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Pilot Test Study on Steam Flooding of Jin-45 Block Flooded Area

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Abstract
After 30 years' steam huff and puff, Jin-45 block has been flooded seriously, to continue relying on the steam simulation has been difficult to have a effective development and it has been exposed a series of questions[1-3]. According to the serious reservoir water influx, the development of huff and puff can't develop questions effectively and sustainably, it's necessary to find an effective approach to take over it . In order to demonstrate the feasibility of steam-flooding in flooded area, we need to built geologic model by Petrel, to finish history matching and steam flooding test by CMG[4-8]. Optimize the layer series of development and the projects of injecting, finally to formulate the reasonable flooding project that to solve the replacing of the last stage's development approach in water flooded reservoir turnover, to improve block recovery ratio, and provided reference of huff and puff into steam drive in water flooding[5-11].

Key words: Water flooding; Steam flooding; Numerical simulation; Scheme optimization

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INTRODUCTION
Jin-45 block is the largest heavy oil blocks in Liaohe Oilfield, which has the highest annual output of 123 × 104 t in the block. Its main fault block is Jin 91 block. The block was put into production in 1984, which has experienced the throughput test development and well pattern adjustment, large-scale throughput development process. Until June 1, 2013, the study area of steam stimulation recovery rate has reached 45%; the cumulative oil/gas ratio has been 0.614, the good development effect has been achieved. At present, the Jin-45 block has been into the production tail stage, the development effect becomes poor gradually, the new development mode is in badly need now. Water content is 93.85%, the recovery rate is as high as 260%, formation pressure is only 20% - 31% of the initial pressure. Because the reservoir exists in active edge and bottom water, the formation pressure is low and the flooding is serious, which put forward a new challenge to the flooding. To construct the small back well shaped net on the basis of the original square well pattern, which needs to enable the old or increase new wells. According to the situation of new wells' sufficient energy and the uncoordinated problem of the old wells, two kinds of injection production program were put forward and to optimize flooding layers, which provide reasonable solution for the flooded block.

1. GEOLOGIC ASPECTS AND CURRENT STATUS OF EXPLOITATION

1.1 Geologic Aspects
The research area locates in southern Jin-45 block of Jin-91 block. The well group for the east-west direction Jin-91 block lays in the middle of the 014 row to the 018 row. In the north-south direction, the south to the north block without wells, production wells is 86 (including the number of lateral drilling), the target being studied is located in the I group. Jin-91 block belongs to Jin-45 secondary fault block, whose structure locates in the western depression of Liaohe Oilfield southern section

of the western slope of Jin-45 block south, and the construction area is 5.29 km^2. Development objective layer are Paleogene Shahe Street Group in building a middle sand YuLou reservoir and sand about two sand of Xinglongtai reservoir. Both of two sets of reservoir are the independent oil-water system and heavy oil reservoir with strata water layer.

1.2 Current Status of Exploitation

Edge and bottom water is more active in severe flooding area. The water volume is large, which is about 2.05 times lager than the volume of oil reservoir, energy is sufficient and steam stimulation development has special rules. Mainly as follows: the periodic oil production, oil/gas ratio and period of cyclic water recovery rate are very high. The study area is divided into two well groups. The east well group has 0.054 km^2 oil-bearing area, geological reserves 51.6 × 104 t and the west one has 0.059 km^2 oil-bearing area, geological reserves 46.1 × 104 t. The existing production wells are less than ten, the majority of wells are closed because of poor well conditions and socked ring. The incursion of edge and bottom water makes the late stage of cyclic steam stimulation effect to be bad, which becomes the main problem affecting the efficient the development of block.

1.3 Main Problems

(a) The block has entered the late period of steam stimulation development; cyclic steam stimulation is no longer economic.

At present, the well spacing of group I in Jin-91 block have been encrypted to 83 m. The recovery rate is up to 42.85%, and the average oil production of single well is 1.2 t/d. The development of cyclic steam stimulation has reached the limit, so keeping on it is no longer economic.

(b) The formation pressure is very low, which is in urgent need to the transform development mode.

The formation pressure is 2.0 MPa at present, which only equivalent to 20% of the original formation pressure, which has reached the formation pressure limit of cyclic steam stimulation.

(c) Water flooding is serious, which brings difficulties to the transformation of development mode.

The water flooded zone has a film distribution in South and East block planes because of the heterogeneity of the block and huff and puff blow down or several years. The most place of the 5 and 6 small layers are flooded vertically, and the 3 and 4 layers of the main development are flooded seriously too. The transformation of development mode is more difficult.

(c) The well condition is poor and the well startup rate is low.

Jin-91 block averages 15.35 rounds per well to huff and puff. The well condition is poor as a result of huff and puff for a long time. There are 59 percents of wells have well condition problems such as lost item and set of bad. Poor well condition not only makes the interlayer contradiction, but also makes the reservoir plane reserves is not balanced. Besides the direct effects of huff and puff effect, it also will directly lead to the degree of control pattern of reserves variation, adverse effect on flooding.

2. RESERVOIR ENGINEERIN OPTIMIZATION DESIGN

On the basis of expanding the pilot area to drive experience, using 83 m square well spacing constitutes a small back-shaped pattern deploy 3 steam flooding well groups, 3 steam injection wells, and all wells are new. Deploying 42 production wells, 9 new wells, 33 old wells, deployment pattern as shown in Figure 1. Simulation using CMG software calculation of different schemes, the screening criteria are the highest oil and gas ratio and million tons of oil into the net.

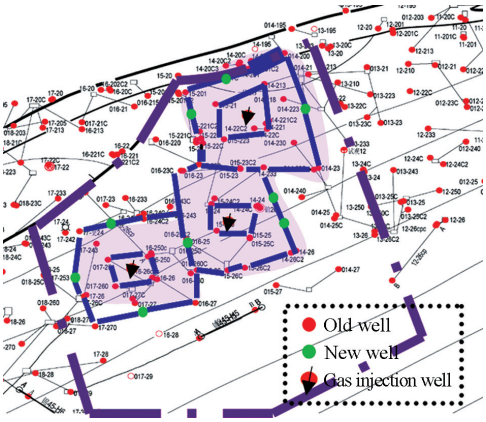

Figure 1
Small "Back"-Shaped Well Network Deployment Diagram

2.1 Optimization Design of Injection and Production Scheme

Scheme 1: Setting steam injection intensity according to the liquid producing capacity and injecting production ratio.

When in the design of produced liquid in thermal communication stage after flooding, going on the current state of production that the daily fluid output of huff and puff wells is unchanged, other stop production wells continue to product. Setting the liquid producing capacity should refer on the daily fluid production rule. Change the injecting production ratio, and calculate gas injection. Drilling 9 new wells to build a small back well shaped net. Setting the liquid producing capacity to the minimum cut-off wells daily fluid output. The produced fluid volume of displacement stage is set based on the setting of present produced fluid volume of connected stage. Referring to the changed rules of daily fluid output volume in Jin45 pilot test , which can arise the produced fluid volume.

Scheme 2: Setting liquid production according to the gas injection intensity and injecting production ratio.

Refer to the drive experience in pilot test area, and determine the gas injection intensity according to the well group area and effective thickness of formation.

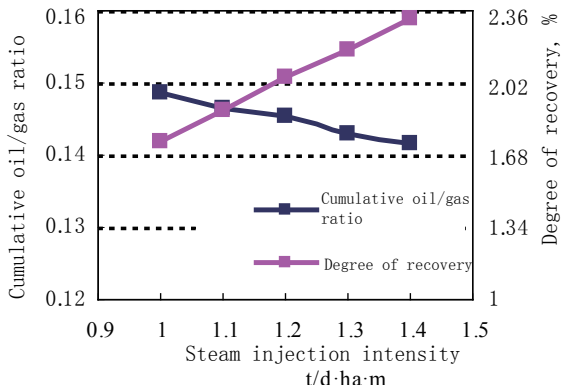

Figure 2
Heat Communication Stage of Steam Injection Intensity, Cumulative Gas Intensity and the Degree of Recovery

Determine the single well average daily fluid production according to the steam injection intensity and injecting production ratio.

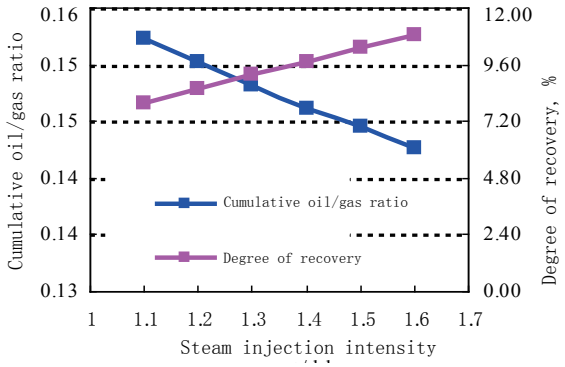

Figure 3
Displacement Stage of Steam Injection Intensity, Cumulative Gas Intensity and the Degree of Recovery

Table 1
The Calculation Results of Different Schemes

	Cumulative oil production × 10^4 t	Cumulative gas injection × 10^4t	Cumulative oil/ gas ratio	The degree of recovery %	Net oil × 10^4 t	Net one million tons of oil × 10^4 t
Sch1	11.77	86.25	0.136	11.76	6.49	55.13
Sch2	11.26	76.32	0.15	11.25	6.58	58.47

The calculative results of Scheme 1 and Scheme 2 are shown in Table 1, Scheme 2 is more economical, because million tons of net production of Scheme 2 is significantly higher than that in Scheme 1.

2.2 Optimization Design of Development Layer System

Years of cyclic steam stimulation and steam flooding development test, the original development layer division is more reasonable, so the steam flooding is still in the I formation as a whole set of layer series of development. But considered the reservoir development and water invasion status are difference, as shown in Figure 4. Experimental Zone flooding layer is considered as the I group's three schemes of 1-4 layer, 1-5 layer, 1-6 layer. Mainly on the basis of the following:

(a) In the I group, each layer converting to steam flooding still has a certain degree of recoverable reserves, At present, the remaining oil saturation, the single well control reserves and recoverable reserves tell (states) that converting to steam flooding has a solid material foundation;

(b) In the I group, each layer development and concentrated , reservoir connectivity is good. The connectivity coefficient of layer is 82% on average, the connectivity coefficient of thickness is 85.1%;

(c) There are good barrier condition in the layers , which can meet the need of injection, and mining;

(d) Water invasion of water flooded zone is dominated by the incursion of edge and bottom water, At present ,the I group of 6 small layers have been invaded water seriously, in order to avoid the water invasion of steam flooding causes adverse effects, choose 1-4 layers to have a steam flooding prediction.

By numerical simulation to predict index, cumulative oil/gas ratio of four layers and million tons of net oil producing are the highest, and has the best economic benefits, so choose the development of four layer scheme.

Table 2
The Development of Horizon Optimization

Layer	Cumulative oil production × 10^4 t	Cumulative gas injection × 10^4 t	Cumulative gas oil ratio	The degree of recovery %	Net oil × 10^4 t	Millions of tons of net oil × 10^4 t
4	11.26	76.32	0.147	11.25	6.58	58.48
5	14.26	12.58	0.113	14.25	6.56	45.98
6	16.59	14	0.118	16.57	8	48.28

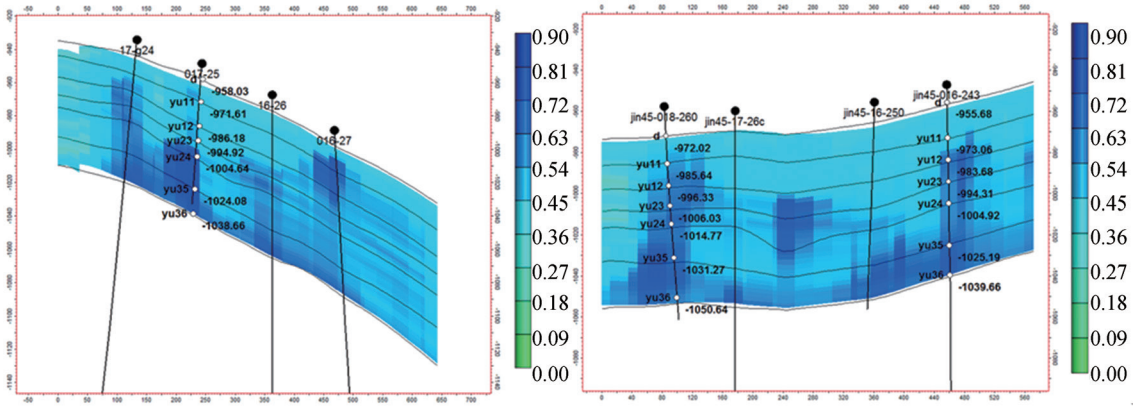

Figure 4
Production Well Water Saturation Longitudinal Field Map

3. PREDICTION OF DEVELOPMENT INDEX

The regional average thickness of small back shape 3 well groups is 34.4 m, test area connection area is 17.38 ha, geological reserves 100 × 104 t, which is expected to steam flooding stage cumulative steam injection of 223.4 × 104 t, cumulative oil production is 34 × 104 t, cumulative oil steam ratio is 0.134, stage of recovery degree is 13.25%, recovery rate is 55.5% and the cyclic steam stimulation development of calibration is 42.5%, recovery rate is increased by 15.73% compared with stream simulation development .

Table 3
Drive for 7.5 Years' Index Prediction

Development period	daily oil production t/d	Daily liquid-producingt/ d	Daily gas injection t/d	Annual oil production 10^4 t	With an annual output of liquid 10^4 t	Years of gas injection 10^4 t	Moisture content %	Gas oil ratio	Production rate %	The degree of recovery %
1	57.1	307.8	391.9	2.08	11.24	14.31	81.46	0.15	2.08	2.08
2	73.9	502.3	424.5	2.70	18.33	15.49	85.28	0.17	2.70	4.78
3	64.3	500.3	425.7	2.35	18.26	15.54	87.15	0.15	2.34	7.12
4	58.4	495.2	424.5	2.13	18.08	15.49	88.20	0.14	2.13	9.25
5	54.7	490.4	424.5	2.00	17.90	15.49	88.84	0.13	2.00	11.25
6	45.9	429.0	389.9	1.67	15.66	14.23	89.30	0.12	1.67	12.92
7	39.7	392.6	359.9	1.45	14.33	13.14	89.90	0.11	1.45	14.37
7.5	36.0	356.8	326.9	0.66	6.51	5.97	89.91	0.11	0.66	15.02
Total				15.04	120.31	109.66				15.02

CONCLUSION

(a) The existing production wells is less than ten now, the majority of wells are closed because of poor well conditions and the bad socket ring. To construct the back shape of well network, we need to make another new 9 production wells, enable the 23 old wells, these wells have limited production capacity, at the initial stage of development, which should be taken into consideration before shut production capacity of wells, further increases the liquid producing capacity later.

(b) From the pilot test area to drive experience, to set liquid production according to the effective thickness and gas injection. The million tons of net oil is high and economic benefits are high, which is the recommended scheme.

(c) The 5, 6 small layer of heavy water flooded zone is watered seriously, which reduces the thermal efficiency of steam and affects development result of steam flooding. The design of 1-4 layer, 1-5 layer, 1-6 layer development scheme serve for steam flooding development index prediction, by contrast, cumulative gas oil ratio and million tons of net oil of 4 small layer are the highest, so the development choice of 1-4 layers are recommended.

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