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Pressure Enhancement for Siba Field using Non-Hydrcarbon Gases

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Abstract— Gas condensate reservoirs are becoming more important due to the increased production of gas in the global gas production system of these reservoirs. Accumulation of condensate in a reservoir may lead to a decrease in the gas's relative permeability and a loss in the reservoir of valuable heavy components. Despite this, condensate gas reservoirs can be the perfect place for the injection of carbon dioxide and nitrogen. The ultimate purpose of this research is to enhancement pressure the potential for enhanced condensate gas recovery using carbon dioxide and nitrogen as injection gas. This study focuses on optimizing the Siba field, which means maximizing the recovery of liquid hydrocarbons and Yamama Formation's enhancement pressure to increase gas condensation efficiency through non-hydrocarbon gases (carbon dioxide and nitrogen). The simulation results from the use of experimental and laboratory data to investigate their capacity for condensate vaporization near the wellbore region in different scenarios, as a function of non-hydrocarbon gases, different injection rates, and periodic gas injection (huff 'n' puff method). The results of the simulation explained what factors are favorable for Enhanced Gas Recovery and favorable for (nitrogen) injection in the case of a stable (70 MMSCF/DAY) gas production rate for (15) years.

Keywords— Gas Condensate Reservoir, CO2-EGR, N2-EGR, Underground injection, Siba Gas Field.

1. Introduction

Many companies have been looking to increase the production of natural gas reserves; petroleum companies are increasingly interested in using CO_2, N_2 for enhanced oil or/and gas (EOR & EGR) reservoirs because of the capacity of such reservoirs to permeate gas during production to stand up with rapid growth in world energy demand. These concepts suggest that non-hydrocarbon gas injection is a promising technological application for enhanced hydrocarbon recovery projects [6]. The use of CO_2, N_2 for enhanced recovery of oil has been a technical and economic success for more than 40 years, but a similar level of confidence in the injection of CO_2, N_2 for enhanced recovery of gas has not been applied to this technology. Although the concept of improved gas recovery through the injection of CO_2, N_2 seems to be technically promising for enhanced pressure in condensate gas reservoirs, [12]. Economically, nitrogen is a possible gas for injection. It is available everywhere by using cryogenic or membrane separation. It can be produced from the air at low cost, and carbon dioxide is promising to increase the pressure of gas condensate reservoirs while significantly reducing greenhouse gas emissions. However, the high cost is why it is less important to inject CO_2 into condensate gas reservoirs. There are still concerns that the injected CO_2 in the gas reservoir mixes with native gases [9]. An EGR (Enhancement Gas Recovery) success by CO_2, N_2 injection is linked to the injection strategy, reservoir characteristics, and operational parameters in previous studies investigating depleted natural gas reservoirs. However, no investigations have been performed of the injection of non-hydrocarbon gases in Yamama formation of Siba Field [4].

2. Selected Gas Field and Reservoir Fluid Properties

Siba Field is among the three most important gas fields in Iraq alongside AKKAS Field in Anbar Province and the Mansourieh Field in the Diyala Province. The Siba Gas Field is located in Southern Iraq in the Basra Governorate, 30 Km South-East of Basra (Abu Al-Khaaseeb Town). It extends in a North-Eastern direction to the Shatt Al-Arab.

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The field is opposite to anticline tendencies; its structure is NE-SW with several peaks separated by simple structural bottoms; it's about (21) Km long and (6-13) Km wide.
Gas and oil accumulations were discovered in the field. The reserve amounts to (1.5) trillion cubic meters, and the gas was tested in the formation of the cretaceous Yamama show in the **Table 1**. At the same time, oil was confirmed in Zubair's formation and the cretaceous Yamama in **Table 2**. In 1969, Siba Field was discovered by the Iraqi Company with a French oil company. Siba field has two domes in the North- East, and South-West. The North-East dome expands beyond Iran's borders through Shatt Al-Arab, but it is the largest and (90 %) within Iraq.

Table 1: Selected reservoir fluid properties in unit C and D

Components	Mole %
CO_2	3.3
C_1	81.69
C_2	4.93
C_3	2.36
IC_4	0.52
NC_4	1.05
IC_5	0.46
NC_5	0.51
C_6	1.04
C_7	0.73
C_8	0.82
$C9^+$	2.59
sum	100%

Table 2: Fluid distribution in Yamama formation units

unit	Type of fluid	
	N-E Dome	S-W Dome
A	Heavy oil + Tar	Heavy Oil
B	Impermeable	Oil
C	Gas	Impermeable
D	Gas + Water	Impermeable
E	Water	Oil
F-G	Oil	Oil
H-I	Water	Water

3. Splitting and Lumping Processes and ($C9^+$) Characterization

Thousands of different components may be present in the gas condensate mixtures. In flash calculations, such high numbers are impractical; it can also cause errors in such calculations by representing the hydrocarbon component higher than (C8) with one pseudo component ($C9^+$). For these reasons, to be represented as pseudo components, some components must be split and then, lumped together. Characterization (C9+) consists of representing a hydrocarbon with nine or more carbon atoms (C9+) is a convenient number of pseudo-components and finding the necessary EOS parameters for each of these pseudo-components (Tc, Pc, and W). Characterization of the plus fraction can, however, be done to decrease the need for extensive tuning of the EOS. Thus the characterization of ($C9^+$) is considered the most important step related to the description of reservoir fluids. In this research, (C9+) is considered to be a normal heavy component in the gas condensate sample from well Siba 1(units C and D) in **Table 3**. So (C9+) has been split up to (C80). With the aid of PVT simulation software, the splitting process has been completed. The total number of pure and pseudo components (CO2, C1, C2, C3, iC4, nC4, iC5, nC5, C6 ...Cn......C80) after the splitting process was (83).

Table 3: Compositions of reservoir fluids after splitting and lumping

Components	Mol%	Critical T F°	Critical P Psia	Acentric Factor
CO_2	3.3	87.89	1069.8	0.225
C_1	81.69	-116.59	667.2	0.008
C_2	4.93	90.05	708.35	0.098
C_3	2.36	205.97	615.76	0.152
IC_4	0.52	274.91	529.06	0.176
NC_4	1.05	305.69	551.1	0.193
IC_5	0.46	369.05	490.85	0.227
NC_5	0.51	385.61	489.38	0.251
C_6	1.04	453.65	430.59	0.296
C_7	0.73	503.93	463.46	0.468
C_8	0.82	540.88	431.56	0.499
C_9	0.195	549.96	417.57	0.6104
C_{10}-C_{17}	1.116	678.12	306.49	0.8026
C_{18}-C_{25}	0.598	854.85	233.15	1.1001
C_{26}-C_{37}	0.42	1026.9	208.56	1.3659
C_{38}-C_{80}	0.261	1326.3	196.53	1.4587

4. Phase Envelope Change of Siba Field

During N2 and CO2 injection, the resulting of two-phase envelope **Figure 1** was simulated using reservoir and wellbore conditions based on the Peng-Robinson framework, using the fluid composition listed in **Table 3**. and **Figure 1** shows the flowing gas composition in the reservoir becomes lighter during its way to the wellbore area. As pressure reduces, the heavy components drop out of the gas phase. The composition of the generated well stream varies with the injection pressure and average reservoir pressure. A single dense fluid phase exists if sufficient amounts of the CO2 components are added to a reservoir fluid, and the reservoir pressure is kept above the phase envelope. Although the actual mechanism is more complex, the solubility is the primary driving force behind the improved gas recovery project for miscible flooding. On the other hand, nitrogen elevates the cricondenbar and decreases miscibility. It is sometimes used to increase pressure. The phase envelope of the mixture shifts significantly to the left. The point of the cricondentherm also shifts to the left as the acid gas concentration increases. Improving miscibility, shrinkage of the two-phase region and expanding the liquid phase region is the net effect. For enhanced gas recovery, these are all desirable.Where in the condensate gas, the higher the N2 or CO2 content, the critical point is shifted to the lower left, the phase diagram is shifted to the left, and the envelope area of the two phases is reduced, which means that the system becomes lighter.

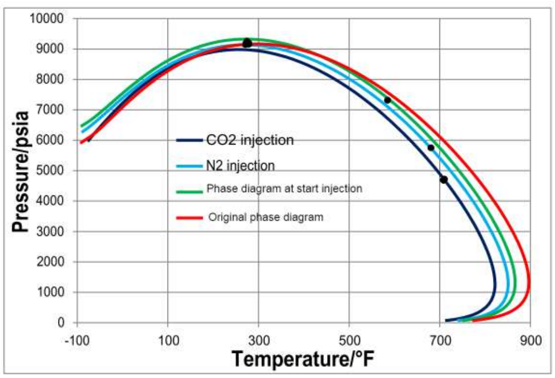

Figure 1: A shift in the phase envelope of the Yamama gas condensate formation at CO2 and N2 injection

5. Injection (N2, CO2) Gas

Pressure maintenance must be explained, particularly in the gas-condensate Yamama reservoir, before discussing results obtained during the gas injection (CO2, N2) scenarios by Huff-n-Puff method. A primary objective of the maintenance of pressure is to fill a voidage area left after the production of gas. Since there are heavy components in the initial reservoir gas-condensate, its compressibility under reservoir conditions is fixed. These heavy ends are, however, removed as condensate after the production and the separation process. In maintaining reservoir pressure, two gases act differently as can be seen from **Figure 2**. Because CO2 is highly compressible, the pressure above the dew point is not enough to maintain pressure. N2, on the other hand, shows a better ability to maintain pressure. This can be linked to nitrogen's less compressible property than that of carbon dioxide gas, resulting in a complete replacement of the produced reservoir fluid by voidage.

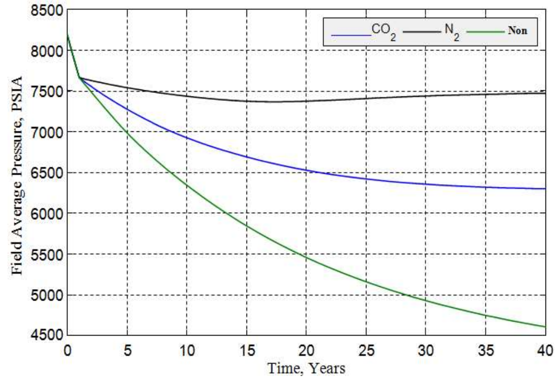

Figure 2: Reservoir pressure during injection of nitrogen, carbon dioxide, and non-injection

Results of recovery were reported in **Figure 3.** CO2 has a lower recovery factor, as expected than N2 gas, which is almost 56 percent. More than 60 percent of the condensate initially in place was recovered by N2. In the recovery factor plot, due to its high-pressure maintenance at the early stage of production (i.e. up to 25 years), the nitrogen injection produced more condensate than carbon dioxide. The condensate production rate, however, began to decline after the breakthrough, as did the cumulative condensate recovery.

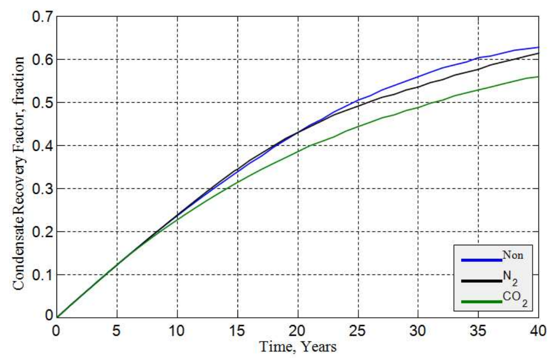

Figure 3: Fractions of condensate recovered during gas injection (CO2, N2) and non-injection

6. Optimization of Huff-n-Puff Gas Injection Work

6.1 *Soaking time*

A series of the simulation were performed using different soaking periods : (0, 50 days, and 100 days) for N2 injection. Three cycles were simulated in these three cases: 100 days of injection and 200 days of production, all three cases were shown in **Table 4** with pressures (8000,7000,6000) psia; however, simulation without soaking had the greatest condensate recovery (15.1%) while simulation had the lowest condensate recovery with the longest soaking time (100 days). The reason why the soaking time has a negative effect, in this case, is related to the gas condensate fluid properties. In these three simulation cases, the injection pressure was already set at a high value of 8000 psi. When the gas was injected into the formation, the pressure of the nearby well-bore region increased rapidly above the initial pressure, the condensate was vaporized to the gas phase, and the oil (condensate) saturation decreased.

Table 4: Simulation parameters and results of soaking time

Cycle number	N2 injection pressure psia	Soaking time days	Condensate recovery %
1st	8000	0	15.1
2nd	8000	0	8.53
3rd	8000	0	3.22
1st	7000	50	13.21
2nd	7000	50	7.25
3rd	7000	50	3.32
1st	6000	100	9.35
2nd	6000	100	6.32
3rd	6000	100	3.36

All of these research findings from three simulation works prove no benefit from applying a longer soaking time. Longer soaking time indicates a longer waiting period, reducing the production period. The longer soaking time also had the lowest recovery in these three simulation instances.

6.2 *Number of cycles and production period for huff-n-puff*

The number of huff-n-puff cycles is considered essential and must be taken seriously into account when applying the huff-n-puff gas injection (CO2, N2) method to gas condensate reservoirs. Cycles of huff-n-puff were simulated to investigate the 3 effectiveness of huff-n-puff over multiple cycles. 50 injection days and 400 production days were made up of each cycle; the soaking time in this model was not taken. Fewer huff-n-puff cycles are needed to increase the recovery of condensate by following this principle. Also, fewer cycle numbers mean that less gas volume is required to be injected into the reservoir. In huff-n-puff gas injection projects, this implies fewer costs. **Table 5** presents the analysis of different huff-n-puff gas injection cycle numbers for 3 huff-n-puff cycles with 400 days of production time.

Table 5: Analysis of different cycle numbers

Cycle no	Conden -sate RE %	Rise %	Prod oil,bbl	Inj Gas,ft^3	Prod gas,ft^3
0	15.1	not applic -able	15027	229,69 1776	490,94 8000
1	15.67	0.2	15220	266,75 8272	528,25 2032
2	15.82	0.15	15373	303,57 8592	565,87 7120
3	15.95	0.13	15493	338,84 6784	602,44 8000

6.3 Effect of injection pressure

The condensate recovery of the three (1–3) cycles of the N2 huff and puff process under various N2 injection pressures have been shown in **Table 5**. Without any soaking time, it can be seen that the condensate recoveries in the first and second cycles were greater with higher N2 injection pressure. In the third cycle, the injection pressure showed little effect on condensate recovery. In the first cycle, the enhancement pressure was clearly higher for 8000 psia than for 7000 psia, as can be seen in **Figure 4**. This means that in the first cycle of the N2 huff and puff method, increasing the N2 injection pressure effectively improved the condensate recovery, To improve the efficiency of enhancement pressure. The enhancement pressure for 6000 psia was similar in the third cycle of the N2 huff and puff process. Because when the pressure was reduced, the vaporized condensate could be re-formed into liquid. Condensate saturation in the near-wellbore region also increased again.

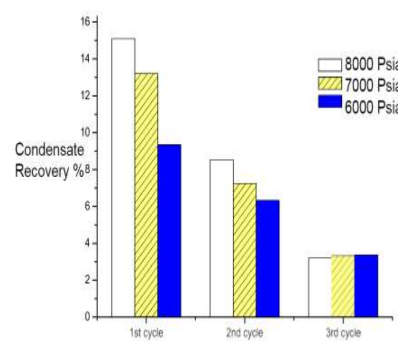

Figure 4: Condensate recovery of N2 huff and puff process under different injection pressures

It is predicted that the injected N2 will distribute faster in the formation of Yamama reservoir. It results in a stable reservoir re-pressurization. However, for a Yamama reservoir, re-pressurization takes more time during the injection of CO2. The simulation results show improvement in recovery of gas condensation by nitrogen injection, as shown in **Figure 5**.

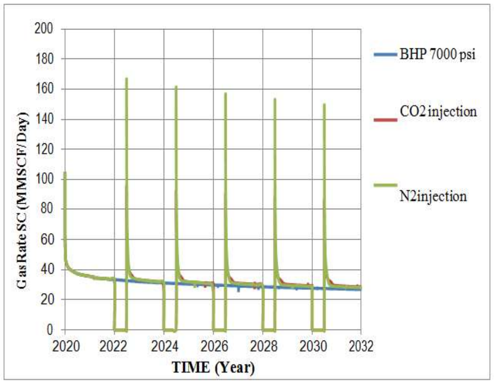

Figure 5: Comparison of Condensate flow rate by injection N2, CO2 for BHP 7000 psi, vs. time

7. Conclusions

1- The phase diagram has been shifted to the left, reducing the envelope area of the two phases by injecting N2 and CO2. This means that the system is getting lighter.

2- Accumulation of condensate in the near-wellbore region could not return to its original composition if CO2 and N2 were injected due to a change in composition, confirmed by condensate presence in the near-wellbore region after the shut-in period.

3- Nitrogen can replace the significant voidage space due to its less compressible quality. On the contrary, this property is not shared by the CO2 gas investigated in this research.

4- The injection of nitrogen was an entirely immiscible process of displacement.

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Abbreviations

EGR	Enhancement Gas Recovery
CO2	Carbon Dixoide
N2	Nitrogen
EOS	Equation of State
TC	Critical Temperature
PC	Critical Pressure
W	Accentric Factor
MMSCF	Million of Standard Cubics Feet
BHP	Bottom Hole Pressure

تحسين الضغط في حقل ألسيبة باستخدام الغازات غير ألهيدروكاربونية

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الخلاصة – تعتبر مكامن مكثفات الغاز أكثر أهمية في الصناعه النفطية بسبب زيادة الطلب على إنتاج الغازفي الاسواق العالمية من هذه المكامن. تتراجع المكثفات عن جوف قاع البئر مبتعدة عنه عندما ينخفض ضغط البئر إلى ما دون ضغط نقطة الندى ، مما تسبب تراكم المكثفات بالمنطقة القريبة من قاع البئر. وقد يؤدي تراكم هذه المكثفات في المكمن إلى انخفاض في النفاذية النسبية للغاز (انخفاض في إنتاجية بئر الغاز وخسارة في انتاج المركبات الثقيلة القيمة). على الرغم من ذلك ، تكون مكامن غاز المكثفات المكان المثالي لحقن ثاني أكسيد الكربون والنيتروجين.وهذا هو الهدف الرئيسي من هذا البحث هو إمكانية تعزيزالضغط باستخدام ثاني أوكسيد الكربون والنيتروجين كغازات حقن لزيادة استخلاص المكثفات حيث ركزت هذه الدراسة على حقل ألسيبة ، مما يعني تعظيم استخلاص الهيدروكربونات السائلة بواسطة حقن الغازات غير الهيدروكربونية. كانت نتائج دراسات المحاكات التي توصلنا لها باستخدام البيانات التجريبية والمختبرية الناتجه عن شركة نفط البصرة وتمت تحت سيناريوهات حالات مختلفة كدالة للغازات غير الهيدروكربونية ومعدلات الحقن المختلفة والحقن الدوري للغاز. حيث أوضحت نتائج المحاكاة ما هي العوامل المفضلة لتعزيزضغط تكوين اليمامة في حقل السيبة والتي كانت جيدة بواسطة الحقن ب (النيتروجين) في حالة الانتاج بمعدل إنتاج ثابت للغاز يبلغ (70 مليون قدم مكعب في اليوم) لمدة (15) سنة ، وهي واعدة كطريقة لتقليل انبعاث غاز (ثاني أكسيد الكربون).

الكلمات الرئيسية – مكمن مكثفات الغاز,حقن تحت الأرض , تعزيز استرداد الغاز بالنتروجين, تعزيز استرداد الغاز بثاني وكسيد الكربون.