

TECHNICAL REPORT
For the U.S. Department of Energy

GEOHERMAL RESEARCH AT THE PUNA FACILITY
I.D. No. DE-FG03-85SF15799
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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.

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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 The samples that have been archived for analysis during the last five years of operations of the generator facility include brine and steam samples, for oxygen-16/oxygen-18 analysis and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. The 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.

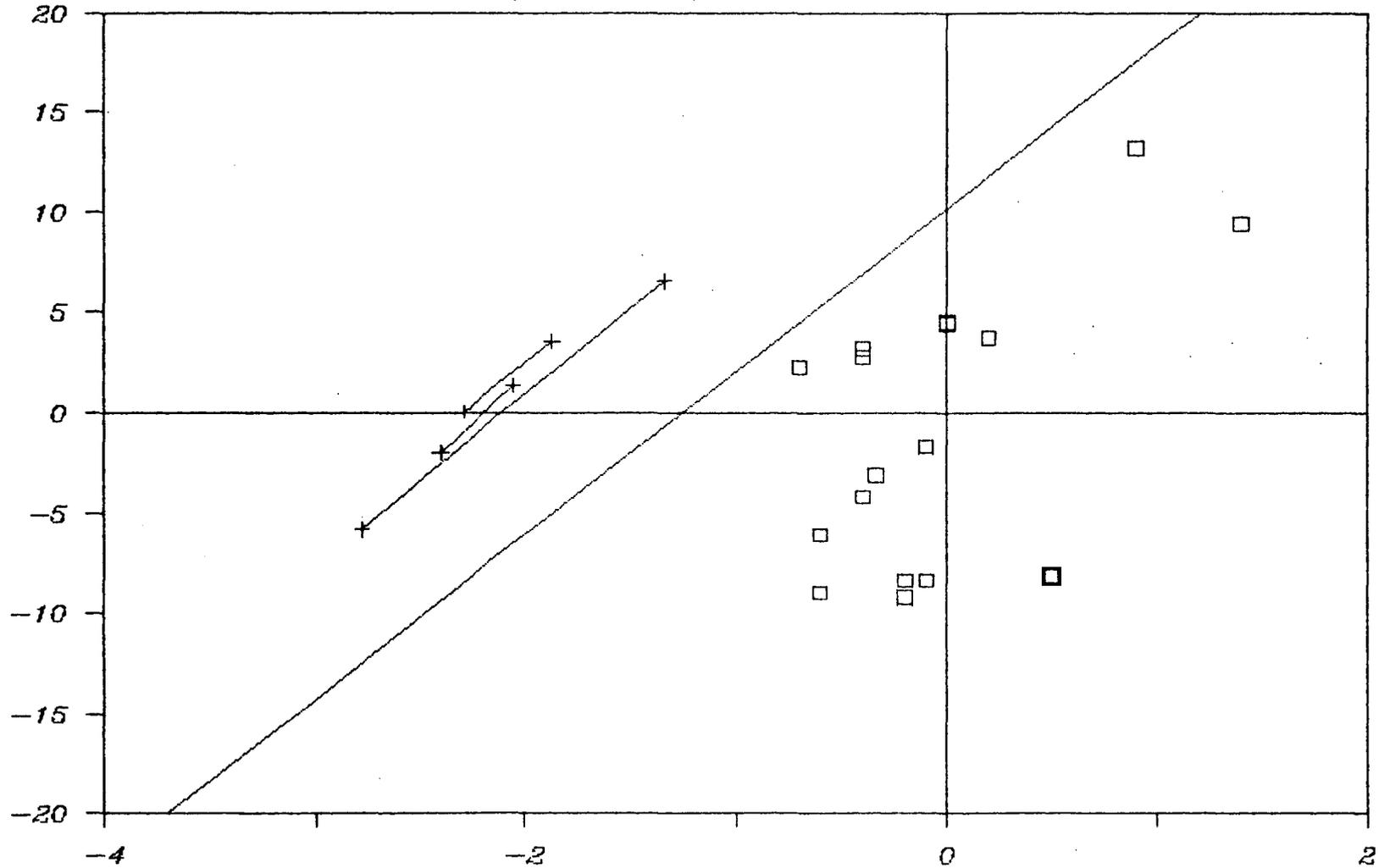
A second investigation that has only recently begun has been a study of the mineralogy of the cuttings from the HGP-A well. The objective of this effort is to determine whether iron present in the deeper reservoir rocks has been substantially oxidized by reaction with sulfate ions brought into the reservoir 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

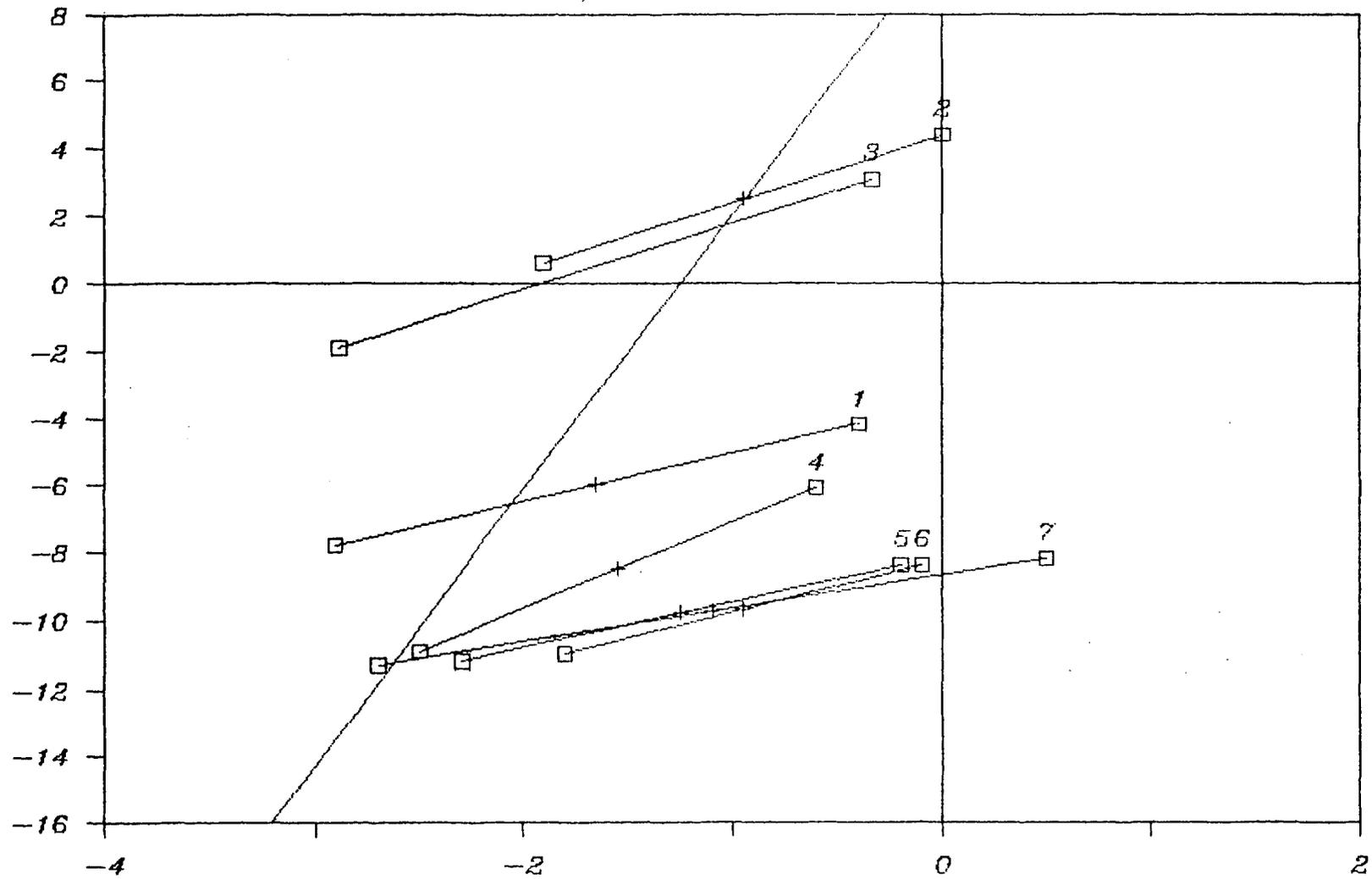


□ Brine + Rainwater — Meteoric water line

Figure 2

HGP-A Brine D/H vs O-18/O-16

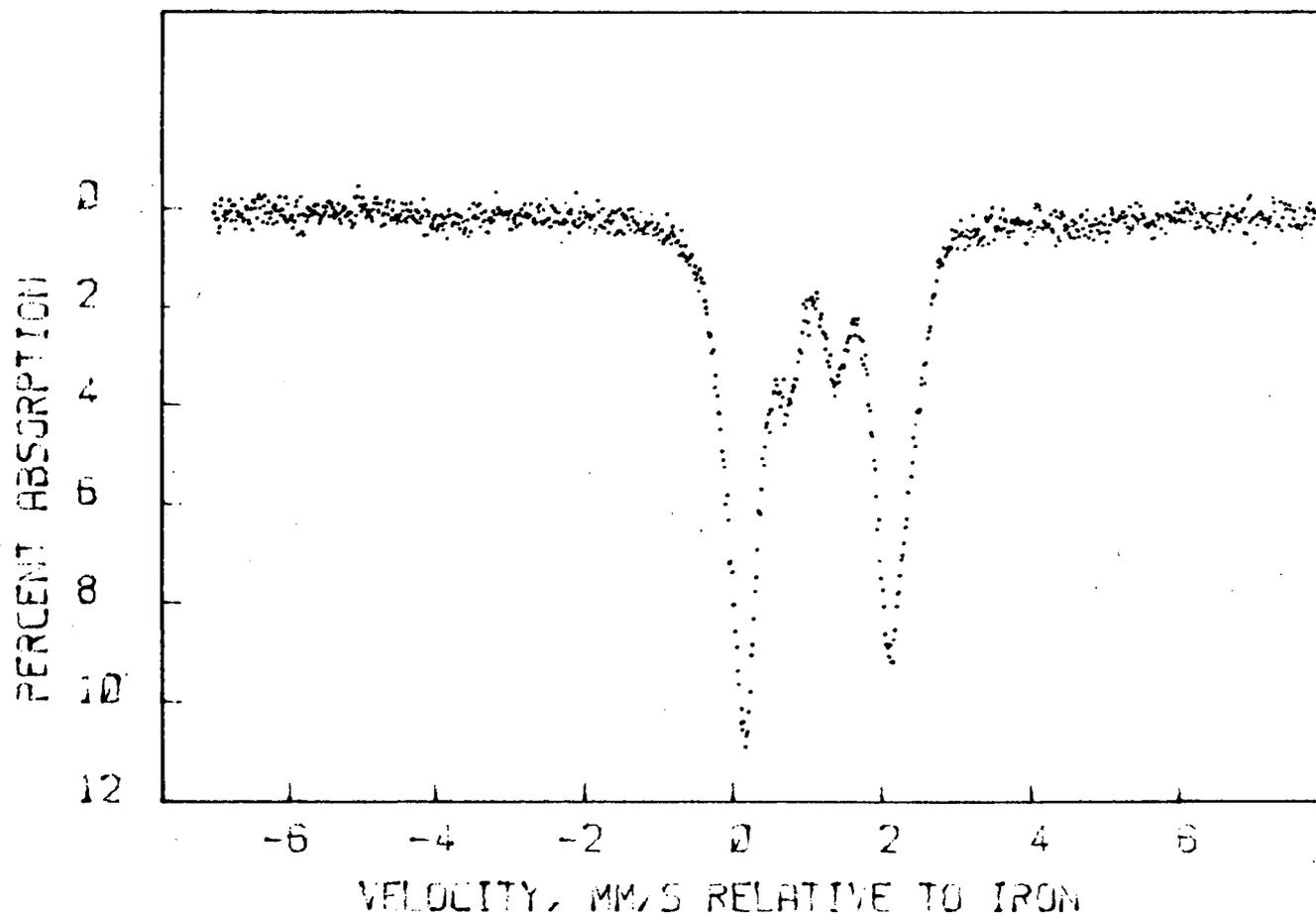
Brine/Condensate Pairs



□ Brine/Steam Pairs + Mean Value — Meteoric Water

Figure 3

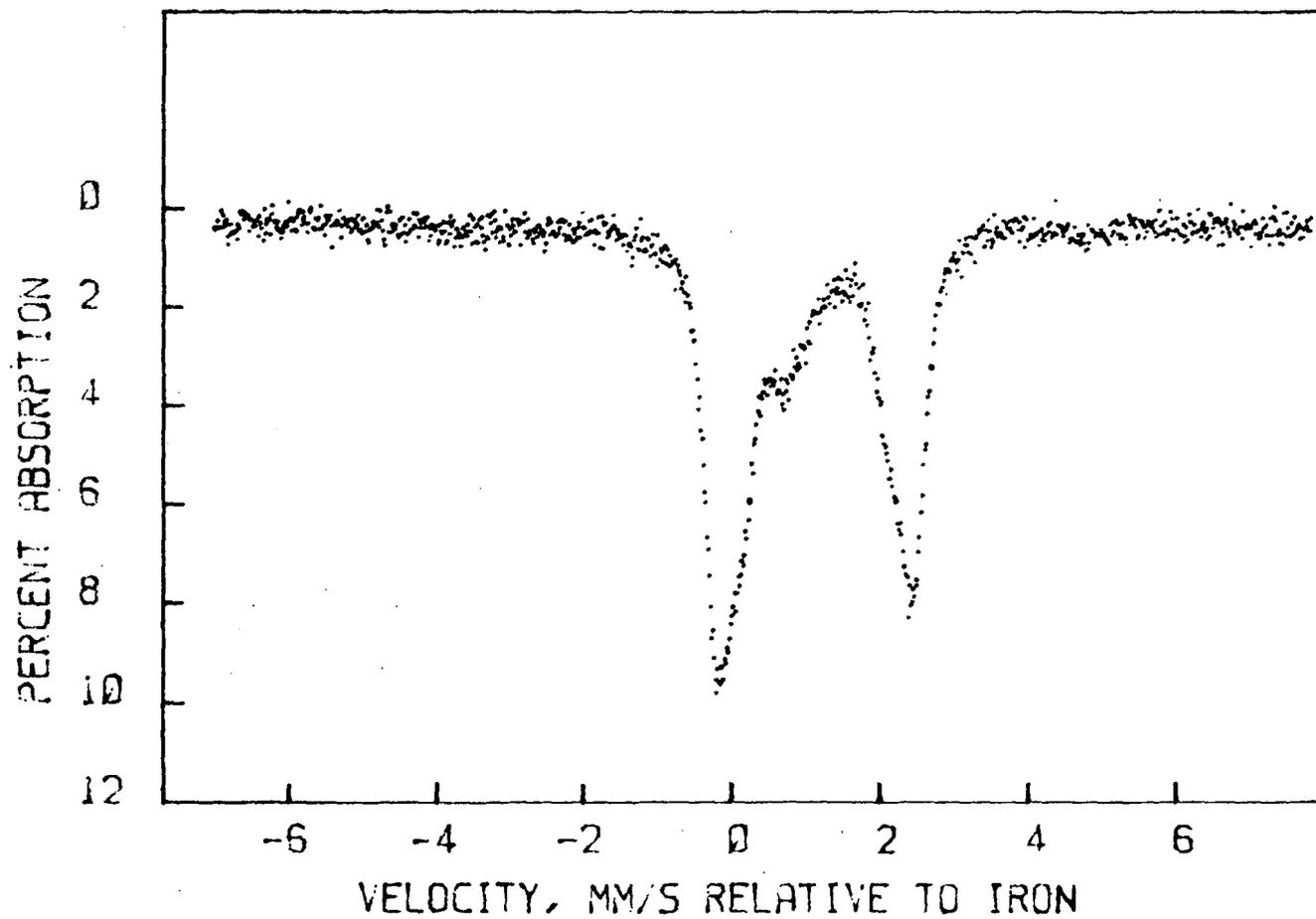
68A A.S.A. I.C.



Cuttings from 68 ft. depth

Figure 4

HGPA A.S.R. INC. SAMPLE: 6440B



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
Principal Investigator

REPORT 1905
 FREQUENCY: MONTHLY

UNIVERSITY OF HAWAII
 RESEARCH AND TRAINING BUDGET STATUS REPORT
 AS OF MAY 31, 1987

PAGE 471
 DATE 5/26/87

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 06/30/86

BUDGET-AMOUNT 100,000.00

AWARD NO. DE-FG03-85SF15799

PROJECT PERIOD 06/23/85 TO 06/30/86

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 MONTH	CURRENT FISCAL YEAR YTD EXPEND	* * * * * ENCUMBERED	UNENCUMBERED BALANCE
PERSONAL SERVICES						
SALARIES/WAGES REGULAR	47,685.00	16,859.00		12,221.00		16,003.00
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

REPORT 1060F
 FREQUENCY: SEMI-MONTHLY

UNIVERSITY OF HAWAII
 ENCUMBRANCE AND EXPENDITURE LEDGER
 AS OF MAY 31, 1987

PAGE 5
 DATE 5/26/87

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					4,853.05	
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

PAGE 6
 DATE 5/15/87

ACCOUNT CODE: F-87-212-F-470-D-402
 ACCOUNT TITLE: DE-FG03-85SF15799GEDTHERML RES

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

ACTIVITY CODE: 0
 FISCAL OFFICER: 010

DOCUMENT NUMBER	DATE	NAME	CHECK/SVV 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 **