Study of single well pressurization and water injection experiments in low permeability reservoirs

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Abstract: In the process of water injection development in low-permeability and extra-low-permeability oil fields, the water absorption capacity of injection wells continues to decline, and the number of under-injection wells is increasing, which affects the development effect of oil fields. In this paper, we take X oilfield as an example and carry out single-well pressurized water injection tests to determine the range of reasonable injection pressure for pressurized water injection and the geological conditions suitable for pressurized water injection. Through this project research, the water absorption capacity of injection wells can be effectively improved, and the oilfield development effect is improved, which provides a new idea to solve the problem of water injection difficulties in low permeability oilfield.

Keywords: pressurized water injection, dynamic change characteristics, development effect, reasonable water injection pressure

1. Introduction

Low-permeability reservoirs are influenced by the depositional environment, with poor reservoir physical properties and heavy mud and calcium content, and strong sensitivity. After water injection development, the reservoir water absorption capacity often decreases to a large extent, which affects the field development effect. X field is a typical low permeability field with an average permeability of 1.45Md. During water injection development, the number of under-injected wells is increasing, resulting in low reservoir pressure maintenance, poor well reception and low single well production. Conventional fracturing and acidizing measures have not achieved the desired effect, and pressurized water injection is one of the effective ways to solve this problem. Influenced by the non-homogeneity of the plane, the overall pressurization operation cost is high and efficiency is low. Through the single well pressurization injection method, the water injection volume can be effectively increased, promote the effect of oil wells to increase production and achieve the purpose significance of improving the water injection wave volume and recovery rate of low permeability oil fields.

2. Basic information of X oil field

2.1 Overview of X Field Development

The X field was put into development in 2006 with a 300×300m square inverse nine-point method injection well network, mainly exploiting the Grapevine formation. Over the past six years of water injection development, the injection pressure has risen rapidly, the proportion of under-injected wells is high, and the formation pressure maintenance level is low. There are 124 wells with water injection pressure greater than 18MPa. Among them, 68 wells were under-injected, accounting for 24.2% of the total number of wells.

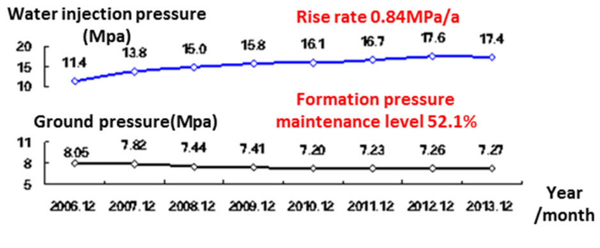

Fig.1 X oilfield water injection pressure and formation pressure variation curve

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2.2 Analysis of the effect of conventional injection increase

In 2014, 6 wells were fractured in X oil field, 4 with poor results and 2 with good results. The two wells with good initial effect became worse after an average of 8 months of injection and could not finish the allotment. Fracturing can improve the water absorption capacity of wells to a certain extent, but the fracturing period in low-permeability fields is short. The main reason for this is that the reservoir properties are poor, and the fracturing has a certain effect at the beginning of implementation, but the artificial fracture closes at a later stage, resulting in the injection water being stored near the artificial fracture, causing the injection well to hold pressure.

In 2014, six wells were acidized at high pressure and slow speed in X oilfield, and four wells had poor results. The main reason for the poor effect is that the overall physical properties of the block are poor, and the effective replacement cannot be established, so the wells cannot be injected and recovered, and the water wells hold pressure rather than the reservoir pollution in the near-well zone, so the acidizing has no effect. High-pressure slow acidizing is only effective in unblocking, but not effective in under-injecting wells due to poor physical properties.

3. The principle of pressurized water injection and the preference of pressurized water injection method

3.1 Principle of pressurized water injection

When the injection well bottom pressure reaches the formation fracture pressure, it opens potential microfractures in the formation near the bottom of the well, resulting in a significant increase in injection volume. When the injection pressure and injection rate exceed the formation breakdown pressure, a short fracture starts to be made. If the injection pressure and injection rate continue to increase, the initial short fracture may become wider and extend forward or create a new microfracture in the vertical direction. The expansion of each original crack or the generation of new cracks induces a temporary relative balance of the stresses in each direction [2].

3.2 The preference of pressurized water injection method

Oilfield X uses a single trunk pipe single well water distribution process, the distribution of under-injection wells is relatively scattered, if the overall pressure boosting transformation is adopted, a new longer high-pressure pipeline is required, and the construction investment is higher. Single-well booster water injection installs the booster pump at the injection well site, eliminating the need to build long-distance high-pressure pipelines. In addition, single well booster shows the advantages of small investment and relatively low power consumption in the construction and operation process.

Therefore, single well pressure injection can substantially increase the incoming water pressure, increase the differential pressure between oil and water wells, establish effective replacement, and has a strong target and adaptability for the management of scattered under-injection wells.

4. Application of pressurized water injection technology

4.1 Selection of booster injection wells

In order to achieve oil enhancement effect, all under-injection wells in X oilfield were selectively pressurized and injected with water, and the following principles were considered for the selection of pressurized injection wells:

(1) Good oil-water well connection relationship and high geological reserves of recoverable oil controlled by the well group.

(2) Water injection wells and oil recovery wells are connected to avoid the main stress direction of the formation, avoiding direct collusion between water injection wells and oil recovery wells fractures.

(3) The casing pressure-bearing capacity can meet the pressure increase requirements, and the weakest part of the casing will not be damaged under the highest injection pump pressure.

4.2 Determination of pressurized water injection pressure

The water injection pressure is determined based on the inflection point (fracture opening pressure or rupture pressure) of the water injection indication curve, which is designed to reach a maximum of 23 MPa. From the experimental well indicator curve, the average value of the inflection pressure is 20.6, i.e. the maximum injection pressure does not exceed 1.1 times the inflection pressure.

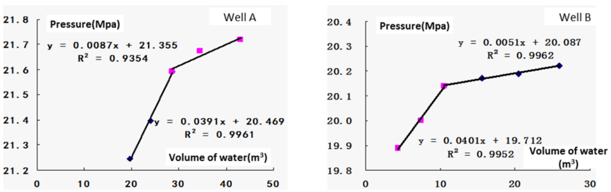

Fig.2 Typical well injection indication curve

5. Analysis of the effect of pressurized water injection

5.1 Pressurization test results

First, the water absorption capacity of single wells was significantly enhanced. According to the above principles, four wells in X oilfield were selected for water boosting injection. Comparing before and after the pressurization, the oil pressure rose by 1.9MPa and the average single well was injected with 15m3 more.

Table 1. Table of single well pressurization and injection increase

Well number	Pressurization time	Before the measure			After the measure			Cumulative increase (m³)
		Oil pressure (MPa)	Daily allotment (m³)	Actual daily injection (m³)	Oil pressure (MPa)	Daily allotment (m³)	Actual daily injection (m³)	
A	2012.10	20.3	10	6	22.0	25	25	13200
B	2013.06	18.2	15	7	21.6	15	15	1870
C	2013.06	18.9	10	8	19.4	30	30	1740
D	2013.11	19.1	15	10	20.9	20	20	2218
Average		19.1	13	8	21.0	23	23	4757

Second, the surrounding oil wells saw signs of effect. At present, two wells around well A have been affected by the effect of one well, with a daily oil increase of 0.5t and a cumulative oil increase of 245t, valid for 12 months. three wells around well D have shown signs of effect, with a daily oil increase of 1.8t and a cumulative oil increase of 340t, valid for an average of 5 months.

Table 2. Single-well pressurization and injection of surrounding oil wells to be effective table

Boosting wells	Peripheral oil wells	Before boosting			After boosting			whether validated	Valid period (month)	Accumulated oil increase (t)
		Daily Production Fluid (t)	Daily Production oil (t)	water content (%)	Daily Production Fluid (t)	Daily Production oil (t)	water content (%)			
A	A-1	1.3	1.2	6.0	1.2	1.2	2.1	No		
	A-2	1.1	1.1	1.2	1.6	1.6	1.3	Yes	12	245
	Total	2.4	2.3	99.0	2.8	2.8	99.0		12	245
	Average	1.2	1.1	3.6	1.4	1.4	1.7		12	245
D	D-1	0.4	0.4	5.0	1.2	1.1	5.0	Yes	5	105
	D-2	4.0	3.9	1.8	4.8	4.7	1.5	Yes	7	140
	D-3	2.6	2.6	1.2	2.8	2.8	1.8	Yes	3	95
	Total	7.0	6.9	8.0	8.8	8.6	8.3		15	340
	Average	2.3	2.3	2.7	2.9	2.9	2.8		5	113

Thirdly, the injection and extraction condition has been improved significantly, and the formation pressure has increased steadily. From the isotope absorption profile, the number of water-absorbing layers increased, and the proportion of water-absorbing thickness increased from 54.1% to 78.4% before pressurization. From the comparison of the output profiles of the surrounding wells, the output thickness ratio increased from 68.7% to 86.6%. In the comparison of six pressure measurement wells around the pressurized injection wells, the formation pressure increased from 6.89MPa to 7.09MPa, and the formation energy gradually recovered.

5.2 Geological conditions affecting the effect of pressurized water injection

The thickness differences of the three wells are different. The average sandstone strength and effective thickness of wells A and C, which have stronger water lifting capacity, are 5.3m and 2.6m respectively, while the sandstone strength and effective thickness of single well D are 2.8m and 1.5m respectively, and the analysis suggests that the thicker the reservoir thickness, the better the effect of pressurized water injection.

Table 3. Single well booster well pressure situation table

Well number	thickness		Connectivity status			
	sandstone (m)	effective (m)	Number of wells (mouth)	Number of layers (pcs)	sandstone (m)	effective (m)
A	5.1	2.5	2	11	14.9	5.7
C	5.4	2.6	5	27	36.3	18.1
D	2.8	1.5	6	21	30.9	29.1
Average	4.8	1.9	4	22	28.7	15.9

From the logging curve, there is an obvious magnitude difference in the lateral logging of A, with the best permeability and the best physical properties, followed by well C and the worst in well D. The analysis suggests that the difference in physical properties is also an important factor affecting the effect of pressurized water injection, and the better the physical properties, the better the effect of pressurized water injection.

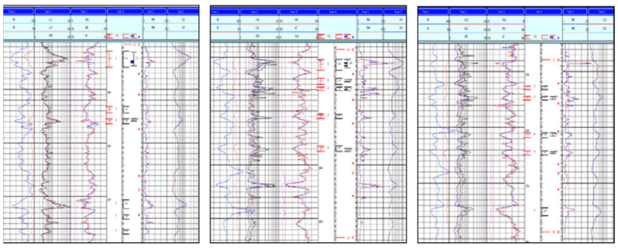

Fig.3 Single well logging curve (well A - C - D)

6. Conclusions and Recommendations

(1) Practice has proven that single-well pressurization and water injection in X oilfield is feasible and effective. Block local water well pressurization does not need to carry out the overall water injection pipeline network boosting transformation, which can make full use of the original equipment process and avoid reinvestment of materials.

(2) Ensure good injection water quality and keep the reservoir with stable water absorption capacity. Pressurized injection wells, with poor reservoir physical properties, are very likely to cause blockage or contamination of the reservoir. Therefore, improving water quality to reduce deep contamination in pressurized injection wells is one of the keys to protecting effective water injection in low permeability reservoirs and is a fundamental guarantee for developing good low permeability oil fields.

(3) As the underground casing pressure-bearing capacity is not confirmed, the next step should be to strengthen the monitoring of casing damage in pressurized water injection wells, to clarify the mechanism of casing damage and prevent casing damage.

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