Injection-production Process Technology for High Water-cut Oilfields

Science & Technology Management Department

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CHINA NATIONAL PETROLEUM CORPORATION

China National Petroleum Corporation ,
the oil production expert in high water-cut oilfields!

Contents

China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. As an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integration of upstream and downstream operations, internal and external trade and production and marketing. CNPC has 17 upstream companies, 33 downstream companies and 36 large-scale marketing companies. It is China's largest producer and supplier of oil and gas, and also one of the largest refined oil products and petrochemicals. In 2010 CNPC produced 105 million tons of crude oil and 72.5 billion cubic meters of natural gas, while crude processing volume reached 135 million tons. The total revenue of RMB1, 720 billion with a profit of RMB172.7 billion had been achieved the same year. Its profit is among the highest of the domestic enterprises in China.

CNPC was ranked 10rd in Fortune Global 500 in 2010 and 5th among global top 50 oil companies.

CNPC strictly follows by the combined strategies of increasing resource capacity, expanding market shares and consolidating the international role, and persists in regarding technical innovation as a key framework to advance technological progress. To develop its core businesses, focuses will be placed on the solutions of key bottleneck technologies and key proprietary technologies. Thanks to continuously improving of the technical innovation system, optimizing the configuration of technological resources and strengthening the construction of strong talent teams, CNPC's technological creativity has been considerably upgraded. Consequently, a large number of technologies have been developed independently, with its own intellectual property.

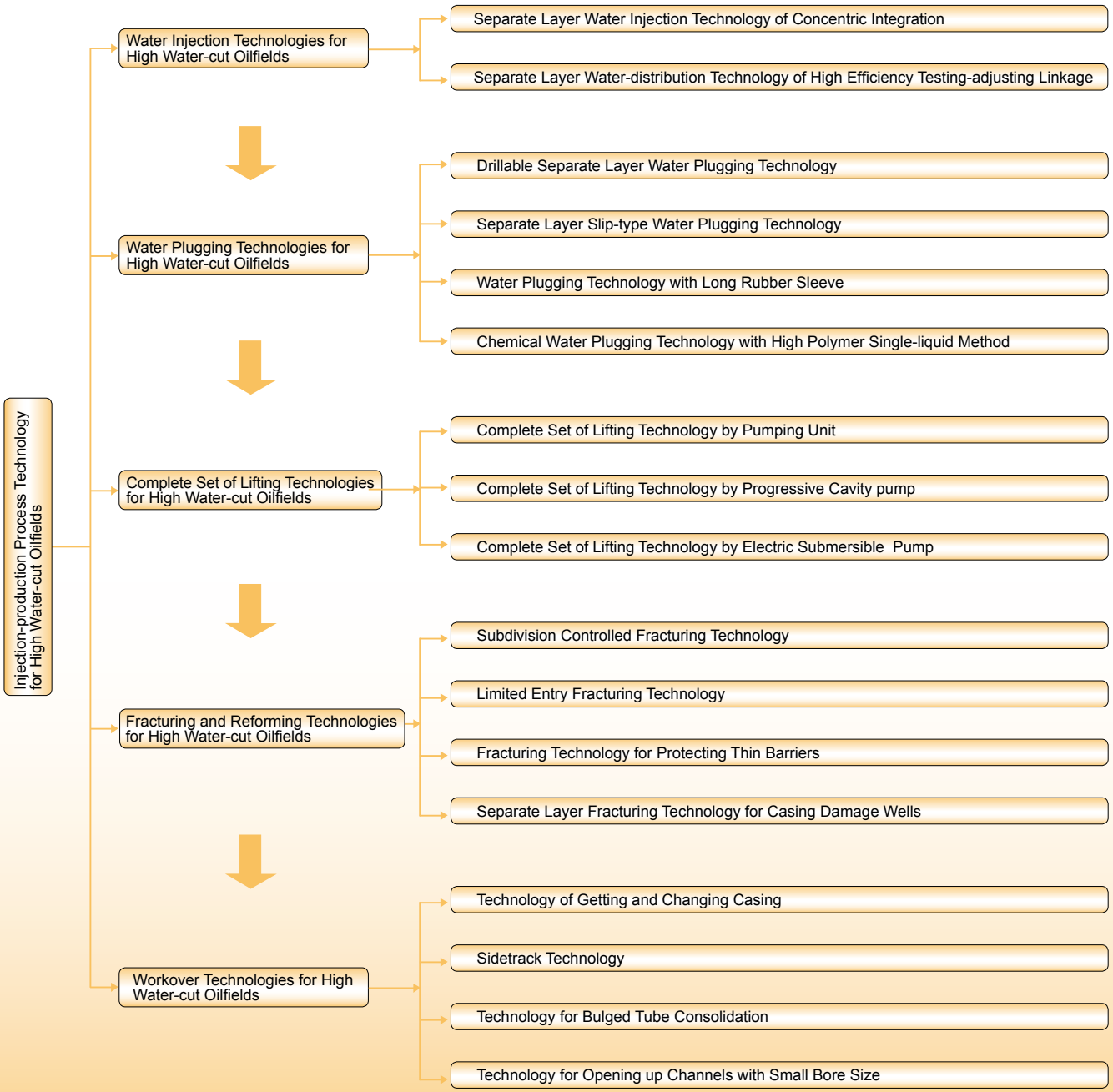
The Injection-production Process Technology for High Water-cut Oilfields is one of representatives for major innovations of CNPC.

CLEAN ENERGY SUPPLY FOR BETTER ENVIRONMENT

1 INTRODUCTION

CNPC has dedicated itself to exploration and practice of separate layer production technology for oilfields for a long time, in view of the reservoir feature of anisotropic and multiple zone, and water-cut status of the oilfield at different development stages, formed a full set of technologies (e.g. separate layer water injection, separate layer water plugging, lifting process, fracturing reformation, and workover)— 5 major technologies and 17 individual technologies suitable for high water-cut oilfields. The Injection-production Process Technology at the high water-cut stage has been applied increasingly and widely at home and abroad, making an important contribution to the high and stable production and EOR of oilfields.

CNPC, equipped with many technical talents in the injection-production filed, the corresponding injection-production process equipment and the professional service teams, is able to provide all technical services corresponding to the injection-production process.


Injection-production Process Technology for High Water-cut Oilfields
Water Injection Technologies for High Water-cut Oilfields
Separate Layer Water Injection Technology of Concentric Integration
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Water Plugging Technologies for High Water-cut Oilfields
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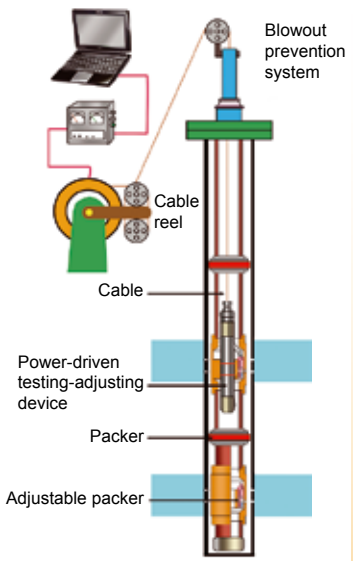
Workover Technologies for High Water-cut Oilfields
Technology of Getting and Changing Casing
Sidetrack Technology
Technology for Bulged Tube Consolidation
Technology for Opening up Channels with Small Bore Size

2 UNIQUE TECHNOLOGIES

2.1 Separate Layer Water Injection Technologies for High Water-cut Oilfields

The Separate Layer Water Injection Technologies for High Water-cut Oilfields can solve such problems as the poor subdivision degree of injectors, short life of pipe string, low testing and adjusting efficiency, predominant interlayer contradiction at the late oil recovery stage of high water-cut, which restricts the water-flooding development. As per different oil layer conditions, Separate Layer Water Injection Technology of Concentric Integration and Separate Layer Water-distribution Technology of High-efficiency Testing-adjusting Linkage are conducted to realize the real-time allocation and to control the water injection rate to each interval effectively.

(1) The 2m packer interspacing for Separate Layer Water Injection Technology of Concentric Integration is suitable for the subdivided water injection of 4 intervals. The separate layer injection rate and separate layer pressure can be tested simultaneously, with high efficiency.



Separate Layer Water Injection Technology of Direct-reading Testing-adjusting Linkage

(2) The bridge-type channel design is used for the pipe string for the Separate Layer Water-distribution Technology of High-efficiency Testing-adjusting Linkage to remove the testing interlayer interference. The individual layer flow rate and pressure, etc. can be measured accurately during production. The Mechanical and Electrical Integration Technology is used to realize the continuously adjustable separate layer injection rate and the surface real-time direct-reading of the oil layer pressure, injection rate and data. The testing-adjusting efficiency is high.

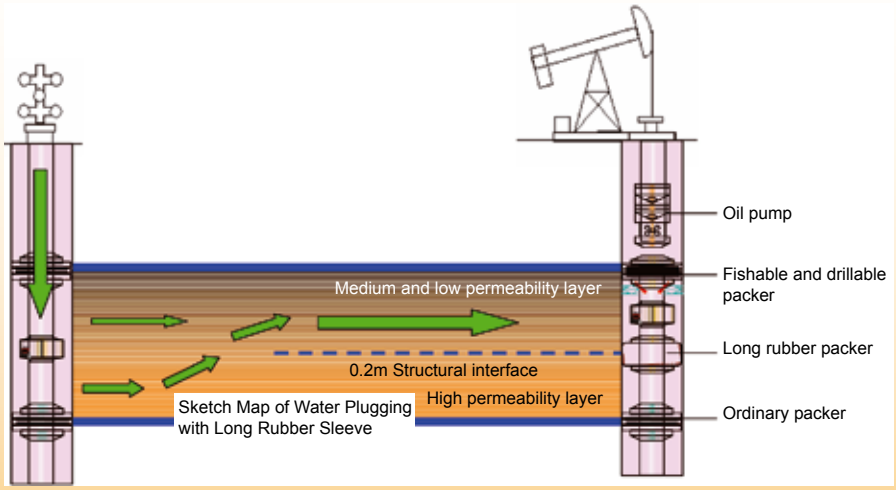
2.2 Water Plugging Technologies for High Water-cut Oilfields

The Water Plugging Technologies for High Water-cut Oilfields includes Drillable Separate Layer Water Plugging Technology, Separate Layer Slip-type Water Plugging Technology and Water Plugging Technology with Long Rubber Sleeve, and satisfies the requirements of different oil production manners and casing systems. Meanwhile, in view of the wells where the mechanical water plugging cannot be applied due to the limitation of geology and wellbore conditions, our researchers study the application of Chemical Water Plugging Technology with high polymer single-liquid method.

Drillable Packer

(1) For the Drillable Separate Layer Water Plugging Technology, the bearing pressure and temperature resisting performance is high, the working differential pressure is 100MPa and the working temperature is 160 ℃ . Packers are thrown and carried with the pipe string, able to be used at any multi-stage. The technology has been applied in more than 1,000 wells in 8 domestic oilfields, with the success rate of one-time downhole operation exceeding 98% during the field application of various pipe strings and downhole tools.

(2) For the Separate Layer Slip-type Water Plugging Technology, the bearing pressure of pipe string is 25MPa, the resisting temperature is 120 ℃ and the service life is 3~5 years. Meanwhile, the water plugging string and the production string are separated, and the pumping and pump inspection do not affect the water plugging string. The technology is suitable for the multi-layer water plugging of wells equipped with large and electrical pumps.



Sketch Map of Water Plugging with Long Rubber Sleeve

(3) For the Water Plugging Technology with Long Rubber Sleeve, the bearing pressure of string is 25MPa and the resisting temperature is 120 . Moreover, the perforation tunnels can be plugged and the in-layer plugging can be realized. The technology is suitable for the in-layer water plugging of the thick oil layers that have the structural interface and the invalid injection-production circulation.

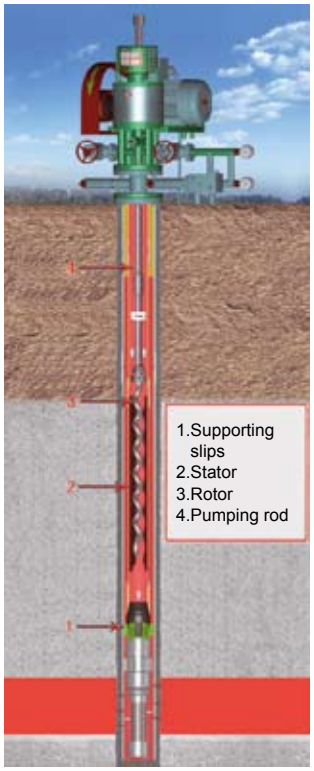
(4) The Chemical Water Plugging Technology with high polymer single-liquid method can be used to the comprehensive management of difficult wells, such as plugging of high water-cut layer in conventional producers and injectors, plugging of layer system, and plugging of channeling wells. The technology has been applied in 6 domestic oilfields and over 300 wells, with the term of validity more than 3 years and the success rate over 98%. The technology has been applied to the oilfields in Kazakhstan.

2.3 Lifting Technologies for High Water-cut Oilfields

The Lifting Technologies for High Water-cut Oilfields includes a complete set of technologies involving the pumping unit, submersible electric centrifugal pump and progressive cavity pump, etc. The products have adopted a complete series of

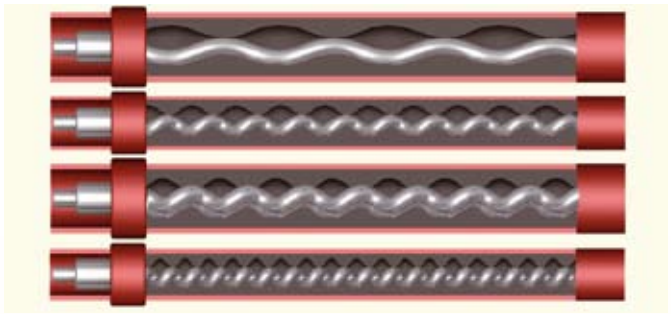
Sketch Map of Oil Production System for Pumping Unit—Plunger Displacement Pump

Pump plunger with low friction drag



Sketch Map of Oil Production System with Progressive Cavity Pump

Behavior diagnosis site



Stator and rotor of progressive cavity pump

process technologies, which, with the long pump inspection period, high systematic efficiency and strong adaptability, are able to satisfy the lifting need of producers with different liquid production, production rate, well depth, and structure.

(1) The Complete Set of Lifting Technology for High Water-cut Oilfields includes 13 kinds of pumping units, such as beam pumping unit, involute pumping unit, dual-horse head pumping unit, and low-stroke pumping unit, encompassing 13 relevant patents. A series of developed energy-saving pumping units, such as the low-stroke pumping unit, is the important means for energy-saving and consumption-reduction in oilfields.

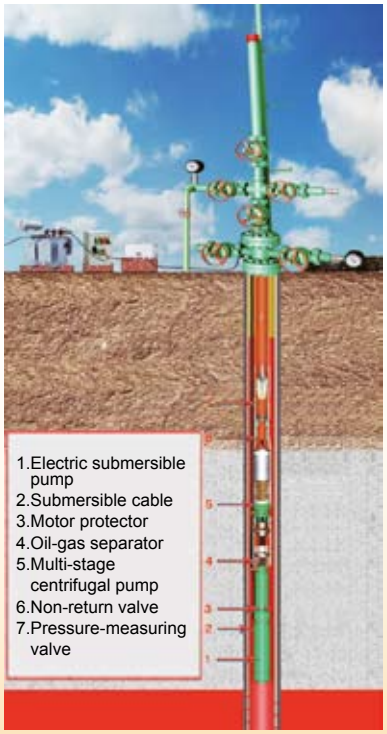
(2) The Complete Set of Lifting Technology by Progressive Cavity Pump can adapt to the progressive cavity pumps with large, medium and small discharges which are used in the oilfield water-flooding lifting. Meanwhile, the matching technologies can be provided, which covers the conventional progressive cavity pump, hollow rotor progressive cavity pump for clean-up, anti-leakage driving device, special pumping rod, eccentric testing progressive cavity pump, intelligent surface

control system, and testing and diagnosis system, etc.

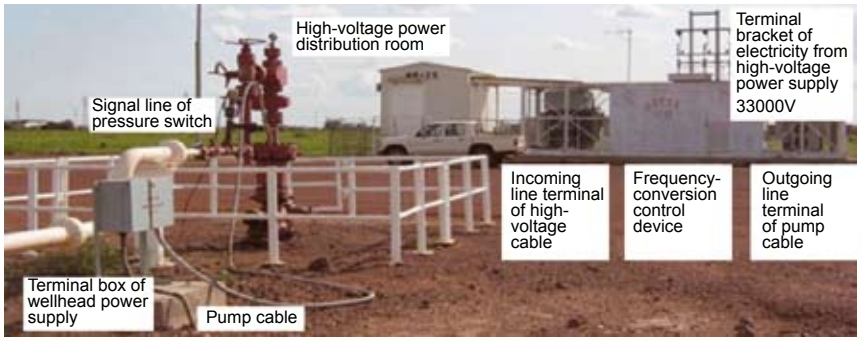
(3) The Complete Set of Lifting Technology by Electric Submersible Pump includes 4 practical series of technologies involving the conventional electric submersible pump assembly, electric submersible pump assembly that adapt to specific well conditions, energy-saving electric submersible pump assembly, and electric ground control. At 50Hz, the discharge range is 20-4,700m^3/d, the maximum discharge head is 3,500m, and the adaptable well temperature is 90-180℃ .

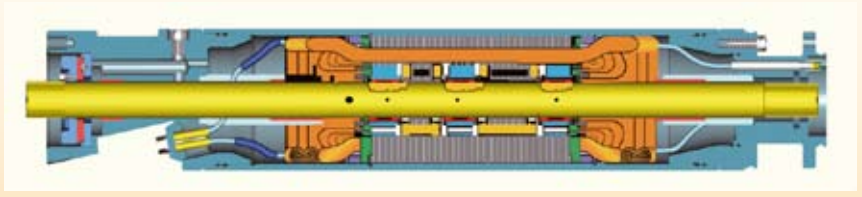
2.4 Fracturing and Reforming Technologies for High Water-cut Oilfields

In view of different geological conditions, the Complete Set of Fracturing and Reforming Technologies, such as Subdivision Controlled Fracturing, Limited Entry Fracturing, Fracturing Technology for Protecting Thin Barriers, Separate Layer Fracturing Technology for Casing Damage Wells, which provide the effective means for tapping the remaining oil potential of high water-cut oilfields.



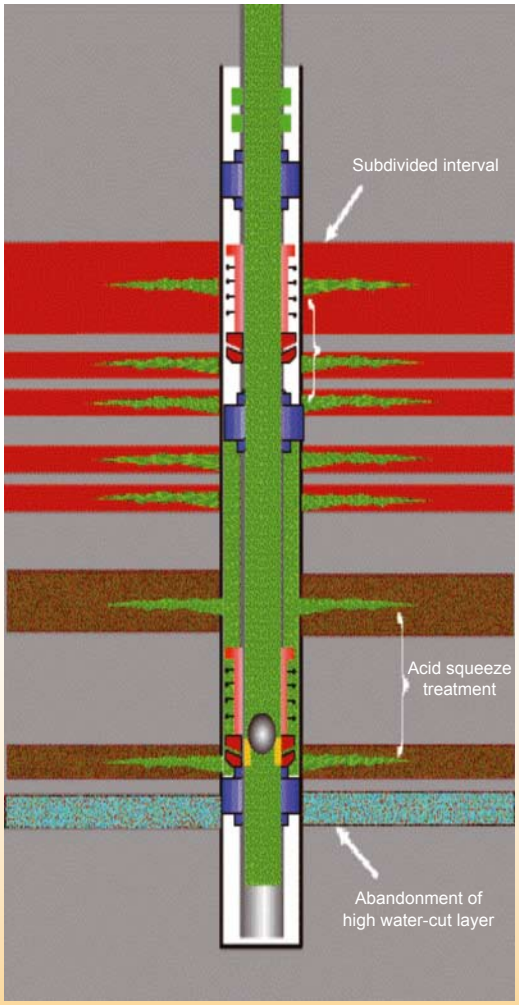
Sketch Map of Oil Production System with Electric Submersible Centrifugal Pump





Permanent-magnet oil submersible motor

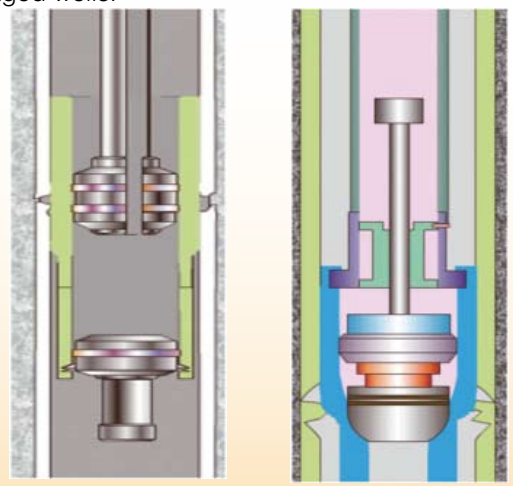
For the Subdivision Controlled Fracturing Technology, on the basis of the fine geological study, the effective fracturing rate of sublayer is above 90% through the fine layer selection, reasonable division of fractured intervals, optimized perforation, reasonable determination of discharge capacity from single well. In addition, the minimum barrier thickness is 0.4m.



2.5 Workover Technologies for High Water-cut Oilfields

All high water-cut oilfields face the problem of casing damages of production and injection wells. CNPC has formed the Workover Technologies, i.e. Technology of Getting and Changing Casing, Sidetrack Technology, Technology for Bulged Tube Consolidation, Technology for Opening up Channels with Small Bore Size, which satisfy the demand of oilfield development for the capital repair of production and injection wells.

Technology for Bulged Tube Consolidation is the technology applying patch and consolidation to the damaged part of the casing in view of the casing damage situations (e.g. casing corrosion, failure and leap), through plastic treatment and with the consideration of the plastic deformation property of metal materials, thus increasing the repair rate of damaged wells.



From bottom to top From top to bottom

Swelling Manner of Bulged Tube

3 TYPICAL CASES

3.1 Application of Separate Layer Water Injection Technology for High Water-cut Oilfields

Separate Layer Water Injection Technology of Concentric Integration, with the features like high testing accuracy and high success rate, has been popularized and applied in more than 450 wells of 11 Chinese oilfields, with 2,000 layers having undergone the sealing pressure measurement and 4,000 layers the flow rate allocation.

Separate Layer Water-distribution Technology of High-efficiency Testing-adjusting Linkage has been applied in more than 4,000 wells of 7 Chinese oilfields and Kazakhstan oilfields, the testing-adjusting efficiency increases by over 3 times as compared with the conventional testing-adjusting process.

3.2 Application of Lifting Technologies for High Water-cut Oilfields

Besides satisfying the demand from all domestic oilfields, the Lifting Technology by Electric Submersible Pump has been marketed to America, Peru, Sudan, Indonesia, Oman, Kazakhstan and Russia.

In Sudan, the Sand Control and Frequency Conversion Application Technology for electric submersible pump has been applied as defined below: the comprehensive sand control technology is employed for the electric submersible pump; the hard alloy is used as the friction pairs for the radial centralization; the bulk compaction pump is adopted to remove the axial abrasive wear; the high bearing thrust protector is suitably used to enhance the resisting sand ability of the pumping unit. The technology has been applied in 285 wells, with nearly 50% market share, and the average pump inspection period is up to about 600 days.

In view of the locally serious CO_2-corrosion problem, the application technologies for anti-corrosion of electric submersible pump and direction well have been applied in Indonesia offshore oilfields, the material for the electric pumping unit's components that contact the well liquid are replaced by the anti-corrosion material, and the bulk Monel flame spraying is adopted to remove the corrosion of the pumping unit. The treated electric pumping unit operates reliably, reaching a level equal to that of the similar foreign products applied in this area.

Besides satisfying the demand from all domestic oilfields, the Lifting Technology by Pumping Unit has entered the world market successfully, exported in batches to 14 countries and regions, such as America, Canada, England, France, Kazakhstan and Africa.

4 R&D EQUIPMENT

To satisfy the development of high water-cut oilfields, CNPC improves the scientific research conditions continuously. The laboratory is fully armed with the equipment for simulation, detection, etc.

Comprehensive simulation test system for downhole tools: It is used to simulate the field conditions and conduct the tests of drill, mill and polish of downhole tools with different specifications and model numbers as well as the tests of hydraulic power, machinery, rotary setting, unsetting for packers, etc.

Simulation test system for subdivision recovery: It is used for the simulation test of the strings for the separate layer water injection process, the online calibration test of downhole flowmeter as well as the tests of setting, bearing pressure, backwash, unsetting for downhole tools, etc.

Detection system for plunger displacement pump: It can implement the conventional performance and characteristic tests for oil pumps, test and calculate the suspension point loading, discharge rate coefficient, effective power and pump efficiency for plunger displacement pump.

Detection system for submersible electric centrifugal pump: can finish the corresponding tests required by GB/T 16750.3-1997, that is, zero load, overspeed, rotor-blocking, temperature rise, the performance of electric submersible pump, and so on.

Type test stand for electric submersible pump: It is used for the new product design, product process alteration as well as tests of zero load, loading, temperature rise of submersible motor, with complete testing items and high testing accuracy.

Detection system for hydraulic performance of progressive cavity pump: can simulate the actual behavior of well with progressive cavity pump and implement hydraulic performance detection for progressive cavity pump.

Experimental system for fracturing: It is used for tests, such as the measurement of rock mechanics parameters, conventional performance evaluation of fracturing liquid and thickening agent, high temperature (⩽ 200℃) performance evaluation of fracturing liquid and thickening agent, screening and flow conductivity of proppant, and so on.

5 QUALIFICATION AND STANDARD

CNPC owns the perfect qualifications in the field of high water-cut oilfield development.

5.1 Qualification

In 1996, it obtained the Certificate of ISO9001 Quality Management System.

In 2001, it passed the API certification from American Petroleum Society.

In 2003, it passed the certification of HSE System.

In 2003, it obtained the Certificate of Quality Management System from Great Wall (Tianjin) Quality Assurance Center.

In 2009, it obtained the Production License of National Industrial Product.

In 2009, it obtained the Laboratory Accreditation Certificate of China National Accreditation Service for Conformity Assessment.

In 2009, it obtained the National Metrology Authentication Certificate and Vesting Instrument.

5.2 Standard

No.	Standard name	Standard No.
1	Deformation beam pumping unit	Q/CNPC-DQ1485-2003
2	Special-shaped beam pumping unit	Q/CNPC-DQ1481-2003
3	Low stroke pumping unit	Q/CNPC-DQ1583-2006
4	Friction reversion pumping unit	Q/CNPC-DQ1232-1999
5	Pumping unit with involute head sheave	Q/CNPC-DQ1480-2003
6	Installation of electric submersible pumping unit	GB/T 17388-1998
7	Electric submersible pumping unit	GB/T 16750-2008
8	Recommended practice for use and inspection of electric submersible pump protector	SY/T 6598-2004
9	Operation, maintenance and troubleshooting of electric submersible pumping unit	GB/T 17387-1998
10	Well selection principle and pump selection design method for electric submersible pump	SY/T 5904-2004
11	Specification and selection of electric submersible pumping unit	GB/T 17386-1998
12	Recommended practice for electric submersible pump and centrifugal pump	SY/T 6599-2004

6 EXPERT TEAM

Liu He: (Chief engineer, oil production expert)

He has been engaged in the injection-production technology research and field application of high water-cut oilfields for a long time. He has undertaken and finished many new practical process and technological research projects, such as the Injection-production Process. He has published more than 20 research papers and obtained 10 patents.

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Lan Zhongxiao: (Chief engineer, oil production expert)

He has been engaged in the technical research and field application of workover, exploration, development, stimulation and reformation for a long time. He has organized and undertaken many new process and technological research projects, such as workover, fracturing. Moreover, he has published more than 20 research papers and obtained 21 patents.

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Yang Ye: (Professor-level senior engineer, oil production expert)

He has been engaged in the research and new technology deployment of the injection-production technology in oil production engineering for a long time. He has undertaken, organized and finished more than 20 key difficult research and promotion projects in the oil production process technology. He has published more than 20 research papers.

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Zhou Wanfu: (Chief engineer, oil production expert)

He has been engaged in the research and field application of injection-production technology for high water-cut oilfields for a long time. He has undertaken and participated in more than 20 key difficult research and promotion projects in the oil production process technology, and has published more than 10 research papers.

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Wang Yan: (Chief engineer, oil production expert)

He has been engaged in the scientific research and technical management in oil production engineering specialty for a long time. He has taken charge of many key difficult scientific research projects, published more than 20 research papers and obtained 9 patents.

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Zheng Xuefeng: (Senior engineer, mechanical engineering expert)

He has been engaged in the development and design of pumping units for a long time. He has undertaken and fulfilled many developments in pumping units. He has developed and designed many API-standard pumping units with different structures and types. Besides, he has published more than 10 research papers.

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Yang Yuanjian: (Senior engineer, oil production engineering expert)

He has been engaged in the development and design of electric submersible pumping unit for a long time. He has undertaken and fulfilled many research projects related to the Electric Submersible Pumping Unit Technology. In addition, he has published 8 research papers and obtained 4 patents.

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