Research Summary

P&T Effects on Filtration Efficiency of Nanoporous Media

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Motivation

- Porous medium acts like a semi-permeable membrane
- Current models of production from nanoporous, unconventional reservoirs do not consider hindered transport
- Explore the potential of thermal methods to enhance recovery from nanoporous formations

Problem Statement

- The passage of larger particles in a fluid mixture is hindered by tight pore throats
- Filtration efficiency of a nanoporous medium is a function of pressure and temperature
- Drastically different approach from the conventional definition of filtration

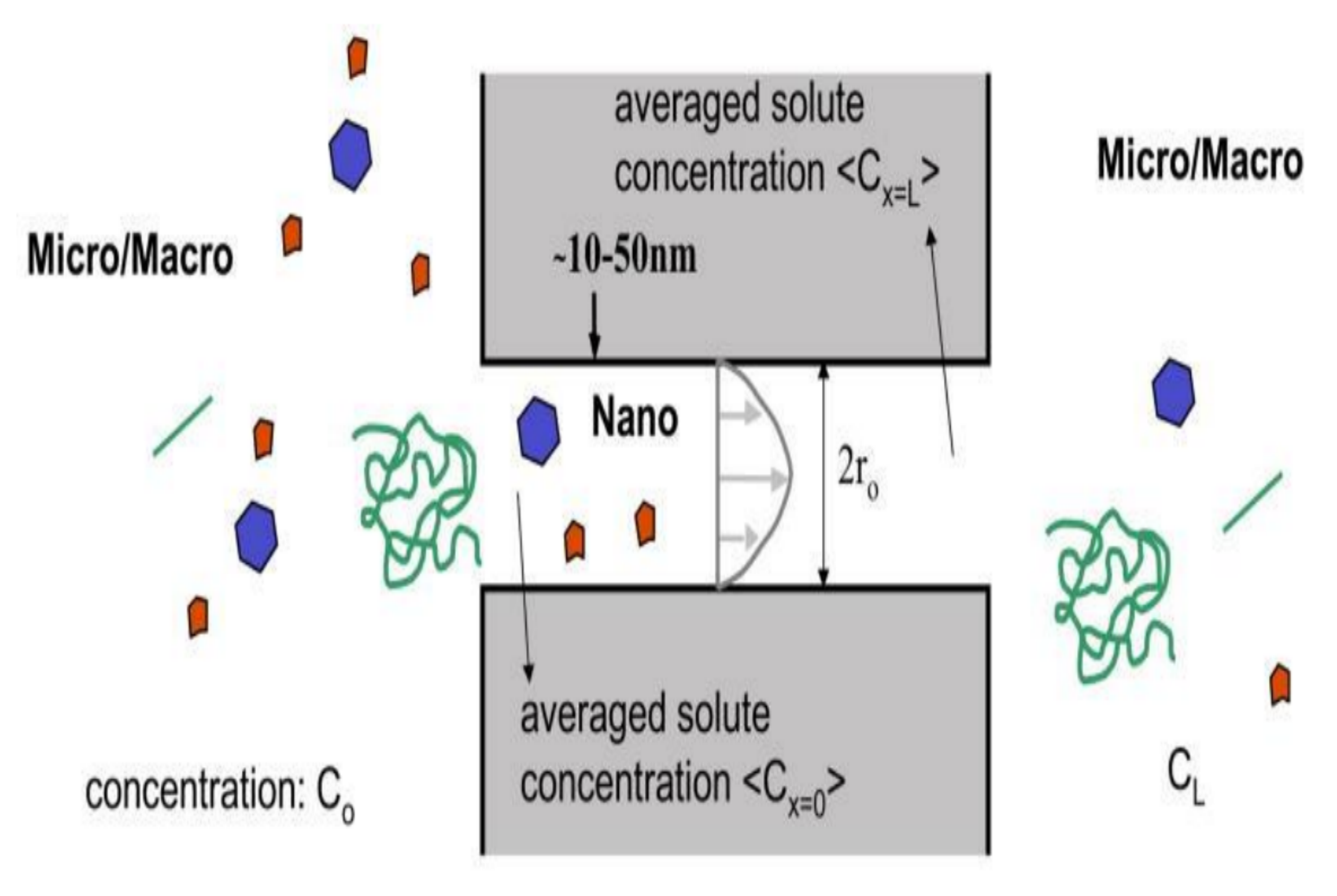
Objectives

Present:

- A filtration model based on the filtration efficiency concept
- The impact of temperature and pressure on filtration efficiency
- The possibility of thermal techniques to decrease filtration efficiency and increase recovery

Hindered Transport

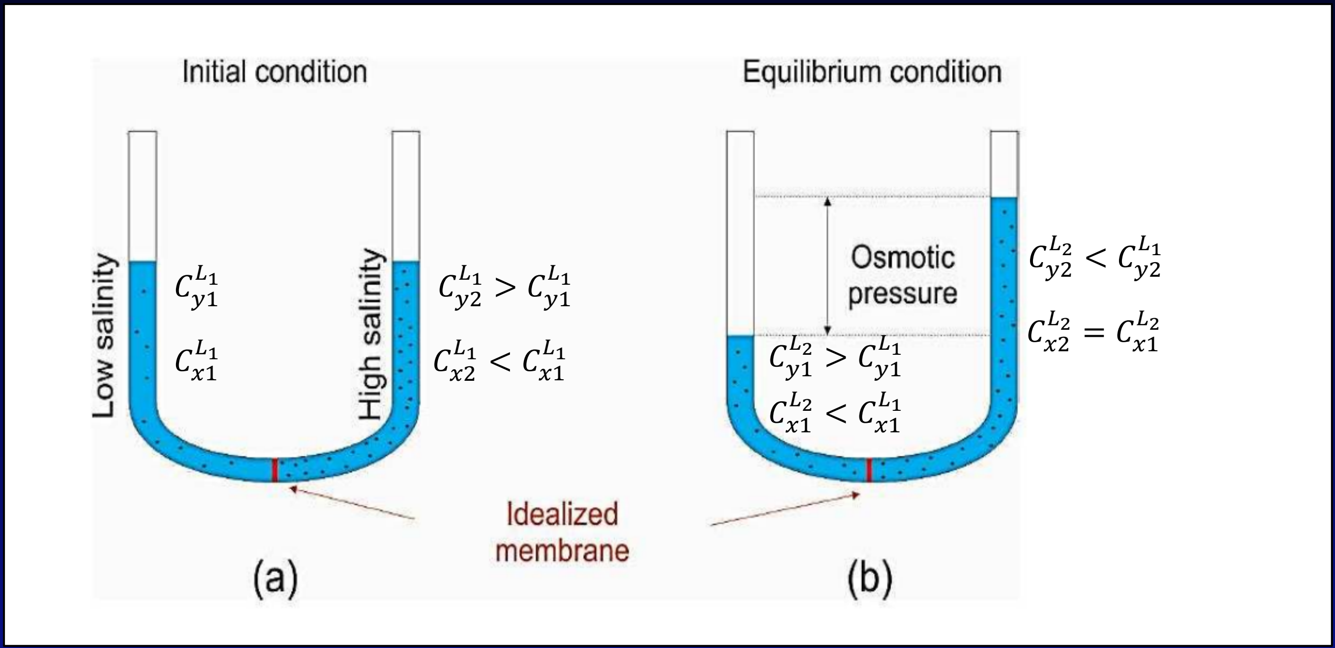
Selective passage of components



[Han 2008]

Hindered Transport

Osmosis

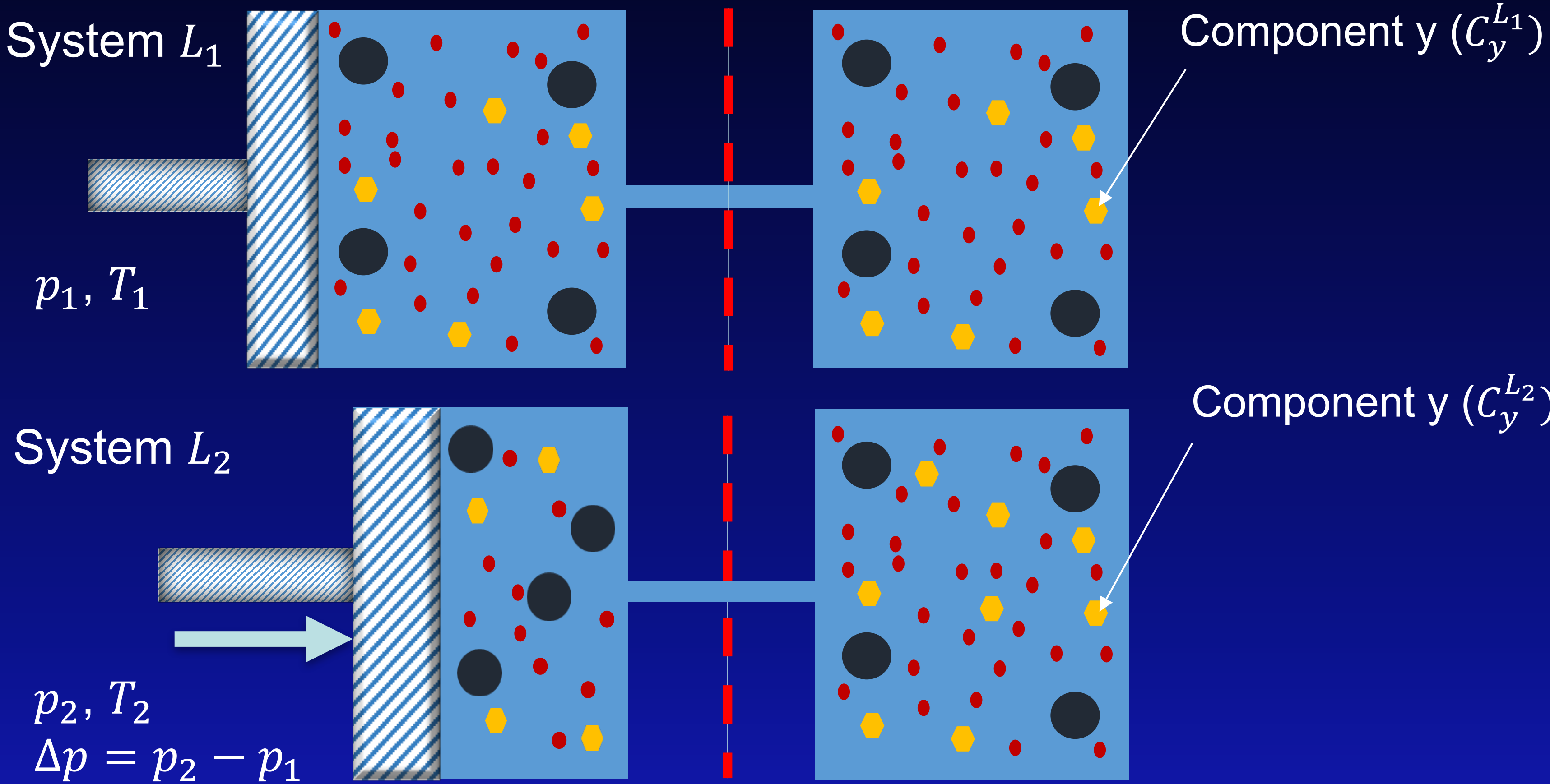


Partition Coefficient $\Phi = \Delta C_y / C_{y2}^{L_1}$ $\Delta C_y = C_{y2}^{L_1}$-$C_{y2}^{L_2}$

Osmotic Efficiency (reflection coefficient) $\sigma_o = (1 - \Phi)^2$

Hindered Transport

Partition Coefficient, $\Phi = \Delta C_y / C_y^{L_1}$ $\Delta C_y = C_y^{L_2} - C_y^{L_1}$



Φ depends on p & T

Hindered Transport

Volume and Solute Fluxes across a Semipermeable Membrane

Volume Flux: $J_v = L_p(\Delta p_\infty - \sigma_o \Delta\Pi_\infty)$

Solute Flux : $J_s = \omega\Delta\Pi_\infty + \left(1 - \sigma_f\right) C_\infty J_v$

Δp_∞ : hydraulic pressure gradient (unhindered)

$\Delta\Pi_\infty$: osmotic pressure gradient ($\Delta\Pi_\infty = RT\Delta C_\infty$, unhindered)

L_p : hydraulic permeability [$L_p = \gamma r_o^2/(8\mu L)$]

ω : permeation coefficient [$\omega = (J_s/\Delta\Pi_\infty)_{J_v=0}$]

σ_o : osmotic reflection (rejection) coefficient [$\sigma_o = (\Delta p_\infty/\Delta\Pi_\infty)_{J_v=0}$]

σ_f : filtration reflection coefficient {$\sigma_f = 1 - [J_s/(C_\infty J_v)]_{\Delta C_\infty=0}$}

$\sigma_o \approx \sigma_f$ Staverman (1951), Anderson (1981), Levitt (1975)

$\sigma_o = (1 - \Phi)^2$

Hindered Transport

Filtration Efficiency

$$\omega_f = (1 - \Phi)^2$$

$\omega_f = 1$ Ideal membrane

$\omega_f = 0$ Non – selective

$0 < \omega_f < 1$ Non – ideal membrane

For solid filtrates of fixed size and geometry

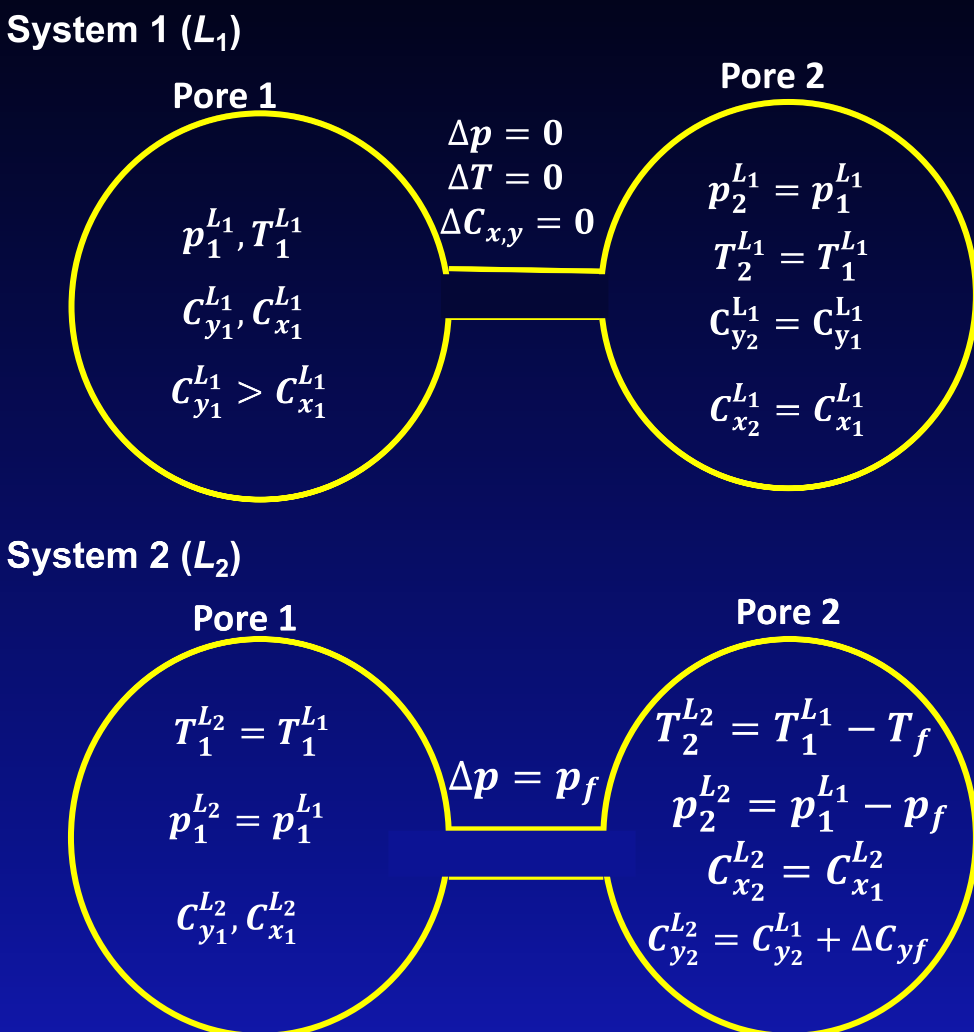
$\Phi = (1 - \lambda)^2$ → *independent of p & T*

$\lambda = r_s / r_o$: r_s: filtrate particle radius r_o: pore channel radius

For molecular sieving due to steric effects

$\Phi = \Delta C_y / C_y^{L_1}$ → *function of p & T*

Methodology



- Perform flash calculations
- Filtration parameters

  $$p_f \equiv \Delta\Pi = p_1^{L_2} - p_2^{L_2} = \Delta p$$

  $$T_f = T_1^{L_2} - T_2^{L_2} = \Delta T$$

- Compute fugacities

  $$f_{C_x}^{L_1} = f_{C_x}^{L_2} \qquad f_{C_{y_2}}^{L_2} \neq f_{C_{y_1}}^{L_2}$$

- Compute filtration efficiency

Results

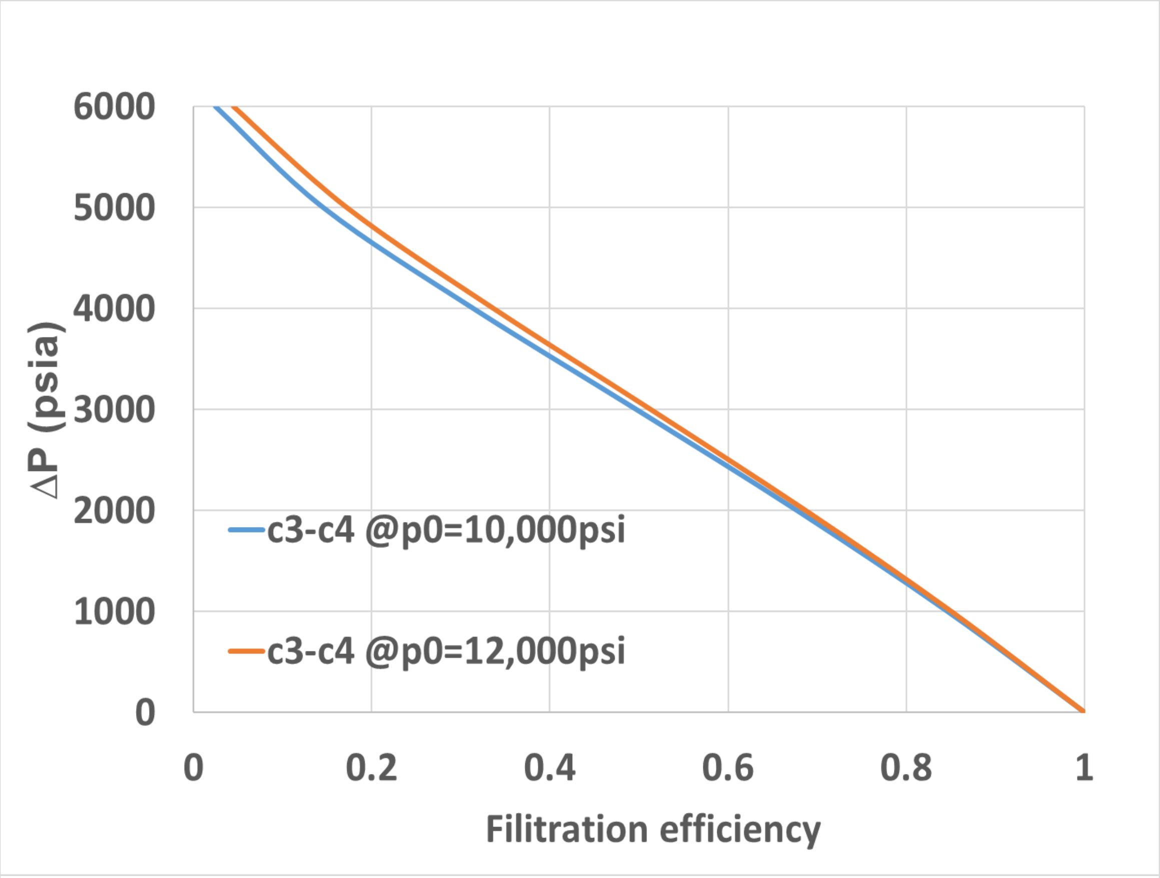
Case 1:

- 2 Components
- Mole fraction:

  30% 70%
- Constant temperature:

  200 °F
- Pressure change:

  0 psi-4000 psi



Results

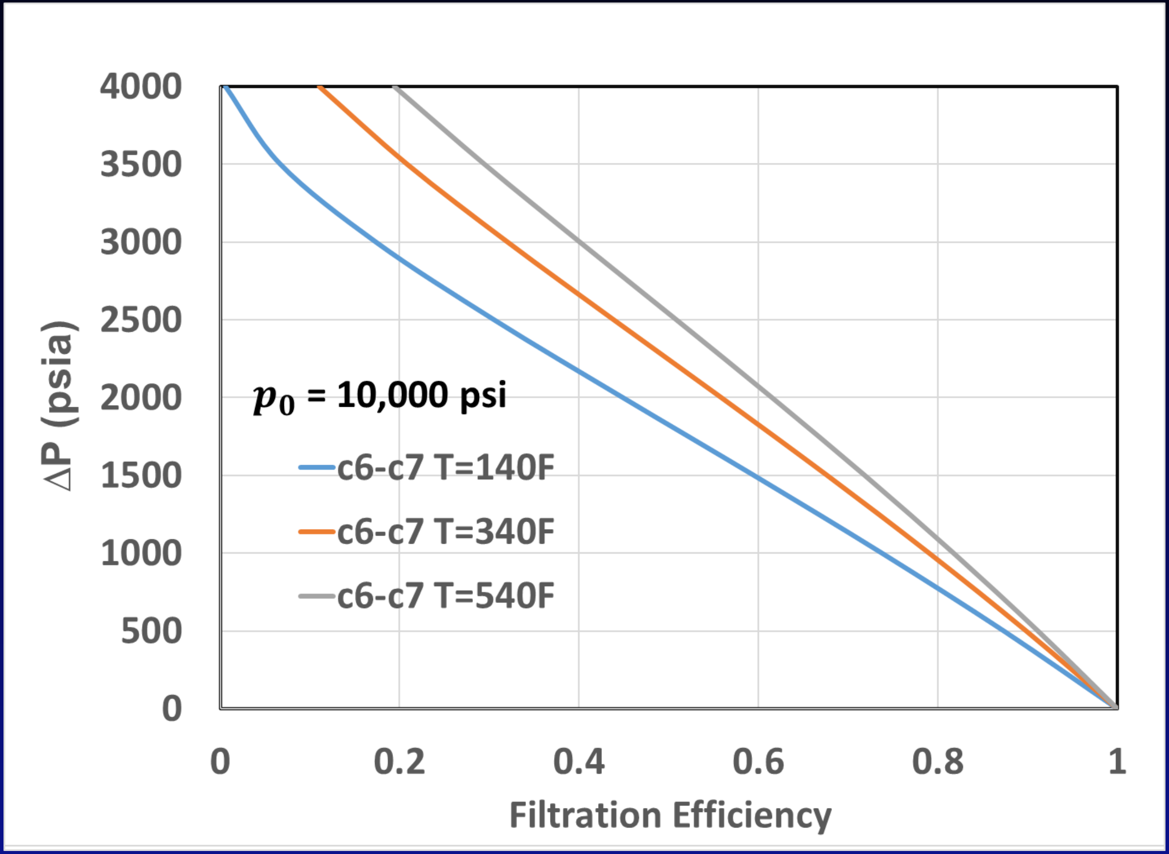
Case 2:

- 2 Components
- Mole fraction:

  30% 70%
- Temperature:

  140°F,340 °F,540 °F
- Pressure change:

  0 psi-4000 psi



May create a stimulation effect

Results

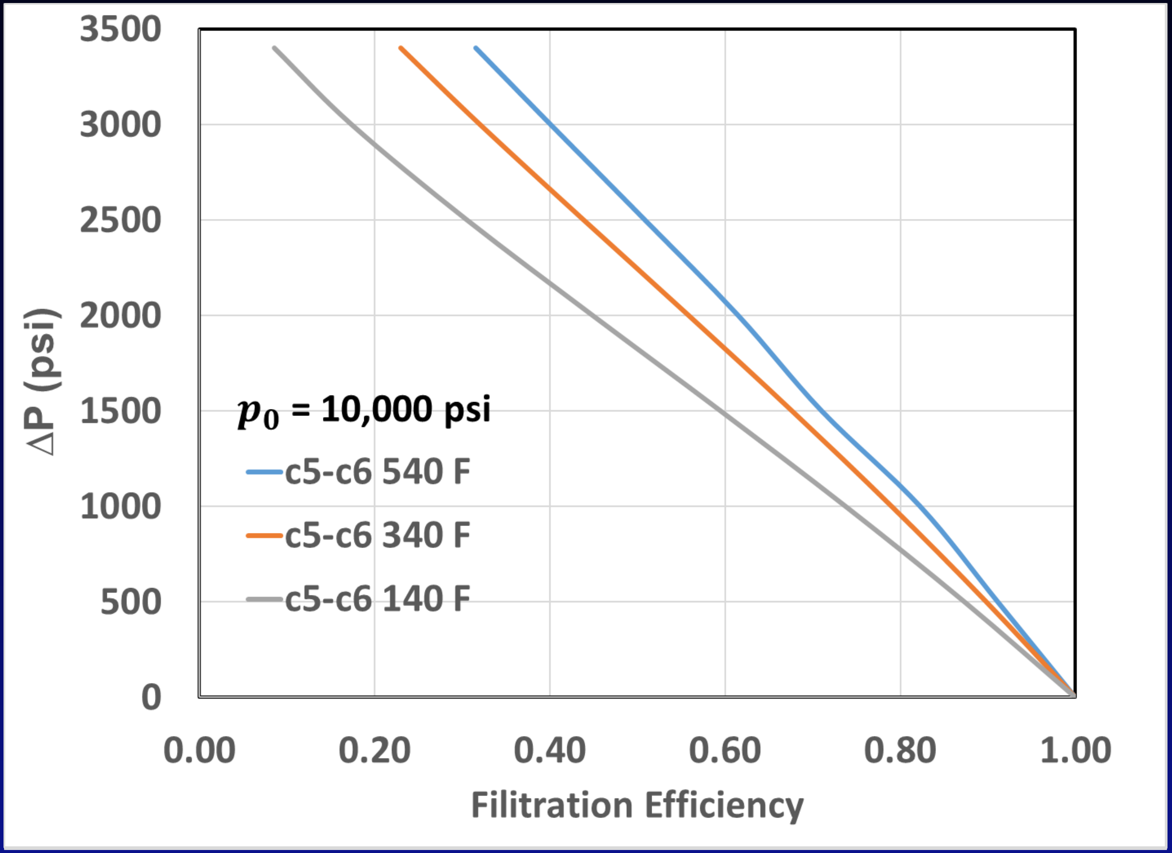
Case 3:

- 2 Components
- Mole fraction:

  30% 70%
- Temperature:

  140°F,340 °F,540 °F
- Pressure change:

  0 psi-4000 psi

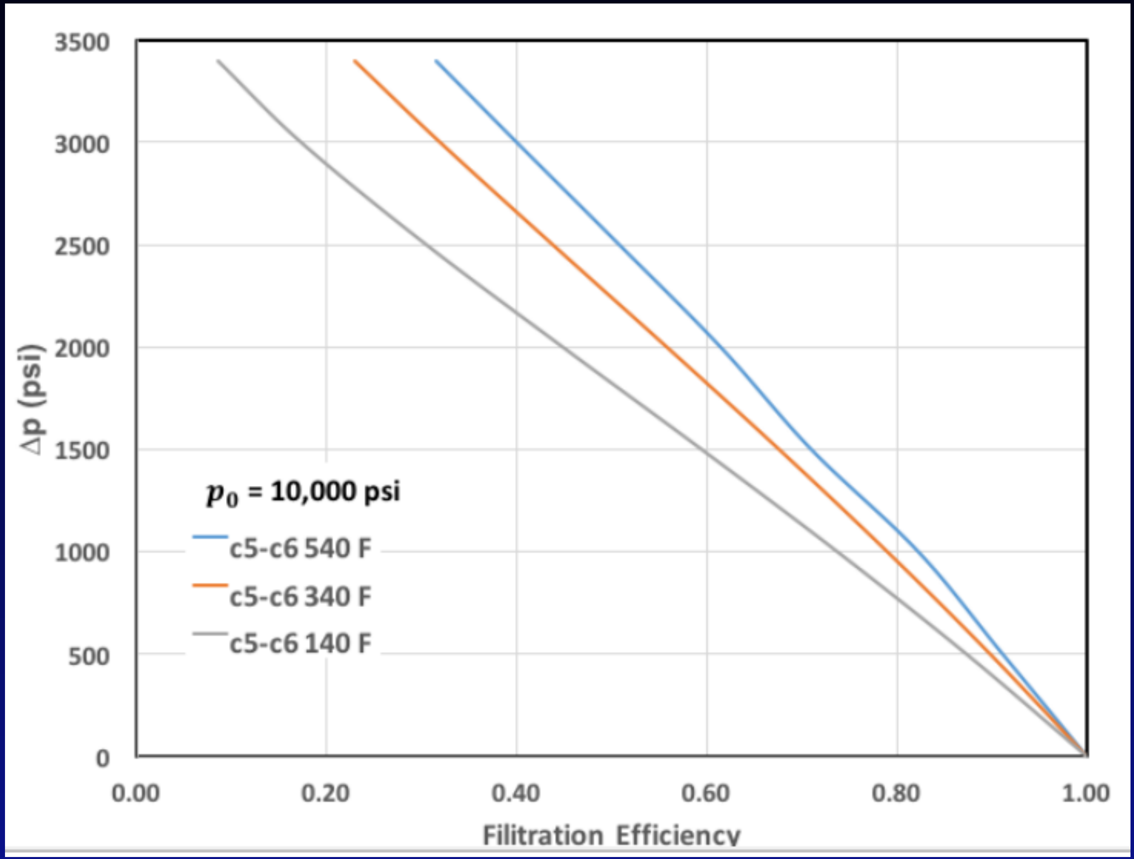


Results

Case 4:

Continuous Change of Composition

- 2 Components
- Mole fraction:
  30% 70%
- Temperature:
  540°F
- Pressure change:
  0 psi-4000 psi



Conclusions

- Filtration efficiency of the medium decreases with increasing pressure and temperature
- Heavier components have lower filtration efficiency at lower temperatures
- For a given filtration pressure, cooling porous medium reduces the filtration efficiency and increases the passage of the heavier components
- Because lighter hydrocarbons are produced during early production, cooling the vicinity of the wellbore may increase the recovery of heavier components
- Model can be applied to multicomponent mixtures by pseudo component grouping

Future Works

- Extend calculations to filtration in a multi-cell system representing a porous medium with varying pore sizes

- Develop a compositional model based on the fluxes for the hindered and unhindered components

- Include water phase in the system and incorporate the steric hindrance of solid particles (salt) and osmotic flows in the model

Thank you!