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FIELD SCALING TESTS ON GEOTHERMAL BRINES

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The single largest obstacle that must be surmounted in order to make geothermal fluids a viable energy resource is the problem of scaling. Several studies have dealt with the presence and bulk chemical compositions of the various scales but few attempts have been made to determine the rates of scale formation. As part of the Penn State geothermal project sponsored by the U. S. Bureau of Mines, we designed an inexpensive field test to determine scaling rates and compositions from homogeneous geothermal fluids. The technique used in these experiments is to abruptly cool the geothermal fluid to a controlled temperature. Brine flow was maintained at a set rate until sufficient scale had been precipitated to determine its composition and distribution along the flow path.

The experimental design (Figure 1) includes a brine flow-through system, a cooling fluid system and an interfacing heat exchanger. A portion of the geothermal brine is mixed with other water at ambient temperature to produce a cooling fluid at the required temperature. This cooling fluid can be returned to the reservoir or can be reinjected with the geothermal brine. The remainder of the geothermal brine flows through a small-volume tube-in-shell heat exchanger. The heat exchanger (Figure 2) was fabricated from a two-foot section of six-inch diameter pipe. Originally, both the geothermal brine and the cooling fluid entered the heat exchanger through the end plates. This design was later modified so that the cooling fluid entered through the bottom of the heat exchanger and exited from the top. The geothermal brine is quenched within a 25-foot, helical coil of copper tubing.

Several series of experiments have been conducted using this design. The first two series of experiments were run at the U.S. Bureau of Mines Test Facility, Nyland, California. Brines from Magmamax 1 and Woolsey 1 (courtesy of the San Diego Gas and Electric Company) were individually passed through the heat exchanger. Magmamax 1 brines were introduced into the heat exchanger at 225°C and 25 bars. Brines from Woolsey 1 were introduced at 175°C and 25 bars. Both brines were quenched at 25°C intervals between their maximum temperatures and 50°C. Temperatures were monitored every 15 minutes and flow rates every half hour. In order to maintain consistent flow rates and entrance temperatures, it was necessary to make minor, periodic adjustments to the exit valves. Exit valves were used to control the flow rate in order to maintain pressure on the brine and thus prevent separation of a vapor phase and the concomitant increase in the concentration of dissolved solids in the brine. The chloride concentration in the brine was monitored.
During individual experiments to determine whether upstream flashing was altering the composition of the incoming brine, Runs which included flashed brines were discarded. At the conclusion of each experiment, the coils were removed, weighed and stored.

The Magmamax No. 1 and Woolsey No. 1 wells are approximately one half mile apart in the central part of the Salton Sea known geothermal resource area. At the time these experiments were conducted, there was a difference of 50°C in the maximum temperatures of the brines available from the two wells. Scaling characteristics of the two wells were considerably different. Brines from the Magmamax well produced the maximum amount of scale with quench temperatures between 125 and 175°C (Figure 3). At quench temperatures of 100°C and below, the kinetics of scale precipitation were slow enough that the brine was able to pass through the system before appreciable scale was deposited. It was, therefore, possible to quench the Magmamax scales into solution at low temperatures.

Brine from the Woolsey well deposited little scale until it was quenched to 125°C. The maximum amount of scale was precipitated at 100°C and below (Figure 4). Once the scaling rate reached a maximum, there was no significant decrease at lower quench temperatures. Chemical and X-ray analyses of both scales indicate that they are predominantly carbonates with admixed sulfides.

In addition to the experiments on the high-salinity Salton Sea brines, a series of experiments has been conducted on the lower temperature, lower salinity geothermal waters at the Idaho National Engineering Laboratory's Raft River Area in southern Idaho. In these experiments the apparatus was modified to mix geothermal waters from two wells immediately before they entered the heat exchanger. The...