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Enhanced Oil Recovery by using Polymer Flooding in Oil and Gas Industry in Tertiary Recovery Process

Dr. R. Giri Prasad[1],
[1]*Associate Professor, Dept. Of Petroleum Engineering, Aditya Engineering College,*

Abstract: ***In very early days of the oil industry, the general practice in land-based shallow reservoirs was to produce oil by primary depletion. In this method, the compression al energy of the reservoir was used to force oil to the producer wells, with a consequent drop in the reservoir pressure. However, it was recognized that reservoirs would ultimately drop below bubble point pressure, such that dissolved gas would be released from the oil. As a result of the appearance of this extra phase, production impairment would occur. In order to maintain reservoir pressure and also to sweep out oil in a more efficient displacement process, water flooding became the standard practice in many reservoir formations and still finds a wide application. When water is injected under pressure, it would seek the path of least resistance to point of lowest pressure, which is generally producing well. If the mobility ratio is one or less, the displacement of oil by water is found to be efficient. In effect, the displacement occurs in a piston like fashion. On the other hand if mobility ratio is greater than one, the more mobile water fingers through the oil leaving it in place in the reservoir.***

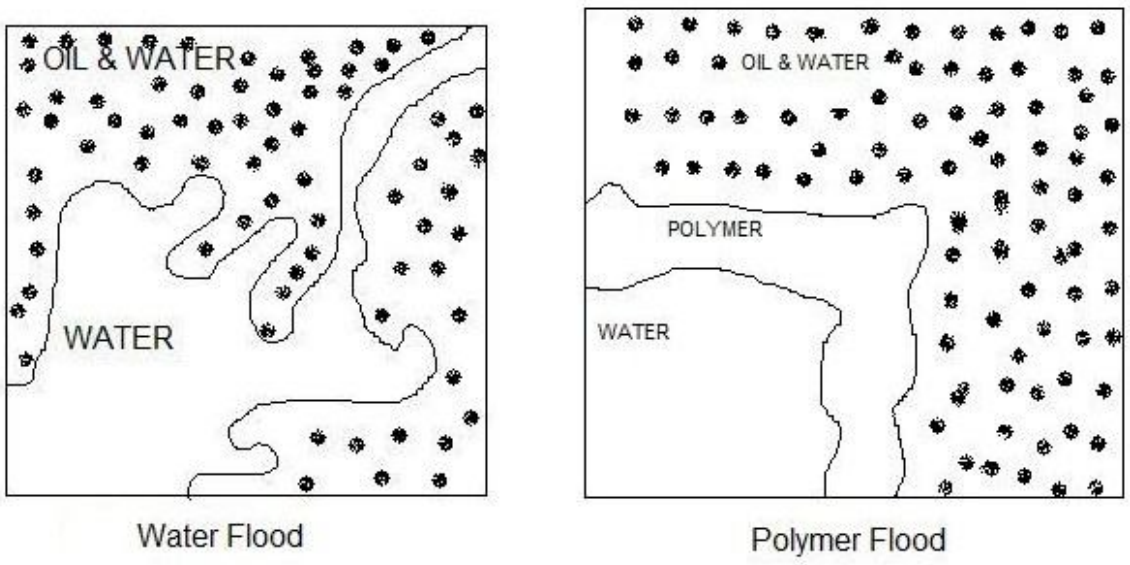


Figure 1.1: Water Flooding vs. Polymer Flooding Sweep Efficiency

I. INTRODUCTION

By polymer flooding a poor sweep efficiency may be improved, because the polymer solution of course first follows the paths prepared by water and then because of its high viscosity tends to ―block‖ these parts of the reservoir, so that oil that was previously immobile starts flowing. The pressure gradient in the reservoir and especially in those zones where oil was immobile becomes higher in a polymer flood than it was during water drive. Polymer improves the mobility ratio by its high viscosity solution and thereby increases the displacement efficiency.

A. Where Polymer Flooding

There are several broad guidelines which can be used to eliminate reservoirs as poor candidates for polymer flooding. These guidelines have been developed largely on the basis of past mistakes in field tests, (Jennings 1977).

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Polymer flooding offers significant potential over existing water flooding if the existing mobility ratios are poor (2 to 20) and/or significant permeability distribution variation exists. If the existing mobility ratio is greater than 20, the economics of the process are almost certain to be unfavorable. On the other hand, of the existing ratio is close to 1, very little will be gained by a polymer flood (Jennings 1977). If the existing water flood is performing poorly for reasons other than poor mobility ratio or permeability variation, the polymer flood is unlikely to solve the problem. (Dow, 1965)

Stated another way, if the high water-oil ratio is due to water coning, a high permeability zone or high viscosity oil (up to approximately 300 cP.) the use of polymer should be economically attractive.

Fluid injection should approximately equal fluid production. If there is significant imbalance, polymer will be wasted filling up gas caps or other void zones. The existence of extensive aquifers would also lead to a significant loss of polymer. Another inefficient use of polymer would be in highly fractured. These formations allow polymer to bypass without decreasing the mobility in the porous media.

Reservoir temperature should be less than 175-180o F. laboratory studies have shown that polymer solutions degrade noticeably at these elevated temperatures, losing their effectiveness.

The mobile oil saturation must be reasonably high to afford economic potential for polymer injection. Very low porosities, high residual oil or high recovery from primary or secondary operations would be some of the factors which would limit the mobile oil saturation. (Dow, 1965)

Water drive reservoirs which had little or no water production initially are good candidates for polymer flooding. (White et al, 1972)

B. Heterogeneous Reservoirs

Although oil reservoirs are characterized as porous media with certain porosities and permeabilities, they are almost never homogeneous beds with constant properties. Generally there are numerous strata with wide ranging properties. In terms of enhanced oil recovery, the divergence of reservoir permeability is a significant factor. There may be numerous fractures also. Together, the permeability variation and fractures can have a profound effect on the flow of fluids in a reservoir and thereby influence oil recovery.

As the high permeability zones and fractures offer the least resistance to flow, most of the injected fluids follow this path. In doing so, most of the oil remaining in the lower permeability zones is bypassed. The oil which is displaced from the high permeability zones and produced is replaced with injected fluid, lowering the residual oil saturation in these regions. As the oil saturation decreases, the permeability to water increases, further exaggerating the inequality in relative flow rates between the high and low permeability zones. The result is ever increasing water-to-oil ratios in the producing wells and low ultimate recovery of oil-in-place.

Variations of permeability in the vertical plane cause the injected fluid to advance from the injected fluid to advance from the injection point as an irregular front. A measure of this variation is the vertical sweep efficiency or invasion efficiency. It is defined as the cross sectional area contacted by the injected fluid divided by the cross-sectional area contacted enclosed in all layers behind the injected fluid front.

Adverse Mobility Ratio:

Even in the absence of reservoir heterogeneity, sweep efficiency may be low because of an unfavorable mobility ratio. The mobility of a fluid in a reservoir is defined as the permeability of the media to that fluid divided by the viscosity of that fluid. The mobility ratio of water to oil is the mobility of water in the reservoir divided by the mobility of oil in the reservoir.

$M = (Kw/\mu w)/ (Ko/\mu o) = (Kwr/\mu w)/ (Ko/\mu o)$

The permeabilities are not constant. They depend on relative fluid saturations in the reservoir and thus change as oil is displaced in the reservoir and thus change as oil is displaced in the reservoir. Because the permeability of water increases as the oil saturation decreases, the mobility ratio will increase as oil is produced. If the mobility ratio is one or less, the displacement of oil by water is found to be efficient. In effect, the displacement occurs in a piston like fashion. On the other hand if mobility ratio is greater than one, the

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Structure	Characteristics	Sample Polymer
–O– in the backbone	Low thermal stability, thermal degradation at high T, only suitable at <80°C	Polyoxyethylene, sodium alginate, sodiumcarboxymethylcellulose, HEC, xanthan gum
Carbon chain in the backbone	Good thermal stability, degradation not severe at <110°C	Polyvinyl, sodium polyacrylate, polyacrylamide, HPAM
–COO− in hydrophilic group	Good viscosifier, less adsorption on sandstones due to the repulsion between chain links, but precipitation with Ca2+ and Mg2+, less chemical stability	Sodium alginate, sodium carboxymethyl cellulose, HPAM, xanthan gum
–OH or –CONH2 in hydrophilic group	No precipitation with Ca2+ and Mg2+, good chemical stability, but no repulsion between chain links, thus less viscosifing powder, high adsorption due to hydrogen bond formed on sandstone rocks	Polyvinyl, HEC, polyacrylamide, HPAM
Source: Zhao (1991).		

more mobile water fingers through the oil leaving it in place in the reservoir. Polymers can improve the mobility ratio and thus increase the displacement efficiency in a reservoir.

C. Types of Polymers

Although a number of polymers and other viscosifying chemicals have been used to improve the mobility ratio between the displacing fluid and displaced fluids, two types of polymers have been identified as suitable polymers for modified water flood purpose. The two main types of polymers are synthetic polymers such as hydrolyzed polyacrylamide (HPAM) and biopolymers such as xanthan gum. Less commonly used are natural polymers and their derivatives, such as guar gum, sodium carboxymethyl cellulose, and hydroxyl ethyl cellulose (HEC). Table 1 summarizes the characteristics of different polymer structures.

D. Polymer Structures and their Characteristics

Table 1: Types of polymers

From Table 1, we learn that a good polymer should have the following properties:

No –O– in the backbone (carbon chain) for thermal stability

Negative ionic hydrophilic group to reduce adsorption on rock surfaces Good viscosifying powder Nonionic hydrophilic group for chemical stability

Based on these criteria, Hydrolyzed Polyacrylamide is a good polymer.

1) *Polyacrylamide:* Polyacrylamide are water soluble polymers which are produced by many manufacturers in many ways for different purposes, the monomer acrylamide is a compound derived from acrylic acid. In polymer flooding, Polyacrylamides undergo partial hydrolysis, which causes anionic (negatively charged) carboxyl groups (---COO^-) to be scattered along the

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backbone chain. These polymers are called Partially Hydrolyzed Polyacrylamides (PHPA), the degree of hydrolysis is 25-35% of the Acrylamide monomers, the PHPA molecule is negatively charged.

2) *Polysaccharides or Biopolymers:* Xanthan is produced in an industrial fermentation process using certain starch feeder material such as corn starch as the starting material from which Xanthamonascampestris ultimately produces the xanthan. The major advantages of the biopolymer over polyacrylamides are the good shear stability and the good thickening power at high salinity. The major disadvantages of the biopolymer have been the high cost, the difficulty of preparing solutions that do not plug core material,

E. Other Polymers

Other polymers which have been proposed and tested under laboratory conditions and the prevention of viscosity loss from biochemical or chemical reactions for evaluating their suitability as water thickeners for EOR purposes are:

1) Hydroxy Ethyl Cellulose (HEC)
2) Cellulose Sulphate Esters
3) Starch-Acrylamide Graft Copolymers
4) Polyethylene Oxides (Polyox)

Hydroxy Ethyl Cellulose (HEC), like polysaccharides, is less sensitive to salinity & shear and is stable at higher temperature (200 °F). However, HEC is less shear thinning than either polysaccharides or polyacrylamides and requires higher concentrations for the same viscosity however, these polymers have not been field tested so far.

F. Characterization of PHPA

Partially hydrolyzed polyacrylamide (PHPA or HPAM) used for IOR/EOR is known to be sensitive to temperature and divalent ions. The amide groups present in these polymers will hydrolyze in aqueous solution to an extent that depends on pH and temperature. The resultant more hydrolyzed polyacrylamide may have a degree of hydrolysis sufficient to cause precipitation in the reservoir or injection water used at high temperature.

1) *Effect of Shear Rate on PHPA :* PHPA solutions are shear rate sensitive. As the rate of shear strain is increased; the apparent viscosity decreases. This is because polymer particles break into small molecules into the solution.
2) *Effect of Water Salinity on PHPA :* The drastic reduction in viscosity occurs when % of NaCl (salinity) goes on increasing. Adding salt to polymer solutions alteration of the molecules occurs from distended to more nearly spherical shape molecules.
3) *Effect of Divalent ions on PHPA :* The divalent cations (such as calcium) have a more pronounced effect on viscosity reduction than does sodium. The drastic reduction in the effectiveness of the polymer solution accrued in presence of small amount of calcium cations. The shear degradation of polyacrylamide solutions is more severe in high-salinity brine and that calcium ions are more detrimental than sodium ions.
4) *Effect of Alkali Concentration :* Low concentration of Alkali has a drastic effect on the polymer viscosity. Alkali (or any other salt) decreases the polymer solution viscosity. As salinity (or ionic strength) of water is increased, the viscosity decreases. This is because the long polymer chains tend to "ball up" to expose less of the molecule to the harsh environment. Therefore, adding an alkaline "salt" like soda ash will decrease the solution viscosity.
5) *PHPA Degradation :* Polymers are used in oil recovery operations, but it is also important that the polymer properties are not rapidly degraded. The main property of interest in this respect is generally the polymer solution viscosity although, for some polymers, the ability of the polymer to reduce the permeability of the reservoir formation may also be of some importance. Polymer degradation refers to any process that will break down the molecular structure of the macromolecule leading to loss in viscosity. The main degradation pathways of concern in oil recovery application are as follows:
6) *Chemical Degradation:* The chemical degradation of polymer in aqueous solutions is mainly effected by the presence of divalent ions, dissolved oxygen and the temperature. Divalent cations, such as Ca^{++}, Mg^{++} influence the hydrolysis of polyacrylamide and thus their solution stability or tendency to flocculate. Apart from calcium and magnesium, NaCl, iron, Fe^{++} is also present in small amounts in formation brines which also affect polymer viscosity.
7) *Mechanical Degradation:* Mechanical degradation describes the breakdown of a molecule in the high flow rate region close to the well as a result of the high mechanical stresses on the macromolecule. This is a short term effect and is only important in the reservoir near the well bore and also in some of the polymer handling equipment, in chokes, or during injection in perforations, or in the formation near the well bore where the polymer solution is flowing at high velocities.

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8) *Biological Degradation*: Biological degradation is mainly a problem for biopolymers and preferentially at lower temperatures and salinities. Biological degradation means that the polymer molecule is destroyed by bacteria or by chemical process governed by enzymes.

G. Polymer Flooding Process and Mechanism:

Flooding petroleum reservoirs with water soluble polymers may be regarded as the most economic improved oil recovery method, though by definition polymer flooding does not increase the microscopic sweep efficiency of the reservoir rock. The two phase flow of crude oil and polymer solution may be described by using the relative permeability concept. Oil and water are immiscible fluids. As such, neither can completely displace the other. It is because of this character that residual oil saturation (ROS) and irreducible water saturation (S_{wi}) are encountered in the oil reservoir. This also points out that irrespective of the quantity of water injected; oil saturation cannot be reduced below ROS. In polymer flooding, small quantity of polymer is added to water giving rise to higher viscosity to water; all other characteristics of water remaining intact. As such, polymer flooding or modified water flooding cannot reduce ROS in the oil reservoir. However, depending upon the type of polymer used, there may be certain changes in the characteristics of porous medium after coming in contact of the polymer solution. In case of polyacrylamide polymer, there is appreciable decrease in permeability of the porous medium to water due to adsorption of polymer in the pore channels. This is almost an irreversible phenomenon. Such behavior is not found in case of other types of polymers such as biopolymers.

H. Mobility Control Effects

The displacing fluid cannot sweep oil reservoirs completely and uniformly. Even in the so-called homogeneous reservoirs; areal sweep efficiency is much less than 100% at breakthrough and at economically available water-oil-ratios (WOR's).

Areal sweep efficiency depends upon the mobility ratio between the displacing and displaced fluids for a given well pattern and spacing. Mathematically, it can be expressed as:

$M = M_w/M_o$

$M = (K_w/\mu_w)/ (K_o/\mu_o)$

Where,

K_w = Relative permeability to water K_o = Relative permeability to oil μ_w = Water viscosity μ_o = Oil viscosity

Typically, M is calculated considering K_w at S_{or} (Residual Oil Saturation, ROS) and K_o at S_{wi} (irreducible water saturation). This signifies M during displacement process when oil bank has formed, i.e., M_o for oil in oil bank and M_w for water behind the oil bank. However, the exact estimation of M requires considering the exact relative permeabilities at prevailing phase saturations.

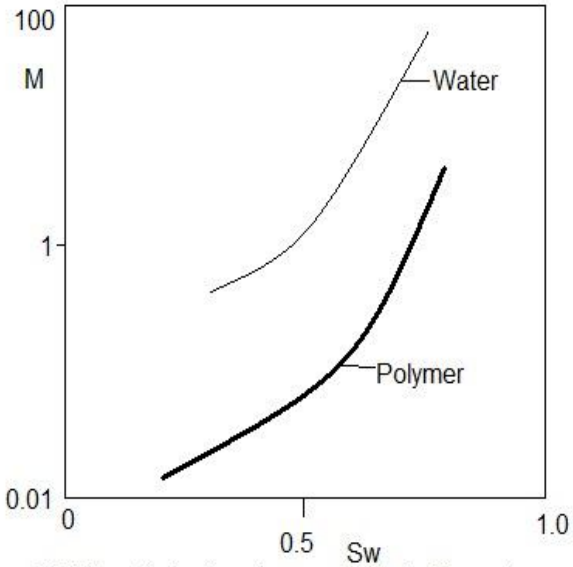


Fig. : Mobility ratio for the dispacement of oil by water and polymer solution as a function of the saturation of the displacing phase

Figure 1.2: Mobility Ratio for water and polymer to displace oil

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The above figure 1.2 shows the influence of viscosity ratio on oil recovery. This figure clearly demonstrates the improvement in oil recovery related to the viscosity of the displacing phase. The irreducible oil saturation or residual oil saturation after a sufficiently high number of flooded pore volumes should, however, be the same for all viscosity ratios. The improvement in oil recovery is that the oil is recovered earlier at a lower water cut and thus in practical at lower lifting costs.

These explanations on the effect of viscosity and mobility ratio on oil recovery do not consider the fact that mobility ratio is not constant during the flood but varies according to the saturations of the flowing phases. From the above figure 1.2, it can be seen that the mobility ratio in a water flood at low water saturations may be below1, and that at high saturations the mobility ratio for polymer flood may become greater than1.

Apart from microscopic and areal sweep efficiency, the vertical sweep efficiency determines the performance of a water flood, in many cases more than any other parameter.

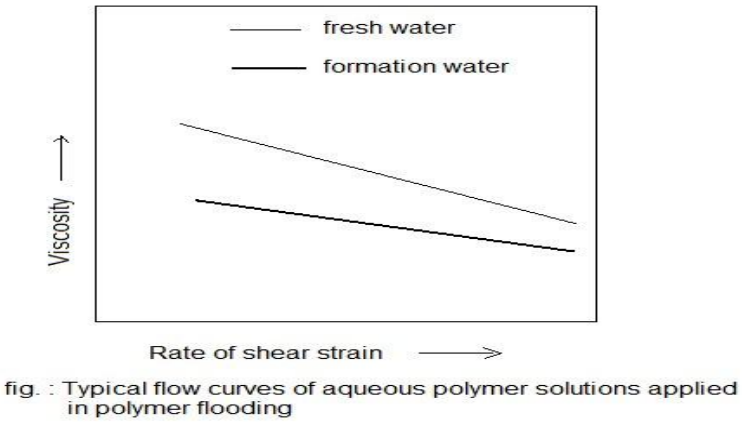


fig. : Typical flow curves of aqueous polymer solutions applied in polymer flooding

Figure 1.3: Aqueous polymer solution flow curves applied in polymer flooding

I. The Effect of Mobility Ratio on Areal Sweep Efficiency

It is clear from the figure 1.3 that the lower the mobility ratio the higher is the areal sweep efficiency. It isalso evident from the figure 1.3 that mobility ratio around unity results into almost 100% areal sweep efficiency at 1.5 PV of fluid injected. Formability ratios lower than unity; the change in the areal sweep efficiency is significantly small; whereas for mobility ratios higher than unity the change, rather decrease, in the areal sweep efficiency is rather sharp, so much so that mobility ratio around 10 gives areal sweep efficiency as low as around 70% at 1.5 pore volumes of injection.

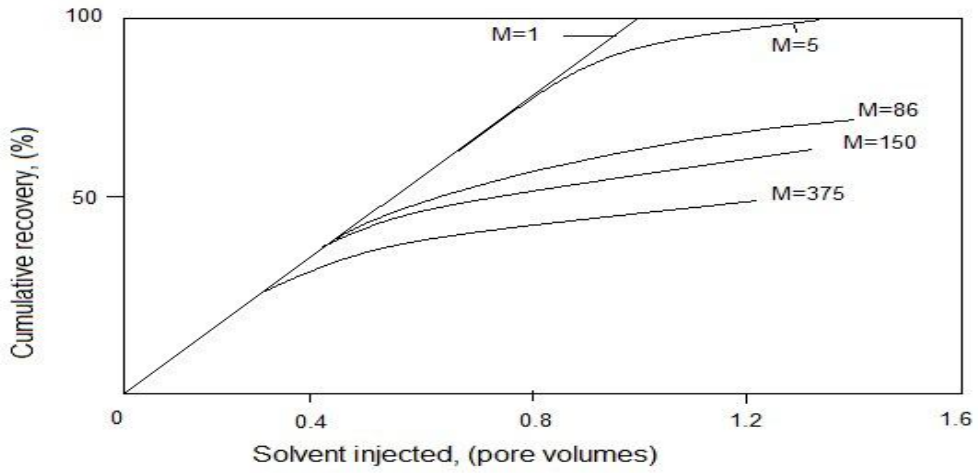


Fig. : Effect of mobility ratio on cumulative recovery

Figure 1.4: Effect of mobility ratio on cumulative recovery

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The areal sweep efficiency also seems to increase marginally with pore volume of water injected after breakthrough. This explains why oil keeps on trickling from the heavy oil reservoirs during water flooding. At extremely adverse mobility ratio of more than 50, the areal sweep efficiency approaches only to about 50%, if the water injected is equal to 1.5 PV and gain corresponding to 1.5 PV injected volume seems to peter out and appears to approach to the one corresponding to 1.0 PV injection. This indicates that from highly viscous oil reservoirs, recovery will not increase appreciably with increase in the volume of water injected. The curve also shows that at extreme mobility ratios, i.e. at lower than unity and more than 100; the difference in areal sweep efficiency corresponding to 1.0 PV and 1.5 PV water injections is negligibly small. Notable difference between the two areal sweep efficiencies is found in the intermediate range of mobility ratio i.e. 1 to 10.

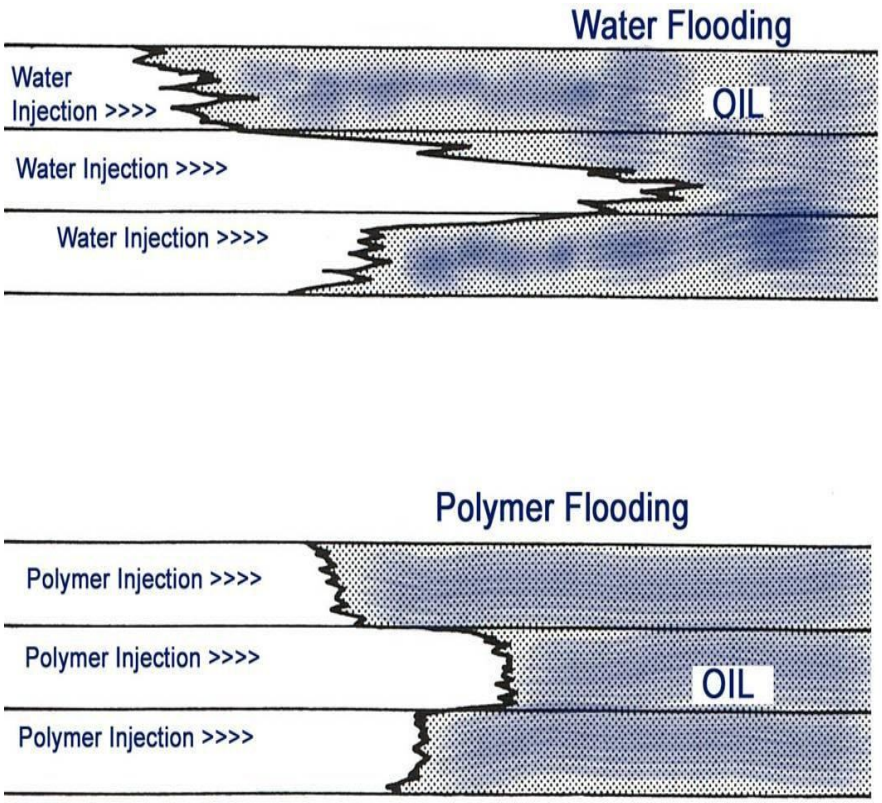


Figure 1.5: Sweep Efficiency of water to polymer

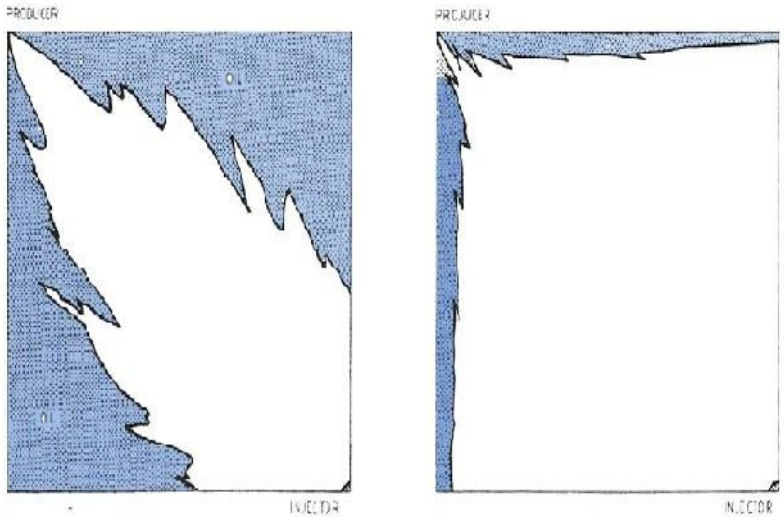


Figure 1..6: Areal sweep efficiency of water to polymer

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II. CONCLUSION

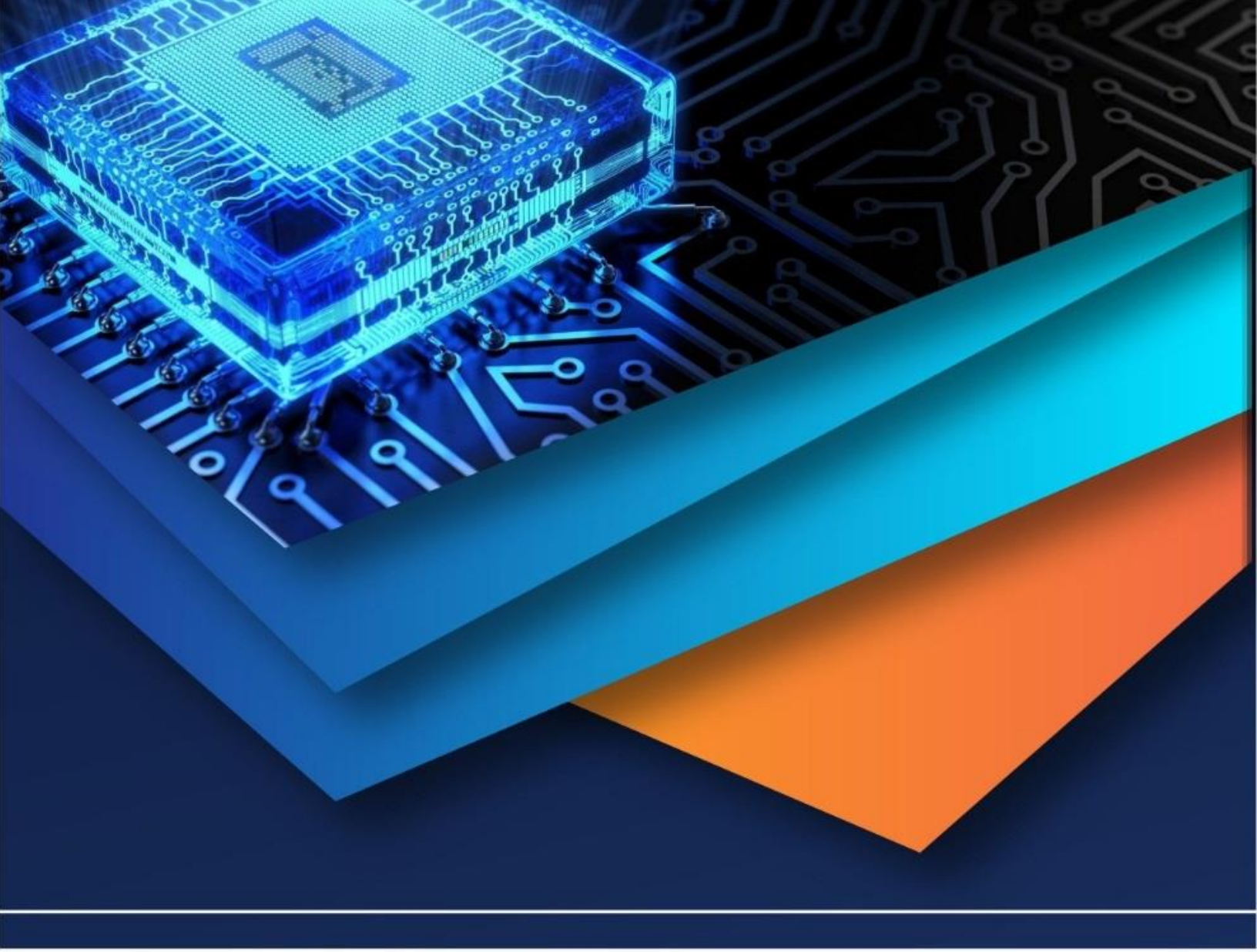
When conducting a polymer waterflood, a high-molecular-weight and viscosity-enhancing polymer is added to the water of the waterflood to decrease the mobility of the flood water and, as a consequence, improve the sweep efficiency of the waterflood. The primary purpose of adding polymer to most polymer waterfloods is to increase the viscosity of the flood water; however, polymer addition to the flood water in many instances also imparts a secondary permeability-reduction component. Polymer waterflooding is normally applied when the waterflood mobility ratio is high or the heterogeneity of the reservoir is high.

REFERENCES

[1] Applied Enhanced Oil Recovery by AurelCarcoana.
[2] Enhanced Oil Recovery, Field Planning and Development Strategies‖ by Vladimir Alvarado and Eduardo Manrique
[3] Enhanced Oil Recovery‖ by Marcel Latil

[4] Enhanced oil Recovery‖, Larry W. Lake University of Texas at Austin, Prentice Hall Publication
[5] Modern Chemical Enhanced Oil Recovery theory and practice‖ by James J. Sheng
[6] Volume 17B. Enhanced Oil Recovery, II‖ by E.C. Donaldson, G.V. Chilingarian , T.F. Yen
[7] World Energy Outlook 2015‖ by International Energy Agency (iea)
[8] BP Statistical Review of World Energy June 2015 9. Data base of Chemical Flood Lab, IRS Ahmedabad.
[9] David B.Levitt, University of Texas ―Selection and Screening of Polymers for Enhanced Oil Recovery‖ SPE 113845, April 2008.
[10] David Benjamin Levitt, ―The Optimal Use of Enhanced Oil Recovery Polymers under Hostile Conditions‖ dissertation report presented for award of Ph.D. at The University of Texas at Austin, May 2009
[11] Enhanced Oil Recovery By Marcel Latil
[12] EOR Screening Criteria Revisited by Joseph J. Taber, F. David Martin and R. S. Seright SPE 35385.

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