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LOST CIRCULATION IN GEOTHERMAL WELLS: RESEARCH AND DEVELOPMENT STATUS*

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ABSTRACT

Three of the most-common severe problems encountered in drilling and completing geothermal wells are lost circulation, stuck pipe, and inadequate cementing. Since lost circulation may cause or aggravate the other problems, it is considered the single most-serious well-development problem. Sandia National Laboratories has initiated a multi-faceted program directed at understanding and helping to solve this problem. The program involves characterizing loss zones, developing an analytic fluid dynamics model of zone plugging, screening lost circulation materials in the laboratory and testing some solutions in a large-scale test facility. The status and plans for this program are presented.

INTRODUCTION

Sandia National Laboratories manages the U.S. Department of Energy's Geothermal Technology Development Program. A survey and evaluation of lost circulation in geothermal wells (Goodman, 1981) revealed that no major new advancements in methods or materials were being undertaken by the industry. A subsequent study (Carson and Lin, 1982), which investigated well development problems and their severity, identified lost circulation as the predominant problem plaguing geothermal developers. For these reasons, Sandia has begun a major multi-year program to address lost circulation in geothermal wells.

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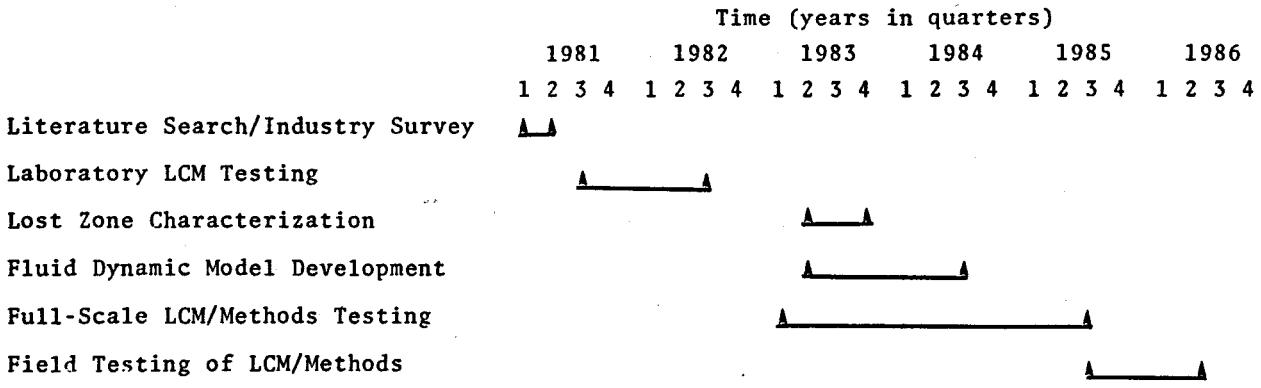
LOST CIRCULATION PROGRAM

The six elements of the Lost Circulation Program are:

1. Literature Search/Industry Survey
2. Laboratory Lost Circulation Material Testing
3. Loss Zone Characterization
4. Fluid Dynamic Model Development
5. Full-Scale LCM/Methods Testing
6. Field Testing of LCM/Methods

The program schedule, encompassing a six year period, is presented in Table 1. Each element is described below.

TABLE 1. LOST CIRCULATION PROGRAM SCHEDULE



DISCLAIMER

LITERATURE SEARCH/INDUSTRY SURVEY

A detailed search for lost circulation related papers and patents was conducted for Sandia (Goodman, 1981). Of the 59 references reviewed, none addressed geothermal lost circulation specifically. However, many of the techniques and materials discussed may be relevant for geothermal applications. Goodman also interviewed operators representing experience from the major geothermal resources in the U.S. The survey showed that, although conventional petroleum methods were being used to combat lost circulation, these methods are not satisfactory. Since very little research and development was being undertaken by industry, it was decided that a DOE-sponsored effort was justified. Continued literature review and contact with industry is an ongoing part of this program.

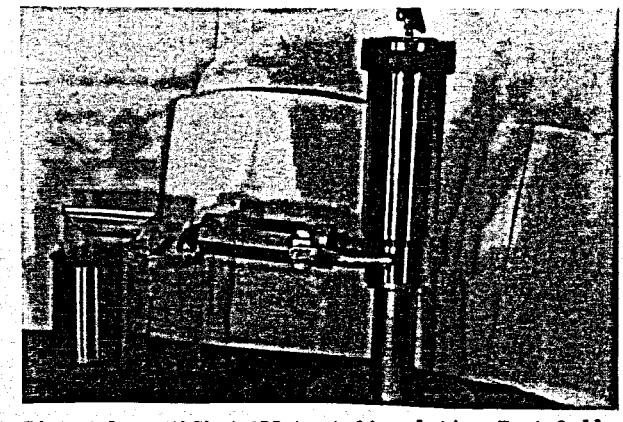


Figure 1. Modified API Lost Circulation Test Cell

LABORATORY LCM TESTING

As reported by Hinkebein et al. (1983), Sandia performed 266 tests on various lost circulation materials (LCM) at both room temperature and temperature-aged conditions (simulating geothermal conditions). Tests were performed in a modified API Lost Circulation Test Cell (Figure 1). Modifications included constructing a 6-inch long slot as shown in Figure 2. (The standard API slots are only about 1/4 inch long). LCM was forced through the slot with pressure differentials up to 1000 psi. LCM concentrations and slot widths were varied. Some results are shown in Table 3. Only Thermo-set seal (ground battery casings), of the LCMs tested, performed adequately after 400°F aging. This test facility will be used to continue to screen candidate LCM for future work.

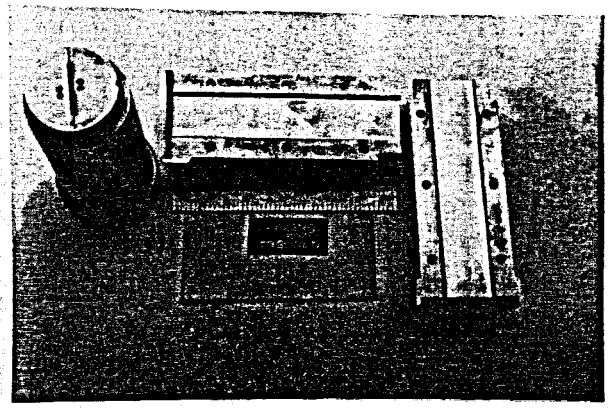


Figure 2. Six-Inch Long Modified API Slot

TABLE 2. RESULTS OF LABORATORY TESTING OF TEMPERATURE-AGED LCM USING THE MODIFIED API LOST CIRCULATION TEST CELL (from Hinkebein, 1983)

Material	Sealing Pressure (psig)			Concentration (lb/bbl)	Slot Width (inches)
	Exposure Temperature (°F)				
	Ambient	250	400		
Cotton Seed Hulls	1000	380	-0-	5	0.06
Ruf-Plug®	1000	1000	30	10	0.06
Kwik-Seal®	1000	1000	710	10	0.06
Thermo-Set Seal*	1000	1000	1000	5	0.08

*Product name for ground battery casings.

LOSS ZONE CHARACTERIZATION

Sandia has upgraded an Acoustic Borehole Televiewer (ABT)(Figure 3) to operate in the geothermal high temperature environment (Heard and Bauman, 1983). The ABT provides an acoustic ultrasonic image of the borehole wall. Logging is accomplished at 5 ft/min on a 7-conductor wireline. The ABT uses a 3-degree conical beam and 600 pulses per revolution (600 "caliper" arms). Features as small as 0.05-inches in an 8-inch wellbore can be detected - resolution is about 0.18-inches. It also contains a magnetometer to obtain a north reference. Figure 4 shows data taken from a 10 foot wellbore interval containing a depression and an angled fracture that demonstrates the tool's capability.

In May 1983, attempts were made to characterize lost zones in some Imperial Valley geothermal wells with this tool. Failure of the logging company's cablehead foiled these attempts. Subsequent runs will be made when the cablehead problems are resolved.

FLUID DYNAMIC MODEL DEVELOPMENT

Efforts have begun to develop an analytic model of the "plugging" mechanisms involved with LCM. An incompressible finite element code, NACHOS, is being used to model the LCM rich mud and the annulus/fracture geometry. Variables such as flow velocity and pressure differential across the fracture are included. Initial results are encouraging - calculations show that the viscosity of the mud increases in the vicinity of the fracture. Parametric studies will be performed for a range of LCM concentrations and particle size distributions. Laboratory experiments will be run as required to facilitate and verify the model. Upon completion, the model will aid in designing solutions to specific lost circulation problems.

FULL-SCALE LCM/METHODS TESTING

Sandia has designed and built a full-size (well-bore diameter) lost circulation test facility that has recently become operational. Its physical and operational characteristics are described in detail by Loeppke and Caskey (1983). Initial testing during the current facility checkout phase utilizes a steel core which can accommodate up to 12 modified API slots (Figure 5). The results of the limited testing performed to date are presented in Table 3. Figure 6 shows the test vessel configuration utilized. Tests using this setup are planned to:

1. Confirm laboratory LCM test results.
2. Investigate the effect of flow past the slot on LCM plugging.

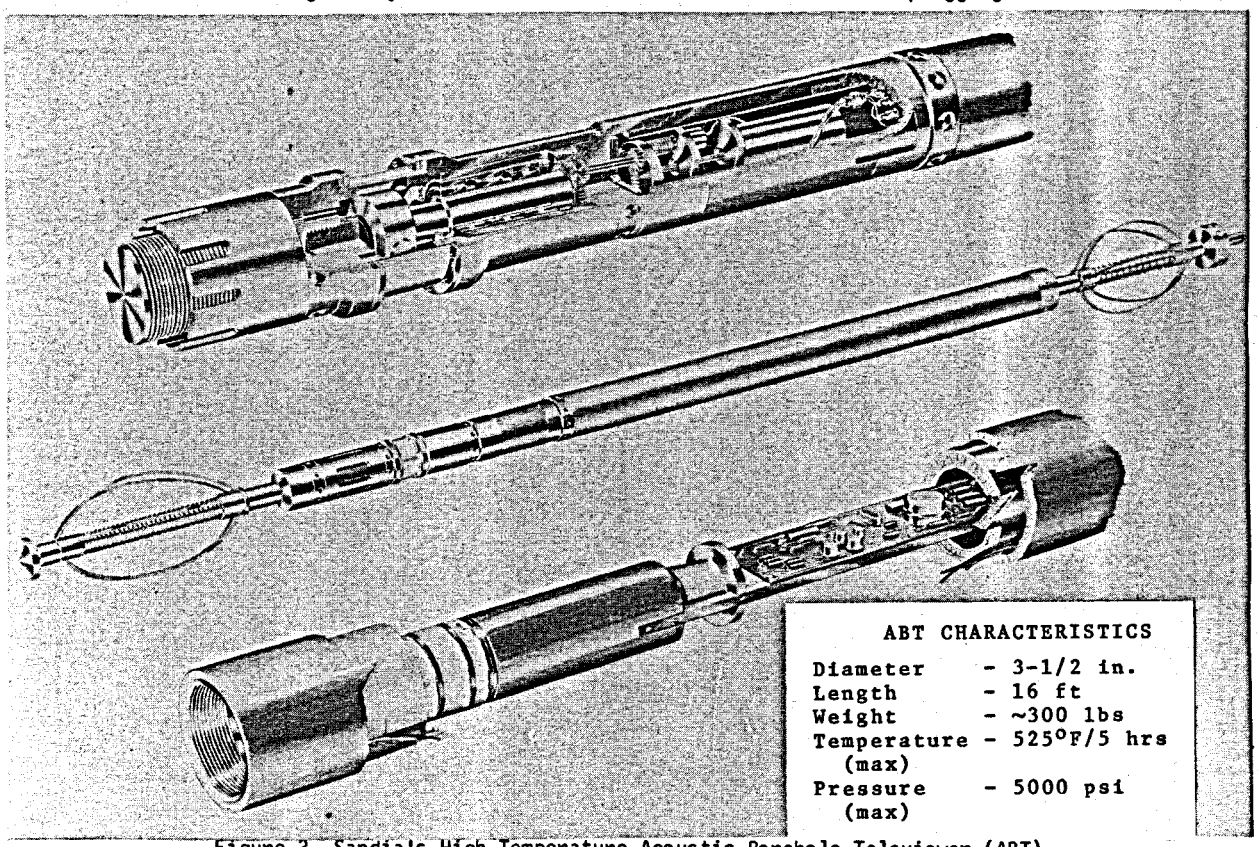


Figure 3. Sandia's High Temperature Acoustic Borehole Televiewer (ABT)

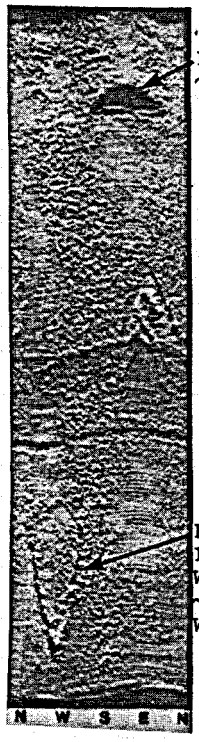


Figure 4. ABT Display of 10 feet of GT-2 Wellbore, LANL Hot Dry Rock Project, May 1981

3. Investigate the effect of temperature (up to 400°F) on LCM plugging.

Tests later this year will utilize a fractured permeable core. As lost circulation mechanisms are more fully understood (as testing and modelling progress), appropriate materials and techniques will be evaluated.

FIELD TESTING OF LCM/METHODS

Based on successful testing of LCM and placement techniques, the most promising will be evaluated, in cooperation with geothermal operators, in actual lost circulation zones in geothermal wells under development. Hopefully, a field test can be run in 1985.

SUMMARY

Sandia is mounting an aggressive attack on the troublesome lost circulation problem during geothermal well development. Much background work has been accomplished--full-scale testing is just beginning and a more complete understanding of problem solutions will be forthcoming during the next three years. Progress will be reported each year.

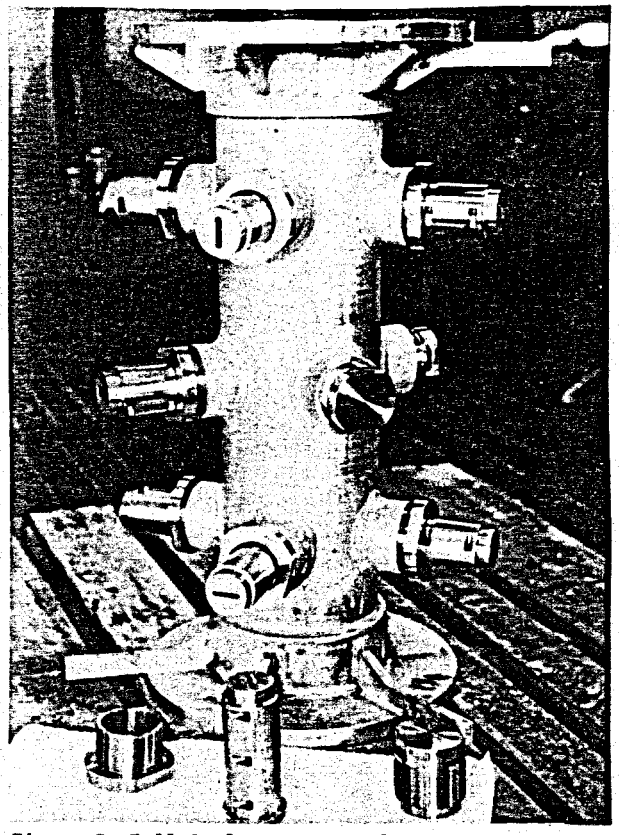


Figure 5. Full-Scale Lost Circulation Test Facility Impermeable Core Utilizing Modified API Slots

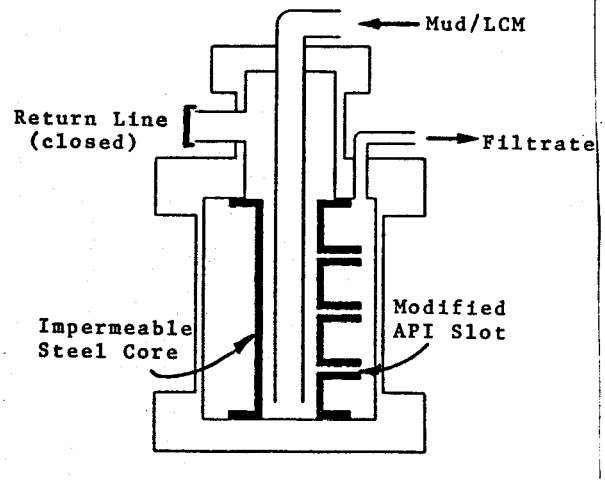


Figure 6. Full-Scale Test Facility with Impermeable Steel Core and Modified API Slots

TABLE 3. FULL-SCALE FACILITY LCM TEST RESULTS--
Initial Series at Room Temperature with
No Flow Past the Slot. All Slots that
Plugged Subsequently Held 1000 psi
Differential for 15 Minutes

Number	Date	Pressure Differential (psi)	Type	Concentration (lb/bbl)	Slot Width (inches)	Results	Remarks
1	11 MAR 83	200	Thermo-Set Medium	10	0.040	plugged	--
2	10 MAY 83	200	Thermo-Set Medium	20	0.120	no seal	--
3	16 MAY 83	200	Thermo-Set Coarse	20	0.120	plugged	plug held w/200 gpm flow past plug
4	16 MAY 83	500	Thermo-Set Coarse	10	0.120	plugged	--
5	17 MAY 83	200	Thermo-Set Coarse	5	0.120	plugged	--
6	17 MAY 83	200	Thermo-Set Coarse	5	0.120	plugged	--
7	19 MAY 83	600	Thermo-Set Coarse	10	0.120, 0.160, 0.200	plugged	annulus plugged

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