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Research on Countermeasures for Improving the Recovery Rate in the Later Stage of Steam Throughput Development in Ultra-Heavy Oil Reservoirs

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ABSTRACT

More than two decades after the development of Block D, it has entered the later stage of reservoir steam uptake development, and the difficulty of oil and gas exploration is increasing. To enhance the recovery rate of the block, countermeasures were studied in response to the current contradictions of poor steam injection effect, low formation energy, increased steam flow, uneven longitudinal utilization, and a large number of casing loss Wells. Planning and deployment were carried out to optimize steam injection parameters, implement carbon dioxide uptake, complement profile control technology measures, implement stratified steam injection and increase the intensity of major overhauls. In the field application process, the production effect was effectively improved. To propose development directions for high-cycle ultra-heavy oil blocks.

KEYWORDS

Super heavy oil; Dynamic development; High-cycle development.

1. INTRODUCTION

Heavy oil reservoirs are limited by the physical properties of crude oil, with high viscosity, and are mainly developed through steam throughput. As super-heavy oil reservoirs enter the later stage of throughput development, the degree of steam flow during steam injection gradually intensifies, the steam injection effect is affected, the oil-steam ratio decreases, formation pressure drops, the well condition deteriorates and leads to an increase in shutdowns, and the contradiction of uneven utilization becomes prominent, affecting the reservoir's recovery rate. Taking block D as an example, this paper studies countermeasures for improving reservoir recovery and puts forward targeted suggestions.

2. RESEARCH BACKGROUND

The main target layer of Block D is the Xinglongtai oil layer of the Sha Yi + II section. The reservoir properties of the oil layer are high porosity and high permeability reservoirs. The nature of the oil is super-heavy oil, and the crude oil has the characteristics of "four highs and one low": high density, high viscosity, high freezing point and low wax content. The block as a whole is a monoclinic structure sloping from north west to south east. The Xinglongtai oil layer as a whole is a lateral-bottom water reservoir controlled by structural lithology, without a unified oil-water interface.

Since its development and construction began in 2001, the block has mainly gone through two stages: rolling development to increase production and expansion to adjust and stabilize production. Rolling development and production stage: In 2000-2001, steam throughput tests were successfully carried out in the main part of the reservoir using a 70-meter square well pattern. Rolling deployment development with a 70-meter well spacing was adopted from 2002 to 2008.

Expansion adjustment and stable production phase: With the completion of the basic well pattern deployment in the main area, regional expansion and interwell densest horizontal Wells were implemented in 2010.

The block is now in the later stage of steam throughput, with an average of 23 cycles per well. In 2024, the block's annual oil-steam ratio will be 0.3, and the formation pressure coefficient will drop from the original 0.98 to 0.2, which is at a relatively low level. The steam flow in the block has been increasing year by year, affecting the quality of steam injection in steam throughput; Due to the severe heterogeneity of the reservoir, the contradiction of uneven utilization of blocks is also more prominent; The number of faulty Wells is increasing, seriously affecting normal production in the block.

3. COUNTERMEASURE RESEARCH AND APPLICATION

3.1. Carry out steam injection parameter optimization to ensure the scientific nature of injection and extraction parameters

In order to ensure the steam injection effect and increase the periodic production of the oil well, research is conducted on the optimization of steam injection parameters.

Based on the previous optimization design of steam injection intensity, the production effects of different cycles and different steam injection intensities were re-evaluated to obtain the optimization design standard of steam injection intensity for the block and the optimization design of on-site parameters of indicators to improve the steam injection effect.

By counting the production effects of different steam injection intensities and different steam injection cycles in the production well, the appropriate steam injection intensities in different cycles were determined: The optimal steam injection intensity for cycle 1 is 64 tons/m, for cycle 2 it is 66 tons/m, for cycle 3 it is 77 tons/m, for cycle 4 it is 73 tons/m, for cycle 5 it is 80 tons/m, for cycles 6-10 it is 78 tons/m, and the higher the optimal steam injection intensity in the later stages of production, and 80 tons/m can be achieved for cycles 15 and above. It indicates that with the increase of throughput, the required steam injection volume increases, and the steam injection volume should be appropriately increased in accordance with the throughput to achieve the best production effect.

Well D-69-45 has performed well in field applications. The 10th cycle of this well has a steam injection volume of 1,600 tons, a steam injection intensity of 85 tons per meter, and a cycle oil production of 624 tons. In the 11th cycle, to improve the production effect of the cycle, the steam injection parameters were optimized and the steam injection intensity was increased. The cycle steam injection volume was 2,100 tons, the steam injection intensity was 112 tons per meter, and the cycle oil production was 857 tons. The production effect was improved.

3.2. Implement carbon dioxide uptake and release to replenish the energy of the formation

The development of ultra-heavy oil focuses on reducing viscosity, friction and improving rheology [2]. The D block has been under development for more than two decades, and the formation energy has continued to decline. The average steam injection pressure in the early stage was around 14MPa, but it has now dropped to 10.8MPa. The formation pressure has dropped from the original 7.05MPa to the current 2.01Mpa; The pressure coefficient has dropped from the original 0.98 to the current 0.2, and the pressure coefficient of all production Wells is generally below 0.3. The decrease in formation pressure indicates a decrease in formation energy in the block, and measures should be taken to reduce viscosity to increase formation energy in order to improve block recovery rate.

Carbon dioxide has an extremely significant viscosity-reducing effect on very heavy oil. Moreover, carbon dioxide dissolves in heavy oil and causes its volume to expand, thereby increasing the oil saturation, the relative permeability and fluidity of the oil phase, and the volume expansion increases the elastic energy of the reservoir. This is also one of the mechanisms by which carbon dioxide enhances the recovery rate of heavy oil [3].

Block selection of Wells with a significant decrease in formation pressure and a lower steam injection pressure. In 2024, a total of 45 Wells with carbon dioxide uptake and release measures were implemented, with a cumulative increase of 10,800 tons of oil. After the measures, the steam injection pressure of the Wells increased, effectively replenishing formation energy.

3.3. Supporting processes to block steam flow channels and reduce the impact of steam flow

In block D, the well distance from the vertical well is 70 meters, while in the densified horizontal well area, the well distance is only 35 meters. The steam ejection process is highly prone to steam ejection reaction, and the degree of steam ejection gradually intensifies with the increase of ejection rounds. Severe steam ejection leads to a sharp deterioration in ejection effect.

High-temperature resistant plugging agent was used to squeeze into the oil layer before steam injection. When the plugging agent solidified under formation conditions, it reduced the permeability and porosity of the steam injection channel or high permeability zone, adjusted the steam absorption difference between the high and low permeability zones of the formation, changed the direction of the injected steam, and achieved the purpose of expanding the steam injection wave volume and increasing the periodic oil production.

In the past three years, the block has intensified the implementation of profile control measures for steam channeling Wells, with priority given to those with severe steam channeling. On average, 28 Wells were carried out each year, with an average increase of 0.4 million tons of oil per year. Through profile control measures, the impact of gas seepage on the block's production was effectively reduced.

3.4. Implement stratified steam injection and adjust the utilization status of oil layers

In the later stages of heavy oil oilfield throughput, due to geological reasons, that is, the relative permeability of each layer varies greatly and the thickness of each oil layer is uneven, resulting in uneven reservoir utilization after multiple rounds of steam injection production, the contradiction between high and low permeability layers is prominent and they influence and interfere with each other. Stratified steam injection can limit the steam absorption of the better-activated oil layer and inject the more steam into the lower-activated reservoir to adjust the longitudinal utilization status [4].

A comprehensive analysis of the steam absorption profile data in block D reveals that the degree of longitudinal utilization is uneven due to the influence of throughput development. The oil layers are classified into strongly utilized layers, generally utilized layers, and poorly utilized or unutilized layers based on the range of different percentages of the ratio of single-layer vapor absorption intensity to the average vapor absorption intensity of each layer. In the statistics block, some of the well vapor profiles (214 Wells) were included, with 51.2% being strongly utilized, 24.7% being generally utilized, and 24.1% being poorly utilized or not utilized. The contradiction of uneven utilization was more prominent.

To adjust the longitudinal utilization situation, the block has continuously carried out steam profile monitoring over the past three years and implemented stratified steam injection measures for Wells with uneven utilization, with an average of 32 Wells implemented each year and an average increase of 8,000 tons of oil per year, and the adjustment effect has been good.

3.5. Intensify the management of casing damage Wells to ensure the stability of production scale

Due to years of throughput development, the casing damage in block production Wells is relatively severe. The block has historically damaged 346 Wells, accounting for 76% of the total number of Wells. There are currently 264 faulty Wells, including 162 faulty production Wells and 102 faulty shutdowns. The number of faulty Wells is increasing day by day, seriously affecting normal production in the block. To restore the production capacity of this part of the Wells, based on the principle of well selection for major overhauls (the oil layer is well developed and the thickness of the oil layer is greater than 20m; The production capacity was high before the shutdown, with a daily output of more than 5t before the shutdown and periodic oil production reaching up to 1200t; In the past three years, 57 Wells have been overworked and resumed production, with an annual increase of 22,900 tons and an average increase of 401 tons per well, which is of great significance for maintaining a stable production scale.

4. CONCLUSIONS

Block D, after more than two decades of development, has entered the later stage of the development of steam uptake in the ultra-heavy oil reservoir. With the aim of enhancing the recovery rate of Block D, countermeasures were studied in response to the current contradictions of poor steam injection effect, low formation energy, increased steam flow, uneven longitudinal utilization, and a large number of casing loss Wells. Planning and deployment were carried out to optimize steam injection parameters, implement carbon dioxide uptake, complement profile control technology measures, implement stratified steam injection and increase the intensity of major overhauls, and good results were achieved in production, development and application. This has effectively increased the oil recovery rate of the block.

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