IMPROVEMENTS IN SIMPLIFIED MODELING OF CO2 GEOLOGIC SEQUESTRATION

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CO2 geologic sequestration in deep saline aquifers and depleted oil and gas fields offers a pragmatic solution to meeting greenhouse gas emission reduction targets. Many computational modeling tools have been developed in recent years to address CO2 migration dynamics in oil and/or brine-filled systems as well as associated geo-chemical and geo-mechanical changes. A proper application of these tools requires considerable information regarding the geologic framework of the target reservoir, and detailed phase behavior data for the fluid systems of interest. Often, such information is found to be lacking during the screening or initial planning stages of many geologic sequestration projects. This has led to the development of simplified analytical models for CO2 plume movement and associated pressure buildup. However, a rigorous evaluation of such models against detailed multi-physics reservoir simulators appears to be lacking in the literature.

This paper will describe a benchmarking exercise that compares the simplified model of Burton et al. (2008) against the numerical simulator STOMP (White and Oostrom, 2006), and suggest improvements that result in a better match with the rigorous computational modeling results. The Burton et al. model is based on fractional flow and steady-state pressure gradient considerations following CO2 injection into a saline aquifer. The system is conceptualized as: (1) a near-wellbore single-phase region consisting of dry CO2, (2) a far-field single-phase region consisting of native brine, and (2) an intermediate two-phase region where both CO2 and brine are flowing. STOMP (Subsurface Transport Over Multiple Phases) is an integral volume finite difference simulator originally developed by the Pacific Northwest National Laboratory for modeling subsurface flow and transport systems and remediation technologies, and has since been extended for CO2-brine systems.

Simulations are carried out for CO2 injection into a well in a radial aquifer. Temperature and pressure conditions used in these simulations correspond to the "warm, shallow" and "cold, deep" aquifer conditions typically used in the CCS literature. Performance metrics are: (a) saturation profile in the formation, (b) pressure profile in the formation, and (c) pressure buildup history at the injection well. A comparison of STOMP results with those predicted by the Burton et al. model indicate good agreement for the saturation profile, but significant differences in predictions of radial propagation and temporal evolution of pressure. We have introduced three modifications that result in a much better match between the two models:

• Calculating gas viscosity and gas density at the "quasi-steady" wellbore pressure, and brine viscosity at the initial undisturbed formation pressure.

• Calculating a representative value for the two-phase mobility $M2_{eff}$ based on the assumption that the inverse of the two-phase region mobility varies linearly with radial distance (as opposed to evaluating the two-phase region mobility, MBL, at an average gas saturation between the saturations immediately upstream of the Buckley-Leverett front, and immediately downstream of the drying front).

• Using the concept of radius of investigation to model pressure transients in an infinite-acting system as an equivalent steady-state pressure propagation (instead of assuming a constant pressure at the outer boundary).

When applying the improved analytical model to a problem where the wellbore pressure is unknown a priori (and consequently the pressure at which the gas properties are evaluated is unknown), an iterative procedure needs to be employed to converge upon the correct well pressure. We describe such a procedure and its application to a different set of injection conditions than that used in the benchmarking, and show that the analytical model predictions of pressure and saturation compare well with those from STOMP simulations.