Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

HRE031-18 Room:303 Time:May 24 14:30-14:45

Design of experimental facility for steady state relative permeability measurements in water-supercritical CO2 systems

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Relative permeability curves are important to simulate the movement of multiphase flow in porous media. Carbon dioxide capture and storage technologies (CCS) require the information about relative permeability curves to predict the behavior of CO2 injected into reservoirs which are usually located at about 1000 m under ground. The CO2 in the reservoirs are in supercritical phase due to the reservoir conditions (40oC, 100 atm). Therefore, laboratory experiments were conducted to measure the relative permeability in water-supercritical CO2 systems.

Laboratory measurement techniques for relative permeability determination are of two sorts. The most reliable relative permeability data are obtained by steady state methods in which two or three fluids are injected simultaneously at constant rates or pressure for extended durations to reach equilibrium. The saturations, flow rates, and pressure gradients are measured and used in Darcy's law to obtain the effective permeability for each phase. Conventionally, relative permeability curves vs. saturation are obtained, in a stepwise fashion, by changing the ratio of injection rates and repeating the measurements as equilibrium is attained.

Relative permeability measurement systems usually consist of a core holder, pumps controlling the pressure and the flow rates of flows in the core, and separator. Relative permeability can be calculated from the measurement of the changes of liquid level through the separator. However, the pressure resistance of almost all separators in many researches is too low to be used for the experiments mimicking reservoir conditions. This fails to measure the volume of CO2 precisely because of the change of the CO2 phase. Therefore, a new separator with high pressure resistance was made and used for this measurement.

The rock samples, Berea and Tako sandstone, are 5 cm diameter cylinders with a length of 10 cm and absolute permeability of 10 mD. The samples are saturated with water in which CO2 is dissolved just before the measurements. Then water and supercritical CO2 are co-injected in different proportions (fractional flows) to measure a relative permeability curve: the conditions are 40oC and 100 atm, and the injection flow rate is 0.5 ml/min in total. Steady state flow is achieved by continuous experiments over 3 days for Berea sandstone and a week for Tako sandstone. Although the measurements take a long time, steady state relative permeability in water-supercritical CO2 systems can be measured through our experimental facility.

Keywords: relative permeability measurements, steady state, water-supercritical CO2 systems