

# The efficiency analysis of applying hydraulic fracturing of formation at AB<sub>1-2</sub> facility of Potochnoye field

E M Almukhametova, D I Fattakhov, A I Zakirov1

Branch of Ufa State Petroleum Technical University in the City of Oktyabrsky,  
452600, 54a Devonskaya Street, the City of Oktyabrsky

E-mail: elikaza@mail.ru

**Abstract.** Nowadays the large-scale deposits of the Russian Federation are at the closing stage of development. Taking into account this fact, new technologies are required for enhanced oil recovery at the closing stage of development and for formations with oil reserves which are difficult to recover. Applying hydraulic fracturing of formation allows enhancing the rate of oil recovery from watered zones, optimizing oil production and prolonging cost-effective field life. The given paper is focused on applying hydraulic fracturing treatment at AB<sub>1-2</sub> facility of Potochnoye field. The obtained results based on the analysis of AB<sub>1-2</sub> formation reveal that the highest liquid rates after applying hydraulic fracturing were got at formations with higher bed formation thickness. Moreover, using bigger masses of proppant allows getting higher liquid rates after hydraulic fracturing treatment. Similarly, the growth of the specific liquid rate after applying hydraulic fracturing takes place along with the growth of proppant specific gravity.

## 1. Introduction

Hydraulic fracturing of formation (HFF) is used as

- A productive physical method for incremental oil production.
- An effective means to enhance well injection capacity.

The technique of hydraulic fracturing consists in forming highly conductive pathways into the target formation where liquid is pumped under high pressure to provide, in future, the production fluid influx to the bottom hole [1].

## 2. Methods and materials

The obtained results considered in the article are proved by using geological description, technological parameters and operational characteristics before and after hydraulic fracturing at AB<sub>1-2</sub> facility of Potochnoye field. Well-known and time-tried methods of analyzing were applied by using personal computers when processing the oilfield information. The worked-out recommendations were tested in the oilfield and showed a positive technological result [2].

The results contained in this paper have been applied when planning and implementing ways of enhanced oil recovery aimed at further high-performance development of Potochnoye field.

## 3. Results and discussions

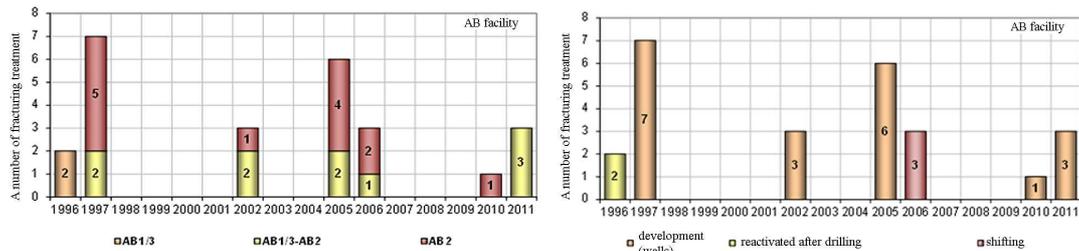
Applying fracturing treatment at AB<sub>1-2</sub> facility of Potochnoye field started in 1996 and aggregates 25 treatments out of 399 which were carried out all over the field [3]. The number of wells where hydraulic fracturing of formation was applied accounts for 4.9%. Monitoring of incremental oil production shows that incremental oil production owing to 25 fracturing treatments at the producing oil wells of the deposit accounts for 74.3 thousand tons or 3.0 thousand tons per well with a single job



(considering the oil field it accounts for 2490.9 thousand tons or 6.4 thousand tons per well), including 20 development wells – 51.4 thousand tons or 2.6 thousand tons per well, 3 wells with shifting from fracturing treatment – 3.2 thousand tons or 1.1 thousand tons per well, 2 wells reactivated after drilling – 19.7 thousand tons or 9.9 thousand tons per well [4].

After having applied fracturing treatment at the facility 25 producing oil wells were placed under production. The biggest number of fracturing treatments goes to AB<sub>2</sub> formation – 13 treatments, as well as combined treatment goes to AB<sub>1</sub><sup>3</sup> and AB<sub>2</sub> r formations – 10 treatments, 2 treatments were carried out for AB<sub>1</sub><sup>3</sup> formation in addition (Figure 1) [5].

At present, the share of incremental oil production owing to fracturing treatments in general cumulative oil production accounts for 2.1%.



**Figure 1.** The number distribution of hydraulic fracturing treatment according to the periods, well categories and the formations of AB<sub>1-2</sub> facility

The first treatments of hydraulic fracturing, carried out in 1996, entered AB<sub>1</sub><sup>3</sup> formation with low net thickness and permeability (~1.9m and ~2.4 mD, Table 1) by using 6 tons of proppant and with fracturing fluid injection rate equal to 4.5 m<sup>3</sup>/min [6]. In the next few years the treatments of hydraulic fracturing were carried out with a bigger value of net thickness and permeability (~8.8m and ~86,3mD) by using 20,8 tons of proppant for treatments in 2005 and 17.1 tons – in 2011 but the injection rate, on the contrary, slowed down over the years (in 2011 it accounted for 2.4 m<sup>3</sup>/min).

**Table 1.** The main geological-physical, technological parameters and factors of well operation before and after applying hydraulic fracturing of formation according to the periods of treating AB<sub>1-2</sub> facility as of 01.01.2012

Parameter	1996	1997	2002	2005	2006	2010	2011	Total
A number of fracturing treatments	2	7	3	6	3	1	3	25
<b>Geological parameters</b>								
Net thickness, m	1.9	8.4	10.7	8.6	12.6	2.7	6.7	8.3
Net oil thickness, m	1.9	7.8	9.6	7.5	7.4	2.7	6.5	7.1
Porosity, unit fraction	0.18	0.22	0.22	0.22	0.22	0.17	0.20	0.21
Permeability, mD	2.4	98.9	125.4	106.5	74.9	3.2	16.7	79.6
Net to gross, unit fraction	0.18	0.29	0.34	0.32	0.43	0.11	0.19	0.28
kh-value of formation, mD*m	4.9	879.9	1245.9	1114.0	1421.0	8.7	118.8	848.8
<b>Technological parameters</b>								
Proppant mass, tons	6.0	8.3	9.0	20.8	12.1	15.7	17.1	12.7
Proppant specific gravity, tons per meter	3.1	1.0	0.8	2.4	1.0	5.8	2.5	1.5
Maximum concentration, kg/m <sup>3</sup>		891	900	740	702	1000	967	837
Injection rate, m <sup>3</sup> /min	4.5	4.0	2.2	2.0	1.9	2.2	2.4	2.8
<b>Operational characteristics</b>								
Liquid rate within 3 months before hydraulic fracturing, tons per day	-	5.2	5.0	9.7	-	-	-	6.8

Oil production rate within 3 months before hydraulic fracturing, tons per day	-	2.2	3.1	4.2	-	-	-	3.1
Water cut within 3 months before hydraulic fracturing, %	-	58.8	37.6	57.2	-	-	-	54.6
Liquid rate within 3 months after hydraulic fracturing, tons per day	9.4	42.6	13.2	56.1	48.9	15.6	35.4	38.5
Oil production rate within 3 months after hydraulic fracturing, tons per day	6.8	6.6	6.1	15.9	2.2	5.3	4.5	8.0
Water cut within 3 months after hydraulic fracturing, %	27.8	84.5	54.2	71.6	95.5	65.7	87.3	79.3
Specific liquid rate after hydraulic fracturing, tons per day per meter	4.8	5.1	1.2	6.5	3.9	5.8	5.3	4.7
Initial incremental liquid rate, tons per day	9.4	37.4	8.2	46.4	48.9	15.6	35.4	31.7
Initial incremental oil production rate, tons per day	6.8	4.4	2.9	11.8	2.2	5.3	4.5	4.9
Total incremental oil production within the period, thousands of tons	19.7	7.5	2.0	40.0	3.2	1.7	0.2	74.3
Total time in operation within the period, days	4754	2019	1069	8155	1940	659	42	18638
Average incremental oil rate within the period, tons per day	4.1	3.7	1.9	4.9	1.6	2.5	5.0	4.0

Within the period of 3 month after hydraulic fracturing maximum oil and liquid flow rates were got after fracturing treatment in 2005 – 15.9 and 56.1 tons per day and with the water cut accounted for 71.6 %. In 2006 three fracturing treatments were carried out for the wells № 850, 1809 and 208 when shifting them from underlying bed. Besides, the fluid flow reached high values that averaged within 3 months – 48.9 tons per day, however, the efficiency of the given actions was not high since oil production rate ranged from 1.9 to 2.7 tons per day and the water cut was 95.5 % (due to this reasons wells №208 and 1809 were shut down in 9 months of working) [7]. In 2011 the secondary hydraulic fracturing was conducted at the same zone of well № 208 with the net thickness of formation of 8.9m and permeability of 25.7mD but applying different technique: less mass of proppant was used (30 tons for the first treatment and 19.8 tons for the second one). The concentration was 998 kg/m<sup>3</sup> for the first treatment and 900 kg/m<sup>3</sup> for the second one, the injection rate was increased from 2.0m<sup>3</sup>/min to 2.4m<sup>3</sup>/min. After the first fracturing treatment oil production and liquid rates within 1 month accounted for 5.0 и 23.5 tons per day respectively, the water cut – 79.0 %, after the second fracturing treatment – 4.0 and 23.7 tons per day, 83.1% respectively [8].

All in all, as for AB<sub>1-2</sub> facility the average oil and liquid flow rates within 3 months after hydraulic fracturing amounted for 8.0 and 38.5 tons per day, the water cut – 79.3%. Let us analyze the results of applying hydraulic fracturing according to the formations of AB<sub>1-2</sub> facility (Table 2).

**Table 2.** The main geological, technological parameters and factors of well operation before and after applying hydraulic fracturing for AB<sub>1-2</sub> formations as of 01.01.2012

Parameter	AB1/3	AB1/3-AB2	AB2	Total
A number of fracturing treatment	2	10	13	25
<i>Geological parameters</i>				
Net thickness, m	1.9	7.2	10.1	8.3
Net oil thickness, m	1.9	7.0	7.9	7.1

Porosity, unit fraction	0.18	0.21	0.22	0.21
Permeability, mD	2.4	59.1	107.3	79.6
Net to gross, unit fraction	0.18	0.22	0.37	0.28
kh-value of formation, mD*m	4.9	426.4	1303.4	848.8
<b>Technological parameters</b>				
Proppant mass, tons	6.0	16.3	11.5	12.7
Specific gravity, tons per meter	3.1	2.3	1.1	1.5
Maximum concentration, kg/m <sup>3</sup>	-	920	783	837
Injection rate, m <sup>3</sup> /min	4.5	2.5	2.8	2.8
<b>Operational characteristics</b>				
Liquid rate within 3 months before hydraulic fracturing, tons per day	-	4.2	8.7	6.8
Oil production rate within 3 months before hydraulic fracturing, tons per day	-	2.3	3.6	3.1
Water cut within 3 months before hydraulic fracturing, %	-	44.7	58.3	54.6
Liquid rate within 3 months after hydraulic fracturing, tons per day	9.4	29.5	49.9	38.5
Oil production rate within 3 months after hydraulic fracturing, tons per day	6.8	5.9	9.7	8.0
Water cut within 3 months after hydraulic fracturing, %	27.8	80.0	80.5	79.3
Specific liquid rate after hydraulic fracturing, tons per day per meter	4.8	4.1	4.9	4.7
Initial incremental liquid rate, tons per day	9.4	25.2	41.2	31.7
Initial incremental oil production rate, tons per day	6.8	3.6	6.1	4.9
Total incremental oil production within the period, thousands of tons	19.7	7.9	46.7	74.3
Total time in operation within the period, days	4754	7186	6698	18638
Average incremental oil rate within the period, tons per day	4.1	1.1	7.0	4.0

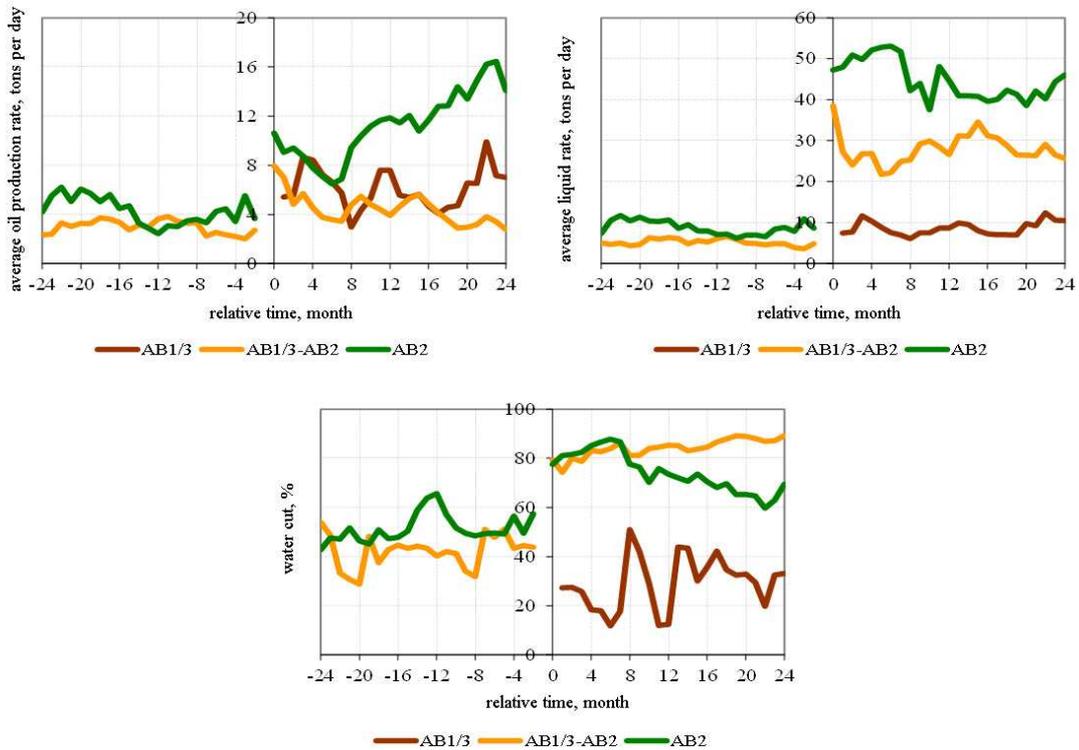
As it was registered earlier, AB<sub>1</sub><sup>3</sup> formation is characterized by low porosity and permeability properties: net thickness of formation accounts for 1.9m, permeability – 2.4mD. Due to this fact the obtained results of hydraulic fracturing were not high: oil production and liquid rates within 3 months accounted for 6.8 and 9.4 tons per day respectively, the water cut – 27.8%.

According to the fracturing treatment separately for AB<sub>2</sub> formation the highest oil production and liquid rates were obtained – 9.7 and 49.9 tons per day respectively, the water cut – 80.5 %. Within the period of 24 months the water cut increased up to 89.2 % but oil production rate went down to 2.8 tons per day (Figure 2) [9].

In Figure 2 there are paired associations between performance characteristics of hydraulic fracturing and key influencing factors. The increase of liquid rate after applying hydraulic fracturing of formation is registered with the increase of net oil thickness. There is no evident connection between the liquid rate and proppant mass as well as between the specific liquid rate and proppant specific gravity. According to the fracturing treatments with considerable water cut (more than 80 %) oil production rate, on average, accounted for 3.8 tons per day. Well № 145B obtained the highest oil flow – 61.1 tons per day with the biggest liquid rate – 153.5 tons per day, the water cut accounted for 60.2 %.

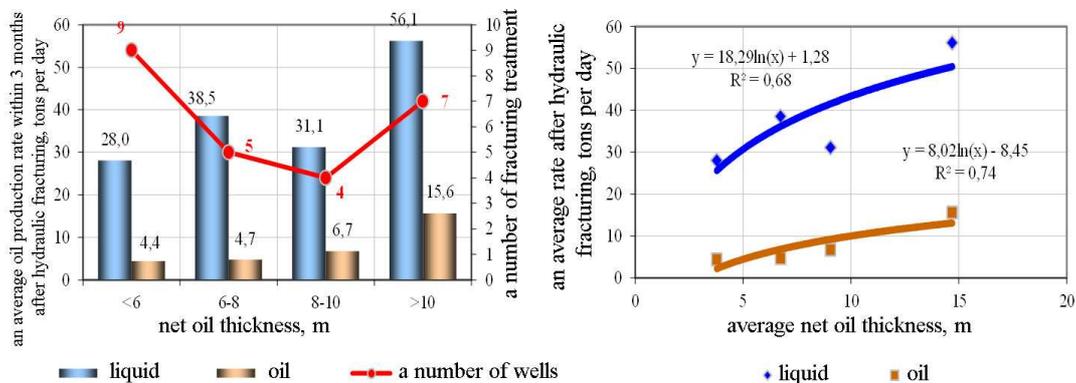
According to the histograms of distributing hydraulic fracturing due to the net thickness (Figure 3) it was revealed that with the increase of net thickness, oil and liquid flows also increase after hydraulic fracturing. In the figure there are common connections between oil production and liquid rates after hydraulic fracturing due to the average net oil thickness which are accepted to be applied as the

expected ones [10].



**Figure 2.** The average liquid and oil production rates obtained at the date of hydraulic fracturing treatment according to the formation groups of AB<sub>1-2</sub> facility

Thus, considerable water cut of the facility AB<sub>1-2</sub> as a result of water flooding and bottom water coning makes the use of hydraulic fracturing rather limited. According to the formation AB<sub>1</sub><sup>3</sup> with the net thickness of 1.9 m and the proppant mass of 6 tons, the liquid flow after hydraulic fracturing accounted for 9.4 tons per day. According to AB<sub>2</sub> formation with the net thickness of 10.1 m and the proppant mass of 11.5 tons, the liquid flow accounted for 49.9 tons per day (increase ratio – 5.7 times). When applying the combined fracturing treatment for AB<sub>1</sub><sup>3</sup> and AB<sub>2</sub> formations with the net thickness of hydraulic fracturing interval of 7.2 m and proppant mass of 16.3 tons, the liquid flow accounted for 29.5 tons per day (increase ratio – 7 times). The average incremental oil rate of AB<sub>1-2</sub> facility during the period of efficient service (for 2 years on average) accounted for 4 tons per day.



**Figure 3.** The distribution of oil production and liquid rates after hydraulic fracturing due to the range of bed formation thickness and master curves of oil production and liquid rates after hydraulic fracturing due to average bed formation thickness

#### 4. Conclusion

At AB<sub>1-2</sub> facility the number of wells where hydraulic fracturing of formation was applied accounted for 4.9 %.

At present, the incremental oil production owing to hydraulic fracturing treatment accounts for 74.3 thousand tons or 3.0 thousand tons per well. The share of incremental oil production owing to hydraulic fracturing in general cumulative oil production accounts for 2.1%.

All in all, as for AB<sub>1-2</sub> facility the average oil and liquid flow rates within 3 months after hydraulic fracturing accounted for 8.0 and 38.5 tons per day, the water cut – 79 %. The used proppant mass was up to 20 tons averaging 12.7 tons, the specific gravity – less than 4 tons per meter.

On the whole, the main factor causing the low result of hydraulic fracturing for AB<sub>1</sub><sup>3</sup> formation is considered to be low porosity and permeability properties: net thickness of formation was 1.9m, permeability – 2.4mD. As for AB<sub>2</sub> formation with the net thickness of 10.1 m and the proppant mass of 11.5 tons, the liquid flow accounted for 49.9 tons per day (increase ratio – 5.7 times). When applying the combined fracturing treatment for AB<sub>1</sub><sup>3</sup> and AB<sub>2</sub> formations with the net thickness of hydraulic fracturing interval of 7.2 m and proppant mass of 16.3 tons, the liquid flow accounted for 29.5 tons per day (increase ratio –7 times). The average incremental oil rate of AB<sub>1-2</sub> facility during the period of efficient service (for 2 years on average) accounted for 4 tons per day.

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