PUB 354

NEWS of

Geothermal Energy Conversion Technology

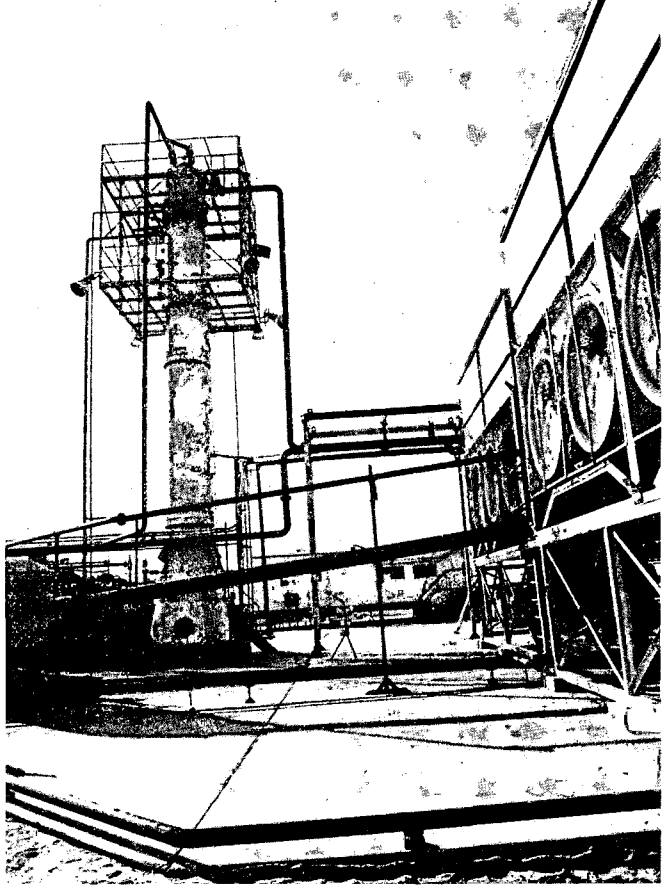
Published for:
Hydrothermal Technology Section
U.S. DEPARTMENT OF ENERGY — DIVISION OF GEOTHERMAL ENERGY

Vol. II, No. 1, May 1980

This is the third 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 Clifton B. McFarland, Chief, and Raymond LaSala, Program Manager. It is published by the Lawrence Berkeley Laboratory as part of LBL's geothermal program. This third issue discusses recent developments in some individual projects while briefly summarizing the other projects.

DOE GEOTHERMAL ENERGY CONVERSION TECHNOLOGY PROGRAM

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. 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. The thermophysical properties and heat transfer performance of hydrocarbon Rankine cycle working fluids are under study.



Direct-contact heat exchanger (left) and evaporative condenser (right) are major components of a new 500 kWe direct-contact pilot plant. *(Story on page 2).*

EARTH SCIENCES DIVISION
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DIRECT-CONTACT PILOT PLANT BEGINS TESTING

Assembly of the 500 kWe direct-contact pilot plant was completed in January at DOE's East Mesa Geothermal Component Test Facility. Initial debugging and a short baseline test run were also completed. The baseline test verified the basic pilot plant design. Component operation and integrity were verified and each module of the pilot plant operated as expected with the exception of the hydrocarbon turbine. Brine and isobutane flow rates of 211 gpm and 304 gpm, respectively, were achieved.

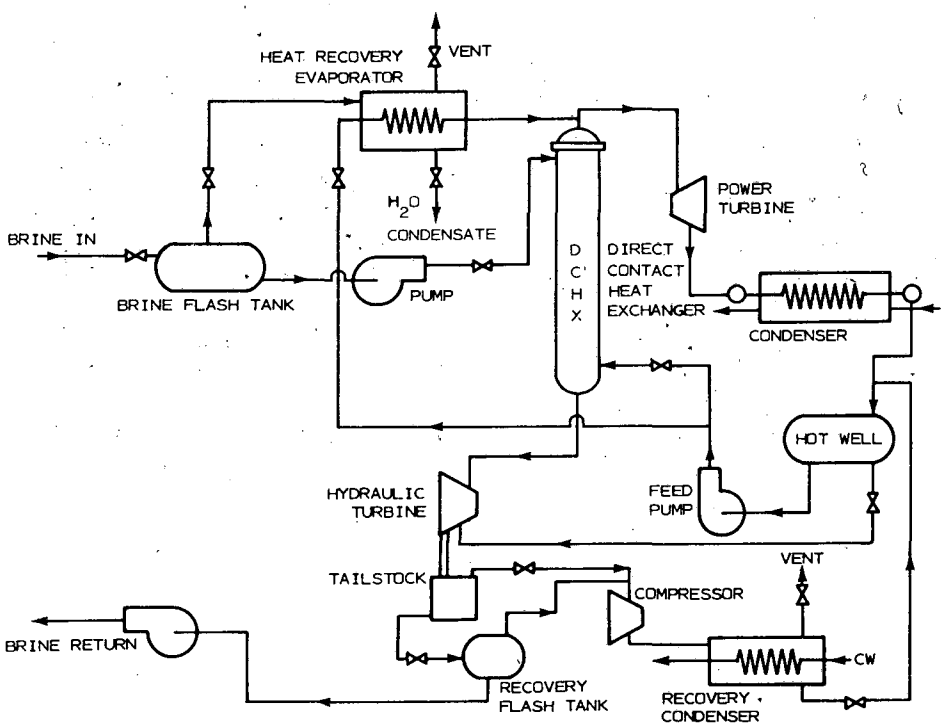
The unit, designed and built by Barber-Nichols Engineering, Arvada, Colorado, under subcontract to the Lawrence Berkeley Laboratory, features a 40 in diameter, 35 ft high direct-contact heat exchanger (DCHX). In the DCHX, isobutane droplets rise through downward flowing geothermal brine and are heated and vaporized at 467 psia. The 250°F isobutane vapor, with approximately 1.5% steam, is expanded through the power turbine and condensed in a 4-module condenser. Isobutane and steam condensate are separated in the hot well. The brine enters the DCHX at 340°F and exits at 150°F. After leaving the DCHX, the brine passes through a hydraulic turbine. This accomplishes two things: the resultant shaft work is returned to the brine pump to reduce the plant's parasitic power requirements, and dissolved isobutane in the brine is liberated for recovery in the recovery condenser. An additional recovery flash tank is available for a second stage of hydrocarbon recovery, if required. At the inlet to the plant, a brine flash tank permits a small flashdown that strips noncondensable gas from the incoming brine. The heat in the brine flash tank vent stream is recovered by vaporizing a sidestream of isobutane.

The power turbine failed during the baseline test. Subsequent tests and analyses have identified two major causes of the radial-inflow turbine blade failures: a piping configuration that permitted liquid ingestion during turbine startup, and high centrifugal bending stresses in the blades. Piping modifications have been completed and a new turbine wheel is being built.

A report is in preparation that describes the unit and presents the baseline test results. An extended test program began after the baseline test and will include performance mapping of the pilot plant and its subsystems.

DOE BEGINS DISCUSSIONS ON BINARY DEMONSTRATION POWER PLANT

DOE's Division of Geothermal Energy has begun negotiations with San Diego Gas and Electric Company that will lead to government support of a 45 MWe binary-cycle power plant in



Flow diagram of the 500 kWe direct-contact pilot plant

California's Imperial Valley. The plant, which will feature a supercritical Rankine cycle using a mixture of isobutane and isopentane as the working fluid, is scheduled for completion in 1984. Government support will include funding a portion of the plant's capital cost and also a portion of its operating cost for a two-year demonstration period after startup.

San Diego Gas and Electric will lead a consortium of utilities, including Southern California Edison and the Imperial Irrigation District, that would own the plant. Contributions are also expected from several other utilities, the Electric Power Research Institute, and the California Division of Water Resources. Fluor Corporation will be the architect/engineer for the plant.

The plant will operate initially on 182°C geothermal fluid supplied by Chevron Resource Company from its Heber field. Design of the plant will incorporate provisions for maintaining its net generating capacity while experiencing a predicted geothermal fluid temperature decline to 170°C after 30 years.

DOE plans to engage a separate organization as a data subcontractor to gather, analyze, and disseminate information on the plant design and performance during the demonstration period. The DOE objectives are to demonstrate binary-cycle technology and economics, along with demonstrating geothermal reservoir performance characteristics and validating reservoir engineering estimates.

Downhole Geothermal Pump Technology

R.J. Hanold/Los Alamos Scientific Laboratory/ (505) 667-2631

The Division of Geothermal Energy's downhole pump technology project was initiated to stimulate the development of pumping systems that can withstand the geothermal environment.

REDA Pump Company is continuing to make improvements in the geothermal version of their downhole electric submersible pumping systems. Field experience at East Mesa, California, has led to an improved seal package to retard leakage into the motor assembly. A 70 hp unit has been producing 163°C fluid from an East Mesa well since mid-November. A second pump that will be operated in a 177°C well has been ordered for East Mesa.

Los Alamos Scientific Laboratory (LASL) has also purchased a 680 hp REDA geothermal pump that will initially be used at Raft River, Idaho.

The Geothermal Pump Test Facility (GPTF) is currently in operation at the CENTRILIFT pump plant in Tulsa, Oklahoma. Presently operating at 150°C, the GPTF is being used to test brine seal designs for the CENTRILIFT electric pumping systems and to determine their potential for low to moderate temperature geothermal well applications. Barber-Nichols Engineering, Arvada, Colorado, is assisting CENTRILIFT with the test program in the GPTF and L'Garde Inc., Newport Beach, California, operating under its technology transfer contract, is working on improved elastomeric seals for pump applications in a brine/lubricating oil environment.

LASL is assisting the Raft River 5 MW pilot plant in the selection of production pumping systems. Both CENTRILIFT and REDA standard oil field pumps have been tested in production wells at Raft River with varying degrees of success. The production pumping systems will employ geothermal hardened components that have been tested in the GPTF at temperatures appreciably above the Raft River well temperatures.

Sperry Vickers, Jackson, Mississppi, is continuing development of a downhole steam turbine pumping system. Candidate wells are being evaluated with the initial field test planned for 1981 in a 200-230°C well with low-to-moderate salinity.

Binary Fluid Experiment

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

This project provides laboratory-quality experimental data on heat-transfer film coefficients for heating and condensing candidate binary-cycle working fluids. Data have been obtained and reported on film coefficients for heating supercritical isobutane and isobutane/ isopentane mixtures.

Recent experiments indicate that condensation film coefficients for isobutane/isopentane mixtures are significantly lower than those for pure isobutane. Preliminary data show condensation film coefficients for an 80-mole percent isobutane/20-mole percent isopentane mixture are only 30% of the value predicted for pure isobutane by the Nusselt correlation at a 5°C temperature difference between the vapor and tube wall.

Additional tests at other mixture compositions are underway. A report on the mixture condensation coefficients will be presented at the 15th Intersociety Energy Conversion Engineering Conference, Seattle, Washington, August 18-22, 1980.

SUMMARY OF CURRENT PROJECTS

Heat Exchanger Scale Control

J.P. Nesewich/Aerojet Energy Conversion Company/ (916) 355-2056

The objective of this project is to develop a liquid/solids handling system to control the carryover of injected scale-control solids in an "APEX" self-cleaning geothermal heat exchanger. Laboratory tests will demonstrate

the ability to control solids dispersement and to provide high efficiency solids removal and recovery. The project is scheduled for completion August 31, 1980.

Direct-Contact Power System

B. Huebner/Arkansas Power & Light/ (501) 371-4108

This project is jointly funded by DOE/DGE, Arkansas Power & Light, and Great Lakes Chemical Company. The objective is to demonstrate the technical and economic viability of electric power generation from low-temperature geothermal brines. A 100 kWe direct-contact Rankine-cycle power system has been installed in southwestern Arkansas to generate electricity from a bromine extraction plant's "tail brine". After being started up in the fall of 1979, the system was shut down during the winter. It was restarted in April, 1980, and a four month test program is scheduled.

Electrical Energy from Moderate-Temperature Resources

J. Whitbeck/Idaho National Engineering Laboratory/(208) 526-1879

The objective of the project is to lower the hydrothermal resource temperature that can be used to economically produce electricity. Experimental work has centered around a 60 kWe prototype power plant installed at Raft River, Idaho.

The prototype unit has been shut down and modifications required for the installation of a direct-contact heat exchanger and fluted tube condenser are proceeding. A cooling water treatment system which will allow evaluation of various methods of treating geothermal water for cooling tower makeup is being set up concurrently with the other modifications. Water treatment testing will start when weather conditions permit. A preliminary report has been issued giving the history and operational experience with the prototype to date.

It was previously reported that testing had revealed the potential for severe pitting corrosion of the Raft River 5MW Pilot Plant condenser exists when using geothermal fluid as cooling water with the presently specified chemical treatment. Tests are now underway to establish procedures for cleaning and pretreating the tubes which may allow the corrosion rate to be better controlled. Backup approaches are also being evaluated. Puckorius and Associates are acting as the water treatment consultants, and Radian Corporation, Austin, Texas, is providing the laboratory evaluation of the treated samples.

The Office of Water Research and Technology is funding a cost-sharing pilot plant study by Permutit, Mammouth Junction, New Jersey, and INEL for the development of effective economical means for silica removal and for water recovery for reuse by reverse osmosis. The proposed method employs hydrous iron oxide from turnings and is based on a method developed by Walter Leaf for boiler water treatment during World War II [Silica Removal with Iron Shavings, JAWWA, 40, 980-988 (1948)]. Pilot Plant operation of the water treatment system for the 60 kw prototype is scheduled to start in May. This system will include recovery of chromate by ion exchange as the metallurgy is carbon steel which requires high levels of corrosion protection. Softening by chemical means and ion exchange are included in the study; in addition to reverse osmosis desalination which is expected to increase cycles of concentration to 10 to 15 cycles.

Evaluation of Helical Rotary Screw Expander Power System Utilizing Geothermal Brines

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

The objective of this project is to determine the performance characteristics of the helical screw expander over a broad range of operating conditions. Using a 1 MWe expander/generator unit, initial field tests were conducted at the Phillips Petroleum Company flow test facility, Roosevelt KGRA, Utah. Peak expander efficiency of 55% and peak load of 1 MWe were measured under non-optimum conditions. Test conditions included inlet steam fraction from zero to 99% and inlet pressure from 84 to 258 psia.

The unit has been installed on well M-11, Cerro Prieto, Mexico, for wellhead testing, with joint funding by DOE/DGE and the Comision Federal de Electricidad under the auspices of the International Energy Agency. Testing began in April, 1980.

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. In addition to the 500 kWe pilot plant (see story on page 2), project activities include laboratory heat transfer studies, chemical modeling, hydrocarbon recovery tests, and economic and environmental considerations.

Studies are underway at the University of California at Santa Barbara under Professor E. Marschall to characterize heat transfer during droplet formation in a direct-contact heat exchanger. Professor J. Perona, University of Tennessee, is preparing a predictive computer model of the chemical partioning of hydrocarbon, steam, and noncondensable gases into the various flow streams of a direct contact binary plant.

Performance data from the various parts of the program will be incorporated into a conceptual design and cost estimate of a commercial-size direct-contact binary power plant.

Heat Exchanger Technology

L.O. Beaulaurier/Lawrence Berkeley Laboratory/
(415) 486-4704

This project, which is being conducted in cooperation with EPRI, has the objective of determining the performance of shell-and-tube heat exchangers under field geothermal conditions. Both heating at supercritical pressures and condensing of pure isobutane and isobutane/isopentane mixtures are under study. The experimental apparatus has been relocated to the DOE East Mesa Geothermal Component Test Facility and further tests are to begin in June.

Thermodynamic Cycle Analysis

W.L. Pope/Lawrence Berkeley Laboratory/
(415) 486-4663

The goal of this project is to develop and apply a general cost-effective thermodynamic cycle simulator for the analysis and optimization of geothermal energy conversion processes and power plant designs. The GEOTHM computer code is presently being used to study optimized working fluid mixtures and turbine inlet conditions as functions of geothermal resource temperature. An LBL report on the results is in preparation.

Analysis of Advanced Waste Heat Rejection Technologies

J.W. Michel/Oak Ridge National Laboratory/
(615) 574-5271

This project's objective is to increase the projected geothermal electric generating capacity by relaxing the constraints imposed on development by the limited availability of cooling water. The availability of water in the major geothermal areas is presently being reviewed, and the potential of advanced cooling technologies for reducing net water deficits will be assessed. A field test of the advanced cooling technologies is planned for 1981.

Moderate Temperature Heat Transport

J.W. Michel/Oak Ridge National Laboratory/
(615) 574-5271

Laboratory tests using a glass-shell condenser are examining the outside heat transfer performance for R-11 (trichlorofluoromethane) condensing on a variety of tubes as a function of tube inclination. Tubes being tested range from the conventional smooth wall tube to a variety of enhanced surface tubes of spiral and fluted design. Recent data show that the horizontal arrangement yields higher heat transfer coefficients than the vertical arrangement, except for the fluted tubes, where this trend reversed.

A replacement vertical fluted tube (VFT) for the Raft River 60 kWe prototype loop has been designed at ORNL and is being built by Patterson-Kelly Company. The unit is designed to handle some noncondensable gasses that may be present when the system is operated in the direct-contact evaporator mode. A VFT condenser is also being procured for installation in August 1980 in the 500 kWe direct-contact pilot plant at East Mesa.

Low-Temperature Geothermal Conversion Systems

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

The objective is to determine the feasibility and performance of novel system approaches to downhole pumping and electric power generation for 120° to 204°C hydrothermal resources. The system uses an organic working fluid, downhole heat exchangers and turbine-pumps, as well as gravity head pressurization of the working fluid. A well has been drilled to 6000 ft at the DOE Geothermal Component Test Facility at East Mesa, California. A test of the downhole turbine-pump is scheduled to begin in October, 1980.

INFORMATION FOR FURTHER ISSUES

The mailing list for this third issue of News of Geothermal Energy Conversion Technology has been expanded from that for the second issue. Names and addresses of others who might be interested in receiving current and future issues are also 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 this publication a success is appreciated.

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