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MASTER

Quarterly Report

ENERGY PROGRAMS

at The Johns Hopkins University Applied Physics Laboratory

JANUARY—MARCH 1979

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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:

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Surface Missile Systems	WQR
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Space	SQR
Exploratory Development for Missile Propulsion	DQR
<u>Civil Programs</u>	
Energy	EQR
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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 several agencies of the federal government and an agency of the state of Maryland, is engaged in developing energy resources, utilization concepts, and storage methods. This Quarterly Report summarizes the work on the various tasks that can be succinctly reported as of 31 March 1979.

The Energy Quarterly Report is divided into three sections. The first, Geothermal Energy Development Planning, supported by the Division of Resource Application of the Department of Energy (DOE/RA), contains reports on the progress of those geothermal-related tasks where effort was concentrated during the quarter. The tasks include the ongoing Atlantic Coastal Plain Geothermal Energy Market Survey, the Delmarva Geothermal Development Prospectus, Evaluation of Federal Strategies for Hydrothermal Developments, and comments on limited tasks performed in support of the major tasks.

The second section of the Quarterly, Operational Research, Hydroelectric Power Development, also supported by DOE/RA, includes reports on a method for quantifying institutional constraints (based on a study of dam sites in Pennsylvania) and on institutional and regulatory restraints in New Jersey.

The third section, Energy Conservation and Storage Techniques, contains a report on flywheel development supported by the Division of Energy Storage Systems (ESS) of DOE.

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GEOHERMAL ENERGY MARKETS IN THE ATLANTIC COASTAL PLAIN—MARKET DEFINITION

APL is performing a Geothermal Energy Market Study (GEMS) for DOE/RA in four of the areas on the Atlantic Coastal Plain that offer promise of geothermal resources (Fig. 1). The purposes of the study are: (a) to identify existing energy requirements for space and water heating and for process heat at temperatures below 250°F; (b) to determine the technical feasibility of supplying the energy requirements with expected geothermal resources; (c) to estimate the cost of geothermal energy for potential applications; and (d) to estimate the penetration of geothermal energy into energy markets that are technically and economically attractive. The tasks can be divided into two categories: market definition and market penetration. Some results of the market definition work are presented here. The JHU Center for Metropolitan Planning and Research (Metro Center) is assisting in the economics and the market penetration work, which is described in §10 of this report.

SUMMARY

The first phase of GEMS efforts is being completed in the four northern resource areas on the Atlantic Coastal Plain (Fig. 1). Results of GEMS efforts and recommendations for the site of the deep test well were presented to DOE and the Site Selection Committee (Ref. 1). As a result, Crisfield, Maryland, was selected. GEMS results have been presented at the Sixth Energy Technology Conference (Ref. 2) and will be published in a series of topical reports, the first of which has been released (Ref. 3). Three others are planned for release during the second quarter of 1979.

DISCUSSION

The background, rationale, methodology, and some preliminary results of the GEMS efforts

Fig. 1 The four areas of interest in the Atlantic Coastal Plain. (79-1/23)

have been presented in previous Quarterly Reports. The four study areas shown in Fig. 1 were chosen to coincide with the progress of the DOE gradient drilling program. By the beginning of 1979, preliminary results of the drilling program and of gravimetric and seismic studies by the Virginia Polytechnic Institute and State University (VPI&SU) were available. DGE Site Selection Committee met at Blacksburg, Virginia; the results of both the drilling program and the GEMS studies were presented. Recommendations for the deep well location were given on the basis of geophysical and market considerations. Both studies indicated that the Delmarva Peninsula was the best of the four resource areas. Because of the importance of finding a resource with the first deep well, geophysical considerations took precedence, and Crisfield, Maryland, was chosen as the specific site.

Table 1 summarizes the findings of the GEMS market definition efforts in the four resource areas.

The greatest requirements for thermal energy at temperatures below 250°F are in space and water heating for residential and commercial sectors. However, because of the diffuse distribution of such requirements, expensive community distribution networks must be provided to satisfy many individual small loads. The seasonal and hourly variations of these loads place additional constraints on a commun-

Table 1
 Total energy demand in each resource area by sector
 (units of 10^{11} Btu/yr).

Area	Residential and Commercial	Military	Agriculture	Industrial
S.E. New Jersey	290	25	0.2	5.2
Delmarva	125	8	14.5	14.8
Norfolk	280	97	0.5	8.3
E. North Carolina	80	15	9.5	9.0

Table 2
Market considerations.

Area	Pro	Con
S.E. New Jersey	Large residential/commercial market Ample groundwater for industrial expansion	Old, economically depressed metropolitan areas Pine Barrens to be environmentally guarded area
Delmarva	Large industrial market Large agricultural market Moderate residential/commercial market Ample groundwater for industrial expansion in Maryland and Delaware	Markets distributed over a large area
Norfolk	Very large military market Large residential/commercial market Moderate industrial market	Reinjection prohibited Thin sedimentary sections Critical groundwater area
E. North Carolina	Ample surface and groundwater for industrial expansion	Large swamp and water areas Sparse markets

ity distribution system, all of which manifest themselves in higher costs for delivered energy. Thus it is necessary to identify areas with high population densities so that distribution systems can be limited in size and cost. Likewise, most agricultural markets are quite diffuse and probably are best served by incorporating them into dual-purpose community systems. For these reasons, the availability of these markets is limited in the short term and significant activities probably will not occur until at least 1985.

Military markets are the most attractive in the near term: (a) they are "captive" markets; (b) they are large, high-density markets that need a number of geothermal wells to satisfy their energy demands; (c) they currently use hot water or steam distribution systems that may minimize conversion costs and time; and (d), because they are under directives to reduce energy consumption, they are exploring alternate energy sources. A definite commitment by the federal government to develop such resources on a large scale would provide a great deal of encouragement for private concerns in local resource areas to become involved in the commercialization of geothermal resources. Unfortunately there is a great deal of institutional inertia to be overcome in this sector. Therefore the industrial sector probably has the greatest near-term potential for geothermal energy applications, and it was investigated in the greatest detail in this study. As Table 1 indicates, the Delmarva Peninsula has the largest industrial market, the largest part of which consists of the extensive local poultry industry, which is extremely well suited to direct-use applications of geothermal energy. In addition, large grain-drying facilities are often collocated with poultry plants, further increasing potential near-term markets. The availability of the industrial market is quite good, but significant progress will be delayed until the local geothermal resources have been fully characterized. With proper government assistance and guarantees, industrial involvement in the Delmarva Peninsula could occur as soon as 1982.

In addition to the magnitude of the markets, a number of other factors must be taken

into consideration. For example, the critical shortage of available groundwater in the Norfolk area could seriously limit the growth of industries that could use geothermal energy most beneficially in new facilities. In addition, the reinjection of cooled geothermal fluids is currently prohibited by Virginia state law. Table 2 lists a number of such factors for each resource area and indicates whether they would have a positive or negative influence on geothermal development.

From these results and market considerations, the Delmarva Peninsula appears to offer the most attractive near-term markets for geothermal energy and has been recommended to DOE and the Site Selection Committee. Fortunately, Delmarva Peninsula also offers attractive resource prospects.

FUTURE PLANS

The first phase of the GEMS work on the four northern resource areas will be completed with the issuance of the final results. The data and results will be published in a series of topical reports, the first of which has been issued (Ref. 3). At least three additional reports are planned for the second quarter of 1979. The second phase of the GEMS work involves market surveys in the resource areas of the southern Atlantic Coastal Plain. These activities are scheduled for early spring, 1979.

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GEOHERMAL ENERGY MARKETS IN THE ATLANTIC COASTAL PLAIN- ECONOMICS AND MARKET PENETRA- TION

The cost of geothermal energy depends on local resource and market conditions to a far greater extent than do the costs of such traditional fuels as oil, natural gas, and coal. To permit the economics of potential geothermal projects to be evaluated, DOE requires information on the impact of a wide range of local conditions on the cost of producing geothermal energy. It also needs the projected price trends for energy forms that geothermal resources may replace in certain applications. To provide this information, Metro Center and APL have developed the Geothermal Resource Economic Evaluation System (GREES), an economic accounting program that accepts user-specified values for a wide range of resources and economic parameters. Metro Center has surveyed price projections from DOE, Brookhaven National Laboratory, and private research firms to provide a reference with which the cost estimates for geothermal energy may be compared (Ref. 1). While the price projections for traditional fuels will require future updating, recent work by Metro Center and APL has concentrated on improving the capability of GREES to model more adequately the economics of geothermal utilization projects over their entire life. The improved model is called the Geothermal Resource Interactive Temporal Simulation (GRITS) model and will simulate the annual cost and revenue streams of a geothermal utilization project.

Estimates of geothermal market penetration are also needed because the costs of geothermal energy are largely determined by the concentration of users. However, it is difficult to make market penetration estimates for new energy technologies because of the lack of sufficient experience with them when the costs for traditional energy sources are rising rapidly. Therefore, novel approaches to the problem are needed. As an initial effort, Metro Center and APL are developing a market penetration model that reflects the special characteristics of geothermal energy.

SUMMARY

A report giving a detailed description of the GREES model is being prepared. Results of the survey of price projections for conventional fuels have been published (Ref. 1). An extension of the GREES model to permit estimates of costs and revenues for various resource and market conditions is being developed. Efforts are also under way to develop a market penetration model to account for the special characteristics of geothermal energy and markets.

DISCUSSION

Economics. The rationale and methods for estimating the cost of delivered geothermal energy have been presented in previous Quarterly Reports. The GREES computer model was developed by Metro Center and APL to provide cost estimates under various resource and market conditions. However, the GREES model reflects average static conditions for only a single year. While an average year is a useful starting point, a number of factors are likely to change over the lifetime of a geothermal resource. The impacts of these various factors on the total cost cannot be reflected adequately by a model that only calculates average annual costs. Therefore, Metro Center and APL have found it necessary to develop an extension of the GREES model.

This extended computer model, GRITS, evaluates the impact on delivered energy costs of such changes in resource conditions as declines in the temperatures of geothermal waters, declines in the flow rates from the wells, and increases in drawdowns in the wells. Other factors are also considered, such as changes in the rate at which customers hook up to a geothermal energy system, in the rate of inflation, and in the cost of alternative forms of energy. The modified model takes new resources and economic conditions into account.

Although little information is available on the extent to which resources are likely to change, it is important to be able to simulate such events and, through extensive sensitivity analysis, to develop a better understanding of the significance of changes on the production costs.

It is evident that the rate at which new customers join the geothermal system and the rate of inflation will be crucial to the economics of geothermal heating, even if resource conditions do not change. The capital costs of geothermal systems are very high compared with variable costs, so much of the capital would have to come from commercial institutions. Because such loans are generally fixed in nominal dollar amounts, the real purchasing power (and hence the opportunity costs) of the fixed payments declines each year as inflation continues. During the early years of a project, the system would have fewer customers, would be underutilized, and would experience high average costs. It is important to model the impact of these changing costs (Ref. 2).

Market Penetration. Standard approaches to studying the market penetration of geother-

mal energy are of limited use because of their inability to handle new energy technologies when the costs of traditional sources of energy are rising rapidly. Further, large community systems are required in order to make geothermal energy available to individual home owners, and new market strategies must reflect this fact. A market penetration model is under development that will account for these special problems.

The conversion of individual homes and apartment buildings to geothermal energy requires that existing heating systems be compatible with retrofit equipment that will provide heat with a hot water source (e.g., electric baseboard heating systems cannot be practically retrofitted). The building owners must also pay the cost for connecting pipes, energy meters, and heat exchangers in addition to retrofit costs if they join a community heating system. An alternate market strategy calls for the geothermal utility to assume the conversion costs and add these charges to the monthly heating bill. Both cases will be examined.

The costs of joining the community heating system will be offset by eliminating a conventional furnace. The market penetration model assumes that building owners who face outlays for a new furnace because of the failure of their old furnace will be more likely to join a community heating system than will those whose furnaces are in good working order. Thus, the model segments the housing stock into three categories: units with heat distribution systems that are incompatible with geothermal community heating systems; buildings that are compatible and that must incur the costs of a new furnace or hookup charges for joining the system; and buildings for which the owner faces hookup charges if he joins but no capital outlays if he stays with his old fuel supply.

The units with incompatible heat distribution systems are removed from the market definition. Data are available from the Census of Housing and from local planning agencies by which the housing market can be categorized. Although there is considerable uncertainty about the proportion of building owners in the latter two categories who would join the community heating system under certain assumptions

(such as perceived security of supply), the model provides a starting point for estimating market penetration.

The use of housing characteristics to segment the market has several advantages. First, it provides an objective criterion by which the differences in the economic incentives of joining a community heating system can be measured. Based on various levels of economic incentives, it can reasonably be hypothesized that one group would be more likely to join a geothermal community heating system than another. Second, the data on housing characteristics are reasonably detailed and are available at the local level, thus permitting areas to be ranked according to housing characteristics.

Efforts by others to estimate the price elasticities for traditional fuels are continuing, and several models have been developed to estimate the acceptance rate for new energy technologies. The value of these undertakings is still in doubt, but useful estimates can be added to the housing characteristics model. Further work on the market penetration model will be reported in future Quarterly Reports.

FUTURE PLANS

A report describing the methods and results of the GREES model will be issued shortly. Efforts are continuing to extend and refine the model to account for changes in resource and economic conditions more realistically. Efforts are also continuing to develop a market penetration model. By the summer of 1979, APL and Metro Center hope to estimate the extent of possible geothermal energy use and the resultant decrease in fossil fuel use in each of the resource areas on the Atlantic Coastal Plain.

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1. "A Review of Recent Energy Price Projections for Traditional Space Heating Fuel 1985-2000," APL/JHU GEMS-005, QM-79-016, MCGER-79-001, Mar 1979.
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A PROSPECTUS FOR THE DEVELOPMENT OF GEOTHERMAL ENERGY ON THE DELMARVA PENINSULA

The approach used in the prospectus scenario for the Delmarva Peninsula has evolved from earlier scenarios that served as planning tools for DOE. It is a tutorial narrative designed to provide local interests and agencies with information that will assist them in planning and developing a geothermal energy resource. Technical, environmental, legal, economic, and institutional information that affects development is discussed. Since development initiatives must originate from the local level, the prospectus has been written in conjunction with state and local authorities. Therefore the report is more useful to them since it illustrates the relationship of the time phasing of their development plans and federal programs that define the extent and limitations of the resource. It identifies the initiatives that must be undertaken at the state and local levels.

FUTURE PLANS

The Delmarva prospectus will be issued when the final two chapters are written on the development process itself and the initiatives required by federal, state, and local governments. The first six chapters are being rewritten and simplified. When the prospectus is complete, southern New Jersey, Norfolk, Va., North Carolina, South Carolina, and Georgia will be investigated. With inputs from the Market Survey Study, which is continuing into the southern regions, the next area for a comparable prospectus will be selected and work on it begun.

SUMMARY

The first six chapters of the prospectus have been reviewed and rewritten in order to shorten them and make the material more useful for local developers and government agencies.

DISCUSSION

The previous scenarios written by APL for DOE are summarized in Ref. 1. They were intended primarily for planning purposes by DOE/DGE, although two narrative-style scenarios (for the Madison Aquifer and Kyle, S. Dak.) were written for distribution to the local communities.

The Delmarva prospectus is the first of a new series that concentrates on a specific resource area. Since the series is intended for a larger and less-informed audience, sufficient textual material is included to describe the nature of geothermal energy and problems to be expected in using it. The current

Fig. 1 Area of prospectus for Delmarva Peninsula. (79-1/24)

status of technical, environmental, and legal efforts and problems is discussed, and an attempt made to estimate the economics of geothermal energy for the specific locality.

Figure 1 shows the area covered by the Delmarva prospectus. Also shown are the locations of the 1000 ft geothermal gradient test holes drilled by DOE in 1978. The first geothermal test hole into basement on the Atlantic Coastal Plain is scheduled to be drilled at Crisfield, Md., in May 1979 (see §9 and §13). This experimental test hole will provide, for the first time, direct evidence of the character of the geologic strata, water availability, and water temperatures down to basement for the Delmarva Peninsula.

The outline of the Delmarva prospectus is as follows:

- I. Introduction
- II. Resource description
- III. Potential energy content of the sedimentary sequence beneath Delmarva
- IV. Geothermal reservoir parameters for energy retrieval
- V. Characteristics of geothermal wells and well pumping systems
- VI. Applications engineering and economic considerations
- VII. Procedures required by developers and local governments for geothermal energy extraction
- VIII. Use and management of geothermal energy resources
- IX. Problem areas and initiatives to be taken by federal and local governments

Appendixes

- A. Potential near-term uses for geothermal energy on the Delmarva Peninsula
- B. DOE/DGE resource definition plan

C. Discussion of state geothermal regulations

D. Federal assistance programs

E. References and contacts

Much of the material for the prospectus has been supplied by state and county agencies and local industries or developers. The interaction among these local entities and APL, both in this effort and in the concurrent market study (see §10), has resulted in a lively interest in geothermal energy on the Delmarva Peninsula. DOE received five responses to Program Research and Development Announcement (PRDA) 03-78-ET-27004 from local government agencies and private firms for studies of site-specific geothermal installations in Delmarva. All of these PRDA responses show the effects of the interaction of these agencies with the APL geothermal effort.

To serve as a viable planning instrument, a prospectus must be updated as new information becomes available. When the results from the deep well to be drilled in Crisfield become available (presumably in the second half of CY 79), much that is speculative in the present prospectus can be replaced with information of substance.

REFERENCE

- 1. Section 13, Quarterly Report, Oct-Dec 1978, APL/JHU EQR/78-4.

GEOHERMAL ENERGY DEVELOPMENT PLANNING § 12
Regional Operational Research, Eastern U. S.

ZJ70CAS
 Support: DOE/RA

F. Mitchell January-March 1979

A METHODOLOGY FOR EVALUATING BACKGROUND FEDERAL STRATEGIES FOR FUTURE HYDROTHERMAL DEVELOPMENT

The evaluation of federal strategies for stimulating the commercialization of direct-use geothermal resources requires a methodology for assessing the prime prospects in the eastern and central United States. Although geologic and reservoir-engineering parameters must be considered, the suitability of commercialization ultimately will be determined by the cost of geothermal energy compared with alternative energy sources for a particular application. The methodology described here combines the results of studies that quantify the geologic, engineering, and economic implications of development. It permits the periodic reassessment of geothermal prospects and suggests alternative courses of action.

A summary discussion of the geological factors entering the definition of a hydrothermal prospect was contained in Ref. 1. The availability of subsurface hydrologic data is the main reason the evaluation is limited to the 15 states listed in Table 1. Temperature data were taken from Ref. 2 and the depth-to-basement data from Ref. 3. The contours were plotted to a common scale so that regions where the gradient exceeded 1.8°F/100 ft and where the depth to basement exceeded 3000 ft could be located by county.

DISCUSSION

The assessment methodology being developed by APL seeks to combine the results and data of geologic, engineering, and economic studies to suggest future courses of action. A simple evaluation procedure that can be re-

Table 1
 Cost of fuel.*

Use Code	Food 20	Tobacco 21	Textile 22	Lumber 24	Paper 26	Chem. 28	Weighted Average Cost of Fuel
Ala.	1.47		1.31	1.59	1.39	1.33	1.39
Ark.	1.13		1.00	1.58	1.36	1.00	1.10
Ga.	1.59		1.47	1.87	1.52	1.45	1.50
Ill.	1.56		1.60	1.70	1.47	1.27	1.59
Ind.	1.39		1.00	1.63	1.45	1.42	1.51
Miss.	1.36		1.25	1.48	1.42	1.04	1.10
N.Y.	2.06		2.10	2.04	1.83	1.63	1.82
Ohio	1.69		1.46	1.70	1.29	1.33	1.65
Pa.	2.04	2.20	2.10	2.06	1.48	1.50	1.72
Md.	1.95		2.50	2.07	1.25	1.85	1.70
Va.	1.98	1.77	1.72	1.97	1.49	1.49	1.65
N.C.	2.02	1.68	1.85	2.01	1.59	1.77	1.79
S.C.	1.70		1.65	2.19	1.62	1.40	1.56
N.J.	2.13		2.06	2.14	2.10	2.11	2.07
Mich.	1.73		1.71	1.78	1.49	1.45	1.67

*Costs were measured in 1976 dollars per million Btu.

applied whenever new data are acquired seems appropriate to the current situation because the amount and quality of data are changing rapidly.

To compare several prospects, a basis for comparison must be chosen that reflects the purpose and preferences underlying the selection. The basis on which the resource areas are ranked includes three elements: geothermal resource characteristics, cost elements, and market factors. To these must be added a greater emphasis on energy applications. The parameters in the expanded categories are, therefore:

- Resource characteristics
 - Temperature
 - Energy flow
- Cost elements
 - Drilling and casing
- Market factors
 - Distribution of towns by population
 - Energy usage levels
 - Space heating
 - Process heat
 - Local fuel costs

The characteristics of the geothermal resource, temperature, and estimated energy flow or extractable heat, as well as the cost of drilling and casing the well, are calculated at 75% of the depth to basement or to 3000 ft, whichever is greater. Energy flow is calculated on the assumption of a ground temperature of 55°F and a spent water temperature of 100°F. The drilling cost is derived from Ref. 4.

On reconsideration, it now seems that the usefulness of a geothermal resource might be more easily related to the size of the towns overlying it than to the population density of the region. Very small towns probably do not have the commercial or residential re-

quirement to support geothermal development, while very large towns may find geothermal development too disrupting to present residential and commercial patterns to be economically feasible.

Data are being collected or revised for the 15 states listed in Table 1 for the residential, commercial, and industrial use of fuels (Refs. 5 and 6). The use of fuels for industry has been restricted to the standard industrial codes indicated in Table 1 in cases where process heat from geothermal sources might replace some fuel. The cost of fuels varies so much from industry to industry and state to state (Table 1) that it seems appropriate to include it in the comparison. Further study of the use of process heat and fuel cost will be undertaken to see how these factors can be made representative of possible market penetration.

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6. Annual Survey of Manufacturers, 1976, Fuels and Electrical Energy Consumed, States by Industry Group, U.S. Department of Commerce, Bureau of the Census, May 1978.

ERRATA SHEET

In Section 14, "Alternative Federal Strategies," of Quarterly Report, Oct-Dec 1978, APL/JHU EQR 78-4, the fourth column of Table 2 is incorrect. The correct values are given in the table printed below. (Costs are given in 1976 dollars and are doubled in the sense that the cost per 100 ft includes the cost of both 100 feet of production and 100 feet of reinjection well. According to the American Petroleum Institute, oil well drilling costs on land increased by 10% in 1977; the increase in 1978 is not available.)

Table 2
Comparison of geothermal prospects.

State/County	1 Basement (thousand ft)	2 Gradient (°F/hundred ft)	3 Heat Flow (Btu/gal)	4 Cost (\$ per hundred ft)	5 Population (thousands)	6 Population Density (No./mi ²)	7 Energy (trillion Btu)
Arkansas							
Calhoun	10.0	1.9	813.6	8682	5.6	9.0	0.4
Clark	10.0	1.9	813.6	8682	21.5	25.0	1.5
Cleburne	5.0	1.8	187.8	5246	10.3	19.0	0.7
Cross	10.0	1.9	813.6	8682	19.8	32.0	1.4
Drew	10.0	1.8	751.0	8682	15.2	18.0	1.0
Franklin	5.0	1.8	187.8	5246	11.3	18.0	0.8
Howard	10.0	1.9	813.6	8682	11.4	20.0	0.8
Jackson	10.0	1.9	813.6	8682	20.4	33.0	1.4
Jefferson	10.0	1.9	813.6	8682	85.3	98.0	5.8
Lincoln	10.0	1.8	751.0	8682	12.9	23.0	0.9
Little River	10.0	1.9	813.6	8682	11.1	23.0	0.8
Lonoke	10.0	1.9	813.6	8682	26.2	33.0	1.8
Ouchita	10.0	1.9	813.6	8682	30.9	42.0	2.1
Pike	10.0	1.9	813.6	8682	8.7	15.0	0.6
Poinsett	10.0	1.9	813.6	8682	26.8	35.0	1.8
Sevier	10.0	1.9	813.6	8682	11.2	22.0	0.8
VanBuren	5.0	1.8	187.8	5246	8.3	12.0	0.6
Georgia							
Evans	3.5	1.8	75.1	4743	7.3	39.0	0.3
Long	3.5	1.8	75.1	4743	3.8	9.0	0.2
Montgomery	3.5	1.8	75.1	4743	6.1	26.0	0.3
Tattnall	3.5	1.8	75.1	4743	16.5	34.0	0.7
Toombs	3.5	2.0	125.2	4743	19.2	52.0	0.8
Wayne	3.5	1.8	75.1	4743	17.9	28.0	0.7
Illinois							
Coles	8.0	2.0	625.9	7097	47.8	94.0	4.1
Macoupin	4.5	1.9	159.6	4988	44.6	51.0	3.8
Madison	4.0	1.9	100.1	4743	250.9	342.0	21.5
Menard	4.5	2.0	187.8	4988	9.7	31.0	0.8
Shelby	7.5	1.9	516.3	6749	22.6	30.0	1.9
Indiana							
Carroll	4.0	1.9	100.1	4743	17.7	47.0	1.4
Clay	7.0	1.9	456.9	6417	23.9	66.0	1.9
Davies	9.0	1.9	694.7	7850	26.6	62.0	2.1
Gibson	10.0	1.8	751.0	8682	30.4	61.0	2.4
Green	8.0	2.0	625.9	7097	26.9	49.0	2.1
Knox	9.0	1.9	694.7	7850	41.5	81.0	3.3
Montgomery	6.0	1.8	300.4	5802	33.9	67.0	2.7
Morgan	6.5	1.8	356.7	6102	44.2	109.0	3.5
Owen	7.0	1.8	413.1	6417	12.2	31.0	1.0
Parke	6.0	1.8	300.4	5802	14.6	33.0	1.2
Putnam	6.5	1.9	397.4	6102	26.9	55.0	2.1
Sullivan	8.0	2.0	625.9	7097	19.9	44.0	1.6
Vigo	7.0	2.0	500.7	6417	114.5	276.0	9.1
White	4.0	1.9	100.1	4743	21.0	42.0	1.7
Mississippi							
Grenada	11.5	1.9	892.9	9285	19.8	46.0	0.9
Holmes	10.5	1.8	807.4	9130	23.1	30.0	1.0
Lafayette	9.5	1.9	754.2	8255	24.2	36.0	1.1
Madison	10.5	1.8	807.4	9130	29.7	41.0	1.3
Monroe	8.0	1.8	525.7	9285	34.0	44.0	1.5
Montgomery	11.5	1.9	892.9	7097	12.9	32.0	0.6
Noxubee	12.0	2.0	959.7	9285	14.3	21.0	0.6
Pontotoc	9.5	1.9	754.2	8255	17.4	35.0	0.8

GEOHERMAL ENERGY DEVELOPMENT PLANNING § 13
Regional Operational Research, Eastern U. S.

ZJ70CQO

Support: DOE/RA

F. C. Paddison

January-March 1979

**COMMENTS ON LIMITED TASKS:
GEOHERMAL ENERGY DEVELOP-
MENT PLANNING**

SITE-SELECTION COMMITTEE MEETING

The site-selection committee for the DOE geothermal deep test well met in Blacksburg, Va., on 16 and 17 January. Results of targeting studies by VPI&SU and potential users and marketing studies by APL were presented (see Ref. 1). Crisfield, Md., was chosen by the committee as the site for the deep test well on the basis of its high geothermal gradient. Hot water in the range between 160 and 180°F is expected near the bottom of the coastal plain sedimentary wedge at 4200 ft. Although no distinct-gravity low occurs in this area, Crisfield overlies the edge of a large regional low. Unfortunately, there is only a marginal market for the energy in this region.

Discussions were held concerning the pump-testing plan for the deep well. Gruy Federal, Inc., outlined its test plan, which was based on petroleum engineering technology. Representatives from the U.S. Geological Survey thought that water-well technology was more appropriate.

The well will be drilled in May; tests will be run for several months.

The Los Alamos Scientific Laboratory plans to extend the well 700 ft into basement to obtain data for their Hot Dry Rock Program.

REFERENCE

1. F. C. Paddison, W. J. Toth, and J. E. Tillman, "Site Selection Committee Meeting," APL/JHU QM-79-025, 9 Feb 1979.

RESOURCE APPLICATIONS WORKSHOP

During the 29 January through 9 February period, APL representatives attended a DOE/RA workshop hosted by the Mitre Corp., McLean, Va. The workshop was divided into committees to review prior documented effort on hydrothermal development energy with regard to planning or writing geothermal development scenarios, marketing, progress monitoring and reporting, and economic analysis. The workshop was interactive and there were frequent discussions of progress and results with DOE/RA personnel. In addition to reviewing past efforts, the subcommittees were to recommend the efforts in each area that should be continued and completed. The reports have been refined and missing data

compiled. A final version will be published by Metrek/Mitre Corp.

Laboratory and University personnel who participated in the workshop are as follows:

F. C. Paddison, Chairman, Planning Effort Scenarios
W. J. Toth, Marketing
R. F. Meier, Progress Monitor
R. S. P. Weissbrod and W. Barron, Economics

**VISIT BY THE MARYLAND ASSISTANT
LEGISLATIVE SCIENCE ADVISOR**

On 26 January, D. C. Willis, the Assistant Legislative Science Advisor for the State of Maryland, met with F. C. Paddison, A. M. Stone, and J. E. Tillman. Ms. Willis described her position and explained that she was responsible for questions asked by state legislators concerning geothermal development in Maryland. Mr. Paddison discussed APL's role in geothermal development and emphasized the need for Maryland to review and monitor geothermal exploration and development drilling on the Eastern Shore. DOE is planning to drill a test well near Crisfield; if the results are favorable, further development may begin. A regulatory body is needed to ensure that the life of the hydrothermal reservoir is maximized and that the environment is protected. Mr. Tillman described the test plan that will be used by Gruy Federal, Inc. for the Crisfield well.

REFERENCE

1. J. E. Tillman, "Visit by the Maryland Assistant Legislative Science Advisor," APL/JHU QM-79-039, 12 Mar 1979.

**PRESENTATION TO SALISBURY WICOMICO
ECONOMIC DEVELOPMENT, INC**

On 8 February, W. J. Toth gave a 45-min presentation to approximately 75 local government and business leaders (Ref. 1) in Salisbury, Md. In attendance were officials and employees from Salisbury Wicomico Economic Development, Inc. (SWED), former Maryland Governor Tawes, Crisfield Mayor Charles McClenahan, the President of the Salisbury City Council, and the Chairman of the Wicomico County Commissioners. Representatives of the Salisbury Times and the Salisbury TV station were also present. The presentation covered the following topics: a general discussion of the nature of geothermal resources, efforts by VPI&SU to identify Delmarva resources, worldwide applications of geothermal energy, the results of the APL geothermal energy market study, APL scenario development efforts, and future DOE plans and efforts at Crisfield.

REFERENCE

1. W. J. Toth, "Presentation to Salisbury Wicomico Economic Development Corporation (SWED)," APL/JHU QM-79-048, 22 Mar 1979.

STATE OF DELAWARE LEGISLATIVE WORKSHOP - GEOTHERMAL LEGISLATION

On 23 February, the National Conference of State Legislatures held their second workshop at Dover, Del., to discuss the type of legislation that might be required to solve problems created by the use of geothermal energy. The audience consisted of representatives from industrial, architectural, engineering, and energy companies in Delaware that were interested in geothermal energy; the attendance and APL's presentation are documented in Ref. 1. State Senator H. B. McDowell asked what he should request from DOE in regard to geothermal resource engineering in Delmarva. The suggestions are documented in Ref. 2.

REFERENCES

1. F. C. Paddison, "Second NCSL Geothermal Workshop Delaware Legislation," APL/JHU QM-79-053, 26 Mar 1979.
2. F. C. Paddison, "Geothermal Reservoir Engineering," APL/JHU Lett. CQO-2392, 8 Mar 1979.

GEOTHERMAL PUBLICITY ON CHANNEL 9 TELEVISION

On 24 February (repeated on 1 March) Channel 9 TV (Washington, D.C.) devoted the entire half-hour of its regular program, Probe, to energy issues. Included were such topics as ocean thermal energy conversion (OTEC), conservation, heat pumps, methane from land fills, and, as a lead-off item, geothermal energy in the Eastern United States. A. M. Stone was interviewed concerning DOE's eastern geothermal program. After giving a general introduction to geothermal energy, Dr. Stone described the gradient-hole drilling program of VPI/Gruy and expectations from the program. He speculated that geothermal energy would eventually be a significant contributor to the energy supply of the United States but would certainly not be expected to solve energy shortage problems all by itself. A video tape of the program is available.

SIXTH ENERGY TECHNOLOGY CONFERENCE

On 26 February, W. J. Toth presented an invited paper entitled "Geothermal Energy Markets on the Atlantic Coastal Plain" to attendees of the Sixth Energy Technology Conference (Ref. 1). The paper summarized some of the results of APL's Geothermal Energy Market Study by identifying potential markets, estimating geothermal energy costs, and identifying considerations for developing a strategy to commercialize geothermal energy on the Atlantic Coastal Plain. That paper and one by John Costain of VPI&SU comprised the session on geothermal energy, which was chaired by D. Lombard of DOE.

REFERENCE

1. W. J. Toth and F. C. Paddison, "Geothermal Energy Markets on the Atlantic Coastal Plain," Proc. Sixth Energy Technology Conference (in press) and APL/JHU QM-79-032, 23 Feb 1979.

NEW DIRECTOR OF MARYLAND STATE PLANNING OFFICE

On 26 February, F. C. Paddison met with the Delmarva Regional Planning representatives, W. Livingston and E. Philips, and with the newly appointed Secretary of State Planning, C. Lieder. The meeting was to inform Secretary Lieder of the potential of geothermal energy on Maryland's Eastern Shore and of the status of the DOE program in resource definition and applications studies. The Lower Eastern Shore Regional Office is part of the Maryland Department of State Planning. It is located at Salisbury and has assisted APL and DOE in writing the section of the site prospectus covering future potential uses of geothermal energy. The office has also assisted local and county personnel interested in the potential of geothermal energy by a workshop on the status and results of the DOE program.

The APL presentation on geothermal energy in Maryland is documented in Ref. 1.

REFERENCE

1. F. C. Paddison, "Meeting with Secretary Constance Lieder," APL/JHU QM-79-054, 26 Mar 1979.

MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA

On 1 March, J. E. Tillman presented a paper entitled "Near Term Potential for Geothermal Energy in the Eastern U.S." to the Northeast Section Meeting of the Geological Society of America in Hershey, Pa. The paper focused attention on the connate brines in Paleozoic sedimentary basins and the significance of structural analysis in exploration. Following the presentation, discussion ensued on the most appropriate techniques for locating zones of high permeability. Suggestions were offered for complementary structural models that are applicable in certain tectonic provinces. APL publications were forwarded to several people who desired more information on the DOE program and the involvement of industry in the East.

MEETING OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

On 28 March, J. E. Tillman was the guest speaker at the quarterly meeting of the American Society of Civil Engineers. The contribution of geotechnical engineers in the exploration, development, and production of geothermal energy was the principal topic of the formal presentation and the ensuing discussions. One of the main points discussed was that, in addition to handling and disposing of the geothermal brine, the careful management of the resource was necessary to ensure its continuing productivity and life. Representatives of the major consulting and engineering firms in the Baltimore-Washington area were present, including several who have already been involved in joint responses to Program Research and Development Announcements (PRDA's) for funding by DOE.

(continued)

GEO THERMAL RESOURCES COUNCIL NEWS

The "Symposium on Geothermal Energy and Its Uses in the Eastern United States," which was originally scheduled for 5-7 April at Hot Springs, Va., has been moved to Roanoke, Va., because of insufficient accommodations at the former location. Papers will be presented at the meeting by W. J. Toth, F. C. Paddison, and the APL subcontractor, Metro Center. In addition, W. J. Toth will be a member of a panel in a session being organized by the National Conference of State Legislatures.

Efforts by W. J. Toth and J. L. Renner of Gruy Federal, Inc., to form a mid-Atlantic section of the Geothermal Resources Council are continuing. Letters and questionnaires have been sent to Council members and other parties to determine the degree of interest in a local section. The first organizational meeting will

be held during the Roanoke symposium; the first formal meeting will be held in May 1979.

TECHNICAL SUPPORT TO LOCAL COMMUNITIES

During this quarter, APL provided technical support to municipalities in the Delmarva area as they began to assess the potential for geothermal energy in their areas. Several towns and industrial parks have initiated efforts to assess the engineering and economic consequences of developing geothermal resources. Discussions have been held with the Accomac County Industrial Authority, the City Manager of Newport News, Dover Air Force Base, Solar Energetics Inc. of Dover, Del., and Shore Engineering of Teasley, Va.

OPERATIONAL RESEARCH, HYDROELECTRIC POWER
DEVELOPMENT § 14
Small Dam Hydroelectric Retrofit Program ZP30CPE
Support: DOE/RA
R. J. Taylor
January-March 1979

A METHOD FOR QUANTIFYING INSTITUTIONAL CONSTRAINTS

APL is conducting an investigation for DOE to determine the institutional problems associated with the development of hydroelectric power at existing low-head dams in the eastern United States. The Laboratory is seeking to identify and understand the institutional, economic, and environmental constraints that affect hydroelectric resource development. We have had interviews with large and small, privately owned, and municipal utilities; state energy, environmental, and water resource offices; public utility commissions; insurance companies; district offices of the Corps of Engineers; and entrepreneurs to determine the problems and prospects for hydroelectric development at existing dams. We are working with Metro Center on an interdisciplinary economic/political study to determine the amount of a subsidy and how best to apply it for maximum leverage in encouraging hydroelectric development. To support the study, a data base for the Middle Atlantic States and a methodology for its use have been constructed. This article describes the methodology and illustrates its use in terms of conditions in Pennsylvania.

DISCUSSION

The methodology involves determining the potential hydroelectric energy output within a designated area versus the incremental costs of hydroelectric generation. The resulting hydroelectric-energy supply curve (kWh versus ¢/kWh) is valuable for determining the governmental policies that will encourage the greatest development of the resource. Some of the questions this should help to answer are: What type of hydroelectric development should be encouraged and how should that be done? What are the effects of present licensing procedures? What are the effects of present environmental and recreational requirements? Are government subsidies, loans, assistance, and risk-sharing (e.g., a federally assisted liability insurance program) needed?

The impact of the type of developer - public or private - is manifested in the annual fixed charge rate (AFCR). The expected AFCR for private and public developers is given in Table 1.

Using these two AFCR's, the hydroelectric supply curve for Pennsylvania can be derived (see Fig. 1).

Some very interesting results in the neighborhood of the 2 through 3¢/kWh electrical energy "wholesale" price range can be seen in the figure. At 2.5¢/kWh (the 1978 average rate for the Pennsylvania, New Jersey, and Maryland pow-

Table 1
AFCR expected for private and public developers

	Private Developer (%)	Public Developer (%)
Cost of capital	12	8
Income taxes	1.5	0
Other taxes	2.56	0.5
Insurance rate	0.2	0.2
Depreciation	1.67	1.67
Total AFCR	17.93	10.37

Fig. 1 Potential hydroelectric energy supply curve for 347 nonhydroelectric dams in Pennsylvania, two levels of AFCR. (79-1/25)

er pool), the amount of hydroelectric energy available annually from developers with an AFCR of 10.4% is 3.7 times the energy available annually from developers with an AFCR of 17.9%. (Note that 17.93 divided by 10.4 is only 1.7.) At 3¢/kWh, the amount of hydroelectric energy available from developers with an AFCR of 10.4% is 4.5 times the energy available annually from developers with an AFCR of 17.9%. Thus AFCR is a very sensitive parameter in the development of hydroelectric power from existing dams in Pennsylvania.

The cause of this unusual situation is the potential to develop 17 navigation dams. For 2.5¢/kWh, 4.66×10^8 kWh are available from these 17 dams if the AFCR is 10.4%. If the AFCR is 17.9%, no energy is available from them for a price to the developer of 2.5 or even 3¢/kWh. The AFCR is not as sensitive for dams

not used for navigation. There are 35 non-navigation, non-hydroelectric dams in Pennsylvania with a potential greater than 1000 kW. Changing the AFCR from 17.9 to 10.4% for them results in only a 36% increase in the available hydroelectric energy at 2.5¢/kWh to the developer.

If private developers were relied on for hydroelectric development, a government subsidy of 1.5¢/kWh over a 2.5¢/kWh price would be required for an equivalent development by public developers. This would mean an annual public expenditure of 11.4 million dollars in Pennsylvania. Another possible solution would be to offer low-cost loans. If federal loans at 6.875% were made available for 90% of the financing, the cost of capital to a private developer would be 7.69% (assuming a 15% rate of return on equity). Using the other components in Table 1, the AFCR would be 13.6% for private developers. It appears that this approach would provide 70% of the energy potentially available from public developers at 2.5¢/kWh. This points to the need to reduce other parts of the AFCR — such as taxes — for private developers.

Taxes and Insurance. Taxes and insurance are components of the AFCR. Changes in them can have significant effects on the hydroelectric power supply. Decreases in the tax rates can be justified because development of the renewable hydroelectric resource can decrease our dependence on foreign oil. Decreases in local tax rates for hydroelectric sites may require increased revenue sharing by the federal government; however, decreases in the tax rates by 2%, in addition to federal loans, could bring the previous AFCR for private developers down to 11.6%. They could then provide 85% of the energy potentially available from public developers at a price of 2.5¢/kWh.

However, these gains for private development could be eliminated by increases in the insurance rates. The insurance rate assumed in the model was 0.2%. Liability insurance rates for dams may be in flux because of recent dam failures. Acts of vandalism have increased insurance costs at some sites, and rates of 2% or higher have been estimated for a few projects. The potential effect of high insurance rates on the supply of hydroelectric power is very complex. It depends on the developer's present AFCR and the price he is receiving for the energy. For a better understanding of the potential impact of high insurance rates and lower tax rates, a plot of the Pennsylvania supply versus the AFCR and price to the developer is shown in Fig. 2.

Three different types of general changes in the potential supply of electric power are observed for the ranges of price and AFCR shown in Fig. 2. For low prices, such as 1.5¢/kWh, the change in supply per change in AFCR is relatively small (about 8×10^6 kWh/1% AFCR). For high prices, such as 10¢/kWh, the change in supply per change in AFCR is relatively moderate (about 30×10^6 kWh/1% AFCR). The middle range prices, 2.5 to 6¢/kWh, have relatively large changes in supply per change in AFCR. For 4¢/kWh, the change in supply is about 100×10^6 kWh/1% AFCR. The major reason for these three distinct ranges of change in supply is again the 17 navigation dams in Pennsylvania. At 10¢/kWh, all these navigation dams are economical for power generation over the given range of AFCR. None is viable at 1.5¢/kWh and

Fig. 2 Potential hydroelectric energy supply for 347 nonhydroelectric dams in Pennsylvania versus the AFCR at constant price levels to the developers. (79-1/26)

an AFCR greater than 10.4%, at 2¢/kWh and an AFCR greater than 12.2%, at 2.5¢/kWh and an AFCR greater than 15.4%, and at 3¢/kWh and an AFCR greater than 17.9% (see Fig. 2). At 4¢/kWh, 15 of these dams are viable for an AFCR of 10.4%, while at an AFCR of 19.7% only 4 of these dams are viable.

For a given price, one can use Fig. 2 to determine the actual impact of changes in the AFCR. For example, if the price of electricity is 2.5¢/kWh and the AFCR is 12.2%, a decrease of 1.8% in the AFCR will result in a 30% increase in the supply. However, if the AFCR is 15.4% and the AFCR decreases by 1.8%, the supply increases by 130%. Figure 2 indicates that government policy makers should seek not only the highest price possible for developers but also the lowest AFCR if the greatest potential of hydroelectric power is to be realized.

Cost of Licensing. The cost of licensing is assumed to be \$40 000 per site for the computer model of the supply curve. This cost was set to zero for the supply model of Pennsylvania (AFCR equals 10.4%), and the changes in

(continued)

Fig. 3 Change in the potential hydroelectric energy supply curve for 347 nonhydroelectric dams in Pennsylvania when the licensing cost to the developer is zero. The licensing cost was assumed to be \$40 000 for each site in the supply model. (79-1/27)

supply were determined. Figure 3 is a plot of the changes in supply versus the price of electricity for the developer. The changes appear surprisingly small. The maximum observed increase in energy output was +2.7%. The cost decrease of \$40 000 per site has a small impact on the supply curve because of the high cost of developing those sites that make the greatest contribution to the supply. For example, the average cost of development for the navigation dams is estimated to be \$18 000 000 each. Obviously a \$40 000 decrease in cost per site is insignificant.

Low-Cost Turbine-Generators. The government has been encouraging standardized turbine-generators for small sites. Lower costs should stimulate greater production, which traditionally has also lowered costs. If the costs of the powerhouse and equipment were decreased by 30%, the effect on the supply would be as shown in Fig. 4. The effect is significant if the price of electricity to the developer is 3¢/kWh or less. At 5¢/kWh or more, the effect is relatively minor. For example, at 10¢/kWh, the increase in supply is less than 5%. If the reasonable price for the power is 25 mills/kWh, lowering the cost of the powerhouse and equipment by 30% increases the supply by 77%.

REFERENCES

1. "Dams, Reservoirs, and Natural Lakes," Comprehensive Water Resources, Planning Inventory No. 1, Bureau of Engineers, Harrisburg, Pa., Bulletin No. 5, 1970.

Fig. 4 Change in the potential hydroelectric energy supply curve for the 52 largest nonhydroelectric dams in Pennsylvania when the powerhouse costs are decreased 30%. (79-1/28)

2. "Problems of Hydroelectric Development at Existing Dams, Interim Report on the Middle Atlantic States and the Ohio Valley," APL/JHU and Metro Center HE-003/QM-78-243, Nov 1978.

OPERATIONAL RESEARCH, HYDROELECTRIC POWER
DEVELOPMENT § 15

Small Dam Hydroelectric Retrofit Program ZP30CQO

Support: DOE/RA

S. Briscoe (JHU/Metro Center)

January-March 1979

INSTITUTIONAL AND REGULATORY CONSTRAINTS ON SMALL-SCALE HYDROELECTRIC DEVELOPMENT IN NEW JERSEY

In New Jersey, legal and institutional constraints to the development of small-scale hydroelectric energy, and their effects on developers, do not follow the pattern observed in Maryland and Pennsylvania (Ref. 1). Future clarification of the powers and procedures of the newly created New Jersey Department of Energy (NJDOE) will undoubtedly increase these differences.

DISCUSSION

Market Accessibility. In almost all cases, the marketability of power currently depends on the attitudes of the Board of Public Utility (BPU) Commissioners and of the municipalities. A project whose transmission facilities occupy public streets must obtain a municipal consent from the municipality. With the exception of bulk wholesale transactions involving only one customer, the development of commercial power will probably qualify as a utility activity that is subject to BPU regulation. In contrast to Maryland and Pennsylvania, there is no legislation or BPU ruling assigning fixed distribution service areas to existing power distributors. As a result, it is possible to form new utilities, depending on the BPU's finding of need. However, the marketing of power developed for wholesale distribution depends on the willingness of existing distributors to purchase it. There are two constraints on the development of energy for own use by individuals or businesses: the need for municipal consent and the lack of authority to take private land by condemnation proceedings for use by transmission facilities.

In spite of BPU's opposition, the NJDOE is moving in the direction of absorbing all BPU functions except rate setting. In view of its interest in promoting energy production that does not rely on fossil fuels, NJDOE's assumption of the authority to determine need will act as a spur to small-scale hydroelectric projects. If present distributors are unwilling to participate, the department will encourage the private development of such projects. Legislation is pending that would enable NJDOE to extend condemnation powers to non-utility and own-use developers.

Total coordination of resource development under the aegis of NJDOE will not take place in the near future. Opposition to recent attempts to transfer the administration of zoning permits to NJDOE indicates that municipalities will retain control of the granting of municipal consents.

Licensing Procedures. Small-scale hydroelectric projects will require licenses and permits from four separate levels of government: federal, state, local, and the regional Delaware River Basin Commission, where applicable. Exactly which permits must be obtained will vary according to the specific characteristics of each project. At present, the licensing process has no fixed structure. The sequence by which permits are obtained and the relationship among permits issued by the different levels of government have not been established. No single agency at the federal, state, or local level has been designated the clearinghouse for all approvals needed from that level by all types of developers. However, legislation has been introduced in the General Assembly that would make the NJDOE the sole permitting agency for resource development. Because of local opposition to those portions of Senate Bill 1179 that would transfer certain municipal permit powers to NJDOE, it is unlikely that the bill will emerge intact. Regardless of how the local issue is resolved, it is anticipated that NJDOE will become the clearinghouse for all state-level permits and the coordinator of approvals from other levels of government.

Tax Liability. Rough estimates of the relative yields of gross receipts and real property taxes indicate that gross-receipt taxation contributes significantly to the tax burden of projects taxed as utilities. Because their gross-receipt tax liabilities outweigh the reduction in tax burden due to their reduced property tax liability, such projects pay more dollars of total tax than do projects not taxed as utilities.

However, the ultimate tax burden on utilities is lighter than that on nonutility developers. Because taxes are incorporated into utility rates, the utility tax burden is shifted forward in toto to consumers. For developers whose markets are not secure, such shifting of tax incidence may not be possible. Their particular tax burden depends on the write-offs of business expenses and taxes allowed under state and federal tax legislation.

The structure of tax burden varies as significantly as its incidence. Approximately 90% of the total liability of developers who are not subject to utility taxes is directly attributable to the local property tax. For utilities, less than 50% of their tax liability is property-related and thus fixed. The bulk of liability stems from the gross receipts tax and is based on ability to pay. The disproportionate amount of the tax burden attributable to the property tax may discourage project development by nonutilities.

REFERENCE

1. Section 18, Quarterly Report, Oct-Dec 1978, APL/JHU EQR/78-4.

A DEVELOPMENT AND DEMONSTRATION PLAN FOR A LOW-COST FLYWHEEL

At the request of DOE/ESS, APL proposed (Ref. 1) a development plan for demonstrating the feasibility of a very-low-cost flywheel. The proposal was approved and work began in October 1977; the completion date was recently amended to 31 May 1979. The primary objective of the program was to develop a flywheel able to store 20 Wh of electrical energy per dollar of flywheel cost. A secondary objective was to develop low-loss, long-lived bearing systems to use in subsequent flywheel systems. A lesser objective was to demonstrate the low-cost flywheel in a complete energy storage system that could carry a typical home electrical load and be charged through an ordinary home wall socket. The final objective was to translate a satisfactory design of a low-cost flywheel energy-storage system into a functional home-sized unit.

BACKGROUND

Modern composite flywheels can be made from a variety of filamentary super-materials that would produce more energy per unit weight and volume than their isotropic flywheel predecessors. However, usually the cost of the new flywheels is actually higher because of manufacturing costs and other expenses. APL has recently developed new flywheel configurations that offer lower costs than were previously believed possible.

There are a growing number of applications for energy storage by flywheel where the flywheel cost factor is the dominant consideration and flywheel weight and volume are relatively unimportant. Most of these applications are stationary, such as nighttime storage in the home or factory, where the system can pay for itself in a few years by using low-cost off-peak electrical power.

DISCUSSION

Following the scale-model flywheel testing described in Ref. 2, a full-scale 1 kWh rotor design was developed based on the use of vinyl-impregnated fiberglass strand material. The design weight of this rotor was approximately 70 lb; it was 24 in. OD with a 4 by 4 in. cross section of the wound vinyl-impregnated fiberglass strands. On the basis of this configuration, a full-scale rotor winding tool was designed and built. It consists of a winding mandrel having an approximately 4% subcircular shape in four lobes, with circular and parallel side plates that allowed winding the rotor on the mandrel to an outside diameter of approximately 24 in. The design called for the completed rotor to have a subcircularity of ap-

Fig. 1 Demonstration system No. 1 installed in test cell No. 4. (79-1/29)

proximately 1% at the outside surface. In other words, at the four mid-quadrant locations, the rotor diameter was to be 1% less than at the bonded areas in the four quadrant locations.

The first of two flywheel energy-storage systems was completed (see Fig. 1), and considerable effort was expended in troubleshooting the electronic control system. With the assistance of the manufacturer of the electronic equipment, the problems were solved satisfactorily, and good operation of the energy storage system was demonstrated repeatedly. Although relatively simple, the modifications to the control circuitry recommended by the manufacturer during the evaluation tests allowed the system to be operated continuously in the charge and discharge cycles, as designed.

The design of the various components for the demonstration system No. 2 was completed during the period, as was the fabrication of most of them. The principal differences between the No. 2 demonstration system and the No. 1 system already described are as follows. System No. 1 used a "battleship" model aluminum-slab flywheel designed to operate in the correct rotational speed range, but at a much lower energy storage level. System No. 2 was designed to use the flywheel configuration with the vinyl-glass-wound bare filament, and therefore had a somewhat larger flywheel container. A tuned suspension system was incorporated to accommodate the new flywheel system.

An off-the-shelf vacuum pump evaluated for use with the system was advertised as being able to produce 10^{-4} Torr, but evaluation tests clearly established that it could provide only about 5×10^{-3} Torr. Although this is somewhat below the design condition, we elected to proceed in view of the tight schedule.

Demonstration system No. 2 also uses the low-loss bearings described in Ref. 3. With only a 10 mm bore, they have a measured drag of about 1 W at 10 000 rpm with the design load conditions and minimum oiling. Demonstration system No. 2 also includes the minimum oiling system, which provides approximately one drop of Mobil No. 1 oil per day during the life of the bearing. The system also includes a magnetic bearing relief system designed to carry 90 to 95% of the rotating-mass gravity loads, thereby allowing the bearings to operate at an axial load condition of 5 to 10 lb. It can be seen from the bearing specifications that this

is the approximate range of the recommended pre-load for the bearings and accounts for their very low losses and very long projected lifetime.

REFERENCES

1. "Unsolicited Proposal to ERDA for Advanced Flywheel Technology," APL/JHU report, 15 Apr 1976, revised 1 Mar 1977.
2. Section 25, Quarterly Report, Oct-Dec 1978, APL/JHU EQR/78-4.
3. Section 24, Quarterly Report, Apr-Jun 1978, APL/JHU EQR/78-2.

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