SOME TEST RESULTS OF THE PTS LOGGING TOOL AS LOST CIRCULATION DETECTOR UNDER THE DRILLING MUD CONDITION

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1. Introduction

The objective of the lost circulation detection test is to determine the condition, location, and scale of lost circulation using an modified version of the conventional pressure/temperature/spinner (PTS) logging tool.

The test was carried out at wellbores being drilled in August 1986 and 1987, but since it had to be taken place in mud water accompanied with very precarious borehole walls, spinner sensitivity was found a problem of particular interest.

A report follows on the progress and results of the lost circulation detection test up to date.

This paper represents some of the research achievements included in the "Research and Development of Lost Circulation Techniques in Geothermal Wells" that is a part of the "Development of geothermal hot water power generation plant" an undertaking aided by the MITI Sunshine Project.

2. Measurement procedure

2.1 PTS logging tool and measuring system

For the measurements, PTS logging tool that is produced by SDI (Scientific Drilling International) in United States was adopted taking account of thermal resistance, data acquisition system, etc. The outline is shown in Fig. 1.

Meanwhile, the measuring system is composed of PTS downhole tool, high temperature logging cable, surface control panel, computer (HP-1000), and software; it is capable of simultaneous measurements for pressure, temperature, and spinner. The features of this system are summarized below.

(1) Owing to simultaneous measurements available of pressure, temperature, and flow rate:

  (a) No time log between P/T/S.
  (b) No depthwise errors.
  (c) Measuring time can be shortened.

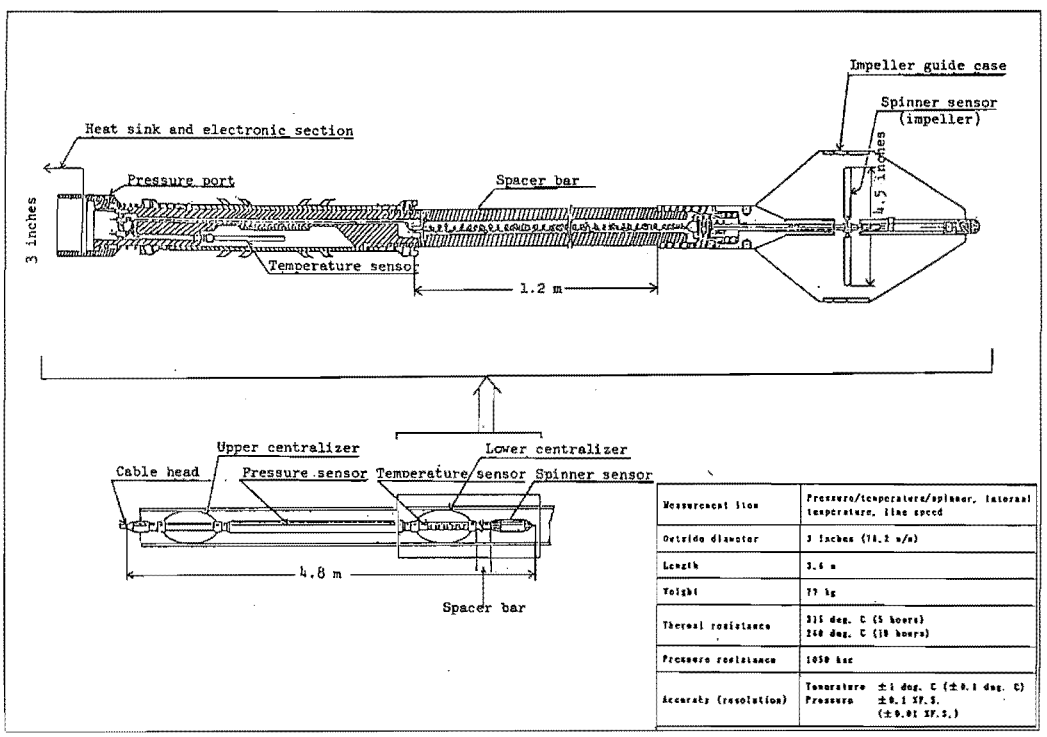
(2) Continuous measurements can be acquired for all logging section.

(3) Digital data transmission and digital recording.

(4) High thermal resistance (8 hours at 300 deg. C)

2.2 Test well condition

In the test run at well BS-4 in the Sugawara area of Oita Prefecture in August



Measurement item	Pressure/temperature/spinner, internal temperature, line speed
Outside diameter	3 inches (76.2 m/m)
Length	3.6 m
Weight	77 kg
Thermal resistance	315 deg. C (5 hours) 260 deg. C (10 hours)
Pressure resistance	1050 kgc
Accuracy (resolution)	Temperature ±1 deg. C (±0.1 deg. C) Pressure ±0.1 KF.S. (±0.01 KF.S.)

Fig. 1 Lost circulation detector(PTS tool)

1986, injection logging could not be carried out because no lost circulation had occurred, so the location of a loss zone could not be ascertained. Therefore, PTS tool lost circulation detector was tested for operation in mud condition.

In the test of August 1987 on well BS-6, integrated work was possible on static, build-up (two-flow rate), injection (two-flow rate), and fall-off logging.

2.3 Test procedure

(1) Test of tool assembly (at well BS-5)
Prior to logging in the course of lost circulation at well BS-6, the following tests were carried out under static condition at well BS-5 being drilled in order to determine the spinner characteristics.

(a) Spacer bar (1-3/4" O.D.) + 3" spinner + basket
(b) Conventional tool + 4.5" impeller
(c) Spacer bar (1-3/4" O.D.) + 4.5" impeller

(2) Logging under the lost circulation condition (at well BS-6)
In order to evaluate the location and scale of a total lost circulation at well BS-6 in the course of drilling, a logging tool capable of simultaneous measurement of the three components -- temperature, pressure, and spinner (PTS) -- was run into the well, and their measured values continuously recorded digitally at the surface. Shown below are the ways of logging that were practiced.

(a) Static logging
This process measures the wellbore temperature, pressure, and spinner under drilling mud condition with no flow rate; the fluid level, formation recovery temperature, loss zone pressure, spinner characteristics, etc., can be derived from the logging results.

(b) Build-up logging
In this process, logging equipment is installed near the loss zone and the injection of mud is started through the wellhead at a given rate to make measurements; lost circulation capability can be evaluated from the logging results.

(c) Injection logging
This process makes measurements of the wellbore temperature, pressure, and flow rate while injecting mud into the wellbore at a given rate; depth of lost circulation, scale of lost circulation, pressure of loss zone, etc., can be obtained from the logging results. In addition, the mud injection rate was varied in two grades to investigate the variations in characteristics due to differences in the mud injection rate.

(d) Fall-off logging
In this process, at the well being injected with mud at a given rate the injection is stopped in a moment and the recovery of pressure near the loss zone from that time is measured. Lost circulation capability can be evaluated from the logging results.

(e) Stop check
This process is not affected by the movement of logging tool in the well being injected with mud. That is, the number of spinner revolutions caused only by mud water flowing in the wellbore is measured; the location and size of loss zone can be evaluated from the logging results.

The mud used for injection had an apparent viscosity of 28 sec (500 cc/500cc), specific gravity of 1.05. (the same properties as those of mud that had been used in lost circulation drilling.)

3. Test results

3.1 Results of tool assembly test

(1) Spacer bar + 3" spinner + basket
The 3" spinner sometimes ceased to rotate in the course of measurements because of the mud being ready to stand in the device.

(2) Conventional tool + 4.5" impeller
Although the mud almost ceased to stand in the spinner, the spinner characteristics at up-measurements (that is, fluid downflows) were found inferior to those at down-measurements, thereby causing the tool body to retard fluid passage into the spinner.

(3) Spacer bar + 4.5" impeller
Nearly the same spinner characteristics were obtained both in up- and down-measurements with little mud standing in the spinner. This indicates that fluid passage was facilitated by separating the spinner from the tool body by spacer bar.

From the above results, the spacer bar fitted with a 4.5" impeller (spinner cage diameter; 6") was adopted in the well BS-6 test during lost circulation.

3.2 Logging results under lost circulation condition

(1) Spinner characteristics
The spinner characteristics under the setup of conventional tool + spacer bar + 4.5" impeller were determined from the results of the static, injection flow No.1, injection flow No.2, and stop check measurements that were carried out at well BS-6. The spinner calibration curve at down-measurements and that at up-measurements are shown in Figs. 2 and 3, respectively.
These test results revealed the following:

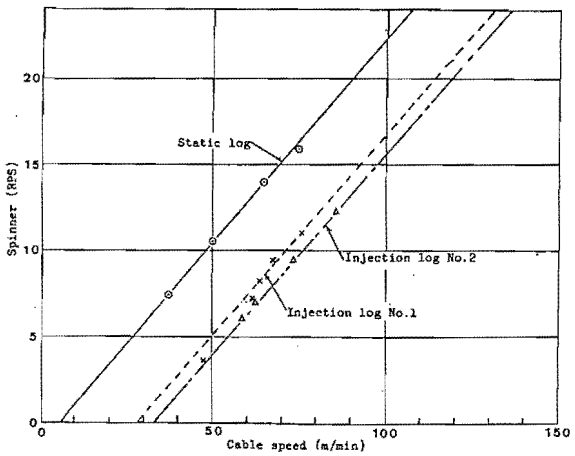


Fig. 2 Spinner calibration curve (down-measurements)

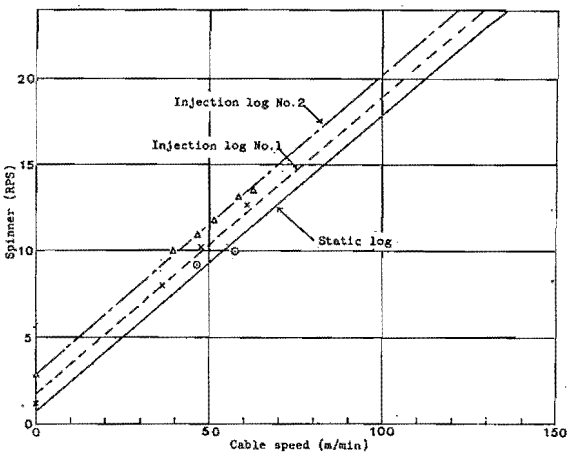


Fig. 3 Spinner calibration curve (up-measurements)

(a) The spinner sensitivity was improved by applying the impeller; O.D. 4.5".
(b) Mud almost ceased to stand because of the guide case not covering all the impeller. Also, even any mud sticking to the impeller could be flushed away in the wellbore by moving the tool up and down.
(c) The spacer reduced fluid disturbances from the tool body relative to the impeller, offering nearly the same spinner sensitivity both in up- and down-measurements.
(d) Enlargement of the impeller led to an increased fluid passage, causing the impeller to rotate even with slow flow rates and thereby improving the limit speed.

3.3 Summary of the test results

Integration results of injection logging No.1 and No.2 are shown in Fig. 4, the lost circulation percentage and volume by zones, in Fig. 5.

Here, the lost circulation point (LC3, 528.3 m) could be newly confirmed, which could not be noticed while drilling. As will be apparent from Fig. 5, it seems that the lost circulation of LC3 could not be detected while drilling owing its small volume.

Again, increasing the flow rate caused LC2 (536.0 m) to decrease, and LC1 (547.5 m) and LC3 to increase. This is for the plugging of LC2 and the rise in water head which had taken place in flow No.2, that is, rise of the bottom hole pressure caused LC1 to develop a lost circulation equally to LC2.

Besides, Fig. 6 shows the results of fall-off matching based on MRMW, which is the software to simulate the pressure transient test. This provides the reservoir parameters that are shown below.

Transmissivity(kh/μ)=$4.99X10^{5}$darcy.m/poise
Storativity(ϕ ch)=$5.00X10^{-3}$m/psi

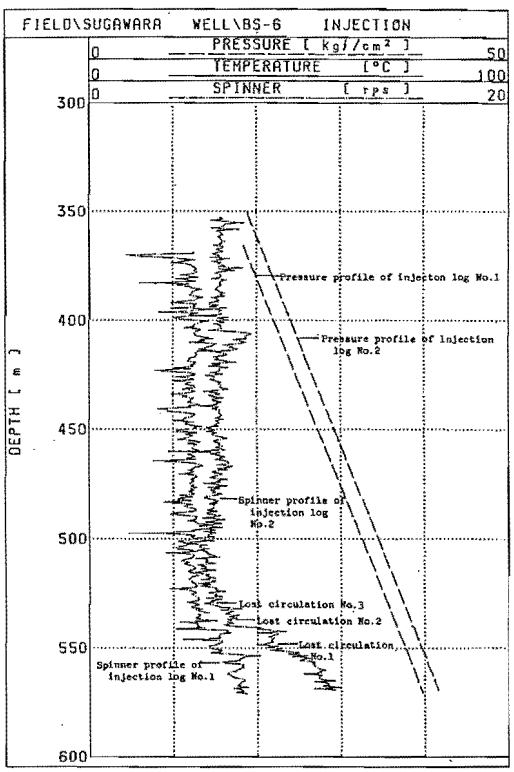


Fig. 4 Injection logging merge effects

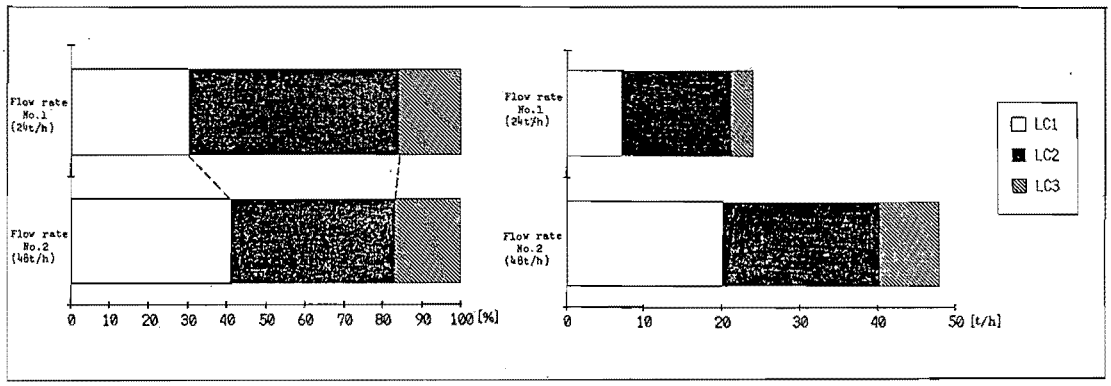


Fig. 5 Lost circulation percentage & volume by zones

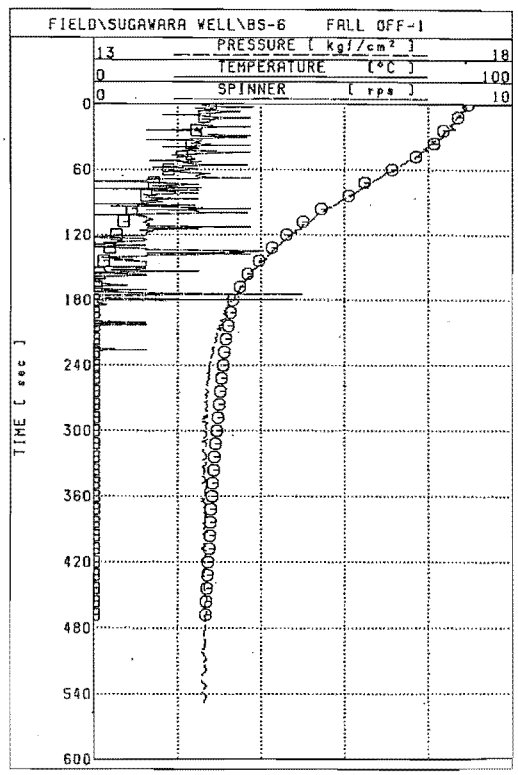


Fig. 6 Results of fall-off matching based on MRMW

4. Conclusion and future problems

Lost circulation (L/C) zones could determined by updated PTS logging tool that is used for production logging or the like. Following two points were improved;

(1) The spinner was separated 1.2 m in position from the tool body by spacer bar.
(2) The impeller was made 4.5" in diameter and the open style guide case was applied.

And the spinner was found most effective in detecting lost circulations, and a lost circulation (LC1) that could not be noticed while drilling, could be determined.

The following may be cited as problems for the future:

(1) Improving the spinner resolution at low revolution region.
(2) Making not only the spacer bar but also the whole logging tool more slender and more compact in order to reduce the impact of fluid friction.