JHU/APL
EQR/80-2

Quarterly Report

ENERGY PROGRAMS

at The Johns Hopkins University Applied Physics Laboratory

APRIL—JUNE 1980

THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY

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Johns Hopkins Road, Laurel, Maryland 20810

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FOREWORD

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

<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 30 June 1980.

The Energy Quarterly Report is divided into three 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, Energy Conversion and Storage Techniques, contains three articles. The first is on data analysis of OTEC core unit condenser tests, and is supported by the Department of Energy/Division of Central Solar Technology (DOE/CST). The second is on the current status of the Community Annual Storage Energy System at the U.S. Naval Air Station, Norfolk, Va., and is supported by the Department of Energy and the Department of Defense, Naval Facilities Engineering Command/Atlantic Division. The third is on utilization of landfill methane and is supported by Argonne National Laboratory.

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GEOHERMAL 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,
F. C. Paddison, F. K. Hill, and R. W. Henderson
April-June 1980

GEOHERMAL TECHNICAL ASSISTANCE

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.
9. Geothermal space heating at the Naval Air Rework Facility (NARF), Naval Air Station (NAS), Norfolk, Va.

Analyses in Process.

1. Geothermal space heating, Wallops Flight Test Center, Va.
2. Space heating and industrial process heat, Auburn and Montezuma, Cayuga County, N.Y.
3. 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 Indiana.
7. Geothermal energy potential and application in Gainesville, Fla.
8. Geothermal applications for McGuire AFB, N.J.
9. Geothermal, coupled with wood chips, for wet-corn mill, Pamlico Refineries, Inc., Raeford, N.C.
10. Geothermal energy potential at the Dover AFB, Dover, Del.
11. Space heating for the Naval Submarine Support Base, Kings Bay, Ga.

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. It is planned that approximately 50% of the future effort will be subcontracted. Counseling for prospective users (within the limitations of the Geothermal Loan Guarantee Program and other programs of financial assistance for geothermal applications)

will be provided by APL through Analytic Services, Inc., Rockville, Md.

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

1. Reference 2 is a report of discussions with personnel from Clinton Corn Products and Cayuga County Industrial Development concerning the potential utilization of geothermal energy in the wet-corn mill fructose plant of Clinton Corn Products, Montezuma, N.Y. As a result of these discussions, the New York State Energy Research and Development Authority (NYSERDA) submitted a proposal to drill a geothermal well at or near the Montezuma plant to measure water temperature and availability. Laboratory suggestions for the well and its testing (at the request of NYSERDA) are found in Refs. 3 and 4. Further effort in the Montezuma and nearby Auburn areas will await the results of the well tests.
2. Reference 5 is the final report on the potential of geothermal space heating at the

Naval Air Rework Facility (NARF), NAS, Norfolk, Va. Section 19 of this report summarizes this effort.

REFERENCES

1. "Technical Assistance, Eastern Hydrothermal Program," JHU/APL CQO-2845, 20 Mar 1980.
2. F. C. Paddison, "Geothermal Energy in Cayuga County, New York," JHU/APL QM-80-082, 28 May 1980.
3. "Requirements for Hydrologic Test Well in Western New York State," JHU/APL CQO-2852, 3 Apr 1980.
4. F. C. Paddison, "Further Comments on Hydrologic Test Well, Western New York State," JHU/APL unnumbered letter, 4 Apr 1980.
5. F. K. Hill and R. W. Henderson, "Technical Assistance Report No. 5, Geothermal Space Heating - NARF," JHU/APL QM-80-102, Jun 1980.

**GEOHERMAL ENERGY DEVELOPMENT PLANNING AND
TECHNICAL ASSISTANCE** § 19
Development of Geothermal Energy in the Eastern
U.S. ZJ7AE0
Support: DOE/DGE
F. K. Hill
April-June 1980

**TECHNICAL ASSISTANCE – GEO-
THERMAL SPACE HEATING FOR
NARF, NAS, 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. In the last Quarterly Report (Ref. 1), the background and objectives of the analysis of the Naval Air Rework Facility (NARF) were presented, and several practical methods were described for using the thermal output of a well drilled near the Electronics Integration Hangar (building LP-167). In this quarter, the capital cost of necessary equipment, operation, maintenance, and amortization of capital expenditures are compared with the savings of oil. There is also a potential of supplying heat for other uses. The analysis and necessary equipment to use geothermal energy in this application are described in the final report (Ref. 2) covering the work.

DISCUSSION

In order to use the geothermal source to heat the building, it was necessary either to design an alternative radiation and convection system in the building for low temperature water or to boost the temperature of the well output to near 180°F for the existing hot water system. Furthermore, to supply heat rates at two to five times that of the well output, a storage reservoir had to be included to store the heat during nonworking hours. Raising the temperature out of the well heat-exchanger necessitated the use of heat pumps. These choices were dealt with separately as particular case applications and were denoted for convenience as options A, B, C, and D. Block diagrams of each of these systems are shown in Ref. 1; option A (with the storage reservoir) is reproduced here (Fig. 1).

Option A uses geothermal heat directly in a floor radiating system and retains the existing oil-fired heaters for additional (peak) heating (15% of the total) during only the coldest weather. Option B, on the other hand, uses a heat pump to raise the temperature of the well output in order to use the existing heating system, providing 73% of the annual heat load. Options C and D are variations of option B that include the installation of a storage reservoir nearby and another heat pump to provide all the heat required by the building. With available heat pumps, almost twice the thermal energy from the well is recoverable so that, with a storage reservoir, enough heat is available to heat one or more additional buildings without significant additional capital investment.

The results of the computations made for the four options are shown in Table 1. The net

Fig. 1 Direct use of geothermal energy to heat building LP-167 using floor radiation (option A). (80-2/40)

saving on operating cost is made up of: (a) the cost of oil, escalating at 3.5% (plus a 9% inflation rate); (b) the electrical operating cost of the equipment in the geothermal system, escalating at 1.5% (plus 9% inflation) for electricity as well as any oil costs for peak heating; and (c) the maintenance cost of the geothermal system less the maintenance cost of the oil-fired system. The net operating return each year is given by [(oil cost in 1980) $(1.125)^n$ + maintenance cost of oil-fired system] - [(electric power cost in 1980) $(1.105)^n$ + (peaking oil cost in 1980) $(1.125)^n$ + maintenance cost of geothermal systems].

Table 2 shows the conservation of oil at NARF (as derived in Table 1) and the corresponding potential oil use transferred to the electrical power company by the geothermal system; e.g., we see that, for option A, the use of oil at NARF would be decreased from 73,100 gal/yr to 10,965 gal/yr. The electricity for the geo-

Table 1
Cost summary.

Costs	Option			
	A	B	C	D
Capital cost	\$560.2k	\$501.1k	\$914k	\$829.1k
Operating	Geothermal 17.9k(1.105) ⁿ + 9.87k(1.125) ⁿ 100% Oil 65.79k(1.125) ⁿ + 4k(1.09) ⁿ	Geothermal 39.32k(1.105) ⁿ + 17.76k(1.125) ⁿ 100% Oil 65.79k(1.125) ⁿ + 4k(1.09) ⁿ	Geothermal 49.68k(1.105) ⁿ + 6.8k(1.09) ⁿ 100% Oil 65.79k(1.125) ⁿ + 4k(1.09) ⁿ	Geothermal 74.4k(1.105) ⁿ + 5.96k(1.09) ⁿ 100% Oil 65.79k(1.125) ⁿ + 4k(1.09) ⁿ
Net	55.92k(1.125) ⁿ - 17.9k(1.105) ⁿ	55.13k(1.125) ⁿ - 39.32k(1.105) ⁿ	65.79k(1.125) ⁿ - 49.68k(1.105) ⁿ -2.8k(1.09) ⁿ	65.79k(1.125) ⁿ - 74.4k(1.105) ⁿ - 1.96k(1.09) ⁿ
Amortization	11.5 years	22.5 years	26 years	< 40 years
Equipment required	Geothermal well source Reinjection well Heat exchanger Floor radiation system Existing oil-fired boiler system (for 15% heating) Storage reservoir (100 by 100 by 8 ft)	Geothermal well source Reinjection well Heat exchanger Heat pump: 391 hp Oil-fired system (for 27% of heat load)	Geothermal well source Reinjection well Heat exchanger Three heat pumps: 391 hp 327 hp 756 hp Storage reservoir (100 by 50 by 6 ft)	Geothermal well source Reinjection well Heat exchanger Two heat pumps: 195 hp 1004 hp Storage reservoir (100 by 50 by 6 ft)

Table 2
Oil use.

Option	Capital (\$)	Amortization (yr)	Oil used at LP-167 (gal)	Oil at power plant* (gal)	Net saving (gal)
Existing oil-fired system	-	-	73,100 (avg.)	0	0
A	560,200	11.5	10,965	12,058	50,077
B	501,100	22.5	19,737	33,000	20,363
C	914,000	26	0	41,694	31,406
D	829,100	< 40	0	62,441	10,659

Notes:

*Coal or nuclear would zero this item.

- Options A and B retain use of the existing oil-fired hot water system for peak heating, needed only in the coldest weather.
- Option C uses the waste heat from the geothermal well, thus doubling its useful output. It also provides a large reservoir of heat available for heating a similar building in the area. If additional use is made of this heat, the savings in oil burned could increase significantly and the amortization time decrease as well.
- Option D is less desirable and more expensive, although this system also makes available the 24 h output of the well, which is twice the total annual demand of building LP-167.

thermal well and circulating pump system could require as much as 12,058 additional gallons of oil to be burned at the power plant. Thus the net saving in oil consumption would amount to 50,077 gal. Similar calculations for the other options point out that, not only is the economic cost in dollars over a period of years significant, but so is the net saving in the nation's oil supply.

CONCLUSIONS

Because they are single-story buildings with large floor areas, military aircraft hangars are particularly suitable and adaptable to the use of low-temperature geothermal energy. A

6 in. thick concrete slab must be installed over the existing floor with pipes or water conduits inside for water circulation.

A warm water storage reservoir is only moderately expensive to install and is very useful for a variety of heating systems. It solves the peak heating problem and can furnish enough heat to sustain a second building (in the case of option C, two more buildings).

Current inflation rates, as well as the escalation rates for oil and electricity, make rather costly capital equipment economically feasible for long payback periods. Thus options A and B can be amortized in less than 23 years and displace 50,000 to 62,000 gal/yr of fuel oil. However, amortization beyond 20 years is ques-

(continued)

tionable, regardless of the options, because economic conditions, newer equipment, and industrial growth rates may change significantly. On the other hand, in 20 years, energy supply availability may outweigh cost.

Additional work is required to locate and evaluate an optimum well site.

The possible disposal of waste water in the Atlantic Ocean should be determined.

Combined heating and cooling using heat pumps would increase utilization and improve system economics.

Modifications in costs caused by changes in the resource characteristics (e.g., output temperature, pumping rate, and drawdown) are possible. The extent of these changes must await operating experience with geothermal wells in the Atlantic Coastal Plain, and on a model of

the hydrology and thermal properties of the resource.

It has been suggested that the next step is to extend one of the gradient or other experimental wells in the area to basement to confirm the water temperature, the thickness and productivity of the basal sands.

REFERENCES

1. Section 21, Quarterly Report, Jan-Mar 1980, JHU/APL EQR/80-1.
2. "Technical Assistance Report No. 5, Geothermal Space Heating - Naval Air Rework Facility, Norfolk, Virginia," JHU/APL QM-80-102, Jun 1980.

GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE

§ 20

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

W. J. Toth

April-June 1980

GEOHERMAL ENERGY MARKETS ON THE ATLANTIC COASTAL PLAIN-- MARKET DEFINITION

A Geothermal Energy Market Study (GEMS) has been performed in four of the six potential geothermal resource areas on the Atlantic Coastal Plain. The purposes of the study were (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 those 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 conducted the first two efforts. The Center for Metropolitan Planning and Research of The Johns Hopkins University (Metro Center) assisted in the last two efforts, which are reported elsewhere in this Quarterly Report.

SUMMARY

The markets for thermal energy at temperatures 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 published shortly. Extension of the GEMS efforts to South Carolina and Georgia should begin by the summer of 1980.

DISCUSSION

All data on thermal energy demands at temperatures below 250° have been reviewed for each

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

resource area; the findings are summarized in Table 1. As these data illustrate, the largest demands are for residential and commercial space and water heating. 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 support methods, such systems are not universally applicable. Reference 1 indicates that only a fraction of the demand (e.g., less than 10% on the Delmarva Peninsula) can be satisfied by such systems because, to be economically feasible, they require moderate to high population densities.

The second largest category is water and space heating for the military. District heating systems would be required, but nearly all of the military demand probably would be satisfied because the military population is reasonably well concentrated. However, in addition to the institutional problems that may be encountered, there may be a major economic problem in retrofitting the steam systems in current use. Furthermore, so far as is known, most of the military installations are not colocated with re-

Table 1

Current demands (in Btu/yr $\times 10^{11}$) for thermal energy at temperatures below 250°F in the four resource areas.

Resource area	Residential and commercial	Military	Agricultural	Industrial
Southeastern New Jersey	307.8	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 $\times 10^{11}$ Btu/yr.

sources 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 the Delmarva Peninsula, meeting existing agricultural demands with geothermal energy is not likely to be economically feasible. If future demands can be concentrated, or if several demands can be combined at one location, the economics may be more attractive.

Heat demands for industrial processes offer the best prospects for the near-term use of geothermal energy. 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 demand (and about half of the industrial demand) on the Delmarva Peninsula. In addition, many of the poultry plants are believed to be colocated 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 efforts toward commercialization of geothermal energy by DOE. Southeastern New Jersey, with a total demand 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 colocated with resources whose temperatures are reasonable, most of the industrial demand lies inland where resource temperatures are probably lower. Norfolk, with 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 greatest potential.

In summary, the GEMS results to date indicate that the Delmarva Peninsula is the most attractive resource area. Southeastern New Jersey is second because some of its demand is colocated with warmer resources and because land

is available in these areas for future industry. Norfolk is probably a reasonable third choice because of the lower temperature resources in the area for water-referenced heat pumps. Eastern North Carolina, with 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. The major recommendations that have emerged from the GEMS efforts are summarized in Table 2.

Table 2

Conclusions and recommendations.

1. The Delmarva Peninsula is the most attractive area from a market point of view.
2. Initial efforts at commercialization should be directed primarily at the industrial sector.
3. There should be an aggressive resource exploration program where wells are turned over to users.
4. Interagency cooperation for immediate exploration of resource quality at large government and military facilities should be encouraged.
5. An enlarged DOE program for educating the public sector on the benefits of district heating and for putting such systems in place should be initiated.

FUTURE PLANS

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

REFERENCES

1. Section 13, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
2. J. K. Costain, L. Glover III, and A. R. Sinha, "Evaluation and Targeting of Geothermal Resources in the Southeastern United States, Progress Report," VPI&SU-5648-5, 1 Oct 1978 to 30 Mar 1979.

GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE

\$ 21

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

Support: DOE/DGE

A. Goodman, R. Dubin, and W. Barron (Metro
Center)

April-June 1980

GEOHERMAL ENERGY MARKETS ON THE ATLANTIC COASTAL PLAIN- MARKET PENETRATION

In connection with its assessment of the potential impact of geothermal energy and the development of plans to ensure its maximum use, DOE has asked APL to develop a methodology for estimating the energy market penetration of moderate-temperature geothermal resources on the Atlantic Coastal Plain.

The initial emphasis in this investigation has been related to the residential and commercial space-heating market, by far the largest user of modest temperature energy in the eastern United States.

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 three areas. The first involves further refinement of a theoretical model that discusses the explicit decision made by an individual homeowner faced with a choice of geothermal or conventional heating systems (Ref. 1). The second area involves the use of the Geothermal Resource Interactive Temporal Simulation (GRITS) model to estimate the advantages of accelerated market penetration for two hypothetical utilities (Ref. 2). The third area of research studies the decision-making process in which the developer chooses the type of heating system to be installed in a new development (Ref. 3).

DISCUSSION

Theoretical Model. There has been substantial interest in and a growing literature about market penetration by geothermal heating technology. Generally this has been done at a "macro" level where a resource is located and, based on housing and geographical data, the market penetration is calculated. This type of analysis does not address the homeowner's decision with respect to the conversion of heating systems and ignores the financial constraints that face homeowners in the provision of home space heating.

The theoretical model that has been developed to analyze the individual homeowner's choice of geothermal or conventional heating systems has been further refined (Refs. 1 and 4). From the model, the market penetration is seen to be a function of age of the existing furnace, differential in efficiency of the two systems, and costs of conversion (hook-up costs). It is

seen that sizable differentials in efficiency (60% or more) may be necessary to offset capital losses and hook-up costs attendant to conversion. Furthermore, the model can be used to calculate a set of incentive payments necessary to induce households to convert when the efficiency differentials are unattractive. A paper discussing this model in greater detail has been sent to the Geothermal Resources Council for its Salt Lake City Conference.

Application of GRITS Model. 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. The benefits of accelerated market penetration are calculated through changes in the net revenue stream over the economic life of the project (e.g., 20 years of operation). The costs of accelerated penetration are calculated according to the projected response to a range of cash bonus offers. The level of response is estimated from the assumed capital costs of geothermal and traditional heating plants, as well as from differences in the operating costs of each type of housing. Although the homeowner will choose the system with the lower total costs, the utility can influence the decision with cash bonus offers that make geothermal more attractive.

Since the decision to convert depends on the age of the current heating system, geothermal heating is likely to be an attractive option to only a fraction of the market. However, the utility can speed up the rate of market penetration by making cash bonus offers in order to overcome the value remaining in the existing heating plant. The bonus offer, as considered here, takes the form of a tender offer to pay a specified cash amount to any customer who joins the community heating system. The offer remains in effect over the entire project evaluation period.

In the analysis, the heating plant stock is assumed to have a uniform distribution of ages, t , from 1 to 20. Thus, based on the decision variables, an additional 5% of the potential customers within the utility's market service area would accept the bonus offer each successive year as their heating plants aged and the service values declined.

The benefits of a specified initial level of market penetration followed by a 5% annual increase until complete penetration is attained are calculated for one utility exploiting a relatively good geothermal resource and for one using a resource of only fair quality. For this comparison, demand and financial conditions were the same for the two utilities. Each utility is assumed to sell its energy at a constant 1980 real price of \$7 per million Btu.

The gross profit (revenues minus costs) associated with a given initial market penetration followed by the 5% annual increase was calculated. The GRITS model was used to compute gross profit as a function of market penetration under the two extreme conditions of no bonus offer (real geothermal price advantage) and zero geothermal price advantage (a significant bonus offer).

The utility would presumably compare the gross profit associated with a given initial penetration with the costs required to attain that level. The optimal tender offer is the point at which the marginal costs and marginal profits are equal. Figure 1 shows the marginal

Fig. 1 Initial percentage market penetration followed by 5% annual increase. (80-2/41)

curves for the fair resource utility. The optimal market penetration changes relatively little even with the substantial drops in the required bonus as the geothermal price advantage increases. For resources of relatively low quality, payment of the full or even a substantial portion of the conversion costs makes the undertaking unprofitable.

This analysis illustrates some of the implications of the investment in existing home

heating. A more complete explanation of the current work can be found in Ref. 4.

Reaction of Residential Real Estate Developers to Alternative Heating Systems. The market penetration model indicates that new developments may be attractive markets for geothermal residential heating. The large, dense developments currently being built by large tract developers are particularly suited to geothermal heating systems because no incentive or conversion costs need be paid by the geothermal provider, the buildings in the development are often located in a geographically compact area, and the decision concerning the type of heating system to be used in the entire development is made by one party (the developer). The last two characteristics in particular make large tract developments well suited to the type of community heating system required for geothermal space heating.

In light of the attractiveness of new developments as a market for geothermal space heating, the large and dense developments under construction in the period from 1977 to 1979 in Anne Arundel County, Md., were identified (Ref. 2). These developments contained 45% of all new units that were built in tract developments during this period. The purpose of this portion of the market penetration research was to study the decision-making process by which the developer chooses the types of heating systems to be installed in the new development.

The questionnaire shown in Fig. 2 was administered to the developers in a telephone survey. Developers of 10 out of the 18 developments identified in Ref. 2 were contacted, representing 1410 (66%) of the 2133 housing units of interest. One developer concerned exclusively with the development of solar housing developments was also interviewed.

(continued)

Name _____
 Company _____
 Phone Number _____
 Date _____

Developer Questionnaire

- Can you briefly describe the process by which decisions regarding the type of heating system installed in the development was reached.
 - How much input do each of the following parties have in the decision:
 _____ Engineer
 _____ Architect
 _____ Developer
 _____ Mortgage Banker
 - Who makes the final decision?
- On what basis is this decision made?
 - Which of the following factors are most important in shaping this decision (if possible, rate these in order of importance)?
 _____ Installation Cost
 _____ Consumer Cost
 _____ Consumer Appeal
 _____ Utility Pressure

Developer Questionnaire
 Page 2

- Which of these factors are least important? Reasons?

 d. Consumer cost is composed of
 _____ Operating Costs (fuel costs)
 _____ Maintenance Costs
 Which of these is most important? Why?
 - Consumer appeal is composed of
 _____ Convenience
 _____ Cleanliness
 _____ Expectations regarding fuel availability
 _____ Expectations of future fuel prices
 Which of these is most important? Least important? Why?
 - Are there any other factors not previously discussed which influence this decision?
- What is your feeling about installing innovative heating systems, such as solar, geothermal, etc., in new housing development? Why?
 - What do you think _____'s (the person with final decision if different from person being interviewed) feeling is?
 - Do you see these systems becoming important in the housing industry in the future? Why?

Fig. 2 Developer questionnaire. (80-2/42)

The responses to the questions in part 1 of the survey indicate that, while the decision-making authority varies with the structure of the firm, in most cases the developer makes the final choice of the type of heating system. Some of the larger firms have an architectural and engineering department in which the decision is actually made (although it must be approved by the president). In the smaller companies, the developer makes the decision after consulting with his engineers and/or architects.

The answers to the questions in part 2 revealed that the developers of large tracts of houses are primarily interested in high volume sales. In order to produce the volume that they need, the developers strive to offer consumers popular systems at the lowest possible cost. Because of the emphasis on maintaining a low selling price, the cost of the installation of the heating system becomes an important factor in determining which type of heating system to use. However, if the developer feels that there is a market for a particular type of system, he will use it, even though it may cost more to install. Utilities affect the choice of heating system in a development in that they often determine what fuels are available. Utilities are sometimes consulted for estimates by fuel type of heating costs for the units in the development, enabling the developer to make the most economical choice.

The majority of builders interviewed felt that operating costs and expectation of future fuel prices and availability were important considerations in determining the choice of heating system. Maintenance costs were important only in the sense that developers prefer installing mechanically simple heating systems to complicated ones, because simple systems are less prone to high maintenance costs. However, most developers felt that maintenance cost considerations were secondary.

The answers to part 3 of the survey indicate that most developers feel that alternative heating systems will become important in the future. At present, they feel that there are no good systems available to compete with the more traditional fuels. Some of the developers expressed the opinion that, as consumer demand for such systems increased, better products will become available and developers will begin installing such systems in housing developments. The

major result to come out of this part of the survey is that developers are generally averse to risking large amounts of capital on unproven systems.

The remarks made by the interviewed developers indicate that, if geothermal energy can be demonstrated to be a reliable and economical method of heating homes, large tract developers may find geothermal space heating an attractive option. Geothermal energy will be attractive to these developers because it will allow them to build dense developments, and thus to sell more houses (the desire to build dense developments is a major obstacle to the use of solar heating in these developments). However, the high installation cost of geothermal community systems may discourage their use in developments unless it can be demonstrated that consumers are willing to pay for this added cost. The major obstacle to getting geothermal space heating installed in these developments will probably be in demonstrating the reliability and economic feasibility of the systems.

FUTURE PLANS

The analysis of benefits and costs of accelerated market penetration by a geothermal community heating system will be studied further. The GRITS model will continue to be used to develop the estimates of the advantages of increased market penetration.

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2. W. Barron, P. Kroll, and W. J. Toth, "GRITS: A Computer Program for the Economic Evaluation of Direct-Use Applications of Geothermal Energy," JHU/APL GEMS-008/QM-80-077, Jun 1980.
3. Section 14, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
4. A. C. Goodman, "Geothermal Market Penetration in the Residential Sector: Capital Stock Impediments and Compensatory Incentives," Center for Metropolitan Planning and Research/JHU (submitted to Geothermal Resources Council).

GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE

§ 22

Development of Geothermal Energy in the Eastern

U. S. ZJ7CAS

Support: DOE/DGE

F. O. Mitchell

April-June 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

The report of this methodology has been revised (Ref. 2) to incorporate additional data for Mississippi (Ref. 3) and Pennsylvania (Ref. 4). Small changes in the method of calculation were made, and the prospects (260 counties in 12 states) were reranked. Table 1 displays the 39 counties (in seven states) that rank among the first 25 counties under at least one of the following criteria. The first overall ranking gives equal weight to temperature, cost, energy use in the next three categories, the number of towns and cities, the number of heating degree-days, and value added in manufacturing. The second ranking, residential use, selects as the bases of comparison temperature, well cost, current residential use of energy, the number of towns and cities, and the number of heating degree-days. The third, commercial applications, uses the same bases of comparison as the second, except that the current commercial use of energy is substituted for residential use. The fourth emphasizes industrial development and selects temperature, well cost, current industrial use, the number of towns and cities, and value added in manufacturing. In these examples, the weightings are always taken as equal, although it is obvious that a particular criterion (e.g., the number of towns and cities) should have a greater importance in the residential ranking than in industrial.

FUTURE PLANS

The revised report (Ref. 2) will be distributed early in the next quarter. In the future, as new data develop from resource definition programs (Ref. 5), this comparative analysis will be exercised.

REFERENCES

1. F. O. Mitchell, "Evaluation of Potential Geothermal Resource Areas," JHU/APL QM-79-163/GT, Jul 1979.

Table 1

Select prospects under different criteria.

States/Counties	Overall	Residential	Commercial	Industrial
Illinois				
Champaign	19	27	27	44
Sangamon	9	13	13	11
Vermillion	13	30	29	21
Indiana				
Knox	38	34	36	25
Tippecanoe	28	25	26	23
Michigan				
Tuscola	31	22	24	70
Mississippi				
*Harrison	60	77	74	20
*Hinds	18	36	32	1
*Jackson	79	95	88	16
*Madison	84	89	80	15
Montgomery	72	94	82	17
*Washington	42	45	44	6
New York				
Allegany	36	26	25	97
Cattaraugus	20	17	16	59
Cayuga	26	10	9	52
Chemung	30	15	15	33
Steuben	7	1	1	10
Tioga	33	12	11	64
Wyoming	43	24	22	84
Ohio				
Belmont	23	19	21	26
Pennsylvania				
Blair	21	32	33	34
*Butler	5	2	2	2
Cambria	12	23	23	19
*Carbon	17	14	14	22
Centre	22	29	30	45
Clearfield	24	21	20	39
*Columbia	25	28	28	24
Crawford	10	8	8	12
Jefferson	29	16	17	35
*Lackawanna	2	4	4	5
Lawrence	14	20	19	18
*Luzerne	1	3	3	7
Lycoming	15	31	31	27
McKean	16	9	10	14
*Northampton	4	6	6	3
*Northumberland	11	11	12	9
*Schuylkill	6	7	7	8
Washington	3	5	5	4
Westmoreland	8	18	18	13

*New data.

2. F. O. Mitchell, "Evaluation of Potential Geothermal Resource Areas: Revised," JHU/APL, QM-79-163R/GT, Jul 1980.
3. 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.
4. "Geothermal Gradient of Pennsylvania/Western New York (Portfolio Map Area No. 3), Geothermal Survey of North America," American Association of Petroleum Geologists.
5. "Resource Assessment/Commercialization Planning Meeting," Salt Lake City, DOE-DGE/DGRM, 21-24 Jan 1980.

GEOHERMAL ENERGY DEVELOPMENT PLANNING AND TECHNICAL ASSISTANCE

§23

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

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

April-June 1980

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

APL and the Metro Center are investigating legal, institutional, and environmental barriers to the development of direct applications of geothermal resources in Delaware, Maryland, and Virginia. Reports have been prepared that assess the legal and institutional contexts for commercialization in Maryland (Ref. 1). The investigation of Delaware and Virginia is continuing (see articles elsewhere in this Quarterly Report). To further this effort, the Metro Center has begun to identify more specific issues of concern to geothermal energy development. The latest completed report assessed the potential for minority business participation in development (Ref. 2), while the current thrust of research addresses the question of public utility regulation by state public service commissions (PSC's).

SUMMARY

The extent and nature of PSC regulation of a variety of potential users in the three states are currently under consideration. To aid this analysis, a typology of administrative entities and resource applications is proposed. Preliminary findings indicate that most industrial process-heat applications of geothermal resources would be exempted from regulation by the PSC, as would municipally run utilities and most other forms of local multipurpose governments (counties), though this varies by state. Special districts (local single-purpose governments such as water authorities or Oregon's geothermal heating districts) would also be likely to avoid regulation as public service companies. The status of cooperative associations and private developers is less clear, and the three states

examined are far from uniform in their treatment of public utilities codes.

DISCUSSION

The issue of PSC jurisdiction over a geothermal district heating system or other entity is one that has not, as far as this investigation has determined, been addressed in geothermal literature dealing with the east. In addition, only one project has looked at the problem for the western states (Refs. 3 and 4). PSC regulation becomes an important question in the east when it is placed in a matrix of other potential barriers to development, including physical, economic, legal, environmental, and institutional barriers. Lack of primary information about the resource has also impeded development on the part of local governments, private concerns, and other interested parties in the mid-Atlantic region. When the prospect of PSC regulation is added to these difficulties, the decision to adopt or even to consider use of geothermal resources becomes more problematic.

To aid in the task of cross-jurisdictional analysis, a typology of potential users and administrative entities is proposed (Table 1). This typology attempts to encompass accurately all the potential direct applications and administrative arrangements that could arise in the mid-Atlantic region and is adapted from a similar scheme used by the western investigators (Ref. 3).

On the application side, the division in production between single and multiple users is meant to reflect the difference between a potential single user such as the Perdue chicken complex near Salisbury, Md., and an integrated industrial park where several different processes and companies would share in the production of one or several wells. The division in space-conditioning users is meant to distinguish between isolated applications like the Crisfield, Md., High School and district heating systems of the sort envisioned for Ocean City, Md., or Lewes, Del. A cascaded application would combine multiple space-conditioning applications with industrial process heat users in the same system, with the uses designed to maximize efficient use of the captured enthalpy. An example of this sort is the proposed system for Susanville, Calif., a model that may be replicable in the east at selected sites such as Salisbury, Md.

Administrative entities for a geothermal system could encompass virtually any sort of institutional arrangement, as is reflected in the typology. Federal or state demonstration projects (the Maryland Geothermal Resources Act of 1978 authorizes such activities, though the ap-

Table 1

Typology for geothermal end-users by application and administration.

Application	Administration
Production:* single user	Government: federal/state
Production: multiple users	Government: local multipurpose
Space-conditioning: single user	Government: special district
Space-conditioning: multiple users	Private sector
Cascaded application	Cooperative association

*Production includes all process-heat users and agricultural and aquacultural applications, as well as any potential production-oriented cooling.

Table 2
Exemptions from PSC regulation.

Application	Government: federal/state	Governments: local/multi- purpose	Government: special district	Private sector	Cooperative association
Production: single user	Delaware Maryland Virginia	Delaware Maryland Virginia	Delaware Maryland Virginia	Delaware Maryland Virginia	Delaware Maryland Virginia
Production: multiple users	Delaware Maryland ¹ Virginia	Delaware ² Maryland Virginia	Maryland Virginia		Maryland
Space- conditioning: single user	Delaware Maryland Virginia	Delaware Maryland Virginia	Maryland Virginia	Delaware Maryland Virginia	Maryland
Space- conditioning: multiple users	Delaware Maryland Virginia	Delaware Maryland Virginia	Maryland Virginia		Maryland
Cascaded application	Delaware Maryland Virginia	Delaware Maryland Virginia	Maryland Virginia		Maryland

Notes:

¹Maryland exemptions in this table are based on the assumption of not-for-profit applications, the sole criterion in the Maryland Public Utilities Code.

²Only municipalities, not counties, are exempt in Delaware.

This tabulation is based on preliminary findings through June 1980.

propriation of state monies for such purposes is unlikely at present), municipal or county authorities, or local single-purpose entities (such as special heating districts or even school districts) could find themselves administering a geothermal system. Private developers may be interested in providing geothermal resources, as could existing utilities (although now their interest in the east is minimal) or cooperative associations of homeowners or process heat users. The typology provides a convenient means of comparing the level of regulation of similar entities across state borders. This comparison (still at the preliminary stage) is summarized in Table 2.

In summary, any private developer of geothermal resources (apart from most industrial applications) would be subject to regulation as a public service company. Additionally, recent investigations indicate that the municipal exemptions from regulation based on the premise that elected officials are sufficiently accountable as to obviate the necessity for PSC oversight of municipal functions may be under attack; this may be especially true in Delaware, where counties would not be exempted from regulation, while municipalities are.

FUTURE PLANS

In assessing the impact on geothermal development, future plans will include specific inquiries into the decision-making process of developers in the various classes to determine the precise impact of factors such as public utility regulation. If the impact, even for certain classes of users alone, is sufficient to substantially deter development, state legislatures will be urged to specifically exempt geothermal developments from regulation or to lessen the weight of such regulation. Alternatively, legislatures may enact comprehensive district heating statutes

that would clarify the status and vulnerability of geothermal energy, or they may follow the example of Oregon, which enacted enabling legislation for geothermal heating districts.

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2. J. G. Cherim, "Small Minority Business Opportunities for Direct-Use Geothermal Energy," The Johns Hopkins University Center for Metropolitan Planning and Research, Contract APL-600830, Feb 1980.
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2. Maryland Annotated Code, Public Service Commission Law, Article 78 §1-91, 1957.
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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

R. von Briesen, F. C. Paddison, A. M. Stone, C. S.
Leffel, Jr., R. F. Meier, W. B. Chapman, and
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April-June 1980

COMMENTS ON LIMITED TASKS: GEO- THERMAL ENERGY DEVELOPMENT PLANNING

FORMATION OF STATE TEAMS

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 (Delaware, Maryland, and Virginia). 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 written by APL. Each state was required to submit a proposal to DOE in order to obtain DOE funding to complete its prospectus.

As reported in Ref. 1, the Delaware proposal for completion of the state-specific prospectus has been finished and submitted to DOE. The proposal assigned the responsibility for organizing the state team to the State Energy Office. Maryland and Virginia have not organized their state teams or completed their proposals. During this quarter, APL has continued its efforts to encourage these states to complete their tasks.

On 10 April, APL held a meeting with Felicity Evans, Conservation Chief of the Maryland Energy Office; a representative of DOE also attended. APL reviewed the status of current DOE geothermal programs on the Delmarva Peninsula as well as projected future activities. In particular, the results of the application studies that APL had performed for interested parties, public and private, were reviewed. Mrs. Evans stated that Maryland is interested in completing the prospectus and forming the state team if the Energy Office thinks it can get the cooperation of other state agencies to ensure a competent effort. While no DOE funding for a Maryland effort will be available in FY 80, DOE would welcome a proposal from Maryland and recognized the desirability of supporting a state team over a useful period if a viable one can be organized.

REFERENCE

1. Section 16, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.

ASSISTANCE TO THE NCSL GEOTHERMAL WORKSHOP

State of Delaware. Following a series of workshops organized by the National Conference of State Legislatures (NCSL) to discuss geothermal resources and their potential use in the State of Delaware, a Geothermal Resources Act

was passed (Ref. 1). At the time of discussion of the bill on the floor of the Senate, J. G. Cherim of The Johns Hopkins University Metro Center was asked to provide expert testimony regarding the issue of state ownership (Ref. 2).

Chris Warner, Director of the State Energy Office, requested further elaboration of this and other issues in preparation for discussion in the House of Delegates. Reference 3 documents APL's suggestions. (The bill, now passed by both houses of the legislature, awaits the governor's signature.)

State of Maryland. On 15 May 1980, the State Special Joint Legislative Committee on Energy met with Sherri Valentine of NCSL to discuss possible reconsideration of the Maryland Geothermal Resources Act. NCSL provided two publications, one dealing with the geothermal act (Ref. 4) and the second dealing with heat pumps (Ref. 5). APL representatives spoke on the issue of public versus private ownership and briefly reviewed current interest and activities in geothermal energy in Delmarva. Reference 6 documents these discussions. Reference 7 is the official minutes of the meeting published by the Secretary of the Special Joint Legislative Committee on Energy. A narrative discussion of ownership and other issues and a compilation of significant documents pertaining to geothermal energy development in the area were forwarded to the committee (Ref. 8). A follow-on meeting is planned for early July 1980.

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2. J. C. Cherim, "Testimony before Delaware State Senate on Tuesday, 20 May 1980," Metro Center memorandum, 28 May 1980.
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5. "Guidebook to Groundwater Heat Pumps," National Conference of State Legislatures, May 1980.
6. F. C. Paddison, "NCSL Presentation to Maryland Joint Legislative Committee on Energy," JHU/APL QM-80-080, 22 May 1980.
7. Special Joint Committee on Energy, "Minutes," 15 May 1980.
8. "Geothermal Energy and Maryland Geothermal Resources Act," JHU/APL Lett. CQO-2901, 23 Jun 1980.

GEOHERMAL RESOURCES AS COMMON PROPERTY RESOURCES

The Delaware Geothermal Resources Act of 1980, S.B. 469, passed both houses of the Delaware legislature in June 1980 and now awaits the signature of the governor. Among other considerations, this act classifies geothermal resources as *sui generis* (unique) and vests ownership and management of the resource in the state. In Maryland, the Special Joint Legislative Committee on Energy is considering revision of the Maryland Geothermal Resources Act of 1978 (M.A.C. 8-8A) to remove current ambiguity in language as to who owns the resources in Maryland. Committee and staff discussion to date has resulted in a consensus favoring state ownership and allocation. The differences between the eastern and western resources in the United States - in terms of economic viability expressed in temper-

atures, flow rates, rates of recharge, etc. - cannot be overstated. Unique eastern resources must be treated with new legal and institutional arrangements, not according to other, less appropriate models. While geothermal resources are not unlike groundwater in the mode of extraction and delivery, or minerals in terms of applications (energy), the facts of resource conditions have posed new problems for technical policy planners in the East.

DOE, in its reservoir engineering program (Ref. 1), is developing generic tools to assist persons interested in the quantitative assessment of hydrologic, thermal, chemical, and compaction problems attendant on the withdrawal of geothermal fluids. APL will apprise the state teams of the programs and their applicability. Further, a body of literature and information relating to geothermal resources and legal and economic theory is being examined as a source of guidance to the states.

A major consideration in the development of geothermal resources is the economic issue of inefficiency accompanying common property resources. The common property resource classification applies to resources in which no authority exists to restrict the entry of additional users of the resource or to limit the degree of use by each participant (Ref. 2) and where the resource is largely interconnected, not differentiated into separate user units (Ref. 3). In addition to geothermal resources, well-known examples of common property resources include fish in an ocean or lake, a commonly held sheep-grazing area, and pools of oil.

The common resource problem arises from the inability of initial users to exclude newcomers or from the inability to monitor increased use by the initial users, leading to overexploitation of the resource. No one "owns" the resource; therefore no one has the incentive to limit use to that level at which the resource can be best utilized. The immediate gain to the individual far exceeds the long-run consequences of such actions that the individual will have to bear. Private and social efficiencies diverge greatly. The gains from socially inefficient actions accrue to the private individual user, while costs of such private actions are spread among all users. There is no reward for users who exercise restraint, if new users can begin to utilize the resource or other existing users can expand their levels of effort. Common property features of resources have led to waste of capital investment and destruction of resources (e.g., the extinction of species and the loss of pressure in oil fields).

A substantial body of literature exists on problems caused by the common property nature of fish and oil-field resources (Ref. 4). The economics of common property resources has important implications for identifying institutional/legal/economic barriers to development as well as problems associated with determining the most appropriate levels of use (i.e., number of wells, level of utilization per well, well spacing, etc.).

In relation to geothermal development, a fairly substantial and rather similar body of literature in the legal realm has developed that explores these difficulties as they relate to western resource pools (Refs. 5, 6, and 7). Common responses have involved the application of the western water law doctrine of correlative rights or the oil and gas mineral doctrine of the rule of capture, modified by regulations on well

spacing requirements, staggered limits on volume extracted, and enforced unitization of fields with the designation of a lead operator (Ref. 8). To date, no rigorous examination of the eastern context has been undertaken outside of site-specific analyses. Preliminary indications are that the eastern water law is rather inhospitable to the development of moderate-temperature hydrothermal resources (Ref. 9). Because the economic viability of these resource pools is a delicate equation, treatment of the resource as a mineral is likely to open the possibility of a tangled web of ownership litigation detrimental to development.

The approach taken by Delaware was to let the state assume the burden of possible litigation rather than the developer and to let development rights remain in the hands of the private landowner. Current research indicates that this combination - public domain ownership for legal purposes and *sui generis* (unique) characterization for legal and regulatory purposes - offers the best opportunity for the early commercialization of eastern hydrothermal resources.

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9. A. D. Tarlock, "Eastern Water Law and Geothermal Development," presented at NCSL Symposium on Geothermal Energy and Its Direct Uses in the Eastern U.S., Roanoke, Va., Apr 1979.

FRENCH EXPERIENCE IN GOVERNMENT LOANS/GUARANTEES FOR GEOTHERMAL ENERGY

On 11 February 1980, a series of questions was Telexed to the French Committee on Geothermal Energy of the Ministry of Industry to determine generally the outcome of the French experience in the commercialization of geothermal energy by means of government support by guaranteed or forgivable loans or grants. A reply was received this quarter, with specific answers

(continued)

to each question; both the list of questions and the answers are given in Ref. 1. The significant points were

1. Loans are forgiven (i.e., become grants) if the temperature is too low or the output insufficient. The terms are negotiated prior to the loan; the Geothermal Committee makes the final determination.
2. All French geothermal efforts to date (a dozen or so) have obtained government loans.
3. At present, only three loans have had to be converted to grants (see item 1 above).
4. The present trend is toward government ownership of all geothermal enterprises, mainly municipalities, new city planning agencies, the low-cost housing bureau, and so on.

REFERENCE

1. JHU/APL Lett. CQO-2887 to R. Stephens from A. M. Stone, 20 May 1980.

COSTS OF GEOTHERMAL WELLS

One of the difficulties that APL has experienced in its Technical Assistance program for potential geothermal developers on the Delmarva Peninsula is obtaining a reasonable estimate for the cost of drilling geothermal wells. As reported in Refs. 1 and 2, the Maryland Geological Survey convened a meeting on 28 March 1980 with a water-well driller, A. C. Schultes and Sons, Inc., to discuss the problems of drilling a high-yielding geothermal water well at Cove Point, Md. As a consequence of that meeting, the Schultes company agreed to supply estimates for several wells, including a meaningful test well, a production well, and a reinjection well.

On 24 April 1980, Mr. Schultes presented to APL the design and cost estimates for seven wells; these estimates are (Ref. 3)

Design features	Yield (gal/min)	Cost
3000-ft production well, 8-in. screen, gravel pack	1000	\$700,000
4000-ft production well, 8-in. screen, gravel pack	1000	\$950,000
3000-ft production well, 6-in. screen	300	\$480,000
2900-ft reinjection well, 4-in. screen	100, capacity	\$230,000
4000-ft production well, 4-in. screen	100	\$250,000
3000-ft production well, 6-in. screen, gravel pack	500	\$850,000
3000-ft reinjection well, 6-in. screen, gravel pack	500, capacity	\$850,000

These costs are higher than APL had originally estimated from costs derived from oil-well drilling information. At the Washington, D.C., sectional meeting of the Geothermal Research Council in May, Burns and Roe Industrial Services presented cost figures obtained in its Program Research and Development Announcement (PRDA) study of the geothermal conversion of the Camp-

bell Soup plant at Salisbury, Md. For two wells, 5000-ft deep and finished with a stainless steel screen and gravel pack, Burns and Roe quoted cost estimates as follows:

Gruy Federal, Inc.	\$1,037,000
D'Appalonia	800,000
A. C. Schultes and Sons	1,080,000 - 1,650,000

These costs are documented in Ref. 4.

The cost of drilling geothermal wells on the Atlantic Coastal Plain is somewhat uncertain and will remain so until bids are let for an actual production well in the area.

REFERENCES

1. Section 28, Quarterly Report, Jan-Mar 1980, JHU/APL EQR/80-1.
2. "Meeting with A. C. Schultes and Sons, Inc., to Discuss Drilling of Cove Point Water Wells, March 28, 1980," JHU/APL QM-80-065, 3 Apr 1980.
3. "Cost of Wells in the Atlantic Coastal Plain," JHU/APL QM-80-079, 21 May 1980.
4. Burns and Roe Industrial Service Corp. and Campbell Soup Co., "Direct Applications of East Coast Geothermal Resources in a Frozen Food Plant - Final Report," Jun 1980.

REQUEST FOR TECHNICAL ASSISTANCE-GEOTHERMAL HEATING OF NAVAL SUBMARINE SUPPORT BASE, KINGS BAY, GA.

The Naval Submarine Support Base, Kings Bay, Ga., is currently in the late design stages. Circulating hot water heated by coal is planned for space heating and domestic hot water. The Navy has asked for technical assistance to try to make the design compatible with geothermal energy. Reference 1 forwarded a suggestion to DOE and VPI&SU to consider a gradient well in that locale. If DOE authorizes VPI&SU to drill a gradient well, the resulting data will permit the Laboratory to suggest how best to use this resource with the proposed heating system.

REFERENCE

1. "Suggested Location for Gradient Well in Georgia," JHU/APL Lett. CQO-2863, 22 Apr 1980.

PAMLICO REFINERIES

On 18 April 1980, Furman O. Clark, Jr., Chairman of the Board of Pamlico Refineries, visited APL to help ascertain the feasibility of siting an ethanol anhydrous alcohol plant at one of three locations that would be advantageous for the use of geothermal energy. Mr. Clark plans a wet corn mill, producing ethanol, corn oil, gluten, animal feed, and fertilizer. The plant would use geothermal heat, augmented as required by a boiler fueled with wood chips, for the process water in the wet corn mill process. Warm water used to steep the corn continues through the process and is not returned to the boiler. Accordingly, water of modest temperature (125 to 150°F) can be used most effectively. Mr. Clark said the plant's output would be approximately 33×10^6 gallons of 199-proof anhydrous ethanol. John K. Costain of VPI&SU was consulted (Ref. 1)

and has estimated the temperatures and depths of aquifers that might be used for a hydrothermal heat source at each site (Ref. 2). The data have been sent to Mr. Clark. Further effort is planned as Mr. Clark's plans progress.

REFERENCES

1. "Temperature and Depth Data for North Carolina," JHU/APL Lett. CQO-2868, 29 Apr 1980.
2. Lett. from R. J. Gleason and W. S. McClung (VPI&SU) to F. C. Paddison (JHU/APL), 6 May 1980.

ANNUAL GEOTHERMAL RESOURCES COUNCIL MEETING, SEPTEMBER 1980

APL and the Metro Center have submitted the following papers to the Geothermal Resources Council annual meeting to be held in September 1980 in Salt Lake City, Utah. All are to be published; the third will also be presented in a posterboard session; and the fourth will, in addition, be presented at the session, "Utilization Case Studies." Preprints of these articles will be distributed separately.

1. "Geothermal Market Penetration in the Residential Sector: Capital Stock Impediments and Compensatory Incentives," Allen C. Goodman (Metro Center).
2. "GRITS: A Computer Model for Economic Evaluations of Direct-Uses of Geothermal Energy," W. J. Toth (JHU/APL) and W. F. Barron, S. Kane, and B. Nilo (Metro Center).
3. "Technical Assistance - Hydrothermal Resource Application in the Eastern U.S.," K. Yu and F. C. Paddison (JHU/APL).

THE EASTERN U.S. GEOTHERMAL MARKET POTENTIAL AND ESTIMATED UTILIZATION VERSUS TIME

DOE/DGE has requested the Economics, Engineering, and Research Corp. of Arlington, Va., to develop an industrialization plan for hydrothermal energy. The following forms of information were requested of APL: industrial adaptability to use geothermal energy, outreach and commercialization potential, identification of barriers to development, and suggestions as to what actions are recommended for DOE/DGE. Reference 1 forwarded the available information.

DGE has requested that the New Mexico Energy Institute, together with the University of Utah Research Institute, compile a projected match of hydrothermal resources and energy markets and their possible development versus time. On 1 May 1980, a meeting was held to discuss the data. Reference 2 documents the forwarding of the data.

REFERENCES

1. "Data for Industrialization Plan for Hydrothermal," JHU/APL Lett. CQO-2862, 14 Apr 1980.
2. "Forwarding of Data," JHU/APL Lett. CQO-2874, 1 May 1980.

ASTM MEETING, 19 and 20 MAY 1980 AT DENVER, COLO.

The organizational meeting of the Committee on Geothermal Resources and Energy (designated E45) of the American Society for Testing and

Materials (ASTM) was reported in Refs. 1 and 2. The committee was broken down into the following subcommittees:

Geothermal Resources and Energy Committee	E45
Field Development	E45.10
Utilization	E45.20
Geothermal Residuals	E45.30

The subcommittees were broken down into task groups; C. S. Leffel, Jr., of APL was assigned to the Logging and Surface Geophysics task group, E45.10.04, of subcommittee E45.10. He was able to attend the meetings of task group E45.10.04 and task group E45.10.03 (Geothermal Drilling) at the Denver meeting.

Because the task groups had been in existence only since October 1979, all results reported were preliminary. The reports of the task groups that were attended are summarized below.

E45.10.03 GEOTHERMAL DRILLING

Sandia Laboratories is examining the well-casing problem with emphasis on structural response and external corrosion. Nonmetallic casings will not be considered seriously by Sandia since they cost more than steel for use at high temperatures; this does not preclude their use at lower temperatures. The American Petroleum Institute (API) has formed a committee to investigate the cementing problem for geothermal wells. The ASTM task force will await the API results.

E45.10.04 LOGGING AND SURFACE GEOPHYSICS

API has established standards for nuclear and electric logging. The task group chairman proposed that ASTM follow API standards when applicable. Logging companies, such as Dresser Industries and Schlumberger, own their own standardization facilities and are not interested in a "standard" test facility. Logging services required for geothermal wells were discussed; in general, all suggested that procedures follow current oil-well practices. The demand for geothermal logging is not great enough to encourage the logging companies to develop special instrumentation. The Sandia program to develop down-hole electronics has been essentially completed, and the results have been turned over to private industry. Sandia has demonstrated that down-hole electronics can be constructed to perform satisfactorily at temperatures in excess of 500°F. The only geophysicist present objected to any attempt to institute standards for surface exploration as being premature or useless. However, the committee consensus was that the problem required review.

Minutes of all task group meetings have been distributed to the attendees. In the concluding planning session, it was agreed that a new subcommittee on Materials, which at present is distributed throughout all three subcommittees (each with its own materials task force), should be organized.

REFERENCES

1. Section 22, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
2. C. S. Leffel, Jr., "Attendance at the ASTM Meeting, 17 and 18 October 1979, Philadelphia, PA," JHU/APL QM-79-244, 1 Nov 1979.

(continued)

TRADITIONAL SPACE AND PROCESS HEATING FUEL-PRICE PROJECTION - REFERENCE UPDATED

The Metro Center has updated the traditional space and process heating fuel-price projection reference (Ref. 1). This reference has been developed to facilitate the comparison of geothermal energy and traditional fuel cost estimates. The new report (Ref. 2) has been published and supersedes the original reference. Prices were reviewed through the third quarter of 1979 and included those published by Brookhaven National Laboratory, Energy Information Administration, and Foster Associates for the Electric Power Research Institute. It was confirmed that energy prices rose more rapidly than had been anticipated. Brookhaven's projections were found to be the most accurate of all those reviewed. Electricity was identified as the most likely competitor for solar and geothermal space-heating systems within the next two decades for new housing and for much of the existing housing stock.

Regional price differentials show the Northeast paying above national average prices for oil, natural gas, and electricity. The West enjoys the lowest energy price levels overall. Oil prices are relatively uniform across the country, while natural gas and electricity prices may vary by more than 50% from one region to another.

REFERENCES

1. "A Review of Recent Energy Price Projections for Traditional Space Heating Fuel, 1985-2000," APL/JHU GEMS-005 (QM-79-016), Mar 1979.
2. "A Review of Recent Energy Price Projections for Traditional Space and Process Heating Fuels in the Post 1985 Period," JHU/APL GEMS-007 (QM-80-070), Apr 1980.

GEOHERMAL FACT SHEETS

The current revision of the Fact Sheets on geothermal and energy data to cover all 50 states is expected to be printed shortly. The material will provide a quick summation of the energy production in each state, with a short description of the geologic and geothermal situation, a review of the legislative progress relating to geothermal activities, and a list of contacts involved in energy matters.

EASTERN GEOTHERMAL DRILLING PROJECT

The evaluation of proposals submitted in response to DOE's Solicitation for Cooperative Agreement (SCA), Agreement No. DE-RP-80ID12132, took place on 24-25 June 1980, at the DOE Idaho Operations Office. The SCA was intended to solicit proposals for a joint venture between DOE/DGE, which desired to drill a deep geothermal exploration well on the Delmarva Peninsula, and a user who had substantial requirements for process and space heating and domestic hot water. W. J. Toth of APL and J. K. Costain of VPI&SU were selected by DOE to represent the eastern United States and to participate in the evaluation. The results will be issued by DOE after the award decision has been made.

DISTRIBUTION OF DOE SOLICITATIONS

Suggested distribution lists for DOE solicitations for the development of geothermal energy have been compiled for the Delmarva area and the eastern United States. The lists were supplied to DOE-designated offices for the following solicitations:

1. Eastern Geothermal Drilling Project, SCA No. DE-RP-80ID12132 (Refs. 1 and 2 forwarded a suggested Delmarva distribution list).
2. User-Coupled Confirmation Drilling Program (Ref. 3 forwarded a suggested eastern United States distribution list).
3. PRDA DE-RA03-80RA50121 (Refs. 4 and 5 forwarded a suggested eastern United States distribution list).
4. Solicitation for R&D information on geothermal direct heat applications project No. DE-RP-7-80ID12099 (Ref. 6 forwarded the suggested list).

These lists will be maintained for future solicitations or mailings.

REFERENCES

1. "List of Recipients, User Coupled Reservoir Confirmation Program RFQ," JHU/APL Lett. CQO-2823, 7 Feb 1980.
2. "A Revised List of Suggested Recipients of User Coupled Resource Confirmation RFP, Delmarva," JHU/APL 2823-1, 28 Feb 1980.
3. Telefax 152016Z to S. Moore, Earth Science Laboratory, University of Utah Research Institute.
4. "Distribution List for 1980 Geothermal PRDA," JHU/APL Lett. CQO-2843, 14 Mar 1980.
5. "Additional Name for Distribution List for 1980 Geothermal PRDA," JHU/APL Lett. CQO-2864, 18 Apr 1980.
6. Telefax 312115Z Mar 1980 to K. R. Hastings, Idaho Operations Office, Idaho Falls, ID.

PROGRAM REVIEW

On 2 June 1980, a program review meeting was held at DOE/DGE headquarters to discuss the results of the FY 80 JHU/APL effort to date, to present the effort planned for the balance of FY 80, and to preview the program for FY 81. The references contain copies of the visual aid material used in the conference.

REFERENCES

1. "Progress Report: Geothermal Energy and the Eastern U.S.," JHU/APL QM-80-085, 2 Jun 1980.
2. "Proposed APL/JHU FY 1981 Programs, 2 Jun 1980, Development of Geothermal Energy in the Eastern U.S."

GEOHERMAL PROGRESS MONITOR

Summaries of geothermal activities in the eastern United States were submitted by Ref. 1 for inclusion in the Geothermal Progress Monitor, Progress Report No. 3. Included were Outreach and Technical Assistance items in Arkansas, Maryland, Virginia, and Vermont; loan guarantee investigations; and pertinent publications.

(continued)

REFERENCE

1. "Progress Monitor Report No. 3," JHU/APL Lett. CQO-2866 to DOE/DGE, 24 Apr 1980.

REQUEST OF NATIONAL GEOGRAPHIC SOCIETY

Oliver Payne of the National Geographic Society visited the Laboratory on 30 April 1980 for technical and illustrative material pertaining to geothermal energy and its application in the eastern United States. The Society is planning an energy issue of the National Geographic later this year.

MID-ATLANTIC SECTION OF THE GEOTHERMAL RESOURCES COUNCIL

The spring meeting of the Mid-Atlantic Section of the Geothermal Resources Council (GRC) was held on 22 May 1980 at Hogate's Restaurant in Washington, D.C. The 1979 President, W. J. Toth, announced the results of the election of section officers. Joel Renner, co-founder of the section, past vice-president, and program chair-

man, was elected president. Eric Peterson, past treasurer, was elected vice-president. Ratus Kelly, the previous secretary, was reelected to the same post. Gene Beeland was elected treasurer.

Domenic Falcone, chairman of the Geothermal Resources Council Sections Committee, was introduced to the section. Mr. Falcone pledged his support for building stronger ties between the GRC sections and the national organization and solicited comments and suggestions from the section members.

The featured speaker was Ray Costello of Burns and Roe Industrial Services, who described the results of a PRDA study performed by Burns and Roe on the application of geothermal energy to the Campbell Soup Co. plant in Salisbury, Md. His results show that, under good resource conditions, geothermal energy can be quite cost-competitive with fuel oil. Details of the study are given in Ref. 1.

REFERENCE

1. Burns and Roe Industrial Services Corp. and Campbell Soup Co., "Direct Applications of East Coast Geothermal Resources in a Frozen Food Plant - Final Report," Jun 1980.

**OPERATIONAL RESEARCH, HYDROELECTRIC POWER
DEVELOPMENT**

§ 25

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

C. S. Leffel, Jr.

April-June 1980

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

An outline has been prepared for APL's final report on the problems of hydroelectric development at existing dams in the Southeastern United States as reported in Ref. 1. The study pertains to the states of Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi. It covers the institutional, legal, environmental, and economic factors that affect the development of small-scale hydroelectric power (SSH).

The preliminary text for JHU/APL HE-005, Vol. 1, has been written. In this volume the hydrology of the South Atlantic region of the United States is discussed in detail and the implications are given of the effect of the peculiar terrain and rainfall in this region on the possible development of SSH.

In this region, the production of electricity is dominated by a few large investor-owned utilities. For economic, public relations, and legal reasons, the utilities are at last receptive to the development of SSH. For historical reasons, much of the area of the southeast (if not the population) is serviced by municipal utilities or by rural electric cooperatives. These organizations, which in several states have formed a superstructure for the procurement of electricity, are in a favorable economic position for installing generating capacity, and their plans include hydroelectric installations, where possible.

Concern for energy problems has increased in the southeast, as elsewhere, in the last few years. State agencies responsible for energy concerns are interested in alternative sources of energy. As a general rule, they express the opinion that the hydroelectric developer who can meet federal requirements should experience no

particular obstacles from state agencies. Federal initiatives to encourage the development of SSH, such as the simplification of licensing procedures by the Federal Energy Regulatory Commission and the legal consequences of the Public Utilities Regulatory Policies Act of 1978, can be expected to have the same effect in the southeast as they have in the rest of the country. The efforts of DOE have succeeded in creating an interest in SSH development. State agencies are now reasonably current in their awareness of the opportunities for SSH development that are available. Federal financial incentives for hydroelectric power development are discussed in the report.

The most detailed national study of hydroelectric potential for the United States is the National Hydropower Study, Form 2 (NHSF2) currently being made by the U.S. Army Corps of Engineers. This site-specific study, which is not limited to existing dams, gives for existing dams an estimate of the power that can be installed and the annual production of electrical energy that would result. While the economic feasibility is determined on the basis of Corps economics, the NHSF2 does give a reliable estimate (in mid-1978 dollars) of the cost of the hydroelectric installations. Although the results from NHSF2 are presently available for only a limited number of existing sites with potentials of from 1 to 15 MW, when completed it promises to offer the hydroelectric developer the best available estimate of the energy capability of an existing dam and the cost of the hydroelectric installation. It will be necessary for the prospective developer to determine the income that his installation can produce; this subject will be discussed in detail in Vol. 2 of JHU/APL HE-005.

REFERENCE

1. Section 32, Quarterly Report, Jan-Mar 1979, JHU/APL EQR/80-1.

OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT

§ 26

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

C. S. Leffel, Jr.

April-June 1980

HYDROELECTRIC COSTS DERIVED FROM NHSF2

The National Hydropower Study is a computerized program of the U.S. Army Corps of Engineers designed to estimate, site by site, the hydroelectric potential of the United States. During the latter part of April 1980, APL received from the Corps' South Atlantic Division (Atlanta, Ga.) complete printouts of the results of the current computer studies for 40 hydroelectric sites in North Carolina, South Carolina, and Georgia. The total annual costs for each site have been used to determine the original installation cost for a range of hydroelectric generating capacities installed at each site.

DISCUSSION

The installation cost for a hydroelectric facility at an existing dam site can be calculated by the procedures given in the Corps' Guide Manual (Ref. 1); however, the procedure is laborious. As has been pointed out in Ref. 2, using the National Hydropower Study Form 2 (NHSF2) yields results in good agreement with those derived by using Ref. 1. Therefore, to determine the economic feasibility of a hydroelectric installation, it would be helpful if the capital cost could be obtained from NHSF2.

The NHSF2 printout obtained from the Corps of Engineers contains information on 40 hydroelectric installations, 21 of which are at existing dam sites. The printout gives the capital cost of one installed generating capacity for each site - the one that yields the maximum net annual benefit as the Corps calculates annual benefits and costs. However, if different financial assumptions are used, the optimum capacity of the hydroelectric installation might differ from that chosen by the Corps, and the capital cost of the hydroelectric installation would change.

NHSF2 gives for each site ten values of exceedance (the percentage of time the stream flow exceeds a selected value) and, for the river flow matching the exceedance, gives the installed capacity, the amount of electricity generated, and the annual cost of that installation. The annual cost is the sum of the amortization cost of capitalization and the annual operating costs (operation plus maintenance plus replacement costs). Unfortunately, the annual cost is not explicitly separated into amortization cost and operating cost for those ten capacities. Therefore, it is necessary to find a way to estimate the annual operating cost and thus determine the annual amortization cost. Since in NHSF2 the Corps assumes an interest rate of 6.875% and a lifetime of 100 years, the original capital investment is obtained by dividing the annual amortization cost by 0.06884.

However, NHSF2 does explicitly list the annual operating cost for the one optimum capac-

Fig. 1 Annual operating cost versus installed capacity. (80-2/43)

ity, as determined by Corps economics, for each site. The optimum installations vary in capacity from 2 kW to 16.2 MW. If the explicit operating costs are plotted versus installed capacity for the 40 sites for which NHSF2 data are available (see Fig. 1), the suggested approximation for the annual operating cost is

$$\text{Annual operating cost (\$)} = 40,000 + 160 (\text{capacity in kW})^{0.775} \quad (1)$$

Figure 1 contains a plot of Eq. 1 in addition to raw data taken from NHSF2. The scatter of the Corps operating costs from the plot is significant, but the error in the estimation of the original capital cost is much less.

For example, consider dam NCASAW0013 in Fig. 1. The annual operating cost as given by NHSF2 for the optimum 11.0 MW power installation is \$300,000 per year. From Eq. 1, it is \$256,000 a year, an error of 14.3%. From NHSF2, the total annual cost of the installation is \$1,239,693 per year; subtracting from this annual cost the calculated operating cost of \$256,000 given by Eq. 1 leaves \$982,823 as the annual cost of amortization. Dividing this number by 0.06884 gives \$14,276,918 as the original cost of the installation. From NHSF2, the explicit cost of the installation is estimated to be \$13,680,000. Thus the indirect method of calculating capital cost, as outlined above, is in error by 4.36%, a small error when the difficulties and uncertainties of calculating the capital costs of hydroelectric facilities are considered.

A reasonably accurate estimate of the capital cost for an installation listed on NHSF2 can be obtained by subtracting the annual operating cost as given by Eq. 1 from the total annual operating cost as given by NHSF2 and dividing by 0.06884. This method is designed to recover from the NHSF2 printout the capital cost of any size installation for which total annual costs are given and is independent of the applicability of the Corps' method of computing operating costs to the hydroelectric developer.

REFERENCES

1. "Feasibility Studies of Small Scale Hydro-power Additions, A Guide Manual," U.S. Army Corps of Engineers, Jul 1979.
2. Section 31, Quarterly Report, Jan-Mar 1980, JHU/APL EQR/80-1.

**OPERATIONAL RESEARCH, HYDROELECTRIC POWER
DEVELOPMENT**

\$ 27

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

S. Briscoe and F. Bennett (Metro Center)

April-June 1980

**ECONOMIC FACTORS AFFECTING
POTENTIAL HYDROELECTRIC
DEVELOPMENT AT EXISTING DAMS
IN NORTH CAROLINA, SOUTH
CAROLINA, AND GEORGIA**

The Metro Center has conducted a study of the economic factors affecting potential hydroelectric development at existing dams in North Carolina, South Carolina, and Georgia. The study covers the identification of the state and local tax environments that will be faced by developers in these states, together with other cost factors.

ECONOMIC ANALYSIS

Cost data (Ref. 1) for 22 potential small hydroelectric sites with existing dams in North Carolina, South Carolina, and Georgia have been converted for use in the Metro Center's hydroelectric economic evaluation program. As a result of the Corps' screening process, these sites represent the relatively larger ones (greater than 1 MW potential) available in the three-state area and have amounts of dependable capacity that should earn a capacity benefit. The Corps' computer program evaluates the economics of the sites from the standpoint of the Corps as developer and thus uses a lower-than-market interest rate. It also uses a capacity benefit per firm kilowatt, which is inversely related to the plant or capacity factor, and an average energy benefit per kilowatt-hour, which varies directly with the plant factor. Ten possible installed capacities are evaluated at each site.

The Metro Center program performs an economic and financial analysis of each site for four possible types of developer (investor-owner utilities, municipalities and other governmental entities, rural electric cooperatives, and private entrepreneurs) and for two possible uses of the electricity (sale to an electric customer or own consumption). Thus the program permits economic evaluation of a small-scale hydroelectric project whether it involves a private developer selling electricity to an electric supplier or to a retail customer, or using it on-site; a utility developing it to avoid certain capacity and energy costs it would otherwise incur; or a cooperative or municipality developing it to avoid purchasing electricity from a utility.

For sales to a utility, a set dollar rate per kilowatt per year is assigned to dependable capacity, while the rate for energy is pegged to the average of the purchasing utility's incremental cost of generation. The rate for dependable capacity used in the analysis is based on: (a) current construction costs in North Carolina, South Carolina, and Georgia, for base-load coal plants (i.e., for plants recently completed or

nearing completion); (b) current capacity charges for firm power purchases by utilities from other utilities in the three-state area; and (c) any parallel generation rate schedules already developed by the utilities in the area. Only Duke Power Co. and Virginia Electric and Power Co. (VEPCO) have formulated parallel generator rate schedules. Duke's was filed with the North Carolina Utilities Commission in April 1980, while VEPCO's has served only as a basis of discussion with interested parties and has not yet been filed in any jurisdiction.

The parallel generation rate, unlike the rate for energy, is assumed to be constant in real terms over the life of the project. The real capacity cost of coal plants, after increasing in the 1970's because of the required installation of costly antipollution equipment, is expected to stabilize in the future, since few new environmental requirements are anticipated.

If the hydroelectric project output displaces capacity and energy otherwise purchased from an electric supplier (as in the own-use case), we have set the value of that output equal to the average cost of the displaced electricity. However, the average cost figure is the average for the entire customer class (residential, commercial, industrial, or wholesale) and therefore can only be an approximation of the actual value of the hydroelectric plant's output.

Current incremental capacity costs in the South Atlantic region are lower than the national average as a result of significantly lower construction costs (especially labor). To account for this, the Army Corps of Engineers' study (Ref. 1) adjusts downward the total first cost of hydroelectric development at each site by a geographic factor of 0.80. These adjusted cost data are used in the Metro Center program.

Incremental and average energy costs also are lower, in general, in the three-state area than in the mid-Atlantic region, largely because of a greater proportion of coal-fired than oil-fired generation. For example, in 1979, 18 to 24 mills was the approximate range of the average of the incremental energy cost for the utilities with thermal generation in the three states, excluding VEPCO and the Savannah Electric and Power Co. (Savannah). With 24% of VEPCO's electric generation in 1979 supplied by oil- and gas-fired units (contrasted with 1% for Carolina Power and Light Co., 0.3% for Duke Power Co., 19% for South Carolina Electric and Gas Co., and 3% for Georgia Power Co.), the monthly average of VEPCO's incremental energy cost ranged from 40.5 to 56.8 mills in the peak period and from 22.5 to 38.3 mills in the off-peak period (in 1978 mills). Fifty-four percent of Savannah's generation in 1979 was from oil- and gas-fired sources; as a result, its average energy cost, 25.3 mills, was the highest of any utility in the region.

The generally lower energy costs to utilities in the South Atlantic area reduce the number of potential small hydroelectric sites that can be economically developed, especially within the subgroup of sites that would earn no capacity

credit. Moreover, these energy costs, comprised mainly of coal and nuclear fuel costs, are expected to rise more slowly in real terms than energy costs in the mid-Atlantic.

Concerning utility plans for hydroelectric expansion, all of the large investor-owned utilities in the area except Carolina Power and Light Co. have pumped-storage hydroelectric plants planned, under construction, or recently placed in commercial operation. In general, these utilities are not interested in developing small hydroelectric power themselves because of the minor contribution it makes to system capability and because of the often high front-end costs per kilowatt (e.g., land, licensing). Licensing cost is especially burdensome in cases in which a new dam must be built.

Only Duke Power Co. has conducted studies of sites with and without existing dams in its

service area to determine the cost of development. It has included sites of from less than 1 MW up to 142 MW potential but would actually consider developing or expanding only sites of 10 to 15 MW potential or greater. It foresees little utility development of this small- and medium-scale hydroelectric power because of the size and cost factors mentioned above. On the other hand, smaller electric suppliers (municipal utilities and electric cooperatives) are increasingly interested in this resource.

REFERENCE

1. "Feasibility Studies for Small-Scale Hydropower Additions, A Guide Manual," U.S. Army Corps of Engineers, The Hydroelectric Engineering Center, Davis, Calif., Jul 1979.

OPERATIONAL RESEARCH, HYDROELECTRIC POWER DEVELOPMENT

§ 28

Small-Scale Hydroelectric ZP30CQO

Support: DOE/RA

S. Briscoe and F. Bennett (Metro Center)

April-June 1980

INSTITUTIONAL AND ENVIRONMENTAL FACTORS AFFECTING POTENTIAL HYDROELECTRIC DEVELOPMENT

The Metro Center has conducted a study of the institutional and environmental factors affecting potential hydroelectric development at existing dams in North Carolina, South Carolina, and Georgia. The analysis draws on methodologies developed in a similar study (Ref. 1) of the mid-Atlantic states, discussed in previous Quarterly Reports. The final report will include: an evaluation of the economic and financial feasibility of a subset of dams identified in the National Hydro Study (Ref. 2) published by the U.S. Army Corps of Engineers; an analysis of market access issues and of permit and license requirements and procedures; identification of state and local taxes for which various types of developers will be liable; and a discussion of major environmental problems and ownership-access issues affecting the use of the resource.

DISCUSSION

Organization of Existing Suppliers. In these three states, municipal electric systems and rural electric cooperatives have been coordinated structurally by the formation of generation and transmission joint ownership agencies. With few exceptions, each joint ownership agency's membership is composed of those distribution systems which purchase energy from the same utility supplier. This grouping around the primary supplier is limited to contractual arrangements for the purchase of full or partial energy requirements and in no way implies a subsidiary relationship. The joint agencies are independent of their primary suppliers.

In North Carolina, there are three municipal power agencies, one composed of systems served by Duke Power, one of systems served by Carolina Power and Light, and one of systems served by Virginia Electric and Power. In South Carolina, recent legislation requires that municipal joint ownership agencies be formed of systems within a single utility's general service area. Piedmont Municipal Power Agency, the first to be established under the new law, is comprised of Duke Power's municipal customers.

In North Carolina, all 28 cooperatives belong to the North Carolina Electric Membership Corp., there being no legal requirement that utility service areas be observed. However, cooperatives in South Carolina have followed the more traditional grouping, Saluda River Electric Cooperative's membership being drawn from Duke Power's area, while Central Electric Power Cooperative's membership is based on historic association with Santee Cooper (a state-owned generating and distributing utility).

In Georgia, centralization of the distribution systems is even more pronounced since there is effectively only one primary supplier around which the systems have grouped - Georgia Power. The Municipal Electric Authority of Georgia

(MEAG) serves all but six municipal electric systems, and Oglethorpe Power Corp. serves all but three cooperatives.

What effect the existence of these joint agencies will have on development of small-scale hydroelectric projects in all three states is unclear. In almost all cases, the agencies serve as sole electric supplier to their members by contractual agreement. As a result, development of hydroelectric projects will most likely be undertaken by an agency rather than by an individual distribution system. This may adversely affect future development by municipalities and cooperatives. As a general rule, interest in small-scale projects is directly related to the percentage of total energy requirements a project might supply. Whereas a project of less than 1 MW might be attractive to a small municipal system, a joint agency such as MEAG may regard it as marginal at best in view of the significantly greater amounts of energy MEAG must supply to its 47 members. We anticipate that the attractiveness of small hydroelectric development will depend to some degree on the size of the agency in question.

Marketing Considerations. The market positions of various types of developer are strikingly similar in the three states. In each state, new private development of power primarily for retail sale will be prohibited without the active consent of existing suppliers. The Georgia Territorial Act provides one possible exception. New customers whose demand is 900 kW or more are permitted to choose their own suppliers. New private developers may be allowed to compete for those customers.

Private development of power for the wholesale market historically has depended on the willingness of existing suppliers to purchase. However, with the passage of the Federal Public Utility Regulatory Policies Act of 1978 (PURPA), the rates and regulations worked out by the Federal Energy Regulatory Commission (FERC) and the states' utility regulatory commissions will become the critical factors in stimulating this type of development.

The private development of power for private use by the developer faces no general legal or institutional obstacles, with the possible exception of lack of condemnation power should the project not require a FERC license.

Cooperatives are well situated to undertake small hydroelectric projects. In general, regulation by the state regulatory commissions is limited to assignment of service territories, and, in the case of North Carolina, issuance of a certificate for construction. (The certificate requirement in South Carolina applies only to projects of 75 MW capacity or greater, thus exceeding the upper capacity limit of 15 MW for small-scale hydroelectricity.) If a project does not impinge on territorial assignments, regulation by state agencies presents no obstacle to development.

In general, the cooperative joint agencies have all the powers and authorizations needed to undertake a power project. However, activity by an individual cooperative may be hindered by contract renegotiations with its primary supplier, be it a joint agency or a utility.

Existing municipal systems are in much the same position as cooperatives. No interference by the state utility regulatory commission is anticipated unless the project in some way disturbs existing territorial assignments. Again, the one obstacle might be the negotiation of a partial requirements contract with the principal supplier.

It is unlikely that a municipality that does not presently own its electric system would undertake a hydroelectric project. Legal difficul-

ties aside, a municipality could not afford to purchase part of a functioning system. Such a system is prohibitively expensive, as would be the cost of duplicating it.

State Permits for Hydroelectric Projects.

State permit requirements are few in number and similar in type in all three states: a dam safety permit, archeological permits, and road-access, rights-of-way, and oversize-vehicle permits are required. Mosquito-control and water-use permits are required in two states. Only South Carolina has a separate permit for construction or other activities in streambeds.

The three states have established agencies that are authorized to issue EPA's Water Quality Certifications and National Pollution Discharge Elimination System (NPDES) permits. North Carolina has an abbreviated National Environmental Protection Act (mini-NEPA) provision requiring full environmental impact statements for state-operated or state-funded projects. The other two states have no requirements for impact statements to be filed either by state agencies or by the applicant.

The three states have some form of scenic-rivers legislation and endangered-species programs. Neither, in themselves, will have much impact on small projects, either because of overlap with federal lists or because the protection offered is minimal. Georgia and South Carolina require that fish ladders be provided at the discretion of the appropriate state agency.

Of particular importance to hydroelectric development are permit stipulations that regulate water release - minimum downstream flow and reservoir level regulations. Whether such stipulations can be put in a state permit is a complex question, given the fact that all three states follow riparian law. Under riparian law, controls on the use of water are the prerogative of the courts. It is unclear whether permitting agencies have the proper statutory authority to set such conditions in their permits. At the moment, the problem is addressed on a case-by-case basis. Very rarely are flow requirements set, and even then usually only with the consent of the applicant and only in cases where significant potential adverse effects can be documented.

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. "Feasibility Studies for Small-Scale Hydro-power Additions, A Guide Manual," U.S. Army Corps of Engineers, The Hydrologic Engineering Center, Davis, Calif. Jul 1979.

**GEOHERMAL ENERGY DEVELOPMENT PLANNING AND
SMALL-SCALE HYDROELECTRIC** § 29
Development of Geothermal Energy ZJ7CQO
Small-Scale Hydroelectric ZP3CQO
Support: DOE/RA, DGE
A. M. Stone
April-June 1980

LIST OF GEOTHERMAL AND LOW-HEAD HYDROELECTRIC REPORTS PUBLISHED BY JHU/APL, JANUARY-JUNE 1980

In order to provide information on all significant papers issued by APL in the first half of CY 80 on various aspects of geothermal energy, the following lists of reports, papers, letters, and internal memoranda are submitted. Reference 1 is a previous listing.

REFERENCE

1. Section 21, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4

FORMAL REPORTS AND PAPERS

Report No.	Date	Title	Author(s)
CQO-2544 QM-80-001	12 Nov 79 3 Jan	The Crisfield, Maryland Well and Geothermal Energy Neotectonic Investigations in Southwest New York and Southwest Connecticut - Progress Report for the Quarter Ending December 31, 1979	F. C. Paddison J. E. Tillman
QM-80-010	15 Jan	Survey of Facilities at the Savage Mill Dam and Powerhouse	W. B. Chapman
QM-80-013	30 Jan	Application of Geothermal Energy for Mariculture (forwarded by JHU/APL Lett. CQO-2828, 18 Feb 1980)	K. Yu
QM-80-047	10 Mar	Preliminary Results for the Technical Assistance to Columbia LNG Corporation (forwarded by JHU/APL Lett. CQO-2850, 28 Mar 1980)	K. Yu
QM-80-048	11 Mar	Cost and Income Estimates for a Hydropower Installation at the Savage Mill Site	C. S. Leffel, Jr.
QM-80-070 (GEMS-007)	May	A Review of Recent Energy Price Projections for Traditional Space and Process Heating Fuels in the Post 1985 Period	W. F. Barron (Metro Center)
QM-80-075 (GEMS 002)	May	Geothermal Energy Market Study on the Atlantic Coastal Plain - Definition of Markets for Geothermal Energy in the Northern Atlantic Coastal Plain	W. J. Toth
QM-80-076	9 May	Public Meeting of the U.S. Army Corps of Engineers about the National Hydroelectric Power Study (NAPS)	R. von Brieson
QM-80-077	Jun	Geothermal Energy Market Study on the Atlantic Coastal Plain, GRITS: A Computer Program for the Economic Evaluation of Direct Use Application of Geothermal Energy	W. F. Barron (Metro Center)
QM-80-087	29 May	Use of National Hydropower Study Form 2 for the Estimation of the Costs of Hydroelectric Installation at Existing Dams	C. S. Leffel, Jr.
QM-80-092*	9 Jun	Neotectonic Investigations in Southwest New York and Southwest Connecticut - Progress Report for the Quarter Ending June 30, 1980	J. E. Tillman
QM-80-101	Jun	Geothermal Energy Development in the Eastern U.S., Technical Assistance Report No. 4 - Geothermal Space Heating, Pittsville Middle/Elementary School, Pittsville, Maryland	R. von Brieson
QM-80-102	Jun	Technical Assistance Report No. 5 - Geothermal Space Heating - NARF	F. K. Hill

*Funded by the Nuclear Regulatory Commission.

Papers submitted to the Geothermal Resources Council for the Annual Meeting in September 1980, Salt Lake City, Utah:

1. A. C. Goodman (Metro Center), "Geothermal Market Penetration in the Residential Sector: Capital Stock Impediments and Compensatory Incentives."
2. A. C. Goodman and W. F. Barron (Metro Center), "Geothermal Energy Markets on the Atlantic Coastal Plain - Market Penetration."
3. W. J. Toth (APL) and W. F. Barron (Metro Center), "GRITS: A Computer Model for Economic Evaluations of Direct Uses of Geothermal Energy."
4. K. Yu and F. C. Paddison, "Technical Assistance - Hydrothermal Resource Application in the Eastern U.S.."

F. C. Paddison, "Eastern Program," Resource Assessment/Commercialization Planning Meeting, Salt Lake City, Utah, 21-24 Jan 1980, pp. 26-31.

LETTERS

Letter No.	Date	Title	Author(s)
CQO-2785	2 Jan	The Availability of the Applied Physics Laboratory of The Johns Hopkins University to Advise on Geothermal Energy	F. C. Paddison
CQO-2786	2 Jan	Forwarding Information on Geothermal	F. C. Paddison
CQO-2788	8 Jan	Letter to Dr. Paul Massicot, Annapolis, MD Forwarding Information on DOE Utah Meeting	C. S. Leffel, Jr.
CQO-2792	9 Jan	Potential of Geothermal Energy in Pennsylvania	A. M. Stone
CQO-2805	11 Jan	Maryland Geothermal Resources Act	F. C. Paddison
CQO-2808	1 Feb	Forwarding Proposed Program Outline Methodology for the Assessment of New York and Pennsylvania	J. E. Tillman
CQO-2811	1 Feb	IGCC Fourth Annual Report	F. C. Paddison
CQO-2821	5 Feb	Use of Geothermal Energy for Fish Rearing	J. E. Tillman
CQO-2825	11 Feb	Meeting with Somerset County Commissioners	F. C. Paddison
CQO-2832	25 Feb	Lowest Temperature for Residential and Commercial Space Heat	F. C. Paddison
CQO-2835	25 Feb	Geothermal Effort in the Eastern U.S.	F. C. Paddison
CQO-2837	5 Mar	First User-Coupled Resource Confirmation Solicitation	F. C. Paddison
CQO-2840	11 Mar	Geothermal Energy in Maryland	C. S. Leffel, Jr., and F. C. Paddison
CQO-2842	14 Mar	Eastern Geothermal Laws	F. C. Paddison
CQO-2843	14 Mar	Distribution List for 1980 PRDA	F. C. Paddison
CQO-2844	17 Mar	Geothermal Energy and the Mariculture Industry	F. C. Paddison
CQO-2845	19 Mar	Technical Assistance, Eastern Hydrothermal Program	F. C. Paddison
CQO-2849	20 Mar	Crisfield High School Conversion to Geothermal Energy	F. C. Paddison
CQO-2851	28 Mar	Comments on Columbia LNG Corporation Report	F. C. Paddison and A. M. Stone
CQO-2852	2 Apr	Requirements for Hydroelectric Test Well in Western New York State	F. C. Paddison
CQO-2855	8 Apr	Hydrothermal Resource Engineering and Management	F. C. Paddison
CQO-2856	8 Apr	Forwarding Comments on Cove Point Consideration of Geothermal Water for Vaporization of LNG	F. C. Paddison
CQO-2862	15 Apr	Data for Industrialization Plan for Hydrothermal	F. C. Paddison
CQO-2866	22 Apr	Progress Monitor Report No. 3	F. C. Paddison
CQO-2867	29 Apr	Additional Effort Geothermal Technical Assistance	A. M. Stone and F. C. Paddison
CQO-2868	29 Apr	Temperature and Depth Data for North Carolina	F. C. Paddison
CQO-2869	29 Apr	Laboratory Reports on Geothermal Energy for the Delmarva Area	F. C. Paddison
CQO-2873	29 Apr	Forwarding of Data	F. C. Paddison
CQO-2876	6 May	Forwarding of Reports	F. C. Paddison
CQO-2884	7 May	Family Health Care, Inc. Proposal	F. C. Paddison
CQO-2886	14 May	Suggested Mailing of Geothermal Information	F. C. Paddison
CQO-2887	20 May	Questions to the French	A. M. Stone
CQO-2893	20 May	"Your Request for Technical Assistance" to Mayor Paul Lattimore, Albany, NY	F. C. Paddison
CQO-2894	20 May	"Your Request for Technical Assistance" to Mr. Matthew R. Creamer, Salisbury, MD	F. C. Paddison
CQO-2898	10 Jun	State Senate Action of Delaware Proposed Geothermal Resources Act	F. C. Paddison
CQO-2899	10 Jun	Legislative Issues for Geothermal Energy in Maryland: Ownership Considerations	F. C. Paddison
CQO-2900	10 Jun	Forwarding Comments on Draft Environmental Impact Statements	F. C. Paddison
CQO-2902	13 Jun	Letter to Dr. D. B. Lombard, DOE, Forwarding Geothermal Employment in Virginia Material	A. M. Stone

INTERNAL MEMORANDA

Report No.	Date	Title	Author(s)
QM-80-002	2 Jan	A Profile of the Delmarva Poultry Industry	W. J. Toth
QM-80-004	8 Jan	Residential Hot Water Demands	W. J. Toth
QM-80-014	22 Jan	Delmarva Companies that Should Receive DOE Well Solicitation	W. J. Toth
QM-80-015	23 Jan	Geothermal Energy - From Soup to (Pea)Nuts and Crackers	W. J. Toth
QM-80-018	23 Jan	Geothermal Brochure for Use in Energy Surveys and Outer Outreach Activities	W. J. Toth
QM-80-020	24 Jan	Suggested Recipients of Future DOE Solicitations	W. J. Toth
QM-80-021	25 Jan	Workshop to Draft Delaware Geothermal Law	J. E. Tillman
QM-80-024	1 Feb	Proposed Program Outline, Methodology for the Assessment of Hydrothermal Resources in Western New York and Pennsylvania	J. E. Tillman
QM-80-025	1 Feb	Eastern Geothermal Development Status	F. C. Paddison
QM-80-027	5 Feb	Meeting with Ike Bracy	F. C. Paddison
QM-80-028	5 Feb	National Fishery Research and Development Laboratory	J. E. Tillman
QM-80-029	7 Feb	Questions for France and Iceland	A. M. Stone
QM-80-030	11 Feb	State Commercialization and Resource Planning Meeting	F. C. Paddison
QM-80-032	12 Feb	Outline of Geothermal Analysis in Western NY and Northwestern Pennsylvania	F. C. Paddison
QM-80-033	13 Feb	Water-Referenced Heat Pump Manufacturers	W. J. Toth
QM-80-035	20 Feb	Summary of Delmarva Survey and Some Suggestions	F. C. Paddison
QM-80-037	22 Feb	NRC Seminar	J. E. Tillman
QM-80-039	29 Feb	10th Well Drilling Seminar	R. von Briesen
QM-80-043	6 Mar	Capital Recovery Period	K. Yu
QM-80-045	7 Mar	Geothermal Presentation to the Delmarva Poultry Industry, Inc.	W. J. Toth
QM-80-052	14 Mar	Comments on Draft of Memo on Legislative Considerations - State Geothermal Act	F. C. Paddison
QM-80-053	14 Mar	Loans Available from the Farmer's Home Administration	F. C. Paddison
QM-80-054	14 Mar	Meeting with Lucio D'Andrea/DOE, 29 February 1980	F. C. Paddison and J. E. Tillman
QM-80-055	17 Mar	Geothermal (GT) Space Heating the Pittsville School, Wicomico County, Pittsville, MD	R. von Briesen
QM-80-056	20 Mar	Crisfield, MD Well Characteristics Determined Using All Test Data	K. Yu
QM-80-063	31 Mar	FHA/EDA Alcohol Fuels Workshop, Atlanta	F. C. Paddison
QM-80-065	3 Apr	Meeting with A. C. Schultes and Sons, Inc. to Discuss Drilling of Cove Point Water Wells, March 28, 1980	C. S. Leffel, Jr.
QM-80-067	9 Apr	Delmarva Industrial Process Heat Demand by Temperature Range	W. J. Toth
QM-80-068	10 Apr	Energy Requirements - Delmarva	F. C. Paddison
QM-80-080	21 May	NCSL Presentation to Maryland Joint Legislative Committee on Energy	F. C. Paddison
QM-80-082	28 May	Geothermal Energy in Cayuga County, NY	F. C. Paddison
QM-80-083	28 May	Maryland Energy Office	F. C. Paddison
QM-80-084	28 May	Lebanon Springs, NY	F. C. Paddison
QM-80-085	2 Jun	Progress Report, Geothermal Energy and the Eastern U.S.	F. C. Paddison
QM-80-086	29 May	Legislative Issues for Geothermal Energy in Maryland: Ownership Considerations	J. G. Cherim (Metro Center)
QM-80-088	2 Jun	State Policy Toward the Installation and Use of Water Referenced Heat Pumps for the States of Maryland, Pennsylvania, Delaware, and Virginia	R. von Briesen
QM-80-091	4 Jun	Temperature Set-Back Standard for Domestic Hot Water Heaters	W. B. Chapman
QM-80-093	6 Jun	Comments on Mississippi Coastal Program	R. von Briesen
QM-80-096	10 Jun	Proposed New Jersey Coastal Management Program Draft Environmental Impact Statement	C. S. Leffel, Jr.
QM-80-097	10 Jun	Brief Comments on Draft ETS NJ and Mississippi	J. G. Cherim (Metro Center)
QM-80-107	30 Jun	Visit to Atlanta	F. C. Paddison

ENERGY CONVERSION AND STORAGE TECHNIQUES

OTEC Core Unit Testing ZY32BBP

\$ 30

Support: DOE/CS

P. P. Pandolfini

April-June 1980

DATA ANALYSIS OF CORE UNIT CONDENSER TESTS

APL is studying a potentially cost-effective option for OTEC plantship heat exchangers using shell-less, folded 3 in. O.D. aluminum tubes with ammonia flowing inside. Vertical planes of these tubes (seven nested tubes per plane) connected in parallel form a heat exchanger module. Seawater is pumped to a head pond above the module and flows downward by gravity to either evaporate or condense the ammonia.

A full-scale core unit of this heat exchanger design was tested as an evaporator (Ref. 1). The evaporator performance was better than predicted, and subsequent modifications of the simulation used to design full-scale modules led to testing the core unit as a condenser. Reference 2 presents the measurements of overall heat transfer coefficients for the condenser tests; this report presents the final test data and discusses the modifications to the analytical simulation needed for agreement with the experimental results.

DISCUSSION

A description and photographs of the core unit are presented in Ref. 3. For the condenser tests, ammonia vapor was introduced into the top of the unit, flowed downward through the tubes, and issued from the bottom (completely condensed) into a receiver. The water entrance temperature was maintained at 41 to 42°F by a chiller during the tests. Reference 2 presents the range of test conditions covered and the resulting higher-than-predicted measurements for the overall heat transfer coefficients (U). These results indicated that the annular flow film coefficient model used for the ammonia side underpredicted the measured values by a considerable amount. Further analysis using a flow regime map based on Ref. 4 has led to a better model for predicting the experimental results. In the range of interest for OTEC condenser operations (0.49 to 0.85 lb/s-tube), the flow is predominantly stratified; use of stratified models for the void fraction and ammonia film coefficient (Refs. 5 and 6) yields results such as those shown in Fig. 1 (in which the data and the results of the annular flow model are also shown). For ammonia flow rates higher than 0.85 lb/s-tube, use of a combination of stratified and annular film coefficient models is indicated (Fig. 1e).

The measured ammonia pressure drop, Δp , is shown in Fig. 2; in general, the measured Δp was higher than predicted. This is because the measured U was also higher than the original predictions for which a two-phase friction multiplier was directly coupled with ammonia film coefficient. The components of this pressure drop are as follows: the two-phase loss in the horizontal runs, the two-phase loss in the bends,

Fig. 1 Comparison of measurement with stratified and annular flow model predictions covering ammonia flows 0.49 to 1.07 lb/s (0.22 to 0.49 kg/s) per tube. (80-2/35)

the deceleration gain due to conversion of vapor into liquid, and a gravity recovery as liquid is formed in the downward flow. These data were examined with the stratified model used to successfully explain U : the two-phase friction loss was calculated using existing correlations for large bore pipes (Ref. 5), the gravity pressure recovery was neglected due to the stratified nature of the flow, the deceleration gain was determined using the stratified void fraction, and the resulting two-phase bend loss coefficient was computed by subtracting these three components of pressure drop from the measured value of Δp . From these calculations, a value of 1.5 ± 0.2 was found for the bend loss

Fig. 2 Measured and predicted ammonia pressure drop versus ammonia flow rate and Reynolds number. Negative values indicate predicted pressure recovery due to gravity effects. Nominal and low water flows yield water velocities in a minimum tube gap of 2.5 ft/s (0.76 m/s) and 1.25 ft/s (0.38 m/s), respectively. (80-2/36)

coefficient (which is a two-phase dimensionless equivalent length for the bends), representing a reduction in the value that was being used (2.0).

In summary, the experimental results of the condenser core tests for both U and Δp have been adequately explained by using a stratified flow model for the ammonia flow.

FUTURE PLANS

The analytical simulation that has been modified to reflect the results of both the evaporator and condenser core tests will now be used to design the heat exchangers of an OTEC pilot plant. Performance estimates, based on this updated simulation, for on- and off-design conditions at potential OTEC sites will be examined.

REFERENCES

1. Section 27, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
2. Section 36, Quarterly Report, Jan-Mar 1980, JHU/APL EQR/80-1.
3. Section 13, Quarterly Report, Apr-Jun 1979, JHU/APL EQR/79-2.
4. Y. Taitel and A. E. Dukler, "A Model for Predicting Flow Regime Transition in Horizontal and Near Horizontal Gas-Liquid Flow," *AIChE J.*, Vol. 22, No. 1, Jan 1976, pp. 47-55.
5. J. F. Collier, *Convective Boiling and Condensation*, McGraw-Hill, New York, 1973.
6. J. W. Palen, G. Breber, and J. Taborek, "Predictions of Flow Regimes in Horizontal Tube-Side Condensation," *Heat Transfer Eng.*, Vol. 1, No. 2, Oct-Dec 1979, pp. 47-57.

ENERGY CONVERSION AND STORAGE TECHNIQUES

Community Annual Storage Energy System \$31

ZX20CPE/S4A

Support: DOE/DoD/ NAVFAC/LANTDN

W. R. Powell and C. E. Williams

April-June 1980

COMMUNITY ANNUAL STORAGE ENERGY SYSTEM

The Community Annual Storage Energy System (CASES) is a plan to save energy by 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 the U.S. Navy base 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.

The plan for introducing CASES concepts (Ref. 1) at Norfolk is divided into three stages (Ref. 2). The first stage creates a central chilled water cooling system to cool the CINCLANTFLT office building complex. The second stage begins with an extension of this cold water distribution system to other buildings, but the additional cooling capacity required for peak loads will be satisfied by stored chilled water instead of new refrigeration equipment. Surplus chiller capacity at off-peak hours will be used to fill an insulated cold water storage basin that will be constructed from part of an existing but unused water storage reservoir. Also included in stage 2 is a small-scale test of the natural underground water supply (aquifer) as both a source of heat for water-source heat pumps and as a way to store cold water produced in a spray pond during winter and reinjected into the aquifer for storage until summer. During this test, water removed from the aquifer can be stored in the existing reservoir until the reinjection period begins, so that only one test well is required. The final stage uses multiple water wells to store separately both the warm water obtained during summer while cooling buildings and the cold water effluent obtained during winter from water-source heat pumps or the water-spray pond. If storing warm and cold water in aquifers proves to be impractical, ice produced during winter may be saved for summer peak load cooling. An insulated ice/water basin, constructed from part of the existing reservoir, would be used for seasonal storage of ice. The CASES development plan was evolved to permit a feasibility analysis to proceed. It is not presently scheduled for implementation.

SUMMARY

During the second quarter of 1980, work centered on the development of stage 1 concepts in greater detail. Also, work was initiated on methods for calculating pumping power requirements useful in both stages 1 and 2. The peak cooling loads for the buildings included in the stage 1 chilled water system were estimated us-

ing data obtained during the first quarter of 1980 and prior study results. The resulting "design cooling loads" are given in Table 1. The route illustrated in Fig. 1 for the stage 1 distribution system was developed primarily for the collection of realistic cost data from suppliers of prefabricated insulated pipe, etc. These cost data, estimated pumping power and thermal losses, and refrigeration cost data will be evaluated to permit pipe sizes to be selected for the preliminary stage 1 chilled water distribution system.

DISCUSSION

Many of the office buildings in the CINCLANTFLT area (Fig. 1) were World War II hospital wards with all rooms on the outside walls. Those older buildings are typically air conditioned by window air-conditioning units, although some have small ground-based packaged units as well. Some of the CINCLANTFLT buildings (which are not included in Table 1) contain central chillers with roof-mounted cooling towers. One large building (no. 95) on the west side of CINCLANTFLT has 900 tons of efficient air-conditioning equipment installed. This building and the others also equipped with central chillers have winter air-conditioning loads totaling several hundred tons. The site has 3451 heating degree-days and 1707 cooling degree-days. An existing central steam heating system will continue to supply CINCLANTFLT heating requirements.

The stage 1 central chilled water distribution system will be interconnected with existing individual building systems and will supply their chilled water needs for most of the year. However, the existing equipment will be used for peak loads. Approximately 1600 tons of new refrigeration capacity will be required for the central chiller plant shown by dashed lines in Fig. 1. It is tentatively planned that four 400-ton machines will be used to permit efficient partial load operation and assure that 75% of full capacity is always available. Fan-coil cooling units will be installed in buildings that use window air conditioners so that the central chilling system can supply their cooling requirements. More efficient cooling and lower life-cycle costs should result when window air conditioners and small packaged units are replaced by a central chilling system, even if no use is made of the heat removed from the buildings.

The centralization of the heat now removed by air-conditioning equipment dispersed throughout CINCLANTFLT is the primary feature of the central chilled water system related to CASES.

Table 1

Design cooling requirements (1612 tons total).

Building No.	1	1A	2	3	4	5	6	7
Tons required	96	30	90	96	96	76	88	88
Building No.	12	13	14	15	16	17	18	19
Tons required	90	90	38	34	28	20	24	30
Building No.	20	21	25	28	30	31	34	35
Tons required	60	136	30	16	20	18	34	10
Building No.	38	39	40	41	42	47	218	223
Tons required	26	26	10	76	30	76	22	8

Fig. 1 Central chilled water system planned for stage 1. (80-2/44)

concepts for energy conservation. Rather than waste the heat, CASES attempts to make beneficial use of it. At present, a potable hot water loop serving 15 CINCLANTFLT buildings is supplied by a pair of steam-condensing hot water heaters capable of transferring 6×10^6 Btu/h. One fully loaded 400-ton chiller rejects essentially this same thermal power. Thus one chiller, designed for coproduction of hot and cold water, could meet most of the hot water loop's energy requirements year-round because several hundred tons of cooling are needed even in winter for large CINCLANTFLT buildings that contain electronic equipment requiring air conditioning.

Assuming that institutional and technical limitations can be resolved favorably, one or more of the other chillers would be used in conjunction with an aquifer storage system to conserve part of the heat removed from CINCLANTFLT buildings during summer to use it for heating the following winter in residential buildings in adjoining parts of the base. For efficient operation, water-source heat pumps in these buildings would use the stored warm water as a source of heat.

It may be possible to cool one or more of the chillers used at times of peak load during stage 1 with groundwater obtained from shallow wells north of the chiller building. Groundwater for condenser cooling would permit more

efficient peak load chiller operation than a cooling tower because a lower condenser temperature is possible. A marsh is located less than 1000 ft north of the chiller building, and water from the marsh would naturally recharge the shallow wells. During stage 2, cold water for peak load cooling would be produced primarily at night when cooling towers are most efficient. Thus groundwater cooling may not be attractive compared to cooling towers unless the heat is saved in an aquifer for subsequent use.

FUTURE PLANS

A simulation model of the stage 1 and 2 chilled water system will be constructed, and various different parameters will be varied to determine the effect on cost and performance. Design level details will be omitted because the goal is to determine if any of the CASES energy conservation concepts are feasible. A utilization test of a portion of the existing reservoir in a test of spray-pond cooling and aquifer storage will be planned.

REFERENCES

1. W. R. Powell, "The Case of CASES," *Environment*, Vol. 20, Jul 1978, pp. 14-20, 40, 41.
2. Section 37, Quarterly Report, Jan-Mar 1980, JHU/APL EQR/80-1.

LANDFILL METHANE PROJECTS AT APL

Methane from decomposing organic matter in sanitary landfills has recently been developed into a viable and economically competitive energy resource. APL is under contract to Argonne National Laboratory (ANL) to study various aspects of landfill methane recovery and utilization. Under this contract, APL has recently released a workbook that contains basic facts regarding landfill gas recovery, summaries of landfill gas recovery projects, a discussion of legal aspects of landfill gas recovery, guidelines and sources of support for landfill gas recovery, and an annotated bibliography (Ref. 1).

APL and ANL hosted the third annual landfill methane utilization symposium, held this year at the Asilomar Conference Grounds in Pacific Grove, Calif., 23 to 26 March. Fifty-seven participants, including representatives from Canada, England, and West Germany, shared information and experiences on landfill methane recovery. Proceedings of the symposium have been prepared by APL.

Additional work by APL includes computer modeling of landfill gas for the generation of the gas in sanitary landfills and for the economics related to options for processing the gas and managing the landfill. At least two of the economic options evaluated will be implemented in the model, which will be used to simulate situations at specific landfills.

Since regulatory obstacles to the recovery of landfill methane are sometimes complex, APL is keeping abreast of federal legislation dealing with the subject, drafting model legislation that would streamline the approval of such projects,

and reporting on case law relevant to their ownership and liability. APL will also report to ANL on the environmental/socioeconomic effects of landfill methane recovery and on an investigation into alternative methods and apparatus to measure the porosity/density of a landfill and the radius of influence of landfill wells.

In addition to work for ANL, APL has recently completed field testing for a feasibility study for the National Capital Region of the National Park Service (NPS) at the Kenilworth and Oxon Cove landfills in the Washington, D.C., area. The results indicate that there is a sufficient supply of landfill methane at Kenilworth to provide for the space heating and the generation of electricity for both the White House and the aquatic garden greenhouses. Although planned end-uses are not complete, an ample supply of landfill methane is available at Oxon Cove to provide heat for a facility to produce alcohol to fuel NPS lawn-care equipment in the Washington, D.C., area and to provide space heating and/or electricity generation requirements for the buildings at the Oxon Hill Farm.

APL is also beginning a field testing program for Howard County, Md., to determine the quality and quantity of landfill gas at the New Cut Road landfill near Ellicott City. The project includes the evaluation of gas migration control and gas recovery alternatives, with a preliminary selection of the best control and recovery options for the landfill.

REFERENCE

1. R. C. Eberhart et al., "Landfill Methane Utilization Technology Workbook," JHU/APL CPE-7909, 1979.

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