Seismic Studies in Carbon Sequestration for Enhanced Oil Recovery

Syringe Pump Application Note
AN23

Using Teledyne ISCO Syringe Pumps

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Abstract

Both CO_2-based enhanced oil recovery (EOR) and CO_2 geological sequestration involve injecting CO_2 into deep rocks. Currently, it is unclear what the short and long term effects may be, or what changes may occur in these rocks, as a result of injecting CO_2, especially if the rocks are composed of carbonates. At the University of North Dakota Petroleum Engineering Lab, Teledyne ISCO syringe pumps were used to provide needed pressures to simulate conditions encountered in deep petroleum reservoirs and saline aquifers, and to control flow rates accurately during experimental investigation of CO_2 phase–transition-induced seismic velocity changes.

Overview

Carbon dioxide (CO_2) has been injected into mature petroleum reservoirs for enhanced oil recovery since the early 1970s[1]. Storing CO_2 in geological formations is considered one of the most effective options for carbon management[2]. In both cases, CO_2 is assumed to be in the supercritical state. However, geological complexity might change the CO_2 state from supercritical to subcritical, which could eventually ruin the EOR and sequestration projects[3]. To prevent this from occurring, a tool that can be used to monitor both the space distribution and the phase status of the stored CO_2 is needed. Experiments were designed to investigate seismic imaging as a tool to monitor CO_2 phase transition. This technical note presents how ISCO pumps were used in the research.

Seismic Imaging

Seismic imaging has been considered one of the most promising methods for monitoring injected hydraulic fracturing fluid and CO_2 in petroleum reservoir formations[4]. In order to investigate the possibility of using seismic velocity change as an indicator for CO_2 phase transition, the Petroleum Engineering Lab at the University of North Dakota developed a system that can be used to measure the compressional (P-) and shear (S-) wave velocities while the rock sample is being flooded by CO_2 under controlled pressure and temperature conditions and deep reservoir in-situ stress fields[4]. In this research, an Indiana limestone sample saturated with CO_2 was heated and then cooled across the CO_2 critical temperature while the pore pressure was maintained above the critical pressure and the confining pressure was kept constant. Seismic velocities were measured during the heating and cooling process.

ISCO Pump Application

ISCO pumps played a critical role in this research. One ISCO pump (model 500D) was used for CO_2 injection to accurately control the flow rate; another pump (model 260D) was used to keep constant confining pressure while the rock was being heated and cooled across the critical point of CO_2 [see note]. Figure 1 below shows the arrangement of pumps and other CO_2 handling apparatus in the experiment.

On the last page, Table 1 compares detailed technical specifications of these and other ISCO pumps.

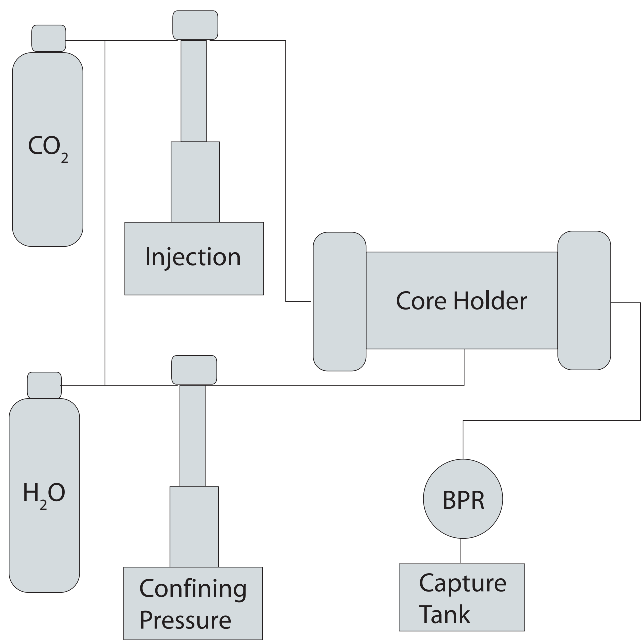
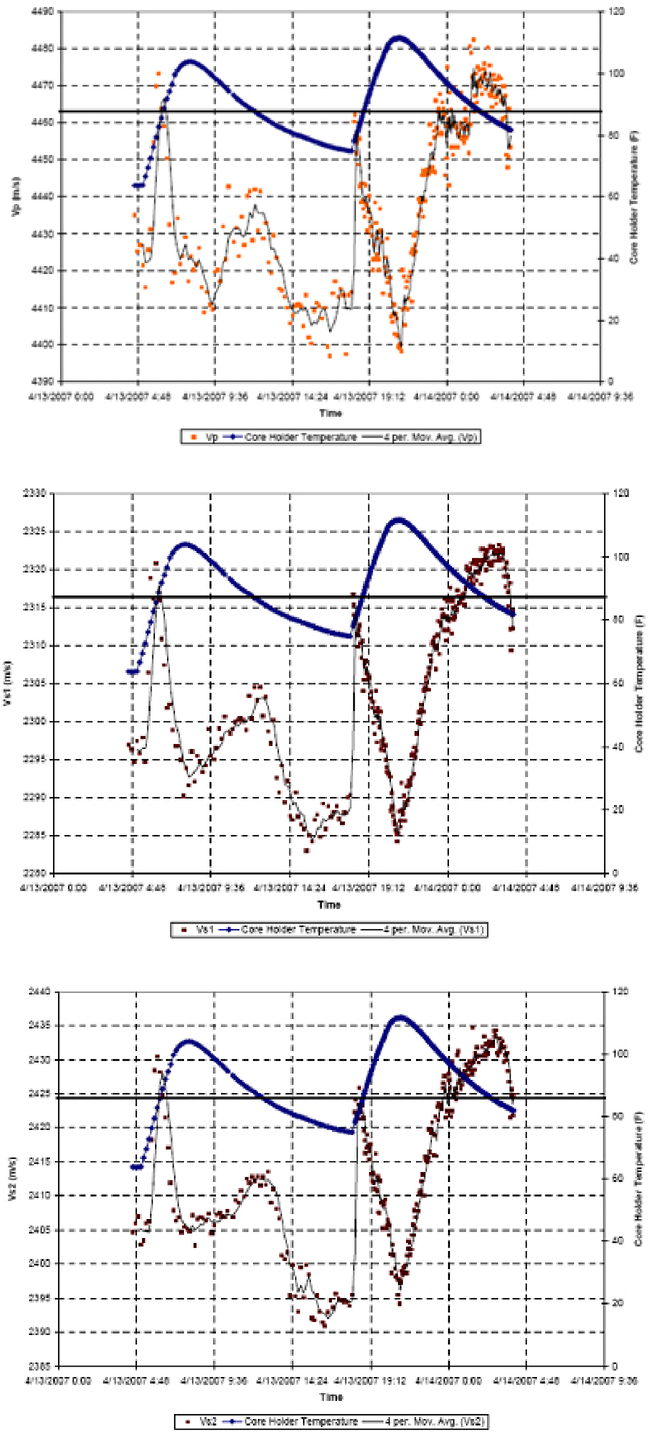


Figure 1: ISCO pump application in CO_2 phase-transition-induced seismic velocity change experiments

Research results

The experiments clearly showed that seismic velocity changes occurred as a result of CO_2 phase transition. Figure 2 shows the observed velocity changes of compressional (P-), vertical shear (SV-), and horizontal shear (SH-) waves during this process.[5]



(a) P-wave

(b) SV-wave

(c) SH-wave

Figure 2: CO_2 phase-transition-induced seismic velocity change in Indiana limestone: (a) compressional (P) wave, (b) vertical shear (SV) wave, and (c) horizontal shear (SH) wave.

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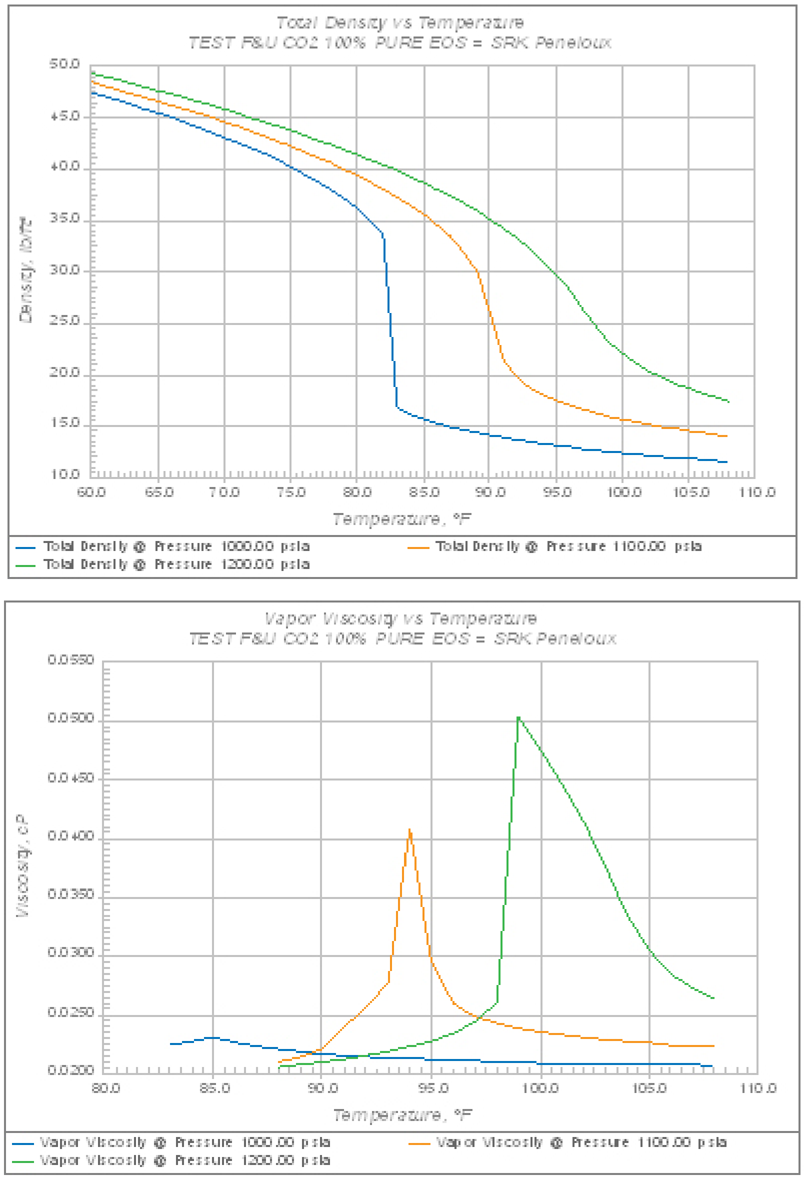
Discussion

Because velocities of dry rock only change linearly and slightly with temperature[4], the observed nonlinear velocity changes in Figure 2 are mainly due to CO_2. CO_2 properties, especially density and viscosity, are very sensitive to temperature change near the critical point, as shown in Figure 3. Therefore, it can be concluded that the seismic velocity changes observed in Figure 2 are induced by CO_2 phase transition.

During the CO_2 EOR/sequestration experiments, the Teledyne ISCO syringe pumps were not only able to handle different types of fluids, but also allowed for accurate measurements and control of flow rate, volume, and pressure.



(a) Total density

(b) Viscosity

Figure 3: CO_2 total density (a) and viscosity (b) with temperature at three pressures (Reprinted with the permission of the American Rock Mechanics Association.[5])

Table 1: Pumps Used in Seismic Study‡

	500D	260D
Flow Range (ml/min)	0.001 - 204	0.001 - 107
Pressure Range (psi)	0 - 3,750	0 - 7,500

‡ These are discontinued; see Table 2 for current alternatives.

Table 2: Current ISCO Pumps

	500x	260x
Flow Range (ml/min)	0.001 - 204	0.001 - 107
Pressure Range (psi)	0 - 5,000	0 - 9,500

References

1) Jarrell, P.M., Fox, C.E., Stein, M.H., and Webb, S.L. 2002. Practical Aspects of CO_2 Flooding. Society of Petroleum Engineers, Richardson, Texas, USA.
2) U.S. Department of Energy. 1999. Carbon Sequestration Research and Development. National technical Information Service, Springfield, Virginia, USA.
3) Grigg, R.B, Zeng, Z. and Bethapudi, L. V. 2004. Comparison of non-Darcy flow of CO_2 and N_2 in a carbonate rock. Paper SPE 89471. In Proc. SPE/DOE 14th Symp on Improved Oil Recovery, Tulsa, Oklahoma, USA, April 17–21.
4) Zeng, Z. 2006. Multipurpose Tri-axial Core Flooding System. Research Report, University of North Dakota, Grand Forks, North Dakota, USA.
5) Zeng, Z., Jakupi, A., Bigelow, T., Grigg, R.B., Kringstad, J., Belobraydic, M., and Zhou, X. 2008. Laboratory Observation of CO_2 Phase Transition Induced Seismic Velocity Change, paper ARMA08-329, Proc. 42nd US Rock Mechanics Symposium and 2nd U.S.-Canada Rock Mechanics Symposium, San Francisco, June 29-July 2.

Note:

The 500D and 260D model pumps, which were used during the original experiment, are discontinued. Current models 500x and 260x, respectively, are the recommended replacements for those older models.

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Product model names have been updated in this document to reflect current pump offerings.

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