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The IEA's Role in Advanced Geothermal Drilling

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ABSTRACT

The International Energy Agency's Geothermal Implementing Agreement contains several "Annexes" directed at various areas of geothermal research. Annex 7 aims to improve the state of the art in geothermal drilling, and has the following three subtasks: an international database on drilling cost and performance; a "best practices" drilling handbook; and collaborative testing among participating countries. This paper describes the rationale for each subtask in Annex 7, the progress made to date, and the planned continuation of future activities. This work was performed in association with the Geothermal Implementing Agreement (GIA) under the auspices of the International Energy Agency.

1. INTRODUCTION

In 1997 the International Energy Agency approved an "Implementing Agreement for a Cooperative Programme on Geothermal Energy Research and Technology" that has been previously described by Rybach (1998). One of the four active Annexes to this Implementing Agreement is Annex 7, which was approved by the GIA Executive Committee in March 2001, and is aimed at improvement of geothermal drilling. Original participants in Annex 7 were Mexico, New Zealand, Iceland, Japan, the European Commission, and the United States. Sandia National Laboratories, USA, serves as Operating Agent for the Annex. As of May 2004, however, Japan has withdrawn from the Annex and Italy is considering participation. The rationale for inclusion of drilling as a separate Annex flows from the fact that, in many locations, drilling cost is a serious barrier to geothermal development.

2. DESCRIPTION OF ANNEX 7

Drilling is an essential and expensive part of geothermal exploration, production, and maintenance. High temperature, corrosive fluids, and hard, fractured formations increase the cost of drilling, logging, and completing geothermal wells, compared to, say, oil and gas. Cost reductions are critical because drilling and completing the production and injection well field can account for approximately half the capital cost for a geothermal power project.

Geothermal drilling cost reduction can take many forms, including faster drilling rates, increased bit or tool life, less trouble (twist-offs, stuck pipe, etc.), higher per-well production through multi-laterals, and others. Annex 7 addresses all aspects of geothermal well construction, including developing a detailed understanding of worldwide geothermal drilling costs, understanding geothermal drilling practices and how they vary across the globe, and development of improved drilling technology.

Objectives for Annex 7 include:

1. Quantitatively understand geothermal drilling costs and performance from around the world and identify ways to improve costs, performance, and productivity.

2. Identify and develop new and improved technologies for significantly reducing the cost of geothermal well construction.

3. Inform the international geothermal community about these drilling technologies.

4. Provide a vehicle for international cooperation, collaborative field tests, and data sharing toward the development and demonstration of improved geothermal drilling technology.

The path to these objectives lies through the three major subtasks that make up the Annex. These subtasks and their leaders are described below with direct quotes from the Annex definitions, followed by brief updates on status of each subtask.

3. SUBTASK DESCRIPTION AND STATUS

3.1 **Subtask A**: Compile geothermal well drilling cost and performance information. Subtask Leader: Originally, The New Energy and Industrial Technology Development Organization (NEDO), Japan; now, Comisión Federal de Electricidad (CFE), Mexico.

"The participants shall compile actual costs associated with the development, construction and operation of geothermal wells in their countries and elsewhere. This information will be maintained in a single database for use by all participants. Data may include, but is not limited to R&D cost, project cost, operation and maintenance cost, and overall cost of energy. It will include information on wells for electricity and direct-use applications (including geothermal heat pumps), and include information from 1990 to date."

Analysis of cost data will have two major benefits: it will allow assessment of drilling performance at a given location compared to worldwide averages, and it will help predict the cost impact of improved technology and knowledge.

Status/A: Collection of cost and performance data from varied geothermal reservoirs will allow researchers to identify common problems, assess those problems' costs, and focus development efforts on high-payoff projects. Actual construction of a database, however, faces three major questions: how much data will be available from operators and governmental agencies; in what format should the data be presented; and how will the database be evaluated to achieve the objectives? The problem of cost data availability stems from operators' reluctance to share cost data and from the incomplete nature of much cost information that is publicly available. In light of this

situation, the Annex 7 working group has decided to focus effort on collection of performance data, augmented with cost data when available.

For useful comparison of information from various sources, it is essential that the data collection format be uniform. Well records with substantial cost data will be collected in a spreadsheet format showing performance data and associated costs. An example sheet that describes the pre-drilling phase of two Japanese wells is shown in Figure 1. Sufficiently detailed information of this sort, showing all phases of well construction, can be used to compare drilling costs at different locations and to identify high-cost activities that deserve concerted attention. Many spreadsheet drilling-cost models are available, so these cost data can also be used to predict the impact of improved technology (e.g., immediate evaluation of cost reduction due to improved rate of penetration or reduced trouble) and can thus help focus drilling research.

An alternative display when little cost data is available is the curve of depth versus time, with flat time periods annotated to identify their causes. An example of this display is shown in Figure 2. Even though actual cost values are not included, these diagrams provide a relatively straightforward way of evaluating drilling performance. Because many drilling costs are time-related, the total time required to drill a well is a reasonable indicator of total cost, and the average slope of the line is indicative of average penetration rate, or overall drilling performance in a given rock type or reservoir.

Several Participants have agreed to supply the subtask leader with data for sample wells from their countries, so that the subtask leader can construct a prototype database for the working group's consideration. In addition to the information shown on the sample pages, the contributors will also provide as much information as possible about the rock types, the temperature profile in the well, and the pore pressure.

3.2 Subtask B: Geothermal Drilling Best Practices. Co-Subtask Leaders: Comisión Federal de Electricidad (CFE), Mexico (Electricity); Orkustofnun – Iceland (Direct use)

"The Participants shall identify and catalogue the technologies that have been most successful for drilling, logging and completing geothermal wells. Practices from the various Participants' countries will be compared and contrasted. This work will be published as a Handbook on Geothermal Drilling: Best Practices for use by the Participants. The study will include, but not be limited to: design criteria for the drilling and completion programs, drilling practices for least cost, problem diagnosis and remediation during slim hole drilling, trouble avoidance, well testing, geophysical logging, and wellbore preservation."

Status/B: The Handbook, as originally envisioned, would comprise a great deal of material and would require significant effort to edit and assemble. To accelerate the production of a publication, the Annex 7 working group agreed to reduce the scope of the Handbook's first draft and include only those topics related to drilling for high-temperature (power plant) resources. Many sources of literature are, or may be, available – Geothermal Resources Council (GRC) papers, Society of Petroleum Engineers (SPE) papers, publications from Sandia National Laboratories or other US Department of Energy sources, the New Zealand Code of Practice for Deep Geothermal Wells, and Proceedings of the New Zealand geothermal workshops. Most of these sources are either publicly available or involve copyright issues that can be resolved at nominal cost.

The importance of documenting best practices has been repeatedly demonstrated in the oil and gas drilling industry by, among others, Iyoho, et. al. (2004). They have used learning-curve analysis to show the value of drilling experience, which often means that the worst well in a given field costs more than twice as much as the best well.

The Handbook will document practices that have been found safe, efficient, and cost-effective in international geothermal drilling, but assembly of a complete Handbook is a substantial task that needs significant funding support. Two options for completing the Subtask are currently under consideration: (1) compile a set of references that would serve as a guide to the literature of best practices; (2) proceed with the Handbook as originally planned. Option (1) could be accomplished with nominal cost; option (2) would require the establishment of a common fund within the GIA.

Distribution of a complete Handbook or any related documentation would also be expensive, so the working group has agreed that only a few paper copies of the Handbook will be produced. The subtask leaders have produced a detailed draft outline for the Handbook and have circulated it to the working group for comments. From this point, the most desirable option for distribution of the draft outline or for the complete Handbook will be through a link on the GIA web site. The draft outline, the proposed list of references, and, eventually, the complete Handbook, will be posted for comments by the international geothermal community for approximately one year before completion of the final Handbook format.

3.3 Subtask C: Advanced Drilling Collaboration. Subtask Leader: Sandia National Laboratories, USA

"The Participants will endeavor to stay abreast of drilling technology development and application activities in their respective countries. Meetings to share information will be conducted at least twice annually. The meetings will be used to identify activities and projects for collaboration, and then collaboration plans will be developed. For example, it is anticipated that Participants will identify opportunities to field test in one country a technology/system that is being developed in another Participant's country."

Status/C: This subtask is designed to facilitate drilling technology transfer among countries with established geothermal industries. The mechanism for this process will be solicitation of proposals for collaborative testing from the Participating Countries. Collaboration may take at least the following three forms: experiments in fields or reservoirs that are different from those in which a researcher has experience; use of drilling hardware or software in unfamiliar conditions; or data exchange for improved validation of various drilling models or simulators. This subtask is least well defined, in the sense that it aims to create opportunities for collaborative testing. To date, the working group meetings have served as a forum for researchers to discuss their projects and to solicit Participants for collaboration. Examples of these opportunities include:

- The Iceland Deep Drilling Project (IDDP) is expected to penetrate extremely high temperatures and pressures, and there is still an opportunity to propose experiments or tests in support of advanced drilling

technology. Any person or company interested in testing tools or technology in this rigorous environment should contact IDDP as soon as possible.

- A numerical model for estimation of formation temperatures has been developed at IIE (Instituto de Investigaciones Electricas) in Mexico. Although the model has been tested against measurements in a few wells, it would be useful to have data sets from other locations that could be used for additional validation. A request for this drilling data was distributed to the working group. This data would be very useful in possibly bringing to the industry a wellbore simulator that can estimate wellbore temperatures, even with the occurrence of lost circulation.

- Various items of advanced Japanese technology were described in a brochure, and a list of contact information for people associated with those projects was compiled; both of these were distributed to the working group. These descriptions and contacts should be useful in facilitating application of these technologies outside Japan.

4. SUMMARY

Annex 7 has the potential to be a significant driver in advancement of geothermal drilling technology. The Annex 7 working group represents a broad spectrum of research agencies, industry, and government, and it can leverage its connections within the participating countries to greatly expand the available knowledge base. Because the Annex is organized on a "task-sharing" rather than a "cost-sharing" basis, however, it is handicapped in some countries by the lack of manpower and budget dedicated to Annex goals. A solution to this obstacle is not clear, although access to the GIA common fund, or other support, would enable some of the subtasks to go forward more efficiently.

We should not forget, however, that the Participating Countries in Annex 7 represent five of the seven largest producers, and well over half the world's production, of geothermal electricity, so that technology advances made under the Annex would be widely shared and effectively implemented in a majority of the world's geothermal reservoirs.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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Iyoho, A. W., Millheim, K. K., Virginillo, B. K., Adeleye, A. R., and Crumrine, M. J.: Methodology and Benefits of a Drilling Analysis Paradigm, SPE paper 87121, presented at the IADC/SPE Drilling Conference, Dallas, TX USA, 2-4 March 2004

General Information			Site A			Site B	
Total days for rig up			20.5			23	
Total days for site construction			75			No data	
Total days for site survey			No data			No data	
Total man-days for rig up			348			392	
Site size (m x m)							
Draw works type			NM-2000			80UE	
Number of active mud tank and capacity			3 tanks; 60KL			3 tanks; 60KL	
Number of storage mud tank and capacity			1 tank; 20KL			2 tank; 40KL	
Mud pump type and number			8P-80 x 1, JD200 x 1			9P-100 x 2	
Cementing pump type and number			SKD4□i HT400□j	x 1		SKD4□i HT400□j	x 1
Number of cement storage tank and capacity			4 tanks ; (96.9m3)			5 tanks ; (121.1m3)	
Exchange rate (Local unit to US$)			108 (VUS$)	(July, 10, 2000)		108 (VUS$)	(June, 01, 2000)

		Site A			Site B		
ITEMS	Sub-Items	Specification	volume	Actual cost (US$)	Specification	volume	Actual cost (US$)
Tangibles							
Surface pipe		20", STPG, Sch40,	55m	11,000			
Others							
Intangibles							
Permit							
Survey							
Site construction				376,000			0
Pre-drilling (Set conductor)				111,500			0
Company Stuff transport							
Rig mobilization (Contractor)	Total			**137,000**			**280,500**
	Trucking	11ton	56 Trucks	18,000	10ton	27 Trucks	20,000
	Trucking	15ton Trailer	10 Trailers	7,000	23ton Trailer	18 Trailers	20,000
	Trucking	20ton Trailer	10 Trailers	9,500	30ton Trailer	5 Trailers	7,000
	Cranes for trucking	25ton Rafter	5 days-Crane	3,500	25ton Rafter	5 days-Crane	3,000
	Cranes for trucking	45ton Rafter	3 days-Crane	4,000	45ton Rafter	2 days-Crane	2,500
	Cranes	25ton Rafter	10 days-Crane	6,500	25ton Rafter	12 days-Crane	7,000
	Cranes	45ton Rafter	5 days-Crane	7,000	45ton Rafter	1 days-Crane	1,500
					100ton Crane	7 days-Crane	28,500
					Rental, Lease		10,000
					Rig Rental		85,000
	Labor		380 man x days	63,500		392 man x days	62,500
	Labor transport					54 cars	1,500
	Accommodation		280 man-days	18,000		410 man-days	32,000
Consumption				15,500			23,000
Others				0			1,000
Pre-Drilling Cost Total				**651,000**			**304,500**

Figure 1 – Sample cost data sheet

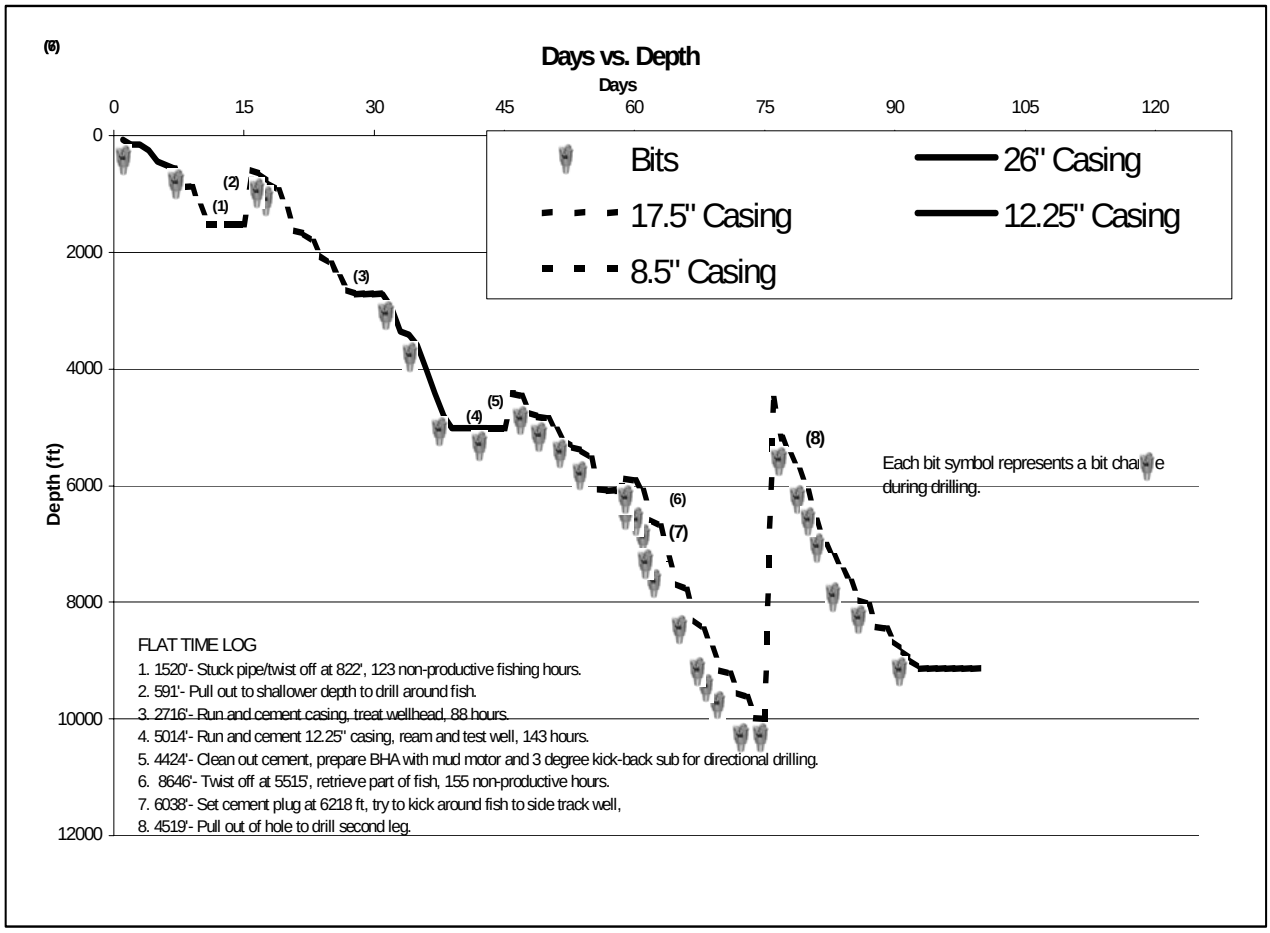


Figure 2 – Sample Annotated Days vs. Depth curve