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**PROGRAM REVIEW X  
WRAP-UP**

Chairperson: John E. Mock  
Director, Geothermal Division  
U.S. Department of Energy

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## Closing Remarks

Roland R. Kessler  
Director, Office of Renewable Energy Conversion  
U.S. Department of Energy

Last year's meeting stressed communications, partnerships, technology transfer, and accomplishments. There was talk of the evolving "Geothermal Partnership" and opinions expressed about the challenges that we are facing in the 1990s. We are impressed with your enthusiastic commitment and your optimistic attitude about achieving the goal of increased use of geothermal energy. We are convinced that geothermal has many great stories to tell. However, we can and must do better in telling these stories, especially along the East coast.

Throughout these past two days, the activities that you reported are proof that the Geothermal Partnership is growing and thriving -- the cooperative **work** being conducted at The Geysers to stabilize the declining production and to optimize field operations, the commercialization of the rotary head seal for use by both the geothermal and oil & gas industries, and the willingness of industry to field test new materials developed to resist corrosion. These are just **a few** of the many examples of industry involvement in cooperative R&D efforts and the important benefits that can result. These are also examples of the good news stories we have to tell and must tell often and well.

State governments and other federal agencies are also making contributions. As you know, Phase II drilling at the Long Valley Exploratory Well was possible because of the support from the California Energy Commission, and DOE's Office of Energy Research/Basic Energy Sciences is the major sponsor of the science experiments being conducted at the well site. These experiments have provided a fundamental new geologic observation that lends strong support for the classical geologic **view** of large intra-continental calderas at Long Valley. This tentative result would not have been possible without the coring operations being undertaken. In addition, the character of the basement rocks encountered thus far raises the possibility of deep recharge of the hydrothermal system, a condition of vital interest to the potential for long-term industrial use of the reservoir.

Geothermal heat pump usage is growing exponentially and is helping utilities to reduce electric power demand. To further expand the use of this technology, DOE is joining with several other interested organizations -- such as EPRI, EEI, EPA, and the National Rural Electric Cooperative Association -- to conduct a series of three promotional national teleconferences on geothermal heat pumps. The first one -- in July of this year -- will target utilities; the others will reach A&E firms and HVAC contractors.

The commencement of the long-term flow test of the hot dry rock reservoir at Fenton Hill is of great interest to all involved with geothermal. If the long-term flow test goes as expected, industry should have no doubts as to the viability of tapping this vast resource.

We have made significant progress in other areas, too. Research efforts to develop new and advanced exploration methods, such as the use of self-potential and magnetotelluric measurements, have shown promise. If these techniques can be refined and demonstrated successfully in the field, the potential for discovering and characterizing new geothermal resources at lower cost and risk is enhanced. Lowering overall drilling costs will have a major impact on the ultimate price of electricity generated from geothermal resources. The progress being made in detecting, characterizing, and controlling lost circulation is impressive, yet a lot more work still needs to be done. Research in the area of binary cycle technology is improving the efficiency of energy conversion, bringing the possibility of more efficient plants closer to reality and stretching the temperature range of usable geothermal brine ever lower.

These outstanding accomplishments are inconsequential without the transfer of the research results to the end user. The Geothermal Energy R&D Program, in its entirety, has been recognized time and again for its ability to successfully conduct technology transfer activities. In DOE, the Geothermal Program has often been cited as the TT model. We have been informed that major oil companies have expressed an interest in the use of geopressed resources for thermal enhanced oil recovery efforts; that several industries and utilities are looking into biotechnology -- a process initially being developed for use with geothermal sludges -- to remove heavy and toxic metals from oil field and refinery sludges; and that corrosion-resistant cements are being considered for use by a variety of industries to extend equipment life.

These technology improvements and innovations must continue -- these are the fundamental elements on which we can build to demonstrate and reap the benefits of geothermal energy. In today's market-based business climate, where the electric utility industry is facing extraordinary challenges -- the emergence of IPPs, mergers and acquisitions, cost and price competition, environmental regulations -- the ways in which this sector must operate are changing. Geothermal energy is positioned to take advantage of new and developing opportunities and could contribute a larger share of our future energy needs with advanced exploration, development, and production technologies and more favorable public policies. Our strategy of working together to try to answer your most pressing needs is yielding results, but we need to continue to share our concerns and to widely herald our successes in order to achieve our goal.

We should not feel any hesitancy to inform energy decision-makers at every level that geothermal energy is a natural •problem-solver. It is a winner in implementing public policy -- beginning with the National Energy Strategy goal of greater fuel and energy technology choices.

Thank you for your participation.

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**NGA INDUSTRY  
CRITIQUE PANEL**

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**SUMMARY OF COMMENTS ON DOE-INDUSTRY COOPERATION  
BY GEOTHERMAL INDUSTRY PANEL**

**James B. Koenig  
GeotbennEx, Inc.  
and  
National Geothermal iation, President**

The geothermal industry **has** matured significantly in recent years, going from early stages of prospect identification and exploration, through drilling and resource assessment, field development and power plant construction, and finally to the operation of mature geothermal fields. All of this **has** been done within the space of a brief quarter century.

f.. Probably no other resource industry in modern times has seen the dramatic growth and maturation as has the geothermal industry. 1: Certainly there **has** been no comparable speed of development and maturation in, for example, the biomass or solar or wind or photovoltaic resource industries. And nuclear, despite double the number of decades of research and development, and infinitely greater cash outlay, is still sinking under unresolved problems of public health and safety. .

The enormous and rapid geothermal growth, resulting in the installation and operation of some 2,800 MW of power generation facilities, plus perhaps 2,000 thermal MW of non-electric facilities, all within the past 25 years, has left unresolved issues in its wake. (This **has been** unavoidable: any new and immensely successful technology inevitably pushes forward so fast on so many fronts that there is not a smooth or complete coverage of all points of importance..",

The Department of Energy, through its Geothermal Program, has heli;ed the growing geothermal industry in many ways. (And this has not **been** give-aways: the DOE geothermal dollars have enables a reliable, safe, environmentally acceptable technology to come on-line for Americans at an acceptable price at-a time when energy has been needed. This is an indigenous, jobs-creating, imports-reducing industry. Exports of American geothermal goods and services are being seen all across the world.::

'; However, because we,,are in many ways a highly mature industry, with commercial equity- and debt financing for typical development projects, and with new interest being expressed by electric utilities in additional geothermal power facilities, we are caught in a "Catch 22" that is deeply troubling.

\ . . . We are congratulated - and then ignored;- by government officials, and told to move forward .on our own feet; while at the same time, financiers and electric utilities tell us that for there to be more geothermal development, **we** must resolve the unresolved issues: better predictive exploration, greater drilling success rates, more accurate reserves assessments, problem-free field operations, lower development costs, improved methodology for risk reduction.

This requires money, research facilities, time, and cooperative support from our government, and more specifically from the Department of Energy.

To explain why this government support is warranted for a mature industry, I need only refer to the highly mature coal industry, which still, today, requires vast government support to resolve its environmental and safety issues, despite the enormous size of the industry and many of its member companies.

By contrast, the geothermal industry is composed of numerous, small companies, typically working in consortia, without vast financial backing or large research budgets, developing new technology on a seat-of-the-pants method as the need arises. This is very laudable, but it is not always efficient, and it certainly is deserving of more support by our own tax dollars. We do not want our industry to be dominated by one or two megacompanies: **we** want our diversity and our justifiable growth, and in this we want the support of the Department of Energy.

We in the industry believe that there are several thousand megawatts of geothermal energy waiting to be developed, in the Cascades, the Aleutians, Hawaii, Imperial Valley, Nevada and Utah, and the Gulf Coast. And there are tens of thousands of thermal MW waiting to be developed in shallow geo-heat pumps all across the frost belt of America. This is no small potatoes. And it must be treated accordingly.

We have heard several interesting talks on research being sponsored by the Geothermal Program. Several of the Industry Panel have commented favorably on the progress in reservoir engineering, drilling technology, use of new materials, and advanced resource research. This is proper, and I refer the DOE administration to those detailed comments for a picture of the effectiveness of the many projects currently being sponsored by the Department.

It is also the view of this Panel that the budget allocated by the Department of Energy to its Geothermal Program is utterly insufficient. By this is meant not an increase of ten or twenty percent. What is needed now is a twenty-fold increase - to \$500,000,000 - in the Geothermal Program budget.

This recommendation may sound as if it is delivered tongue in cheek. This is not so. It is spoken with grim seriousness. The lilies are upon us: increased imports of oil and natural gas with destructive impact on jobs, the environment, and the U.S. balance of payments? Continuing hazard of a major nuclear accident? Ozone-destroying coal emissions? Or environmentally safe, indigenous, vast, jobs-creating, cheap geothermal power now?

The benefits to the American people are potentially so vast that the decision has to be geothermal power now.

It is recommended that the Department of Energy finance a workshop at the earliest opportunity, composed of selected senior representatives of the geothermal industry and selected senior government officials, to prepare the objectives, timetable, roles, and budget for the new \$500,000,000 Geothermal Program. One agenda item will be industry cost-sharing. Another will be integration with the environmental program to obtain funds for geothermal development. Another will be a jobs-creation program within the industry. Still another will be the valuable experience of government and industry working jointly in Japan.

This is a serious matter, not offered lightly. The American people deserve this from their Department of Energy.

## NGA INDUSTRY CRITIQUE OF THE EXPLORATION COMPONENT

J. L. Iovanetti  
**Wea** Associates  
Emeryville, CA

Good morning. My name is Joe Iovanetti of Weiss Associates, and I have been asked to critique the Exploration component of the U.S. Department of Energy (DOE) Geothermal Program Review X. -My comments focus principally on the hydrothermal portion of the DOE program, but I also make some commentary on the Long Valley Exploratory Well and Geopressured-Geothermal components of the program, as well as some general comments.

Before I do that, I would like to review the current state of geothermal exploration in the United States. 1

According to Koenig (1989, 1990) who critiqued the DOE Geothermal Program in those years, geothermal exploration in the western U.S. has been conducted in virtually all of the apparent geothermal resource areas. Many of these areas which were under exploration in the 1960s and 1970s, and were explored in part under the U.S. DOE Industry Coupled Program have progressed to commercial status in the 80s. The DOE March (1992) Draft Multi-Year Program Plan for FY 1993-1997 states that 8 out of the 14 geothermal resource areas explored under this Industry Coupled Program in the late 1970s are currently under production. I do not think we will find anyone in this room, in the geothermal industry, or in the United States that will argue with the clear and outstanding success of that government program.

When the prices of oil dropped in the 1980s, many geothermal operators left the industry, and with the dramatic decrease in activity, many of the service companies went by the wayside also. By and large, the domestic geothermal industry today is emaciated.

As a result of the capital intensive nature of geothermal development, the historical long lead times to go from exploration to production, the highly entrepreneurial nature of the industry, and the lack of an economic market, virtually no new exploration has been conducted in the U.S. in about 10 years. The consequence of this lack of activity is an almost non-existent geothermal reserve base, outside of known producing fields and their immediate surrounds.

The U.S. DOE Deep Thermal Gradient Drilling Program in the Cascade Range is a notable exception to this stagnant condition. Like its predecessor, the industry coupled program, the Thermal Gradient Drilling Program identified at least, one potentially viable geothermal resource: Newberry Volcano.

Combs (1991) in his critique of the U.S. DOE Geothermal Program Review IX, identified the following classic geothermal catch-22:

Some companies have found and do find themselves in the position of having to prove a viable geothermal resource with little capital to make a long-term power sales contract secure, which in turn, can be used to finance the drilling and testing programs to prove the viability of the geothermal power generation project.

Another geothermal catch-219 is:

Windows of electrical market opportunities may develop for geothermal resources but unless the reserves are in place, the industry may not be able to respond to these market opportunities.

As stated by some of the earlier speakers at this conference, to be cost-competitive with other energy resources, we must reduce the cost of exploration, development, and production activities, demonstrate geothermal's reliability, and instill confidence.

It is important to realize that exploration activities form the basis for: (a) **detecting and delineating** the resource; and (b) providing the foundation for understanding how to efficiently and cost-effectively develop and produce the resource.

The National Energy Strategy as reported in the DOE March (1992) Draft Multi-Year Program Plan for FY 1993-1997, predicts that 4,500 MWe of geothermal electrical generation capacity can be available by 1997, 11,000 MWe by 2010, and 22,000 MWe by 2030. In contrast, the most current geothermal reserve estimates reported in this Plan are 5,000 MWe and these are in producing fields.

Koenig (1989, 1990), Combs (1991), Wright (1991), and Meidav (1992) have all written on the need to explore now and begin to establish the nation's geothermal reserve base. Exploration forms the corner stone of a natural resource industry. If not pursued, we risk not improving our cost-competitiveness, and not being ready when the market window develops.

## DOE GEOTHERMAL EXPLORATION PROGRAM

I will now make specific comments on the Exploration Component of the U.S. DOE Geothermal Program. These comments are part my own, part from the Geothermal Exploration Workshop held at LBL in September, and part from discussions with some of you at this conference.

There is no formal Geothermal Exploration Technology Component to this DOE Program Review. Some exploration activities do **OCCUR** Under reservoir Technology, Hard Rock Penetration, the Long Valley Exploration Well, and Geopressured-Geothermal. My recommendations to OOB follow.

1. Establish a formal Exploration Technology Program to address industry exploration requirements. The industry is in concert that basic exploration must be re-initiated. this exploration will in large part be directed towards undiscovered and generally blind systems, since virtually all the obvious ones have reportedly been drilled.

2. Conduct, document and publish a comprehensive integrated case studies for producing geothermal fields in various U.S. geothermal provinces.

In this effort, the inverse problem with respect to delineating geothermal reservoirs should be examined. That is, we know in producing fields where production is coming from, as well as it's geologic nature. Given this, is there any data set of combination of data sets that identify the reservoir and its internal structure. Such an analysis would allow calibration of exploration techniques and identification of those techniques which worked and didn't work, and most importantly, why. Additionally, these fields should become the laboratory for testing new exploration techniques, as well as improvements in existing methodologies.

This work would form the basis for critical understanding of the nature of the systems selected, their occurrence, and how to explore and develop them.

3. Develop conceptual geothermal geoscientific models for each of the US geothermal provinces to guide exploration, and eventually development and production activities.

4. Develop laboratory physical models of hydrothermal systems to support field exploration activities and numerical simulations. For example it will be very interesting and informative to see what would happen if we would take the clay deformation models of Cloos (1968) as reported in Wright (1991) and place them in a hydrologic and thermal field.

5. Develop slim-hole reservoir engineering techniques, the associated geophysical logging tools and drilling capabilities, as recommended by Combs (1991). The latter are currently being worked on but I have not seen any documentation on the reservoir engineering component. The need for this is obvious (see Combs, 1991).

6. Upgrade the methodology to evaluate the geothermal resource potential of an area. No major new work on this methodology has been completed since USGS Circular 790 in 1978. In addition, correlations between heat-in-place and fluid deliverability should be developed.

7. Establish a strategic alliance between DOE, United States Geological Survey (USGS), academia, and industry, along with a functional mechanism which will allow for such an alliance.

8. Establish international cooperation on exploration issues in the form of conferences, technical exchanges, joint programs, etc.

9. Fund existing methodology and new technology development. An example of the former is a more critical understanding of temperature data and heat transfer mechanisms. An example of the later are the geophysical techniques discussed by Philip Wannermaker, earlier at this conference.

10. Train a new generation of geothermal explorationists to inject new ideas, and vitality into our industry. New and bright people will not be attracted to an emaciated industry. Many in the industry have spoken of the need to identify our geothermal reserves in the ground, equally important is our industry's need for a people reserve.

11. Establish a computer data base for raw data, interpreted data, articles, reports, etc., so published information could be readily obtained and evaluated.

12. Establish ASTM standards on critical geothermal exploration activities such as determining resource potential, reservoir size and production capacity.
13. Establish either a cost-shared industry coupled exploration program, or a revolving fund industry exploration program.
14. Establish a Peer Review Committee consisting of DOE, USGS, academia, and industry to evaluate the programs, to keep the program focused, practical, and pertinent, as well as to justify each of the program components under its purview.

## **LONG VALLEY EXPLORATORY WELL**

1. This is the Magma Energy Program. The Long Valley Exploratory well satisfies the near-term efforts of the U.S. DOE Geothermal Division's which as stated in the DOE March (1992) DRAFT Multi-Year Program Plan for FY 1993-1997 are "... to expand the Nation's use of this flexible renewable energy option.", in that it is investigating the hydrothermal system at Long Valley. The well also addresses long-term energy research (e.g., deep drilling in hostile environments).
2. I am disappointed to find no mention of the Magma Energy Program or the Long Valley Exploratory Well in the DOE March (1992) DRAFT Multi-Year Program Plan for FY 1993-1997. This reflects, in my opinion, a significant imbalance in the DOE Geothermal Program, see General Comments below. I recommend that this activity continue to be funded.

## **GEOPRESSURED-GEOTHERMAL AND EXPLORATION**

1. The California Energy Commission with match share funding from the Idaho National Engineering Laboratory (INEL) will be investigating the existence of geopressured resources within the State of California.

This effort must be applauded for it is exactly the type of forward thinking required to identify the U.S. geothermal reserve base. However, it is extremely ironic that federal funds are being spent through INEL on this resource base which is significantly more immature than hydrothermal, when no comparable programs exist for hydrothermal resources. This, in my opinion, is another major imbalance in program priorities.

## **GENERAL COMMENTARY**

The U.S. DOE should be funding projects with a short-term payoff, as well as those that provide a long-term payoff. Certainly, the majority of the funding will not be in the latter category, but nevertheless, some funds should be appropriated.

I recommend that DOE take a more balanced approach to funding geothermal energy related projects. I challenge the DOE to establish a system that will be accountable to the geothermal energy industry and the country. Possibly the strategic alliance between DOE, USGS, academia, and industry (described above) may provide this accountability.

Short-term issues to move the geothermal energy industry forward should always take priority, because by definition, if short-term industry problems are not addressed there may not be a geothermal energy industry in the U.S. for DOE to assist.

Long-term issues should also be addressed such that our industry can become and remain technologically competitive, and cost-effective. The funding levels for long-term projects should be adequate to deal with the next phase of issues, but moderated by the results of an analysis of the likelihood and significance of success. In other words, we need to know the potential benefit to the geothermal industry of any activity being considered for funding. The outcome of such an analysis should prioritize how that portion of the U.S. DOE geothermal energy budget is set aside for long-term efforts.

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## Summary

1 For a number of years the Department of Energy has been funding research to reduce the cost of drilling geothermal wells. Generally that research has been effective and helped to make geothermal energy economically attractive to developers. With the increased competition for the electrical market, geothermal energy needs every advantage it can acquire to allow it to continue as a viable force in the marketplace. In drilling related research, there is essentially continuous dialogue between industry and the national laboratories. Therefore, the projects presented in the Program Review are focused on subjects that were previously recommended or approved by industry.

## Drilling Research Projects Presented

Drilling research projects currently ongoing were discussed at the Program Review by representatives of two different sections--Hard Rock Penetration and Hydrothermal Energy Conversion. Topics discussed included "Acoustic Telemetry in Drillstrings", "Lost Circulation Control", "Downhole Memory Logging Tools" and "Materials for Geothermal Production". There was also an overview of work being done by the Hard Rock Penetration Group that proposed some future projects. Of major interest in the overview was proposed research into the reduction of exploration well drilling costs by combining slim hole drilling with wireline coring technology common in the mining industry.

## Slim Hole Exploration

If hybrid slim holes--a combination of a rotary drilled surface interval with cemented casing and a wireline cored reservoir interval--can provide adequate reservoir parameters for resource evaluation, exploration well drilling costs could be reduced to an extent that would make geothermal exploration much more attractive to industry. It has long been recognized that a significant deterrent to geothermal development is the time lost between successful exploration and cash flow from the ensuing development project. The cost of the capital expended for exploration can double due to interest charges by the time production begins. Reducing exploration costs would therefore have an even larger effect on improving

geothermal economics than reducing development costs by an equivalent dollar amount.

The critical factor to remember in considering slim holes for exploration drilling is that the well must still yield sufficient information to determine reservoir parameters.

## Acoustic Telemetry in Drillstrings

The desire to transmit data more effectively from downhole to the surface has been the subject of a large volume of research by industry for years. Acoustic telemetry would not only improve the speed of data transmission over mud-pulse technology, but could also result in lower cost for the in-hole tool package. Due to the large market for this technology, industry has already signed a license agreement.

## Lost circulation

Lost circulation treatment has been the focus of more DOE funded research than any other subject area. This was very appropriate since lost circulation is widely acknowledged to be the single most costly problem associated with geothermal drilling. Recently an improved flow line meter has been developed to replace the traditional paddle meter that lacked the accuracy necessary to be an effective instrument. The rolling float meter is quicker to indicate lost circulation, and should work equally well to provide advance notice of fluids entering the wellbore. This could be especially advantageous in slim hole drilling where early kick detection is an essential part of well control.

Development is continuing on a straddle packer for isolating lost circulation zones for treatment with cement or similar slurries. The system being developed is based on fiberglass bags that inflate to provide zone isolation. An upcoming field test should be especially interesting to show the practicality of the system.

Investigation is continuing with a borehole televiewer with a long term goal of characterizing lost circulation zones or fractures. Intuitively, it seems obvious that lost circulation could be more easily treated with a picture of the loss zone.

## Downhole telemetry logging tools

Downhole telemetry logging tools will be a necessity for effective slim hole geothermal exploration because tools to log all diameter holes are not available from private industry. Effectively isolating electronics from downhole temperatures and recording data for later download, a problem on the surface is not an impossible problem, but there has heretofore been little demand for this type of system. If slim hole exploration should become popular, tools that would operate in these small diameter holes will be in great demand.

The investigator on this project made a point that DOE involvement would not include the interpretation of data, but merely the development of tools to gather the data. There is substantial debate about what logging data means in geothermal exploration, and most interpretations are considered proprietary. It would be difficult for a national laboratory to enter this debate and data interpretation is rightfully left to industry.

An anticipated byproduct of these downhole logging tools is an improved fluid sampler. Again, this would prove very effective in slim hole exploration where difficulty is anticipated in making the wells flow and produce fluid samples.

## Materials Research

At Brookhaven National Laboratory, research is continuing into various materials for use in drilling and producing geothermal wells. Among the ongoing projects are carbonation resistant cements, elastomer bonding, anti-corrosion linings for use at the Geysers and lost circulation materials.

Carbonation resistant cements are very interesting to geothermal drillers. Since geothermal resources are commonly found in association with carbon dioxide gas, long term viability of the bond between the casing and the formation is in question if the cement undergoes the strength retrogression associated with carbonation. **Solving this problem could add a significant number of years of safe operation to the life of future geothermal wells.**

Elastomer bonding is a continuation of a GOR project to develop drill pipe protective rubbers for use in geothermal wells. Most of the test specimens failed due to disbonding between the rubber and the metal liner.

Use of cementitious liners in the Geysers is interesting since the economics of

development there will not support corrosion resistant alloys in production systems. Continued research into linings suitable for high temperature applications would be at least equally attractive to developers.

Lost circulation material development is also continuing at Brookhaven. New materials and placement methods are due to be field tested soon. The placement method described appears to be costly (requiring coil tubing) and dependent on keeping a downhole valve functional during drilling. Further research should emphasize simplicity in placement techniques.

## Other Projects in the 5 Year Plan

A number of other projects are listed in the 5 Year Plan that were not discussed at the Program Review. Among these are a lost circulation expert system, fiber optic cables and sensors for logging and "Measurement While Coring", Application of electronic intelligence to drilling operations is essentially nonexistent. Commercial efforts to improve high temperature reliability of logging cables has been only partially successful. Measurement-While-Coring is especially interesting in conjunction with proposed slim hole drilling research. The practicality of installing data collection and transmitting devices in the extremely small and highly stressed cross sectional area available needs to be proven early in the investigation.

## conclusions

As anticipated, there were no research projects that did not have direct application to reducing the cost of geothermal drilling. The dialogue that occurs year round between industry and the researchers is only summarized at the Program Review and projects presented are those that have been confirmed by geothermal developers as having the highest potential for success and greatest impact on reducing geothermal drilling costs.

With increasing pressure on the geothermal industry to reduce drilling costs, the primary goal of current research should be to make new techniques and tools commercially available in the minimum possible time. An increasing number of developers are exiting the industry because of inability to compete in an energy market dominated by currently cheap fossil fuels. Only rapid transfer of research to industry can be effective in helping geothermal energy remain a viable alternative for the generation of electricity.

## Critique Panel Comments on Reservoir Engineering DOE Geothermal Technology Development

Dennis Kaspereit  
California Energy Company, Inc.

As our geothermal fields mature and the inevitable problems arise with their exploitation, it will be reservoir engineers that will evaluate out possible future courses of action in order to solve these problems. But first they must have the right tools and data.

To date, the best reservoir engineering tool we have in geothermal is our reservoir simulators. (The reason for this is our severe lack of definition of reservoir parameters. Within a simulation there are checks and balances on the interrelation of reservoir parameters that keep the result within certain realistic bounds. These uncertain parameters make most traditional reservoir engineering methods such as volumetrics of little use for anything beyond preliminary work. Parametric studies such as those by Mike Shook help in determining the range and sensitivity of unconstrained variables in simulator work and are valuable. However, as two non-unique simulations can yield similar results on an established field configuration, the same two can then give different results if used for investigating different future scenarios, injection cases or other what-ifs. Therefore, I do not use simulators as a development or management tool with greater confidence, a more unique solution is desired, requiring greater definition of the parameters input into the model. By determining these parameters a greater assortment of reservoir engineering methods also becomes available. However, I do not see enough research directed to determining these parameters at this time, and there should be a lot more.

These parameters and other methods will be needed to use in the important slim hole evaluations being researched, as simulations are more for developed producing fields with some history, not exploration prospects. One of the best ways to get some of these parameters is by logging methods. The slim hole tools discussed by Peter Lysne on Tuesday afternoon will be needed to get these parameters in exploration prospects. Besides a natural gamma ray spectrometry tool I see a neutron tool as a first choice, and a resistivity tool as a second choice that will also be needed as a minimum logging suite. The research that is needed soon, rather than later, is what Peter was calling inversion technology, and what I would call the calibration of logging responses to geothermal reservoirs.

While productive core holes may or may not be too hot for some conventional tools, we have found it possible to log full

size wells that stabilize at over 600 degrees at under 300 degrees within 12 hours of reaching total depth and pulling off bottom. This is within conventional tool limits. I would propose the correlation of logging responses to core results and cross-plots with the publication of a Geothermal Chart Book as soon as possible. This work can be done in full size holes with full suites of logs before the slim hole tools are fully developed. In fact, full size tools are probably preferable as it will take a full logging suite to define the end points, correlations and charts needed, before a limited suite can be used. Probably only a limited suite will be available in the case of the slim hole tools. Determining the logging response correlations now will also be helpful in determining which slim hole tools to pursue development first. Also, until the response of the slim hole tools are tied back to the response of the full size tools and boreholes their full value will not be reached.

As an industry we have realized the importance of pressure maintenance and the need for efficient reinjection of fluids, and I am glad to see the level of work in this area as it will become our lifeblood. The work in hot dry rock can, and should be, tied back to conventional geothermal reservoirs, as our existing fields could be described as naturally occurring, unbounded, precharged hot dry rock reservoirs.

Several people mentioned the borehole televiwer, with one person developing methods to determine fracture aperture. I am puzzled that the Formation Microscanner, which is resistivity based instead of acoustic, was not mentioned. Commercially available software already exists to determine fracture aperture from this tool. Being a pad tool it can also be expanded to large boreholes such as the Long Valley Well. The development of a slim hole televiwer or Formation Microscanner would be extremely valuable to exploration and development efforts. I hope that the current effort in this area is actively pursued and expanded.

Although not directly presented here, I also want to mention the adsorption/desorption work at Stanford. I consider this to be very valuable work and it deserves full support.

I would like to thank you for this opportunity to express my views.



DOE Geothermal **Program Review** • Critique on Production

Douglas B. Jung  
Two-Phase Engineering & Research, Inc.

I think it is wonderful that our Country can support research projects. Innovations and the development of cost-effective technology is a strategic issue for our industry. We all know that this is important . . . in fact, required to keep the industry healthy. The objective must be to continuously develop technology which will do things better for less money. This is the ultimate goal of research.

I've **been asked** to comment on production research issues. And so, I will limit my discussion to just that.

I think what we've heard in the last few days concerning cements, waste processing, and scale prediction is encouraging. In particular, the work that is being conducted on polymer cements may be of significant importance. As you may know, many parts of "The Geysa T" and other fields are incurring high corrosion rates. The question before us is, do we plug and abandon these wells? Install hang-down strings of small diameter liner using expensive metallurgy such as Inconel, Hastelloy or Titanium? Or, drill new wells? With current economics, it behooves us to seek the least expensive option which can extend the economic life of these deteriorating facilities.

Our current option may be to run inner-liners utilizing these new polymer cements. However, coatings can be damaged and the smaller diameter inner-liner can significantly reduce the amount of steam produced. I would like to suggest to Research, that you investigate or develop alternative means of placing cements or modified coatings directly down-hole onto the corroded casing itself. Inexpensive treatments may be the only salvation for these marginal producers during these times.

How can we accomplish this? Some methods we might consider include: spray coating down-hole, or displace and plug techniques. Polymer curing might be accomplished with the use of down-hole heaters. Obviously, there are many options and details which remain to be worked out. But, it is clear that a simple and inexpensive technique would enhance the economic viability of existing geothermal projects.

It is important to remember that these coatings need not provide indefinite erosion/corrosion protection. It is possible that re-coating may be required on a periodic basis, if cost permits. The bottom-line objective here is to extend the life of the project.

Although alternative corrosion mitigation through the use of chemical titration is a valuable tool, its use will not replace lost metal nor eliminate normal erosional wear. Chemical abatement applied at the surface will reduce back-pressure and allow more steam to be produced. Coatings applied directly onto eroded/corroded casing, well-head equipment, pipe and fittings may provide additional working safety and reduce further deterioration of the base metal. Higher steam production and extended facility life may be achieved.

There are many projects that justify production research expenditures, but none that come to mind more than cost-effectively extending the useful economic lives of existing facilities. 1



## COMMENTS ON THE DOE HYDROTHERMAL ENERGY CONVERSION R&D PROGRAM

David L Mendive, P.E.  
Geothermal Development Associates

In his closing remarks at last year's program **review**, Roland Kessler pointed out two critical questions that must be asked with regard to any program funding:

1. What specifically will be accomplished with the funds requested and why does it matter?
2. What important accomplishments have been made With the funds you have spent?

These seem to be good questions, whether in times of tight budgets or not. I kept these questions in mind as I reviewed the papers summarizing this year's progress in the Energy Conversion Program.

The Materials research effort appears to be accomplishing useful results, some of which are already being tested by industry. In many ways, the past and present achievements of the geothermal industry are a direct result of materials problems overcome. The future growth of this industry will be facilitated by new and improved materials. It often follows from such developments that an industry will leapfrog itself. I therefore support the continuation of this work.

The Brine Chemistry research project is of great value. Plant designers and permitting agencies alike benefit from predictive modeling tools which are both accurate and easy to use. I am especially pleased with UCSD's efforts **at** information transfer. **The** tutorials **and** free distribution of source code are to **be** commended. The preliminary models dealing with H<sub>2</sub>S gas/liquid distributions and acid-base properties should be tested and **finished** as soon **as** possible. **The** work in **progress** which will allow better prediction of gas-liquid distributions after flashing is valuable and it too should be expedited.

The Geothermal Waste Treatment research is important and necessary if we are to keep the industry from becoming another source of environmental disaster. Geothermal energy presently enjoys a reputation as a relatively benign power production technology. The nuclear power industry had that same reputation in its early days, but look at it now. Research on the neutralization and elimination of waste products must **be** given the highest priority. Success in **this** area **is** imperative. I recommend continued work at Brookhaven, perhaps even an accelerated program that assures successful results sooner than later.

The Heat Cycle research project has produced some interesting results, but I believe that some of the work being done is duplicative of work done long ago by engineers at firms such as The Ben Holt Company, Barber-Nichols, and many others. Plant and process engineers are well aware of the efficiency improvements that *might* be made if cost were no object. Most efficiency improvements are costly and financial concerns generally focus on first cost-not life cycle cost. Even when an engineering evaluation of competing alternatives is made, short payback periods are the rule, and many efficiency improvements just don't measure up.

I therefore recommend that this research be redirected toward other energy conversion problems. For instance, the industry lacks general purpose design tools for two-phase flow problems. A public domain computer program that could be used to model and predict two-**phase** flow in gathering systems with uphill and downhill topography would be of great value to industry. Relief valve sizing and flow metering are two more areas relating to two-phase flow that warrant further research. Other possibilities include:

- basic research on heat transfer in ammonia/ water mixtures.
- basic research on materials suitable for condenser tubes in ammonia/ water cycles with wet cooling systems.
- basic research on non-CFC working fluids suitable for use in low temperature binary cycles (<125°C).

**Finally**, the transfer of knowledge developed through these programs **is** of concern to me. Too often the results are published in obscure journals and end up on too few library shelves. I would like to suggest a mechanism for improving the transfer of this valuable work to those **working** day to day in the geothermal industry. The National Geothermal Association sponsors workshops that are noticed to all active geothermal organizations, public and private, and generally well attended. I would like to see the principal investigators present their findings at workshops sponsored by NGA. NGA would need about \$10,000 per workshop to cover expenses. Such an arrangement would insure maximum technology transfer directly to the geothermal industry.



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# FINAL AGENDA

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## FINAL AGENDA

### U.S. DEPARTMENT OF ENERGY GEOTHERMAL PROGRAM REVIEW X

"Geothermal Energy and the Utility Market - The Opportunities  
and Challenges for Expanding Geothermal Energy  
in a Competitive Supply Market"

#### MONDAY (March 23)

7:00 pm Registration and Reception

#### TUESDAY (March 24)

8:00 am Registration and Continental Breakfast

### OVERVIEW

*Chairman, John E. Mock, Director, DOE Geothermal Division*

9:00 am	DOE Welcome and Announcements	John E. <b>Mock</b> , Director, DOE Geothermal Division
9:05 am	<b>Welcome Ad</b>	<b>Terry Vaeth</b> , Deputy Director, <b>DOE San Francisco Field Office</b>
9:10 am	<i>Geothermal Energy Market in Southern California: Past, Present and Future</i>	Vikram Budraja, Vice President of System Planning and Operations, Southern California Edison Company
9:40 am	<i>Taking the High Ground: Geothermal's Place in the Revolving Energy Market</i>	Richard Jaros, President and Chief Operating Officer, California Energy Company
10:10 am	<b>Break</b>	
10:40 am	<i>Recent Development in Japan's HDR Program</i>	Tsutomu Yamaguchi, Geothermal Energy Technology Department, New Energy and Industrial Technology Development Organization (NEDO)
11:10 am	<i>Technology Advancements to Support Growth in Geothermal Power Sales in a Dynamic Utility Market</i>	John E. <b>Mock</b> , Director, DOE Geothermal Division
11:45 am	NGA Luncheon <i>The Future of S04 Contracts after the Eleventh Year</i>	Thomas C. Hinrichs, Vice President, Magma Power Company

### RESERVOIR TECHNOLOGY

*Chairperson: Joel L. Renner, Idaho National Engineering Laboratory*

1:30 pm	Introduction	Joel L. Renner, Idaho National Engineering Laboratory
1:35 pm	<i>Geothermal Research Program of the U.S. Geological Survey</i>	L.J. Patrick Muffler, U.S. Geological Survey

2:00 pm	<i>LBL Research on the Geysers: Conceptual Model, Simulation and Monitoring Studies</i>	Gudmundur S. Bodvarsson, Lawrence Berkeley Laboratory
2:25 pm	<i>Geothermal Geophysical Research in Remote Methods at UURI</i>	Philip E. Wannamaker, University of Utah Research Institute
2:50 pm	<i>Optimizing ReInjection Strategy Using Geochemical Data</i>	Roland N. Home, Stanford University
3:15 pm	<i>TETRAD Reservoir Simulation</i>	G. Michael Shook, Idaho National Engineering Laboratory
3:40 pm	Break	

## HARD ROCK PENETRATION

*Chairperson:* George P. Tennyson, Jr., DOE Albuquerque Field Office

4:00 pm	<i>Overview - <b>Hard</b> Rock Penetration</i>	James C. Dunn, Sandia National Laboratories
4:15 pm	<i>An Overview of Acoustic Telemetry</i>	Douglas S. Drumheller, Sandia National Laboratories
4:40 pm	<i>Lost <b>arc</b> Technology Development Status</i>	David A. Glowka, Sandia National Laboratories
5:10 pm	<i>Downhole Memory-Logging Tools</i>	Peter Lysne, Sandia National Laboratories
5:30 pm	Adjourn for the Day	

WFJ-NF.sDAY (Mardi 25)

7:00 am Continental **Breakfast**

## ENERGY CONVERSION

*Chairperson:* **Raymond J. LaSala, DOE Geothermal Division,  
David Robertson, DOE Idaho Field Office**

8:00 am	<b>Introduction</b>	Raymond J. LaSala, DOE Geothermal Division David Robertson, DOE Idaho Field Office
8:05 am	<i>Materials for Geothermal Production</i>	Lawrence E. Kukacka, Brookhaven National Laboratory
8:50 am	<i>Supercritical Turbine Expansions for Binary Geothermal Power Plants</i>	Carl J. Bliem, Idaho National Engineering Laboratory
9:10 am	<i>Geothermal Waste Treatment Biotechnology: Progress and Advantages to the Utilities</i>	Eugene T. Premuzic, Brookhaven National Laboratory
9:35 am	<i>Geothermal Brine Chemistry Modeling Program</i>	John H. Weare, University of California, San Diego
10:00 am	<b>Break</b>	

## WNG VALLEY EXPWRATORY WELL

***non:*** George P. Tennyson, Jr., DOE Albuquerque Field Office

10:30 am	<i>'7mnud Regimes</i>	William C. Luth, DOE Office of F.nergy Research
10:45 am	<i>7h Long Valley WeU - Phase II Operations</i>	John T. Finger, Sandia National Laboratories
11:10 am	<i>Downhok Science inthe Long Valley Erp/oratory WeU</i>	John H. Sass, U.S. Geological Survey
11:35 am	<i>Geologic Results from th, Long Valley Erp/oratory WeU</i>	John C. Eichelberger, Geophysical Institute, University of Alaska
11:55 am	<i>A Motl,l for Large-Scah 11,,mu,l Convection in th, Long Valley G,oth,mu,J R,gion</i>	Charles E. Hickox, Sandia National Laboratories
12:15 pm	Lunch.(not hosted)	

## HOT DRY ROCK

***Chairperson:*** George P. Tennyson, Jr., DOE Albuquerque Field Office

2:00 pm	<b><i>HDR: Opportunities and Challeng,s Bqond the Long Tenn FIDw T,a</i></b>	David V. Duchane, Los Alamos National Laboratory
2:30 pm	<b><i>Stan-Up Operations at the Fenton HUI HDR PiJDt Plant</i></b>	Raymond F. Ponden, Los Alamos National Laboratory
3:00 pm	<b><i>Update on the Long-Tenn Flow Testing Program</i></b>	Donald W. Brown, Los Alamos National Laboratory
3:30 pm	<b>Break</b>	

## GEOPRESSURED-GEOTHERMAL

***Chaitpenon:*** Allan J. Jelacic, DOE Geothermal Division

4:00 pm	Introduction	Allan J. Jelacic, DOE Geothermal Division
4:05 pm	<i>Geoth,mu,J W,U Operations and Autonulllon in a Comp,t/llN Market</i>	Ben A. Eaton, F.aton Operating Company
4:20 pm	<i>Res,noir ModeUng and Pmlktu,n at Pleasant Bayou Geopremuw-l-hoth,mu,J Reservoir</i>	G. Michael Shook, Idaho National Engineering Laboratory

4:35 pm, **fl/ PJ!Vfl**  
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**Michael Kramer, California Energy Commission**

4:50 pm **Tfff, lqgy r, ll.eaching the Marie for**  
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Jane Negus-de Wys, Idaho National F.ngineerin 4l>onU,qff

### **PROGRAM REVIEW X WRAP-UP**

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### **THURSDAY (March 26)**

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#### **Moderator**

**James Koenig, GeothermEx, Inc.**

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#### **Power Generation:**

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### **11:00 am Conference Adjourns**

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