SALTON SEA SCIENTIFIC DRILLING PROGRAM

Report of the First Quarter

FY 1987

March 1987

U.S. DEPARTMENT OF ENERGY
Office of Renewable Energy Technologies
Geothermal Technology Division

SALTON SEA SCIENTIFIC DRILLING PROGRAM

Ninth Quarterly Progress Report:
Report of the First Quarter
(October through December)
FY-1987

MARCH 1987

U.S. Department of Energy
Office of Renewable Energy Technologies
Geothermal Technology Division

EXECUTIVE SUMMARY

The Salton Sea Scientific Drilling Program (SSSDP) has been documented in a series of quarterly reports. This ninth report covers the first quarter of fiscal year 1987, the period from October 1 through December 31, 1986. Subsequent to temporary repair of the damaged wellbore, emphasis has been placed upon acquisition of post-drilling temperature data and assessment of options for continuation of the SSSDP.

Studies to determine causes for collar failure and parting of the 7-inch liner in the scientific well continued in this reporting period. A draft report of failure analysis of collar and liner material by Brookhaven National Laboratory revealed that the collars probably failed by a stress corrosion and hydrogen embrittlement mechanism. Hopefully, this analysis will help reduce the possibility of reoccurrence.

Electronic memory and Kuster temperature instruments were lowered into the well in late-October in an effort to successfully complete the equilibrium temperature studies. However, the deepest temperature reading taken was at 5,822 ft. Apparently, the water injected to clean-out mud from the repair operations disappeared into the annulus at the top of the liner. Now, a viscous mud-gel probably fills the wellbore from approximately 5,800 to 8,000 ft.

During an attempt to calibrate the dewared high-temperature Kuster tool and the Madden Systems electronic temperature tool, the electronic tool was found to record closer to actual temperature, up to 204^{o}C. Exceeding 204^{o}C temperatures, the electronic memory tool failed to dump data. The tool was sent back to Madden Systems. Further calibration tests will be scheduled following repair.

Planning continues for the performance of a long-term (up to 30-days) flow test and continued scientific experimentation. Planning includes provision for removal and replacement of the damaged 7-inch liner, construction and operation of flow test facilities, and fluid disposal through a 1.25 mile pipeline into an injection well to be provided by Kennecott.

Analysis of scientific data and reporting of results continued during this quarter. Since SSSDP logs are needed for current investigations, the "Preliminary Report on Geophysical Well-logging Activity on the Salton Sea Scientific Drilling Project, Imperial Valley, California," by Paillet and others, has been issued as a USGS Open-file Report (No. 86-544). The first collective report of scientific results from the SSSDP will take the form of an all-day symposium at the spring meeting of the American Geophysical Union in Baltimore, MD, in the latter part of May 1987. Negotiations continue with the Journal of Geophysical Research to publish a special issue reporting these initial results.

During their October 1986 meeting with DOE in El Centro, California, representatives of Mexico's Comision Federal de Electricidad (CFE) expressed great interest in the progress made and research completed at the SSSDP. The CFE officials showed particular interest in materials used in the fabrication of SSSDP tubulars and other equipment. The usefulness of various geophysical logs run in the SSSDP well was also of interest for application in interpreting volcanic settings.

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INTRODUCTION

Drilling of the scientific well ended at a depth of 10,564 ft on March 17, 1986. During and shortly after the drilling phase, two short-duration flow-testing and fluid-sampling sessions were performed in addition to several periods of geophysical logging. While running a wireline temperature survey during the shut-in period following completion of the well, an obstruction was encountered in the wellbore at about 6,380 ft, indicating that the 7-inch liner had either parted or collapsed. Workover operations performed in August verified liner parting and provided temporary repair of the wellbore, allowing resumption of scheduled temperature surveys. The wellbore was reamed clear to 8000 ft and a temporary liner installed.

The main concern during the October 1-December 31, 1986 reporting period was completion of a primary Stage-I objective -- obtaining post-drilling equilibrium temperature logs to the greatest depth possible. The next priority will be to obtain uncontaminated fluid samples from the scientific well (State 2-14) below 10,000 ft. If the State 2-14 well cannot be reopened to this depth, fluid samples will be taken from the deepest reservoir, greater than 8,000 ft, that can be isolated and flow tested.

Stage-II of the SSSDP entails deepening the State 2-14 well, either by modification of well construction as proposed in April 1986, or by sidetracking past the broken liner. No definitive action can be taken on the Stage-II plans during this fiscal year, because additional funds beyond those available in FY-1987 would be required.

PROGRAM PLAN AND ACTIVITIES

Drilling & Engineering Program

During this reporting period, a failure analysis of the damaged casing from the SSSDP well was completed by scientists at Brookhaven National Laboratory. Samples of well casing and collar were cut from the hanging part of the parted liner (i.e. from the base of the ninth joint, upward), and the mechanical properties evaluated (Table 1). Analysis revealed that the collars probably failed by a stress corrosion and hydrogen embrittlement mechanism. This was caused by a martensitic structure, high tightening tensile stress, and the presence of H_2S and O_2 in the environment. The tendency of collar material to crack in this environment would probably be reduced substantially by tempering the martensitic collar material to increase ductility, and decrease hardness and yield strength to values below RC-20 and 75,000 psi. The chemical composition of the material used for both casing and collars was found to be of good quality and identical, except for the difference in heat treatments of the two. The higher strength of the collar steel, and cracking susceptibility, was probably enhanced by normal tightening during assembly, as well as by some untempered martensite in the collar steel.

		Hardness (Rc)			
Collar	0.2% offset Yield stress, psi	Inside Surface	Surface of Cross Section	Outer Surface	% Elogation
Sample 1	91,200	20 Range: (19.5-22)	20.5 (20-21)	24.0 (23-28)	15
Sample 2	91,650	-	-	-	-
Casing (Pipe)					
Sample 3	82,400	18.9 Range:(18-19.5)	20.0 (19.5-21)	21.0 (18.5-22.0)	19
Sample 4	82,700	-	-	-	18
Casing steel test report, N-80, quench and tempered condition (duplicate specimens)	94,940 93,140	- -	- -	- -	23 24

Table 1: Mechanical Properties of Collar and Casing Alloys Cut from Joint No. 2

Prior to failure of the collar at the tenth joint of 7-inch liner in the Salton Sea well, options for long-term flow testing and deepening the well to 13,000 or 14,000 ft were already being considered. However, the high cost and risk of inadequately controlling lost-circulation zones has tended to discourage conducting further operations in the well. In searching for better means of controlling lost circulation in the well, a mixture of bentonite, ammonium polyphosphate, borax and magnesium-oxide was suggested for use as an LCM pill. If lost-circulation zones can be sealed effectively, it should be feasible to cement-in a new hang-down liner, eliminating numerous problems associated with performing extended flow test and well deepening operations.

In FY-1987, Congress continued to support the SSSDP effort by providing $1.3 million in new funding. The House had provided $2 million more for deepening the scientific well, but the Senate did not concur. The Conference Committee adopted the Senate position. Funds will be used to repair the scientific well, perform a flow test for up to 30-days and conduct limited experiments. A breakdown of prior funding, by category and funding agency through FY-1986, is provided in Table 2. Estimated liner removal and flow test costs are presented in Tables 3 and 4, respectively.

	FUNDING BY AGENCY (IN $ 000'S)				
CATEGORY	NSF	GTD	USGS	OBES	TOTAL
Drilling & Engineering	25	7,061	25	25	7,136
Geochemistry	168	--	165	103	436
Petrology	280	--	--	150	430
Geophysics (Lab)	--	105	15	132	252
Geophysics (Site)	--	--	180	170	350
Bio-Organic	--	--	70	--	70
Instrumentation	--	597	120	--	717
Science Support & Management	--	--	300	146	446
Total Funding	473	7,763	875	726	9,837
Total Activities	7	11	13	11	42

Table 2: Summary of Drilling and Engineering, and Scientific Program Funding Through FY-1986

Activity	Duration	Estimated Cost ($1,000)
Three Fishing Operations	14 days	385.6
Additional Fishing Operations	3 days (each)	58.3 (each)

Table 3: Estimated Cost for Fishing Operations to Remove Parted 7-inch Liner

Activity	Estimated Cost ($1,000)
Flow Test Facility: engineering, procurement, reconditioning shipment Flow Test Facility: construction Flow Test Pipeline: engineering, procurement, construction	482.9
Flow Test	119.2
Decommission/Decontamination	160.5
Onsite Support (telephone, water, power, trailers, etc.)	43.9
Stand-by and Final Report	45.0
Subtotals	851.5
Less contributions	<50>
Total	801.5
Estimated Budget for Remedial Work	498.5

Table 4: Estimated Cost of Flow Test (Up to 30-days)

A no-cost, 3-month extension of the Bechtel contract has been authorized through March 31, 1987. In the meantime, Kennecott will seek management approval to drill a well (Wilson 1-12) for use as an injection well during the flow test. Also, Bechtel is preparing the final report of its SSSDP activity through 1986. The first draft is in review.

The first task under the FY-1987 program will be removal of the damaged 7-inch liner, to the maximum extent possible, and installation of a new 7-inch liner, isolating the deepest production zone below 8,000 ft. In the event that the damaged liner cannot be removed completely, drilling of a sidetrack well may be an option.

The next task will be to fabricate and construct flow test facilities. Current plans are for Kennecott Corporation to drill the Wilson 1-12 well, to be located about 1.25 miles north of State 2-14, to a depth between 3,500 and 6,000 ft. This well would be tested initially by Kennecott for commercial production of geothermal energy, then be made available for injection of fluid produced from the State 2-14 well during the 30-day (maximum) flow test.

Facilities for the flow test will be constructed according to DOE provided design standards. Government-owned equipment and materials that meet the required standards will be used whenever possible. A source for the flow test equipment has been identified. Surplus pipe located at the DOE Geothermal Test Facility at East Mesa, California, according to DOE/SAN, was examined and found to be unsuitable for use in the proposed 30-day flow test. However, another source for surplus pipe has been identified. If it is necessary to purchase additional tubular goods, cost estimates may increase.

The long-term flow test will probably be the final task performed during FY-1987. The test is scheduled to be performed for a period not to exceed 30 days. A general operations schedule is as follows:

- o renovate flow test equipment - March to April
- o install pipeline between two sites - March to April
- o spud-in, drill and flow test Wilson 1-12 well - June to July, and
- o flow test State 2-14 using a full-flow separator - July to August.

Activity		Time (days)	Cumulative Time(days)
Mobilize Drilling Rig		1.5	1.5
Laydown wellhead		0.5	2.0
Make-up blow-out preventer equipment		0.5	2.5
Test blow-out preventer equipment		0.25	2.75
Mix mud, kill well		0.25	3.0
Pick-up (PU) & run in hole (RIH) with spear and 5-inch drill pipe		0.33	3.33
Pull out of hole (POOH) with 7-inch fish and lay down (Assumes recovery of temporary liner)		0.5	3.83
RIH with spear and spear 7-inch		0.33	4.16
POOH with 7-inch fish and lay down (Assumes recovery of ~4,000 ft of 7-inch, 1st pull)		1.0	5.16
*Assumes 2nd pull to recover remaining 7-inch			
Release and POOH	0.33		
RIH with mill	0.33		
Mill	0.5		
POOH with mill	0.33	3.3	8.46
PU 3 1/2-inch drill pipe and RIH with cutter	0.5		
Cut, mud sweep, POOH with cutter	0.5		
RIH with spear	0.33		
POOH with fish and lay down	0.5		
Assuming Complete Recovery of Parted 7-inch Liner			
Set sand on bottom of wellbore	0.25		
PU and RIH with liner	0.5		
Rig-up (RU) Halco	0.5		
Cement liner/work liner	0.5		
Wait-on-cement (WOC)	0.33		
Make-up bit and RIH	0.5		
Drill cement and circulate sand out	0.5	5.07	13.53
POOH and lay down drill pipe	0.33		
RIH, POOH, lay down 3 1/2-inch drill pipe	0.5		
Lay-down blow-out preventer equipment	0.5		
Make-up wellhead	0.33		
Clean pits	0.33		

* Each additional fishing operation takes about 3-days.

Table 5: Planned 1987 Remedial Program

Specific activities with preliminary estimates of durations are provided in Table 5. Also, a preliminary milestone chart is given in Table 6. These plans assume that the State 2-14 well will be repaired, government-owned equipment and supplies will be available, and the Wilson 1-12 well will be available for produced-fluid injection. After use in the flow test, the State 2-14 well is planned for further use with the Wilson 1-12 well in a DOE-sponsored brine injection technology development experiment.

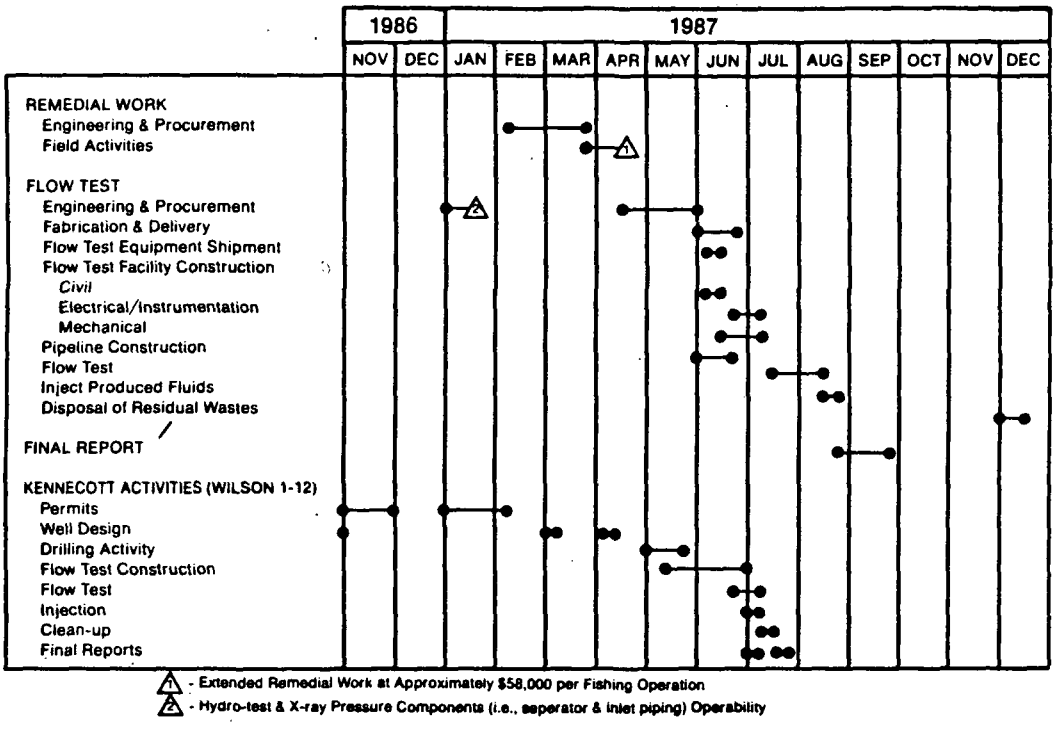

Table 6: TENTATIVE 1987 SSSDP SCHEDULE

Scientific Experiments Program

Partial remedial actions performed in August made possible the continuation of thermal equilibrium studies. USGS personnel coordinated with Bechtel and Cleveland Drilling Company personnel to attempt to obtain additional post-drilling temperature data on October 21. The dewared Kuster tool was run to a depth of 5,810 ft, where it encountered resistance 10-ft below a soft "bridge." It was pulled up and the deepest temperature reading

was taken at 5,796 ft. On October 23 (first anniversary of the spud-in date), an 8-ft length of 2-inch sinker bar with a spade tip was lowered to 6,717 ft after 6-hours. To retrieve the bar, a pull of up-to 300 lbs over the weight of both tool and cable was required. The electronic memory temperature tool was lowered October 24 to a depth of 5,822 ft. A chronology of these operations is given in Table 7. Electronic tool results appear to verify 305 $\pm$ 5^{o}C as the temperature of the 3,127 ft reservoir.

Date	Action	Result
10/21	Ran "Dummy" Probe	Hung up on top of the 7-inch liner, because the makeshift bullnose had an insufficient bevel
10/22	Ran dewared Kuster tool	Encountered a soft "bridge" at 5,800 ft
	Worked Kuster tool down	Resistance to lowering stiffened considerably at 5,810 ft
	Pulled back up	Took deepest temperature reading at 5,796 ft
10/23	Ran 8-foot length of 2-inch sinker bar with a spade tip	After spudding on "bridge" for 6 hours, worked spear down to 6,717 feet
	Pulled out	Pull of 300 lbs over combined weight of tool and cable required to get back up to 5,800 ft, an indication that temperature tools would not get much deeper
10/24	Ran electronic temperature tool with 80 lbs of sinker bar	Significant weight loss was encountered (over 25 lbs) at 5,822 ft (only marginally deeper than Kuster tool was run). Took deepest reading and pulled out.

Table 7: Chronology of Post-drilling Temperature Survey Operations, October 1986

With benefit of hindsight (and additional funds), it can be recommended that mud be circulated-out with 2 7/8-inch drill pipe or Hydril tubing at the end of repair. It seems that flush-water injected at the time successfully eliminated this need only down to the top of the liner, where it disappeared into the annulus, leaving mud in the wellbore at greater depth. The sinker-bar

spudding event of October 23rd indicates that the hole now contains viscous, gelled mud, possibly from about 5,800 to 8,000 ft. A suggestion to perform a low-cost, "coiled tubing" job to clean-out the gelled mud was considered, but rejected on the basis of unlikely success at the depths required in relation to risk.

Instrument calibration problems have produced differences in the post-drilling temperature survey data recovered from the two probes. During the second week in December, Bill Livesay, consultant, and Sue Priest, USGS, attempted to calibrate, at the Kuster Company in Long Beach, California, the high-temperature Kuster tool and the Madden Systems electronic temperature tool. Both temperature tools were immersed in oil baths while temperatures were elevated from 38 to 316°C (100 to 600°F), and in salt baths as temperatures were raised from 316 to 399°C (600 to 750°F). Data from the oil bath test are shown in Figure 1. As a result of these tests, the electronic

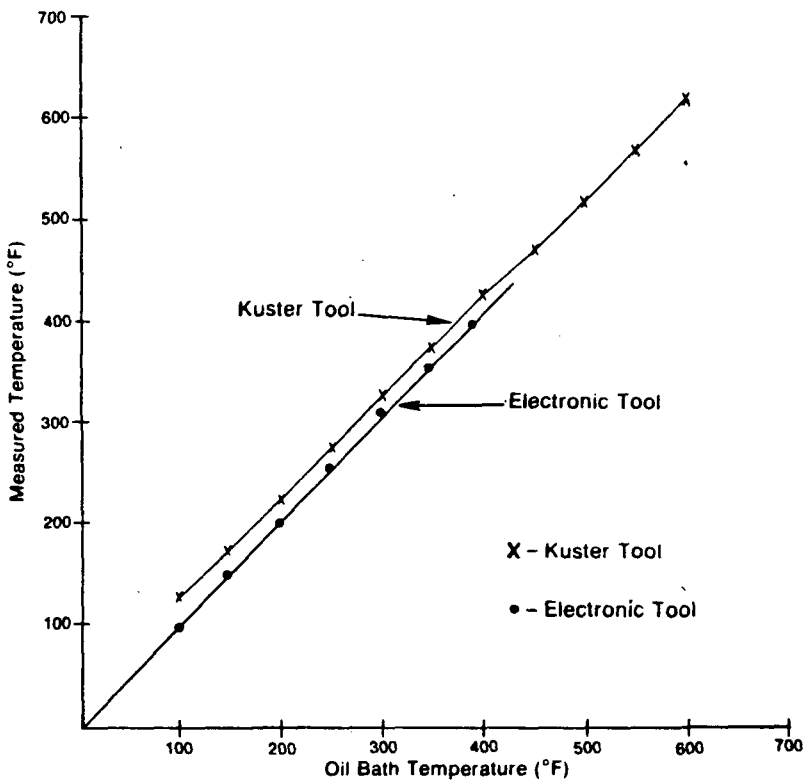

Figure 1: CALIBRATION TEST OF ELECTRONIC MEMORY AND DEWARED KUSTER TEMPERATURE TOOLS

temperature tool was shown to read closer to actual, at least to 204°C (400°F). It failed to dump its data at higher temperature and was returned to Madden Systems for repair. Completion of the calibration test will be rescheduled after repair.

In the absence of calibrated temperature data, three graphs, Figures 2-4, are provided to show preliminary results of the temperature surveys. A comparison of all the electronic memory tool temperature logging runs, along with two early runs of the USGS, Water Resources Division (WRD) tool, is provided in Figure 2. Figure 3 depicts the electronic and dewared Kuster tool temperature logs run in May, and Figure 4 depicts electronic and Kuster temperature logs run in October. Comparison of the electronic and Kuster tool results indicates that the electronic tool data are likely more reliable. Final judgement must await complete calibration results.

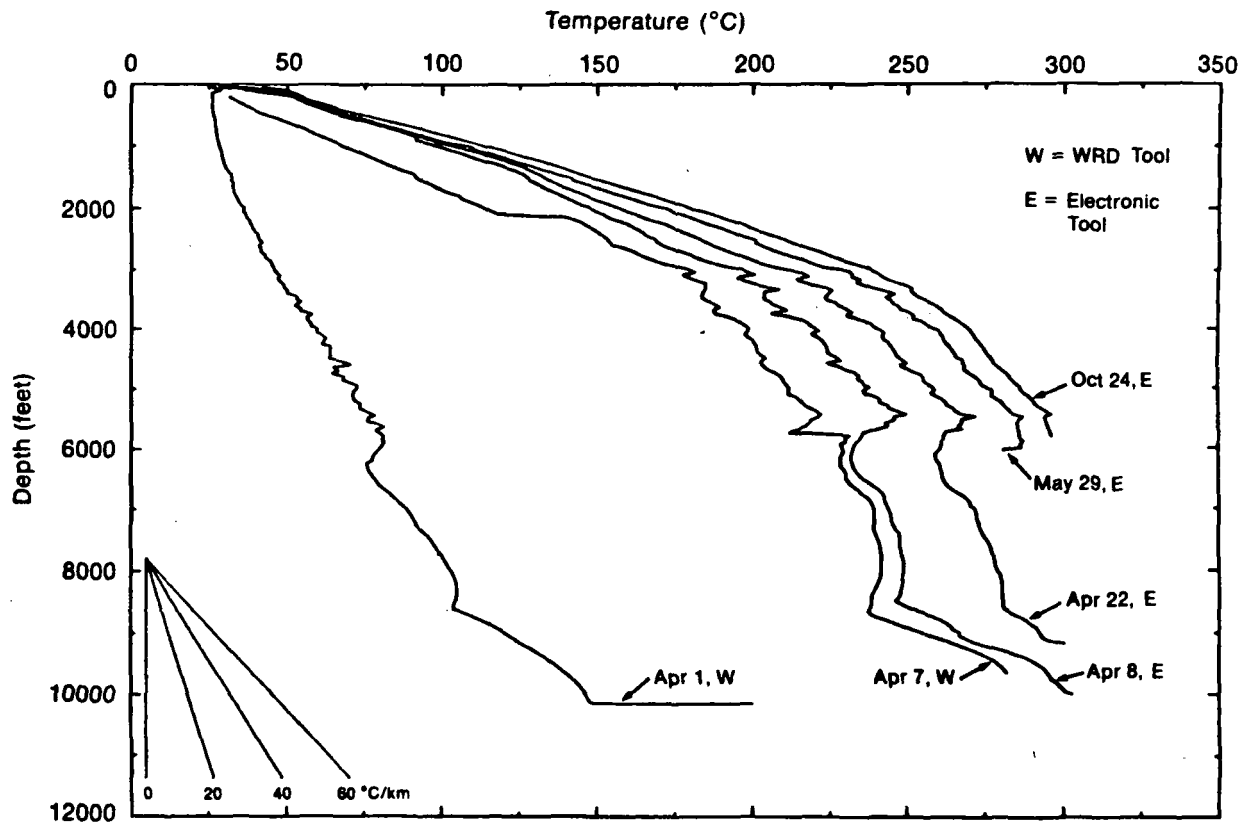

Figure 2: SERIES OF USGS TEMPERATURE LOGS FROM STATE 2-14 WELL (Uncalibrated)

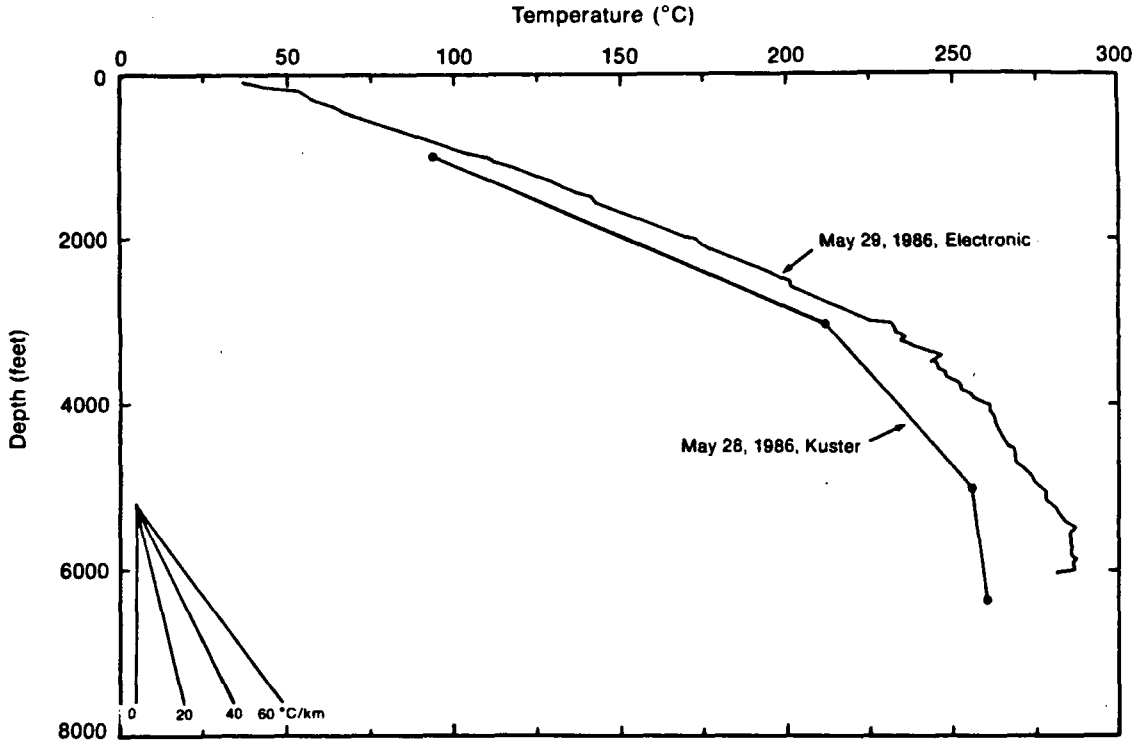

Figure 3: COMPARISON OF ELECTRONIC AND KUSTER TEMPERATURE LOGS OF MAY 1986 (Uncalibrated)

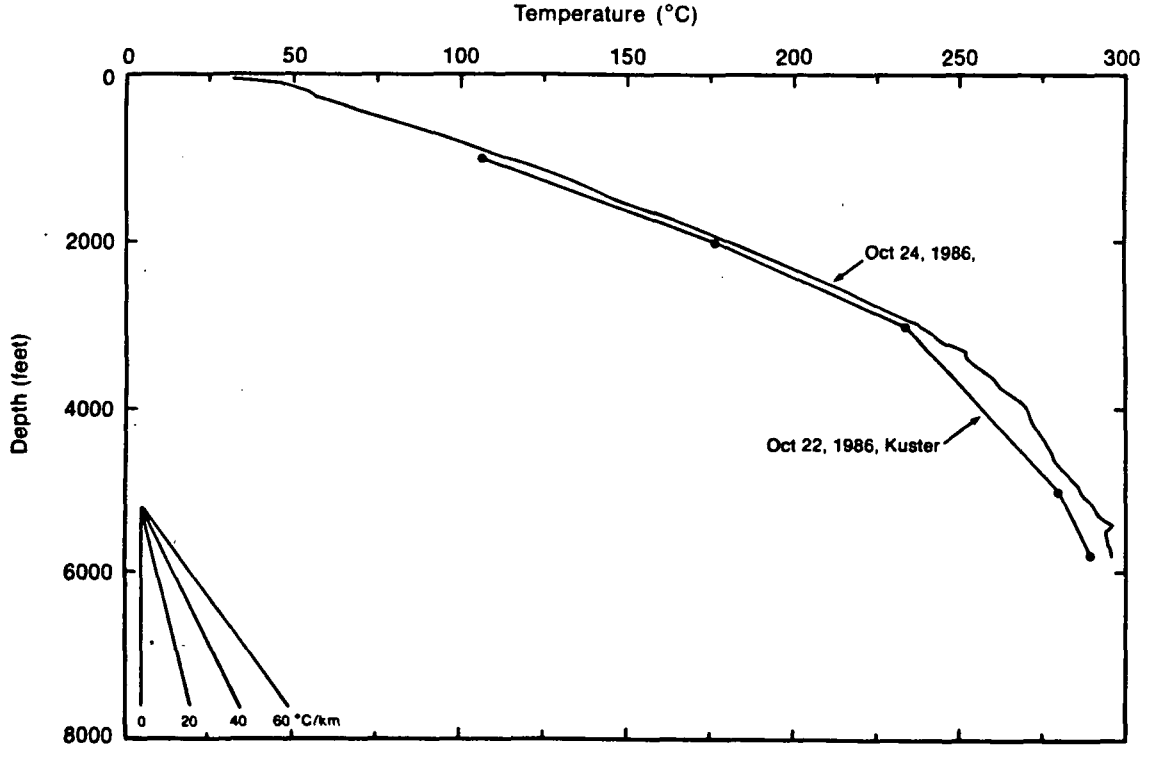

Figure 4: COMPARISON OF ELECTRONIC AND KUSTER TEMPERATURE LOGS OF OCTOBER 1986 (Uncalibrated)

Reporting of SSSDP Results

Documentation and dissemination of SSSDP results continued in accordance with established protocol during this reporting period. General and technical presentations were made at the Geothermal Resources Council (GRC) Annual meeting in Palm Springs, California on October 1, 1986. Technical papers of these presentations were published in the Transactions volume. The updated SSSDP bibliography follows:

(* = Status)

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Andes, J., Jackson, J., Lilje, A., Sullivan, R., and Herzig, C.T., 1986, Salton Sea Scientific Drilling Project, California State 2-14 Well, Visual Core Descriptions; Herzig, C.T. and Mehegan, J.M., eds: Institute of Geophysics and Planetary Physics, University of California, Riverside, UCR/IGPP-86/1, v. 2, April, 93 p.

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* Draft - in Review

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SIGNIFICANT MEETINGS & VISITS

U.S. Department of Energy (DOE)/Comision Federal de Electricidad (CFE) Meeting - October 8-11, 1986

A meeting with CFE (Mexico) to identify areas of mutual interest for bilateral agreement in geothermal research was convened in El Centro, California, October 8-11, 1986. CFE officials were extremely interested in SSSDP progress and research. The CFE staff was interested in obtaining reports on the general drilling activities and scientific research in the SSSDP well, materials used to fabricate equipment, and the usefulness of various geophysical logs in interpreting volcanic settings.

Continental Scientific Drilling, Interagency Coordinating Group (ICG) Meeting - October 17, 1986

The status of the SSSDP was discussed at the Continental Scientific Drilling ICG meeting on October 17, 1986. The DOE/GTD Program Manager summarized well workover operations performed in August to allow continuation

of the thermal equilibrium studies. The goal of concluding the thermal equilibrium studies, at least to a depth of 8,000 ft, by year-end was stated. Attaining this goal was dependent upon the success of instrument runs scheduled for the following week. Next, plans and funding for continuation of SSSDP activities in FY-1987 were discussed. The long term (up to 30 days) flow test was stated to be dependent upon Kennecott's participation and successfully repairing the scientific well at reasonable cost. Continued participation by USGS, NSF and DOE/OBES was solicited through funding of follow-on scientific activities. The need for early coordination was expressed. The ICG approved tasking the Scientific Experiments Committee (SEC) to provide anticipated science support requirements.

House Science & Technology (HS&T) Staff Visit - December 4, 1986

HS&T staff members Nancy Jeffrey and Dave Beightol were accompanied by Harold Lechtenberg and Tom Heenan of DOE/SAN to the Salton Sea Scientific well-site and to other Imperial Valley geothermal sites on December 4, 1986. In addition, the HS&T staff members were shown equipment at geothermal power plants (reactor-clarifier, crystallizers) required for processing highly-saline brines.

Meeting of the Scientific Experiments Committee (SEC), representatives of Bechtel, Kennecott and DOE, San Francisco, CA - December 9, 1986

The Interagency Coordinating Group (ICG) requested input from the SEC on science support requirements for completion of Stage-I and for follow-on studies. As a result of this request, a meeting of the SEC was convened with representatives from Bechtel, Kennecott and DOE/SAN to discuss priorities for follow-on work. The scientific priorities were defined as follows:

(a) The first aim should be to complete the original objectives of Stage-I of the SSSDP rather than embark on Stage-II (i.e. deepening).

(b) Obtaining an equilibrium temperature log to the greatest depth possible in the State 2-14 well remains a high priority.

(c) The next priority should be to obtain uncontaminated fluid samples from the shallowest flow zones encountered in the Wilson 1-12 well.

(d) If repair or replacement of the liner is successful, obtaining uncontaminated fluid samples from the State 2-14 well below 10,000 ft, or failing that from 8,700 ft, is the next priority. Achieving (b), (c) and (d) would allow completion of the original Stage-I objectives.

(e) Study of drill cuttings from the Wilson 1-12 well for comparison with those from the State 2-14 well is worthwhile.

(f) Deepening the State 2-14 well, either as proposed in April 1986 or by sidetracking past the broken liner, remains a desirable goal, but would require additional funds beyond those available in FY-1987. Thus, Stage-II of the SSSDP must wait until FY-1988 or beyond. However, seeking FY-1988 funds would require immediate action and strong support from the scientific community.