University of Mosul

College of Petroleum & Mining Engineering

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Enhanced Oil Recovery Processes

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Lecture 7

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Gas injection

This method is similar to waterflood in principal, and is used to maintain gas cap pressure even if oil displacement is not required. Immiscible gas is injected to maintain formation pressure, to slow the rate of decline of natural reservoir drives, and sometimes to enhance gravity drainage. Immiscible gas is commonly injected in alternating steps with water to improve recovery. Immiscible gases include natural gas produced with the oil, nitrogen, or flue gas. Gas injection requires the use of compressors to raise the pressure of the gas so that it will enter the formation pores.

Immiscible gas injection projects on average render lower oil recovery if compared to waterflooding projects, however in some situations the only practicable secondary recovery process is immiscible gas injection. Those situations include very low permeability oil formations (i.e. shales), reservoir rock containing swelling clays, and thin formations in which the primary driving mechanism is solution-gas drive.

Gasflooding can be an immiscible or miscible displacement process, depending on pressure and temperature of the reservoir, the type of injection gas, the composition of the injection gas, the composition of the reservoir fluid, and the nature of reservoir heterogeneities.

Gas injection in an oil reservoir takes place either into a gas-cap if one exists, or directly into the oil zone.

A- Gas injection into a gas- cap:

When a gas-cap originally exists in a reservoir, or when one has been formed by segregation during primary production, gas injection helps to maintain the reservoir pressure while forcing gas into the oil zone and driving the oil towards the production wells. This process is analogous to the rise of the oil water contact when water is injected into an underlying aquifer.

B- Gas injection into an oil zone:

When gas injection takes place in a reservoir without a gas-cap the injected gas flows radially from the injection wells, driving the oil towards the production wells.

The principal factor involved in the decision to commence gas injection is the availability of a nearby source of cheap gas in sufficient quantities. The recycling of produced gas is a major source. Secondary gas must be obtained either from an adjacent gas reservoir or from a nearby gas pipeline.

It should be noted that if dry gas is injected into an oil reservoir, the produced oil is made up of both oil displaced from the porous medium and oil fractions vapourised by the injected gas. If the oil is very light, the mass of oil vapourised may be extremely high and a high oil recovery will result.

There are certain conditions under which water injection should not be considered:

(a) A very extensive gas-cap may form a preferential path for injected water which will thus by-pass the oil zone. By comparison, gas injection into the gas cap may result in additional oil recovery for the price of a few gas injection wells.

(b) A reservoir with a high initial water saturation may not be suitable for water injection. There is a risk that no front will be formed and that oil and water will flow in parallel, giving a low recovery efficiency.

Under these conditions, oil recovery by gas recycling may be possible, as long as the free gas saturation in the reservoir is not too high. If the reservoir has sufficiently high vertical permeability, gas-cap injection will result in higher recovery than injection into the oil zone.

It is advantageous to start gas injection into the gas-cap as soon as possible. In this way the formation of a high free gas saturation in the oil zone and an increase in oil viscosity are avoided, thus allowing a high oil relative permeability and productivity to be maintained.

Injection well location

In general, the increase in recovery which gas injection can provide does not warrant the drilling of a large number of new injection wells, thus most of the injection wells are obtained by the conversion of existing producers.

A- Injection into the gas-cap:

All the injection wells (converted producers or new wells) are concentrated around the top of the structure. The converted production wells may need to have their existing perforations cemented off and new perforations made in the gas-cap. The adequate number of injection wells depends on the total injection rate required.

B- Injection into the oil zone:

In this case the well density varies widely, but there is always less than one injection well per production well, whereas this ratio is most common in water injection projects.

Sweep efficiency

Both gas and water injection result in the formation of a displacement front, but for gas injection the front is less distinct (less variation in oil saturation). The injected gas does not wet the rock surfaces but sweeps through the oil and tends to form a continuous gas phase throughout the reservoir.

This happens very rapidly, because the critical gas saturation is low. During injection into the gas-cap, there is more chance that a distinct front will be maintained, since gravity will assist in the segregation of the gas and liquid phases.

Injection well completions

In the case of the conversion of existing production wells, the old completion must first be pulled out and the well cleaned at the reservoir interval by scraping or chemical washing. The condition of the casing must be checked and any leaks repaired.

The type of injection (gas-cap or oil zone) has a direct influence on the completion interval. In the first case, the oil producing interval is plugged off and the casing perforated at gas-cap level. In the second case it is not normally necessary to change the completion interval, unless certain zones are required to be eliminated because their permeability to gas would cause " short circuiting". If the well is cased, cement squeezes or packers can be used to limit the injection zone. If not, it may be necessary to cement a liner in place which can then be perforated where required.

Surface installations, compression and treatment

Injection gas sources (separator gas, gas from nearby fields, inert or flue gases) may contain the following impurities:

(a) Hydrogen sulphide.

(b) Carbon dioxide.

(c) Oxygen.

(d) Water vapour.

H2S, CO2 and O2 may cause corrosion of the surface pipework and downhole equipment, especially in the presence of traces of water. In addition to the effect on the installations, precipitates are formed which may damage (plug off) the formation.

The pressure of water vapour, under certain conditions of temperature and pressure, may cause the formation of hydrates which can block the pipework.

Special applications of gas injection

1- The formation of a secondary gas-cap

In regions of complex geology, oil may become trapped at the top of an inclined formation, beyond the reach of the existing wells. One way of recovering this oil is to inject gas into the lower part of the reservoir. If the permeability and dip of the reservoir are great enough the gas will migrate to the top of the structure and form a secondary gas-cap. The trapped oil is thus displaced down-dip and may be recovered by the same wells used to inject the gas.

2- Combined gas and water injection

It is thought that by successively injecting slugs of water and gas, a homogeneous mixture will be formed within the pores; due to relative permeability effects this mixture will behave as a fluid of low mobility; thus the mobility ratio of the system gas + water / oil will be reduced and the displacement efficiency improved.