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Enhanced Oil Recovery

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Abstract: ***Oil exploration and production actively began 100 years ago, from the present day. What we see now, known as primary production by natural flowing of oil by pumped wells. This covers 15% of oil recovery from reservoir. Later 25% of oil is recovered by water flooding is activated which is termed as secondary production. There is still significant oil left in the reservoir, if there is no proper employment of commercial valuable techniques for the production, the oilwell would simply be abandoned. But as the demand for oil kept raising new techniques emerged, eventually from those EOR was a successful in artificial up lifting of oil from the reservoir by providing enough pressure to the trapped oil to flow out of well. It is a tertiary production. EOR is different because it works from microscopic levels as well as by injecting the substances like gases, special liquid (polymers) and stream in the form of injection through injecting wells for oil recovery, which is termed as Enhanced Oil Recovery (EOR). The flooding in EOR, categorized as chemical flooding (by chemicals), stream or thermal injection (by stream) and miscible gas drive (CO_2, N_2 and LPG). These flooding will alter the physical and chemical properties of reservoirs for the flow of oil out of the well. EOR can unlock a percentage of 30-45% of trapped oil. After naming as successful technique in onshore for tertiary production, research is still going to implement EOR in offshore, to improve tertiary production and exploit hidden billion barrels of oil.***

Keywords: Primary production, tertiaryproduction, chemical flooding, Thermal injection, miscible gas drive

1. Introduction

Primary production is the oil produced by original reservoir drive energy. It depends on the type of reservoir drive, oil viscosity, and reservoir permeability but averages 30 to 35% of the oil in place and can be as low as 5%. This leaves a considerable amount of oil in the reservoir after the pressure has been depleted. This has leaded the industry towards the techniques that would include recover more oil. Ultimate oil recovery is the over-all production from the field by primary production, water flood and enhanced oil recovery, if justified by economic conditions.

A typical gas reservoir will produce 80% of the gas by primary production. Because so little gas is left in the depleted reservoir, gas fields are plugged and abandoned after primary production.

As the water flooding which is very important in driving the oil and gas towards producing well after losing the natural pressure of reservoir. Is it is done by injecting water in the injection well into the depleted reservoir. It can be performed either before or after the primary production. Water sweeps the oil towards the producing well by reducing the oil viscosity. It can recover from 5 to 50% of oil from depleted reservoir. At present EOR is achieved by three techniques depending on the reservoir condition, expenditure, hydrocarbon behavior etc. reflect the type of EOR to be employed. Three commercial techniques of EOR which are performed upon depending on reservoir formation. In this paper, these techniques are explained with respect to their operation.

2. Miscible Gas Drive

A gas miscible process involve gases into the reservoir that dissolves in the oil. Inert gas injection uses carbon dioxide, nitrogen and LPG. These gases should not corrode the equipment and mix with gas reservoir.

2.1 BY CO_2

During this gas, the CO_2 is brought to the project by pipeline from CO_2 plants. As a liquid state. When CO_2 is injected in the reservoir through injection well at pre-determined location from production well. The carbon dioxide is miscible with the oil, making oil more fluid and oil react very different with gas. The carbon dioxide gas pushes the fluid oil through the reservoir towards the producing well. It can often recover about 35% of the remaining oil. Largest CO_2 flood project is located in the Kelly-Snyder oil field in Texas (USA).

Disadvantage: Because of the low viscosity of the carbon dioxide, it tends to finger and break through to producing wells leaving un-swept areas in reservoir or channeling affect. The channeling effect is shown in fig.1. Its controlled measure is water-alternate-gas process (WAG).

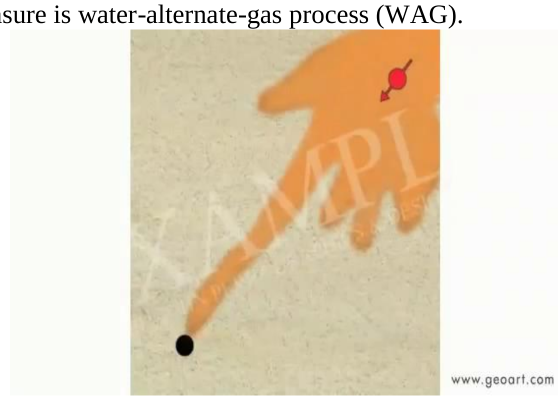


Figure 1: Channeling Effect (www.geort.com)

WAG process: To prevent the above disadvantage, alternating amounts of water and gas can injected into the reservoir by the injection wells by utilizing water-alternate-gas process (WAG). This process creates the stable force and reduces the channeling effect. The WAG process is represented in fig.2

Figure 2: WAG process (www.geoart.com)

The entire $CO_{2\ EOR}$ project is showed in the fig.3 in the form of the flow chart.

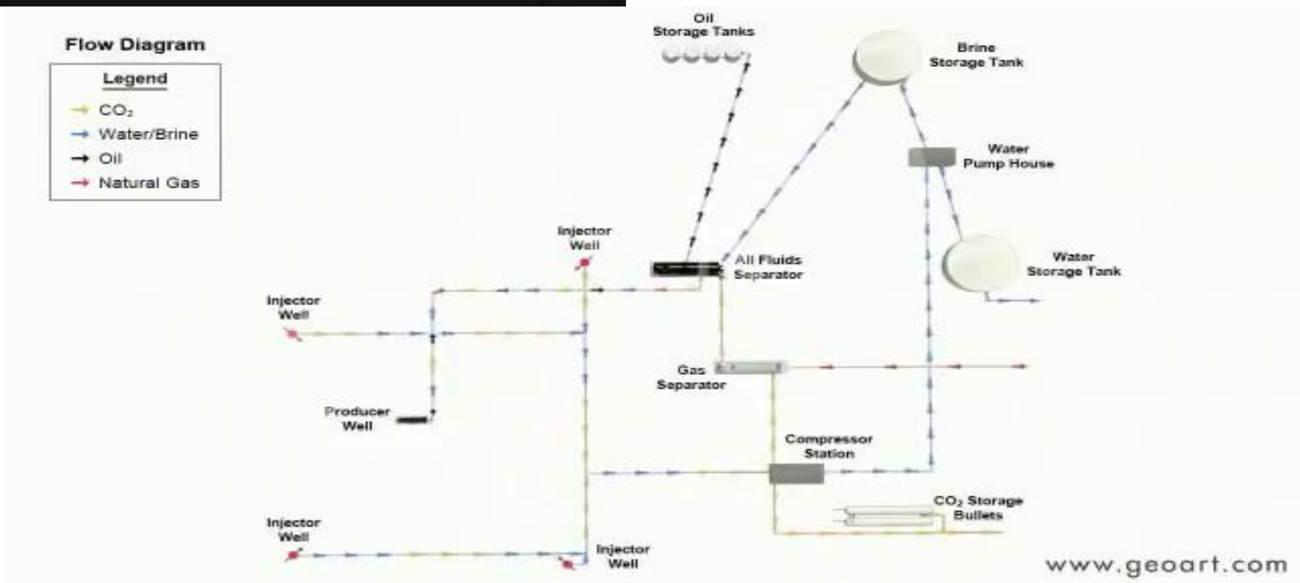


Figure 3: Flow chart of entire CO_2 EOR project (www.geoart.com)

During the EOR, carbon dioxide is either brought back to the plant because of its need or permanent storage in the reservoir.

2.1.1 Co_2 Permanent Storage

Extensive geological analysis performed on the Oxy Elkyhills Fields, California are one of the premier field for EOR with permanent storage of CO_2. Millions of years oil has been migrated and trapped in the reservoir rock which comes in the process of migration, accumulation of hydrocarbons, in which tiny pore spaces of sandstone rock (reservoir rock) has retained the oil in place by thick dome like structure (anticline trap) which is enclosed by an impermeable member called as cap rock shown in fig. 4 which is 100's feet thick but in natural many cap rock thickness varies among different ranges. The cap rock and oil accumulation in the anticline trap is shown in fig.4

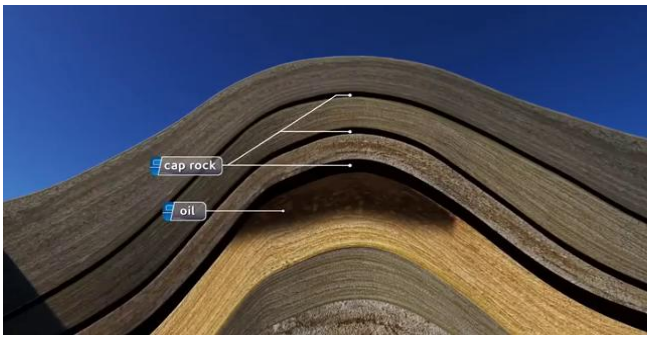


Figure 4: Anticline trap

EOR, with carbon dioxide (permanent storage) is a process where CO_2 is injected into the deep reservoir to improve oil production. It is a technique already used in more 108 wells in USA. CO_2 is transported from the storage to the injection well where EOR is operated with permanent storage of CO_2. The CO_2 is injected in a liquid like state through the injection well. Injection well is located in précised and predetermined location in the reservoir rock formation. As the CO_2 mixes with oil in the formation, the oil swells, reducing its viscosity by allowing the oil to flow more easily by inter connected pore spaces towards the production well. In the fig.5 shows the CO_2, injected into interconnected pores such that it mixes with oil.

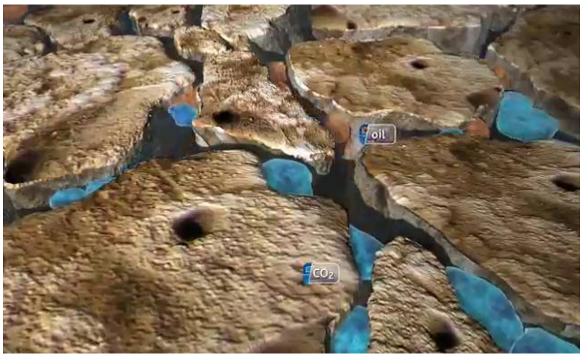


Figure 5: CO_2 and oil in the pores

In the fig.6, which shows the injected and projected well, from the injected well CO_2 is injected into reservoir such that it mixes with oil and reduces viscosity and also increases the sweep efficiency which finally leads the oil flow into the producing well and oil can produced. In fig.6 shown below represent the CO_2 trapped in the reservoir and CO_2, oil flowing towards the producing well

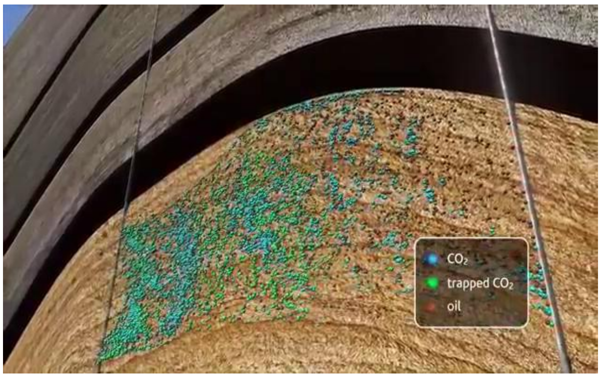


Figure 6: CO_2 EOR

This may lead to 10 to 30 % oil recovery from depleted reservoir. During, this process the CO_2 becomes trapped in the rock and is permanently store in the pore spaces. In the same way the oil which is trapped in formations for millions of years, with cap rock serving as severe physical bearer for the containment of CO_2. The other trappingmechanisms are CO_2 dissolution in formaton fluid, CO_2 mineralisation with in the rock pore spaces. As the fluids and gases are produced from the production wells all the way flowing through the series of vessels to get seperated as oil, gas and CO_2 in processing plant. A portion of CO_2 may be produced with the oil which is processed in the plant, this CO_2 remains contained in the process system all the time . This CO_2 seperated and combined with CO_2 injected which is termed as "re-injection". The process of capturing CO_2 of and separtion of it is shown in fig.8.

Figure 7: Processing unit of CO_2

This process of reinjection of CO_2 is known as the closed loops process. This process is shown in below fig.7

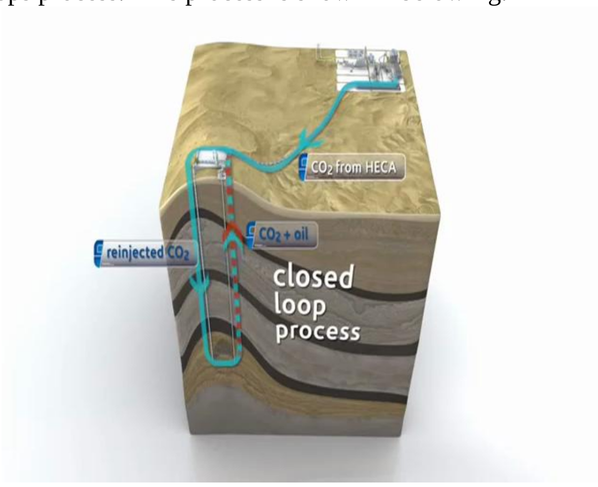


Figure 9: Closed loop process

2.2 BY LPG

By using LPG, drive which is also a miscible drive with oil used with liquefied petroleum gas drive. The source of LPG is wet-gas. The use of nitrogen in EOR for offshore production still in research.

3. Thermal Recovery

The thermal recovery techniques utilize heat to make heavy oil (<20^0 API) more fluid for recovery. Thermal recovery can be done by

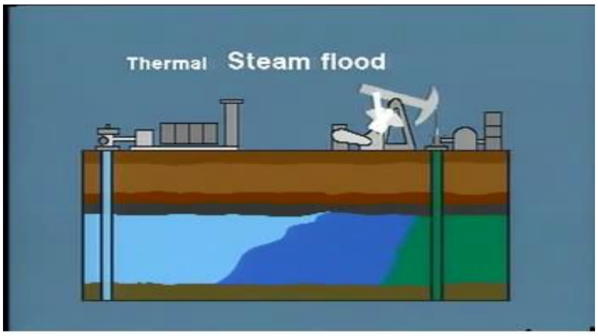
1. Cyclic steam injection
2. Stream flooding
3. In-situ combustion (or) Fireflood.

3.1 Cyclic Steam Injection

It is also called as the huff and puff method. This method uses single well to inject the steam and produce the oil such that injected steam is allowed into the heavy oil reservoir for a period of time up to two weeks during the "injection period". This period is also referred as soak period. The well is shunt in for some days to allow the stream to heat the heavy oil and make it more fluid which has more ease to flow towards the producing well. From the same well, during "production period" the heated oil will produce by using sucker rod pup.

3.2 Stream Flooding

A stream flooding or stream drive uses both injection and production wells. The superheated stream in pumped down the injection well into a heavy oil reservoir. The stream heats the heavy oil to greatly, reduce its viscosity and to increase its mobility ratio. As stream gives up its heat and condenses into hot water that drives the oil towards the production well. It is similar to water flood. In stream flood, both injection and production are very closely spaced. It constitutes a recovery, which will be vary in between25 to 65% of the oil reservoir. In the fig.10 shown below describes the steam flooding.



light blue--- stream
thick blue--- hot water

Figure 10: Stream flooding

3.3 Fire Flooding

It is also termed as "in-situ combustion". This recovery involves setting the subsurface on fire. For a shallow well, phosphorous bomb or a gas burner lowered down the well. For deep reservoir, pumping air into the reservoir to start he fire by spontaneous combustion. As the oil is burning, to sustain the fire large volumes of air is injected into deep reservoir, which is technically called as "air pumping". The fire generates heat, causing the oil to become more fluid and less viscous. The large volumes of hot gases generated by fire drives the heated oil towards the producing wells.

Types of fireflood are

a) Forward combustion: in this, the fire and injected air originate at injection wells. Then the oil flows towards the producing well.
b) Dry combustion: only air is injected.
c) Wet combustion: water and air are injected either alternately or together. It is also called as Combustion of Forward Combustion and Water Flooding (COFACAW). The generated stream from water helps drive the oil.

The recovery from a fireflood can be 30 to 45% of the oil in place. The fig.11 shows the fire flooding process such that oil is indicated by green color, light blue color indicating stream, blue color showing hot water and rest of colors in the figure represents fire.

Disadvantages: Air pumping is expensive and its cost increases with increase in depth of oil reservoir. A fireflood would fail if there were no enough oil in place to sustain the fire. Corrosion of the equipment because of high temperature and corrosive gases that are generated.

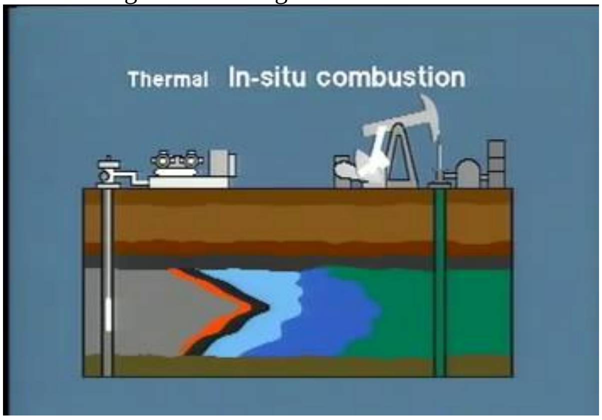


Figure 11: Fire flooding

4. Chemical Flooding

A chemical flooding is a process in which different fluids or chemicals are injected into the depleted reservoir in separate batches (slugs). It can recover about 40% of the remaining oil. Chemical flooding is involves in addition of polymers;

1) Polymer
2) Surfactants
3) Caustic

The fluids or chemicals each serving a different purpose, move as separate fronts from the injected wells, through the reservoir rock toward the producing wells.

4.1 Polymer Flooding

In polymer flooding, polymers are injected with water in injection well down the reservoir. As the polymers are expensive, only little slug of polymer is injected in the water. These slugs of polymers are pushed by conventional water injection. The polymers increase the viscosity of water and thereby improving the mobility ratio and increase in recovery efficiency. The primary benefit of polymer flooding is

a. Improves the volumetric sweep efficiency
b. Acceleration of oil production

The fig.12 shown below polymer flooding such that oil is indicated by the green color, blue color indicates the water and pink color indicates the polymer slug.

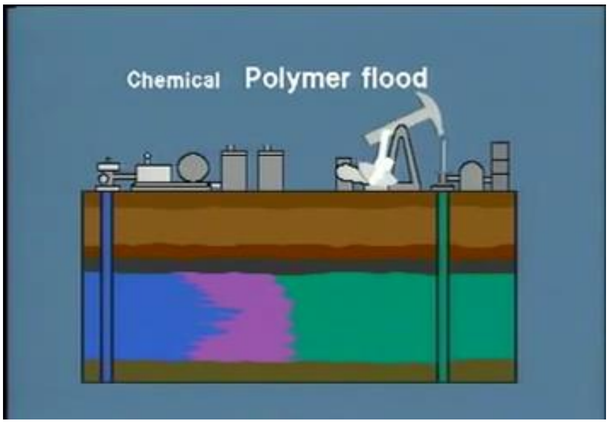


Figure 12: Polymer Flooding

4.2 In Surfactant Flood (micellar –polymer flood)

In micellar-polymer flood, a slug of reservoir water is first injected to condition the reservoir as it moves ahead of other slugs of injected chemicals. Next, a slug of surfactant solution is injected into the reservoir. The surfactant act as a detergent, reducing the interfacial tension between oil and water in the reservoir. This may leads to washing of oil out of the reservoir pore spaces. Micro-emulsion, are formed due to oil forms small droplets suspended in the water. The next is water thickened with polymer. The pressure of the polymer water from the injection well drives the surfactants and oil micro-emulsions front ahead through the reservoir rock toward producing wells.

The fig.13 shows the in surfactant flooding process such that green color is of oil moving towards the producing well, yellow color indicates slug of reservoir water injected first and pink, blue color indicates the surfactant and water.

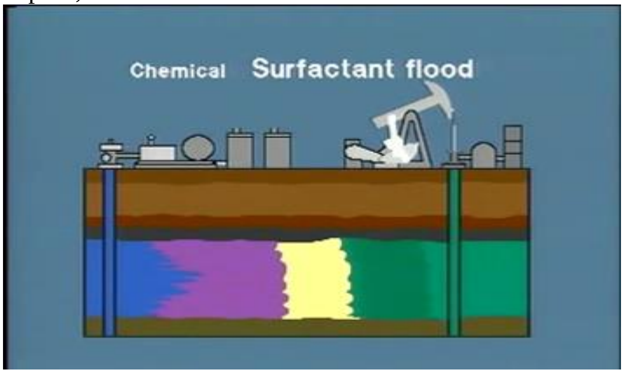


Figure 13: In- Surfactant flooding

4.3 Caustic Flooding

In case of caustic flooding, sodium hydroxide is added to the injection water, reacts with crude oils at the oil-water contact forming the surfactant in-situ. This in-situ surfactant reduces the interfacial tension and residual oil saturation. The heavier and more viscous crudes are usually most responsive to the caustic flooding.

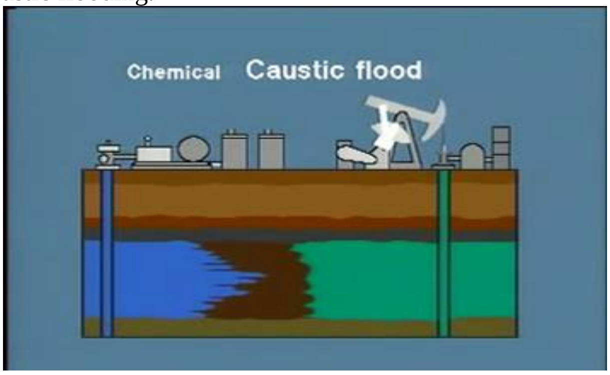


Figure 14: Caustic Flooding

The fig.14 shown above represents Caustic flooding process by indicating oil with green color, brown with NaOH and blue with water.

Disadvantage: A chemical flood can be used for sandstone reservoirs as carbonates absorb the surfactant. It's an expensive process.

5. Conclusion

EOR is a tertiary method but plays a crucial role in recovery of hydrocarbon to a percentage of 30-45%. All the EOR techniques which are discussed in this paperare employed according to the companies policies, amount of hydrocarbons left in the reservoir, cost of the technique and behavior of hydrocarbon. With EOR's significant recovery percentage it shows it's a commercial valuable technique for oil and gas industry. The designing of injection well for different EOR techniques is based on the company decision and behavior of hydrocarbon. The EOR techniques not only increase the depleted reservoir pressure but also reduces viscosity and interfacial tension, increases sweep efficiency.

6. Future Scope

EOR with Nitrogen is under research which has high scope in both onshore and offshore fields. The carbon capture techniques using miscible gas drive with carbon dioxide is a great scope of research in carbon storage and processing which can be extended with new innovative methods for storage and reusing. The usage of various polymers in polymer flooding is under research can improve the sweep efficiency of fluids

References

[1] Anthony, Mark J., Tim D. Taylor, and Bill J. Gallagher. Fireflooding a High Gravity Crude in a Watered Out West Texas Sandstone. Presented at the 1981 Permian Basin Oil and Gas Rec. Symposium, Midland, TX, Mar. 12-13, 1981. SPE paper 9711.

[2] Benton, J.P. et al. Pressure Maintenance by In Situ Combustion, West Heidelberg Unit, Jasper County, Mississippi. SPE 56th Ann. Tech. Conf., San Antonio, TX, Oct. 5-7, 1981. SPE paper 10247.

[3] Cardenas, Richard Limon et al. Laboratory Design of a Gravity Stable, Miscible C02 Process. Presented at the SPE 56th Ann. Tech. Conf., San Antonio, TX, Oct. 5-7, 1981. SPE paper 10270.

[4] Christopher, C.A. et al. Performance and Operation of a Successful Polymer Flood in the Sleepy Hollow Reagan Unit. Presented at the SPEIDOE Enhanced Oil Recovery Symposium, Tulsa, OK, Apr. 17-20, 1988. SPE/DOE paper 17395.

[5] Kane, A.V. Performance Review of a Large Scale CO2-WAG Project SACROC Unit - Kelly Snyder Field. Presented at the Fifth Symposium on Improved Methods for Oil Recovery, Tulsa, OK, Apr. 16-19, 1978. SPE paper 7091.

[6] Green D. W. &Willhite G. P. Enhanced Oil Recovery. Richardson, Texas: Society of Petroleum Engineers, 1998.

[7] Lake L. W. Enhanced Oil Recovery. Englewood Cliffs, New Jersey: Prentice Hall, 1989.

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