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Application of selective water plugging technology for slotted pipe horizontal well

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Abstract. Chemical selectivity plugging technology is targeted to the slotted pipe horizontal wells which 70% domestic, 90% foreign horizontal wells using. However, according the practices in the field, there is low water shutoff effective because of chemistry plugging agents' poor ability of water selectivity and plugging plans' unreasonable. By analyzing the dynamics and PNN test data, there is a dot or segment water production section which producing water from the edge and bottom water in horizontal section. Basing on this, targeted plugging plan for well H2 is designed selecting high selective gel. Plugging construction results show that the pipe pressure climbing gently, displaying that gel DM103 can enter the reservoir deep. After reopen well H2, liquid production rate was maintained at 27 t/d, as well as oil production rate increased from 4 t/d to 20 t/d, while water cut was decreased from 75% to 25%. The success of water plugging proves the judgment of water production section and the limitation of PNN testing. In addition, a water shutoff successful demonstration is established for specific slotted pipe horizontal wells which are early in water channeling, far from the edge and bottom water in heavy oil reservoirs.

1. Introduction

Horizontal well completion methods mainly include perforation completion, slotted liner (screen) completion and open hole completion [1], 70% of the domestic and 90% of the horizontal wells in the country are finished with slotted liners [2]. With the deepening of oilfield development, horizontal wells in major oilfields in China have entered the middle and high water cut periods. Water shutoff has become the main means of enhancing oil recovery in the later stage of horizontal well development.

At present, horizontal well water blocking technology can be divided into mechanical card sealing water and chemical selective water blocking according to the injection process [3]. Mechanical card seals include preset work tubes, packers, etc. Chemical blocking means include general injection blocking agent, ACP sealing section, etc. Mechanical card sealing water is suitable for casing completion [1], It is effective at the beginning of the lower pump, but the formation water at the water outlet is easy to see through the pipe to the vicinity of the wellbore in the production well, resulting in a short effective period of water shutoff, and the effect of the measures is not satisfactory [4].



Chemically selective water shutoff relies on the different chemical properties of the plugging agent in the oil and water environment to achieve the purpose of blocking water without blocking oil or less oil. It is suitable for horizontal wells where the effluent layer is unclear or cannot be physically separated due to well structure or process technology [5]. As of 2013, Tahe Oilfield has carried out selective shut-in of horizontal wells for more than 50 wells[6]:The emulsion plugging agent was carried out 42 times, the effective rate was 59.5%, and the cumulative oil increase was 2.61×10^4 t; The phase infiltration regulator is implemented in 1 well, the effective period is more than 4 months, the cumulative oil increase in a single well is 160t; the temperature-resistant organic jelly is carried out in 7 wells, the effective rate is 71%, and the cumulative oil increase is 0.54×10^4 t; The particle and emulsion composite plugging agent was implemented in 2 wells with an efficiency of 100% and a cumulative oil increase of 704.43t.

In general, there is still a technical bottleneck in the selection of chemical plugging and chemical injection in horizontal wells [7-9]. (1) There is still a lack of good reservoir applicability and strong oil and water blocking agent, when injected in general [10-14], the plugging strength of the phase infiltration adjusting agent plugging agent is too low, easy to return to the vomit, and the implementation effect is poor; the gel blocking agent easily enters the production layer and causes productivity damage [15]. (2) There is still a lack of mature plugging technology for selective plugging of horizontal wells in slotted liners [16].

2. Analysis of the outlet section of H2 well

2.1. Analysis of water intrusion types

The H2 well is a low-lying adjacent well of the H2 well, with a water production of 7.3%. After November 2013, the water quickly rose to over 60% in 2 months, and the violent flooding was about 1 year before the H2 well (Fig. 1). Combined with reservoir structure analysis, it is clear that the direction of water intrusion comes from the bottom water.

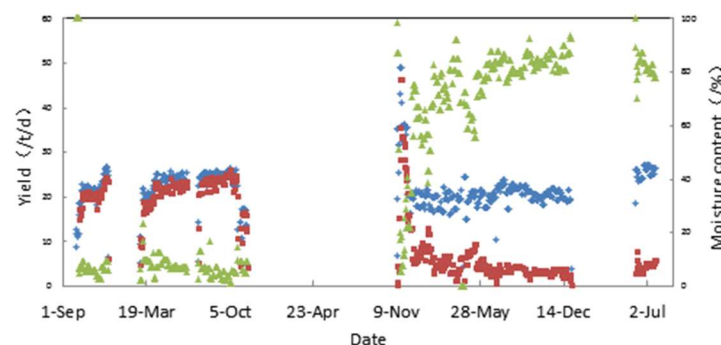


Fig.1 Production curves of well H2
(blue, liquid production rate; red, oil production rate, green, water cut)

2.2. Judging the water position of the horizontal section

Analyse the results of the PNN test interpretation of H2 well (Fig. 2). The water saturation between the horizontal well sections of 1765.5m-2000m is low, and the possibility of effluent is small; There is a water outlet point between 2000m and 2330m in the horizontal well section, but the location of the water point cannot be accurately determined.

The water saturation between 2000m-2330 in the horizontal section is about 60%. On the one hand, compared with the water saturation of H2 well and the water saturation between 1765.5m-2000m, it is considered that there is water in this section; on the other hand, combined with the law and magnitude of water rise in H2 well, it is considered that there is obvious abnormality in the water saturation data of this section. The main basis includes: (1) in the short-term, more than 50% of the wells are less likely to

produce water uniformly; (2) the latter part has the lowest structure, and the middle section of the effluent can be back-flowed to form an illusion. Since the PNN test data is too uniform, it is impossible to accurately find a reliable water outlet point. Therefore, the judgment of point (or small) water discharge is maintained, and the water point can only be qualitatively determined to be located in the second half of the horizontal section.

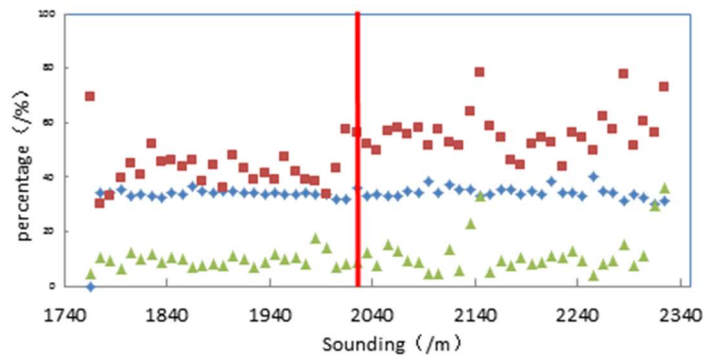


Fig. 2 PNN test results of well H2
(blue, porosity; red, water saturation, green, VSH)

In summary, combined with the dynamic production curve and PNN test results, the H2 well is the edge-bottom water raft affected by the structure, and the water outlet point (segment) is located after 2000m; The horizontal section is a point (or small section) of water, and the length of the strong outlet section is predicted to be 3-5 m.

3. H2 well water blocking scheme design

3.1. Design of blocking agent blocking range

According to the equivalent seepage resistance method, the resistance of the oil discharge section and the discharge section after plugging are as shown in formulas (1) and (2), respectively.

$$R_o = \frac{\mu_o}{2\pi K h_o} \ln \frac{r_e}{r_w} \quad (1)$$

$$R_w = \frac{\mu_{gel} R_{ff}}{2\pi K h_w} \ln \frac{r_{e1}}{r_w} + \frac{\mu_w}{2\pi K h_w} \ln \frac{(r_e - r_{e1})}{r_w} \quad (2)$$

Where R_o is oil section resistance, atm/(cm³/s); μ_o is underground crude oil viscosity, mPa.s; μ_{gel} is gel viscosity, mPa.s; μ_w is oil-water mixture viscosity in water channel, mPa.s; K is formation average permeability, μm^2 ; h_o is length of oil outlet, cm; h_w is outlet length, cm; r_g is liquid supply radius, cm; r_w is wellbore radius, cm; R_{ff} is residual resistance coefficient.

Table 1. The value of parameters

parameter	Value	parameter	Value
Underground crude oil viscosity (mPa.s)	800	Residual drag coefficient	15
Oil layer thickness (cm)	1000	Water channel mixture viscosity (mPa.s)	120
Liquid supply radius (cm)	25000	Gel viscosity (mPa.s)	200
Wellbore radius (cm)	5	Formation average permeability (μm^2)	2.1

When $h_w=5$, Considering the microscopic heterogeneity of the leech channel, in order to make $R_w>10R_0$, the blocking range of the plugging agent should be calculated to be greater than 4m.

3.2. Design of plugging agent dosage

According to the judgment of the point (segment) water, the length of the plugging section is designed to be 50m, and the amount of plugging agent is calculated according to formula (3), the main plugging agent dosage is 1055m³.

$$Q = \pi r_{el}^2 L \phi c \quad (3)$$

Where Q is blocking agent dosage, m³; c is correction factor, take 1.2; L is length of the blocking section, take 50m; Φ is effective porosity, take 0.35.

According to the point (segment) shape of the water, the length of the plugging section is designed to be 50m. Then, according to formula (3), the amount of plugging agent is calculated to be 1055 m³. Consider the necessary protective slugs. The specific injection slug design is shown in Table 2.

Table 2. The amount of each injection slug

Dosing sequence	Slug	Drug concentration(%)				Dosage (m ³)	System performance index
		Yang PAM	Yin PAM	Crosslinker	Enhancer		
1	Pre-fluid	0.2				30	Reduce glue loss and protect oil layers
2	Slug 1		0.3	0.3	0.25	300	Strong slug plugging
3	Slug 2		0.25	0.3	0.2	500	Weakly frozen rubber deep seat slug
4	Slug 3		0.3	0.3	0.3	300	Strong slug seal, anti-blocking agent
5	Positive replacement		0.1			10	Prevent breakdown plugging agent
6	Positive replacement		Clear water			10	
7	Anti-replacement		Clear water			30	Remove oil seal annulus, near well zone residual plugging agent
8	Total					1190	

4. Application practice of water blocking in H2 well

H2 Well products after 11 days of waiting for condensation. First, the injected over-displacement liquid is produced, and the jelly is left in the formation to form a plug. The effect after construction is shown in Table 3.

Table 3. Results of water plugging in well H2

	Date	Daily liquid production (/t/d)	Daily oil production(/t/d)	Moisture content (/%)
Before construction	2015/6/4	19.8	4.7	76.3
	2015/6/5	21.5	5.4	74.9
	2015/6/6	14.3	3.6	74.8
	2015/7/6	22.8	0	100
	2015/7/7	29.6	0	100
	2015/7/8	28.4	0	100
	2015/7/9	28.1	1.7	94.0
After construction	2015/7/10	28.4	5.1	82.0
	2015/7/11	27.5	21	23.6
	2015/7/12	27.3	19.6	28.2
	2015/7/13	27.6	20.2	26.8
	2015/7/14	27.6	20.2	26.8
	2015/7/15	27.3	20.4	25.3

5. Conclusion

According to the analysis of the outlet section of the horizontal well and the performance evaluation results of the plugging agent, the application and practice of selective gelation in the horizontal well of the slotted liner were carried out.

(1) The water intrusion direction of the H2 well comes from the bottom water, which is a point (or small section) of water. According to the PNN data, the water point is located in the second half of the horizontal section.

(3) In the early stage of seeing the water, the horizontal well of the ordinary heavy oil slotted liner with the wellbore far from the bottom water is suitable for selective water shutoff.

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References

- [1] Li Yikun, Hu Pin, Feng Jilei, et al. Background, current situation and trend of development for water shutoff in horizontal wells[J]. Journal of Oil and Gas Technology, 2005, 27(5): 757-760.
- [2] Wei Falin, Liu Yuzhang, Li Yikun, et al. Developing trend and current situation of water plugging technology for slotted pipe horizontal wells[J]. Oil Drilling & Production Technology, 2007, 29(1): 40-43.
- [3] Ge Hongjiang, Gou Jingfeng, Lei Qiling, et al. Chemicals for water shutoff in horizontal wells[J]. Oilfield Chemistry, 2009, 26(4): 387-390.
- [4] Liu Jiasheng. Improvement and test of water plugging technology for horizontal wells in heavy oil reservoirs with edge and bottom water[J]. Contemporary Chemical Industry, 2013, 42(3): 290-293.
- [5] Liu Wei, Qu Pingping, Wang Yefei. Research on inorganic precipitator as water shut-off agent and profile modifier[J]. Inorganic Chemicals Industry, 2007, 39(1): 41-43.

- [6] Liu guangyan, Qin Fei, Wu Wenming, et al. Watering analysis and matching water plugging technology for horizontal wells in sandstone reservoir of Tahe Oilfield[J]. Fault-Block oil & Gas Field, 2013, 20(2): 248-251.
- [7] Zhao Fulin, Chen Dong, Zang Jinfu. Alkaline silicic acid gel used for water shutoff[J]. Journal of the China University of Petroleum: Natural Science Edition, 1988, 12(4): 1-9.
- [8] Gan Zhenwei. EOR technology by water plugging for horizontal well of bottom water sandstone reservoir in Tahe Oilfield[J]. Fault-Block oil & Gas Field, 2010, 17(3): 372-375.
- [9] Makkia A, Redhah, Saleh A, et al. Rigless water shut-off experience in offshore Saudi Arabia[J]. SPE 81443, 2003.
- [10] Shahab Uddin, Jimmy D Dolan, Ricardo A. Lessons learned from the first open hole horizontal well shutoff job using two new polymer systems- A case history from Wafra Ratawi Field[R]. SPE 81447, 2003.
- [11] Dai Caili, Zhao Fulin, Li Yaolin, et al. Control technology for bottom water coning in horizontal well of offshore oilfield[J]. Acta Petrolei Sinica, 2005, 26(4): 69-72.
- [12] Zaitoun A, Kohler N, Montemurro M A. Control of water influx in heavy-oil horizontal wells by polymer treatment[R]. SPE 24611, 1992.
- [13] Lovel Land K R, Bond A J. Recent application of coiled tubing in remedial well work at Prude Bay[R]. SPE 35587, 1996.
- [14] Arangth R, Mkpasi. Water shut-off treatments in open hole horizontal wells completed with slotted liners [R]. SPE 74806, 2002.
- [15] Fully Love R J, Morgan J C, Stevens D G. Water shut-off in oil production wells-lessons from 12 treatments[R]. SPE 36211, 1996.
- [16] Yin Jie. Practice and awareness on water shutoff of sandstone horizontal well in Tahe oilfield[J]. Tuha Oil & Gas, 2007, 12(4): 355-357.