EFFECTS OF RESERVOIR TEMPERATURE AND PERCENT LEVELS OF METHANE AND ETHANE ON CO_2/OIL MMP VALUES AS DETERMINED USING VANISHING INTERFACIAL TENSION/CAPILLARY RISE

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Abstract

Geological CO_2 storage combined with enhanced oil recovery (EOR) can be a viable approach to storing CO_2 while increasing oil recoveries. CO_2 mobilizes oil at pressures above the minimum miscibility pressure (MMP) by forming a separate "miscible" CO_2/hydrocarbon mixed phase. MMP is a major input variable for models used to optimize EOR efficiencies, but established methods to determine MMP (e.g., the "slim tube") can be costly, slow, and subject to operational variations. In contrast, newer methods rely on a more fundamental definition of miscibility, i.e., the conditions at which there is no interfacial tension (IFT) between the two fluids. EERC's method determines MMP by observing the height of oil in a capillary at increasing pressures, and extrapolating the height vs. pressure plot to zero height (i.e., zero IFT). This innovation greatly decreases the time and cost for determining MMP, thus allowing the effects of various reservoir conditions on MMP to be investigated such as temperature, changing gas composition (e.g., the effect of methane in recycle CO_2), and changes in crude oil composition. For example, methane mixed with CO_2 increases MMP (which has implications for CO_2 recycle during EOR). In contrast, the presence of ethane in CO_2 lowers the MMP indicating that both EOR and CO_2 storage may be possible in reservoirs that were previously considered too shallow (i.e., limited injection pressures). Additional MMP determinations using different concentrations of methane and ethane in CO_2 are being performed using crude oil from a conventional reservoir, and the results of these experiments will be reported.

Why Determine MMP (Minimum Miscibility Pressure)?

- MMP is the pressure at which an injected fluid (e.g., CO_2) and crude oil form a "miscible" phase with enhanced mobility.
- MMP is a fundamental parameter required for optimizing EOR projects.

Background

- Currently, most CO_2 storage is likely to occur in conjunction with enhanced oil recovery (EOR) projects.
- CO_2 reduction may also be achieved by injecting rather than flaring natural gas associated with unconventional reservoirs (e.g., the Bakken).
- Even when natural gas collection/distribution facilities are available, ethane often has little or no commercial value in locations having no nearby petrochemical plants.

Purpose of These Investigations

- To develop and utilize a simple, rapid, and reliable method for determining minimum miscibility pressure (MMP).
- To determine the effects of CO_2 and light hydrocarbon mixes on MMP in support of EOR project development/implementation.

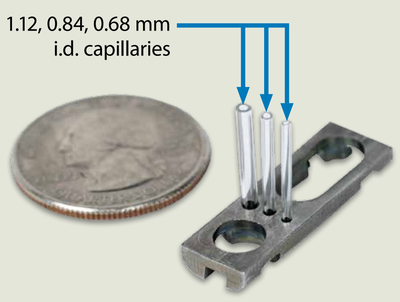
Executive Summary Based On MMP Determinations

1. Pure methane is bad-doubles MMP compared to CO_2.
2. Pure ethane is good-cuts MMP in half compared to CO_2
3. Methane mixed in CO_2 raises MMP.
4. Ethane mixed in CO_2 reduces MMP.

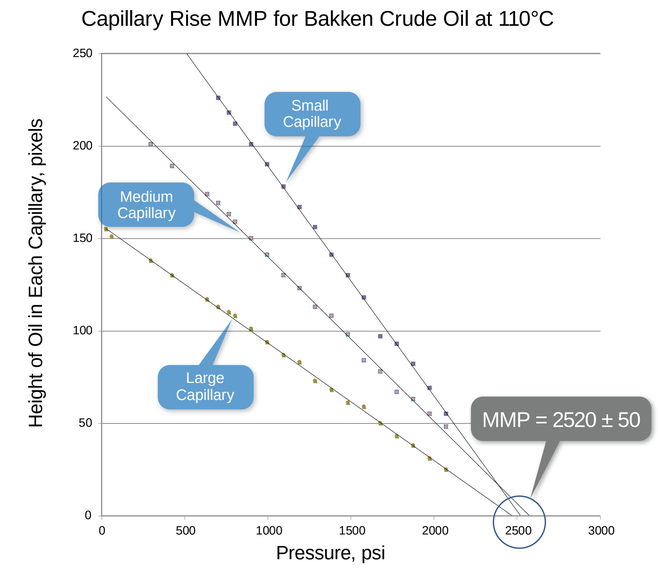
How is MMP determined in the lab?

- The standard "slim tube" method is too slow and expensive to use for fundamental investigations, so.....
- EERC has simplified a vanishing interfacial technique (VIT) initially developed by Rao et al. (EERC, patent pending).
- The method defines MMP as the pressure at which the interfacial tension between the CO_2 and the bulk oil phase goes to zero, as evidenced by no oil rise in capillary tubes.
- Multiple MMP determinations can be performed in a day.
- The method has been validated by comparison to the slim tube MMP for a "live" Bakken crude oil.

A high pressure view cell is used to observe the oil height in three capillary tubes as the CO_2 pressure is increased at reservoir temperature.

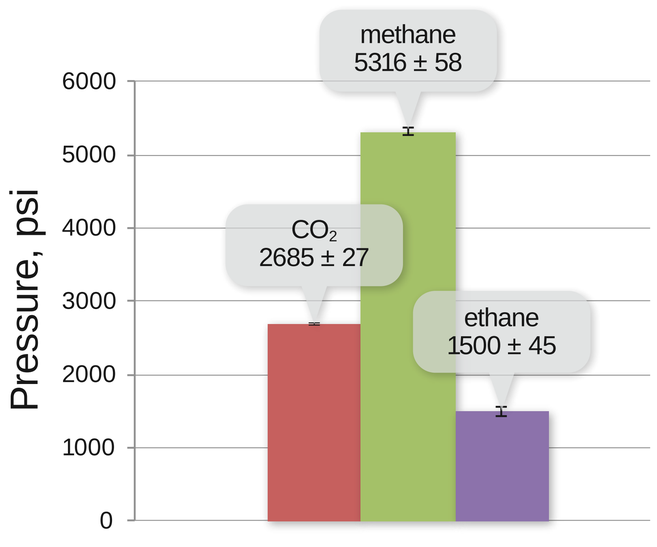


MMP is determined by measuring the height of the oil in capillary tubes at increasing CO_2 pressures, plotting as capillary height vs. pressure, and extrapolating to zero capillary height (i.e., the pressure where there is no interfacial tension) .

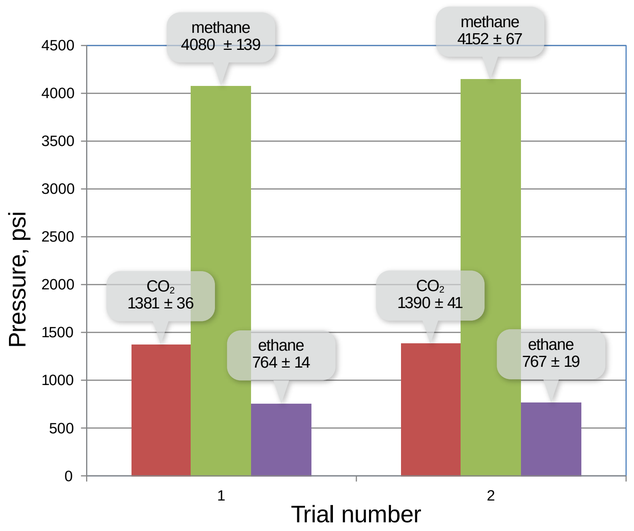


How do MMP values compare for crude oils from a conventional oil reservoir (Bell Creek) and an unconventional reservoir (Bakken) for CO_2, methane, and ethane?

MMP values for Bakken Crude Oil (110 °C) with CO_2, Methane, and Ethane

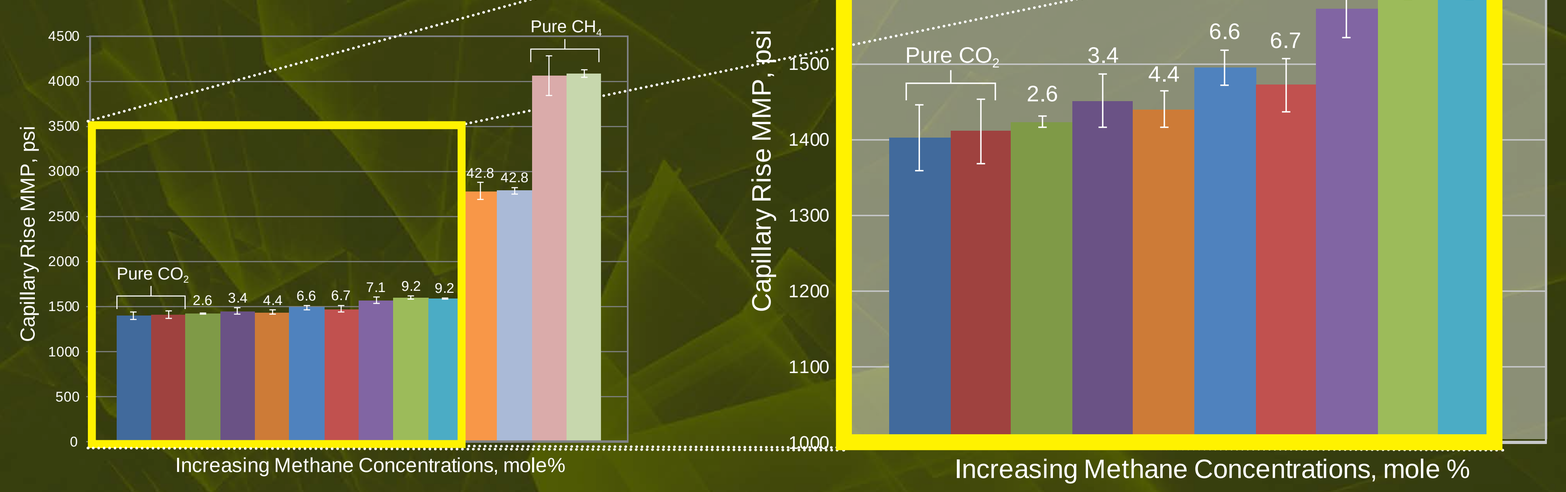


Conventional Oil MMP values with CO_2, methane, and ethane (42 °C)



If methane raises MMP, does methane added to CO_2 also raise MMP?

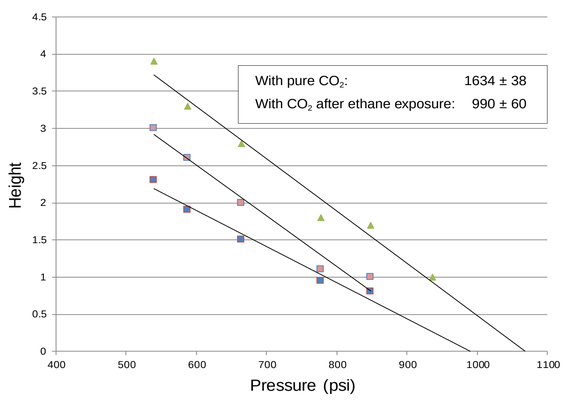
(E.g., how does methane in Bell Creek recycle CO_2 affect MMP?)



If ethane lowers MMP, does ethane added to CO_2 lower MMP?

(Oil exposed to 540 psi ethane headspace prior to CO_2 MMP determination)

Conventional Oil MMP (42 °C)



Results and Conclusions Based on MMP Testing

- Ethane can achieve MMP at lower pressures than CO_2, and CO_2 can achieve MMP at lower pressures than methane.
- Methane content in CO_2 more than ca. 6 mole % can significantly increase MMP, but adding ethane to CO_2 lowers MMP (experiments in progress).
- Lower MMP values with mixed ethane/CO_2 mean shallower reservoirs could be subjected to EOR and CO_2 storage than with pure CO_2.

Current and Future Efforts

Do small to moderate amounts of methane in ethane reduce its effectiveness?

How effective is mixing ethane with CO_2 to lower MMP values?

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