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CO_2 Injection By Huff & Puff At Jatibarang Field

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CO_2 INJECTION BY HUFF & PUFF AT JATIBARANG FIELD

Setia Bungsu[1], Irma Primasari[1], F. Indra Purba[1], T. Adam Aliefan[1]

PT Pertamina EP[1]

Abstract

CO_2 EOR is one of EOR methods that proven in the world but a full-scale CO_2 EOR needs huge investment and must be prepared very carefully. Thus, for the first step of CO_2 EOR, Pertamina EP proposed to inject a small volume of CO_2 by using Huff & Puff method. Huff & Puff consist of three steps, (1) CO_2 injected down to production well or "Huff" stage, (2) soaking stage, and (3) produce the well or "Puff" stage.

Jatibarang Field is chosen to apply Huff-n-Puff CO_2 injection due to its oil characteristic and having CO_2 source nearby. Jatibarang oil field is located about 30 KM southwest of Cirebon city within the Pertamina EP concession area, discovered in November 1969. Field Jatibarang Layer F began to be produced in March 1975. The F layer consists of carbonate rock and shale which deposited in continental shelf platform or reefal environment, and the thickness of the reservoir is 4-5 m. Jatibarang reservoir has API 36, 0.5-0.9 cP of viscosities, 10.87-21.38 % of porosities, 3727-3937 feet of reservoir depth and permeabilities ranging from 40 to 60 mD. With these reservoir properties, the EOR screening shows that CO_2 EOR was suited to be applied in Jatibarang. Pertamina EP will conduct 3 (three) CO_2 Huff & Puff in Jatibarang field which planned to be implemented in Q4 2018.

This paper presents overview of EOR Field experiences in worldwide using CO_2 Injection Huff & Puff. Brief study to screen well candidates for Huff & Puff and identify viable practice surveillance basis of past EOR experiences.

Keywords: CO_2, Huff & Puff, Screening, Execution Plan, Surveillance, Jatibarang

1. Introduction

EOR CO_2 Flood is one of the "Well Established" EOR methods and is proven to be able to increase oil recovery. Based on the preliminary screening, there are several fields in Pertamina EP that are suitable for CO_2 flood implementation, and Jatibarang is one of the best candidate due to its oil in place (OOIP) and CO_2 source availability. CO_2 flooding is a very high-cost project; thus it is proposed to implement CO_2 on a smaller scale first through the Huff and Puff method. The Huff and Puff CO_2 method is a method of injecting CO_2 with a certain volume in a production well, then let it stand for a predetermined period of time and then it is produced at the production well. With the Huff and Puff method, it is expected to understand the phenomenon of CO_2 in the oil recovery process and as a good learning medium before going to a larger scale (full scale CO_2 flooding).

2. Basic Theory

Of the several EOR methods available to date, CO_2 EOR is one of the proven EOR methods in the world. The EOR CO_2 Project was the 2nd most popular projects after Thermal EOR (Figure 1) and the highest oil increase trend in the USA (Figure 2). Another advantage of CO_2 EOR is that it participates in the greenhouse effect reduction program, because some CO_2 gas (the main cause of greenhouse / global warming) can be stored in the oil reservoir. Because Global warming and CO_2 gas emissions are getting higher over time (Figures 3 & 4), the United Nations since 1992 has made an international environmental agreement / UNFCCC (The United Nations Framework Convention on Climate Change) and holds conventions on climate every year with products that most famous is the Kyoto Protocol. The Kyoto Protocol introduces the definition of Carbon Credit or Carbon Trading that allows a country or company to obtain a financial benefit from its efforts to reduce CO_2 emissions.

Today, CO_2 is also known as a powerful solvent when become supercritical state. If the temperature and pressure are both increased from room condition to be at or above the critical point for carbon dioxide, it can adopt properties midway between a gas and a liquid. More specifically, it behaves as a supercritical fluid above its critical temperature (304.25 K, 31.10 °C, 87.98 °F) and critical pressure (72.9 atm, 7.39 MPa, 1,071 psi), expanding to fill its container like a gas but with a density like that of a liquid.

Huff-n-Puff is a well stimulation technique by injecting fluid (CO_2) into an oil well, soaking and then producing the well again. The CO_2 requirement for this process is much less than the full scale CO_2 flooding, so Huff-n-Puff can be used as a learning medium and a way to increase production quickly with less cost and time. With Huff-n-Puff, the CO_2 injected will mix with oil in the reservoir so that the oil will swelling and the viscosity will drop, so that oil will flow more easily into the wellbore.

3. Methodology

Many reference about CO_2 Huff & Puff founded[1,4,6,10,1214,16], thus CO_2 injection by Huff & Puff technique is actually common activity, especially in US. However, CO_2 Huff & Puff is still very rare in Indonesia, accounting for only 1 (one) CO_2 Huff & Puff ever done until now, namely in year 2015 at the Meruap field which is a collaboration between KSO Pertamina Meruap, ITB and South Korea. The first CO_2 Huff & Puff in Meruap is totally funded by South Korean Government, but the production result is not conclusive yet.[15]

3.1 Candidate Selection and Design

From several literature available[1,4,6,10,1214,16], there are guideline for candidate selection and common design. Statistic data is built to ensure common design parameter such as CO_2 injection efficiency for estimation oil gain, injection volume and duration for soaking.

From Tabel 1-3, typical CO_2 injection efficiency, CO_2 volume and soaking duration respectively are 2 - 3.4 Mcf/bo, 195 – 567 ton and 16 – 28 days.

3.2 Operational Consideration

There are two main consideration when choosing how to inject CO_2 down to reservoir, they are cost and time. CO_2 Huff & Puff only involves less CO_2 volume when compared to full scale CO_2 flooding, thus making procurement on lease from existing plant seems more economically and much faster than making a new investment (build a new plant, piping, etc.), thus buying liquid CO_2 from available market was chosen.

Second consideration is how to inject that liquid CO_2? There are two possible method, by pump or by compressor. Injected by pump is simpler and less energy loss than using compressor. When using compressor, liquid CO_2 must be converted to gas state for feeding compressor, so there are some loss energy occur. Huff & Puff CO_2 injection with pumps also has more experience than compressors, for example Huff & Puff in the US, Abu Dhabi and Vietnam (Figure 5)[13]. The use of compressors for Huff & Puff has only found 1 job, which is in Indonesia (Figure 6).

4. Case Study

The Jatibarang field is included in the top 5 oil fields in Pertamina EP with an original oil in-place content of around 446 MMSTB with a cumulative production of 99 MMSTB (22%). Jatibarang Structure in the Second Level Region of Indramayu Regency, West Java Province. Geographically, the Jatibarang Structure is about 40 km to the northwest of the city of Cirebon (Figure 7).

The Jatibarang structure has a productive layer in volcanic and Cibulakan Formation, with the main layers in the volcanic and Cibulakan-F layers. Produced from 1971 to 2017, the Jatibarang structure has 170 wells consisting of 63 active production wells, 29 injector wells and 78 suspended or abandoned wells.

Based on the screening results, the most suitable EOR metrode for Jatibarang structure is CO_2 injection, Figure 8 shows the screening that has been carried out.

For CO_2 source, there are abundant CO_2 near to Jatibarang field (Figure 9). First, Subang gas field has potential about 30 MMcfd of CO_2, there are CO_2 removal plant with CO_2 purity above 95% and today only 2 MMcfd utilized by current market, thus there is 28 MMcfd CO_2 gas can be used for EOR. Second, Balongan refinery has CO_2 potential about 57 MMcfd but CO_2 capture plant not available yet. Because of these CO_2 source potential, Jatibarang field become first option for CO_2 EOR of Pertamina EP.

5. Result and Discussion

5.1 Well Selection and Design

Based on criteria from reference 11, Jatibarang F-Layer is suitable for Huff & Puff CO_2 (Table 4). All wells then rank by cement evaluation, current water cut and peak production, thus selected JTB-161, JTB-140 and JTB-137 as the best 3 (three) candidate for CO_2 Huff & Puff (Table 5).

CO_2 injection in Jatibarang F-layer will be immiscible injection, because the fract pressure (2000 psi) is lower than minimum miscibility pressure or MMP (Figure 10).

For job design, pessimistic value was chosen, they are CO_2 injection efficiency is 3.4 Mcf/bo, CO_2 volume is 567 ton and soaking period is 28 days. For CO_2 volume, 1000 ton then selected to ensure CO_2 effect which is same amount of Meruap project. Oil gain estimation calculated using 3.4 Mcf/bo, 1000 ton CO_2 injected thus expected 5600 bbl oil gain can be recovered. Figure 11 is estimation oil gain for each well. High oil gain usually occurred at 2 weeks from start of “puff” period and then decline matched baseline after about 6 month production.

5.2 CO_2 Transportation

CO_2 pumping block diagram and transportation described at Figure 12, liquid CO_2 will transport by trucking from expected CO_2 seller near Subang field, 115 km from Jatibarang and about 4 hours of driving. For storage, specialized container for CO_2 is used, commonly called as “isotank”. The 18 ton of isotank was chosen due to that capacity is highest capacity which can be transported normally.

5.3 Injection Rate & Pressure

The rate is determined as high as possible, because to pursue the highest oil swelling, the injection pressure will be limited to a maximum of 2000 psi (before fract pressure). Because the volume to be injected is 1000 tons causing a volume of that size cannot be placed on the field at once, so pumping is carried out on-fly with a continuous supply of liquid CO_2 from the source. The maximum injection rate with this system supply is 180 tons/day, the value is estimated from the distance between CO_2 sources to Jatibarang field and road conditions.

5.4 Surveillance Program

To ensure comprehensive results, several surveillance programs will be carried out:

- Well lifting

  Production after CO_2 injection is expected to produce large amounts of CO_2 gas, this can contaminate gas production which can be rejected by gas buyers. Therefore the composition of the gas in the "puff" period must be monitored especially at the beginning, when the CO_2 content is still high, the gas must not be inserted into the gas network or must be venting at well site. Since the previous lifting using gas lifts system and annulus gas cannot be vented, thus it is necessary to change the lifting to a pump, in this case the rod pump with hydraulic pump unit is chosen.

- Fluid analysis

  Apart from production tests, fluid analysis is needed before and after injection to determine changes in composition and viscosity. Fluid analysis will be carried out in a laboratory consisting of swelling test, composition analysis, viscosity measurement, etc.

- Oil saturation

  Changes in oil saturation can be measured using a pulse neutron log

- Corrosion Study

  To estimate and measure corrosion tendency after CO_2 injection and preparing needed mitigation plan to prevent further corrosion threat on existing production facility.

- Onsite Separation Unit

  In order to prevent CO_2 rich gas entering gas network which can be lowering gas sales quality and to minimize corrosion effect.

- Downhole Pressure and Temperature Data Acquisition During CO_2 Pumping.

5.5 Current Progress

Currently, required procurement for the job still on progress, it is expected to be completed in the first quarter of 2019 and the first work is planned in the second quarter of 2019.

6. Conclusion

CO_2 can be injected by Huff & Puff technique and getting popular especially in US. Huff & Puff can be a very good tool for learning CO_2 response in oil wells, before going to bigger project such as CO_2 pilot well-to-well injection or full scale CO_2 flooding.

Based on past experience, Jatibarang oil is suitable for CO_2 Huff & Puff, besides that, available abundant CO_2 source near Jatibarang would be good situation for further CO_2 development.

JTB-161, 140 and 137 are selected among the others because of cement quality and current water cut. Job design is decided by statistical data from several real past experience which well documented in several SPE papers.

The first Huff & Puff job will be carried out the second quarter of 2019 and this paper will be updated after that.

7. Recommendation

For better job design, single well simulation study should be carried out to conduct sensitivity analysis and to optimize job design for better result.

8. Acknowledgement

We would like to thank VP EOR PEP and Management for giving advice and permission for the publication of this paper.

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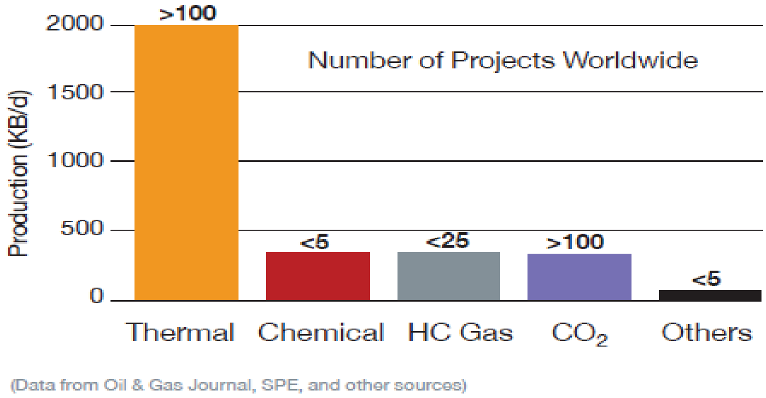

Figure 1. Worldwide EOR Production Rates & Number of Projects.[8]

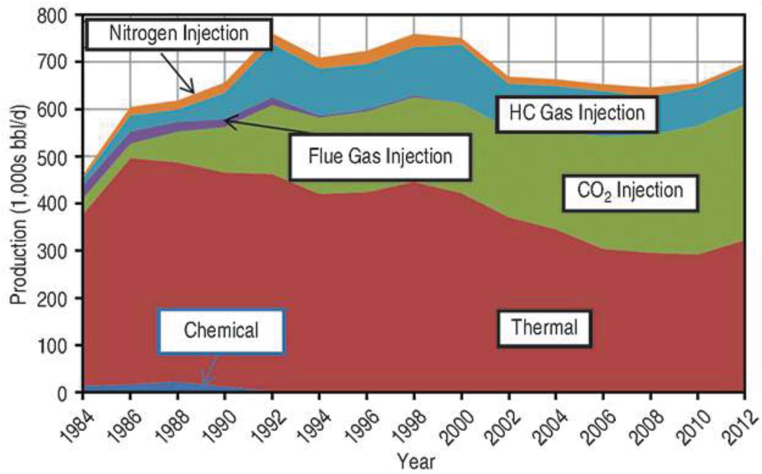

Figure 2. US EOR Production by Recovery Mechanism.[9]

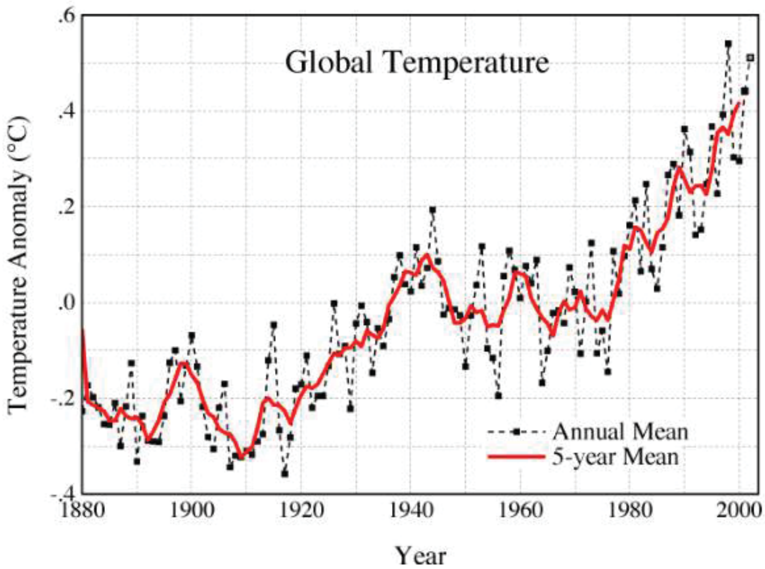

Figure 3. Global Temperature Trends.[3]

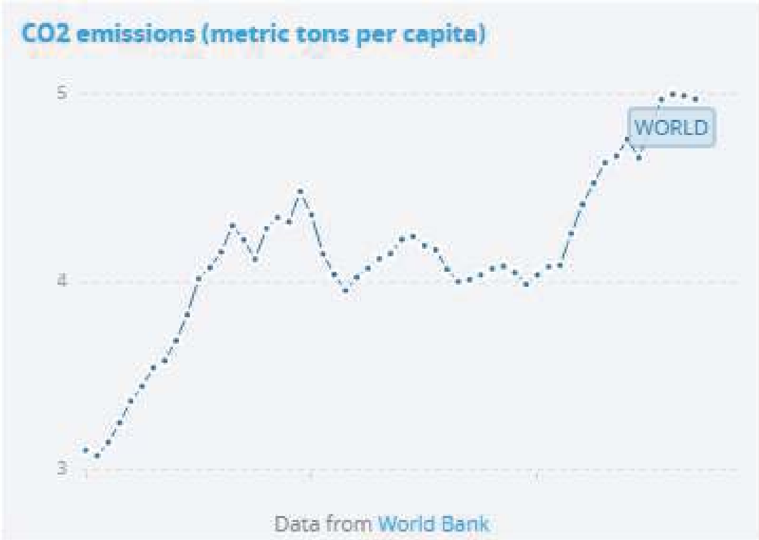

Figure 4. World CO_2 Emission.[2]

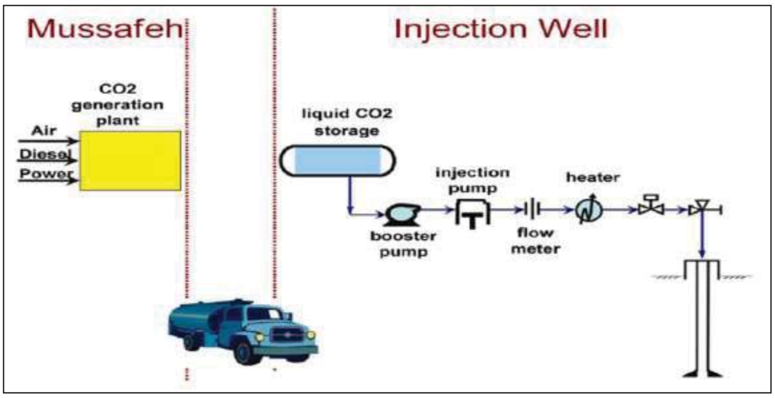

Figure 5. CO_2 Injection Facilities in Abu-Dhabi case.[13]

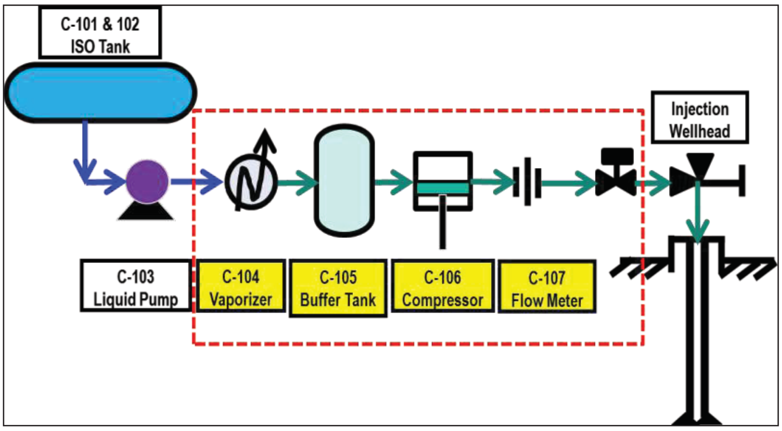

Figure 6. CO_2 Injection Facilities in Meruap case.

Figure 7. Jatibarang Field Location.

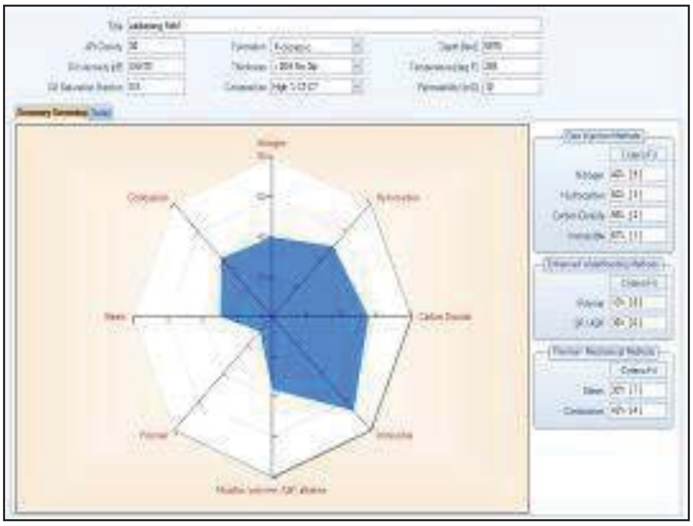
Figure 8. EOR Methodology Screening.

Figure 9. CO_2 Source near Jatibarang field.

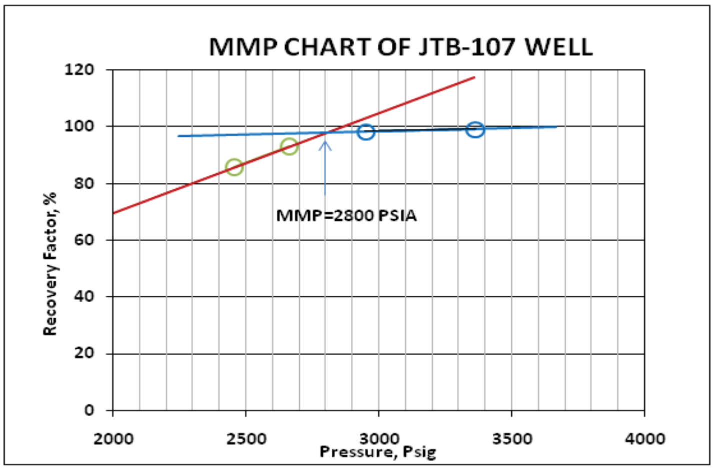

Figure 10. Slim-tube Experiment of JTB-107.

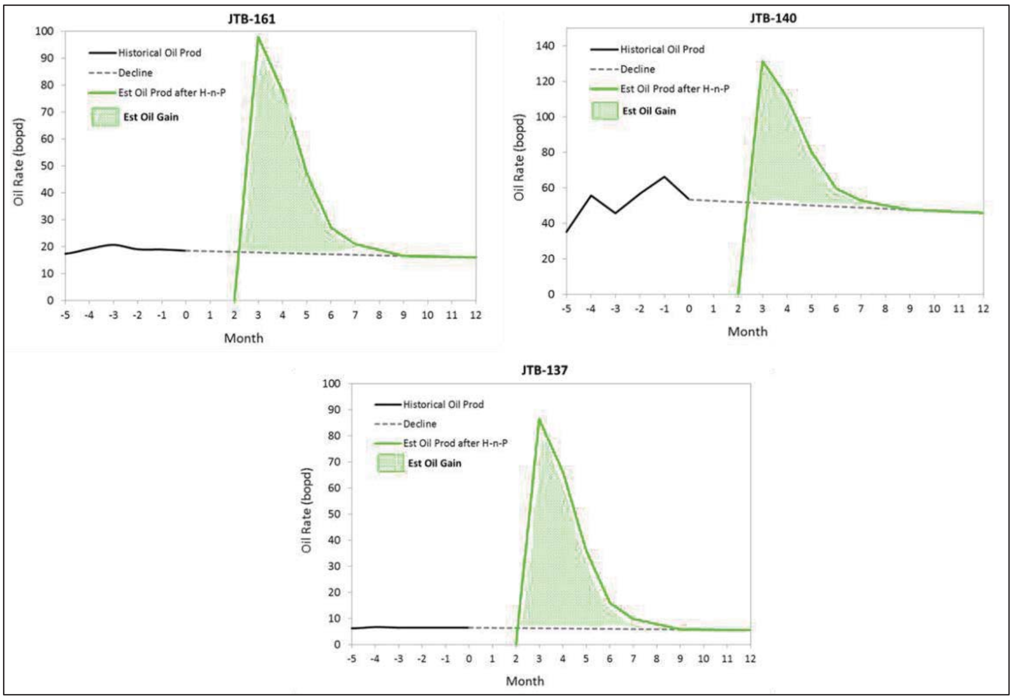

Figure 11. Oil Gain Estimation.

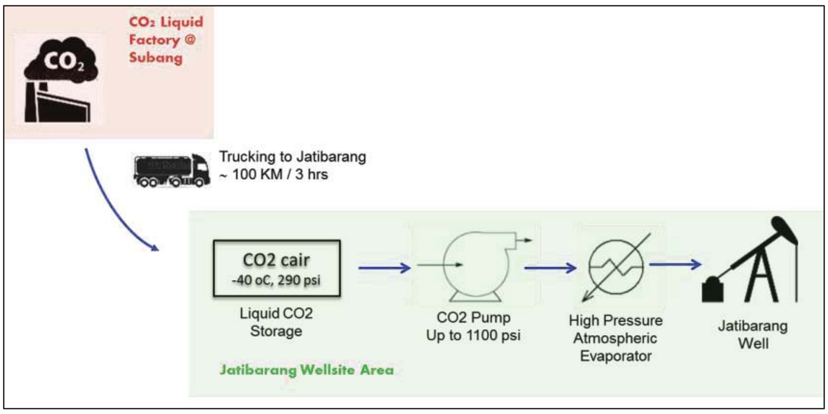

Figure 12. Block Diagram Pumping Scenario.

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Table 1. CO_2 Injection Efficiency.

Paper No	country	Depth, m	API	Number of Job	Efficiency (Mcf/bbl)	% Job	Eff x Num Job
SPE 15502	USA	1280.098	23.3	2	4.9	0%	9.8
SPE 15749	Turkey	1257.239	12	2	5	0%	10
SPE 15749	Turkey	1562.024	17	2	1.3	0%	2.6
SPE 100044	Trinidad	761.9628	20	11	26	2%	286
SPE 27677	USA	396.2207	38	290	1.1	59%	319
SPE 15502	USA	1676.318	26	1	1.1	0%	1.1
SPE 15502	USA	1392.868	25	1	8.2	0%	8.2
SPE 15502	USA	1600.122	25.7	1	2.8	0%	2.8
SPE 15502	USA	1600.122	25.7	1	10.2	0%	10.2
SPE 15502	USA	1523.926	26	1	2.4	0%	2.4
SPE 15502	USA	792.4413	30	1	10.2	0%	10.2
SPE 18977	USA	3108.808	38	11	1.9	2%	20.9
SPE 20208	USA	2480.951	30	1	2.7	0%	2.7
SPE 20208	USA	3148.43	30	2	2	0%	4
SPE 20208	USA	3922.585	33	3	0.3	1%	0.9
SPE 20208	USA	1496.19	30	4	1.5	1%	6
SPE 20208	USA	609.5703	30	9	1.8	2%	16.2
SPE 20208	USA	396.2207	30	66	1.2	13%	79.2
SPE 20208	USA	3066.138	30	1	0.7	0%	0.7
SPE 20208	USA	2712.588	34	1	0.7	0%	0.7
SPE 16720	USA	1486.742	26	2	2	0%	4
SPE 15501	USA	1523.926	32.3	14	7.9	3%	110.6
SPE 139599	China	2500	39.5	68	1.56	14%	106.08
Sum				**495**	**97.46**	**100%**	**1014.28**
Avg				**2.02**			

Avg without SPE 27677 = 3.4 Mscf CO_2 / bo

Table 2. CO_2 Injection Volume.

Paper No	country	Depth, m	API	Vol (MMcf)	Number of Job	% Job	Vol x Number Job
SPE 15502	USA	1280	23.3	4.0	2.0	0%	8
SPE 15749	Turkey	1257	12	10.5	2.0	0%	21
SPE 15749	Turkey	1562	17	6.0	2.0	0%	12
SPE 100044	Trinidad	762	20	74.1	11.0	3%	814.6
SPE 27677	USA	396	38	0.7	290.0	70%	210
SPE 15502	USA	1676	26	4.0	1.0	0%	4
SPE 15502	USA	1393	25	1.0	1.0	0%	1
SPE 15502	USA	1493	24.4	8.0	1.0	0%	8

SPE 15502	USA	1417	23	5.0	1.0	0%	5
SPE 15502	USA	1600	25.7	5.0	1.0	0%	5
SPE 15502	USA	1600	25.7	5.0	1.0	0%	5
SPE 15502	USA	1585	25.2	4.0	1.0	0%	4
SPE 15502	USA	2364	37	4.0	1.0	0%	4
SPE 15502	USA	1250	25	4.0	1.0	0%	4
SPE 15502	USA	1524	26	4.0	1.0	0%	4
SPE 15502	USA	792	30	4.0	1.0	0%	4
SPE 18977	USA	3109	38	1.6	11.0	3%	18
SPE 16720	USA	1487	26	11.5	2.0	0%	23
SPE 15501	USA	1524	32.3	11.0	14.0	3%	154
SPE 139599	China	2500	39.5	3.5	68.0	16%	238
Sum				**170.9**	**413.0**	**100%**	**1546.6**
Avg				**3.7**			

Avg without SPE 27677 = 10.9 MMcf (567 ton)

Table 3. Soaking Time.

Paper No	country	Depth, m	API	Days of Soak	Number of Job	% Job	Days x Number Job
SPE 15502	USA	1280.1	23	31	2	0%	62
SPE 15749	Turkey	1257.2	12	12	2	0%	24
SPE 15749	Turkey	1562.0	17	12	2	0%	24
SPE 100044	Trinidad	762.0	20	4	11	3%	44
SPE 27677	USA	396.2	38	10	290	66%	2900
SPE 15502	USA	1676.3	26	12	1	0%	12
SPE 15502	USA	1392.9	25	7	1	0%	7
SPE 15502	USA	1493.4	24	25	1	0%	25
SPE 15502	USA	1417.3	23	20	1	0%	20
SPE 15502	USA	1600.1	26	17	1	0%	17
SPE 15502	USA	1600.1	26	17	1	0%	17
SPE 15502	USA	1584.9	25	36	1	0%	36
SPE 15502	USA	2363.9	37	23	1	0%	23
SPE 15502	USA	1249.6	25	23	1	0%	23
SPE 15502	USA	1523.9	26	21	1	0%	21
SPE 15502	USA	792.4	30	13	1	0%	13
SPE 18977	USA	3108.8	38	21	11	3%	231
SPE 20208	USA	2481.0	30	31	1	0%	31
SPE 20208	USA	3148.4	30	20	2	0%	40
SPE 20208	USA	3922.6	33	29	3	1%	87
SPE 20208	USA	1496.2	30	100	4	1%	400
SPE 20208	USA	609.6	30	40	9	2%	360
SPE 20208	USA	1904.3	30	22	2	0%	44
SPE 20208	USA	3066.1	30	47	1	0%	47
SPE 20208	USA	2712.6	34	17	1	0%	17
SPE 20208	USA	2998.2	30	35	3	1%	105
SPE 16720	USA	1486.7	26	60	2	0%	120
SPE 15501	USA	1523.9	32	35	14	3%	490
SPE 139599	China	2500.0	40	28	68	15%	1904

SUM				768	439	100%	7144
				16.3			

Avg without SPE 27677 = 28.5 days

Table 4. CO_2 Huff & Puff Criteria on Jatibarang Field.[11]

No	Properties	Criteria from SPE 1000444	Jatibarang Lapisan F		Note
1	API Gravity	11 - 38	38.7 - 39.5	✓	
2	Viscosity (cp)	0.5 - 3000	0.59 - 0.98	✓	
3	Porosity (%)	11 - 32	20	✓	
4	Depth (m)	345 - 3900	1136	✓	
5	Thickness (m)	2 - 67	8	✓	
6	Permeability (md)	10 - 2500	20	✓	
7	High Oil Saturation	Yes	?		Avg WC 76.6%
8	Mild Pressure Support	Yes	Yes	✓	Water Inj.

Table 5. Jatibarang Well Screening.

Rank	Nama Sumur	Lap	Oil Cum. (Mbbl)	Liq Cum. (Mbbl)	Peak Oil Rate (bopd)	Produksi (Gross/Oil/WC)	Lifting	CBL Log Evaluation	
								CBL Quality	Keterangan
1	JTB-137	F	291.9	755.2	100	224 / 7 / 97%	Gas Lift	Good	CBL < 15 mV
2	JTB-161	F	1191.6	1645.9	450	302 / 18 / 94%	Gas Lift	Good	CBL < 10 mV
3	JTB-140	F	1229.1	1583	100	73 / 44 / 40%	Gas Lift	Medium	CBL < 25 mV
4	JTB-199	F	182.6	436.1	100	10 / 3 / 70%	Gas Lift	N/A	No CBL
5	JTB-104	F	130.3	434.5	100	49 / 14 / 72%	Gas Lift	N/A	No CBL
6	JTB-172	F	428.7	712.9	150	56 / 21 / 63%	Gas Lift	N/A	No CBL
7	JTB-176	F	379.9	436.3	120	41 / 33 / 20%	Gas Lift	N/A	No CBL
8	JTB-130	F	867.8	1168.4	400	100 / 38 / 62%	Gas Lift	N/A	CNo CBL
9	JTB-057	F	592.5	856.3	400	76 / 7 / 91%	Gas Lift	Poor	Free pipe