Evaluation of a Geothermal Well
Logging, DST and Pit Test

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Introduction

This paper briefly discusses logging and testing operations and certain related physical aspects in geothermal well evaluations.

A good understanding of thermal and hydrological characteristics of geothermal reservoirs are essential in geothermal well evaluations, Within geothermal reservoirs, in evaluating the wells, the two most important parameters that first could be estimated, then measured or calculated, are temperature and productivity. Well logs and wireline surveys are means of measuring formation temperatures. Drill Stern Tests (DST's) or Pit Tests are means of determining formation productivity.

Geochemistry and Petrology are currently accepted as two evaluation yardsticks in geothermal well evaluations. Investigations of cuttings and cores during drilling operations, along with studies on formation waters could be used in a predictive nature for temperature and productivity and could yield useful information on the resource.

Logging in Geothermal Wells

Logs in general are extremely useful devices in single or multiwell reservoir evaluations. Formation Density, Neutron, Induction, Sonic, SP, Gamma-Ray, Caliper and Dipmeter logs are widely accepted by the geothermal industry. Depending on the types of formations penetrated by the well, some logs are preferred or rather have a higher priority than others. For example, in volcanic rocks density and sonic logs could be preferred to dipmeter and to neutron logs.

The above formation logs could also be used in estimation of static formation temperatures at various depths. The temperatures, obtained from maximum reading thermometers attached to these logs in individual logging runs, are used in a buildup analysis to estimate final temperatures.

A current problem with the use of some logs is their temperature limitations, This limitation sometimes proves troublesome and costly in geothermal well evaluations. However, careful plans relating to a) type of logs, b) the number of logs to be run, c) their schedule, could result in significant time savings and cost reduction.

A critical review of available literature and field evaluations revealed the current temperature limitations for some of the existing logs:

Type of Log		Temperature Pating (°F)
Resistivity	Standard: Dual Induction (DIL)	350
	Hot Hole: Single Induction (IL)	500
Porosity	Borehole Compensated Sonic (BHC)	350
	Hot Hole BHC, No Sp, No GR	500
	No SP, with GR	400
	Long Spaced Sonic	350
Density	Formation Density Compensated (FDC)	400
	Compensated Neutron Log (CNL)	400
Dipmeter	Four Arm High Resolution	350

For example, in evaluating a +500°F well, at a depth of 6,000 to 10,000 feet, it becomes difficult, even with a cooling run, to obtain a DIL, or a Long Spaced Sonic or a Dipmeter for the entire well depth.

Given the above limitations, in hot water geothermal wells with static temperatures around 500°F, it is recommended that SP be run with the Hot Hole Single Induction Log. The Hot Hole BHC Sonic could be run alone. FDC-CNL-Gamma Ray-Caliper could be run in combination on one trip, preferably after a second cooling run. If Dipmeter Log is desired it should be scheduled immediately after a cooling run.

If lost circulation is expected, further planning is necessary in an attempt to obtain some of the logs. If total lost circulation occurs and if one is unable to continue circulation to cool the well, the chances of obtaining logs are drastically reduced.

To increase the chances of obtaining all desired logs, and to save considerable time by eliminating the prerequisite temperature surveys along with multiple cooling runs, logging industry is pursuing research and development on tools for high temperature environments. DOE sponsored programs in advanced high temperature electronics for geothermal well logging applications are also continuing,

A Drill Stem Test (DST) vs. a Pit Test

A DS or a Pit test is usually conducted as a first step in the productivity evaluation of a geothermal well. The objective is to gather flowing bottom hole and wellhead data. Analysis of successful tests can yield information on a productivity index for the well, and a permeability-thickness product, preferably from a pressure buildup. Usually a DST is run in an open hole while rigged up, a pit test is run in a cased hole, after the rig release and installation of a X-mas tree. The costs of these tests, though relatively comparable, are beyond the scope of this discussion. If a DST is elected in evaluation of the well, the results of this test could be used in a decision to run a liner, to abandon the well without running a liner, or possibly to continue drilling.

There is a greater chance of getting (good) bottom hole data through a DST. In a pit test one relies on either a) wireline pressure and temperature bombs at mid-perf's, or b) bottom hole pressure (only) estimation through nitrogen tubing pressure, which is surface recorded, and the nitrogen volume data.

A disadvantage in both DST and Pit tests with bottom hole recordings is that the data is not available until the tests are over. Surprises and disappointments are not uncommon when tools or charts are brought to surface.

A severe limitation for both tests is the limited water volumes that can be produced during a relatively short time. Often these tests only serve in a partial cleanup of lost circulation, or they merely enable production of few wellbore volumes before running out of storage capacity. Disposal of the produced formation brine and mud proves costly and time consuming. Higher production rates and slightly longer test times, however, are possible through a pit test.

DST was designed by the oil industry to test the hydrocarbon potential of limited intervals, usually «200 feet. In geothermal wells the intervals of interest are usually greater. Therefore, DST's are not suitable, neither for the large intervals to be tested nor the high flow rates desired.

One practice is to attach both outside and inside pressure recorders and the temperature bomb to the end of the drill pipe, and set the packers, as deep as possible, between the drill pipe and the intermediate casing. A 15-25 feet perforated tail pipe preferably above the pressure and temperature bombs, permits the entire hole below to be open to flow. See Figure 1A.

An alternate, in an open hole test, is to run the drill pipe to the desired depth and inject nitrogen, producing the well through the annulus. Pressure and temperature bombs could be attached to the bottom of the drill pipe. This method eliminates the cost of a drill stem test and avoids the possible - high temperature related - problems with the packers. See Figure 1B.

Flow rates in both tests are usually estimated by volumetric measurements. An estimation of wellhead steam quality is also necessary to determine the total mass rate from the well. Numerical wellbore models could be used to estimate wellbore heat losses and pressure drops, hence wellhead qualities. In the absence of bottom hole data wellbore models could also be used, starting with wellhead data, to predict flowing bottom hole pressures and temperatures.

Given these limitations of Drill Stem and Pit tests, long term production tests, where a nearby injection well is available, becomes necessary in further or final evaluation of a well. Long term tests are especially important for wells with fracture production.

More research is required to find new ways and means of short time testing hot water geothermal wells.

FIG. I

TWO CURRENT PRACTICES IN GEQTHERMAL WELL TESTING