Investigation the highest rate of the water alternating gas injection recovery factor (WAG) in ratio with injection of water or gas

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Abstract: Based on increase of hydrocarbon development in the world, it's tending to increase the production of hydrocarbon fields were considered further than before. Therefore, new recovery methods are proposed and used. One of the common methods for increasing the injection reservoir recovery factor (WAG) is injection of gas and water to them. In this way, water and gas are injected frequently and in a local repository. The main objective of the process of periodically injecting water and gas injection, gas injection, water efficiency by increasing the contact area injected fluid reservoir management and reservoir oil mobility ratio between injected fluid and the motion of the front is stable. Miscible water alternating gas injection methods, Immiscible, hybrid, hybrid, and online selection is done online. In this study, different methods of injection and water alternating gas reservoirs in the National Iranian Oil Company ECLIPSE 100 simulated using commercial software, and gain shaping and influencing parameters such as cumulative production cycles (cycles), and method of administration (Immiscible, hybrid (blended), and optional online) were studied. The single injection methods for water, gas injection and water alternating gas for optimum EOR method were compared. Finally, water alternating gas injection scenarios designed to separate water and gas injection, four-and five-spot injection patterns, Factor productivity, Cumulative production and remaining oil saturation model to determine the optimal injection methods were calculated and compared. The results show that if the parameters affecting water alternating gas injection well designed and chosen, factor productivity and production in this way than in a separate injection of water and gas.
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Keywords: Alternating water and gas injection, water injection, gas injection, immiscible injection, cycle, WAG

Introduction

Generally, the exploitation and production, reservoir pressure decreases, leading to gas tank production is reduced. The role of oil and oil products in the world economy, World and take appropriate measures and optimal recovery methods to improve efficiency and increase productivity, the top oil-producing countries are located. Due to the pressure of the reservoir, EOR methods for stabilizing and increasing pressure are felt more than ever before. Despite the country's gas reserves, recovery methods such as water alternating gas injection (WAG) with a higher recovery factor than conventional miscible, immiscible gas is essential. Water and gas injection WAG at specified periods of time are alternately injected into the reservoir. This method increases the efficiency of the injected fluid contact surface areas, especially areas that have not been swept by the gas moving upward) in gas (or water to move down) water the injection of (who have not had affected. In this way, the gas is injected into the cavity occupied with high oil saturation and thus to move the oil tank is not part of the broom. Then, with the remaining oil and water injection as well as enclosed in the reservoir rock movement and reduces oil saturation and less efficiency is produced. After addition of water and gas injection prevents the increase in gas saturation and relative mobility, control and reduced mobility, and creates the sustainable movement in front of the tank. The battle to prevent the premature phenomena fingering gas wells is produced. In general, the residual oil saturation than conventional water injection, gas injection (WAG). Therefore, this method has the potential to increase the efficiency of moving macroscopic and microscopic repository. In this way, Cole, in the late '60s with laboratory and field studies, increasing productivity and production in the region of three phase surface tension of the gas in the tank - as the oil. He based his observations in a three-phase system consisting of water, oil and gas, the fluid tends to the equilibrium configuration with the lowest energy, surface tension, gas system - the lower the surface tension of oil and gas - water can be assumed. In this case, the gas molecules are forced into close contact with oil and oil droplet size is increased. The displacement of oil by water injection in the presence of gas bubbles in the oil droplets, the amount of oil remaining in the tank to reduce the amount of gas bubbles. Water alternating gas injection and thus reduces the residual saturation and reservoir productivity index is increased.

1- Repository Profile

The primary reservoir of oil and gas in place of 2.6 billion barrels, respectively, and 2.78 billion cubic feet at standard conditions is standard. Based on this information, in order to measure the pressure of the initial reservoir pressure reservoir in depth of 5767 feet, on the basis of 5400 feet was considered. Based on rock samples obtained from the drilling of wells, petrochemical evaluation of core samples taken from the wells and the wells and the reservoir of carbonate rocks, is relatively compact form it. To avoid the complexity of modeling the petrochemical characteristics of the rock layer is assumed to be constant. Petrochemical properties of the different layers are shown in Table PROPS. PVT experiments are conducted on four samples of fluid taken from the same reservoir tank shows the saturation pressure of the initial reservoir conditions under saturated and supersaturated gas cap is missing. An important parameter of the fluid pressure on the characteristic of the model is shown. Based on DST and RFT tests in wells and petrochemical plot of the original water - the depth of the oil tank under the sea level is 2585 feet. In order to simulate two-phase fluid behavior in the reservoir capillary pressure and relative permeability curves for water phases - oil, oil and gas have been measured in the laboratory were used. Dynamic curves used in the simulation are shown.

1-1 History of production and reservoir pressure

Production from the reservoir through the hole (1) the rate of 1971 stb/day, 4084 began. At different times according to the conditions prevailing in the reservoir tank and wells production rate has changed, so that between 1980 and 1984 because of the general policies of the country and no need for oil production rate has not been productive reservoir tank and virtually zero. In mid-1984 until 2002, the reservoir has restarted production at different rates. Production history of the reservoir is shown in Fig. It should be noted production history of the reservoir and prediction of reservoir performance in 2002 was carried out from 2002 onwards. As mentioned before producing the initial pressure of the reservoir is 5767 feet. Production started in 5767 with an initial reservoir pressure of pressure foot, my foot decreased from 2002 to 3785. In other words, the production of 0.24 billion barrels of oil pressure has fallen 1982 feet.

1-2 Specifications and Description of Model

The model input data block type, block number, block size, depth of reservoir simulation model, fracture dimensions, porosity and permeability rock crack and generally determine all parameters of the reservoir are. Here, we investigate how modeling and simulation parameters used in the model are stated. Characteristics of the reservoir simulation has been used as follows: a tank-type piers and network grid layout in line with the x and y and z respectively 22, 8 and 30 blocks on which the piers of the tank 15, the layer that the matrix has been split into 15 layers. In all layers of the matrix permeability is considered constant, but the gap is different permeability layers, conversely, permeability and porosity of the matrix layer is variable but the gap is fixed numerical values are given in Table 2. Relative permeability (for oil, gas and water) for matrix and fractures in terms of saturation, other information that must be entered into the model was considered. It is worth noting that the two regions should be considered for each type of stone: the relative permeability of water - relative permeability to oil and gas - oil. The capillary pressure of the reservoir rock surface tension and pressure changes must be modeled. In order to define the motion of the fluid in the gap of the model was given a stone water relative permeability curve – oil, the gas in terms of the has been shown to saturation. It is noteworthy that the capillary pressure in the gap was zero. Initial pressure, saturation pressure, initial oil and water saturation in the matrix and fractures, and pressure at the depth of the base depth, surface - water and oil reservoir crest generally, all the information about the initial conditions of the tank (before operation) any other information that must be entered. PSI 5767 ft5400 depth below sea level of the initial pressure and the surface of the water - oil ft6569 below sea level to the data model was considered. Due to lack of gas cap gas and oil in the reservoir surface to the depth of the reservoir crest was placed. To start the simulation scenarios and evaluate all relevant information must be entered into the wells and the operations that are described next season, depending on the scenario in place. Information such as grouping of wells, production wells start date, dates to get the desired output, and type of wells) or potential manufacturing (location of wells, limiting factors for controlling operation of wells for water-cut or gas compared to the oil production, the injected fluid, the minimum flow rate for production wells or injection wells at any time of closing, or opening them again if needed. built a model which consists of 19 wells, the wells in two groups were defined the first group includes the oil production wells, injection wells, and the second group. maximum allowable gas production rate, equivalent to 1,300 cubic feet per barrel of oil, water cut and a minimum of 5% of the daily production rate of 1,000 barrels of oil per day were considered. Reservoir rock and fluid properties are shown in the following tables and charts:

Table 1: Porosity, permeability and thickness ratio of net to gross reservoir

NTG	Kz(md)	Kx=Ky(md)	ϕ	Layer No.	
0.4	2	2	0.03	1	Matrix
0.4	2	2	0.05	2	
0.4	2	2	0.02	3	
0.4	2	2	0.08	4	
0.4	2	2	0.02	5	
0.4	2	2	0.02	6	
0.4	2	2	0.04	7	
0.4	2	2	0.06	8	
0.4	2	2	0.01	9	
0.4	2	2	0.04	10	
0.4	2	2	0.05	11	
0.4	2	2	0.03	12	
0.4	2	2	0.05	13	
0.4	2	2	0.04	14	
0.4	2	2	0.03	15	
0.4	500	5000	0.005	16	Gap
0.4	300	3000	0.005	17	
0.4	800	8000	0.005	18	
0.4	100	1000	0.005	19	
0.4	200	2000	0.005	20	
0.4	400	4000	0.005	21	
0.4	600	6000	0.005	22	
0.4	200	2000	0.005	23	
0.4	700	7000	0.005	24	
0.4	100	1000	0.005	25	
0.4	700	7000	0.005	26	
0.4	600	6000	0.005	27	
0.4	500	5000	0.005	28	
0.4	400	4000	0.005	29	
0.4	300	3000	0.005	30	

Table 2: Relative permeability and capillary pressure as a function of water saturation in the matrix

sw	krw	kro	Pcwo
0.2	0	1	50
0.227	0.011	0.614	27.025
0.253	0.017	0.539	15.897
0.28	0.021	0.484	10
0.307	0.024	0.436	6.667
0.333	0.036	0.398	4.917
0.36	0.052	0.36	3.25
0.387	0.072	0.324	2.625
0.413	0.095	0.29	2.075
0.44	0.121	0.26	1.825
0.467	0.149	0.223	1.575
0.493	0.18	0.191	1.347
0.52	0.215	0.157	1.208
0.547	0.252	0.124	1.07
0.573	0.294	0.089	0.931
0.6	0.337	0.058	0.792
0.627	0.384	0.027	0.653
0.653	0.434	0.004	0.514
0.66	0.447	0	0.494
1	1	0	0.0248

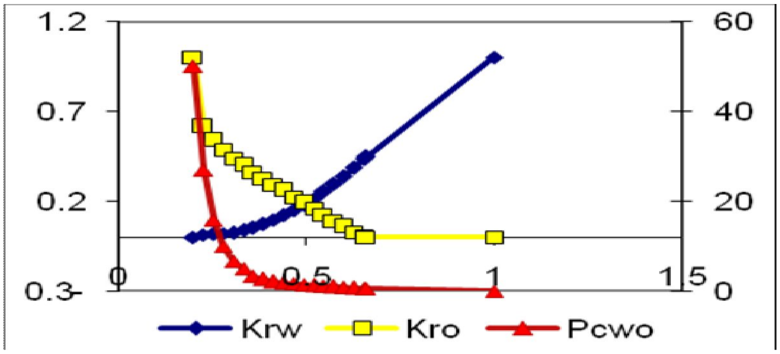

Figure 1: Diagram of relative permeability and capillary pressure as a function of water saturation in the matrix

Table 3: Relative permeability and capillary pressure as a function of water saturation on the split

sw	krw	kro	Pcwo
0	0	1	0
0.1	0	0.9	0
0.2	0	0.8	0
0.3	0	0.7	0
0.4	0	0.6	0
0.5	0.16665	0.5	0
0.6	0.33332	0.4	0
0.7	0.49999	0.3	0
0.8	0.66666	0.2	0
0.9	0.83333	0.1	0
1	1	0	0

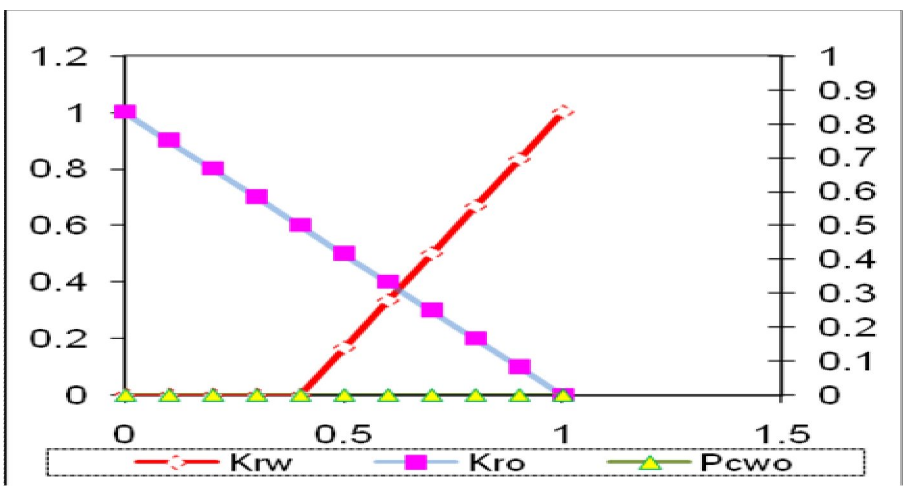

Figure 2: Diagram of relative permeability and capillary pressure as a function of water saturation on the split

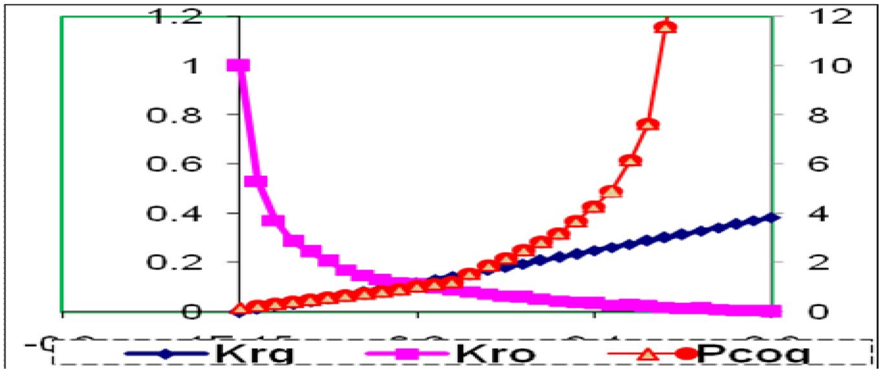

Figure 3: Diagram changes in relative permeability and capillary pressure as functions of gas saturation in the matrix

1-3 History matching of reservoir

After entering the information about how to build a simulation model and completing wells and production history matching in reservoir pressure history was on the agenda. Because of the lack of a strong discharge of gas cap in the reservoir pressure reservoir rock compressibility of the oil initially in place was consistent. The sensitivity analysis results are shown in Fig. As one can see, the best agreement history of rock compressibility Tank 006E-6 and 009 + E2.5957 oil initially in place is obtained.

1-4 Operational conditions

After building the model and the accuracy of the four methods of production, including natural depletion, gas injection, water injection, gas injection, water injection and water alternating WAG studied and carry different scenarios were defined. Problems which mainly occur during the model predictions, conical phenomenon of gas and water was considered. Production constraints to control production conditions in the well bore and reservoir simulation model were defined as follows:

• The minimum oil production rate at reservoir 1000stb / day

• The minimum oil production rate for each well 100stb / day

• The maximum gas-oil ratio wells 1500 scf / stb

The restrictions for the economic production of the tank and prevent damage to surface facilities are located in the model. So if any of the limitations mentioned production conditions in the tank to reach production from the well / reservoir is disconnected. For example, the oil production rate of 100 barrels per day reached in a few wells, the wells are closed. Well when the gas-oil ratio wells, the maximum limit or the maximum water cut is reached, maintenance simulation Wells for deals with this problem and make connections from wells that are most effective in reaching these limits, it automatically closes.

1-5 Types of Oil Production

Natural drainage
Gas Injection
Water injection
Water alternating gas injection and WAG

2- Natural Depletion

As we know, natural of natural forces in the reservoir is used for production. In the reservoir due to the lack of a strong discharge of gas cap rock and fluid expansion mechanisms are produced. During the production history of the reservoir because the reservoir pressure below the saturation pressure at the reservoir crest, secondary gas cap in the reservoir is formed. Activation of secondary gas cap formation mechanism of gravity drainage reservoir tank was part of the generation mechanism of action is. Plot cumulative oil drainage is shown in Figures 4. As can be seen from the figures, the natural drainage of the reservoir in 2018 to 40 thousand barrels per day of oil continues to flow, then the restrictions imposed on the model to control the water-cut gas-oil ratio, tank is disconnected. Reservoir simulation model of cumulative production of 475 million barrels equivalent in this scenario shows. In other words, the ultimate recovery factor of natural depletion scenario 18.35 per cent was considered. An oil recovery factor change with time is shown in Figure 6. Figure 5 shows a graph of pressure drop in the reservoir. Based on the initial reservoir pressure at 5757 feet to 3015 feet by 2018; the pressure decreases which shows in Figure 5.

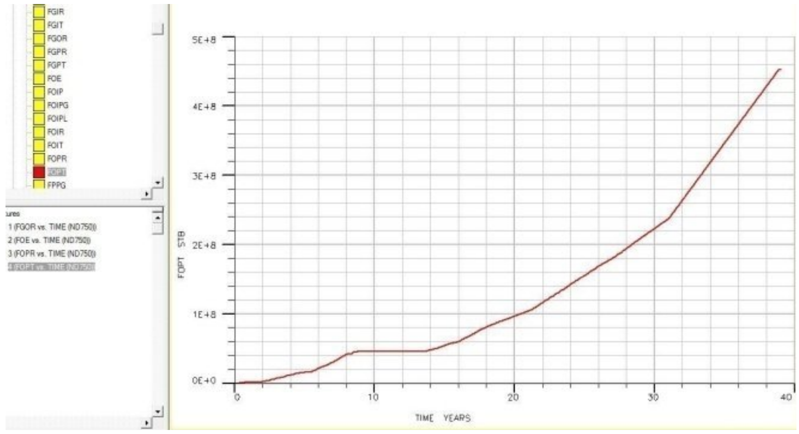

Figure 4: The cumulative oil production tank

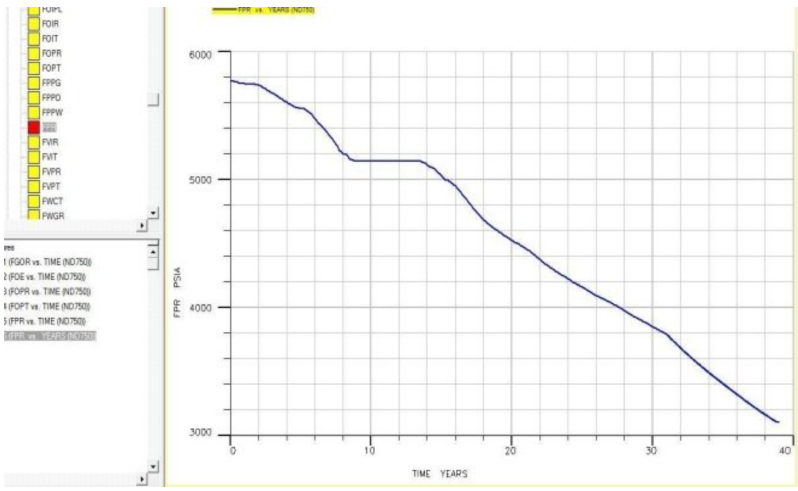

Figure 5: Changes in reservoir pressure

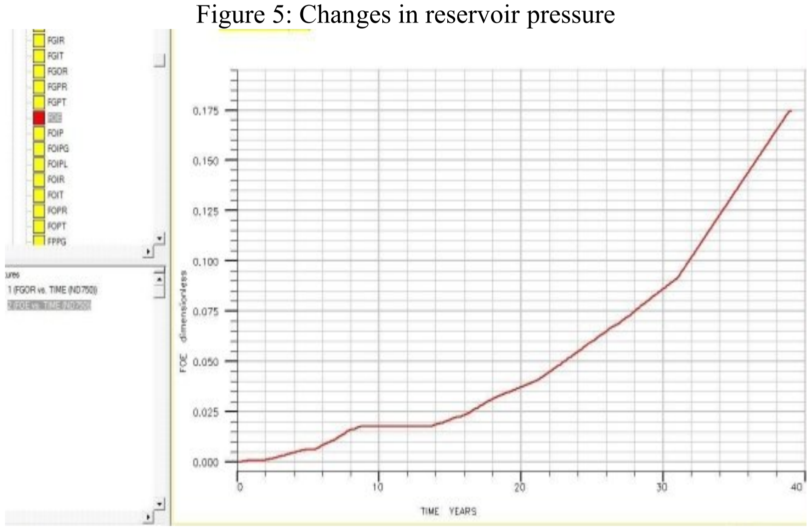

Figure 6: Oil Recycling

3- Gas injection scenario

One way is to increase the recovery factor of oil in the gas tank. To estimate the rate of oil recovery factor models were built. For this reason, 3 model was defined as wells as injection wells. After entering the required information in a tank of gas injection scenario was predicted in 2002 and scenarios for optimizing the performance of gas injection in this model, fractured ran. One of the most important factors that influence the efficiency of gas injection project, especially in fractured reservoirs, the flow rate of gas. Accurate calculation of the optimum injection rate can cause problems such as fingering phenomenon, and the breaking of fast moving gas in the matrix, these factors, in turn, reduces the amount of recovered oil and gas output is reduced. In order to get the best daily flow rate of gas flow model was different. First, it is necessary for a given flow rate should be estimated in this model s activities such as tank size, pressure tank and the extent and depth of the fractured surface of equipment capacity consider. The initial flow rate of gas injection, gas injection, based on simulation models was similar. If the gas flow is insufficient to reduce ultimate recovery factor of oil was considered. This is due to the high permeability fracture causes the gas velocity and the gap to the other routes of oil falls into the trap. To obtain an optimum flow rate of gas injection, gas injection, and four scenarios were defined.

Table 4: summarizes the results of a gas injection wells

Compare the results of simulations of gas injection scenarios						
Storage life expiration date	Reservoir pressure at the end of life (psi)	Volume of injected gas (mscf)	Cumulative oil production (stb)	Recovery %	Gas injection rate (mmscf/day)	No.
2026	3475	4.38E+08	5.80E+08	22.6	50	1
2031	3950	8.25E+08	.6E+086	25.6	80	2
2049	5550	1.96E+09	9.30E+08	36	100	3
2023	5350	1.20E+09	5.50E+08	21	150	4

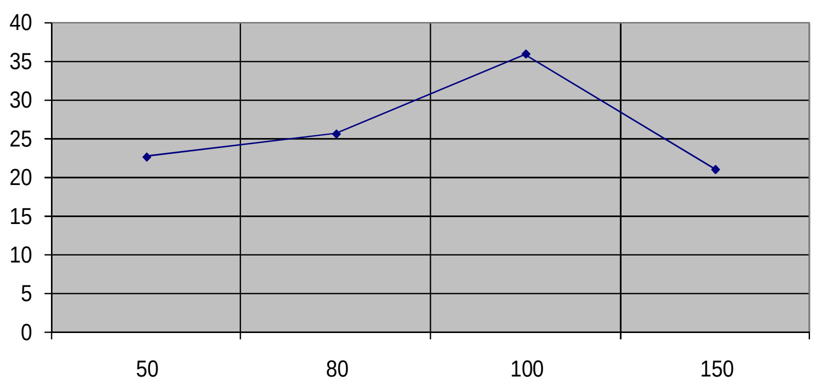

Figure 7: oil recovery (%) of the gas injection rate (million barrels per day)

3-1 The highest recovery factor of gas injection rate 100mmSCF/day

In this scenario, the gas discharge in 2002, 100 mmSCF / day is injected into the reservoir, the reservoir simulation in the charts below, the reservoir until 2039, with a recovery of 28.5% of the production will continue after other conditions will not allow the production of the tank. Cumulative oil production at the end of the tank 7.35 E +8 STB, 1.2796E +9 mSCF total injected gas and reservoir pressure is 4507 feet.

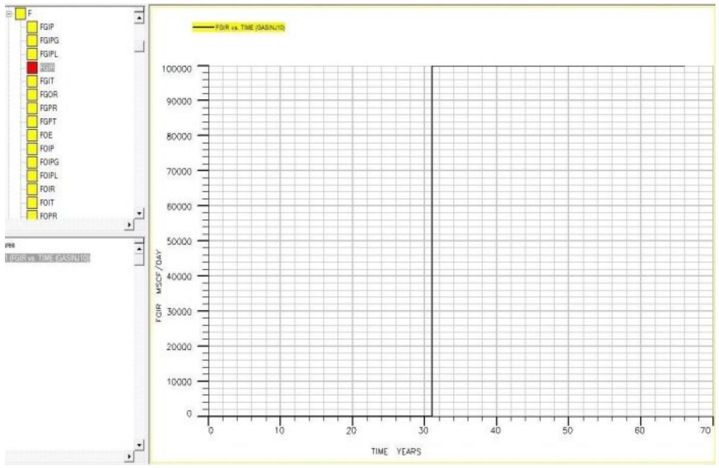

Figure 8: Flow diagram of gas injection

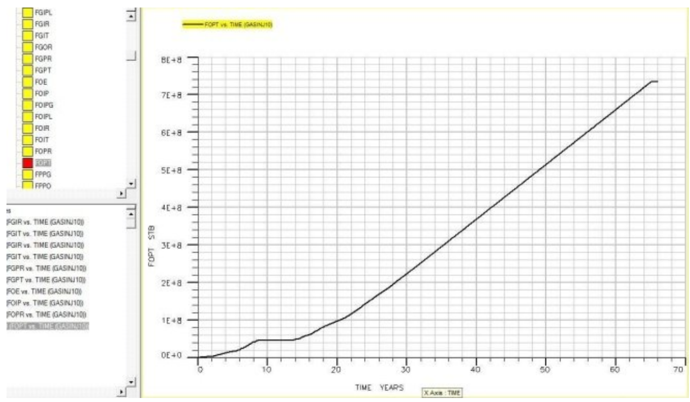

Figure 9: graphs the cumulative oil production

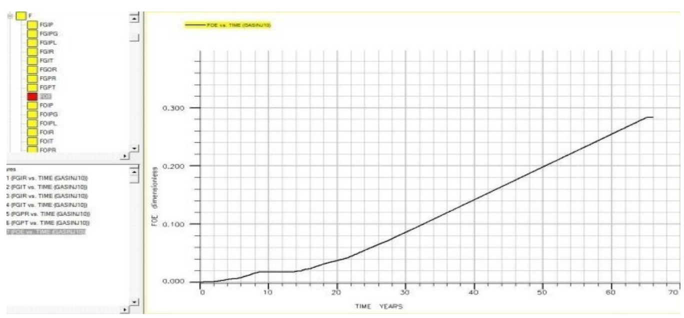

Figure 10: Oil Recycling

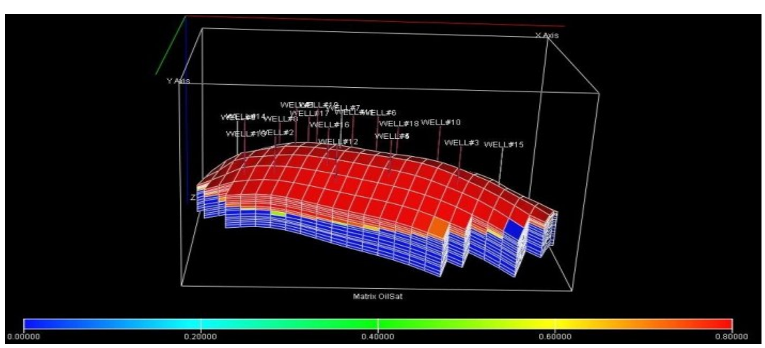

Figure 11: 3D shape of the tank before the gas injection

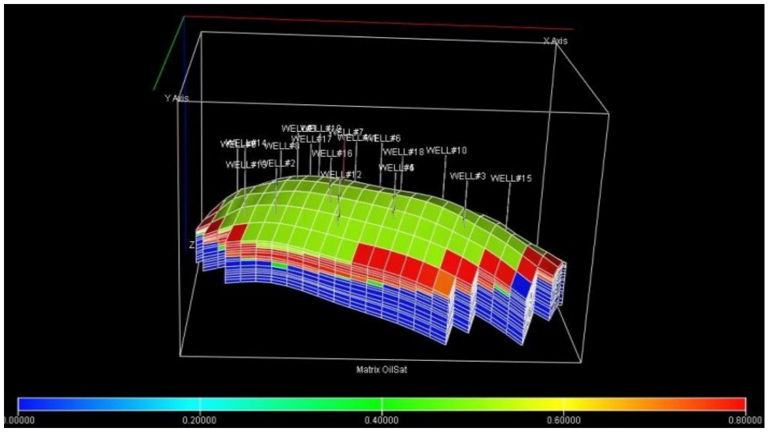

Figure 12: 3D shape of tank after gas injection

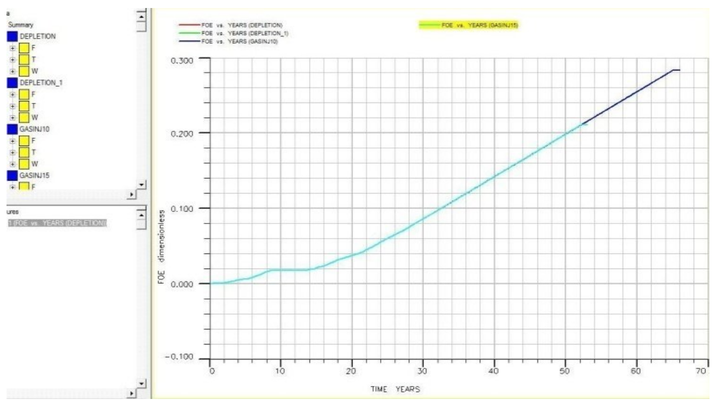

Figure 13: compares the recycled thermoplastic discharge 50.80, 100 and 150 MMSCF / DAY

4 - Water injection scenario

Fixed pressure water injection to increase oil recovery, after 30 years of reservoir drainage was performed and scenarios to optimize the efficiency of water injection in fractured model was implemented. Obviously, the water injection increased the likelihood of occurrence of water cone and cone gas phenomenon postponed. One of the key factors in the efficiency of water-injection project is particularly effective in fractured reservoirs, the water flow rate. Accurate calculation of the optimum injection rate can cause problems such as fingering phenomenon, and the breaking of the fast moving water in the matrix, which in turn causes a decrease in the efficiency of oil recovery and reduce water injection. To obtain an optimum flow rate of water injection, water injection was defined in the following three scenarios are described as follows.

4-1 The highest oil recovery rate with the water injection rate 80000 STB/DAY

During 2002, water discharge scenario Stb/day80000 is injected into the reservoir, the reservoir simulation in the charts below, the reservoir until 2042, the recycling 31.2 percent will continue to be produced and then other conditions will not allow the production of the tank. Cumulative oil production at the end of the tank 8.2 E +8 STB, cumulative water injected 5.5 E +8 STB and the pressure will be 5700.

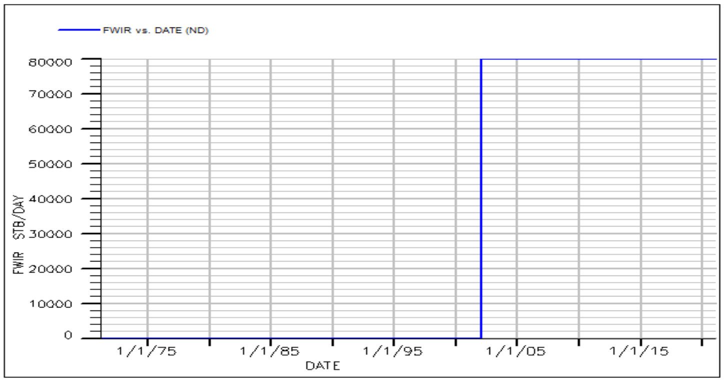

Figure 14: Flow chart of water injection

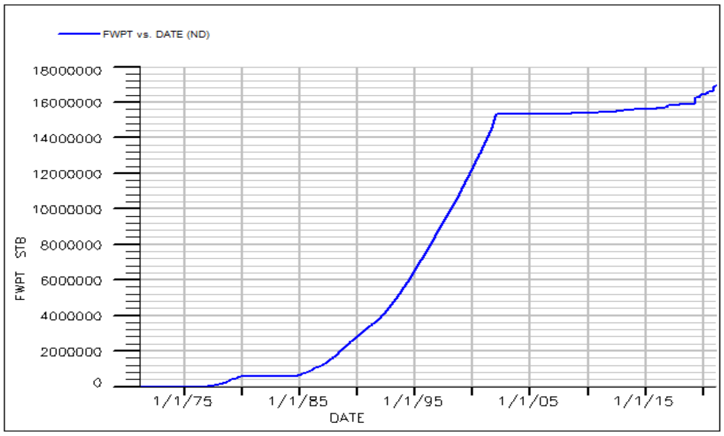

Figure 15: graphs the cumulative water production

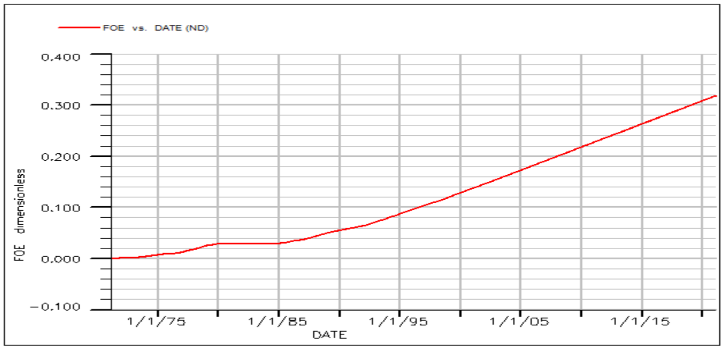

Figure 16: Oil Recycling

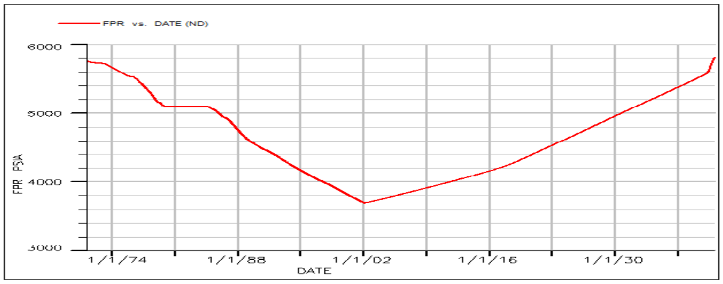

Figure 17: graphs of tank pressure

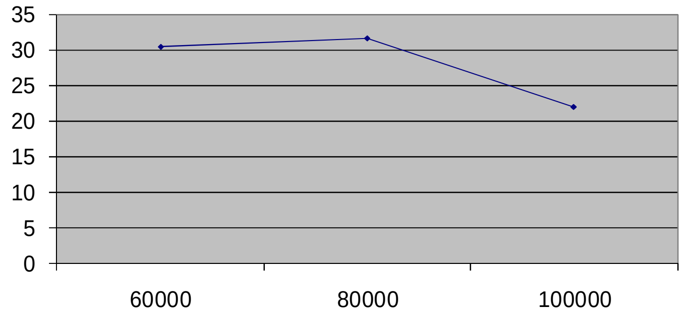

Figure 18: graphs the results of different simulation scenarios for water injection rate

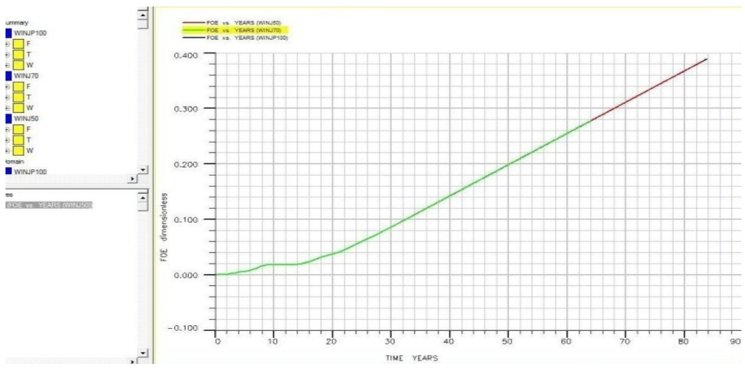

Figure 19: compares the recycled water injection rates 00060, 80000, 100000 STB / DAY

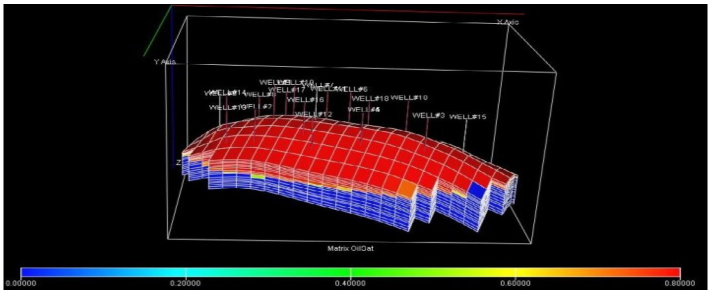

Figure 20: 3D shape of the tank before water injection

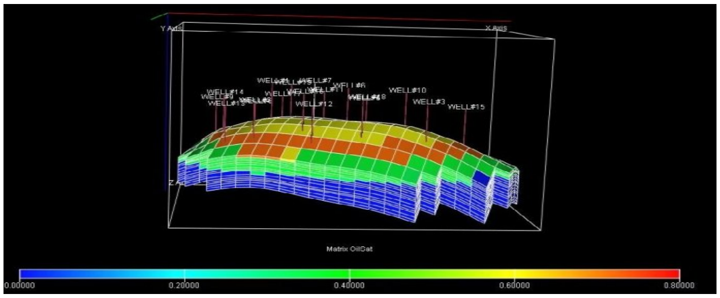

Figure 21: 3D shape of the reservoir after water injection

5- WAG injection scenarios

Generally, the exploitation and production, reservoir pressure decreases, leading to gas tank production is reduced. The role of oil and oil products in the world economy, World and take appropriate measures and optimal recovery methods to improve efficiency and increase productivity, the top oil-producing countries are located. Due to the pressure of the reservoir, EOR methods for stabilization and be felt more than ever. Despite the country's gas reserves, recovery methods such as water alternating gas injection (WAG) with a higher recovery factor than conventional miscible, immiscible gas is essential. Water and gas injection WAG at specified periods of time are alternately injected into the reservoir. This method increases the efficiency of the injected fluid contact surface areas, especially areas that have not been swept by the gas moving upward) in gas (or water to move down) water the injection of (who have not had affected. In this way, the gas is injected into the cavity occupied with high oil saturation and thus to move the oil tank is not part of the broom. Water injection well and the oil remains trapped in the reservoir rock movement and reduces oil saturation and increase manufacturing productivity. After addition of water and gas injection prevents the increase in gas saturation and relative mobility, control and reduced mobility, and creates the sustainable movement in front of the tank. The battle to prevent the premature phenomena fingering gas wells is produced. In general, the residual oil saturation than conventional water injection, gas injection (WAG). Therefore, this method has the potential to increase the efficiency of moving macroscopic and microscopic repository. In this way, Cole, in the late '60s with laboratory and field studies, increasing productivity and production in the region of three phase surface tension of the gas in the tank - Oil said. He based his observations in a three-phase system consisting of water, oil and gas, the fluid tends to the equilibrium configuration with the lowest energy, surface tension, gas system - the lower the surface tension of oil and gas - water can be assumed. In this case, the gas molecules are forced into close contact with oil and oil droplet size is increased. The displacement of oil by water injection in the presence of gas bubbles in the oil droplets, the amount of oil remaining in the tank to reduce the amount of gas bubbles. Water alternating gas injection and thus reduces the residual saturation and reservoir productivity index is increased.

5-1 Beat the highest oil recovery and water alternating gas injection period of 5 months, 15 days, gas and water

In this scenario, the gas discharge in 2002 is 100 mmSCF / day and water sails 80000 STB / DAY is injected into the reservoir, the reservoir simulation in the diagram below. The reservoir until 2061, with a recovery of 42.6% and will continue to produce other conditions permit, and then the tank will produce. Cumulative oil production at the end of the tank 1.1E +9 STB, total gas injected 1.96 E +8 mSCF and 9.8E +8 total injected water and reservoir pressure is 3705.4 feet.

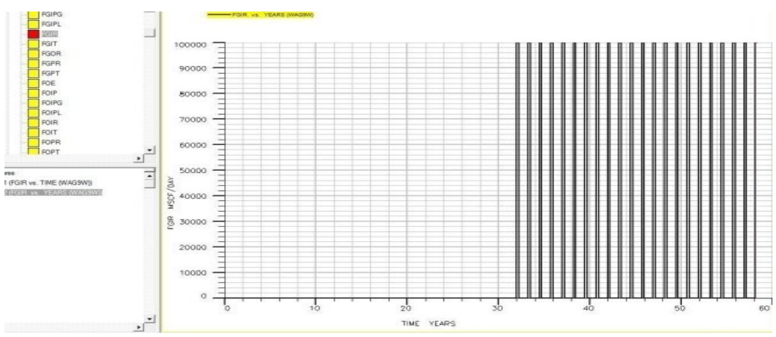

Figure 22: Diagram of gas injection rate

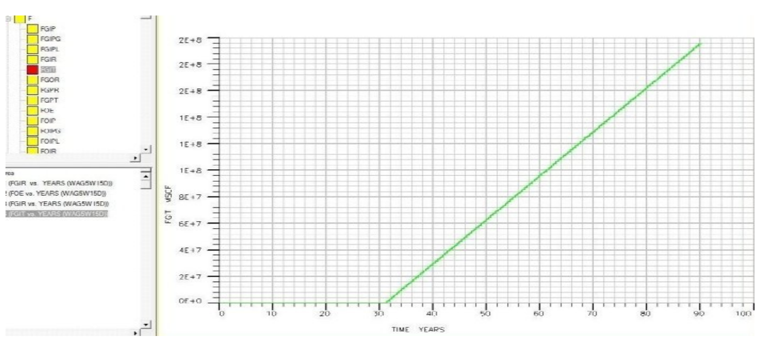

Figure 23: graphs the cumulative injected gas

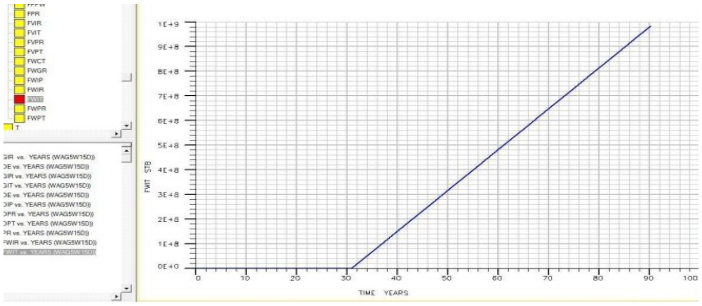
Figure 24: graphs the cumulative water injection

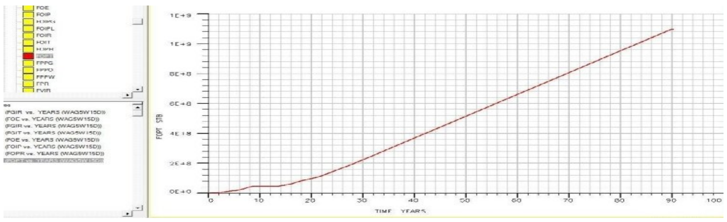
Figure 25: graphs the cumulative oil production

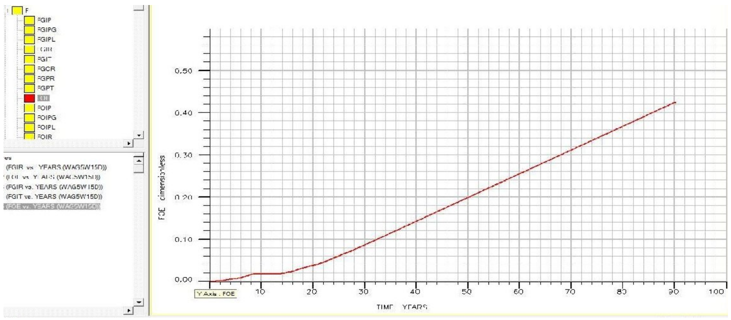
Figure 26: Diagram of oil recycling

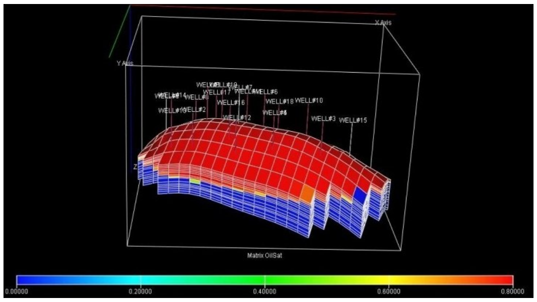
Figure 27: 3D shape of the container before WAG operations

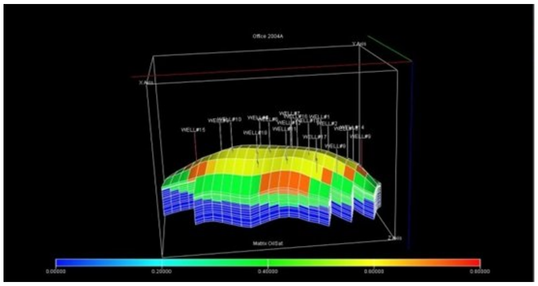
Figure 28: 3D shape of the tank after the WAG operation

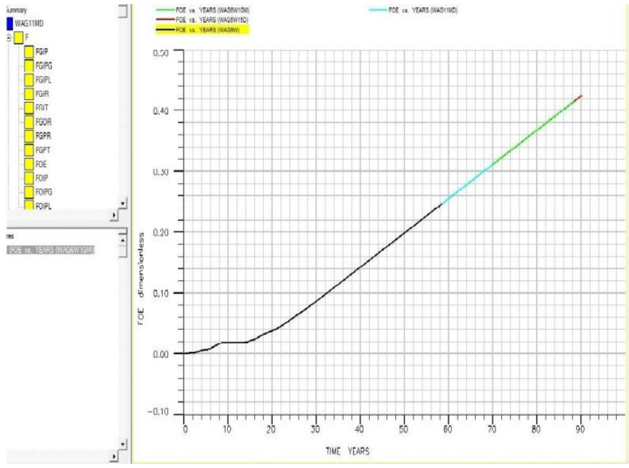

Figure 29: compares the recovery in WAG operations with different time periods

Table 5: compares the results of simulation scenarios for water injection and gas injection

Compare the results of simulation scenarios for water injection and gas injection							
Storage life expiration date	Reservoir pressure at the end of life **(psi)**	Volume of injected water **(STB)**	Volume of injected gas **(Mscf)**	Cumulative oil production **(STB)**	Recovery %	Scenario	**No.**
2018	**3045**	**0**	**0**	**4.75E+08**	**18.35**	Natural drainage	1
2039	**4000**	**4.20E+07**	**0**	**7.90E+08**	**30.5**	Water injection rate 60000 stb/day	4
2042	**5700**	**5.50E+08**	**0**	**8.20E+08**	**31.7**	Water injection rate 80000 stb/day	5
2025	**6100**	**7.30E+08**	**0**	**5.70E+08**	**22**	Water injection rate 100000 stb/day	6
2026	**3475**	**0**	**4.30E+08**	**5.80E+08**	**22.6**	Gas injection rate 50 mmscf/day	8
2031	**3950**	**0**	**8.48E+08**	**6.6E+08**	**25.6**	Gas injection rate 80 mmscf/day	9
2049	**5550**	**0**	**1.96E+09**	**9.30E+08**	**36**	Gas injection rate 100 mmscf/day	10
2023	**5350**	**0**	**1.20E+09**	**5.50E+08**	**21**	Gas injection rate 150 mmscf/day	11
2029	**3820.4**	**4E+08**	**1.94E09**	**6.4E+08**	**24.6**	Water alternating gas injection and 1 month to 3 months	12
2061	**3705.4**	**9.8E+08**	**1.96E+08**	**1.1E+09**	**42.6**	Water alternating gas injection and 5 months and 15 days	13
2059	**3757**	**9E+08**	**2.94E+08**	**1.07E09**	**41.5**	Water alternating gas injection and 6 months to 1 year	14
2040	**3796**	**5.98E+08**	**2.36E+08**	**8.06E+08**	**31.2**	Water alternating gas injection and 3 months to 1 year	15

Conclusion:

1. The container piers of gas injection to water injection from higher returns and minimal, the ultimate recovery factor in the depletion of natural 18.35 percent in the best case scenario, gas injection to 36% and the best scenario of water injection to 31.7 percent in 5 months and 15 days alternating water and gas injection scenario of 42.6% increase.
2. Volume of injected gas is one of the parameters in the recovery tank. Among the scenarios for gas injection, gas injection rate

scenario 100000 MScf/ day will have the highest oil recovery factor.

3. Volume of injected water is one of the parameters in the recovery tank. Among scenarios, water injection, water injection flow scenario 80000 Stb/ day had the highest oil recovery factor.
4. As seen in the figure, we took most of alternating immiscible injection of water and gas. Because the injected alternately above and below the reservoir covers all parts.

Suggestions:

1- Using a hybrid model such as the Eclipse 300 and Co2 injection of miscible hydrocarbon gas on the recovery factor was investigated.

2- Due to the heterogeneous nature of fractured reservoirs, changes in rock and fluid properties can be seen in the simulation model.

3- In order to prevent this problem from a complex type of stone was used to define the dynamic characteristics of the stone. In order to better define the dynamic characteristics of rock higher number of stones used.

4- It can be injected and water alternating gas injection into fusion, and also can be injected into the reservoir and water alternating gas composition and gas FOAM can be used to raise the gas viscosity.

5- Uncertain parameters are input to the simulation model. To estimate the effect of uncertainty on the simulation results, the sensitivity of the parameters to be measured. Measuring the viscosity and density of the injected water in the tank in the laboratory and can be changed with the help of Eclipse 100 recovery factor may be seen.

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