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Analysis of Fracturing Effect of Recovered Wells in Class II Oil Reservoirs and Practices to Safeguard Fracturing Result

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Abstract: In recent years, as the polymer drive of the main class I oil reservoir has been transferred to the subsequent water drive development, the class II oil reservoir has gradually become the main target of the three times oil recovery development, compared with the class I oil reservoir, the class II oil reservoir has the characteristics of relatively poor oil reservoir development and strong non-homogeneity. With the effect of the second-class oil layer successively, the fracturing target is mainly the second-class oil layer, but the fracturing effect becomes worse year by year, and it is difficult to produce in the next step. Therefore, it is important to optimize well selection for fracturing. In this paper, we analyze the effect of fracturing wells in Class II reservoirs in recent years and summarize the factors affecting the effect of fracturing in Class II reservoirs and the practices to ensure the effect of fracturing in Class II reservoirs, so as to provide a reference basis for the selection of wells for Class II fracturing in the future, which is of certain significance.

Keywords: Class II reservoir, fracturing, residual oil, degree of control.

1. Basic information on fracturing in previous years

Extraction well fracturing as one of the main production tools for oilfield development, the second-class oil layer has entered the peak of effectiveness one after another and has become the main fracturing target. The oil recovery rate is rising, but the fracturing effect is getting worse year by year, and it is difficult to go up to production next since 2005. The oil recovery rate has been rising, but the fracturing effect has become worse year by year, making the next step to production difficult. 2018, through optimizing the fracturing selection, the average single well fracturing of the extraction wells increased oil by more than 6t per day. In terms of fracturing scale, the proportion of fracturing in the late injection block reached more than 70%. Based on the analysis of the fracturing oil increase effect, the proportion of "high efficiency wells" can be effectively increased by optimizing the well selection conditions and implementing measures to ensure the fracturing effect.

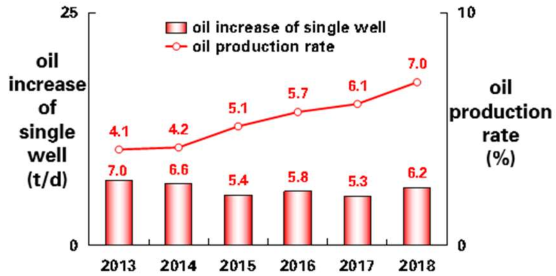

Figure 1 Fracturing of recovery wells to add oil over the years

Table 1 Table of fracturing of wells in Class II oil blocks

Block	Number of wells (wells)	Pressure cast Number of wells (wells)	Fracturing Number of wells (wells)	Fracturing Proportion (%)
Block A	244	97	139	96.72
Block B	197	70	122	97.46
Block C	316	125	101	71.52
Block D	315	124	120	77.46
Block E	248	78	40	47.58
Total	1320	494	522	76.97

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2. Summary of experience with fracturing effects

Based on the fracturing results of Class II reservoirs in previous years, the experience is summarized in terms of "factors affecting the fracturing effect of recovery wells" and "practices to ensure the fracturing effect of recovery wells".

The analysis concluded that the effect of fracturing on the oil increase in the recovery well is mainly related to factors such as "the remaining oil in the fractured well, the degree of control, the timing of fracturing, and the injection status of the well area". The approach to ensure the fracturing effect of the extraction well mainly includes "pre-fracturing training, timely post-fracturing adjustment and optimization of the fracturing process".

2.1 Analysis of factors affecting the effectiveness of fracturing of recovery wells

2.1.1 Good fracturing effect in the remaining oil-rich well area.

According to the oil increase effect of different fractured wells, when the water content before injection is less than 96%, the oil increase effect of fracturing is better, and the lower the water content before fracturing, the higher the initial oil increase after the measure. From the oil increase of wells with different water saturation before fracturing, the oil increase effect of fracturing is better when the water saturation is less than 56%, and the lower the water saturation, the higher the initial oil increase after the measure. In addition, the oil increase classification of fracturing wells with different water flooding thickness ratios shows that when the high-water flooding thickness ratio exceeds 40%, the oil increase is relatively low due to the low remaining oil, high water content saturation and relatively high-water content before injection.

Therefore, when selecting wells for oil fracturing, try to select wells with a high-water flood thickness of less than 40% and wells containing less than 96% water before injection.

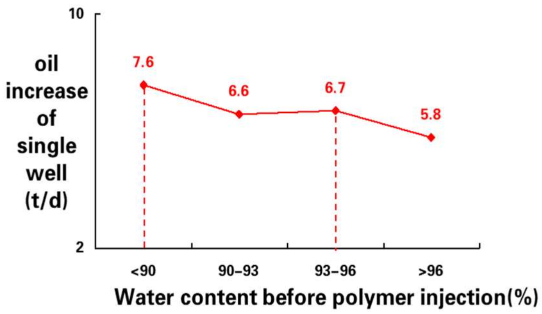

Figure 2 Oil enhancement curves for fractured wells with different pre-injection water contents

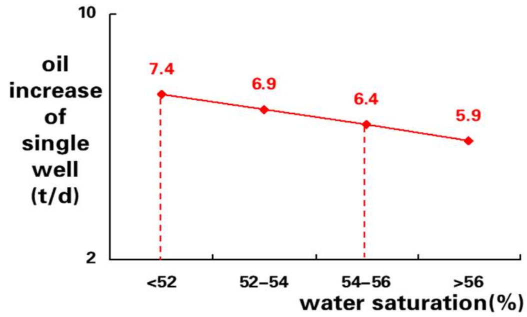

Figure 3 Oil enhancement curve for fractured wells with different water saturation

Table 2 Grading table for oil increase in fractured wells at different high water flood thickness ratios

High flooding Thickness Proportion (%)	Wells	Effective Thickness (m)	Water content Saturation (%)	Water content at different stages			Compare to pre-press	
				Poly injection Aqueous (%)	Before pressing water content (%)	After compression water content (%)	Daily liquid volume (t)	Oil production per day (t)
>40	26	9.7	56.17	93.59	86.07	84.75	35	5.7
20-40	44	6.6	55.59	92.40	85.34	83.25	40	7.1
<20	141	7.5	53.69	91.78	85.11	82.8	36	6.8
Total	211	7.6	54.39	92.15	85.3	83.15	37	6.7

According to the results of the above analysis, the extraction wells are located near the original water-driven injection well rows or wells in the mainstream line of water-driven oil and water wells with poor fracturing effect. According to the statistics of fracturing effect of Class II oil layer in recent years, there are 10 wells affected by the interference of water-driven wells, the water content saturation of these wells is higher than other well areas, the water content before fracturing is greater than 96%, the effect of fracturing to increase oil is not satisfactory, so when conducting fracturing selection avoid water-driven interference wells as far as possible.

Table 3 Comparison of the effectiveness of fractured wells in different areas

Fracturing Wells Location	wells	Effective Thickness (m)	Penetration rate (mD)	Water content Saturation (%)	Pre-pressure situation			Comparison with before and after fracturing		
					Before pressing water content (%)	Liquid production Strength (t/m)	Water content Drop (%)	Daily liquid volume (t)	Oil production per day (t)	Containing water (%)
Water-driven interference	10	9.4	269	55.35	89.04	2.61	7.33	39	3.8	0.7
Fault margin	81	7.8	315	53.41	84.53	3	6.33	34	7.3	-3.42
Injection mining perfection area	120	7.3	273	54.95	85.49	3.56	8.09	38	6.6	-1.7
Total	211	7.6	289	54.38	85.33	3.28	7.41	37	6.7	-2.18

2.1.2 Good fracturing effect during the water content decline period and water content stabilization period.

According to the analysis results of the oil increase effect of fractured wells in different periods in recent years, the oil increase effect of fracturing wells in the declining and stable water-bearing periods is significantly better than that of wells in the non-effective, poorly effective and rebounding water-bearing periods. Based on this experience, 38 wells were fractured in 2018, accounting for 60.32% of the wells fractured, 5.17% more compared to last year. A better oil enhancement effect was achieved.

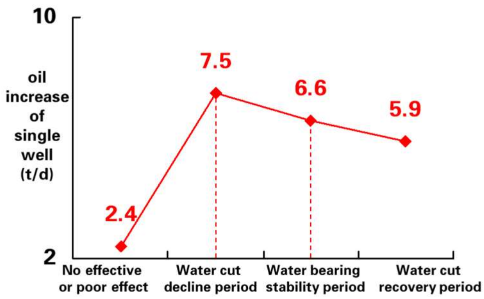

Figure 4 Oil increase curve with different fracturing timing

Table 4 Comparison of fracturing results of extracted wells 2017-2018

	Types	2017			2018			Differential	
		wells	Proportion (%)	Daily oil increase (t)	wells	Proportion (%)	Daily oil increase (t)	Proportion (%)	Daily oil increase (t)
	No effect Poor results	6	4.41	1.8	2	3.17	5	-1.24	3.3
	Declining Period	33	24.26	6.6	28	44.44	7.6	20.18	0.9
	Stabilization period	42	30.88	5.6	10	15.87	6.7	-15.01	1.1
	Rebound period	55	40.44	4.2	23	36.51	4.8	-3.93	0.6
Figure 4 Oil increase curve with different fracturing timing	Total	136	100	5.3	63	100	6.2	0	0.9

Through further analysis, the fracturing effect of the recovery wells with a high degree of effectiveness was good. From the oil increase effect of wells with different water content reduction rate before fracturing, when the water content reduction rate before fracturing exceeds 5%, the oil increase effect is better, and the higher the water content reduction rate, the greater the oil increase by fracturing the wells. Therefore, when selecting wells for fracturing, we should try to select wells with a water content decline and water content stabilization period, while the water content decline rate is greater than 5 percentage points for fracturing.

Table 5 Grading table for fracturing and adding oil in wells with different water content reduction rates

Before fracturing Water content reduction (%)	wells	wells Proportion (%)	Before fracturing				Before and after fracturing comparison		
			Daily liquid volume (t)	Daily oil production (t)	Contains water (%)	Water content Drop (%)	Daily liquid volume (t)	Daily oil production (t)	Containing water (%)
<5	68	32.55	27	3	88.95	1.14	32	5.5	-3.34
5-8	37	17.45	28	3.4	87.77	6.43	43	6.4	-1.6
8-11	40	18.87	25	3.7	85.32	9.44	39	6.5	-1.18
>11	66	31.13	21	4.4	78.44	14.94	37	8.3	-0.75
Total	211	100	25	3.6	85.33	7.41	37	6.7	-2.18

2.1.3 A high degree of control to fracture the recovered well.

According to the oil increase effect of fractured wells with different degrees of control, the oil increase effect of fracturing wells with a degree of control greater than 60% is higher than that of wells with a degree of control less than 60% at different stages, and the proportion of wells with oil increase greater than 6t is also higher, so fracturing wells with a degree of control greater than 60% should be selected for fracturing as far as possible.

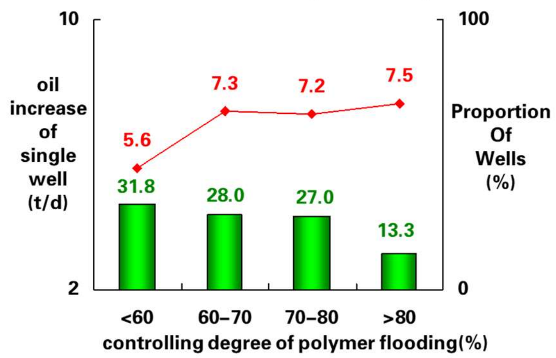

Figure 5 Oil increase curves for fractured wells with different levels of control

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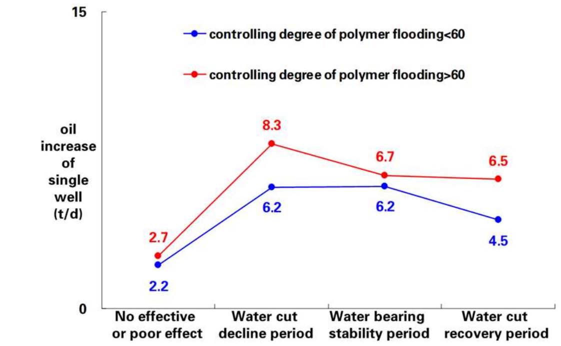

Figure 6 Oil increase curves for different stages of fracturing wells with different levels of control

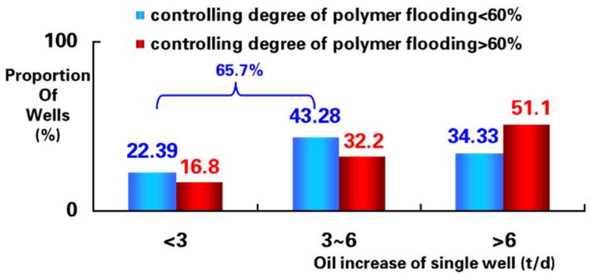

Figure 7 Histogram of the proportion of wells adding oil from fractured wells with different levels of control

2.1.4 Good fracturing of well sets with good well injection in connected wells.

Based on the analysis of fractured well results, among the fractured wells with similar recovery well see-through conditions, connection conditions and well relationships, the well group with good well zone injection conditions had good results. Take two fractured wells in Block D as an example.

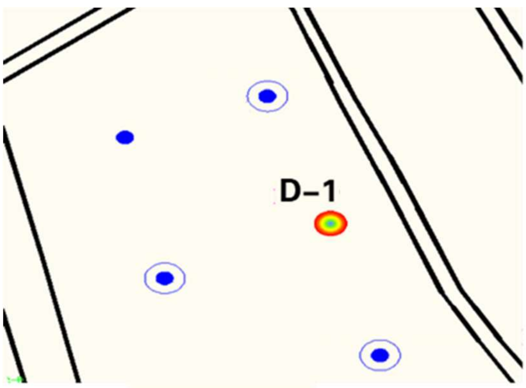

Figure 8 Well location map for well D-1

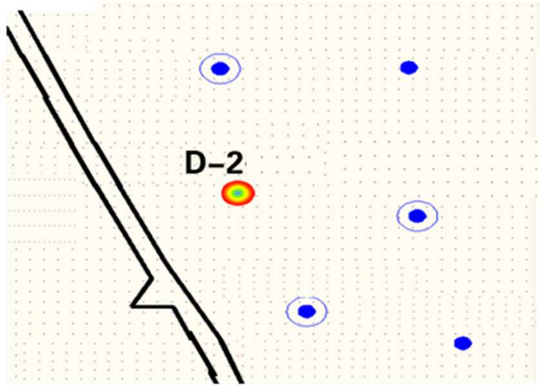

Figure 9 Well location map for well D-2

Table 6 Basic information table for different frac wells

Classification	Fracturing Effect	Extraction wells			Connected injection wells					Compare to pre-press	
		Effective Thickness (m)	Penetration rate (mD)	Poly Drive Control Degree of control (%)	Effective Thickness (m)	Penetration rate (mD)	Allowable differential pressure of injection (MPa)	Injecting Pressure (MPa)	Daily actual injection (m^3)	Daily liquid volume (t)	Daily oil production (t)
D-1well	Bad	8.4	248	79.3	8.7	327	1.42	8.61	130	10	4.4
D-2well	good	6.5	211	79.6	11.8	313	1.64	9.35	153	25	13.3
D Block		7.3	275	63.8	7.3	266					

Both wells are free from water-driven well interference. From the fracturing timing, D1 is fractured during the water-bearing decline period and D2 is fractured during the water-bearing stability period. In terms of effectiveness, both wells have shown good results. Based on the experience of the previous analysis, both wells are suitable for fracturing. However, poor injection in the well zone before D1 pressure, decreasing injection volume leads to a continuous decrease in fluid production and sinkage before pressure in the recovery well, and insufficient fluid supply in the well zone, resulting in a small increase in fluid after fracturing the recovery well. And the injection volume of the D2 well group was reduced at the beginning of the injection period due to the rapid rise in injection pressure, after which only one well in the well area had difficulty in injection after testing and recovered after well washing, and the pre-fracturing sinkage had an improving trend, proving that the injection volume was guaranteed and a better fluid and oil increase was achieved after fracturing.

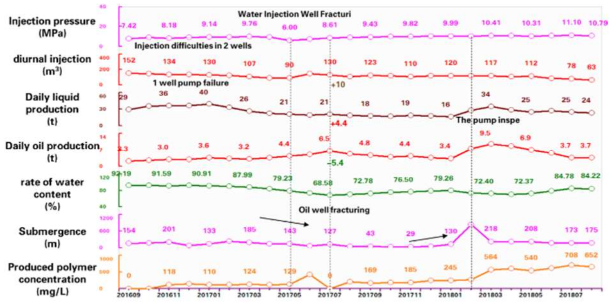

Figure 10 Production curve for well D-1

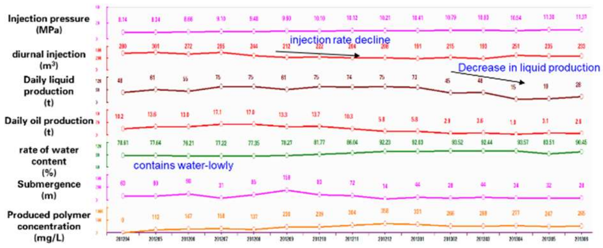

Figure 11 Production curve for well D-2

2.2 Practices to Safeguard the Effectiveness of Fracturing Extraction Wells

2.2.1 Pre-press cultivation to ensure fracturing of the recovery well.

It has been proven that for wells with fracture selection conditions, but poor well zone injection conditions, pre-fracture cultivation can be implemented to ensure that the fractured well increases fluid and oil. Take well A-1 as an example.

The A-1 well is an oil well located in the central area of Block A. The well is dominated by a thin differential layer development and the numerical model oil saturation results indicate that the well is relatively rich in remaining oil.

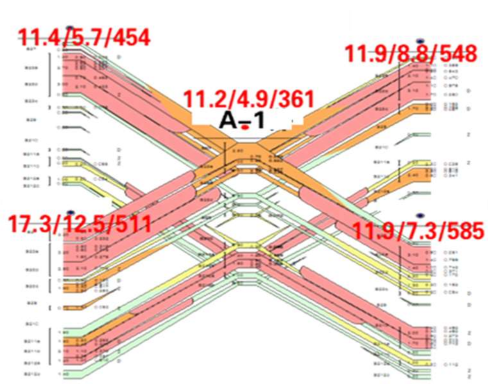

Figure 12 Censored map of the A-1 well group

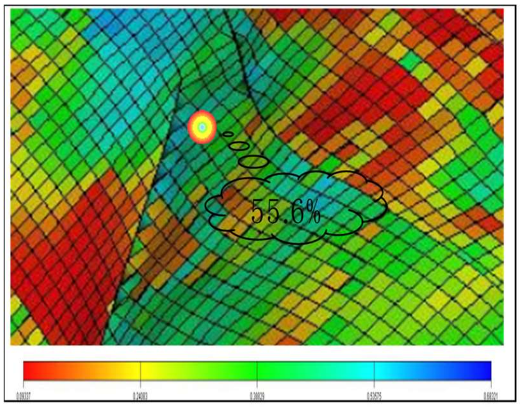

Figure 13 Numerical simulation of oil-bearing saturation in Block A

As can be seen from the production curve, the well has low initial water content and relatively enriched remaining oil. The significant drop in injection volume in the well area is mainly due to the implementation of dissection and controlled injection in three wells in the well area, injection difficulties in one well and operational reallocation, which resulted in a large drop in fluid volume in the recovered well.

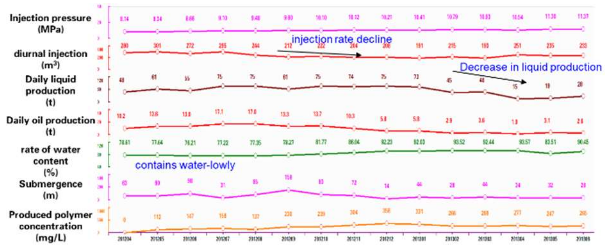

Figure 14 Pre-frac extraction curve for well A-1

In order to guarantee the fracturing effect, the injection wells in the well area were planned to implement programmed fluid withdrawal and fracturing to increase injection in the first five months of the measure, and after ensuring the fluid supply capacity, the fracturing of the extraction wells was implemented, and the daily oil increase reached 13.7t after the measure, and the water content dropped significantly.

Table 7 Comparison of well group A-1 before and after adjustment

Well number	Adjustment Type	Adjustment time	Before adjustment			After adjustment		
			Oil pressure (MPa)	Daily allotment (m^3)	Daily actual injection (m^3)	Oil pressure (MPa)	Daily allotment (m^3)	Daily actual injection (m^3)
A-w1	Fracturing and injection	2013.3	10	80	51	7.31	80	80
A-w2	Program Extraction Solution	2013.6	11.3	60	60	11.9	80	79

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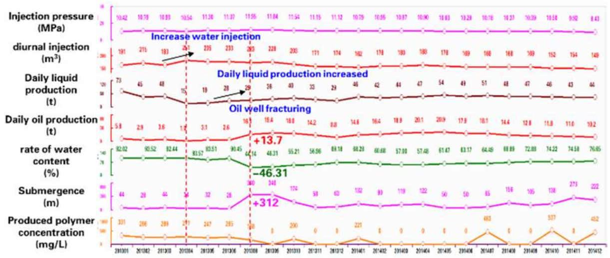


Figure 15 Extraction curve for well group A

2.2.2 Timely adjustment after fracturing to ensure the fracturing effect

After the fracturing program is implemented, the production pressure differential should be amplified in a timely manner according to the dynamic characteristics of the well area to safeguard the fracturing effect and extend the fracturing period as far as possible. Take well D-3 as an example.

The D-3 well is located at the edge of the fault adjacent to Block D and Block C. The well area is connected to a total of three injection wells, two of which belong to Block C and one to Block D. The well is mainly developed with medium and low water flooding, with a water content saturation of 48.5%, which is 7.33% lower than that of the whole area, and relatively rich in remaining oil.

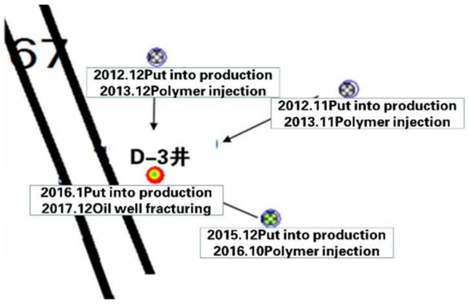


Figure 16 Well location map of the D-3 well group

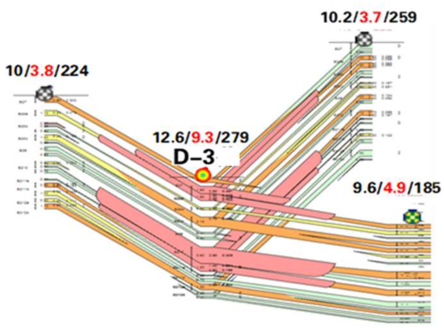


Figure 17 Censored map of the D-3 well group

Influenced by the earlier injection and gathering time in Block C, the well started to see results two months after it was put into production, with a large drop in water content and relatively rich residual oil. After the implementation of fracturing in December 2017, the initial daily fluid increase of 24t and daily oil increase of 14.7t were achieved with good oil increase effect, Two main problems existed at the stage from the production curve, one is that the sinkage has been at the wellhead after fracturing and the production capacity has not been effectively released, and the other is that the fracturing The injection capacity of the well area before fracturing decreased, and the fracturing validity period was difficult to guarantee.

In order to ensure the fracturing effect, firstly, in response to the actual high sinkage, timely implementation of the adjustment of the large participation to enlarge the production pressure difference, the initial period after the adjustment of the participation, the daily fluid increase of 22t, the daily oil increase of 12.6t, to achieve a better fluid and oil increase effect. Second, the timely implementation of fracturing transformation for injection wells in block D of the well area where injection has deteriorated, the injection volume was guaranteed after the measure, and the effect of fracturing the recovery well to increase oil lasted for 7 months, with a cumulative increase of 3,133t.

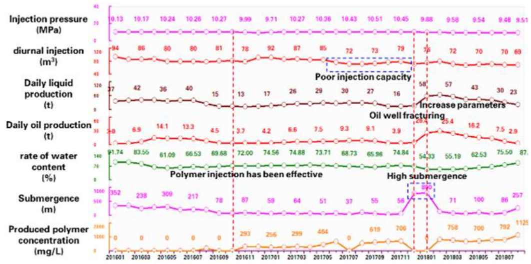


Figure 18 Extraction curve for the D-3 well group

2.2.3 Optimizing the fracturing process to guarantee fracturing results

According to the relationship curve between the fracture penetration ratio and the degree of recovery for Class II reservoirs, when the fracture penetration ratio reaches a certain value, the degree of recovery reaches its highest point, and when the penetration ratio is greater than that value, the degree of recovery begins to decline. This is due to the fact that when the penetration ratio is too high, it tends to cause the injected media to burst in, resulting in a rapid rise in water content. The penetration ratio is determined by the fracture radius. According to the formula for the relationship between sand addition and fracture radius, the amount of sand addition needs to be optimized to keep the fracture penetration ratio around 0.12-0.18 as much as possible to ensure the maximum fracturing effect, so when there is a high water absorption ratio layer in the injection well in the well area, the amount of sand addition should be controlled to prevent the penetration ratio from being too high and causing the injection media to break through.

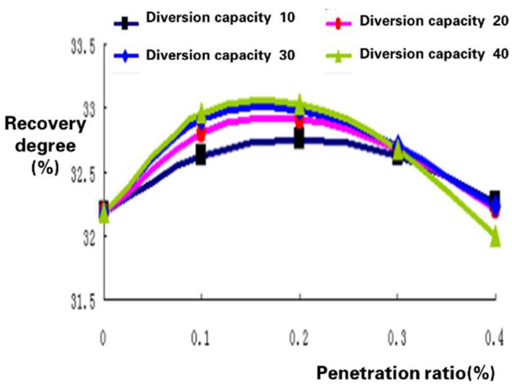
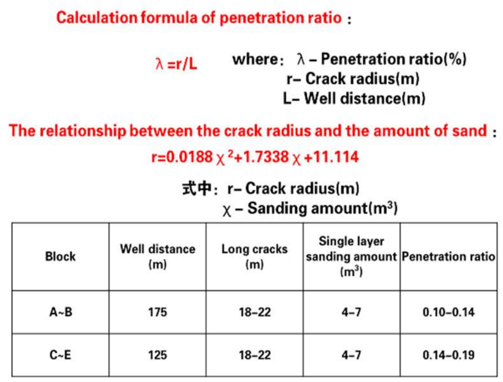


Figure 19 Curve of the effect of fracture penetration ratio on the degree of recovery



Calculation formula of penetration ratio：

λ =r/L   where：λ – Penetration ratio(%)
r– Crack radius(m)
L– Well distance(m)

The relationship between the crack radius and the amount of sand：

r=0.0188χ²+1.7338χ+11.114

式中：r– Crack radius(m)
χ – Sanding amount(m³)

Block	Well distance (m)	Long cracks (m)	Single layer sanding amount (m³)	Penetration ratio
A~B	175	18~22	4~7	0.10~0.14
C~E	125	18~22	4~7	0.14~0.19

Figure 20 Equation for penetration ratio and fracture radius versus sand addition

3. A few points of awareness

3.1 The effect of fracturing a well from a Class II formation is highly uncertain and is usually not determined by one factor, but rather by the co-existence of several factors that affect the fracturing effect.

3.2 Based on past experience with fracturing to increase oil, select wells with characteristics such as "rich residual oil, water content in the declining and rebounding phases with a high degree of effectiveness, and strong injection capacity in the well area" for fracturing as far as possible to increase the probability of producing fractured high-efficiency wells.

3.3 According to the well area injection and extraction conditions, adopt pre-pressing cultivation, timely and effective post-pressing tracking and adjustment and optimization of the fracturing process, which can guarantee the fracturing effect of the recovery well.

References

1. Zhou Dehua, Jiao Fangzheng, Ge Jiali. Recent progress in fracture seepage research[J]. Offshore Petroleum, 2004(6)
2. Li Jingcai, Li Lingyun, Yang Shengxian. Establishment and Application of Economic Boundary Plates for Oil Well Fracturing Process Measures [J]. Special Oil and Gas Reservoirs, 2005(6)
3. Sun Fuguang. Analysis of fracturing effect and optimization of process plan for the second-class oil reservoir in Sanan Development Zone. Chemical Engineering and Equipment, 2005(9)