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EXPLANATION OF STEAM ASSISTED GRAVITY DRAINAGE PROCESS

In the SAGD process, two parallel horizontal oil wells are drilled in the formation, one about 4 to 6 metres above the other. The upper well injects steam, and the lower one collects the heated crude oil or bitumen that flows down due to gravity, plus recovered water from the condensation of the injected steam. The basis of the SAGD process is that thermal communication is established with the reservoir so that the injected steam forms a "steam chamber". The heat from the steam reduces the viscosity of the heavy crude oil or bitumen which allows it to flow down into the lower wellbore. The steam and associated gas rise because of their low density compared to the heavy crude oil below, ensuring that steam is not produced at the lower production well, tend to rise in the steam chamber, filling the void space left by the oil. Associated gas forms, to a certain extent, an insulating heat blanket above (and around) the steam. Oil and water flow is by a countercurrent, gravity driven drainage into the lower well bore. The condensed water and crude oil or bitumen is recovered to the surface by pumps such as progressive cavity pumps that work well for moving high-viscosity fluids with suspended solids. Sub-cool is the difference between the saturation temperature (boiling point) of water at the producer pressure and the actual temperature at the same place where the pressure is measured. The higher the liquid level above the producer the lower the temperature and higher is the sub-cool. However real life reservoirs are invariably heterogeneous therefore it becomes extremely difficult to achieve a uniform sub-cool along the entire horizontal length of a well. As a consequence many operators, when faced with uneven stunted steam chamber development, allow a small quantity of steam to enter into the producer to keep the bitumen in the entire wellbore hot hence keeping

its viscosity low with the added benefit of transferring heat to colder parts of the reservoir along the wellbore. Another variation sometimes called Partial SAGD is used when operators deliberately circulate steam in the producer following a long shut-in period or as a startup procedure. Though a high value of sub-cool is desirable from a thermal efficiency standpoint as it generally includes reduction of steam injection rates but it also results in slightly reduced production due to a corresponding higher viscosity and lower mobility of bitumen caused by lower temperature. Another drawback of very high sub-cool is the possibility of steam pressure eventually not being enough to sustain steam chamber development above the injector, sometimes resulting in collapsed steam chambers where condensed steam floods the injector and precludes further development of the chamber. The process is relatively insensitive to shale streaks and other vertical barriers to steam and fluid flow because, as the rock is heated, differential thermal expansion allows steam and fluids to gravity flow through to the production well. This allows recovery rates of 60% to 70% of oil in place, even in formations with many thin shale barriers. Thermally, SAGD is generally twice as efficient as the older cyclic steam stimulation (CSS) process, and it results in far fewer wells being damaged by the high pressures associated with CSS. Combined with the higher oil recovery rates achieved, this means that SAGD is much more economic than cyclic steam processes where the reservoir is reasonably thick

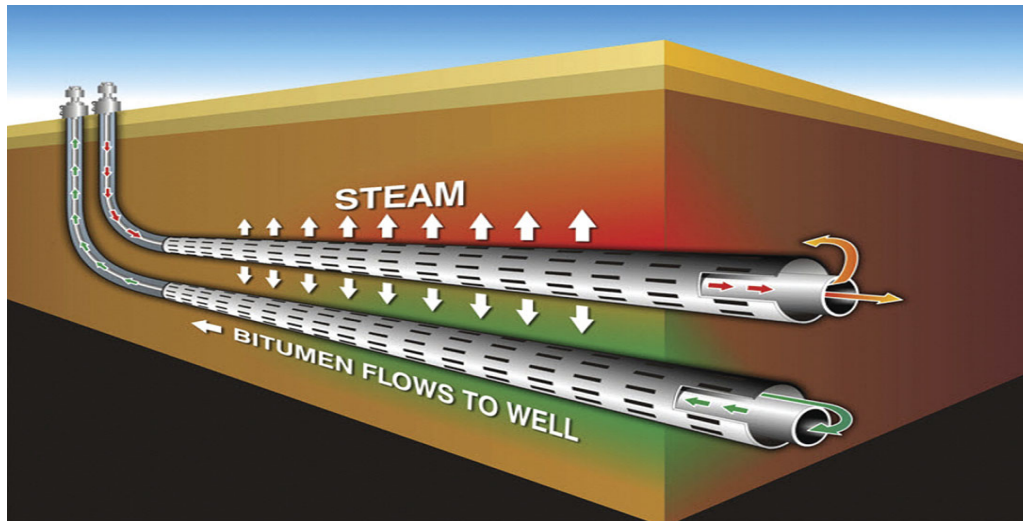


Figure 1.0: A typical steam assisted gravity drainage

EXPLANATION ON CYCLIC STEAM STIMULATION

This technique is by far the most popular thermal stimulation process and will be discussed in great detail in this thesis. Steam is injected into a formation at high rates for several weeks through a vertical well. The well is then shut-in for a certain period of time, which is called “soak” period. Steam condenses in the formation, thus heating the reservoir rock and fluids around the wellbore. During this period the oil viscosity is reduced by many times. The amount of oil produced in a cyclic steam injection process depends largely on how much the viscosity of oil is reduced, which is controlled by the amount of heat that is transferred from the injected steam to the reservoir. The heated sand contains mobilized oil, steam and water. The oil and other fluids are expelled out as the sand face pressure is lowered when the well is put on production. Oil is produced until the well reaches an economic limit and the cycle is repeated again.

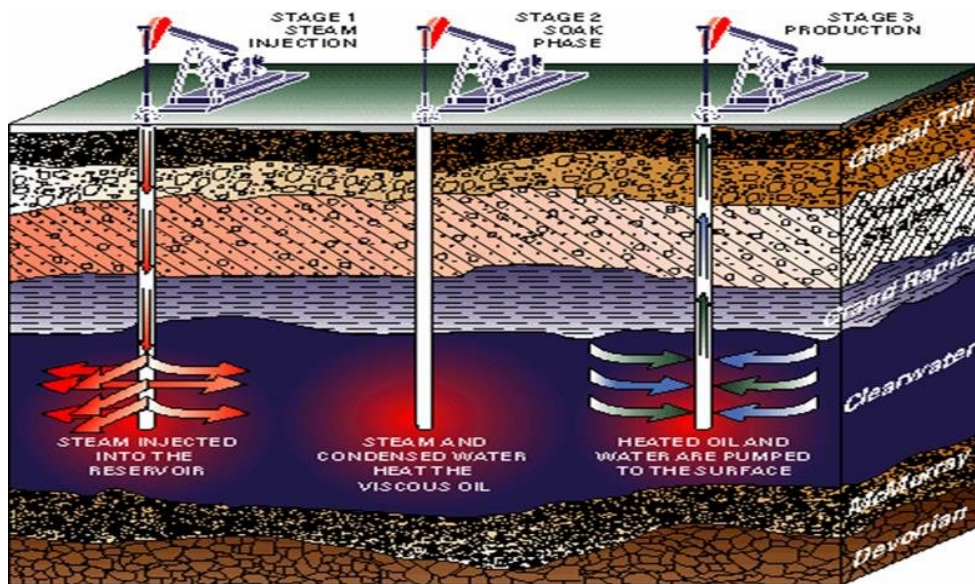


Figure 2.0: A typical cyclic steam injection process

There are several mechanics of oil production during this process. In high pressure reservoirs, oil is produced at higher rates due to the availability of the driving force, increase in oil mobility as a result of decreased viscosity. Gravity drainage is also a significant mechanism in thick formations, pressure depleted reservoirs. The low density phase i.e., steam, in this case, displaces the oil as it drains. Another mechanism is the compaction drive, which is seen in Bolivar Coast in Western Venezuela. As the pore pressure falls, there is a consolidation in the reservoir rock, which results in decrease in average porosity, and hence, oil is squeezed out from the porous rock. Another significant mechanism which is the key to success in Cold Lake is formation fracturing. Steam is injected at fracture pressure creating fractures in the formation and resulting in increase in the productivity of the reservoir. A part of the injected energy is stored in the form of potential energy by lifting the ground at the surface. When the well is put on production, the fluids are squeezed out of the formation⁵.

EXPLANATION OF HOT WATER FLOODING

Hot water flooding also known as hot water injection is a technique of increasing crude oil production from a producing well by injecting hot water into the reservoir. The hot water is injected through an injection well which is drilled parallel to the primary producing well. The heat from the hot water acts as a way of reducing the viscosity of crude oil, making it to flow toward the producing well with ease. Hot water flooding is generally used to extract crude oil which has an API degree of less than 20. Hot water flooding is considered as one of the techniques of increasing crude oil production under Enhanced Oil Recovery Technique (EOR) and thermal recovery. It is less effective than steam injection process, due to the fact that hot water has a lower heat content as compared to steam. Over time the pressure in an oil reservoir slowly and steadily decreases and as a result the production rate decreases. This is one of the techniques used by E&P organizations to enhance the production of heavy to medium category

crude oil from a reservoir. To use this technique, an injection well is drilled parallel to the primary producing well through which hot water is injected forcefully into the reservoir in the direction of the producing well.

The benefits of injecting water into the reservoir are:

- It supports the reservoir pressure, also known as voidage replacement.
- As oil is lighter than water hence it floats on top of the water. Also, the heat content of the water reduces the viscosity of heavy crude oil, making it not to stick on the edges of the reservoir and move quickly toward the producing well. Thus, water helps in displacing oil from its location in the reservoir and pushes it toward the producing well.

With this technique, oil recovery factor can be increased and well production rate can be maintained for a longer period.

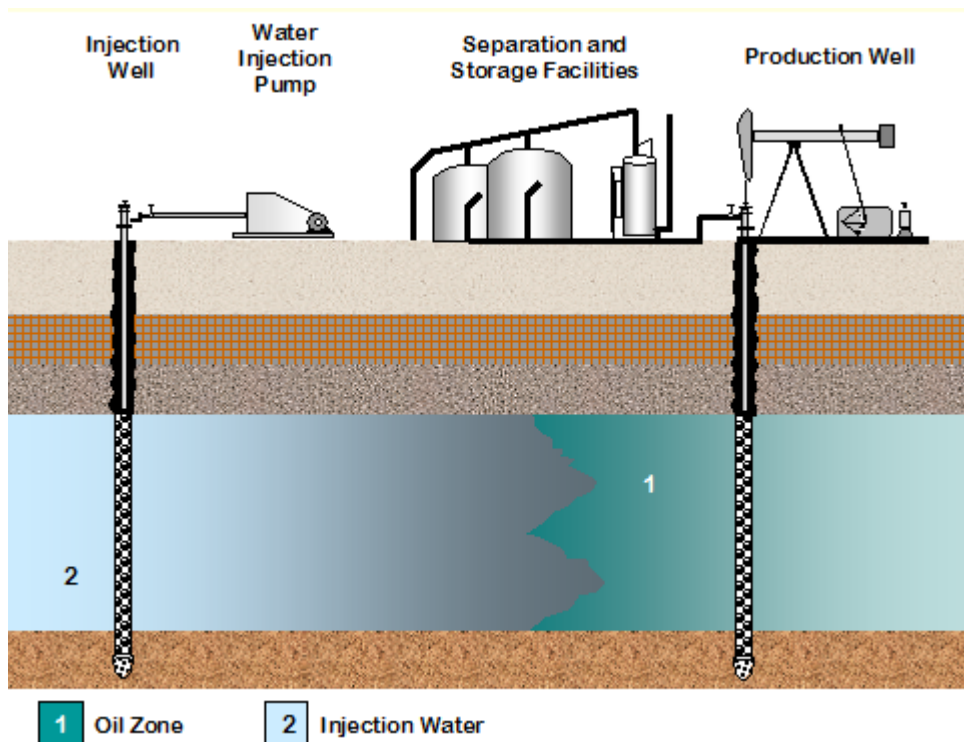


Figure 3.0: A typical Hot water flooding process