GL00951

University of Hawaii at Manoa

Hawaii Natural Energy Institute
Holmes Hall 246 • 2540 Dole Street • Honolulu, Hawaii 96822

Enclosed are copies of the latest report on Geothermal Research at the Puna Facility, (I.D. No. DE-FG03-85SF15799) a project receiving funding assistance from the U.S. Department of Energy.

Questions or comments regarding these reports should be directed to:

Jim Woodruff
Project Coordinator
Hawaii Natural Energy Institute
2540 Dole Street, Holmes Hall 206
Honolulu, HI 96822
(808) 948-8788

Howard,
Please take a look at this work. Please make copies for Peggy and Duncan.
Thanks,
Marshall
7/10/87

HR

TECHNICAL REPORT
For the U.S. Department of Energy

GEOTHERMAL RESEARCH AT THE PUNA FACILITY

I.D. No. DE-FG03-85SF15799
June 1987

Principal Investigator
Dr. Bill Chen
University of Hawaii at Hilo
Hilo, Hawaii

Introduction

This report on Geothermal Research at the Puna Facility consists of two research papers: (1) Isotopic and Mineralogical Analyses of Samples from the HGP-A Well, by Donald M. Thomas and, (2) Report on Kapoho Geothermal Reservoir Study at the Puna Facility, by Bill Chen, Deane Kihara, and Carolyn Ishimoto. These papers contain results of recent research and outline future activities.

A current budget status report is also included.

Isotopic and Mineralogical Analyses of Samples from the HGP-A Well

Donald M. Thomas

The current focus of geothermal research under the present contract is the isotopic analysis of archived samples of geothermal fluids from the HGP-A well. The samples that have been archived for analysis during the last five years of operations of the generator facility include brine and steam samples, for oxygen-16/oxygen-18 analysis and hydrogen/deuterium analysis, and samples of steam condensate containing carbonate and dissolved sulfide for carbon-13 and sulfur-34 analysis. Because the analysis of carbon and sulfur isotopes will require substantially more sample preparation effort, this work has been delayed until additional staff can be hired for this specific task. However, the oxygen and hydrogen isotopic analyses are being conducted in collaboration with researchers at the U.S. Geological Survey at Menlo Park and hence the analytical facilities and the majority of the sample preparation and analysis effort is being provided at minimal cost to the project. Because of the number of samples available and the complexity of the analysis of the data, it is anticipated that this work will not be complete for several more months. The results obtained to date, however, suggest that continued investigations will provide valuable information regarding the geothermal reservoir.

The objectives of the oxygen and hydrogen isotope analyses have been to: determine the source of fluids generated by the well; determine whether production of fluids has had an impact on their isotopic character that is consistent with the major element chemical changes that have occurred; and to determine whether the observed changes can be of value in projecting the size or longevity of the geothermal aquifer being drawn upon by HGP-A.

The analyses that have been completed to the present time have generally spanned (at very broad intervals) the full production life of the well up to approximately August, 1986. The isotopic data that have been obtained indicate that the geothermal fluids produced during the last five years have quite distinctive isotopic compositions: the isotopic ratio of oxygen in the brine phase has been relatively constant at around 0 to -1 per mill relative to SMOW (Standard Mean Ocean Water) and the hydrogen isotope ratios have varied between a high of +13 per mill (vs SMOW) to a low of -11 per mill (Figure 1). The total fluid produced by the well, when brine and steam both are considered, has somewhat lower isotopic ratios as shown by analysis of a few paired steam/brine samples shown in Figure 2. Comparison of these ratios with rainfall samples taken from Kilauea or with a generalized meteoric water isotopic ratios indicates that these waters are enriched in oxygen-18 and depleted in deuterium isotopes relative to rainwater (Figure 1). The enrichment of the oxygen-18 isotope is probably due to the isotopic exchange of oxygen between the reservoir fluids and silicates in the reservoir rocks. The near constancy of the oxygen isotope ratio of the brines suggests that the exchange has been rapid and hence neither the available silicate minerals nor the available heat in the rock has been substantially depleted in the vicinity of the wellbore.

The behavior of the hydrogen isotopic composition has been substantially different from that of oxygen, however. The ratios have been somewhat more erratic but have shown an apparent decline with time. This reasons behind this behavior are not presently well understood: the most obvious mechanism to explain the decline in deuterium is the incursion of high altitude meteoric recharge to the geothermal reservoir. This mechanism appears to conflict with the obviously increasing seawater influx into the reservoir that is indicated by the increasing chloride concentrations present in the brine phase that have occurred during the last five years. An alternative mechanism is that the decline in deuterium isotope concentration is the result of clay mineral formation that is driven by the intrusion of seawater into the reservoir. Although either of these mechanisms would have the effect of lowering the deuterium concentration in the intruding geothermal brines, further isotopic analyses will have to be conducted in order to determine whether one or the other can be confirmed.

Thus the tentative conclusions that can be drawn from the isotopic data acquired to the present time are that the fluids produced by the well indicate extensive exchange between the silicates and water, suggesting continued availability of heat in the reservoir, and possibly extensive clay mineral formation in the aquifers through which seawater is entering the reservoir tapped by HGP-A. The latter finding suggests that the deposition of secondary clays could choke off seawater entry into the reservoir; recent declines in chloride concentrations in the brine phase suggest that this phenomenon is already occurring.

A second investigation that has only recently begun has been a study of the mineralogy of the cuttings from the HGP-A well. The objective of this effort is to determine whether iron present in the deeper reservoir rocks has been substantially oxidized by reaction with sulfate ions brought into the reservoir by intruding seawater. The presence of high concentration of sulfate in seawater entering basaltic geothermal systems at mid-ocean ridges and its virtual absence in the geothermal fluids being discharged from hydrothermal systems there (and in Hawaii) have raised questions regarding the fate of sulfate and its relationship to sulfides present in the geothermal fluid. Analysis of cuttings and cores from the hydrothermal system in Hawaii for changes in the oxidation state of iron in the minerals should enable us to determine whether iron plays a significant role in the loss of sulfate and the increase in sulfides that have been observed.

This phase of research has progressed only to the initial testing stage at present. However, samples of rock chips have been analyzed using mossbauer spectroscopy and have generally shown that peak heights for ferric and ferrous iron in the cuttings are resolvable and that there are significant differences between samples taken from different depths in the well (Figures 3 and 4). Results of this research will be reported as they become available.

Figure 1

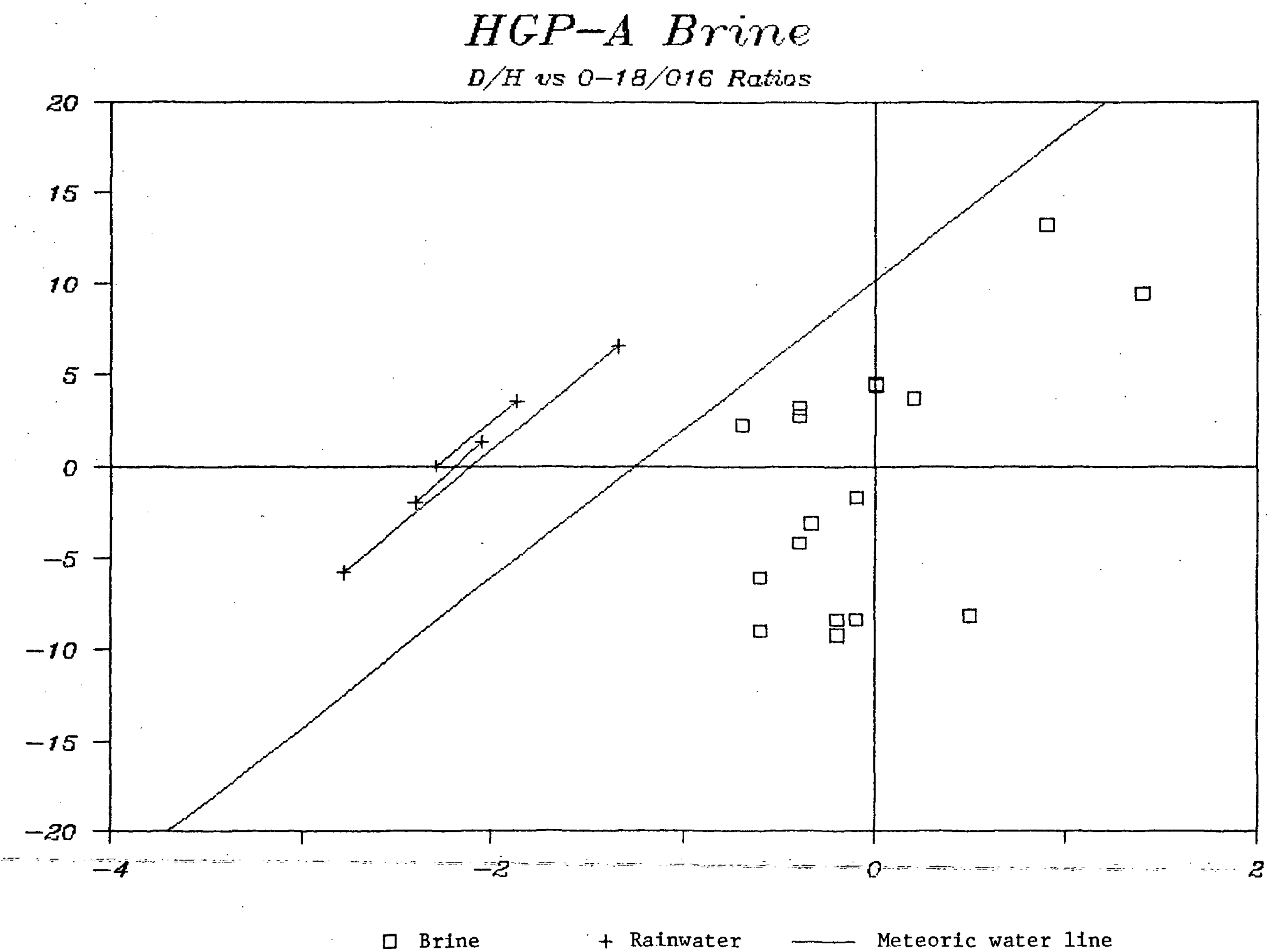
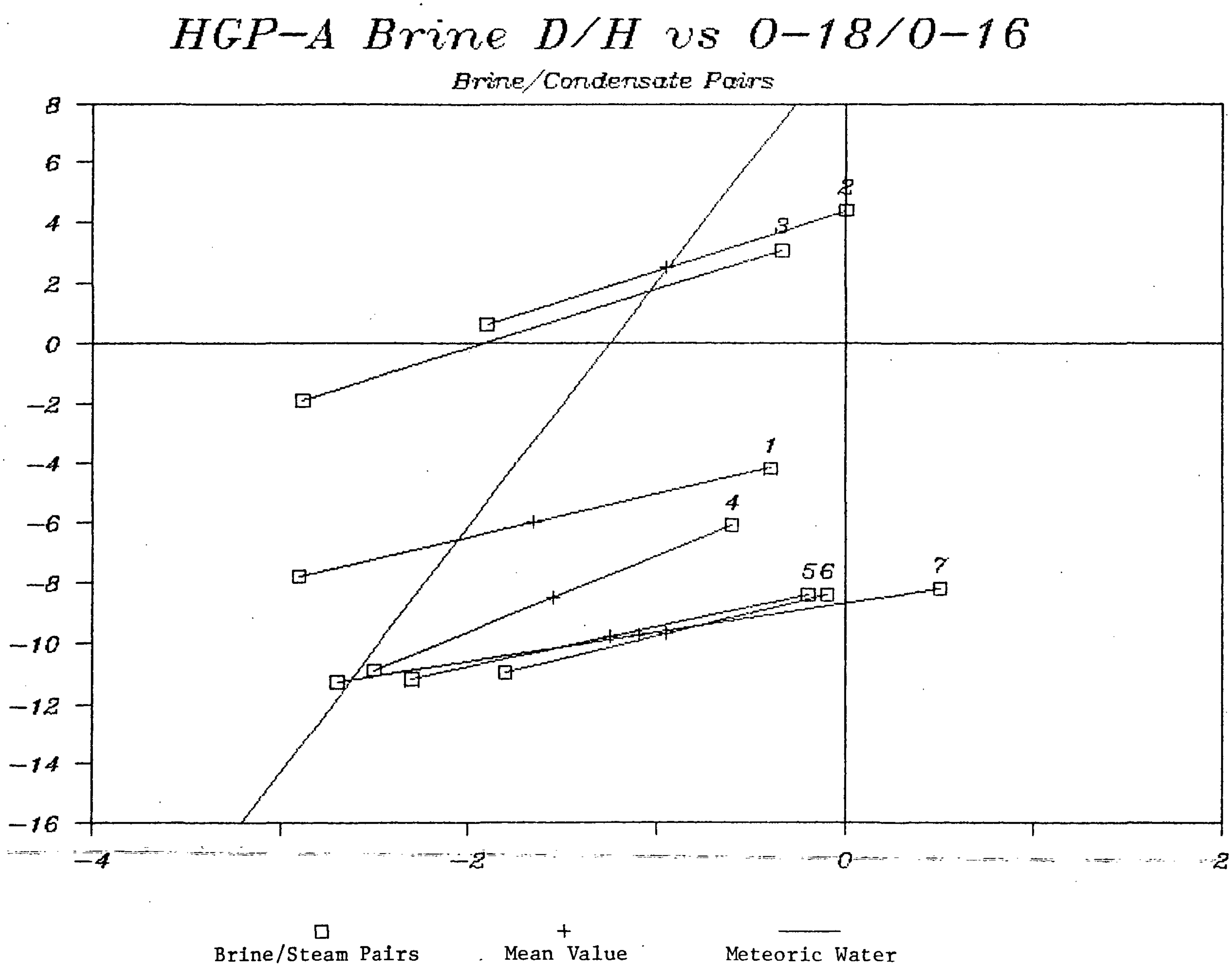
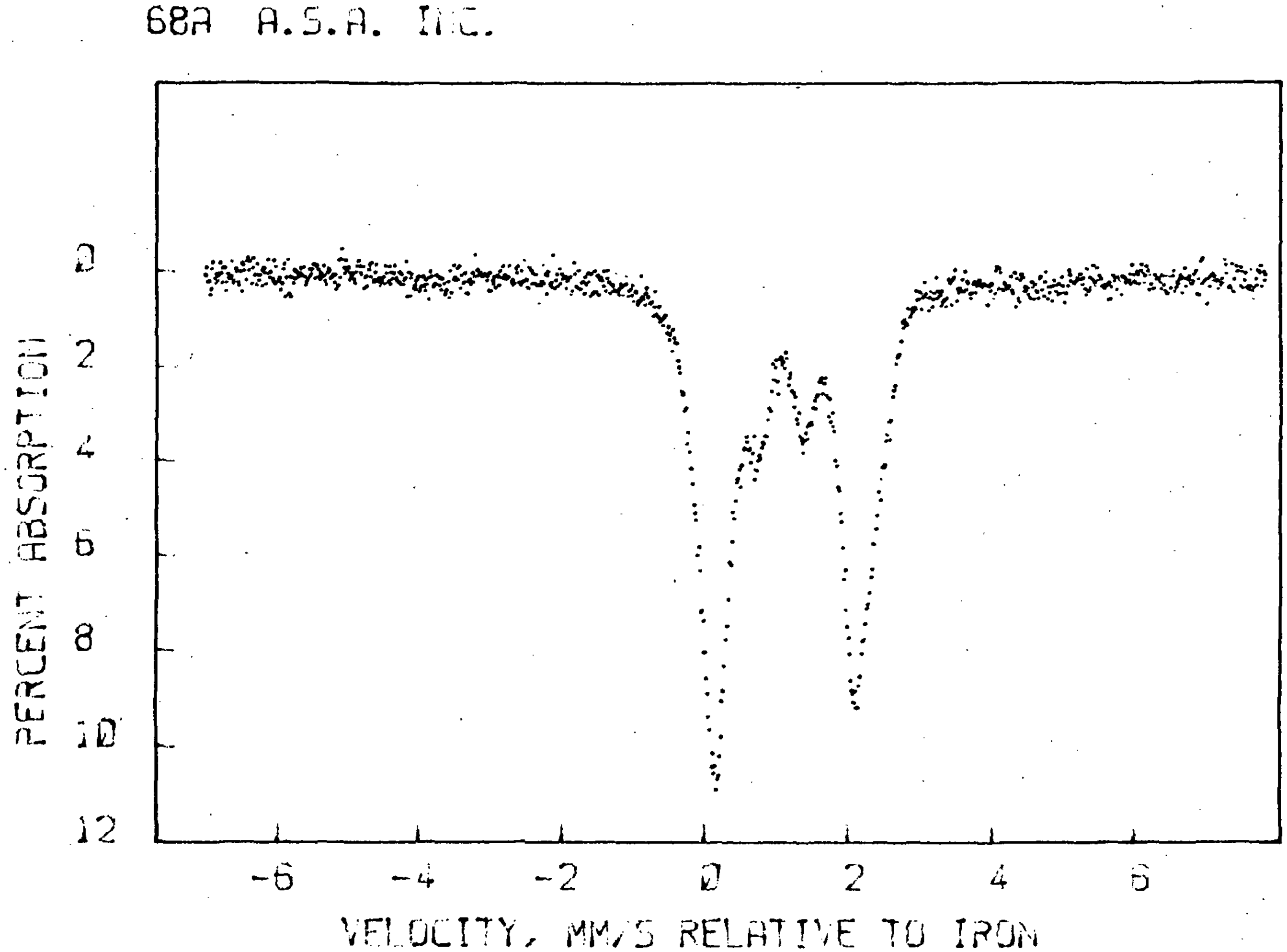

HGP–A Brine
D/H vs O–18/O16 Ratios
20
15
10
5
0
–5
–10
–15
–20
–4
–2
0
2
Brine
Rainwater
Meteoric water line

Figure 2



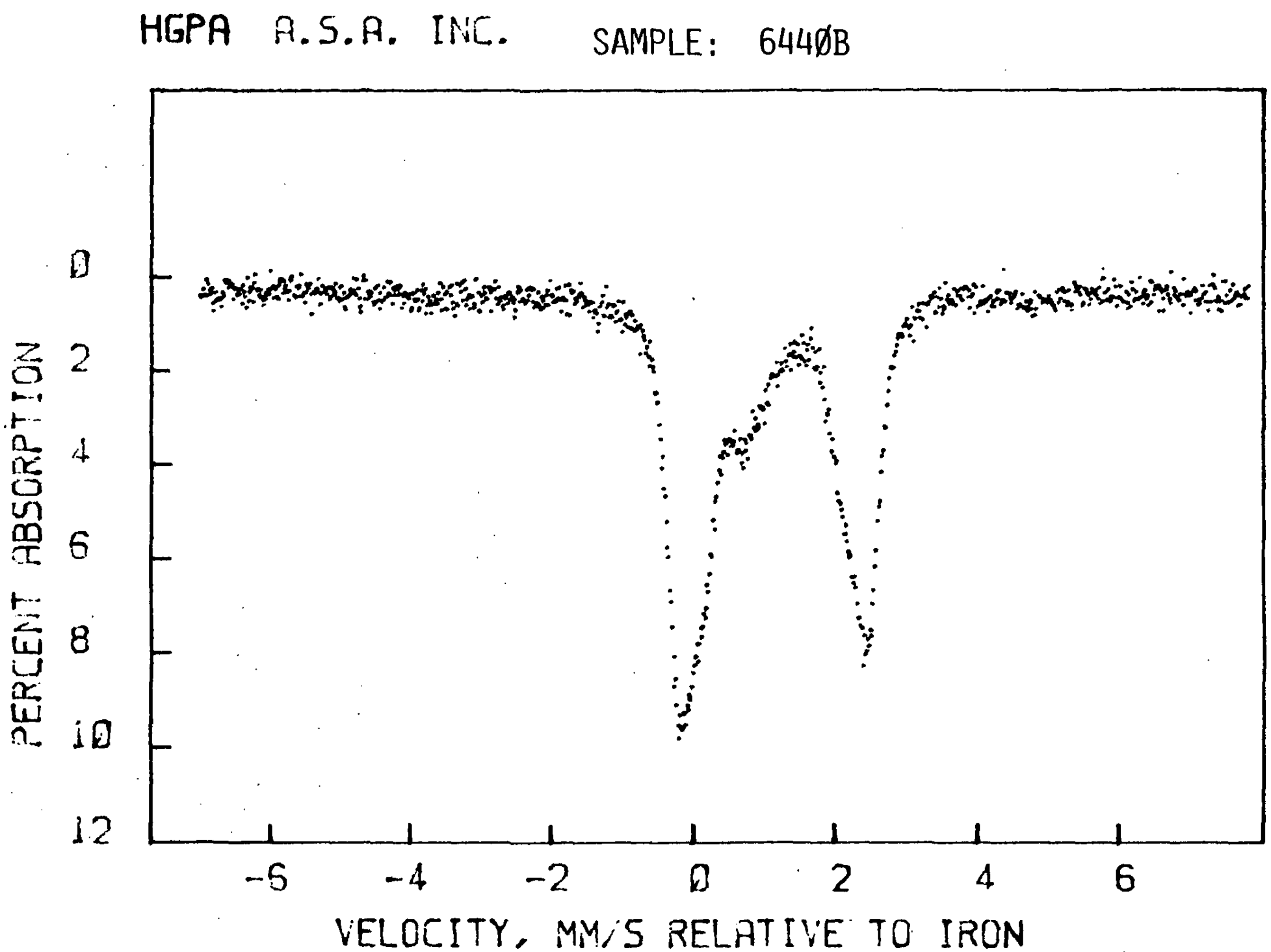
HGP-A Brine D/H vs O-18/O-16
Brine/Condensate Pairs
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-4
-2
0
2
1
2
3
4
5 6
7
Brine/Steam Pairs
Mean Value
Meteoric Water

Figure 3



Cuttings from 68 ft. depth

Figure 4



Cuttings from 6440 ft.

Report on Kapoho Geothermal Reservoir Study
Geothermal Research at the Puna Facility
by
Bill Chen, Deane Kihara, and Carolyn Ishimoto

A two phase flow model for predicting pressure drops in the HGP-A is being developed. The model is patterned after Orkiszewski (1967) and Chierici et al (1974). Basically, the model divides the flow into four basic regimes, namely, bubble flow, slug flow, transition, and annular-mist.

In the bubble flow regime, small bubbles of vapor are dispersed in the liquid phase, slip velocity (difference between vapor velocity and liquid velocity) is small, and frictional pressure drop is due primarily to liquid phase.

In the slug flow regime, vapor bubbles coagulate in the middle of well bore, forming vapor slugs, with liquid phase continuous throughout. Frictional Pressure drop is due largely to the viscosity of liquid phase.

The transition regime is the change from a continuous liquid phase to a continuous gas phase. Normally this is a very rapid change. In our first attempt, we will ignore this particular flow regime.

In the annular-mist regime, the vapor phase is continuous and a thin film of liquid adheres to the pipe wall and effects of liquid are small. The vapor phase is the predominant factor and controls the frictional pressure drop.

Currently, we have finished the formulation of the problem. This includes the formulation of the conservation of mass, momentum and energy equations, determination of flow regimes, and the prediction of pressure drops. A computer program is being developed. The program will be written in FORTRAN and initially will be run on IBM PC. If the calculations take too much time then migration to a mini or mainframe computer will be considered.

Current schedule indicates that the preliminary programming, which can predict pressure drops only in any one of the three regimes without changing regimes, will be completed by June 19. Testing of that portion of the program will follow and be completed by July 10. Programs to adjust automatically to regime changes and provisions to accept fluids input at different elevations will be incorporated next.

REFERENCES

Chierici et al, "Two-Phase Vertical Flow in Oil Wells - Prediction of Pressure Drop", Journal of Petroleum Technology, August 1974.

Orkiszewski, "Predicting Two-Phase Pressure Drops in Vertical Pipe", Journal of Petroleum Technology, June 1967.

Bill Chen
Bill Chen
Principal Investigator

REPORT 1905
FREQUENCY: MONTHLY

UNIVERSITY OF HAWAII
RESEARCH AND TRAINING BUDGET STATUS REPORT
AS OF MAY 31, 1957

ACCOUNT NO. F-87-212-F-470-B-402 | INDIRECT COST TYPE MTDC | TYPE OF PROJECT RESEARCH

SPONSORING AGENCY DOE | BUDGET PERIOD 08/23/85 TO 06/30/88 | BUDGET-AMOUNT 100,000.00

AWARD NO. DE-FG03-85SF15799 | PROJECT PERIOD 08/23/85 TO 06/30/88 | PROJECT AMOUNT 100,000.00

PRINCIPAL INVESTIGATOR CHEN, B/TAKAHASHI, P | FISCAL OFFICER (010) II, WILFRED

<PLEASE INPUT MISSING INFORMATION INDICATED BY *>

BUDGET CATEGORY	ALLOCATIONS TO DATE	PRIOR YEARS EXPENDITURES	* * * * * * CURRENT FISCAL YEAR * * * * * * * CURRENT MONTH	YTD EXPEND	ENCUMBERED	UNENCUMBERED BALANCE
PERSONAL SERVICES						
SALARIES/WAGES REGULAR	47,685.00	16,859.00		12,221.00		16,603.00
OVERLOAD				7,620.00		7,620.00-
STUDENT HELP - REGULAR		540.00		681.60		1,221.60-
SUB-TOTAL	47,685.00	17,399.00		20,522.60		9,763.40
FRINGE BENEFITS	12,722.00	4,945.27		2,572.38		5,204.35
SERVICES - FEE BASIS		195.50		812.50		1,008.00-
MATERIALS & SUPPLIES	6,500.00	2,966.72	133.50	133.50		3,399.78
COMMUNICATION		4.67		23.75		28.42-
TRAVEL - DOMESTIC	8,700.00	2,556.38	74.10	1,378.05		4,765.57
FREIGHT & DELIVERY		96.51				96.51-
PRINTING & PUBLICATION				760.50		760.50-
OTHERS	5,038.00	1,112.23	5.00	1,623.85		2,101.92
INVESTIGATOR TOTAL	80,645.00	29,276.28	212.60	28,027.13		23,341.59
INDIRECT COST 24.00	19,355.00	7,026.32	51.02	6,726.51		5,602.17
IC SUB-TOTAL	19,355.00	7,026.32	51.02	6,726.51		5,602.17
ADMINISTRATIVE TOTAL	100,000.00	36,302.60	263.62	34,753.64		28,943.76

ACCOUNT CODE: F-87-212-F-470-8-402
ACCOUNT TITLE: DE-FG03-85SF15799GEOTHERML RES

EXPEND.FUNCTIONAL CODE: 08C
PRINCIPAL INVESTIGATOR: CHEN, B/TAKAHASHI, P

ACTIVITY CODE: 0
FISCAL OFFICER: 010

DOCUMENT NUMBER	DATE	NAME	CHECK/SWV NUMBER	OBJ SYM	BEGINNING ENCUMBRANCES	CHANGES IN ENCUMBRANCES	EXPENDITURES	ENC & EXP TOTAL
REGULAR PERSONAL SERVICES								
BEGINNING BALANCE							14,761.00	
REGULAR PERSONAL SERVICES - FYTD TOTAL					*	*	14,761.00 *	14,761.00 *
LECTURERS								
BEGINNING BALANCE							7,649.72	
LECTURERS - FYTD TOTAL					*	*	7,649.72 *	7,649.72 *
STUDENT HELP								
BEGINNING BALANCE							684.26	
STUDENT HELP - FYTD TOTAL					*	*	684.26 *	684.26 *
OTHER CURRENT EXPENDITURES								
BEGINNING BALANCE							4,853.05	
A10580	05/28/87	NAGAHARA, LOIS	P61830	4111			6.60	
A10580	05/28/87	NAGAHARA, LOIS	P61830	4301			67.50	
A10580	05/28/87	NAGAHARA, LOIS	P61830	7200			5.00	
THIS PERIOD TOTAL							79.10 *	
OTHER CURRENT EXP - FYTD TOTAL					*	*	4,932.15 *	4,932.15 *
ACCOUNT FYTD TOTAL					**	**	28,027.13 **	28,027.13 **

REPORT 1060F
FREQUENCY: SEMI-MONTHLY

UNIVERSITY OF HAWAII
ENCUMBRANCE AND EXPENDITURE LEDGER
AS OF MAY 15, 1987

ACCOUNT CODE: F-87-212-F-470-B-402
ACCOUNT TITLE: DE-FG03-85SF15799GEOTHERML RES

EXPEND.FUNCTIONAL CODE: OBC
PRINCIPAL INVESTIGATOR: CHEN, B/TAKAHASHI, P

ACTIVITY CODE: 0
FISCAL OFFICER: 010

DOCUMENT NUMBER	DATE	NAME	CHECK/SWV NUMBER	OBJ SYM	BEGINNING ENCUMBRANCES	CHANGES IN ENCUMBRANCES	EXPENDITURES	ENC & EXP TOTAL
REGULAR PERSONAL SERVICES								
BEGINNING BALANCE							14,761.00	
REGULAR PERSONAL SERVICES - FYTD TOTAL					*	*	14,761.00 *	14,761.00 *
LECTURERS								
BEGINNING BALANCE							7,649.72	
LECTURERS - FYTD TOTAL					*	*	7,649.72 *	7,649.72 *
STUDENT HELP								
BEGINNING BALANCE							684.26	
STUDENT HELP - FYTD TOTAL					*	*	684.26 *	684.26 *
OTHER CURRENT EXPENDITURES								
BEGINNING BALANCE							4,719.55	
A10582	05/06/87	RESEARCH CORP OF UNIV OF	P57547	3015			133.50	
OTHER CURRENT EXP - FYTD TOTAL					*	*	4,853.05 *	4,853.05 *
ACCOUNT FYTD TOTAL					**	**	27,948.03 **	27,948.03 **

University of Hawaii at Manoa

Hawaii Natural Energy Institute
Holmes Hall 246 • 2540 Dole Street • Honolulu, Hawaii 96822

April 25, 1985

Mr. Duncan Foley
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

Dear Duncan:

Enclosed is a copy of a proposal that Marshall Reed asked me to prepare for him on the geochemistry of the fluid phase in the hydrothermal system on the Kilauea East Rift Zone.

It, unfortunately, had to be a "quickie" because I'm in the throes of putting together two or three of these papers and proposals and Marshall gave me a fairly short deadline.

If you have any questions on it or need other information, drop me a note or call me.

Best regards,

Don Thomas

Don Thomas

Enclosure

DRAFT

PROPOSAL TO USDOE

The chemistry of the fluids produced by HGP-A well has yielded a number of insights into both the specific characteristics of the well itself and of the nature of the reservoir on the Kilauea East Rift Zone. The most important of the findings from the chemical data obtained to the present is that HGP-A is producing fluids from two separate aquifers: one produces a two phase steam/brine mixture and the other yields dry steam. The existence of a dry steam resource has been further substantiated by privately drilled wells on the East Rift Zone northeast of HGP-A. The presence of a high temperature dry steam reservoir on the Kilauea East Rift Zone clearly increases the economic value of the reservoir due to both the lower cost and fewer technical barriers to its future development.

Of equal importance however is the discovery that the brines produced by the HGP-A well are chemically very similar to those produced by hydrothermal vents present at the sea floor spreading centers.

Enrichments of potassium, lithium, and calcium and depletions of magnesium in the HGP-A brines are virtually identical to those found in hydrothermal systems. Several aspects of this similarity are important to future geothermal development on the East Rift Zone. Studies of sea floor systems and laboratory experimentation have shown that the pH of the fluids generated by mid-ocean hydrothermal systems is strongly affected by seawater basalt reactions and at high SW: basalt ratios the fluids can become extremely acid: to a pH of approximately 2. These pH levels would have a major impact on development of the brine dominated system if high water:rock ratios are present in the reservoir.

A second aspect of the similarity of the fluids to sea floor hydrothermal systems is that at very high temperatures—in the range of those found in HGP-A and other commercial wells on the East Rift, the fluids are capable of mobilizing high concentrations of trace transition elements. The presence of pyrrhotite in the fluids from the East Rift Zone confirm this finding. There are both positive and negative implications arising from this trace element mobility: their impacts on the environment could be substantial if hydrothermal fluids are allowed to escape but, with high enough concentrations, it may be feasible to recover these metals from high temperature brines.

The fluid compositions found also have clear analogies to ore forming fluids and hence the investigation of the basic chemical processes occurring on the East Rift Zone may yield insight into the mechanisms of base and precious metal ore deposition. In addition, the processes occurring on the rift are clearly analogous to trace element and rare earth element cycling in the natural environment. Availability of both fluid and rock samples from the East Rift Zone will enable us, under the currently requested funding, to make a preliminary attempt to investigate both the chemical processes and mass balances present in an active hydrothermal system.

Proposed Research

The research proposed is an investigation of the chemical and isotopic composition of the fluids produced by the HGP-A well and other privately funded wells in the East Rift Zone. Access to the latter has been given by one private venture and, if this program is funded, will be sought from the second currently active on the Rift Zone. This work will be intended to complement the ongoing monitoring effort at HGP-A that consists of major element analysis (Na, K, Ca, Mg, Cl, SiO_2) in the brines and major gas analysis (H_2S, CO_2, N_2, H_2) in the steam phases. The proposed analyses that will be conducted under this program will include the trace elements: Fe, Al, Zn, Mn, Co, Ni, Ag, Hg, Pb, Cd, and Au. These will be analyzed on a monthly basis for future samples, and an attempt will be made to conduct analyses of these elements on archived samples extending back to the beginning of the operation of the generator facility.

Isotopic analysis will be conducted on CO_2, H_2S, SO_4 (if sufficient quantities can be extracted from the brine), and water from brine and steam phases. A cooperative agreement has been reached with Dr. Ivan Barnes at the U.S. Geological Survey in Menlo Park to provide analysis of water and CO_2 isotopes. Sulfur isotope analyses have been conducted on a limited suite of samples by Dr. Hitoshi Sakai at the University of Tokyo; Dr. Sakai has also agreed to conduct this type of analysis in the future as well.

An effort will also be made to determine the concentrations of a suite of rare earth elements present in the liquid phase obtained from the deep holes and their corresponding concentrations in the cuttings samples from the holes. Although this will have to be a preliminary effort due to the totally unknown nature of the REE concentrations in the geothermal fluids and cuttings, an attempt will also be made to identify specific mineral phases associated with REE concentrations in the alteration mineralogy.

The second aspect of the proposed program will be sampling and analysis of geothermal fluids from privately drilled wells. In most cases, the samples will be taken from static wells using downhole samplers but, if well testing is conducted during the course of the proposed study samples will be obtained from these wells as permitted and analyses will be conducted of major and trace element compositions.

Finally, we propose to conduct a preliminary analysis of the cuttings obtained, and presently archived, from the HGP-A and five of the six privately funded geothermal wells. The cuttings will be examined for mineral alteration suites, and for the concentration of iron, zinc, lead, and manganese. If significant correlation can be drawn between the geochemistry of the cuttings and the fluid chemistry and reservoir temperature, further analyses will be conducted as time and funding permit.

The result of the proposed studies will be integrated into the already existing geochemical, geological, and geophysical data base for the Kilauea East Rift Zone in an effort to define the important characteristics of the reservoir from the perspective of the feasibility of future development and optimization of resource utilization.

Budget Justification.

The funding requested for the proposed program is primarily for the support of a technician and a graduate student. These personnel will devote their time primarily to sample acquisition and analysis of trace element composition and the preparation of samples for analysis at other laboratories. Because isotopic analyses are being provided by researchers at no cost to this program, we anticipate being able to perform a far more comprehensive investigation than would be possible if we were attempting to conduct the analysis at the Hawaii Institute of Geophysics.

The State of Hawaii and the Hawaii Electric Light Company will provide the majority of the salary support for the Principal Investigator hence only one month of overhead is being requested.

The majority of the facilities and equipment necessary for chemical analysis of the thermal fluids are available at the Hawaii Institute of Geophysic: a Perkin Elmer Atomic Absorption Spectrophotometer and a Leaman Labs Ion Coupled Agron Plasma Spectrophotometer are available for use on this project. The only equipment item requested is a downhole geothermal well sampler which will be necessary for sampling of the geothermal fluids in the non-flowing geothermal wells.

Travel funds are requested in order to travel to the geothermal area on the island of Hawaii to conduct sampling of the geothermal fluids and for one trip to attend a scientific conference on the mainland.

BUDGET

I.	Personnel			
	Senior Personnel			
	Don Thomas, 1 month overhead @ $2,891			2,891.00
	Technical Assistant			
	12 months @ 100% @ $1,700/month			20,400.00
	Graduate Student			
	9 months @ 50% and 3 months @ 100% @ $1,161/month			8,708.00
	SUBTOTAL SALARY			31,999.00
II.	Fringe Benefits			
	@ 40% of $20,460			8,160.00
	@ 8% of $8,708			697.00
	@ @% of $2,891			58.00
				8,915.00
III.	Equipment			
	1 Downhole Sampler			3,000.00
IV.	Supplies			1,500.00
	Analytical chemicals, glassware instrument supplies			
V.	Travel			
	6 interisland airfare @$100.00 ea.			600.00
	18 days per diem @ $45.00/day			810.00
	Ground transportation			180.00
	1 mainland airfare @ $600.00			600.00
	4 days per diem @ $90.00/day			360.00
				2,550.00
VI.	Other Direct Costs			
	Analytical instrument changes			500.00
	Shipping			300.00
	Other (communications, reprography, etc.)			500.00
				1,300.00
TOTAL DIRECT COSTS				49,264.00
INDIRECT COSTS				
	Off Campus 50% @ 24%	(28,560)	(6,854)	
	On Campus 50% @ 42.5% MTDC	(17,704)	(7,524)	14,378.00
TOTAL COSTS				$63,642.00