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MASTER

Quarterly Report

ENERGY PROGRAMS

at The Johns Hopkins Univerisity Applied Physics Laboratory

JANUARY—MARCH 1978

THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY

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Johns Hopkins Road, Laurel, Maryland 20810

FOREWORD

The Applied Physics Laboratory issues the Quarterly Report series to provide the defense establishment and the scientific community with current awareness of selected APL activities. At present, the Quarterly consists of the following volumes:

Programs	Report Designators
Department of Defense Programs	
Surface Missile Systems	WQR
Research and Development	RQR
Space	SQR
Exploratory Development for Missile Propulsion	DQR
Civil Programs	
Energy	EQR
Biomedical Research, Development, and Engineering (Annual Report)	MQR

The nomenclature for the APL Quarterly Report is as follows. The designation for Quarterly Report, "QR," is preceded in each case by a letter that indicates the volume's program area. After the "QR," a virgule is followed by a year indicator (e.g., "77-") and a number from 1 to 4 to specify the calendar quarter.

The format is flexibly designed so that most technical articles can be presented on a single sheet of paper. Each article is given a section number (e.g., §24), which applies to the current Quarterly only. Each article is keyed to its major program area (e.g., Research and Exploratory Development), its technical instruction (e.g., Amorphous Semiconductors), its budget code (e.g., A13B), the Laboratory Group or Groups that performed the work (e.g., BBE), and the agency that supported it (e.g., SEA-033).

Certain Laboratory programs, including some which report a portion of their activities through the Quarterly Report, use document series other than the QR to report the bulk of their activities. Those series are available only to individuals and organizations that are directly concerned with the specific programs involved.

Requests for Quarterly Reports should be directed to: Supervisor, Technical Publications Group, Applied Physics Laboratory, Johns Hopkins Road, Laurel, Maryland 20810.

PREFACE

The Johns Hopkins University Applied Physics Laboratory, under contracts with the U.S. Department of Energy (DOE), with the National Science Foundation (NSF), with the U.S. Maritime Administration, Department of Commerce, and the U.S. Fish and Wildlife Service, is engaged in the development of energy resources, energy utilization concepts, and energy storage methods. This Quarterly Report summarizes the work completed on the various tasks as of 31 March 1978.

The Energy Programs Quarterly Report is divided into two sections. The first section, Comments on Limited Tasks, contains short descriptions of meetings, trips, presentations, and other limited tasks of note performed in connection with major program tasks. The second, Major Tasks, is made up of articles that describe these program tasks briefly, summarize the progress made to date, and indicate future efforts to be made.

The major tasks fall into the following categories. The first, Geothermal Energy Development Planning, is part of the Operations Research Contract. Efforts in this field are concentrated on the survey of potential geothermal resources and the development of scenarios for possible exploitation and utilization in DOE/DGE Region 5, which includes all the United States east of the Rocky Mountains, excluding Texas and Louisiana. The second, Applications Study of DOE/DGE Region 5, concerns a study of geothermal energy applications in DOE-selected areas of the Atlantic Coastal Plain. The third is concerned with the Low-Head Hydroelectric Program. The fourth contains a report on the Community Annual Storage Energy System (CASES) and the status of a development and demonstration plan for a low-cost flywheel. The fifth describes multiple-objective modeling of power plant locations.

Future volumes will report the results of these and other energy-related projects in which APL is currently engaged.

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COMMENTS ON LIMITED TASKS

GEOTHERMAL ENERGY PROGRAM

VISIT TO PENNSYLVANIA GEOLOGIC SURVEY AND GOVERNOR'S COUNCIL ON ENERGY

On 29 March 1978, F. C. Paddison of APL and J. Maxwell of the Los Alamos Scientific Laboratory (LASL) visited the Pennsylvania State Geologic Survey and the Governor's Council on Energy.

State Geologic Survey. Discussions of thermal properties of the State of Pennsylvania were held with D. M. Hoskins and S. I. Root of the State Geologic Survey. The Survey has no regulatory function but has a branch in Pittsburgh to support the Oil and Gas Commission.

A bill (Ref. 1) has been proposed to the State Legislature to regulate all bore holes in the state as part of the surface mining law and would require filing of all well logs and cuttings if requested. Current law does not require these data if the hole is less than 3800 ft deep or does not penetrate the Onondaga formation.

There are warm springs in Perry County near the Juanita River and at Bedford Springs. These waters are of modest temperature, approximately 70°F. Although no measurements of the age of the water or its thermal history have been made, it is considered to be meteoric (Refs. 2 and 3).

Figure 1 is a thermal-gradient map of Pennsylvania and western New York State by the American Association of Petroleum Geologists (AAPG) and the U.S. Geological Survey (USGS). The thermal gradients for western Pennsylvania are greater than 1.6°F/100 ft and in many spots they exceed 1.8°F/100 ft. The thermal highs coincide with two geologic provinces.

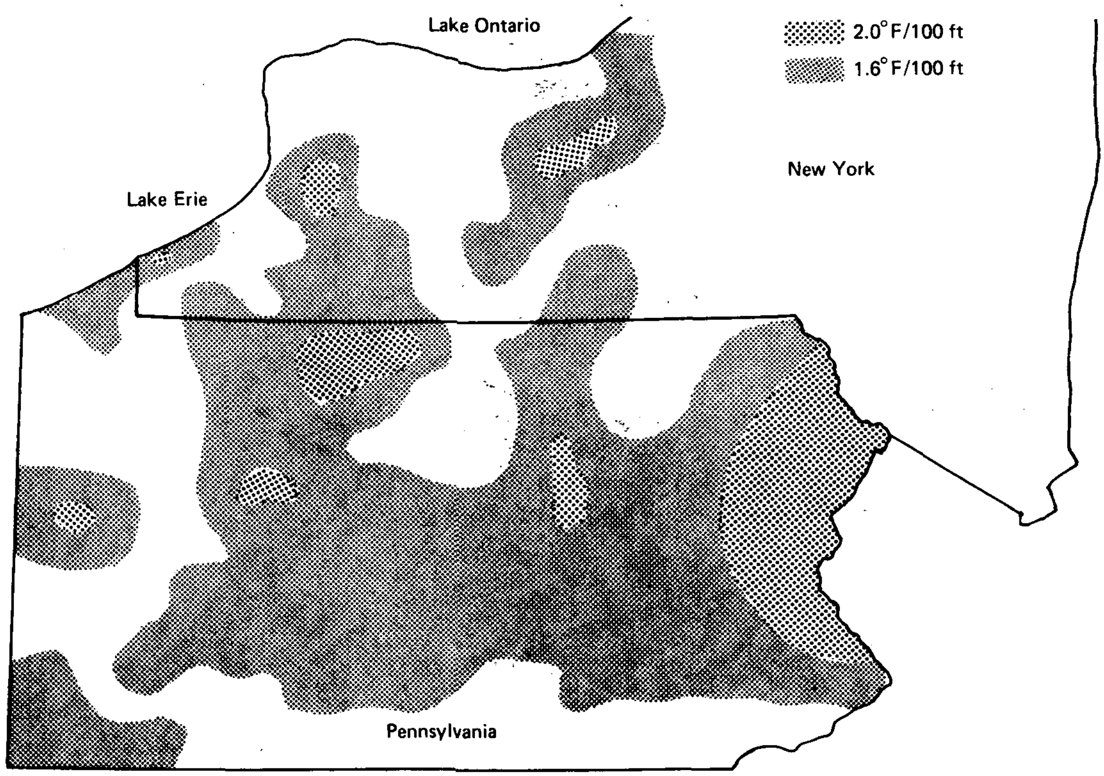

Fig. 1 Geothermal Gradient of Pennsylvania and Western New York; Source AAPG/USGS. (78-1/38)

The Greene-Potter fault zone, discussed by S. I. Root and D. M. Hoskins in an AAPG paper soon to be published, is a band trending from the southwest corner of the state in a northeast direction into New York State. The band is approximately 50 mi wide and is at least 250 mi long. Several Kimberly dikes have been found in the fault zone, which coincides not only with a series of geothermal gradient highs but also with the deepest portion of the Allegheny Basin. If water is available in the deep sediments, then a substantial hydrothermal resource in Pennsylvania coincides with large demographic and industrial load centers.

Reference 4 discusses a new interpretation of the fault zones in the continental plate that trend to coincide with the 40°N latitude line in western and central Pennsylvania (see Fig. 2). Significantly, the 1.6°F/100-ft geothermal contour follows this same trend.

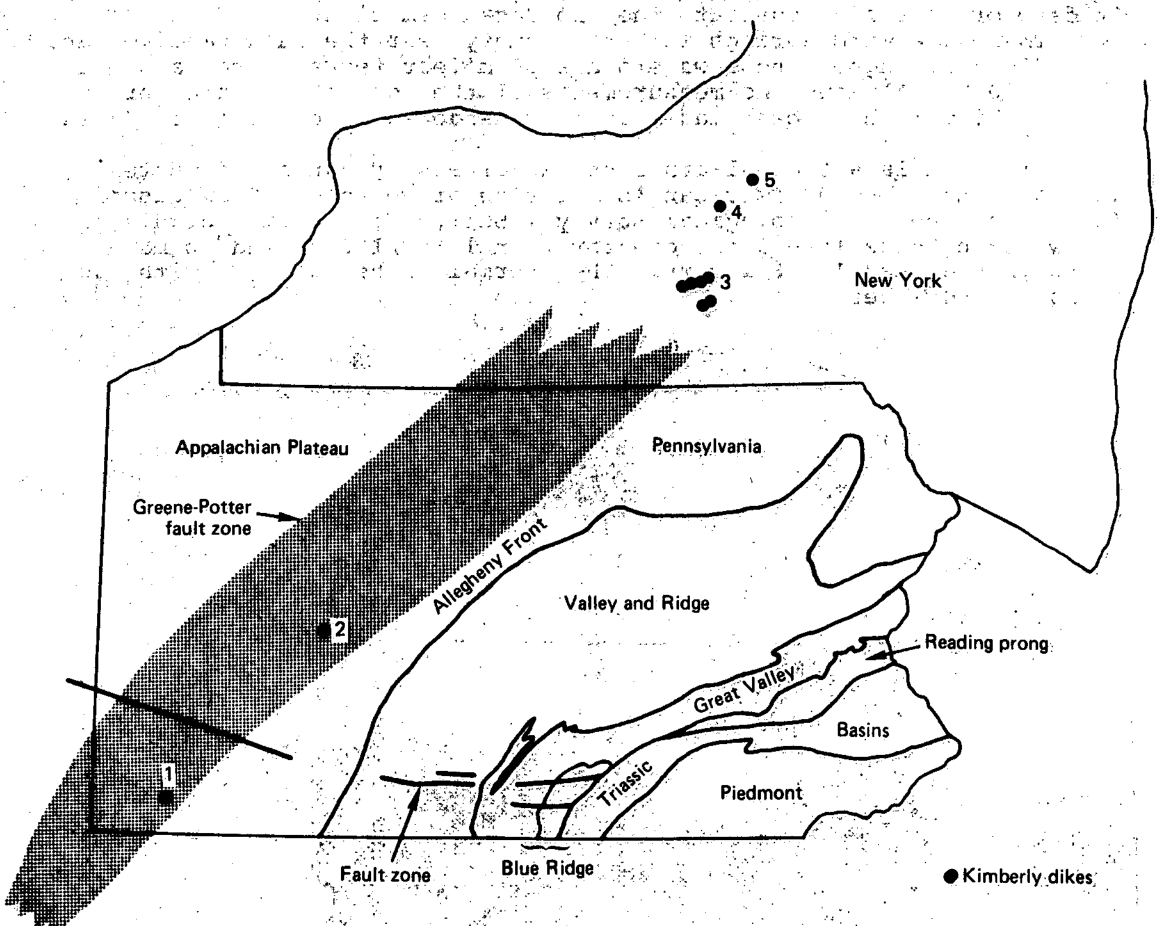

Fig. 2 Pennsylvania Fault System that Correlates with High Thermal Gradients. (78-1/39)

Finally, there are two areas where substantial high gradients are shown on the AAPG geothermal gradient maps; both are located in the valley and ridge province in eastern Pennsylvania. These areas contain known deposits of uranium.

Governor's Council on Energy. G. J. Ridzon is responsible for alternate energy systems for the state. His office has surveyed energy requirements and has pressed for commercialization of solar energy, in addition to acting as a clearinghouse for information and environmental issues. They plan to issue a newsletter and an industry listing.

The considerable potential of geothermal energy in the form of hydrothermal and hot dry rock in Pennsylvania was discussed with Mr. Ridzon, who will, in turn, discuss the subject with Dr. Hoskins. Finally, Mr. Ridzon was referred to D. Sacarto of the National Conference of State Legislatures for information about geothermal legislation. Mr. Ridzon asked to receive Program Research and Development Announcements and Program Opportunity Notices on direct geothermal applications and low-head hydroelectric power development. The proper offices will be notified.

Contact will be made with the State Geologic Branch attached to the Oil and Gas Commission to determine what data can be obtained on temperature and water availability in the Allegheny Basin.

REFERENCES

1. Pennsylvania State House Bill 1063, 1977 Session, Printers No. 2557, 4th Printing.
2. R. W. Stone, "So-Called 'Warm' Springs in Pennsylvania," Pennsylvania Geological Survey.
3. R. W. Stone, "Huntingdon 'Warm Springs' in Pioneer Days," Pennsylvania Geological Survey.
4. S. I. Root and D. M. Hoskins, "Lat 40°N Fault Zone, Pennsylvania: A New Intepretation," Pennsylvania Geological Survey, Geology, Vol. 5, pp. 719-723.

VISIT TO NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (NYSERDA)

On 29 March A. M. Stone and F. C. Paddison of APL met with the director of NYSERDA, R. Bishop, in Albany, NY. Also present were J. Maxwell of the Los Alamos Scientific Laboratory (LASL), Y. W. Isachsen of the New York State Geologist's Office, and three representatives of Dunn Associates, the geothermal contractors for NYSERDA.

Dunn Associates are investigating the area near Saratoga Springs, NY. Geochronological studies have indicated a temperature of 250°C at depth (although the surface spring water is only 4 to 5°F above ambient). The sedimentary cover is at least 10 000 ft of thick shale and may be 15 000 ft to basement. The region shows a large area of low gravity running in a north-south direction, with a magnetic high in an orthogonal direction. This is east of the Adirondack fold belt. Recent deep seismic studies have been performed in the area by Geo-Science Inc. for Gulf Oil.

Dr. Isachsen discussed the Adirondack uplift and suggested that a hot spot may be responsible for the rise. In 1000-ft holes a heat flow value of 1.28 heat flow units (HFU) has been measured. Surface measurements show an HFU of only 0.8. It is conjectured that the thermal pulse causing the uplift has not yet reached the surface. There is also an indication of a sudden rise in electrical conductivity at 15 km.

Dr. Isachsen also mentioned an area of high heat flow south of Buffalo and Syracuse. State University of New York, Buffalo (D. Hodge) has proposed a study of the geochemistry in the Syracuse anomaly.

Dr. Bishop said that in addition to the Saratoga Springs contract, Dunn Associates also has a contract (in conjunction with the American Water Well Association) to study the use of water-source heat pumps.

Dr. Maxwell outlined the LASL Hot Dry Rock Program, and Mr. Paddison gave an extensive review of the DOE/DGE program in the east and outlined APL's role. In future meetings, NYSERDA plans further investigations of the geothermal potential in New York State.

MEETING WITH THE NEW JERSEY STATE ENERGY OFFICE

F. C. Paddison of APL and J. Maxwell of LASL visited the New Jersey State Energy Office (NJSEO) in Newark on 10 March 1978. K. Widmer and C. Luiez of the State Geologic Survey joined the meeting. Also present were J. Jacobson, NJSEO Commissioner; L. Lewis and N. Attermann, NJSEO Planning; J. Oliva and D. O'Malley, NJSEO Office of Alternate Technology; J. Wright, PSE&G Co.; B. C. Patel, NJSEO Director, Office of Technical Assistance; and C. Richman, NJSEO Director, Division of Planning.

APL presented the following topics:

1. DOE/DGE organization;
2. Geothermal programs in Region 5;
3. Low-head hydroelectric programs in Region 5;
4. Plans for Atlantic Coastal Plains, i.e., the Atlantic Coastal Plain scenario and the proposed application study;
5. Federal program to stimulate development, consisting of Program Research and Development Announcements and Program Opportunity Notices;
6. DOE/DGE state-coupled programs potentially of interest to New Jersey in areas of geology and planning;
7. National Conference of State Legislatures and their plans to assist states in issues pertinent to geothermal legislation; and
8. Hot dry rock scenario for New Jersey.

LASL presented the status of the Hot Dry Rock Program.

The State Geologic Survey presented current data and summarized a conversation of the previous day with J. K. Costain of the Virginia Polytechnic Institute and State University.

The State Geologic Survey has prepared a brief report on geothermal gradients from existing well logs, qradients that range from 9.6 to 16.4°F/1000 ft (Ref. 1). K. Widmer has met with Dr. Costain and is currently informed about the DOE/DGE programs on the coastal plain. Dr. Costain has acquired the gravity data for New Jersey and has suggested some seismic work, particularly around Asbury Park. Dr. Widmer will check with Princeton University personnel to inquire if they can do the acoustic work so that a better definition of the basement can be obtained. The only basement data are from a 1450-ft-deep hole at Barneget Light, Toms River, NJ.

The sediments near the basement are sandstone; in the southern part of the state they are thought to be quite impermeable, i.e., they are bedded tightly together for the last several thousand feet. Whether the lack of permeability is from chemical or pressure effects or both is not known. The deep waters in the lower half of the state range from brackish to brine.

In northern New Jersey, where the sediments are shallower and apparently not so tightly bedded, the water may be reasonably good. Public utilities, which are interested in the underground storage of natural gas, plan a drilling program to the basement to analyze the potential. Seismic exploration of the area is a precursor, but it would not define the Asbury Park area. However, the area in which they plan to drill is thought to be indicative of the Asbury Park area; accordingly, a joint exploratory program may be warranted that could be sponsored jointly by DGE and the state. The New Jersey State Energy Office will explore future plans with DOE.

REFERENCE

1. F. C. Paddison, "The State of New Jersey and Geothermal Energy," APL/JHU QM-78-021, 20 Mar 1978.

ARKANSAS GEOLOGICAL DESCRIPTION

The geology of the State of Arkansas has been described in Ref. 1, which summarizes the geology and potential geothermal resources as described to APL by A. Giles, formerly at Arkansas Polytechnic University and currently with the Virginia State Water Control Board. The description covers each of the five geologically distinct regions of Arkansas. The region of greatest initial interest for geothermal scenario development includes roughly the southeastern half of the state; it is part of the Mississippi Embayment of the Gulf Coastal Plain. The remainder of the state is divided into four areas: Southwestern Arkansas, the Oachita Mountain Region, the Arkansas Valley, and the Ozark Region.

REFERENCE

1. F. C. Paddison and W. J. Toth, "Arkansas Geology," APL/JHU QM-78-039, 11 Apr 1978.

RESERVOIR ENGINEERING OF THE MADISON LIMESTONE FORMATION

The Madison limestone formation underlies parts of Wyoming, North Dakota, South Dakota, and Montana. Since the Madison waters in the western part of South Dakota have temperatures exceeding those due to the normal geothermal gradient and the depth is relatively shallow, it is economically feasible to recover the goethermal energy (Ref. 1). The current most appropriate application of this resource appears to be community heating. Recent cost analyses indicate that conversion from fossil fuels to geothermal energy can substantially reduce the long-term expenses for towns with more than 300 people. However, more precise reservoir-engineering data are required before the practical economics for specific towns can be stated definitively.

The USGS Central Regional Office in Denver is studying the effects that large withdrawals of water from the Madison aquifer would have over a limited area. The water would be used for a proposed coal-slurry pipeline in Wyoming (Ref. 2). Although it encompasses parts of the Madison formation around the Black Hills of South Dakota, the study is primarily intended to predict the effects of water withdrawal in Wyoming. The extension of the rather comprehensive study to include all of the Madison formation in South Dakota as well as water needed in the future by the state for proposed geothermal community heating appears to be the most practical and cost-effective way to obtain an engineering definition of the Madison limestone aquifer. Letters of Agreement have been prepared by APL for the Resource Assessment and Engineering Branch of DOE/DGE (Refs. 3 and 4) that suggest how the study might be modified to provide the desired data. USGS has agreed to extend the study to include reservoir engineering of the Madison aquifer system in South Dakota, provided that the necessary data are supplied to validate the simulation. The extension of the study should identify the heat source through heat flow and geochemical analysis, establish allowable withdrawal rates, and determine the effects of withdrawal and injection on the potentiometric surface and water temperature (see Fig. 3 and Ref. 5). L. R. Mink of DOE/DGE has given APL permission to develop a plan, with the aid of South

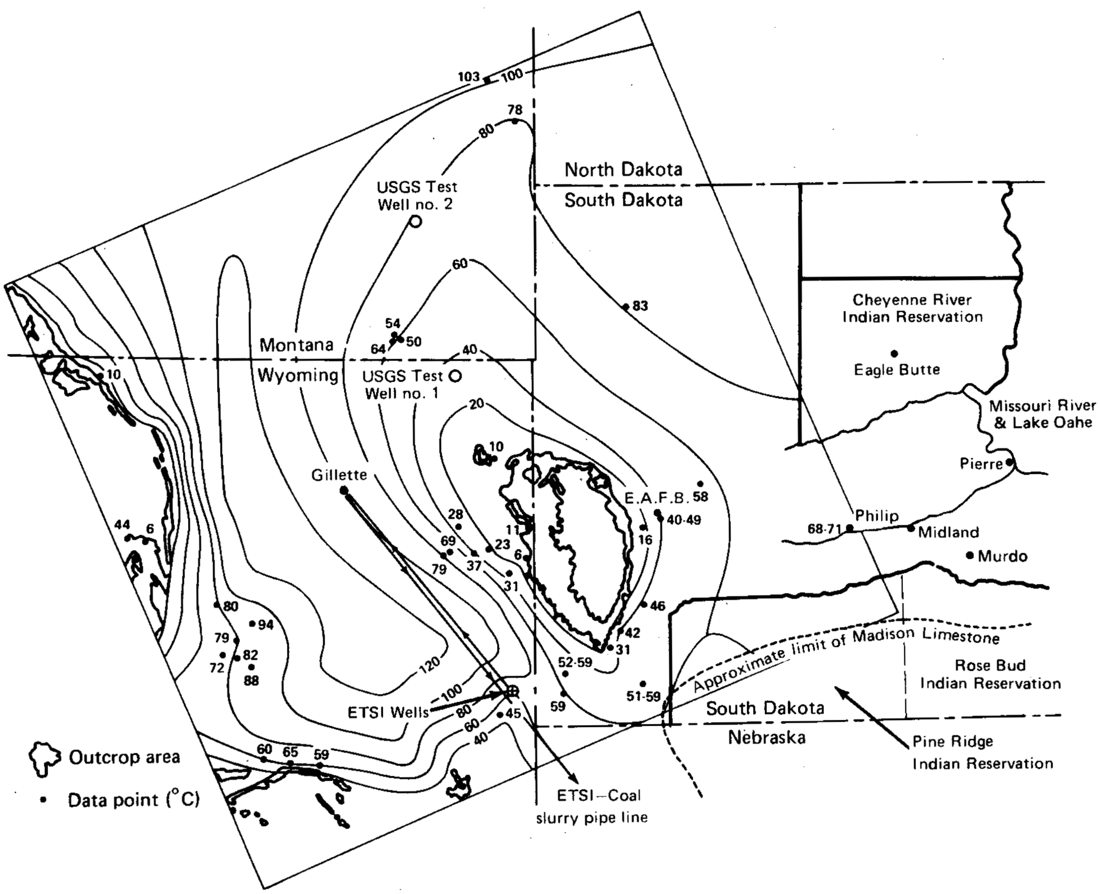

Fig. 3 Temperatures in a Limited Area of the Madison Limestone Aquifer in South Dakota. (77-4/27)

Dakota officials, to collect the required data for the study. Data will be collected based on tests of existing wells, new wells of opportunity (such as one planned at Box Elder), and new well sites. APL has outlined the plan and has proposed to the South Dakota School of Mines and Technology that they could help by suggesting possible improvements and by sharing pertinent data (Ref. 6).

REFERENCES

1. "Geothermal Energy and the Eastern United States, Second Progress Report," APL/JHU Lett. QM 77-073, 11 Jul 1977.
2. "Plan of Study of the Hydrology of the Madison Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming," U.S. Department of Interior, Geological Survey, open-file report 75-631.
3. "Forwarding of Suggested Letter of Agreement," APL/JHU Lett. CQO-1888, 14 Jan 1977.
4. "The Consideration of Geothermal Interests in the Madison Study," APL/JHU Lett. CQO-1917, 14 Mar 1977.
5. Letter from U.S. Dept. of Interior, Geological Survey, Denver, to A. M. Stone, APL/JHU, 29 Apr 1977.
6. "Madison Data Base — South Dakota," APL/JHU Lett. CQO-2153, 28 Feb 1978.

POSSIBLE FEDERAL-, STATE-, AND COMMUNITY-COUPLED PROGRAMS

Close cooperation between the various levels of government is of great importance in developing community use of geothermal energy. This is true for any size community, but it is paramount in rural areas where county and state engineers and surveyors would have to supply needed services to communities too small to support such qualified personnel. Geologic surveying and reservoir engineering are other examples of areas where state and Federal support are required.

However, beyond these technical areas lies the fundamental question of financing community energy conversions. Two Federal departments have been contacted to investigate the possibility of coupling Federal programs to such project financing. Rural communities in general and South Dakota communities in particular were discussed.

APL representatives met with A. Mecure, Assistant Secretary of Agriculture, and members of the Farmers Home Administration. A general survey of APL's work in geothermal energy and the specific operations research findings in South Dakota were presented. Because the Madison is fairly well known as a region that can be used as a geothermal resource and because its potential has been demonstrated in various projects, the general feeling was that community space-heating would not qualify as a research project. However, two types of Federal participation were considered appropriate; these would be applicable when the engineering designs for a community were completed.

Community facility loans could be available to towns that would then administer the funds as needed and establish appropriate charges for consumers. The current interest rate on this type of loan is 5%. For individual households, home mortgage loans could be available at a current rate of 8.25% or at a much lower rate for subsidized housing.

Personnel at the Department of Agriculture expressed considerable concern for the life expectancy of any potential energy resource.

The Department of Housing and Urban Development (HUD) was also contacted and their Block Grant Program was discussed with K. Williams, the Desk Officer for HUD's Region 8, which includes South Dakota. Block grants are available to towns on the basis of (a) home rehabilitation and (b) upgrading the standard of a utility. The latter would appear to be the more applicable basis for community space-heating conversions. Here, again, grants would be for well-engineered projects, and a community's grant application would be in competition with other applications in the region. A major consideration in processing grants is the inclusion of low-income housing.

PROPOSED STATE OF MARYLAND GEOTHERMAL ACT

APL, together with DOE/DGE Policy Planning Office personnel, assisted the sponsors of the Maryland Geothermal Act in identifying the issues that the act should address and in drafting a bill. A primary issue was public versus private ownership of the resource. Pros and cons were discussed in an informal paper (Ref. 1). Other considerations were detailed in a draft act (Ref. 2) and presented on 15 March 1978 to B. Barrio and his consultant, D. W. Chapman, representatives of the Senate Leadership; N. Lawson, of the State's Attorney Office; K. Schwartz, of the State Geologic Survey; and P. Massicott, representative of the Natural Resources Department of Power Plant Siting. Numerous visits and discussions with people from the State Energy Office (Refs. 3 and 4) and the Department of Natural Resources (Ref. 5) took place to assist the State in formulating the final bill.

The resulting Senate Bill No. 1154, "An Act Concerning: Maryland Geothermal Resources Act," was reviewed by the Economic Affairs Committee (Ref. 6) and, after being amended, was passed by the Senate and sent to the House, where it was reviewed by the Environmental Affairs Committee. Reference 7 is a report on the bill by the Department of Natural Resources to the legislature. Reference 8, distributed for information to representatives of the State Legislature, pertains to geothermal energy and contains sections of APL reports documenting the status of the DOE/DGE effort in the Atlantic Coastal Plain.

REFERENCES

1. "Analytic Options for Public Regulation of Geothermal Resources," 8 Feb 1978.
2. R. C. Eberhart, "Maryland Geothermal Energy Resources Act," APL/JHU CPE-78-041, 23 Feb 1978.
3. "Proposed Maryland Geothermal Act," APL/JHU Lett. CQO-2145, 15 Feb 1978.
4. "Meeting with State of Maryland," APL/JHU Lett. CQO-2160, 9 Mar 1978.
5. Telephone conversation, J. Vukovich, Department of Natural Resources, and F. C. Paddison, APL/JHU, re Proposed Geothermal Act, 14 Mar 1978.
6. Presentation in support of Bill No. 1154 to the Economic Affairs Committee by R. C. Eberhart, 15 Mar 1978.
7. Presentation in support of Bill No. 1154 to the Environmental Affairs Committee by R. C. Eberhart, 27 Mar 1978.
8. Letter to R. E. Oliver of DOE/DGE, APL/JHU CQO-2130, 23 Jan 1978.

VISIT OF DOUGLAS SACARTO

On 27 February 1978, D. Sacarto of the National Conference of State Legislators (NCSL) visited APL to discuss their contract with DOE/DGE to help states identify relevant issues in drafting geothermal legislation and rules and regulations for its implementation.

It was agreed that if states in Region 5 request data or assistance on these issues they will be referred to NCSL. Mr. Sacarto visited the Maryland Legislature to see if they could assist in the preparation of the Maryland Geothermal Resources Act.

MARYLAND STATE PLANNING MEETING

On 8 February 1978, R. C. Eberhart and F. C. Paddison attended a meeting of the State Planning Agency to discuss plans relating to Ocean City, MD, and the possible use of geothermal energy in the proposed year-round recreation/community services facility. Reference 1 briefly documents the agenda and gives information relating to geothermal energy developed by the State Planning Agency.

REFERENCE

1. "Meetings with State of Maryland," APL/JHU Lett. CQO-2160, 9 Mar 1978.

GEOTHERMAL PRESENTATION TO WORCESTER COUNTY, MD, COMMISSIONERS

On 7 March 1978, at the request of W. Livingston of the Maryland Department of State Planning and E. Phillips of the Coastal Zone Management Office, W. J. Toth of APL gave a short presentation on the activities of DOE/DGE, Virginia Polytechnic Institute and State University (VPI&SU), and APL on the Atlantic Coastal Plain to the Worcester County Commissioners. The presentation provided definitions of the various types of geothermal resources and the regions of the United States in which they might be found. The nature of normal-gradient hydrothermal resources was described, as well as the potential of above-normal-gradient resources associated with buried igneous intrusions.

The general geology and nature of potential resources of the Delmarva Peninsula were discussed, taking into account the lack of precise knowledge of the potential resource. The goals of the DOE/DGE-VPI&SU Gradient Drilling Program for targeting and evaluating such resources were also discussed. An APL study of the potential applications of geothermal energy in the region was described as a companion study to the Gradient Drilling Program, with resulting recommendations for selecting a site for a deep well to the igneous pluton and/or crystalline basement.

The current considerations of the Maryland General Assembly concerning a Maryland Geothermal Resources Act were mentioned; E. Phillips elaborated on the details. In response to questions of the County Commissioners about the State ownership provisions, some rationale was given for such ownership.

REFERENCE

1. W. J. Toth, "Geothermal Presentation to Worcester County, Maryland, County Commissioners," APL/JHU QM-78-032, 27 Mar 1978.

MEETINGS OF VPI&SU WITH THE MARYLAND GEOLOGICAL SURVEY

On 30 March 1978, J. K. Costain and L. Glover III of VPI&SU met with representatives of the Maryland Geological Survey and APL to discuss the location of four geothermal-gradient wells in the Maryland portion of the Delmarva Peninsula. The reasons were discussed for the selection of the location of the gradient holes. K. Schwartz of the USGS estimated from the resistivity log that the bottom-hole salinity of the old Ocean City well was surprisingly low, 4000 ppm; however, he promised a more accurate value of salinity and an estimated porosity value when the well log could be analyzed more carefully.

Dr. Costain offered to allow APL to interact on the placement of some of the gradient wells on the east coast to permit the gradient wells to be located close to potential markets. Tentative locations will be forwarded to APL for a careful examination, and a meeting was scheduled for 11 April 1978. A composite aeromagnetic map of Maryland will be published shortly by the USGS.

REFERENCE

1. W. J. Toth and F. C. Paddison, "Meeting with VPI&SU and the Maryland Geological Survey" (to be published).

MEETING WITH DR. L. R. MINK

A meeting was held with L. R. Mink of DOE/DGE in January to discuss the Geothermal Reservoir Engineering Management Program (GREMP) (Ref. 1). GREMP efforts will be oriented toward areas of geothermal research rather than applications. The six major research areas will include: (a) properties of materials, (b) definition of reservoir characteristics, (c) description of example reservoirs, (d) behavior modeling of geothermal systems, (e) exploitation strategies, and (f) economics. Subcontractors will be selected to work in each area; their work will be monitored by the Lawrence Berkeley Laboratory.

Over the next several years, one deep well and up to 60 shallow wells will be drilled along the east coast to assess geothermal resources. By mid-1978 DOE/DGE with APL's help will begin developing a reservoir engineering plan for the area.

REFERENCE

1. "Geothermal Reservoir Engineering Management Program Plan (GREMP)," Lawrence Berkeley Laboratory, Oct 1977.

PROGRESS REPORT TO REGION 5 MISSION TEAM

On 3 March 1978, APL presented a detailed review of scenarios completed to date and those pending. They are as follows: The Madison Limestone Aquifer in Western South Dakota, The Eastern Gulf Coastal Plain, The Coastal Plain in Southern Arkansas, The Atlantic Coastal Plain, Hot Dry Rock, and Oil Field Waters.

Reference 1 gives the visual aids used for the progress report.

REFERENCE

1. "Progress Report to Region 5 Mission Team, Geothermal Energy and the Eastern U.S.," APL/JHU QM-78-023, 3 Mar 1978.

MEETING WITH THE REGION 5 MISSION TEAM

On 6 January and 20 March 1978, part of the Mission Team met at APL to discuss the forthcoming proposal for APL support to the Team's efforts. Present were: D. B. Lombard, I. K. Paik, and R. E. Oliver of DOE/DGE; R. Weissbrod of JHU; and A. M. Stone, W. J. Toth, R. C. Eberhart, F. C. Paddison, L. C. Kohlenstein, E. J. Francis, E. M. Portner, C. L. Blinder, and J. M. Bramhall of APL.

Presentations were made on the economic and market-penetration studies performed at APL on OTEC, Power Plant Siting, and Low-Head Hydroelectric programs at APL. Prof. Weissbrod discussed some of the work at the The Johns Hopkins University Center for Metropolitan Planning (Metro) relevant to the Mission Team's concern. Dr. Stone and Mr. Paddison elaborated on the technical work plan submitted to DOE/DGE (Ref. 1), particularly how the economic and market factors would be handled.

At the conclusion of the meeting it was generally agreed that the Mission Team's objective of stressing market-penetration studies would be adequately considered, a specific leader for this work would be designated, strong support from all relevant quarters of APL would be made available, and close liaison with the Mission Team would be maintained. Subsequently, the effort proposed in Ref. 1 was funded and is currently under way.

REFERENCE

1. "Contract N00017-72-C-4401; Technical Program Plan and Cost Estimates for Support of Regional Development of Geothermal Energy in the Midwestern, Central, and Eastern United States (Region 5), for the January 1978 - December 1978 Period," APL/JHU Lett. AD-7324, 3 Jan 1978.

REVIEW OF DRAFT OF REGION 5 MISSION TEAM PLAN

At the request of D. Lombard of DOE/DGE, APL made a careful review of the draft entitled, "Mission Plan for the Development and Utilization of Geothermal Resources, Region 5 (U.S. East), February 1978." The draft was circulated among the geothermal team members and comments were collected. In general, the plan was thought to be well considered, but a few suggestions were made. On 9 March 1978, F. C. Paddison and A. M. Stone met with Dr. Lombard and offered APL's comments and suggestions.

OPERATIONS RESEARCH MEETING 21-22 MARCH 1978

F. C. Paddison and W. J. Toth attended the Region Operations Research Project Review and Project Directors Workshop on 21 and 22 March. The status of effort and scenarios for Region 5 were presented.

SEWELL'S POINT NAVAL COMPLEX, NORFOLK, VA

The Research and Development Office of the Naval Facilities Engineering Command (NFEC), Alexandria, VA, has analyzed energy utilization patterns and alternate energy forms needed to reduce the use of oil and natural gas at Naval installations. Reference 1 is an analysis of how to develop an integrated alternative energy plan for the Sewell's Point Naval complex at Norfolk, VA. The analysis was supported by DOE (Community Energy System Branch) and was administered by NFEC's Atlantic Division.

APL personnel visited Sewell's Point (Ref. 2) to discuss the application of potential geothermal energy located nearby and DOE/DGE-supported studies of the resource definition and application in the Norfolk area (Refs. 3 and 4). Until these efforts are completed next year, it was suggested (Ref. 5) that the Navy fund an analysis of the Community Annual Storage Energy System (CASES) applied to a substantial area of the Sewell's Point complex for space heating and cooling. The study would be integrated with the geothermal resource analysis and other related energy programs at APL. Further, the Sewell's Point study could be applied to other military installations that are unfortunately not as close to a geothermal resource.

Two presentations were made: the first to W. M. Adams and LCDR R. Owens, DCNO (Logistics) on 29 December, and the second on 24 January to W. M. Adams (NAVFAC 03), W. R. Austen (NAVFAC 1022A), R. H. Brewer (NAVFAC 1023F), R. D. Crowson and J. D. Torma (LANTDIV, Norfolk), CAPT W. R. Daniel, Jr. and T. A. Ladd (NAVFAC PC-3), and P. J. Ritzcovan and B. P. Sobers (NAVMAT 08T3).

A technical program plan and funding requirements for the Sewell's complex analysis were forwarded in Ref. 5.

REFERENCES

1. "The Development of the Basis for an Integrated Alternative Energy Plan for the Sewell's Point Naval Complex, Norfolk, Virginia, Final Report and Appendixes A through P for the period 1 September 1976 to 30 October 1977," Battelle report, Nov 1977.
2. F. C. Paddison, "Visit to Norfolk, Virginia," APL/JHU QM-77-089, 22 Jul 1977.
3. J. K. Costain, L. Glover III, and A. K. Sinha, "Evaluation and Targeting of Geothermal Energy Resources in the Southeastern United States," VPI&SU-5103-1 through -4 progress reports.
4. "Contract N00017-72-C-4401; Technical Program Plan and Cost Estimates for Support of Regional Development of Geothermal Energy in the MIdwestern, Central, and Eastern United States (Region 5), for the January 1978-December 1978 Period," APL/JHU Lett. AD-7324, Jan 1978.
5. "Contract N00017-72-C-4401; Technical Program Statement and Cost Estimates for CASES Concept at Norfolk Naval Base," APL/JHU Lett. AD-7410, 27 Mar 1978.

MEETINGS WITH SCIENCE APPLICATIONS, INC. (SAI) AND OREGON INSTITUTE OF TECHNOLOGY (OIT) AT SAN DIEGO, CA

F. C. Paddison and A. M. Stone attended the Geothermal Resource Council Meeting on Direct Utilization (31 January – 3 February 1978) for a successful interchange of information.

At the request of J. Wiegand, we agreed to arrive a day early and discuss with SAI personnel our approach toward regional scenarios. The meeting was held at the SAI building in La Jolla, CA. The following SAI personnel attended: L. Grant, T. Larson, F. Rigby, G. Chen, and D. Irvine. In addition, C. Cummings of the Los Angeles Office and M. Eggers of the San Francisco Office of DOE/DGE attended.

SAI had just been awarded a contract to act as regional operations research contractor for Geothermal Region 1 (California and Hawaii). Their principal focus will be on direct utilization. Since that has also been the focus of APL's work in Region 5, we were glad to "walk them through" the scenarios we had done for South Dakota, Arkansas, and the

East and Gulf Coasts. We explained the sources of our data, how they were analyzed, and how they were agglomerated.

On 1 February 1978, we joined SAI, OIT, and representatives of the San Francisco Office of DOE/DGE in another general discussion of operations research in geothermal planning. In this case, OIT was able to discuss the somewhat different method they used in Region 2 where each state was the province of a subgroup and a representative of the state energy office participated directly in each subgroup.

VISIT OF D. B. DOAN TO APL 2 MARCH 1978

Mr. Doan is currently an instructor of petroleum geology at the University of Maryland and was formerly an oil industry consultant and USGS employee. He discussed the geothermal potential of Northwestern New York. Although the USGS basement map indicates a relatively thin sedimentary cover (< 3000 ft) over this region, Mr. Doan believes, based on his previous experience in that area, that the local basement structure is a series of fault blocks defining a horst and graben type of basement surface topography. He believes the thicker sedimentary layers overlying the grabens could act as localized hydrothermal reservoirs of moderate temperatures.

DISCUSSION WITH G. BRIMHALL, THE JOHNS HOPKINS UNIVERSITY

On 2 March 1978, Prof. Brimhall made a presentation to APL on his attempts to model the deposits in the Anaconda copper mine at Butte, MT. The model begins with the assumption of a hot igneous intrusion and then models the water circulation, water temperature, mineral transport, and mineral deposition as a function of time. The result is that useful concentrations of the ore are found in cylindrical rings about the intrusion. A computer program uses the input from drill core samples and a laboratory analysis to predict the location of ore concentrations. The model has been successfully used for the large ore body at Butte.

The ore concentrations provide a time history of the temperature of the hydrothermal circulation that has occurred. There is no obvious way to turn the program around and use mineral concentrations to determine the properties of an existing hydrothermal current. However, where the model applies, it may be possible for the model to contribute to the interpretation of conventional geochemical data.

DOE/INDUSTRY GEOPRESSURED GEOTHERMAL RESOURCE DEVELOPMENT PROGRAM

The second meeting of the Legal and Institutional Working Subgroup and the third meeting of the Environmental/Laboratory Research Working Subgroup of the DOE-sponsored Geopressured Geothermal Workshop Program were held on 22 and 23 February 1978, respectively, in Houston, TX. Since there are indications of geopressured geothermal resources in Mississippi and possibly in Alabama, W. J. Toth attended the meetings to observe the technical, environmental, legal, and institutional processes and problems encountered with the development of geopressured resources of Region 2 (Texas and Louisiana). Information learned by participation in such meetings will allow APL to serve better as Operations Research Contractor in planning possible development of the resources in Mississippi and Alabama. For example, it was learned that Gruy Federal, the firm in charge of the DOE/DGE "wells of opportunity" program in Region 2, is also operating in Region 5. They have been involved in extending a dry oil well to basement in Wayne County, GA. They would be interested in learning of other wells of opportunity in Mississippi and Alabama.

The new spud date for the Brazoria County, TX, test well was set for 15 March 1978. Problems encountered with the environmental impact statements have been resolved. In the Environmental/Laboratory Working Subgroup Meeting, Louisiana State University discussed possible areas of geopressured resources in Louisiana that may be chosen for a test well. C. K. Geo Energy of Las Vegas conducts these meetings for DOE/DGE; detailed minutes may be obtained from them.

REFERENCE

1. W. J. Toth, "DOE/Industrial Geopressured Geothermal Resource Development Program," APL/JHU QM-78-024, 6 Mar 1978.

LOW-HEAD HYDROELECTRIC PROGRAM

LOW-HEAD HYDROELECTRIC MEETING

On 24 and 25 January 1978, R. McDonald convened a low-head hydroelectric meeting at DOE/DGE headquarters. The purpose of the meeting was to review progress in the various assigned tasks. The following were in attendance, in addition to R. McDonald and R. Toms of DOE/DGE and representatives from Mitre/Metrek and the Idaho Operations Office of DOE/DGE: A. M. Stone and R. Taylor, APL; G. Smith and S. Metzger, Idaho National Engineering Lab. (INEL); J. Leslie, Consultant; P. Frick, Oregon State University; L. Hutz, University of Idaho; W. Brink, Bureau of Reclamation; and R. Handy, Army Corps of Engineers.

Mr. Toms and Mr. McDonald introduced the group to the latest administrative information on the program. In particular, they emphasized the DOE/DGE goal of 1500 MW on line by 1985, which consists of about 500 projects. The program responsibilities for FY 78 are briefly as follows:

1. University of Idaho, leader of a five-university consortium involved with the Pacific Northwest;
2. APL, New England and Mid-Atlantic regions;
3. INEL, cost reduction technology;
4. Corps of Engineers, resource assessment and engineering techniques;
5. Bureau of Reclamation, power marketing, lower limits of practical installations, cost reduction of civil works, and intertie with power grids;
6. Oregon State University, control problems; and
7. Mitre/Metrek, U.S. scenario.

Each organization made presentations relative to its areas of responsibility.

VISIT TO ALLIS-CHALMERS HYDRO-TURBINE DIVISION, YORK, PA

APL representatives met with H. A. Mayo, Manager of Small Hydroelectric United, to discuss the cost reduction of hydroelectric components and a specific method of peak-power storage. Various methods of cost reduction were recommended to APL including the standardization of hydroelectric units. Discussions about peak-power storage using DC generators with flywheels were followed by recommendations and a price estimate to APL.

VISIT TO J. P. PALUMBO, WILKES-BARRE, PA, 24 JANUARY 1978

J. P. Palumbo is an engineer employed by the Pennsylvania Gas and Water Company (PG&W), a private utility that supplies gas and water to about 50 000 customers in the Wilkes-Barre-Scranton area. The company supplies no electricity and is not interested in electric power production.

PG&W owns about 40 dams, the larger reservoirs positioned at altitudes several hundred feet higher than their distribution system. The water pressure is reduced to a level acceptable to their distribution system by dumping the water to a downstream reservoir. Mr. Palumbo proposes to use this wasted energy to produce hydrogen by using a turbine, a DC generator, and an electrolysis cell. He will add the hydrogen to his gas distribution system or sell it to a supplier of bottled hydrogen. He estimates his cost of producing hydrogen as \$6.60 per 10^6 Btu. He says that a supplier of tank hydrogen has offered a price of \$15.43 per 10^6 Btu (\$4.40 per 1000 ft^3) for all the hydrogen he can produce. PG&W is seeking DOE support for a 600-kW demonstration plant.

REFERENCE

1. C. S. Leffel, Jr., and E. H. Boyd, "Visit to J. P. Palumbo, January 24, 1978," APL/JHU QM 78-017.

MEETING AT METRO CENTER

On 15 March 1978, A. M. Stone and J. W. Follin visited The Johns Hopkins University Center for Metropolitan Planning (Metro) to discuss the Low-Head Hydroelectric Program. The following also attended: M. G. Wolman (Chairman), R. Weissbrod, and J. J. Boland, Department of Geography and Environmental Engineering/Metro (DOGEE/Metro), and R. A. Makofski, APL/Metro. Drs. Stone and Follin presented a briefing on APL work in New England. In addition, the possibility was discussed of Metro assistance in economic/political studies on the best way Federal funds could be used to encourage the development of low-head hydroelectric power.

It is expected that DOGEE/Metro will provide support by making a man available half-time for the coming year.

WILDLIFE FEDERATION MEETING

On 25 January 1978, a meeting on low-head hydroelectric facilities, problems, and potentials was held at the National Wildlife Federation in Washington, DC. Conservationists, environmentalists, government representatives, and hydroelectric experts attended the meeting. The fluctuation of reservoir levels for peak-power operation and the maintenance of minimum stream-flow levels were the main topics of discussion. The conversations and dialog indicated that the need for minimum stream flow at all times was a fundamental and nonnegotiable requirement of most of the environmentalists present. Also, the practice of fluctuating the reservoir levels for peak-power operation appeared to be unacceptable to many of the environmentalists. However, the tone of the meeting seemed sympathetic to the use of run-of-the-river water for low-head hydroelectric generation at existing dams.

COMMENTS ON LIMITED TASKS

GEOTHERMAL ENERGY DEVELOPMENT PLANNING §19
Regional Operational Research, DOE/DGE Region 5
ZJ70CQO
Support: DOE/DGE
C. S. Leffel, Jr.
January-March 1978

A SCENARIO FOR THE USE OF ENERGY AVAILABLE FROM HOT DRY ROCK

The energy available from the hot dry rock (HDR) of the earth's crust is enormous; for the continental United States at depths of 10 km or less, this useful energy resource is estimated to exceed 10×10^{21} Btu. However, the utilization of HDR resources is much more difficult than that of hydrothermal systems because the low conductivity of rock does not permit the transfer of useful quantities of heat into a heat exchanger of reasonable size. The most promising technique, now in the demonstration stage, consists of fracturing a useful volume of rock and making water flow through the fractured region to extract the heat. In contrast to the western U.S. where the demonstration project is located, Region 5 presents the additional problem that few, if any, hot igneous intrusions are close to the surface.

SUMMARY

In general terms, the conditions for the most economical use of HDR in Region 5 have been examined, and criteria for the selection of these areas have been determined. Assuming that the problems of fracturing and energy extraction will be solved, a preliminary scenario for resource development has been written. Four areas have been chosen as candidates for use of HDR resources to supply energy for domestic heating.

DISCUSSION

The theoretical consideration for the evaluation of HDR resources has been discussed in Ref. 1. Following the heat flow theory as summarized in Ref. 2 and assuming that the basement is overlain by a sedimentary layer of uniform conductivity, the temperature, θ, down to basement as a function of the depth Z is given by

$$\theta(Z) = \theta_0 + \frac{q^*}{K_1} Z + \frac{D^2 A_0}{K} (1 - e^{-Z/D}), \quad (1)$$

where θ_0 is the surface temperature, K_1 is the conductivity of the rock, q^* is the heat flow from the deep mantle, D is a scale factor for the depth of radioactive heat generation, and A_0 is the measure of heat generated by radioactive decay. For Region 5, q^* is assumed to be a constant (0.8×10^{-6} cal/cm^2-s), and D is assumed to be 7.5 km. The heat flow at the surface of the earth is given by

$$q_0 = q^* + DA_0 , \quad (2)$$

and the radioactive generation term is assumed to obey a law of the form

$$A(Z) = A_0 e^{-Z/D} . \quad (3)$$

If the heat flow at the surface is known, A_0 can be calculated from

$$A_0 = \frac{q_0 - q^*}{D} . \quad (4)$$

If the geothermal gradient at the surface is known, the conductivity can be calculated from

$$K_1 = q_0/d\theta/dZ . \quad (5)$$

Within the basement, the temperature is given by

$$\theta(Z) = \theta_b + \frac{q^*}{K_2} (Z - Z_b) + \frac{D^2 A_0}{K_2} \left(e^{-\frac{Zb}{D}} - e^{-Z/D} \right), (6)$$

where θ_b is the temperature at basement depth, Z_b, as calculated from Eq. 1, and K_2 is the thermal conductivity in the basement rock. From Eqs. 1 and 6, the temperature is a function of basement depth.

Northeastern New Jersey is an area where the geothermal gradient is relatively large (33°C/km). The basement contours of the area are shown in Fig. 1, along with contours of equal geothermal gradients from Ref. 3. Using Eqs. 1 and 6, $\theta(Z)$ is calculated and plotted in Fig. 2 for basement depths of 0.5 and 1.5 km.

For the HDR scenario, the following criteria are used for resource assessent:

1. The geothermal gradient measured near the surface is equal to or greater than 33°C/km (1.8°F/100 ft),
2. Heat flow is equal to or more than 1.2×10^{-6} cal/cm^2-s, and
3. The basement lies from 1 to 4 km below the surface.

Applying the above criteria, promising areas in Region 5 are Northeastern New Jersey; Peoria, IL; Buffalo, NY; and Terre Haute, IN. These areas are sufficiently large and well populated to ensure a reasonable market for moderate-temperature geothermal energy. The resource estimates above 120°F down to a depth of 5.5 km and the energy requirements for domestic heating are given in Table 1.

The amount of resources is clearly no limitation. The striking limitation lies in the questionable ability to extract a useful amount of energy from a single well. If it is assumed that the equivalent of a 100-m sphere can be fractured at a depth of 4.5 km, that the heat down to 120°F or 48°C can be extracted, and that the well lifetime is 10 yr, the single well output is as shown in Table 2.

The course of action that will be pursued in the future will depend on the results of an experiment being conducted by Los Alamos Scientific Laboratory at Fenton Hill, NM.

FUTURE PLANS

Following the initial reaction to the HDR scenario as written, it will be corrected and

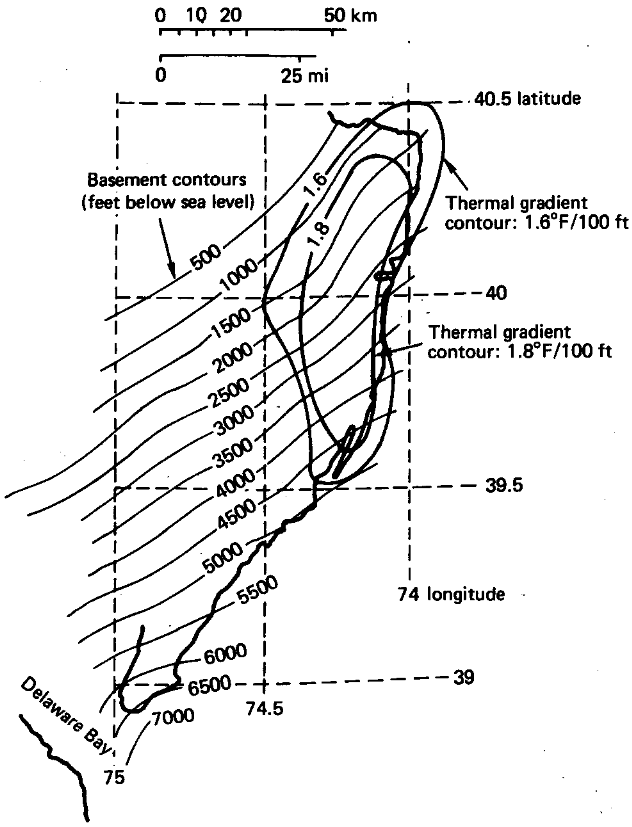

Fig. 1 Thermal Gradient and Basement Contours, Northeastern New Jersey Area. (78-1/28)

Table 1
Resource Estimates above 120°F to a Depth of 5.5 km and Energy Required for Domestic Heating

Area	HDR Resource to 5.5 km(quad)	Number of Housing Units	Heat Required (milliquad/yr)
Terre Haute, IN	2500	55 000	7.2
Peoria, IL	770	139 000	18.1
Northeastern New Jersey	660	223 500	29.0
Buffalo, NY	170	433 500	68.4

1 quad = 10^{15} Btu

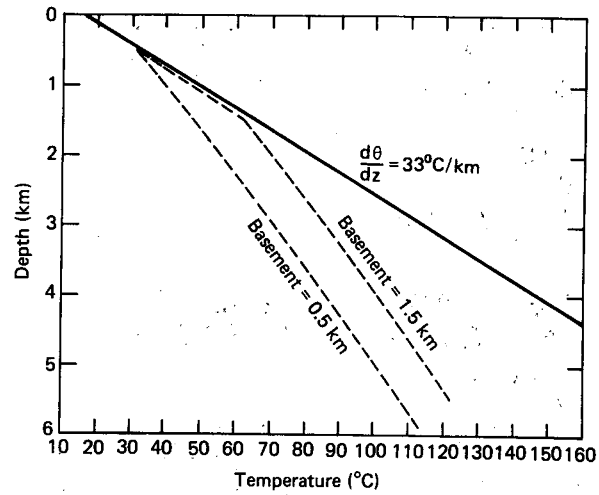

Fig. 2 Temperature versus Depth Calculated from Eqs. 1 and 6, Northeastern New Jersey Area. (78-1/29)

Table 2
Output from a Geothermal Well

Area	Btu/yr	No. of Homes Heated
New Jersey and Illinois	5.98×10^{10} (2.0×10^{6} W av.)	460
Buffalo, NY	6.0×10^{10}	378
Terre Haute, IN	8.37×10^{10}	643

updated as the national HDR resource development plan dictates.

REFERENCES

1. Section 17, Quarterly Report, Oct-Dec 1977, APL/JHU EQR/77-4.
2. "Assessment of Geothermal Resources of the United States – 1975," Geological Survey Circular 726, pp 84-103.
3. "Geothermal Gradient Map of North America," American Association of Petroleum Geologists and the U.S. Geological Survey, 1976.

GEOTHERMAL ENERGY DEVELOPMENT PLANNING §20
Regional Operational Research, DOE/DGE Region 5
ZJ70CAS
Support: DOE/DGE
R. F. Meier and R. A. Freeman
January-March 1978

A SCENARIO FOR GEOTHERMAL ENERGY USE IN SOUTH DAKOTA

There is evidence of a significant geothermal resource in South Dakota. Reference 1 notes that most of the western half of the state is underlain by a limestone geological formation called the Madison, an aquifer containing considerable quantities of water at temperatures up to 180°F. At present, the aquifer is tapped primarily for municipal or agricultural water supplies by at least 30 wells distributed over the region. The temperature range and wide availability of the water make it a significant potential source of energy for commercial and residential space heating and other low-temperature energy uses.

Reference 2 summarizes the documentation for the initial scenario. The documentation was compiled into booklet form and forwarded to DOE/DGE (Ref. 3). By means of interaction with the local communities, state legislatures, and local planning agencies, the initial scenario will be updated and revised to provide an iterative realistic model for future geothermal energy development in South Dakota.

SUMMARY

L. Mink of DOE/DGE has authorized APL to develop a plan to collect data for reservoir engineering in South Dakota. At the suggestion of Duncan McGregor of the South Dakota Survey, John P. Gries of the South Dakota School of Mines and Technology has been contacted. Dr. Gries indicated that he would be interested in assisting with the project. A letter was sent (Ref. 4) outlining the plan for collecting the data. The letter requests that Dr. Gries provide comments, suggestions, and cost estimates for services that could be provided by the South Dakota School of Mines and Technology.

A narrative report is being prepared on the development of geothermal energy in western South Dakota. It will be distributed to local municipalities in western South Dakota that are potential locations for developing geothermal energy.

Four geothermal project proposals from South Dakota were recently selected by DOE's San Francisco Operations Office in response to a September 1977 program opportunity notice (PON) on direct heat utilization (Ref. 5).

DISCUSSION

The Madison Study. The Central Regional Office of the U.S. Geological Survey (USGS) in Denver is studying the effects of withdrawing large quantities of water from the Madison aquifer in southeastern Wyoming. The study was necessitated after a coal slurry pipeline was proposed in 1975 to withdraw an average of about 20 ft^3/s (15 000 acre-ft/yr) from the Madison in Niobrara County, WY (Ref. 6). This removal rate would be equal to approximately one-tenth of the recharge rate of the Madison. Because insufficient data exist on the Madison aquifer for predicting accurately the long-term effects of the proposed project, the USGS began in 1975 to study the hydrogeology of the Madison aquifer. The study is intended to aid understanding of the local and regional groundwater flow through the aquifer, to help make preliminary estimates of the effects of large groundwater withdrawals on the potentiometric levels, to validate data, and to identify the areas where additional data are needed.

Preparation of Plans for Reservoir Engineering. In response to a proposed letter of agreement (Ref. 7), the USGS has agreed to extend the Madison study to include a larger area of the Madison aquifer, provided it is supplied sufficient data for the South Dakota area of interest (Ref. 8). Dr. Mink has authorized APL to develop a plan to provide these data for his consideration. Data on aquifer permeability, thickness, temperature, water chemistry, porosity, and potentiometric head are required for the area in South Dakota covered by the Madison.

Some of the necessary data have been or are being collected as part of the DOE contract to the South Dakota School of Mines and Technology and the geochemistry program of the USGS Madison Limestone Study. Accordingly, the emphasis of this reservoir engineering program will be to collect the data and review them with the State Geological Survey to ensure their self-consistency. It will be necessary to obtain further measures of permeability, formation thickness, local porosity, and well-head pressure as a function of flow for existing wells, for planned wells (i.e., the town of Box Elder), and for selected areas where new wells will be proposed both for this purpose and for subsequent potential geothermal community heating.

A letter recently sent to Dr. Gries contained an outline for collecting the data (Ref. 4). It proposes to identify and determine the status of wells into the Madison, test existing wells into the Madison, add a supplemental data-gathering extension to the drilling program of future wells, select areas for drilling new test wells that could be used for geothermal space heating, and arrange with DOE/DGE for compensation to well owners if damages occur during well tests. The letter requests that Dr. Gries provide comments, suggestions, and cost estimates for services that could be provided by the South Dakota School of Mines and Technology.

Scenario — Narrative Report. A report is being prepared on the development of geothermal energy in western South Dakota. It will be distributed to all local municipalities in western South Dakota that are potential developers and users of the Madison geothermal resources. The Fifth and Sixth District Planning Organizations (Refs. 9 through 12) have indicated that they would be willing to assist APL in distributing the report and to arrange meetings between APL and the local municipalities.

The report will demonstrate the technical and economic feasibility of the broad use of naturally occurring, underground hot waters in the state of South Dakota for community space heating. The information will assist citizens, governing bodies, and advisory groups in considering geothermal energy as an alternative to other forms of energy, mainly fuel oil and propane gas, which are widely used for space heating.

The report will explain the role of the DOE in developing alternate sources of energy. It will also suggest possible funding assistance to communities and individuals who change from their present energy base and will mention legal and jurisdictional factors that need to be considered in making such changes.

New Studies. Four geothermal projects (Ref. 5) in South Dakota have been selected by DOE's San Francisco Operations Office in response to a PON on direct heat utilization. The four proposers from South Dakota with whom contacts will be negotiated are:

1. South Dakota School of Mines and Technology, for use of a low-temperature geothermal resource for space heating of ranch buildings and grain drying, and to provide warm stock water;
2. Douglas High School, Ellsworth Air Force Base, in the community of Box Elder, to heat the school complex with water from a new well to be drilled into the Madison aquifer;
3. Haakon School District, for heating the school buildings at Philip with geothermal water from a new well to be drilled into the Madison aquifer; and
4. St. Mary's Hospital, Pierre, for hot water from the Madison aquifer to be used to reduce the annual consumption of heating fuel by St. Mary's Hospital and by businesses near the hospital.

REFERENCES

1. Section 1, Quarterly Report, Jul-Sep 1976, APL/JHU EQR/76-3.
2. Section 23, Quarterly Report, Jul-Sep 1977, APL/JHU EQR/77-3.
3. "Geothermal Energy and the Eastern U.S. — A Scenario for Geothermal Energy Development — The Madison Limestone Aquifer in Western South Dakota," APL/JHU QM 77-129-2, Nov 1977.
4. "Madison Data Base—South Dakota," APL/JHU Lett. CQO-2153, 1 Mar 1978.
5. News Release, Department of Energy, San Francisco Operations Office, Subject — The Selection of Geothermal Projects in Response to 1977 PON.
6. "Plan of Study of the Hydrology of the Madison Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming," U.S. Department of Interior Geological Survey, Open File Report 75-631.
7. "The Consideration of Geothermal Interests in the Madison Study," APL/JHU Lett. CQO-1917, 14 Mar 1977.
8. U.S. Department of Interior Geological Survey, Denver, Lett. to A. M. Stone, 29 Apr 1977.
9. "Visit to South Dakota, 26-27 October 1977," APL/JHU QM 77-138, 7 Nov 1977.
10. APL/JHU Lett. CQO-2105 to D. W. Potter, Fifth District Planning and Development Commission, 20 Dec 1977.
11. "Iteration of ERDA Scenarios," APL/JHU Lett. CQO-2050, 20 Sep 1977.
12. Fifth District Planning and Development Commission, Lett. to F. C. Paddison, 30 Sep 1977.

GEOTHERMAL ENERGY DEVELOPMENT PLANNING §21
Regional Operational Research, DOE/DGE Region 5
ZJ70CQO
Support: DOE/DGE
W. J. Toth
January-March 1978

A SCENARIO FOR GEOTHERMAL ENERGY USE IN THE EASTERN GULF COASTAL PLAIN

The Eastern Gulf Coastal Plain (Mississippi, Alabama, and Florida) contains some of the thickest sedimentary deposits in Region 5. Because sedimentary deposits are more porous than are crystalline crustal formations, this area may contain some of the highest-temperature hydrothermal-geothermal resources in the region, even if only normal geothermal gradients (1.5°F/100 ft or 25°C/km) are found. In addition, some of the deposits are abnormally pressured; i.e., formation pressures in some locations are far in excess of hydrostatic pressures. These two characteristics may combine to yield the only geothermal resource (besides hot dry rock) in Region 5 that will support the generation of electricity. In addition, large amounts of methane may be dissolved in the hot, pressurized, saline waters of these formations, since high-pressure natural gas is currently being produced in the Mississippi Salt Dome Basin. The possible existence of buried, insulated igneous intrusions and the large number of salt domes found in the Salt Dome Basin may indicate other exploitable resources in this area.

The stimulation of interest in the exploration, assessment, and commercial development of such resources is a primary goal of DOE/DGE. APL has been given the task of gathering information on these potential resources and on potential applications and markets for geothermal energy. APL has prepared a set of suggestions in the form of a preliminary development scenario and has submitted it to DOE/DGE for review. Revisions of this scenario will be made as feedback is received from DOE/DGE and other sources. Some of the information that has been gathered is discussed below.

SUMMARY AND FUTURE PLANS

The preliminary work described in the previous Quarterly Report (Ref. 1) has been completed. A preliminary development scenario that suggests one possible course of events for the exploration, assessment, and commercialization of the geothermal resources in the area has been prepared and submitted to DOE/DGE for review. We plan to revise it after DOE/DGE's review, and discuss it with the states, municipalities, and other concerned principals. More detailed scenarios will be required for the development of each specific resource.

DISCUSSION

Thermal Content. A description of the nature of the resources in the Eastern Gulf Coastal Plain was presented in Ref. 1. In order to prepare a development scenario, it is useful to identify areas that contain common resources, applications, and markets. This has been done (Fig. 1). The five indicated areas have significant resources and applications. The two remaining areas may have other geothermal resources, but for the present study they were not considered to have significant hydrothermal resources above 120°F.

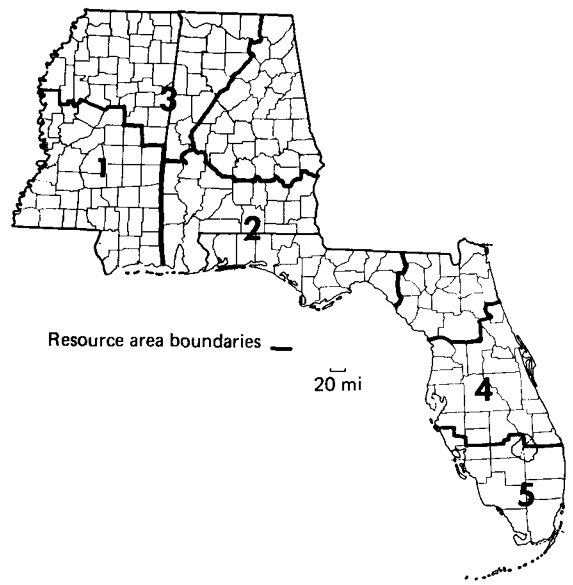

Fig. 1 Geothermal Resource Areas that Contain Common Resources, Applications, and Markets. (78-1/37)

The magnitude of hydrothermal resources in each area has been estimated in order to assess resource potential for satisfying existing and future energy demands. By combining geothermal gradient information with available data on the thickness of sedimentary deposits, estimates of the maximum temperature at the bottom of the sedimentary pile were made for each area. The volumes of the sediments whose temperature falls within a given temperature range also were estimated. Since water is the principal medium for transporting geothermal energy to the surface, an estimate of the volume of water in each temperature range is desirable; however, porosity data were insufficient to allow an accurate calculation. Thus, a conservative value of 10% was chosen for the porosity in each formation, and the volume of water within each temperature range was estimated. The heat content of this water was then calculated by referencing to a minimum temperature of 90°F.

Table 1 summarizes the results. Note that the thermal content of the sediments themselves (90% of the volume) is not included in these calculations; however, it is estimated to be about 4.5 times the values shown for the heat content of the water (the specific heat of rock is only about 20% that of water, but its density is about 2.5 times that of water). As can be seen, considerable quantities of energy may be present, and resource areas 1, 2, and 5 may even have the potential for generating electricity.

Table 1

Estimated Energy Content (in Quads) of Geothermal Waters in the Sedimentary Deposits in Each Resource Area (1 Quad = 10^{15} Btu)

Temperature Range	Resource Area 1	2	3	4	5
Over 350°F	2200	≤20	-	-	≤5
300-350°F	1600	10	-	-	15
250-300°F	1500	100	≤10	-	170
212-250°F	480	490	40	-	800
180-212°F	1100	350	420	170	590
150-180°F	560	700	300	210	260
120-150°F	460	520	150	230	190
Total above 120°F	7900	2190	920	610	2030

Potential Applications Market. The energy markets in each area have been surveyed and the total size estimated. If the market is very small with respect to the resource, the nonelectric applications of geothermal energy will be limited, and full use of the resource may not be possible. On the other hand, if the potential market is large with respect to the resource, caution must be exercised to ensure a rate of development that will allow the lifetime of the resource to be long enough for amortization of capital investments.

There are five basic energy-consuming sectors to which geothermal energy might be applied directly: residential space and water heating, commercial space and water heating, military space and water heating, industrial process heat and space and water heating, and agricultural processes (such as brooding, crop drying, and frost protection). To be useful in matching resource and potential market locations, the data must be available on a county-by-county basis. Unfortunately, this type of breakdown is seldom encountered. Therefore, methods must be devised for estimating local energy requirements.

In the residential sector, space heating requirements are directly proportional to the population and to the number of heating degree-days. Reference 2 gives a useful method of calculating the space-heating energy requirements for the residential and commercial sectors using Bureau of the Census population data and National Oceanic and Atmospheric Administration climatic data. The reference also provides a way to calculate water heating requirements based only on population data. The calculations have been made and maps have been prepared to show the spatial distribution of the energy consumption in the residential and commercial sectors. Table 2 summarizes the totals in each resource area.

In the military sector, the Department of Defense has compiled energy-consumption data for all military installations in the country. APL has recently obtained these data; they will be analyzed in the near future.

In the industrial sector, five industries have been selected as being the most promising candidates for the use of geothermal energy for process heat. They are food and kindred products, textile mill products, lumber and wood products, paper and allied products, and chemicals and allied products. A statewide average energy consumption per employee can be calculated for each industry using the Bureau of the

Table 2

Energy Consumption by Sector in Milliquads (1 mQ = 10^{12} Btu)

Sector	Resource Area 1	2	3	4	5
Residential	24.2	23.0	50.6	25.8	17.8
Commercial	5.4	5.1	12.0	6.6	4.9
Industrial	73.6	144.5	99.0	72.3	24.6
Agricultural	1.0	1.0	1.0	24.0	-

Census statistics of total energy consumed and total employment by industry (Ref. 3). State directories of industrial plants will be used to obtain the number of employees per plant. The total energy consumption of each plant can be estimated by using figures on the average energy per employee. The figures may not be very accurate on a per-plant basis, but on a county basis averaging over several plants reduces these fluctuations to provide the best data currently available. In addition, the figures represent the total energy consumption, not a breakdown for applicable processes. More detailed studies should improve their reliability. The totals for the five industries for each resource area are shown in Table 2 under the Industrial Sector, as are the estimated totals for relevant agricultural processes. The large agricultural consumption in resource area 4 results primarily from frost protection for the large citrus groves.

Development Scenario. In addition to the above analyses, the preparation of a scenario requires an assessment of the impact of state and local rules and regulations. Relevant state agencies (such as oil and gas boards, water resource divisions, and environmental protection agencies) have been contracted for permits, licenses, environmental reports, and other requirements and processes that must be considered in exploring and developing geothermal energy resources.

With this information in hand, a preliminary development scenario was prepared. It consists of a set of suggestions on one way in which geothermal resources could be developed in this region, including (to the extent that they could be determined) all the necessary steps for exploration, assessment, and commercialization of geothermal resources. In order for it to serve as a planning tool for geothermal development, additional input is required from many sources, and revising and updating of the scenario are anticipated to be ongoing processes. After review and revision by DOE/DGE, the scenario will be discussed with the proper state and local agencies and other interested parties. The information thus gained will assist in the preparation of the more detailed site-specific scenarios that are required for actual development.

REFERENCES

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GEOTHERMAL ENERGY DEVELOPMENT PLANNING §22
Regional Operational Research, DOE/DGE Region 5
ZJ70CQ0
Support: DOE/DGE
K. Yu
January-March 1978

PROGRESS MONITORING AND REPORTING SYSTEM AND DATA BASE FOR DOE/DGE GEOTHERMAL REGION 5

An essential component of the geothermal planning and development efforts of DOE/DGE is a comprehensive and flexible information system to provide up-to-date monitoring of progress and reporting of activities within Region 5. Conceptually, a computer-based Progress Monitoring and Reporting System could be the answer.

BACKGROUND

Since there is presently no official DOE/DGE specification for such a progress monitoring and reporting system, a major effort was aimed at defining a system to monitor the progress of geothermal energy development in a timely and comprehensive manner.

The system should provide DOE/DGE planners with various options for possible future programs and present a comprehensive status report on the use of geothermal resources. Further, the system should monitor contributory developments, including research and development, and legal, economic, regulatory, and institutional factors.

DISCUSSION

The work done on the conceptual organization of the Progress Monitoring and Reporting System and for the Region 5 data base has been previously reported (Refs. 1 and 2). The main effort during the current quarter was directed toward identifying the details of the resource data system so that file generation could begin. As discussed in Ref. 2, the Region 5 portion of the U.S. Geological Survey's (USGS) GEOTHERM data file is to form the initial nucleus of the known resource data file. This file has been requested through J. Swanson of USGS/Menlo Park. In addition, work was initiated during the quarter on the basic interactive software package that is to be used in the Progress Monitoring and Reporting System. The same package will be used in the Region 5 database management system. The work is expected to continue.

Work on software for the Progress Monitoring and Reporting System began at the end of the quarter. Figure 1 shows the expected functional organization of the system. The main effort during the next quarter will be to specify the nature of the tasks to be included in the "Task definition" box and to look at the corresponding data-processing requirements.

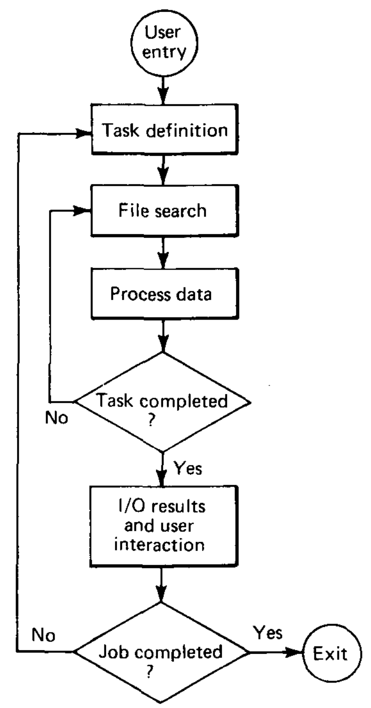

Fig. 1 Functional Organization of Progress Monitoring and Reporting System. (78-1/31)

REFERENCES

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GEOTHERMAL ENERGY DEVELOPMENT PLANNING §23
Applications Study, DOE/DGE Region 5 ZR40CQO
Support: DOE/DGE
W. J. Toth
January-March 1978

A STUDY OF GEOTHERMAL ENERGY APPLICATIONS IN THE ATLANTIC COASTAL PLAIN

Two studies are being performed for DOE/DGE to identify and plan the development of geothermal resources in the Atlantic Coastal Plain. In one study, Virginia Polytechnic Institute and State University (VPI&SU) has identified several areas of anomalous geothermal gradients (Fig. 1) that may be associated with radioactive igneous intrusions buried beneath the sediments of the Coastal Plain (Ref. 1). In the other study, APL prepared a preliminary development scenario (Ref. 2) that suggests one possible course of events through which these geothermal resources might be explored, assessed, and developed in an orderly and timely fashion. A brief description of this scenario is available in Ref. 3.

As a result of the two studies, two new programs have been initiated to identify potential resources and applications in more detail. Both new programs will furnish suggestions for DOE/DGE's selection of a site for a deep (5000 ft or more) test well on the Coastal Plain. In the first program, DOE/DGE is sponsoring a drilling program proposed by VPI&SU (Ref. 4) in which up to sixty 1000-ft-deep wells will be drilled along the Atlantic Coast from Florida to New Jersey. Geothermal gradient information obtained from the 1000-ft wells will be used in selecting the site of the deep test well, which will be a part of the drilling program. In a companion study, APL has been asked to perform a geothermal energy application study for the three most promising resource areas. The study will include an energy market survey, applications analyses, and market penetration analyses. Its results will also be considered in selecting the deep well site. The study, which is just beginning, is described below.

SUMMARY

A study of the applications of geothermal energy in three selected areas of the Atlantic Coastal Plain has been funded by DOE/DGE, and work should begin during the second quarter of 1978. A contract has been negotiated with the Center for Metropolitan Planning and Research of The Johns Hopkins University (JHU) for assistance in the economic analyses and in market penetration studies (Ref. 6).

DISCUSSION

Over 40% of the population of the United States lives in the Eastern one-eighth of the country. This region has very little indigenous fossil fuel reserves other than coal. Thus, the development of alternative energy sources for this region is crucial. Potential alternative energy resources such as geothermal energy can be of great value. Unfortunately, high-grade geothermal resources (such as the steam and hot water resources of California) do not exist in this region. However, there may be lower temperature resources that can be used directly for nonelectric applications. One of the goals of DOE/DGE is to stimulate interest in the exploration, assessment, and commercial development of such potential resources.

Working for DOE/DGE, VPI&SU has been developing a methodology for locating and quantifying geothermal resources (Ref. 1). Their studies to date have identified eight areas on the Atlantic Coastal Plain that appear to have geothermal gradients greater than the normal 1.5°F/100 ft (25°C/km) (Fig. 1). Each of the eight areas shown in Fig. 1 exhibits similar geothermal gradient anomalies; however, the maximum temperature that may exist depends on (a) the concentration and extent of radioactive elements in and around the igneous intrusive bodies, (b) how deeply it is buried beneath the sediments, and (c) the thermal conductivity of the rocks. Simple calculations using the geothermal gradients given in Ref. 1 and information on sedimentary layer thicknesses in the respective areas may predict probable maximum temperatures that may be encountered at the bottom of the sedimentary pile (Table 1).

APL is working with DOE/DGE to identify and plan the necessary activities required for an orderly and timely approach to the exploration, assessment, and commercial development of such resources. This work has entailed several studies that will enable APL to make logical suggestions to DOE/DGE on how to stimulate interest in the public and private sectors in the development of geothermal resources. One set of suggestions was provided in the scenario described in Ref. 3. As feedback is received, changes and improvements will be made in this development scenario.

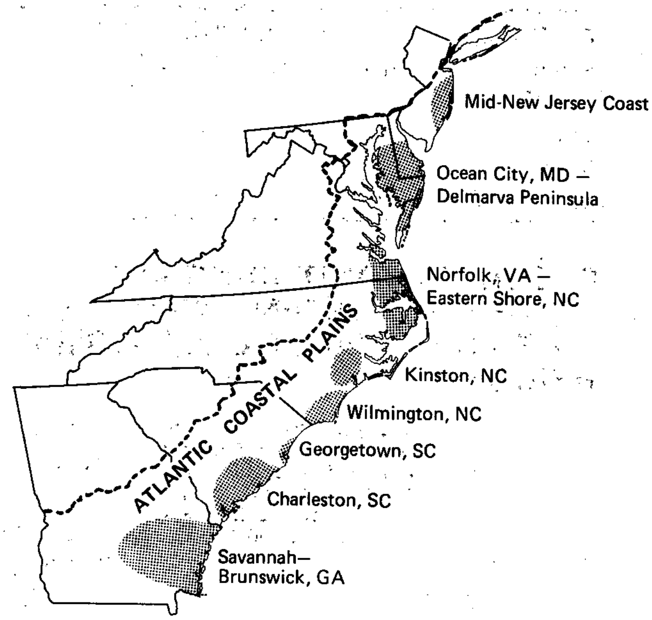

Fig. 1 Potential Geothermal Resource Areas in the Atlantic Coastal Plain Region. (78-1/30)

Table 1
Estimated Maximum Temperatures at the Bottom of the Sedimentary Pile

Resource Area	Temperature	
Delmarva Peninsula	>217°F	>103°C
Norfolk, VA, to Eastern NC	>212	>100
Brunswick, GA	155	68
Charleston, SC	123	50
New Jersey	120	48
Georgetown, SC	107	42
Wilmington, NC	93	34
Kinston, NC	91	33

As an outgrowth of the work of VPI&SU and APL, two new DOE/DGE programs are under way. In the first, initial resource exploration and assessment are beginning with an exploratory drilling program suggested by VPI&SU (Ref. 4). Up to 60 wells 1000 ft deep and one well of at least 5000-ft depth will be drilled in the Coastal Plain from Florida to New Jersey by a drilling contractor and management firm to be selected. The 1000-ft wells will provide accurate data on geothermal gradients and other geological indicators to aid in targeting resource locations. One deep well will then be drilled into basement rock to confirm the methodology used to locate resources and to test the resource itself.

In the second study APL will perform a detailed applications study and will recommend the most advantageous location for immediate application of geothermal energy. This recommendation will complement that of VPI&SU, and should provide DOE/DGE with enough information for selecting the best location for the deep well. Because the first three areas listed in Table 1 show the greatest initial resource potential, the initial study will include only the Delmarva Peninsula, the Norfolk area of eastern Virginia and the eastern shore of North Carolina, and the area of central Georgia between Brunswick and Savannah.

In the first phases of the study, accurate energy consumption surveys will be made in each area to identify and characterize better the energy requirements that could be satisfied by geothermal energy resources. State agencies, utilities, and corporations will be contacted for detailed information on energy consumption by application, by temperature, and by fuel type currently used. These data will be analyzed to reveal patterns of energy consumption according to market sector, geographic location, temperature requirements, and temporal use patterns. These analyses should enable the areas to be ranked on the basis of their geothermal energy market potential.

However, these results alone do not suffice for making a recommendation for the site of the deep well. An area that has a large potential market may involve expensive conversions from a cheaper nonfossil fuel source to what may prove to be a costly geothermal resource. Clearly, the economics must be considered. Thus, several other tasks are required. Projections of costs and availabilities of current fuels, as well as for geothermal energy, will be made to compare the delivery price of geothermal energy with that of other fuels. Projections of energy demands will be made to determine if availabilities of current fuels will keep pace with demand. These analyses should indicate the time frame in which the delivery price of each energy type will be economically competitive.

Generic engineering studies will then be performed on specific applications of geothermal energy in order to assess ancillary equipment costs. Properly sized heat exchangers (for a particular application with a specific resource), the need for heat pumps or other hybrid systems, and other equipments needed for an interface between the application and the resource will be determined. With such generic engineering designs, capital conversion costs can be estimated. Estimates can then be made of the projected delivery prices of geothermal energy, life-cycle costs, and amortization periods.

When these economic and engineering studies are completed, market penetration analyses can provide a picture of the extent and time frame in which geothermal energy can become a viable alternative energy source. At this point, the choice can be made of the best of the three areas for the deep geothermal test well, and this location will be recommended for consideration by DOE/DGE.

R. Weissbrod of the Center for Metropolitan Planning and Research of The Johns Hopkins University will assist in the economic analyses and projections and the market penetration analyses. He will help gather relevant economic data and provide assistance in analyzing these data and those supplied by APL.

FUTURE PLANS

DOE/DGE has only recently funded this work. Manpower staffing and data requirements are now being assessed. In-depth work will begin in the second quarter of 1978.

REFERENCES

1. J. K. Costain, L. Glover, III, and A. K. Sinha, "Evaluation and Targeting of Geothermal Energy Resources in the Southeastern United States — Progress Report," VPI&SU-5103-3, Mar 1977.
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3. Section 22, Quarterly Report, Jul-Sep 1977, APL/JHU EQR/77-3.
4. "Evaluation and Targeting of Geothermal Energy Resources in the Southeastern United States," VPI&SU Proposal No. 78-019-07, 18 Jul 1977.
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OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT §24
Small Dam Hydroelectric Retrofit Program ZP30CQO
Support: DOE/DGE
J. W. Follin, Jr.
January-March 1978

INSTITUTIONAL PROBLEMS FOR LOW-HEAD HYDROELECTRIC POWER DEVELOPMENT IN NEW ENGLAND

Since August 1977, APL has been investigating for DOE institutional and other constraints on the redevelopment of small, low-head hydroelectric generating facilities (50 kW to 15 MW, head no greater than 50 ft) in New England. The investigation resulted in Ref. 1.

Reference 2 on the redevelopment of low-head hydroelectric power in New England is being prepared for publication. While we have not yet documented all the statistical factors involving hydroelectric development, we have obtained considerable information about the authority and procedures of the Public Utility Commissions (PUC) and about large public utility policies in New England. Additional work is needed to determine (a) the environmental problems related to energy storage by varying the levels on the reservoirs, (b) dam safety, and (c) insurance problems. However, it is anticipated that most of the effort will shift to problems in the Mid-Atlantic and Ohio Valley States in the next reporting period.

The following paragraphs contain material from the concluding section of Ref. 2.

CONCLUSIONS

The work performed since Ref. 1 was issued has tended to confirm the tentative conclusions that (a) there are no insurmountable institutional reasons why low-head hydroelectric power cannot be developed in New England, and (b) the existing impediments (not barriers) are dominated by economic factors.

Some specific conclusions concerning key problems and issues in the redevelopment of old hydroelectric power dams discussed in Ref. 1 follow:

1. Electric utilities desire modern, large, centralized generating facilities. Hydroelectric power is sometimes associated with old technology and is considered to be antiquated and uneconomical. The cost savings associated with economies of scale seem to disappear when many small generating facilities are used. Thus some utilities are not interested in facilities below a certain size, e.g., 5 MW.
2. Many developers are limited in their development of sites by monopolistic control by electric utilities of electrical power distribution. They typically must accept the price offered by the utilities for their power.
3. The perceived unavailability or high cost of insurance for dams may hinder development in some areas.
4. Environmental and ecological restrictions on raising and lowering reservoir levels greatly change the economics of operations.
5. Feasibility studies and licensing procedures for hydroelectric sites are costly, while the results and time scales are uncertain.
6. Redevelopment of existing dams for hydroelectric generation is capital-intensive.

RECOMMENDATIONS

1. Demonstration projects should use the latest state-of-the-art technology for automation, control, storage, and monitoring of hydroelectric facilities. Emphasis should be on sites smaller than 5 MW. In situations where energy storage in water is not possible, alternate forms of energy storage need to be explored. More data on low-cost flywheels and other energy storage systems need to be gathered.
2. Cost reduction should be sought by standardizing hydroelectric generating equipment (i.e., by using less completely site-optimized equipment). At the same time, the development of high-rpm power trains for possible cost-reduction potential should be explored.
3. The potential role and authority of state PUC's to affect wholesale prices of hydroelectric energy should be further documented.
4. More information about the availability of dam insurance and its cost is needed. The availability of insurance must be assured somehow, if private firms cannot provide adequate and reasonable coverage.
5. The actual environmental impact of raising and lowering reservoir levels needs to be documented and made public.

Firm conclusions about encouraging the development of low-head hydroelectric power in New England must await the economic/political analysis that is planned. Many of the inputs required for the study have been acquired, but several factors must be quantified.

FUTURE PLANS

APL will make an economic/political study to evaluate the various options for developing low-head hydroelectric sites. Low-cost loans, guarantees, and other resources will be explored for financing feasibility studies, licensing, and redevelopment of hydroelectric sites. Other resources that may be analyzed include a Federal revolving-fund agency; state and local bodies to educate, advise, and assess hydroelectric potential in a way similar to that practiced by the Agricultural Extension Services; or the development of a Federal Power Marketing Corporation to maintain reasonable prices for the energy generated. An estimate of the benefit to the national interest of low-head hydroelectric power and the incorporation, as appropriate, of the results of the Program Research and Development Announcements requested by the Idaho Operations Office will be included.

APL will continue its evaluation of insurance requirements, availability, and costs. The authority of the PUC's will be explored further and documented. An effort will be made to suggest approaches for reconciling state concerns with national interests.

APL will document the environmental and ecological factors involved in raising and lowering the water level in reservoirs. APL will also try to determine the cost of hydroelectric equipment and energy storage systems and will assist in defining "standardized" turbine designs for cost reduction.

REFERENCES

1. "Problems in Redevelopment of Old Hydroelectric Power Dams — Interim Report on New England," APL/JHU QM-77-142/HE-001, Nov 1977.
2. "Problems in Redevelopment of Old Hydroelectric Power Dams — Second Report on New England," APL/JHU QM-78-013/HE-002 (to be published).

INSURANCE ISSUES, INSURANCE MODELING PROJECT, AND DETERMINATION OF PUBLIC UTILITY COMMISSION ROLE

Because of conflicting information obtained from various individuals connected with hydroelectric power development in New England concerning the availability and costs of insurance to cover hydroelectric projects, APL is attempting to arrange an insurance-modeling demonstration. The demonstration will establish whether dam liability insurance and associated coverages are (a) not generally available in the domestic insurance market, (b) available in the domestic insurance market at reasonable premium rates, or (c) available in the domestic insurance market at premium rates that, as a practical matter, are deemed exorbitant in relation to the amount of coverage (liability limits) provided.

In April 1977, the Governor's Commission on Hydroelectric Energy published a report on the existing and potential development of hydroelectric energy in New Hampshire (Ref. 1). Included in the report was the result of a rather limited survey taken from insurance companies operating within the state indicating that "... liability insurance for hydroelectric development is not available in New Hampshire." If this is true in New Hampshire and other New England states under investigation, it would appear to represent a serious institutional impediment to the development of small, low-head hydroelectric projects in that region. Even if dam liability insurance were not necessary to protect the financial interests of the investors in the redevelopment project, the insurance is normally required by financial institutions as a condition for advancing funds for project development. It could reasonably be assumed that the availability or nonavailability of such insurance would not be peculiar to hydroelectric projects in New Hampshire and could, therefore, have national implications.

Therefore, APL has identified two small hydroelectric new-development and redevelopment sites whose developers have agreed to participate as models in an insurance engineering and underwriting program aimed at establishing with certainty whether dam liability insurance and associated coverages are or are not available, not only in New Hampshire but elsewhere.

We are now dealing with the special-risk department of the Insurance Company of North America (INA) in an effort to engineer and underwrite the hydroelectric developments mentioned above. At this point, only INA has invited us to submit the engineering, hydraulic, hydrologic, and flood-plain exposure data necessary to undertake a "live" underwriting of the two model projects. All necessary data were submitted to INA in March; we expect a preliminary evaluation shortly. When INA is familiar with the model projects and has made a preliminary determination of risk acceptability, arrangements will be made for an on-site inspection of the proposed dam projects, at which time final dam-engineering requirements will be established. With this technique, we hope to determine the priority of underwriting considerations that can thereafter be used in evaluating the prospective insurability of individual dam sites.

We have also noted what is considered to be a fairly broad effort by insurance companies in the New England area not to renew existing dam owner's liability insurance or, alternately, to raise renewal premiums and applicable deductibles to figures many times previous levels. We hope to determine more precisely the breadth of the situation and its underlying cause if the practice is as widespread as we believe.

PUBLIC UTILITY COMMISSION ROLE

It seems reasonable to assume that the redevelopment of low-head hydroelectric sites will be controlled, or at least influenced, by the degree of authority each Public Utility Commission (PUC) may exercise in the redevelopment process, from dam reclamation to power distribution. Therefore, we have contacted each PUC to determine the areas within the rate-making and franchise-establishment framework wherein the PUC of each New England state might interface in the redevelopment process.

We have approached the subject area not in an effort to create a precisely defined, legalistic analysis of each PUC, but rather to establish whether or not the various PUC's are in a position to assist in the redevelopment of low-head hydroelectric sites. We are now confirming preliminary data gathered from the six New England PUC's.

REFERENCE

1. "Report on Hydroelectric Energy in New Hampshire," prepared by the Governor's Commission on Hydroelectric Energy, Apr 1977.

OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT §26
Small Dam Hydroelectric Retrofit Program ZP30CPE
Support: DOE/DGE
R. J. Taylor
January-March 1978

STORAGE OF ELECTRICAL ENERGY BY FLYWHEEL AND BATTERY FOR SMALL HYDROELECTRIC SITES

If hydroelectric energy can be sold during periods of peak demand, the value of the energy is significantly higher than if it is sold on a run-of-the-river basis. However, storage of water in reservoirs for use in the generation of electricity during periods of peak demand is not always possible. Environmental and other reasons may limit the construction of reservoirs. Even when reservoirs are available, their use for the cyclic storage and release of water has been limited because of the protests of property owners and environmentalists. Other means of energy storage, the flywheel and the battery, are being examined by APL with regard to their peak-demand price advantage.

SUMMARY

The greater potential lifetime of flywheels and their greater potential efficiency make them more economical than batteries for energy storage, assuming that projected costs presented here are reasonable.

DISCUSSION

The costs, efficiencies, and lifetimes of flywheels and batteries are taken from projections made by proponents of each. The capital-cost goal for low-cost flywheels is $50/kWh. The efficiency goal for low-cost flywheels is 1% energy loss per hour. The lifetime goal is 30 years with 10 000 or more charging and discharging cycles (Ref. 1). The target capital cost for batteries of an advanced design is $20 to $35/kWh. The round-trip battery efficiency goal is 70 to 75%; the lifetime goal with 2500 cycles is 10 yr (Ref. 2).

The capital cost of a flywheel system is estimated to be $70 to $150/kWh (Ref. 1). If energy were evenly fed into the flywheel during a 20-h period and then used for peak-load generation for 4 h (the average storage period being 12 h), the round-trip efficiency of the low-cost flywheel would be 88%. Using motor generators that are 90 to 95% efficient, the total system efficiency would be 71 to 79%.

Assuming that the annual rate of interest is 8.5%, the monthly payments for 30-yr loans of $70 and $150 are $0.538 and $1.153, respectively. These figures were derived from the following equation for monthly payments, MP:

$$MP = cost \times \frac{mi}{1-\left(\frac{1}{1+mi}\right)^{N}}, \quad (1)$$

where

cost = the capital cost of the item,
mi = monthly interest rate, and
N = number of monthly payments.

Assuming 30.4 average cycles per month and a system efficiency of 0.79 to 0.71, the capital cost per kWh per cycle is shown in Table 1.

Table 1
Flywheel Capital Cost/Cycle

Total Capital Cost	Efficiency 0.79	Efficiency 0.71
$ 70/kWh	2.24¢/kWh	2.49¢/kWh
$150/kWh	4.80¢/kWh	5.34¢/kWh

The cost per cycle does not include maintenance, labor, or taxes.

Assuming a 70 to 75% round-trip efficiency for the batteries and a 90 to 95% efficiency for motor-DC generators and DC-AC converters, the total storage system efficiency would be 57 to 68% (0.70 × 0.90 × 0.90 to 0.75 × 0.95 × 0.95).

The capital cost of the battery system is assumed to be $50 to $125/kWh. Assuming that 3650 cycles are feasible (the goal in Ref. 2 was 2500) and that the annual interest rate is 8.5%, the monthly payment for 10-yr loans of $50 and $125 are $0.620 and $1.55, respectively.

Assuming 30.4 average cycles per month and the above system efficiencies, the capital cost per kWh per cycle is shown in Table 2.

Table 2
Battery Capital Cost/Cycle

Total Capital Cost	Efficiency 0.68	Efficiency 0.57
$ 50/kWh	3.00¢/kWh	3.58¢/kWh
$125/kWh	7.50¢/kWh	8.95¢/kWh

The cost per cycle does not include maintenance, labor, or taxes. Note also that the batteries must be replaced every 10 yr. The costs given in Table 2 are for the first 10 yr. Because of inflation, the next 10 yr would be more expensive and the next 10 yr even more so. For comparison, suppose the flywheel loan was for only 10 yr, the same as for the first battery system. The monthly payments for 10-yr loans of $70 and $150 are $0.868 and $1.86, respectively. Assuming 30.4 average cycles per month, the capital cost per kWh per cycle is shown in Table 3.

Table 3

Flywheel Capital Cost/Cycle (10-yr loan)

	Efficiency	
Total Capital Cost	0.79	0.71
$ 70/kWh	3.61¢/kWh	4.02¢/kWh
$150/kWh	7.74¢/kWh	8.61¢/kWh

If one compares a possible $70/kWh flywheel system (highest efficiency) with a possible $50/kWh battery system (highest efficiency), the capital costs of the battery (per cycle) are 3.0¢/kWh for the first 10 yr, after which the batteries must be replaced at a greater cost during the next 10 yr. The flywheel capital costs are 3.61¢/kWh for 10 yr and no capital costs for the next 20 yr, or 2.24¢/kWh for the whole 30-yr life using a 30-yr loan.

The much greater lifetime of potential flywheels and their greater potential efficiency make flywheels appear more economical than projected batteries. Without accounting for inflation, it appears that potential flywheels could initially be at least 1.9 times as expensive as batteries without exceeding the cost of potential battery systems. If inflation were included at 5%/yr the factor would be 3.3.

Note that the capital cost estimate for the flywheel ($50/kWh) comes from the presently achievable energy density of 20 Wh/lb and a fairly reasonable material and manufacturing economic goal of $1/lb. The origin of the battery "target" costs is unknown. It may be based on technical information and reasonable economic goals or it may be the "target costs" required for economic viability.

REFERENCES

1. D. W. Rabenhorst and T. R. Small, "Composite Flywheel Development Program: Final Report," APL/JHU SDO 46 16A, Apr 1977.
2. "Priorities in Energy Storage," EPRI J., Jan-Feb 1977, p. 21.

Support: DOE/ANL, Contract 31-109-38-3995
W. R. Powell
January-March 1978

COMMUNITY ANNUAL STORAGE ENERGY SYSTEM

The Community Annual Storage Energy System (CASES) is planned to be a thermal utility to provide heating and cooling services to a community via water pipelines from a central energy-storage facility. Much of the heat required by the community is collected energy-free at times of heat surplus and stored until it is needed. Ice is also collected energy-free in winter and saved to be used for summer cooling. Water-source heat pumps supply heating and cooling whenever the store of energy-free ice and thermal water is inadequate for the community's needs.

Since much of the energy required for heating and cooling is collected energy-free as surplus summer heat or winter ice, the use of energy from other sources for heating and cooling can be reduced by as much as 80%. It appears possible that the total capital invested for heating and cooling may be less than what electric utility companies, building owners, and oil companies would have to invest for conventional electrical air-conditioning and heating systems. Building owners can subscribe to the CASES utility instead of purchasing independent heating and cooling equipment, resulting in a considerable reduction in building costs.

SUMMARY

The first results have become available for one full year of CASES simulations of a model community. The results are summarized in Table 1. The system achieves an annual coefficient of performance, ACOP, of 5.52, thus reinforcing the claim that energy consumption can be reduced by as much as 80% compared to that of an all-electric community.

The economic results of CASES are just as encouraging as its potential energy conservation. In the CASES simulation, the price of heat is approximately $2.70/MBtu (million Btu) which either matches or is cheaper than alternatives, with the possible exception of regulated natural gas. The capital required to construct CASES in a new community is less than the extra capital required to expand electrical gen-

Table 1
Summary of CASES Simulation Results

Month	Services Provided			Electrical Energy Usage			Efficiency
	Heating (MBtu)	Cooling (MBtu)	Total (MBtu)	Buildings (MBtu)	Plant (MBtu)	Total (MBtu)	Combined COP
Jan	59 460	15 150	74 610	11 230	5 317	16 547	4.509
Feb	69 430	13 130	82 560	14 020	6 616	20 636	4.001
Mar	43 240	16 190	59 430	8 124	3 133	11 257	5.279
Apr	25 780	17 410	43 190	5 127	1 313	6 440	6.707
May	38 170	16 100	54 270	8 016	2 008	10 024	5.414
Jun	8 285	21 110	29 395	2 179	242	2 421	12.142
Jul	4 809	22 220	27 029	1 517	53	1 570	17.216
Aug	7 000	20 210	27 210	1 899	130	2 029	13.411
Sep	11 120	19 500	30 620	2 510	402	2 912	10.515
Oct	30 230	17 310	47 540	5 974	2 246	8 220	5.783
Nov	49 760	14 880	64 640	9 161	3 840	13 001	4.972
Dec	60 580	14 870	75 450	11 310	5 144	16 454	4.586
Annual	407 864	208 290	615 944	81 076	30 444	111 511	5.524

Capital cost at central plant	$ 5 097 449	Cost of electric energy in community	$ 808 400
Capital cost for pipelines	1 435 000	Cost of electric energy in plant	238 537
Capital cost of buildings	8 758 400	Total electric cost	$1 047 000
Total capital invested	$15 291 000	15% of capital total as annual cost	$2 294 000
(Electrical utility capital excluded)		Total revenue required annually	$3 341 000

Thus, $2.69/MBtu of heat, if cooling is sold at four times the price of heating.

eration and distribution facilities to handle the larger peak loads required for an all-electric community or a community using air-source heat pumps. This is true for communities with comparable annual heating and cooling requirements regardless of when the peak demand of the local electric grid occurs.

DISCUSSION

Cooling. Water at 40°F is first distributed through pipes that extend through the community and is then passed through cooling coils in the various buildings. Leaving these cooling coils at a temperature of about 60°F, the water is returned to a central ice deposit where it is again cooled to 40°F prior to being repumped through the flow loop. The heat imparted to the water when it is used for cooling is saved within the system until needed or until it can be ejected without an energy-consuming heat pump. This is in contrast to conventional air-conditioning systems that remove heat from buildings and eject it by means of a heat pump (air conditioner) into the atmosphere, where it is lost.

Heating. The community is heated by water-source heat pumps. Conventional air-source heat pumps become inefficient when the outside air temperature falls below 32°F, but the heat pumps used in CASES remain highly efficient because 60°F water, distributed from the central CASES plant, is always available as a source of heat. The heat pumps extract thermal energy from the water, lowering its temperature to 40°F. The 40°F water is returned to the central facility in the same 40°F mainline used for cooling water, thus avoiding additional piping expense. Likewise, the pipeline used to supply 60°F heat-source water to the heat pumps is the same as the 60°F pipeline used to return water to the central ice store during the cooling cycle. Thus, CASES has only two uninsulated pipelines, one for 40°F water and one for 60°F water, yet both heating and cooling are always available to all users.

The heat that is used to warm the 40°F water for recirculation at 60°F to the community heat pumps comes from three sources. First, even in subfreezing weather, large buildings often require cooling. The excess heat is recovered through building cooling coils that raise the temperature of the 40°F water to 60°F. Second, the central facility contains a warm-water storage basin large enough to provide part of the community's thermal needs for several days. The short-term warm-water supply is replenished by heat collected energy-free whenever the air temperature is above 60°F. Third, when a cold spell lasts beyond the ability of the warm-water storage to provide adequate heating water, ice machines at the central facility are used to supply more than 10 000 Btu for each cubic foot of water processed into ice. These ice machines are of conventional design but operate more efficiently and with a higher capacity than normal, since the condenser temperature need not exceed 70°F and the ice is not subcooled. If energy-free heat, instead of ice-machine exhaust heat, is the dominant heat source during the winter, the total ice produced by the ice machines as a by-product of winter heating may not suffice for summer cooling needs. Then winter ice collection is necessary to avoid electrical air conditioning.

CASES Model. The first of four computer program modules contained in the CASES simulation is called HCLOAD. This program produces a file of hourly heating and cooling loads (Btu/h) for each of the nine building types and two core zones. In addition to this hourly data, certain monthly and annual peak and total loads are recorded. These auxiliary data are used in subsequent program modules to determine efficiently both the size of heating and cooling equipment required in each building and the size of various energy storage facilities needed at the central CASES plant.

The second module of the simulation code, CDIST, requires the water temperature of the warm and cold water distribution mains in addition to the files written by HCLOAD as input data. CDIST calculates the size and cost of user heating and cooling equipment needed for each building. It produces an hourly record of the electric power required for operating the heating and cooling equipment. It also converts the load data into a demand (pounds of water per hour) data file. This conversion depends upon the water temperatures and the efficiency of the equipment.

Next CDIST uses the water-demand file and data on the pipeline route to each terminal building to determine the size and capital cost of all pipes and trenches in the distribution system. More refined editions of CDIST also calculate pumping and thermal losses and the associated costs. The current simulation model doubles costs of the pipe and trench to form a conservative estimate of pipeline and other cost details omitted from the distribution system. Finally, CDIST reduces all of the demand data down to a single user demand file.

The third simulation module, CAPS, simulates hourly operation of the central CASES plant as it services this user under an assumed set of operating rules. CAPS determines the size and cost of the various energy storage facilities and ice machines required at the central plant. CAPS also computes the hourly requirements for electric power.

The final module, COST (still in progress), will process all of the various cost and energy consumption files written by CDIST, and CAPS. Various financial rates and Btu prices will be used in COST along with the processed CASES data to determine the total cost of CASES and the expected rate of return on invested capital. COST will also total all energy consumption and compare it to the heating and cooling services supplied to evaluate the efficiency and annual energy savings. Presently, hand calculations have been used to combine the results of CDIST and CAPS. In lieu of detailed economic analysis, it is assumed that 15% of the capital is recovered annually.

Community. It is necessary to specify the community in order to evaluate quantitatively the extent of synergistic interaction among the various buildings of the community and to predict the cost of heat pumps, cooling coils, and pipelines. The selected model community is similar to Wilde Lake Village in Columbia, MD. It has 8000 residents (2500 households) and 866 buildings in three neighborhoods (NE, NW, and N) that share a common village center, all on 2500 acres of land. Each neighborhood has its own elementary school and civic-commercial center. The community's middle school, high school, office buildings, factory, shops, and CASES facility are located in the village center. These buildings and clusters of residential units comprise the 43 zones (local load centers) shown in Fig. 1 of Ref. 1.

REFERENCE

1. Section 24, Quarterly Report, Oct-Dec 1977, APL/JHU EQR/77-4.

Low-Cost Advanced Flywheel Technology F9Q0SDO
Support: DOE Contract EC-77-C-01-5085
D. W. Rabenhorst and T. R. Small
January-March 1978

DEVELOPMENT AND DEMONSTRATION PLAN FOR A LOW-COST FLYWHEEL

At the request of the Energy Research and Development Administration (now part of DOE), APL has prepared a proposal (Ref. 1) outlining a development and demonstration plan for producing an energy storage system using a very-low-cost superflywheel. The proposal was subsequently approved, and work on the new program began in October 1977. The primary objective of the program is to develop and evaluate a flywheel that can store 20 Wh of energy per dollar of flywheel cost ($50.00/kWh), with the additional requirement that two prototype units be designed and fabricated that will receive power from the electric power mains of normal households. The units are to store 1 kWh of energy and are to make the energy available at power levels up to 2000 W at household voltage and frequency. Electrical and electromechanical equipment for the project has been ordered, and work on the design and development of a suitable low-cost flywheel has reached the test evaluation stage.

BACKGROUND

Modern composite flywheels can be made from a variety of filamentary materials resulting in more energy per unit weight and more energy per unit volume than their isotropic predecessors. However, in most cases the cost of the new flywheels is correspondingly higher. There are more and more applications for energy storage by flywheel where the flywheel cost factor is the dominant consideration, while flywheel weight and volume are of negligible importance. Most of these are stationary applications, such as nighttime storage in the home or factory. In such applications it has been determined that, in production quantities, the low-cost flywheel system may pay for itself in a few years by making use of off-peak power that is usually available from the utility company at low cost.

DISCUSSION

The proposed program will continue for 15 months at a funding level of $355 190. The principal items of hardware development are the low-cost superflywheel, a bearing system with low energy loss and long life, the evacuated containment chamber, and the electrical and electromechanical components required for compatibility with household electric power. Development of each of these items will account for about one-fourth of the program effort, with the balance allotted to system test and evaluation. The final product will be two complete superflywheel energy-storage systems.

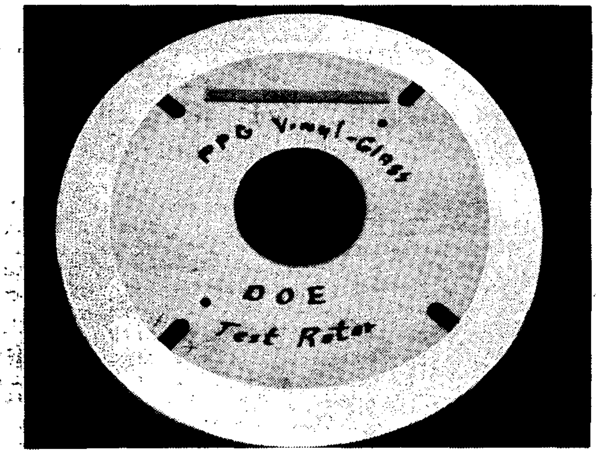

Fig. 1 Scaled-Down Version of Test Rotor. (78-1/33)

The basic flywheel configuration that will be investigated is the bare-filament type developed by APL. The test rotor shown in Fig. 1 is a scaled-down version used to confirm the design. The flywheel uses birch plywood for the hub and has a rim of vinyl-coated fiberglass yarn secured to the hub with four radial wraps of Kevlar-49 yarn.

The test and evaluation of superflywheels for the project have been delayed by a requirement to eliminate the hazard posed to test and visitor personnel by dust that is produced when flywheels made from glass and graphite materials disintegrate. Necessary changes to the spin test chamber have been completed, and the test phase is about to begin.

The primary low-cost flywheel materials considered for the current program are metglass, steel wire, wood, coated-glass filaments, and small amounts of Kevlar-49.

REFERENCE

1. "Unsolicited Proposal to ERDA for Advanced Flywheel Technology," 15 Apr 1976 (revised 1 Mar 1977).

MULTIPLE-OBJECTIVE MODELING OF POWER PLANT LOCATIONS

In 1977, APL developed a multiple-objective model for locating electric power plants, under the sponsorship of the Electric Power Research Institute (EPRI). Development of the model was reported in Ref. 1. Since then, model development work has continued for the U.S. Fish and Wildlife Service (USFWS) of the Department of Interior to incorporate economic and ecological concerns into the model. Once incorporated, the economic and ecological objectives can be used to demonstrate the biological impacts and cost tradeoffs associated with major decisions concerning electric power supply.

SUMMARY

As developed for EPRI (Ref. 2), the model used linear programming to choose sets of power plant locations so as to minimize one or a combination of objectives involving transmission, coal shipment, water supply, and population concentration. No attempt was made to address the question of total system cost or to determine the ecological impact of the location of a group of plants. The USFWS wanted a modified model that could be used to assess the tradeoffs between cost and biological impact of electric power supply decisions. In response to that need, two new model components were developed. First, a cost objective was formulated that allows the model to choose sets of power plant locations that would be the least costly over the entire analysis period (1975 to 2000). Second, two ecological objectives were developed that cause the model to choose locations that minimize ecological impact. In addition, a more realistic formulation of coal use and sulfur removal was added.

DISCUSSION

The cost objective is to minimize the sum of the capital and operating costs for all plants that will be built over the period covered by the model. Capital costs include the basic plants plus sulfur-removal equipment, reservoirs necessary for cooling water supply during droughts, and transmission lines. Operating costs include fuel, transmission losses, and the operation of sulfur-removal systems. For coal plants, coal transportation is a large part of the fuel cost.

The model treats the timely problem of air quality versus sulfur emissions in a particularly realistic manner. The entire Appalachian coal region was surveyed by county for estimates of the future production capability of coals with a range of sulfur contents; the prices and quantities available by county were also estimated. The model can choose coals of lower sulfur content to satisfy sulfur-emission regulations; alternately, it can select varying degrees of sulfur removal via stack-gas "scrubbers." The particular combination of scrubbers and low-sulfur coal for each plant is chosen so that the total cost is minimized. In this region, the lower-sulfur coals tend to be in the more remote areas, thus making the cost of coal transportation an important factor.

The ecological objectives were adapted from ongoing work being done by several units of the USFWS and by APL's Power Plant Site Evaluation Group. Both objectives are based on the idea that local fish and wildlife experts can provide an importance ranking of the various types of terrestrial and aquatic habitats within a region. Given these rankings, objectives can be formulated that cause the model to select plant locations away from important habitats. The resulting model shows the tradeoffs between cost and environmental impact in such a way that the knowledge can be integrated into decision processes early. The use of such a model might allow various decision-makers with diverse interests the opportunity to evaluate cooperatively the many long-term consequences of major electric energy decisions before the decisions are made.

REFERENCES

1. Section 29, Quarterly Report, Jul-Sep 1977, APL/JHU EQR/77-3.
2. "Probable Distribution of Effluent Sources from Energy Supply and Conversion—Final Report," APL/JHU (to be published).

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