SGP-TR-107

- Injection Technology -
Geothermal Reservoir Engineering Research at Stanford

Principal Investigator:
Roland N. Horne

September 1986

Second Annual Report
Department of Energy Contract Number
DE-AS07-84ID12529
For the Period
October 1, 1985 through September 30, 1986

Stanford Geothermal Program
Interdisciplinary Research in
Engineering and Earth Sciences
STANFORD UNIVERSITY
Stanford, California

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PREFACE

The Stanford Geothermal Program conducts interdisciplinary research and training in engineering and earth sciences. The central objective of the Program is to carry out research on geothermal reservoir engineering techniques useful to the geothermal industry. A parallel objective is the training of geothermal engineers and scientists for employment in the industry. The research is focused toward accelerated development of hydrothermal resources through the evaluation of fluid reserves, and the forecasting of field behavior with time. Injection technology is a research area receiving special attention. The Program is geared to maintain a balance between theoretical, laboratory, and matching field applications.

Technology transfer is an integral part of the Stanford Geothermal Program. Major activities include a Geothermal Reservoir Engineering Workshop held annually, and weekly Seminars held throughout the academic year. The Workshop has produced a series of Proceedings that are a prominent literature source on geothermal energy. The Program publishes technical reports on all of its research projects. Research findings are also presented at conferences and published in the literature.

Geothermal reservoir engineering research at Stanford has gained considerable breadth through the Program's international cooperative projects. There are research agreements with Italy, Mexico, New Zealand, and Turkey. These international projects provide a wide spectrum of field experience for Stanford researchers, and produce field data with which to develop and test new geothermal reservoir engineering techniques.

The Stanford Geothermal Program was initiated under grants from the National Science Foundation in **1972** and continued under contracts from the Energy Research and Development Administration and, since **1977,** the Department of Energy. This publication is the Sixth Annual Report to the Department of Energy under contract

DE-AS03-80SF11459 (previously DE-AT03-80SF11459) which was initiated in fiscal year 1981. The report covers the period from October 1, 1985 through September 30, 1986. The Injection Technology activities are now separate from the Reservoir Technology activities and are presented in the Second Annual Report to the Department of Energy under contract DE-AS07-841D12529.

The successful completion of the Stanford Geothermal Program's objectives depends on significant help and support by members of federal agencies, the geothermal industry, national laboratories, and university programs. These are too many to acknowledge by name. The major financial contribution to the Program is the Department of Energy though its San Francisco and Idaho offices. We are most grateful for this support and for the continued cooperation and help we receive from the agency staff.

INTRODUCTION

The Injection Technology portion of the Stanford Geothermal Program in fiscal year 1986 was divided into several **task** areas, as defined in the Department of Energy contract DE-AS07-84ID12529. Three of the **task** areas were carried out within tha Petroleum Engineering Department and one within the Civil Engineering Department.

The injection of spent geothermal fluids has rapidly become a pressing research problem in reservoir engineering. Although injection has the potential of maintaining, reservoir pressure, world-wide experience from liquid-dominated fields indicates that rapid breakthrough can occur. The cold fluid short-circuits from the injection well to production wells along high conductivity fractures. A powerful method for investigating such flow is the use of external tracers. A balance between theoretical and experimental studies **is** sought. One goal **is** to develop new methods **of** observing reservoir behavior and to test these new methods in the field.

2. INJECTION TECHNOLOGY

The major emphasis in this task is development of new techniques for predicting the behavior of injected cool separated brine through fractured geothermal reservoirs, The key to forecast the thermal breakthrough of injected water is to develop a better comprehension of both tracer behavior and its flow through fractured systems. Emphasis is placed on identifying the transport mechanism by a combination of theoretical, experimental and field test methods. The current project is broken down into three areas of activity. The activities include laboratory tracer studies, improvements in tracer test design, and tracer test interpretation.

2.1 Effect of Transverse Mixing on Tracer Dispersion in a Fracture

L. W. Bouett and R. N. Horne

The experimental work begun by ***Gilardi*** (1984) to investigate Taylor dispersion in a fracture was continued in the present work. The result of this work is a Master's Report[1]. Investigations into other possible physical mechanisms present in the laboratory model continued during the previous quarter. Of special interest is the role that variation in fracture width plays in the experimental determination of the fracture dispersion coefficient.

Laboratory investigations into the physical mechanisms of tracer dispersion and retention in a planar fracture were conducted. Iodide and chloride tracers were flowed in a fracture, first without obstructions and again with a nylon mesh to simulate transverse mixing and to provide closed pore volume. Tracer was flowed as a step input across the fracture width. Tracer concentration within the fracture was measured

[1] Bouett, L. W.: "The Effect of Transverse Mixing on Tracer Dispersion in a Fracture", Masters Report, Stanford University (1986).

at a series of electrodes embedded in one of the confining plates. The measurements were controlled by and stored in a microcomputer. The theoretical response for linear Taylor dispersion was matched to the data to determine the non-linear parameters velocity and dispersivity (Fig. **2.1.1).** Several data sets were fitted using the derivative of the analytical solution for a step input (Fig. **2.1.2),** which is the analytical solution for a spike. Despite noisy data it was observed that the presence of the nylon mesh did not significantly change the dispersivity (Fig. **2.1.3).** Proposals **are** presented to improve the quality of the data acquired.

Several experimental runs were performed in which the injected tracer was colored with food coloring. This was done to provide a visual means of tracking the tracer front. Unfortunately the color contrast was not sufficient for photographic film to record the event; however it was observed that there was some skewing of the front, presumably due to a variation in thickness of the fracture width. When the fracture width was adjusted and another run made it was observed that the skewing of the front had been greatly reduced. Analysis of the results of the two **types** of runs (slightly skewed front versus nearly even front) continues; however preliminary analysis seems to imply statistically similar results. There is still noise in the data which tends to obscure small variations in the arrival time of the tracer front at a particular electrode.

Analysis of recent runs should be completed before a legitimate comparison with previous results will be fully known. In addition, attempts continue to produce good visual contrast between the two flowing fluids so that a photographic record may be obtained.

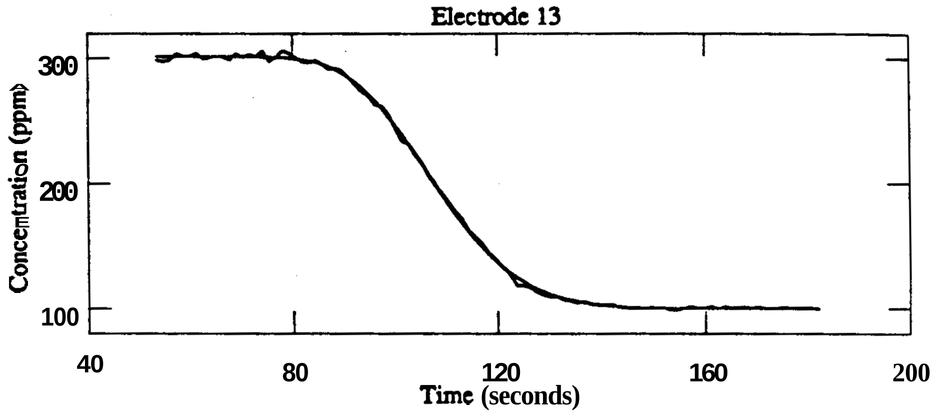

Figure 1. Match of the data for a **step** input.

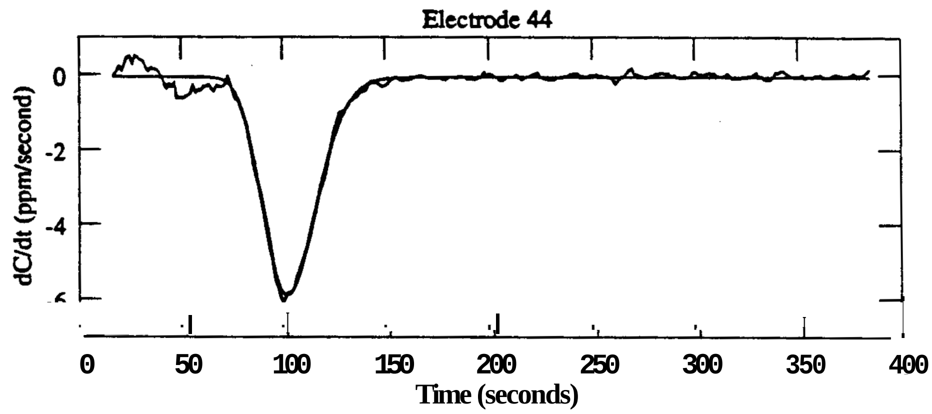

Figure **2.** Match of the derivative of the data.

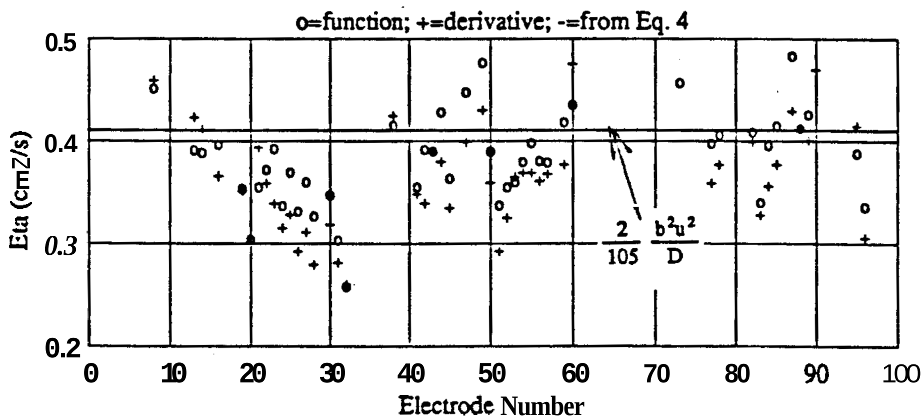

Figure **3.** Comparison of the data to derived expression for η.

2.2 Injection Through Fractures

R. Johns and R. N. Horne

The objective of this study is to perform laboratory trac r tests n fractured cores, analyze the tracer test data using analytical tracer models and relate the model results to the lab results (Fig. 2.2.1). The mechanisms controlling tracer movement and the effects of reservoir properties on tracer transport can then be studied in the controlled lab environment. The advantage of a lab test is that reservoir description is precisely known. In a field tracer test there is always a large uncertainty in geologic description.

The work this past year has been primarily experimental. A great deal of effort was spent in the early stages defining lab procedures, equipment and data acquisition systems which realistically emulates an actual field tracer test and provides adequate data for interpretation. The lab techniques were defined through a number of experimental *dry* runs and in the third quarter all procedures were in place. Tracer tests were then conducted during the fourth quarter on both fractured and unfractured core samples under a variety of flow conditions. At this point the laboratory effort has been successfully completed and future work will address analysis of the past year's' experimental results.

Experimental Procedures

Initial test procedures were similar to those employed in a field test. Tracer was introduced at the core inlet and samples **of** the core effluent were collected downstream of the flow control valve at the core holder outlet. These discrete samples were subsequently analyzed to determine tracer concentration. Unfortunately, this simple method which works well in field tests was not suited to lab tests. The volumes of core effluent are small **(2-4** ml/min) and the minimum sample size necessary for tracer

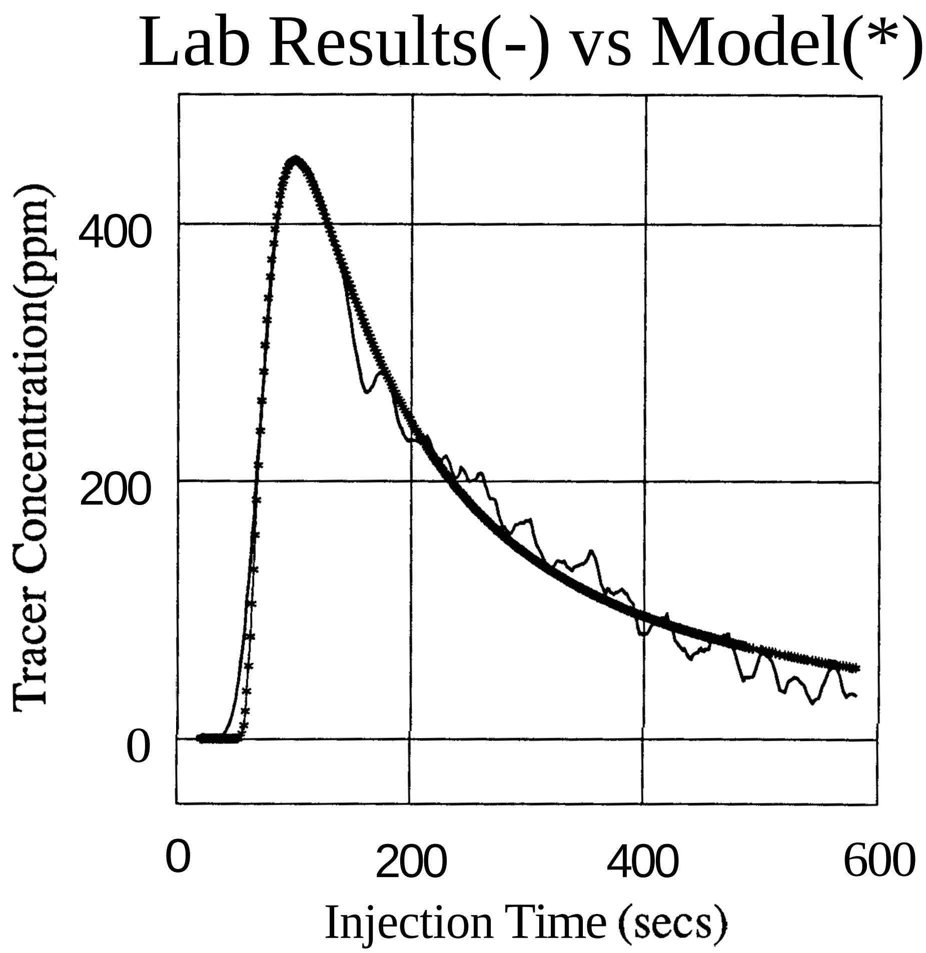

Figure **4.** Laboratory results vs. model results.

detection methods is large **(2-3** ml/min). Thus, only one data point was possible every minute and the data point represented a time average -rather than instantaneous- concentration for that minute. **As** the transient **period** of tracer response is only 3-4 minutes, this method could not sufficiently resolve the shape of the transient.

Using the previous lab experience to define our test requirements, new procedures were developed. An electrode was inserted in the flow stream to measure the resistivity of the fluid at the valve exit. The resistivity measurements, which correlate to tracer concentration, could be taken at a very high frequency providing instantaneous -rather than time average- data. Initial runs using a mini-computer for control and data storage and a microprocessor for A/D conversion and interface provided nearly continuous data collection **(4-5** data points/second if desired).

Two final procedural improvements were made. An additional electrode was inserted at the core inlet to detect tracer entering the core. This "quality control" measure will detect any problems introducing tracer to the core which could cause an erroneous response at the exit. Also, the outlet electrode was moved directly downstream of the core to avoid any mixing caused by the control valve at the flowstream exit. This final system was tested for repeatability in several *dry* runs and performed well. The data was sufficient for both real time and time derivative methods of analysis, as shown in Figs. **2.2.2** and **2.2.3.**

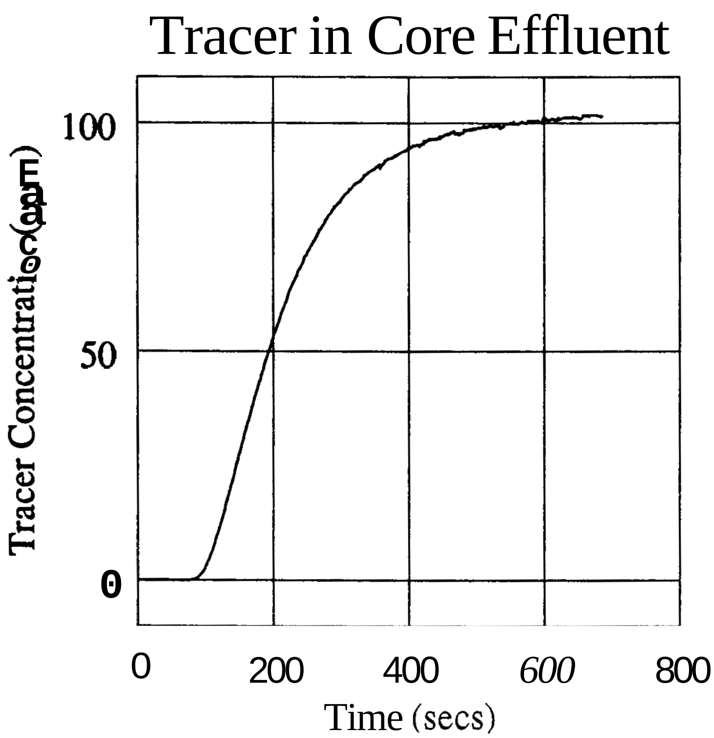

Figure *5*. Tracer concentration in core effluent.

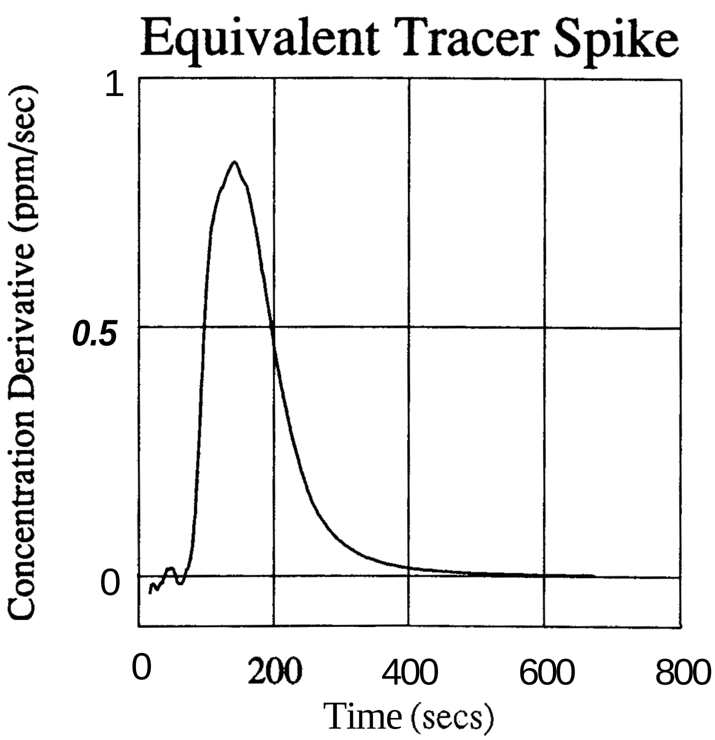

Figure 6. Equivalent tracer spike.

Experimental Results

During the final quarter over ten tracer tests were conducted on fractured core samples. Also, several experiments were made on unfractured cores to provide a reference or contrast case for comparison with the results from the fractured core. The fractured samples were tested over a wide range of injection rates. The rates, which range from 0.1-10.0 ml/min, will provide velocities that cover the wide range seen in field tests. In addition, velocity effects on tracer transport mechanisms can be studied.

Future Work Plans

Currently, the work effort has shifted from the laboratory. The future study program is to analyze and interpret the experimental results gathered to date. To complete the study, several mathematical tracer flow models will be used to model the experimental results. Using the model which best replicates test data, the model variables will be evaluated for comparison with the physical core properties. Finally, the model will be tuned to provide estimates of physical properties which match core observations.

2.3 Optimization of Injection Scheduling

J. Lovekin and R. N. Horne

Developers of geothermal fields typically choose a configuration for injection wells after a number of development wells have already been drilled. Injection is used as a means of (1) disposing of waste brines, (2) maintaining reservoir pressure, and (3) increasing the thermal recovery from the reservoir rock. However, because of the highly fractured nature of most geothermal reservoirs, injection can lead to premature breakthrough of cooler injected fluids at producing wells. The goal of the current work is to provide a systematic method by which operators can decide on both the configuration of injection wells and the allocation of injection rates given an existing set of wells.

The proposed approach involves optimization algorithms from operations research to the results of tracer tests. The approach assumes that a rapid transit of tracer between two wells correlates with a high likelihood of premature thermal breakthrough. Since fractures in the reservoir make it difficult to model actual flow paths, the approach considers each well to have a potential direct connection with every other well in the field. In effect, the geothermal reservoir is treated as a network of pipes, with different pipe diameters corresponding to the ease with which breakthrough occurs between each well pair. The problem of minimizing the potential for breakthrough is thus analogous to that of distributing water to various points in a pipe network while minimizing the total head loss.

Problem Formulation

In the formulation of injection optimization as a linear programming problem, the likelihood of thermal breakthrough is called the field's breakthrough potential, Φ_b. It is treated as an objective function to be minimized, subject to constraints which include (1) achieving a specified total field injection rate, Q, and (2) staying within a maximum feasible injection rate, q_{imax}, for each individual well, i. In the preliminary approach used to date, Φ_b has been defined as the summation of the product of injection rate (q_i) and the apparent tracer velocity (v_{ij}) for every well pair, i, j. This definition makes intuitive sense, because higher injection rates and faster apparent tracer velocities should produce rapid thermal breakthrough. Using this definition, the formulation of the linear programming problem is as follows:

$$\text{Minimize} \quad \Phi_b = \sum v_{ij}\, q_i$$

$$\text{Subject to} \quad \sum q_i \le Q$$

$$q_i \le q_{imax}$$

$$q_i \ge 0$$

In this formulation, the injection rate for each well, q_i, is the decision variable, and the coefficients of q_i in the objective function (v_{ij}) are presumed to be inferabld from tracer tests. It is also presumed that Q is known (based on anticipated rates of brine production or estimated make-up water requirements for pressure maintenance) and that q_{imax} is known for each well (based on injectivity testing). This linear programming problem may be solved by the Simplex method. In the resulting solution, the optimal injectors and the rates into each well are determined by positive values **of** q_i, while wells with q_i equal to zero should be retained as producers.

This formulation of the problem as a linear program is considered preliminary, because it is not clear that the product of tracer velocities and injection rates should be linear. If a dependence of v_i on q_i can be quantified, it may be appropriate to apply non-linear optimization techniques to minimize breakthrough potential. Furthermore, it may be desirable to refine the definition of breakthrough potential by including other parameters from tracer tests, such as the peak tracer concentration, the degree of dispersion in the tracer profile, or differences in pressure and elevation between injectors and producers.

Accomplishments

Work on this project began in Autumn Quarter, 1985. To date there have been four main accomplishments. First, a literature search was performed on applications of optimization algorithms from operations research to petroleum and geothermal reservoir engineering. This search used the DOE Energy Database and revealed that there has not been much previous work on the subject. Second, the problem of optimizing geothermal injection was formulated on a preliminary basis as a linear programming problem. To do this, the researcher took a course in linear programming theory from the Operations Research Department during Winter Quarter. The problem formulation and its limitations are described in the following paragraph. Third, a commercial computer program for solving linear programming problems by the Simplex method was reviewed and applied to several sample problems. Fourth, data from three 1979 tracer tests in the Wairakei Geothermal Field were reviewed. Distances between each tracer injection well and the surrounding monitoring wells were tabulated, and the tracer profiles were inspected to identify the exact time to first arrival for each injector/monitor pair. These distances and transit times permit a quantification of the potential for thermal breakthrough between different wells in Wairakei and will provide an actual data set for use in the refinement of an injection optimization routine.

Future Work

The principle tasks remaining in the project are as follows. First, the preliminary

2.4 Boundary Integral Equation Method for the Solution of Fluid Displacement Problems

J. Kikani and R. N. Horne

Computing time and storage requirements are a major problem in any large scale three dimensional simulation study of a complicated reservoir aquifer system. These requirements are solution oriented, that is it depends on the way you discretize and treat your problem domain. Finite difference and finite element methods are quite popular and widely used in oil and geothermal industries. These techniques require the discretization of the whole problem domain into a number of grid blocks accommodating the boundaries. Finite difference methods have problems in handling complicated geometries whereas finite elements conform to such in a better way. Both of the above techniques though are quite storage as well as computing-time intensive.

A relatively new technique known as the boundary integral element method BIEM is more conducive to our needs in terms of handling complicated geometries as well as low computational time. The major advantage of this method comes from the fact that for a 3-D problem only the boundary surface of the domain need be discretized in planar elements as contrasted with the other two techniques which need the whole domain of interest to be discretized. Boundary element technique is compatible with any kind of system geometry as well.

Current Status

As extensive literature search was done in groundwater hydrology and related areas where some work of this nature has been done. We then started with the problem formulation for the two-dimensional steady flow of a single fluid in porous medium, which is the 2-D Laplace's equation. With the aid of Green's second identity and the free space Green's function for Laplace's equation this problem was transformed into a difference of two integrals over the boundary of the problem domain. The governing equation was then discretized over the boundary of the region. Computer programs were written to evaluate the flow potentials and velocities inside the region. Time stepping and front tracking routines were included. The program was then used on a variety of problems to check its validity.

As the next step well singularities were included in the program so that any number of wells could be handled within the program. Singularity programming was done to accomplish this since the flow potential contribution due to the presence of sources and sinks is well established. The program has been tested on a variety of cases. These are:

1) Flow between two parallel plates
2) Flow between two parallel plates with a wedge intrusion in the form of a singularity
3) Flow through the parallel sides of a trapezoid (Figure 2.4.1)
4) Radial flow with and without a source and linearly spaced boundary elements
5) Radial flow with and without a source and exponentially spaced boundary elements
6) Irrotational flow in a corner (Figure 2.4.2)

The results obtained have been compared to the analytical solutions and they match quite well.

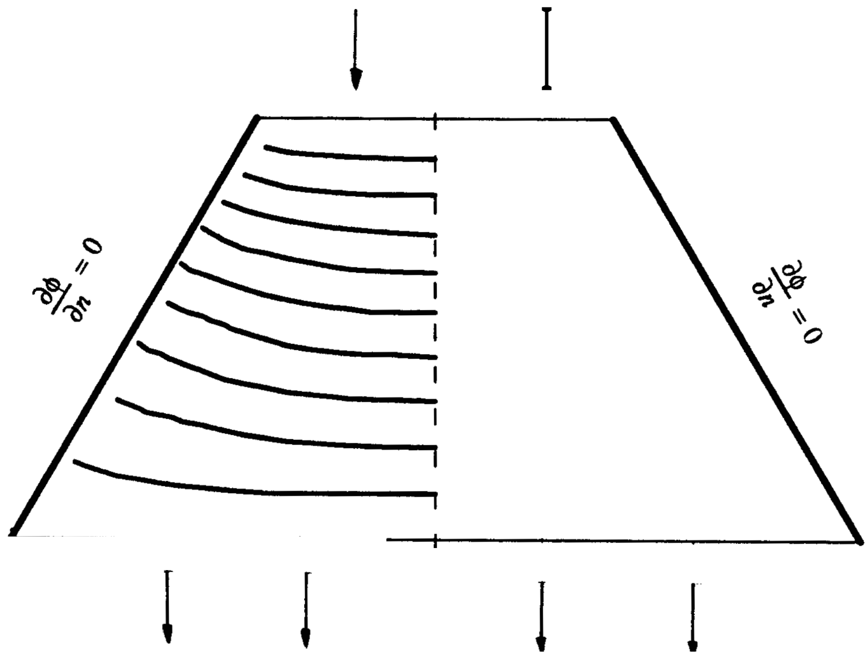

Figure 7. Steady flow across the parallel sides of a trapezoid.

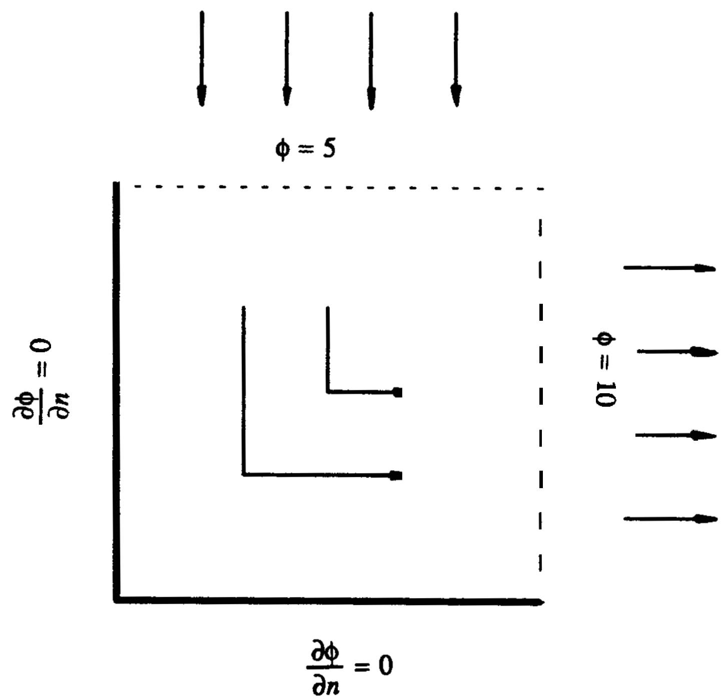

Figure 8. Irrotational flow in a corner.

Of special interest is the problem of irrotational flow in a corner wherein one of the boundary conditions is such that it gives rise to an infinite flux at a point (singular point). In order to avoid it, we skewed the boundary slightly to include a no flux segment instead of the singular point. This gave **us** very **good** results which were within 0.1% of the analytical results with a fairly small number of boundary elements. These results were much better than those obtained by Numbere et al., who had a maximum error of **8.3%** at some points.

Future Work

Currently a computer program is being developed to incorporate two fluids in the system. Sources and sinks could be handled adequately. **A** front tracking routine would be added, and non-unit mobility ratio cases will be tested extensively.

2.5 Activable Tracers

C. Chrysikopoulos and P. Kruger

During the contract year, efforts were successfully concluded on evaluating the thermal stability and adsorption properties of indium, chelated with EDTA and NTA to provide high sensitivity for enhanced reservoir tracer testing. Earlier efforts had shown that indium, among a group of four activable tracers suitable as high precision tracers in geothermal fluids, was the most promising for neutron activation and gamma-ray spectroscopy measurement. The chelated form was selected as the best means to enhance solubility in the difficult high-temperature rock-fluid geothermal environment, but uncertainty existed about its thermal stability and persistence in geothermal reservoirs during the life of a tracer flow test.

The chelated tracers, InEDTA and InNTA, were exposed to geothermal reservoir temperatures ranging from 150 to 240 C in special gold-lined vessels (provided by the USGS, Menlo **Park)** to remove material interferences in the thermal stability tests. Experimental stability data were obtained by activating samples in the 2 ug Cf-252 neutron source (provided by the Stanford Linear Accelerator Center). The experimental results were shown in Figures **2.5.1** and **2.5.2.** The data indicate that indium, chelated with EDTA, could be thermally stable in geothermal reservoirs at temperatures up to about 200°C for at least **20** days.

The tracer was also tested for adsorption non-conservation by interaction with ground graywacke sandstones, typical of rocks in geothermal reservoirs. The resulting data are shown in Figure 2.5.3. The data indicate that the chelated form of indium is chemically stable, even in the presence of iron with a stronger EDTA chelate formation constant, and that the time limit on its use **is** influenced essentially by thermal degradation.

The data and conclusions of these experiments underwent Technology Transfer by means of (1) presentation at the 1lth **SGP** Workshop on Geothermal Reservior Engineering*; (2) the Engineer Thesis of Costas Chrysikopoulos**; and ***(3)* a** SGP Technical Report***. The latter manuscript has been condensed and submitted for achival publication.

Other activities included the contact with the Cornwall Hot Dry Rock group in England to assist with the interpretation of the first application of indium EDTA-chelated activable tracer in a geothermal reservoir tracer test. The experiment was **run** in May, **1986** and the samples were shipped to the Harwell National Laboratories for neutron activation and radiation measurement. It is anticipated that the results of the Cornwall experiment will be made available to the **U.S.** geothermal community.

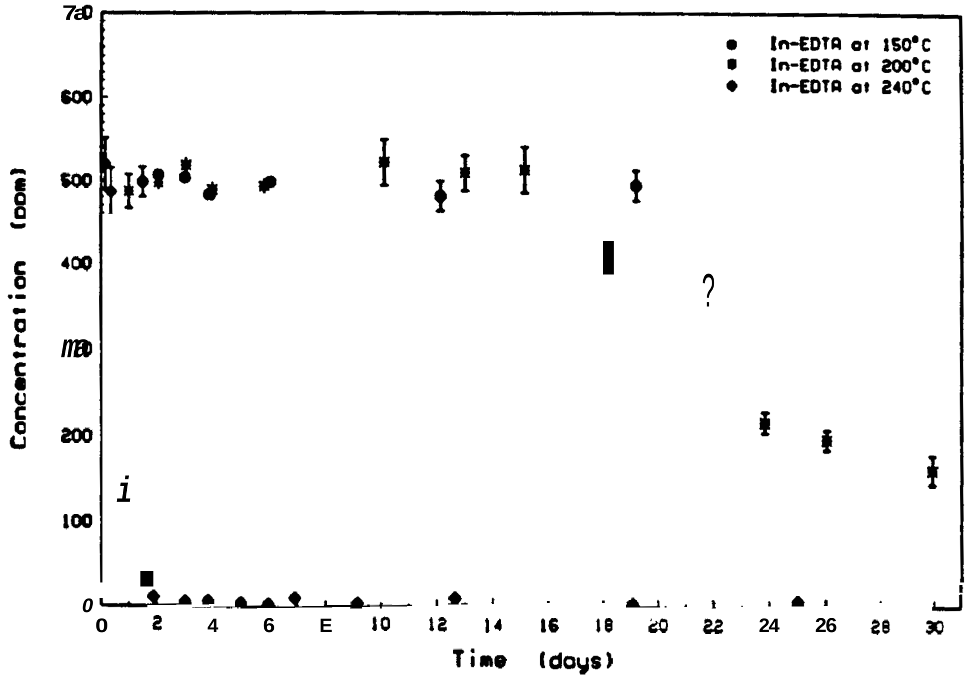

Figure **2.5.1** Effect of temperature and time on InEDTA stability.

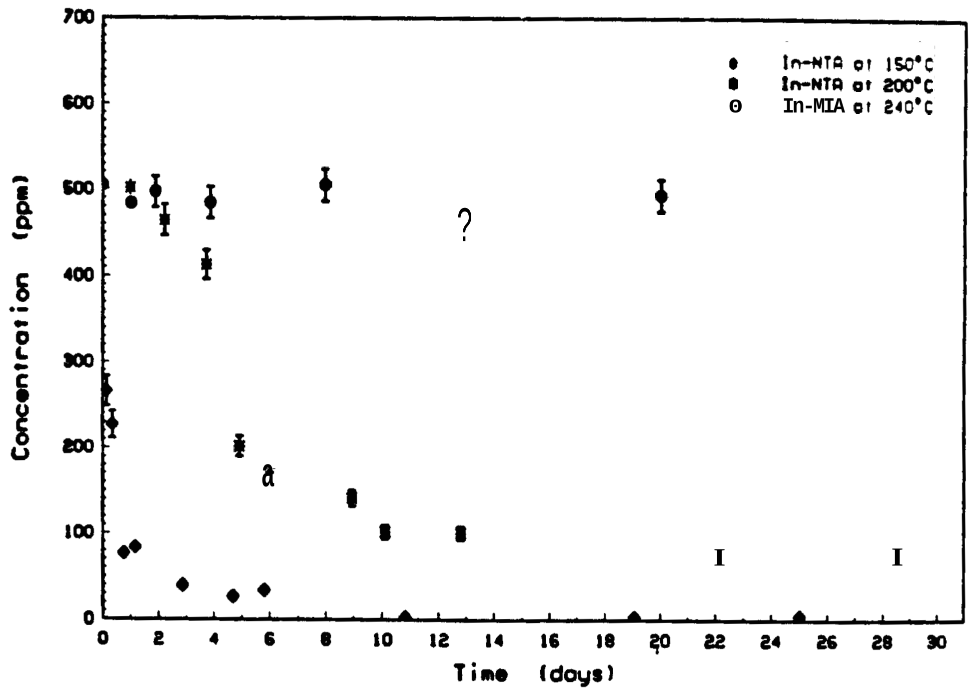

Figure **2.5.2** Effect of temperature and time on InNTA stability.

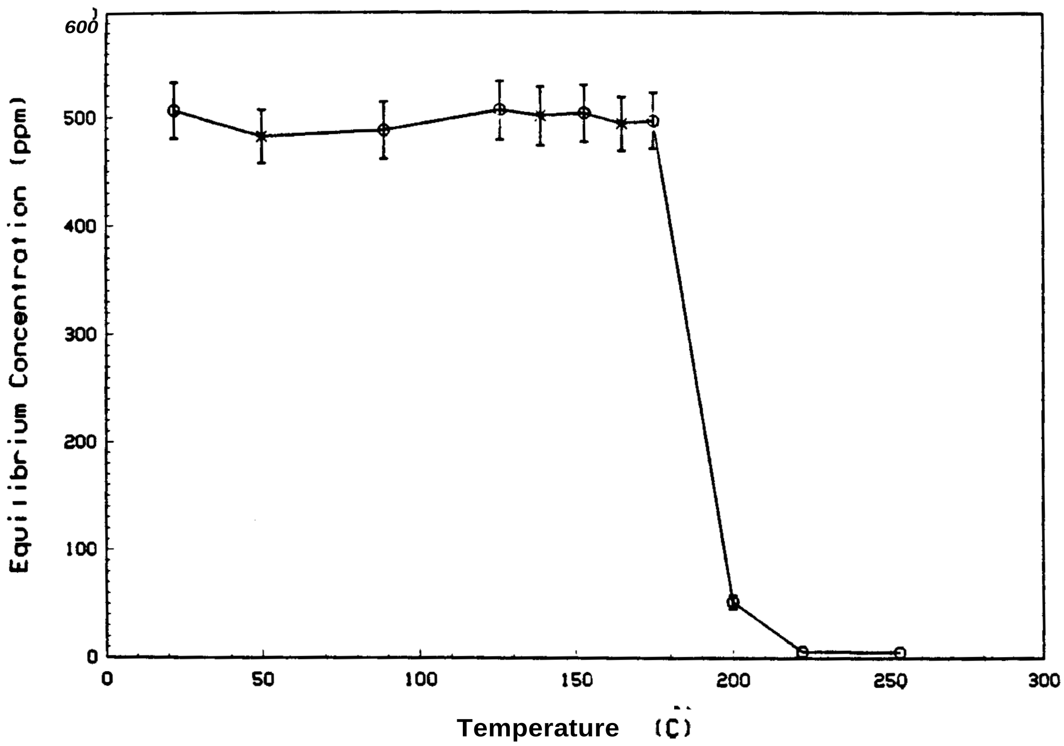

Figure **2.5.3 Effect of T(°C) on InEDTA adsorption onto Graywacke sandstone.**

Further analysis was made of the potential for a field laboratory facility using a mobile neutron generator and radiation detection eqiupment for on-site measurement. The high cost of a large isotopic neutron source and regulatory restrictions on radioactive materials make this a difficult problem. Attention is also being given to the potential of the rare gases (chemically inert) Xenon and Krypton, in activable or stable form as clathrates, as useful high-sensitivity tracers for vapor-state fluids in vapor-dominated or two-phase geothermal reservoirs, The potential for such tracers is enhanced by their chemical inertness, low background in geothermal fluids, and sensitive methods for measurement, such as radiation spectroscopy and nuclear magnetic resonance.

* C. Chrysikopoulos and P. Kruger: "Thermal Stability **of** Chelated Indium Activable Tracers", Proceedings, 11th Annual Workshop on Geothermal Reservoir Engineering, SGP TR 93, January, 1986.

** C. Chrysikopoulos, Engineering Degree Thesis, School of Engineering, Stanford University, 1986.

*** C. Chrysikopoulos and P. Kruger: "Chelated Indium Activable Tracer for Geothermal Reservoirs", SGP Technical Report TR 99, June, 1986.

3. TECHNOLOGY TRANSFER

The Eleventh Workshop on Geothermal Reservoir Engineering was held at Stanford University on January 21-23, 1986. The attendance was at the same level as the previous year with about 144 registered participants. Ten foreign countries were represented: Canada, England, France, Iceland, Indonesia, Italy, Japan, Mexico, New Zealand and Turkey.

The purposes of the Workshop are to bring together researchers, engineers, and managers involved in geothermal reservoir studies and development, and to provide for prompt and open reporting of progress and the exchange of ideas. There were 38 technical presentations at the Workshop which were published as papers in the 11th Proceedings volume and one presentation was not published. Six technical papers not presented at the Workshop were also published in the Proceedings volume. In addition to these 45 technical presentations or papers, the introductory address was given by J. E. Mock from the Department of Energy.

Weekly seminars were held during the academic year on geothermal energy topics. Appendix A includes a list of the seminar topics for autumn, winter and spring quarters. These Seminars are attended by Stanford researchers and personnel of the U.S. Geological Survey and geothermal companies in the San Francisco area. The seminars are also attended by representatives of geothermal companies in Santa Rosa.

Results of geothermal research at Stanford University were presented at several professional meetings during the year and issued. Appendix D includes a list of these publications and reports. The contents of the Proceedings of the Eleventh Workshop on Geothermal Reservoir Engineering are included in Appendix B.

APPENDIX A: Seminar Schedules

STANFORD GEOTHERMAL PROGRAM
STANFORD UNIVERSITY
STANFORD. CALIFORNIA 94305

Paul Kruger
Civil Engineering Dept.
Terman Bldg., Room M-19
(415) 497-4123 or 497-4744

S E M I N A R   S C H E D U L E

Autumn Quarter 1985	Room 124, Noble Building	Thursday, 1:15-2:30 p.m.
Date	**Title**	**Speaker**
Sept. 26	SGP Student Meeting	
Oct. 3	Tracer Dispersion Experiments	Roland N. Horne SGP
Oct. 10	Linear Boundary Detection in a Single Interference Test	Jonathan Leaver and Avrami Sageev SGP
Oct. 17	Application of the 1-D Linear Heat Sweep Model	Paul Kruger SGP
Oct. 24	Reservoir Testing	Henry J. Ramey, Jr. SGP
Oct. 31	No Seminar IIE-SGP Joint Meeting	
Nov. 7	Hydrothermal Alterations in Geothermal Systems	Dennis Bird Geology
Nov. 14	Geological and Mineralogical Evaluation of Surface Geothermal Manifestations	Y. Yamaguchi and Ronald Lyon AES
Nov. 21	Study of Natural Fractured Systems with Digital Borehole Televiewer Analysis	Mark Zoback Geophysics
Nov. 28	Thanksgiving Recess	

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SEMINAR SCHEDULE

Winter Quarter 1986 | Room 124, Noble Building | Thursday, 1:15-2:30 p.m.

Date	Title	Speaker
Jan. 9	SGP Student Meeting	
Jan. 16	SGP Staff: Workshop Preparation	
Jan. 23	Eleventh Annual SGP Workshop (Jan. 21-23)	
Jan. 30	Review of Seventh NZ Workshop	Abraham Sageev SGP
	Review of IIE-SGP Meeting	Frank G. Miller SGP
Feb. 6	Geologic and Fluid-Flow Characteristics of the Cerro Prieto Geothermal Field	Susan Halfman Lawrence Berkeley Lab.
Feb. 13	Update on Operations at The Geysers	Joel Robinson Union Oil Company,
Feb. 20	Chevron Geothermal Activities in Nevada	Jerry Epperson Chevron Resources
Feb. 27	Environmental Aspects of Power Generation at The Geysers	Ron Suess PGCE
Mar. 6	Temperature Drop Model for Two-Phase Flow in Wellbores	Don Michels

STANFORD GEOTHERMAL PROGRAM
STANFORD UNIVERSITY

STANFORD. CALIFORNIA 94305

John R. Counsil
Petroleum Eng. Dept.
Mitchell Bldg., Room 360
(415) 723-1218 or 723-4746

S E M I N A R   S C H E D U L E

Spring Quarter 1986 | Room 124, Noble Building | Thursdav. 1:15-2:30 p.m.

Date	Title	Speaker
April 10	Organizational Meeting	SGP Faculty
April 17	No Seminar (Affiliates Meeting)	
April 24	Use of the Hurst Simplified Method to History Match the Performance of Five Geothermal Fields	Dave Brock Petroleum Engineering
May 1	Injection Tracer Backflow Tests	Ibrahim Kocabas Petroleum Engineering
May 8	Tracer Dispersivity in Fractures	Larry Bouett Petroleum Engineering
May 15	Linear Skin Boundaries	Anil Ambastha Abraham Sageev Petroleum Engineering
May 22	Adsorption of Steam on Geothermal Cores	Jeralvn Luetkehens Paul Pettit Petroleum Engineering
May 29	Computer Generation of Type Curves Interference Testing with Boundaries	Brenna Surritt Abraham Sageev Petroleum Engineering

APPENDIX B: Table of Contents Proceedings Eleventh Workshop

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Modeling

Geosciences

Discussion on Maturing Geothermal Fields

Field Studier

Logging

• This work is available as a Stanford University, Department of Geology Master's Report, "Solution Mineral Equilibria in the Coso Geothermal System," B. Bishop, 1983.

APPENDIX C: Participants in the Stanford Geothermal Program

Faculty	Reservoir Technology Research Assistants (and others)
Henry J. Ramey, Jr.	Dave Brock
Paul Kruger	James W. Lovekin
Roland N. Home	Jeralyn Luetkehans
Frank G. Miller	Tom Lyons
William E. Brigham	Steve Lamb
Abraham Sageev	Beatriz Salas
John Counsil	Anil Ambastha
	Costos Chrysikopoulos

APPENDIX D: Papers Presented and Published 1985-86

1. Barua, J., Home, R. N., Greenstadt, J. L., and Lopez, L.: "Improved Estimation Algorithms for Automated Type Curve Analysis of Well Tests", paper SPE 14255, Proceedings, 1985 SPE Annual Conference and Exhibition, Las Vegas, NV, Sept 23-25, 1985.
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