GL00602

SALTON SEA SCIENTIFIC DRILLING PROGRAM REVIEW

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ABSTRACT

Drilling, coring, logging, and flow-testing of the well, State 2-14, was completed in March 1986. In the 160 days following spud-in, all the major operational objectives of the program were achieved. Producible geothermal reservoirs were encountered during two flow tests, the first from a flow zone at 6,120 ft and the second from multiple flow zones down to 10,475 ft. Numerous opportunities were provided for scientific study and experimentation. High-temperature downhole samplers, a televiewer, and temperature and pressure logging tools show promise of being available for use by industry in the future. Advanced lost-circulation materials and control procedures were tested under extremely adverse conditions, with generally poor long-term results.

An extended flow test and accompanying reinjection test are planned for 1987, if a damaged liner in State 2-14 can be repaired within the available budget. The testing will ~~supply~~ definitive information on the reservoir properties of one of the deeper flow zones in State 2-14. Injection and productivity experimentation between State 2-14 and a new well, to be drilled by Kennecott, will furnish valuable data for a variety of innovative geothermal reservoir engineering techniques.

INTRODUCTION

Spud-in of the Salton Sea Scientific Drilling Project (SSSDP) well took place on October 23, 1985. The second of two flow tests was completed and the rig released on April 1, 1986. During the intervening 5-month period, the following activities were carried out:

- The well was drilled to 10,564 ft, exceeding the 10,000 ft target-depth objective.
- Cores were taken from 36 depth intervals, with a total of approximately 725 ft recovered.
- Two flow tests were completed, providing fluid samples for study and estimates of productivity from an upper zone at 6,120 ft and a lower interval with mixed flow, primarily from zones at 8,600 ft and 10,475 ft.
- Downhole geophysical logging and fluid sampling were performed by researchers (about 425 hours) and commercial companies (about 60 hours).

Temperature buildup measurements, scheduled about every 2-months through the summer of 1986, were discontinued in October when an attempt to repair a parted 7-in. hangdown liner was only partially successful. Residual drilling mud gelled within the liner, preventing passage of logging tools below about 5,800 ft. As a result, the stable bottom-hole temperature is still unknown.

The details of the events through 1986 are presented in Salton Sea Scientific Drilling Program, Drilling and Engineering Program, Final Report, Vols. I and II, April 1987, prepared by Bechtel National, Inc., under contract number DE-AC-03-84-SF1294. The report is currently in final review.

1986 ACCOMPLISHMENTS AND RESULTS USEFUL TO INDUSTRY

Kennecott, the primary industrial participant, provided a site for the project. The company holds an exploratory permit from the state of California for the parcel of land on which State 2-14 was drilled. Some of the data from the two flow tests, summarized in Table 1, are being used to qualify Kennecott's permit for conversion to a full-mineral lease.

On September 17, 1986, an interagency workshop was held at DOE/OBES in Germantown, Maryland, to review Technology Barriers to Deep Drilling in Thermal Regimes. Bechtel presented a summary of the experience from the SSSDP, much of which is of direct interest to future commercial developers of deep, highly-saline hydrothermal resources in areas such as the Salton Sea Geothermal Field. The problems, limits, and barriers in deep drilling and exploration are set forth in Table 2.

Table 1: PRELIMINARY FLOW TEST RESULTS*

	Well Depth (ft)	Estimated Flow Zone(s) (ft)	Approximate Duration (hr)	at Flow Rate (lb/hr)	Wellhead Temperature (°F)	Wellhead Pressure (psig)	Estimated Enthalpy** (Btu/lb)
First Test	6,227	6,120	4	600,000	400	200	400
			12	80,000	460	440	400
			2	430,000	410	220	400
			9	150,000	460	450	400
Second Test	10,564	Mixed flow from four depths***	3	475,000	445	310	520
			24	280,000	475	450	480
			1	700,000	460	380	480
			4	300,000	490	485	450

* Analysis by GeothermEx, Inc.
** Based on James's correlation with TDS correction.
*** 6,120 ft, 6,600 ft, 8,600 ft, and 10,475 ft.

Table 2: PROBLEMS, LIMITS, AND BARRIERS ENCOUNTERED IN DRILLING WELL STATE 2-14*

Key Considerations	Remarks
Hierarchy of Problems:	
Drilling	o Lost circulation and well flow control below 6,000 ft became expensive and hazardous. Eight to nine lost-circulation zones were penetrated before reaching total depth. Advanced control materials and techniques, including ground-up battery casings, were only temporarily effective.
	o Bit life was generally short because of: - The need to ream after coring - Accelerated bearing and button wear below 6,100 ft because of high temperatures and very hard formations - Drilling during lost-circulation conditions - Inappropriate use of button bits with high-speed turbo-motors
	o Directional drilling was unusually costly because of short turbo-motor life in the high-temperature, highly saline drilling environment.
Conventional Coring (730 ft recovered)	o Trip-times to take spot cores added considerably to the project cost.
	o Reaming after coring (down to 6,000 ft) required an extra round-trip and resulted in excessive bit wear.
	o Coring blind (during a lost-circulation situation) resulted in accelerated bit-wear due to overheating and abrasion, and in jamming of lost-circulation material between the rotating and nonrotating parts of the coring assembly.
	o Instability and bouncing of the drill string and coring assembly led to poor coring and core recovery.
	o Very hot, very hard rock types at depths greater than about 8,000 ft shatter when the overburden pressure is removed, and they are "chilled" by cooler drilling fluids during coring. Core barrel jamming and poor core recovery result.

Table 2 (Cont'd)

Key Considerations	Remarks
Commercial Logging	o Virtually all commercial logging tools and wirelines are temperature-limited at about 350°F, with only a few able to go to 500°F.
Scientific Logging	o Experimental high-temperature tools are difficult to calibrate, have questionable repeatability, and, especially for the more complex designs, are not fully reliable. The slickline-deployed, electronic-memory temperature and pressure tool shows considerable value to industry.
Sampling	o Problems in downhole fluid sampling occurred because of: - Brine flashing upon entry into the sample bottle of the LANL-Sandia sampler - Malfunction of battery system in the LANL-Sandia sampler - Seal failure in the LANL-Sandia fluid sampler, causing the motor to flood and short-circuit - Lost-circulation material clogging the bullnose in the Leutert sampler - Stopped clock preventing canister closing in the Leutert sampler - O-rings failing on the sample bottle in the Leutert sampler - Failure of the sample port to open in the LANL-Sandia sampler when a wire was broken during tool makeup prior to deployment - Loss of the gas sample from the LBL sampler when the tool had to be left downhole longer than anticipated
Limits and Barriers:	
Barriers to Going Deeper	o Difficulty in gaining and keeping control of multiple lost-circulation zones in the deeper, hotter formations. Effective high-temperature lost-circulation materials, cements, and techniques are required. o Early failure of rotary bits, especially loss of buttons, bearing failure, and loss of gauge-cutting capability. o Very slow cutting and early failure of diamond bits, resulting from poor cooling and poor removal of cuttings. o Slow cutting and early failure of PDC bits in hard formations. o The need for high-temperature, efficient drill bits. o Short life of mud- and turbo-motors in high-temperature, saline environments. Thermal operating limits must be improved.
Barriers to Obtaining More Core	o See "Barriers to Going Deeper," above. o Improved stability of the coring assembly and drill string. o Improved core barrels and core catchers needed to reduce jamming and improve recovery. When the formation begins spalling and discing from thermal shock and changes in geostatic pressure, conventional equipment is ill-adapted.

Table 2 (Cont'd)

Key Considerations	Remarks
	o Ultimately, trip times for coring become prohibitively expensive. The need to make frequent stops (in and out) to cool the well adds significantly to trip time. When a lost-circulation condition exists, ~~where~~ and drilling-fluid weighting cannot be relied upon for well control, the problem can become critical.
Barriers to Obtaining Geophysical Logs and Fluid Samples	o Construction and packaging materials, especially seals, are temperature-limited.
	o Failure-potential of wireline increases with time of exposure to temperature and corrosivity.
	o Signal conducting cables are temperature-limited to about 300°C.

* This table was originally presented in "Salton Sea Scientific Drilling Program, Report of the Fourth Quarter, FY1986," U.S. Department of Energy, Office of Renewable Energy Technologies, Geothermal Technology Division, January 1987, and was prepared under the direction of R. H. Wallace, Jr.

The time and materials costs of the SSSDP for the three main drilling problems are summarized in Table 3.

Table 3: PROBLEM AREAS AND ESTIMATED COSTS INCURRED DURING DRILLING AND COMPLETION

Activity	Duration (days)	Estimated Cost ($1000s)	Drilling and Completion Cost (%)
Lost Circulation and Well Control	20	640	21.5
Directional Drilling	18	390	13
Fishing and Stuck-Pipe	8	275	9

1987 PLANS AND OBJECTIVES

For 1987, Kennecott has proposed a joint technology development and research program that may provide the opportunity to conduct a flow test of up to 30 days from a reservoir deeper than 8,000 ft in State 2-14 well, using a conventional high-pressure separator system at the surface for measurements. Kennecott will be drilling a new well, Wilson 1-12, approximately 1-1/4 miles north of State 2-14, as part of their lease qualification effort. Kennecott has offered to make the well available as an injection well for the SSSDP, after they have completed a brief flow test. They have also offered to make this well available for scientific experiments. Details are now being negotiated between DOE, Kennecott, and Bechtel to integrate the two projects.

A prerequisite to conducting an extended flow test of State 2-14 is the successful repair of the damaged liner and isolation of a single, deep acceptable flow zone. This work must be accomplished within a severely constrained budget. If the remedial work is unsuccessful, the flow test program for State 2-14 will be canceled.

If the repair is successful, DOE/Idaho will direct a sampling and injection program designed to furnish definitive data on transient temperature and pressure conditions and mass-flow rates that will be of use in determining the reservoir properties. High-quality liquid and gas~~eous~~ samples will be available from the high- pressure separator for use in further scientific study. As presently envisioned, DOE/Idaho will also manage ~~the~~ testing of the following innovative reservoir engineering techniques during injection:

- o Geothermal tracer stability and reactivity
- o Thermal breakthrough analysis
- o Nonisothermal injection testing
- o Geomechanical effects of injection
- o Coupled surface and borehole resistivity surveys
- o Heat-sweep modeling
- o Geophysical front-tracking