The Integration of Checking Seal and Testing Regulation of Bridge Concentric Layered Water Injection Technology Research and Application

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Abstract. Fine-layered water injection is the most economical and effective technical means to keep the formation of energy and improve water driving use in low permeability reservoirs. Changqing oil field adopts directional well and small water flow-rate development, and the problem of short duration of injection pipe column, low success rate of test, and low efficiency restrict the efficient development of low permeability reservoir. With the advancement of low permeability oil field water injection work, focusing on the demand of the oil field development efficiency, this paper puts forward the integration technology of bridge concentric layered water injection, which keeps the water distributor and adjustable water nozzle concentric integrated design, breaks through the original test, inspection seal traditional process step by step, innovative research and development of the second-generation bridge concentric layered water injection key tool, and forms on testing the integration process, with a process to finish each layer checking seal and testing and regulation, so it improves test mixing efficiency significantly by all the advantages. In Nanliang experimental zone water injection development, the field application of bridge concentric layered water injection technology is 65 wells and enlarges the

This paper was prepared for presentation at the 2018 International Field Exploration and Development Conference in Xi'an, China, 18–20 September, 2018.

J. Lin (ed.), *Proceedings of the International Field Exploration and Development Conference 2018*, Springer Series in Geomechanics and Geoengineering, https://doi.org/10.1007/978-981-13-7127-1_5

comprehensive application covering Changqing oil field in 2018. Meanwhile, the success rate of measured is 95%, and the average checking seal and testing time of single well are 4–6 h. Bridge concentric layered water injection technology for highly inclined wells significantly improves the success rate and efficiency of the injection well test, saving single well's operation time more than 30% and cost over 20%, and enhances water driving use degree by 10.7%. The successful application of this technology has enriched and improved the technology system of layered water injection technology, which has realized the upgrading of the fine-layered waterflooding technology and has a wide application prospect.

Keywords: Integration · Bridge concentric · Layered water injection · Efficiency

1 Introduction

Changqing oil field is a typical three low reservoirs, low permeability, low pressure, and low abundance, and requires energy supplement by water injection reservoir, but due to the interlayer contradiction from reservoir interlayer development and uneven water injection profile, layer water injection becomes the key method to improve production and ultimate recovery [1–3]. Combining with directional well and small water flow rate, in 2012, Changqing oil field developed bridge concentric layered water injection technology, adopting concentric structure design and cable-efficient testing method to improve the efficiency and precision of measuring success rate in high angle well [4–8]. Furthermore, this technology relieves the contradictions of the longitudinal water-drive reservoir section effectively and improves the effect of the fine water flooding development [9, 10]. As the separate injection wells increasing year by year, adjustable volume (14000 times) is larger, and the cost (200 million yuan nearly) is higher. In order to enhance the efficiency and quality of the separate injection, in 2015, Changqing oil field innovation has formed an integration technology of bridge concentric inspection testing, and packer sealing has developed the second-generation bridge concentric water distributor and the integrated instrument of testing and packer sealing as the key tools. The integrated technology realizes each job in a well including packer sealing, testing, and water flow rate controlling, so that it improves measuring adjustment efficiency, saves operating costs 3500 yuan per test, and helps bridge concentric separate injection technology updates.

2 Integrated Technology of Packer Sealing and Testing in Bridge Concentric Separate Injection

2.1 Pipe String Structure

Bridge concentric layered water injection string is shown in Fig. 1, mainly by the pipeline compensator, long-term packer, the second-generation bridge concentric water

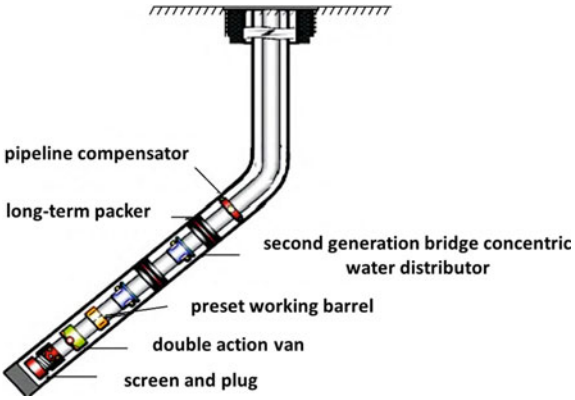

Fig. 1. Bridge concentric layered water injection string

distributor, preset working barrel, double action van, screen, and plug. The tubing compensator acts as a compensation for peristaltic deformation and protects the packer for a long time. Long-term packer designs non-metallic anchor institution and long plastic tube sealing mechanism, sets the packer centralizer structure to support string in the inclined well, uses non-metal anchor claw surface of vulcanization processing mode, to ensure that the string anchoring effect, and to avoid casing extrusion and wear, ascending anti-wearing effect, extending the string seal by long rubber tube with metal composite rubber material. Second-generation bridge concentric water distributor keep early integration of adjustable water nozzle concentric integration design, optimize concentric canister to bottom water nozzle structure, docking adjustment from the upper adjusting adjustment to lower adjustment to ensure that the high-angle well-stratified flow test deployment success rate, to improve the test efficiency at the same time.

2.2 Theory

Bridge concentric layered water injection technology uses long-term packer to separate each layer, uses compensator for separate injection tubing string expansion amount caused by the reservoir pressure fluctuation, and applies the second-generation bridge concentric water distributor for each layer water injection. In test process, the bridge concentric integration of packer seal checking and testing communicates with the ground controller and matches to the second-generation bridge concentric water distributor under test. Then, the inspection seal structure promotes test sealing glue tube setting and checks the packer seal. After that, the controlling structure adjusts water nozzle, changing the opening of nozzle and obtaining the right injected water volume adjustment. Data acquisition control system controller is connected with the ground, which can real-time online monitoring of packer test situation, flow rate, temperature, and pressure, achieve seal checking, testing and controlling in a trip, and meet the demand of geological injection allocation.

Technical characteristics

(1) High success rate of the measurement. With the concentric structure design of the water distributor, the integrated instrument is aligned with the water distributor to ensure the success rate of the measurement, and it can meet the needs of the high angle well and deep well-stratified water distribution.
(2) High measurement efficiency. Check seal structure and adjustable structure are integrated in one instrument, firstly check packer seal, then test regulating stratified flow, so one trip operation can complete the whole test of one well. And the testing results are shown on the ground controller directly in the visual operation, so the process increases efficiency of the fieldwork.
(3) High string series. With the water injection in central channel mode, the length of the water distributor is shortened, the series is not limited, and the difficulty of multi-level subdivision measurement is solved.
(4) Small interference between layers. Bridge concentric water distributor has a large area of overpass, which does not affect normal water flooding in other layers.

3 Key Tools

3.1 Long-Term Packer

Compared with common injection well packer, long-term packer is designed its anchoring mechanism, adopt hydraulic setting, pull the string up to unseal. The packer is mainly composed of upper joint, anchoring mechanism, unlocking mechanism, sealant plastic tube, protection plastic tube, backwashing well mechanism, setting mechanism, center pipe, and lower joint (shown as Fig. 2), which working pressure is 45 MPa, and working temperature is 120 °C.

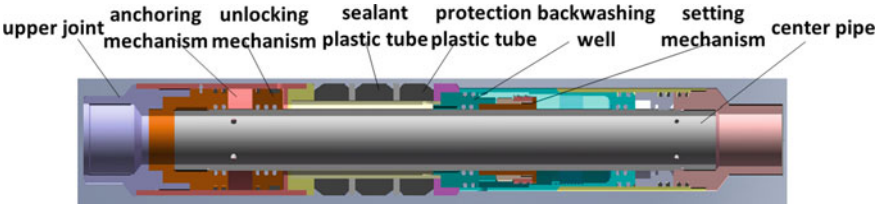

Fig. 2. Long-term packer

Technical features: It uses multiple sets of packer rubber tube; first, the protection rubber tube is composite metal rubber materials which can improve the compressive strength, wear-resisting properties of the rubber tube. Second, sealant tube uses new rubber polymer materials to ensure the rubber tube elasticity, improve the anti-aging performance of the rubber tube, increase the radial expansion volume, and improve the contact stress at the same time. The anchor mechanism is added, the metal anchor claw is designed, and the surface is treated with non-metallic material, so it guarantees the

anchoring effect of the pipe column and avoids the wear of casing surface. By improving the setting mechanism, the design of multi-stage push tube and balance pressure structure is realized, and the sealing effect is improved, which solves the problem of peristalsis and unsealing during pressure fluctuation.

3.2 Second-Generation Bridge Concentric Water Distributor

Second-generation bridge concentric water distributor is the key part of the integrated technology; it contains upper joint, positioning mechanism, outer protector, main body, adjustable nozzle, concentric movable tube, centralizing mechanism, and lower joint (shown as in Fig. 3).

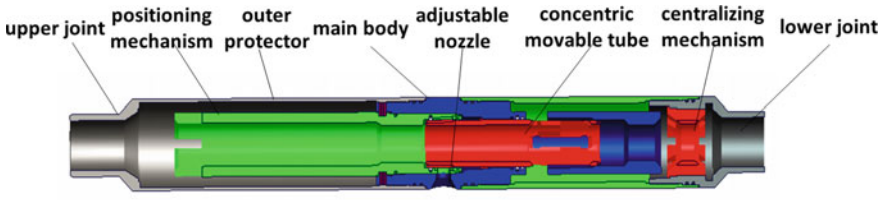

Fig. 3. Second-generation bridge concentric water distributor

Compared with first-generation bridge concentric water distributor, the second-generation bridge concentric water distributor retains the adjustable water nozzle and the water distributor integration design, water nozzle and the main structure are optimization to the central water distributor, and concentric movable tube becomes downward adjustment instead of the upward adjustment, meanwhile centralizer body synchronization design on the lower part of water distributor. In the completion process, the nozzle is in a fully closed position, meeting the requirement of packer setting and realizing the free throw for the whole job. At the time of the sealing, the integrated instrument and the water distributor are concentric positioning and docking, and the sealing rubber tubes of the sealing mechanism under the action of the motor are compressed and sealed to complete the packer inspection. When measuring and adjusting, the integrated instrument drives the concentric movable tube and the movable nozzle to turn up and down, so it can change the opening degree of the water nozzle and realize the adjustment of the water injection amount. Between main body and outer protector it designs greater bridge type of channel, when the integration takes up the center channel, part of the injected water flow from bridge type the path of circulation to the next level bridge concentric water distributor, in order to meet the needs of other interval stratified water distribution, minimize interference between the layers.

3.3 The Integrated Instrument of Packer Seal Checking and Flow Rate Adjusting

The integrated instrument is the other key part of the integrated technology, and it integrates two tools into one, concentric adjusting instrument and electric packer seal checker. Checking seal mechanism and adjusting mechanism are in clutch structure design, so it can implement a motor, respectively, complete sealing mechanism of the longitudinal compression action, and adjust claw rotation action. The instrument is mainly composed of cable joint, centralizing mechanism, flow meter, magnetic orientation, circuit device, motor, positioning mechanism, seal checking institution and regulate claw structure, and so on (Fig. 4).

Under the effect of the centralizer and the magnetic orientation, the bridge concentric inspection and adjustment integrated instrument realize to match to the second-generation bridge concentric water distributor. The upper and lower parts of the sealing mechanism are located in the upper and lower parts of the water distributor, the sealing machine is sealed through the motor, and the water injection system is changed through the ground control valve to complete the sealing work.

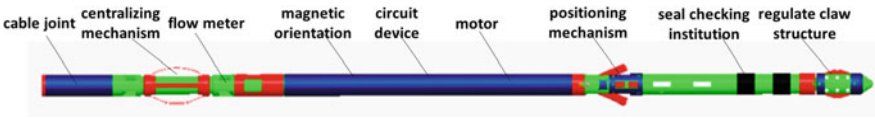

Fig. 4. Integrated instrument of packer seal checking and flow rate adjusting

In the test process, the anti-rotating claw is attached to the main positioning end of the positioning mechanism to prevent the device from turning. The adjustable jaw matches to the hole of the concentric movable tube to adjust the flow rate under the drive of the motor. The power transmission design of the integrated instrument is a concentric connecting rod mechanism with simple mechanical structure and high-power transmission efficiency. The integrated instrument can adjust the integration of the packer seal checking and the stratified flow test, and greatly improve the efficiency of the test.

4 Field Application

In low permeability reservoirs of Changqing oil field, the integrated technology of bridge concentric water injection applies 92 wells, testing success rate is 100%, measuring the success rate is 95%, measuring the qualification rate is 96%, and injection string is valid for more than 3 years. In 2018, the comprehensive promotion application, Changqing oil field is expected to promote more than 500 wells. In 2015–2017, 65 wells were tested in the large angle wells in Nanliang oil field, and the water flooding reserve in the pilot area increases by 10.7%.

Well S4-2 is an example in Nanliang oil field. The well is put into operation in general water injection in 2010, with four water injection layers. Due to poor reservoir

physical properties, strong heterogeneity, great difference in water absorption between layers, 13.8% of water absorption in the second layer, and no water absorption in the fourth layer, so the separate injection measures for the well were implemented to improve the longitudinal profile. Combined with the well deviation is larger (49.5° deviation) of the actual situation, in 2015, it was implemented the integration technology of bridge concentric water injection; four points on injection allocation of each layer is 10, 15, 10, and 10 m^3, respectively. First of all, after the injection pipe is placed into the design position, the long-term packer can be seated and anchored by a gradual pressure down to 15 MPa through the tubing. The cable carries the integrated instrument to open the water nozzle and complete the packer test. After passing the seal, according to the geological injection allocation quantity of four layers of water injection test, a trip to complete open nozzle, packer seal checking, and each layer flow test, measuring adjustment layers after all meet the requirements of geological injection allocation, measuring the time 4.6 h, the average measurement error within 5%. After stratified water injection, the water absorption thickness increased by 6.3 m, the water absorption profile was uniform, the water driving degree was improved, and the production effect of the oil well was greatly improved, as shown in Table 1.

Table 1. Well S4-2 injection data

Term	Water injection (m^3)				Absorption thickness /m	Average output ($t\ d^{-1}$)
	First	Second	Third	Fourth		
Before	19.86	6.21	16.25	2.31	8.50	1.65
After	10.21	14.88	10.55	9.49	14.8	2.12

5 Conclusion

(1) The integrated technology of packer seal checking and flow rate adjusting effectively solves the high-angle well layer injection problem, not only improves the success rate of the measurement and test efficiency and extends the validity of the separate injection string, but also helps bridge concentric layered water injection technology updates.

(2) The integrated technology of packer seal checking and flow rate adjusting in the Nanliang oil field scale applies 65 wells in directional well, implements a trip to finish all test well testing operation, saves the average check testing time from 6–8 h to 5 h, improves measuring the efficiency, and boosts quality and efficiency of separate injection technology.

(3) The success rate of the integrated technology of the bridge concentric and the qualified rate of the test are kept above 95%, which improve the water driving degree of the pilot area and the development effect of reservoir water flooding.

Acknowledgements. The authors wish to thank the management and personnel of Oil and Gas Technology Research Institute, Changqing Oil field Company for their support of this work. A special acknowledgement is made to Yu Jiuzheng and Ju Yafeng for collecting data and Trican technical and engineering staff for their contributions on the collection of field results.

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Author Biography

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