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MASTER

Quarterly Report

ENERGY PROGRAMS

at The Johns Hopkins University Applied Physics Laboratory

JANUARY—MARCH 1980

THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY

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208

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:

<u>Programs</u>	<u>Report Designators</u>
<u>Department of Defense Programs</u>	
Research and Development	RQR
Exploratory Development for Missile Propulsion	DQR
<u>Civil Programs</u>	
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., A3), the Laboratory Group or Groups that performed the work (e.g., BBE), and the agency that supported it (e.g., SEA-62R).

Certain Laboratory programs, including some that 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 monitoring and storage methods. This Quarterly Report summarizes the work on the various tasks as of 31 March 1980.

The Energy Quarterly Report is divided into four sections. The first, Geothermal Energy Development Planning and Technical Assistance, supported by the Department of Energy/Division of Geothermal Energy (DOE/DGE), contains reports on the progress of geothermal-related tasks on which effort was concentrated during the quarter.

The second section, Operational Research, Hydroelectric Power Development, supported by the Department of Energy/Resource Applications (DOE/RA), contains reports on small-scale hydroelectric investigations in the southeastern states.

The third section, Seismotectonic Investigation, supported by the Reactor Safety Research Division of the Nuclear Regulatory Commission, reports on a neotectonic investigation in Connecticut.

The fourth section, Energy Conversion and Storage Techniques, contains two articles, the first on OTEC core unit testing supported by the Department of Energy/Division of Central Solar Technology (DOE/CST), and the second on an analysis of the Community Annual Storage Energy System at the U.S. Naval Air Station, Norfolk, Va. This work is supported by the Department of Energy and the Department of Defense, Naval Facilities Engineering Command/Atlantic Division.

TABLE OF CONTENTS

GEOTHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE

DEVELOPMENT OF GEOTHERMAL ENERGY IN THE EASTERN U.S.

\$18	Geothermal Technical Assistance	9
\$19	Technical Assistance - Application of Geothermal Energy for the Columbia LNG Corporation	11
\$20	Technical Assistance - Geothermal Space Heating of the Pittsville Middle School, Wicomico County, Md.	15
\$21	Technical Assistance - Geothermal Space Heating for the Naval Air Rework Facility, Naval Air Station, Norfolk, Va.	17
\$22	Technical Assistance - Application of Geothermal Energy for Mariculture	19
\$23	Geothermal Energy Markets on the Atlantic Coastal Plain - Market Definition	25
\$24	Geothermal Energy Markets on the Atlantic Coastal Plain - Economic Modeling	27
\$25	Geothermal Energy Markets on the Atlantic Coastal Plain - Market Penetration	29
\$26	Legal, Institutional, Access, Insurance, and Similar Issues Relating to Geothermal Energy Development in the Eastern U.S.	31
\$27	A Methodology for Evaluating Federal Strategies for Future Hydrothermal Development	33
\$28	Comments on Limited Tasks: Geothermal Energy Development Planning	35

OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT

SMALL-SCALE HYDROELECTRIC

\$29	Environmental Regulatory Constraints in North Carolina, South Carolina, and Georgia	41
\$30	Economic and Institutional Factors in North Carolina, South Carolina, and Georgia	43
\$31	Installation Costs Derived from NHSF2 and Corps of Engineers Guide Manual	45
\$32	Final Report on Small-Scale Hydroelectric Power in the Southeastern U.S.	47
\$33	Costs of a Hydroelectric Installation at Savage, Md.	49
\$34	Comments on Limited Tasks: Small-Scale Hydroelectric Power	51

SEISMOTECTONIC INVESTIGATION

NEW ENGLAND SEISMOTECTONIC INVESTIGATIONS, WESTON OBSERVATORY

§35 Neotectonic Investigation in Connecticut	53
--	----

ENERGY CONVERSION AND STORAGE TECHNIQUES

OTEC CORE UNIT TESTING

§36 Tests of the APL Core Heat Exchanger as a Condenser	55
---	----

COMMUNITY ANNUAL STORAGE ENERGY SYSTEM

§37 Community Annual Storage Energy System	57
--	----

GEOTHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE

§ 18

Development of Geothermal Energy in the Eastern
U.S. ZJ7CQO

Support: DOE/DGE

K. Yu, R. von Briesen, J. E. Tillman, and F. C.
Paddison

January-March 1980

GEOTHERMAL TECHNICAL ASSIS- TANCE

APL has been designated by the Department of Energy's Division of Geothermal Energy (DOE/DGE) as a center for technical assistance for the application of geothermal energy. Normally constrained to a maximum of 100 hours for each request, APL assistance is in the form of preliminary feasibility, engineering, or economic studies and is not a substitute for detailed design, which is the province of the consulting engineering community. APL efforts can include the following:

1. Counsel on known information concerning geothermal resources in an area and DOE programs that are in process there;
2. Preliminary estimates of the hydrologic properties of geothermal resources as functions of time and usage;
3. Advice on recovering geothermal energy in a specific case (e.g., an engineering feasibility study);
4. The estimated life-cycle cost of applying geothermal energy in a specific case;
5. The legal, institutional, and other requirements for the application of geothermal energy; and
6. Advice on available federal geothermal opportunities or other federal programs that relate to the use of geothermal energy.

Limited feasibility and application analyses that have been requested are as follows.

Completed Studies.

1. Space heating of Crisfield High School, Somerset County, Md.
2. Application of geothermal water in mariculture, i.e., growing oysters and clams in Chesapeake Bay, Md.
3. Well productivity, water withdrawal strategy, and well field size for liquefied natural gas (LNG) vaporization at Cove Point, Md.
4. Space heating of remodeled middle school in Pittsville, Wicomico County, Md.
5. Geothermal space heating of bathhouses in Hot Springs National Park, Hot Springs, Ark.
6. Aquifer storage of river water and heat pump retrieval for space heating in Bellows Falls, Vt.
7. Space heat using shallow well and heat pump versus ground-coupled heat pump in New Hope, Pa.
8. Multi-use geothermal energy in Lewes, Del.

Analyses in Process.

1. Geothermal space heating at the Naval Air Rework Facility, Naval Air Station, Norfolk, Va.
2. Geothermal space heating, Wallops Flight Test Center, Va.
3. Space heating and industrial process heat, Auburn and Montezuma, Cayuga County, N.Y.
4. Geothermal energy for alcohol distillation, Natural Resource Energy, Inc., Daphne, Ala.

Analyses Pending.

1. Space heating of the city hall and other public buildings, using heat pumps and water from flooded coal mines, Forty Fort, Pa.
2. Fresh water mariculture, Federal Fish Hatchery, Wellsborough, Pa.
3. Space heating planned for the Senior Citizens Center, Ocean City, Md.
4. Space heating of industrial park, mall, and public buildings, Salisbury, Md.
5. Space heating, water-referenced heat pumps, Harlan, Ky.
6. Geothermal potential in the state of Indiana.
7. Geothermal energy potential and application in Gainesville, Fla.

DISCUSSION

The technical assistance program provided by the DOE through APL and other institutions has been helpful in determining the potential, the method of application, and the approximate cost of developing geothermal energy. It also informs DOE/DGE and the states involved of the problems the potential user faces from a technical, financial risk, or management point of view. APL (Ref. 1) reviewed (for DOE/DGE) the considerable growth of this effort during the current fiscal year and recommended additional funding and effort to provide timely response to requests for assistance.

Documentation and status of individual requests not previously reported are as follows.

1. Reference 2 is the letter report for the Crisfield High School (Somerset County, Md.) analysis. A search for methods of financing has continued, by request of the County Council and the School Board. The Farmers Home Administration (FHA) would consider financing the school construction (Ref. 3), and, accordingly, the payback period for conversion to geothermal energy was recalculated using the FHA interest rate of 5% and the current cost of oil (\$1.00/gal) (Fig. 1). Reference 4 reported these data to the School Board.
2. The Pittsville Middle School analysis is reported in section 20 of this Quarterly Report.
3. Mariculture in the Chesapeake Bay is reported in section 22 of this Quarterly Report.
4. The water withdrawal and well field size analysis for the Columbia LNG terminal, Cove Point, Md., was presented at a meeting with DOE/DGE and Columbia LNG Corporation on 11 March 1980. This analysis is

Fig. 1 Revised capital recovery time calculations, Crisfield High School. (80-1/35)

reported in sections 19 and 28 of this Quarterly Report.

5. A meeting was held in Atlanta, Ga., with personnel of Natural Resource Energy, Inc., of Daphne, Ala., on the distillation of alcohol using geothermal heat. A further meeting is planned at the completion of a review of geothermal resources in the Eastern Coastal Plain and the Eastern Gulf Coastal Plain.

6. APL personnel visited Auburn, N.Y., on 18 December 1979 to discuss the geothermal potential of Auburn and Montezuma in Cayuga County, N.Y. (Ref. 5). On 25 and 26 March 1980, APL, DOE/DGE, and New York State Energy Research and Development Authority personnel attended a meeting with town and county representatives to discuss the potential use of geothermal energy at the Clinton Corn Products (a subsidiary of Standard Brands) wet corn mill plant in Montezuma, N.Y. (see section 28 of this Quarterly Report).
7. APL and DOE/DGE personnel visited the Naval Air Rework Facility (NARF), Naval Air Station, Norfolk, Va., on 13 February 1980 to discuss geothermal energy. Section 21 of this Quarterly Report discusses the effort to date. Following this meeting a coordination meeting was held with Thomas Ladd of the U.S. Navy's Naval Facilities Engineering Command and DOE/DGE personnel on 14 February 1980. At this meeting the NARF request and the APL plans were discussed. Other APL suggestions pertaining to eastern U.S. military installations and geothermal energy were elicited by Mr. Ladd. Dover AFB, Dover, Del.; Trident Base, Kings Bay, Ga.; Ellsworth AFB, S.D.; Scott AFB, Little Rock, Ark.; Griffiss AFB, Rome, N.Y.; and all military installations on the Southern Atlantic Coastal Plain and Gulf Coast Plain are of potential interest.

REFERENCES

1. "Technical Assistance, Eastern Hydrothermal Program," JHU/APL Lett. CQO-2845, 20 Mar 1980.
2. "The Crisfield, Maryland Well and Geothermal Energy," JHU/APL Lett. CQO-2544, 12 Nov 1979.
3. F. C. Paddison and A. M. Stone, "Loans Available from Farmers Home Administration," JHU/APL QM-80-053, 14 Mar 1980.
4. "Crisfield High School Conversion to Geothermal Energy," JHU/APL Lett. CQO-2849, 20 Mar 1980.
5. F. C. Paddison, "Meeting with Auburn, N.Y., Mayor Paul Lattimore," JHU/APL QM-79-083, 28 Dec 1979.

**GEOHERMAL ENERGY DEVELOPMENT PLANNING AND
TECHNICAL ASSISTANCE** § 19

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

K. Yu

January-March 1980

**TECHNICAL ASSISTANCE – APPLI-
CATION OF GEOTHERMAL ENERGY
FOR THE COLUMBIA LNG CORPO-
RATION**

APL is one of several centers in the United States supported by DOE/DGE that are providing technical assistance on the application of geothermal energy.

At the request of the Columbia LNG Corporation (as a part of the Technical Assistance Program), APL has performed a preliminary feasibility analysis for obtaining 8000 gal/min of geothermal water to be used to gasify liquefied natural gas prior to insertion in the interstate pipeline. Columbia LNG Corporation estimated this as its requirement at its facility at Cove Point, Md.

DISCUSSION

Since no hydrologic or geologic data exist for the desired location, hydrologic conditions similar to those found at Crisfield, Md., were assumed (the suggestion of the Maryland Geological Survey (MGS)). Hydrologic geothermal resources of sufficient dimension (at least a few tens of miles square) exist that, for the preliminary analysis, may be approximated as confined, horizontal, isotropic, homogeneous, infinite aquifers with a transmissivity of 0.50 cm^2/s or greater and a storage coefficient of about 10^{-3} or more (Ref. 1).

Pressure Response to Withdrawal of Large Volume of Water. The pumping rate of 8000 gal/min amounts to a removal of 16 km^3 of water per year, so that reinjection of the spent water into the same aquifer is mandatory.

Reinjection to Minimize Drawdown. We considered a pair of wells (one production and one reinjection) separated by a distance, d , drilled into the same aquifer. Unlike the Theis solution, this doublet admits an asymptotic solution that is the steady state. Figure 1 shows the drawdown as a function of time for several values of d . Figure 2 shows the (eventual) maximum drawdown as a function of separation. From this it is clear that at the end of the first year drawdown is close to the terminal drawdown, and that the drawdown is less for smaller separation (an obvious result).

Thermal Breakthrough. The reinjection into the same aquifer is associated with a penalty of thermal degradation of the resource. But the transmission of water from the reinjection point to the production point does take a finite period, during which time heat transfer can take place.

Fig. 1 Drawdown of a doublet pan. (80-1/36)

The period after which the thermal degradation is observed may be called the thermal breakthrough time (Ref. 2). Figure 3 shows the thermal breakthrough time as a function of the well separation.

Required Well Field Size. Examining Figs. 1 through 3, a well separation of between 1 and 2 km would provide an adequate performance:

Drawdown: 540 to 590 ft at 100 gal/min
1600 to 1800 ft at 300 gal/min

Thermal breakthrough: 160 to 640 yr at
100 gal/min
53 to 215 yr at
300 gal/min

Based on the above, we considered an example field based upon a rectangular grid of 1.5 km lattice separation (Fig. 4). In steady state, each production well will receive a quarter of its water from its four neighboring reinjection wells; due to the arrangement, the interference effect is of second order compared to the primary effect. Then, ignoring this effect and taking a 300 gal/min production rate as feasible, we

Fig. 2 Well drawdown as a function of separation. (80-1/37)

estimate a requirement of 4.5 km^2 per 300 gal/min. From this, we conclude that about 120 km^2 (about 47 mi^2) will be needed for production of 8000 gal/min. This amounts to a production field of 7 by 7 mi.

These results clearly are sensitive to the choice of well parameters. Firm predictions can only be made after the transmissivity and capacity for storage at the Cove Point location have been measured. However, the results quoted here are encouraging for this application.

A Note on the Possibility of Turbulent Head Loss. To examine the possibility of turbulent head core, let us assume 800 ft of sand sequence, a 10 in. radius gravel pack, and a sand size distribution similar to that found at Crisfield, Md. (Ref. 3). For a 300 gal/min production rate, the velocity at the boundary (10 in. outer radius) of the gravel pack and formation sand is 1.64 cm/s. Table 1 shows the Reynolds number for several sand sizes and flow withdrawal rates.

As is well known, a Reynolds number of about 10 is considered to be the onset of turbulent flow in porous media. Therefore, we expect the deviation from a pure Darcian flow to be noticeable, but we do not expect the additional head loss to be severe (Dr. G. Achmad of MGS, in private discussion, concurs with this conclusion). Actually, in this regime the deviation is more due to the "inertial" effect (the "dynamic pressure" effect). Once the flow deviates from Darcy's law, the subsequent "turbulent" head loss increases very rapidly. It is

Fig. 3 Thermal breakthrough time as a function of well separation. (80-1/38)

Table 1

Reynolds number for sand sizes and flow withdrawal rates.

Spacing between sand grains (mm)	Reynolds number at two rates	
	400 gal/min	300 gal/min
0.55	15.1	11.3
0.50	13.7	10.3
0.40	11.0	8.2

Approximately 4.5 km^2 per doublet (300 gal/min each),
27 doublets

Fig. 4 Example of field, square grid. (80-1/39)

for this reason that we consider 400 gal/min excessive. Even the 300 gal/min figure is not quite certain since the estimates of mean grain size are from the recovered Crisfield core sample and we do not know the tortuosity of the aquifer topology. We therefore used the 300 gal/min figure in our preliminary analysis as a reasonably optimistic upper bound.

Fully turbulent flow occurs when the Reynolds number is in the 60 to 600 range. Although none of the numbers in the table would indicate a full turbulence, the 300 gal/min figure is used here in the interest of conservatism. Step pump tests are the only way to predict accurately the onset of turbulent flow. It is recommended that at the time a hydrologic test well is available at Cove Point, the well be drilled and completed as close to a water production well as possible and that step pump tests be performed in addition to normal constant flow pump tests (Ref. 4).

REFERENCES

1. K. Yu, "Crisfield, Maryland Well Characteristics Determined Using All Test Data," JHU/APL, QM-80-056, 20 Mar 1980.
2. A. C. Gringarten and J. P. Sauty, *J. Geophys. Res.*, Vol. 80, 1975, p. 4956.
3. F. C. Paddison, "Size Distribution of Sand Particles, Crisfield Well," JHU/APL QM-79-249, 6 Nov 1979.
4. "Comments on Columbia LNG Corporation Considerations for Use of Geothermal Energy," JHU/APL Lett. CQO-2851, 28 Mar 1980.

GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE § 20

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

R. von Briesen

January-March 1980

TECHNICAL ASSISTANCE – GEO- THERMAL SPACE HEATING OF THE PITTSVILLE MIDDLE SCHOOL, WICOMICO COUNTY, MD.

APL is one of several centers in the United States supported by DOE/DGE that are providing technical assistance on the application of geothermal energy.

At the request of the Wicomico County Board of Education, APL is evaluating the feasibility and economics of converting the heating system of the Pittsville Middle School to use geothermal energy. The school is being renovated extensively, and a new building will replace most of the existing school complex.

DISCUSSION

The feasibility study has been completed and documentation is in process. The conclusions have shown that, for aquifer conditions similar to the Crisfield, Md., geothermal well and for the anticipated water temperature of 127°F (Ref. 1), the 48 500 ft² school complex could be heated easily, with geothermal carrying 87% of the yearly heating load. Fossil-fired boilers (operating only on the coldest days) would provide the other 13% of the annual load. The conclusions also show that part of the school complex (the middle wing) is so poorly insulated that its heating load is approximately the same as that expected for the new building, although the new building will be 2.5 times the size of the middle wing.

The study was done for two cases. One looked at the new building only, and the other included the new building and the middle wing. Capital cost recovery time curves as a function of savings in fuel oil cost were made. These curves show a very short payoff time when the middle wing is included with the new building, which suggests conservation measures may be warranted.

Figure 1 shows the payoff time for the school complex, assuming a conventional interest rate for school construction of 7%, the current cost of fossil fuel of approximately \$1.00/gal, the escalation rate of fossil fuel in the future, and county, state, or federal (i.e., National Energy Act Conservation grants, Ref. 2) assistance as variables. The final report will show the effects of other interest rates (e.g., FHA) on the payback period. It will also discuss the new construction and older middle school economics, treated separately.

It is concluded that geothermal space heating can be cost-effective and should be considered. DOE's Eastern Geothermal Drilling Project

Fig. 1 Capital recovery time for new construction and middle wing of Pittsville Middle School. (80-1/40)

(Ref. 3), its later user-coupled resource confirmation program (Ref. 4), the FHA (Ref. 5), or DOE's Loan Guarantee Program (Ref. 6) are all potential methods to confirm the presence and characteristics of the resource without serious financial risk to Wicomico County.

REFERENCES

1. S. S. Dashevsky, "Estimation of Subsurface Temperature Beneath Pittsville, Maryland," VPI&SU Lett., 27 Nov 1979.
2. Technical Assistance and Energy Conservation Measures Grant Programs for Schools and Hospitals and Buildings Owned by Units of Local Government and Public Care Institutions, DOE Rules and Regulations, Part II.
3. "Eastern Geothermal Drilling Project, Solicitation for Cooperative Agreement No. DE-RD-80ID12132," closing date 9 Jun 1980.
4. "DOE User-Coupled Resource Confirmation Program" (to be issued).
5. "Farmers Home Administration, Community Facilities Loan," FHA Instructions 1942-A, and "Business, Industrial Loan, and Loan Guarantee Loans," FHA Instruction 180-E.
6. "DOE Loan Guarantee Program Established by the Enactment of the Geothermal Energy Research, Development and Demonstration Act of 1974," P.L. 93-410, 3 Sep 1974.

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GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE §21

Development of Geothermal Energy in the Eastern

U.S. ZJ7AEO

Support: DOE/DGE

F. K. Hill

January-March 1980

TECHNICAL ASSISTANCE - GEO- THERMAL SPACE HEATING FOR THE NAVAL AIR REWORK FACILITY, NAVAL AIR STATION, NORFOLK, VA.

APL is one of several centers in the United States supported by DOE/DGE that are providing technical assistance on the application of geothermal energy.

At the request of William Maxwell of NARF, with the concurrence of DOE/DGE and the U.S. Naval Facilities Engineering Command, APL agreed to analyze geothermal use for space heating for a large new building at NARF, the Electronics Integration Hangar (building LP-167). The building was selected because it has a self-contained fossil-fuel heating system, it would serve to illustrate how geothermal energy of rather modest temperature (i.e., 107°F) could be applied, and because the experiment would determine the potential for geothermal energy at that locale.

The expected temperature at the bottom of the sedimentary sequence is 107°F under Sewell's Point, Va. (Ref. 1).

DISCUSSION

At the request of the Industrial Engineering Department of NARF, DOE/DGE and APL personnel visited NARF in Norfolk, Va., and agreed on a plan to conduct a limited feasibility study of the use of geothermal energy (Ref. 2). An evaluation of the cost of heating one of the aircraft hangars at NARF by a geothermal well is in process. The capital and operating costs are to be compared with the existing oil-fired hot water heating system. The hangar's peak heating requirement is equal to two to three times the thermal output conservatively estimated to be available from a 2500 ft well delivering 225 gal/min of water at a temperature of 107°F with a 1500 ft maximum drawdown. The heating load in the hangar is intermittent (both annually and diurnally), while the well can produce continuously. Therefore, a thermal storage reservoir could be used to permit a heat output of three to four times the well delivery rate for intermittent high-demand periods.

The warm water output from the heat exchanger is not sufficient to heat buildings directly using the existing hot water radiation system. The percentage of annual heating that could be carried by geothermal energy could be increased by floor radiant heat; i.e., by installing a 6 in. layer of concrete over the existing floor with a network of embedded pipes through which the warm heat exchanger water could be continuously circulated. This would not provide the high heating rates needed in the coldest weather, so the existing hot water boiler and radiation system would be retained for peak heating.

Alternatively, the existing hot water radiating system in the building can be used by adding a heat pump to raise the temperature of the working fluid to 180°F. The heat pump may operate either directly, with the heat delivered by the geothermal heat exchanger, or from the storage reservoir, depending on the heat load called for.

It is assumed that the geothermal water, after passing through the heat exchanger, would be at a temperature of 85°F. The use of a second heat pump to extract additional heat from this waste water before reinjection could double the geothermal energy output.

It is evident that several options are available by using one or more heat pumps, a storage reservoir of modest capacity, geothermal production at least 20 h/day, and the addition of oil-fired burner hot water as a peak load supply. The purpose of this evaluation is to identify the most cost effective system and to determine if the capital costs can be amortized in a reasonable time by a saving in the operating costs. An alternative method of increasing the thermal delivery is to provide a second well. Although the capital costs to drill, prepare, and assay a second well are significant, this has been considered as a possible approach. The basic problem of the use of low-temperature water remains; the thermal potential is lower than necessary to produce the heat needed for an effective radiation system.

The various options possible for using geothermal energy for heating are illustrated in Figs. 1 through 4.

Fig. 1 Direct use of geothermal energy to heat building LP-167 using radiant floor radiation. (80-1/41)

Fig. 2 Heating of building LP-167 with geothermal energy boosted by a heat pump and using the existing radiation. (80-1/42)

Fig. 4 Heating of building LP-167 with a system similar to that in Fig. 2, but with thermal storage. (80-1/44)

Fig. 3 Heating of building LP-167 with a system similar to that in Fig. 2, but with a second heat pump to recover additional geothermal energy prior to reinjection. (80-1/43)

FUTURE PLANS

The performance, estimated cost, and payback period for each system will be developed. To illustrate the sensitivity of the various potential systems, water at higher and lower temperatures than the 107°F, as well as increased well flow rate and less drawdown, will be examined.

REFERENCES

1. Telephone conversation between F. C. Paddison, JHU/APL, and Samuel Dashevsky, VPI&SU.
2. R. von Briesen and F. C. Paddison, "One Hundred Hour Geothermal Request from the Naval Air Rework Facility (NARF) in Norfolk, Virginia," JHU/APL QM-80-034, 20 Feb 1980.

**GEOHERMAL ENERGY DEVELOPMENT PLANNING AND
TECHNICAL ASSISTANCE § 22**
Development of Geothermal Energy in the Eastern
U. S. ZJ7CQO
Support: DOE/DGE
K. Yu and F. C. Paddison
January-March 1980

TECHNICAL ASSISTANCE — APPLICATION OF GEOTHERMAL ENERGY FOR MARICULTURE

APL is one of several centers in the United States supported by DOE/DGE that are providing technical assistance on the application of geothermal energy.

The Ceda Corporation of Annapolis, Md., requested technical assistance in the evaluation and planning of the possible use of geothermal energy in a mariculture facility currently being planned. The facility is to be located in Talbot County on the Eastern Shore of Chesapeake Bay. With geothermal energy, it is hoped that the facility will grow oysters and clams on a year-round basis, both for seed stock and to maturity.

DISCUSSION

According to Ceda personnel, the harvest of oysters and clams has steadily declined for nearly a century due to over-harvesting, a disease called MSX, and an increase of freshwater runoff into Bay waters. Since these shellfish grow significantly only during the summer months, it is hoped that with a geothermally heated mariculture facility the production time can be cut by a factor of 2 or more (3 to 5 years cut to 1.5 years) and, more important, there can be a improvement in the larvae survival rate.

It is estimated that approximately 200 gal/min of warm saline water is needed in the facility. The water is to be provided by mixing Bay water with geothermal water. An estimate for space heating the planned facility (a 40 by 25 ft building) was also desired.

This report presents the geothermal-water pumping rate schedule required for near-optimum temperature and salinity, as well as estimates of the annual pumping cost as a function of pumping rate and additional pumping that will be required for space heating. Finally, the cost of the geothermal system is compared with the present fossil-fuel version.

Resource Assumption. The only resource information available in the mid-Atlantic Coastal Plain has been obtained at the Crisfield well. We assume the characteristics of the postulated resource (the aquifer) to be the same as those proven to exist at the Crisfield well (Ref. 1).

The result presented here can only be taken as an illustration of the analyses and planning required to demonstrate the feasibility and economics of the geothermal application to mariculture. At this time, no resource data exist for locations at or near the planned facility. For a more definitive analysis, a test well is mandatory to confirm the existence of the resource and to obtain the necessary resource data.

Our assumptions are as follows:

Depth to basement	3000 ft
Sealed horizontal infinite aquifer	
Assumed aquifer transmissibility (T) (Ref. 1)	0.50 cm ² /s
Assumed storage coefficient (S) (Ref. 1)	3.9 × 10 ⁻³
Average surface temperature	65°F
Average temperature gradient	1.70°F/100 ft
Water temperature (at 3000 ft)	115°F
Salinity	7‰
Initial head	0 ft

Head Loss, Well Life, and Pumping Cost. It is assumed that the well is completed with gravel pack and screen, with the gravel outer radius (r_e) of 10 in. The drawdown associated with various constant pumping rates is shown in Table 1 and Fig. 1 as a function of time.

Table 1

Drawdown at various pumping rates.

Time (yr)	Drawdown (ft)					
	100*	125	150	175	200	225
0.1	466	583	700	816	933	1050
0.5	519	649	779	909	1040	1170
1	542	678	813	949	1080	1220
2	565	706	848	989	1130	1270
5	595	744	893	1040	1190	1340
10	618	773	927	1080	1240	1390
20	641	801	961	1120	1280	1440
50	671	839	1010	1170	1340	1510

*gal/min

The associated pumping energy required is given in Table 2. (Pump efficiency is ignored; typical efficiencies are about 70%.) The cost of this pumping energy is presented in Fig. 2 in \$/yr, calculated at 5¢/kWh. The 50-year average cost is very nearly the 20th-year cost.

Table 2

Pumping energy.

Year	Pumping energy required (kWh/yr)			
	100*	125	175	200
1	87 000	136 000	266 000	347 000
10	105 000	164 000	322 000	420 000
20	109 000	170 000	334 000	436 000
30	111 000	174 000	341 000	446 000
40	113 000	177 000	346 000	452 000
50	114 000	179 000	350 000	457 000

*gal/min

Another quantity of interest is the well life. A reasonable definition for the life of a geothermal well may be taken as the time at which

Fig. 1 Well drawdown versus time at various pumping rates. (80-1/51)

Fig. 2 Pumping cost versus time at various pumping rates. (80-1/52)

the drawdown is such that the energy production cost (the penalty) equals the geothermal energy production (the benefit). Although we have not calculated this carefully, for a low temperature hydrothermal resource on the East Coast it may be taken as the time to reach, for example, 200-ft drawdown. Since there are many other factors not considered here, in Table 3 we will give the drawdown time (i.e., well life) as a function of the maximum head loss.

As can be seen from Table 3, the life of a well is heavily dependent on the maximum acceptable head loss level and the water withdrawal rate. Thus, a larger water withdrawal involves at least two penalties: a drastically reduced well life and a substantially increased pumping cost per unit quantity of energy produced.

Table 3

Time to given drawdown.

Drawdown (ft)	Drawdown time (yr)				
	100*	125	150	175	200
500	0.3	0.01	0	0	0
750	550	5.8	0.3	0.03	0.01
1000	1.1×10^6	2500	44	2.4	0.3
1250	2.1×10^9	1.1×10^6	6900	190	12
1500	$>10^{10}$	4.7×10^8	1.1×10^6	14 000	550
2000	$>10^{10}$	$>10^{10}$	$>10^{10}$	8.3×10^7	1.1×10^6

*gal/min

Note: The large numbers are not to be believed literally, since the aquifers are never infinite. But the recharge effects, neglected here (and totally unknown as to where, how much, how fast, etc.), can help very much. This table, however, serves to illustrate the need for a very careful resource management.

Oysters - Growth/Survival Data. For ease of reference, we include here the data provided by William Carroll of the Ceda Corporation as Figs. 3 and 4. We have been informed that the data for clams are the same as those for oysters. In Figs. 5 and 6, we have combined the survival and the growth in length into what may be called the "net (weight) growth," where

$$\text{net growth} = \text{survival fraction} \times \left(1 + \frac{\% \text{ growth}}{100}\right)^3.$$

For the salinity (Fig. 7), the data were extrapolated to 3.5‰ under the assumption that the natural habitat (open ocean) salinity would not damage the shellfish.

Further, we have taken the liberty of drawing a line through the 75% value of the smoothed peak for each. In what follows, the water mixing rates chosen will be based upon an attempt to keep the temperature and salinity within the 75% (maximum) range.

Seasonal Geothermal Water Mixing Ratio. As stated previously, the assumed characteristics of the geothermal water are a temperature of 115°F (= 46°C) and a salinity of 7‰.

From the data provided by Mr. Carroll, we have the following variations in the neighborhood of the intended facility:

Fig. 3 Pumping rate versus well life at various drawdown values. (80-1/53)

Fig. 4 Survival and growth of larvae of *O. edulia* (European oyster) at different temperatures. (80-1/54)

Fig. 5 Effect of salinity at 325°C on embryonic development of American oysters and on survival and growth of the larvae. (80-1/55)

Fig. 6 Temperature effect on the weight gain of oysters. (80-1/57)

Table 4
Mixture temperature and salinity.

Spring			Summer			Fall			Winter		
x	T	S	x	T	S	x	T	S	x	T	S
1.0	28.0	38.5	1	36.3	41.5	1.0	28.5	41.5	1.0	23.5	38.5
1.5	24.4	32.2	1.5	34.3	35.8	1.5	25.0	35.8	1.25	21.0	35.0
2.0	22.0	28.0	2	33.0	32.0	2.0	22.7	32.0	1.5	19.0	32.2
2.5	20.3	25.0	3	31.4	27.3	2.5	21.0	29.3	1.75	17.4	29.9
3.0	19.0	22.8	4	30.4	24.4	3.0	19.8	27.3	2.0	16.0	28.0
3.5	18.0	21.0	5	29.8	22.5	3.5	18.8	25.7	2.25	14.9	26.4
4.0	17.2	19.6	6	29.3	21.1	4.0	18.0	24.4	2.5	13.9	25.0
4.5	16.6	18.5	8	28.7	19.3	4.5	17.4	23.4			
5.0	16.0	17.5	10	28.3	18.2	5.0	16.8	22.5			
5.5	15.5	16.7	12	28.0	17.4	5.5	16.4	21.8			
6.0	15.1	16.0	15	27.7	16.6	6.0	16.0	21.1			

Note: T is the temperature in °C and S is the salinity in ppt.

	Average water temperature (°C)	Salinity (ppt)
Spring	10	7.0
Summer	26.5	13
Fall	11	13
Winter	1	7.0

We now define our variable, the geothermal water mixing ratio, x, as

$$x = \frac{V_B}{V_{GT}}$$

where V_B is the volume of Bay water in the mix and V_{GT} is the volume of geothermal water in the mix.

In Table 4, we give the temperature and salinity of the mixture parametrically for various values of x.

Comparing these with Figs. 5 and 6, we may choose the values shown in Table 5.

Table 5

Recommended mixture ratio and resulting parameters.

Season	x	T	S	V_{GT} (gal/min)
Spring	2.0	22.0	28.0	66.7
Summer	15	27.7	16.6	12.5
Fall	2.5	21.0	29.3	57.1
Winter	1.5	19.0	32.2	80.0

In Table 5, V_{GT} is the volume of geothermal water that must be pumped per minute in order to provide the mixture of 200 gal/min mixed at the ratio x. Further refinement can be made to maximize the net profit while maintaining an acceptable well behavior, if adequate data are available. However, it does not appear worthwhile at this time.

Space Heating Requirement. Further, in winter, the geothermal water can be used for space

Fig. 7 Salinity effect on the weight gain of oysters. (80-1/57)

heating of the facility building (40 by 25 ft). If we can extract a temperature difference, ΔT , of 15°F, we get:

Outside temperature	0°F
Interior temperature	65°F
Heating need	0.615 Btu/h-°F-ft ²

So, for a building 40 by 25 ft, we need 40×10^3 Btu/h, which translates to 5.3 gal/min. If ΔT is 10°F, it increases to 8.0 gal/min.

Thus, a 100 gal/min pump will take care of both the mariculture need (80 gal/min) and the space heating need (6 to 8 gal/min).

Recommended Pumping Rates and the Cost Estimate. The seasonal pumping rates combining the mariculture need and the space heating needs are shown in Fig. 8.

Actually, the detailed pumping costs will require a separate calculation; for our purpose, it is sufficient to take one-half of the constant pumping rate cost. This gives approximately 57 600 kWh/yr, or \$2880/yr at 5¢ per kWh (with 70% pump efficiency).

The well and other system costs may be estimated as follows:

Well	\$ 75 000
Well analysis	20 000
Variable speed pump, surface motor driven	22 000
Miscellaneous	15 000
Total	\$132 000

The cost of the heat exchanger (for space heating) was considered negligible compared with other elements. In the above we chose a pump driven by a surface motor, since its life expectancy in geothermal application is expected to be considerably longer than that of a submerged pump. Further, its annual maintenance cost is superior (estimated to be about 15% of the pump cost, i.e., \$3300/yr).

To summarize, the estimated costs are as follows:

Initial capital layout	\$132 000	
Annual maintenance	3 300	} \$6200
Annual pumping cost	2 900	

Cost Estimate for an Oil-Heated System. For comparison, we considered an oil-heated system providing exactly 200 gal/min at the same temperature as the mixture of geothermal water and Bay water that would be provided by the geothermal system. To be conservative, we will take the furnace/heat exchanger efficiency to be 100% (usually it is about 70%). We then get an estimated fuel consumption of 12 500 gal/yr. For the space heating, another 800 gal/yr will be needed. The total fuel consumption will thus be 13 300 gal/yr.

Now, during the winter months, the furnace must furnish (on the average) 3.25×10^6 Btu/h just to heat the 200 gal/min of water. Assuming that a pair of 2.5×10^6 Btu/h furnaces are installed to take care of various needs, and estimating the cost of each unit (installed) as \$37 500, we get an estimate of \$75 000 for the furnaces. Thus, for the oil-based system, the cost summary is:

Initial capital expenditure	\$75 000
Annual fuel use (13 300 gal at \$1.00/gal)	13 300 (100% efficient energy coupling)

At 70% efficient energy coupling, the fuel expenditure increases to 19 000 gal/yr.

COMPARISON

The annual cost of the two systems can now be compared. We start with the annual operating costs. The following assumes zero inflation. Actually, the cost of various energy-intensive products tracks the energy price. Consequently, their relative cost should remain fairly constant even with inflation and escalating oil cost. The pump efficiency has been assumed to be 70%. The price of oil is estimated at \$1.00/

Fig. 8 Recommended seasonal pumping rates. (80-1/58)

gal. The annual operating cost for the two systems is as follows:

Geothermal	\$ 6 300
Oil (70% efficiency)	\$19 000

In a cost comparison of the two systems during the period of capital recovery, although a detailed consideration with various assumptions can be made, the fuel cost in the oil-based system is so high that oil price will dictate the cost figure. A crude estimate, ignoring inflation, shows that the two-system cost will be essentially the same during the capital recovery period (assumed to be 15 years).

It should be noted that the above comparison is based only on the temperature and excludes any consideration of the salinity.

This work is documented in Ref. 2.

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GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE

§ 23

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

W. J. Toth

January-March 1980

GEOHERMAL ENERGY MARKETS ON THE ATLANTIC COASTAL PLAIN — MARKET DEFINITION

A Geothermal Energy Market Study (GEMS) is being performed in four of the six potential geothermal resource areas on the Atlantic Coastal Plain. 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 meeting these energy requirements with the type of geothermal resources expected on the Atlantic Coastal Plain; (c) to estimate the cost of geothermal energy for potential applications; and (d) to estimate the penetration of geothermal energy into the energy markets that are technically and economically attractive. APL is conducting the first two efforts, and the Center for Metropolitan Planning and Research of The Johns Hopkins University (Metro Center) is assisting in the last two efforts, which are reported in Sections 24 and 25.

SUMMARY

The markets for thermal energy below 250°F have been defined and surveyed. The final report has been prepared for the four resource areas shown in Fig. 1; it will be available shortly. Extension of the GEMS efforts to South Carolina and Georgia should begin by summer.

Fig. 1 The four areas of interest in the Atlantic Coastal Plain. (79-4/40)

DISCUSSION

All data on the thermal energy demands below 250°F have been reviewed for each resource area and the findings are summarized in Table 1. Table 2 presents the results in terms of equivalent barrels of oil (5.6×10^6 Btu per barrel).

As these data illustrate, residential and commercial space and water heating are the largest of the demands. However, meeting these demands requires large, relatively expensive district heating systems that are not widely used in the United States at present. In addition to requiring a change in heating supply methods, such systems are not universally applicable. Reference 1 indicates that only a fraction of the demand (less than 10% on Delmarva) can be satisfied by such systems because, on the basis of

Table 1

Current demands (in units of 10^{11} Btu/yr) for thermal energy below 250°F in the four resource areas.

Resource area	Residential and commercial	Military	Agricultural	Industrial
Southeastern New Jersey	307.5	25.0	6.0	9.3
Delmarva Peninsula	135.2	8.2	17.8*	18.4*
Norfolk area	207.9	96.5	1.0	9.5
Eastern North Carolina	83.8	15.1	10.8	13.8

*If large grain-drying facilities and hatcheries are included in industry instead of agriculture, the respective totals become 12.6 and 23.6×10^{11} Btu/yr.

Table 2

Current demands (in millions of equivalent barrels of oil per year) for thermal energy below 250°F.

Resource area	Residential and commercial	Military	Agricultural	Industrial	Total
Southeastern New Jersey	5.49	0.45	0.11	0.17	6.22
Delmarva Peninsula	2.41	0.15	0.32	0.33	3.21
Norfolk area	3.71	1.72	0.02	0.17	5.62
Eastern North Carolina	1.50	0.27	0.19	0.25	2.21
Total	13.11	2.59	0.64	0.92	17.26*

*Equivalent to about 47 250 barrels of oil/day.

economics, moderate to high population densities are required.

Water and space heating for the military represents the second largest category. District heating systems would be required, but nearly all of the military demand would probably be satisfied because the military population is reasonably well concentrated. However, in addition to the institutional problems that may be encountered, there may arise a major economic problem in retrofitting the prevalent steam systems in current use. Furthermore, so far as is known, most of the military installations are not collocated with resources that have temperatures high enough to meet the entire demand.

In general, agricultural demands are even more diffuse than those of residential areas. Except for some poultry hatcheries and the large centralized grain-drying facilities of Delmarva, satisfying agricultural demands with geothermal energy is not likely to be economically feasible in current locations. If future demands can be concentrated or if several demands can be combined at one location, the economics can become more attractive.

Heat demands for industrial processes offer the best prospects for the near-term use of geothermal energy. Typically, most industries run year-round; hence they offer a high utilization factor that, in turn, reduces overall energy costs. In many cases, retrofit costs for existing plants should be minimal. The largest and one of the best suited industries on the Atlantic Coastal Plain is the large Delmarva poultry industry, which comprises most of the agricultural and about half of the industrial demand on Delmarva. In addition, many of the poultry plants are believed to be collocated with compatible geothermal resources.

Based on the large industrial demand, the centralized crop-drying demands, and the potential for compatible resources, the Delmarva Peninsula appears to be the most attractive of the four resource areas for future commercialization efforts by DOE. Southeastern New Jersey, which has a total demand that is only slightly

lower than that of Norfolk, has slightly higher potential resource temperatures than Norfolk (Ref. 2). While the populous Atlantic City area seems to be collocated with resources that provide temperatures that are reasonable for use, most of the industrial demand lies inland, where resource temperatures are probably lower. Norfolk, which has the highest overall demand, is expected to have resources only in the 100 to 120°F range; hence retrofit costs will be greater, making the use of these resources marginally economical or uneconomical for many applications. Eastern North Carolina has attractive potential resources but little demand in the areas that offer the best potential.

In summary, the GEMS results to date indicate that the Delmarva Peninsula is the most attractive resource area. Southeastern New Jersey is the second best because some of its demand is collocated with warmer resources and land is available in these areas for future industry. Norfolk is probably a reasonable third choice because of the large demand and the potential use of the lower temperature resources in the area for water-referenced heat pumps. Eastern North Carolina, while it has some of the best resources on the Atlantic Coastal Plain, is rather remote from population and industrial centers and is not likely to attract either one.

FUTURE PLANS

Energy survey efforts should begin in South Carolina and Georgia by the summer of 1980.

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GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE §24

Development of Geothermal Energy in the Eastern
U. S. ZJ7CQO

Support: DOE/DGE

W. F. Barron (Metro Center), W. J. Toth (APL),
and B. Nilo (Metro Center)

January-March 1980

GEOHERMAL ENERGY MARKETS ON THE ATLANTIC COASTAL PLAIN — ECONOMIC MODELING

A computer model called GRITS (Geothermal Resource Interactive Temporal Simulation) was developed to estimate costs of geothermal energy for various applications and for various resource, market, and financial conditions. The discounted revenue and the cost streams, both of which are needed to determine the net present value of the system, are estimated. The GRITS model is a logical development from the simpler GREES (Geothermal Resource Economic Evaluation System) (Ref. 1) reported in previous Quarterly Reports.

GRITS (Ref. 2) is being used to estimate costs and to determine areas and conditions where geothermal energy is economically viable, and its results are being compared with other economic estimates to assess its credibility.

SUMMARY

Current work with the GRITS model includes extensive sensitivity analysis of the impact of resource, demand, and financial conditions on the cost of geothermal energy. Results of this analysis will be included in a report on the economics of direct applications of low-to-moderate-temperature geothermal resources. A second area of investigation is the evaluation of the potential for residential applications of geothermal energy in the southern portion of the Atlantic Coastal Plain. Preliminary results indicate that most areas in this region have high proportions of housing units that are unattractive for conversion to geothermal energy (e.g., room or electric baseboard heaters). The combined effect of milder climate and the types of heating systems appears to make residential applications unattractive except in areas of new housing or very favorable resource conditions.

DISCUSSION

Continued uncertainty about the actual resource characteristics on the Atlantic Coastal Plain makes definitive economic assessments of these resources difficult. However, it is possible to gain important insights into the importance of specific conditions by examining the impact of a wide range of conditions on calculated costs. A limited sensitivity analysis of this type was conducted with the GREES model. Over the past year, considerable effort was devoted to improving the formulations in the GRITS program and making it applicable to a wider range of resource conditions and economic analyses. Table 1 shows the current resource, demand, and financial parameters that may be determined by users of the GRITS model.

Fig. 1 Average costs as a function of utilization level. (80-1/46)

Since there are no current plans for major additional modifications to the model, it is possible to begin the systematic investigation of the functional relationships between specific parameters and the cost of energy. When the forthcoming report on GRITS (Ref. 2) is complete, a user will be able to determine how sensitive the results of an analysis are to the specific parameter value used. For example, it is useful to know the impact of a cost calculation of a 5 to 10% error in the estimated use of the well. Figure 1 shows average costs as a function of utilization level in a process heating application of two hypothetical reservoirs. As shown in Fig. 1, average costs for higher quality resources become relatively insensitive to increases in utilization beyond about 45%. However, as utilization falls below about 25%, average costs rise steeply with even minor decreases in utilization. This type of information is useful for determining usage and permits the marginal benefits of increased usage to be analyzed. Several costs are not included in GRITS, e.g., the cost of organizational adjustments of adding an additional shift or additional drawdown. These costs, external to the model, are likely to be highly application-specific, but where such information is available, it could be compared to the marginal benefit function derived from Fig. 1 to determine the optional utilization level.

As part of the demand analysis, census data for all tracted areas in the southern Atlantic Coastal Plain were examined. This investigation indicates that many of the housing units in densely populated areas are unattractive for community heating because they lack a forced air or hot water heat distribution system. In many areas, the percentage of housing units with prohibitive conversion costs was typically above 50% and ranged as high as 70 to 80%.

Weather data for Charleston, S.C., were used in GRITS to estimate the effect of lower heating loads on the economic viability of community heating systems in this region. While the lower

Table 1
User-specified parameters in GRITS.

Resource conditions	Demand conditions	Financial conditions
Number of production wells Production well depth Number of reinjection wells Reinjection well depth Wellhead temperature Initial Functional form of change Reinjection temperature Average annual drawdown Initial Functional form of change Maximum flow rate per well Initial Functional form of change Transport distance	Process heating specific Industrial utilization factor Residential and commercial specific Area under consideration System design temperature Rate of installation for distribution system Housing type Market saturation level Rate of market penetration Hookup cost for housing unit Number of types at commer- cial buildings Average floor space for building of each type Average heat demand for building of each type Number of buildings of each type Rate of commercial market penetration Average cost per hookup of commercial building Length of commercial dis- tribution system	Economic accounting method Energy selling price Initial Trend Length of evaluation period Length of resource assessment period Annual cost of resource assess- ment Well cost adjustment factor Heat exchanger adjustment fac- tor Storage tank capacity Capital equipment lifetime Discount rate Interest rate Inflation rate Calculation in real or nomi- nal dollars Cost of electricity Initial Trend Cost of peaking fuel Initial Trend Operating and maintenance costs Boiler cost Distribution system cost per mile

loads alone do not preclude community heating systems, the combined effect of the conversion costs for most homes and the lower loads virtually eliminates the South from consideration for community heating. If resource conditions in the South prove favorable, the load for a community heating system could be raised significantly by air conditioning. However, the absence of central air distribution systems would remain as a major obstacle. This study indicates that the economic evaluation of geothermal energy in the South should concentrate on potential industrial applications.

FUTURE PLANS

The report on GRITS will be issued during the next quarter. A summary paper is planned to

be submitted for the 1980 annual meeting of the Geothermal Resource Council.

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GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE § 25

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

A. Goodman and W. Barron (Metro Center)

January-March 1980

GEOHERMAL ENERGY MARKETS ON THE ATLANTIC COASTAL PLAIN — MARKET PENETRATION

DOE is assessing the potential impact of geothermal energy and is developing plans to ensure its maximum use. DOE has asked APL to develop a methodology estimating the energy market penetration of moderate-temperature geothermal resources on the Atlantic Coastal Plain.

SUMMARY

The investigation of economic issues related to the penetration of a local market service area by a geothermal community heating system has continued in two areas. The first involves investigation of the literature on asset investment decisions. Among the works reviewed, Ref. 1 has potentially useful implications for the theoretical approach used in the market penetration model. The second area involves the use of the GRITS model to quantify the benefits to the utility of more rapid rates of market penetration (see Section 24 of this Quarterly Report). Optimal incentive schemes to stimulate market penetration require an understanding of the factors relevant to investment decisions faced by potential customers and of the monetary advantages to the utility of higher energy sales and more efficient use of its large fixed plant.

DISCUSSION

The theoretical model of geothermal market penetration developed in Ref. 2 evaluates the decision by a potential customer based on the projected operating cost (fuel price) differential between geothermal and traditional fuel, and the difference in the capital outlays required to use each system. While the operating cost differentials and the cost of converting to geothermal will differ greatly depending on local conditions, the cost of maintaining the existing heating system is expected to vary systematically throughout the population of potential customers. This systematic variation in the size of the capital cost differential provides insights into the size of the incentive required by each customer to make the switch to geothermal profitable.

Reference 1 evaluated the asset replacement decision with respect to the value of the existing asset and the operating cost differential between the new and existing asset. Using the same approach, it is possible to estimate the price differential between geothermal energy and traditional fuel required to make the conversion profitable. Since the size of this required differential varies with the value (age) of the

existing heating system, the approach has direct implications for geothermal pricing and incentive policies.

This analysis can be used to discuss the market penetration of a new resource. Assume that all homeowners have furnaces of vintage A that originally cost \$2000. Furnaces last 20 years and there are equal numbers of furnaces at each age. Assume now that vintage B furnaces are introduced at the same cost (\$2000), but they produce more heat per dollar of fuel than do the old ones (i.e., they are more efficient). The question to be answered is who will buy the new furnaces (or alternatively, how much more efficient must the new furnaces be to induce homeowners to switch)?

Homeowners will replace vintage A furnaces with vintage B furnaces when the former are ready for scrap. However, if the present vintage A furnace is less than 20 years old, it still has a useful life. By way of analogy, consider the purchase of a new car. When this occurs, the old one is sold to someone else for its value in use. A furnace cannot generally be resold even though it is still operational; in a very simple model, the vintage A furnace will sit idle next to the vintage B furnace, even though the former still has useful life. In terms of market penetration, it is intuitively clear that, if purchasing a new car meant that the old one had to be left in the driveway without being driven, the rate of market penetration of any new car would be substantially lower than is generally the case. This, in fact, is the problem with the market for alternative heating systems.

Clearly, then, the newer the furnace, the more efficient its replacement must be in order to induce a change. This increased efficiency could be the result, for example, of lower overall fuel cost of vintage B furnaces relative to vintage A furnaces. Figure 1 (prepared by computer modeling) shows that the owner of a brand new vintage A furnace (in the example above)

Fig. 1 Efficiency differential versus age of current furnace. (80-1/47)

will not switch unless the new vintage B furnace is 62% more efficient than the vintage A furnace. This efficiency differential falls to zero by the time the vintage A furnace is 20 years old and has no remaining useful life. Alternatively, this implies that a new energy resource that is 25% more efficient than current resources, for example, will penetrate the market only for those furnaces that are 15 years of age or older.

In fact, the analysis above does not consider the cost of hooking up the new furnace. If it is included, the efficiency differential must be still higher. Current research is considering this problem.

To complement the theoretical work on inducements to potential geothermal customers, the GRITS model is being used to develop estimates of the benefits of changes in the rate of market penetration to the geothermal utility. These benefits will be compared with the cost of the inducements required to accelerate the rate of

market penetration. Current work involves development of appropriate values for the capital outlays, projected prices for geothermal and traditional fuels, and discount rates used in the present value calculations. With this information, estimates will be made of baseline rates of market penetration under various conditions (e.g., in the size of the operating cost differential). The value of the utility of increases in the baseline rates can then be compared to the size of the inducements needed to achieve the faster rate. These efforts will continue in the next quarter.

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GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE § 26

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

H. P. Henderson and J. G. Cherim (Metro Center),

C. S. Leffel, Jr., J. E. Tillman, and F. C.

Paddison (APL)

January-March 1980

LEGAL, INSTITUTIONAL, ACCESS, INSURANCE, AND SIMILAR ISSUES RELATING TO GEOHERMAL ENERGY DEVELOPMENT IN THE EASTERN U.S.

APL assisted the State of Maryland in drafting its Geothermal Resources Act (GRA), which was signed into law in 1978. Since that time, the National Conference of State Legislatures (NCSL) has been contracted by DOE to assist states in considering geothermal legislation by conducting geothermal workshops. APL has participated in these workshops, providing technical and economic information on the potential development of geothermal energy in each state.

DISCUSSION

Delaware. The State of Delaware has drafted a GRA (Ref. 1) for consideration by the 130th General Assembly, 80th Legislative Session. This act has emerged as a clear and thorough piece of proposed legislation where resource ownership "is declared to be sui generis [legally unique] and to be held and owned by the state as a public trust for the people of Delaware." The third of a series of legislative workshops arranged by the NCSL occurred on 17 January 1980 (Refs. 2 and 3).

Maryland. In Ref. 4, the NCSL forwarded to the Maryland Joint Committee on Energy of the Maryland State Legislature a survey of issues regarding geothermal development in Maryland needing legislative attention. These are resource characterization, allocation, power plant siting environmental concerns, district heating, taxation, and leasing. Reference 5 amplifies some of these issues. The report begins with a historical discussion and description of the Maryland GRA of 1978. The GRA was found to be inadequate for the state's needs in several key areas:

1. No assertion of state (or other) ownership was made in the act;
2. The resource was not classified as either water, mineral, or sui generis for ownership purposes;
3. Leasing and district heating considerations were not addressed; and
4. The resource was treated in a manner similar to a water resource, while legitimate concerns for its unique character as an energy source were not considered in the act.

Implementation of the GRA by developing rules and regulations is just beginning. No new legislative efforts are contemplated, and the agency charged with administration of the resource (the Water Resource Agency of the Department of Natural Resources) has placed a low priority on policy development of geothermal energy. Early predilections toward public ownership were not pressed in the legislature, and the State's Attorney's office is not planning to offer an opinion on the ownership question in the near future.

The discussion of alternatives for resource characterization (water, mineral, sui generis) assessed Maryland water law from the standpoint of liability from various sorts of damage. It was found that if the resource was found to be "water," geothermal pumpers would be less likely to be held liable for possible subsidence damages. While some western states have used a sui generis classification, the trend in the case law is toward classification of the resource as mineral, though subject to extensive regulation. If the resource were to be classified as mineral, techniques of regulation involving enforced usage of fields and stringent well-spacing and flow-rate regulation would be required on the state's part, while preserving private development. As water, the state would also have to play an activist role in regulation and would possibly have greater control over the resource from a management point of view. As a sui generis resource, the state would be able to assert ownership most easily, and prompt access schemes might be devised to aid the development of the resource. Full control over aspects of resource management is anticipated under a sui generis classification, and the likelihood of litigation would be reduced.

The report concludes that access to the resource would best be assured by public ownership of the resource. Alternative access schemes are outlined, and a sample public ownership plan is described. The principal advantage of this system is in the developer's right, whether public or private, to assert a right of access to the surface if he holds authorization to extract the underlying resource. Rights of the surface owner are discussed.

District heating potential is briefly discussed in the final section. The report concludes that more research is required in this area.

The preliminary narrative report on ownership and access issues of geothermal resources in Delaware, currently being revised, is complementary to assistance being provided the state by the NCSL Geothermal Policy Project. In a letter to the Chairman of the Maryland Joint Committee on Energy of the General Assembly (Ref. 4), the NCSL Project noted:

The nature of the state's overall relationship to the resource is, however, unclear. This includes questions of ownership. The Act makes geothermal resources at least quasi-public in nature as production is subject to state approval and control. Whether such state control implies ownership of the resource, as well, is uncertain. ... To characterize geothermal resources for purposes of ownership, the legislature may wish to assign the resource to the surface or mineral estate, or to the public domain. ...

The letter also expressed concern with the uncertain nature of the state's dealing with such issues as authorization to public or private entities to implement geothermal district heating, clarification of Maryland tax provisions with respect to geothermal development, and the establishment of leasing procedures for the resource. All of these issues, in turn, are interrelated with the issue of ownership and access to the resource. The preliminary report has sought to complement NCSL work and promote the development of the geothermal resources of Maryland by furthering discussion and presenting recommendations concerning the critical geothermal development issue of resource ownership and access.

The report on small minority business opportunities in direct-use geothermal projects in the East was prepared in January 1980 (Ref. 6). It assessed the federal and state assistance programs available to the small firm in the energy area and briefly attempted to identify sources of local support for such efforts.

Development prospects in geothermal energy for small minority businesses in the mid-Atlantic region were found to be rather minimal. Involvement as a contractor for a municipality in the R&D or planning stages of a project would seem to present the greatest opportunities. A role could also be envisioned in the field of community mobilization, publicity, and the like for metropolitan areas interested in direct-use applications. Whether technical firms exist to do the engineering and environmental studies contracted by DOE in the future (in the minority business sector) is an open question.

While local booster organizations such as the Baltimore Council for Equal Business Opportunities (CEBO) express the desire for closer

involvement than previously, of minority business at the "ground floor" of new energy sources such as geothermal, it seems clear that until the resource has been further proven, small firms in general and small minority firms in particular will be restricted to limited involvement. A note of optimism is that the kinds of federal and state aid that are available to small businesses in this area seem well suited to the possible roles, however limited, that small companies might play in the future.

REFERENCES

1. An Act to Title 7, Delaware Code, Relating to the Establishment of Public Policy in Promoting the Discovery, Development, Production and Regulation of Geothermal Resources in the State of Delaware. Senate bill No. 469, 20 Mar 1980.
2. Summary of Proceedings, Delaware Workshop, 17 Jan 1980, Geothermal Policy Workshop, National Conference of State Legislatures.
3. J. E. Tillman, "Workshop to Draft Delaware Geothermal Law," JHU/APL QM-80-021, 25 Jan 1980.
4. "Legislative Issues Regarding Geothermal Development in Maryland," NCSL Geothermal Policy Project Memorandum to the Maryland Legislative Joint Committee on Energy, 5 Jul 1979.
5. H. Henderson and J. G. Cherim, "Ownership and Related Issues Relating to Geothermal Development in the State of Maryland," JHU Metro Center (draft preliminary report).
6. J. G. Cherim, "Small Minority Business Opportunities in Direct-Use Geothermal Energy Development," Metro Center, The Johns Hopkins University, Baltimore, Md., Feb 1980.

GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE § 27

Development of Geothermal Energy in the Eastern

U. S. ZJ7CAS

Support: DOE/DGE

F. O. Mitchell

January-March 1980

A METHODOLOGY FOR EVALUATING FEDERAL STRATEGIES FOR FUTURE HYDROTHERMAL DEVELOPMENT

In its role of supporting the development of geothermal energy in the eastern United States, APL has developed a methodology (Ref. 1) for evaluating the various potential resource areas in the region. The improvement of the data base for using the methodology is an essential part of the program.

DISCUSSION

A geothermal gradient map (Ref. 2) of Pennsylvania/Western New York, with a scale of 1:1 000 000, has been compared with the data previously cross plotted on the USGS basement map (Ref. 3). Figure 1 shows this information for Pennsylvania. These additional data extend the area of high gradient further eastward into central and eastern Pennsylvania where the sedimen-

tary layering is deeper. The following Pennsylvania counties will be introduced into the revision of Ref. 1:

Bradford	Montour
Butler	Northampton
Carbon	Northumberland
Columbia	Pike
Lackawanna	Schuylkill
Luzerne	Wayne
Monroe	

The map (Ref. 2) with the larger scale may also be of help in selecting sites within a prospective county.

FUTURE PLANS

Additional data have also been received from the Mississippi Geological, Economic, and Topographical Survey (Ref. 4), which provided maps of potential geothermal resources in southern Mississippi. These data are in the form of isothermal subsurface contour maps and will require rather different treatment than the present data that are based on geothermal gradient.

Data for Delaware, Maryland, and Virginia, collected in other projects, are being assembled and, together with the two classes of data discussed above, will be used to update and revise the earlier report (Ref. 1).

Additional data for western and central New York were presented at the Technical Information Interchange Meeting at Coolfont, Berkeley Springs, W.Va. (Ref. 5). These data confirm the higher gradient regions near East Aurora and Cayuga Lake

Fig. 1 Map of Pennsylvania showing areas of high geothermal gradient. (80-1/48)

and suggest including Ontario county in the revision of Ref. 1.

The methodology of Ref. 1 is also being reviewed and compared with the methods of Keeney and Raiffa (Ref. 6), which have been used by T. S. Margulies of APL in another context. These methods may permit the refinement of the assignment of weights to the bases of comparison used for ranking the geothermal prospects.

REFERENCES

1. F. O. Mitchell, "Evaluation of Potential Geothermal Resource Areas," JHU/APL QM-79-163/GT, Jul 1979.
2. "Geothermal Gradient of Pennsylvania/Western New York (Portfolio Map Area No. 3), Geothermal Survey of North America," American Association of Petroleum Geologists.
3. R. W. Bailey and W. R. Muehlenberger, "Basement Rock Map of the United States," U.S. Geologic Survey, U.S. Dept. of Interior G67280, 1968.
4. E. E. Luper, "An Investigation of Potential Geothermal Energy Sources in Mississippi," Final Report, DOE Contract No. EG-77-S-05-5361, Mississippi Geological, Economic, and Topographic Survey, 31 Oct 1978.
5. D. S. Hodge et al., "Preliminary Investigations in New York State," Minutes of the Technical Information Interchange Meeting, Berkeley Springs, W.Va., JHU/APL QM-79-261, Dec 1979.
6. R. L. Keeney and H. Raiffa, Decisions with Multiple Objectives; Preferences and Value Tradeoffs, Wiley, 1976.

GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE

\$28

Development of Geothermal Energy in the Eastern
U. S. ZJ7CQO

Support: DOE/DGE

F. C. Paddison, C. S. Leffel, Jr., W. J. Toth,
R. F. Meier, J. E. Tillman, and A. M. Stone
January-March 1980

COMMENTS ON LIMITED TASKS: GEOHERMAL ENERGY DEVELOP- MENT PLANNING

GEOHERMAL ENERGY AND WESTERN NEW YORK

It was indicated in Ref. 1 that several counties in western New York State may contain hydrothermal resources and also that they were areas of substantial population and industrial and commercial use of energy. As noted in Ref. 2, this same area is of interest to the Eastern Hot Dry Rock Program. Whether a hydrothermal resource exists in New York and northern Pennsylvania depends upon the availability of water at depth. To this end, the Laboratory submitted a proposed study (Ref. 3) to the U.S. Geological Survey Extramural Program to analyze systematically the numerous gas well logs from the area to obtain an understanding of the structural control on permeabilities.

A meeting was held with representatives from the Town of Auburn and Cayuga County, N.Y., on 17 December 1979, to discuss the potential of geothermal energy (Ref. 4). Later, Mayor Paul Lattimore of Auburn contacted APL to request that geothermal energy considerations be a part of the Small Community and Rural Development Policy Program announced on 13 March 1980. Mayor Lattimore asked that we meet with the Division of Gas, Department of Energy Resource Applications, to discuss the feasibility of extending exploratory gas wells in the area to determine temperatures at depth and the availability of water (Ref. 5).

At the request of Mayor Lattimore, a meeting was held at Auburn, N.Y., on 26 March, attended by representatives of the Cayuga County Industrial Development Authority and Planning, New York State Energy Research and Development Authority (NYSERDA), DOE/DGE, Laboratory personnel, and personnel from the Clinton Corn Products Division of Standard Brands, Inc. Standard Brands has a corn wet milling processing plant at Montezuma, a town near Auburn, that produces high-fructose corn syrups. The Montezuma plant is the smaller of two operated by Standard Brands, Inc. The larger is located at Clinton, Oh.

The New York plant uses 13 million gallons of fuel oil annually to reduce 30 000 bushels of corn per day to fructose corn syrup, corn oil, gluten, animal feed, dextrose, and corn starch. The object of the meeting was to discuss the possible use of geothermal energy to replace part of the fossil fuel. The plant uses oil to produce high-pressure, high-temperature steam for heating the steep water in which

corn is softened, for temperature control during enzymatic reduction of starch to fructose, and in the steam injectors used for vacuum concentration of fructose and gluten. The plant is highly automated, with three shifts per day and 26 people per shift. It is located next to the New York State Barge Canal and uses 100 000 lb/h of potable water. There are many steps in the corn wet milling process where water of modest temperatures could be used; however, the most apparent usage was in the preheating of water from the canal.

When the presence of a geothermal resource is confirmed, Standard Brands will consider other possibilities.

The temperature gradients in the Auburn area, defined by the American Association of Petroleum Geologists (AAPG) and the U.S. Geological Survey (USGS) program (Ref. 6) and a later survey by the State University of New York (SUNY) at Buffalo (Ref. 7), indicate a 30 to 40°C/km resource with a basement depth of approximately 1400 m. These combine to predict a temperature at the basement of 51 to 65°C (124 to 150°F). If 70 Btu/lb of geothermal energy were available to preheat the boiler feedwater, approximately 200 gal/min of geothermal water would supply seven million Btu/h, saving over one-half million gallons of oil each year.

Since the most critical parameters are unknown - the availability of water at depth and the permeability and the thickness of sedimentary sequences that carry the water - DOE/DGE requested the NYSERDA to submit a proposal for drilling a deep well in the area for measuring these parameters. The well would also serve as an exploratory well for basement complex analysis. During the week of 1 April, APL will outline hydrologic requirements and the Los Alamos Scientific Laboratory's Hot Dry Rock requirements to NYSERDA. The possibility of extending future exploratory gas wells will continue to be evaluated.

REFERENCES

1. F. O. Mitchell, "Evaluation of Potential Geothermal Resource Areas," JHU/APL QM-79-163/GT, Jul 1979.
2. "Geothermal Energy and the Eastern U.S., A Draft Scenario for Geothermal Energy Development, Hot Dry Rock," JHU/APL QM-77-129-4, Mar 1978.
3. "Extramural Program," JHU/APL Lett. CQO-2779, 12 Dec 1979.
4. F. C. Paddison, "Meeting with Auburn, N.Y. Mayor Paul Lattimore," JHU/APL QM-79-283, 28 Dec 1979.
5. F. C. Paddison and J. E. Tillman, "Meeting with Lucio D'Andrea/DOE, February 29, 1980," JHU/APL QM-80-054, 14 Mar 1980.
6. AAPG/USGS Gradient Maps.
7. D. S. Hodge et al., "Preliminary Geothermal Investigations in New York State," minutes of the Technical Information Interchange Meeting, Berkeley Springs, W. Va., JHU/APL QM-79-261, Dec 1979.

WATER WELL DESIGN FOR COVE POINT, MD., 28 MARCH 1980

Harry Hanson of the Maryland Geological Survey held a meeting with A. C. Schultes and J. F. Schultes of A. C. Schultes and Sons, Inc., a water-drilling corporation, to discuss the suggested design of production and exploratory water wells that would be required for the pro-

posal of the Columbia LNG Corp. to use geothermal water for vaporizing liquid natural gas (LNG) at the Cove Point receiving terminal (Ref. 1). The meeting was also attended by K. Schwarz of the Maryland Geological Survey, C. Carwile of DOE/DGE, and F. C. Paddison and C. S. Leffel, Jr., of APL.

The Schultes Corp. presented suggestions for drilling a 3000-ft production well at Cove Point, using its water completion techniques to maximize water production with minimum head loss while at the same time minimizing the possibility of sand production. The well would begin as a 24 in. well at the surface; after completion, it would be a 10-in. cased well finished at the bottom with a 23-in.-diameter gravel pack. Schultes did not question his ability to complete the well in a manner that would guarantee the required 300 to 500 gal/min if the bottom aquifers can support such a flow.

The possibility of drilling a test well of small diameter was discussed. The State of Maryland is particularly interested in the potable water aquifers (probably down to 1500 ft) and in the location of the potable water/brackish water interface. The State survey would be agreeable to contributing to the cost of the well. The information can presumably be obtained from a carefully designed test well, but it is not clear whether it is possible from the production (or test-production) well as proposed by Schultes. Schultes will examine the mechanics of this requirement. APL strongly urged that any test well be designed so that an accurate determination of the amount of warm water that can be drawn steadily from the lower aquifers can be made. Schultes personnel asserted that alternative well drilling methods and well design can result in a factor of five variation in well productivity. The problem of reinjection and what effect cooling the water would have on its viscosity were discussed.

Schultes agreed to submit cost estimates to Dr. Hanson for a meaningful test well, a production well, and a reinjection well. Heretofore, the best estimate that APL could make on the magnitude of the well-drilling problem is given in Ref. 2; this study was extrapolated from the deep geothermal test well at Crisfield, Md.

REFERENCES

1. "Utilization of Geothermal Energy at Cove Point LNG Receiving Terminal," Columbia LNG Corp. report, Mar 1980. Also Section 16, Quarterly Report, Jan-Mar 1980, JHU/APL EQR/80-1.
2. "Preliminary Results for the Technical Assistance to Columbia LNG Corp," JHU/APL QM-80-047, 10 Mar 1980.

FORMATION OF STATE TEAMS: DELAWARE, MARYLAND, AND VIRGINIA

The objectives and description of the geothermal prospectus for the Delmarva Peninsula, as originally written by APL, were discussed in Ref. 1. The intent is to have the prospectus completed, state-specific, by the three states of the Delmarva Peninsula. Each state would create an organization to complete its prospectus, familiarize itself with the problems of developing geothermal energy, and add the state-specific information not included in the generic prospectus as written by APL. Each state was required to submit a proposal to DOE in order to obtain DOE funding for completion of the state-specific prospectus.

As reported in Ref. 1, Delaware has submitted its proposal. The proposal assigned the responsibility for organizing the state team to complete the prospectus to the State Energy Office. The Virginia proposal, which has not yet been submitted, would assign this responsibility to State Office of Emergency and Energy Services. Each proposal specified that the respective state departments of natural resources, water control, and geology and environmental control would be part of the state team dedicated to the development of geothermal energy. The Delaware proposal has been completed and submitted to DOE.

Maryland and Virginia have not yet organized teams to complete their prospectuses. In this quarter, APL has continued its efforts to interest various departments of the state in geothermal energy development. A letter to the Maryland Energy Policy Office (Ref. 2) resulted in a meeting scheduled for early April 1980, in which APL will present to that office the possible extent of the geothermal resource in the state, the high level of interest in geothermal energy by various county governments and private industries, and the reasons why the state should organize a team to complete the state-specific prospectus and give active assistance to geothermal development.

REFERENCES

1. Section 16, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
2. Letter to D. E. Milsten, Director, Maryland Energy Policy Office, JHU/APL Lett. CQO-2840, 11 Mar 1980.

GEOHERMAL ENERGY AND INDUSTRIAL APPLICATIONS

On 16 and 17 January 1980, W. J. Toth assisted Eric Peterson (DOE/DGE) and Debra W. Struhsacker (Associate Geologist, University of Utah Research Institute Earth Science Lab.) in giving introductory presentations on geothermal energy to the New Jersey headquarters of CPC International, Inc. (Hellman's, Mazola, Skippy, Karo, etc.); Nabisco, Inc.; and Campbell Soup Co. Representatives of Burns and Roe Industrial Services Corp. were also present. The visits to each company consisted of a 45-min tutorial on the mechanics of geothermal energy by Ms. Struhsacker and an overview of DOE programs by Mr. Peterson, followed by a question and answer period in which Dr. Toth answered questions on industrial markets, economics, and APL's technical assistance program. This type of presentation to the management of large, multifacility industries is most important for an effective outreach program in that it educates the upper management in the potential of geothermal energy and may allow them to consider it in both new and existing plants, where they may be collocated with suitable resources.

REFERENCE

1. W. J. Toth, "Geothermal Energy - From Soup to (Pea)nuts and Crackers," JHU/APL QM-80-015, 23 Jan 1980.

AVAILABILITY OF GEOHERMAL LOANS AT LOW INTEREST RATES FROM THE FHA

On 15 January, F. C. Paddison and A. M. Stone visited R. L. Persons and R. Bour at the FHA District Office in Wilmington, Del.

The mission of FHA is to administer the Community Facilities Loan and Business and In-

dustrial Loan Programs, which are to provide low cost capital financing for municipal, industrial, and farm entities in rural America. The former program is available to public entities, such as municipalities, counties, special districts, and nonprofit corporations for such purposes as buildings, roads, bridges, and other improvements. The loans have a maximum term of 40 years at 5% interest. Large portions of the Delmarva Peninsula qualify under the rules as rural areas, and geothermal projects in these areas would appear to qualify for low-cost, long-term borrowing from the federal government. The viability of each project, the availability of funds, and the relative contribution of the project to the economic vitality of the region are taken into account.

The Business and Industrial Loan Program is available for business and industrial development related to high population density cities with a population of 50 000 or more. Loans are guaranteed up to 90% of the principal.

Further information will be found in Ref. 1.

REFERENCE

1. F. C. Paddison and A. M. Stone, "Loans Available from the Farmers Home Administration," JHU/APL QM-80-053, 14 Mar 1980.

GASOHOL WORKSHOP

FHA conducted a series of workshops on the production of ethanol to be mixed with gasoline for gasohol production. The workshop was to inform FHA personnel and others interested in the mechanics and economics of ethanol production so that they could judge loan applications to be used for procuring or building plants. The course distinguished between sugar, starch, and cellulose as feedstock. An APL representative attended the 16 January 1980 workshop in Atlanta, Ga. Reference 1 is the workshop notes; Ref. 2 is the APL trip report.

In summary, the simplest plant, the best economics, and the best energy balance are achieved with high sugar content materials, i.e., molasses, whey, sugar beets, and sweet sorghum. It should be mentioned that the energy balance is positive only with very careful accounting, and there is much controversy as to whether it is positive or negative. The manufacture of ethanol is an ideal application for solar, geopressured, and hydrothermal energy. In the case of hydrothermal energy, the resource temperature either must be hotter than 212°F to use existing distillation towers or, if a cooler resource is available, the system must use vacuum distillation with a modified distillation chamber.

REFERENCES

1. "Alcohol Fuels Workshop," Farmers Home Administration and Economic Development Administration, Jan 1980.
2. F. C. Paddison, "FHA/EDA Alcohol Fuels Workshop, Atlanta," JHU/APL QM-80-063, 31 Mar 1980.

REQUEST FOR INFORMATION ON FRENCH EXPERIENCE IN GOVERNMENT LOANS TO THE GEOTHERMAL INDUSTRY

At the request of DOE/DGE, the following cable was sent on 11 February to the French Geothermal Committee:

THE JOHNS HOPKINS UNIVERSITY • APPLIED PHYSICS LABORATORY

Subject: Request for Information Regarding French Experience with Government Loans for Geothermal Wells.

Mr. J. C. Colli suggested that we forward this request to your office.

The U.S. Department of Energy is considering recommending a program similar to that in France of lending a portion of the cost of geothermal wells to the developer. Your answers to the questions below will be of immense aid to us in evaluating such a procedure.

We will be very grateful for your assistance. We will also be grateful if you will send a copy of this Telex to Mr. J. Colli.

The U.S. Department of Energy is interested in the mechanics and the general utility of your government's program of loaning all or a portion of the costs of geothermal wells to geothermal developers, to be repaid if the wells are successful.

To assist in its assessment the following questions are posed:

1. What is the form of the contract between the government and the developer in regard to the forgivable loan? Is a copy of such an agreement available? Who adjudicates disputes in regard to interpretation of failure or poor performance of the well?
2. How many geothermal wells have been drilled, and what percentage has applied for this forgivable loan? Does this percentage vary by resource region and, if so, can you explain why or how? What is your estimate of the degree to which the availability of such loans has accelerated development of geothermal energy?
3. Are the loans available for exploration for purposes of electric power production, for direct heat applications, or both?
4. Who have been the major recipients of the loans? How many have gone to resource developers, cities, or other government entities, housing owners, utilities, factory owners, or others? Has there been a difference in your experience with loans between these classes of borrowers?
5. Are your loans available for wildcat exploration wells? Step-out and reservoir confirmation wells? Production wells? Are the results different between categories of wells? What degree of information is required of an applicant?
6. What is the period of time covered by the forgivable loan? What is the schedule of repayment? Is the repayment rate based on the stream of well revenues or fossil-fuel displaced?
7. How many of the forgivable loans are in default? What has been your experience with repayment?
8. Who owns the well during the loan period? Who insured the longevity of the well?
9. It is our impression from conversations with personnel from General Heating Company that industry and users in France are reluctant to own geothermal wells. Is this because of the size of these obligations or the period of the capital investment, i.e., 20 or 30 years? Or, alternately, because of the risk even though underwritten (in part) by government? Is it generally perceived that, when geothermal energy is used for community heating, in case of failure of the well the heating distribution and control systems are in place and only the heat source must be replaced with fossil

(continued)

- fuel at worst? Therefore that their entire investment is not totally at risk?
10. Finally, with the experience you now have with this incentive to geothermal development, would you recommend this precise method to the U.S., or, if not, what modifications are desirable?

PREPARATION FOR DOE SOLICITATION, "EASTERN GEOTHERMAL DRILLING PROJECT"

At the request of DOE/DGE, APL surveyed potential respondents to planned solicitation of a user-coupled, resource confirmation program, planned exclusively for the Delmarva area. The results of the survey (Ref. 1) suggested a slightly different approach in the Eastern U.S. The less restrictive approach was motivated by the fact that the only deep geothermal well to date is at Crisfield, Md., and thus there is no experience with geothermal energy, its use, and reliability elsewhere in the Delmarva Peninsula. Reference 2 forwarded recommendations resulting from this survey.

REFERENCES

1. "First User-Coupled Resource Confirmation Solicitation," JHU/APL Lett. CQO-2837, 5 Mar 1980.
2. F. C. Paddison, "Summary of Delmarva Survey and Some Suggestions," JHU/APL QM-80-035, 20 Feb 1980.

FOURTH ANNUAL INTERAGENCY GEOTHERMAL COORDINATING COUNCIL REPORT ON GEO- THERMAL ENERGY

At the request of F. Abel of DOE/DGE, APL provided material for the Fourth Annual intergovernmental Coordinating Council (IGCC) report, Eastern U.S. section (Refs. 1 and 2).

REFERENCES

1. F. C. Paddison, "Preliminary Draft IGCC - 4th Annual Report," JHU/APL QM-79-261A, 1 Feb 1980.
2. "IGCC Fourth Annual Report," JHU/APL Lett. CQO-2811, 1 Feb 1980.

FACT SHEETS

The updated and expanded book of fact sheets (Refs. 1 and 2) is now being prepared. The projected delivery schedule is approximately 15 May 1980.

The format of the data and material will be the same for all states of the U.S. and will follow the pattern used for the initial issue on the eastern states only. Information to be sent to APL by the various states following the initial issue will be incorporated in this issue.

This information is to be presented in loose-leaf form for the convenience of the user.

REFERENCES

1. Section 19, Quarterly Report, Jul-Sep 1979, JHU/APL EQR/79-3.
2. "Fact Sheets Relating to Use of Geothermal Energy (Eastern United States)," APL/JHU QM-79-037, Jan 1979.

EASTERN U.S. HYDROTHERMAL RESOURCE ENGINEERING AND MANAGEMENT

Several informal discussions with DOE/DGE personnel have called attention to the fast-

approaching need for systematic hydrologic modeling of hydrothermal resources in the Eastern U.S. This information will provide a quantitative basis for estimating the reservoir response to thermal withdrawal and reinjection, particularly for individual states in resource allocation, permitting, and general resource management. Recommendations of how to meet these requirements will be forwarded in Ref. 1.

REFERENCE

1. "Hydrothermal Resource Engineering and Management," JHU/APL Lett. 2855, 8 Apr 1980.

ASSESSMENT OF HYDROTHERMAL RESOURCES IN THE NORTHERN APPALACHIAN BASIN

Based on known geologic conditions (i.e., high surface temperatures, deep permeable zones, thick cover of low conductivity sediments, etc.) the northern Appalachian Basin in western New York and Pennsylvania offers the greatest potential for utilization of geothermal resources in the east. A technical program plan (Ref. 1) has been developed to make the best use of all existing data in an evaluation of the hydrothermal resource in this area.

Phase I consists of an evaluation of the many deep gas exploratory wells that have been drilled in this area. Geophysical logs (gamma and neutron) from these wells can be used to define horizons of fluid saturation. Drill stem tests conducted in several wells have yielded pressure build-up curves that can provide us with an estimate of well permeability.

Much of the permeability in the well-cemented sediments is known to be caused by natural fractures. Previous studies by J. E. Tillman of APL have resulted in the definition of fracture facies of several of the deeper rock units in the area. The results will be used in Phase II to interpret zones of high productivity recorded for gas wells.

The third phase of the program integrates the results of the first two phases to define depths and extents of hydrothermal reservoirs.

The proposed program has been discussed with the USGS, DOE/DGE, and NYSEDA, all of whom agree with the technical merit and need for the appraisal (Refs. 2 and 3). A formal letter to DOE/DGE requesting funding for this effort is in process.

REFERENCES

1. J. E. Tillman, "Proposed Program Outline, Methodology for the Assessment of Hydrothermal Resources in Western New York and Pennsylvania," JHU/APL QM-80-024, 1 Feb 1980.
2. "Extramural Program," JHU/APL Lett. CQO-2779, 12 Dec 1979.
3. "Forwarding Proposed Program Outline Methodology for the Assessment of Hydrothermal Resources in Western New York and Pennsylvania," JHU/APL Lett. CQO-2808, 1 Feb 1980.

DEVELOPMENT OF CENOZOIC SEISMOTEC- TONIC DOMAINS BY FLUID INCLUSION ANALYSIS

Seminars were presented to the Geophysical and Space Science Branch of the USGS at Reston, Va., and the Nuclear Regulatory Commission (NRC) staff at Bethesda, Md., concerning the application of a combined structural-geochemical technique for determining the detailed faulting his-

tories of major geologic structures in the Eastern U.S. The technique is the only proven way to obtain geologic ages for fault movements during the Mesozoic and Cenozoic in intraplate regimes where no post-Paleozoic cover rocks exist (Ref. 1). The application of this approach to defining seismotectonic provinces is of great interest to the NRC. In the east these provinces need to be better defined for determining the seismic design for critical facilities, e.g., nuclear power plants.

The method involves the detailed field mapping of a fault zone to define the types and sequence of movements. Carefully selected mineral samples are obtained from well-documented pre-, syn-, or post-kinematic structural settings. The samples are analyzed in the laboratory to determine the paragenetic sequence of mineral phase precipitation relative to deformational textures. Then the minerals that contain two-phase primary or secondary fluid inclusions are heated on a gas or electric thermal stage to the temperature level where the two phases become homogeneous. This value provides a minimum temperature for the formation of the mineral and thus the fault fabric in which it occurs. A historical temperature curve can then be related to the geothermal gradient and depth history of the sample, and a geologic age can be determined.

REFERENCE

1. J. E. Tillman, "Hydrothermal and Uplift Histories of the Northern Appalachian Basin," *AAPG Bull.*, Vol. 63, No. 9, p. 1589.

GEOTHERMAL PRESENTATION TO THE DELMARVA POULTRY INDUSTRY, INC.

On 5 March 1980, the Energy Committee of the Delmarva Poultry Industry, Inc., met at its facility near Georgetown, Del., to hear four presentations on alternate energy sources for the poultry industry. G. Trafford of NASA Wallops described his wind monitoring efforts at Princess Anne, Md. He estimates that wind power can satisfy 100% of the electrical requirements of a grain mill for only 15% of the year.

R. Brinsfield described two solar energy systems, one with and one without storage. Systems with storage do not appear to be very economical; systems without are able to satisfy only 15% of annual energy requirements. Mr. Brinsfield suggested that a combined solar-wind energy system would handle a much larger portion of these needs.

J. Guenveur described his efforts to convert wind energy to heat by using a toror-stator arrangement to heat water mechanically to 190°F with nearly 100% efficiency. He hopes to have the system operating in May of this year.

W. J. Toth of APL gave a presentation on geothermal energy applications in the poultry industry. The major points made were: (a) geothermal resources exist in Delmarva; (b) broiler-house space heating is not economically feasible unless 40 to 75 houses are located at one site, which is not currently considered practical by the industry; (c) some larger hatcheries may be feasible at this time, but most need another load to increase utilization; (d) grain mills are marginally economical, since the short period (two months per year) of high demand means low system utilization; increases in utilization reduce costs per million Btu and may be

achieved by locating other demands, such as a nearby hatchery; (e) processing plants look quite attractive now; cheaper energy is available in smaller plants by using storage tanks and 24-hour pumping at lower pumping rates; larger plants are also quite attractive, but energy costs are higher because of increased pumping costs; and (f) DOE has a number of user assistance programs available. Reference 1 is an APL summary of the mechanics and energy use by the poultry industry in the Delmarva area.

The audience seemed interested in geothermal energy and should be interested in the solicitation for cooperative agreement (Ref. 2) and Program Research and Development Announcement (PRDA) for industrial use of geothermal energy.

REFERENCES

1. W. J. Toth, "A Profile of the Delmarva Poultry Industry," JHU/APL QM-80-002, 2 Jan 1980.
2. Eastern Geothermal Drilling Project, DOE Solicitation for Cooperative Agreement (SCA) No. DE-RP-80ID12132, closing date 9 Jun 1980.

PRESENTATION OF EASTERN GEOTHERMAL PROGRAM STATUS, OGLE COMMITTEE MEETING, JANUARY 1980

On 24 January 1980 F. C. Paddison presented the status of the eastern geothermal program to the January 1980 meeting of the Ogle Committee meeting at New Orleans, La. Reference 1 documents the data.

REFERENCE

1. F. C. Paddison, "First CY 80 Ogle Meeting," JHU/APL QM-80-057, 24 Mar 1980.

FEBRUARY MEETING OF THE MID-ATLANTIC SECTION OF THE GEOTHERMAL RESOURCES COUNCIL

The winter meeting of the Mid-Atlantic section of the GRC took place on 19 February in Washington, D.C. The featured speaker was P. Rodzianko, Vice-President of the New York section and President of the Geothermal Energy Corp. and Geothermal Food Processors. He gave an illustrated talk on the Geothermal Food Processors' onion-drying plant in Brady, Nev., and delivered some general comments on the financial promises and possibilities of direct-use projects.

Additional business included nomination of Mid-Atlantic section officers for the next fiscal year. Ballots will be mailed about the first of April.

R. C. Stephens gave a short report on pending geothermal legislation. The House-Senate conference committee on the Windfall Profits Tax Bill reached a compromise on geothermal investment tax credits, which included extending the time for their availability, but eliminated the credits for builders, landlords, and utilities. The geothermal leasing amendments have been agreed to in the House and Senate.

R. Gray of DOE/DGE brought the group up to date on the status of the proposed second eastern geothermal well as well as the status of the proposed variable cost-sharing or cooperative agreement arrangements being contemplated.

(continued)

E. Peterson of DOE/DGE reported on the status of DOE's PRDA.

INTEGRATED ENERGY SYSTEM TASK GROUP MEETING, 12 FEBRUARY 1980

The major presentation at this meeting of the Task Group covered the Department of Housing and Urban Development programs designed to encourage energy conservation, utilization of alternate energy sources, and the development of community systems.

A. Carey, Office of the Assistant Secretary for Community Planning and Development (HUD/CPD), explained (a) the Innovative Grant program, which includes DOE funds and which is to promote new techniques for community development, including energy-beneficial projects; (b) the Block Grant program, which is to require that community development plans that are submitted include energy conservation, development, or management if they are to qualify; and (c) the Urban Development Action Grants (UDAG) program designed to generate private investment in city and county projects that will produce fixed assets and generate local employment. Energy projects that are considered appropriate for grant consideration include geothermal and district heating. One quarter of the total UDAG fund (\$675 million

in FY 80) is reserved for small cities. This is of considerable interest since many potential geothermal resource areas contain only cities with a population of 50 000 or less.

STATE COMMERCIALIZATION AND RESOURCE PLANNING MEETING, SALT LAKE CITY, UTAH

The meeting was held by DOE on 21 to 23 January 1980 to provide a forum for joint discussions by the state-coupled resource teams and state-coupled utilization teams. The meeting was attended by A. M. Stone and F. C. Paddison of APL. APL activities in the Eastern United States were reported by Mr. Paddison. They are discussed in Ref. 1, which summarizes the status of federal and state programs to spur the development of hydrothermal energy in the East and gives a general analysis of potential applications. The principal area discussed was the Atlantic Coastal Plain; however, the interior sedimentary basins were included in other resource assessment programs by DOE/Gruy and market assessment studies by APL.

REFERENCE

1. F. C. Paddison, "Eastern Geothermal Development Status," JHU/APL QM-80-025, 1 Feb 1980.

OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT

§ 29

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

H. P. Henderson and J. Carroon (Metro Center)

January-March 1980

ENVIRONMENTAL REGULATORY CONSTRAINTS IN NORTH CAROLINA, SOUTH CAROLINA, AND GEORGIA

An analysis has been made at Metro Center of environmental constraints on the development of small-scale hydroelectric (SSH) power. The analysis is currently limited to SSH development at existing dams in Georgia, North Carolina, and South Carolina and includes the areas of major environmental problems and ownership-access issues.

DISCUSSION

The analysis is focused on state and local government site-specific considerations including state and local laws, operating policies and practices, and court decisions and traditions. Given the sovereign and reserve powers of states and the home rule and permissive local legislation concepts, such state-local site-specific considerations are highly variable among states as well as among localities within states. These variable and frequently unpredictable sources of legal/institutional influence on SSH may become manifest in several ways: state involvement in joint federal-state programs (such as the Federal Water Pollution Control Act and state granting of Section 401 water quality permits); state or local laws largely independent of federal influence (water use, wild and scenic river designation, and land use regulation); state or local administrative policy discretion within legally established authority (policies toward fish ladders or in-stream flow conditions as aspects of fish and wildlife laws, historic preservation designations, and land use classifications around existing dam sites); and previous court decisions and safeguarded traditions (public access to resources held in trust, rights of adjacent landowners, and traditions in interpreting legislative intent). These state and local site-specific considerations have received little attention to date and are an on-going aspect of the overall Johns Hopkins research project.

On a state-by-state basis, using local governments where small dam sites are known to exist, the analysis will identify the legal/institutional constraints that exist in the three states being studied, the decision-making process likely to take place in relating the constraints to SSH development, and possible means to overcome development problems. An example of the state-specific nature of an ownership-access issue is the existing dam site at High Falls State Park on the Towaliga River in Monroe County, Ga. (estimated capacity of 600 kW) (Ref. 1). The dam (built in 1904) and the surrounding lands were donated to the state in 1961 and are currently owned and managed as a park by the Georgia Department of Natural Resources. In this case, the Department does not have the necessary legislative

authority to construct or operate an SSH project at High Falls or any similar site. Obtaining the necessary enabling authority from the Georgia state legislature for either the Department or another state agency to establish even a demonstration SSH project represents a legal/institutional ownership barrier to SSH development highly specific to both the site and the state. Other sites in Georgia or similar park sites in other states might have different institutional and regulatory constraints.

State environmental impact statements (EIS) are also state-specific. Georgia and South Carolina do not require a state EIS, but North Carolina does when projects use state funds. This shows that the nature of the project developer, as well as the state and site, is a variable that may cause differing legal/institutional constraints. Localities in the state may establish local-option EIS programs (as Transylvania County has done) (Ref. 2).

Local and court roles become significant to the analysis in such matters as planning and zoning. Each of the three states permits county and municipal land-use regulation, and regulation is becoming common in the less urbanized regions of the states (where many existing small dams are located). To the extent that SSH development at such sites would require local zoning changes (e.g., from agricultural and low-density residential zones to commercial or special-use districts) or court resolution of adjacent landowner conflicts, these actions would represent highly local and site-specific legal and institutional barriers. These illustrations indicate the scope of concerns currently under investigation in this aspect of the Johns Hopkins SSH studies.

SOCIAL CONSIDERATIONS

In order to estimate more fully the benefits of SSH projects, the environmental and social costs of alternative methods of obtaining electricity must be considered. The Metro Center has completed a literature search concerning energy and the environment. Current work involves completion of the annotator and cross referencing of the material reviewed. The search sought specific information about costs and impacts of electricity generation by conventional and non-conventional means. Of the 350 publications reviewed, approximately 150 contained relevant information, but in a wide variety of forms. To permit ready access to this matter, the information is being organized by energy source and operational stage. Energy sources reviewed are petroleum, natural gas, coal, nuclear, geothermal, and shale oil. Environmental and social costs are evaluated at four operational stages: extraction, transportation, electrical production, and waste disposal.

Where possible, a description of methodologies used and criteria considered will be included in the report. Unfortunately, cost estimates and specific data used in these studies vary widely. Standardization of cost estimates is beyond the scope of the present effort.

REFERENCES

1. P. W. Brown et al., "Executive Summary of Case Study of Potential Hydroelectric Development at the High Falls State Park, Georgia," Energy Law Institute, Jan 1979.
2. R. W. Burchell and D. Liatokin, Environmental Impact Handbook, Center for Urban Policy Research, Rutgers State University, New Brunswick, N.J., 1975.

OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT

§ 30

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

F. Bennett and S. Briscoe (Metro Center)

January-March 1980

ECONOMIC AND INSTITUTIONAL FACTORS IN NORTH CAROLINA, SOUTH CAROLINA, AND GEORGIA

Metro Center is conducting a study of the economic, institutional, and environmental factors affecting potential hydroelectric development at existing dams in North Carolina, South Carolina, and Georgia.

ECONOMIC ANALYSIS

Further adaptation and testing of the economic analysis model have been done in this quarter. The model was originally designed to evaluate the economic and financial feasibility of a single installed capacity at a given site and was used in this form to generate results on 11 potential SSH sites in Pennsylvania and Maryland (Ref. 1). In its present form, the model determines feasibility as well as the optimal capacity from a range of possible installed capacities at a given site. The model will be run with Corps of Engineers data when they become available.

The model generates a supply curve for each variation made in the basic economic and financial parameters. Special consideration is given to the magnitudes of potential subsidies necessary to effect significant increases in potentially feasible SSH capacity in the southeast. These can be contrasted with the impact on SSH feasibility of changes in the rate of increase in the real cost of alternate forms of energy. To provide some perspective on this section of the analysis, information on several subsidy instruments and their effect on alternate energy development is being collected.

One preliminary conclusion from work to date is that the lower utility rates in Georgia, South Carolina, and North Carolina (as compared to those in the Mid-Atlantic region) will probably create problems for private developers of SSH sites wishing to sell energy to the utilities. In the absence of significant amounts of firm capacity, SSH selling prices to utilities will be based on the utility's avoided energy (fuel) costs only, as stated in Federal Energy Regulatory Commission (FERC) rules (Refs. 2 and 3).

Developers of SSH power for private use in Georgia, South Carolina, and North Carolina face a replacement value of 4 to 4.5¢ per kWh (retail). The value of their output is reduced by the extent of their need for back-up power. Implementation of new FERC rules could lead to lower back-up charges.

Runs of the economic model will begin as soon as revised cost data for potential SSH sites in the three-state area are received from the Corps of Engineers.

INSTITUTIONAL, REGULATORY, AND TAX ANALYSES

Current work in these areas has focused on North Carolina. The pattern of simplification in tax, licensing, and regulatory structures that was observed in Georgia exists in North Carolina. At the state level, utility taxes are identical to those imposed on corporations and individuals except for a franchise tax on electric power corporations. Utility status for tax purposes is clearly defined. Electric membership corporations (EMC) are exempt from income taxes, and municipal services are exempt from all taxation. Preliminary findings indicate that only two permits from state agencies are required for small-scale projects (i.e., a safety permit and water quality certification).

As in Georgia, generation and transmission corporations are in the process of being established in North Carolina to supply bulk power to their member municipal services and EMC's. Three municipal power agencies will serve municipal electric systems located within the service areas of the Duke Power Company, Virginia Electric Power Company, and Carolina Power and Light Company. North Carolina EMC will serve 25 of the 28 existing EMC's in the state. These bulk suppliers may be expected to control decisions to purchase or generate SSH power by these groups.

The status of the private developer selling power is also clearly defined in the North Carolina Public Utilities Law. Any retail sale constitutes utility services and will be regulated by the North Carolina Utilities Commission (NCUC). No hydroelectric power project may be constructed or operated without a certificate of public convenience and necessity from the NCUC. No utility may retail power without being assigned a service area by the NCUC. Since regulations governing service areas cover both incorporated and unincorporated areas, market access for new suppliers is severely limited.

Preliminary research indicates that state agencies will require only a dam safety permit and water quality certification for SSH projects. Projects licensed by FERC are exempted from the dam safety permit, and water quality certification applies only to projects that are federally licensed. In almost all cases, application review for state concerns such as historical preservation and recreational needs will depend on the efficiency of the FERC review process.

REFERENCES

1. F. Bennett and S. Briscoe, "Problems of Hydroelectric Development at Existing Dams - An Analysis of Institutional, Economic, and Environmental Restraints in Pennsylvania, New Jersey, and Maryland," JHU/APL HE-004, Vol. 1, QM-79-237, Aug 1979.
2. "Small Power Production and Cogeneration - Rates and Exemptions," FERC proposed rules, Docket RM79-55, Federal Register, Vol. 44, No. 207, 24 Oct 1979.
3. "Final Rule Regarding the Implementation of Section 210 of the Public Utility Regulatory Policies Act of 1978," FERC Order No. 69, 19 Feb 1980.

[The text in this section is extremely faint and illegible. It appears to be a multi-paragraph document, possibly a letter or a report, but the specific content cannot be discerned.]

OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT §31

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

C. S. Leffel, Jr.

January-March 1980

INSTALLATION COSTS DERIVED FROM NHSF2 AND CORPS OF ENGINEERS GUIDE MANUAL

The National Hydropower Study is a computerized program of the Army Corps of Engineers designed to estimate, site by site, the hydroelectric potential of the United States. As reported in Ref. 1, the National Hydropower Study, Form 1 (NHSF1) underestimated the cost of hydroelectric installations at existing dam sites. The new study by the Corps of Engineers, the National Hydropower Study, Form 2 (NHSF2), gives what are believed to be more accurate cost figures. As pointed out in Ref. 1, the consequences of NHSF1 were that it not only gave an overly optimistic estimate of the economic feasibility of existing dam sites, but it biased the optimum installed capacity toward the larger values.

The differences in the results of NHSF1 and NHSF2 for the dam site on the Savage River in western Maryland are discussed in Ref. 1. In addition to the continuing effort of reworking NHSF1 into NHSF2, the Corps of Engineers issued in July 1979 a guide manual (Ref. 2) for estimating costs of hydroelectric installations. Reference 2 provides the graphs and equations for calculating the costs of the complete hydroelectric installations as a function of installed capacity and hydraulic head.

The calculations in this report were made using Ref. 2 to compare its costs, so estimated, with the printout of NHSF2 for the one site that was available to us, the Savage River dam site. The Corps of Engineers has not, as of this writing, released the results of NHSF2; the NHSF2 data for the Savage River site are preliminary estimates obtained as described in Ref. 1.

Samples of the installation costs as a function of water flow and installed capacity for the Savage River dam site (project MD00014 in NHSF1 and MDCNAB0011 in NHSF2) were obtained by applying the procedures from Ref. 2, Vols. V and VI, and are given in Table 1.

Table 1

Total cost as a function of water flow and installed capacity, as calculated from Ref. 2.

Water flow (ft ³ /s)	137	215.7
Installed capacity (kW)	1129	1778.1
Annual plant factor	0.48	0.38
Annual energy (MWh)	4748	5919
Total cost (dollars)	1 156 000	1 603 000

From the NHSF2 printout, the optimum installed capacity (determined by the maximum net benefit as computed by the Corps of Engineers, NHSF2) was 1400 kW and the installation cost was \$1 290 000. Interpolating the results of Table 1, the cost for a 1400 kW installation as calculated from Ref. 2 is \$1 285 000. This close agreement is certainly somewhat fortuitous, but it does give us some confidence that Ref. 2 can be used to compute the installation costs for hydropower installations.

The annual costs have been computed for four sites in South Carolina, using Ref. 2, and the results were compared with those printed in NHSF1. The comparison for an installation sized for approximately the average stream flow has been made and the results listed in Table 2. Table 2 supports the contention of Ref. 1 that NHSF1 seriously underestimates the cost of hydropower installation. The results from Ref. 2 and NHSF2 will be compared when the cost data from NHSF2 become available.

Table 2

Comparison of annual costs, as calculated from Ref. 2 and given by NHSF1, for specified installed capacities at four sites in South Carolina.

Project no.	Ref. 2	NHSF1
SC00001		
Installed capacity	33 kW	
Annual cost	\$ 16 000	\$ 4 374
SC00261		
Installed capacity	36 kW	
Annual cost	\$ 15 000	\$ 4 147
SC00629		
Installed capacity	5000 kW	
Annual cost	\$832 000	\$518 000
SC001061		
Installed capacity	1200 kW	
Annual cost	\$158 000	\$ 86 200

Note: Annual cost = capital cost at 6-5/8% for 50 years, plus the annual operating expenses.

REFERENCES

- Section 25, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
- "Feasibility Studies for Small-Scale Hydropower Additions, a Guide Manual", Vols. V and VI, U.S. Army Corps of Engineers, The Hydrologic Engineering Center, Davis, Calif., Jul 1979.

**OPERATIONAL RESEARCH, HYDROELECTRIC POWER
DEVELOPMENT**

§ 32

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

J. W. Follin, Jr.

January-March 1980

**FINAL REPORT ON SMALL-SCALE
HYDROELECTRIC POWER IN THE
SOUTHEASTERN U.S.**

An outline has been prepared for APL's final report on problems of hydroelectric development at existing dams for the Southeastern United States. The study, which includes the states of Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi, will cover the institutional, legal, environmental, and economic factors that affect the development of small-scale hydroelectric power. A more detailed study of the economic and legal factors will be contained in a second report, written for North Carolina, South Carolina, and Georgia by the Metro Center under subcontract to APL.

As it presently exists, the outline of the report is as follows:

1. Introduction - nature and scope of the report,
2. General hydrology of the Southeast,
3. Electricity production in the Southeast,
4. State issues involved in small-scale hydro,
5. Current small-scale hydro activities in the Southeast,
6. Government activities and increased public awareness of small-scale hydro, and
7. Conclusions and recommendations.

Since the publication of the last APL small-scale hydro reports, HE-004, Vol. I (Ref. 1) and Vol. II (Ref. 2), in August and April 1979, public awareness of the potential of SSH has increased, and several activities at the federal level have served to promote SSH development. The National Hydropower Study, performed by the Army Corps of Engineers, will provide detailed information for all potential hydroelectric sites on the Corps lists. The study will provide the water-flow duration curves for each dam site and cost estimates for installing a range of power installations. This information, which has not

previously been available, will greatly simplify the evaluation of a site for a potential developer. The FERC plans to simplify licensing procedures at existing dam sites. Several states have begun to simplify their permitting procedures. Large investor-owned utilities are now aware of SSH and seem to be more receptive to its development. The Public Utilities Regulatory Policies Act (PURPA) should assist the private developer in his negotiations with the large utilities.

In its final report, APL will assess the effects of recent federal initiatives that affect SSH development. The large number of municipal and local electric cooperatives in the southeast (which, at least in a few states, are organized and interested in power production) offers a new class of potential hydroelectric developers. From the environmental point of view, the southeast has a few unique problems caused by its climate and the large flow of water in rivers with small amounts of fall. However, as a general rule, it appears that state agencies will cooperate in SSH development. The APL report will point out what is unique in the southeast in the context of the general problem of developing hydroelectric power at existing dam sites.

REFERENCES

1. "Problems of Hydroelectric Development at Existing Dams, An Analysis of Institutional, Economic, and Environmental Restraints in Pennsylvania, New Jersey, and Maryland," Vol. I, APL/JHU HE-004 (QM-79-237), Aug 1979.
2. "Problems of Hydroelectric Development at Existing Dams, An Analysis of Institutional, Economic, and Environmental Restraints in Pennsylvania, New Jersey, and Maryland," Vol. II, APL/JHU HE-004 (QM-79-133), Apr 1979.

OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT

§ 33

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

C. S. Leffel, Jr.

January-March 1980

COSTS OF A HYDROELECTRIC INSTALLATION AT SAVAGE, MD.

In the fall of 1979, Howard County, Md., asked APL to investigate the feasibility of installing hydroelectric power at the Savage Mill site on the Little Patuxent River (Fig. 1). Reference 1 describes the geography and the physical plant at the Savage Mill site and gives a preliminary APL estimate of the cost of replacing the Savage dam (which was destroyed in 1963-1964) and of installing a 300 kW turbine-generator set in the existing powerhouse on the Savage Mill site. The total cost was estimated to be \$798 000.

Reference 2 recomputes the water flow duration curve at the Savage Mill site (using stream gauge data supplied by the U.S. Geological Survey), calculates the ideal plant factor for a range of installed generator capacities, and estimates the cost of installation versus installed capacity using Ref. 3. A sample of the results is given in Table 1.

Table 1

Cost of hydroelectric installation for two installed capacities at the Savage mill site.

Water flow (ft ³ /s)	100	124
Capacity (kW)	288	357
Plant factor	0.711	0.630
Energy (MWh)	1794	1970
Total cost	\$790 000	\$867 000
Total annual cost	\$ 65 600	\$ 72 000
Annual capital cost	\$ 54 500	\$ 59 900
Annual operating cost	\$ 11 100	\$ 12 100

In Table 1, the annual capital cost is computed as is done in the National Hydropower Study of the U.S. Army Corps of Engineers; i.e., the interest rate is assumed to be 6.625% and the lifetime to be 50 years. Operating costs are taken from Ref. 3.

As Ref. 2 shows, using the above cost figures and a value of electricity of \$40/MWh (4¢/kWh) or more, the installation has a positive benefit. For the range of installed capacities of from 75 to 760 kW, the maximum benefit exists for an installed capacity of about 325 kW.

The land surrounding the Savage Mill site and the reservoir that would result from the rebuilding of the dam is (or will be) part of the Howard County park system. Therefore, the

Fig. 1 Location of Savage Mill. (80-1/49)

decision to study this hydroelectric installation further will probably be made on how the park is developed, since the benefits of the hydroelectric installation, although positive, are marginal.

REFERENCES

1. W. B. Chapman, "Survey of Facilities at the Savage Mill Dam and Powerhouse," JHU/APL QM-80-010, 15 Jan 1980.
2. C. S. Leffel, Jr., "Cost and Income Estimates for a Hydropower Installation at the Savage Mill Site," JHU/APL QM-80-048, 11 Mar 1980.
3. "Feasibility Studies for Small-Scale Hydropower Additions, A Guide Manual," the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, Calif., Jul 1979 (six volumes).

THE UNIVERSITY OF CHICAGO
 
R. H. MESSENGER

**OPERATIONAL RESEARCH, HYDROELECTRIC POWER
DEVELOPMENT**

§ 34

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

C. S. Leffel, Jr.

January-March 1980

**COMMENTS ON LIMITED TASKS:
SMALL-SCALE HYDROELECTRIC
POWER**

**DATA FROM NATIONAL HYDROPOWER
STUDY, FORM 2**

As part of its study of potential hydroelectric development at existing dams for North Carolina, South Carolina, and Georgia, the Metro Center will perform a detailed analysis of the energy potential as a function of various economic factors (Ref. 1). To derive the supply curve, the energy produced by and the cost of the hydroelectric installation as a function of installed capacity at each selected site must be computed. The computations appear in the National Hydropower Study Forms NHSF1 and NHSF2 conducted by the U.S. Army Corps of Engineers. Both NHSF1 and NHSF2 compute the flow duration curves for the sites on the Corps dam lists and estimate the costs of installing a range of generating capacities at those sites. From the flow duration curve, the annual plant factor is computed for each installed capacity and thus the electrical energy produced per year is known.

Estimating the installation cost for a hydroelectric installation and the annual plant factor for each of the existing dam sites in North Carolina, South Carolina, and Georgia is a large task. As was pointed out in Ref. 2, NHSF1 seriously underestimates the installation

cost of hydroelectric generating capacity. Thus it predicts erroneous annual benefits to be realized by a given power installation and produces an erroneous estimate of the optimum size of the hydroelectric installation at any given site. Since NHSF2 contains what the Corps of Engineers believes to be much more accurate cost data, APL has asked (Ref. 3) the Corps of Engineers for the cost data for the sites in North Carolina, South Carolina, and Georgia. The Southeastern Division of the Corps (Atlanta) has agreed to supply this information as a function of installed capacity as soon as it can be released (Ref. 4). This information is to be delivered in April 1980.

REFERENCES

1. Section 23, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
2. Section 25, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
3. "Request for Information Contained in the National Hydro Study, Form 2," JHU/APL Lett. CQO-2803, 31 Jan 1980.
4. Letter to C. S. Leffel, Jr. from C. G. White, Chief Planning Division, SADPD-P, U.S. Army Engineer Division, South Atlantic Corps of Engineers, 26 Feb 1980.

SEISMOTECTONIC INVESTIGATION § 35
New England Seismotectonic Investigations, Weston
Observatory F7K6CQO
Support: NRC/Reactor Safety Res. Div.
J. E. Tillman
January-March 1980

NEOTECTONIC INVESTIGATION IN CONNECTICUT

Mapping of the brittle structures of the Manhattan Prong in New York and Connecticut continued during this quarter. The effort is part of the New England Seismotectonic Investigation being managed by Weston Observatory of Boston University for NRC (Ref. 1). APL has been engaged in the project since August 1979 and expects continued funding in 1980-81.

DISCUSSION

The Saw Mill River lineament was examined during a three-week field effort, and several zones of intense brecciation and faulting were identified along it. The evidence suggests that this lineament has served as a major brittle structure in post-orogenic time. Mapping of the extent, types of displacement, and ages of movement will be pursued in the future.

Stratigraphic and structural mapping proceeded on schedule in the Danbury Quadrangle. This area is at the intersection of north-south

structural trends to the north and northeast-southwest trends to the southwest. It is the only place where surface bedrock stratigraphy trends at a high angle to the major northeast faults and aeromagnetic lineaments in this region. If offsets occur along these lineaments, documentation of displacements should be possible in this quadrangle. The evolving map pattern is distinctly different from earlier interpretations but agrees closely with aeromagnetic signatures of the rock units.

A presentation of the results was made at the annual meeting of the Northeast Section of the Geological Society of America at Philadelphia, Pa., on 14 March 1980. A field trip was conducted on 1 April 1980 to show the results of the project to date. P. Barosh of Weston Observatory, M. Pease of the USGS, and S. Quarrier of the Connecticut Geological Survey were taken to the best exposures of faulting in the area.

The annual report is due at NRC for publication by June 1980.

REFERENCE

1. Section 26, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.

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ENERGY CONVERSION AND STORAGE TECHNIQUES

OTEC Core Unit Testing ZM76BBP

§ 36

Support: DOE/CST

P. P. Pandolfini, J. L. Keirse, and J. A. Funk

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TESTS OF THE APL CORE HEAT EXCHANGER AS A CONDENSER

In the APL Ocean Thermal Energy Conversion (OTEC) plant concept, shell-less, folded aluminum tube heat exchangers containing ammonia as the working fluid are being studied as a potentially cost-effective option. Vertical planes of 3 in. OD tubes (seven nested tubes per plane) connected in parallel (Ref. 1) form a heat exchanger module. Seawater from a head pond flows downward by gravity over the tubes and out the bottom of the module.

A full-scale core unit was previously tested as an evaporator at the Argonne National Laboratory (ANL) (Ref. 2). The success of these evaporator tests in proving better-than-predicted heat exchanger performance led to testing of the unit as a condenser. The core test unit (fabricated by the Trane Co.) consists of three full-scale folded aluminum tubes contained in a water box. The objectives of the present tests are to obtain experimental data on the condenser design and to validate or provide a basis for modification of an analytical simulation that will be used to design the plant-ship heat exchangers. This report presents the results of the latest tests.

DISCUSSION

Reference 3 contains a description and photographs of the core test unit. In the condenser tests, the flow loop was modified so that ammonia vapor (slightly superheated) was introduced into the top of the unit and flowed downward through the tubes, exhausting at the bottom (completely condensed) into a receiver. A chiller in the water loop maintained the entrance water temperature at 41 to 42°F. In February 1980, 61 condenser tests were conducted, covering the range of test variables outlined in Table 1. Because of system limitations on heat duty (the maximum achievable value was about 5.0×10^6 Btu/h) and the coupling of ammonia flow with heat duty in these tests, the tests on high ammonia flow (>1.0 lbm/s per tube) were made with the two outer tubes blocked and all the ammonia flow going into the center tube.

Figure 1 illustrates the measured overall heat transfer coefficient, U , for all the tests, plotted against the water Reynolds number, Re_w , and the maximum water velocity in the minimum tube gap, V_w . Almost all the data were correlated to within $\pm 5\%$ regardless of the ammonia flow. The two points that lie more than 5% above the correlation, as well as those near this upper bound, were for the lowest ammonia flow tested (0.43 lb/s per tube). Wall effects, although minor and constant for all the tests, are also included in the correlation, which should only be used over the tested range. The

Table 1

Conditions for condenser core tests.

Parameter	Range	Nominal value
Heat duty, 10^6 Btu/h*	2.5-5.0	3.2
Water flow rate, gal/min	1500-4800	3200
Water inlet temperature, °F	41-42	41
Ammonia flow rate, lb/s per tube*	0.4-2.2	0.7
Ammonia inlet temperature, °F	45-58	50
Ammonia piping, number of active tubes	1 and 3	3

*Because of the system configuration and the requirements of 100% quality ammonia vapor inlet flow and 0% quality ammonia exit flow, the heat duty and ammonia flow are not independent of each other. Setting the heat duty of the system was equivalent to specifying a system ammonia flow.

Fig. 1 Measured overall heat transfer coefficient versus water flow Reynolds number and water velocity in minimum tube gap for all ammonia flows tested. (80-1/50)

U values are computed from the experimental data by the equation used by ANL in their data reduction:

$$U = \frac{Q}{A \Delta t_m}$$

where

$$\Delta t_m = \frac{(T_{in} - t_{avg}) - (T_{out} - t_{avg})}{\ln \left(\frac{T_{in} - t_{avg}}{T_{out} - t_{avg}} \right)}$$

Q is the heat duty determined from the water temperature change and water flow, A is the area involved in the heat exchange based on the inside tube diameter (1290 ft²), and Δt_m is a log mean temperature difference formulated with T_{in} and T_{out} (the entrance and exit water temperatures, respectively) and t_{avg} (the saturation temperature of the ammonia based on the average inlet and outlet pressures). Examination of these results indicates that the water-side heat transfer coefficient has the major influence on the overall U, and the ammonia-side heat transfer coefficient has a measurable but minor influence. This implies that although the ammonia-side heat transfer coefficient may change as ammonia flow changes, it is of larger magnitude than that of the water.

The condenser core tests covered as wide an ammonia flow range as possible with the ANL facility. The results established a large data base for optimization studies of the entire power plant cycle. Preliminary comparisons of the experimental data with predictions indicate values of heat transfer and pressure drop on

the ammonia side that are higher than predicted. Preliminary estimates of revised power cycle performance indicate that the two effects offset each other and confirm the analyses based on the revised evaporator performance from the earlier tests without any condenser improvement.

The results of the tests are now being used to modify the analytical simulation so that calculations agree with the experimental observations.

FUTURE PLANS

No further testing with the core unit is planned. The experimental results of these tests and the evaporator core tests are now being evaluated for integration into the pilot plant simulation.

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ENERGY CONVERSION AND STORAGE TECHNIQUES

Community Annual Storage Energy System § 37

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W. R. Powell and C. E. Williams

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COMMUNITY ANNUAL STORAGE ENERGY SYSTEM

The Community Annual Storage Energy System (CASES) is a plan to save energy using water distribution pipelines and water-source heat pumps to heat and cool a community of diverse buildings. DoD and DOE are jointly supporting the use of DoD bases for demonstrations of energy conservation technologies in an Energy Showcase program. The Navy Energy Showcase, located at Norfolk, Va., includes CASES as one of its program elements. The Norfolk CASES program is in the feasibility analysis stage of the Energy Showcase plan.

SUMMARY

During the first quarter of 1980, APL obtained basic data relating to current building heating and cooling requirements and equipment in service in the proposed CASES service district. The CASES district includes buildings in the Camp Allen, Staff College, and CINCLANTFLT subareas of the Norfolk U.S. Navy base. An adaptation of the general CASES concept (Ref. 1) that specifically addresses the unique problems and opportunities present at the Norfolk site was developed and reviewed with the energy office and building maintenance personnel who are responsible for heating and cooling services in the CASES service district at Norfolk. A methodology for cost and benefit analysis for the various components of the Norfolk CASES plan is being developed.

DISCUSSION

The CASES plan for the Norfolk subareas included in the service district now consists of three phases. The presently separate chillers that cool individual buildings in the CINCLANTFLT office complex will be connected to support a cold water distribution loop. During stage 1, numerous window air conditioning units in service in this area will be replaced (as they break down) by fan-coil units connected to the chilled water loop. The warm water discharged by the new fan-coil units will be collected by a warm water pipeline and returned to the chillers for recooling. During stage 1, the cooling towers associated with the existing chillers will continue to waste the heat now recovered from buildings, but in a later phase this heat will either be saved by injecting it into warm water storage wells and/or be used to preheat potable hot water.

During stage 2 of the Norfolk CASES plan, the chilled water loop will be extended to an existing but unused concrete water storage basin, part of which will be refurbished, enclosed, and insulated to provide short-term (diurnal) storage facilities. Certain large

residential buildings adjoining the extension route and already equipped with chillers will be connected to the chilled water loop. The expansion of cooling capacity and provision of storage will permit most buildings in the CINCLANTFLT area to eliminate window cooling units. Some reduction in electrical demand charges should be possible with more efficient cooling equipment and off-peak recharge of the storage reservoir. Smaller and less efficient chillers in buildings connected to the chilled water loop will not be replaced or repaired near the end of their service life. Instead, larger, more efficient chillers will be acquired and located near the storage reservoir.

Also during stage 2 some of the older single-family and duplex residential units in the Staff College area will have their gas furnaces replaced by water-source heat pumps connected to one or more shallow water wells via a common pipeline. The cold water effluent from these heat pumps will be collected via a parallel pipeline and injected into a deep, cold water storage well. Additional cold water for this storage well may be generated in winter by a spray pond using a part of the existing water storage reservoir not refurbished and used for chilled water storage. Several million gallons of cold water from the storage well will be recovered the following summer as a test of cooling by seasonal storage of cold water. Part of this flow will pass through one or more experimental fan-coil units to simulate residential cooling. Stage 2 provides further reduction in electrical demand for air conditioning and some reduction of fossil energy use on base. It is also a practical test of heating by water-source heat pumps using local groundwater plus a test of cooling via fan-coil units using cold water recovered from a seasonal storage well.

Stage 3 of the Norfolk CASES plan provides beneficial use of seasonally stored energy. If the seasonal storage well tests of stage 2 confirm the practicality of thermal storage wells at Norfolk, small air conditioning units in Staff College and Camp Allen residential buildings will be replaced by fan-coil units connected via a cold water distribution pipeline to the cold storage well. The heat collected from these buildings in summer as they are cooled by cold water ($\approx 40^{\circ}\text{F}$) from the storage wells converts the water passing through the fan-coil units into tepid water ($\approx 60^{\circ}\text{F}$). This tepid water will be injected into one or more heat storage wells along with warm water ($\approx 85^{\circ}\text{F}$) from the condensers of chillers used along the CINCLANTFLT chilled water distribution loop. These chillers will not require cooling towers in stage 3. They should become both more efficient and less subject to fouling when ground-

water from shallow wells is used instead of recirculating cooling tower water for heat removal.

If seasonal storage of thermal energy in water wells is shown to be impractical in stage 2 tests, ice machines will be acquired and installed near the central cold water storage facility. The ice machines will function as heat pumps, supplying tepid water to water-source heat pumps in residential buildings in the Staff College and Camp Allen. The ice produced during winter heating will be saved for nonelectrical cooling at times of peak electric demand on the base, provided it is economically attractive to modify a portion of the existing water reservoir for ice storage.

It must be emphasized that the above plan is a specific concept, potentially applicable in a CASES service district at Norfolk, but not a plan for implementation. The plan, in its more complete statement with reference to speci-

fic buildings etc., will permit a feasibility analysis to be performed. Implementation of CASES concepts at Norfolk must await feasibility analysis results and will require a subsequent, more expensive program to develop a detailed design.

FUTURE PLANS

Work during the second quarter of 1980 will focus on the development of analytical methods for evaluation of the performance and cost of the above CASES plan. These methods will permit hourly simulation of CASES heating and cooling in the proposed CASES service area.

REFERENCE

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