050 THIN UNDER GAS OIL RIMS — NEW TECHNOLOGY FOR EFFICIENT OIL PRODUCTION USING FOAM GENERATING OIL/WATER POLYMERS

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Abstract

Worldwide experience shows that oil production from thin under gas cup zones with active aquifer is not efficient due to quick gas/water breakthrough and depends on oil column thickness and the ratio between gas cap and oil part thickness. New WAG Technology based on injection of water solution of oil/water soluble polymers for efficient oil production from thin (5-15m) oil rims have been developed. Results of lab studies and simulation are discussed. New WAG technology can be used for production of both, light and heavy oils. For heavy oils this technology can be considered to be as alternative to thermal EOR.

Introduction

Development of thin, under-gas, oil-saturated zones with 5-15m thicknesses becomes considerably complicated in the presence of active aquifer and thick gas cap due to water and gas coning forms during oil production. The last circumstances cause rapid water cut and gas-oil ratio (GOR) increase and ultimately results in shutting-off oil producing wells.

Investigation of geological models, which describe particular chosen elements of some oil-bearing formations of the Western Siberia oil-gas fields, has shown that development of the type of zones with no more than 10-11m thicknesses, led to rapid stopping wells in the presence of a proper contact between water and gas zones, by natural drive condition due to water production and GOR increasing. The oil recovery factor was no more than 3-4%. Practically, waterflooding in such zones is almost unable to improve the oil recovery factor, which could be increased only up to 4-6 %.

In the view of this the new technology (1-3) provided for injection of water solutions of oil/water-soluble polymers has been developed. According to this technology, the injection is to be done into gas-saturated layers under a gas-oil contact and with subsequent waterflooding with such a depression, which ensures a proper WAG process in the presence of oil/water-soluble polymers.

Description of Technology and Results

Preliminary experimental investigations and calculations of oil displacement with both traditional WAG and WAG with polymer have shown that new technology was considerably more efficient than traditional WAG (Fig. 1). For the WAG with polymer, oil displacement was by 15% more. Gas breakthrough was not observed during the injection up to one pore volume, whereas by the traditional WAG they became apparent already at injecting of 0.5 PV.

Investigations of the WAG with polymer for the similar geological models of five chosen elements in one of the West Siberian formation, for which the calculations for both natural drive and water injection had been done before, showed that the efficiency of oil recovery process could be increased by 1.5-2.5 times in comparison with the natural drive and waterflooding. By that, it was revealed that a certain chosen depression could ensure a sufficient long production period, which could be equal or more than 15-years whereas the other technologies provided no more than 1-3 year of normal production time.

Each of the five elements is a square 500m×500m area of formation with one injecting well and four producing ones, that is to use five spot pattern.

The elements #1 and #2 are situated in the edge zone of the formation and are very different in their geological characteristics (Table 1).

The element #1 is characterized by the presence of a thin gas cap (with 0.5m thickness in average), which is partially separated from an oil-saturated zone by clay interlayers and from a water zone by a low permeable oil-saturated reservoir. At the same time the area contains a high permeable layer with medium thickness being equal to about 3.2m (Table 1).

The element #2 is characterized by the presence of the gas cap with thickness of 1.5m. The oil-saturated portion is characterized by a relatively medium and low permeability (from 0.1 to 0.3mkm²). A contact between the gas cap and the oil portion is good. Better contact has place between the oil-saturated portion and the water-saturated one (Table 1).

These peculiarities of the geological characteristics of the elements #1 and #2 having the nearly equal ratio between their oil- and gas-saturated portions cause the different calculating results of technical characteristics of their exploitation.

For the element #1, a current oil recovery factor (ORF) under natural drive or waterflooding is less than 3-4% by a low depression (a bottom-hole pressure (P_{BH}) is 10MPa and a formation pressure (P_F) is 12.2MPa) for similar conditions, using of WAG with polymer provides as long as 15 years oil production and ORF obtains up to 21% (Fig. 2).

When WAG with polymer is introduced in element #1 water cut reaches 75% after 15 years production and gas breakthrough is not observed, so that oil production can be continued.

Development of the element #2 by natural drive and waterflooding gives an opportunity to recover only 2-3% of oil by the same depression during 15 years. New WAG technology increases the ORF up to 6.8% during the same time (Fig. 3). However, for the element #2 under

natural drive or waterflooding, increasing of the depression lets heighten the process efficiency up to 5-7.5% for 15 years if $P_{BH} = 8.2\text{MPa}$. By that, ORF increases up to 12.5% by the new WAG technology or 1.7 times in comparison with the traditional waterflooding.

For the element #2, the water cut is already about 90% in fifth year of production at $P_{BH} = 10\text{MPa}$, but by injecting polymer it becomes 75-77%. Gas breakthroughs have a place by the natural drive and by the waterflooding on the fourth year of production. By the new WAG, the gas breakthroughs are not observed practically.

The basical difference between the production characteristics of the elements is conditioned by the strong differences of the permeabilities of oil-saturated zones. Both the high average permeability and the relative small thickness of the oil-saturated part of the element #1 provide its complete development in a relatively short period such as 15 years whereas the relatively low permeability of the oil-saturated portion of the element #2 (0.242 mkm^2) makes for a relatively small withdrawal rate (0.8% of oil reserves per year) even by a higher depression.

Nevertheless, development of the elements situated in the edge zone can be successfully conducted by means of injection of water slug with polymer and subsequent waterflooding while a portion of oil-phase is more than 75%. In some cases the waterflooding can be in cyclic mode with the purpose to reinforce the influence of the gas cap, that is in order that gas streams from the gas cap partially reduce the water cut and make for a more efficient oil displacement process.

The elements #3, #4 and #5 are situated in the central zone. All are different one another as well as the previous two ones (Table 1).

The element #3 has a considerable thick gas cap and a largest thickness of the oil-saturated portion of the reservoir. Some small clay interlayers separate the gas cap from the oil portion, which has a relatively high permeability being from 0.7 to 4.3 mkm^2 , especially in the lower section of formation. The high permeability and oil saturation in the part of the section can lead the exploiting of the element to an imminent water breakthrough in its first years production and a gas breakthrough in 3-4 years by a natural drive and a small depression ($P_{BH} = 10\text{MPa}$). The maximum ORF of the element #3 is less than 3% (Fig. 4).

Injection of polymer slug followed by waterflooding enables to obtain 21.5% value for 15 years by $P_{BH} = 10\text{MPa}$. The water cut is maintained at 70-75% through gas streams from the gas cap and the high gas-saturated zones situated under the gas-oil contact. In such situation gas mobility is relatively small through the polymer injection and basically is observed during first 2-4 years.

The element #4 is characterized by the presence of higher gas-saturated thickness and less oil-saturated one. The area is characterized by the presence of clay interlayers above the gas-oil contact and a relatively high permeability of the oil-saturated portion in zone of its contact with the gas cap as well as with the water-saturated portion of the section. ORF obtains 4.0% in 3 years by a natural drive (Fig. 5). Approximately the same results have been received using the nine spot well pattern, but in this case oil production has ended after 1-2 years because of rapid water cut or increasing gas factor. The oil production under water injection is practically by 5% higher than by a natural drive. Using the new technology with $P_{BH} = 10\text{MPa}$ increases ORF up to 14% and water cut becomes lower than 75%.

The element #5 is the worst of the rest (Tab. 1). It is characterized by a higher permeability of the lower oil zone and small clay interlayers separating the gas and oil portions.

Development of the area by the natural drive leads to water cut and GOR increasing during 1-2 years (Fig. 6). Application of the new WAG technology prolongs the production period up to 5 years and practically increases the process efficiency twice. Nevertheless, the method cannot be offered for similar areas as the only way of production due to its low efficiency. Such area can be successfully exploited using a periodical treatment of producing wells with oil and water both containing oil/water soluble polymers (4). In order to maintain formation pressure in such areas, it can be recommended to pump some water into injection wells during injecting of a slug of polymer. Such procedure enables to prolong oil production and increases its efficiency.

With the purpose to generalize the given results, a new X-Factor has been induced. The factor is a product of average thickness to average permeability and to an oil-saturated portion of a zone divided by an oil volume in a stratum. In Fig. 7 the changing of ORF from X-Factor is shown for the edge zone by injecting water with the polymer. Depending on the X-Factor the ORF for the elements #1 and #2 can change from 5 to 23% by varying τ -ratio, which is a total volume of produced fluid at reservoir conditions as a share of initial oil reserves.

ORF vs. X-Factor at various τ -values for new technology application in central zone is shown in Fig.8. As it is seen from Fig.8, ORF can change from 3 to 21% for different areas if $\tau = 1$. By that, it was revealed that ORF grows together with increasing the X-Factor by a constant τ -ratio. By the calculation of value of τ -ratio, not only oil and water but also gas production were taken into account.

For all zones ORF-X relations has different slope. Oil recovery factors increases more intensively for the edge zone and do some less for the central zone.

In that way, it follows from above that the geological structure, the ratio between thicknesses of the gas- and oil-saturated portions, the formation heterogeneity and the presence of clay interlayers have considerable influences on results of oil production.

Nevertheless, it was revealed that injection of water slug of polymers is quiet effective for high permeable sections by an optimum condition.

New technology enables to increase ORF by 1.5-2.5 times in comparison with a natural drive or traditional waterflooding. From cost estimation point of view, new technology involves such as a purchasing, supplying and injecting of polymers, in comparison with a waterflooding. The estimation of additional oil production per 1 tone injected reagent is shown in Fig.9. Apparently, if a value of specific efficiency less than 1000, the process can become unprofitable. The same concerns the element #5. For the rest elements, the process is practically always profitable. By all that, it should be taken into account that specific efficiency grows together with increasing the total volume of produced fluid as a share of initial oil reserves.

Table 1. Characteristics of Elements of Formation and Results of Estimation

Zone	element №	K mkm ²	H m	H _{gas} m	a	X 10 ³	OWC	Heterogen.	ORF, ⁽¹⁾ %				Add'l ORF, ⁽²⁾ %			
									τ=0.25	0.5	0.75	1.0	τ=0.25	0.5	0.75	1.0
Edge	1	3.07 0.01*	3.2 3.8*	0.5	0.86	17.4	bad	very high	16.4	23.0	—	—	13.4	20.0	—	—
	2	0.24	8.5	1.5	0.85	3.1	good	med	5.8	8.0	—	—	3.8	6.0	—	—
Cen	3	1.83	11.0	13.6	0.45	12.8	good	med	5.0	12.0	17.0	21.5	3.0	10.0	15.0	19.5
	4	1.28	8.0	24.2	0.25	5.0	good	high	6.5	8.3	9.5	10.7	4.5	6.0	7.5	8.2
	5	0.86	4.8	19.6	0.2	2.6	good	high	2.8	4.0	5.0	—	1.2	1.3	—	—

* Part of Low Permeable Zone; K - Average Permeability of Oil Zone;

H - Thickness of Oil-Saturated Zone; H_{gas} - Thickness of Gas Cap; a - Portion of Oil Saturated Zone;

(1) ORF at New WAG (at P_{BH} = 10.2MPa);

(2) Additional ORF at New WAG, compared to Natural Drive.

Conclusions

New WAG technology based on injection into formation oil/water soluble polymers has been developed. It can be applied for efficient oil production from thin under-gas zones with thicknesses between 5-15m. By that, both a gas energy and a natural water drive conditions are used for oil displacement. Introduction of oil-soluble polymers into formation leads to preventing from gas and water breakthrough and coning, to what in-stratum forming of foam-emulsion systems is conductive.

References

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Fig.1. Displacement vs. Injected Volume

Fig.2. Edge Zone, Element #1. Oil Recovery Factor

Fig.3. Edge Zone, Element #2. Oil Recovery Factor

Fig.4. Central Zone, Element #3. Oil Recovery Factor

Fig.5. Central Zone, Element #4. Oil Recovery Factor

Fig.6. Central Zone, Element #5. Oil Recovery Factor

Fig. 7. Oil Recovery Factor vs. Universal Factor (X) for Edge Zone

Fig. 8. Oil Recovery Factor vs. Universal Factor (X) for Central Zone

Fig. 9. Specific Efficiency of New Technology