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QUESTION:
Briefly discuss the following thermal enhanced oil recovery methods (diagrams inclusive):

01 Steam assisted gravity drainage (SAGD)
02 Cyclic steam stimulation (CSS)
03 Hot water flood.

ANSWERS

(i) Introduction:

Oil recovery processes are increased due to dependency of the industry to them and the requirements to petrochemical products. This leads to oil extraction from unconventional reservoirs to compensate the possible deficiency between product and demand; and oil with low API gravity. The total amount of bitumen and heavy oils is about 9 trillion barrels. The properties of these oils include low API gravity, high viscosity, and asphaltene content. One technique for increasing the displacement which leads to enhancement of heavy oil recovery is viscosity reduction. This facts states the significance of EOR (thermal EOR) processes, in which the generated heat at the surface or in situ from steam or hot water is injected through the porous media.

(ii) Brief insight or overview.

However, various methods of thermal EOR are applied in different ranges of viscosity. For instance, steam flooding is effective for heavy oil extraction, , cyclic steam stimulation (CSS) is applicable for extra-heavy oil, and steam-assisted gravity

drainage (SAGD) process is introduced for the recovery of bitumen. This process leads to generation of greenhouse gases as a result of burning the fuel which may cause environmental problems.

To deeply understand the mechanism of thermal EOR processes, it is necessary to review various mechanisms of heat transfer including conduction, convection and radiation. The momentum equation reveals the dependency of flow to viscosity. Variations of interfacial tension and the phase change lead to application of mass transfer equations and complications reactions which occur in thermal EOR processes. This complexity and difficulty in prediction of the reservoir behaviour may lead to reviewing of thermal EOR processes.

Below, i'll be briefly discussing some methods of Thermal, EOR and how they're compared to each other.

) Steam-assisted-gravity drainage (SAGD):-

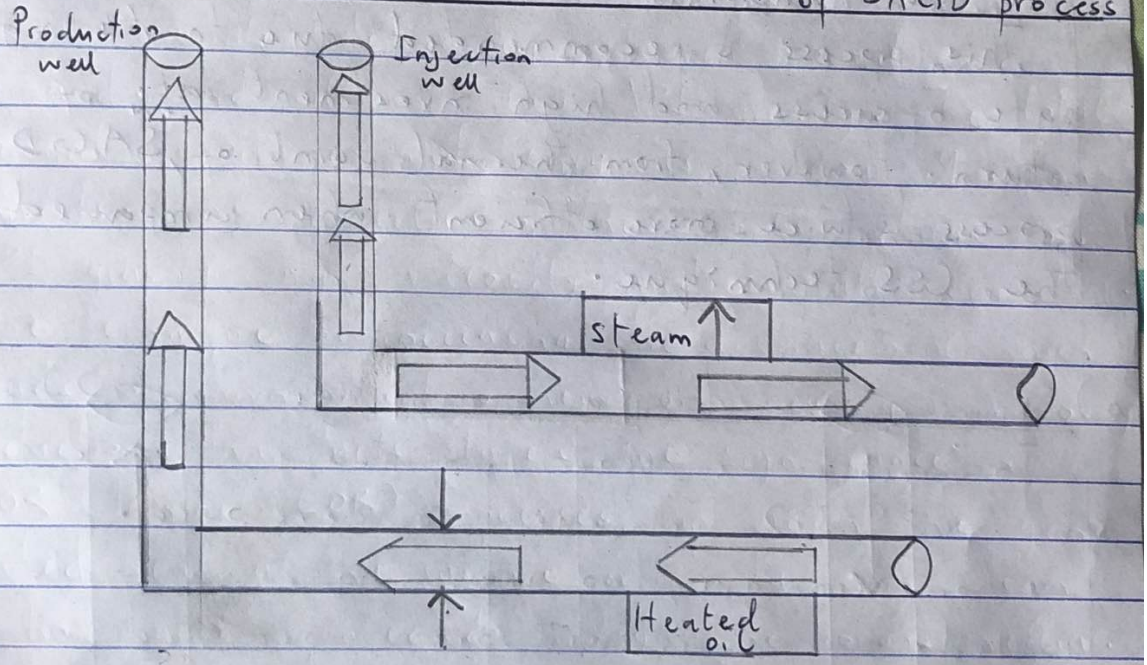
To increase the recovery of heavy oil and bitume n, the SAGD technique was developed. In this method/technique, two uneven horizontal wells are drilled. The upper wellbore is occupied with continuos stream of high pressure gas. This heat leads to oil viscosity reduction and moves the heated oil from upper well to the lower one and pumps it out. However, this method is best suited for heavy oil extraction in carbonate reservoirs as reported by Hosseini et al.

As the heat transfer has occurred in this process

, the steam which is injected creates a 'steam chamber'. steam and other gases are accumulated within the upper well due to their lower density in comparison to oil and fill it's empty space left by the oil. The associated gas forms an insulating space over the steam. No vapor is produced in the lower well. This fluid is pumped to the surface using cavity pump which is appropriate for viscous fluids containing suspended solids.

Lastly, in the field, SAGD is considered the most popular in the oil sands and extra-heavy crudes. The output for the SAGD process would be 70% - 80% recovery of the OIP for suitable reservoirs.

Figure 1: Schematic illustration of SAGD process




: Cyclic steam stimulation (CSS):-

The CSS is a technique for enhanced oil recovery of heavy oils at primary production phase. Although, this method is also known as huff and puff method). involves three stages, which are namely; injection of steam, soaking period, and production of oil.

In this technique, steam is injected into the well for a period of time to raise the oil temperature resulting in reduced oil viscosity, which facilitates its mobility. After ensuring that there is enough amount of steam in the well, it is shut-in for a period of time, extended from few days to few weeks to make sure that the thermal energy is spread well, and the process is known as the "huff and puff" and is repeated until there would be a considerable amount of produced water. This process is then continued to heat the oil and compensate the pressure decline in the reservoir the production. In this technique, some injection wells may be converted to production wells and the total number of production wells would increase.

This process is recommended due to it's high rate of success and high investment rate of return. However, from thermal point of new, SAGD process is twice more effient. when compared to the CSS technique.

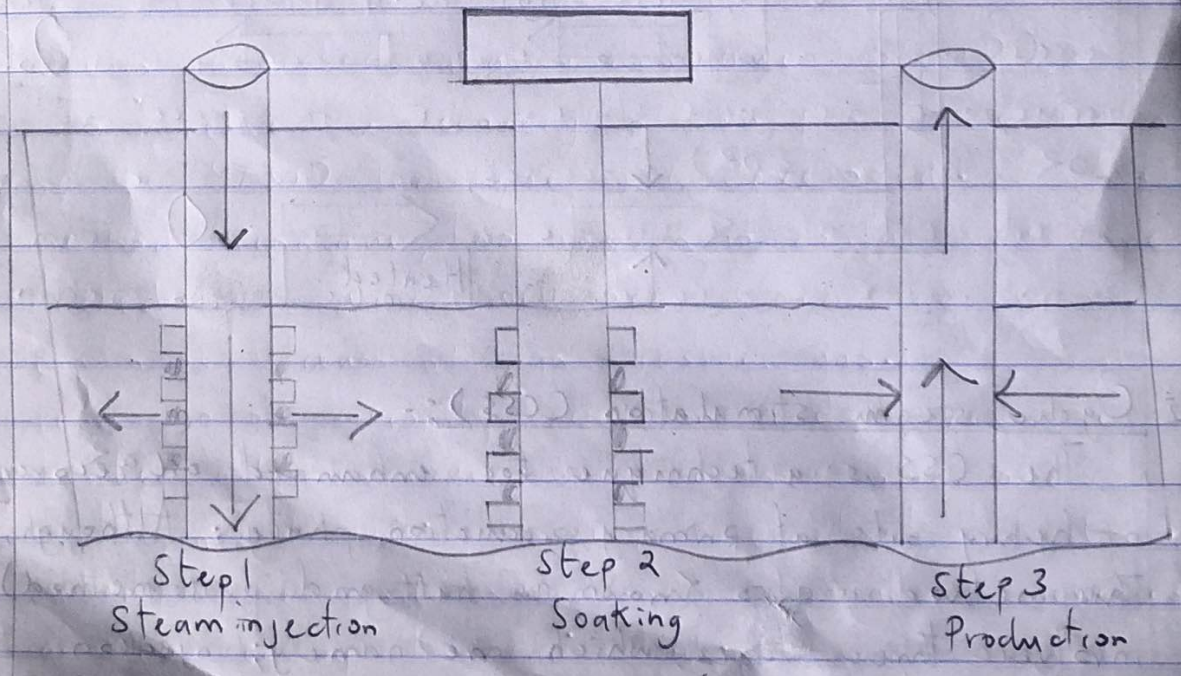
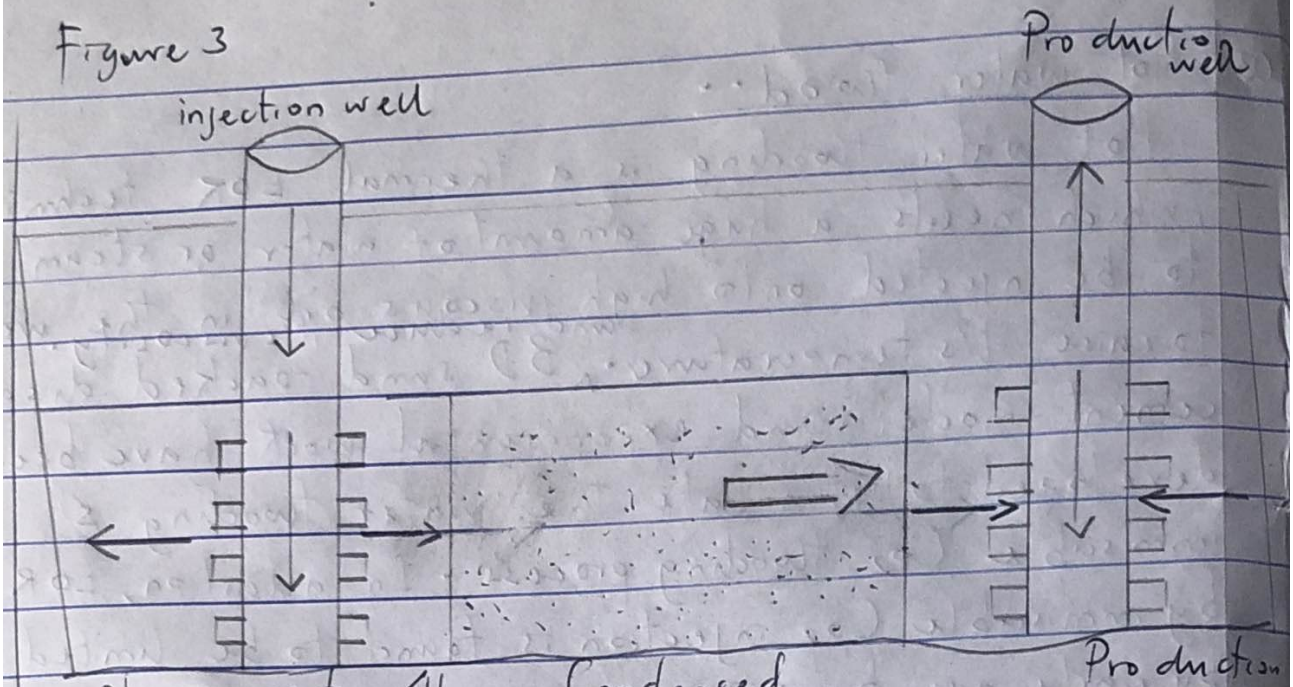



Figure 2 SCHEMATIC ILLUSTRATION OF C.S.S

03 Hot water flood:

Hot water flooding is a thermal EOR technique, which needs a huge amount of water or steam to be injected onto high viscous oil in the well to raise it's temperature. A 3D sand-packed displacement model and experimental work have been developed to stimulate the water flooding & immisible $Co_2$ flooding process. In addition, EOR by immisible $Co_2$ injection is found to be limited by early gas breakthrough, due to, mainly, the unfavorable mobility ratio between $Co_2$ and heavy oil. N/B: Hot water flooding is less efficient than steam injection due to the lower thermal energy content of water. On the other hand, the driving force of water is very high in relation to steam. The steam injection process involves continuous steam injection into an oil-bearing porous medium. The highly mobilized oil within the steam zone is subjected to a vaporizing gas drive as a result of which the final oil saturation is reduced to as low as 10%. Steam flooding has a typical RF ranging from 50% - 60%. Lastly, a numerical study has been conducted on steam injection in heavy oil revealed that it improves oil recovery up to 60% during a fixed period of time, and that only 30% of OOIP can be recovered by hot water injection method.

Figure 3




SCHEMATIC ILLUSTRATION OF STEAM/HOT WATER FLOODING PROCESS

Other figures: Figure 4.

Thermal EOR processes