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Laboratory and Numerical Studies of Heat Extraction from Porous Media by Means of CO2 - Implications for Field-Scale Enhanced Geothermal Systems

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The use of CO_2 as a heat transfer fluid has been proposed as an alternative to water in enhanced geothermal systems (EGS). Numerical simulations have shown that under expected EGS operating conditions CO_2 would achieve more efficient heat extraction performance compared to water. In a set of laboratory experiments, we have investigated heat extraction by flowing dry supercritical CO_2 through a heated porous core in a laboratory pressure vessel. Measurements were made at pressures ranging from 77 to 121 bar, temperatures from 20 to 75°C, and a range of mass flow rates. We have implemented a model of the experimental system in TOUGH2 and have obtained reasonable agreement between the laboratory measurements and the predictions of the numerical simulation. While the data collected from the current apparatus is useful for testing, refining, and confirming theoretically-derived heat transfer predictions, it provides little insight into the actual performance of field-scale EGS due to differences in scale and geometry. This makes comparing the efficiencies of water and CO2 as heat transmission fluids in EGS beyond the capabilities of our current laboratory system.

Field-scale EGS heat transfer is dominated by convection, while lab-scale heat transfer tends to be strongly affected by conduction. In order to bridge the gap between the lab-scale experimental results and field-scale EGS, numerical studies have been conducted to explore alternative laboratory experimental designs and operating conditions. Laboratory assemblies of several porous cores with different temperatures in series were found to achieve conditions that can approximate the field-scale interplay between advective heat transport and heat conduction. We also explore the use of alternative (linear vs. radial) flow geometries, and the transition from an aqueous to a CO2-based reservoir through continuous circulation of CO2.