Research and Application of Cable Controlled Layered Water Injection Technology in Daqing Oilfield

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Abstract. Daqing Oilfield has entered the development stage of high water cut later stage, the contradiction between inter layers and interior layers is more prominent, the rate of water injection pass rate decreases rapidly, the manual test workload is huge, the existing test team can not meet the requirements; at the same time, the existing high-efficiency measurement and adjustment technology cannot provide Continuous monitoring data and real-time dynamic adjustment of downhole injection volume, for this purpose, Daqing Oilfield carried out research and research on cable-controlled intelligent layered water injection technology. The technology is mainly composed of two parts: underground cable-controlled intelligent water injection technology pipe column and ground wireless remote control system. It can realize real-time monitoring and control of underground stratified flow and pressure in the office, realize online inspection, automatic measurement and adjustment, and report output. With the function, 30 wells were tested in the field and achieved good results. This technology is a continuous, efficient and real-time new generation water injection technology.

Key words: Cable controlled water injection, layered water injection, cable controlled water distributor, packer.

1. Introduction
The layered water injection technology is an effective technical means for controlling the water-bearing rising speed and improving oil recovery in the heterogeneous multi-layer sandstone oilfield. At present, Daqing Oilfield has entered the late stage of high water cut, the contradiction is more prominent, the qualified rate of water injection decreases rapidly, the test workload is large, and the existing team cannot meet the requirements; conventional technology cannot provide continuous monitoring data. To is end Daqing Oilfield has carried out the research of cable-controlled stratified water injection technology. The technology is to put the monitoring, communication and automatic control systems into the underground cable-controlled water distributor. The layered water injection realizes the ground real-time control through the cable, which greatly reduces the number. Manually test the workload so that the water injection pass rate is maintained at over 90% for a long time [1-5].

2. Cable control layered water injection technology
The cable-controlled layered water injection technology is mainly composed of two parts (Fig. 1): the underground cable-controlled intelligent water injection technology pipe column and the ground
wireless remote control system. The underground cable-controlled intelligent water injection process pipe string is composed of cable-controlled intelligent water distributor, cable through packer, communication cable, cable connector, cable protector and other tools. The ground wireless remote control system consists of office terminal, oil network, and wellhead ground. Control system and other components.

Technical principle: This technology uses a 3.5mm cable to connect the downhole cable-controlled intelligent water distributor, cable traversing cable packer and cable connector to the wellhead ground control system. The technicians use the office terminal to issue commands and send them to the oil network. The ground control system, the cable power supply transmits signals through the carrier technology, controls the underground cable control water distribution device to realize the real-time continuous monitoring and monitoring of the flow and pressure of the injection well interval, and the remote online regulation of the injection quantity, and can realize on-line verification, static pressure test, Water absorption indicator curve drawing and other functions.

Figure 1. Schematic diagram of cable-controlled layered water injection technology

2.1. Cable Control Intelligent Water Distribution Device
The overall structure of the cable-controlled intelligent water distributor adopts the split design (Fig. 2). The flow control valve, flow meter and pressure gauge are respectively assembled on the main body to form the functional component part of the water distribution device, which can realize the real-time collection and opening of the downhole flow pressure data. Degree adjustment; the control system is mainly composed of a series of modular design control circuits, which are mainly responsible for communicating with the ground control box and transmitting control signals to various functional components. The center channel of the water distributor is 46mm, which meets the requirements of conventional magnetic positioning, flow test, and water absorption profile test.

During normal operation, the pressure gauge and flow meter transmit the measured single-layer injection pressure and injection amount data to the control module, which is directly uploaded to the ground control system by the control module, and then transmitted to the office through the wireless network. The technician can compare the single layer. The dispensing quantity adjusts the flow control valve. In the cable control water distribution device, the fluid enters the flowmeter from the filter net, flows through the U-shaped channel of the main body, is controlled by the flow control valve and enters the formation, and realizes the axial movement of the valve core. Single layer flow control.
2.2. Cable crossing packer

Cable traversing packer is another core tool of this technology (Fig. 3). It mainly consists of upper and lower joints, cable sealing components, cable tunnels, rubber cylinders and setting. It is innovatively designed on the basis of conventional washable packers. The cable crosses the channel, and the control cable can be directly sealed from the packer after the on-site construction, which effectively solves the problem of interlayer cable crossing and ensures the construction is efficient and convenient. At the same time, the packer innovatively designs the low force deblocking. The balance mechanism and the dewatering load of the pipe column above 6 layers are less than 30 tons, which meets the needs of the current oilfield fine water injection development.

![Figure 3. Schematic diagram of cable traversing packer structure](image3)

1—sealing assembly; 2—wash device; 3—sitting mechanism; 4—cable crossing channel

2.3. Terrestrial wireless remote control system

The ground remote control system is the management terminal in the cable-controlled layered water injection technology (Fig. 4). Combined with the oilfield's own conditions and information security requirements, the existing production wireless network is selected as the data transmission channel, and the server is placed in the production network zone. The site installs a wireless communication module for the intelligent water injection well. The ground control system connects to through this device, and transmits the underground layered data to the server. The user accesses the server through the white-list of the firewall to realize the remote measurement and data query of the injection well.

![Figure 4. Structure of the ground remote control system](image4)

2. Indoor experiment

The cable-controlled intelligent water distributor is put into the standard experimental well, and the key parameters such as the overall sealing performance, flow measurement accuracy, and flow control valve switching smoothness are systematically tested.
The injection pressure of the experimental well is raised to 35 MPa, and after 2 hours of voltage regulation, the communication cable is connected with the ground control system, and the parameters such as downhole pressure, temperature and power supply in formation can be read; the injection amount of the test system is controlled from 5 m$^3$/d to 50 m$^3$/d. Change, the feedback current value is normal during the adjustment process, the switch is smooth, the measured flow rate of the cable control water distribution device is shown in Table 1. Compared with the laboratory calibration value, the measurement error is within the range of ±3%FS, which meets the design requirements. Laboratory experiments show that the cable-controlled water distribution device has good sealing performance and the test accuracy meets the requirements of on-site construction.

| Number | Water distributor flow (m$^3$/d) | Standard flow (m$^3$/d) | Deviation (m$^3$/d) | Full scale error (%) |
|--------|----------------------------------|------------------------|---------------------|---------------------|
| 1      | 4.9                              | 5.05                   | 0.15                | 0.15                |
| 2      | 9.7                              | 10.15                  | 0.45                | 0.45                |
| 3      | 14.85                            | 15.12                  | 0.27                | 0.27                |
| 4      | 19.76                            | 21.15                  | 1.39                | 1.39                |
| 5      | 25.35                            | 25.51                  | 0.16                | 0.16                |
| 6      | 29.58                            | 29.83                  | 0.25                | 0.25                |
| 7      | 35.12                            | 35.36                  | 0.24                | 0.24                |
| 8      | 40.71                            | 40.93                  | 0.22                | 0.22                |
| 9      | 44.65                            | 44.39                  | -0.26               | -0.26               |
| 10     | 51.23                            | 51.55                  | 0.32                | 0.32                |

### 4. Field application and effect

#### 4.1. Completion online inspection and flow distribution

Taking the x well as an example, after the underground cable-in-line intelligent layered water injection and completion technology pipe string, the online sealing and measuring and adjusting work is carried out. The pressure curve (Fig. 5) shows that the cable passes through the packer and the sealing state is well. Meet the dispensing requirements (Table 2).

By measuring the change of the water absorption profile of the x well (Fig. 6), the water absorption profile was improved after the intelligent injection, the striking layer was controlled, the thickness ratio of the sandstone was increased from 50.7% to 77.5%, the daily output of the four connected oil wells was decreased by 27t, and the water content decreased by 0.17 percentage points. The oil production is unchanged.

| layer | Injection volume (m$^3$/d) | Pre-adjustment injection (m$^3$/d) | Adjusted injection volume (m$^3$/d) |
|-------|---------------------------|-----------------------------------|------------------------------------|
| X1    | 20                        | 18                                | 21                                 |
| X2    | 20                        | 13                                | 20                                 |
| X3    | 10                        | 4.8                               | 10.5                               |
| X4    | 20                        | 22                                | 20                                 |
| X5    | 10                        | 8.5                               | 10.5                               |
| X6    | 20                        | 5.3                               | 20.3                               |
| X7    | 20                        | 31                                | 21                                 |
| total | 120                       | 102.6                             | 123.3                              |
4.2. Remote online monitoring
Taking the x-hole I layer as an example, through the remote monitoring function, the cumulative injection volume and injection pressure in the required time period after the completion of the production are obtained, and the real-time adjustment can be made. The collection and deployment results are transmitted to the office terminal equipment for deepening. Understand the dispensing situation and optimize the water injection parameters to provide online services (Fig. 7).

4.3. Overall application
Daqing Oilfield cable-controlled layered water injection technology realizes real-time monitoring and control of underground stratified flow and pressure. It has functions such as online seal inspection, automatic measurement and adjustment, and report output. It has 30 wells in field test and the longest running time is 4 years. The number of layers is 7 layers. The average single well measurement time of 7 wells is less than 1 hour. The test well test rate is increased by 13%, the test pass rate is increased by 3.2%, and the qualified rate of water injection in the restricted layer is over 90%. The successful application of technology provides powerful technical support for the efficient and effective development of oil fields.

5. Conclusion
1. Cable control layered water injection technology test and adjustment without manual participation, can effectively reduce the test workload, improve the efficiency of measurement and adjustment and the rate of water injection.
2. Cable-controlled layered water injection technology can realize real-time monitoring and continuous adjustment of single-layer flow and pressure in underground, and stratified pressure data can further optimize the adjustment scheme of water injection wells, and provide data acquisition means for fine geology analysis of blocks, which can effectively improve Oilfield development results.

3. Cable-controlled layered water injection technology as a new generation of intelligent dispensing technology will provide key support for the construction of digital oil fields.

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