Maximize Liquid Oil Production from Shale Oil and Gas Condensate Reservoirs by Cyclic Gas Injection

Project Number: DE-FE0024311

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U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology, Innovation and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 16-18, 2016

Presentation Outline

- Benefits to the program
- Project overview
- Technical Status
- Accomplishments to date
- Synergy opportunities
- Project summary

Benefit to the Program

Program goals

- Minimize environmental impacts of UOG development
- Maximizing its economic and national energy security benefits.

This project goals

- Develop cyclic gas injection technology to maximize liquid oil production from shale oil and condensate reservoirs.

Impacts

- Reduce flared gas, sequester CO2, save water, and drill less wells, while increasing oil production.

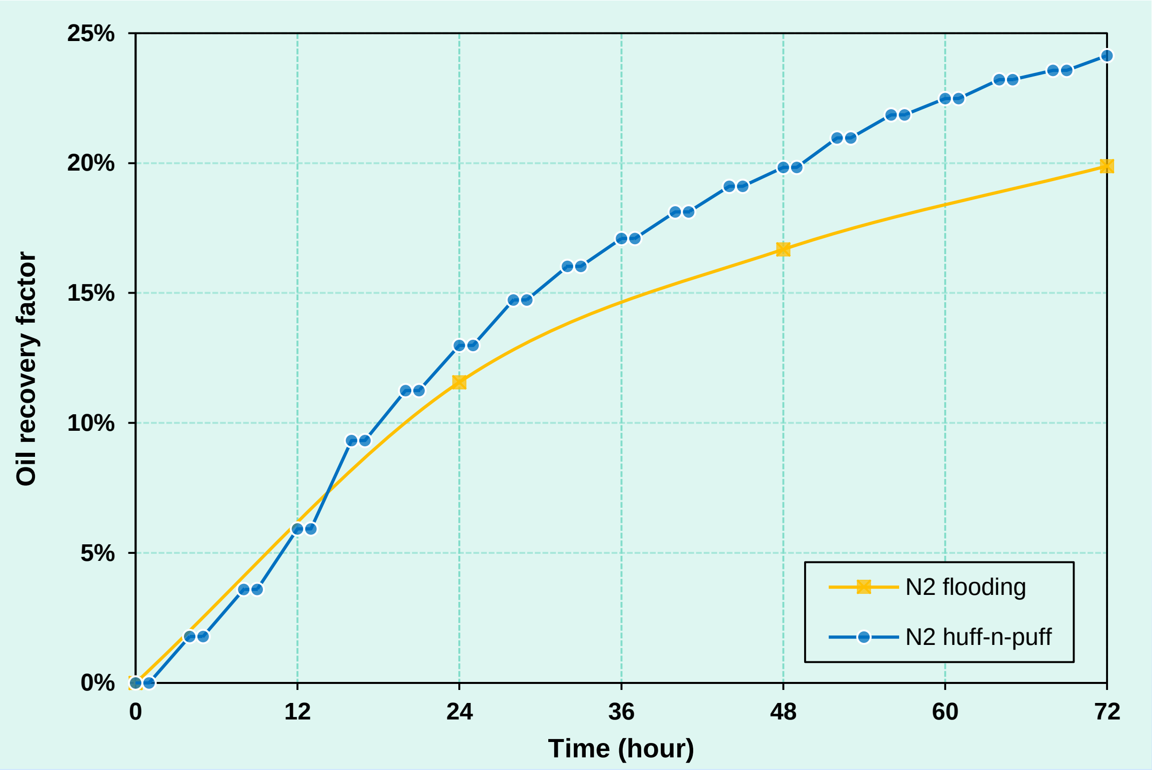
Project Overview: Goals and Objectives

- Overall goal: evaluate gas injection EOR potential
  - confirmed in lab and reservoir-scale modeling
- Environmental impacts
  - Sequester CO_2
  - Reduce gas flaring, water usage
- Technical goals/status
  - Much more achieved than proposed
  - Details to follow next

Technical Status

- Experimental setup
  - Cyclic gas injection for shale oil and condensate experiments worked
  - Microfludic setup worked
- Fundamental studies
  - Many experimental and modeling studies (details to follow)
- Field pilot tests
  - Completed pilot location selection, facility design and modeling work for a Wolfcamp reservoir
  - Modeling work performed for an Eagle Ford condensate reservoir
  - Current status: tests suspended.
- More new studies initiated
  - Asphaltene, air injection, water huff-n-puff, chemical or solvents

Gas huff-n-puff vs. gas flooding



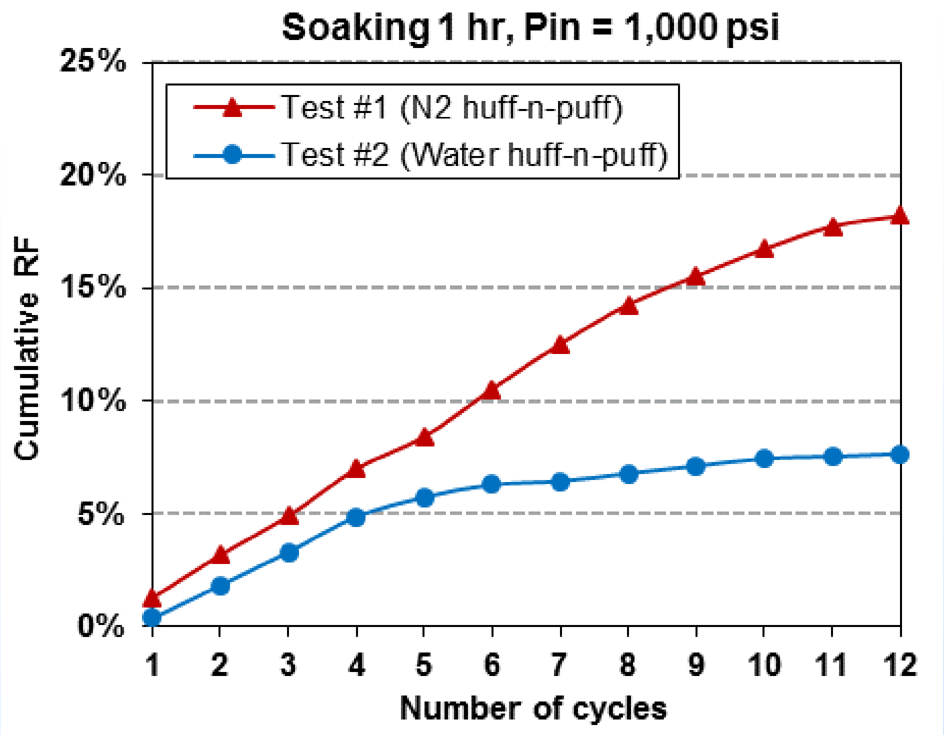
Conditions:

- Soaking time 1 hr
- Production time 3 hrs
- Soaking pressure 1000 psi

Observations:

- In the beginning, same oil recovery.
- Later, Huff-n-puff had higher oil recovery than flooding.

Gas huff-n-puff vs. water huff-n-puff



Conditions:

- Soaking time 1 hr
- Production time 3 hrs
- Soaking pressure 1000 psi

Observations:

- N2 huff-n-puff had higher oil recovery than water.

Effect of Water Saturation on Cyclic N_2 and CO_2 Injection

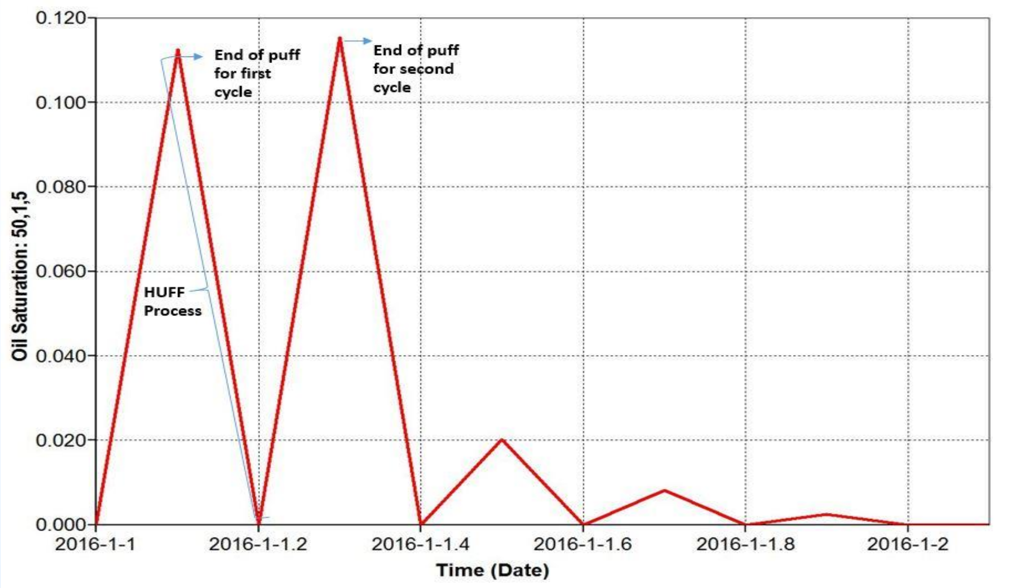
Water and oil could not be split, define liquid recovery:

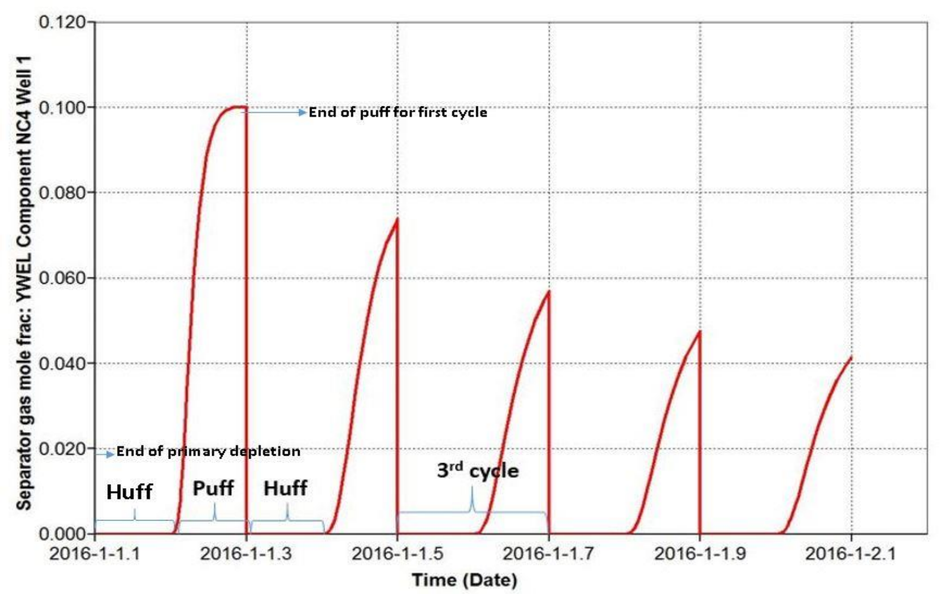
$$R.F.,\% = \frac{Produced\ liquid}{Original\ liquid} \times 100$$

Results:

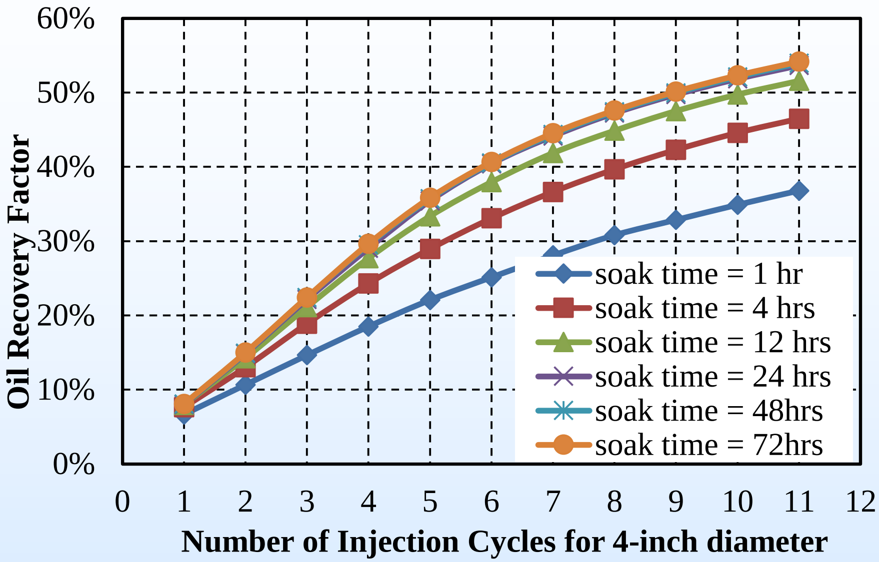
- Liquid RF < oil RF – water saturation negative effect!
- Confirmed CO2 RF > N2 RF
- More flow back desirable?

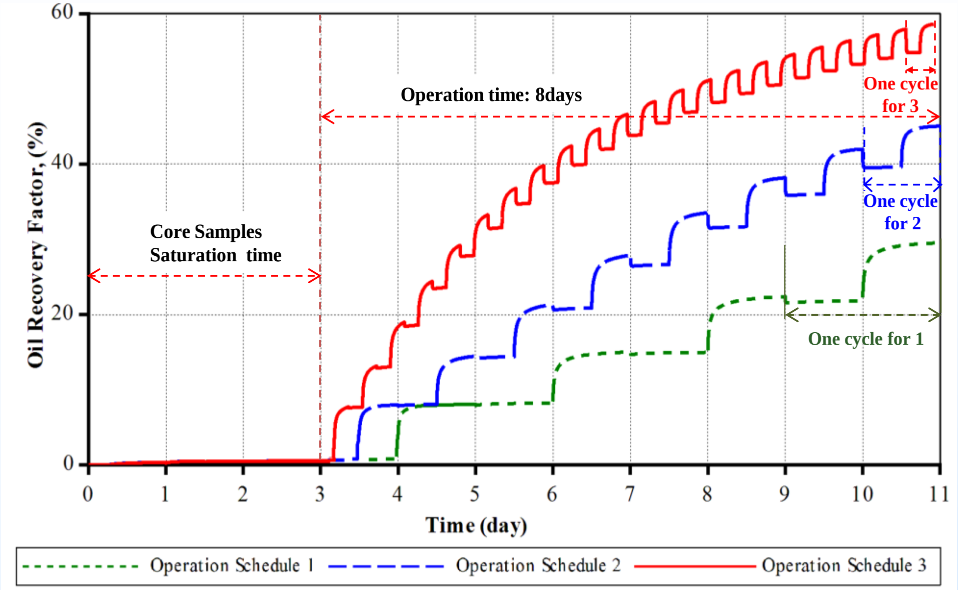
Re-vaporization mechanism of huff-n-puff gas injection in a condensate system





Effect of soaking time on gas huff-n-puff

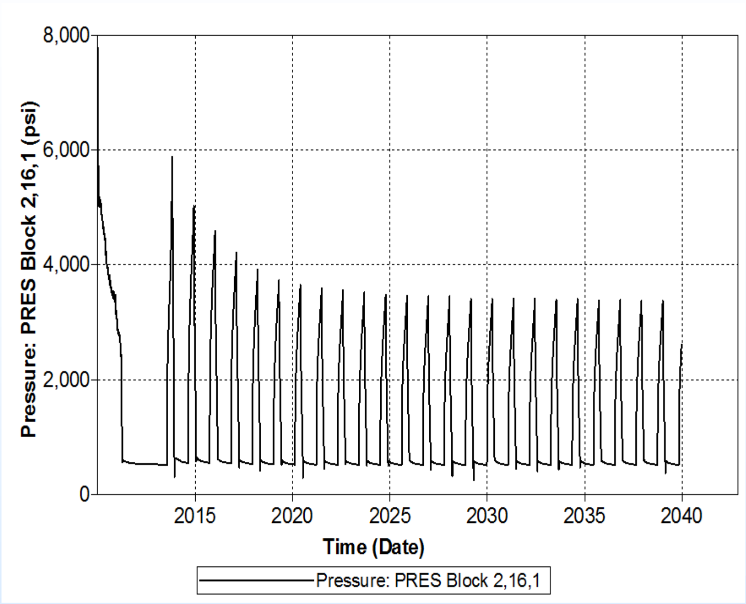




With a cycle,
Longer soaking time
Higher oil recovery

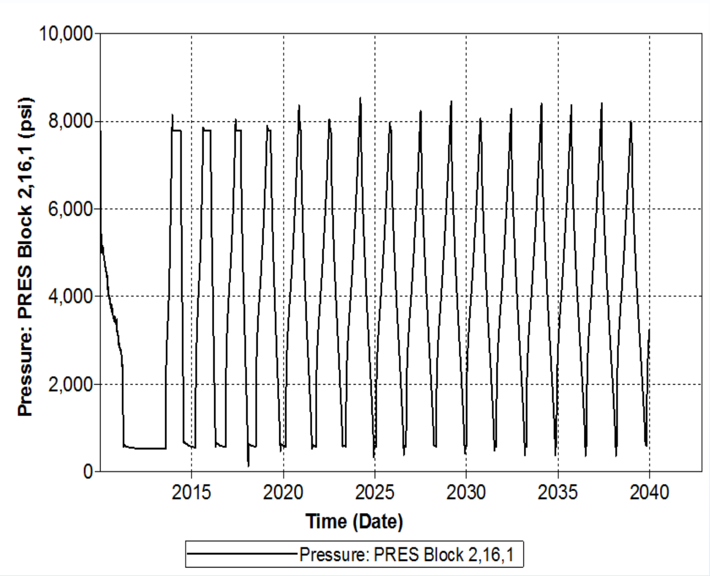
With the same operation time,
Longer soaking time
Lower oil recovery

Optimization of huff-n-puff gas injection



100 days of huff time & puff time

Oil RF: 15%



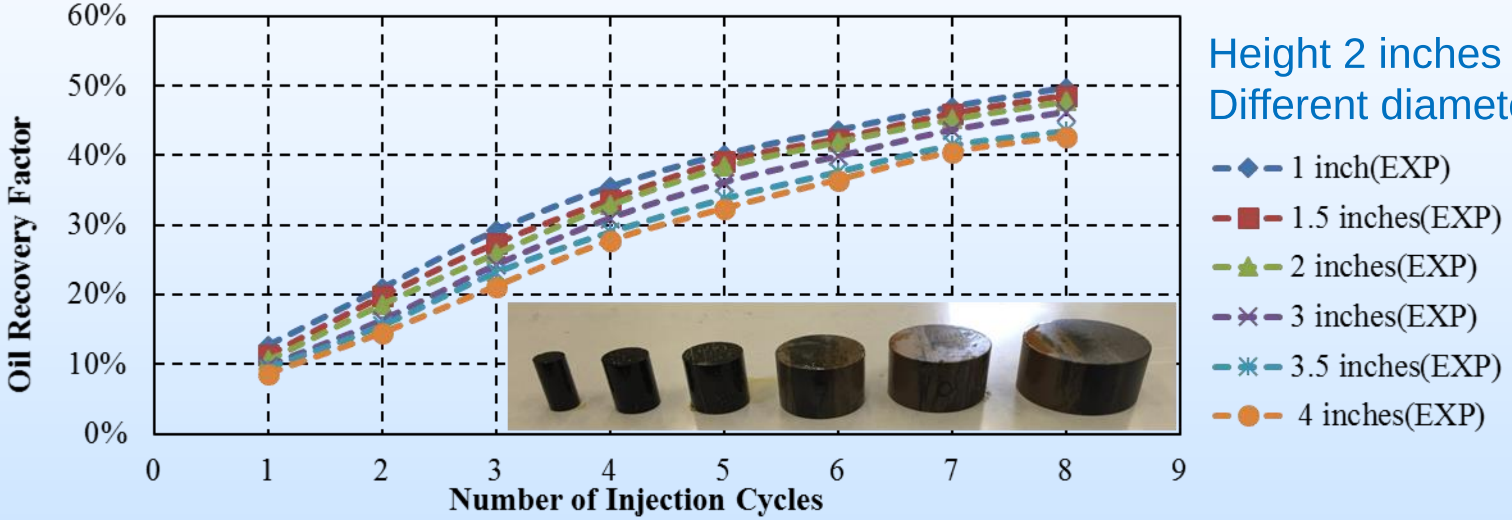
300 days of huff time & puff time

OIL RF 21%

Conclusions:

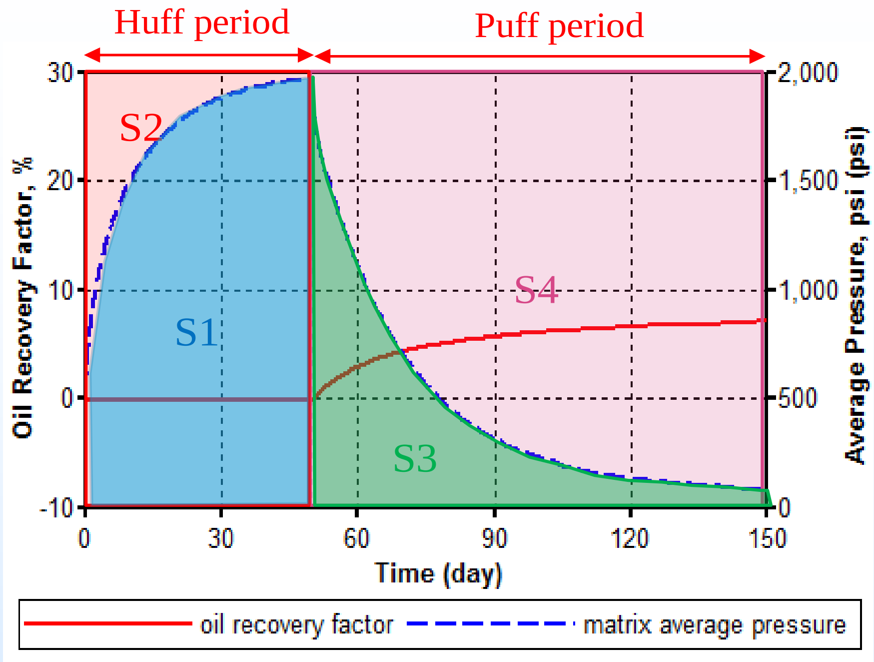
- Huff time: Injection reaches max. allowed
- Puff time: Production pressure reaches min. allowed

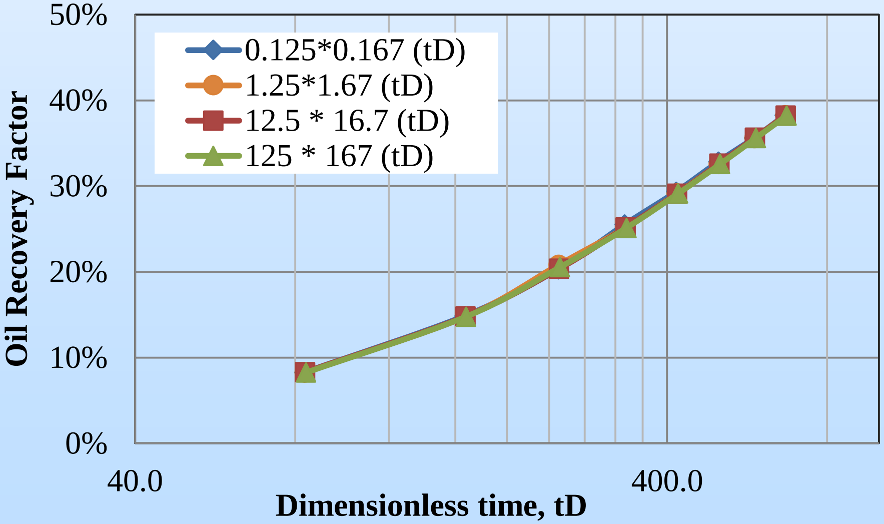
Core size effect on gas huff-n-puff



Height 2 inches
Different diameters

Upscale methodology for gas huff-n-puff process in shale oil reservoirs





Dimensionless time:

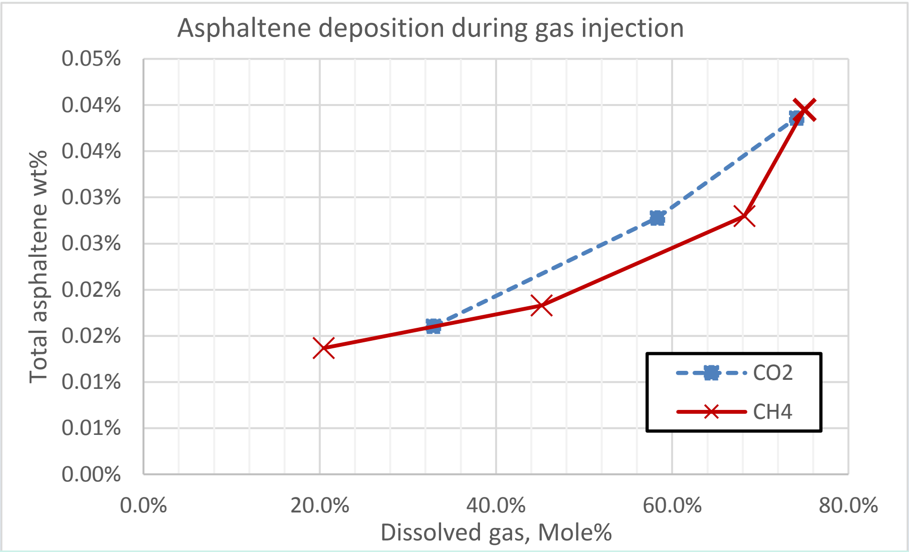
$$t_D = \frac{Ckt}{\emptyset \mu c_t (L^2)({P_D}^2)}$$

Dimensionless pressure:

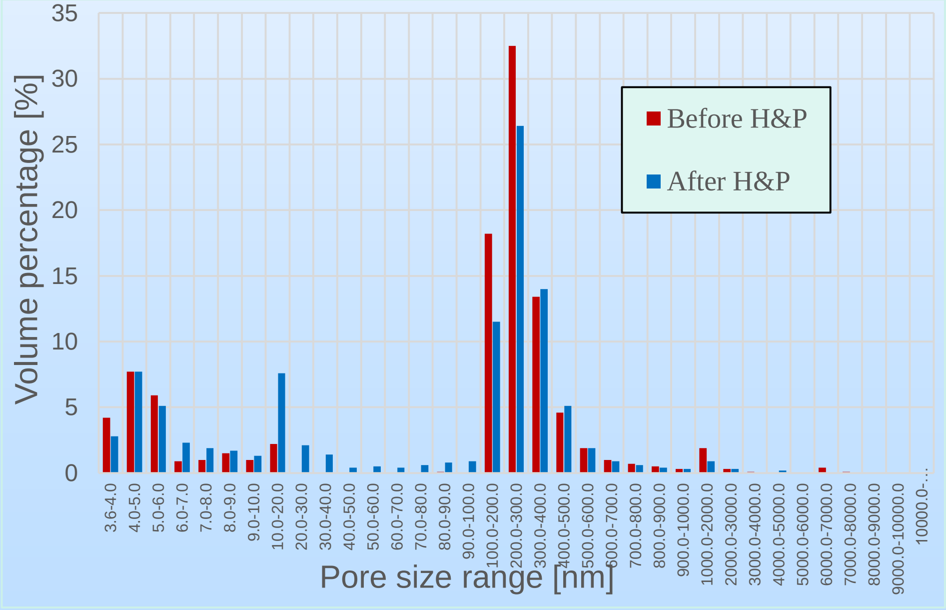
$$P_{\mathrm{D}} = P_{\mathrm{huff}} - P_{\mathrm{puff}}$$

$$= \frac{\int_0^{t_{\mathrm{huff}}} P_{\mathrm{avg}} dt}{S_{\mathrm{huff}}} - \frac{\int_0^{t_{\mathrm{puff}}} P_{\mathrm{avg}} dt}{S_{\mathrm{puff}}}$$

Asphaltene aggregation and deposition during CO2 and CH4 injection in shale



As more gas dissolved,
more asphletne aggregation



After 6 cycles of huff-n-puff,
Large pores (100-500 nm) decreased,
Smaller pores (< 100 nm) increased.
Indicating pores blocked by deposition.

Permeability reduced from 127 to 78.5 nD

Air injection

Conducted laboratory screening tests and simulation study

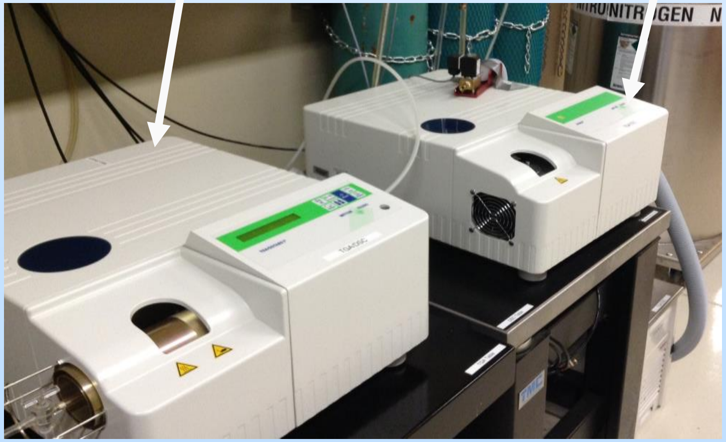
- TG and DSC tests
- Small batch reactor

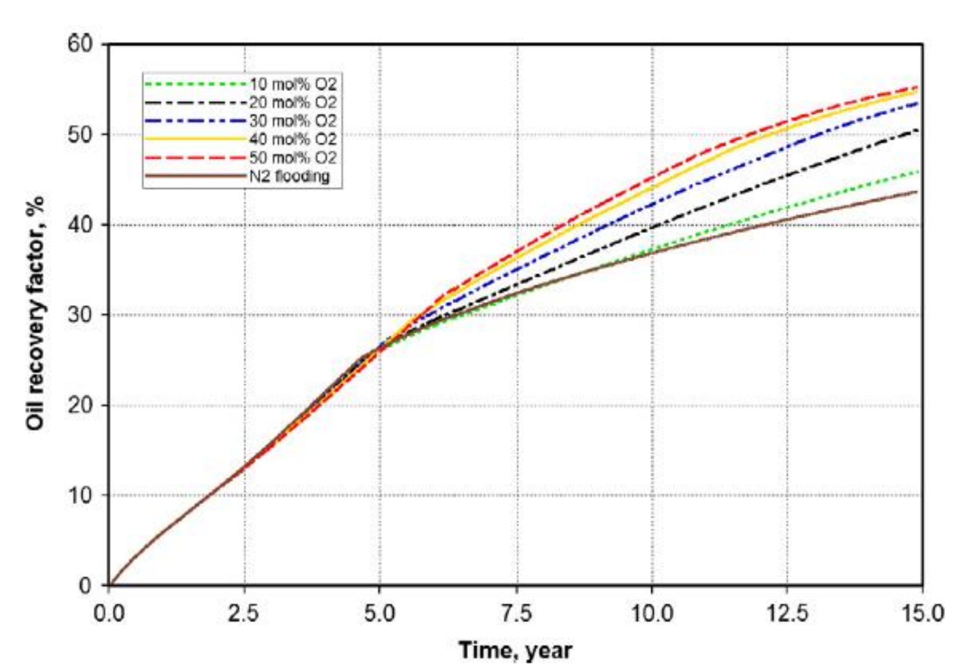
Work done:

- Estimated kinetic parameters:
  - Reaction order and activation energy etc. for Wolfcamp oil
- Studied low-temperature oxidati

Thermogravimetry (TG)

Differential Scanning Calorimetry (DSC)





Accomplishments to Date

- Publications:
  - 2 patent disclosures filed
  - 14 peer-reviewed journal papers published
  - 17 papers submitted for review
  - 21 conference papers presented

- Graduated students:
  - 3 PhDs
  - 2 Masters

Synergy Opportunities

- We focus more on macroscale (reservoir)
- LBNL focus more microscale (molecular, nano-scale simulation)
- Wish for future collaboration
  - Joint proposals
  - Summer interns for students (co-supervise students)
  - Collaboration with the industry
- We are looking for:
  - micro- or nano- CT
  - Instruments to measure diffusion
  - Combustion facilities for air injection

Summary

– Key Findings
  - Confirmed gas injection EOR potential
  - Gas injection better than water injection
  - Huff-n-puff injection mode better than gas flooding
  - CO2 has higher recovery than other gases

– Lessons Learned
  - A field test will take a long time to execute

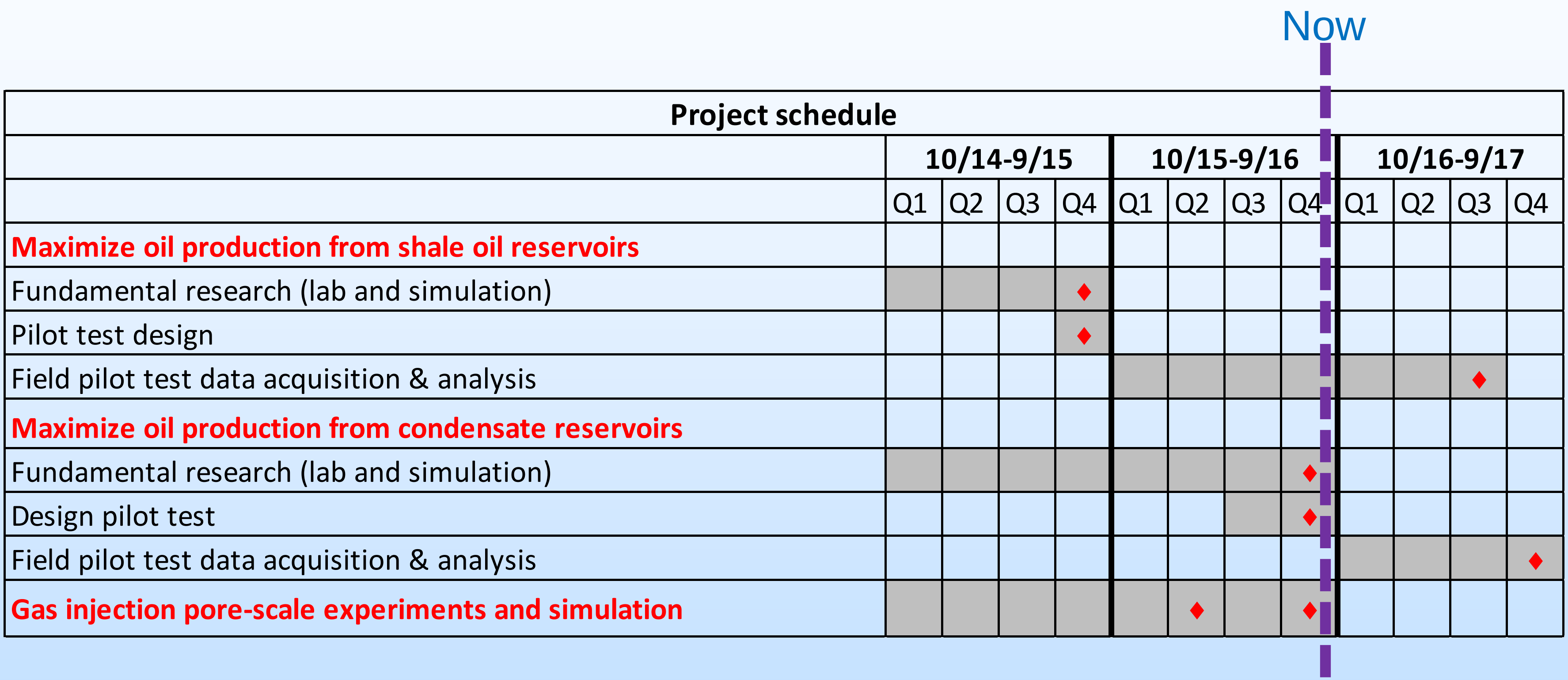
– Future Plans
  - More studies to compare with other methods
  - Fundamental studies of mechanisms
  - Field data collection and analysis

Appendix

Organization Chart

- Texas Tech University (contractor)
  - Responsible for fundamental studies, field test design and data analysis
  - PI: James Sheng, Co-PI: Marshall Watson, Students, Postdocs
- Apache Corporation (partner)
  - Field tests, cost share
- Los Alamos National Lab (subcontractor)
  - Microscale experiments and modeling
  - Hari Viswanathan and Mark Porter

Gantt Chart



Now
Project schedule
10/14-9/15
10/15-9/16
10/16-9/17
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Maximize oil production from shale oil reservoirs
Fundamental research (lab and simulation)
Pilot test design
Field pilot test data acquisition & analysis
Maximize oil production from condensate reservoirs
Fundamental research (lab and simulation)
Design pilot test
Field pilot test data acquisition & analysis
Gas injection pore-scale experiments and simulation

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