The Studies of CO₂ Injected into Porous Media Filled with Water by MRI

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ABSTRACT

The fast spin echo Magnetic Resonance Imaging technique is an appropriate imaging tool for the direct and quantitative evaluation of two-phase flow of supercritical CO₂ and water in porous media at sequestration conditions. Fundamental characteristics of the two-phase flow process such as the CO₂ frontal, the velocity of CO₂ frontal, residual water saturation, onset of fluid flow instabilities (CO₂ fingering and channeling) due to fluid viscosity, buoyancy and porous media conformance problems, can be accurately detected using the MRI technique.

KEY WORDS: Magnetic Resonance Imaging; porous media; residual water saturation; CO₂ fingering.

INTRODUCTION

CO₂ storage in depleted oil and gas reservoirs or aquifer is considered to be one of the most practical options for reducing CO₂ emissions in the atmosphere and has been practiced in different locations worldwide. At depths below 700m, supercritical CO₂ has a density similar to liquids, but it is still lighter than the saline formation fluids. The upward buoyancy force may cause the sequestered CO₂ flow back to the surface. The behavior of immiscible two-phase flow of supercritical CO₂ and water in porous media should be understood and the necessary data should be obtained for assessing the safety and validity of geological sequestration of CO₂. Suekane et al (2004; 2005; 2006; 2009) have done many researches on this area. However, more researches are required to further understand the complexity of the two-phase flow. The aim of this paper is to understand the behavior of immiscible two-phase flow of water and supercritical CO₂ in porous media. This article addresses the application of magnetic resonance imaging (MRI) technique to capture the images of water displacement by supercritical CO₂ in high-permeability sand-pack models at temperatures and pressures that approximate aquifers at a depth about 800m.

EXPERIMENTAL APPARATUS AND MATERIALS

A simplified schematic diagram of the experimental setup is shown in Fig. 1. A high pressure sand-pack cell was inserted vertically into the MRI system. Liquid CO₂ was forced into a transfer vessel in the thermostatic chamber by a CO₂ pump, pure water and supercritical CO₂ was forced into the process line by a syringe pump, respectively. The flow rate and back pressure were controlled by the pump and a back pressure regulator. The pressure drop through the sand-pack was measured using a low differential pressure transmitter. The fluorinert FC-40 was used to control the temperature of the sand-pack. The high pressure test cell was constructed of a polyamide-imide pipe with 15mm inner diameter and 200mm length, which material was selected because it is nonmagnetic and hence should not interfere with the RF signals used in the experiments. Temperatures at the inlet and exit of the sand-pack cell were measured using thermocouples inserted into the coaxial pipes.

In the test, the soda glass beads of Japan with a 0.115mm average diameter were employed to pack the cylindrical sand-pack cell. The sand-pack porosity was 35%, which was calculated from weight measurements method. The water phase is deionized water and gas phase is CO₂ with 99% purity.

Fig. 1 Simplified schematic of the experimental set-up

MRI MEASUREMENT TECHNIQUES

All MRI measurements were performed on a Varian NMR Systems with 9.4T, widebore, vertical superconducting magnet. A home-made 40mm inner diameter RF probe was used and the gradient coils