Oil & Gas Research

Smirnov VI , Al-Obaidi, Oil Gas Res 2008, 1:1
DOI: 10.4172/2472-0518.1000e10

Research Article OMICS International

Innovative methods of enhanced oil recovery

*Smirnov VI , Al-Obaidi Sudad H

Petroleum Engineering Dept., Mining Institute, Russia

Abstract

The production of oil and gas from hydrocarbon reservoirs with the aging of these reservoirs makes them consuming their natural production energy and become depleted. Then, conducting researches and investigations to use other energy resources to improve oil production becomes an urgent need. The article presents the general directions of methods for enhancing oil recovery and focuses on steam-thermal methods. Based on the classification of enhanced oil recovery methods, it has been shown that thermal methods (in particular, thermal steam) are the most favourable when applied in fields with a depth of about 1000 meters. The technology of cyclic steam injection is presented and the main stages of this process are indicated. Recommendations on the technology of steam-thermal treatment are given. For example, two oil fields have been selected to show the efficiency of the use of thermal steam treatment for reservoirs with high-viscosity oils.

Keywords: EOR; Oil production; Oil viscosity; Permeability; Thermal methods; Waterflooding.

Introduction

As known, oil recovery depends on many factors. Usually, there are factors associated with the technology of extracting oil from reservoirs in general. Therefore, oil recovery can be represented as follows[1][2]:

$$C_{oil} = C_d * C_s * C_f$$

where C_d - coefficient of oil displacement from the reservoir, C_s - sweep coefficient of the reservoir by development, C_f - field flooding factor.

The displacement coefficient (C_d) of oil by water is the ratio of the volume of oil, displaced by water from a rock sample or reservoir model until the resulting product is completely watered, to the initial volume of oil contained in the rock sample or reservoir model:

$$C_d = V_o / V_{oi}$$

where, V_o is the volume of oil displaced by any agent from a rock sample or reservoir model, V_{oi} is the initial volume of oil.

Since not only water can be used to displace oil from a rock sample or reservoir model, but also any other agent (gas, alcohols, foams, etc.), a more general definition of the displacement coefficient should be given, which characterizes the completeness of oil displacement in laboratory conditions from a rock sample or reservoir model. To characterize the completeness of oil displacement by water from the reservoir model for a certain period of time, as well as for anhydrous and aqueous periods, the displacement coefficients for these periods can be used [3][4]. This is meaning the share of oil from its initial content obtained from the rock sample, respectively, for a certain period of time, for anhydrous and aqueous periods of displacement. The sweep efficiency (C_s) is defined as the ratio of the volume of the productive formation swept by displacement to the initial oil-saturated volume of the formation[5][6]:

$$C_s = V_{rs} / V_r$$

where, V_{rs} is the volume of the reservoir swept by the displacement process, V_r is initial oil-bearing reservoir volume.

The waterflooding factor depends on a large number of factors. Therefore, it is convenient to represent it in the form of a product of a number of coefficients that take into account the influence of one or another factor that has a corresponding effect on the overall sweep ratio[7][8]:

$$C_f = C_1 \times C_2 \times C_3 \times C_4 \times C_5$$

where C_1 is the sweep factor that takes into account the effect of reservoir heterogeneity in terms of permeability, C_2 is the reservoir sweep factor that depends on the well pattern, taking into account the discontinuity of the productive formation, that is, zone heterogeneity, C_3 is the sweep factor that takes into account oil losses in the zone of the collapsing row of wells, C_4– sweep factor, taking into account oil losses in the zone of a cutting row of wells, C_5 - sweep factor, taking into account oil losses in undeveloped areas of the reservoir. Thus, oil recovery factor (RF) is a relative value that shows how much oil from the initial balance reserves is extracted or can be extracted from a developed or presumably developed reservoir, up to the limit of economic profitability of operation. RF is also an indicator of a completed development process or one that is expected to be completed under certain conditions. It follows from the definition that it does not characterize the physically possible maximum completeness of oil recovery. It shows only the fraction of oil that can be recovered from the reservoir during its development to the economically feasible limit. Thus, the concept of "oil recovery factor" is, in fact, conditional: it defines only that part of the balance reserves, the extraction of which is economically feasible[9].

*Corresponding author: Smirnov VI, Doctoral Candidate, Petroleum Engineering Dept., Mining Institute, E-mail: vi620929 @gmail.com

Received January 12, 2008; Accepted January 28, 2008; Published February 10, 2008

Citation: Smirnov VI and Al-Obaidi Sudad H (2008) Innovative methods of enhanced oil recovery. Oil Gas Res 1: e101. doi: 10.4172/2472-0518.1000e10

Citation: Smirnov VI , Al-Obaidi Sudad H (2008) Innovative methods of enhanced oil recovery. Oil Gas Res 2008, 1:1
DOI: 10.4172/2472-0518.1000e10

Enhanced Oil Recovery Methods

In order to increase the economic efficiency of hydrocarbon development, reduce direct investment, as well as create optimal conditions for reinvesting capital, various methods are used to increase oil recovery during the entire development period of the field. This development is divided into three main stages (Fig. 1).

At the first stage, for oil production, whenever possible, the natural energy of the field (reservoir pressure) is used, including elastic energy, the energy of dissolved gas, aquifer waters, gas caps, as well as the potential energy of gravitational forces. In practice, when developing fields in natural mode, the volume of oil recovery varies from 5% to 15% [10][11].

At the third stage, when the field is already characterized by a high degree of water cut and depletion (Fig. 1), enhanced oil recovery methods are used to improve the development efficiency, which are the target of our study. It is these methods that increase the level of oil recovery by 35–75% [13]. Currently, under modern tertiary EOR, with all their diversity, as a rule, they mean the following:

- Gas displacement - injection of carbon dioxide (CO2), nitrogen (air) or gas.
- Physico-chemical methods - injection of chemicals (eg alkali, surfactant or polymer).
- Thermal methods - steam injection.
- Drilling of horizontal wells with multi-stage hydraulic fracturing (MSHF), which consists in carrying out hydrosand-jet perforation through tubing with subsequent hydraulic fracturing in one operation.

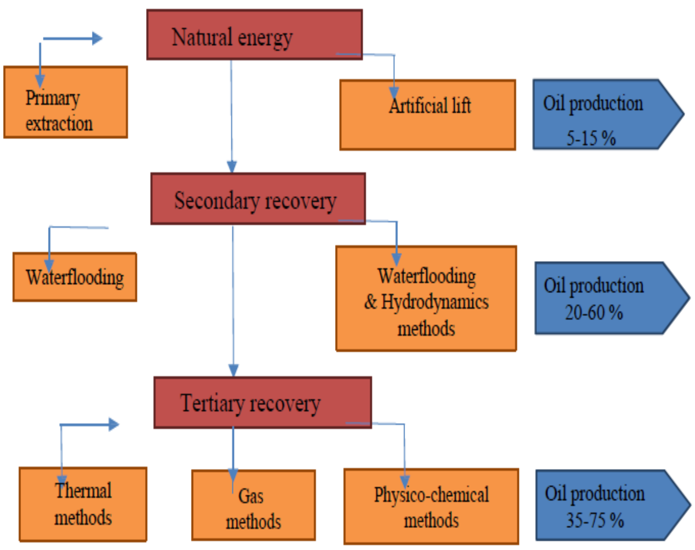

Figure 1: Methods of oil recovery

World experience testifies to the possibility of increasing oil recovery through the use of gas methods by 5-10%, physicochemical - by 3-8% and thermal - by 15-20% . According to our estimates, thermal projects account for about 50% of the EOR production worldwide, nitrogen and CO2 injection - 45%, and chemical methods - only 5% (Fig. 2).

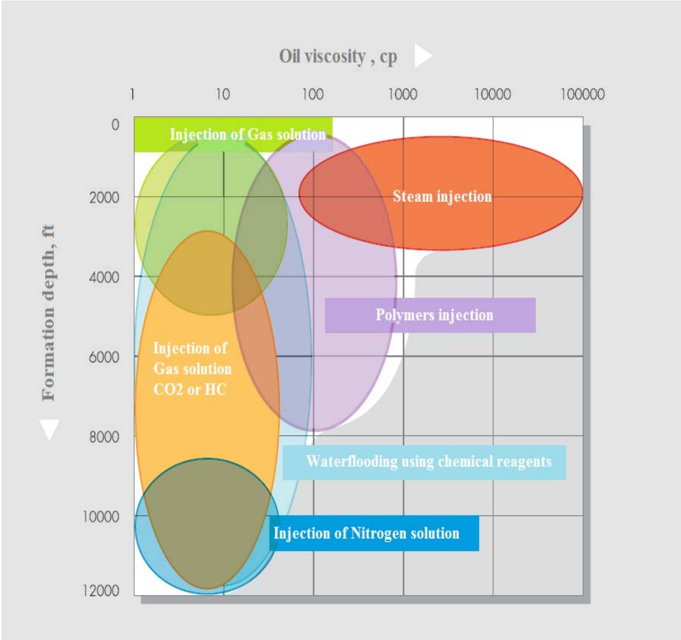

Figure 2 : World experience on the possibility of enhanced oil recovery

In the USA, the most widespread are gas and thermal EOR [14].

The International Energy Agency provides extended criteria for the application of EOR, which include depth, current recovery, temperature, density, permeability, rock type. In general, their applicability is tied to two main criteria: the depth of the productive formation and the physicochemical properties of oil (primarily density and viscosity). An assessment of the selection criteria for the method of average Russian indicators (excluding super heavy and / or bituminous oil) is presented. As the viscosity (density) of oil increases and the depth of its occurrence, the possibility of extraction by a certain method is determined. Thus, chemical methods can be carried out at a depth of up to 2500 meters, and thermal methods - up to 1000 meters [15].

Thermal Steam Treatment

Cyclic steam injection into the reservoirs, or steam cyclic treatment of production wells, is carried out by periodic direct steam injection into the oil reservoir through the production wells, keeping them closed for some time and then operating the same wells to extract oil with reduced viscosity and condensed steam from the reservoir[16]. The purpose of this technology is to warm up the formation and oil in the bottomhole zones of production wells, reduce oil viscosity, increase pressure, facilitate flow conditions and increase oil flow to the wells. The mechanism of the processes occurring in the reservoir is rather complex and is accompanied by the same phenomena as the displacement of oil by steam. Moreover, there are also counter-current capillary flow and redistribution of oil and water (condensate) in a micro-heterogeneous medium during holding without extracting fluid from wells. When steam is injected into the formation, it naturally penetrates into the most permeable layers and large pores of the formation.

During holding in the heated zone of the formation, an active redistribution of saturation occurs due to capillary forces: hot condensate displaces, replaces low-viscosity oil from small pores and low-permeability lenses (layers) into large pores and highly permeable layers, that is, it changes places with it [17].

It is this redistribution of reservoir saturation with oil and condensate that is the physical basis of the oil recovery process by means of steam-cyclic action on the reservoir. Without capillary exchange of oil and condensate, the effect of cyclic steam action would be minimal and would be exhausted in the first cycle.

Steam-thermal treatment of wells as a method of stimulating oil inflow and increasing the productivity of wells, based on an artificial increase in temperature in their wellbore and near-wellbore zone. It is mainly used in the extraction of highly viscous paraffinic and resinous oils [18]. Heating leads to the liquefaction of oil, melting of paraffin, resinous substances that have settled during the operation of wells on the walls, lifting pipes and in the bottom-hole zone. Upon resumption of operation, these substances are carried along with the oil to the surface. Wells that have reduced production rate due to waxing of the bottomhole zone restore it after heat treatment of the wells.

Heating leads to the liquefaction of oil, melting of paraffin, resinous substances that have settled during the operation of wells on the walls, lifting pipes and in the bottom-hole zone. Upon resumption of operation, these substances are carried along with the oil to the surface. Wells that have reduced production rate due to waxing of the bottomhole zone restore it after heat treatment of the wells. Heating is carried out by injection of a heated heat transfer fluid (oil, gasoline, kerosene, diesel fuel, water) into the reservoir, cyclical steam-thermal, electric-thermal, thermal-acid treatment, electromagnetic and thermo-acoustic effects [19].

Injection of a heated heat transfer fluid into the well is carried out on viscous resinous and paraffinic oils located at a depth of up to 1.5 km. It is carried out in two ways: without interrupting the operation or with shutting down the well. During continuous operation of the submersible pump, hot fluid is pumped through the annulus. During shut-in well way, a pump is removed from the shut-in well before injection, a packer is installed in the top of the productive formation, after which the heat carrier is pumped through pipes and pushed into the bottomhole zone. Then the packer is removed, the pump is lowered and the well is resumed [20].

Cyclic steam-thermal treatment is used in fields up to 1000 m deep with high-viscosity (over 50 MPa.s) and (or) paraffinic oils. Saturated dry steam is pumped through the pump and compressor pipes into a shut-in well equipped with a heat-resistant packer or without it (at a depth of up to 500 m). Then the well is sealed and maintained for 2-5 days, after which the pumping equipment is lowered and operation is resumed. The heated zone remains 2-3 months [21].

In one of the two tested fields , wells with a depth of 730 - 830 m, with a flow rate of 4 t/day were processed. The duration of steam-heat treatment varied from 7.5 to 21 days, with an average of 13.85 days. The holding time after steam injection is 0.5-0.8 days. The steam injection pressure at the mouth is 0.24-4.5 MPa, with an average of 1.5 MPa. The temperature at the mouth is 125-256 °C, with an average of 186.4 °C. Steam consumption per treatment is 196 -1904 tons, with an average of 568.6 tons.

The bottomhole temperature before treatment is 13 -18 ° C, on average of 16.19 ° C. After treatment 72 to 256 ° C, on average of 123 ° C. The average production rate before treatment (for 15 wells) is 1.212 tons / day with fluctuations from 0.1 to 4 tons / day.

The amount of heat introduced into the well per treatment is 5.44 - 931.65 million kJ, on average 194.72 million kJ per treatment. The duration of the effect is 48-1698 days, on average 711.5 days. Additionally, oil was produced from 28 to 1905 t / well, on average 585 t / well. Specific steam consumption was 0.12 - 9.31 t / t with an average specific steam consumption of 1.94 t / t.

Thermal treatment of the near wellbore zone is successfully used not only for stimulation of inflow in production wells, but also for injection wells. Heat treatment is especially important when converting production wells for water injection or, in other words, for the development of injection wells in cutting rows after they have been developed for oil, especially if the reservoir temperatures are low and the content of paraffins and asphalt-resinous substances in the oil is high [22].

In the heat treatment of near-wellbore zones, mobile steam units (MSU) are sometimes used to dewax tubing in wells and flow lines [23]. MSU is a small capacity direct-flow steam boiler installed on a truck chassis. The productivity of such an installation is 1 t / h of steam at a pressure of up to 10 MPa. The temperature of the outgoing steam is up to 310°C. Due to the low performance, up to six MSU are used for parallel operation. Although this gives a technological effect, it is ultimately not economically justified.

However, electric heating, due to the low thermal conductivity of rocks, fails to heat up a more or less significant zone, and the radius of the isotherm with an excess temperature of 40 ° C, as calculations and studies show, barely reaches 1 m.

When pumping a heat carrier, the radius of the heating zone can be easily brought to 10 - 20 m, but this requires stationary boiler installations - steam generators. With periodic electric heating of the near-wellbore, an electric heater with a capacity of several tens of kW is lowered into the well on a special cable-rope to the required depth. An increase in power leads to an increase in the temperature in the area of the heater up to 180 - 200 0C, causing the formation of coke from the oil.

The practice of using electric heating of the near-wellbore zone has shown that the temperature at the bottomhole stabilizes after 4-5 days of continuous heating. In some cases, stabilization occurs after 2.5 days [24]. Temperature measurements along the wellbore showed that the heated zone extends approximately 20-50 m up and 10-20 m down from the electric heater installation site. After turning it off, the bottomhole temperature drops at a rate of about 3 - 5 ° C / h. Therefore, it is necessary to put the well into operation after electric heating without delay. The heating effect lasts about 3-4 months. Repeated warming up usually shows a decrease in efficiency.

The main disadvantages of the method [25]:

1. The need to use clean high quality water for the steam generator. Water treatment is needed with chemical reagents.
2. The displacement of oil by steam from sand layers, after warming up, to production wells is accompanied by the removal of sand, and from clay layers by a decrease in permeability.
3. At a depth of more than 1000 m, heat loss occurs up to 45%.

Conclusions

Steam-thermal treatment of wells is a method of stimulating oil inflow and increasing the productivity of wells. It is mainly used in the extraction of highly viscous paraffinic and resinous oils . The implementation of the this technology ,as one of the EOR methods, has shown that by heating up the formation and oil in the bottomhole zones of production wells leads to reduce oil viscosity, increase pressure, facilitate flow conditions and increase oil flow to wells.

Cyclic steam-thermal treatment is used in fields up to 1000 m deep with high-viscosity (over 50 MPa.s) and (or) paraffinic oils. Wells that have reduced production rate due to waxing of the bottomhole zone restore it after heat treatment of the wells.

In the heat treatment of near-wellbore zones, mobile steam units (MSU) are sometimes used to dewax tubing in wells and flow lines.

Heat treatment is especially important when converting production wells for water injection or, in other words, for the development of injection wells in cutting rows after they have been developed for oil.

References

1. Khayitov, OG (1997). "Evaluation of the final oil recovery by multivariate regression analysis". Uzbek Geological Journal 1: 70-73.

2. Al-Obaidi, Sudad H.(1996) . "Разработка Методики И Технологии Обработки Данных ГИС И Керна Для Определения Подсчетных Параметров Нефтегазовых Месторождений Ирака : На Прим. Месторождения Вост. Багдад." OSF Preprints, 10.31219/osf.io/f6vka .

3. Akramov, B.Sh and Hayitov, OG (2003). "Development of oil and gas fields in conditions of abnormally high reservoir pressures". Institute for Modeling Problems in Energy, Kiev 21:113-118.

4. Al-Obaidi, Sudad H. and Guliaeva NI. (2002). "Determination of Flow and Volumetric Properties of Core Samples Using Laboratory NMR Relaxometry." engrXiv,10.31224/osf.io/ t46wj .

5. Akramov, B.Sh and et al. (2004). "Investigation of the dependence of oil viscosity on pressure at the reconciliation of developed fields". Bulletin of Tashkent State Technical University 2 :105-110.

6. Al-Obaidi, Sudad H.(1990) "Comparison of Different Logging Techniques for Porosity Determination to Evaluate Water Saturation." engrXiv, 10.31224/osf.io/fvj9u.

7. Surguchev, ML and Gorbunov AT (1991). "Residual oil recovery methods". M , Nedra: 347.

8. Al-Obaidi, Sudad H. and Аль Обейди, Судад Х. (1996)." Определение Глинистости Продуктивных Пластов Месторождений Нефти И Газа Восточного Багдада." OSF Preprints, 10.31219/osf.io dmw9c .

9. Boyko, VS (1990). "Development and operation of oil fields". Textbook for universities, M , Nedra: 427.

10. Al-Obaidi, Sudad H.(1998) . "Areas of Effective Application of Submersible Centrifugal Pump Installations with and Without a Gas Separator." engrXiv, 10.31224 osf.io/2c84h .

11. Surguchev, ML and Sharbatova IN (1988). "Cyclic impact on heterogeneous oil reservoirs". - M .: Nedra: 121.

12. Al-Obaidi, Sudad H. 2004. "Modified Use of Microbial Technology as an Effective Enhanced Oil Recovery." OSF Preprints, doi:10.31219/osf.io/xgthz .

13. Surguchev, ML (1985) . "Secondary and tertiary methods of enhanced oil recovery". - M .: Nedra :308.

14. Al-Obaidi, Sudad H.(1999) "Submersible Screw Pumps in Oil Industry."engrXiv, 10.31224/ osf.io/zqu3c.

15. Batycky, J and et al. (1997). "A Mechanistic Model of CyclicSteam Stimulation," International Thermal Operations and Heavy Oil Sympo-sium, Bakersfield, CA, Feb. 10–12, SPE: 37550.

16. Al-Obaidi, Sudad H., Patkin AA, and Guliaeva NI. 2020. "Advance Use for the NMR Relaxometry to Investigate Reservoir Rocks." OSF Preprints,10.31219/osf.io/jmb9t.

17. Altunina, LK and Kuvshinov, VA (2007). "Enhanced oil recovery of viscous oildeposits using physical and chemical methods". Technologiya TEK, 1(32): 46–52.

18. Al-Obaidi, Sudad H. (1996). "Разработка Методики И Технологии Обработки Данных ГИС." OSF Preprints, 10.31219/osf.io/e68us .

19. Cheremisin, NA and et al. (1997) . "Conditions for the formation of residual oil saturation in polymictic reservoirs during flooding" .Oil industry 9: 40–45.

20. Al-Obaidi, Sudad H. (1996) "Модификация Уравнения Арчи Для Определения Водонасыщенности Нефтяного Месторождения Восточный Багдад." OSF Preprints, 10.31219/ osf.io/ tqpn5 .

21. Gazizov, AA (2002). "The increase in oil recovery from heterogeneous reservoirs at the late stage of development". Moscow: Nedra-Businesscentre.

22. Al-Obaidi, Sudad H., and Galkin AP. 2005. "Dependences of Reservoir Oil Properties on Surface Oil." OSF Preprints, doi:10.31219/osf.io/789wp .

23. Leaute, RP and et al. (2004). "Liquid Addition to Steam for Enhancing Recovery of Cyclic Steam Stimulation or LASER-CSS". Patent No. 6708759.

24. Al-Obaidi, Sudad H. 2021. "Analysis of Hydrodynamic Methods for Enhancing Oil Recovery." OSF Preprints. January 12. doi:10.31219/osf.io/fvh5w.

25. Ghoodjani, E. and et al. (2012). "AReview on Thermal Enhanced Heavy Oil Recovery From Fractured CarbonateReservoirs". SPE Heavy Oil Conference Canada, Calgary, AB, Canada, June12–14, SPE:150147-MS.