JHU/APL
EQR/80-4

Quarterly Report

ENERGY PROGRAMS

at The Johns Hopkins University Applied Physics Laboratory

OCTOBER—DECEMBER 1980

THE JOHNS HOPKINS UNIVERSITY • APPLIED PHYSICS LABORATORY

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THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY
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.

 

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Figure 1

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PREFACE

The Johns Hopkins University Applied Physics Laboratory, under contracts with several agencies of the federal government, is engaged in developing energy resources, utilization concepts, and monitoring and storage methods. This Quarterly Report summarizes the work on the various tasks as of 31 December 1980.

The Energy Quarterly Report is divided into five 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 a report on institutional problems for small-scale hydroelectric power development in the southeastern states and a list of documents published by APL in the hydroelectric program and in the geothermal program, above.

The third section, Seismotectonic Investigations, contains an article on work on the geologic structure of the Danbury Quadrangle that is supported by the Reactor Safety Research Division of the Nuclear Regulatory Commission (NRC) and an in-house supported study on a new method for assessing earthquakes in intraplate regions.

The fourth section, Energy Conversion and Storage Techniques, contains four articles. The first is an evaluation of the Einstein refrigerator, supported by independent IR&D funds. The second concerns fly-wheel technology development at APL supported by the Department of Energy, Division of Energy Storage (DOE/STOR). The third is a report on APL energy conservation efforts at its own buildings, and the fourth is an article on liquefied natural gas (LNG) safety evaluation, supported by the National Academy of Sciences.

The fifth section explores the value of establishing an Energy Research Institute at The Johns Hopkins University.

THE
FEDERAL BUREAU OF INVESTIGATION
UNITED STATES DEPARTMENT OF JUSTICE
WASHINGTON, D. C. 20535

MEMORANDUM FOR THE DIRECTOR

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GEOHERMAL ENERGY DEVELOPMENT PLANNING § 14 AND TECHNICAL ASSISTANCE

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

Support: DOE/DGE

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

Paddison, and C. S. Leffel, Jr.

October-December 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. Estimates of the life-cycle cost of applying geothermal energy in a specific case;
5. Advice on the legal, institutional, and other requirements for the application of geothermal energy;
6. Advice on available federal geothermal opportunities or other federal programs that relate to the use of geothermal energy; and
7. Counsel on available financial assistance and details and mechanics of the geothermal loan guarantee program.

DISCUSSION

The technical assistance program provided by 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 parties involved of the problems the potential user faces from a technical, financial risk, or management point of view.

Documentation and Assistance Not Previously Reported. A review of technical assistance in the eastern United States was presented at the Fifth Annual Technical Information Interchange Meeting at Berkeley Springs, W. Va., in November 1980 (Ref. 1). Table 1 is a list of technical assistance completed or still in process in the eastern United States; Table 2 is a list of technical assistance that has been requested.

REFERENCE

1. "Fifth Technical Information Interchange Meeting - Minutes," JHU/APL QM-80-185, Dec 1980.

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Table 1

Technical assistance in the Eastern United States completed or still in process.

Space Heating

Crisfield, Md., High School
Crisfield, Md., Hospital
Pittsville, Md., Middle School
Hot Springs, Ark.
Newport News, Va.
Naval Air Rework Facility, Norfolk, Va.
NASA-Wallops Flight Test Center, Va.
Kings Bay, Ga.

Geothermal Industrial or Agricultural Process Heat

Standard Brands Fructose Plant, Montezuma, N.Y.
Mariculture, Chesapeake Bay
Wet corn mill, Alabama - ethanol
Wet corn mill, North Carolina - ethanol
Seafood terminal, Newport News, Va.
Liquefied Natural Gas Terminal, Cove Point, Md.
Showell Farms - poultry industry

Combinations of Above

Industrial park, Melfa, Va.
Lewes, Del.

Heat Pumps

Bellows Falls, Vt.
Lebanon Springs, N.Y.
Individuals (3)
Energy Concepts Corp., Md.
New Hope, Pa.
McGuire AFB, N.J.

Table 2

Requested technical assistance in the Eastern United States.

Geothermal Space Heating

Senior Citizens Center, Ocean City, Md.
Dover AFB, Dover, Del.
Charleston AFB, Charleston, S.C.
Auburn, N.Y.

Industrial or Agricultural Process Heat

Bristol Meyers, Syracuse, N.Y.
Federal Fish Hatcheries, Pa.
Burlington Industries, N.C.
Smith Point, Va.

Combinations

Salisbury, Md.

Heat Pumps

Forty Fort, Pa.
Harlan, Ky.
Richmond, Ind.
Indianapolis, Ind.

TECHNICAL ASSISTANCE ON THE DELMARVA PENINSULA

In CY 79, APL was requested by the Mayor's office of Ocean City, Md., and the County Council of Wicomico, Md., to provide technical assistance for geothermal heating of several public buildings that were to be constructed. Recent contacts with these local governments (December 1980) indicate that they are still interested.

Active consideration is being given to constructing a Community Center in Ocean City, Md., using geothermal energy for heating. The Civic Center in Salisbury, Md., has been completed, and a new high school will soon be constructed across the street. The County Administrative Director regards the juxtaposition of the two facilities, which have peak heating demands in different periods of the day, as promising for geothermal heating.

These two projects have been on APL's list for possible technical assistance for some time (Ref. 1), but, because of the pressure to complete other studies and manpower limitations, they have not been actively pursued. Discussions have been held with one large private engineering firm, with recognized competence in geothermal energy, to determine the feasibility of subcontracting some of these technical assistance studies. The principal concern expressed by the firm was that a small technical assistance study could, because of conflict of interest clauses that might exist in the subcontract, prevent bids from being made on any major items of geothermal development that would result from the technical assistance study. The solution will depend on the policies of DOE and may limit any subcontracting of technical assistance studies by APL to small local engineering firms that have no interest in contracts that accompany actual geothermal development. Conversations with officials in Wicomico County have indicated that such local contractors exist, and APL will pursue this approach in early CY 81.

REFERENCE

1. "Fifth Technical Information Interchange Meeting - Minutes," JHU/APL QM-80-185, Dec 1980.

GEOTHERMAL PRODUCTION OF ETHANOL - MELFA, VA., INDUSTRIAL PARK

The Melfa Industrial Park, being developed by the Accomack County Industrial Development Authority, is a large rural area, with a small population, near the Accomack County Community College and an airport. The primary industries are the NASA Wallops Flight Test Center and the hatching, brooding, and preparation plants of the poultry industry distributed through the county. The nearest town is Parksley, Va.

The development authority for the industrial park has been interested in geothermal energy since it was informed that the temperature gradient in the area was higher than normal and that modest temperature warm water could most probably be found. There have been several possible uses for geothermal energy in the park other than space heat, the most significant being the distillation of ethanol.

Typically, ethanol is distilled in a tall column where the liquor resulting from fermentation pours over a series of baffles within the column. Distillation begins at the top and the

liquor falls to the bottom. Normally, steam at a temperature high enough to maintain reasonable pressure is introduced at the bottom of the column; it works its way up the column, heating the falling liquor. When the temperature of the liquor reaches 170°F, the ethanol vaporizes, travels up the column, and is condensed elsewhere. If a potential vacuum is maintained within the column, the ethanol turns into gas at a lower temperature - one that may be available at Parksley. The Accomack Industrial Authority has a company ready to build a modest ethanol plant using coal to make steam. The authority has applied for a Farm Home Loan Guarantee and hopes to have a plant in operation in six months with an output of a million gallons per year using corn as the feedstock. However, the authority wishes to study a system using vacuum distillation combined with geothermal for future replacement of coal. Support for this study is being identified.

FEASIBILITY OF GEOTHERMAL DISTRICT HEATING, BERLIN, MD.

The town of Berlin, Md., located approximately 8 miles west of Ocean City, Md., is applying for funding from HUD to study the feasibility of using geothermal energy for district heating of the town's central area. T. McLaughlin from the Mayor and Town Council Office has contacted UPI&SU and APL for information that would help him to prepare a proposal to HUD for funds to study geothermal district heating. The electric log from a nearby oil and gas test well that was drilled in 1945 and other geological information will be used for the study. VPI&SU has estimated the temperature at depth and the geothermal gradient above that depth. APL has estimated the average useful water temperature and the flow possible from a geothermal well drilled at Berlin (Ref. 1). This information has been forwarded to Mr. McLaughlin. Ebasco Services, Inc., is helping Mr. McLaughlin respond to the HUD proposal (Ref. 2).

REFERENCES

1. "Geothermal Study Proposal," JHU/APL Lett. CQO-2974, 12 Dec 1980.
2. "Request for Cooperative Agreement Application No. 6500 Access District Heating/Cooling Systems Potential in Community Development Block Grant Eligible Communities, DHUD, 17 Nov 1980."

TECHNICAL ASSISTANCE STUDY FOR DOVER AFB, DEL.

The Air Force, through DOE, has requested a Technical Assistance (TA) study of the potential use of geothermal energy on Dover AFB. On November 21, 1980, F. K. Hill and R. von Briesen visited the Chief of Engineering at Dover AFB (Ref. 1) to gather information. Various uses of geothermal energy were investigated, such as washing airplanes, multihousing space heating, and space heating of maintenance hangars that house CSA aircraft.

APL has had many requests for geothermal technical assistance studies. To expedite the Dover request, APL is proposing subcontracting the study to Solar Energetics of Wilmington, Del. A meeting with Solar Energetics was held on December 14, 1980. The contract will call for the finished report on March 15, 1981.

REFERENCE

1. R. von Briesen, "Trip Report to Dover AFB," JHU/APL QM-80-192, 31 Dec 1980.

WATER-REFERENCED HEAT PUMPS IN MUNICIPAL BUILDINGS, FORTY FORT, PA.

The borough of Forty Fort, Pa., a small community in the northeastern part of the state, is interested in finding an alternate method for heating buildings such as the City Hall and the fire department. Since much of the borough is near deserted horizontal coal mine shafts filled with water whose temperature remains constant, it has been suggested that this water be used with water-referenced heat pumps for heating and cooling the public buildings.

It is necessary to locate these abandoned mines (owned by the Delaware-Lackawana Mine Co.), determine the water temperature, and estimate the volume of water. The type and cost of heat pumps and pumping and the extent of retrofitting each building can then be analyzed.

The borough plans to respond to the HUD request for Cooperative Agreement No. 6500 to obtain a grant. The first building to be considered is approximately 100 by 100 ft and is 2½ stories tall. It is planned to circulate the groundwater from the mine through the building and reinject it back into the mine. This process is now being used to heat the Radio Shack Store in the Midway Shopping Center in Wyoming, Pa. The Department of Mines of the Pennsylvania Department of the Interior is assisting these projects, and the borough has requested technical assistance from APL. A visit is planned to Forty Fort to assess the best use of the groundwater.

WATER-REFERENCED HEAT PUMPS IN PUBLIC BUILDINGS, RICHMOND, IND.

Richmond is a small town east of Indianapolis, Ind. The town has always had a problem with shallow groundwater, i.e. wet basements; accordingly, it has been suggested that water-referenced heat pumps could be used for space heating and cooling of several municipal and private buildings.

The shallow aquifer that underlies the town has to be defined, its size established, and the mechanics of recharge and drainage determined. An estimate has been made of the possible extent of heating and cooling and of the cost of conversion. The town has asked for technical assistance from APL, which is planned for early CY 81.

DRILLING OF A GEOTHERMAL WELL, MONTEZUMA, N.Y.

Plans have been made to drill a geothermal well in 1981 on the Clinton Corn Products property near Montezuma, N.Y. B. Krakow of the New York State Energy Research and Development Authority (NYSERDA) is managing the program, which is a joint effort of his organization and DOE/DGE. B. Foster, an oil geologist in western New York with many years experience, is assisting NYSERDA in the design of the well. A Request for Proposal (RFP) for drilling, management, and analysis will be released by the first of the year.

The well is designed to penetrate a short distance into the basement rock to recover a 20 ft core sample of unweathered Precambrian material. Core samples (20 ft) will be obtained in the Theresa and Potsdam formations. The well will be cased below fresh water, salt horizons, and gas horizons. Following APL recommen-

dations (Refs. 1 and 2), several pump tests will be conducted in the open hole.

A meeting was held to discuss siting considerations during the Fifth Annual Geothermal Technical Information Interchange Meeting at Berkeley Springs, W. Va. Representatives from DOE, Los Alamos Scientific Laboratory, the University of Buffalo, the New York Geologic Survey, NYSERDA, and APL were in attendance. The sparsity of the available data was discussed as well as methods to obtain more accurate data. It was concluded that, if the well were to be used by Clinton Corn Products, it must be on or very near its property, and thus the existing limited well data are not very helpful in site selection.

REFERENCES

1. "Requirements for Hydrologic Test Well in Western New York State," JHU/APL CQO-2852, 3 Apr 1980.
2. F. C. Paddison, "Further Comments on Hydrologic Test Well, Western New York State," JHU/APL Lett., 4 Apr 1980.

GEOTHERMAL ENERGY, COVE POINT LNG RECEIVING TERMINAL

The Columbia LNG Corp. at Cove Point, Md., has been considering the use of geothermal water for gasifying LNG prior to its insertion into the transportation pipeline (Ref. 1). The Laboratory documented a brief analysis of the geothermal well field that might be required for the maximum LNG delivery rate anticipated (Refs. 2 and 3).

To check the previous estimate of drawdown for the Columbia LNG Corp., which was based on the results for a production-reinjection doublet, a square grid of a 64-well field (32 pairs) was studied. The study indicated a slight reduction in the drawdown, but the reduction is small compared to the uncertainties caused by the lack of resource knowledge (Ref. 4).

DOE/DGE is currently funding the drilling of a well at the Cove Point facility by VPI&SU to determine resource conditions. When this information becomes available, a reexamination of the production field behavior is planned.

REFERENCES

1. "Utilization of Geothermal Energy at the Cove Point LNG Receiving Terminal," Columbia LNG Corp., Mar 1980.
2. "Report on Technical Assistance for Columbia LNG Corporation," APL/JHU Lett. CQO-2850, 28 Mar 1980.
3. "Geothermal: Energy for the Eighties, Geothermal Resources Council Transactions," pp. 629-632, Vol. 4, Geothermal Resources Council Annual Meeting, 9-11 Sep 1980, Salt Lake City.
4. K. Yu, "Preliminary Results for the Technical Assistance to Columbia LNG Corp.," JHU/APL QM-80-047, 10 Mar 1980.

GEOTHERMAL LOAN GUARANTEE INFORMATION

At the request of DOE/DGE, a subcontract has been consummated with Washington Analytical Service Center of EG&G, Rockville, Md., to inform those requesting counsel what financial assistance is available and, in particular, the details and mechanics of the Geothermal Loan Guarantee Program. During December, L. Falick of EG&G assisted in the DOE Resource Applications draft (Ref. 1).

REFERENCE

1. "Loans to Construct Geothermal Direct Heat and Small Hydroelectric Power Facilities; Proposed Rulemaking and Public Hearings," DOE/RA, 10 CFR Part XXX.

GEOHERMAL ENERGY DEVELOPMENT PLANNING § 15 AND TECHNICAL ASSISTANCE

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

F. K. Hill and R. von Briesen

October-December 1980

TECHNICAL ASSISTANCE — MCGUIRE AFB, N.J.

APL has completed a technical assistance (TA) study (Ref. 1) for McGuire Air Force Base, N.J. The study shows how geothermal energy (in the form of low-temperature hydrothermal water) can be used with heat pumps for space heating and air-conditioning multifamily housing units on the base.

McGuire AFB has over 1200 multifamily homes, arranged in complexes of 20 units, that are located in an area called North Falcon Courts. This housing area is being modernized, a program that includes insulating, converting from hot-water radiant heating to forced air, and installing a split-unit system of air conditioning. The modernization program is half completed. The TA study is concerned with the remaining units, which have not been retrofitted. Each complex is heated by a central heat exchanger, which is fed with high-temperature (380°F), high-pressure (300 psi) water from the main gas-fired heating plant on the base. The distribution line for the high-temperature, high-pressure system is over 2 miles long. The line has a fairly large thermal loss rate caused by water leaks and deteriorating insulation. The use of groundwater heat pumps to heat and cool the housing units will remove a significant portion of the thermal load from the high-temperature distribution system. The conditions are ideal for using groundwater heat pumps. The water is considered potable down to basement (approximately 1000 ft depth).

Information obtained from VPI&SU (Ref. 2) and the Department of Environmental Protection, Division of Water Resources, Bureau of Water Allocation in Trenton, N.J., (Ref. 3) indicates that the aquifers near the 1000 ft level have a large transmissivity value; the drawdown is minimal for a well that is fairly heavily pumped. For example, a well at McGuire AFB, which was pump tested for 8 hours at 700 gal/min, had a drawdown of 53 ft. The temperature at the 1000 ft level is approximately 66°F (Ref. 2), a temperature ideally suited for matching with a Westinghouse Templifier heat pump as a heat source or heat sink.

The TA report discusses the mechanics of conversion to geothermal energy and the economics of heating and cooling 10 complexes (200 housing units) with one production and one reinjection well. For example, each complex of 20 housing units has its own hot-water distribution system. The system includes a fan coil unit in each attic and a main heat exchanger room attached to one of the housing units. A feedline from the high-temperature, high-pressure system at the base enters the main heat exchanger room; hot water at 180°F is then distributed to each housing unit. For air conditioning, each housing unit has (or will have) its own 1.5 ton split-system unit.

Converting the housing complex to use low-temperature hydrothermal water (groundwater at approximately 1000 ft depth) can be accomplished by installing a Westinghouse Templifier or a similar heat pump in the heat exchanger room, and using the 66°F groundwater as a heat source for space heating and a heat sink for cooling. The hydrothermal water system from one production well would replace the high-temperature distribution system for 10 housing complexes or 200 homes. With the production and reinjection wells spaced 2 km apart, drawdown would be minimal, with a 500 gal/min withdrawal and reinjection rate. Conclusions indicate that space heating and cooling with groundwater source heat pumps that operate with a coefficient of performance of 3.4 in the heating mode and 4.5 in the cooling mode can be cost effective. Of course this is dependent upon the projected fossil fuel and electrical costs.

REFERENCES

1. F. K. Hill and R. von Briesen, "Technical Assistance Report - Geothermal Space Heating at McGuire AFB, New Jersey," JHU/APL QM-80-190, Dec 1980.
2. Geothermal Potential at McGuire AFB, N. J., VPI&SU Lett., 27 Oct 1980.
3. Water Well Information at McGuire AFB, N. J., Dept. of Environmental Protection, Div. of Water Resources, Bureau of Water Allocation, Trenton, N. J., Lett., 17 Nov 1980.

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GEOHERMAL ENERGY DEVELOPMENT PLANNING § 16 AND TECHNICAL ASSISTANCE

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

Support: DOE/DGE

F. K. Hill and R. W. Henderson

October-December 1980

TECHNICAL ASSISTANCE — KINGS BAY, GA.

APL was asked to review a report (Ref. 1) prepared by Fosdick and Hilmer, Inc., Consulting Engineers for the Navy. A brief commentary (Ref. 2) and suggestions as to how geothermal energy might be exploited for space heating at the Naval Submarine Support Base, Kings Bay, Ga., were sent to T. A. Ladd at the Naval Facilities Engineering Command (NAVFAC) on December 11, 1980.

SUMMARY

The climate at Kings Bay is relatively warm, with about twice as many degree cooling days as degree heating days. Air conditioning is a year-long requirement for comfort, but it is necessary to provide heat only 7 months of the year. Use of the heating system would be only 7 to 8%; i.e., a heating system capable of meeting the demand for heat on the coldest day would need to operate only 600 to 700 h per year. It is estimated that the geothermal resource at the Base may be adequate to supply a significant portion of the energy needed for space heating.

The water temperature at depth is estimated by VPI&SU to be between 118 and 123°F, and, because of the thickness of the permeable sand and the short heating season, withdrawal rates of 200 to 400 gal/min should be permissible. Well output, based on 35 Btu/lb of water, should range from 3.5 to 7 million Btu/h. Space would permit three sets of production and reinjection wells at the Base and thus a geothermal output of 10.5 to 21 million Btu/h should be available. Use of storage systems (Ref. 3) would provide peak load capability at 31.5 to 63 million Btu/h. To confirm the quality and quantity of the geothermal resource, a test well should be drilled to ascertain the feasibility of using geothermal energy for space heating at Kings Bay.

Geothermal Resource. Based on the assumptions about the resource, use of geothermal energy could reduce the consumption of fossil fuel by a factor of 7 and reduce the cost for energy by a factor of 4. Depending on how much of the estimated requirement (54×10^6 Btu/h) at the Base could be met with geothermal energy, this would reduce the operating cost for fuel as much as \$100,000 per year (using the projected costs (Ref. 4) of \$3 per 10^6 Btu for coal and \$0.058 per kWh for electricity in 1985). The possibility of such savings would seem to justify drilling a test well as soon as possible.

Storage for Peak Demand. At Kings Bay, there are about 3000 h in the year when the temperature is below 65°F. A heating system designed to meet the heating load on the coldest day would operate about 600 h/yr. So, for every hour it must operate during the heating season,

Fig. 1 Heat storage system required to boost the heat output rate of a geothermal well. (80-4/36)

it will be idle on the average for 4 h during the heating season. Use of a heat storage system to boost the heat output rate of a geothermal well (Fig. 1) would appear quite feasible since there is considerable time for recharging between demand periods. Based on the average recharge to demand time, a well delivering 3.5×10^6 Btu/h used in conjunction with a storage system would be able to deliver 17.5×10^6 Btu/h. However, the normal daily mean temperature at Kings Bay in the coldest month of the year, i.e., January, is 55°F, and, for a sustained period of 55°F, the system would have to deliver heat 33.3% of the time. This would allow only 2 h for recharging for every hour of heat demand. The maintenance of a 17.5×10^6 Btu/h rate under these circumstances would require a very large reservoir and long term storage. A more practical rate would be 10.5×10^6 Btu/h based on the 2 h of recharging per hour of heat demand for the coldest period of the year. A storage capacity of about 200×10^3 gal would be required. Similarly a geothermal well delivering 7×10^6 Btu/h used in conjunction with 400×10^3 gal of storage would deliver 21×10^6 Btu/h. The use of storage as suggested here increases utilization of the geothermal well by a factor of 3.

FUTURE PLANS

A meeting will be held with representatives of NAVFAC at APL on January 8, 1981, in which the

possibilities for using geothermal energy for space heating at Kings Bay will be explored. It will be pointed out by APL that the DOE, USCGS, and Georgia Geological Office have an interest and might participate in a joint venture to drill a test well at Kings Bay. NAVFAC will be asked to pursue this possibility.

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GEOHERMAL ENERGY DEVELOPMENT PLANNING § 17 AND TECHNICAL ASSISTANCE

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

Support: DOE/DGE

P. Kroll

October-December 1980

ENHANCEMENT OF THE GRITS ECONOMIC ANALYSIS COMPUTER PROGRAM

The GRITS computer program (Refs. 1 and 2), designed to perform preliminary economic analyses of potential geothermal projects, underwent enhancement and improvement during the final quarter of 1980. The most important structural change was the incorporation of calculations to size the system according to a demand constraint, in addition to the resource-constrained case already formulated. Thus, the main distinguishing feature of DSM (Demand Specified Model), an earlier demand-constrained computer model (Ref. 3), was made part of GRITS.

DISCUSSION

The significant changes in the GRITS computer program are listed below.

1. The most important change was in demand-constrained modeling, which allows GRITS to supersede the earlier DSM. The preceding version of GRITS based its size on the available resource and attracted (by assumption) enough households to use the resource to capacity. We can term this a resource-constrained or resource-specified model. The new version of GRITS also permits a demand-constrained or demand-specified mode of operation. In this mode, the demand on the system (number of households and/or commercial buildings and their heating demand characteristics, or industrial process heat demand) is specified by the user, and the GRITS simulation sizes the geothermal installation to be large enough only to satisfy the specified demand, rather than using the full resource (if it is not necessary).
2. New engineering equations for capital equipment components have been inserted. As field experience increases and newer cost estimates become available, they will continue to be incorporated in GRITS.
3. A few assumptions have been revised in the use of resource parameters to size certain capital equipment.
4. An additional financial measure, the cost savings (payback) of conversion to geother-

mal, as opposed to a fossil fuel system, has been added. The time when the cumulative savings equal the initial capital investment is reported as the payback period.

5. Several computational and data manipulation routines have been streamlined within the source code.
6. Additional aids to the interactive user have been inserted.
7. Access to the weather data library for 134 cities has been revised, improving ease of use and efficiency.
8. In one step the user can run through a sequence of design temperatures, with the choice of several new result reporting options. As a major design parameter in system sizing, the design temperature's optimal value can be determined easily.
9. Residential sanitary hot water demand is now a user-specified option.
10. A greater variety of output detail can be chosen when results are reported on the user's terminal and/or line printer.

FUTURE PLANS

Subsequent economic analyses will use this enhanced version of the GRITS computer program. As additional modeling needs and updates materialize, GRITS will continue to be expanded to deal with them.

REFERENCES

1. W. F. Barron, P. Kroll, R. Weissbrod, and W. J. Toth, "Geothermal Energy Market Study on the Atlantic Coastal Plain, GRITS: A Computer Program for the Economic Evaluation of Direct Application of Geothermal Energy," JHU/APL GEMS-008 (QM-80-077) Jun 1980.
2. Section 18, Quarterly Report, Jul-Sep 1980, JHU/APL EQR/80-3.
3. P. Kroll, W. Barron, and W. J. Toth, "The Demand Specified Model for Direct Applications of Geothermal Energy: A User's Guide," JHU/APL QM-80-131, Dec 1980.

GEOHERMAL ENERGY DEVELOPMENT PLANNING § 18 AND TECHNICAL ASSISTANCE

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

Support: DOE/DGE

J. E. Tillman, C. S. Leffel, Jr., and F. C.
Paddison (APL) and B. Nilo (Metro Center)

October-December 1980

AID TO STATE AND LOCAL GOVERNMENTS

Resource assessment on the Atlantic Coastal Plain has identified broad regions with hydrothermal resources in the Delmarva Peninsula areas of Delaware, Maryland, and Virginia. New Jersey and northern North Carolina have also been shown to possess areas with hydrothermal potential. This work, supported by DOE/DGE, has been done by VPI&SU, now extending its assessment efforts to the southern Atlantic Coastal States (Ref. 1).

A complementary assessment of the market for modest temperature hydrothermal energy in the identified areas of New Jersey, Delaware, Maryland, Virginia, and North Carolina has been performed by APL (Ref. 2). This work is also being extended to the southern Atlantic Coastal areas as they are identified by resource assessment efforts.

As a result of the DOE efforts, individuals and state agencies have become interested in the application of geothermal energy. Many requests have been received for assistance in drafting legislation and developing rules and regulations for geothermal energy development and use, as well as for the organization of state teams to focus state, local individual, and industrial efforts in developing geothermal energy. The National Conference of State Legislatures (NCSL) is supported by individual states and by DOE to formulate legislative issues relating to geothermal energy and groundwater heat pumps. The State of Maryland passed a Geothermal Resources Act in 1978 that is presently being reviewed. Delaware and Virginia are in the process of drafting legislation. APL provides technical, market, and economic assistance as requested in this effort.

State of Maryland. The Maryland Geothermal Resources Act (Senate Bill 1154) became law on 1 July 1978. The Act has been criticized on the ground that the question of ownership is left ambiguous. A Joint House/Senate Energy Committee has held a series of meetings to discuss amendments, which may be submitted to the 1981 Legislature. On 30 September, an evening meeting of the Special Joint Committee on Energy of the General Assembly convened to review an NCSL report on options available for improving the Maryland Geothermal Act. The subjects that the Committee has asked NCSL to review were: characterization and ownership, access and allocation, regulatory procedures and financing, and marketability. A subcommittee was named to write the proposed amendments to the Geothermal Act. Reference 3 is an APL memorandum on this meeting.

A meeting on 17 December reviewed proposed amendments and/or clarifying language to sections

of the Geothermal Resources Act pertaining to ownership, access, allocation, definition of Public Service Commission, tax credits for geothermal energy equipment, the Board of Public Works, and state lands. Reference 4 documents these discussions.

State of Virginia. The Virginia Coal and Energy Commission has established a Geothermal Subcommittee to study and make recommendations pertaining to the issues to be addressed in geothermal legislation. A Legislative Workshop was held on 9 September (Ref. 5), followed by a more detailed discussion of issues on 22 October (Ref. 6). APL was asked to suggest (a) a statement on the purpose of the proposed Virginia Geothermal Act, (b) a definition of the resource, (c) comments on forms of ownership and allocation, and (d) a quantitative discussion of the economics of Virginia geothermal resources for industrial process heat or residential space heat and the effect of form of ownership and resource management on overall costs (Ref. 7). NCSL forwarded (Ref. 8) its recommendations as a result of the 22 October meeting.

The Geothermal Subcommittee has reported to the Virginia Coal and Energy Commission (Ref. 9) with the following recommendations:

1. Geothermal resources are neither a mineral nor a water resource. Therefore, the definition should be "the natural heat of the earth and the energy in whatever form that may be obtained from a warm or hot water aquifer or from a fluid circulated through hot dry rock."
2. Ownership rights to geothermal resources should be held by the owner of the surface property underlain by the geothermal resources.
3. The Department of Labor and Industry should be given primary responsibility to regulate geothermal resources in the Commonwealth of Virginia.
4. Legislation should be enacted to give the Department of Labor and Industry the responsibility and authority to develop a comprehensive geothermal permitting system for the Commonwealth, which would establish access to explore for and develop the geothermal resource.
5. The Department of Labor and Industry should be required to promulgate comprehensive rules and regulations relating to geothermal drilling, exploration, and development in Virginia. The rules and regulations should be based on a system of equitable apportionment (correlative rights).
6. The Department of Labor and Industry should be required to consult with the State Water

Control Board when geothermal development endangers potable water supplies, and the Water Control Board should be given enforcement powers as applicable.

7. The Coal and Energy Commission should give consideration to a comprehensive constitutional amendment that would set forth tax exemptions or incentives for alternative and renewable energy resources.

New York State. DOE and the New York State Energy Research and Development Authority (NYSERDA) are drilling a resource confirmation well at Montezuma, N.Y., near the Clinton Corn Products Wet Corn Mill Plant, which manufactures fructose, a corn syrup. This effort, together with other resource assessment efforts by Dunn Geosciences, Inc., in the capitol area around Albany, and a Program Research and Development Announcement awarded to evaluate hydrothermal energy for cottage cheese manufacture in Fairfield, N.Y., will necessitate consideration of state legislation. Data on the status of legislation have been supplied to NYSERDA and the Cayuga County Industrial Development Authority in Refs. 10 and 11.

Formation of State Teams. The formation of the state teams is being done jointly by APL and DOE. The state team in the Atlantic Coastal Plain is a single group combining resource and commercialization interests. APL (Refs. 12, 13, and 14) has recommended a charter for the state team and has drafted suggested objectives and a description of a geothermal prospectus for the states sharing parts of the Delmarva Peninsula (Ref. 15). It is intended that each state team would have the prospectus completed specifically for its state and then continue to serve as necessary to assist the development of geothermal energy. DOE would contribute to the support of the state teams. Delaware has submitted an organizational plan and has been funded by DOE/DGE. Virginia is in the process of forming a team and plans to submit a request for support early in the next quarter. Maryland is proposing the formulation of a new entity, "The Maryland Energy and Supply Conservation Authority," within the state government to serve the function outlined for geothermal as well as other energy forms.

Water Source Heat Pumps. The NCSL is preparing state policy issues and options for water source heat pumps. APL collaborated (Ref. 16) on an early version of a guidebook on water source heat pumps and is now preparing comments on drafts of three summary tables for the next version of the book. These tables summarize:

1. Potential environmental problems and corresponding regulatory options,

2. Heat pump design to increase efficiency, and
3. The relative advantages and disadvantages of different types of water source heat pump systems.

REFERENCES

1. J. K. Costain et al., "Evaluation and Targeting of Geothermal Resources in the Southeastern United States," VPI & SU-5648 series of progress reports.
2. W. J. Toth, "Definition of Markets for Geothermal Energy in the Northern Atlantic Coastal Plain, JHU/APL GEMS-002/QM-80-075, May 1980.
3. C. S. Leffel, Jr., "Meeting of the Special Joint Committee on Energy of the General Assembly of Maryland, Annapolis, September 30, 1980," JHU/APL QM-80-156, 2 Oct 1980.
4. F. C. Paddison and C. S. Leffel, "Meeting of the Special Joint Committee on Energy of the General Assembly of Maryland, Annapolis, December 17, 1980," JHU/APL QM-80-193, 30 Dec 1980.
5. J. E. Tillman, "Geothermal Energy Workshop in Virginia," JHU/APL QM-80-143, 10 Sep 1980.
6. F. C. Paddison, "NCSL Workshop - Virginia Coal and Energy Commission Geothermal Subcommittee, 22 October 1980," JHU/APL QM-80-194, 30 Dec 1980.
7. "Comments on Selected Issues for Future Virginia Geothermal Legislative Workshops," draft of JHU/APL Lett. to S. Valentine, NCSL.
8. "Recommendations of the Geothermal Subcommittee to the Virginia Coal and Energy Commission, NCSL memo., 4 Nov 1980.
9. "Report of Geothermal Subcommittee to the Virginia Coal and Energy Commission," Commonwealth of Virginia, Richmond, 1980.
10. "Proposed Geothermal Act - Delaware," JHU/APL Lett. CQO-2871, 29 Apr 1980.
11. "Forwarding of Reports," JHU/APL Lett. CQO-2914, 25 Jul 1980.
12. "Geothermal Energy in Maryland," JHU/APL Lett. CQO-2840, 11 Mar 1980.
13. J. E. Tillman, "Geothermal Meeting in Richmond, Virginia," JHU/APL QM-79-144, 21 Jun 1979.
14. J. E. Tillman, "Delaware Geothermal Prospectus," JHU/APL QM-79-117, 24 May, 1979.
15. "Geothermal Energy and the Eastern U.S., A Framework for a Site Prospectus for Geothermal Energy Development, Delmarva Peninsula," JHU/APL QM-79-145, Jun 1979.
16. "Heat Pumps," JHU/APL Lett. CQO-2925, 26 Aug 1980.

GEOHERMAL ENERGY DEVELOPMENT PLANNING § 19 AND TECHNICAL ASSISTANCE

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

Support: DOE/DGE

S. Kane, P. Kroll, and B. Nilo (Metro Center)

October-December 1980

TECHNICAL ASSISTANCE — NEW YORK STATE

During the third quarter of 1980, a request was received from B. Krakow of the New York State Energy Research and Development Authority (NYSERDA) for assistance in evaluating potential geothermal resource development in the Syracuse area (Refs. 1 and 2). In support of this effort, the Metro Center used the computer economic evaluation model (Geothermal Resources Interactive Temporal Simulation, GRITS) to aid in studying the prospective resource. This article reports on an analysis of the results.

DISCUSSION

Various scenarios were used by the Metro Center to test resource conditions ranging from optimistic to conservative (Table 1). The hourly temperature distribution of Syracuse was used with the optimal design temperature for hybrid geothermal fossil fuel peaking boiler systems (the design temperature is the temperature down to which all of the heating demand is supplied by the geothermal resource alone, as opposed to the peaking boiler). Five district heating systems were simulated, each composed entirely of either suburban single-family housing, single-family dense housing, townhouses, garden apartments, or high-rise housing. To examine the effect of alternative fuels for the peaking boiler, both oil and gas prices were specified as the peaking fuel in the scenarios. In addition, another scenario was improvised using GRITS in order to compare the geothermal district heating systems with one heated solely by a fossil fuel boiler.

Data resulting from preliminary sensitivity analyses are shown in Tables 2, 3, and 4. Table 2 displays the discounted average cost (DAC) and number of households served by a district heating system (hybrid geothermal/fossil fuel peaking boiler) under several resource conditions. The DAC declines and the number of households increases as a function of housing density, keeping all other conditions exactly the same. In addition, substituting oil, currently a more expensive fossil fuel, for gas to fuel the peaking boilers serves to raise the DAC and lower the number of households that the system can support. Last, DAC increases in response to the decline of geothermal wellhead water temperature and the increase of well depth.

Table 3 provides the design temperatures for the geothermal/fossil fuel hybrid system as resource conditions are varied. The lower the wellhead water temperature, the lower the potential heating load for the system, and the higher is the optimum design temperature (i.e., the temperature above which all the heat is supplied by the geothermal resource alone). Given the

Table 1

Range of resource conditions.

Resource	Temperature (°F)	Well depth (ft)	Flow rate (gal/min)	Drawdown (%)
1	145	5000	200	20
2	125	5000	200	20
3	125	4000	200	20
4	105	3000	200	20

Table 2

Discounted average cost (in dollars) and number of households according to resource conditions.

Resource conditions	Housing type	Gas		Oil	
		DAC	HH	DAC	HH
145°/ 5000 ft	TH	6.73	197	7.11	167
	GA	6.59	317	6.92	317
	HR	6.38	361	6.69	361
125°/ 5000 ft	TH	8.86	183	9.64	128
	GA	8.79	279	9.49	207
	HR	8.61	321	9.28	236
125°/ 4000 ft	TH	7.59	183	7.90	128
	GA	7.42	279	7.70	207
	HR	7.21	312	7.48	236
105°/ 3000 ft	TH	9.35	111	10.34	67
	GA	9.32	164	10.20	108
	HR	9.15	181	10.00	123

DAC - discounted average cost

HH - households

TH - townhouses

GA - garden apartments

HR - highrise housing

Table 3

Design temperature from test scenarios.

	Gas (°F)	Oil (°F)
145°/5000 ft	33	26
125°/5000 ft	44	32
125°/4000 ft	44	32
105°/3000 ft	49	34

Table 4

Comparison of hybrid and all fossil-fuel heating systems, discounted average cost (in dollars).

		All oil	Hybrid oil	All gas	Hybrid gas
145°/ 5000 ft	TH	14.04	7.11	9.61	6.75
	HR	13.61	6.69	9.18	6.38

same resource conditions, the design temperature is lower for a peaking boiler using the more costly fuel. It can be noted that well depth has no effect on optimum design temperature in this case; design temperature for well-head temperature of 125°F is the same whether the depth is 4000 or 5000 ft.

Hybrid heating systems were compared with all fossil fuel boiler systems in Table 4. Given the most optimistic resource condition (145°F, 5000 ft depth), the DAC's for townhouse and high-rise heating systems have been provided. All fossil fuel systems (given equal number of users and exact composition of users as geothermal hybrid systems) have a higher DAC than geothermal hybrid systems. This indicates substantial savings from the use of geothermal energy in a hybrid heating system.

REFERENCES

1. W. Barron, P. Kroll, R. Weissbrod, and W. J. Toth, "Geothermal Energy Market Study on the Atlantic Coastal Plain, GRITS: A Computer Program for the Economic Evaluation of Direct-Use Applications of Geothermal Energy," JHU/APL GEMS-008 (QM-80-077), Jun 1980.
2. Section 18, Quarterly Report, Jul-Sep 1980, JHU/APL EQR/80-3.

**GEOHERMAL ENERGY DEVELOPMENT PLANNING § 20
AND TECHNICAL ASSISTANCE**

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Support: DOE/DGE

A. M. Stone

October-December 1980

**GEOHERMAL TECHNICAL INTER-
CHANGE MEETING**

The Technical Information Interchange Meeting held at Berkeley Springs, W. Va., on November 6-7, 1980, was the fifth in a series. The first Technical Information Interchange Meeting on eastern geothermal programs, the Near-Normal Gradient Workshop, was held in March 1975 under the aegis of the Energy Research and Development Administration. The second was held at APL in September 1978 under the auspices of DOE/DGE. A symposium on Geothermal Energy and Its Direct Use in the Eastern United States was sponsored by the Geothermal Resources Council in Roanoke, Va., in April 1979. The fourth such meeting was sponsored by the Division of Geothermal Resource Management, DOE.

The fifth meeting was again sponsored by DOE/DGE; the 74 attendees represented DOE/RA, the U. S. Geologic Survey (USGS), National Oceanic and Atmospheric Administration, state geologic offices, state energy offices, DOE Regional Offices, Program Research and Development Announcement recipients, industrial representatives, the national laboratories, a financial analyst, and interested county officials. Virtually all attendees participated in the program, summarizing their efforts in promoting the use of geothermal energy in the East. By all accounts, this was an enthusiastic and successful interchange meeting, with most participants expressing a desire for additional meetings in this format.

In the evening of the first day, an informal talk was given by P. Rodzianko, president of the Geothermal Energy Co., who is a skilled lecturer and writer and a practitioner in the art of organizing, financing, and operating a direct-use geothermal project.

During the first morning, an overview of the current programs of DOE/DGE was presented by the keynote speaker, as well as a review of the eastern geothermal resource assessment program by the DGE contractors, Gruy Federal and VPI&SU. The Eastern Hot Dry Rock program was reported by the Los Alamos Scientific Laboratory (LASL) and its contractors. Studies included here were: a detailed study of the area between Crisfield, Md., and Wallops Island, Va., by D'Appolonia, Inc.; Florida and the eastern Gulf coastal plains by the University of Florida;

potential hot dry rock sites located in mid-continent and in northeastern New England by LASL; Ohio and western Pennsylvania state resources by Kent State University; and, finally, the extensive geothermal resource assessment program funded by DGE and New York State Energy Research Administration (NYSERDA). The last talk in this series consisted of a resumé of the User-Coupled Resource Confirmation Program by the Idaho Operations Office of DOE. Other eastern programs were presented, notably that of the Oak Ridge Energy Analysis Institute for the Tennessee Valley Authority (TVA) region and the Nebraska resources by the University of Nebraska.

A number of applications papers was presented on the first day, notably one on geothermal vaporization of liquefied natural gas (LNG) at Cove Point, Md., by the Columbia Gas Co. and one on the results of the Eastern PRDA's and PON's by EG&G. In other reports, the forthcoming geothermal drilling programs at Lewes, Del., and at Montezuma, N.Y., were discussed. The session included papers on legislative issues and economic analyses, and concluded with a discussion of the USGS geothermal and regional aquifer programs.

On the second day, reports were made on geothermal commercialization in the eastern states, giving particular emphasis to market penetration and to technical assistance programs. A final report, failure analysis in direct use of geothermal energy for space heating in central Texas by the Radian Corp. and an outline of a service it supplies free of charge in analyzing material compatibility with hydrothermal water, concluded the meeting.

The minutes of the meeting, which consist of the textual and illustrative material as furnished by each speaker, are in the process of being issued (Ref. 1). The primary distribution of these Minutes is being made to a list of attendees to the meeting. Additional copies are available from APL, Attn: CQO.

REFERENCE

1. "Geothermal Energy and the Eastern U.S., Fifth Technical Information Interchange Meeting, Minutes," JHU/APL QM-80-185, Dec 1980.

GEOHERMAL ENERGY DEVELOPMENT PLANNING §21 AND TECHNICAL ASSISTANCE

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

Support: DOE/DGE

C. S. Leffel, Jr., F. C. Paddison, J. E. Tillman,
R. F. Meier, and A. M. Stone

October-December 1980

COMMENTS ON LIMITED TASKS

MEETING OF THE AMERICAN SOCIETY FOR TESTING AND MATERIALS

Previous meetings of the Committee on Geothermal Resources and Energy (designated E45) of the American Society for Testing and Materials (ASTM) were described in Refs. 1 and 2. The meeting in Reno on November 18 and 19, 1980, was the third of Committee E45, which was organized in Philadelphia in October 1979 (Ref. 1).

ASTM Committee E45 is divided into subcommittees and task groups; the actual writing of standards and procedures is performed at the task group level. C. S. Leffel, Jr., the APL member of the committee, is assigned to the Task Group on Logging and Surface Geophysics (E45.1004). At this meeting, he attended as many sessions of other subcommittees and task groups as his schedule permitted.

Since the first meeting of E45 in Philadelphia, several changes have been made in the organization (Ref. 3). Of the greatest significance is the formation of a new Subcommittee on Materials (E45.40), which replaces two previous task groups under the Subcommittees on Field Development (E45.10) and Utilization (E45.20), and the creation of a new Task Group on Heat Pumps (E45.2004).

At the meeting, the Task Group on Logging and Surface Geophysics agreed that any standards for surface geophysics would be premature. The well logging companies, who supply a complete service as well as an interpretation of the results, feel no need for standards but are willing to consider them if requested. Since no standard procedure for pump-testing hydrothermal geothermal wells exists, APL was requested to supply the task group with possible format and procedural standards.

The Task Group on Utilization agreed that some standard method of specifying steam turbine performance was desirable as foreign bidders do not follow American practices. Also considered were the thermal properties of geothermal brines and performance standards for condensers and heat exchangers. There was no discussion of the technical problems involved in the direct application of heat from geothermal energy, but there was a general consensus that numerous computer models for the study of the financial feasibility of district heating and geothermal heating systems were inconsistent and confusing. APL was requested to furnish the Task Group with the description and assumptions used with the APL computer models that have been developed.

The procedures of ASTM require that a committee consist of a mix of producers, users, and general interest members. Although, as a whole,

E45 has a proper mix, this is not always true on the task group level. For example, the Task Group on Logging and Surface Geophysics (E45.1004) suffers from a lack of user representation. Attempts will be made to correct this imbalance.

REFERENCES

1. Section 22, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
2. Section 24, Quarterly Report, Apr-Jun 1980, JHU/APL EQR/80-2.
3. C. S. Leffel, Jr., "Attendance at the ASTM Meeting on Geothermal Resources and Energy, Reno, Nevada, November 18 and 19, 1980," JHU/APL QM-80-182, 21 Nov 1980.

DISTRICT HEATING AND COOLING

The Department of Housing and Urban Development (DHUD) and DOE are soliciting proposals for district heating and cooling. The respondents who suggest using geothermal energy will be assisted by the DOE/DGE District Heating Product Team (see Ref. 1).

To ensure that all potential communities and individuals were aware of the announcement of the solicitation that appeared on October 14, 1980, in the *Commerce and Business Daily*, the announcement was forwarded to 38 interested groups in the Eastern United States (Ref. 2).

REFERENCES

1. Section 19, Quarterly Report, Jul-Sep 1980, JHU/APL EQR/80-3.
2. "HUD Program 'Access Potential District Heating and Cooling System Projects'," JHU/APL Lett. CQO-2958, 27 Oct 1980.

COMPARISON OF ECONOMIC MODELS OF THE DIRECT USE OF GEOTHERMAL ENERGY

DOE/DGE has asked G. Reistad of the Department of Mechanical Engineering at Oregon State University to compare the available models designed for the economic analysis of the use of geothermal energy. Reference 1 forwarded APL reports on various models and suggested possible uses for them.

REFERENCE

1. "Laboratory Reports," JHU/APL Lett. CQO-2946, 9 Oct 1980.

GEOTHERMAL POTENTIAL IN UPSTATE NEW YORK

On October 10, 1980, J. E. Tillman of APL met with J. Markham of Dames & Moore and the Environmental and Research Staffs of the Niagara Mohawk Power Corporation (NMPC) at their headquarters in Syracuse, N.Y. NMPC had requested the meeting to learn more about the geothermal resource potential in its service area, which includes northern and western New York State. Dames & Moore has been providing geotechnical consulting services for NMPC and invited APL to the meeting.

The several geothermal projects that are presently being conducted within New York State were discussed. NMPC is most interested in the Capitol District Project funded by the New York State Energy Research and Development Authority (NYSERDA) and DOE/DGE. This project, being performed by Dunn Geoscience, is searching for

the origin of carbonated waters such as those at Saratoga Springs. Such carbonated waters could have originated from a shallow heat exchange zone buried beneath the shales in the Champlain-Hudson Valley trough.

A much more widespread resource of such water lies beneath western New York where water-bearing sedimentary sequences thicken from several thousand feet along Lake Ontario to 10,000 ft near the Pennsylvania border. A well, shortly to be drilled to basement near Montezuma, will enable the basal sandstones and several overlying sequences to be pump tested. This project is a joint effort of DOE/DGE and NYSERDA; the project manager of NYSERDA is B. Krakow. NMPC has assigned one of its research staff, R. Bebkow, to follow these efforts in order to assess the point at which the utility might take a more active role in developing or using geothermal energy.

ENERGY FAIR, FREDERICK, MD.

APL participated in the Frederick County Energy Fair, November 1-2, 1980, with a display that described the DOE/DGE geothermal energy program in the eastern United States. Activities in the Atlantic Coastal Plain area were illustrated in some detail, and those on the Delmarva peninsula were highlighted. Typical applications were shown for the temperature ranges expected in eastern resources. APL personnel supplied additional information and distributed a geothermal pamphlet to interested attendees (Ref. 1). The fair included about 100 commercial and non-commercial displays of energy resources, systems, and new energy-efficient materials and installations for houses and farms.

REFERENCE

1. R. von Briesen, C. S. Leffel, Jr., and F. C. Paddison, "Geothermal Energy in Maryland," JHU/APL QM-80-171, 28 Oct 1980.

GEOTHERMAL PROGRESS MONITOR

Items relating to geothermal development in the eastern United States were submitted to DOE/DGE for inclusion in the fifth issue of the Geothermal Progress Monitor. These items are summaries of recent technical assistance supplied by APL and the Metro Center of JHU and of papers presented at the 5th Technical Information Interchange Meeting held in Berkeley Springs, W.Va. on November 6-7, 1980.

REFERENCE

1. "Suggested Items for 5th Geothermal Progress Monitor," JHU/APL Lett. CQO-2973, 19 Dec 1980.

COMMENTS ON IRS PROPOSED RULING ON INVESTMENT CREDIT FOR ENERGY PROPERTY

A proposed rule by the IRS was published in the Federal Register of September 19, 1980. Comments were requested (Ref. 1).

A strong case was made in commenting on the proposed rule - that a geothermal resource needed a wellhead temperature in excess of 50°C; instead, a recommendation of 18°C at depth was proposed. It was also suggested that a "peaking plant" should be used in conjunction with the geothermal installation in order to obtain investment tax credit.

REFERENCE

1. "Comments and Request for Public Hearing on Investment Credit for Energy Property," JHU/APL Lett. CQO-2962, 17 Nov 1980.

INSTITUTIONAL PROBLEMS FOR SMALL-SCALE HYDROELECTRIC POWER DEVELOPMENT

Since August 1977, APL has been investigating institutional and other constraints on the redevelopment of hydropower at existing small dams in the eastern United States. The problems considered include the technological, environmental, societal, financial, and legal constraints that affect resource development. In July 1978, the Center for Metropolitan Planning and Research (Metro Center) joined the project and concentrated on the areas of marketing, licensing and permitting, taxation, and economic feasibility.

The original study area was New England. Extensive interviews were conducted with public utility commissions, state energy officials, state environmental officials, environmental groups, public utilities, municipal utilities, REA cooperatives, private dam owners, and equipment manufacturers. Initially there was little interest or market for small-scale hydroelectric power. However, more recently, there has been a significant change in attitude as a result of the DOE program, congressional passage of the Public Utility Regulatory Policy Act (PURPA), and the sharp increases in oil prices. In response to these changes, increasing emphasis has been placed on economic and environmental considerations. The project has been concluded, and seven reports have been issued.

1. "Problems in Redevelopment of Old Hydroelectric Power Dams, Interim Report on

New England," JHU/APL QM-77-142 (HE-001), Nov 1977.

2. "Problems in Redevelopment of Old Hydroelectric Power Dams, Second Report on New England," JHU/APL QM-78-013 (HE-002), Feb 1978.
3. "Problems of Hydroelectric Development at Existing Dams, Interim Report on the Middle Atlantic States and the Ohio Valley," JHU/APL QM-78-243 (HE-003), Nov 1978.
4. "Problems of Hydroelectric Development At Existing Dams, An Analysis of Institutional, Economic, and Environmental Restraints in Pennsylvania, New Jersey, and Maryland," JHU/APL QM-79-237 (HE-004, Vol. I), Aug 1979.
5. "Problems of Hydroelectric Development At Existing Dams, An Analysis of Institutional, Economic, and Environmental Restraints in Pennsylvania, New Jersey, and Maryland," JHU/APL QM-79-133 (HE-004, Vol. II), Apr 1979.
6. "Problems of Hydroelectric Development At Existing Dams, An Analysis of Institutional, Economic, and Environmental Restraints in the Southeastern United States," JHU/APL QM-80-165 (HE-005, Vol. I), Sep 1980.
7. "Problems of Hydroelectric Development At Existing Dams, A Detailed Analysis of Institutional, Economic, and Environmental Restraints in North Carolina, South Carolina and Georgia," JHU/APL QM-80-166 (HE-005, Vol. II), Sep 1980.

**GEOHERMAL ENERGY DEVELOPMENT PLANNING § 23
AND TECHNICAL ASSISTANCE
OPERATIONAL RESEARCH, HYDROELECTRIC POWER
DEVELOPMENT**

Development of Geothermal Energy in the Eastern

U. S. ZJ7CQO

Small Scale Hydroelectric ZP3CQO

Support: DOE/DGE, RA

A. M. Stone

July-December 1980

**GEOHERMAL AND LOW-HEAD HYDROELECTRIC DOCUMENTATION,
JULY-DECEMBER 1980**

In order to provide information on all significant papers issued by APL in the second half of CY 80 on various aspects of geothermal energy and small-scale hydroelectric power, the following lists of reports, papers, and letters are submitted. Previous listings are referenced below.

REFERENCES

1. Section 21, Quarterly Report, Oct-Dec 1979, JHU/APL EQR/79-4.
2. Section 29, Quarterly Report, Apr-Jun 1980, JHU/APL EQR/80/2.

FORMAL REPORTS AND INTERNAL MEMORANDA

Report No.	Date	Title	Author
QM-80-111	8 Jul	Comments on Guidebook to Groundwater Heat Pumps (May 1980) Energy Program NCSL	R. von Briesen
QM-80-113	10 Jul	Groundwater Hydrological Data Available from the National Water Well Association, 500 West Wilson Bridge Road, Worthington, Ohio 43085	R. von Briesen
QM-80-118	23 Jul	Report on Participation in the 26th International Geological Congress, July 7-17, 1980	J. E. Tillman
QM-80-119	30 Jul	Einstein Refrigerator Performance	J. W. Follin, Jr.
QM-80-123	6 Aug	Mutual Interference Effects in a Production Doublet	K. Yu
QM-80-125	7 Aug	A Program for Capital Recovery Assessment for the HP-96 and Other Desk Calculators	K. Yu and R. von Briesen
QM-80-130	15 Aug	Groundwater Hydrologic Descriptions and Maps	R. von Briesen
QM-80-131	Dec	The Demand Specified Model for Direct Applications of Geothermal Energy, A User's Guide	P. Kroil and W. Barron
QM-80-132	22 Aug	Discussion with Oak Ridge National Laboratory	F. C. Paddison
QM-80-134	Oct	Papers Presented - Geothermal Resources Council 1980 Annual Meeting	-
QM-80-139	Sep	Deciphering Cenozoic Faulting Histories of Intraplate Regions (An Unsolicited Proposal to the U.S. Nuclear Regulatory Commission Office of Nuclear Regulatory Research)	J. E. Tillman
QM-80-142	9 Sep	Static Dipole Field	K. Yu
QM-80-143	10 Sep	Geothermal Energy Workshop in Virginia	J. E. Tillman
QM-80-147	16 Sep	Geothermal Technical Assistance Available at The Johns Hopkins University	F. C. Paddison
QM-80-154	1 Oct	Structural Evolution of the Sanandaj-Sirjan Ranges Near Esfahan, Iran	J. E. Tillman, A. Poosti, S. Rossello, and A. Eckert
QM-80-156	2 Oct	Meeting of the Special Joint Committee on Energy of the General Assembly of Maryland, Annapolis, Sep 30, 1980	C. S. Leffel, Jr.
QM-80-157	10 Oct	Fracture Systems of the Northern Appalachian Basin	J. E. Tillman and H. L. Barnes
QM-80-158	6 Oct	McGuire Air Force Base (Technical Assistance) Preliminary Visit	R. von Briesen

Report No.	Date	Title	Author
QM-80-161	9 Oct	Bibliography of Documents by The Johns Hopkins University Applied Physics Laboratory Relating to Geothermal Space Heating	F. C. Paddison
QM-80-164	14 Oct	Status of Geothermal Development in the Eastern U.S.	F. C. Paddison
QM-80-165	Oct	Problems of Hydroelectric Development at Existing Dams - An Analysis of Institutional, Economic, and Environmental Restraints in the Southeastern United States	W. B. Chapman, J. W. Follin, Jr., C. S. Leffel, Jr., I. R. Thrall, and R. von Briesen
QM-80-169	28 Oct	DoD Differential Escalation Rates of Fossil Fuel	F. C. Paddison
QM-80-170	28 Oct	Technical Program Statement - Analysis of Market Size for Water Source Heat Pump	F. C. Paddison
QM-80-171	12 Nov	Geothermal Energy in Maryland	R. von Briesen, F. C. Paddison, and C. S. Leffel, Jr.
QM-80-175	10 Nov	Seismological Society Meeting	J. E. Tillman
QM-80-179	14 Nov	Water Wells at McGuire AFB, NJ	R. von Briesen
QM-80-181	21 Nov	Use of Geothermal Energy in the Eastern United States	F. C. Paddison, and K. Yu
QM-80-182	21 Nov	Geothermal Energy - An Overview Attendance at the ASTM Meeting on Geothermal Resources and Energy, Reno, Nevada, Nov. 18 and 19, 1980	A. M. Stone C. S. Leffel, Jr.
QM-80-190	Dec	Geothermal Space Heating at McGuire Air Force Base, New Jersey	F. K. Hill and R. von Briesen

LETTERS

Letters	Date	Title	Author
CQO-2910	18 Jul	Geothermal Progress Monitor, Report No. 4	F. C. Paddison and R. F. Meier
CQO-2918	31 Jul	Geothermal Space Heating of Pittsville Elementary School	R. von Briesen and F. C. Paddison
CQO-2920	4 Aug	Geothermal Energy in Maryland	F. C. Paddison
CQO-2924	25 Aug	Comments on Earl Warren Legal Institute Proposal	A. M. Stone
CQO-2925	26 Aug	Suggestions Relating to National Conference of State Legislatures - Pamphlet on Heat Pumps	F. C. Paddison and C. S. Leffel, Jr.
CQO-2937	17 Sep	Review of the Draft Version of National Hydroelectric Power Resources Study, Regional Report. Vol. XVI	C. S. Leffel, Jr. and J. W. Follin, Jr.
CQO-2944	9 Oct	Additional Correspondence with Hungary	F. C. Paddison
CQO-2959	29 Oct	Comments on Selected Issues for Future Virginia Geothermal Legislative Workshops	F. C. Paddison
CQO-2962	17 Nov	Comments and Request for Public Hearing on Investment Credit for Energy Property	A. M. Stone
CQO-2969	9 Dec	Data Accumulation, Analysis, and Storage at Cape Henlopen and Other Eastern Geothermal Resource-Confirmation-and-Utilization Sites	A. M. Stone
CQO-2972	10 Dec	Kings Bay, Georgia, Trident Submarine Support Base and Geothermal Energy	F. C. Paddison and A. M. Stone
CQO-2973	10 Dec	Suggested Items for 5th Geothermal Progress Monitor	R. F. Meier
CQO-2974	12 Dec	Information for Geothermal Study Proposal	R. von Briesen and F. C. Paddison

JOURNAL ARTICLES

Title	Journal	Author
Geothermal Energy - An Overview	JHU/APL Tech. Dig., Vol. 1, No. 2, pp. 78-87, Apr-Jun 1980	A. M. Stone
Use of Geothermal Energy in the Eastern United States	JHU/APL Tech. Dig., Vol. 1, No. 2, pp. 88-100, Apr-Jun 1980	F. C. Paddison and K. Yu
Eastern Geothermal Resources: Should We Pursue Them?	Science, Vol. 210, pp. 595-600, 7 Nov 1980	J. E. Tillman

GEOLOGIC STRUCTURE OF THE DANBURY QUADRANGLE

In the APL part of the New England Seismotectonic Investigation, centered at the Weston Observatory of Boston College and funded by the Site Safety Research Branch of the Nuclear Regulatory Commission, field effort has concentrated on the geology of the Danbury Quadrangle.

During this quarter, detailed field maps were made of the southern half of the Danbury Quadrangle - in and around the city of Danbury. This area lies at the northeastern end of the Manhattan Prong where stratigraphy and metamorphic structure change orientation from northeast striking to the southwest, to north-south striking to the north. The major faults of the Manhattan Prong also project into this region of more ductile tectonics. This is the only area in the Prong where stratigraphy and structure are at disparate enough angles that magnitudes of offset should be definable.

During October, several weeks were spent in the field defining mappable stratigraphic units. Correlations of rock types used on the existing geologic maps were found to contain a number of both lithologic and structural disparities. New stratigraphic divisions that proved to be mappable units were developed. The stratigraphic relations in the region are complicated by a number of pre-, syn-, and post-metamorphic thrusts that are in part infolded with the tight folding in the area.

A major stratigraphic finding was that two distinctly different but previously nondifferentiated marble units occur in the region. The first is dominated by dolomitic marble, the second by brown weathering calcitic marble. Another finding was the widespread occurrence of a mappable unit that contains massive granulites

and thick bedded feldspathic granulites with sillimanite nodules. A third significant stratigraphic finding was the extension of the outcrop pattern of Precambrian basement farther southeast than previously known. This stratigraphic extension in the nose of a southeastward striking fold parallels another remapped area to the north of Danbury. These two structures strike across a major northeast trending lineament (Refs. 1 and 2), which coincides with a brittle fault in the Manhattan Prong. Stratigraphic mapping suggests that 3 km of dextral offset and several kilometers of reverse faulting (down on the east) must have occurred along this zone after the original period of folding. Several smaller faults that affect the map pattern have also been identified.

Future plans call for determining the exact nature of the offsets in the Danbury Quadrangle, determining the sequence of faulting events, and establishing their respective ages. Once this quadrangle is complete, a fault trace map for the entire region of southeastern New York and western Connecticut will be compiled based on experience on both borders to the Manhattan Prong.

REFERENCES

1. P. J. Barosh, "Interpretation of Aeromagnetic Data in Southwest Connecticut and Evidence for Faulting along the Northern Fall Line," Proc. 2nd Int. Conf. on Basement Tectonics, 1979.
2. J. E. Tillman, "Brittle Deformation of the Manhattan Prong," JHU/APL QM-80-104, 1980.

THE UNITED STATES OF AMERICA
DO hereby certify that
[Name] is a citizen of the United States of America
and is entitled to the rights and privileges of citizenship
under the Constitution and laws of the United States.

IN WITNESS WHEREOF, I have hereunto set my hand and the seal of the United States of America
this [Date] day of [Month], 19[Year].

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DEVELOPMENT OF SEISMOTECTONIC DOMAINS

The Panel on "Earthquake Problems Related to the Siting of Critical Facilities" of the Committee on Seismology in the National Research Council's Assembly of Mathematical and Physical Sciences has recently released a report (Ref. 1). This report emphasizes that an understanding of the seismicity in intraplate regions such as the eastern United States will require significantly greater geologic efforts than the plate boundaries in the West and will almost certainly involve new and innovative techniques. In recognizing this fact, APL has been developing a new method for assessing earthquake occurrence in intraplate regions.

DISCUSSION

There is generally a low level of seismicity in the eastern United States, but the rare large events that do occur are severely damaging. Therefore, a means for predicting where the large shocks may occur is needed. In order to define the seismic provinces, an analysis of the historical seismic record has been performed. However, this record is far too short to be used as the only source. Since seismicity occurs on faults, the mapping of geologic features can be useful in developing more appropriate seismotectonic provinces. This method has been applied in the West; however, the surficial geology that is well known in the eastern states is very old,

and any correlation between the young seismic record and the Paleozoic (400 million years ago) geologic record is tenuous at best.

The geologic work being conducted at APL uses geochemical and structural techniques to decipher the details of the geologic history that occurred in the East between the Paleozoic and the present. These methods have been applied successfully to upstate New York (Ref. 2); it is planned to evaluate the entire Northeast with the same procedure. The results of these tasks will reveal the variation and magnitudes of the crustal dynamics over a 400 million year range. We will also be able to delineate major zones of crustal weakness, which can be monitored further to predict future earthquakes.

The approach and the results were the topics of a recent presentation by J. E. Tillman at a seminar at the Pennsylvania State University and at the annual meeting of the Seismological Society of America (Ref. 3).

REFERENCES

1. "Earthquake Research for the Safer Siting of Critical Facilities," National Academy of Sciences, Washington, D.C., 1980.
2. J. E. Tillman and H. L. Barnes, "Hydrothermal and Uplift Histories of the Northern Appalachian Basin," *Am. Assoc. Petrol. Geol. Bull.*, Vol. 63, No. 9, p. 1589, 1979.
3. J. E. Tillman, H. L. Barnes, and J. A. Fischer, "On Extending the Historical Record," Annual Meeting of the Eastern Section of the Seismological Society of America, Penn. State Univ., 1980.

THE UNITED STATES OF AMERICA
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
WASHINGTON, D. C. 20250

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ENERGY CONVERSION AND STORAGE TECHNIQUES

Cooling with Modest Geothermal or Solar

\$ 26

Temperatures X8DCQO

Support: Task X/N00024-78-C-5384

J. W. Follin, Jr., P. P. Pandolfini, and K. Yu

October-December 1980

EVALUATING THE EINSTEIN REFRIGERATOR

Geothermal resources in the eastern United States in the form of hydrothermal water from deep sedimentary basins and the coastal plain can provide useful energy for space heating and for some industrial processes, such as scalding chickens and seafood on the eastern shore of Maryland, Virginia, and Delaware. It can also be used as clean-up water in many food processing plants and is competitive with other fuels in commercial and residential space heating. However, the Atlantic and Gulf Coastal Plains require space heating for only part of the year; by contrast, cooling is required over the larger portion of the year. Therefore, the duty cycle for geothermal energy applications in space conditioning is small unless it can also be used as an energy source for air conditioning. No useful cooling cycle has been developed that can use temperatures as low as 150°F as an energy source; Einstein's invention (Ref. 1) has been ignored since it cannot use high (180-250°F) temperatures efficiently. However, the low eastern geothermal water temperatures can be used, which at least double the duty cycle of a geothermal well and hence reduce the major capital cost of geothermal heating and cooling by a factor of two.

DISCUSSION

The last Energy Quarterly (Ref. 2) described the Einstein-Szilard three-fluid, isobaric refrigerator with its potential to provide cooling from low temperature energy sources. During this reporting period, a computer simulation of the thermodynamics of

the cooling cycle, including the heat exchangers (which are especially important where small temperature differences are involved) has been completed and a "map" of the performance to be expected has been generated.

An analysis of heat exchanger types leads to the selection of a thin film heat exchanger on the $\text{NH}_3/\text{H}_2\text{O}$ side so that the NH_3 can readily diffuse through the film from a gas in the generator and be absorbed in the condenser. Since NH_3 carries the latent heat, diffuses rapidly, and is deposited uniformly in the film, the effective heat conduction distance is half of the film thickness, leading to an increased heat transfer rate. Because the high latent heat of vaporization of NH_3 must be balanced by the specific heat flux of the geothermal or cooling

water, the water side of the heat exchanger must be more than ten times as thick as the film. A water-filled channel with appropriate velocity is used on the other side. The best choice for packaging is a flat plate unit with a tilt of 20° from the horizontal, but the best structural choice for containing the internal pressures is a vertical arrangement of circular tubes surrounded by heat-exchanger water and supporting thin films on their inner surfaces.

For a 3-ton home air conditioner, the exchanger area must be 20 ft² for a temperature drop of 10°F between the geothermal water and the working fluid. Corresponding areas are needed for the cooling water in the condenser. The cooling efficiency, in terms of cooling Btu's as a function of geothermal and cooling water temperatures (in Ref. 2 only internal temperatures were used), is given in Table 1 for several cases. The efficiency is far below (~10%) the ideal Carnot cycle efficiency, but is far better than any other cycle known to the authors. The best competitor is a water-referenced heat pump using the cooling water source as a heat sink. The original design is actually a water-referenced butane heat pump cycle using a thermally driven NH_3 generator instead of an electric motor to pump the cooling cycle. In addition, this original design is an open-loop device with no feedback from the cooling cycle load to the input heat source and to the liquid and gas circulation in the refrigerator.

Table 1
Performance (in Btu/min) of Einstein refrigerator.

Geothermal water temperature		145°F	140°F	135°F
40 ft ² heat exchanger	Heat absorbed from hot water	1464	1256	1047
	Cooling power at 50°F	313	266	222
20 ft ² heat exchanger	Heat absorbed	1256	1047	840
	Cooling power at 50°F	238	197	150

Cooling water temperature 75°F.
Five gal/min geothermal water flow.

For adequate control of ammonia-water film thickness in the heat exchanger, a settling reservoir is needed at the top of the plates with variable speed pump control. The control logic requires measurements of the liquid level in the sumps and temperature measurements at the input and output of the generator condensor and evaporator. This will suffice to control the refrigerator under different source load conditions.

FUTURE PLANS

This initial quantitative analysis carried out under IR&D funds (Ref. 3) is considered

most encouraging and has many applications in addition to modest temperature, hydrothermally driven cooling. It will be suggested to DOE that a proof-of-principle demonstration be engineered, constructed, and demonstrated.

REFERENCES

1. J. W. Follin, Jr., "Einstein Refrigerator Performance," JHU/APL QM-80-119, 30 Jul 1980.
2. Section 23, Quarterly Report, Jul-Sep 1980, JHU/APL EQR/80-3.
3. A. M. Stone, "Request for Task Z IR&D Funds - Einstein Refrigerator," JHU/APL memo, 4 Aug 1980.

ENERGY CONVERSION AND STORAGE TECHNIQUES

Low-Cost Advanced Flywheel Technology F9QSDO

Support: DOE/STOR

\$27

D. W. Rabenhorst

October-December 1980

FLYWHEEL TECHNOLOGY DEVELOPMENT AT APL

The Flywheel Technology Program began on 21 March 1980 and is scheduled to end on 31 December 1980. This report summarizes APL's flywheel technology efforts in three separate areas during this period. The first area covers a rather extensive design study for an expansion of the APL flywheel spin test facility to accommodate burst testing of flywheels up to a capacity of 50 kWh. The second area covers the preliminary development of flywheels made from metallic glass ribbon. The third area concerns the spin testing of a variety of flywheels provided by the Lawrence Livermore Laboratory (LLL) and fabricated outside APL.

The conceptual design of the new flywheel spin test facility is complete; the preparation of construction details, including cost and schedule items, is proceeding on schedule. The metallic glass flywheel spin tests indicated that it will be quite competitive in terms of energy per unit weight, energy per unit cost, and (especially) energy per unit volume. The outside flywheel spin test program includes seven spin tests involving six different flywheel configurations. All were eventually spin tested to destruction, with complete video coverage.

BACKGROUND

This work was conducted under a single subcontract from LLL and is divided into three sections: Flywheel Spin Test Facility, Metglas Development, and Flywheel Spin Testing. Although the work was initiated in the 1980 fiscal year, it is substantially complete. Positive results were obtained in all three sections of the program, and recommendations are made for the continuation of the work in each section. In view of the diversity of technology in the three sections, they are reported in the following paragraphs as though each is a separate program.

SECTION I. FLYWHEEL SPIN TEST FACILITY

As directed by LLL, the facility improvement design effort is divided into two distinct areas. The first involves the detail design, cost estimates, and projected schedule for improvements to the existing APL facility, which would enable the spin testing of flywheels up to a capacity of 50 kWh. While a new spin pit will be necessary, a substantial portion of the existing instrumentation, controls, video recording, and operating equipment would be used. Also, an important factor in this improvement program is the existence of engine-driven compressors, which would be used to drive the air turbines.

The second requirement stipulated by LLL is that an additional spin test facility be designed that would accommodate flywheels up to a

capacity of 5 kWh to be located within the 50 kWh facility to permit utilizing the essential elements of the drive train, the vacuum container, and the vacuum equipment, as well as the instrumentation and controls of the larger facility, for the 5 kWh flywheel testing. The final design shows that significant savings would result from the combined 5 kWh/50 kWh spin test facility, with relatively few compromises in either case.

A substantial portion of the flywheel test facility effort involves a hardware feasibility demonstration of high speed television equipment, which would be used in the large flywheel test facility.

The general characteristics of the 5 kWh flywheel test facility are shown in Table 1. The performance characteristics represent the respective maximum conditions that would exist over a broad range of flywheel performance conditions and a variety of flywheel configurations. The high rotational speed reflects the characteristics of a high performance flywheel with an energy density of the order of 37 Wh/lb and reflects a flywheel configuration having the highest intrinsic rotational speed for this energy density. This would be typical of the tapered solid disc flywheel which, at an energy density of 37 Wh/lb and a maximum diameter of 32 in., could have a burst speed as high as 60,000 rpm. The high rotating mass of 1500 lb represents the load capability of the turbine selected and is well in excess of the maximum flywheel weight expected to be encountered.

Table 1

5 kWh spin test facility characteristics.

Performance Limits			
Air Turbine	Maximum rpm	Maximum weight (lb)	Nominal horsepower
8 in. with 2:1 increaser	60,000	200	20 to 30
14 in. with 2:1 increaser	36,000	200	60 to 70
8 in. without increaser	30,000	1500	20 to 30

The basic turbine for the 5 kWh facility is the 8 in. Barbour Stockwell model with a nominal rating of 1500 lb rotating mass at rotational speeds up to 30,000 rpm. A 2:1 speed increaser raises the maximum rotational speed to 60,000 rpm but at the reduced rotating mass of 200 lb, which is consistent with the energy density at this rotational speed at 5 kWh total energy. For example, a 5 kWh flywheel having an energy density of 37 Wh/lb will weigh 185 lb.

Although the 8 in. turbine with a 2:1 speed increaser provides an adequate rotational speed range, it does not have sufficient horsepower to cover the life-cycle requirements specified for the 5 kWh test facility. For this reason, a 14 in. Barbour Stockwell air turbine is provided, which is also capable of being used with the same 2:1 speed increaser. The arrangement provides an average of 60 to 70 hp at rotational

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speeds up to 36,000 rpm, which is consistent with the life-cycle requirements expected to be encountered.

The principal characteristics of the 50 kWh flywheel spin test facility are shown in Table 2. The air turbines for this facility are the same as those specified for the 5 kWh facility. However, they are used without the speed increaser to permit maximum rotational weight capability. The 50 kWh flywheel would ordinarily require approximately 400 hp to give comparable life-cycle testing times that the 50 hp turbine would provide for the 5 kWh facility. However, the sponsor recommended that, initially, the 50 hp air turbine be used in the large test facility in order to minimize the time and funding required to make this facility initially available.

Table 2

50 kWh spin test facility characteristics, maximum diameter = 65 in.; maximum axial length = 62 in.

Performance Limits			
Air turbine (in.)	Maximum rpm	Maximum weight (lb)	Nominal horsepower
8	30,000	1500	20 to 30
14	18,000	4000	60 to 70
14 [†]	10,000	5000*	50 to 60 [†]

* Projected value

[†] Temporary limits; horsepower would eventually reach approximately 400.

A somewhat lesser compromise was made in limiting the maximum flywheel diameter to 65 in., although it is conceivable that some stationary flywheel applications could have, as a design parameter, the minimization of flywheel rotational speed, which could result in larger flywheel diameters. However, the proposed facility design covers the most likely flywheel materials, configurations, performance levels, and maximum sizes expected to be encountered in the foreseeable future.

The proposed facility can accommodate the lower cost stationary flywheels as well as the higher performance vehicular flywheels. Included is the capability on the low end of the performance spectrum for flywheels weighing as much as 5000 lb at the lower rotational speed range to flywheels weighing as much as 1500 lb at the rotational speed range of 30,000 rpm.

The proposed APL spin test facility is shown in Fig. 1. In this three-level facility, the complete spin chamber is located below ground with adequate head room allowed for the installation and removal of flywheels and containment rings. The lower level facilitates access at the bottom of the spin chamber for the installation and checkout of optical systems, as well as instrumentation and controls. Obviously, this access is also provided at the top end of the spin chamber.

As indicated in Fig. 1, the engine-driven compressors, which provide the air at 90 to 120 psi to drive the turbines, are located immediately adjacent to the facility. These existing compressors permit the use of the air turbines in lieu of the more expensive electric drive systems and eliminate the additional expense of providing electrical load banks for braking operations. The air turbines have reverse buckets for braking, thus eliminating the need for a separate braking system.

Fig. 1 Artist's concept of the APL proposed flywheel spin test facility. (80-4/37)

The control and instrumentation console is located in the building adjacent to the proposed facility. It consists mostly of existing equipment, which minimizes the cost of the facility.

High speed television equipment developed by the Video Logic Corporation of Sunnyvale, Calif., has demonstrated the feasibility of multiplexing two or more high speed television cameras in a digitally synchronized format at a time interval between respective TV cameras equivalent to that required for a frame rate of 720 frames/s. The picture display from this equipment is a newly developed, wide-screen, high-fidelity format, and the system has an instant replay capability in either variable slow motion or still frame. The equipment can produce hard copy pictures immediately, which are printed directly from the video tape.

The high speed TV demonstration program involves the use of a two-camera system to demonstrate the foregoing capability. However, a considerable amount of work remains before a complete 960 frames/s television system can be put into operation. The TV system may eventually consist of four multiplexed TV cameras operating in conjunction with a video recorder having a 10 MHz bandwidth. All principal elements of the system exist at the present time.

According to the present schedule, a detailed installation design, as well as a cost and implementation plan, will be completed by the end of the current calendar year.

SECTION II. METGLAS FLYWHEEL DEVELOPMENT

The present METGLAS (trademark of Allied Chemical Co., Morristown, N.J.) flywheel program involves the scale-model testing as well as full-scale testing of flywheels to a capacity of 200 Wh. It also includes the complete definition of a METGLAS ribbon flywheel having a 1 kWh capability. The 50 Wh subscale development program was successfully completed, leading to the satisfactory design for the full-scale 200 Wh flywheel. The typical flywheel in the series consisted of several hundred turns of METGLAS ribbon wound on a four-spoked intermediate aluminum hub and bonded only at the hub radial locations. Termination of the outer edge of the flywheel was achieved by bonding the complete final revolution to its substrate layer. The typical construction of the METGLAS amorphous metal ribbon flywheel is shown in Fig. 2.

The results of the METGLAS ribbon flywheel program have been quite encouraging. However, a considerable amount of work must be done before flywheels of this configuration can be considered acceptable for commercial applications. The current program demonstrated that METGLAS flywheels can have an apparent usable energy density in excess of 12 Wh/lb and 4500 Wh/ft³. Studies also indicated that METGLAS ribbon flywheels in a quasi-isotropic disc configuration may have twice the capacity. However, the present program does not include provision for long term testing to demonstrate the material under static fatigue and cyclic fatigue conditions. On the other hand, the encouraging results of the program appear to warrant support for follow-on programs. The current studies have shown that future METGLAS amorphous metal ribbon flywheels might have usable energy densities in the range of 20 to 30 Wh/lb with usable energy per unit volume of about 10,000 Wh/ft³. These studies also indicated that, if the METGLAS ribbon can be produced for \$1 to \$2 per pound

Fig. 2 APL experimental METGLAS ribbon flywheel. (80-4/38)

(as predicted), it can be reasonably expected that the resulting METGLAS ribbon flywheels can be made for less than \$100 per kWh.

SECTION III. FLYWHEEL TESTING

The APL/LLL contract provides for the spin testing of approximately ten flywheels fabricated by other agencies. APL has conducted seven such spin tests involving six flywheels received from LLL. The typical program for the spin testing of each flywheel received is as follows. First, upon receipt at APL, the flywheel is carefully measured and weighed and its polar moment of inertia calculated. A preliminary spin test is then conducted using a dummy aluminum flywheel having approximately the same mass as the test flywheel. The dummy flywheel is spun over the entire rotational speed range expected to be encountered with the test flywheel, and notations are made of any system vibrational perturbations that are encountered. These include the various critical speeds of the system as well as an occasional minor vibration from causes other than critical speeds.

The second pretest is conducted with a second dummy flywheel that is specifically designed to have a polar moment of inertia approximately the same as that of the test flywheel. This flywheel is then spin tested to a rotational speed up to at least the second critical speed of the system to demonstrate that the first and second critical speeds, as well as any other perturbations encountered during the spin test, will not be damaging during the eventual test of the designated flywheel. The locations in the rotational speed range of the various types of disturbances vary from test to test depending upon the mass and moment of inertia of the flywheel being tested.

Each flywheel spin test includes a continuous video recording with phase-locked strobe lighting, so that the flywheel appears to be motionless on any given picture. Figure 3 illustrates a typical TV picture taken at a frame

Table 3
Summary of flywheel testing through December 1980.

APL/LLL Subcontract No. 7825504					
Test No.	Date	Test designation	Other designation	Type of flywheel	rpm reached
1	Prior to Contract	LLL 80-2SR	APL sketch	rpm simulator	51,000
2	2 Jul 80	LLL 80-2SI	APL sketch	Inertia simulator	8,000
3	1 Aug 80	LLL 80-2SI-2	APL sketch	Inertia simulator	9,200
4	22 Aug 80	LLL 80-2	- -	Plain fiber-glass disc	49,050
5	3 Sep 80	LLL 80-2-2	- -	Plain fiber-glass disc	49,320
6	16 Sep 80	LLL 80-3SI	APL sketch	Inertia simulator	8,300
7	18 Sep 80	LLL 80-3	GE Des. 3 No. 20	Ring and α ply	46,000
8	3 Oct 80	LLL 80-4	GE Des. 3 No. 23	Ring and α ply	46,060
9	15 Oct 80	LLL 80-5SI	APL sketch	Inertia simulator	9,000
10	15 Oct 80	LLL 80-5	LLLNL TT-1	Tapered fiber-glass disc	25,690
11	11 Nov 80	LLL 80-6	LLLNL TT-2	Tapered carbon fiber/epoxy	34,940
12	10 Dec 80	LLL 80-7SI	APL sketch	Brobeck dynamic simulator	9,000
13	11 Dec 80	LLL 80-7	Brobeck S/N ²	Wound rings tension spokes	48,120

Fig. 3 Sample of high speed TV picture. (80-4/39)

rate of 240 full pictures per second. In this picture, it can be seen that a peripheral crack has developed in the outer windings of the flywheel, and this crack has proceeded nearly all the way around the flywheel. In this particular instance, the digital code of each television picture enabled the exact correlation of the crack initiation with a sudden increase in the vacuum pressure decay and corresponding axial vibration. Subsequent pictures, together with an examination of the flywheel debris, indicated that the bond between the aluminum hub and the fiberglass flywheel disc failed in shear, probably caused by the delaminated outer ring.

Table 3 is a summary of all the flywheel tests in the current program, which began 21 March 1980.

ENERGY CONVERSION AND STORAGE TECHNIQUES

Applications at APL

§ 28

Support: JHU Funding

A. C. Stucki

October-December 1980

APL ENERGY CONSERVATION EFFORTS, 1980

The first full year of operation of a second high temperature (160°F output) heat pump ended in October 1980. This pump gathers waste heat from the cooling tower that serves buildings 1, 2, 6, 13, and 14 at APL and uses it for heating buildings 13 and 14.

This 2,000,000 Btu/h (nominal) heat pump was the major component responsible for the reduction of fuel oil consumption for the 1979-80 season to 88,296 gallons. This is an 83% reduction from the oil used at APL for heating during the 1972-73 heating season. Also, the consumption of electricity has been reduced by 13.5% during the same period while total building space has increased by 15.2% (Fig. 1). On a square-foot basis, the reductions are 85.3% for oil and 24.9% for electricity. Savings of approximately \$789,000 yearly are currently being made.

During 1980, the control systems were modified for the dual-duct air-conditioning in buildings 4, 6, 7, and 8 to minimize the use of warm air in the ducts. In cold weather, cold air is only available when core areas exceed 78°F; warm air is only available when perimeter areas fall to 68°F. In addition to saving energy, this feature allows the natural heat gain from such items as lighting and people in the core areas to warm the building to more comfortable conditions than would be attainable by adherence to the DOE's 65°F wintertime requirements.

Fig. 1 APL energy consumption. (80-4/40)

An alternate electric heat source was provided to supply requirements other than for space heating in buildings 1, 2, 3, 5, and 6. These changes allowed the oil burning steam plant located in building 1 to be completely shut down during the warmer months, eliminating the inefficiencies inherent in operating such a large plant for a few minor loads (such as cafeteria dishwashing).

We are continuing to upgrade building insulation during refurbishing projects and are continuing to install reduced-wattage fluorescent lighting and ballasts during remodeling projects.

FOR THE OFFICE OF THE ATTORNEY GENERAL
RE: [illegible]
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UNITED STATES DEPARTMENT OF JUSTICE
OFFICE OF THE ATTORNEY GENERAL

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SAFETY ASPECTS OF LIQUEFIED NATURAL GAS IN THE MARINE ENVIRONMENT

A Panel on Liquefied Natural Gas Safety Evaluation was appointed by the Committee on Maritime Hazardous Materials of the National Research Council. The panel, chaired by W. G. Berl of APL, had among its members a number of scientists well known in the field of fire safety.

The report contains an introduction and an executive summary, consisting mainly of conclusions and recommendations, followed by eight chapters giving detailed up-to-date assessments of the following: safety aspects of LNG ship design and operations; collision hazards for LNG carriers; vaporizing and dispersion of LNG following a spill on land or water; flameless vapor explosions; ignition of LNG; thermal radiation from LNG fires; cloud explosion and blast effects; and LNG risk assessment.

There are three appendixes and a bibliography. Two of the appendixes are very substantial and indeed occupy more than half the total volume; they deal with the background on LNG safety research and a critical review of the literature dealing with LNG vaporization and dispersion after spills on land and water.

In spite of a relatively clean record thus far in the transport of LNG, the potential for a catastrophe while transporting this and similar materials in inshore waters of the United States is such as to require an improvement in both present knowledge and practices. The panel therefore makes recommendations with this aim in mind. More stringent regulations are recommended for LNG ships in the areas of navigation, steering, ship control, the supervision of traffic control and berthing in inshore areas, and improved crew training. Scenarios are based on the rapid release of 25,000 m³ of LNG. It is stated that the sea, bay, and harbor lanes and channels to be used by LNG ships should be selected to maximize the distance between the ships and centers of

population. There is no direct indication of what might be a tolerable distance. However, such distance is implied in a further recommendation that, should a catastrophe become imminent, efforts should be made to define conditions that would warrant deliberate ignition of a vapor cloud far enough from populated areas to minimize damage from blast or radiation. A vigorous research program should be pursued on the design principles of such a secondary line of defense.

Where there is a substantial danger that a collision might occur, maximum speeds are recommended that are substantially lower than the 8 knots suggested elsewhere. Recommendations are made for research into the boiling and dispersion of spills and the dynamics and heat transfer associated with open fires and explosions that could result from major spillages of LNG. The panel states that flameless explosions associated with the mixing of water and LNG are an insignificant hazard relative to fire and combustion-supported explosions. There was no comment on the extent to which the penetration of water into an LNG tank could produce over-pressure resulting in much further tank damage caused by rapid vaporization rather than a flameless explosion. However, the panel does recommend research on the extent to which flameless explosions might take place within enclosed spaces in a ship in close proximity to the LNG tankage. These matters are important since they are factors that would cause the sudden release of the bulk, if not all, of the contents of an LNG tank following a collision, which would give substance to the scenario on which the panel's recommendations are based. The normal experience of oil tanker collisions is that the contents of a tank are released over a long period.

Recommendations are also made for improving the reliability of quantitative risk analysis.

**ENERGY RESEARCH INSTITUTE AT THE
JOHNS HOPKINS UNIVERSITY**
Support: JHU Funding
W. G. Berl
November-December 1980

\$30

ENERGY RESEARCH INSTITUTE AT THE JOHNS HOPKINS UNIVERSITY

On November 13, 1979, Provost R. P. Longaker appointed a committee consisting of seven members of The Johns Hopkins University from the Divisions of Arts and Sciences, Engineering, School of Hygiene and Public Health, and the Applied Physics Laboratory to explore the merit of establishing a center to strengthen and, where appropriate, coordinate research in energy-related areas. The committee was also directed to assemble information concerning energy-related research currently being conducted at the University as well as proposals that have been submitted but not yet funded. Further, recommendations were requested concerning the advisability of pursuing additional areas and striving for more

coordination and communication among the various research efforts within the University.

Sixty-two staff members were identified who either had a research grant, had submitted a proposal, or were planning research in this general area. A list of active topics is attached (Table 1). An approximate figure for the annual grant and contract support is approximately 8.7 million dollars (Table 2). The support is concentrated at APL, the Homewood Divisions, and the School of Hygiene and Public Health and applies to the areas of applied science and engineering, basic science, and environment and health, with some interest being shown in the social, economic, and political areas.

Table 1

Energy related research areas, March 1980.

Title	Department*	Source of funds/ annual level (in thousands of dollars)
Environment and Health		
Health effects of low-level radiation in shipyard workers	Hyg	DOE/1475
Biogeochemistry of trace metals in Chesapeake Bay	CBI	DOE/58
The ecology of plankton in the Chesapeake Bay estuary	CBI	DOE/111
Phytoplankton growth, dissipation, and succession in estuarine environment	Hd	DOE/145
Chemical production of excited states in biology	Hd	DOE/62
Environmental impact of proposed electrical power generation facilities	APL	Med. DNR/1648
Chemical and radiation carcinogenesis	Hyg	DOE/420
Predisposing lesions in cancer: nitrates, nitrites	Hd	na
Air and water emissions	Hd	na
Exhaust emissions from a diesel engine	Hyg	EPA/154
Environmental effects of X rays	Hyg	na
Fiber disposition and clearance with respiratory tract	Hyg	NIEHS/62
Biological effects of environmental agents (carbon monoxide)	Hyg	NIEHS/32
Neurobehavioral consequences of simultaneous exposure to environmental agents	Hyg	NIEHS/82
Studies on control of cerebral circulation and metabolism	Hyg	NHLBI/41

* Hd = Homewood (Arts & Sciences and Engineering)
Hyg = Hygiene & Public Health

APL = Applied Physics Laboratory
CBI = Chesapeake Bay Institute
Med = School of Medicine

Table 1
Energy related research areas, March 1980.

Title	Department*	Source of funds/ annual level (in thousands of dollars)
Evaluation of toxicity of combustion products	Hyg	NBS/114
Toxicity of prenatal carbon monoxide exposure	Hyg	NIEHS/82
Cardiovascular adjustments to hypoxic hypoxia and carbon monoxide hypoxia	Hyg	NHLBI/31
Respiratory tract deposition of hygroscopic aerosols	Hyg	NHLBI/111
Molecular basis of mutagenic and lethal effects of UV irradiation	Hyg	na
Mitochondrial calcium and its role in biological calcification	Med	NSF
Energy-coupling processes in mitochondria	Med	NIH
Respiration-coupled transport processes in tumor cells	Med	NIH
Control of enzymatic phosphate transfer in mitochondria	Med	NIH
Phosphate transport processes in animal cells	Med	NSF
Hypolipidemic agents - interaction with liver mitochondria	Med	Md. Heart Assoc.
Three-dimensional structure of proton-translocating adenosine triphosphatases	Med	NIH
Ion transport and energy coupling in bacteria	Med	NIH
<u>Social, Economic, Political, and Policy Areas</u>		
Reduction of electrical energy consumption in master metered buildings	Hd	Term
Location analysis of oil and natural gas facilities in N.J.	Hd	N.J. Dept. Energy/18
Adoption of alternative energy sources. Rate making	Hd	na
Politics and public policy: congress and presidency	Hd	na
Health care costs: Rate making	Hyg	na
Social networks	Hyg	na
Ethical considerations in R&D decisions in industry	Hd	na
<u>Science and Engineering</u>		
Catalysis	Hd	U.S. Army/45
Hot atom and radiation chemistry	Hd	DOE/72
Far infrared chemical lasers	Hd	DOE/74
Control estimation congruence and applications	Hd	ONR/30
Extreme UV and soft X-ray diagnostics of high temperature plasmas	Hd	DOE/396
Theoretical physics	Hd	DOE/56
Nuclear moments and nuclear structure	Hd	DOE/77
Crystal formation in surfactant solutions	Hd	NSF/27
Condensation processes in coal combustion products	Hd	DOE/46
Magnetohydrodynamics	Hd	NSF/15
Location systems analysis of away-from-reactor, spent-fuel storage facilities	Hd	DOE/246

Table 1

Energy related research areas, March 1980.

Title	Department*	Source of funds/ annual level (in thousands of dollars)
Exploration for new hydrocarbon resources	Hd	Pet. Res. Fund/10
Geothermal systems	Hd	NSF/30
Geochemistry; nuclear waste disposal	Hd	na
Geochemistry	Hd	NSF/20
Materials research (5 grants)	Hd	AF/39, Col. Gas/1 NSF/48, APL/9
Materials research	Hd	na
Photovoltaics	Hd	na
Combustion, heat, and mass transfer in fluids	Hd	NSF/106
Alternate energy sources for lighthouses	APL	VSCG/114
Biological fouling processes	Hd	na
Muscle contraction - basic research	Hd	NIH/233
Ocean Thermal Energy Conversion	APL	DOE/556
Polycrystalline silicon solar cells	APL	DOE/203
Semi-conductor-electrolyte photoelectrochemical energy conversion	APL	ONR/30
Organic photovoltaic materials	APL	DOE, SERI/100
Geothermal operations research	APL	DOE/400
Methane generated in landfills	APL	Various/180
Community Annual Storage Energy System	APL	DOE/95
Flywheel energy storage	APL	DOE/232
High energy density batteries	APL	in house
Corrosion in underground natural gas pipelines	APL and Hd, Materials Science Group	Col. Gas Syst. Serv. Corp.
New organic conductors	APL and Hd, Bloch/Corwin	ARPA/NSF c.140
Mechanisms of mutagenesis	Hd	DOE/48
Information storage and retrieval	Hd and Hyg	na
Molecular basis for radiation mutagenesis	Hyg	DOE/25
Molecular basis for mutagenic and lethal effects of UV irradiation	Hyg	DOE/64
Radiation effects on nucleic acids and related compounds	Hyg	DOE/25

* Hd = Homewood (Arts & Sciences and Engineering)

Hyg = Hygiene & Public Health

APL = Applied Physics Laboratory

CBI = Chesapeake Bay Institute

Med = School of Medicine

Table 2

Approximate present research support in energy-related areas
by source of support and area of research
(thousands of dollars per year, 1979-80).

Source of Support	Hygiene	Homewood Divisions	APL	CBI	Totals
DOE	2009	1222	1586	169	4986
NSF	-	246	140	-	386
NIH, etc.	451	233	-	-	684
State agencies	-	18	1648	-	1666
Other	258	327	424	-	1009
Totals	2718	2046	3798	169	8731
Area of Research					
Social, Economic Policy	-	18	-	-	18
Engineering and Technology	-	246	2050	-	2296
Basic Science	89	1575	100	-	1764
Environment and Health	2629	207	1648	169	4653
Totals	2718	2046	3798	169	8731

Note: Figures for the School of Medicine are not available.

Table 3

Members of the Advisory Council for the Energy Research Institute.

Richard Z. Zdanis, Vice Provost

Paul Feldman, Professor, Dept. of Physics

Katherine Lyall, Principal Research Scientist, Center for
Metropolitan Research

Jared Cohon, Associate Professor, Dept. of Geography and Environ-
mental Engineering

Joseph Katz, Professor, Dept. of Chemical Engineering

Gareth M. Green, Professor, Chairman, Dept. of Environmental Health
Sciences

Genevieve Matanoski, Professor, Dept. of Epidemiology

Milton L. Moon, Principal Professional Staff, APL

Walter G. Berl, Principal Professional Staff, APL

Wilfred Kohl, Professor, School of Advanced International Studies

Owen M. Phillips, Professor, Dept. of Earth and Planetary Sciences

The committee considered a variety of possible options concerning an Energy Institute and recommended that an Energy Institute be formed with a director in one division of the University and associate directors who have specific interests in other energy-related areas; the director would be responsible to the Provost of the University. The purpose of the Institute is to offer the services of an information clearing house for faculty and administration and to help in proposal generation and handling. The initial budget of the Institute would be minimal - partial salary support would be provided for the director and associate directors with some secretarial assistance and program support. Faculty

and research staff members of the University would be invited to associate themselves with the Institute by means of secondary appointments while retaining their primary departmental affiliations.

It was also recommended that in the sixth year after its formation, a searching review of the Institute be made by the University Administration to assess the extent to which it has achieved its purpose. If the Institute is found inadequate or marginal in some respects or if it is no longer needed, it would be disbanded.

An Advisory Council to the Energy Research Institute has been appointed, with M. Moon and W. G. Berl as representatives from APL (Table 3).

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<u>Georgia</u>			
State Energy Office	Atlanta, GA	Director	1
Dept. of Natural Resources		Director and State Geologist	1
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<u>Illinois</u>			
Energy Resource Commission	Springfield, IL		1
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