Alkaline flooding process

Alkaline flooding is one of the newest chemical enhanced oil recovery (EOR) methods. This process requires the injection of alkaline chemicals (caustic solutions) into a reservoir. Alkaline generates in situ surfactants when in reacts with acid content of the oil.

The reaction of these chemicals with acid content of the oil in the reservoir rocks results in the in situ formation of surfactants. This economic surfactant generated in oil-water interface, reduces interfacial tension significantly that leads to increase in oil recovery by extracting oil from tiny pores. The oil can then be more easily moved through the reservoir to production wells.

As in the two preceding methods, a polymer-thickened water solution process is introduced after the chemicals are injected to help obtain a more uniform movement or “sweep” through the reservoir. Fresh water is then injected behind the polymer solution to prevent contamination from the final drive water which may be salty or otherwise incompatible with the chemicals (Fig. 1).

In the alkaline waterflooding, the pH of the injection water is increased by the addition of relatively inexpensive alkaline agents such as sodium carbonate, sodium silicate, sodium hydroxide and potassium hydroxide in an effort towards improving oil recovery.

In this process, the alkali reacts with the acidic constituents in the crude leading to lower water-oil interfacial tension. Also, the alkali may react with the reservoir rocks, leading to wettability alteration. All of these mechanisms will potentially increase oil recovery.

Alkaline flooding is usually more efficient if the acid content of the reservoir oil is relatively high. A new modification to the process .is the addition of surfactant and polymer to the alkali, giving rise to an alkaline-surfactant-polymer (ASP) EOR method. This method has shown to be an effective, less costly form of miceller-polymer flooding.

In general, an alkaline (caustic) flood is used only in a sandstone reservoir because of the abundance of calcium in a carbonate reservoir brine. Although the most common chemical used in caustic flooding is sodium hydroxide, sodium orthosilicate and sodium carbonate also are used. Other chemicals that have been used include ammonium hydroxide, potassium hydroxide, sodium silicate. The cost is important, e.g., a chemical such as sodium hydroxide costs less than potassium hydroxide.

Divalent cations such as calcium and magnesium in the connate water can deplete a caustic slug by precipitation of hydroxides. Also, if anhydrite or gypsum is present in the rock, calcium will react with the slug to precipitate calcium hydroxide.

In general, caustic reacts too slowly with silica in sandstone to cause problems. Also, most dolomites and limestones will not react with the caustic to cause deleterious effects.

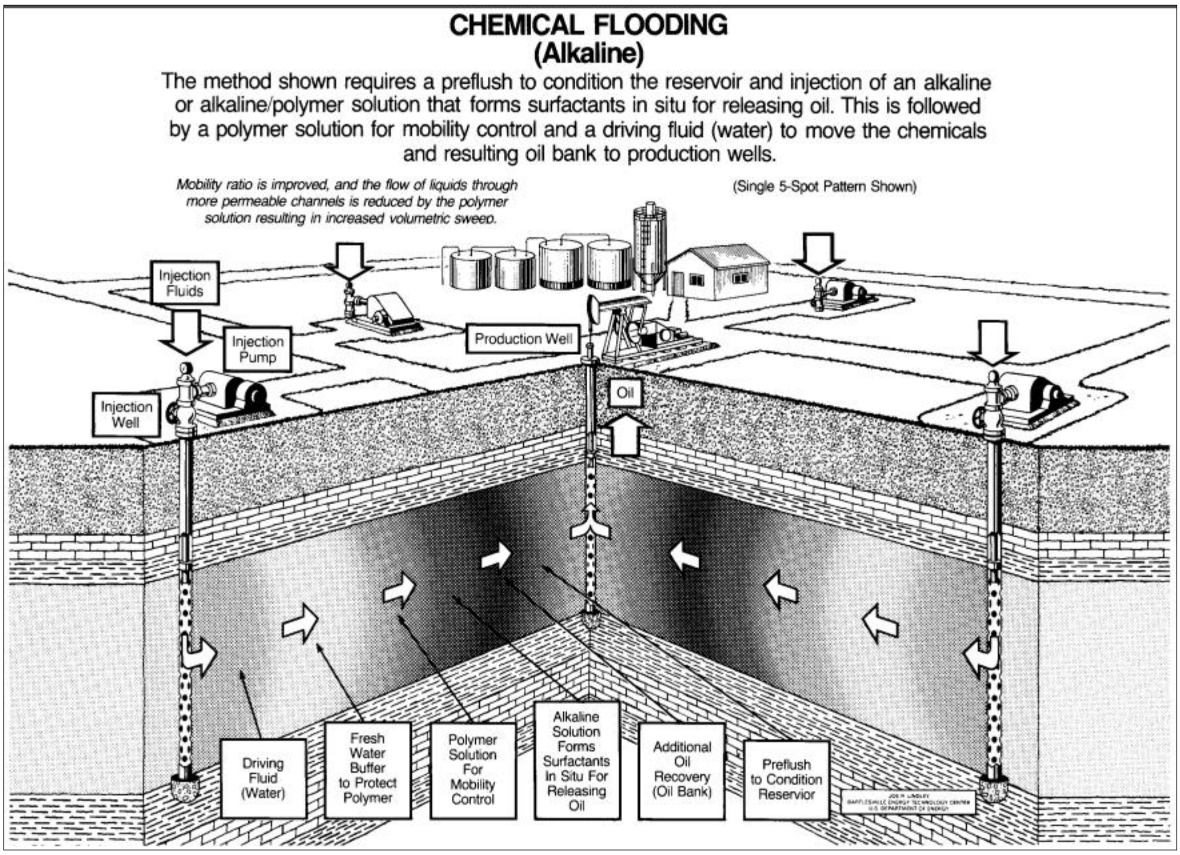

Figure 1: Alkaline flooding process.

Entrapment of residual oil:

The main factors which determine the entrapment and release of oil from a rock matrix are:

1- The geometry of the pore network and the macroscopic heterogeneities of the porous medium.

2- Fluid-fluid properties, such as interfacial tension, phase behaviour, and viscosity.

3- Fluid-rock properties, such as wettability, adsorption ion-exchange, and dissolution reactions.

4- Applied pressure gradients and gravity.

Displacement mechanisms in alkaline flooding:

Alkaline flooding enhances the recovery of acidic oils by two-stage processes. The first stage involves the mobilization of the residual oil by configurational changes like emulsification and wettability alteration. Surface-active salts are formed in situ by the acid-base reaction between the alkali and the organic acids in the residual oil. The surfactants thus generated may: (1) adsorb at the oil-water interface to lower the interfacial tension, and in some cases cause spontaneous emulsification and phase swelling; and (2) react with or adsorb at the rock surface, changing the wettability characteristics of the rock and hence the configuration of the residual ganglia of the crude oil.

The second stage involves the modification of the macroscopic production chatracteristics of the mobilized oil phase. The overall recovery efficiency may be increased in this stage by improvements in the displacement efficiency through mobility control, i.e., by reduction in the floodwater mobility.

Johnson (1976) reviewed the mechanisms by which alkaline flooding may improve recovery of acidic crudes from partially depleted reservoirs:

1- Emulsification and entrainment.

2- Emulsification and entrapment.

3- Wettability reversal from water-wet to oil-wet.

4- Wettability reversal from oil-wet to water-wet.

5- Lowering of interfacial tension.

6- Solubilization of rigid, interfacial films.

Reservoir selection:

A limited number of reservoirs may respond to alkaline flooding. After establishing such suitability, a comparative study must be done with other possible recovery techniques. General caustic flooding experience indicates that the basic criteria presented below may be useful in identifying reservoirs suitable for alkaline flooding.

Oil properties:

1- Amount of residual oil-in-place:

The amount of residual oil is fundamental to the design and evaluation of any recovery mechanism. The residual oil-in-place should at least be 400 bbl/acre-ft with a residual oil saturation of 40%. Higher oil saturations are obviously better.

2- Viscosity – gravity:

In general, chemical floods are applicable to oils the viscosities of which are in the range of applicability of waterfloods. The upper limit is somewhat extended over that of a waterflood to about 100 cp. Crude oils with viscosities in the 100 – 200 cp range may be more amenable to thermal methods.

The gravity should be in the range 13 – 35^o API for best results. Very heavy oils or very volatile oils make poor prospects.

3- Chemical character of the oil:

The chemical character of oil is very important, because it influences the interfacial tension. In caustic flooding, the oil must have acidic components that can react with the caustic to form surface-active agents. The oil should have no dissolved acid gases like H_2S and CO_2 that consume a lot of the injected alkali.

Reservoir characteristics:

Reservoirs that are not responsive to waterflooding are also not suitable for alkaline flooding. The major requirements and considerations are:

1- The reservoir should not be very heterogeneous; otherwise some zones would be inaccessible.

2- There should be no extensive fractures or thief zones causing the alkali to bypass the bulk of the rock with little or no response to the injection. Highly faulted and/ or fractured reservoirs are unsuitable.

3- Large degree of layering and shale barriers of large areal extent are detrimental to alkaline flooding. The net pay thickness should not be a small fraction of the gross formation thickness.

4- The pay zone must be of a sizeable areal extent and sufficiently thick.

5- An aquifer-connected water-drive reservoir is not suitable for alkaline flooding, particularly where a thin pay zone is underlain by a thick aquifer.

6- The reservoir permeability and porosity should be well developed. An adequate injectivity must prevail, in view of the fact that the emulsions formed during alkaline flooding have lower mobility and some plugging always occurs due to formation damage.

7- The reservoir should not have a gas cap, because a sizeable amount of the mobilized oil could move up to resaturate the gas cap.

8- The reservoir temperature is a critical parameter. The alkali consumption increases rapidly at higher temperatures, and a reservoir temperature of less than 200 ^oF is recommended.