Prepared by,
Muhammad Zuhaili Bin Kashim
14678
Petroleum Engineering Department

UNIVERSITI TEKNOLOGI PETRONAS

“ Gas Condensate Recovery : A New Approach to Enhance Condensate Recovery and Improve Well Productivity”

Supervised by,
Mr. Muhammad Aslam Md Yusof
Petroleum Engineering Department

Outline

- Background of Study
- Problem Statement
- Objectives
- Scope of Study
- Literature Review
- Research Methodology
- Project Activities & Key Milestone
- Results & Discussion

Introduction

Background of Study

Natural Gas demand increases

- Advantage of natural gas than other resources
- Forecast of Natural Gas consumption

Gas-condensate reservoir

- Characteristics
- Challenges

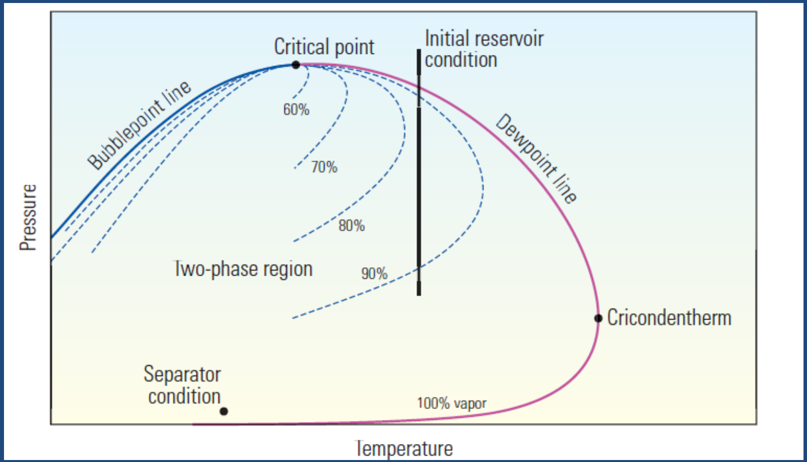


Figure 1 : Typical Gas Condensate System Phase Diagram (Fan et al., 1998)

Problem Statement

- **Condensate Banking problem:**
  - Forming of condensate phase
  - Well deliverables decreases
  - Loss of heavy component
- **Mitigation technique:**
  - Effectiveness of propane in condensate blockage treatment remain ambiguous
  - The studies on proper well distance between injector -producer and injection rate in gas condensate system is very limited

Objective

- To assess the effectiveness of different gas injection techniques which are pure gas injection, gas-gas flooding and gas- solvent flooding from the combination between propane(C_3), carbon dioxide(CO_2), Nitrogen (N_2), and methanol (CH_4O)
- To study the effect of different injection schemes (injection rate and distance between injector and producer) in improving condensate recovery

Scope of Study

- Type of reservoir focused is gas condensate reservoir as the condensate banking problem only occurs in this kind of reservoir
- This study focuses on four different injectant which is carbon dioxide (CO_2), nitrogen (N_2) and propane (C_3), and methanol (CH_4O).
- Purely simulation studies by using a compositional numerical simulator ECLIPSE (E300) and PVTi

Literature Review

Condensate blockage problem in most of the gas condensate field

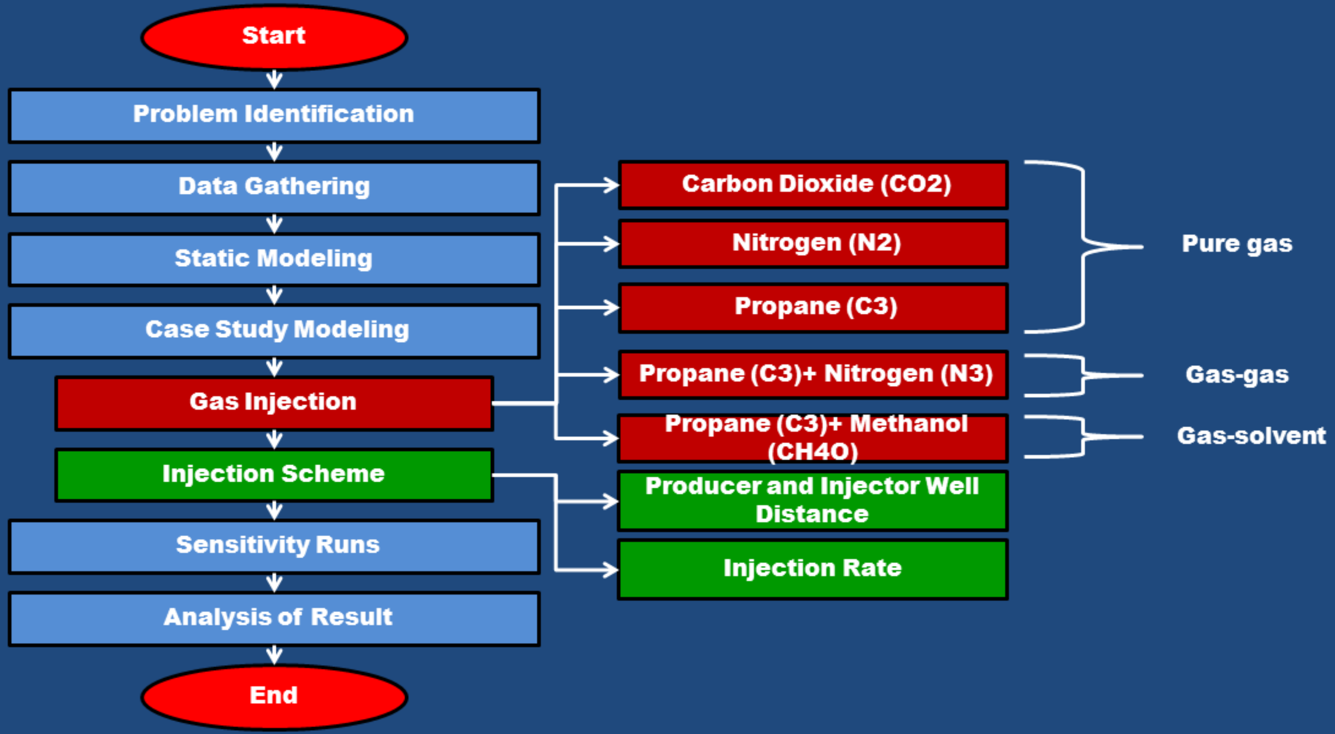
Gas Condensate Field	Challenges
Arun Field, Acheh, Indonesia (Afidick, Kaczorowski, and Bette, 1994)	• Some of the well faced more than 50% of gas productivity losses although laboratory PVT data shows that the reservoir has less than 2% of liquid condensation
Santa Barbara Field , Venezuela (Briones, Zambrano, & Zerpa, 2002)	• Most of the wells undergoes at least 50% to 90% of permeability reduction. • Decline of gas mobility which is mostly detected near the wellbore
Baimiao Field, Henan, China (Miao, McBurney, Wu, Wei, & Zhao, 2014)	• At initial stage, it shows a high rate of gas production which is around 0.8 MMscf/d. • After 1 year of production, the gas production rate undergoes rapid declination to 0.3 MMscf/d. • The reservoir has experienced 68.5% reduction in productivity

Different gas injection performance in removing condensate accumulation

Injectant	Basis
Nitrogen	• Promotes liquid dropout in mixing zone which eventually decrease the gas productivity (Sanger & Hagoort, 1998). • Possessed lower evaporation capacity (Siregar, Hagoort, and Ronde, 1992) • Retain the reservoir pressure above dew point pressure and displace the condensate accumulation (Kossack and Opdal, 1988)
Carbon Dioxide	• Minimize the condensate surface tension and viscosity (Kurdi, Xiao, and Liu, 2012) • Reduce dewpoint pressure at the reservoir temperature (Odi, 2012) • Achieves miscibility with condensate to increase the recovery (Taheri, Hoier, and Torsaeter, 2013)
Propane	• Mobilize the oil by miscible displacement (Holm, 1972) • Increase three times incremental oil recovery compared to pure steam injection (Venturini, Mamora, and Moshfeghian ,2004) • Decreases both dewpoint pressure and total liquid dropout (Jamaluddin et al., 2001).

Research Methodology

Project Flow Chart



Hypothetical Reservoir Model

Properties	Value
Grid Dimension	18x18x9
Hydrocarbon pore volume	20.24 MMrb
Gas/water contact	7500 ft
Water saturation at contact	1.00
Initial pressure at contact	3550 psia
Horizontal permeability	• Layer 1 - 130 mD • Layer 2 - 40 mD • Layer 3- 20 mD • Layer 4 - 150 mD

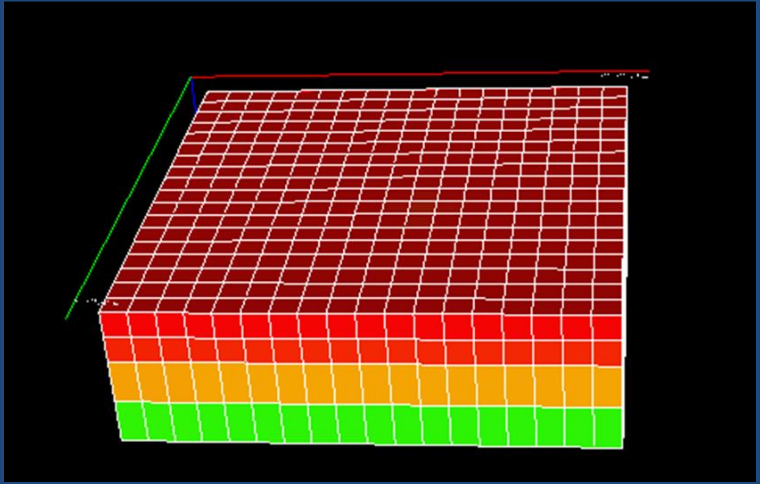


Figure 2: 3D view of hypothetical gas condensate reservoir model. The colour represent gas saturation at initial stage

Base Case

- No treatment is carried out in this case (natural depletion)
- Bottom hole pressure minimally set to 500 psi
- One injector is placed at block (6,6)
  - Perforated at layer 1 & 2
- One producer is placed at block (13, 13)
  - Perforated at layer 3 & 4
- Simulation is carried for 15 years

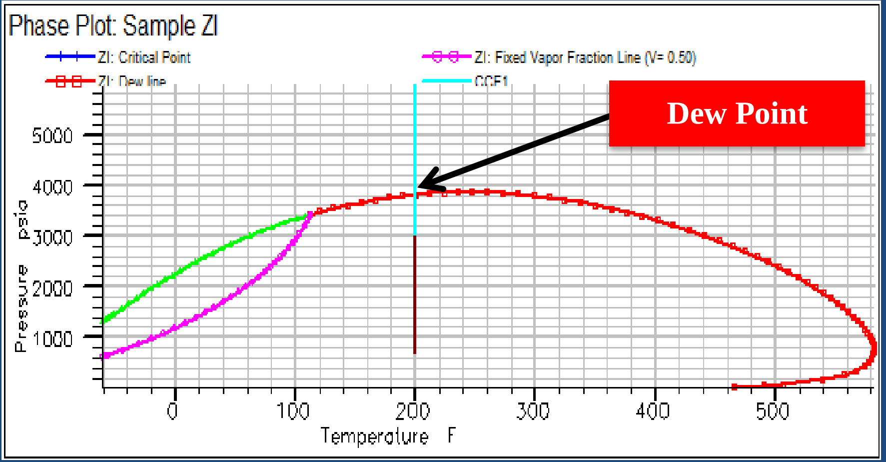
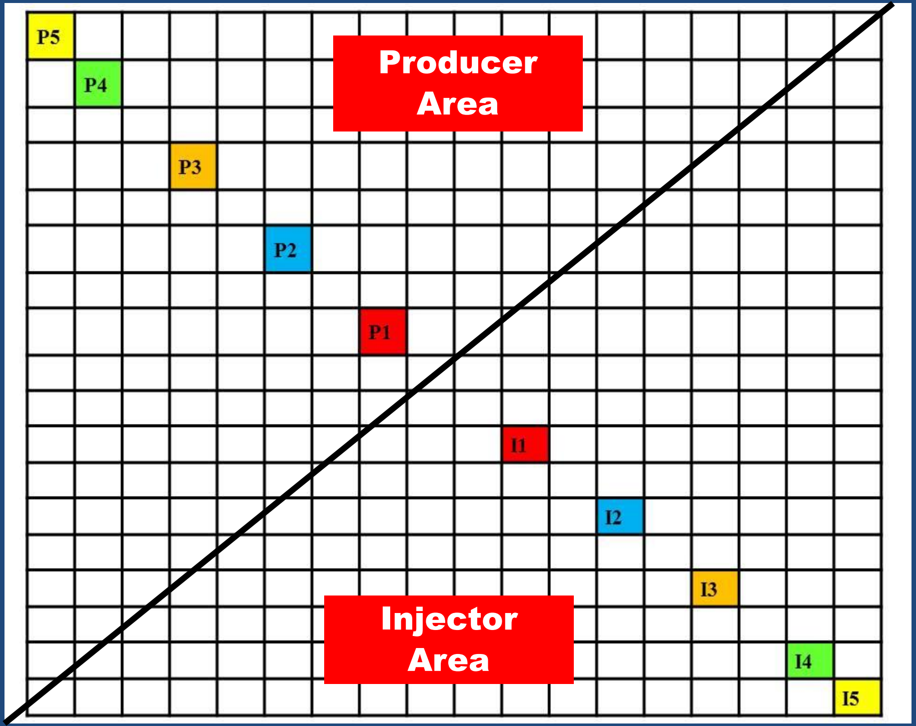


Figure 3 : Phase Diagram of hypothetical gas condensate reservoir. The reservoir temperature is 220 F^o while the dew point pressure of the reservoir is 3817 psi

Study on different gas injection

Test Cases	Injection Rate (MSCF/d)	Condition
Carbon Dioxide	9832	15 years of simulation • First 5 years of natural depletion • Next 10 years of gas injection Total of 1 PV of gas injected
Nitrogen	5437	
Propane	9260	
Propane (Horizontal Well)	9260	
Propane + Nitrogen (Gas – gas flooding)	0.5 PV of propane and 0.5 PV of nitrogen	
Propane + Methanol (Gas – solvent flooding)	0.5 PV of propane and 0.5 PV of methanol	

Study on different well distance



Legend	Block distance/ factor	Distance (ft)
(red)	2	414.8
(blue)	6	1244.4
(orange)	10	2074
(green)	14	2903.6
(yellow)	16	3318.4

Figure 4 : Placement of injector and producer from top view of the reservoir and explanation on Figure 4 is given in table above

Study on different injection rate

- As for the injection rate, three different rates are studied in this project which is:
  - **2000 MSCF/d**
  - **4000 MSCF/d**
  - **8000 MSCF/d**
- The rate increment is in the factor of two to show the significant difference of rate between each case.
- The study is carried out for each well distance to see the relationship between the well distance and injection rate.

Project Activities & Key Project Milestone

Gantt Chart (FYP I)

Activities	Weeks													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Final Year Project topic selection				●										
Introduction on: • Natural Gas – current and future world demand • Gas Condensate Reservoir – Condition and challenges • Condensate Banking – problem and mitigating strategy														
Literature Review: • Mitigating strategy – application, advantages and limitation • Propane, Carbon Dioxide, Nitrogen and Methanol														
Extended Proposal submission								●						
Proposal Defense									●					
Familiarization of ECLIPSE 300 & PVTi														
Interim Report submission														●

Key Milestone ●

Gantt Chart (FYP II)

Activities	Weeks													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Simulation learning (ECLIPSE 300 & PVTi)														
Static Modeling: • Defining Grid • Incorporate porosity, permeability and relative permeability curve														
Fluid Modeling: • Creating a retrograde based fluid system to incorporated in the model based on the literature														
Dynamic Modeling: • Creating different scenario based on the injectant/solvent • Designing cases for different injection scheme														
Progress Report submission							●							
Pre-SEDEX presentation									●					
Dissertation submission												●		
Final Presentation & Viva														●

Key Milestone ●

Results & Discussion

Effect of different gas injection on condensate recovery

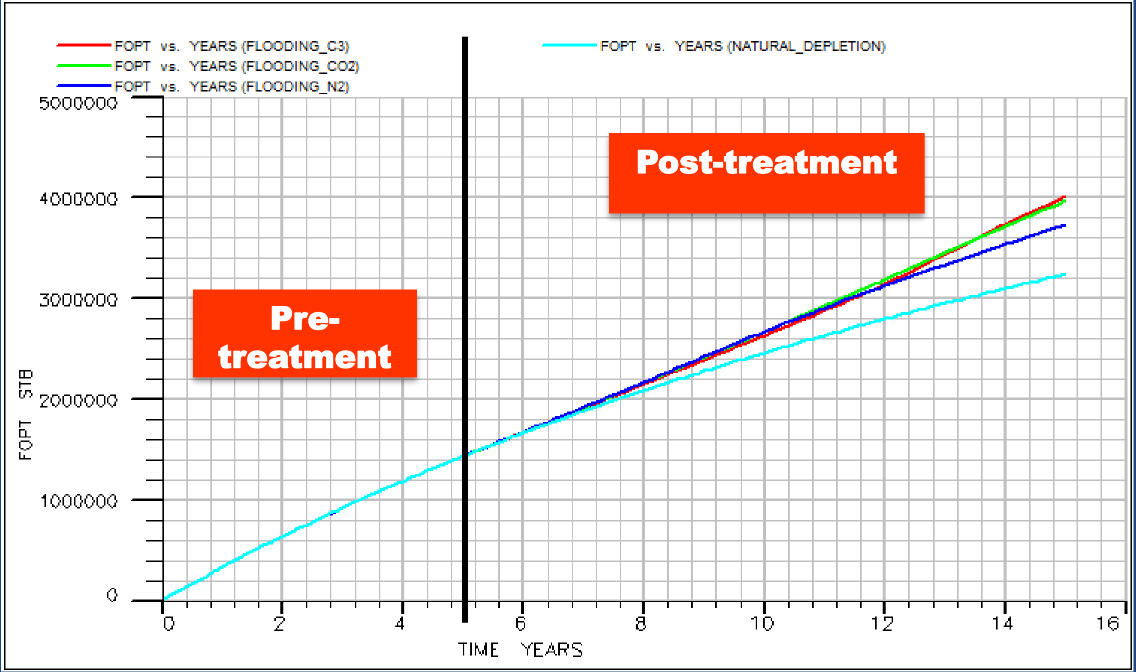


Figure 5: Condensate recovery based on different gas injection

- No treatment is carried out for the first 5 years
- Propane injection shows the highest recovery which is 23.8% of recovery increment compared to base case followed by carbon dioxide (22.5%) and lastly nitrogen (15.2%)

Effect of different gas injection on condensate recovery

Table 1: PVT analysis of different fluid cases

Gas Injection (0.1 mole %)	Viscosity (cp)	Dew Point (psia)	Condensate volume (%)
Original reservoir fluid (no injection)	0.065	3817	18
Carbon Dioxide	0.064	3759	16.2
Nitrogen	0.066	4164	17.4
Propane	0.0625	3493	15

- Injection of propane and carbon dioxide reduce the condensate viscosity, dew point pressure and condensate volume
- Nitrogen injection increases the dew point pressure and condensate viscosity

Effect of different gas injection on condensate recovery

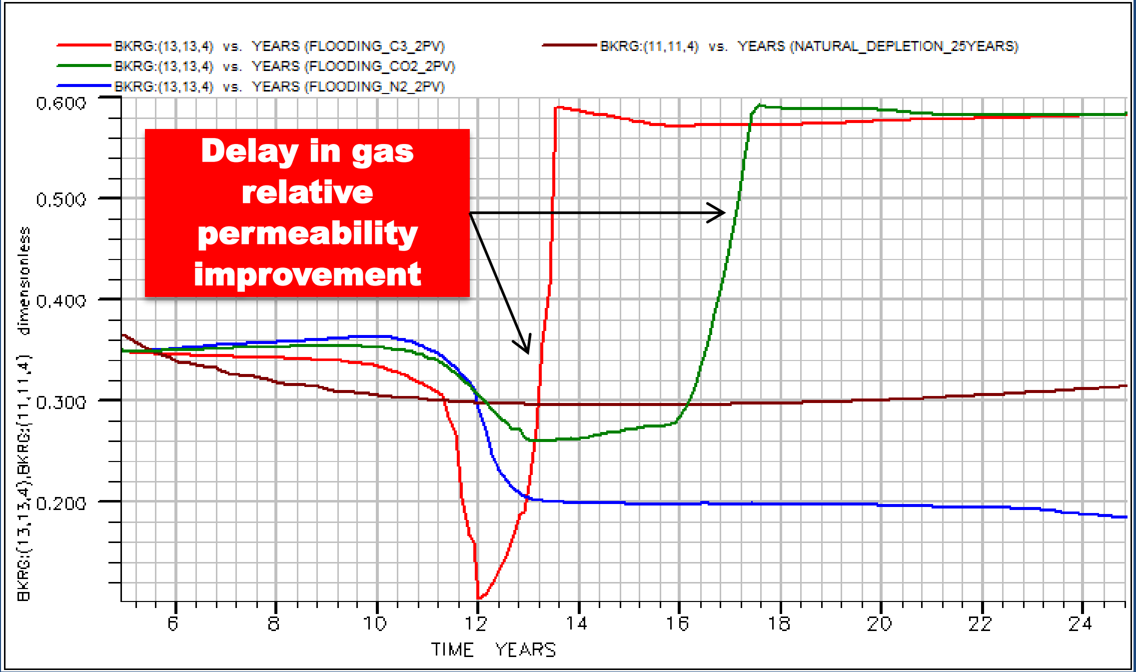


Figure 6: Gas relative permeability based on different gas injection

- Propane shows higher permeability of condensate and gas compared to other conventional gases

$$S_{cond} = (1 - k_{rg,d}) In \left(\frac{r_d}{r_w}\right)$$

- Based on equation above, decrease in gas relative permeability will increase skin factor which will reduce the well productivity

Efficiency of gas-gas and gas-solvent flooding in enhancing condensate recovery

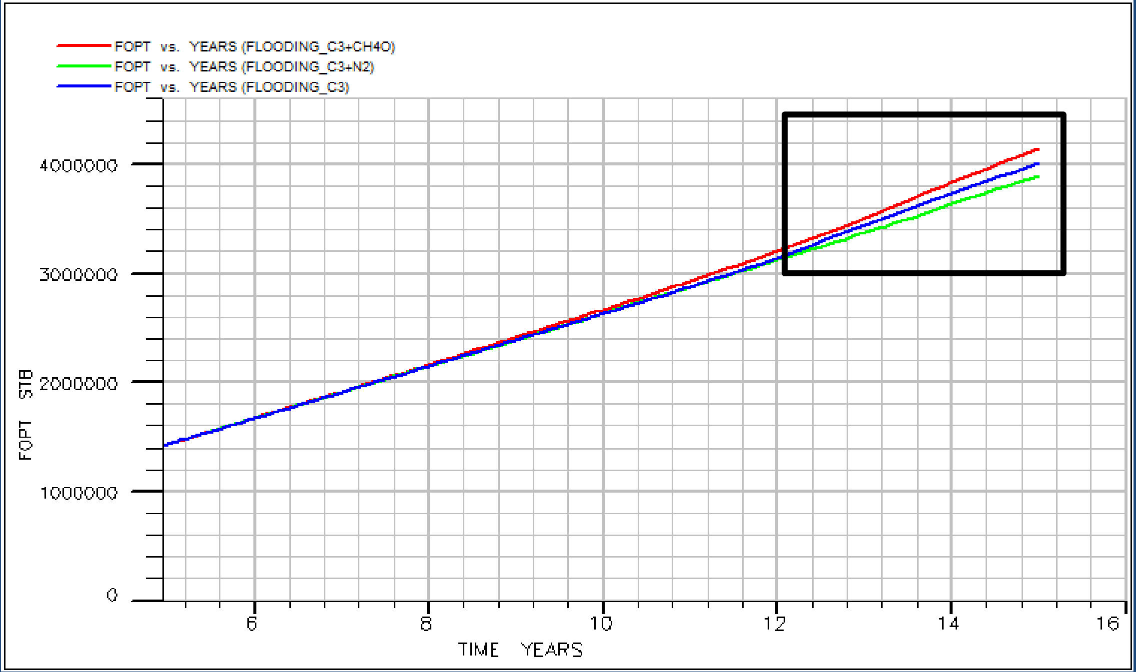


Figure 7: Condensate recovery based on different gas flooding technique

- Gas-solvent (Propane + Methanol) flooding shows the highest recovery followed by pure propane injection and lastly gas-gas (Propane + Nitrogen) flooding
- Methanol reduces dew point pressure, increase gas relative permeability and reduce condensate viscosity

Summary of different gas injection performance

Table 2: Summary of gas injection performance on condensate recovery

Case	Condensate Recovery (STB)	Increment compared to Base Case (%)
Base Case	3,240,164 (16%)	-
Nitrogen (N_2)	3,733,220 (18.5%)	15.2
Carbon Dioxide (CO_2)	3,969,405 (19.5 %)	22.5
Propane (C_3)	4,011,570 (19.8%)	23.8
Propane (Horizontal Drilling)	4,028,328 (20%)	24.3
Propane + Methanol (CH_4O)	4,138,308 (21%)	27.7
Propane + Nitrogen	3,955,401 (19.4%)	22.1

Effect of well distance between injector and producer in condensate recovery

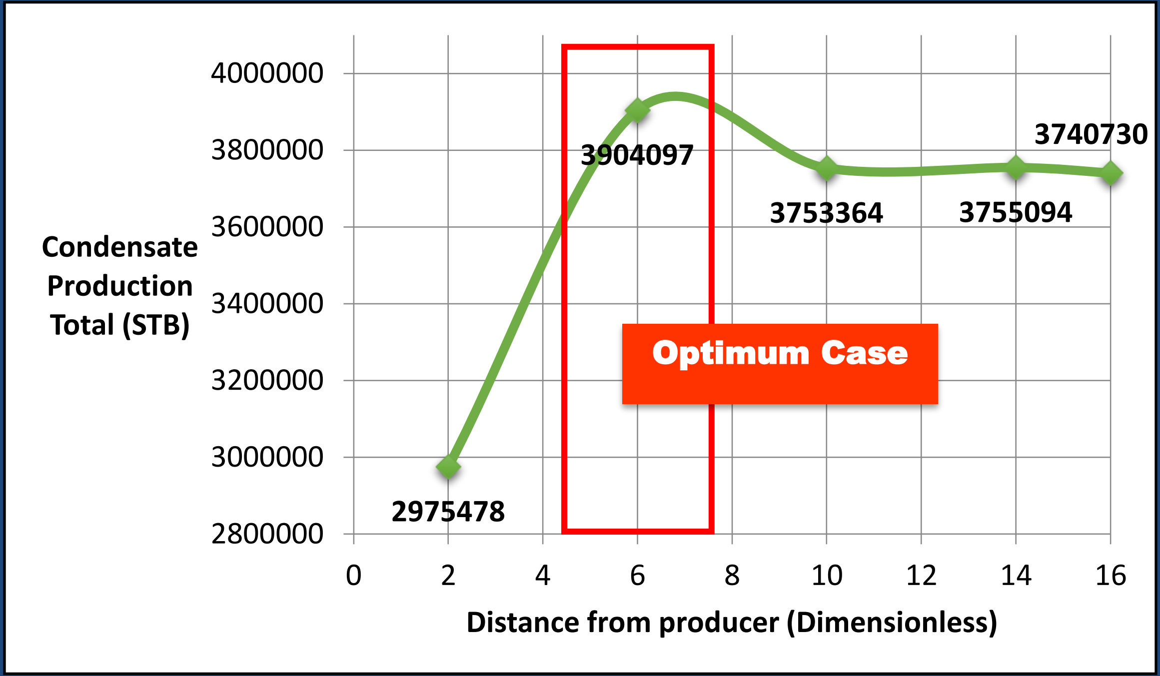


Figure 8: Condensate production based on different well distance

- Smallest distance of well (2 blocks) shows lowest condensate recovery.
- The condensate recovery of medium well distance (6 blocks), is significantly high compared to the further well distance which is 10 blocks, 14 blocks and 16 blocks.

Effect of well distance between injector and producer in condensate recovery

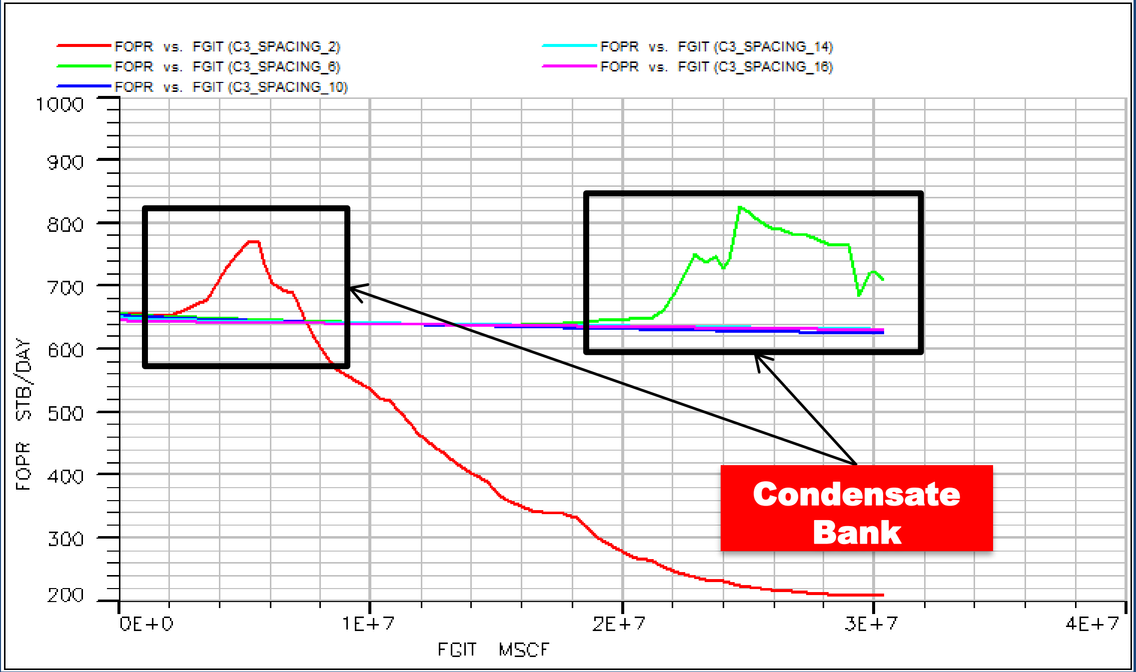


Figure 9: Condensate production rate based on different well distance

- Injected gas propagates to the production well to form condensate bank that will be produced later
- Shorter well distance will cause higher loss of injectant to the reservoir

Effect of different injection rate on condensate production

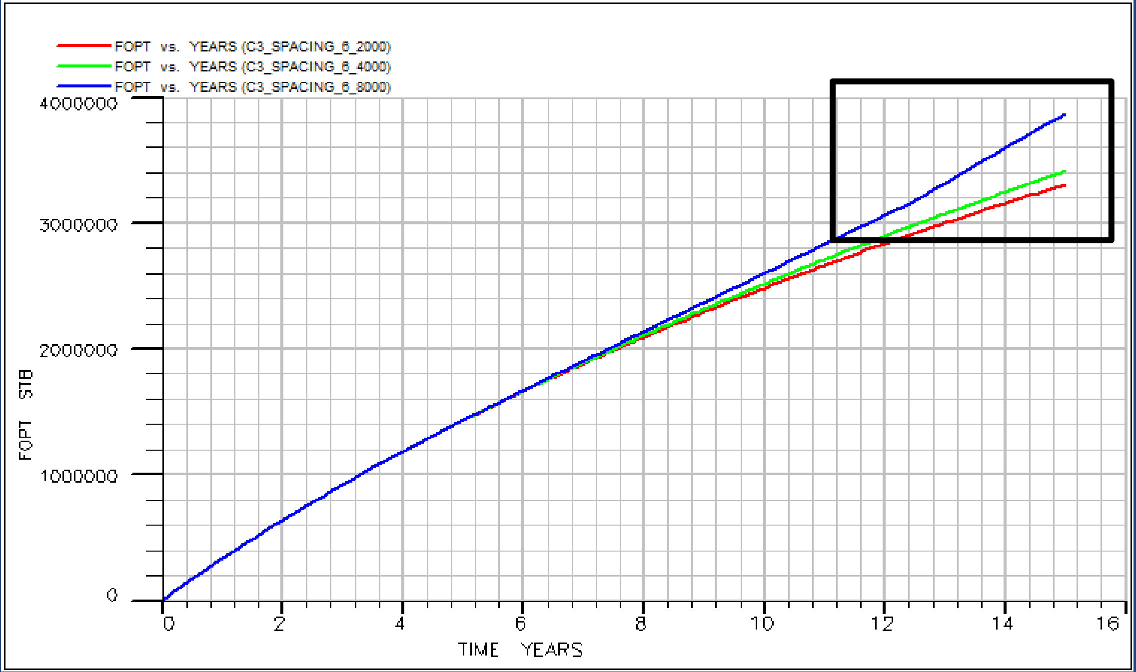


Figure 10: Condensate recovery based on different injection rate

- Highest condensate recovery is from the case of highest injection rate (8000 Mscf/d) followed by 4000 Mscf/d and 2000 Mscf/d
- Based on Amini, Aminshahidy, and Afshar (2011), the injection rate of gases brings considerable effect to the condensate recovery

Conclusion & Recommendation

Conclusion

Injection of propane causes :

- Reduction in the dew point pressure which helps in retarding condensate formation
- Increase the mobility of condensate by reducing the viscosity of condensate
- Improve the condensate and gas relative permeability with only 0.7 PV of propane injection
- Manage to increase the condensate recovery by 23.8% which is the highest among other conventional gases
- Methanol addition improves well productivity and condensate production by 27.7%

The injection scheme also gives a big impact on condensate recovery and well productivity.

- Horizontal well configuration delays condensate build up and increase condensate recovery
- Sufficient injection rate is needed for different well distance where shorter distance works well with lower injection rate while longer distance needs higher injection rate to increase the production

Recommendation

- Deep studies must be done towards propane injection in gas condensate reservoir as the experimental data is very limited and less published in the literature.
- Detailed study most also be done in gas-solvent injection technique as the technique proves to be really efficient in this study.
- Aside from phase behaviour, more attention should be given to relative permeability modeling in gas condensate study as the relative permeability prediction near the well bore still remains ambiguous although there are many studies that has been published on this particular area.
- Detailed experiment which includes swelling test, miscibility test, constant-composition expansion and constant-volume depletion test should be done in order to get correct experimental data which will lead to correct modeling.

Q & A

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