Near Miscible CO₂ Application to Improve Oil Recovery for Small Producers
RPSEA Small Producer Program

**Objective**
- Determine the feasibility of using CO₂ displacement at near miscible conditions to improve oil recovery with injection pressure below minimum miscibility pressure
- Develop appropriate plan for field test if the project shows that significant oil can be recovered by the CO₂ process operating at near miscible conditions

**Why Near Miscible?**
- Many reservoirs are not considered for CO₂ miscible flooding because the maximum reservoir pressure that can be attained is less than the minimum miscibility pressure (MMP).
- Near miscible displacement refers to a process occurring at pressure slightly below MMP and is between immiscible and miscible.
- Within the pressure range near miscible, significant oil recovery was observed in slim-tube experiments and to a lesser extent in the core tests.
- Mechanisms in the displacement include extraction, oil swelling, oil viscosity reduction and favorable relative permeability as a result of reduction of interfacial tension between CO₂ and oil.

**Project Location**

**General Information**
- Oil Field: Ogallah Unit, Trego County, Kansas
- Operator: Carmen Schmitt, Inc.
- Formation: Arbuckle
- Formation depth: 3950-4060 ft
- Reservoir temperature: ~110 – 125 °F
- Reservoir pressure: ~1150 psia
- MMP: 1350-1650 psig (110-125 °F)

**Laboratory Tests**
- Oil characterization
- Density, viscosity measurement
- Swelling/Extraction test
- Slim tube test
- Core flood experiment

**Simulation**
- Phase behavior model
- Geological model
- Compositional reservoir model

**Viscosity of swollen oil**

- Oil was characterized by GC simulated distillation method
- MW: 228.71 gm/gmole
- Density: 0.8584 g/cc
- API gravity: 33.34
- Viscosity: 13.37 cp

- In-house built vapor liquid equilibrium (VLE) view cell is used to conduct swelling and extraction tests
- The swelling factor of oil is determined by the change of interface level as a result of dissolution of CO₂ in the oil

- Swelling test results at 110 °F indicates that the oil swells as CO₂ dissolves in the oil as the pressure is increased.
- The oil swells as much as 24% of its initial volume in which 72 mole% of CO₂ is dissolved in the oil.

- The oil viscosity and swollen oil viscosity were measured with a high pressure viscometer which uses electromagnetic technology to determine fluid’s viscosity.

- The CO₂ saturated oil viscosity is reduced to as much as a factor of five at pressures above 1,000 psig.

- Slim-tube experiments are conducted to determine minimum miscibility pressure (MMP).

- When the oil recovery at 1.2 PV CO₂ injection is plotted against the pressure, the minimum pressure required to reach 0.9 HCPV recovery is defined as the MMP.
- MMP is 1350 psig at 110 °F and 1650 psig at 125 °F.

- At pressures below MMP, the density profile of effluent from slim-tube tests shows an abrupt change after CO₂ breakthrough.
- Density of the mixture is much less than oil density but higher than the pure CO₂ density at each corresponding pressure, indicating that vaporization takes place where light components of oil are extracted into the CO₂ phase at near miscible pressure conditions.