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Advances in Horizontal Well Engineering and Equipment for Low-Permeability Tight Reservoirs

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Abstract

In order to stabilize domestic energy supply and reduce external dependence, the development of low-permeability tight oil reservoirs is the focus of oil and gas field exploration and development in China. Low permeability tight reservoirs usually have the characteristics of high reserves of geological exploration resources, poor physical properties and complex oil-water relationship. These characteristics restrict the development of low permeability tight reservoirs in China. In recent years, due to the maturity of drilling technology, development technology and stimulation technology, as well as the innovation and development of oil field machinery, the low permeability tight oil reservoirs which were difficult to exploit in the past have been effectively developed, so that the utilization rate of resources and the supply capacity of oil have been greatly improved. This paper mainly introduces the development and frontier of horizontal well technology, multi-branch well technology, advanced water injection technology, hydraulic fracturing technology, engineering and equipment development in the development of low-permeability tight reservoirs.

Keywords

Low-permeability Tight Reservoir; Horizontal Well; Multilateral Well; Advanced Water Injection; Multi-stage Fracturing.

1. Introduction

Nowadays, China's oil resources are very dependent on imports, of which the external dependence of oil and natural gas is as high as 72% and 43%. At the same time, it is difficult to make new breakthroughs in the exploration and development of conventional oil and gas fields in China. Therefore, the efficient development of low-permeability tight reservoirs is the key breakthrough in China's oil industry. The porosity and permeability of low-permeability tight reservoirs are very low. The contact area can be significantly increased by drilling horizontal wells. Therefore, water injection development and hydraulic fracturing can effectively develop low-permeability reservoirs and effectively increase recoverable reserves. In addition, with the development of oil and gas field development engineering technology, oil field machinery is also constantly updated and improved to promote each other, making the development of low permeability oil and gas fields gradually move towards a deeper level.

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2. Development Status

Low permeability reservoirs mainly refer to reservoirs with poor permeability. Usually, this type of reservoirs is also called tight reservoirs. Low permeability reservoirs in China can be divided into three types. Reservoirs with permeability of 50~10 mD are called low permeability reservoirs, reservoirs with permeability of 10~1 mD are called ultra-low permeability reservoirs, and reservoirs with permeability of 1~0.1 mD are called ultra-low permeability reservoirs[1]. China's low permeability tight oil reservoirs are widely distributed, represented by Changqing Oilfield, Yanchang Oilfield, Jilin Oilfield and Tuha Oilfield. In the process of developing low permeability tight reservoirs, due to poor reservoir properties, insufficient formation energy, complex natural fractures and complex oil-water relationship, its development is very difficult. At present, although the reservoir reconstruction and reservoir stimulation measures are adopted, the production and ultimate recovery of the reservoir are relatively low. Aiming at the problem of difficult development of low permeability reservoirs, domestic and foreign oil fields have developed a systematic development process.

3. Well Type Optimization Technology

3.1. Conventional Horizontal Well Technology

Horizontal well is a special well with a deviation angle of about 90°and a certain length of horizontal section in the target layer. Horizontal well drilling technology is the extension and development of conventional directional well drilling technology. Horizontal well technology was proposed in the 1920s and put into practice in the 1940s. Due to the technical limitations of the times and the gap in technology, it has not been fully developed. In the 1970s, horizontal well technology began to rise again, and in the 1980s, the technology has been applied in the United States, Canada, France and other countries, and reached the stage of single well oil recovery. Up to now, the United States has the fastest development in horizontal well technology, and has great research results in horizontal well drilling technology. It has the largest number of horizontal wells, with more than 1000 horizontal wells drilled annually.

In the 1970s, after drilling horizontal wells in Sichuan, China became the third country in the world to drill horizontal wells. In the following ten years, China 's horizontal well drilling technology failed to continue to develop. Until 1988, Amoco used the world's most advanced MWD(measurement while drilling) while drilling tool, top drive drilling device, steering drilling system and other technical processes to drill the first horizontal well in the Pearl River Mouth Basin of the South China Sea in 20 days. The well has been tested to be slower than the vertical bottom hole water coning, high production, and water cut is only half of the vertical well. The success of the experimental test of the well provides an important basis for the development of oil and gas fields in the future, and also inspired the development of horizontal well technology in China 's oil fields in the 1980 s.

3.2. Multilateral Well Technology

Multi-branch horizontal well [2] means that two or more horizontal branch boreholes are drilled into the oil and gas reservoirs at different positions on both sides of the main borehole, and even a third-stage borehole can be drilled in the second-stage borehole. The main wellbore can be a vertical well or an inclined well or a horizontal well. TAML(Technology Advancement for Multilaterals) classification system classification system is usually used to evaluate the integrity, connectivity and sealing of multi-branch wells. According to these characteristics, multi-branch wells are divided into six grades.With the development of completion technology, multi-lateral well drilling technology has also been developed and widely used. Compared with conventional drilling technology in offshore oilfields and old oilfields, multi-branch well technology can reduce the demand for fracturing and replace conventional perforation

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technology. It can not only sidetrack multi-branch horizontal wells in old wells, but also sidetrack multi-branch horizontal wells in new wells by pre-windowing system. Multi-branch horizontal well is the integration and development of horizontal well technology. Compared with the current mature horizontal well and sidetracking horizontal well technology, multi-branch horizontal well has greater advantages in developing low permeability reservoirs. By sidetracking several branch horizontal wells in low permeability reservoirs, the drainage area of reservoirs can be increased, so as to improve oil well production and recovery degree. In addition, branch horizontal wells can also reduce the unit technical cost, improve the recovery rate of low permeability reservoirs, as infill wells can greatly increase production and so on. Branch horizontal wells can save the cost of well site occupation, relocation and installation of drilling rig, repeated drilling of main wellbore, casing running, waste drilling fluid and cuttings treatment [3].

In the 1990 s, with the gradual maturity of directional well and horizontal well technology and the rapid development of downhole tools, many national oil companies, mainly in the United States and Canada, began to carry out large-scale research and field application of branch wells. In particular, the rapid development of downhole tools accelerated the development of branch well technology. In 1987, Bechtel Company of the United States developed the hydraulic rock breaking branch horizontal well technology, and drilled more than 600 radial branch horizontal wells in California and Los Angeles oilfields. In 1992, foreign countries began to study the downhole branch device system, and in 1993 and 1994, several oil companies began to carry out field tests. Multilateral well technology has been relatively mature in foreign countries. Baker, Sperry-Sun, Halliburton, Marathon and other oil companies have taken multilateral well technology as a cutting-edge topic for research, and have successfully developed nearly 20 sets of multilateral well drilling and completion systems. Nearly 2000 multi-branch wells have been drilled. In a sense, without the development of downhole drilling tools, it is impossible to have the wide application of branch well technology.

China 's Yumen Oilfield completed a four-branch well in the Laojunmiao area in 1960. In the late 1980 s, the research on multi-branch well technology was gradually carried out in several major domestic oilfields such as Shengli Oilfield, Liaohe Oilfield, Sichuan Oilfield and Nanhai Oilfield, and several multi-branch wells were drilled successively. In recent years, domestic oilfield companies and scientific research institutions have attached great importance to the research of multi-branch well technology. Shengli Oilfield has drilled the first branch horizontal well in China [4]. Liaohe Petroleum Exploration Bureau has developed and applied TAML fourth-grade multi-branch well technology, which is the first unit in China to successfully apply this technology. Because the technology of 5-level and 6-level multi-branch wells is not mature at present, the operation risk is high and the success rate is low, so the multi-branch wells in China mainly adopt the completion method below 4 levels. The application of multi-branch well technology in China is still in the experimental stage, and the technical research is far behind foreign countries. Therefore, it is suggested to carry out the experimental research on the comprehensive supporting tools for branch well drilling and completion as soon as possible, so as to promote China to catch up with the foreign branch well drilling and completion technology level as soon as possible.

In addition, for the stimulation operation of multi-branch wells, the ability of wellbore re-entry and the longer reservoir section should be considered. Multi-branch wells have made progress in increasing production. Halliburton et al.developed coiled tubing re-entry tools, Fishbone Company developed fishbone-shaped multi-branch stimulation technology, and branch well acid fracturing and fracturing technology has been applied on a large scale abroad. At present, there are no coiled tubing reentrant supporting tools in China, there are reliability problems in coiled tubing reentrant technology, and domestic branch well acid fracturing and fracturing technology is in the experimental stage. In the future, the development direction of domestic

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branch well stimulation should focus on the re-entry technology of coiled tubing and the independent research and development of fishbone-shaped multi-branch well stimulation technology.

4. Energy Supplement Technology

4.1. Advanced Water Injection

At present, the primary means of most oilfield development in China is still water injection development. For reservoirs with poor pore structure, insufficient formation energy, low oil saturation, and low water-sensitive clay mineral content, advanced water injection technology can be used. Advanced water injection is to inject water before the oilfield is not developed or when the oilfield is put into production, and inject water in advance to increase the pressure of the formation, so as to ensure that the water injection volume and formation pressure reach a certain level before starting production.

Reasonable timing of water injection development is the guarantee for the oilfield to achieve ideal development results. The later the time of water injection, the greater the decrease of formation pressure. Even if the formation pressure is restored to the original formation pressure after water injection, the effective porosity and air permeability of the reservoir have been irreversibly damaged.

Advanced water injection Advanced water injection can establish an effective pressure displacement system as soon as possible, replenish formation energy in time, reduce reservoir damage and permeability damage caused by formation pressure drop, and maintain the original seepage channel unimpeded [5]. The advanced water injection technology also improves the volume of the injected water wave, so that the oil well can establish a large production pressure difference after the well is opened to overcome the starting pressure gradient, so that the oil well can maintain a high production capacity for a long time.

In 2001, Ansai Oilfield carried out advanced water injection well groups for 12 well groups. Through the implementation of advanced water injection technology, the production rate was increased while the production decline was slowed down, so that the final recovery rate was improved. Nowadays, Jilin Oilfield and Tuha Oilfield have also used advanced water injection technology to develop low permeability reservoirs.

4.2. Horizontal Well Layered Water Injection String

In the oil and gas field development engineering technology for water injection development research at the same time, the corresponding oil field machinery is also constantly improving. At present, low permeability tight reservoirs want to carry out fine development for layered water injection. Horizontal well layered water injection string is an important factor restricting the effect of horizontal well water injection development. In recent years, a lot of research has been carried out on the horizontal well layered water injection string at home and abroad. In 2006, Jilin Oilfield began to study the separate injection technology of horizontal wells. The horizontal well downhole separate injection technology string developed by Jilin Oilfield [6] is mainly composed of casing protection packer, horizontal well centralizer, horizontal well water injection packer, step-by-step unsealing well washing device, horizontal well downhole separate injection device and so on. This kind of string can effectively solve the problem that the packer is difficult to seal, and has been widely used in Jilin Oilfield, which realizes the effective stratified water injection development of horizontal wells.

Zhang Yiyu, Sun Jinfeng, Xin Lintao et al. developed a horizontal well shallow measuring segmented water injection string in Shengli Oilfield [7], which is mainly composed of safety joint, shallow measuring shunt water distributor, integrated packer water distributor, centralizer and horizontal well flushing valve. The horizontal well shallow testing segmented

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water injection string adopts the shallow testing diversion structure and the integrated structure of plugging and expansion sealing of integrated sealing and water distribution, which solves the technical problems of poor sealing reliability, low test efficiency and low success rate of testing and adjustment of horizontal well segmented water injection, and is suitable for horizontal well segmented balanced water injection with serious heterogeneity. The main tools of the pipe string are designed with a track reversing structure, which can realize the start-up and setting of the hydraulic tool without throwing and fishing, and effectively reduce the workload of the field operation. The field application in Dongxin Oil Production Plant of Shengli Oilfield Company shows that the structure design of the string is reasonable and the operation is convenient, which is of great significance for improving the balanced development effect of staged water injection in horizontal wells.

Although the above two pipe strings have been applied in the field and achieved certain results, they still have their advantages and disadvantages. The downhole separate injection string of horizontal wells in Jilin Oilfield can be divided into four sections at most, but it is still difficult to use coiled tubing to put water nozzle in the horizontal section [8]. The horizontal well shallow testing segmented water injection string in Shengli Oilfield has simple structure and convenient adjustment, but the vertical section casing cannot be protected when the two sections are injected separately. In 2022, Zhang Peng, Li Penghui, Pu Chunsheng et al.developed an injection-production integrated string [9]. Compared with the traditional water injection string, this string can not be limited by the number of layered sections. In addition, many control and detection devices have been added to enable real-time monitoring and control of oilfield water injection development dynamics, which greatly reduces the workload of oilfield development.

5. Stimulation Technology

Hydraulic fracturing technology (Hydraulic fracturing) is to pump high-viscosity fracturing fluid (including prepad fluid, sand-carrying fluid, and displacement fluid) into the wellbore through a surface high-pressure pump set to exceed the formation 's absorption capacity. When the high pressure of the fracturing fluid at the bottom of the well is greater than the in-situ stress near the wellbore and the tensile strength of the formation rock, cracks are formed in the formation near the bottom of the well, and the sand-carrying fluid carrying the proppant is continuously injected. The crack extends forward and is filled with proppant. Finally, after the well is shut down, the crack is closed on the proppant, thereby forming a fracture with a certain conductivity in the formation near the bottom of the well to achieve the purpose of increasing production and injection. Horizontal well staged fracturing is a key means to obtain industrial oil flow in low permeability tight reservoirs. According to the sealing method and process principle, it can be divided into three categories : mechanical packer staged fracturing, hydraulic jet staged fracturing and flow limiting staged fracturing.

5.1. Horizontal Well Mechanical Packer Staged Fracturing Technology

5.1.1. Multi-stage Bridge Plug Sealing Horizontal Well Staged Fracturing Technology

The multi-stage bridge plug sealing horizontal well staged fracturing technology is mainly to use the bridge plug to block the formation to achieve layered fracturing, and its core tool is the bridge plug. At present, the bridge plugs widely used are drillable bridge plugs and soluble bridge plugs. The drillable bridge plugs are used to drill through the bridge plugs in turn until the bottom of the well after the fracturing construction is completed. The soluble bridge plug is dissolved in the wellbore liquid after the fracturing is completed, and the bridge plug is returned to the ground by blowing out. The advantage of the drillable bridge plug is that the sealing effect is good, but it is prone to downhole accidents during the drilling tool milling process. At the same time, the generated debris is easy to pollute and block the reservoir, which

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will prolong the fracturing operation time and increase the operation cost. In order to solve the above problems, domestic and foreign oil field companies have carried out research experiments on the selection of drillable bridge plug materials.At present, foreign composite drillable bridge plugs are relatively mature. The composite bridge plugs represented by Quick Drill bridge plug of BakerHughes Company and Fas Drill of Halliburton Company have achieved great results. In 2014, Zhongyuan Oilfield Petroleum Engineering Technology Research Institute developed an easy-to-drill bridge plug with independent intellectual property rights for the development of hydraulic fracturing in ultra-low permeability tight oil fields in Yanchang Oilfield [10]. Compared with the drillable bridge plug, the soluble bridge plug does not need to drill through the bridge plug, which reduces the construction risk and reduces the use cost and time. The drillable bridge plug can reduce the probability of sealing in the middle. If it is stuck, it can also dissolve the bridge plug through rapid processing technology to reduce the risk of overhaul. The Illusion series fracturing bridge plugs of Halliburton company, the soluble bridge plug perforation combined system Infinity of Schlumberger company, and the fully soluble SPECTRE new soluble fracturing bridge plug of Baker Hughes company are more advanced. In 2016, Xinjiang Oilfield developed a low-temperature soluble bridge plug.

5.1.2. Packer Multi-Stage Fracturing Technology

The packer multi-stage fracturing technology produces pressure shielding between each perforation section through the packer, and carries out fracturing transformation on a certain perforation section. According to the different packers, the corresponding packer multi-stage fracturing technology mainly includes the expansion packer multi-stage fracturing technology, the open-hole packer multi-stage fracturing technology, and the double packer lifting multi-stage fracturing technology.

Expandable packer, made of special rubber material. After the packer is lowered into the predetermined position of the bottom hole, the expandable rubber can expand rapidly after encountering oil and gas or water. Therefore, it is also called an oil (water) expansion packer. After the rubber expands to the wellbore position, it continues to expand to generate contact stress, thereby achieving sealing. The expansion rubber can automatically expand and set when it meets oil or water in the well. After expansion, the rubber can adapt to the shape of the irregular wellbore, close to the wellbore wall, and realize layered and segmented sealing. After the expansion of the rubber tube is completed, it does not shrink, and it is always close to the shaft wall to ensure that the sealing quality is qualified. This technology has high reliability, can be quickly transferred to oil test after fracturing, low production cost and operation risk, and is suitable for fracturing of open hole completion in horizontal wells. Halliburton launched the Easy Well series of oil and water expansion packer technology, and TAMFREECAP series of expandable packer technology, etc., which have been widely used abroad. In recent years, major oil fields and research institutes have carried out independent research and development of expandable packers. Hou Naihe, Li Zhang, Guo Chaohui et al. developed a water-immersed self-expanding packer. In June 2012 [11], the Honghe Oilfield of North China Branch of Sinopec carried out staged fracturing of horizontal wells and achieved good results.

The staged fracturing technology of open hole packer in horizontal well is to open the sliding sleeve of plugging the previous perforation section while plugging the fractured section, and to carry out fracturing transformation on the upper section. Return in turn to achieve multi-segment partial pressure ; after the transformation, the sphere is discharged back into the wellbore with the fracturing fluid, and the layer is produced. The technology controls the sliding sleeve through the wellhead pitching system, which has the advantages of short construction time and low cost. The key of this technology lies in the opening of each sliding sleeve and the level difference controlled. The more stages, the more accurate the sliding sleeve control requirements and the higher the construction risk. This technology generally adopts mechanical packer, which is suitable for casing and open hole completion. This type of packer

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requires pressure setting or tool setting, so the process is complex, and the number of tool strings is large. The risk of horizontal well construction is large. Improper handling of any link will lead to construction failure and cause overhaul. Many foreign companies have developed matching open-hole packers. The MPasTM packer developed by Baker Hughes uses solid solid rubber materials, and has two setting designs of hydraulic and static pressure, which has been successfully applied in the Bayu-Undan gas field. The TerraForm open-hole packer developed by Weatherford company uses a leather bowl sealing technology, which can dynamically match the wellbore geometry and is applied in a deep-water oil and gas field in the Gulf of Mexico. There are few researches and developments on open-hole packers in China.Changqing Oilfield independently developed a high-performance composite open-hole packer suitable for 152.4 mm open-hole wells and tested it in Sulige. Sinopec Petroleum Engineering Technology Research Institute has also developed a fully self-dissolving staged fracturing sliding sleeve suitable for open-hole wells.

The double packer lifting staged fracturing technology is to lift the string to the next perforation section, and re-set the packer for the next section of fracturing transformation. After the completion of the transformation, the fracturing string is pulled out, and the fracturing of the multi-section formation is realized by one trip of the string. The advantages of this technology are that the purpose and controllability of fracturing are strong, the fracturing efficiency is high, the cost is low, and the isolation effect of the wellbore is good. However, the shortcomings of this technology are also obvious. Due to the easy occurrence of packer sand sticking, the string is not unsealed, resulting in downhole accidents such as overhaul. In the process of fracturing, the packer needs to be repeatedly set up, and the rubber cylinder is easy to break. It is necessary to restart the string, resulting in a long construction period and increasing the construction cost. After the research and development in recent years, the double-sealing single-stick fracturing technology has gradually matured in the process, which has solved the problems of fracturing fluid backwashing, packer and hydraulic anchor unblocking, fracturing string and tools passing through the curved well section smoothly and tool recovery after fracturing. It is an effective process for horizontal well fracturing and production increase. This technology has successfully completed the fracturing field construction of 15 well sections in one string in Daqing Oilfield, setting a new record for the number of fracturing layers in single string construction of horizontal well staged fracturing in China.

5.2. Horizontal Well Hydraulic Jet Staged Fracturing Technology

Hydraulic jet fracture (HJF) is based on the Bernoulli equation. Through the injection of high-speed fluid and the conversion of kinetic energy and pressure energy, the high-speed and high-pressure fluid carries the sand body to form pressurization in the jet channel. The fluid is pumped into the annulus to increase the annulus pressure. The superposition of the jet fluid pressurization and the annulus pressure exceeds the fracture pressure to open the channel between the formation and the wellbore, increase the fluid flow, and open the fracture.

This technology is a new type of stimulation technology integrating perforation, fracturing and sealing. Hydraulic jet fracturing is completed by three processes : hydraulic sandblasting perforation, hydraulic fracturing and annular extrusion. By using hydraulic jet tools to implement staged fracturing, without packers and bridge plugs and other packers, automatic plugging and accurate sealing, one string to achieve multi-stage transformation. Hydraulic jet staged fracturing is more conducive to the formation of transverse cracks. At present, hydraulic jet staged fracturing technology can be used for fracturing of screen pipe, casing and open hole completion wells, and can also be dragged by coiled tubing to return fracturing layer by layer. After fracturing, the tool can be lifted out, which greatly reduces the amount of workover operations.

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In 1998, Surjaatmadja of Halliburton first proposed the idea and method of hydraulic jet fracturing, which organically combined hydraulic jet perforation technology with hydraulic fracturing, and carried out a large number of numerical simulations and laboratory experiments. Later in 2001, Halliburton successfully applied this technology. In 2005, the United States Barnett oilfield for the first time in the horizontal well using hydraulic jet annular fracturing technology, and achieved certain results. In the United States, Canada and other countries, hundreds of oil wells have been treated by hydraulic jet fracturing technology, and the production has been significantly improved. In China, in 2005, Changqing Oilfield first introduced the water jet staged fracturing technology of Halliburton Company.After the successful test in Jingbian Oilfield, the major domestic oilfield companies and scientific research units gradually began to research and develop the hydraulic jet staged fracturing technology and equipment. In 2007, Chuanqing Drilling Company successfully carried out coiled tubing hydraulic jet staged fracturing for the first time.

At present, hydraulic jet staged fracturing technology has a variety of processes : hydraulic jet assisted fracturing (HAJF), hydraulic jet ring controlled fracturing (HJP-AF), hydraulic jet acid fracturing [12]. In addition, the hydraulic jet staged fracturing technology can use tubing or coiled tubing as the operating string, which can be applied to casing completion, screen completion and open hole completion. Its construction technology is divided into dragging string type and fixed string type. The fixed string type uses the ejector as a sliding sleeve ejector, which can achieve multi-stage fracturing. The advantage of the dragging string type is that the continuous dragging of the construction string can save a lot of time and reduce the construction cost. In addition, due to the accurate positioning of the hydraulic jet perforation, the fracturing is highly targeted and highly controlled for the transformation layer.

5.3. Limited-Entry Fracturing Technology

The current limiting fracturing technology limits the water absorption capacity of each layer by controlling the number of perforation holes and the diameter of perforation holes in each layer, so as to achieve the purpose of fracturing layer by layer [13].

When the oil layer with low fracture pressure is opened, the liquid absorption capacity increases, and the perforation hole produces a throttling pressure loss. Under the condition of increasing displacement, the pressure in the casing continues to rise, and the oil layer with similar fracture pressure is opened in turn. Under a certain fracturing displacement, multiple target layers are treated by one-time fracturing and sanding. The current limiting method requires that the ground can provide a large enough injection displacement, so that more target layers can be processed at the same time. The key to the layered fracturing of the flow-limiting method is to design a reasonable perforation plan according to the requirements of fracturing, including perforation hole, hole density and pore size, so that the fracture pressure of each layer is close, so that the completion and fracturing are connected as a unified whole [14]. The stratified fracturing with limited flow method is suitable for wells with multiple layers and different fracture pressures between layers, which is used for infill wells, thin and poor reservoir completion and transformation. The limited flow fracturing technology has the advantages of short construction period, low cost and low risk, which can ensure the orientation of cracks. In China, the limited flow fracturing horizontal well technology in Daqing Oilfield is relatively mature.

6. Summary

In summary, due to the relatively strong heterogeneity and poor physical properties of low-permeability oilfield reservoirs, it is relatively difficult to develop them. In order to improve the recovery rate of low permeability tight reservoirs, horizontal well technology and multi-branch well technology are important means to increase the production and development of low

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permeability tight reservoirs. Through the application of advanced water injection and staged fracturing in horizontal wells, the production of oil wells can be greatly improved, and finally the high-efficiency and low-cost development of reservoirs can be realized. In order to ensure the development of low permeability tight oil and gas resources to increase production, the following three suggestions are put forward :

Development of horizontal well drilling technology supporting research and tools to meet the actual needs of various types of horizontal wells, improve the rate of mineral drilling, accelerate the construction speed of horizontal wells, in order to promote China to catch up with the international advanced branch well drilling and completion technology as soon as possible, and ultimately improve single well production and economic benefits.

Water injection development is the most widely used method for the development of low-permeability tight reservoirs. At present, it is necessary to accelerate the advanced water injection development of horizontal wells and develop deep layered water injection string for horizontal wells.

At present, the widely used horizontal well staged fracturing technology at home and abroad mainly includes horizontal well drillable bridge plug, soluble bridge plug, expandable packer, open hole packer, double sealing single card staged fracturing, hydraulic sandblasting staged fracturing, limited flow staged fracturing and other technologies. Each technology has its specific advantages and corresponding applicability. Among them, the most widely used fracturing technology is open-hole packer staged fracturing. However, at present, the development of ultra-low permeability tight oil fields should focus on soluble bridge plug staged fracturing and hydraulic jet staged fracturing technology and supporting bridge plugs and jetting tools.

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