a geothermal power project.

Geothermal drilling cost reduction can take many forms, e.g., faster drilling rates, increased bit or tool life, less trouble (twist-offs, stuck pipe, etc.), higher per-well production through multi-laterals, and others. Activities in the Advanced Geothermal Drilling and Logging Technologies Task will address aspects of geothermal well construction, which include:

- 1) Developing a detailed understanding of worldwide geothermal drilling costs;
- 2) Compiling a directory of geothermal drilling practices and how they vary across the globe; and
- 3) Developing improved drilling and logging technologies.

The objectives of Advanced Geothermal Drilling and Logging Technologies are:

1. Quantitatively understand geothermal drilling costs from around the world and identify ways to reduce those costs, while maintaining or enhancing productivity.
2. Identify and develop new and improved technologies for significantly reducing the cost of geothermal well construction to lower the cost of electricity and/or heat produced with geothermal resources.
3. Inform the international geothermal community about these drilling technologies.
4. Provide a vehicle for international cooperation, field tests, etc. toward the development and demonstration of improved geothermal drilling and logging technologies.

b. Annex VII of the Geothermal Implementing Agreement has been developed to pursue advanced geothermal drilling and logging research that will address all aspects of geothermal well construction. Participants in this Annex are: Australia, the European Commission, Iceland, Mexico, New Zealand, Norway, and the United States.

c. Sandia National Laboratories (USA) is the Operating Agent for Annex VII. Stephen Bauer is Task Leader (from Sandia National Laboratories); sjbauer@sandia.gov.



Barbour Rig 77

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2. Task Names

Annex VII has three Tasks, described below. As specified in the Annex VII Charter, all Participants in the Annex are considered to participate in all Tasks.

Task A: *Compile Geothermal Well Drilling Cost and Performance Information*

(a) Task Leader: Sandia National Laboratories (SNL), USA, Stephen Bauer Sandia National Laboratories); (sjbauer@sandia.gov).

This activity is a compilation of drilling cost information associated with the development, construction and operation of geothermal wells. This information/data will be maintained in a single database, so that all participants can use it to identify key cost components that might be reduced by new technology or by different drilling practices.

Data could include R&D cost, project cost, operation and maintenance cost, and overall cost of energy. It will include information on wells for both electricity and direct-use applications (including geothermal heat pumps), and will include information from 1990 to date. The key modification sought in this time period, based on the realization that operators do not want to openly share costs, is to collect depth-time data, from which, performance may be estimated.

Task B: Identification and Publication of “Best Practices” for Geothermal Drilling

Task Leader: Sandia National Laboratories (SNL), USA, Stephen Bauer Sandia National Laboratories); (sjbauer@sandia.gov).

The Participants have identified and catalogued the technologies that have been most successful for drilling, logging and completing geothermal wells. The complete geothermal drilling handbook includes: design criteria for the drilling and completion programs, drilling practices for cost avoidance, problem diagnosis and remediation during slimhole drilling, trouble avoidance, well testing, geophysical logging, and wellbore preservation.

Task C: Advanced Drilling and Logging Collaboration

Task Leader: Sandia National Laboratories (SNL), USA, Stephen Bauer Sandia National Laboratories); (sjbauer@sandia.gov).

The Participants will monitor and exchange information on drilling and logging technology development and new applications in their respective countries. The Participants will also identify activities and projects for collaboration, and then collaboration plans will be developed. For example, the Participants anticipate identifying opportunities to field test in one country a technology/system that is being developed in another participant’s country.

3. Work Performed in 2012 (described by Task)

General

1- Provided reporting to 27th and 28th ExCo meetings, completed written Annex VII reports, and provided Annex VII revised descriptions for the Revised GIA Document.

The Annex VII met in the spring in Oslo, Norway, and in the autumn in Pisa, Italy.

The following is an update of Annex VII activities presented and discussed at those meetings, and that which took place in the past 12 months.

Key Points from the Annex Meetings:

- 1- Australia, Iceland, New Zealand, Norway, and the United States participated in the Oslo Annex meeting; and Australia, the European Commission, Iceland, New Zealand, Norway, and the United States took part in the Pisa meeting. .

- 2- Each Task was discussed, with a view towards maintaining a substantive path forward:

Task A: Some new well data was added to the database in 2012. A well cost model continues in development. During this year collaborations between the US and Australia resulted in analysis of well cost data from some of the Geodynamics wells: Habanero 1, Habanero 2, Habanero 3, Jolokia 1, and Savina 1. These wells were drilled in the Cooper Basin of South Australia and are relatively close together. The first four lie within a six-mile diameter circle, with Savina another five miles outside that, and the lithology for all these wells is reasonably similar. Data from Petratherm's Paralana 2 well, was also evaluated; it is almost 180 miles away from the Geodynamics group, however, and its lithology is noticeably different.

Task B: This task was ended.

Task C: Requests for collaboration have been received, discussed, and information exchanged between principal investigators. Potential for technology sharing continues.

At the Annex VII meeting in the spring of 2012, held at Statoil, Vækerø (nominally Oslo, Norway), Steve Bauer, Annex Leader, of Sandia National Laboratories/US DOE (Operating Agent) gave a presentation on "Data Mining: How you can help the well cost model develop". This was followed by the "*Norwegian Drilling Technologies Expo*" (Jiri Muller helped with organization). The Expo included the following presentations:

1-"Step Change – Geothermal Drilling"

- by Askjell Tonstad, Managing Director, Norwegian Hard Rock Drilling AS

- Challenges and opportunities.
- Key elements in new drilling technology.

2-"Resonator Drilling Technology"

- by Svein Hestevik, CEO, Resonator Drilling Research

3-"Statoil Hard Rock Drilling Experience"

- by Gaute Grindhaug, Principal Engineer, Statoil ASA

At the Annex VII meeting in the autumn of 2012, held at the Enel Office, Pisa, Italy, Steve Bauer, Sandia National Laboratories presented, "Designing a Deep Hole in Crystalline Rock, and Mr. Alessandro Lazzarotto, of the drilling department at Enel, presented "A Review of the drilling history of the Lardarello Geothermal Field.

Also at the autumn meeting Bauer presented and submitted a proposal for funding from the IEA-GIA Common Fund, entitled "Geomechanical challenges associated with geothermal drilling, stimulation and production". It was proposed to reimburse travel costs of invited participants from the US and abroad who will present contributions of topical interest at the 47th US Rock Mechanics/Geomechanics Symposium within Geomechanical Challenges Associated with Geothermal Drilling, Stimulation and

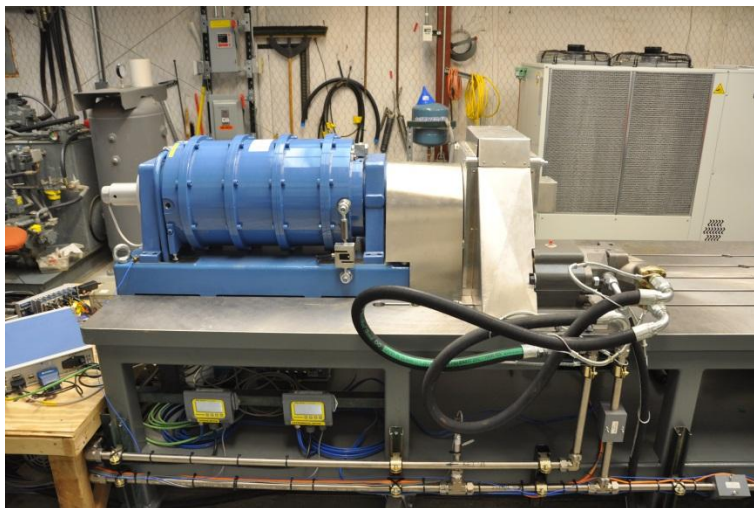
Production Session being held in June 2013. This topic addresses the comprehensive purpose/thrust of Annex VII as a combination of best practices, drilling methods and performance. The proposal was accepted.

4. Highlights of Annex Programme Work for 2012

The efforts related to organizing each of the Annex meetings, especially the “*Norwegian Drilling Technologies Expo*” was significant (see section 3 above).

5. Work Planned for 2013

Increased participation in the Annex is being solicited and is anticipated. A key effort is being mounted for the American Rock Mechanics Meeting in 2013 to have sessions on, Geomechanical Challenges Associated with Geothermal Drilling, Stimulation and Production.



High Temperature Downhole Motor Development Project¹

The Sandia Dynamometer Test Station: close-up of the 48 kw/1200 N-m powder brake dynamometer

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Task A: The U.S. will continue to solicit drilling performance/cost data from operators. The Annex VII participants will discuss, assimilate and analyse information. An outgrowth of this work is expected to be development of a well cost data model. A report will be made to the Executive Committee.

Output: A preliminary cost model and data request.

Task B: this Task is ended and may be replaced.

Output: Report to Executive Committee of distributions of the report and presentations of its contents.

Task C: Solicit, coordinate, and plan international collaborations of technology sharing. Examples of such collaborations include: instrumentation demonstrations and evaluations, information exchanges through visits to foreign sites (ongoing for each year). Organize international exchange program, possibly (and in part) in association with other international travel, for information exchange and sharing.

Output: Report to Executive Committee.

6. Outputs for 2012 (list of publications and meetings, workshops and seminars participated in, etc.)

Papers and Reports

Hart, Darren M., Bion John Merchant and Robert E. Abbott, 2012, Evaluation of ARS16 and ARS24 Rotational Seismic Sensor Designed by Applied Technology Associates, Darren M. Hart, Bion John Merchant and Robert E. Abbott, SAND2013-3674, Sandia National Laboratories.

Kalinina, E.A., T. Hadgu, S.A. McKenna, T.S. Lowry, 2011, “Bridging the gap between complex numerical modeling and rapid scenario assessment: A dimensionless parameter approach”, Geothermal Resources Council Annual Meeting, San Diego, CA, Oct. 2011, SAND2011-7040C

Lowry, T.S., E.A. Kalinina, S.A. McKenna, T. Hadgu, L. Cutler, 2011, “Quantitative risk assessment for enhanced geothermal systems”, American Geophysical Union Annual Conference, San Francisco, CA, Dec. 2011, SAND2011-9151C

Kalinina, E.A., S.A. McKenna, T. Hadgu, T.S. Lowry, 2012, “Analysis of the effects of heterogeneity on heat extraction in an EGS represented with the continuum fracture model”, Stanford Geothermal Workshop, Palo Alto, CA, Jan. 2012, SAND2012-0450C

Kalinina, E.A., S.A. McKenna, K.A. Klise, T. Hadgu, T.S. Lowry, 2012, “Incorporating complex three-dimensional fracture networks into geothermal reservoir simulations”, Geothermal Resources Council Annual Meeting, Reno, NV, Sep. 2012, SAND2012-4451C

King, Dennis, 2012, Evaluation of Thermal Spray Coatings and Shape Memory Alloys as Pressure Seals for Downhole Tools. Geothermal Resources Council Annual Meeting, Reno, NV, Sep. 2012

David Raymond, 2012, “PDC Bits Outperform Conventional Bit in Production Geothermal Drilling Project.” Geothermal Resources Council Annual Meeting, Reno, NV, Sep. 2012

7. Websites Related to Annex Work

<http://www.sandia.gov/geothermal>

<http://www.nrel.gov/geothermal/>

<http://engine.brgm.fr>

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