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Hot Water-Flooding

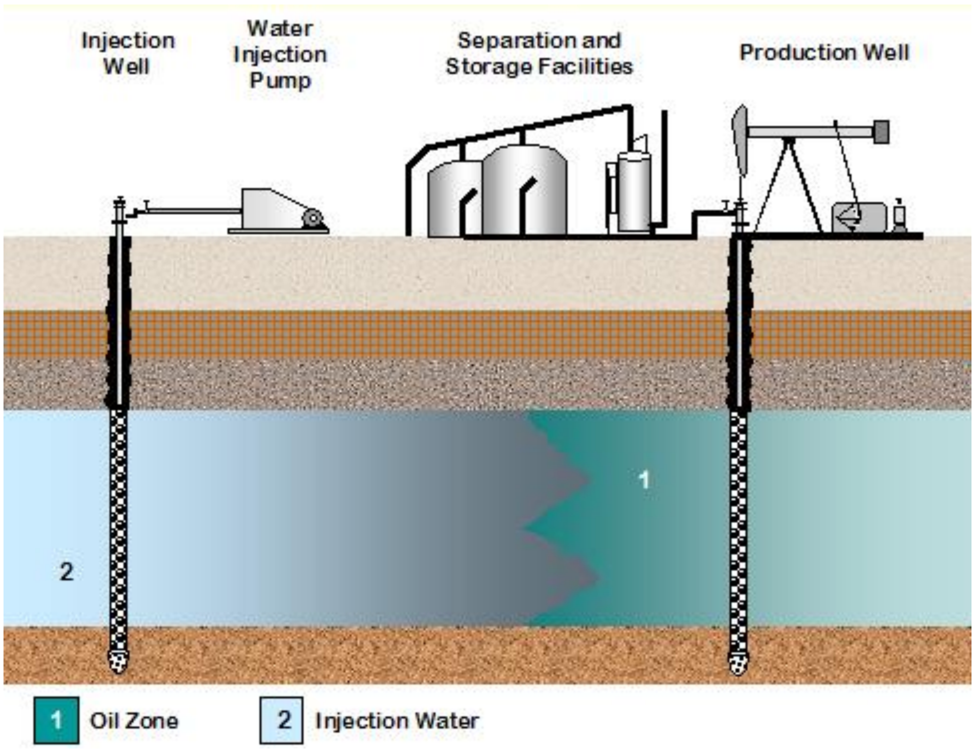

Fig. 1: Hot water flooding

Also known as hot water injection, hot waterflooding is an enhanced oil recovery technique that involves the forceful injection of hot water into the reservoir via an injection well. The injection well is drilled parallel to the main producing well.

The heat from the hot water reduces the viscosity of the heavy oil, easing its flow towards the producer well i.e. improving the sweep efficiency. Hot water is especially effective in the development of fields with high-viscosity oils, which contain large quantities of paraffin and resinous asphaltene substances, and which exhibit non-Newtonian properties as they flow through porous media. Hot water flooding works best for crude oil systems with API gravity less than 20^{o}API.

Hot water flooding is less effective than steam injection process, as hot water has a lower heat content than steam. However, hot waterflooding is preferred under conditions such as formation sensitivity to fresh water.

Sometimes, hot waterflooding occurs when the steam generators are not powerful enough, resulting in only hot water arriving at the reservoir bottom.

Cyclic Steam Stimulation (CSS)

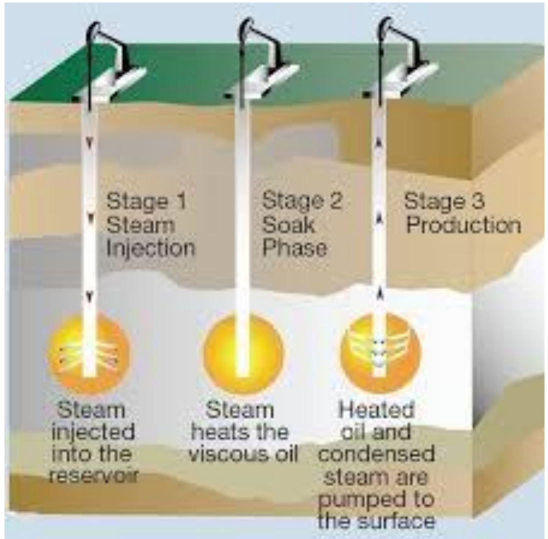

Fig. 2: Cyclic steam injection

Cyclic steam stimulation, also known as cyclic steam injection, as the name implies, involves the injection of steam into the reservoir in cycles. Each cycle consists of three phases;

I. Injection of steam at high pressure into the well.

Here, steam is injected at a pressure greater than the formation fracture pressure. This phase of the cycle usually lasts for several weeks, even months.

II. Soaking period.

In the soaking period, the injected steam is allowed for a period of time, usually five days, to saturate the reservoir formation, reducing the viscosity of the heavy oil and mobilizing the oil. An optimum soaking period must be found to prevent heat loss in long soaking periods, and heat accumulation in short soaking periods.

III. Production of the oil and steam condensate.

This is the final phase in each cycle, where the flow is reversed, converting the injector well to a producer for the production of the now mobilized crude oil. Production goes on until the flowrate has declined below the economic limit due to the cooling of the reservoir. Then, the cycle is repeated with the injection of high-pressure steam. The cycle is repeated until it is no longer economic to continue, usually after a few cycles.

Due to this cyclic operation, CSS is also known as the *huff and puff* technology.

In CSS, a single well acts as both injector and producer.

Historically, CSS is applied in the recovery of heavy oils and bitumen. It is predominantly a vertical well process, leading to the production of heavy oil and steam condensate (Speight, 2013).

According to Tarek and Meehan (2012), CSS significantly improves oil rate by 3 means:

I. Removing accumulated asphaltic and/or paraffinic deposits around the wellbore, resulting in an improvement of the permeability around the wellbore (i.e. a favourable skin factor).
II. Decreasing the crude oil viscosity (μ_o), thus improving oil mobility and well productivity.
III. Increasing the thermal expansion of the oil, which impacts the oil saturation (S_o) and its relative permeability (Kr_o).

According to Ehsan and Fatemeh (2018), CSS is not recommended for the following reservoir systems:

I. Gas cap reservoirs, as gas cap increases gravity override of steam, reducing the overall efficiency of the process.
II. Bottom aquifer drive reservoirs, as the bottom aquifer acts as a competitor for crude oil in receiving the heating energy of steam. This situation makes CSS uneconomical.

Steam-Assisted Gravity Drainage (SAGD)

Fig. 3: Steam-Assisted Gravity Drainage

Steam-assisted gravity drainage is a unique thermal technique of enhanced recovery of heavy oils. It involves the drilling of a pair of horizontal wells, parallel to each other and about 16 feet (5 meters) apart. The upper well is the injector, while the lower well is the producer.

<u>Theory of Operation:</u>

Steam is continuously injected into the upper well at high pressure. The heat from this steam causes a reduction in viscosity of the heavy oil beneath, increasing its mobility. This mobile oil is forced by gravity to drain down into the producer well, from where it is produced to the surface.

SAGD was first proposed in the 1970s by Dr. Roger Butler, and is mainly used for the production of bitumen and heavy oils.

References:

Speight, James G. PhD, DSc (2013). Thermal Methods of Recovery in *Heavy Oil Producing Processes.*

Tarek Ahmed and D. Nathan Meehan (2012). Introduction to Enhanced Oil Recovery in *Advanced Reservoir Management and Engineering*, 2nd Edition.

Schlumberger Oilfield Glossary, https://www.glossary.oilfield.slb.com.