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NEWS of Geothermal Energy Conversion Technology

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U.S. DEPARTMENT OF ENERGY– DIVISION OF GEOTHERMAL ENERGY

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This is the first issue of News of Geothermal Energy Conversion Technology. This publication, which we plan to issue at regular intervals, will disseminate information about all developments in the U.S. Department of Energy's (DOE) Geothermal Energy Conversion Technology program. This first issue provides a summary of current activities and progress. Future issues will discuss individual projects in greater depth.

The Department of Energy's Geothermal Energy Conversion Technology program is under the direction of Clifton B. McFarland, chief, Utilization technology Branch, Division of Geothermal Energy (DGE) with Raymond LaSala as program manager. The Lawrence Berkeley Laboratory portion of this program is led by Robert L. Fulton and William L. Pope under the direction of Kenneth F. Mirk, deputy head, Earth Sciences Division.

At DGE's request, Lawrence Berkeley Laboratory (LBL) has been distributing progress summaries of the program's heat-exchange projects to the program participants and has sponsored an invitational workshop on direct-contact heat exchange, held in September 1978. News of Geothermal Energy Conversion Technology will continue these efforts in information exchange, extending the scope of research topics to reach a wider audience.

DOE GEOTHERMAL ENERGY CONVERSION TECHNOLOGY PROGRAM

The objective of DOE's geothermal energy conversion technology program is to reduce geothermal electric generating cost, particularly for moderate-temperature geothermal resources. These constitute a much larger resource base than is found in high-temperature geothermal areas. Therefore, electrical energy produced from moderate-temperature resources is being emphasized despite the increased expense involved. The greatest potential benefits are identified with binary process conversion systems, toward which the program is strongly directed. Heat exchangers account for 50% to 70% of binary plant costs and also strongly influence the efficiency of binary systems. Several current projects are intended to improve performance and reduce costs of binary heat exchangers. Other efforts under this subprogram include testing the helical screw expander and developing and testing downhole pumps.

Status

Current program activities include field performance testing of 60-, 100-, and 500-kWe binary-process power systems and of a 1-MWe helical screw expander. The binary process systems all include direct-contact heat exchangers. A field test of conventional (shell-and-tube) heat exchangers is being performed in cooperation with the Electric Power Research Institute (EPRI). A pump test rig is being used to evaluate downhole pump designs. Development has begun on a power system that uses a turbine-driven downhole pump and downhole heat exchangers.

EARTH SCIENCES DIVISION
LAWRENCE BERKELEY LABORATORY • UNIVERSITY OF CALIFORNIA, BERKELEY

SUMMARY OF CURRENT PROJECTS

1. Direct-Contact Power System

Organization: Daedalean Associates, Inc.
Principal Investigators: R. S. Weinreich and F. J. Franz
Phone: (301)442-2620
(Project jointly funded by DOE/DGE, Arkansas Power and Light (AP&L), and Great Lakes Chemical Company.)

Objective: To demonstrate the technical and economic viability of electric power generation from low-temperature geothermal brines.

Description: A 100-kWe direct-contact Rankine-cycle power system will be designed, built, and operated by AP&L on geothermal "tail brine" from the Great Lakes Chemical Company's bromine extraction plant in southwestern Arkansas. Following successful test of the 100-kWe unit, a 3 MWe commercial baseload system will be installed and operated at the facility.

Schedule: A six-month test and evaluation period is scheduled for July to December 1979, after which a decision will be made about whether to proceed with the 3-MWe commercial unit. Twenty-four months will be required to design and build the system.

Progress: The 100-kWe power module has been completed and tested. It has just been shipped and set up in Marysville, Arkansas, at a Great Lakes Chemical facility. The six-month on-site test period has been initiated.

References: None to date.

2. Electrical Energy from Moderate-Temperature Resources

Organization: Idaho National Engineering Laboratory
Principal Investigator: J. Whitbeck
Phone: (208) 526-1879; FTS 583-1879.

Objective: To lower the hydrothermal resource temperature that can be used to produce electrical energy economically.

Description: This program consists of both analytical and experimental work. The analytical work involves evaluating advanced binary processes and advanced component performance. The experimental work will verify the analyses and determine actual component performance. Experimental work centers around the prototype power plant system, located at Raft River, Idaho. The system has a generator rating of 60 kWe and a 500-kWe direct-contact system that will be tested at both East Mesa, California, and Raft River, Idaho.

Schedule: The prototype power plant will be operated in an automatic mode in FY 1979. Tests on a high performance condenser being developed at Oak Ridge National Laboratory (ORNL) will start in late summer. A sieve-tray direct-contact heat exchanger is being designed to operate on the prototype. A site for the 500-kWe unit will be completed at Raft River in FY 1979. The unit will be tested in FY 1980.

Progress: During FY 1979, analytical work has been completed on a number of advanced concepts. This work promises performance increases of 20% over present systems. The prototype power plant modification for automated operation will be completed. This system has been used to confirm analytical predictions of the benefits derived from allowing plant capacity to float with ambient conditions. An updated program plan for the Geothermal Energy Conversion Technology Program is being prepared for DOE headquarters. The University of Utah is completing its work on direct-contact condensing and system analysis.

References

Demuth, O. J., 1979. Analysis of binary thermodynamic cycles for a moderatly low temperature geothermal resource. Idaho Falls, EG&G, Report no. TREE-1365.

Kodres, C. A., et al. 1979. Heat transfer to an evaporating, floating, n-pentane lens considering application in the design of geothermal heat exchangers. Prepared for the Joint ASME/AIChE 18th National Heat Transfer Conference, San Diego, August 6-8, 1979, paper no. 79-HT-13.

3. Evaluation of Helical Rotary Screw Expander Power System Utilizing Geothermal Brines

Organization: Jet Propulsion Laboratory
Principal Investigator: R. A. McKay
Phone: (213) 354-9213; FTS 792-9213

Objective: To determine the performance characteristics of the helical-screw-expander power system over a broad range of wellhead conditions and to disseminate the test results to industry for an assessment of its commercial application. The investigation is intended to examine the concept of the total flow wellhead power plant as well as hybrid schemes.

Description: A nominal 1-MW helical-screw-expander power system, including a generator, is being procured from the inventor, Hydrothermal Power Co., Ltd. (HPC), by the Jet Propulsion Laboratory (JPL), which will conduct the evaluation at one or more geothermal sites. The program is divided into three phases: (1) design, fabrication, and site selection, (2) testing at the first site, and (3) testing at three foreign sites.

Schedule: The field evaluation test at Roosevelt Hot Springs, Utah, will be complete by July 1979. The power plant is then scheduled to undergo demonstration testing for approximately six months each in Mexico, Italy, and New Zealand under the auspices of the International Energy Agency and DOE.

Progress: A 50-kWe prototype power system was successfully demonstrated between 1972 and 1975.

JPL and HPC are testing a 1-MWe HPC power plant at the Phillips Petroleum Company flow test facility in the Roosevelt Hot Springs KGRA, Utah. Initial field tests were conducted from March 16 to May 30, 1978. The expander developed a peak efficiency of 48% under nonoptimized conditions. Preparations are under way for an additional month of testing in Utah beginning July 1979.

References

McKay, R. A., and Sprankle, R. S., 1974. Helical rotary screw expander power systems, presented at Conference on Research for the Development of Geothermal Energy Resources. Washington, D.C., National Science Foundation, Report No. NSF-RANN-74-159, pp. 301-309

McKay, R. A., 1977. The helical screw expander evaluation project; presented at 12th Intersociety Energy Conversion Engineering Conference, American Nuclear Society, La Grange Park, Ill., 1977, page 899.

4. Binary Fluid Experiment

Organization: Lawrence Berkeley Laboratory
Principal Investigator: L. F. Silvester
Phone: (415)486-4706; FTS 451-4706

Objective: To provide laboratory-quality experimental data on heat-transfer film coefficients for heating and condensing various hydrocarbon working fluids and to study the effects of working fluid contamination.

Description: The Binary Fluid Experiment (BFE) is a laboratory-scale experiment, designed to determine film coefficients to an accuracy of ± 10%. Special attention is being given to heating and boiling coefficients near each fluid's critical point. Working fluids being studied are iso- and normal butane, pentane, and propane, and various mixtures of these fluids. The effects of water, brine, and lubricating oil contamination will also be measured.

Schedule: Major milestone: the 80 mole % isobutane/20 mole % isopentane mixture tests will be complete in September 1979.

Progress: The experimental apparatus began operating in July 1977. Data taking for isobutane has been completed. Work on an 80/20 mole % mixture of isobutane/isopentane has begun. This includes modifications to the condenser to measure the mixture condensing temperature along the length of the condenser.

References

Tleimat, B. W., Laird, A. D. K., Rie, H., Hsu, I. C., and Seban, R. A., 1979. Hydrocarbon heat transfer coefficients, preliminary iscbutane results. Berkeley, Lawrence Berkeley Laboratory, LBL-8645.

Tleimat, B. W., et al., 1979. Baseline data on film coefficients for heating isobutane inside a tube at 4.14 MPa (600 psia). Prepared for ASME/AIChE 18th National Heat Transfer Conference, San Diego, August 1979. Paper no. 79-HT-14.

5. Direct-Contact Binary Demonstration Program

Organization: Lawrence Berkeley Laboratory
Principal Investigator: R. L. Fulton
Phone: (415)486-4664; FTS 451-4664

Objective: To verify the anticipated advantages of direct-contact heat exchange, when used in geothermal power plants.

Description: The evaluation of direct-contact heat exchange for geothermal power plants involves three activities. (1) Conceptual design studies will delineate the parameters of the optimum processes using direct-contact heat exchange and establish the economics of these optimum processes. (2) Component tests have established the basic performance of small direct-contact heat exchangers in the field. Additional component testing will further establish heat exchanger and auxiliary subsystem performance. (3) A 500-kWe pilot plant will confirm the thermodynamic performance of the direct-contact binary process and provide design information for prototype commercial-size power plants.

Schedule: Operation of a 500-kWe pilot plant will begin at East Mesa, California, in August 1979. A second 500-kWe plant will begin operation at Raft River, Idaho, in May 1980.

Progress: Direct-contact heat exchangers have been successfully operated in the field, and a 500-hour test of a small hydrocarbon turbine and direct-contact heat-exchange loop has been completed. Initial economic studies have shown a capital cost advantage for the direct-contact binary process. The 500-kWe plant is now under construction.

References

Urbanek, M. W., 1978. Development of direct contact heat exchangers for geothermal brines. Berkeley, Lawrence Berkeley Laboratory, LBL-8558.

Barber-Nichols Engineering Co., 1979. Direct contact heat exchanger 10 kW power loop. Berkeley, Lawrence Berkeley Laboratory, LBL-7036, (in preparation).

6. Heat Exchanger Technology

Organization: Lawrence Berkeley Laboratory
Principal Investigator: L. O. Beaulaurier
Phone: (415)486-4704; FTS 451-4704

Objectives: (1) To verify the performance under field conditions, of large-scale shell-and-tube heat exchangers heating and vaporizing hydrocarbon fluids at supercritical conditions with geothermal brine. (2) To establish overall heat-transfer and condensing coefficients, which can be used for design of commercial-scale geothermal power plants using hydrocarbon working fluids. (3) To determine the effects of heat-exchanger cleaning on subsequent heat-exchanger performance. (4) To confirm time rates of accumulation of solid scale and fouling films on tube heat-transfer surfaces.

Description: This project is being conducted in cooperation with EPRI. The test will duplicate the working fluid composition, velocities, pressures, temperatures, and process circuitry which are expected to occur in a commercial-size binary geothermal power plant. Data will be taken from which overall heat transfer coefficients will be developed. Time rates of scale formation will also be obtained, and cleaning procedures will be tested. The tests will be conducted at East Mesa, California, using geothermal fluid supplied by the Magma Power Company.

Schedule: Test will begin August 1979; final report will be complete December 1979.

Progress: Field construction is over 95% complete. Operation of the test loop is scheduled to begin by August 1, 1979. Data gathering is planned for three months.

Reference

Fulton, R. L., 1978. Heat exchanger module test, in Proceedings of the Second Geothermal Conferences and Workshop. Electric Power Research Institute, Report no. EPRI WS-78-79.

7. Thermodynamics Cycle Analysis Code

Organization: Lawrence Berkeley Laboratory
Principal Investigator: W. L. Pope
Phone: (415)486-4663; FTS 451-4663

Objective: To develop, document, and distribute a general, cost-effective thermodynamic cycle simulator that would analyze and optimize geothermal energy conversion processes and power plant designs.

Description: The computer code GEOTHM is under development to meet the above objective. The code provides flexibility by using a modular concept of assembling component models, containing properties of a variety of fluids, and using simple user-oriented input/output features. Cost effectiveness is achieved by incorporating a single-step multiparameter optimization algorithm along with very efficient process simulation routines. Industrial acceptance of GEOTHM is promoted by complete code documentation and by one work with interested users on their particular problems. The code is also used at LBL to study minimum-cost energy-conversion processes and to review proposed plant designs.

Schedule: New economics and fluid mixture routines will be documented by October 1979.

Progress: The code is operational and available for passive-mode design to industrial users. Fifteen papers describing various aspects of the code have been published. A users' manual has been published and a workshop held on the passive-mode (without optimizer) version. Section 8.2. "Conceptual Design Optimization" was prepared for inclusion in the Sourcebook on the Production of Electricity from Geothermal Energy, edited by Joseph Kestin, Brown University (in preparation).

References

Pines, H. S., Green, N. A., Pope, W. L., and Doyle, P. A., 1978. Floating dry cooling, a competitive alternative to evaporative cooling in a binary cycle geothermal power plant. Berkeley, Lawrence Berkeley Laboratory, LBL-7087.

Pope, W. L., Pines, H. S., Fulton, R. L., and Doyle, P. A., 1978. Heat exchanger design--Why guess a design fouling factor when it can be optimized? in Bradley, W. B., Shuck, Z. L., and Sheridan, R., eds, Emerging energy technologies--1978. New York, ASME/AIChE, and Berkeley, Lawrence Berkeley Laboratory, LBL-7067.

8. Downhole Geothermal Pump Technology

Organization: Los Alamos Scientific Laboratory
Principal Investigator: Dr. R. J. Hanold
Phone: (505)667-2631; FTS 843-2631

Objective: To stimulate the development and testing of new downhole pumps which have been environmentally hardened to survive the conditions imposed by production pumping of hot geothermal brines.

Description: An improved high-temperature version of the REDA electric submersible pump is undergoing testing in the DOE Geothermal Pump Test Rig at an operating temperature of 190°C. This test facility has been used to identify pump components that require additional engineering changes before a commercial version is ready for testing. If results from these tests remain favorable, a larger version of this pump will be purchased for downhole testing at the Geothermal Component Test Facility at East Mesa, California. Sperry Vickers is redesigning and reengineering the steam turbine pumping system originally tested by Sperry in a Chevron geothermal well at Heber, California. Arrangements have been made with Phillips Petroleum Company to test this improved pump in a new well at Desert Peak, Nevada. This pumping system, using steam as the working fluid, is a leading candidate for application in hydrothermal wells at temperatures from 185° to 230°C.

Schedule: Testing of the REDA electric pump in the Pump Test Rig will terminate in the third quarter of FY 1979. A downhole test at East Mesa, planned for the last quarter of FY 1979, will use the pump to supply fluid to the LBL 500-kWe pilot plant. The Sperry Vickers development program on the steam pump runs through the last quarter of FY 1980 with the field test at Desert Peak scheduled for the first quarter of FY 1981.

Progress: Contracts are being negotiated with: (1) Sperry Vickers, for downhole steam turbine pumping system; (2) TRW/REDA Pump Division, for high-temperature submersible electric pump; and (3) Barber-Nichols, for operation of pump test rig.

9. Moderate Temperature Heat Transport

Organization: Oak Ridge National Laboratory
Principal Investigator: John Michel
Phone: (615)574-5271; FTS 624-5271

Objective: To obtain and disseminate commercially useful technical and economic information on components and systems for converting heat from geothermal sources to useful work. This activity is directed toward the goal of achieving near-term competitive power-generating plants using geothermal heat sources. The current emphasis is on the heat rejection systems associated with binary processes.

Description: This program is composed of both analytical and experimental studies. The analytical aspect included preparing a chapter on waste heat rejection for the Geothermal Energy Sourcebook; this work includes in-depth assessment of the technical, economic, and environmental factors associated with components and subsystems used for waste heat rejection and use. ORNL also provides programmatic assistance to DOE headquarters. The experimental activity includes improvements and cost reduction for the various options for heat rejection from geothermal power cycles. This activity primarily involved development of advanced heat exchangers for use in geothermal binary power cycles with emphasis on the working-fluid condensers. This work consists of precise single-tube heat transfer experiments, data correlation, and development of design methodology for applying the results to full-size geothermal plant condensers. Also included are design and fabrication of prototype heat exchangers for evaluation of performance under actual operating conditions to confirm size scale-up algorithms. Work is planned for developing improved evaporators for geothermal power cycles.

Schedule: Test bundle for Raft River, Idaho, condenser is scheduled for June 1979 and the condenser for the East Mesa 500-kWe pilot plant is scheduled for September 1979. Single-tube laboratory condenser tests and commercial horizontal tubes are scheduled for June 1979; commercial vertical (spiral flute) tubes for July 1979; and inclined smooth tube for September 1979.

Progress: Data on enhanced surface condensers under both laboratory and actual geothermal operating conditions have been obtained. These data have been used to design a condenser for the 500-kWe direct-contact pilot plant.

References

Combs, S. K., Mailen, G. S., and Murphy, R. W., 1978. Condensation of refrigerants on vertical fluted tubes. Oak Ridge, Oak Ridge National Laboratory, ORNL/TM 5848.

Robertson, R. C., 1978. Waste heat rejection from geothermal power stations. Oak Ridge, Oak Ridge National Laboratory, report no. ORNL/TM-6533.

10. Low-Temperature Geothermal Conversion Systems

Organization: Sperry Research Center
Principal Investigators: W. D. McBee and H. B. Matthews
Phone: (617) 369-4000

Objective: To determine the feasibility and performance of novel system approaches to downhole pumping and electric power generation for 121° to 204°C hydrothermal resources.

Description: The systems use an organic working fluid, downhole primary heat exchangers, and a downhole turbine-pump unit in a novel heat engine cycle, which features gravity heat pressurization of the working fluid. These systems are expected to have significantly higher efficiency and cost effectiveness than alternative approaches. A 5-MWe binary system will be designed, built and operated on a moderate-temperature (177°C) low salinity resource. The design will include a downhole turbine-driven brine pump and counterflow heat exchange between the brine and Freon-114 in the wellbore. By varying heat-exchange surface area as a function of depth, pinch effects can be minimized and cycle efficiency optimized.

Schedule: The program will run through November 1981. Well completion is slated for November 1979. The downhole pump will be laboratory tested in October 1979 and field tested from April to October 1980. Testing on the complete system is scheduled for May to November 1981.

Progress: East Mesa, California, has been selected as the field test site. Measurements are under way of the physical properties of the working fluid and of its compability with proposed construction materials. Laboratory facilities are being constructed for turbomachinery tests.

Reference

Sperry Research Center, 1977. Feasibility demonstration of the Sperry down-well pumping system (final report of contract no. EY-76-C-02-2838). Sudbury, Mass., Sperry Research Center, DOE report no. 000-2838-1, SCRC-CR-77-48.

OTHER NOTES OF INTEREST

Sourcebook on the Production of Electricity from Geothermal Energy, edited by J. Kestin and R. DiPippo of Brown University, will be sent to the printer in early August. The material for this book was supplied by many of the principal investigators of the geothermal energy conversion technology projects described here and by others under DOE Division of Geothermal Energy sponsorship. A companion volume, Geothermal Energy as a Source of Electricity: A Worldwide Survey of the Design and Operation of Geothermal Power Plants, by R. DiPippo, will be printed at the same time. Negotiations with the U.S. Government Printing Office (GPO) are under way to have the books published either by the GPO or by a commercial publisher. The editors expect books to be available by 1980.

The 14th Intersociety Energy Conversion Engineering Conference, August 5-10, Boston, and the ASME/ AIChE 18th National Heat Transfer Conference, August 6-8, San Diego, will both have sessions on geothermal energy. The 1979 Annual Meeting of the Geothermal Resources Council, September 24-27, Reno, Nevada, will also have a session on geothermal energy conversion technology.

INFORMATION FOR FURTHER ISSUES

This first issue of News of Geothermal Energy Conversion Technology is being sent to persons suggested by participants of the DOE/DGE Geothermal Energy Conversion Program. Copies are also being sent to those on the mailing list for the Heat Exchange Technology Program. The program is sponsored by DOE/ Power Systems Division/Office of Fossil Energy Technology and administered by Dr. W. H. Thielbahr, chief, Energy Conservation Branch, DOE/Idaho Operations Office.

To assure that you will receive future issues, please fill out and return the coupon on the last page of the Newsletter. Names and addresses of others who might be interested in receiving current and future editions of this Newsletter are welcome.

Readers are requested to send in any information which they deem of interest for future issues of News of Geothermal Energy Conversion Technology. Such material should include DOE and other federally sponsored programs as well as developments from the industrial and academic sectors.

Your assistance and cooperation in making the News from Geothermal Energy Conversion Technology a success is appreciated.

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July 1979

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