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DOE'S GEOTHERMAL R&D PROGRAM: PROGRESS AND DEVELOPMENTS

John E. Mock, Director

Geothermal Technology Division, U.S. Department of Energy

ABSTRACT

The U.S. Department of Energy's Geothermal R&D Program continues to focus on the major technical and financial hurdles identified by industry that inhibit investment in and development of geothermal resources. The near-term objective is to extend economical geothermal development to those resources which are not competitive today. This paper summarizes the Fiscal Year 1990 research activities designed to make incremental progress toward this objective. It also describes trends at the federal, state, and international levels that appear to favor an expanded geothermal market and provide an impetus to continued technology development.

INTRODUCTION

On receiving Stanford's gracious invitation to meet with you this morning for the university's 15th annual geothermal reservoir engineering workshop, I reflected on the value of these sessions in geothermal development. Is the annual interaction between industry and the research community fruitful? Have we made a difference?

I believe that you will agree that the answer to both questions is an unqualified "yes." The sessions have provided, and continue to do so, the forums for both formal and informal discussions on the industry's technological limitations and for expert consideration of a range of potential solutions to specific problems. Thus, these meetings have helped to identify and prioritize R&D approaches and to guide research dollars into the most useful and constructive pathways for industry's application. While some of the problems discussed 15 years ago are still on our agenda today, we have made considerable progress in solving many basic issues. I believe the effects of the continuing industry/research community interaction can be measured in several ways.

Quantitative measures are the most obvious and are found in statistics with which we are all familiar. These numbers bear repeating, however, as they are "good news" for geothermal energy.

Over 2,750 MWe of geothermal power are on line compared to less than 400 MWe 15 years ago. Over 750 MWe of the total are accounted for by the hot water segment of the geothermal industry which did not exist 15 years ago. Californians now derive about 7 percent of their electric power from geothermal energy. For this growth to occur, the investment community has had to rely very heavily on technology-based forecasts of the dependability and longevity of the resource to support a developing industry with hundreds of millions of dollars. In the meantime, the cost-competitive range of geothermal power has widened somewhat to encompass more reservoirs. Some degree of development has occurred at over 20 geothermal fields, and the resumption of exploration after a virtual hiatus in this activity for some time is particularly exciting. To me, it represents a statement of faith in the future of this resource.

In addition to our technological achievements, geothermal development has also made significant strides in overcoming many institutional problems which inhibited use of this resource in the beginning -- progress that I believe is directly attributable to our technological achievements. Where California regulations once delayed construction of plants at The Geysers almost beyond economic tolerance, the state now subsidizes geothermal projects. More tolerable federal regulations have replaced the excessive and repetitive environmental reviews initially required. Except for those areas placed off-limits by federal land managers because of competition between mineral development and other land values, I am told that federal leases can be obtained without undue delay today. State regulators that were initially perplexed in establishing appropriate requirements for geothermal facilities because they were "different" now find that the geothermal industry is one of their more cooperative "clients" and no longer an enigma. The federal Environmental Protection Agency concluded after a comprehensive study of geothermal wastes destined for land disposal that regulation of these wastes under the hazardous waste management provisions of the Resource Conservation and Recovery Act (RCRA) is "unwarranted because of the relatively low risk of the wastes and the presence of generally effective state and federal regulatory programs."

While the "low risk" of all geothermal waste products is now generally recognized across the energy and environmental communities, this acceptance is only partially due to the relatively benign nature of the resource itself. It has also been fostered by the industry's own costly efforts to meet public demands and the inclusion of environmental considerations in all federally-funded geothermal technology development. It is to be hoped that this responsible approach will reap a well-deserved payoff for the geothermal industry -- both at home and abroad.

Before I discuss our geothermal technology development activities at DOE, I would like to focus for a few minutes on developments in Washington and elsewhere that may

bring the industry greater opportunities and add impetus to our technology development.

WASHINGTON TRENDS APPEAR FAVORABLE TO GEOTHERMAL ENERGY

Among the signals that may indicate a favorable future for geothermal energy is the stated commitment of the Department of Energy to renewable energy in the National Energy Strategy currently in preparation. W. Henson Moore, deputy secretary of the Department of Energy, has stated that to be creditable, a comprehensive plan must emphasize energy conservation and the development of alternatives for nuclear and fossil fuels. "I see the necessity," he said, "for conservation and renewable energy in building consensus" for other components of the overall strategy.

The Department is in the process of compiling all available information on energy supply and demand in one data base to support its analyses and recommendations and will seek the opinion of the National Academy of Sciences on the accuracy of the data. One of the broad themes on which information has been concentrated is how environmental and energy objectives can best be met. Because of the size of the resource and its environmental reputation, geothermal energy should not lose on either criterion. In fact, the use of geothermal energy is entirely consistent with the overall objective of the strategy which is: "To achieve the most secure, reasonably priced supplies of energy in a manner that is most sensitive to the environment, health, and safety needs of the Nation." It is up to the geothermal community, however, to make the responsible parties aware of the special attributes possessed by this remarkable resource for it to receive the attention it deserves.

Other trends are also evident in Washington which could prove favorable to geothermal use. One of them is an official statement issued by EPA in January 1989 -- entitled the "Pollution Prevention Policy Statement" -- that recognized the limitations on the existing "pollution control" approach which emphasizes management after pollutants have been generated. In its stead, the statement called for a major reorientation of the nation's environmental control programs based on prevention. The prevention strategy recognizes that pollutants originate in certain processes -- e.g., fossil-fired power generation -- and that these processes must be changed to eliminate the pollutant or pollutants. In key areas, geothermal energy is available as a substitute for fossil fuels to produce the same product -- electricity -- but the process could be altered to eliminate or drastically reduce emissions of specific pollutants for which major western metropolitan areas are still in violation of federal and state law. None of these pollutants -- called "criteria" pollutants -- is produced in more than insignificant quantities by geothermal operations, and most not at all.

In addition, federal legislation is pending -- entitled the Global Environmental Protection Act -- that would require EPA to set carbon dioxide emission standards for the fossil-fired power industry by January 1, 1991. If the legislation is enacted, the costs of fossil-fired power would be increased by the need to "manage" CO_2 emissions produced by combustion. Substitution of geothermal energy where it is available would conform to the "prevention" of pollutants concept.

SOME CALIFORNIA TRENDS ALSO FAVORABLE TO GEOTHERMAL

The need for alternatives to fossil fuels in Southern California was demonstrated in the summer of 1988 when a natural gas curtailment resulted in degradation of air quality from the increased use of fuel oil. "Clearly," the California Energy Commission stated, "the (resulting) emergency was an air pollution emergency, not an energy emergency as usually defined." The state Public Utilities Commission's response was to include in its Emergency Order authority for the utilities to "obtain as much electricity as possible from generating sources outside the Los Angeles area." Since market trends indicate that gas curtailment will be a recurring phenomenon in this area, a long-term commitment to bring geothermal power from the Imperial Valley, Coso, or Nevada would appear to offer a long-term solution to the problem.

In addition, CEC has taken into account the environmental and social costs of fossil fuels in two ways. First, by asserting that the value of air quality benefits from power projects will be allowed to offset any net ratepayer costs, and by proposing special fuel taxes on combustion in stationary sources and/or a tax on CO_2 emissions from fossil fuel burning.

INCREASED INTERNATIONAL OPPORTUNITIES MAY DEVELOP

As we are all aware, a number of factors are pushing environmental concerns into the international arena. The world leaders assembled at the Economic Summit last summer acknowledged the global scope of the effects of pollution and recognized the role of energy use in this phenomenon. The Economic Declaration issued urges international agencies that fund development projects in underdeveloped countries to "encourage ... efficiency in the use of energy of all kinds and to promote relevant techniques and technologies."

The developing world already accounts for about a fourth of all greenhouse gas emissions, and the World Resources Institute in Washington makes the point that its share could double in 50 years. "Increasingly," a spokesman said, "all countries will be pressed to adopt energy ... strategies that are consistent with containing the greenhouse effect within tolerable limits."

Those countries with geothermal resources can comply with the least disruptive and most cost-effective policies, and I believe we will see greater and greater use of geothermal energy -- particularly if the leaders of the industrial world continue to hold the funding agencies accountable for decisions that will "preserve a healthy and balanced global environment."

HOW WILL THE U.S. GEOTHERMAL COMMUNITY RESPOND TO NEW OPPORTUNITIES?

Everyone here today knows that the U.S. geothermal technology is the best in the world and that research and development are continuing to maintain and refine our unique posture. However, unless we make unrelenting efforts to make these facts known -- to U.S. decision- and policy-makers at every level of government, to the international funding agencies, and to foreign governments -- we will not avail ourselves of the opportunities to put

our technologies to their broadest use.

DOE'S GEOTHERMAL PROGRAM: PROGRESS AND DEVELOPMENT

DOE's geothermal R&D program continues to focus on the major technical and financial hurdles identified by industry that inhibit investment in and development of geothermal resources. The near-term objective is to extend economical geothermal development to those resources which are not competitive today. Progress continues in the development of major products that will be effective in finding and evaluating geothermal prospects, reducing drilling costs, and efficiently and economically converting heat to power. Along with activities in advanced materials and brine management, this research is designed to reduce developer risk and cost, and expand the economically accessible geothermal resource base. Specific reservoir technology R&D tasks and cooperative studies with industry have been planned for FY 1990 to address the technical problems associated with The Geysers field.

Geysers R&D

Since a large segment of this audience is involved in the research dedicated to resolution of the problems confronting operators at The Geysers, and other speakers will address them in detail, I will enumerate the issues only briefly here:

1. Steam production decline
2. Pressure decline
3. Increased hydrogen chloride loadings in some areas
4. Increased noncondensible gases in some areas, sometimes hand-in-hand with increased hydrogen chloride.

In accord with the consensus expressed during several discussions and contacts between industry and the research community, the major R&D effort at The Geysers will focus on water injection as a potential remedy for some or all of these problems. However, while experience has demonstrated that water injection in some wells in the area helps to maintain reservoir pressure and increase steam production, injection per se can not be considered a panacea until it is determined why injection into other wells, especially at high flow rates, has resulted in cold water intrusion in nearby production wells.

It is also thought that injection of surface water may ameliorate the formation of hydrogen chloride since this problem appears to be a phenomenon of continued fluid withdrawal from fractures to the point where insufficient liquid is left to dissolve HCl coming from deeper zones. It thus dissolves in the condensate at the surface resulting in acid corrosion in surface equipment and in the turbines. It is hoped that this problem can be addressed by coring a deep hole of 12,000 - 13,000 feet in order to determine the relationship of surface hydrogen chloride to subsurface minerals. Fluid inclusions in the core will be studied in an effort to detect changes taking place in the saline brine. In addition, thermodynamic studies of hydrogen chloride will be conducted.

The initial thrust in the development of new injection strategies will be to develop new tracers and field techniques for tracer injection, sampling, and interpretation. While considerable progress has been made in characterizing the behavior of a number of compounds that might be used as geothermal tracers, we are dealing here specifically with their performance in steam rather than in hot water fields. The initial objective of this effort is to identify compounds with an excellent degree of stability in high temperatures; high sensitivity in detection -- parts per billion or trillion -- as the material flows through the reservoir; and a high volatility which will permit the compound to mix with the steam for transport. The fluorinated hydrocarbons are the first target for investigation. Pressures and temperatures in production wells around injection wells will be monitored to determine the rate of interference. The test data will be used to refine computer models of The Geysers to confirm methods for the prediction of reservoir processes and to evaluate the response of the system to development.

Concomitantly, it is planned to conduct seismicity tests as a means of tracing injected fluids. We will continue to explore the possibility that stress systems and pressure drops in fractures can be determined from microearthquakes. High resolution seismic images will be used to evaluate the possibility of detecting steam and fracture zones.

The Department fully believes that resolution of the problems at The Geysers is in the best interest of geothermal development in this country and worldwide, and the Geothermal Technology Division has committed $1 million to this R&D effort for this fiscal year. However, these funds alone will not pay for the projects outlined here at today's costs. Thus, cost- and task-sharing by industry will be absolutely essential if this effort is to succeed. As of this writing, industry response has been good. Efforts are being made to coordinate projects funded individually into a cohesive R&D strategy.

Other Current Thrusts of GTD Research

Exploration research activities in FY 1990 include development and evaluation of surface geophysical methods, application of hydrogeochemical models, study of the formation of permeability in hydrothermal systems through brecciation and fracturing, and synthesis of geothermal knowledge to locate unknown hydrothermal systems. In addition, remote sensing from satellites and biogeochemistry technologies will be evaluated for use in geothermal exploration.

A major focus of the hard rock penetration task is new technology to reduce the costs of problems related to lost circulation by identifying the location and magnitude of loss zones and providing new materials and techniques for plugging porous media or minor fractures as well as large fractures or vugular/cavernous zones. Another important research area is the collection of drilling performance data at the bit face during drilling. Results from previous years show that telemetry by acoustical carrier waves within the drill string can improve data rates by 50-fold over commercial mud telemetry. In addition, a second generation prototype downhole radar tool, designed in FY 1989, will be fabricated, assembled, and performance tested this year. It will be used to investigate methods for inspection of multi-component casing being used by geothermal operators at the Salton Sea.

Several Geothermal Drilling Organization projects are coming to fruition. The borehole televiewer is being transferred to industry for use in water- or mud-filled wells to map formation fractures and to inspect the integrity of internal casing surfaces; arrangements have been completed for commercializing the downhole air turbine developed as the first geothermal tool for directional drilling with air; and this year, testing of high-temperature elastomers for use as drill pipe protectors and rotating head seals will be completed.

The heat cycle R&D is focusing on improving the performance of binary cycle technology to levels approaching the maximum practicable thermodynamic efficiency. This year, supercritical cycle testing is continuing at the Heat Cycle Research facility which is currently located at the GEO Inc. plant at East Mesa. The emphasis is on investigating the condensation behavior of supersaturated turbine expansions. These investigations are using the two-dimensional expansion nozzle and laser droplet illumination system developed previously.

The fouling resistance of a polymer-concrete lined heat exchanger tube is also being tested. If this material does not impede heat transfer, its benefits would not be limited to applications with highly saline brines. The typical heat exchanger design allowance for fouling could be eliminated, reducing both the capital cost of conventional binary plants and O&M costs of all binary installations.

In continuing to develop lightweight, CO_2-resistant cements for well completions, the most promising high-alumina cement formulations identified last year are being tested this year. They will be exposed downhole for one year to brines containing a CO_2 concentration sufficient to cause deterioration of conventional calcium-silicate-hydrate-based cements within a short time.

The key issues addressed by the advanced brine chemistry task are the technological problems associated with handling highly complex brines throughout the fluid production and utilization processes of geothermal power production. The current phase of the chemical equilibrium model for predicting fluid behavior emphasizes parameterization of a variable temperature precipitation model for the scale forming minerals, calcite and anhydride. The hydrogen sulfide, alumino-silicate, sulfate, and bisulfate parameters of the equilibrium model are also being updated with data from the research community. The waste handling activity of this task is continuing work on technology using mixed bacterial and elevated temperatures that combines separation of toxic metals from residual sludges with the recovery of valuable minerals.

These are only some of the highlights of our hydrothermal R&D program as space permitted, and if I have overlooked any projects of particular interest, I hope that you will contact me or the Division for current information.

FY 1989 ended on a very high note in geothermal geopressured R&D. In September, we dedicated the small hybrid binary electric power experiment at the Pleasant Bayou well in Texas, co-sponsored by the Electric Power Research Institute. By December 5, 422 megawatt hours of electricity had been produced, and the unit was operating as expected. This is the first power generated with geopressured brines.

In its turn, the hot dry rock project is awaiting the opportunity to make history. Preparations are continuing for the long term flow test of the deepest, hottest man-made geothermal reservoir in the world. I expect these tests to begin in the next fiscal year.

The work of our magma project may also lead at some time in the future to the recovery of a portion of the huge storehouse of energy contained in magmatic systems. In September of 1989, after 12 years of investigating the scientific feasibility of obtaining heat from magma, an exploratory well was spudded in Long Valley, California, in the first attempt to site a hole directly over a magma body. Core recovery is of particular interest to the members of the Continental Scientific Drilling Program -- the U.S. Geological Survey, the National Science Foundation, and DOE's Office of Basic Energy Research.

Conclusions

In summary, I believe that our cooperative R&D efforts are preparing us for a good geothermal market. I believe that there will be opportunities available to the U.S. industry both at home and abroad -- and that we are technologically ready for them. I want to add, however, that it is our responsibility to make it happen. Representatives of our competitor energy sources make themselves heard where it counts, and I believe we can do no less.