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Non-Isothermal Compositional Flow Simulations of Mixed CO2-Water Injection into Geothermal Reservoirs

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Concern about global warming is driving research and development aimed at reducing the emissions of greenhouse gases such as CO2. One way of reducing CO2 emissions is to replace conventional energy sources for heating buildings with geothermal energy. To reduce CO2 emission further, a feasibility study is ongoing to also capture the CO2 and co-inject it with the cooled-down-return water of the geothermal reservoir. In this way, synergy is established between geothermal energy production and subsurface CO2 storage.

For CO2-water injection into a hot-water aquifer, there exist six possible phase states, depending on the overall injected CO2 concentration and reservoir pressure and temperature. In most cases, one interface between the aqueous single-phase and the two-phase region (phase appearance) and one interface between the two-phase region and the hot liquid water (phase disappearance) can exist. The systems of equations that apply for single-phase and for two-phase flow conditions are different, which is inconvenient for numerically simulating injection of cold water mixed with CO2 into geothermal reservoirs. To overcome this inconvenience, we have developed a new and effective solution approach to deal with phase disappearance/appearance, called "the non-isothermal negative saturation (NegSat) solution approach". In the NegSat approach, a single-phase multi-component fluid is replaced by an equivalent fictitious two-phase fluid with specific properties. The properties of the fictitious two-phase fluid are such that in the single-phase region, the extended saturation of the fictitious phase is negative. Another innovative aspect of the NegSat method is the inclusion of phase transitions from subcritical to supercritical conditions for problems that involve complex thermodynamics and heat effects coupled with fluid flow, such as is the case for mixed CO2-water injection into a hot-water aquifer.

In this study, we discuss the influence of various CO2 injection fractions on the storage/production mechanisms of CO2 and on production of hot water from the geothermal reservoir. Furthermore, we provide a plot of stored CO2 versus useful energy extraction as a screening method for optimal geothermal recovery and/or maximal storage of CO2.