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Evaluation the effect of the Reservoir Rock Permeability in the Gas Injection and Optimizing Oil Recovery Factor by Eclipse Software

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Abstract:
This paper examines on the effect of the reservoir rock permeability on gas injection by using reservoir simulation. This task will be performed by using reservoir simulation software (Eclipse). This injection interacts with CO2 to create conditions favorable for oil recovery. The main target of this project is to investigate the effect of the reservoir rock permeability on gas injection and the optimum injection rate to get the optimum recovery. The problems statement of this study is: As the oil and gas in a formation is produced, the hydrocarbons remaining in the reservoir may become trapped because the pressure in the formation has lessened, making production either slow dramatically or stop altogether. Climate change refers to long-term shifts in temperatures and weather

patterns. Burning fossil fuels generates greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures. Examples of greenhouse gas emissions that are causing climate change include carbon dioxide and methane. The result of effect of the reservoir rock permeability on gas injection by using reservoir simulation shows that with the increase in the permeability of reservoir rock, the rate of gas production increases. The greater the permeability of rocks, the rate of water production increases, which is a direct method relationship between water production and permeability. We note after this evaluation that the cumulative oil, water, and gas production increases with the increase in rock permeability.

Keywords: Reservoir Rock Permeability: Gas Injection: Reservoir Simulation "ECLIPSE Software".

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تقييم تأثير نفاذية صخور المكمن في حقن الغاز وتحسين عامل استخلاص النفط بواسطة برنامج Eclipse

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الملخص

تتلخص هذه الورقة في تأثير نفاذية صخور المكمن على حقن الغاز باستخدام محاكاة المكمن. سيتم تنفيذ هذه المهمة باستخدام برنامج محاكاة المكامن (Eclipse). يتم هذا الحقن مع ثاني أكسيد الكربون لتهيئة الظروف الملائمة لاستعادة النفط. الهدف الرئيسي من هذا المشروع هو دراسة تأثير نفاذية صخور المكمن على حقن الغاز ومعدل الحقن الأمثل للحصول على الاسترداد الأمثل. تتلخص مشكلة الدراسة في مع إنتاج النفط والغاز في التكوين، قد تصبح الهيدروكربونات المتبقية في المكمن محاصرة لأن الضغط في التكوين قد انخفض، مما يجعل الإنتاج إما بطيئًا بشكل كبير أو يتوقف تمامًا. وثانيا يشير تغير المناخ إلى التحولات طويلة الأجل في درجات الحرارة وأنماط الطقس. ينتج عن حرق الوقود الأحفوري انبعاثات غازات الاحتباس الحراري التي تعمل مثل غطاء ملفوف حول الأرض، مما يؤدي إلى حبس حرارة الشمس ورفع درجات الحرارة. من أمثلة انبعاثات غازات الاحتباس الحراري التي تسبب تغير المناخ ثاني أكسيد الكربون والميثان. تظهر نتيجة تأثير نفاذية صخر المكمن على حقن الغاز باستخدام محاكاة المكمن أنه مع زيادة نفاذية صخر المكمن، يزداد معدل إنتاج الغاز. كلما زادت نفاذية الصخور، زاد

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معدل إنتاج الماء، وهي علاقة مباشرة بين إنتاج الماء والنفاذية. نلاحظ بعد هذا التقييم أن الإنتاج التراكمي للنفط والماء والغاز يزداد مع زيادة نفاذية الصخور.

الكلمات المفتاحية: نفاذية صخور الخزان: حقن الغاز: محاكاة المكامن "برنامج ECLIPSE".

INTRODUCTION:

Literature Review: Oil makes a significant contribution to the global economy today. To face rising energy consumption in the world, there is an urgent need to produce more crude oil. CO2 can be injected into gas reservoirs for enhanced gas recovery. The main benefit of CO2 injection is pressure support to prevent subsidence and water intrusion (A. Al-Hashami et al 2005). Hence, secondary recovery is given attention to recover more oil from existing oil fields (M.A. Naser et al, 2013). Sarah, 2013 has proved that CO2 injection has successfully enhanced the gas recovery by repressurization. In his study focuses on the effect of different value of CO2 injection rate to the methane production. It is proven that the optimum methane production is by injection a high amount of injection rate. Proper CO2-WAG injection ratio will give an optimum oil recovery. This works will have a great use in the CO2-Enhanced Oil Recovery (EOR) application (Muslim et al 2021). The CO2 injection presents significant opportunities for enhancing gas condensate recovery and CO2 storage, the economics of such projects are contingent upon improving NGU and ensuring the cost-effectiveness of CO2 capture, transport, and injection compared to oil revenue (Ramez et al 2024). CO2 enhanced oil recovery (EOR) can offer exciting opportunities for both upstream and downstream oil businesses, especially if the refinery is located near operating oil fields (Maria et al, 2010). The CO2 capture achieves two goals: to increase the efficiency of oil recovery and to sequester a substantial amount of CO2 for an extended period of time. M Samba et al, 2021, obtained the water alternating gas CO2 injection was found to be significantly more efficient than different gas injection and continues gas injection. The oil recovery depends not only on the fluid-to fluid displacement but also on the compositional phase behavior. MA Naser et al 2024 showed that the gas injection

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scenario has a good plateau and after that started to decrease. The Cumulative oil production, oil recovery factor, and final reservoir pressure is increasing. M Naser, et al 2024, proved that the optimum oil production is by injection a high amount of injection rate. The relationship between oil rate, gas rate, pressure, and oil recovery factor are directing the compressibility of rocks is a direct relationship. MA Naser, et al 2024, showed that the water and gas Injection have the highest reservoir pressure at the end of the project. The highest percentage of oil recovery was when the water and gas were injected and it reached 58%, then when the water was injected and it reached 55%, and then when the gas was actually injected and it reached 54%.

Problem Statement: The problems statement of this study are:
1. As the oil and gas in a formation is produced, the hydrocarbons remaining in the reservoir may become trapped because the pressure in the formation has lessened, making production either slow dramatically or stop altogether.
2. Climate change refers to long-term shifts in temperatures and weather patterns. Burning fossil fuels generates greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures. Examples of greenhouse gas emissions that are causing climate change include carbon dioxide and methane.

Objectives: The main objectives of this study are:
1. To pressure maintenance of the reservoir and displacing the oil from injection towards production wells.
2. To study the effect of the reservoir rock permeability on gas injection.

FIELD INFORMATION:

Reservoir Rock Properties: The table 1 shows real information about the properties of the reservoir rocks. At the pressure of the first reservoir 2950 psi, and the initial temperature 226 F, and the average permeability for three dimensions and porosity 0.25 x = 200 md. Y = 200 md. z = 20 md).

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Table 1:Reservoir Rock Properties

Property	Value	Unit
Initial Reservoir Pressure	2950	Pisa
Initial Reservoir Temperature	226	F
X Permeability	200	Md
Y Permeability	200	Md
Z Permeability	20	Md
Porosity	0.25	Fr

Reservoir Fluid Properties: The table 2 includes the properties of the reservoir fluid. The properties are represented in (the volumetric composition of gas, the volumetric composition of oil, the volumetric composition of water, the viscosity of gas, the viscosity of oil, the viscosity of water, the density of oil, the density of water, the density of gas, the original amount of oil in the reservoir, the original amount of water in the reservoir, the original amount of gas in Reservoir). All values are taken at point pi.

Table 2:Reservoir Rock Properties

Property	Value	United
Reference Pressure	1500	PISA
Gas Formation Volume Factor at Ref	1.7142	RB/STB
Oil Formation Volume Factor at Ref	1.0917	RB/STB
Water Formation Volume Factor at Ref	1.2459	RB/STB
Oil viscosity at Pref	1.135	CP
Gas viscosity at Pref	0.014701	CP
Water viscosity at Pref	0.28	CP
Oil Density	40	IN/FT^3
Water Density	62.808	IN/FT^3
Gas Density	0.062428	IN/FT^3
Original Oil in Place	25055859	STB
Original Water in Place	4.29E+08	STB
Original Gas in Place	1.11E+08	SCF

Well Location Map: The figure 1 shows a map of the well's location. It is a field of a group of wells consisting of 45 wells, so that 12 wells are studied and through them we carry out the injection process. The wells shown in yellow are the wells through which we will perform the injection process. After completing the model, the oil saturation results appear as shown from 0.03031 to 0.06000, and the saturation distribution is considered to be low. The shape is green because it is in the first layer, and as we sterilize, the color changes and the saturation increase.

This table 3 shows the name of each well and its schedule. The first well was drilled on 1/October/2022, and after three months, exactly 1/April/2022, the second well was drilled, and so on, and after every three months, a new well is drilled until it reaches 9 producing wells. Any preparation of a well requires three months to complete all operations, from drilling, completion and installation of equipment to the production stage. After the ninth well, we start drilling the wells that are being injected, namely wells 10, 11, and 12, and with the same previous steps, after every three months, we drill the well.

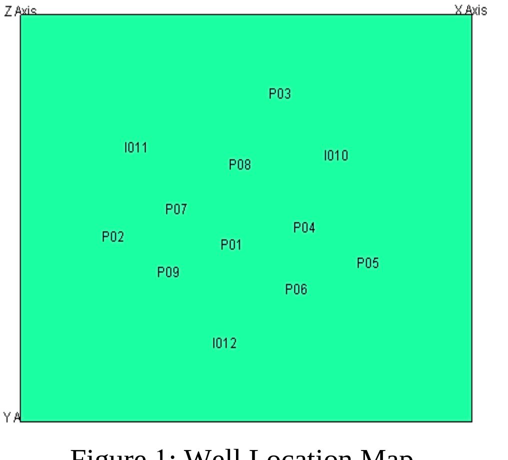

Figure 1: Well Location Map

The transmittance is completely homogeneous in the direction of X=200md as shown in the figure 2. The gas saturation from 0.12000 to 0.666015. We notice a difference in the percentage of gas saturation in all layers of the reservoir. The water saturation in the reservoir from 0.30151 to 0.82000. Water saturation in the reservoir from 0.30151 to 0.82000. Water saturation varies in the reservoir layers. The figure 3 shows the pressure value in the reservoir before the production process, from 56.9 to 2951.9 psia.

Table 3: Injection and Production

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Open Date	Well Name	Well Type
01-OCT-22	P01	Production
01-JAN-23	P02	Production
01-MAR-23	P03	Production
01-JUL-23	P04	Production
01-OCT-23	P05	Production
01-JAN-24	P06	Production
01-APR-24	P07	Production
01-JUL-24	P08	Production
01-OCT-24	P09	Production
01-JAN-25	I010	Injection
01-APR-25	I011	Injection
01-JUL-25	I012	Injection

PRIMARY RECOVERY:

Production Well Names and Schedule from 11 - 2022 to 01 – 2070: After completing drilling the production wells, we study the production forecast from (2022-11) to (2070-1) by the natural forces of the reservoir. In Table4, the first well is drilled on (1-Oct-22), after 3 months, production starts from the second well on (1-Jan-22) as shown in the table 4. Because the process of drilling and completing wells takes about 3 months. Water injection begins with a direct pressure drop to increase and maintain pressure.

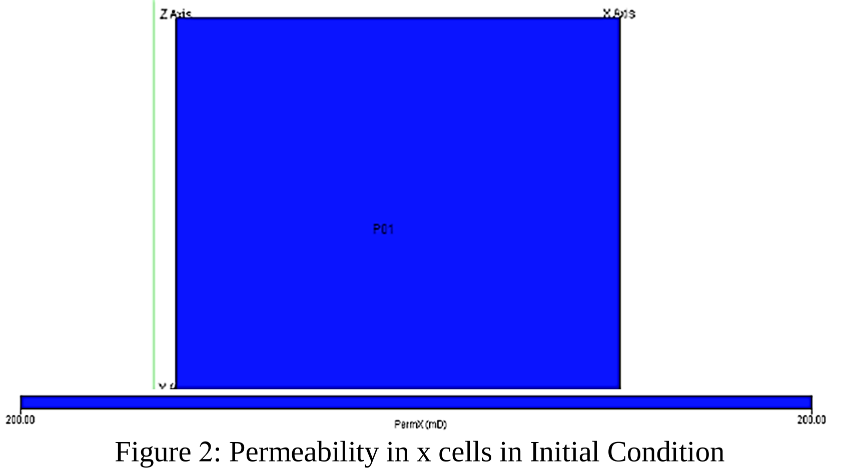

Figure 2: Permeability in x cells in Initial Condition

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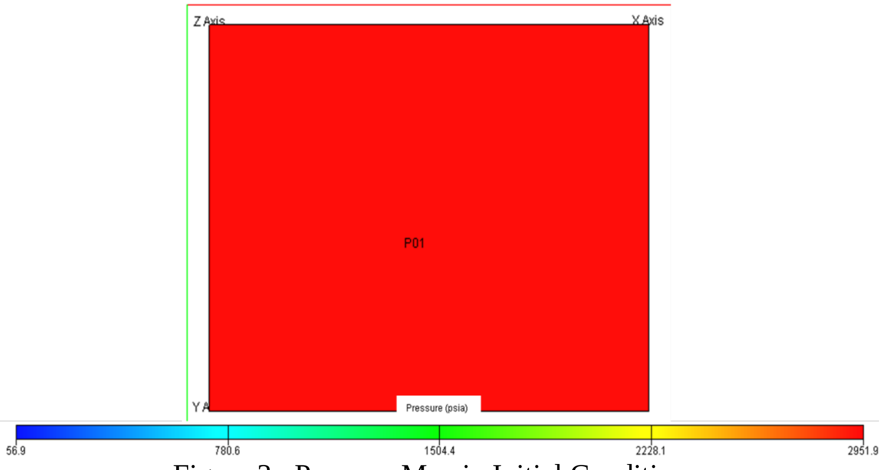

Figure 3: Pressure Map in Initial Condition

Table 4:Well Production Prediction From 11 - 2022 to 01 – 2070

Open Date	Well Name	Well Type
01-OCT-22	P01	Production
01-JAN-23	P02	Production
01-MAR-23	P03	Production
01-JUL-23	P04	Production
01-OCT-23	P05	Production
01-JAN-24	P06	Production
01-APR-24	P07	Production
01-JUL-24	P08	Production
01-OCT-24	P09	Production

Field Oil Production Rate at Primary Recovery (FOPR): This figure shows the relationship between FOPR VS Time (2022-2070) as shown in the figure 4. The field production is considered simple and shows an increase in production when drilling each well (9 production wells). Note the drop-in pressure. The final results show the cause of the pressure drop, whether the reason is the increase in water or gas production. And we determine which (Recovery) is important in this case.

Field Gas Production Rate at Primary Recovery (FGPR): The figure 5 shows the relationship between FGOR VS Time. We notice an increase in gas production to about 100 mm. It is possible to benefit from them and re-inject them into the reservoir. It is also possible to add some of the gases resulting from the emissions and add them to the re-injected gas and benefit from it.

Field Gas Production Total at Primary Recovery (FGPT): The figure 6 shown shows the (FGPT VS DATE) relationship. The total amount of gas produced (cumulative) will reach about scf100 in the year 2070.

Field oil Recovery at Primary Recovery (FOE): The figure 7 shows the relationship (FOE vs DATE). And the production rate is 0.03, meaning that the remaining in the reservoir is about 97%. In this case, we start secondary recovery and Gas injection operations.

Field Pressure at Primary Recovery (FPR): The figure 8 shows the relationship between FPR VS T. We notice a decrease in pressure from (psi2950) to (psi100), which means that the main problem in the reservoir is the drop-in pressure, which means that the reservoir needs (Secondary Recovery), we use (Gas injection).

Field Water Production Total at Primary Recovery (FWPT): The total amount of produced water (cumulative) will reach in the year 2070. It is considered a large amount of cumulative water production, reaching in 2070 to about 300,000,000 barrels as shown in the figure 9.

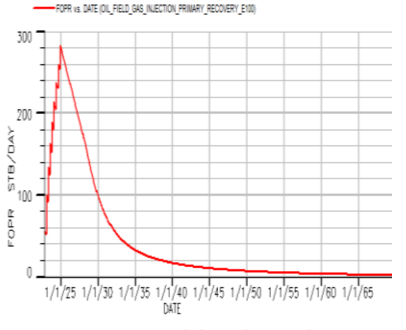

Figure 4: Field Oil Production Rate

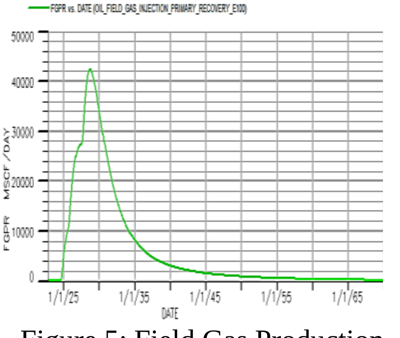

Figure 5: Field Gas Production Rate

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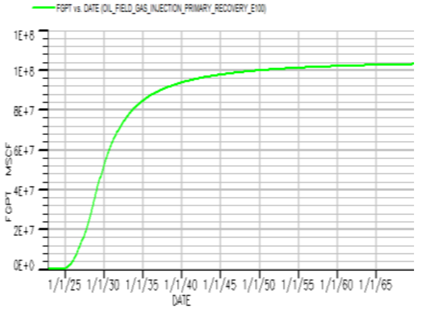

Figure 6: Field Gas Production Total

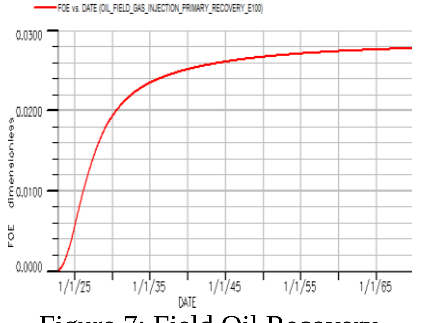

Figure 7: Field Oil Recovery

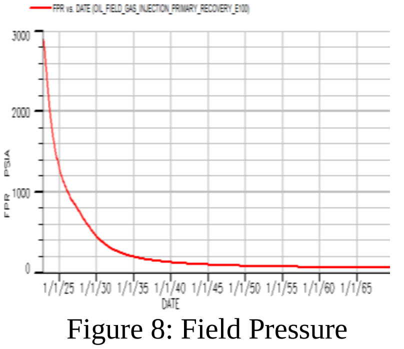

Figure 8: Field Pressure

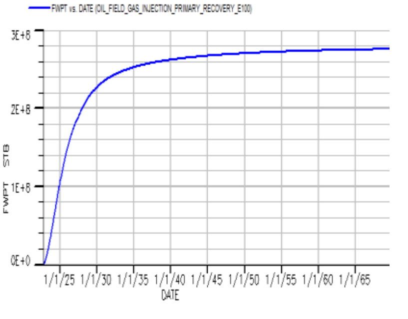

Figure 9: Field Water Production Total

SECONDARY RECOVERY:

Optimization of Gas Injection Rate: In the gas injection process, 3 wells are drilled and the injection process takes place through them. The following table shows a group of 15 cases. Each case includes 3 injection wells, through which gas is injected in equal quantities. Table 5 showed the first case, 1,000,000 SCF of gas is injected per day into each well. The total gas injection for all wells is 3000000SCF per day. In the fifteenth case, we increase the rate of gas injection so that the total gas injection for the field is 45,000,000 SCF per day, because in the natural production of the field, gas production reaches 4000Mscf/day. Through these different gas injection rates, we choose the best gas injection rate.

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Table 5: Gas Injection Rate at Gas Injection

NO	Well Name	Gas Injection Rate per Well	Total
		SCF-DAY	SCF-DAY
Case#1	I010	1000000	3000000
	I011	1000000	
	I012	1000000	
Case#2	I010	2000000	6000000
	I011	2000000	
	I012	2000000	
Case#3	I010	3000000	9000000
	I011	3000000	
	I012	3000000	
Case#4	I010	4000000	12000000
	I011	4000000	
	I012	4000000	
Case#5	I010	5000000	15000000
	I011	5000000	
	I012	5000000	
Case#6	I010	6000000	18000000
	I011	6000000	
	I012	6000000	
Case#7	I010	7000000	21000000
	I011	7000000	
	I012	7000000	
Case#8	I010	8000000	24000000
	I011	8000000	
	I012	8000000	
Case#9	I010	9000000	27000000
	I011	9000000	
	I012	9000000	
Case#10	I010	10000000	30000000
	I011	10000000	
	I012	10000000	
Case#11	I010	11000000	33000000
	I011	11000000	
	I012	11000000	
Case#12٩	I010	12000000	36000000
	I011	12000000	
	I012	12000000	
Case#13	I010	13000000	39000000
	I011	13000000	

	I012	13000000	
Case#14	I010	14000000	42000000
	I011	14000000	
	I012	14000000	
Case#15	I010	15000000	45000000
	I011	15000000	
	I012	15000000	

Field Gas Injection Rate at Gas Injection (FGIR): The figure 10 shows a relationship between FGIR VS Date. Each line indicates the Injection Rate used in the well.

Field Gas Injection Total at Gas Injection (FGIT): The figure 11 shows a relationship between FGIT VS Date. The total amount of injected gas in the period from 2022-2070 is cumulative. We note that the greater the amount of injected gas, the greater the cumulative gas production.

Field Gas Production Rate at Gas Injection (FGPR): The figure 12 shows a relationship between FGPR VS Date. The rate of gas production after Gas Injection is about 80 MM SCF/Day.

Field Oil Production Rate at Gas Injection (FOPR): The figure 13 shows a relationship between FOPR VS DATE. The increase in the process and the quantity of Gas Injection increase with the production.

Field Oil Production Total at Gas Injection (FOPT): The amount of total (cumulative) produced oil increases with the increase in the amount of gas injection as shown in the figure 14.

Field Water Production Rate at Gas Injection (FWPR): The following figure shows the relationship between FOR and time. The amount of water production is very weak due to the injection of gas into the reservoir as shown in the figure 16.

Field Water Production Total at Gas Injection (FWPT): The following figure 17 shows the relationship between FWPT vs DATE. The amount of water produced (cumulative) increases with increasing Gas injection.

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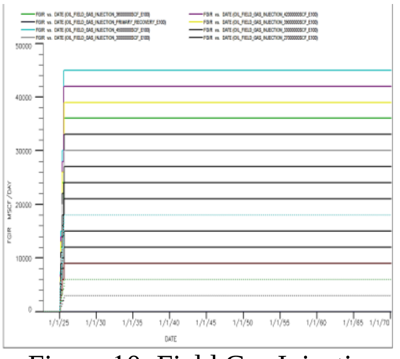

Figure 10: Field Gas Injection Rate at Gas Injection

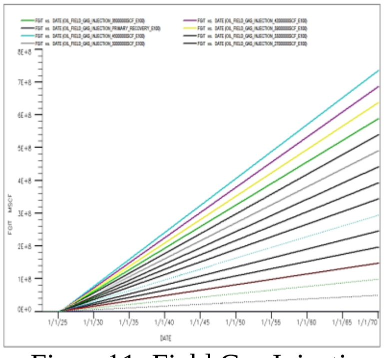

Figure11: Field Gas Injection Total at Gas Injection

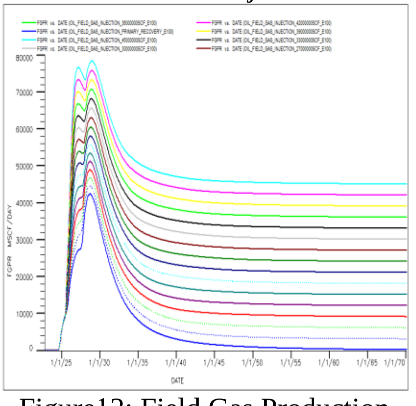

Figure12: Field Gas Production Rate at Gas Injection

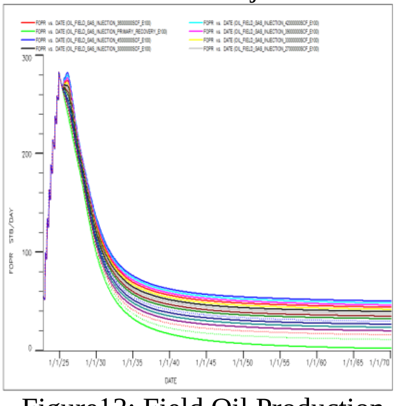

Figure13: Field Oil Production Rate at Gas Injection

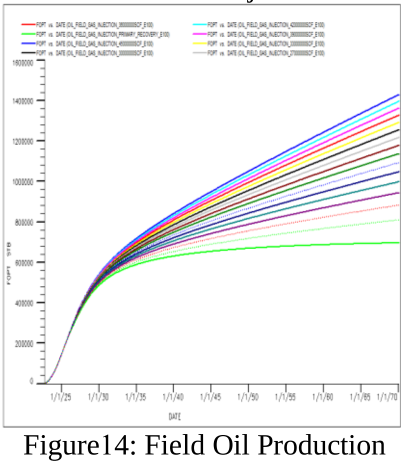

Figure14: Field Oil Production Total at Gas Injection

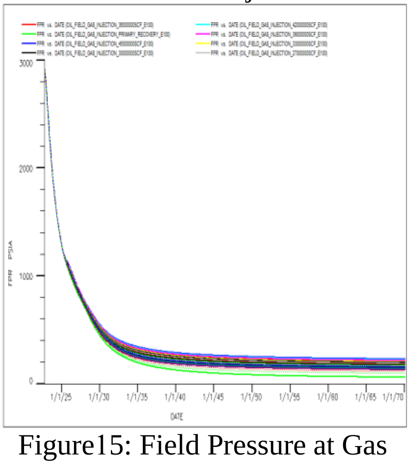

Figure15: Field Pressure at Gas Injection

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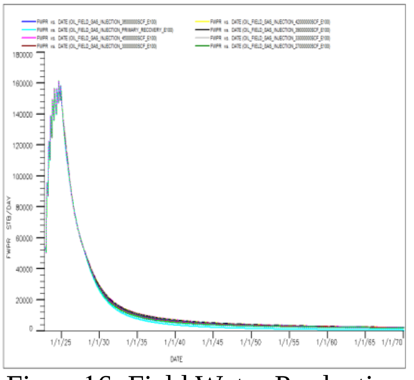

Figure16: Field Water Production Rate at Gas Injection

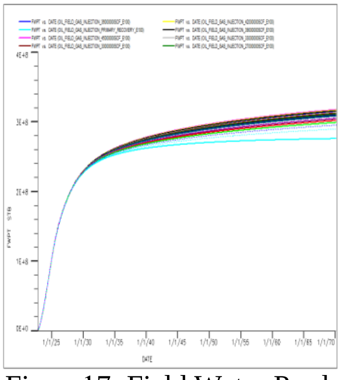

Figure17: Field Water Production Total at Gas Injection

Oil Saturation Map at Gas Injection: Oil saturation at 2070 at 45 mm SCF/day injection rate. The saturation of the layers is between 0 to 0.09982 as shown in the figure 18.

Gas Saturation Map at Gas Injection: Gas saturation in the year 2070 with an injection rate of 45 mm scf. The saturation of the layers is between 0.97982 to 0.12000 as shown in the figure 19.

Water Saturation Map at Gas Injection: Water saturation at 2070 at 45 mm SCF/day injection rate. The saturation range is between 0.82000 to 0.12000 as shown in the figure 20.

Rock Permeability: The following table 6 shows the effect of reservoir depletion on horizontal and vertical depletion. In the first case, the permeability in the horizontal direction x and y is equal to 100md, and in the vertical direction z is equal to 10md. In the second case, the permeability in the horizontal direction x and z is equal to 200md, and in the vertical direction z is equal to 20md. In the third case, the permeability in the horizontal direction x and z is equal to 300md, and in the vertical direction z is equal to 30md. In the fourth case, the permeability in the horizontal direction x and z is equal to 400md, and in the vertical direction z is equal to 40md. Through this permeability, it will show us what is the effect of permeability on production. We notice that the value of z is one tenth of the value of x, y in each case.

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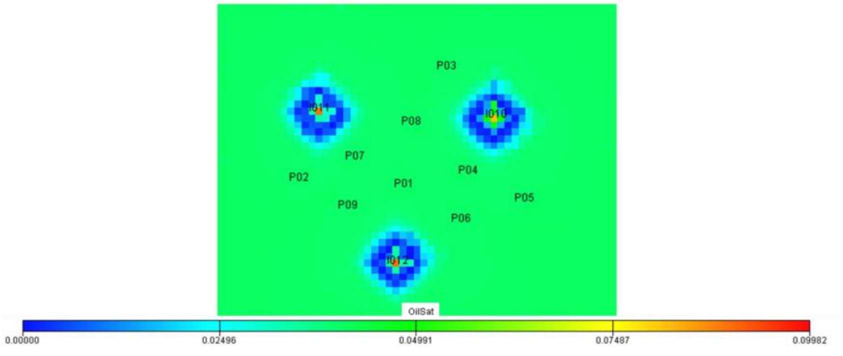

Figure 18: Oil Saturation Map at Gas Injection

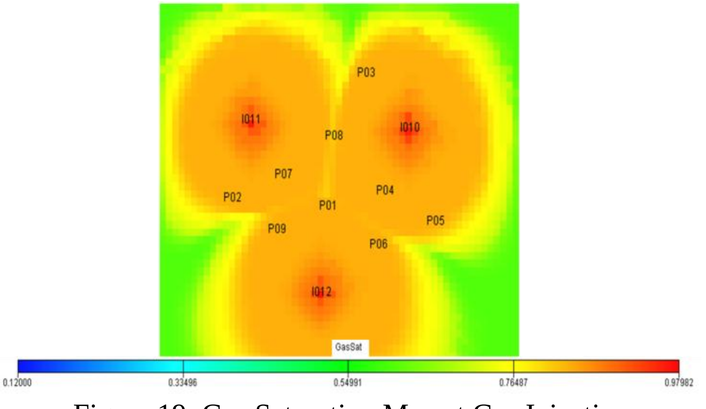

Figure 19: Gas Saturation Map at Gas Injection

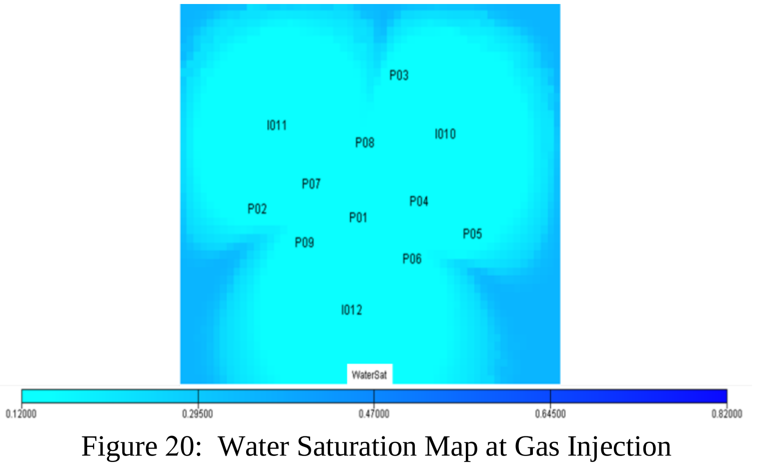

Figure 20: Water Saturation Map at Gas Injection

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Table 6: Rock Permeability Cases

Cases	Case#1	Case#2	Case#3	Case#4
Rock Permeability in X	100	200	300	400
Rock Permeability in Y	100	200	300	400
Rock Permeability in Z	10	20	30	40

Field Oil Production Rate at different Rock Permeability (FOPR): The following figure 21 shows the relationship between (FOPR vs DATE). From the figure, we notice that a set of curves, and each curve represents a specific case. The first case when the depletion value is equal to 150, which is the lowest value of the depletion. We also note from the figure that it is the lowest rate of oil production by approximately 150 barrels per day. The blue curve represents the second case when the depletion value is equal to 200. We also note from the figure that it is the rate of oil production by approximately 300 barrels per day. The green curve represents the third case when the depletion value is equal to 300. We also note from the figure that it is the rate of oil production by approximately 400 barrels per day. The red curve represents the fourth case when the depletion value is equal to 400. We also note from the figure that it is the rate of oil production by approximately 500 barrels per day. Through the figure, we notice that the higher the rock permeability, the higher the oil production rate.

Field Gas Production Rate at different Rock Permeability (FGPR): Figure 22 shows the relationship between FGPR Vs DATE. In this figure, we notice the difference in the rate of gas production in all cases. The pink color curve represents the first case when depletion is equal to (x=100, y=100, z=10). In this case, the gas production rate is 20000Mscf/Day, which is the weakest production rate. The rate of gas production increases in the second case when the depletion equals (x=200, y=200, z=20) to about 40000Mscf/Day. Besides the production rate increases more in the third case when the depletion (x=300, y=300, z=30) is more than 60000Mscf/Day. The green color represents the third case when depletion is equal to (x=400, y=400, z=40), and the highest rate of gas production is estimated at .84000Mscf/Day. We note that with the increase in the depletion of rock, the rate of gas production increases.

Oil Recovery Factor at different Rock Permeability (FOE): Figure 23 shows the relationship between (FOE Vs DATE). We note from the figure that the oil recovery coefficient is affected by the depletion of rocks. When rock depletion increases, oil recovery increases. We notice that the red curve represents the fourth case, which is the largest depletion of rocks. The percentage of oil recovery is higher, while it is less valuable in the first case when it is the lowest value of depletion of rocks.

Field Pressure at different Rock Permeability (FPR): The following figure 24 shows the relationship between FPT vs Date. The red curve represents the fourth case when the depletion is equal to 400. We note that the greater the depletion of rocks, the greater the production and the lower the pressure. In the first case, the highest-pressure value, the lowest exhaust value, and the lowest production rate are recorded. That is, the greater the permeability, the greater the pressure loss due to the increase in the high production rate, and it is considered an inverse relationship between pressure and rock permeability.

Field Water Cut at different Rock Permeability (FWCT): Figure 25 shows the relationship between (FWCT Vs DATE). The WC ratio is approximately equal in all cases. The ratio of WC in any reservoir is equal to 1, but in the figure, it is more than 1, which means that the amount of W is very large in each case.

Field Water Production Rate at different Rock Permeability (FWPR): Figure 26 shows the relationship between (FWPR Vs DATE), which is the rate of water production. Note the difference between the rates of water production in all cases. The highest rate of water production is in the fourth case, estimated at 240,000 STB/day. The lowest rate of water production is in the first case and is estimated at 100,000STB/day. The greater the depletion of rocks, the rate of water production increases, which is a direct method relationship between water production and permeability.

Field Oil Production Total at different Rock Permeability (FOPT): Figure 27 shows the relationship between (FOPT Vs

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DATE) is the total amount of oil produced (cumulative). The red curve represents the fourth case when the transmittance is large. In this case, the cumulative production rate is greater than about 700,000STB. The lowest cumulative production rate is in the first case, when depletion is small. That is, the higher the permeability, the more cumulative oil production.

Field Water Production Total at different Rock Permeability (FWPT): Figure 28 shows the relationship between (FWPR Vs DATE), which is the cumulative water production rate. In the fourth case, the highest cumulative water production rate is about 3E + 8 STB. In the second, third and fourth cases, the cumulative water production rate is very close, while in the first case the cumulative water production is the lowest. This means that the greater the depletion of rocks, the higher the rate of cumulative water production.

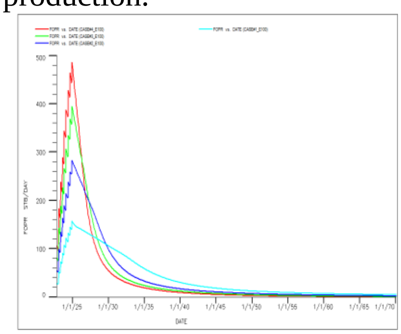

Figure 23: Field Oil Production Rate at different Rock Permeability

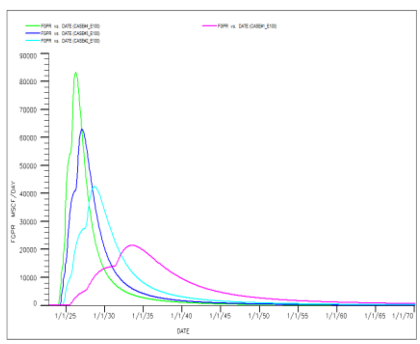

Figure 24: Field Gas Production Rate at different Rock Permeability

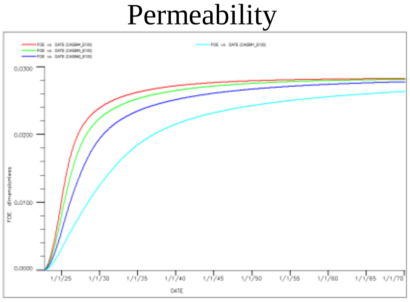

Figure 25: Oil Recovery Factor at different Rock Permeability

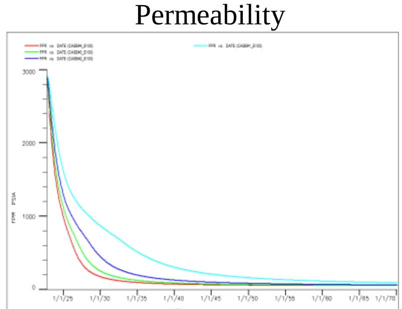

Figure 26: Field Pressure at different Rock Permeability

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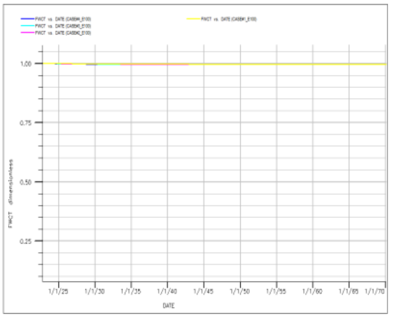

Figure 27: Field Water Cut at different Rock Permeability

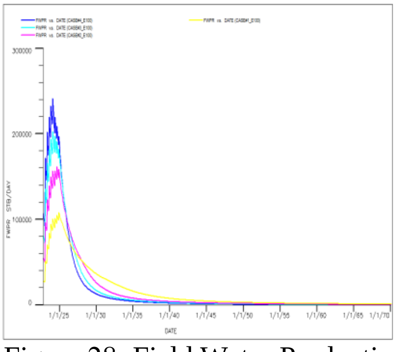

Figure 28: Field Water Production Rate at different Rock Permeability

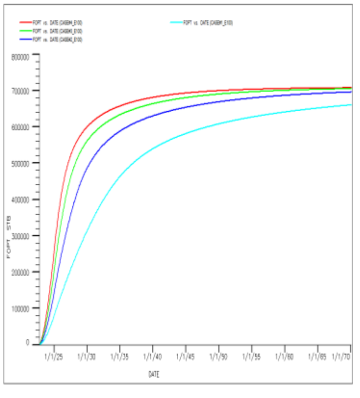

Figure 29: Field Oil Production Total at different Rock Permeability

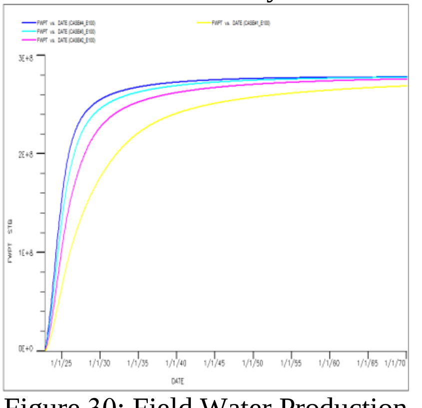

Figure 30: Field Water Production Total at different Rock Permeability

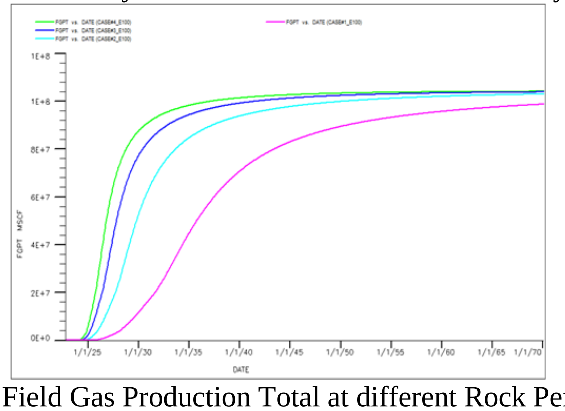

Figure 31: Field Gas Production Total at different Rock Permeability

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Field Gas Production Total at different Rock Permeability (FGPT): Figure 29 shows the relationship between (FGPT Vs DATE) and the cumulative gas production rate. The cumulative gas production in the second, third and fourth cases is close, but the highest in the fourth case due to the high depletion. In the first case, the cumulative gas production rate is lower. The relationship between cumulative gas production and permeability is a direct relationship, the higher the permeability, the higher the cumulative production rate.

Oil Saturation at different Rock Permeability (So): The following figure 30 shows the percentage of oil saturation in the rocks, and it ranges from 0.029 to 0.060. We notice that the oil saturation in the reservoir is not homogeneous and is different in the reservoir layers.

Gas Saturation at Different Rock Permeability (Sg): The figure 31 shows the percentage of gas saturation in the reservoir from 0.12 to 0.66. We notice the difference in the percentage of gas saturation in the reservoir layers.

Water Saturation at Different Rock Permeability (Sw): figure 34 shows the water saturation in the reservoir from 0.29 to 0.82. The water saturation is different in the reservoir layers.

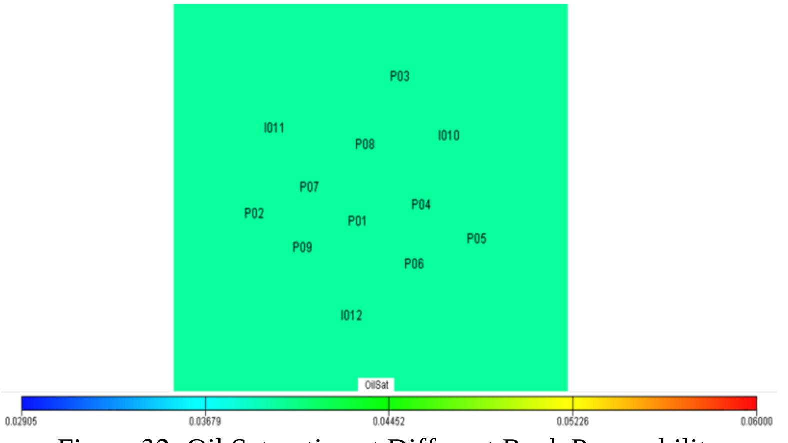

Figure 32: Oil Saturation at Different Rock Permeability

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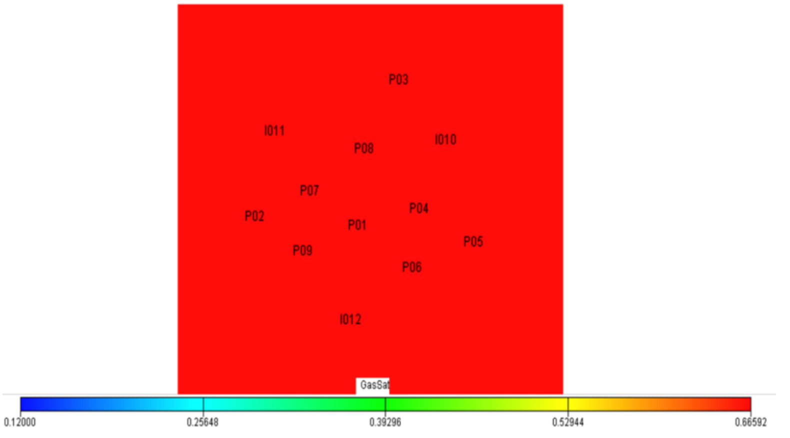

Figure 33: Gas Saturation at Different Rock Permeability

Comparison of Rock Permeability Results: The following table 6 shows the final results for all cases. In the first case, when the permeability is equal to (X=100, Y=100, Z=10), we note that:

- The highest FOE was (0.02634).
- The highest FOPR value was the STB (659994.56).
- The highest FGPR value was (Mscf 98716880).
- The highest FRP value was (88.74 psi).
- The highest (FWCT) value was (0.99527).
- The highest value (FWPT) was STB (268573020).

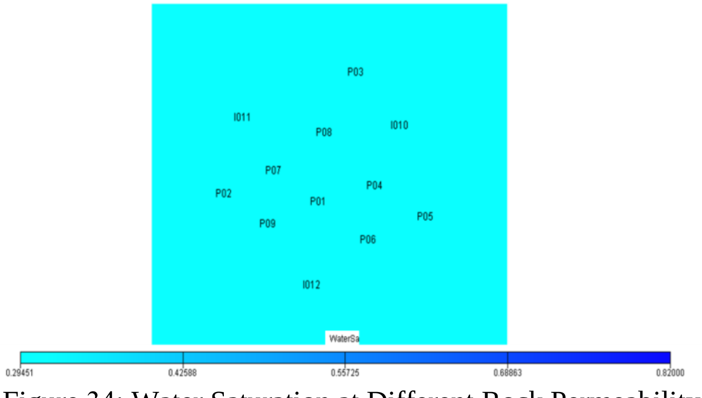

Figure 34: Water Saturation at Different Rock Permeability

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In the second case, when the permeability is equal to (x=200, y=200, z=20), we note that:

- The highest percentage (RF) or (FOE) was (0.02776).
- The highest FOPT value was (695500).
- The highest value (FGPT) was (102971740).
- The highest FPR value was PSI (58.48).
- The highest value (FWCT) was (0.99498).
- The highest value (FWPT) was (275,640,000).

In the third case, when the permeability is equal to (x=300, y=300, z=30), we note that:

- The highest value (RF) was (0.02812).
- The highest FOPT value was (704561.19).
- The highest value (FGPT) was (103839020).
- The highest FRP value was (52.43).
- The highest FWCT value was (0.99491).
- The highest FWPT value was (277286530).

In the fourth case, when the permeability is equal to (x=400, y=400, z=40), we note:

- The highest value (RF) was (0.02823).
- The highest FOPT value was (707234).
- The highest value (FGPT) was (104083070).
- The highest FPR value was (PSI) 50.75.
- The highest FWCT value was (0.99489).
- The highest FWPT value was (277710940).

Table 5: Comparison of Rock Permeability Results

CASE	Case#1	Case#2	Case#3	Case#4
FOE	0.02634	0.02776	0.02812	0.02823
FOPT	659994.56	695500	704561.19	707234
FGPT	98716880	102971740	103839020	104083070
FPR	88.74	58.48	52.43	50.75
FWCT	0.99527	0.99498	0.99491	0.99489
FWPT	268573020	275640000	277286530	277710940

Comparison of Oil Recovery Factor at Rock Permeability Results (FOE): Next Figure 33 shows the comparison of oil

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recovery factor (FOE) at rock permeability results. We note that the increase in FOE was simple due to the increase in permeability, and the highest percentage was in the fourth condition.

Comparison of Field Oil Production Total at Rock Permeability Results (FOPT): Next Figure 34 shows the comparison of field oil production total (FOPT) at rock permeability results. We note that there is a difference between the first and fourth cases in the amount of cumulative oil production. In the first case, the cumulative oil production is the lowest value (559,994.56 barrels), and in the fourth case, the cumulative oil production is the largest value, which is (707,234 barrels). The rate of oil production increases. The cumulative increase in the permeability of reservoir rock.

Comparison of Field Gas Production Total at Rock Permeability Results (FGPT): Next Figure 35 shows the comparison of field gas production total (FGPT) at rock permeability results. The highest value of cumulative gas production is in the fourth case, with a value of 104,083,070, and the lowest value in the first case, with a value of 98,716,880. Cumulative gas production increases with increasing rock permeability.

Comparison of Field Pressure at Rock Permeability Results (FPR): Next Figure 36 shows the comparison of field pressure (FPR) at rock permeability results .We note that it differs from the rest of the results, as the highest-pressure value is in the first case and the lowest value is in the fourth case, due to the amount of production. The lower the permeability, the higher the pressure and the lower the production. The higher the permeability, the higher the production and the lower the pressure.

Comparison of Field Water Cut at Rock Permeability Results (FWCT):

Next Figure 37 shows the comparison of Field Water Cut (FWCT) at rock permeability results.

Comparison of Field Water Production Total at Rock Permeability Results (FWPT): The cumulative water production (FWPT) in the first case is equal to (268,573,020 barrels), which is the lowest value. In the second case, it increases to equal 200 to

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(268,573,020 barrels). In the third case, it increases to equal 300 to (277,286,530 barrels). In the fourth case, the highest amount of cumulative water production is (277,710,940 barrels) when the Rock Permeability is 400. We note after this evaluation that the cumulative water production increases with the increase in rock permeability as shown in the figure 38.

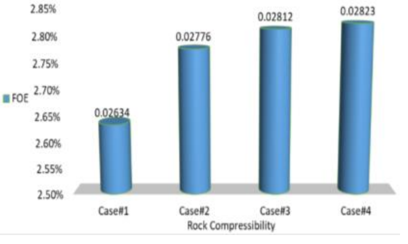

Figure 33: Comparison of Oil Recovery Factor at Rock Permeability Results

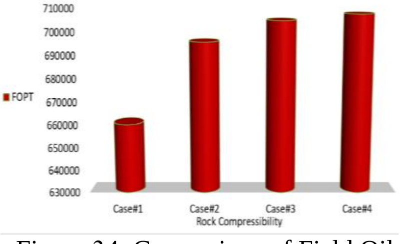

Figure 34: Comparison of Field Oil Production Total at Rock Permeability Results

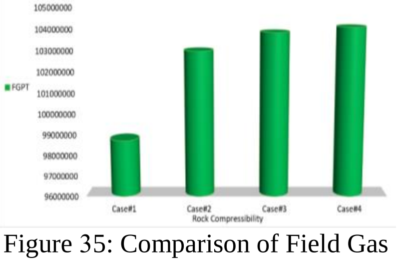

Figure 35: Comparison of Field Gas Production Total at Rock Permeability Results

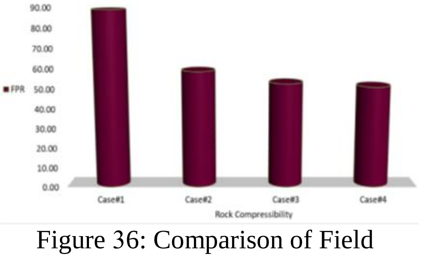

Figure 36: Comparison of Field Pressure at Rock Permeability Results

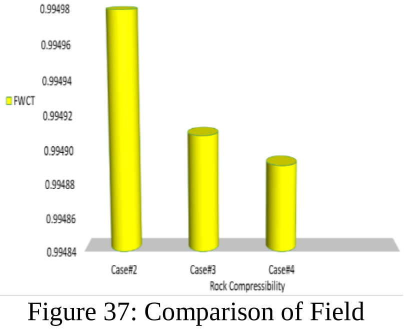

Figure 37: Comparison of Field Water Cut at Rock Permeability Results

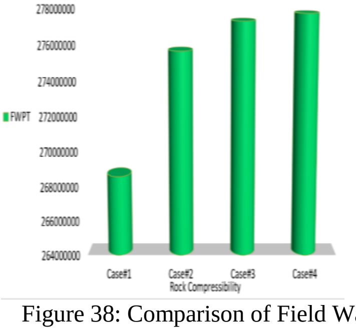

Figure 38: Comparison of Field Water Production Total at Rock Permeability Results

CONCLUSION:

We have investigated is to investigate the effect of the reservoir rock permeability on gas injection and the optimum injection rate to get the optimum recovery. Through the results, we notice that the higher the rock permeability, the higher the oil production rate. We conducted that with the increase in the permeability of reservoir rock, the rate of gas production increases. The percentage of oil recovery is higher, while it is less valuable in the first case when it is the lowest value of depletion of rocks. The greater the permeability of rocks, the rate of water production increases, which is a direct method relationship between water production and permeability. In the first case, the cumulative oil production is the lowest value (559,994.56 barrels), and in the fourth case, the cumulative oil production is the largest value, which is (707,234 barrels). The rate of oil production increases. The cumulative increase in the permeability of reservoir rock. Cumulative gas production increases with increasing rock permeability. The lower the permeability, the higher the pressure and the lower the production. The higher the permeability, the higher the production and the lower the pressure. We note after this evaluation that the cumulative water production increases with the increase in rock permeability.

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