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GEOTHERMAL ENERGY

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Statement by Morton C. Smith, Project Manager, Geothermal Energy, Los Alamos Scientific Laboratory, the University of California, before

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Committee on Science and Astronautics
United States House of Representatives

Hearing on GEOTHERMAL ENERGY

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INTRODUCTION

Mr. Chairman, members of the Subcommittee on Energy:

I am honored to have been invited to testify before you concerning the potential and the problems of extracting energy from hot rock in the earth's crust. It is a particular pleasure to do so in the company of Dr. Robert W. Rex who, more than anyone else, has brought our Nation's vast geothermal resource to the attention of the people and the Congress of the United States.

H.R.9658, THE GEOTHERMAL ENERGY DEVELOPMENT CORPORATION ACT

You have asked me also to address specifically the "Geothermal Energy Development Act" which you, Mr. Chairman, and others have introduced in the House of Representatives.

This bill seems to me to provide very effectively for encouragement and support of the research, development, and application of new technology which will be required to make geothermal energy broadly useful, as well as for a centralized organizational framework within which that can be accomplished efficiently and rapidly. The sequence of research, pilot-scale demonstration, and full-scale power-plant construction outlined in the bill is logical and reasonable, as are the time-frame (15 years) and initial funding level (\$8 million) which it proposes. The provision for carrying over appropriated funds from one fiscal year to the next seems to me a very wise one for a continuing program

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of this type and magnitude. I am sure that all of these aspects of the bill will be supported enthusiastically by nearly everyone to whom geothermal energy research and development are important.

I am less sure of any general agreement that a Development Corporation represents the most desirable arrangement for program coordination and management, but on this aspect of the bill you can find better-informed and probably more objective witnesses than I. I have worked with and for the AEC for many years, and I am frankly biased toward the type of program management that I know it provides. However, the principal objective of our program at Los Alamos is simply to get on with the development of the dry-rock geothermal resource, and I am sure we can do that effectively under the management of a Development Corporation, the AEC, a DENR, an ERDA, or whatever organizational structure is finally settled upon.

There are two minor ambiguities in Section 104(a) of the bill, which I simply bring to your attention.

Line 3 authorizes selection of sites for construction of two or more demonstration installations, but the design, construction, and operation of these installations are not specifically authorized. The intention of the bill in this regard is clear, and so this may not be important.

Line 5 identifies the technologies to be developed as "the generation of steam and electric power." In fact, in some of the most interesting geothermal systems, the energy will be extracted directly from hot water and no steam will ever be produced. This line, therefore, might more appropriately refer to "the extraction of heat and the generation of electric power."

THE DRY HOT ROCK GEOTHERMAL RESOURCE

So far as we know, the Geothermal Energy Group at Los Alamos is the only one anywhere which is actively engaged in experimental

investigations of the extraction of energy from dry hot rock in the earth's crust. We initiated this work several years ago because, in agreement with a subsequent conclusion of your Task Force on Energy, we felt that geothermal energy could become broadly important in the United States only if means were found to extract it economically from dry geothermal reservoirs. We have undertaken to develop and demonstrate those means, and we are gratified that both the report of your Task Force and the legislation which you are now considering give high priority to investigations and demonstrations of this type.

You have asked me, Mr. Chairman, to assess the energy potential of hot rock. As I know you understand, at this stage such an assessment is necessarily based on definitions and assumptions, and these can vary widely. If, for example, I considered only proven technology, I might conclude that the potential of dry rock systems was very small. If instead I assumed that all of the heat in the earth's interior was ultimately available, then I would conclude that the potential was enormous. Evidently, I should begin by stating my actual assumptions, which are intermediate between these extremes.

In general, I assume that in developing a dry rock geothermal system we will begin by drilling holes downward into it, and that the practical limit on drilling depth will be something like 20,000 feet. If we were to encounter a strong flow of steam or hot water, especially from a highly fragmented formation, then the maximum practical depth would probably be 10,000 feet or less. This is common in wet geothermal reservoirs -- and here improvements in drilling technology are urgently needed. Such new methods as the rock-melting drill now being developed at Los Alamos should eventually be very useful.

In developing dry-rock reservoirs, our drilling problems will in general be only those represented by high temperature and hard rock, and these can be met with current technology. In

deep oil and gas wells, rock temperatures above 400°F are fairly common and temperatures above 500°F have occasionally been reported. Drilling in rock this hot is now usually done with air, which is a very effective coolant, or with mud that is cooled artificially -- often simply by dumping ice into it. Even with carbide-tipped bits, drilling rates are low in rock as hard as granite, bit wear is rapid, and cost per foot is high. However, in such rock there are rarely any problems from caving, swelling, lost circulation, or sudden changes in rock type or structure. Drilling in granite is slow and expensive, but it is not especially difficult.

Improved drilling technology will of course be very welcome even for dry-rock exploration and development, to reduce costs, increase rates, and allow deeper holes to be made economically. However, at least the initial needs for drilling in dry hot rock can certainly be met with existing oil-field techniques and equipment.

Holes 20,000 feet deep are now quite common in the oil business, and a good oil well may produce 100 barrels of crude oil per day. In terms of energy, this is a production rate of about 7 megawatts thermal, and it could support a generating capacity of about 3 megawatts electrical. An average steam well at The Geysers supports more than twice that generating capacity -- and we hope to do considerably better with well-engineered dry-rock systems. The analogy of oil and geothermal wells is far from perfect, but it suggests that we can afford to spend even more on a geothermal well than we do on an oil well, and I think that is correct.

The initial development of dry hot rock geothermal energy systems will almost certainly be in the western United States, where rock temperatures at depth are generally higher than in the East, and the hot rock is usually granite. In cooling 40 cubic miles of granite from, say, 500 to 140°F, we would extract an amount of energy just equal to that used for all purposes in

the United States in the year 1970. (This is also approximately the energy content of all of the oil on the north slope of Alaska.) Our estimates indicate that, in the western third of the Nation, at least a quarter of a million square miles of land surface is underlain by rock at least as hot as 500°F, at depths less than 20,000 feet. The potential usefulness of this vast resource is obviously limited by both its temperature and its physical form. Where we can use it, however, it will at least save higher grade fuels for more demanding purposes -- and the saving could be large.

In this resource the eastern United States is less fortunate than the West. However, even in the East there are large areas under which rock temperatures are 350°F or more at depths less than 20,000 feet. With the development of binary cycle power plants, this temperature is at least marginal for generating electricity. It is more than sufficient for many heating and air-conditioning purposes -- a type of use which should certainly be encouraged. I think that, in perhaps 10 or 15 years, geothermal energy will become important even in the East. Its broad development in the West should begin almost as soon as we have demonstrated a reliable method of extracting heat from dry geothermal reservoirs, which we hope to do in less than 5 years.

ENVIRONMENTAL PROBLEMS

Depending largely upon the permeability of the hot rock, there are several ways in which energy might be extracted from a dry geothermal reservoir. The method that we have undertaken to develop and demonstrate first is intended specifically for use in rock such as competent granite, which has very low permeability to water. We propose to drill two holes down into the hot granite; connect them through the granite by means of a large crack made by hydraulic fracturing; connect them at the surface through a heat exchanger; and then circulate pressurized

water around this loop. The water will extract heat from the rock at depth and deliver it to the surface at a rate which, with a large crack system, may be 200 megawatts (thermal) or more.

In our initial experiments on the Jemez Plateau of northern New Mexico, we have had no unexpected difficulty in either drilling or hydraulically fracturing hot granite. With pumping pressures up to at least 1000 pounds per square inch, the fractured granite contains the water extremely well; leak-off rates are about what we would predict from permeability measurements in the laboratory on sound samples of dense granite and are very low. We hope and believe that this general behavior is typical of deeply buried granite, but to prove that we will have to drill more and deeper holes and do many more experiments. In the meantime, our results to this point are very encouraging with regard to the probability that we can create and operate a dry-rock geothermal energy system of the type that I have described to you.

In drilling the holes for such a system, we will take the same precautions normally taken in drilling for oil or gas, to prevent contamination of any ground-water circulation in the rocks and soil above the granite. We will drill with mud until we are well into the granite; we will case this part of the hole with steel pipe; and we will cement the casing in place throughout its length. We expect to produce no contamination of overlying aquifers during either the creation or the operation of the geothermal energy system.

During system operation, it will be necessary to add water to the circulation loop, principally to make up for shrinkage of the granite as it cools. We foresee no reason ever to discharge significant amounts of water from the system, and thus no danger of polluting the surface drainage. In fact, so long as the circulation is contained entirely by granite, we now believe that the water will remain low enough in mineral content so that we could safely drink it. If we should lose the entire

contents of the system at once, the result might be spectacular -- like a geyser -- but once the water had cooled it should not be harmful to people, fish, wildlife, or vegetation.

In spite of its relative purity, the water will flow through the system at a rate high enough to transport several tons of dissolved mineral to the surface every day. The mineral will be chiefly silica, which may tend to plate out in the heat exchanger. If it does so, we will probably try to precipitate the silica as particles and then remove the particles from the system with a filter or a centrifugal separator. Chemically the precipitate will resemble a quartz sand, and it should not be objectionable. It might have a by-product value, but probably it will be simply a nuisance; we may have about a truckload per day of very fine silica sand to dispose of somehow. This should not represent a major disposal problem.

Otherwise the energy-extraction system will be entirely contained, and should be entirely nonpolluting. This, unfortunately, may not be true of the associated surface plant that uses the heat. In particular, if geothermal heat is used to generate electricity, then the power plant has the same waste-heat problem as does every other relatively low-temperature generating system. Low-temperature turbines are inherently inefficient, and the heat that they do not actually use is very likely to appear ultimately as thermal pollution. This, by the way, is another reason to encourage the non-electrical uses of geothermal energy. The direct use of geothermal heat can be very efficient.

SUBSIDENCE AND EARTHQUAKES

An energy extraction system of the type that I have described will be relatively narrow; deeply buried in strong, competent rock; and always full of water under a pressure at least equal to the pore pressure of any fluid originally in the reservoir. It should produce no subsidence of the earth's surface either during

operation or after abandonment. This may not be true of some other types of dry-rock systems which have been suggested for the extraction of energy from more permeable rocks, such as porous sandstones. However, the behavior of these other systems will depend on parameters that cannot yet be predicted. In the meantime, a deep hydraulically fractured system in impermeable rock represents no hazard with regard to subsidence.

Small earthquakes have been stimulated in the Denver and Rangely areas of Colorado and in up-state New York by the injection of large volumes of pressurized water into active fault systems. Significantly, there have been no earthquakes in these areas when the fluid was injected into the same formations at places short distances away from the active faults. Hydraulic fracturing is done hundreds of times a week in oil and gas fields without triggering earthquakes and, in secondary recovery operations, very large volumes of fluid are commonly injected into the producing formation under high pressure, again without producing earthquakes. The evidence is good that simply avoiding active faults will reduce the seismic risk associated with a man-made geothermal system essentially to zero. However, until this has been demonstrated beyond any doubt, we propose to monitor such systems carefully and be prepared to reduce the system pressure promptly if any suspicious seismic signals begin to appear.

CONCLUSION

Dry hot rock in the earth's crust represents the largest and most broadly distributed reservoir of usable energy that is accessible to man. The engineering equipment and methods required to extract and use this energy appear to exist, and are now being investigated actively at Los Alamos Scientific Laboratory. At least for deep systems in relatively impermeable rock, not close to active faults, the extraction of energy from dry geothermal reservoirs should involve no significant environmental hazards. The principal environmental effects of such energy systems will

be those associated with the surface facilities that use the geothermal heat; these will be visual, in land use, and in the thermal-pollution potential of low-temperature power plants. The energy extraction system itself should be clean, safe, unobtrusive, and -- we hope -- economical.

Thank you for the opportunity to testify before you.

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