NEWS of
Geothermal Energy Conversion Technology

Published for:
Hydrothermal Technology Section
U.S. DEPARTMENT OF ENERGY- DIVISION OF GEOTHERMAL ENERGY

Vol. III, No. 2, December 1981

This is the sixth issue of News of Geothermal Energy Conversion Technology. This publication is sponsored by the U.S. Department of Energy's Geothermal Energy Conversion Technology program, under the direction of Raymond LaSala. It is published by the Lawrence Berkeley Laboratory as part of LBL's geothermal program. This sixth issue summarizes recent developments in the individual projects.

Since its inception in 1979 the News of Geothermal Energy Conversion Technology mailing list has grown to nearly 1,200 subscribers. This response to the Newsletter demonstrates the great interest in geothermal energy conversion technology. The requestors represent private industry, national laboratories, Federal and local government agencies, consultants, utilities and academic institutions.

DOE GEOTHERMAL ENERGY CONVERSION TECHNOLOGY PROGRAM

Current program activities include field performance testing of 60- and 500-kWe binary-process power systems and of a 1-MWe helical screw expander. The binary process systems both include direct-contact heat exchangers. 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, but is currently at a standstill due to the unavailability of a geothermal well in which to test the system. The thermophysical properties and heat transfer performance of hydrocarbon Rankine cycle working-fluids are under study.

* *

Direct Contact Binary Demonstration Program

R. L. Fulton/Lawrence Berkeley Laboratory/
(415) 486-4664

This project has the objective of establishing the performance and economics of direct-contact heat exchange in geothermal power plants. Project activities include a 500 kWe direct-contact pilot plant (Vol. 2, No. 1, May, 1980), laboratory heat transfer studies, chemical modeling, hydrocarbon recovery tests, and economic and environmental considerations.

An extended test program completed at the end of April, 1981, provided performance data on the direct-contact heat exchanger, noncondensable gas effects, hydrocarbon recovery and overall system operation. The pilot plant subcontractor, Barber-Nichols Engineering Company of Arvada, Colorado, is preparing a report on the results of the test program. This report will be available from the Lawrence Berkeley Laboratory as LBL-13339.

The pilot plant has recently completed testing of the Oak Ridge National Laboratory (ORNL) enhanced-surface condenser. This condenser, designed to handle the 15 x 10^6 Btu/hr heat rejection load from the pilot plant, incorporates vertical tubes with special grooved outer surfaces that promote condensate drainage and high film coefficients. Design studies of condensers with enhanced surface, vertical tubes estimated that the vertical condensers would cost about 60% as much as a comparable horizontal smooth-tubed condenser for an application similar to the Raft River 5 MW(e) pilot plant using corrosion resistant tube materials. These studies, done by ORNL, were based on previously published results of laboratory and field tests using single tubes and small bundles.

In addition to adding the ORNL condenser to the pilot plant, six shell-and-tube brine/hydrocarbon heat exchangers from LBL's heat exchanger test were installed to operate as the plant's heat source for some of the condenser tests. This allowed testing the condenser with isobutane containing no noncondensables (shell-and-tube heaters) in addition to testing with noncondensable levels typical of the direct-contact heat exchange process. Additional tests of the direct-contact heat exchanger and of hydrocarbon recovery techniques are planned.

The 1981 National Heat Transfer Conference, August 3-6, in Milwaukee contained a session on Direct Contact Heat Transfer that included four papers based on work supported under the geothermal energy conversion technology program. H. R. Jacobs, University of Utah, presented "Comparison Between a Spray Column and a Sieve Tray Column Operating as Liquid-Liquid Heat Exchangers." J. J. Perona, University of Tennessee, presented "A Mass Transfer Model for a Spray Tower Direct-Contact Heat Exchanger." "Design Features and Equilibrium Flash Modeling of Direct Binary Fluid Heat Exchangers for Use with Geothermal Brines" was presented by P. M. Rapier, LBL, and "Heat Transfer and Hydrodynamics During Drop Formation and Release in a Liquid-Liquid Direct Contact Heat Exchanger" was presented by E. Marschall, University of California at Santa Barbara.

* *

Heat Exchange Technology

L. F. Silvester/Lawrence Berkeley Laboratory/ (415) 486-4705

This project has the objective of determining the performance of shell-and-tube heat exchangers under field geothermal conditions. Condensing of pure isobutane and isobutane/isopentane mixtures are under study. The experimental apparatus is located at the DOE East Mesa Geothermal Test Facility.

Field data on the condensation of commerical grade isobutane, and 90/10 and 80/20 mole percent isobutane-isopentane mixtures were obtained during testing in April, 1981. Data on the brine/hydrocarbon heat exchangers had been taken earlier (Vol. III, No. 1, March 1981).

The condenser contained 332 tubes, 3/4 in O.D., 14 ga carbon steel, 24 feet long. Cooling water was supplied from the Facility's cooling tower. The overall heat transfer coefficient, U, ranged from 110-155 Btu/hrft^2°F, with generally higher coefficients for the commercial grade isobutane and lower coefficients for the mixtures.

A summary report on the performance of both the heaters and condenser has been issued as LBL-12850, "Supercritical Heat Exchanger Field Test (SHEFT) I, Field Peformance Data on Shell-and-Tube Heat Exchangers in Geothermal Service." Another report, including more detailed analyses of the data and comparisons with predicted values is in preparation. This report will also discuss the operational problems encountered, primarily hydrocarbon system cleanliness and leaks, and cooling water treatment.

* *

Electrical Enegry from Moderate-Temperature Resource

J. Whitbeck/Idaho National Engineering Laboratory (INEL)/(202) 526-1879

The objective of this project is to lower the hydrothermal resource temperature that can be used to economically produce electricity. Experimental work centers on a 60 kW prototype power plant installed at Raft River, Idaho, where a 5 MW pilot plant is being constructed. Other work involves advanced power cycle studies and use of saline or geothermal water for cooling.

The 5 MW(e) pilot plant was started up during the Fall of 1981. Problems with the isobutane turbine throttle valve and governor prevented full-power operation. The unit was secured for the winter with resumed testing planned for next Spring.

New Peerless line shaft pumps were installed in production wells RRGE-1 and RRGE-2 in July. These pumps use leaded bronze bearings which are lubricated with a soluble oil. A refurbished Peerless pump having Teflon bearings is installed in production well RRGE-3. The use of the three line shaft pumps in the production wells permits the simultaneous operation of all production wells for the first time.

Testing of the Direct-Contact Heat Exchanger in the 60 kW Prototype Power Plant has continued. Data on the performance of the ORNL condenser when supplied by vapor from the direct-contact heat exchanger is also being obtained. Testing has been directed at mapping the performance of the heat exchanger with respect to flooding/instability limits and thermal performance. These tests used isobutane as a working fluid and provide a performance baseline for the next series of tests which will use a mixture of hydrocarbons.

Corrosion tests using aerated high saline and/or geothermal water are continuing. Preliminary results indicate that Seacure and 29-4C (high chromemoly alloys) have excellent corrosion resistance. Higher cost alloys, such as Inconel, also have excellent corrosion resistance. Tests of dispersants to hold silica in solution, and thus reduce cost of pretreating geothermal water for cooling use, are encouraging.

Binary cycles have the ability to lower brine effluent temperatures significantly below the silica deposition limit. When higher brine discharge temperatures are required by this limit, a significant performance penalty is incurred. Analytical work has shown that both recuperation and turbine bleed can be used to restore some or all the reduced performance. Recuperation is generally sufficient; turbine bleed is not necessary. It was also found that the shaping of condensing curves by using mixtures could lead to cooling water conservation and improved potential performance of wet-dry heat rejection systems.

* *

Helical Rotary Screw Expander Power System Utilizing Geothermal Brines

R. McKay/Jet Propulsion Laboratory/ (213) 577-9213

The one megawatt helical screw expander and generator unit arrived in Italy this summer following successful field tests at Roosevelt

KGRA, Utah, and Cerro Prieto, Mexico. Testing in Italy will be conducted by Ente Nazionale Per L 'Energia Elettrica (ENEL) at Ceseno 1 near Rome where salinities of 360,000 parts per million have been measured. DOE/DGE has contributed the 1 MWe expander/generator unit and test support equipment, and Jet Propulsion Laboratory, manager of the unit's construction and the Utah Test Project, will provide technical support to ENEL. The same support was provided to the Comision Federal De Electricidad for the testing in Mexico and will be provided to the ministry of works and development in New Zealand for testing there after the tests in Italy.

Prior to its shipment to Italy, the unit was converted from 60 Hz to 50 Hz by HPC, with the costs shared by DOE/DGE and ENEL. The conversion derates the generator to 833 kW but will allow connecting the wellhead generator to the electric power grid for the tests in Italy and New Zealand.

Information on helical screw expander/generator units can be obtained from Roger Sprankle, Hydrothermal Power Company, Ltd., 26681 Loma Verde, Mission Viejo, California 92691.

* *

Downhole Geothermal Pump Technology

R. J. Hanold/Los Alamos National Laboratory/ (505) 667-1698

The Geothermal Pump Test Facility (GPTF) has completed its operations at the Centrilift pump plant in Claremore, Oklahoma. The facility has been moved and is currently back in operation at the Kobe pump plant in Oklahoma City, Oklahoma. Kobe is currently testing a thermally hardened electric submersible pump (which has been used in very hot oil well service in China) to determine its suitability for geothermal well pumping. After a brief evaluation run at 300°F the loop temperature was raised to 350°F. Operation at this elevated temperature resulted in severe deterioration of the stator insulation varnish and a subsequent motor "burn". Kobe is currently rebuilding the motor with a new higher-temperature insulating coating in preparation for additional testing at 350°F.

Additional downhole pump operating time has been obtained from a REDA 80 hp unit operating at East Mesa to supply brine for the 500 kW pilot plant. After 3 1/2 months of online operation, however, the cable/motor resistance-to-ground reading had severely deteriorated and the unit was pulled for inspection before continuing operations. Downhole reliability of these units has not yet reached the commercial stage with cable-related failures being the principal cause.

Plans are being implemented to construct a pump test facility at East Mesa, California. The objective behind the design of this geothermal pump facility is to provide a test fixture that will allow the large geothermal pumps being considered for use today to be tested under conditions that match the true operating environment in geothermal wells. By simulating well conditions, it will be possible to evaluate and develop these pumps at a lower cost with less liability or risk than would be incurred by trying to achieve the same degree of development utilizing a well. To achieve the well simulation required, a test facility has been designed which will use actual geothermal well water with all of its normal constituents. It is the use of actual hot well water in this test facility that will allow close simulation of operating conditions in a well. Instrumentation to measure pump performance and to monitor degradation during endurance running will be provided, a feature which would be unavailable with typical well installations.

The test facility consists of a high-pressure flow loop and the auxiliary equipment required to achieve automatic control of the pump. Electrically-powered downhole geothermal pumps typically incorporate long single or tandem-unit electric motors. The proposed test facility provides a pump test section approximately 150 feet long that will be located below ground level and will simulate a geothermal well with 13-3/8" OD casing. The simulated well will be contained in a larger, outer casing. The geothermal fluid will flow downward in the annulus between the casings, make a 180° turn at the bottom of the inner casing and enter the 13-3/8" OD well casing. A crane with lifting capabilities of approximately 40 feet and 30,000 lbs. will be included as part of the facility. This will eliminate the costly and time consuming process of renting a workover rig each time a pumping system has to be installed or pulled from an actual geothermal well.

The operating cost of the facility will be reduced by incorporating a power recovery hydraulic turbine which is coupled to an induction generator. This energy recovery technique does not require expensive, complex controls for frequency regulation. Power output from the induction generator will be used to offset the power requirements of the pumping system. The test facility will be designed for the following conditions:

Maximum power power - 750 hp
Maximum suction pressure - 1000 psig
Maximum discharge - 1955 psig
Fresh brine flow during operation - 5 gpm
Maximum pump diameter - 12.6 inch
Maximum operating temperature - 450 °F
Maximum ambient air temperature - 120°F

Construction of this test facility began during the last quarter of 1981 with the initial pumping system test scheduled for the second quarter of 1982.

A 300 hp REDA electric submersible geothermal pumping system is being purchased for testing in a Magma production well at their East Mesa binary power plant facility. Performance of this geothermal unit will be compared with the lineshaft pumps presently installed. Testing of the Sperry Vickers steam turbine pumping system has been delayed as a result of the unavailability of a suitable well. This pumping system requires 13-3/8" casing and a brine temperature of 400-450°F. The existence of candidate wells for this DOE cost-shared pump test should be reported to R. J. Hanold.

* *

Low-Temperature Geothermal Conversion Systems

H. B. Matthews/Sperry Research Center/
(617) 369-4000

An attempt was made to seal off leaks at between 400-feet and 700-feet in the 30-inch casing of DOE Well 87-6 at East Mesa by installing and cementing a liner which later collapsed. The well was plugged and is considered in a safe condition.

Well 87-6 was intended as a test well for the Sperry/DOE thermal pump system. Alternatives being studied are repair of Well 87-6, twinning of Well 87-6, drilling a new large well elsewhere, or testing a reduced diameter thermal pump system in some existing well. In connection with this last option, site suggestions are welcomed and should be sent to W. D. McBee, Sperry Research Center, Sudbury, Massachusett 01776; Phone: (617) 369-4000. A suitable test well should have 13-3/8 inch or larger casing to pump setting depth, have 310°F to 400°F brine temperature, and be compatible with 250 pump horsepower.

* *

Waste Heat Rejection from Geothermal Power Plants

H. G. Arnold/Oak Ridge National Laboratory/
(615) 574-5764

ORNL has published a report for DOE entitled "Water-Related Constraints to the Development of Geothermal Electric Generating Station," (ORNL/TM-7718), that discusses water requirements for geothermal power plants, resource and water supply characteristics of promising geothermal areas in the U.S., and legal issues confronting potential water users in each area. The report concludes that direct and binary cycle geothermal power plants will require 50 to 1000 m^3/yr.KW(e) [40 to 80 acre.ft/yr.MW(e)] of fresh water with current technology and that nine of the twenty-five geothermal areas are designated as critical water resource regions requiring that water be acquired from current appropriators. In addition, the legal structure presents uncertainties that serve to further constrain the ability of geothermal developers to predict water availability for power production. On the other hand, technological improvements in heat rejection, ability of developers to set aside prior appropriated water rights, and the precept of law as a reflection of society's social desires suggest that a beneficial source of energy need not be completely denied to the nation as changes occur.

* *

For further information contact:

Werner J. Schwarz
Building 90, Room 1070
One Cyclotron Road
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720
(415) 486-4706
FTS 451-4706

PUB-399 12-81/1200 This work was supported by the U.S. Department of Energy Contract W-7405-ENG-48.