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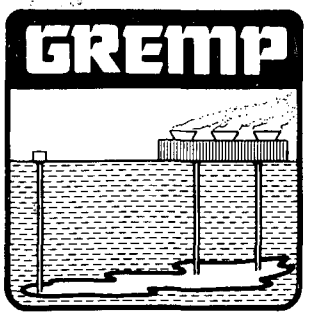


NEWS from Geothermal Reservoir Engineering Management Program

Sponsored by
U.S. DEPARTMENT OF ENERGY - DIVISION OF GEOTHERMAL ENERGY

Vol. II, No. 2
May 1, 1979

This is the fourth edition of *News from GREMP*. This edition is an update and features the specific achievements of seven contracts now in progress, Copies of the *News from GREMP* are being sent to individuals who requested the publication by returning the coupon, attached to Vol. I, No. 1 and 2, and Vol. II, No. 1. For your convenience the coupon is being repeated again in this edition.

PROJECT HIGHLIGHTS

1. MODELING, TRACER AND ANALYTICAL STUDIES OF GEOTHERMAL RESOURCES

Principal Investigator: Henry J. Ramey, Jr., and Paul Kruger (Stanford University)

Objective: Develop experimental data and analytical methods for planning the for optimum performance of the porous and fractured hydrothermal systems.

Progress: The experimental data to study lowering of vapor pressure as a function of absolute pressure, temperature and saturation has been obtained and is being analyzed. The schematic diagram of the experimental apparatus for this work is shown in Fig. 1.

The effect of temperature on absolute permeability was examined for different fluids circulating through carefully defined environments. Water, oil and nitrogen were picked to flow through sandstone, limestone, unconsolidated sands and bits of stainless steel. It is believed that permeability reductions depend on the nature of the solid-liquid boundary,particularly on and intermolecular forces. However, more experiments are in progress to verify these hypotheses.

Construction of a three unit apparatus to study radon emanation as a function of rock type, fragment size, pore fluid density, pressure and temperature has been completed and background experiments are in progress.

References: Quarterly progress reports are available at LBL.

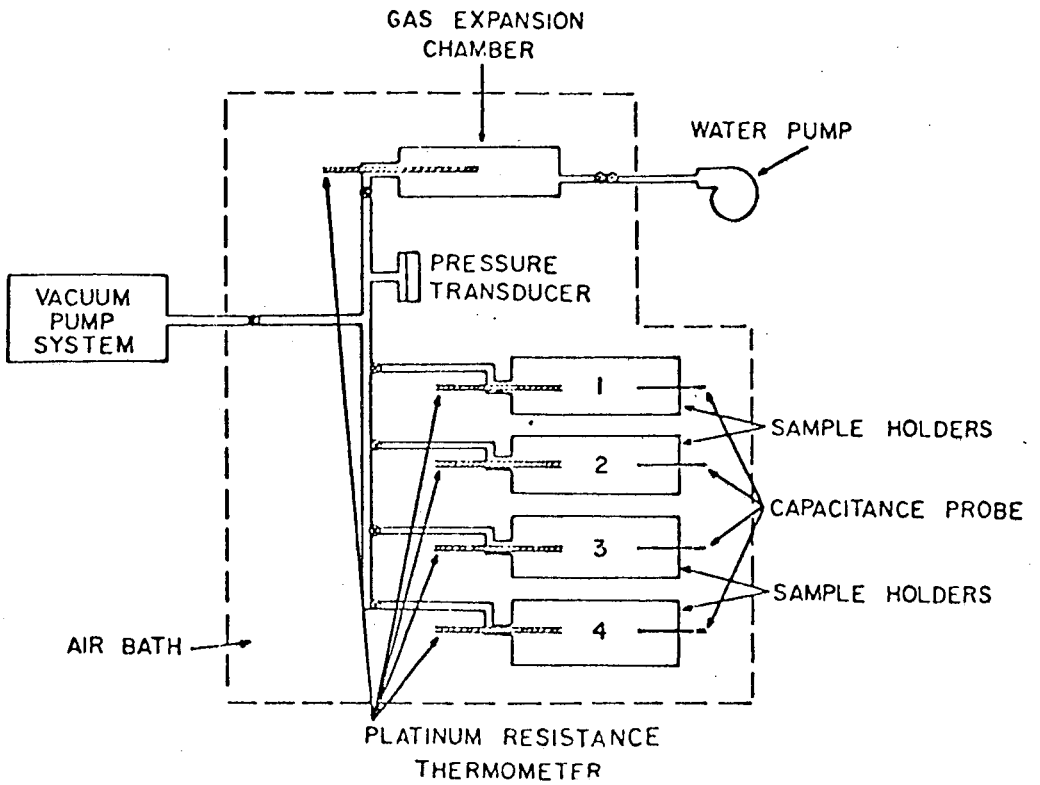


Fig. 1: Apparatus used to determine water adsorption and vapor pressure lowering

2. INTEGRATED SIMULATION MODEL OF THE WAIRAKEI RESERVOIR

Principal Investigator: T. David Riney (Systems, Science and Software)

Objective: Develop two-dimensional areal, two-dimensional vertical and three-dimensional models of the Wairakei geothermal system and predict thermodynamic characteristics of the fluid and surface subsidence under different reinjection conditions.

Progress: A two-dimensional vertical geologic cross section passing through the main field from west to east has been defined as represented in (Fig. 2). Values of the various formation parameters are ascertained for the reservoir. The net mass and heat discharge at the surface had been matched reasonably well by assuming a pre-production temperature distribution in the field. With these defined initial conditions an attempt is underway to match the pressure and enthalpy history during the production period.

Reference: Quarterly progress reports are available at LBL.

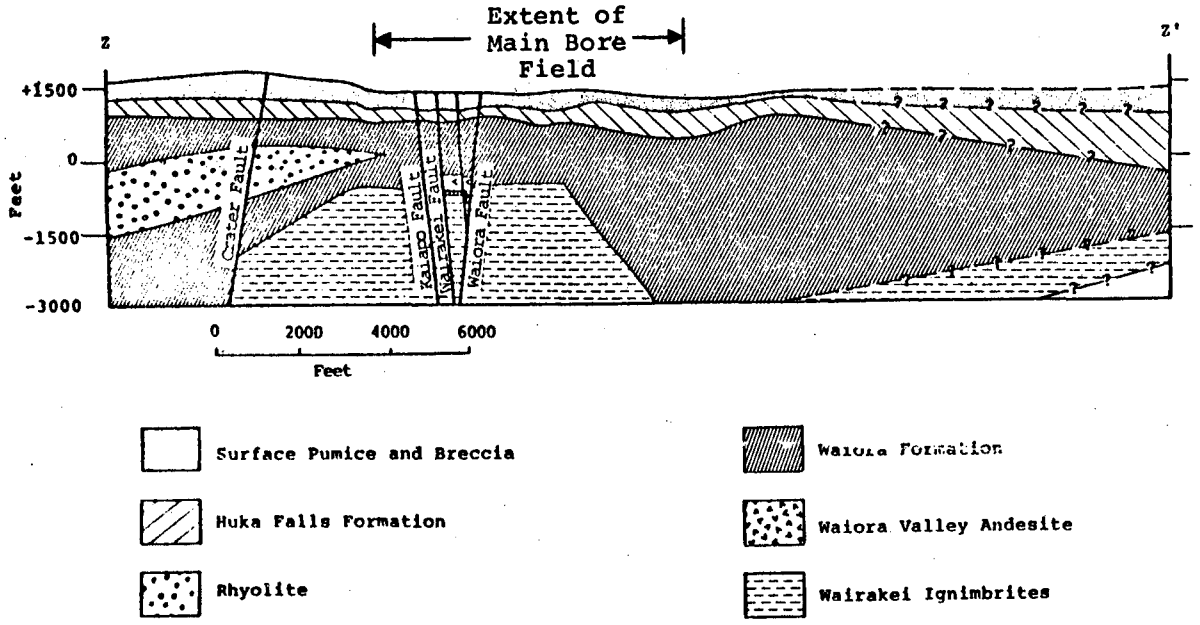


Figure 2: Section ZZ', west to east through the Wairakei geothermal field

3. GEOTHERMAL CALORIMETRY

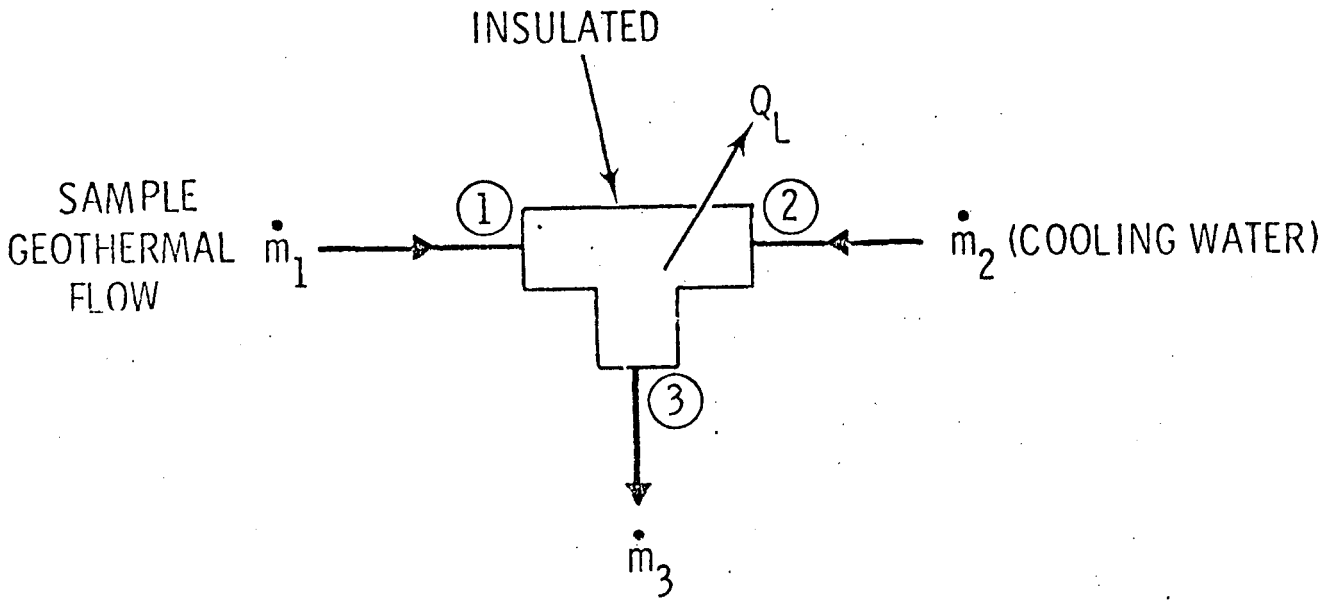
Principal Investigator: William C. Cliff (Battelle Memorial Institute, Pacific Northwest Laboratory).

Objective: Select and design calorimetry systems that permit economical, reliable and accurate measurements of enthalpy values at geothermal wellheads.

Progress: Battelle has evaluated several calorimetry methods for measuring geothermal wellhead enthalpies. Based on the criteria used (which included accuracy, reliability, cost, ways of maintenance and operation, safety, etc.), a mixing tee condenser (see Fig. 3) was recommended when cooling water was available. When cooling water is not available a multiphase tank, from which the geothermal fluid sample is withdrawn into an evacuated tank, was recommended. The other methods considered included a single pass heat exchanger, regenerative heat exchanger, a pressurizer spray condenser, quick closing valves, and a liquidizer.

Battelle has also considered different sampling configurations. It was felt that an accurate sampling technique was very important. The probes considered were single- and multi-port isokinetic probes. A recommendation was made to develop a nonlinear spaced, retractable, multiple equal area port, isokinetic probe. The advantages of this configuration include (1) no interference with plant operation, (2) a radial profile measurement, (3) only intermittent exposure to the geothermal fluid, (4) ability to substitute sample probes and (5) a low flow restriction. A full report on the evaluation will be available in the near future.

Reference: Progress reports are available at LBL.



$$h_1 = \left(\frac{\dot{m}_2}{\dot{m}_2 - \dot{m}_3}\right) h_2 + \left(\frac{\dot{m}_3}{\dot{m}_3 - \dot{m}_2}\right) h_3 + \left(\frac{Q_L}{\dot{m}_3 - \dot{m}_2}\right)$$

Figure 3: Mixing Tee Condenser

4. SIMPLIFIED ANALYTICAL TECHNIQUES TO INTERPRET TWO-PHASE GEOTHERMAL RESERVOIR

Principal Investigator: Billy Taylor, Robert Aydelotte and Keith Coats (Intercomp)

Objective: To develop analytical techniques to interpret two-phase geothermal reservoirs from pressure and temperature data taken at the wellhead.

Progress: The two primary simulators to be used for this project are 1) The geothermal reservoir model developed by Coats (Ref.1); 2) The two-phase wellbore model developed by Gould (Ref.2).

The first task of the project was verification of these simulators, This task has been completed. Favorable comparisons were made with the experimental and numerical results listed below:

a) The Stanford bench model experiment with some additional data reported by Thomas and Pierson (Ref. 3, 4)
b) The pressure transient analysis for two-phase (liquid water/steam) geothermal reservoir presented by Garg (Ref. 5)
c) The two-phase, two-dimensional simulation of a geothermal reservoir and wellbore system by Toronyi (Ref. 6)

The vertical two-phase wellbore model was compared with the actual data from field tests from the Broadlands Area in New Zealand. Comparison with steady state performance of the bore is quite good.

References:
(1) Coats K.H., "Geothermal Reservoir Modelling," SPE 6892 presented at 52nd Annual Meeting of SPE-AIME, Denver, Colorado, October 9-12, 1977.
(2) Gould T.L., "Vertical Two-Phase Steam/Water Flow in Geothermal Wells," J. Pet. Tech. 833-842, August 1974
(3) Kruger P. and Ramey, Jr., H.J., "Stimulation and Reservoir Engineering of Geothermal Resources," Stanford Geothermal Program Report No. SCP-TR 1, June 1974
(4) Thomas L.K. and Pierson R., "Three Dimensional Geothermal Reservoir Simulation," SPE 6104 presented at 51st Annual Meeting of SPE-AIME, New Orleans, Louisiana, October 3-6, 1976.
(5) Garg S.K., "Pressure Transient Analysis for Two-Phase (Liquid Water/ Steam) Geothermal Reservoir," SPE 7479 presented at the 53rd Annual Meeting of SPE-AIME, Houston, Texas, October 1-3, 1978
(6) Toronyi R.M., "Two-Phase, Two-Dimensional Simulations of a Geothermal Reservoir and Wellbore System," PhD Thesis, Penn. State University, University Park, Penn. 1974

5. SCALE INHIBITOR TESTS AT EAST MESA.

Principal Investigator: O. Vetter (Vetter Research)

Objective: To conduct laboratory tests and field experiments to evaluate calcite scale control.

Progress: Two scale inhibitor tests have been performed at Republic Geothermal Inc.'s East Mesa Wells # 16-29 and # 56-30. The complete program of tests at well # 16-29 could not be finished due to downhole pump problems. However, two test runs were completed and a third started before the pump failed.
The tests at well # 56-30 were finished according to the test plan. Typical power plant conditions (pressure drops, temperature drops and flow conditions), were simulated in all tests by using test loops (8" diameter at well # 16-29 and 12" at well # 56-30) as well as field test separators.
The untreated brine exhibited a strong calcium carbonate ($CaCO_3$) scale tendency as soon as the pressure was dropped below 75 psi. For example after a 92.75 hour test run, the brine from well # 16-29 formed a maximum scale thickness of 0.5" in a 8" ID pipe at an average rate of 375,000 lb/hour total mass flow. After an 104 hour test run, the brine from well # 56-30 formed a maximum scale thickness of 1.25" in a 12" ID pipe at an average rate of 722,000 lb/hour total mass flow.

The main results and conclusions of this project are:
1) The $CaCO_3$ scale in RGI's wells can efficiently be inhibited at a maximum cost of approximately 0.5-1.0 Mill/Kwh
2) The most likely inhibitor costs at full field operation will be on the order of 0.3 Mill/Kwh
3) Even though RGI's East Mesa scale problems can be solved additional test work is required to solve the scale problem in other areas and fields, particularly if downhole scale is encountered in the absence of a downhole pump.

The described study must be considered as only a stepping stone in the progress toward solving all carbonate scaling problems in geothermal operations.

Reference: Final report will be available at LBL in May 1979.

6. AN APPRAISAL OF MEASUREMENT METHODS FOR GEOTHERMAL WELL SYSTEM PARAMETERS

Principal Investigator: Michael Lamers (Measurement Analysis Corporation)

Progress: A comprehensive appraisal of geothermal measurement parameters and new associated instrumentation has been completed. Based on this appraisal, it appears that there are existing commercially available technology and instrumentation for all wellhead and process plant measurement requirements, except the two-phase flow measurement. Passive sensors which meet all identified measurement requirements are presently available for downhole measurement of temperature and pressure (low resolution). However, downhole logging tools for the measurement of other key parameters are non-existent. The five parameters identified as having the highest priority for development are: fracture zone identification and orientation mapping, casing integrity, flow mapping, porosity and formation temperature while drilling.

References: Final Report will be published as GREMP Series # 6, May/June 1979.

7. MASS AND HEAT TRANSPORT IN FRACTURED GEOTHERMAL SYSTEMS.

Principal Investigator: George F. Pinder (Princeton University)

Objective: To develop the capability of simulating the behavior of a fractured geothermal reservoir subject to exploitation.

Progress: The two specific problems of current interest are governing equation and solution methodology development. The equation formulation begins with the primitive point equation and proceeds through systematic averaging procedures to arrive at governing porous medium expressions. In order to close the system of equations, it is necessary to employ constitutive theory and certain simplifying assumptions. These latter procedures are of primary interest at this time. The solution methodology element of the research has led to a new and efficient algorithm, which will result in significant savings in computational effort. This algorithm has been tested on model problems, where it provides accurate solutions. The use of this methodology, along with a new numerical scheme in a fractured reservoir geothermal model, is anticipated.

References: "Physics of Flow in Geothermal Systems." Presented at Recent Trends in Hydrogeology Symposium, LBL, February 8-9, 1979.

PUBLICATIONS AND DOCUMENTS

The following publications are or will be available from the GREMP Program office at LBL upon request:

- GREMP Series # 1 (LBL 8664)
  "Annotated Research Bibliograpohy for Geothermal Reservoir Engineering."
  (R. Harrison and G. Randall, Terra Tek, Inc.), due May/June 1979.

- GREMP Series # 2 (LBL 8669)
  "Summary of Reservoir Engineering Data: Wairakei Geothermal Field, New Zealand."
  (D. Riney, Systems, Science and Software).

- GREMP Series # 3 (LBL 8784)
  "Modeling Heat and Mass Transfer at the Mesa Geothermal Anomally, Imperial Valley, California."
  (K. Kassoy and K.P. Goyal, University of Colorado).

- GREMP Series # 4 (LBL 9088)
  "Modeling of the Subsurface Geology in the Cerro Prieto Geothermal Field."
  (W. Elders, UC/Riverside), due May/June 1979.

- GREMP Series # 5 (LBL 9089)
  "Scale Inhibitor Tests at East Mesa."
  (O. Vetter, Vetter Research), due May/June 1979.

- GREMP Series # 6 (LBL 9090)
  "An Appraisal of Measurement Methods for Geothermal Well System Parameters."
  (M. Lamers, Measurement Analysis Corporation), due May/June 1979.

- "Proceedings - Invitational Well Testing Symposium." (LBL 7027).

- "Proceedings - 2nd Invitational Well Testing Symposium." (LBL 8883), due June 1979.

- "News from GREMP" Vol I, No. 1 (Aug. 1, 1978), No. 2 (Nov. 3, 1978) and Vol II, No. 1 (Feb. 1, 1979).

- Subsidence Series # 1 (GSRMP # 1, LBL 8615)
  "Environmental Economic Effects of Subsidence."
  (EDAW/ESA), due June 1979.

- Subsidence Series # 3 (GSRMP # 3, LBL 8617)
  "Guidelines Manual for Surface Monitoring of Geothermal Areas."
  (Woodward Clyde Consultants), due June 1979.

- Subsidence Series # 4 (GSRMP # 4, LBL 8618)
  "Areas of Ground Subsidence due to Geofluid Withdrawal."
  (Systems Control, Inc.), due June 1979.

- "News from Subsidence" Vol. I, No. 1 (Feb. 1, 1979).

PROGRAM STATUS

Since the last edition *News from GREMP* the following contracts were or are about to be awarded:

- Decline Curve Analysis - This GREMP contract is for GREMP Category I.(Well Testing), to review decline and production curve procedures used in the petroleum industry, determine which procedures are applicable to geothermal systems, and establish a theoretical basis for applicability.

  Selection of a proposed contractor has been made, subcontractual negotiations and approvals are in process.

- An Evaluation of James Method for the determination of geothermal wellbore discharge characteristics - University of Hawaii - This GREMP contract is for category I - Well Testing, to evaluate the sensitivity of James tube measurements to such parameters as pipe diameter, tapping position, non-condensibles gases, and dissolved solids in the two-phase fluid using current two-phase critical flow models (e.g. Fauske, Levy, Moody) and to compare James' data to more recent data. The principal investigator for this program is Prof. P. Cheng.

- Ninety-one RFP's for Research of Applications of Tracer Methods to Determine the Measurement of Fluids were sent out on March 27, 1979. with response due to be postmarked April 27, 1979. We anticipate negotiation and award of contract during May/June, 1979.

FUTURE MEETINGS OF INTEREST TO RESERVOIR ENGINEERING

Title	Place	Date	Contact
Italian/American Meeting on Geothermal Resources Assessment and Reservoir Engineering (ENEL/ERDA)	Lawrence Berkeley Laboratory Berkeley, California	March/April 1980 (Tentative)	W.J. Schwarz
Field trip to California Geysers	From LBL	March/April 1980 (Tentative)	W.J. Schwarz

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