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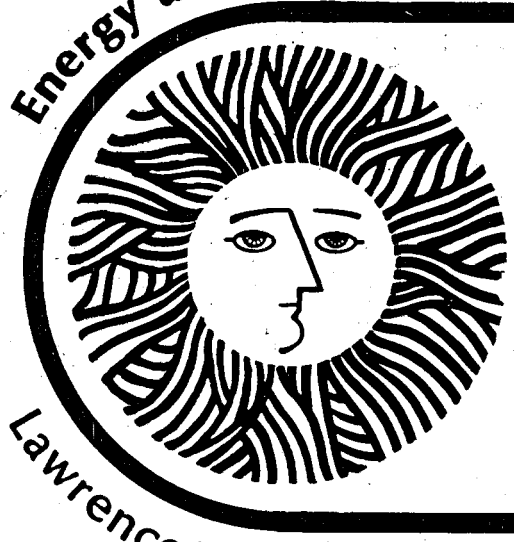
Energy and Environment Division



National Geothermal Information Resource Annual Report, 1977

Sidney L. Phillips

April 19, 1978

Lawrence Berkeley Laboratory University of California/Berkeley

Prepared for the U.S. Department of Energy under Contract No. W-7405-ENG-48

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National Geothermal Information Resource

Annual Report, 1977

by

Sidney L. Phillips
Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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Introduction

The national effort to develop and utilize geothermal energy has resulted in an enormous growth of geothermal data. However, the needed data important to geothermal research and development is widely scattered, difficult to access, and largely unevaluated. Thus, an important task of the geothermal energy development effort is to collect, evaluate and disseminate geothermal data in a timely manner and thereby avoid unnecessary and expensive duplication of effort.

The National Geothermal Information Resource (GRID) of the Lawrence Berkeley Laboratory is chartered by the U.S. Department of Energy (DOE) to provide critically evaluated data and other information for the development and utilization of geothermal energy (Ref. 1). Included are both site dependent and site independent information related to resource evaluation, electrical and direct utilization, environmental aspects, and the basic properties of aqueous electrolytes.

The GRID project is involved in cooperative agreements for the interchange of information and data with other organizations. There are currently three U.S. data centers working to implement the collection and exchange of information on geothermal energy research and production: the DOE Technical Information Center (TIC), Oak Ridge, the GEOTHERM database of the U.S. Geological Survey in Menlo Park, and the GRID project. See for example Reference 2. The data systems of TIC, GEOTHERM and GRID are coordinated for data collection and dissemination, with GRID serving as a clearinghouse having access to files from all geothermal databases including both numerical and bibliographic data. GRID interfaces with DOE/TIC for bibliographic information and with GEOTHERM for certain site-dependent numerical data. The GRID program also maintains interfaces with relevant data efforts; for example, the National Standard Reference Data System for collection and evaluation of basic numerical data.

Computer programming is via the Berkeley Data Base Management System (BDMS) for creating, maintaining and accessing both bibliographic and numerical data. Bibliographic records are readily retrieved from the GRID computer files using BDMS by specifying either one parameter such as the geothermal site, or a combination of parameters such as the geothermal site, the date and designated data measurement. Standards for interchange of bibliographic data are patterned after that of the International Atomic Agency's International Nuclear Information System (INIS). Utilization of the INIS format ensures compatibility with other INIS styled computer centers, thereby promoting the active interchange of data with other groups (Ref. 3, 4). Data is available in the form of bibliographic compilations, numerical tables, or graphical displays disposed to paper, film or magnetic tape. In addition to the maintenance of a current geothermal database, the program is responsible for literature reviews and critical evaluations of the status of data by the technical staff.

The program is organized into four principal areas: (1) basic geothermal energy data; (2) site-dependent data for both electrical and direct utilization; (3) environmental aspects, and (4) data handling development. The four sections of the report which follow are organized in this way.

Attachment I is a news-release and order which was mailed to over 200 geothermal specialists in 1977. Over 50 print-outs containing both bibliographic and numerical data were provided either gratis or by request. Attachment II and Attachment III contain news items about GRID which were published in 1977 and in early 1978.

References

1. S.L. Phillips, J.A. Fair, F.B. Henderson, R.G. Trippe, "National Geothermal Information Resource", Proceedings, 10th Annual Meeting, Geoscience Information Society, Oct. 21, 1975, Salt Lake City, UT, vol. 6, page 52, 1976.

2. S.L. Phillips and J.R. Swanson, "Application of a Geothermal Computer File System to Chemical Geothermometers", LBL-5915, January 1977.

3. J.J. Herr, S.L. Phillips, S.R. Schwartz, T.G. Trippe, "Standards for Multilateral & Worldwide Exchange of Geothermal Data", Mathematical Geology, vol. 9, no. 3, p. 259 (1977).

4. S.R. Schwartz, "GEODOC - The GRID Document File, Record Structure and Data Element Description", LBL-4432, R-1, 1978 (in preparation).

Attachment I

National Geothermal Information Resource
Lawrence Berkeley Laboratory, 90-3117
University of California
Berkeley, CA 94720 USA
Tel. (415) 843-2740 Ext. 5980
FTS 451-5980

December 1977

COMPUTER SEARCHES AVAILABLE FROM THE GRID DATABASE

The National Geothermal Information Resource (GRID) of the Lawrence Berkeley Laboratory is sponsored by the U.S. Department of Energy (DOE) to develop a comprehensive compilation of worldwide literature and data designed to assist in the research and development of geothermal energy for both electrical and non-electrical uses. Included in this compilation is site-dependent and site-independent material related to geothermal exploration, reservoir utilization, physical chemistry, as well as environmental, legal, and economic aspects of geothermal energy. GRID maintains a computerized database which provides the basis for in-depth literature reviews and critical evaluations of the status of data by the technical staff. In addition, computer-produced bibliographies and data tabulations are generated from the databases for distribution at a fixed cost of $19 for DOE users and $25 for non-DOE users per search.

Information in the GRID files includes the following:

EXPLORATION considers resource data including geological, geochemical, and geophysical methods, as well as drilling, resource assessment, and land-use factors involved in locating and evaluating high temperature geothermal resources.

ENVIRONMENTAL considers aspects to the air, land, and water environments of geothermal energy utilization: subsidence, hydrogen sulfide.

PHYSICAL CHEMISTRY deals with the basic thermodynamic and transport data at elevated temperatures and pressures of sodium chloride and other salts.

UTILIZATION encompasses the development and production of a geothermal reservoir for both electrical and non-electrical uses: hot water (brine) transport; space, process, and agricultural heating; corrosion, erosion, and scaling.

NUMERICAL DATA contains site-independent and site-dependent tables.

Please specify your literature and data requests in detail to avoid receiving extraneous information. Examples of requests:

1. Please send a listing of geophysical measurements for the Mono-Long Valley area from 1974-1976.
2. We would like a compilation of numerical data on the viscosity of NaCl solutions from 50°C to 150°C.
3. Please send a listing of references studying the toxicological effects of H_2S to vegetation from 1975 to 1977.
4. Which organizations are involved in corrosion and scaling control for geothermal brines?

NATIONAL GEOTHERMAL INFORMATION RESOURCE ORDER FORM

Please send the following:

_____

_____

_____

(___) Information on updates

(___) Check _____ (___) Purchase Order #_____

Name_____

Address_____

_____

Mail to:

National Geothermal Information Resource
LAWRENCE BERKELEY LABORATORY
University of California
Berkeley, California 94720 USA

Attachment II

NSRDS **Reference data report**
an informal communication of the National Standard Reference Data System
formerly NSRDS NEWS

Office of Standard Reference Data | U.S. DEPARTMENT OF COMMERCE | National Bureau of Standards | JUL/AUG 1977

Diffusion in Metals Data Center series on copper alloys will be published as INCRA monograph

The International Copper Research Association (INCRA) has undertaken to print and distribute a monograph on Diffusion in Copper Alloys, a text made up of five articles which have appeared in the *Journal of Physical and Chemical Reference Data* from 1973 to 1976. The five articles were written by D. B. Butrymowicz, J. R. Manning, and M. E. Read of the Diffusion in Metals Data Center. The monograph will be part of the INCRA series on the metallurgy of copper and will be distributed to approximately 250 members of the Association with further open sales of 750 copies.

Diffusion Data Center Operations

The Diffusion in Metals Data Center, an information analysis center established in 1963, has grown from a one-person operation and several thousand documents in its early years to over 19,000 documents and a staff of four. The Center is located at the National Bureau of Standards in Gaithersburg, Maryland, within the Transformations and Kinetics Section of the Metallurgy Division, and is part of the National Standard Reference Data System. The objectives of the Center are to: serve science and industry by publishing critical analyses and evaluations of the world's published literature within its scope; to develop data evaluation procedures; and to answer technical inquiries from industry and the scientific community.

Users of the Diffusion in Metals Data Center can make use of an author file, or a materials index file, to locate hard copy documents in an open shelf, multitrack, color-coded document filing system

The output of the data center is concentrated on a thorough compilation and evaluation of diffusion data in selected alloy systems with an emphasis placed on commercially important metal systems. (Also see Reference Data Report, Vol. 1, #3, 1977).

(continued on page 4)

NEWS BRIEFS

Crystallography: Chapter 1 of the CODATA Directory of Data Sources for Science and Technology was published in June 1977. The directory is an updating and expansion of the International Compendium of Numerical Data Projects published by Springer-Verlag in 1969. Each successive chapter will be published as an issue of the CODATA Bulletin as it is completed. When all chapters are complete, they will be combined, after appropriate updating, into a single volume.

The format of each chapter includes the following sections:

A. International Data Projects
B. National Data Projects
C. Data Centers
D. Major Publication Series
E. Other Data Sources
F. Bibliographies

For further information, contact CODATA, 51 Boulevard de Montmorency, 75016 Paris, France.

The Sixth International CODATA Conference will be held 22-25 May 1978 in Taormina, Italy at the invitation of the Consiglio Nationale delle Ricerche. Users of data, as well as those involved in data compilation, data evaluation, and data handling are invited to submit papers on such subjects as

- data evaluation methodology
- compilation procedures
- critical evaluation

(continued on page 3)

COMMENT:

Richard F. Taschek
Associate Director for Research
Los Alamos Scientific Laboratory

Western culture has evolved into today's technological world by well-recognized historical pathways, by bumbling, and by sheer accident. In the last few decades there has appeared a recognition that mankind can no longer afford this luxury of laissez-faire in scientific/technological enterprises and must attempt to plan where it is going. It is thus necessary to project the nature of the future technological world, to examine its likely needs and generate the timely support to satisfy those needs.

Although the projections of various analysts will result in a fairly wide variety of model worlds, most will agree that there must exist what is commonly called a technology-base upon which each world edifice rests. A description of a generalized technology-base includes at least basic science, tool and device development, standards, and the compilation and evaluation of data. Note that these areas are highly interactive with each other and the user community, as represented by the designers, engineers, and regulators.

In addition to the purely technical users of the data base, one must now include those legal and political users concerned with the protection of the public weal as represented by the regulatory agencies. Their dependence on a fully evaluated, reliable data base is unprecedented in past history.

In industrial activities of high technical sophistication, the wave of the future is becoming visible with respect to the utilization of data. One need only consider the nuclear reactor designer's multigroup calculations which would be impossible without computer-handled evaluated data. More and more, this trend dominates aircraft design, chemical plant design, and begins to pervade the applied biosciences and other areas.

The sudden appearance of the energy crisis has introduced further complexities into the utilization of data, hopefully evaluated, because of the almost invariably multi-disciplinary requirements of the problems and programs. Thus, added to the conventional physical sciences data is the problem-oriented requirement for socio-economic, resource, demographic and other partially numeric, partially descriptive information. Dialogue between users and compiler/evaluators must determine optimized pathways for dissemination, storage, retrieval, and systems coding so that the information/data from various sources and disciplines can be fed into the calculational procedures at the appropriate nexus. Current understanding of these interactions is inadequate to provide a well-perceived path to what we may require for program execution one and two decades from now.

In many cases the scientific data itself is so voluminous that direct acquisition and handling by computer techniques are required. Often this information never appears even in reprocessed form in the conventional journal representations. Although conventional and traditional methods of information handling and problem solving are today unavoidable, there should be no hesitation to break with the past when it is indicated that this is the correct direction. It is only out of such willingness to make drastic changes that the stimulus for innovation itself derives.

It is likely that, particularly in the field of evaluated data handling, the printed page may no longer be a primary component of the designer/engineer/fabricators' world, other than for archival purposes. This carries implications of formal academic training of future users of data which is other than the conventional approach. The professional compiler/evaluators (and such do now exist) should take a lead role in formulating future directions envisaged here. □

NSRDS National Standard Reference Data System

Reference Data Report
Vol. 1, No. 4, JUL/AUG 1977

Reference Data Report is an informal communication of the National Standard Reference Data System (NSRDS) for the exchange of news and ideas about data centers, publications, meetings, and other activities related to data evaluation and dissemination. The NSRDS, which operates under the authority given in Public Law 90-396, was established to make critically evaluated data in the physical sciences available to the scientific and technical community. The NSRDS is administered and coordinated by the NBS Office of Standard Reference Data. Comments and suggestions on Reference Data Report should be addressed to:

S. P. Fivozinsky,
Office of Standard Reference Data,
National Bureau of Standards,
Washington, D. C.
20234

- mathematical modelling data requirements
- correlation, extrapolation, and estimation procedures
- data systems analysis
- machine techniques for storage, retrieval, and dissemination of numerical data

The title, together with a brief description of the contents of the paper, should be submitted as soon as possible, but not later than October 1, 1977, to Professor J. E. Dubois, Centre d'Informatique et de Documentation Automatique (CIDA), 1, rue Guy de la Brosse, 75005 Paris, France. Authors of papers will be notified before December 1, 1977, about the acceptance of their papers and will receive instructions on providing an abstract at that time. For further information, contact:

CODATA Secretariat
51 Boulevard de Montmorency
75016 Paris, France
Telephone: (01) 525-0496
Telex: 630553 F

The Committee on Data for Science and Technology (CODATA) and Unesco have just released a promotional booklet, "Obtaining Reliable Data." The booklet was prepared for international distribution by the CODATA Task Group on Accessibility and Dissemination of Data. Current distribution is an English text, but French and Spanish translations have been prepared as well.

The booklet is intended to encourage scientists, engineers, educators, and decision-makers (especially those in developing countries) to become more aggressive and more sophisticated in their acquisition and use of reference data. Relevance of reliable data to practical problems is stressed. The booklet urges users to become aware of national data efforts in many countries and to seek data guidance from the CODATA Secretariat in Paris, France.

The "Bibliography of High Pressure Research" can be obtained bimonthly on a subscription basis. It lists the authors, title, and journal reference of papers published in the field of high pressure research, and deals with many of the research areas in chemistry, physics, geology, engineering, and biology. The main emphasis is on work above one kilobar and includes both static and dynamic pressure studies. The bibliography covers current research on a worldwide basis. Annual subscription rates are $8.00 for U. S. and overseas surface mail, and $12.00 for overseas airmail. Remittance must be in the form of United States bank drafts for the indicated amount, drawn on a United States bank. Subscriptions or renewals should be addressed to:

High Pressure Data Center
5093 HBLL
Brigham Young University
Provo, Utah 84602 □

On-line bibliographical files available at Lawrence Berkeley Lab's National Geothermal Information Resource (GRID)

The following bibliographical files are on-line for computer search and retrieval

- Hydrogen Sulfide: pathways, effects, controls, and instrumentation for both the air and water environments
- Subsidence: effects, controls, monitoring, reservoir engineering, measurements, methodology
- Nonelectrical: hot water transport, space heating, process heat, metering, insulation materials
- Physical Chemistry: thermodynamic and transport properties of NaCl and other aqueous solutions
- Brine Chemistry: numerical data on selected hot water reservoirs in the U.S.
- East Mesa KGRA: geology, geochemistry, geophysics, hydrology, logging, reinjection, environmental aspects, and component test facility

The National Geothermal Information Resource screens the world literature on a continuing basis, retrieves and indexes papers relevant to the thermodynamic and transport properties of aqueous electrolyte solutions (e.g. NaCl, silica), extracts the numerical data and carries out critical evaluation leading to the publication of tables and status of data reviews. Emphasis is on extraction of numerical data needed for the development and utilization of geothermal energy resources. GRID develops critically evaluated numerical data for the basic properties of electrolyte solutions at elevated temperatures and pressures, and cooperates with other data centers on the properties of minerals and gases. □

New Publications

A Bibliography of Sources of Experimental Data Leading to Activity or Osmotic Coefficients for Polyvalent Electrolytes in Aqueous Solution by R. N. Goldberg, B. R. Staples, R. L. Nuttall, and R. Arbuckle, NBS-SP 485, 53 pp., 1977. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $2.00 (add 25% for other than U.S. mailing). Order by SD Catalog No. C13.10:485.

Thermodynamic Properties of Nickel and Its Inorganic Compounds by Alla D. Mah and L. B. Pankratz, U.S. Bureau of Mines Bulletin 668, 1976. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $2.70 (add 25% for other than U.S. mailing). Order by SD Catalog No. I28.3:668.

OOPS The above publication was incorrectly listed in Reference Data Report, Vol. 1, No. 2. Sorry, Alla! □

Articles Appearing in Journal of Physical and Chemical Reference Data

Bound reprints of each paper are available at the indicated price from Business Operations, Books and Journals Division, American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. 20036. Single issue copies of the **Journal** are available for $25.00. Checks payable to the American Chemical Society must accompany the order.

Phase Diagrams and Thermodynamic Properties of Ternary Copper-Silver Systems, Y. Austin Chang, Daniel Goldberg, and Joachim P. Newmann, Vol. 6, No. 3, pp. 621-673, $5.00, Reprint #98.

Crystal Data Space-Group Tables, Alan D. Mighell, Helen M. Ondik, and Bettijoyce B. Molino, Vol. 6, No. 3, pp. 675-829, $8.00, Reprint #99.

Energy Levels of One-Electron Atoms, Glen W. Erickson, Vol. 6, No. 3, pp. 831-869, $4.50, Reprint #100.

Rate Constants of ClO_x of Atmospheric Interest, R. T. Watson, Vol. 6, No. 3, pp. 871-917, $4.50, Reprint #101.

NMR Spectral Data: A Compilation of Aromatic Proton Chemical Shifts in Mono- and Di-Substituted Benzenes, Barry L. Shapiro and L. E. Mohrmann, Vol. 6, No. 3, pp. 919-991, $5.50, Reprint #102.

Tables of Molecular Vibrational Frequencies. Consolidated Volume II, Takehiko Shimanouchi, Vol. 6, No. 3, pp. 993-1102, $6.50, Reprint #103. □

Diffusion *(continued)*

The data center operates an information service covering a wide spectrum of diffusion data, and handles some 200 requests per annum. The bulk of the inquiries are from American corporations, and relate to specific technological processes and problems involving diffusion rate data and mass transport phenomena. The information and consulting services are provided on a fee basis and as time permits. Also a wide variety of interactions are carried on between the data center and universities, trade associations, and other data-gathering operations both in this country and abroad. □

NATIONAL GEOTHERMAL INFORMATION RESOURCE (GRID) is sponsored by the US Energy Research and Development Administration to develop a comprehensive compilation of worldwide literature and data designed to assist in the research and development of geothermal energy for electrical and nonelectrical uses. Included in this compilation, located at the University of California's Lawrence Berkeley Laboratory, is site-dependent and site independent material related to geothermal exploration, reservoir utilization, physical chemistry, along with environmental, legal, and economic aspects of geothermal energy.

GRID maintains a computerized data base which provides for in-depth literature reviews and evaluations, by the technical staff, of the status of the data. Computer-produced bibliographies and data tabulations are generated for distribution at a fixed cost of $19 for ERDA users and $25 for non-ERDA users, per search.

The GRID files include the following:

EXPLORATION considers geological, geochemical and geophysical methods, as well as drilling, resource assessment and land-use factors involved in locating and evaluating high temperature geothermal resources.

PHYSICAL CHEMISTRY deals with the basic thermodynamic, thermophysical, and kinetic data at elevated temperatures and pressures of sodium chloride, silicates, rock-solution interactions and isobutane.

UTILIZATION encompasses the development and production of a geothermal reservoir for both electrical and nonelectrical uses: hot water (brine) transport; space, process, and agricultural heating; power generation; corrosion, erosion and scaling; resource evaluation.

ENVIRONMENTAL considers aspects to the air, land and water environments of geothermal energy utilization: subsidence, hydrogen sulfide, metals, boron, ammonia, silica, seismicity, noise and land-use.

INSTITUTIONAL covers federal, state and local organizational, legal and regulatory considerations in the development of geothermal energy: land-use, exploration and production, operating regulations, developmental incentives, sale of geothermal power and fluid transport.

RESERVOIR CHARACTERIZATION includes reviews and evaluation of data relevant to the development and production of wells: porosity, artificial stimulation, natural recharge, artificial recharge, modeling, well tests and measurements.

Information is obtained mainly from primary sources, *i.e.*, published literature and reports. In addition, GRID has exchange programs with other data centers in the US – ERDA Technical Information Center, and the US Geological Survey geothermal data bank. GRID international exchange agreements were initiated under the NATO Committee on Challenges of Modern Society and currently there is a bilateral agreement with the geothermal data bank, Pisa University, Italy, under which computer tapes are exchanged periodically.

CONTACT: Sidney L. Phillips, Principal Investigator, National Geothermal Information Resource, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720. 415-843-2740

AUTOMOTIVE INDUSTRY DATA BASE combines Ward's AutoInfoBank with Interactive Data Corporation's XSIM system for information and analysis, to provide a new computer service offering forecasting and planning tools to the automotive industry. Through simple English commands, users can create economic and financial models, perform time series and regression analyses, and sort and screen data into a variety of reports and graphs. According to Roger F. Kelley, president of Ward's Communications Inc., "these extensive capabilities enable automotive manufacturers and suppliers to apply up-to-the-minute data for more accurate product line forecasts, market research, production planning, and product line mix analysis."

AutoInfoBank includes information on US weekly and monthly auto and truck production, Canadian auto and truck production, domestic and imported car and truck deliveries, US car and truck inventories, factory installed equipment for cars and trucks, and engine sizes.

Interactive Data notes that no computer expertise is required to operate XSIM, which provides explicit conversational prompts for each step of an analysis. (In addition to AutoInfoBank, the XSIM language can be used to access Chase Econometrics, Merrill Lynch Economics, and other economic and financial data bases available on the Interactive Data network.) Annual subscription fee for Ward's AutoInfoBank is $1500, plus usage charges.

CONTACT: Jack Bernstein Associates Inc., 37 West 57 St, New York, NY 10019, 212-751-6670

NSF/DSI NEW PROGRAM ANNOUNCEMENT FOR INFORMATION SCIENCE RESEARCH The present announcement supersedes three previous program

INFORMATION HOTLINE

PUBLISHER: Ivan Lyons

EDITOR: Marilyn G. McCormick

MANAGING EDITOR: Ellen Schneid Coleman

ADVISORY EDITOR: Leonard Cohan
Director of Libraries, Polytechnic Institute of New York

Indexed in *Information Science Abstracts, Library Literature, Library and Information Science Abstracts,* and *Computer and Information Systems*

INHODN 10(1) 1-32 (1978)

Annual subscription (11 issues): $50.00
No claims serviced after six months of issue date.

Section I. Basic Data Evaluation and Compilation

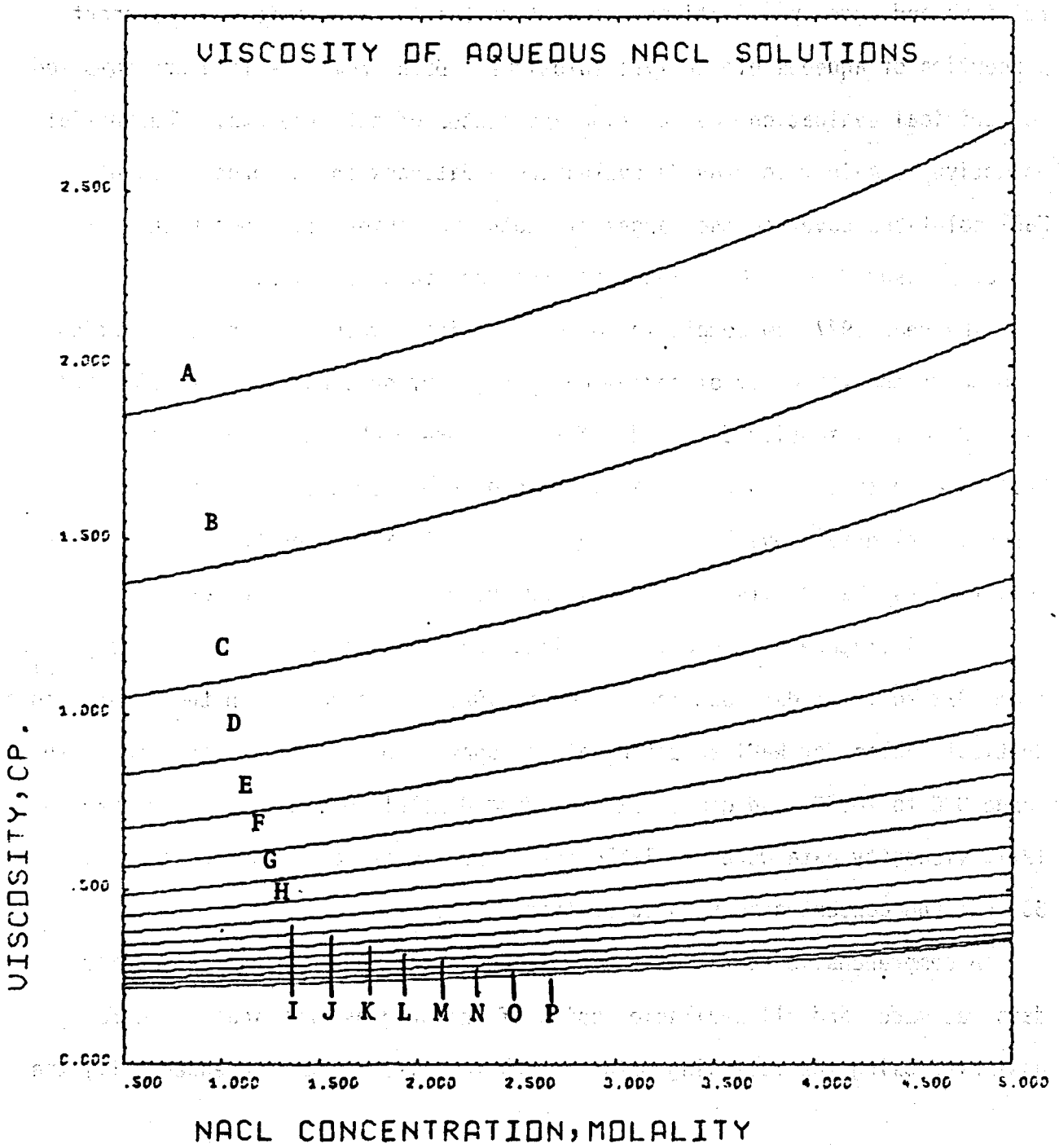
Introduction

The development and utilization of geothermal energy requires scientific and engineering calculations which include basic properties of aqueous sodium chloride and other (e.g., KCl, $CaCl_2$) electrolyte solutions (Ref. 1, 2). In this context, GRID has developed a bibliographic computer file to store, retrieve and index publications relevant to the thermodynamic and transport properties of aqueous electrolyte solutions. Data from this file are compiled for critical evaluation, correlation and status of data reviews. The initial objective is mainly to provide evaluators a databank on the properties of NaCl solutions covering the ranges of geothermal interest: temperatures to 350°C, pressures to 50 MPa, and concentrations to saturation.

The year 1977 saw completion of our critical evaluation and correlation of data on the viscosity of sodium chloride solutions, published as LBL-5931 (Ref. 3, 4). Viscosity data and references were exchanged mainly with Professor Kestin, Brown University, who provided a substantial amount of experimental data above 100°C and to 300 bars (30 MPa) pressures. The viscosity report gives the results of a survey and evaluation of this databank.

The literature screened in compiling the viscosity data covered the period from 1929 to 1977; data obtained prior to 1929 are contained in the International Critical Tables for NaCl solutions at atmospheric pressure over the temperature range 0°C to 100°C, and concentrations from 0 molal to 5 molal. From 1929 to 1977, viscosity data were available for temperatures to 150°C, pressures to 30 MPa, and concentrations to saturation.

A comprehensive search of the published literature for NaCl viscosity data was made, and all available copies of the original publications were assembled using the following main sources for literature references: (1) the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A
B
C
D
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I J K L M N O P
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VISCOSITY, CP.
NACL CONCENTRATION, MOLALITY

XBL 783-7793

DOE Technical Information Center, which includes the Energy Data Base and Water Resources Abstracts; (2) the International Critical Tables; and (3) scientific journals and reports.

The data selected for correlation were experimental and did not include either smoothed or calculated values. All data were converted where necessary to the ^{12}C scale of atomic weights, to the g/cm^3 basis for density, to centipoise for viscosity, from molar to molal concentrations, and from relative to absolute viscosity values. The needed water viscosity data were taken from the results of the Eighth International Conference on the properties of steam.

The following correlation equation was developed from the experimental data:

$$\eta = c_1 + c_2 \exp(\alpha_1 T) + c_3 \exp(\alpha_2 m) + c_4 \exp[\alpha_3 (0.01T + m)] + c_5 \exp[\alpha_4 (0.01T - m)]$$

where

η = viscosity, cp

T = temperature, °C

m = concentration, molality

Equation (1) is valid only to pressures of 30 MPa and at temperatures to 150°C.

Figure 1 shows a plot of viscosity versus concentration according to Eq. (1) for selected temperatures between 0°C and 150°C. Figure 2 is a plot, based on Eq. (1), of viscosity versus temperature. Data may be interpolated with Eq. (1) to a standard deviation of 1.5% over the entire temperature, pressure, and concentration range (see Fig. 3). Information on obtaining tables of experimental data and smoothed values of viscosity may be obtained by contacting GRID.

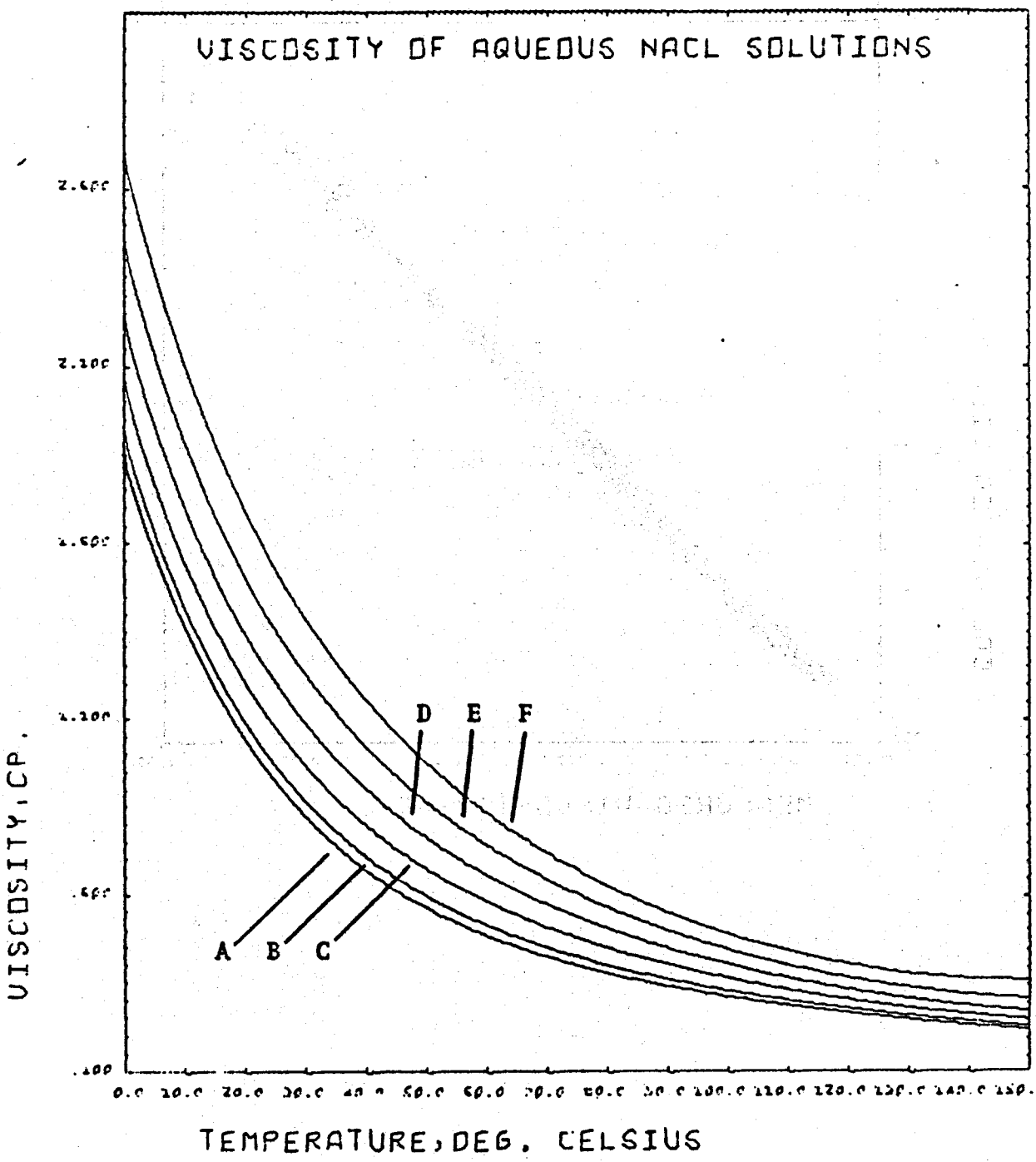
Based on this work, it was concluded that the currently available experimental data on the viscosity of NaCl solutions is sparse and covers mainly pressures from atmospheric to 30 MPa (300 bars), concentrations to saturation, and temperatures to 150°C. A correlation equation was developed which reproduces the experimental data by 1.5% over the temperature range 0°C to 150°C. Additional laboratory measurements on the viscosity of NaCl solutions to 350°C and 500 bars are needed. More details are given in Ref. 3.

Additional Activities in 1977

Besides the report on viscosity, both the aqueous electrolyte database and density and viscosity databanks were on line for storage and retrieval in 1977 (Ref. 2, 5). Printouts were provided gratis to over thirty geothermal specialists. Availability of the aqueous electrolyte file was announced for example by GRID mailing a news-release and order form, included here as Attachment I, and published in the Jul/Aug 1977 issue of NSRDS "Reference Data Report", Attachment II. Information about GRID was also provided on their request to Science Associates/International, Inc. (Attachment III).

Density and Viscosity Databank

Numerical data were compiled from the available literature as shown in the sample printout (1 page each) of the current GRID database on the density and viscosity of NaCl aqueous solutions at elevated temperatures and pressures. See Table 1 and Table 2. The data in the larger databank are tabulated in order of increasing concentration of NaCl, and cover laboratory generated experimental data over the time span 1929 to 1977.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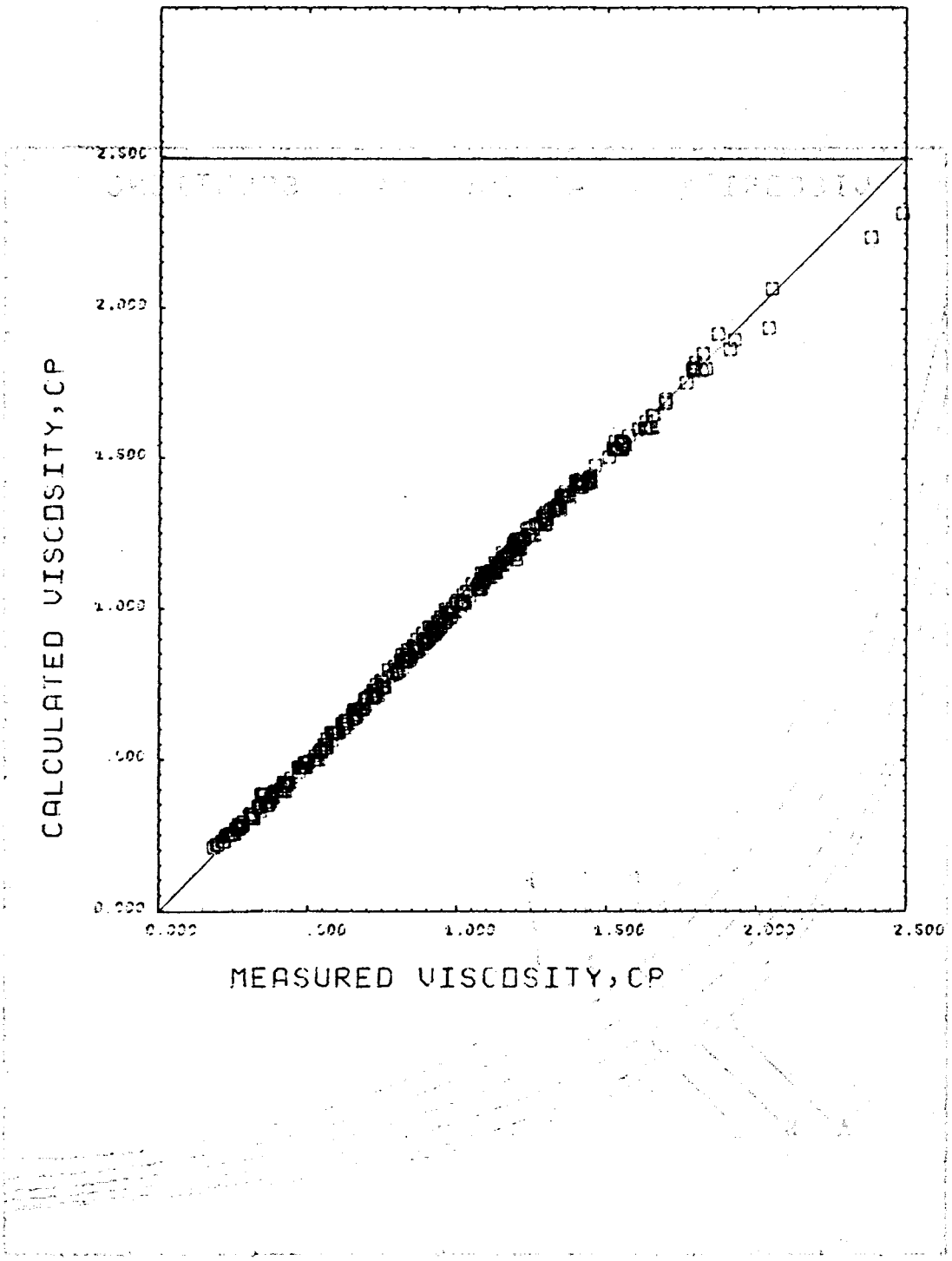
F

XBL 783-7794


2.500
2.000
1.500
1.000
.500
0.000
CALCULATED VISCOSITY,CP
0.000
.500
1.000
1.500
2.000
2.500
MEASURED VISCOSITY,CP

Tabulated numerical data is expected to be added for the following properties of NaCl solutions:

Enthalpy

Solubility

Specific Heat

Free Energy

Entropy

Electric Conductivity

Activity

Osmotic Coefficient

Thermal Conductivity

Aqueous Electrolyte Bibliographic Database to Elevated Temperatures and Pressures

There is a current worldwide research and development program centered around the utilization of geothermal energy for both electrical and non-electrical applications. Scientists and engineers involved in this program require evaluated basic data for the design and modeling of geothermal systems, for example, the thermodynamic and transport properties of aqueous electrolyte solutions at elevated temperatures and pressures. In this context GRID screens the worldwide literature on a continuing basis to collect and store bibliographic material covering aqueous electrolyte solutions. The result of this compilation is maintained as an annotated and indexed computerized file system which provides the basis for critical evaluation of the data by both GRID staff and other evaluators. The file contained over 1000 records in 1977; see the two sample records in Figure 4.

Table 2. Smoothed values of the viscosity of NaCl solutions calculated from Eq 11.

Viscosity, cp

m NaCl / °C	.5	1.0	2.0	3.0	4.0	5.0
0	1.853	1.914	2.058	2.234	2.448	2.701
10.0	1.373	1.428	1.556	1.712	1.899	2.118
20.0	1.049	1.098	1.212	1.349	1.512	1.699
30.0	.827	.871	.972	1.092	1.232	1.391
40.0	.673	.712	.800	.905	1.024	1.158
50.0	.564	.598	.675	.765	.866	.978
60.0	.484	.513	.580	.657	.743	.835
70.0	.423	.449	.507	.572	.644	.719
80.0	.377	.399	.449	.504	.564	.626
90.0	.340	.359	.401	.448	.498	.549
100.0	.310	.326	.362	.401	.443	.487
110.0	.285	.299	.329	.363	.399	.439
120.0	.264	.276	.302	.331	.363	.402
130.0	.246	.256	.279	.305	.336	.376
140.0	.231	.240	.261	.285	.316	.361
150.0	.218	.227	.246	.270	.304	.357

JUNE 1977

GRID-PHYSICAL CHEMISTRY DATA BASE;

DENSITY

UNITS

CONCENTRATION= MOLALITY
TEMPERATURE= DEGREES CELSIUS
PRESSURE= BARS
DENSITY= GRAMS/CC.

CONC.	TEMP.	PRESS.	DENS.	AUTH.
.001000	40.0	101.32	.9967100	GORBACHEV 74
.001000	60.0	101.32	.9876500	GORBACHEV 74
.001000	80.0	101.32	.9762800	GORBACHEV 74
.001000	100.0	101.32	.9628300	GORBACHEV 74
.001000	120.0	101.32	.9477800	GORBACHEV 74
.001000	140.0	101.32	.9311900	GORBACHEV 74
.001000	160.0	101.32	.9127400	GORBACHEV 74
.001000	180.0	101.32	.8927800	GORBACHEV 74
.001000	200.0	101.32	.8709300	GORBACHEV 74
.001000	220.0	101.32	.8472400	GORBACHEV 74
.001000	240.0	101.32	.8202100	GORBACHEV 74
.001000	260.0	101.32	.7902600	GORBACHEV 74
.001000	280.0	101.32	.7557400	GORBACHEV 74
.002000	0	1.01	.9999300	JONES 37
.002000	25.0	1.01	.9971300	JONES 37
.002565	25.0	1.01	.9971772	KRUIS 36
.002565	25.0	1.01	.9971778	KRUIS 36
.002565	25.0	1.01	.9971779	KRUIS 36
.005000	0	1.01	1.0000700	JONES 37
.005000	25.0	1.01	.9972500	JONES 37
.005028	50.0	1.01	.9882402	MILLERO 72B
.009845	45.0	1.01	.9906154	MILLERO 70
.010000	0	1.01	1.0002900	JONES 37
.010000	25.0	1.01	.9974600	JONES 37
.010000	40.0	101.32	.9970100	GORBACHEV 74
.010000	60.0	101.32	.9879500	GORBACHEV 74

The bibliography is organized by records; a typical record contains the following information: a record number, a short code mnemonic; a category/subcategory mnemonic; title of the publication; author; author affiliation at the time of publication; literature reference; and key word annotation (descriptors). See Figure 4.

This database is the result of an initial screening of the worldwide literature covering the basic properties of solutions relevant to geothermal science and engineering. Other records are added to the file on a continuing basis.

Figure 4

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LINDSAY 68
SOLUTIONS/MISC.
SOLUTIONS/THERMODYNAMICS

TITLE- VAPOR PRESSURE LOWERING OF AQUEOUS SOLUTIONS AT ELEVATED TEMPERATURES.

AUTHOR- LINDSAY, W.T.;LIU, C.-T.

REFERENCE- VAPOR PRESSURE LOWERING OF AQUEOUS SOLUTIONS AT ELEVATED TEMPERATURES. NO. 347, U.S. OFF. SALINE WATER, RES. DEV. PROG. REP., 1968, 234 P..

DESCRIPTORS- EMPIRICAL EQUATIONS; EXPERIMENTAL RESULTS; GRAPHS; TABLES; BOILING POINT; EQUILIBRIUM CONSTANT; VAPOR PRESSURE; SATURATED VAPOR; ELEVATED CONCENTRATION; HIGH CONCENTRATION; MODERATE TEMPERATURE; ELEVATED TEMPERATURE; ACTIVITY COEFFICIENT; FREE ENERGY; OSMOTIC COEFFICIENT; PARTIAL MOLAL ENTHALPY; PARTIAL MOLAL ENTROPY; MEASURING INSTRUMENTS; SEA WATER; CESIUM CHLORIDES; HEAVY WATER; LITHIUM CHLORIDES; MAGNESIUM CHLORIDES; SODIUM CHLORIDES; SODIUM SULFATES; WATER.

864

LIU 72
SOLUTIONS/MISC.
SOLUTIONS/THERMODYNAMICS

TITLE- THERMODYNAMICS OF SODIUM CHLORIDE SOLUTIONS AT HIGH TEMPERATURES.

AUTHOR- LIU, C.-T.;LINDSAY, W.T. [WESTINGHOUSE RESEARCH LABS., PITTSBURGH, PA. (USA)].

REFERENCE- J. SOLUTION CHEM., V. 1 (1), P. 45-69(1972).

DESCRIPTORS- REVIEWS; EXPERIMENTAL RESULTS; EMPIRICAL EQUATIONS; GRAPHS; TABLES; DISSOCIATION CONSTANT; SOLUBILITY; VAPOR PRESSURE; INFINITE DILUTION; HIGH CONCENTRATION; LOW PRESSURE; STANDARD PRESSURE; MODERATE PRESSURE; MODERATE TEMPERATURE; ELEVATED TEMPERATURE; THERMODYNAMICS; ACTIVITY COEFFICIENT; OSMOTIC COEFFICIENT; PARTIAL MOLAL ENTROPY; PARTIAL MOLAL SPECIFIC HEAT; SOLUTION HEAT; SODIUM CHLORIDES; WATER.

Magma Bibliographic Database

The feasibility of extracting energy directly from deeply buried circulating molten rock (magma) sources is attractive because temperatures can approach 1000°C thereby representing a potential of great amounts of high-quality energy. Evaluation of magma resources requires the following categories of information: Geophysics/Electrical; Material Compatibility; Heat Transfer/Source; Geophysics/Seismic; Tectonophysics/Rock Deformation; Magma Petrology; and Volcanology/Geophysics.

Knowledge of many chemical and physical properties of molten rock, partly molten rock and of solid rock at high temperatures is essential for evaluating the feasibility of extracting energy directly from magma bodies. These include:

Chemical Composition

Major Element

Minor Element

Fugitives (H, C, O, S, Cl, F)

Magma

Overlying Rock

Physical Properties

Phase Relations of Rock Melts

Phase Relations of Rock Melts in the presence of Aqueous solutions of NaF, NaCl, etc.

Temperature Distribution (thermal modeling)

Thermal Conductivity Heat Capacity, Seismic Property

Rock

Melt

Latent Heat

Heat Transfer Coefficient

Viscosity

  Melt

  Multi-phase

Density

  Bulk (in situ)

  Melt

  Minerals

Thermal Expansivities

Electrical Properties

Permeability

Magnetic Properties

Strength

Ductility

In 1977, an extensive literature search covering magma and magma properties was completed, and an initial bibliographic file was prepared. Figures 5 and 6 illustrate the Author Index for the current file.

BIRCH 43
PLASTICITY OF IGNEOUS ROCKS AT HIGH TEMPERATURES AND PRESSURES:
RECORD NUMBER 170

BLOOM 57
THE COMPRESSIBILITIES OF THE SILICATES - THE LI2O--SIO2 SYSTEM:
RECORD NUMBER 171

BOCKRIS
THE COMPRESSIBILITIES OF CERTAIN MOLTEN ALKALI SILICATES AND BORATES:
RECORD NUMBER 39

BOCKRIS 55
VISCOUS FLOW IN SILICA AND BINARY LIQUID SILICATES:
RECORD NUMBER 40

BOCKRIS 56
THE STRUCTURE OF THE LIQUID SILICATES - PARTIAL MOLAR VOLUMES AND EXPANSIVITIES:
RECORD NUMBER 41

BOLDIZAR 70
TERRESTRIAL HEAT AND VOLCANISM - PURE AND APPL.:
RECORD NUMBER 42

BONDARENKO 68
GENERALIZATION OF DATA ON THE CONDUCTANCE OF IGNEOUS ROCKS AT HIGH TEMPERATURES IN CONNECTION WITH THE STRUCTURE OF THE CRUST AND UPPER MANTLE:
RECORD NUMBER 43

BOTTINGA 72
THE VISCOSITY OF MAGMATIC SILICATE LIQUIDS - A MODEL FOR CALCULATION:
RECORD NUMBER 44

BRACE 70
SOME EFFECTS OF HIGH TEMPERATURE ON THE FRICTIONAL SLIDING OF GRANITE:
RECORD NUMBER 45

BRADLEY 62
ELECTRICAL CONDUCTIVITY OF FAYALITE AND SPINEL:
RECORD NUMBER 46

BRADLEY 64
THE ELECTRICAL CONDUCTIVITY OF OLIVINE AT HIGH TEMPERATURES AND PRESSURES:
RECORD NUMBER 47

BRANDVOLD 74
EXPERIMENTAL RESISTIVITY ELECTRODE EMPLACEMENT FOR THE HAWAII GEOTHERMAL PROJECT: THE UTILIZATION OF VOLCANIC ENERGY:
RECORD NUMBER 48

CARRON 69
VISCOSITE ET DIFFUSION DANS LES MAGMAS SILICATES;
RECORD NUMBER 49

CARRON 69B
REVIEW OF THE RHEOLOGY OF NATURAL SILICATE MAGMAS;
RECORD NUMBER 50

CARTER 70
HIGH TEMPERATURE FLOW OF DUNITE AND PERIDOTITE;
RECORD NUMBER 51

COLP 74
THE UTILIZATION OF VOLCANO ENERGY;
RECORD NUMBER 52

COOMBS 60
CATALOG OF THE ACTIVE VOLCANOES OF THE WORLD INCLUDING SOLFATARA FIELDS;
RECORD NUMBER 53

COSTER 48
THE ELECTRICAL CONDUCTIVITY OF ROCKS AT HIGH TEMPERATURES;
RECORD NUMBER 54

CUKIERMAN 72
VISCOUS FLOW BEHAVIOR OF LUNAR COMPOSITIONS 14259 AND 14310;
RECORD NUMBER 55

CUKIERMAN 74
EFFECTS OF IRON OXIDATION STATE ON VISCOSITY, LUNAR COMPOSITION 15555;
RECORD NUMBER 56

DANEV 72
DYNAMICS OF LAVA FLOWS;
RECORD NUMBER 57

DECKER 63
MAGNETIC STUDIES ON KILAUEA IKI LAVA LAKE, HAWAII;
RECORD NUMBER 61

DECKER 67
DEFORMATION MEASUREMENTS ON KILAUEA VOLCANO, HAWAII;
RECORD NUMBER 58

DECKER 67B
INFRARED RADIATION FROM ALLAE LAVA LAKE, HAWAII;
RECORD NUMBER 59

DECKER 67C
INVESTIGATIONS AT ACTIVE VOLCANOES;
RECORD NUMBER 60

Continental, Marine and Deep Sea Drill-Hole Survey Information and Data Management (Proposed Work)

Recent questions centered on major energy and environmental problems have identified the need for increased knowledge about our earth which is obtained by researchers only from subsurface measurements. The objective of this proposal is to establish a computerized clearinghouse of drill-hole information for these researchers as described in the following two tasks.

Task 1:

It is proposed that a computerized Drill-Hole Data Center be established by GRID at the Lawrence Berkeley Laboratory to collect, organize and disseminate data obtained from a survey of all DOE-sponsored drilling activities. A copy of the survey questionnaire attached would be sent to the various drillers; a listing of the organizations engaged in drilling, for example, geothermal energy drilling, would then be compiled. The data from the questionnaire will be coded and stored on computer tapes for ease of information retrieval and data manipulation using the Berkeley Data Base Management System. See the proposed format in Figure 7 (1 page only).

Task 2:

Under Task 2 a listing would be compiled of scientists and engineers with a need for information contained in the drill-hole data base. The information would automatically be sent to the interested researcher on a periodic basis. Other Federal agencies (e.g., USGS, DOD) with an interest in drill-hole data would be included in this listing. It is expected that the file content eventually will be made available for search by remote users, for example, via the ARPANET, once the data have been computer-stored.

Drilling

Data Element	Data Entry
Current Status	Planned
	In Progress
	Completed
Agency Name	_____
Drilling Dates:	
Start	____/____/____ mo day yr
Completion	____/____/____ mo day yr
Total Planned Depth	_____.
Drilling Stages	
Surface Elevation	_____ Km
Logging Depth Reference	_____ Km (Kelly Bushing
	_____ Km (Derrick Floor)
Stage 1	
Borehole Diameter	_____ cm
Cas.ing Diameter	_____ cm
Cas.ing Depth	_____ Km
Drilling Depth	_____ Km
Cased	_____ (Yes; No)
Cemented	_____ (Yes; No)
Perforated	_____ (Yes: No)
Geological Formation	_____ 1 (See Code)
Logging	_____ 2 (See Code)
Stage 2	
(As in Stage 1)	
Stage 3	
(As in Stage 1)	
Stage 4	
(As in Stage 1)	
Stage 5	
(As in Stage 1)	
Location	
Continental	_____ (State)
	_____ (County)
	_____ (NS)
	_____ (EW)

Summary

In summary, 1977 saw completion of the report on critical evaluation of viscosity of aqueous NaCl solutions, and the availability and dissemination of both bibliographic and numerical material on the basic properties of aqueous electrolytes to elevated temperatures.

References

1. J.A. Fair and S.L. Phillips, "Establishment of a Computer Data Base on Geothermal Properties of Aqueous NaCl, KCl and $CaCl_2$ Solutions", LBL-5227.

2. J.A. Fair and S.L. Phillips, "Establishment of a Computer Database on Geothermal Properties of Aqueous NaCl, KCl, and $CaCl_2$ Solutions", CODATA Bulletin 23, page 15, May 1977.

3. H. Ozbek, J.A. Fair, S.L. Phillips, "Viscosity of Aqueous Sodium Chloride Solutions from 0-150°C", LBL-5931, December 1977.

4. H. Ozbek and S.L. Phillips, "Aqueous Solutions Database for Elevated Temperatures and Pressures", in Proceedings of the Fifth International Conference on Chemical Thermodynamics, Ronneby, Sweden, August 23-26, 1977.

5. J.A. Fair, S.L. Phillips, "Geothermal Properties of Aqueous Sodium Chloride Solutions", Abstracts, 5th International CODATA Conference, Boulder, CO, June 28-July 1, 1976, CODATA Bulletin, 18, page 24, April 1976.

6. J.J. Herr, S.L. Phillips, S.R. Schwartz, T.G. Trippe, "Standards for Multilateral & Worldwide Exchange of Geothermal Data", Mathematical Geology, vol. 9, no. 3, p. 259 (1977).

7. S.R. Schwartz, "GEODOC - The GRID Document File, Record Structure and Data Element Description", LBL-4432, R-1, 1978 (in preparation).

8. S.L. Phillips, J.A. Fair, F.B. Henderson, T.G. Trippe, "National Geothermal Information Resource", Proceedings, 10th Annual Meeting, Geoscience Information Society, Oct. 21, 1975, Salt Lake City, UT, vol. 6, page 52, 1976.

9. S.L. Phillips and J.R. Swanson, "Application of a Geothermal Computer File System to Chemical Geothermometers", LBL-5915, January 1977.

Section II. Site-Dependent Data Compilation

Introduction

The site-dependent compilation program was initiated in 1974 with the objective to collect, organize and disseminate evaluated data on the following major areas of geothermal science and technology: (1) Exploration considers geological, geochemical and geophysical methods, as well as drilling, resource assessment and land-use factors involved in locating and evaluating high temperature geothermal resources. (2) Utilization encompasses the development and production of a geothermal reservoir for both electrical and non-electrical uses: hot water fluid (brine) transport; space, process, and agricultural heating; power generation; corrosion, erosion and scaling; resource evaluation. (3) Environmental aspects to the air, land and water environments of geothermal energy utilization: subsidence, hydrogen sulfide, metals, boron, ammonia, silica, seismicity, noise and land-use. (4) Institutional covers Federal, state and local organizational, legal and regulatory considerations in the development of geothermal power and fluid transport. (5) Reservoir Engineering includes reviews and evaluation of data relevant to the development and production of wells: porosity, artificial recharge, modeling, well tests and measurements.

The National Geothermal Information Resource acquires geothermal data from the literature, from TIC, and through exchange with other data centers such as GEOTHERM (Reston, VA), and CNUCE (Pisa, Italy). GRID systemizes and stores data using descriptive cataloging procedures based on the standardized techniques of INIS (Vienna, Austria). The data is retrieved via the Berkeley Data Base Management System utilizing descriptors selected from a thesaurus of controlled vocabulary terms (Ref. 1). Site-dependent files contain numerical

and descriptive data on important facets of geothermal exploration and utilization including:

Geothermal energy conversion

Geothermal well/drillhole

Land subsidence

Noncondensibles

Space and process heating

Power generation

Geothermal energy site-dependent information is the compilation, critical evaluation and status of data reviews. Included also is data from other fields (e.g., oil and gas) which is relevant to geothermal energy for both electrical and direct utilization. The data are mainly in the following three forms: (1) Computer annotated and indexed bibliographies. Listings from these bibliographies provide references to the numerical data compiled by GRID staff; in 1977 over 50 computer generated listings were provided either gratis or by request to other evaluators. (2) Computer stored tabulated numerical data extracted from the material in the bibliographic listings. These computer tables provide the basis for statistical calculation and data manipulation. (3) Reviews wherein available site-dependent data is surveyed to provide information on the current status of data including recommendations for additional data needs. An example is the report on a Study of Brine Treatment, supported by the Electric Power Research Institute (Ref. 2).

Information from these computer files is for the following typical users: (1) Persons initially entering the field and who require information about specific areas of geothermal energy development. (2) Program managers and

others who provide funding support, and need to know where significant gaps in data exist. (3) Scientists and engineers requiring data for predictive modeling of plant performance, reservoir engineering and direct utilization.

The year 1977 saw completion of bibliographic computer files on: (1) hydrogen sulfide, (2) exploration and evaluation, (3) non-electrical, (4) subsidence. Besides bibliographic information, a noncondensibles numerical databank was established, and draft formats developed for both subsidence and energy conversion.

In this report, the term database refers to bibliographic listings and databank refers to computer-based files containing numerical data.

Geothermal Energy Aspects of Hydrogen Sulfide: A Bibliography

Geothermal vapor and hot water fluids contain a fraction of noncondensible gases composed mainly of carbon dioxide with lesser concentrations of hydrogen sulfide and other gases such as methane, ammonia, nitrogen, hydrogen and ethane. The interest in H_2S aspects of geothermal energy is mainly related to the problem of corrosion of materials, the unpleasant odor at low levels and environmental effects. Although this file highlights the geothermal aspects of hydrogen sulfide, substantial references from other sources of H_2S are included, for example: petroleum refining, smelting of sulfide ores, the manufacture of Kraft pulp, and offal rendering plants. Currently, the topics referenced in the hydrogen sulfide file cover: sources of H_2S, monitoring methods, emission control, environmental effects, health effects, pathways in the air and water environments. The hydrogen sulfide file is the result of an initial screening of the worldwide literature and new citations are expected to be appended periodically. Figure 1 shows typical records contained in this database (Ref. 3).

Figure 1

KOWALENKO 72
HYDROGEN SULFIDE/MONITORING METHODS

TITLE- OBSERVATIONS ON THE BISMUTH SULFIDE COLORIMETRIC PROCEDURE FOR SULFATE ANALYSIS IN SOIL.

AUTHOR- KOWALENKO, C.G.;LOWE, L.E. (BRITISH COLUMBIA UNIV., VANCOUVER (CANADA). DEPT. OF SOIL SCIENCE).

REFERENCE- COMMUN. SOIL SCI. PLANT ANAL., V. 3 (1), P. 79-86(1972).

DESCRIPTORS- TABLES; COMPARATIVE EVALUATIONS; MEASURING METHODS; METHYLENE BLUE METHOD; PPM CONCENTRATION RANGE; FLOW RATES; SOILS; NITROGEN; HYDROGEN SULFIDES; SULFATES.

411

LUND 74
HYDROGEN SULFIDE/ENVIRONMENTAL EFFECTS

TITLE- BIOCHEMICAL AND ANTIBIOTIC SUSCEPTIBILITY STUDIES OF H2S-NEGATIVE CITROBACTER.

AUTHOR- LUND, M.E.;MATSEN, J.M.;BLAZEVIC, D.J. (MINNESOTA UNIV., MINNEAPOLIS (USA). DEPTS. OF LABORATORY MEDICINE AND PATHOLOGY, PEDIATRICS, AND MICROBIOLOGY).

REFERENCE- APPL. MICROBIOL., V. 28 (1), P. 22-25(1974).

DESCRIPTORS- GRAPHS; TABLES; BIOASSAY; MEASURING METHODS; BACTERIA; HUMAN; HYDROGEN SULFIDES.

412

NAVARA 75

TITLE- EFFECTS OF ATMOSPHERES POLLUTED BY INDUSTRY UPON THE YIELDS OF SOME FARM CROPS. (IN SLOVAKIAN).

AUTHOR- NAVARA, J.;HORVATH, I.;HAUSKRECHT, I. (SLOVENSKA AKADEMIA VIED, BRATISLAVA (CZECHOSLOVAKIA). USTAV EXP. BIOL. EKOL.).

REFERENCE- OCHR. OVZDUSI, V. 7 (3), P. 43-47(1975). REFERENCE CHEM. ABSTR., 1975, V. 83, ABSTR. NO.

Figure 2

```
RECORD 6
SC = BROWNE 74:
TY = J/AS:
DES-CAT.1:
  BL = A:
  PT = SUBSIDENCE RATE AT BROADLANDS FROM RADIOCARBON DATES:
  AUTHORS:
    AU = BROWNE, P.R.L.:
    AA = GEOLOGICAL SURVEY, LOWER HUTT (NEW ZEALAND):
DES-CAT.2:
  BL = S:
  OT = N. Z. J. GEOL. GEOPHYS.:
  CODEN = NEZOAY:
  PUD = 1974:
  COL = V. 17 (2), P. 494-495:
INDEX:
  CQ = ENVIRONMENTAL/SUBSIDENCE:
  DE.1 = NEW ZEALAND:
  DE.2 = BROADLANDS GEOTHERMAL FIELD:
  DE.3 = GROUND MOTION:
  DE.4 = GROUND SUBSIDENCE:
  DE.5 = CARBON ISOTOPES:
  PD.1 = CARBON RADIOISOTOPES:
  PD.2 = RADIOACTIVE DATING:
CONTROL:
  DCSO = COPY ON FILE:
```

Figure 3


```
RECORD 7
SC = BULL 73:
TY = J/AS:
DES-CAT.1:
  BL = A:
  PT = GEOLOGIC FACTORS AFFECTING COMPACTION OF DEPOSITS IN A LAND-SUBSIDENCE
       REA:
  AUTHORS:
    AU = BULL, W.B.:
    AA = ARIZONA UNIV., TUCSON (USA). DEPT. OF GEOSCIENCES:
      AC = 0 454 COO:
DES-CAT.2:
  BL = S:
  OT = GEOL. SOC. AM. BULL.:
  CODEN = BUGMAF:
  PUD = 1973:
  COL = V. 84 (12), P. 3783-3802:
INDEX:
  CQ = ENVIRONMENTAL/SUBSIDENCE:
  DE.1 = GROUND SUBSIDENCE:
  DE.2 = CALIFORNIA:
  DE.3 = SAN JOAQUIN VALLEY:
  PD.1 = COMPACTION:
  PD.2 = ALLUVIUM:
  PD.3 = COMPRESSIBILITY:
CONTROL:
  DCSO = COPY ON FILE:
```

Land Subsidence Bibliographic File

An important facet in the development and utilization of geothermal energy is the consideration of any effects to the air, water and land compartments of the environment (Ref. 4). Land subsidence and frequently associated horizontal ground movement is listed among the environmental effects which may be related to withdrawal of geothermal hot water. It is the surface manifestation of subsurface soil compaction and has been observed for many years in some petroleum fields and areas of ground-water pumping. Although the geologic settings of the various areas may vary considerably, the basic cause of subsidence is the same: reduction of fluid pressure causing a marked increase in effective stress.

The interest in subsidence stems from two major concerns: (1) potential damages to the production field pipelines and power plants, for example, the pipe distortion experienced at Wairakei, New Zealand; and (2) possible effects on communities. An example of (2) is the subsidence of Venice, Italy, due in part to non-geothermal water pumping at Porto Marghera, 7 km distance from Venice.

The land subsidence database is on line and available for restricted searches to include subsidence resulting from mining operations and petroleum production, as well as that associated with geothermal fluids withdrawal. Categories of information cover effects, monitoring methods, causes, abatement and costs of subsidence. See the examples in Figures 2, 3.

Direct Utilization Bibliographic Database

The direct utilization of geothermal hot water is mainly for space heating and manufacturing purposes. The file currently includes the following information: (1) hot water transmission; (2) production and distribution; (3) hydro-

ponics; (4) air conditioning; and, (5) district heating concept.

The year 1977 saw completion of a bibliographic file on direct utilization (e.g., space heating, hot water transmission) containing over 200 records. The file is available for limited searches, and is expected to be annotated and edited in 1978. See Figure 4 for a typical record in the GRID/BDMS format.

Geothermal Energy Exploration and Evaluation

The current bibliographic file contains over 500 records, and is on line and available for search and data retrieval. Records are annotated using indexing terms taken from a thesaurus of controlled descriptors. An example of the use of this file is given in Reference 5.

Figure 4

```
RECORD 120
   = SCHMITT 76;
.. = R/M;
DES-CAT;
  BL = M;
  PT = DIRECT APPLICATIONS OF GEOTHERMAL ENERGY;
  AUTHORS.1;
    AU.1 = SCHMITT, R.C.;
    AU.2 = SCHULTZ, R.J.;
    AA = AEROJET NUCLEAR CO., IDAHO FALLS, IDAHO (USA). IDAHO NATIONAL ENGINEER
         ING LAB.;
  AUTHORS.2;
    AU = GRIFFITH J.L.;
    AA = ERDA-IDAHO OPERATIONS OFFICE (USA);
  AUTHORS.3;
    AU = BROWN, W.S.;
    AA = UTAH UNIV., SALT LAKE CITY (USA). COLL. OF ENGINEERING;
      AC = 6 634 000;
  PUD = 1976;
  COL = 7 P.;
  COT = 11TH INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE;
  COD = 1976;
CONTROL;
  DCSO = COPY ON FILE;
```

This bibliographic file is the result of a comprehensive literature search, and contains information which can be used to establish the current status of data covering the following main categories of exploration, evaluation and energy conversion:

Geological Surveys

- Regional geologic evaluation
- Geologic interpretation
- Surface geologic mapping
- Volcanic and intrusive igneous rocks
- Stratigraphy
- Structural geology
- Surface hydrothermal alteration
- Economic mineral deposits

Hydrologic Surveys

- Surface water
  - distribution
  - physical properties
  - rates of flow and water levels
  - quality
- Subsurface water
  - recharge and discharge characteristics
  - physical properties
  - characteristics of aquifers
  - models of deep circulation
  - quality
- Meteorology of geothermal areas

Geochemistry

- Geochemical thermometers
- Isotope studies
- Radiometric age-dating
- Sampling and field analytical methods
- Analyses of thermal fluids
- Analyses of thermal gases
- Interpretation of reservoir conditions

Geophysical Methods

- Regional geophysical compilations
- Electrical methods
  - resistivity
  - electromagnetics
  - tellurics

- Magnetic methods
- Gravity
- Seismic methods
  - passive
  - active
- Thermal measurements
  - surface temperatures
  - temperature gradients
  - heat-flow determinations

Drilling

- Drilling equipment and techniques
- Sampling and logging
  - temperature surveys
  - sampling of downhole fluids
  - electrical and other logs
  - lithologic logging and sampling
- Estimation of downhole parameters
  - stratigraphy and structure
  - porosity and permeability
  - fluid composition and characteristics
  - formation temperature and pressure
- Relationship of surface and subsurface data

Land-use Factors

- Land ownership and existing land use
- Physical conditions
  - accessibility and terrain
  - climate
- Land-use planning
- Water supply and water rights
- Environmental constraints
  - emissions and noise
  - seismicity and land-surface subsidence
  - biota
  - recreational use
  - historical and archeological values
- Proximity to markets and electric transmission lines

Evaluation

- Comparison of exploration and evaluation techniques
- Success ratios in exploration
- Estimation of geothermal reserves
  - high-enthalpy fluids
  - lower-enthalpy fluids
  - hot, dry rock
  - fresh-water from desalination
  - recoverable minerals
- Modeling of geothermal systems

Problems in geothermal exploration and evaluation
Land-use and environmental factors
Costs of exploration and evaluation
Case histories

Figure 5 is typical record contained in the Exploration database in the GRID/BDMS format.

Resource Energy Conversion File

Numerical and descriptive data are extracted from our Exploration and Evaluation file to provide information for the status of data on resource energy conversion. The file provides the user with current information covering the following main categories: location; resource parameters; operational parameters; fluid transmission; exploration and development; well logging; well production; environmental, scaling and corrosion aspects; reservoir engineering; land use factors; legal aspects; and injection well data. See the draft format in Figure 6.

Figure 5

```
RECORD 536
SC = SIMMONS 77;
TY = J/AS;
DES-CAT.1;
  BL = A;
  PT = ECONOMICS AND PROJECTIONS FOR GEOTHERMAL DEVELOPMENT IN THE NORTHWEST;
  AUTHORS;
    AU = SIMMONS, G.M.;
    AA = IDAHO UNIV., MOSCOW (USA). DEPT. OF CHEMICAL ENGINEERING;
DES-CAT.2;
  BL = S;
  OT = GEOTHERMAL ENERGY;
  PUD = 1977;
  COL = V. 5 (10), P. 8;
INDEX;
  CQ = EXPLORATION/EVALUATION;
  DE.1 = DIAGRAMS;
  DE.2 = MAPS;
  DE.3 = TABLES;
  DE.4 = IDAHO;
  DE.5 = OREGON;
  DE.6 = WASHINGTON;
  DE.7 = RAFT RIVER KGRA;
  DE.8 = KLAMATH FALLS KGRA;
  DE.9 = BRUNEAU KGRA;
  DE.1. = AGRICULTURE;
  DE.11 = COSTS;
  DE.12 = DIRECT ENERGY UTILIZATION;
  DE.13 = ECONOMICS;
  DE.14 = ENERGY RESERVES;
  DE.15 = ENVIRONMENTAL EFFECTS;
  DE.16 = FORECASTING;
  DE.17 = PIPELINES;
  DE.18 = PROCESS HEAT;
  DE.19 = POWER GENERATION;
  DE.20 = SPACE HEATING;
  DE.21 = SPACE COOLING;
  DE.22 = TEMPERATURE MEASUREMENTS;
  DE.23 = THERMAL EFFICIENCY;
CONTROL;
  DCSO = IN GRID LIBRARY;
```

Figure 6

NATIONAL GEOTHERMAL INFORMATION RESOURCE

ENERGY CONVERSION FILE
HEBER
APRIL 1978

DATA ELEMENT	DATA ENTRY
GENERAL INFORMATION	
RECORD NUMBER-	2;
SITE NAME-	HEBER KCRA;
LOCATION-COUNTRY	USA;
STATE	CALIFORNIA;
COUNTY	IMPERIAL;
PROJECT LIFE-YEARS/OUTPUT	*25 YEARS/200 MWE (MEIDAV 76);
SITE DEVELOPER-FEDERAL	DOE;
STATE	ERCDC (GEOTHERM. ENERGY MAG. 77;)
INDUSTRIAL	CHEVRON OIL, SDG&E, EPRI (HOLT 78);
SITE DESCRIPTION-	
TERRAIN	DRY LAKE BED;
AREAL EXTENT	50-55 SQ. KM;
NEAREST COMMUNITY	HEBER-2 KM (HOLT 78);
ACCESS ROADS	EXISTING LIGHT DUTY PAVED ROAD, RAILROAD TRACK, 2 KM (HOLT 78);
COMMENT-	WESTERN REGION POWER COMPANIES INVOLVED (GEOTHERMAL ENERGY 77);
RESERVOIR PARAMETERS	
FLUID TEMPERATURE-	146-190 DEG C (MEIDAV 76);
WELL COST-	*$400,000 (RANACHANDRAN 77);
FIELD FLOW RATE-	*3.05 E6 KG/HR (HOLT 78);
WELL LIFE-	
NONCONDENSIBLE GAS CONTENT-	TRACE;
STEAM QUALITY-	~10% (DIETZ 77);
WELLHEAD TEMPERATURE-	
FLUID RATE-	50-150, *340 M3/HR/WELL (MEIDAV 76);
ENTHALPY-	
OPERATIONAL PARAMETERS	
PLANT SIZE-	*50 MWE (HOLT 78);
PLANT COST-	*592 $/KWH (HOLT 78);
POWER COST TO LOAD CENTER-	*35.84 MILLS/KWH (HOLT 78);
POWER CYCLE (FLASHED, BINARY)-	*BINARY, 20% ISOPENTANE/80% ISOBUTANE (HOLT 78);
O & M COST-	
WELL SPACING-	
PARASITIC POWER-	*27-35% FOR BINARY SYSTEM (GEONOMICS 76);

Brine Treatment File

The brine treatment bibliography was a joint development of DOE and EPRI; it is available for computer searches of the following categories of information: geothermal fluids, methods for treatment to control scaling and corrosion, and methods for removing pipe scaling. Figure 7 shows two typical records.

Study of Brine Treatment

The objective of the project was a critical survey of methods useful for treating geothermal brines to control scaling and corrosion, and for fluid injection purposes. The approach used was a critical survey of current data covering brine treatment methodology whereby the geothermal literature was covered in a comprehensive manner, with selected literature included from the oil field, waste water, and boiler water industries to provide information where the geothermal data were either lacking or insufficient. The project work involved screening the world literature for data dealing with brine treatment methodology and storing the references on computer tapes. The results were used to provide information for a survey of methods of brine treatment (Ref. 2, 6).

Present methods for controlling scale dpeosition and materials corrosion in the geothermal industry are mainly cleanup and replacement of pipes and other components on an as-required basis. Scales (e.g., silica, sulfide) from hot brines are usually removed from boreholes by acidizing or reaming; those in piping are mechanically removed by wire-brushing or by using scrapers. Materials rendered unserviceable by corrosion are replaced with new parts.

There is a current effort on treating geothermal fluids to minimize silica, sulfide and calcite deposition from fresh brine, and to remove arsenic

DESCRIPTORS- SCALING; EAST MESA KGRA; GEOTHERMAL BRINES; SCALING CONTROL; CALCITE; BARIUM SULFATES; SILICA MINERALS; BRINE TREATMENT; CHELATING AGENTS; ACIDIZATION; EXPERIMENTAL RESULTS; TABLES; FIGURES.

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TRESEDER 77
BRINE TREATMENT/CORROSION

TITLE- DOWN-HOLE CORROSION IN A SALTON SEA GEOTHERMAL WELL.

AUTHOR- TRESEDER, R.S. (CONSULTANT)

WIELAND, R. (SHELL DEVELOPMENT CO.).

REFERENCE- PROCEEDINGS--INTERNATIONAL SYMPOSIUM ON OILFIELD AND GEOTHERMAL CHEMISTRY. UNIVERSITY OF CALIFORNIA AT SAN DIEGO, JUNE 27-29, 1977. SOC. OF PETROLEUM ENGRS. OF AIME, DALLAS, TEX., 1977, P. 241-248.

DESCRIPTORS- CORROSION; GEOTHERMAL WELLS; SALTON SEA GEOTHERMAL FIELD; FIELD STUDIES; EXPERIMENTAL RESULTS; DATA; SURFACE EQUIPMENT; CORROSION RESISTANT ALLOYS; BRINES; CHEMICAL ANALYSIS; TABLES; FIGURES.

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VETTER 77
BRINE TREATMENT/SCALING

TITLE- SCALE PREDICTION IN GEOTHERMAL OPERATIONS--STATE OF THE ART.

AUTHOR- VETTER, O.J. (CONSULTANT)

REFERENCE- PROCEEDINGS--INTERNATIONAL SYMPOSIUM ON OILFIELD AND GEOTHERMAL CHEMISTRY. UNIVERSITY OF CALIFORNIA AT SAN DIEGO, JUNE 27-29, 1977. SOC. OF PETROLEUM ENGRS. OF AIME, DALLAS, TEX., 1977, P. 37-44.

DESCRIPTORS- PRECIPITATION; SCALING; GEOTHERMAL SYSTEMS; THEORETICAL TREATMENTS.

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and silica prior to spent brine disposal. These include the following: (1) addition of cold dilution water to fresh fluid to reduce silica scale; (2) a holding tank for spent brines to allow deposition of silica in the retention tank, thus reducing scale in the transport lines or in an injection well; (3) coagulation to remove arsenic and silica prior to disposal of the fluid to the Waikato River.

Research and development activities centered around geothermal scale and corrosion control by treatment of brines have been increasing within the past two years. A brine treatment program might include the following:

1. Characterization of brine chemistry and deposited scale composition to help determine the causes and possible means of control. The scale and corrosion products reflect the variable brine composition, and treatment methods can then be devised for the production fluid and for the method of disposal.
2. Basic laboratory investigations on the mechanisms and rates of scale formation due to corrosion or scale deposition. Basic data are transferable to all geothermal sites and will be needed to select, for example, additives and materials which would control scaling and corrosion.
3. Development of instruments to monitor the important geothermal brine scale and corrosion parameters (e.g., silica, pH, H_2S). The instrument sensors should be sufficiently rugged to monitor geothermal fresh fluids in a reliable manner.
4. Correlation of laboratory test results with actual tests in field conditions. In this way, predictions based on laboratory results can be verified and incorporated into brine treatment programs.

5. Development of laboratory screening methods for commercially available scale and corrosion inhibitors to evaluate their effectiveness under geothermal conditions. The inhibitors should be useful at the elevated temperatures and pressures encountered in geothermal systems and should not react with brine constituents.

Noncondensibles Databank

A numerical computer file containing numerical data on noncondensible gases covering mainly H_2S and CO_2 at geothermal areas was initiated. The file covers the Wairakei geothermal field, and is constructed to include the following data: geothermal well location, sampling method, sample location, well-head pressure and gas output. Future geothermal areas to comprise the databank will include all domestic geothermal sites and additional non-U.S. sites such as Lardarello and Cerro Prieto. Figure 8 shows a typical record taken from the larger Wairakei noncondensibles file. See Ref. 3.

Fluids Chemistry File

The geothermal reservoir fluids chemistry numerical databank was developed jointly with the LBL Geoscience Engineering program and is available for searches. The file includes the following data on hot water fluids: chemical composition (e.g., Cl, HCO_3), physical characteristics (e.g., pH), well name and location. See the typical record illustrated in Figure 9.

Information Exchange with Other Data Centers

A. Domestic

GRID is coordinated with three other U.S. data centers working to facilitate the collection and exchange of information on geothermal energy research and production: the DOE Technical Information Center (TIC) at Oak

Figure 8


```
RECORD 44
BASIC-INFO;
  COUNTRY = NEW ZEALAND;
  KGRA = WAIRAKEI GEOTHERMAL FIELD;
  WELL = 4/1;
  WELLHEAD PRESSURE = 200;
    UNITS (WELLHEAD PRESSURE) = PSIG;
  SEPARATING PRESSURE = 200;
    UNITS (SEPARATING PRESSURE) = PSIG;
  ENTHALPY = 450;
    UNITS (ENTHALPY) = BTU/LB;
  STEAM OUTPUT = 30.000;
    UNITS (STEAM OUTPUT) = KLB/HR;
  GAS IN STEAM = 0.37000;
    UNITS (GAS IN STEAM) = WEIGHT PERCENT;
SAMPLING-INFO;
  MEASUREMENT DATE = DECEMBER 1959;
  SITE = GAS IN STEAM AT SEPARATING PRESSURE;
NONCONDENSIBLE GASES;
  UNITS (NONCONDENSIBLE GASES) = MILLIMOLES/100 MOLES;
  H2S = 5.9000;
  CO2 = 150.00;
BIBLIOGRAPHIC DATA;
  SHORT CODE = GLOVER 70;
```

Figure 9

RECORD 256
CODE NAME=MAGMAMAX 1A
SAMPLE TYPE=WATER

WELL MAGMAMAX 1
SALTON SEA KGRA
LOCATION-- T11S, R13E, SEC. 33, 1120FT E, 200FT N, FROM S QUARTER CORNER.
IMPERIAL COUNTY, CA., USA

WELL INFORMATION
OWNER-- IMPERIAL MAGMA (MAGMA POWER CO.)
LESSEE--SAN DIEGO GAS AND ELECTRIC CO.
DATE DRILLED-- 6 JAN 72 - 21 JAN 72
U.S. BUREAU OF MINES AND SAN DIEGO GAS AND ELECTRIC CO. ARE WORKING ON DEVELOPMENT OF MAGMAMAX 1.

WELL DATA
DEPTH ----- 875 METERS
TEMPERATURE 24. C AT WELLHEAD
265 C AT MAXIMUM
FLOW INFORMATION-- HIGH AS 400-500 GPM REPORTED. 50 GPM AT 350 PSI AND 240 C. 542000 LB/HR AT 160 PSI, 13 PERCENT STEAM.
PRODUCTION INTERVAL-- WELL CASED TO 686M, PERFORATED 544-686M.

SAMPLING INFORMATION
DATE-- 13 - 16 JUNE, 1976
SAMPLE NUMBER, LABORATORY-- U.S. BUREAU OF MINES MOBILE CHEMISTRY LAB.
SAMPLE LOCATION-- WELLHEAD
SAMPLING METHOD-- SAMPLE DRAWN FROM PORT AT SIDE OF PIPE, COOLED, COLLECTED INTO 1L NALGENE BOTTLES. ATOMIC ABSORPTION SAMPLES COLLECTED INTO CONC. HNO3. CARBONATE SAMPLES COLLECTED INTO 3 PERCENT HNO3
CONDITION OF WELL DURING SAMPLING-- LARGE FLOW RATE--400-500 GPM.

PHYSICAL DATA
PH= 5.14 PH RANGE= +-.11 TEMP DURING READING= AMBIENT
OTHER DATA--
ENTHALPY = 250 CAL/G.

BRINE DATA
METHOD OF ANALYSIS-- ATOMIC ABSORPTION, STANDARD ADDITION METHOD, AVERAGE OF 3 RUNS. CL BY TITRATION.
UNITS-- PPM

CONSTITUENT	CONCENTRATION	COMMENT
NA	46200	+-6100
K	7360	+-644
LI	192	+-17
CA	61500	+-13200
CL	135900	+-3070
HCO3	4472	+-1570, TOTAL CARBONATE
CU	77	+-29
FE	273	+-68
PB	59	+-15
SR	415	+-98

Ridge, the GEOTHERM project of the U.S. Geological Survey in Menlo Park, and Geopressure Geothermal System at the University of Texas, Austin. The data systems of TIC, GEOTHERM and GRID are coordinated for data collection and dissemination, with GRID serving as a clearinghouse, having access to files from all geothermal databases including both numerical and bibliographic data. GRID interfaces with DOE/TIC for bibliographic information and with the U.S. Geological Survey for certain site-dependent numerical data. An interface is maintained with the Geothermal effort at LBL, other data sources such as the Environmental Protection Agency database, the National Standard Reference Data System and similar research efforts and institutions for the collection of basic numerical data. The work of these other information systems are included in the GRID system thereby avoiding duplication of effort.

B. International

When DOE was formed it retained responsibility for the U.S.-Italy bilateral information exchange agreement, a result of the earlier NATO/CCMS pilot study which was initiated at a CCMS meeting held in New Zealand in 1974, whereby the attendees had agreed on a pilot study for the exchange and collection of worldwide information regarding the development and evaluation of geothermal energy resources (Ref. 7, 8).

Under the initial NATO/CCMS agreement GRID acted on behalf of DOE to provide the Italian data center, CNUCE/Pisa, the following typical material:

1. Computer tape containing the TIC geothermal bibliographic file from the Energy Data Base.
2. Computer tape and printout containing the GRID file on geothermal H_2S.
3. Thesaurus, developed jointly by GRID and the LBL Information Research Group.

In 1977, exchange activities continued: a tape of the fluids chemistry file was provided to CNUCE under the Italy-U.S. Bilateral Data Exchange. In addition, Central and South American contacts were established via CCMS; printouts of the fluids chemistry data were sent to over ten Latin American contacts. Material was received from Costa Rica, and sent to both TIC/Oak Ridge and GEOTHERM/Menlo Park. In turn, GRID received a computer tape from Italy containing geothermal references.

Conclusion

The results of the initial CCMS pilot study and the follow-on bilateral agreement demonstrated the effectiveness of the pilot study concept as applied to the exchange of geothermal information on a worldwide basis, and the advantages of computerized information systems for this kind of operation. The success of the work required the cooperation and coordination of many agencies and data centers on the part of each participating nation. In the U.S., for example, those involved in coordinating the project were the Department of Energy, Department of State, Environmental Protection Agency, U.S. Geological Survey, and Lawrence Berkeley Laboratory of the University of California.

Recommendations for Future Work on International Information Exchange

The primary objective of the CCMS Pilot Study on data exchange was to create an international geothermal energy data base, a pool of information from which all countries may draw. The difficulty does not lie with designing the data system but rather with the mechanics of securing and coding the information. Most participants are eager to contribute to the file but balk at the tedious and sometimes formidable task of coding forms for the computer. This is understandable because such coding could create a drain on manpower and funds. Future work in data exchange must face the reality that responsibility for coding lies

with the data center.

Recommendations for this and other future work include the following:

1. Participating countries should collect copies of data (e.g., internal reports, manually logged data) for transmittal to the designated computer centers. This is especially important for data that is not widely circulated and may be either inaccessible or difficult to obtain. This data is important for evaluation and calculation of energy parameters and should be included in the information exchange.
2. The data centers responsible for maintaining the computer tapes should fill out the input format forms. Participating countries would be required only to provide the necessary copies of reports and other data. The computer centers should therefore make provisions to add needed staff to code the information.
3. The time taken to exchange or transmit material between participating countries needs to be shortened, and site visits by computer center staff with an agreed-on frequency (e.g., yearly interval) to collect reports is required.
4. Each participating country has a different type of data need which should be provided by the data centers. It is important that participating countries be provided the data they need in exchange for their reports.
5. The computer centers should contain two types of information: (a) data evaluated by the center; (b) data evaluated by others. While it is not possible to critically evaluate all data within reasonable time frames, users of the data should be aware of the sources of the information.
6. Priorities in the acquisition of data should be established. For example,

given the choice between data in publications and data in unpublished files, it might be important to concentrate on the unpublished data first. Later, the more generally available data could be secured from libraries.

7. Transcribing the data on forms for computer input is the most difficult task. Three possibilities seem most reasonable.

   a. The data would be copied and sent to the data center for encoding.

   b. People would be sent to the countries to encode the information available there.

   c. Funds would be provided to the country so it may hire staff to do the encoding.

8. A system of responding to the participating countries should be organized. Such a task may include a newsletter and periodic retrievals from the file.

9. Provide computer expertise to those developing nations which currently lack such capability. Large quantities of data are handled most effectively via a computer medium (e.g., magnetic tape); it is therefore imperative that computer expertise be initiated by nations which currently lack this capability.

References

1. J.J. Herr, S.L. Phillips, S.R. Schwartz, T.G. Trippe, "Standards for Multilateral & Worldwide Exchange of Geothermal Data", Mathematical Geology, Vol. 9, no. 3 (1977).

2. S.L. Phillips, A.K. Mathur, R.E. Doebler, "A Survey of Treatment Methods for Geothermal Fluids", 1977 SPE-AIME International Symposium, SPE-6606, June 1977.

3. S.R. Schwartz, "Geothermal Aspects of Hydrogen Sulfide", UCID-3923, Oct. 1977.

4. S.L. Phillips, J.A. Fair, F.B. Henderson, S.R. Schwartz, "Review of Geothermal Subsidence", LBL-3220, Sept. 1975.

5. S.L. Phillips and J.R. Swanson, "Application of a Geothermal Computer File System to Chemical Geothermometers", LBL-5915, Jan. 1977.

6. S.L. Phillips, A.K. Mathur, R.E. Doebler, "A Study of Brine Treatment", Research Project RP-791-1, LBL-6371, May 1977.

7. F.A. Harris and S.L. Phillips, "International Geothermal Information Exchange, The GRID Program", LBL-5295, Oct. 1976.

8. "Creating an International Geothermal Energy Community", J.C. Bresee, W.W.S. Yen, J.E. Metzler, eds., LBL-6869, Draft Report.

Section III. Environmental Information

Introduction

The environmental information activities of the GRID program include development of computer files on environmental aspects of geothermal energy which provide the basis for reports on the current status of data. Environmental aspects in 1977 were mainly the following: (1) hydrogen sulfide emissions; (2) noncondensibles emissions; (3) subsidence; and (4) boron.

Generally, for each environmental parameter, both the computerized database and status of data report provide information on: (1) sources, (2) control methods, (3) measurement and monitoring techniques, (4) effects on man, animals and vegetation, (5) regulatory considerations and environmental standards, and (6) references to the sources of the data used in the reports.

In 1977, the GRID environmental file was on line for searches covering the following new and updated subsets:

Hydrogen Sulfide Database

Geothermal vapor and hot water fluids contain a fraction of noncondensible gases composed mainly of carbon dioxide with lesser concentrations of hydrogen sulfide and other gases including methane, ammonia, nitrogen, hydrogen and ethane. The interest is in H_2S aspects of materials and environmental effects. Although this file highlights the geothermal aspects of hydrogen sulfide, substantial references from other sources of H_2S are included in the file; for example: petroleum refining, smelting of sulfite ores, the manufacture of Kraft pulp and offal rendering plants. Currently, the topics referenced in the hydrogen sulfide file cover the following: sources, monitoring methods, emission control, environmental effects, health effects, pathways in both the air environment and the water environment. The hydrogen sulfide file is the result of an initial

screening of the worldwide literature and new citations will be appended periodically.

Land Subsidence File

The land subsidence file is on line and available for restricted searches. Topics in the file are subsidence resulting from ground water overdraft and petroleum production, as well as subsidence which is possibly associated with geothermal fluids withdrawal.

Brine Treatment Database

The brine treatment file is available for computer searches to include the following areas: coagulation methods, filtration, and aeration to remove dissolved gases.

Noncondensible Gases Numerical File

A numerical file containing data on noncondensible gases (e.g., H_2S, CO_2) at geothermal areas is in preparation. The file is constructed to include descriptive information such as geothermal well location, sampling method and sampling date. The file also includes technical information such as well-head pressure and gas output. A sample subset on the Wairakei geothermal field is on line for searches to interested users. Future geothermal areas to comprise the file will include all domestic geothermal sites and additional non-U.S. sites such as Larderello field in Italy and the Cerro Prieto field in Mexico.

Land Subsidence Databank

1977 saw development of the status of data file on geothermal and other land subsidence in coordination with the LBL Earth Sciences Division subsidence effort. A draft of the initial entry covering Wairakei is shown in Attachment IV.

Copies of this draft were sent (in early 1978) to the following for comments: DOE/DGE staff, USGS/Sacramento; and New Zealand Department of Scientific and Industrial Research, Wellington. Any comments will be incorporated into a final format, which will be expanded to include all available data on geothermal fields, and relevant non-geothermal data, e.g., oil and gas, ground water overdraft.

Fluids Chemistry File

The fluids chemistry numerical file developed with the LBL Geoscience Engineering program is available for searches. The file contains data on the chemical components of geothermal hot waters of environmental interest (e.g., H_2S, boron).

References

S.L. Phillips, J.A. Fair, F.B. Henderson, S.R. Schwartz, "Review of Geothermal Subsidence", LBL-3220, September 1975.

F.A. Harris and S.L. Phillips, "International Geothermal Information Exchange, The GRID Program", LBL-5292, October 1976.

J.J. Herr, S.L. Phillips, S.R. Schwartz, T.G. Trippe, "Standards for Multilateral & Worldwide Exchange of Geothermal Data", Mathematical Geology, vol. 9, no. 3 (1977).

S.R. Schwartz, "GEODOC-The GRID Document File, Record Structure and Data Element Description", LBL-4432, R-1, 1978 (in preparation).

Section IV. The GRID Documentation System

Introduction

The GRID documentation system (GEODOC) is computer based and contains the descriptive cataloging and indexing information for material processed by the National Geothermal Information Resource. The descriptive cataloging techniques are based on those of the International Nuclear Information System (INIS) of the International Atomic Energy Agency. See Table I. Each record contains the descriptive cataloging, abstracting, and indexing information corresponding to a single document; the information within a given record is subdivided into data elements, some of which are indexing keys. Table I and the coding form in the Appendix list the definitions of all the data elements which may appear in a GEODOC record. Some data elements (e.g., author's name) can occur repeatedly within one record; an "m" in the third column of Table I indicates that such multiple occurrences are allowed. The tag used to label the data elements within a record is shown in the left hand column of Table I. The system is managed by the Berkeley Data Base Management System.

The data elements bear certain hierarchical relationships to each other; the structure is indicated in Table I by indenting the tag names of subordinate data elements and placing them after their parents. Data elements are input to the system in any order except that subordinate data elements must follow the occurrence of their parent with which they are associated.

Data handling using computer techniques applied by GRID for geothermal energy have wider applications. In 1977 and early 1978, organizations expressing interest in GRID developed data handling techniques included the LBL Earth Sciences Division; the LBL Information Research Group; Geothermal Data Bank, Pisa, Italy; and the Geopressure Data Bank at the University of Texas.

Table I. OEODOC Data Elements

LBL Tag	INIS Tag	m°	n°	Data Element Definition
SC	008			document short code: unique identifier for document
TY				type of document/bibliographic levels/literary indicator
DES-CAT		m	n	delineates information for one bibliographic level
BL	009			bibliographic level indicator
PT	200			primary title (translated into English if necessary)
PS	201			primary subtitle (translated into English if necessary)
TA	620			title augmentation
L	600			language (for non-English document)
OT	230			original title (non-English) or journal/series title
OS	231			original subtitle (non-English) or journal/series subtitle
ED	250			edition
CODEN				journal CODEN
AUTHORS		m	n	delineates author-affiliation group
AU	100	m		author's name
AN	100			author note (ed., comp., eds., comps.)
AA	100	m		author's affiliation
AC	700			affiliation code
CE	110	m		corporate entry
CC	710			corporate code
DG	111			academic degree
SPO		m		sponsor
SPC				sponsor code
SCN		m		sponsor contract number
RN	300			report or patent number
SN	310	m		secondary numbers
INT	320			International Standard Book Number or Patent Code
PUB	402			publisher
PUP	401			place of publication
PUD	403			publication date
COL	500			collation (volume, issue, page)
N	610			note
COT	210			conference title
COP	211			conference place
COD	213			conference date
AV				availability and price

Continued on next page.

Table I. GEODOC Data Elements (Continued)

LBL Tag	INIS Tag	m*	n	Data Element Definition
REL-REF		m	n	delineates information for one related reference.
RL				relator
RLR				relationship and reference
RSC				related short code
ABSTRACT		m	n	delineates one abstract
ABS				abstract
ABSO		m		abstract source
INDEX		m	n	INDEX.1 general indexing. INDEX.2, 3,...N splits
CQ		m		category/qualifier
TICC		m		TIC category
DE	800	m		descriptor from thesaurus
DD	800	m		data descriptor from thesaurus
ID	m			identifier
PD	810	m		proposed descriptor
CONTROL			n	internal LBL data elements
LA		m		local availability
BR				borrow/return
DCSO		m		descriptive catalogers initials, date and comment
AISO		m		abstractor-indexers initials, date and comment
DATA-FILE		m		data file name
POT		m		data descriptor for potential data
IN		m		data descriptor for included data

*m-This data element may have multiple entries
*n-This data element contains no value and need not be entered on input. It serves to delineate a group of data elements.

Establishing standards for the types of information to be carried in a record is highly desirable. Probably the most difficult aspect is anticipating the degree with which information should be delimited. As an example, some bibliographic systems tend to include in one undelimited field all of the journal reference information while in others the journal name, volume, issue, page and date are in separate fields. The higher the degree of separation of discrete units, the greater the flexibility in manipulation (including format checking) possible. In order to produce data that can be used by other groups, GRID follows the INIS list of types of data. The two major stumbling blocks to adoption of a standard list of data elements are the investments in existing systems, and the costs of processing a detailed structure whose value may not be apparent initially. It is therefore important that new data centers use standard coding procedures such as those of INIS in the early formative stages.

One area is in standardizing and updating contents of the data fields. These specify, for instance, the order of authors' names; abbreviations for journal names; forms of institutional names; and codes for recurring information, such as journal CODEN, corporate author identifiers, and country codes, which are a final check on the consistency of the entries (See Attachment V). The major advantage of standardization in this area is ease of understanding and unambiguously searching the data. Probably the most difficult standardization problem in bibliographic work centers on means of describing the subjects of a document; this includes both the style of the subject description and the particular terms or categories used.

Conclusions

Standardization of data for interchange means that a product generated for one set of users can be used with minimal effort by a wider community. Aspects subject to standardization include physical characteristics of the medium of exchange; overall structure of the file; structure of the individual records; types of information to be included within a record; and style of the information and authority files associated with it. Standards for the exchange of bibliographic data (e.g., INIS) are well established and in active use throughout the world. GRID utilizes these standards for bibliographic work, thus enhancing the value of its product and promoting the active interchange of data with other groups. Similar geoscience data standards would result in an even wider level of compatibility for the interchange of data. Future work on data standards might include:

1. Standardized data elements developed by a consensus between users and data centers. This would facilitate the collection, exchange, and utilization of geothermal information.
2. Uniformity in magnetic tape formats. Time and expense devoted to running a tape from one data center so that the tape information can be utilized by another data center would be minimized.
3. Delegation of responsibility to each participating data center for one or more aspects of the exchange program. For example, it may be desirable to have one data center put all of one type of data into one acceptable format for dissemination to the other participants.
4. Continual updating of authority lists so that they are compatible with current usage. For example, many nations have changed their

methods for mail addresses (e.g., ZIP codes), and these changes should be reflected promptly by a change in the authority list.

5. One set of commonly accepted units for reporting physical measurements. Conversion of many units to a common unit is a time-consuming procedure which also impedes evaluation of the data.
6. Development of tags or flags to indicate the level of quality of numerical data may be desirable. Often, erroneous or unevaluated data are worse than no data at all.
7. A listing of data descriptors in a thesaurus of terms which will impart to the user an idea of the magnitude of the numerical data, the experimental procedure used to obtain the data, and the materials (e.g., chemicals) used in the experiment.

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Attachment IV

NATIONAL
GEOTHERMAL INFORMATION
RESOURCE

LAND SUBSIDENCE/RECORD 1
WAIRAKEI GEOTHERMAL FIELD
NEW ZEALAND

MARCH 31, 1978

TAG	DATA ELEMENT	DATA ENTRY
	A. GENERAL INFORMATION (GI)	
GI010	FIELD OR AREA	WAIRAKEI GEOTHERMAL FIELD;
GI020	NEAREST COMMUNITY	ROTORUA;
GI030	DISTRICT OR COUNTY	
GI040	STATE OR PROVINCE	
GI050	COUNTRY	NEW ZEALAND;
GI060	GEOLOGIC SETTING	WAIRAKEI GEOTHERMAL FIELD IS UNDERLAIN BY A NEAR-FLAT, QUATERNARY, ACID VOLCANIC ROCK SEQUENCE. MAIN PRODUCTION AQUIFER IS ABOUT 1500 FT THICK PUMICE BRECCIA (WAIORA FORMATION). MUDSTONE/SILTSTONE (HUKA FALLS FORMATION) FORMS THE CONFINING BED (BOLTON 73);
GI070	HYDROLOGIC SETTING	
GI080	SUBSIDING AREA LATITUDE/LONGITUDE	112 DEG W/312 DEG S;
GI090	SUBSIDING AREA ELEVATION	
GI100	GEOLOGIC MAPS OF AREA	SEE HATTON 70, HUNT 70, HUNT 70B, AND HUNT 77;
GI110	COMMENTS	
	B. SUBSIDENCE CAUSES AND MECHANISMS (CM)	
CM010	RESOURCE TYPE WITHDRAWN	GEOTHERMAL HOT WATER;
CM020	YEAR PRODUCTION BEGAN	1958;
CM030	SUBSIDENCE MECHANISM	BOTH CONTINUATION AND LOCATION OF THE SUBSIDENCE IS UNEXPLAINED. MASS RECHARGE WAS <50 PERCENT FOR 1958-1963, AND HAS BEEN ABOUT 90 PERCENT SIN-

		CE 1966. TEMPERATURES AND PRESSURES IN THE FIELD HAVE STABILIZED SINCE 1966. SUBSIDENCE MAY NOT BE RELATED TO GEOTHERMAL HOT WATER WITHDRAWAL , BUT RATHER TO NATURAL CAUSES, SUCH AS, (1) FROM SLOW DRAINING OF NEAR-SURFACE (<0.1 KM) ROCKS IN RESPONSE TO WITHDRAWAL OF WATER FROM THE DEEPER (>0.3 KM) PRODUCTION ZONE, (2) FROM THERMAL CONTRACTION CAUSED BY INTRUSION OF COLD WATER INTO HOT ROCK IN THIS AREA (HUNT 77);
CM040	COMMENTS	
	C. SUBSIDENCE DATA (SD)	
SD010	LAND USE	INDUSTRIAL--GEOTHERMAL POWER PRODUCTION;
SD020	YEAR SUBSIDENCE FIRST OBSERVED	VERTICAL(1956), AND HORIZONTAL(1965) (HATTON 70, AXTMANN 74);
SD030	SUBSIDENCE AREA	65 KM2 (1956-1966) (HATTON 70);
SD040	AVERAGE SUBSIDENCE	0.5 M (1952-1964) (STILWELL 75); 3.7 M (1956-1974) (AXTMANN 74);
SD050	MAXIMUM SUBSIDENCE	2.4 M (1952-1964) (STILWELL 75); 3.05 M TO 1967 (BOLTON 73,HATTON 70); 4.5 M (1964-1974) (STILWELL 75);
SD060	SUBSIDENCE RATE	36 CM/YR IN WAIORA FORMATION (1964-1977) (PRITCHETT 76B); MAX. 40 CM/YR TO 1967 (HATTON 70);
SD070	HORIZONTAL GROUND MOVEMENT	MAX. 0.8M (1956-1974) (STILWELL 75);
SD080	HORIZONTAL GROUND MOVEMENT RATE	
SD090	TOTAL RESOURCE WITHDRAWN	653 BILLION KG MASS TO 1968 (HATTON 70); 560 BILLION KG MASS (1950-1970) (HUNT 70);
SD100	NET RESOURCE WITHDRAWN	101 BILLION KG MASS (1950-1961), 234 BILLION KG MASS (1961-1967), AND 36 BILLION KG MASS(1967-1974)(HUNT 77);
SD110	AVERAGE RESOURCE WITHDRAWN	48 BILLION KG MASS/YR (STILWELL 75);
SD120	GROUNDWATER LEVEL DECLINE	
SD130	AQUIFER PRESSURE DECLINE	20.7 BARS (1950-1967) (HATTON 70);

SD140	AQUIFER PRESSURE DECLINE RATE	1.77 BARS/YR IN WAIORA FORMATION (1964-1977) (PRITCHETT 76B);
SD150	SUBSIDENCE CENTER LOCATION	460 M FROM THE NEAREST WELLS AND 1830 M FROM THE REGION OF GREATEST DRAW-OFF (BOLTON 73);
SD160	COMMENTS	AREA OF MAX. SUBSIDENCE (SUBSIDENCE ≥0.5 M) LIES OUTSIDE THE MAIN PRODUCTION FIELD AND IS ABOUT 1 KM NE OF THE CENTER OF THE BOREFIELD (HATTON 70 AND HUNT 77); REGION OF LARGEST PRESSURE DROP LIES DIRECTLY BELOW THE MAXIMUM SUBSIDENCE AREA (PRITCHETT 76); AVERAGE RATIO OF SUBSIDENCE VOLUME TO FLUID DRAW-OFF VOLUME FOR THE PERIOD 1967-1971 WAS 0.0076 (GLOVER 74);

D. SUBSIDENCE DAMAGES AND COSTS (DC)

DC010	TYPE OF DAMAGE	PIPELINES--CHANGE IN DISTANCE BETWEEN PIPE ANCHORS OF EXPANSION LOOP IN STEAM MAINS AND CONCRETE DRAINS CRACKING (HATTON 70);
DC020	ESTIMATED DAMAGE COSTS	
DC030	DAMAGE CONTROL MEASURES	REPLACEMENT OF STEAM PIPE WITH SHORT LENGTHS OF PIPING (HATTON 70);
DC040	ESTIMATED ABATEMENT OR CONTROL COSTS	
DC050	COMMENTS	

E. SUBSIDENCE MONITORING AND CONTROL (MC)

MC010	LAND SURFACE MONITORING	PRECISE LEVEL NETWORK--EVERY 3-4 YEARS FROM 1956 TO 1968, IN 1972 AND IN 1975 (HATTON 70, STILWELL 75);
MC020	HORIZONTAL DISPLACEMENT MONITORING	
MC030	VERTICAL DISPLACEMENT MONITORING	
MC040	DIRECT MONITORING INSTRUMENTATION	
MC050	GRAVITY MEASUREMENTS	GRAVITY DIFFERENCES OF 0.5 MGAL (1961-1967), AND 0.1 MGAL (1967-1968) (HUNT 70B); GRAVITY CHANGES MEASURED IN THE AREA OF MAX. SUBSIDENCE FOR THE PERIOD 1971-1974 ARE SMALL, SUGGESTING NO

		LARGE MASS CHANGE (HUNT 77);
MC060	SUBSIDENCE ABATEMENT OR CONTROL METHODS	NOT CONTROLLED;
MC070	COMMENTS	THE GRAVITY METHOD IS A CHEAP AND RAPID MEANS OF MONITORING THE NET MASS LOSS FROM A GEOTHERMAL FIELD UNDER EXPLOITATION. IT CAN ALSO GIVE AN INDICATION OF THE AREA FROM WHICH THE WATER HAS BEEN DRAWN (HUNT 70B);

F. RESERVOIR PROPERTIES (RP)

(WAIORA AQUIFER, HUKA FALLS AQUITARD AND ASSOCIATED FLUID PROPERTIES (MERCER 75))

RP010	AQUIFER PERMEABILITY	K(XX)=K(YY)=1.00E-13 M2;
RP020	AQUIFER POROSITY	PHI=0.20;
RP030	AQUIFER COMPRESSIBILITY	ALPHA(VERTICAL)=2.90E-10 M2/N;
RP040	AQUIFER HEAT CAPACITY	
RP050	AQUIFER THERMAL CONDUCTIVITY	
RP060	AQUIFER THERMAL DIFFUSIVITY	
RP070	AQUIFER DENSITY	
RP080	CONFINING BED PERMEABILITY	K'(VERTICAL)=1.00E-14 M2;
RP090	CONFINING BED POROSITY	PHI'=0.25;
RP100	CONFINING BED SPECIFIC STORAGE	S(S)=1.00E-03 PER METER;
RP110	HEAT CAPACITY OF SOLID PHASE	C(VS)=0.22 (KCAL/KG).DEG C;
RP120	THERMAL CONDUCTIVITY OF SOLID PHASE	
RP130	THERMAL DIFFUSIVITY OF SOLID PHASE	K(S)=5.20E-04 (KCAL/M).S.DEG C;
RP140	DENSITY OF SOLID PHASE	RHO(S)=2137 KG/M3;
RP150	FLUID COMPRESSIBILITY	BETA(WATER)=4.78E-10 M2/N;

RP160 FLUID HEAT CAPACITY — C(V)(WATER)=1.00 (KCAL/KG).DEG C;

RP170 FLUID THERMAL CONDUCTIVITY — K(D)(WATER)=1.553E-04 (KCAL/S).M. DEG C;

RP180 FLUID DENSITY

RP190 COEFFICIENT OF THERMAL VOLUME EXPANSION — LAMBDA(WATER)=5.00E-04 PER DEG C;

RP200 COMMENTS — UNLESS OTHERWISE INDICATED, DATA GIVEN IN THIS SECTION HAS BEEN TAKEN FROM MERCER 75;

G. SUBSIDENCE PREDICTION (SP)

SP010 PREDICTED MAXIMUM SUBSIDENCE

SP020 PREDICTED EXTENT OF SUBSIDENCE

SP030 PREDICTED SUBSIDENCE RATE

SP040 PREDICTIVE MODEL USED

SP050 COMMENTS

H. BIBLIOGRAPHIC REFERENCES (BR)

BR010 SOURCES

AXTMANN 74

AUTHOR(S)- AXTMANN, R.C.;
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REFERENCE- FEL REPORT NO. 445, DSIR, PHYSICS AND ENGINEERING LAB., NEW ZEALAND, 38 P. (1974);

BOLTON 73

AUTHOR(S)- BOLTON, R.S.;
TITLE- MANAGEMENT OF A GEOTHERMAL FIELD;
REFERENCE- GEOTHERMAL ENERGY, THE UNESCO PRESS, PARIS, FRANCE, P. 175-184 (1973);

GLOVER 74

GLOVER, R.B., LETTER TO THE GEOTHERMAL CO-ORDINATOR, DSIR, NEW ZEALAND, 4 JANUARY 1974, AS REPORTED IN AXMANN 74;

HATTON 70

AUTHOR(S)- HATTON, J.H.;
TITLE- GROUND SUBSIDENCE OF A GEOTHERMAL FIELD DURING EXPLOITATION;
REFERENCE- GEOTHERMICS, SPECIAL ISSUE 2 (2), P. 1294-1296 (1970);

HUNT 70

AUTHOR(S)- HUNT, T.M.;
TITLE- GRAVITY CHANGES AT WAIRAKEI GEOTHERMAL FIELD, NEW ZEALAND;
REFERENCE- GEOL. SOC. AM. BULL., V. 81, P. 529-536 (1970);

HUNT 70B

AUTHOR(S)- HUNT, T.M.;
TITLE- NET MASS LOSS FROM THE WAIRAKEI GEOTHERMAL FIELD, NEW ZEALAND;
REFERENCE- GEOTHERMICS, SPECIAL ISSUE 2 (2), P. 487-490(1970);

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AUTHOR(S)- HUNT, T.M.;
TITLE- RECHARGE OF WATER IN WAIRAKEI GEOTHERMAL FIELD DETERMINED FROM REPEAT GRAVITY MEASUREMENTS;
REFERENCE- N.Z.J. GEOL. GEOPHYS., V. 20 (2), P. 303-317(1977);

MERCER 75

AUTHOR(S)- MERCER, J.W.;
TITLE- A GALERKIN-FINITE ELEMENT ANALYSIS OF THE HYDROTHERMAL SYSTEM AT WAIRAKEI, NEW ZEALAND;
REFERENCE- J. GEOPHYS. RES., V. 80 (17), P. 2608-2621 (1975);

PRITCHETT 76

AUTHOR(S)- PRITCHETT, J.W., GARG, S.K., BROWNELL, D.H., JR., RICE, L.F., RICE, M.H., RINEY, T.D., HENDRICKSON, R.R.;
TITLE- GEOHYDROLOGICAL ENVIRONMENTAL EFFECTS OF GEOTHERMAL POWER PRODUCTION - PHASE IIA;
REFERENCE- SSS-R-77-2998, SYSTEMS, SCIENCE AND SOFTWARE, LA JOLLA, CALIF., 175 P. (1976);

PRITCHETT 76B

AUTHOR(S)- PRITCHETT, J.W., GARG, S.K., BROWNELL, D.H.;
TITLE- NUMERICAL SIMULATION OF PRODUCTION AND SUBSIDENCE AT WAIRAKEI, NEW ZEALAND;
REFERENCE- SYSTEMS, SCIENCE AND SOFTWARE, LA JOLLA, CALIF., 13 P. (1976);

STILWELL 75

AUTHOR(S)- STILWELL, W.B., HALL, B.K., TAWHAI, J.;
TITLE- GROUND MOVEMENT IN NEW ZEALAND GEOTHERMAL FIELDS;
REFERENCE- PROC. 2ND UN SYMP. ON THE DEVELOPMENT AND USE OF GEOTHERMAL RESOURCES, SAN FRANCISCO, CALIF., P. 1427-1434 (1975);

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Attachment V

BOOK	COLLECT	DRAWING	FILM	MAP	PHONO.	J ART.	PATENT	REPORT	COMPUT
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