CQMPD-1 Precise Managed Pressure Drilling (MPD) System

Science & Technology Management Department, CNPC

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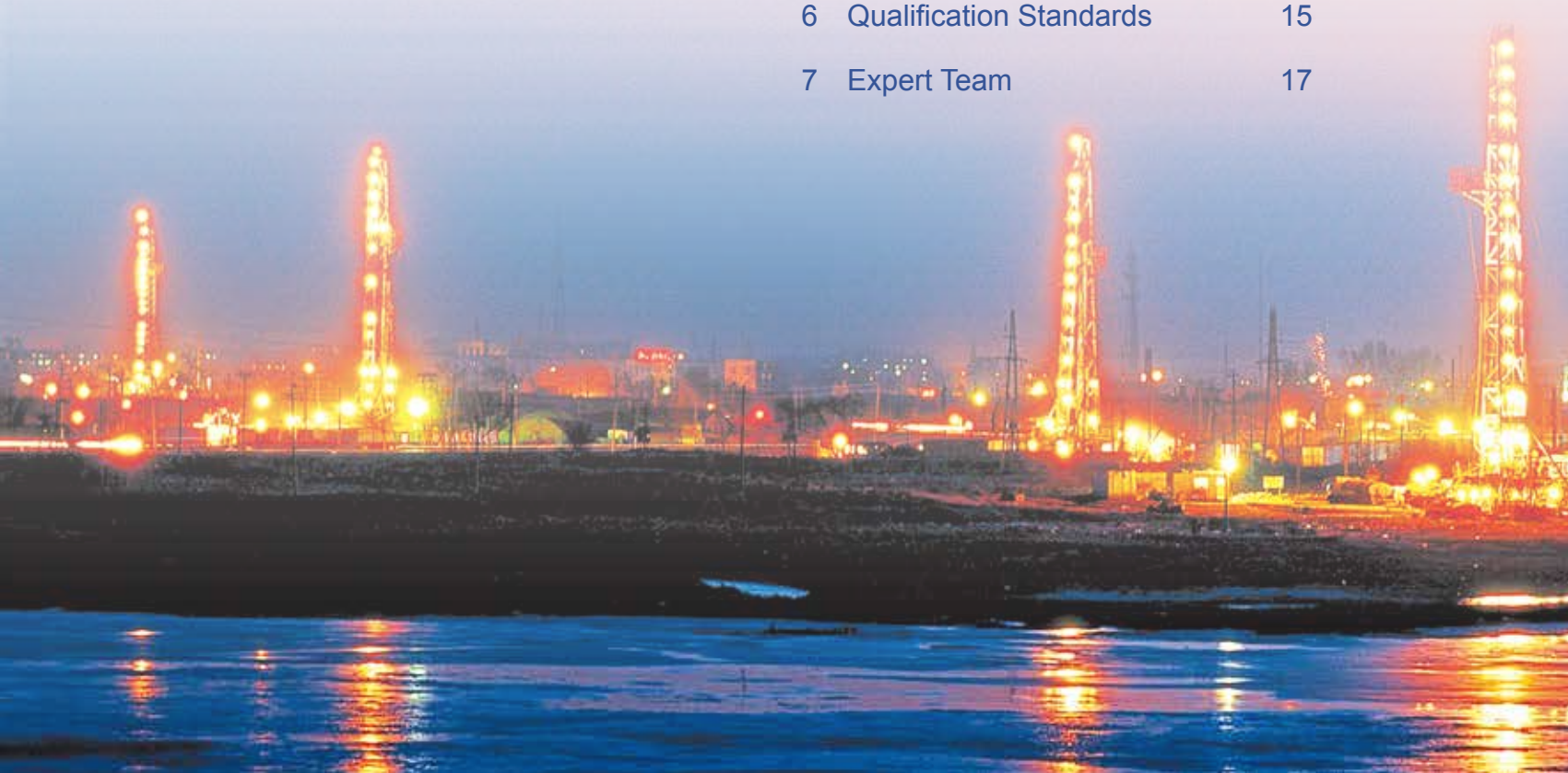
CHINA NATIONAL PETROLEUM CORPORATION

CQMPD-1: A Powerful Tool for Safety Drilling in Complex Formations of Deep Wells!

Contents



China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. On July 1998, with the implementation of the Institutional reform of the State Council, CNPC was reorgnized to become an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integrations of upstream and downstream operations, internal and external trade, production and marketing. CNPC's business covers six main sectors: oil and gas operations, petroleum engineering service, petroleum engineering construction, petroleum equipment manufacturing, financial services and new energy development. In 2014 CNPC produced 113.67 million tons of crude oil and 95.46 billion cubic meters of natural gas, while crude processing volume reached 150.2 million tons. The total revenue of RMB 2,730 billion with a profit of RMB173.4 billion had been achieved the same year.

CNPC was ranked 3th among the world's largest 50 oil companies and 4th in Fortune Global 500 in 2014.

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.

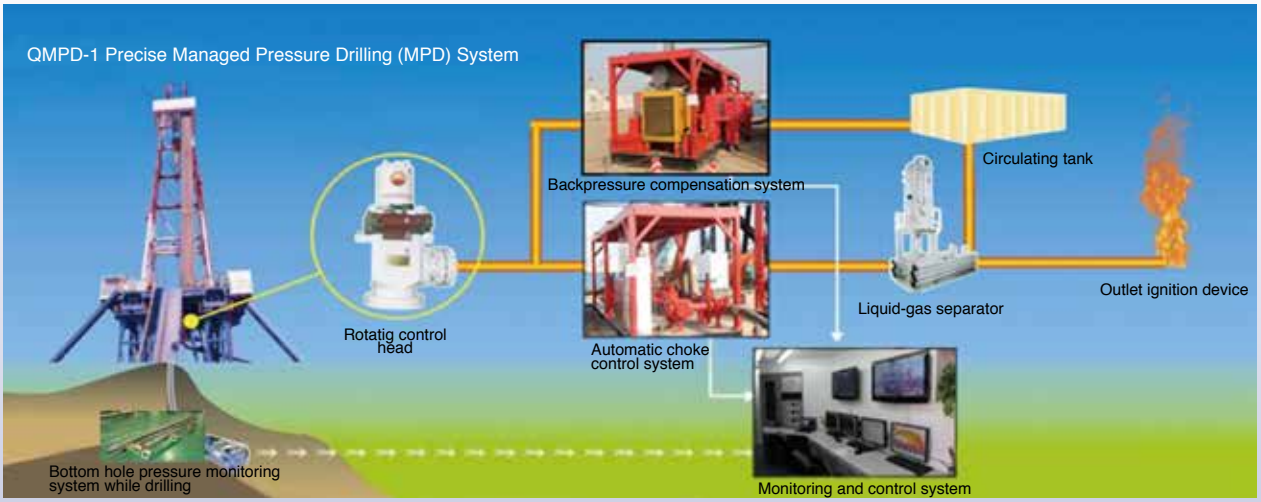
The CQMPD-1 precise managed pressure drilling (MPD) system is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

1 INTRODUCTION

With gradual depletion of oil and gas resources, more and more, deeper and more complex formations will be faced in oil and gas exploration and development. When these deep complex formations are drilled, complex drilling problems including kick, lost circulation, harmful gas leakage, sticking, etc. often occur. This increases drilling cost and operation risks.

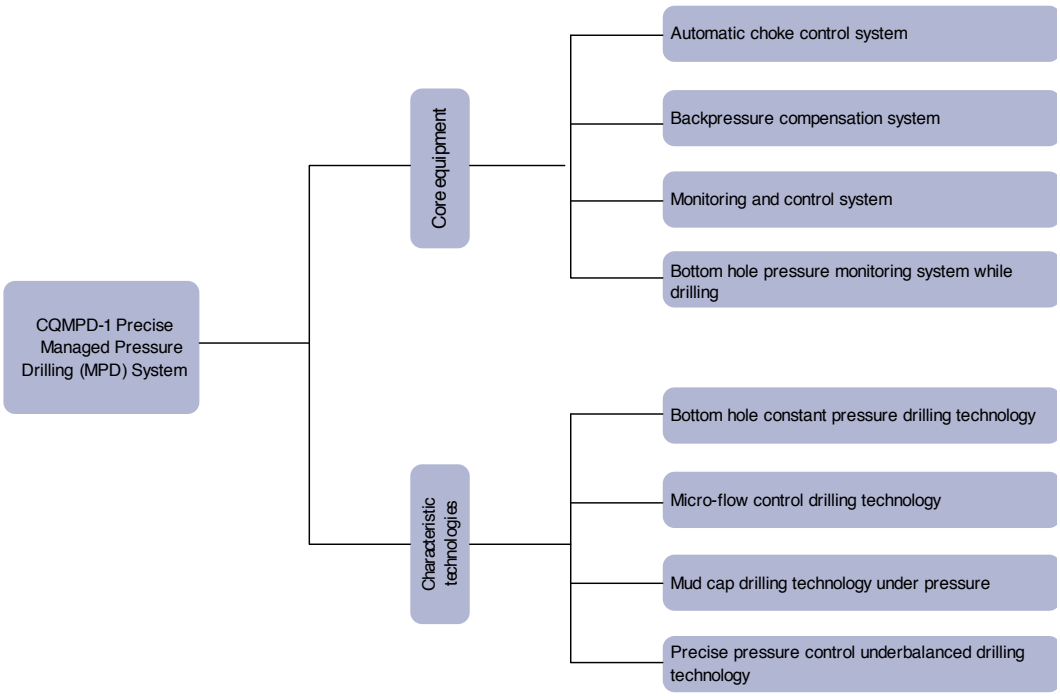
CNPC has carried out comprehensive research on precise MPD theory, technology and equipment and successfully developed CQMPD-1 precise MPD system and matching technologies for solving technical problems encountered in oil and gas exploration and development of complex deep formations. The system integrates technologies involving machinery, electricity, liquid, information, automatic control, etc. and acquires, analyzes and processes bottom hole data and surface data in real time. The system automatically adjusts wellhead casing pressure and realizes precise control of bottom hole pressure. CQMPD-1 system integrates 4 characteristic technologies such as bottom hole constant pressure drilling system, micro-flow control drilling system, mud cap drilling system under pressure and precise pressure control underbalanced drilling system.



CQMPD-1 precise MPD system operation process

CQMPD-1 precise MPD system can effectively solve the downhole complex problems such as lost circulation, kick, etc. caused by narrow safety density window, multi-pressure system and pressure sensitive formations, reduce nonproductive time, shorten drilling period and realize safe and quick drilling.

CQMPD-1 has provided high quality services in blocks such as Sichuan, Jidong, Tarim, etc. successively and solved safety drilling problems in complex formations with “coexistence of overflow and leakage” effectively, thereby providing an important technical support to deep oil and gas exploration.



Technical framework of CQMPD-1 precise managed pressure drilling system

2 CORE EQUIPMENT

The system includes the four sets of core equipment such as automatic choke system (manifold) (ACS), real time data acquisition and control system, backpressure compensation system (BPCS) and annular pressure monitoring system while drilling (PWD). The system uses double ideas including modular and centralized control; i.e. the system can be used integrally and each subsystem can also work independently to realize flexible combination. That is, the system can be used in either precise MPD or underbalanced operation and other drilling operations.

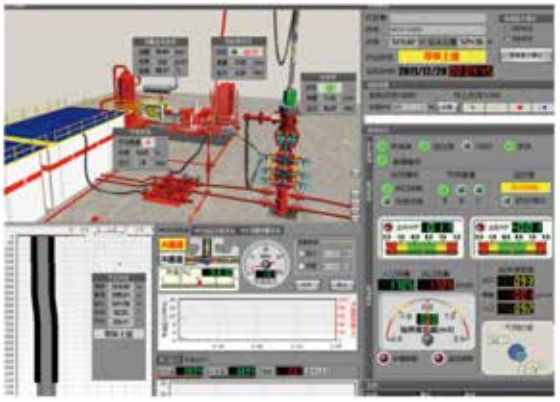
Automatic choke control system

- Function: automatic casing pressure control
- Performance indexes:
  - Choke accuracy: ±0.15 MPa;
  - Rated choke pressure: 10.5 MPa.
- Characteristics:
  - Precise, quick and safe control of casing pressure; electric control of choke valve;
  - Three control modes such as locally manual mode, locally automatic mode and remotely automatic mode, which can be used independently.

Monitoring and control system

- Function: monitor engineering and equipment parameters in real time; analyze, decide and send down casing pressure control commands.
- Performance indexes:
  - ◆Data acquisition time interval 1s;
  - ◆Acquire 200 sets of parameters at the same time.
- Characteristics: integrated monitoring and decision with local and remote network bases and handheld terminals.
- Monitoring and control software system (software registration No.: 2011SRO27533).

Overall interface of system control software



Process control module interface

Backpressure compensation system

- Function: compensation for and automatic control of casing pressure in case of circulation stop in well bore.
- Performance indexes:
  - ◆Maximum displacement: 15L/s
  - ◆Maximum discharge pressure: 10.5MPa
- Characteristics:
  - ◆Diesel engine power
  - ◆Three control modes such as locally manual mode, locally automatic mode and remotely automatic mode, which can be used independently

Downhole pressure measuring system while drilling

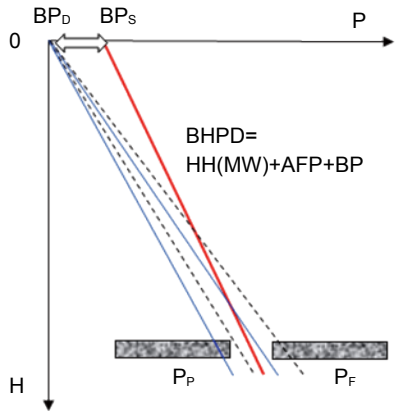
- Data acquisition time interval 4~220s
- Maximum withstanding pressure: 140MPa
- Maximum temperature tolerance: 150℃
- Outer diameter: 121mm/172mm
- Transmission mode: mud positive pulse
- Anti-vibration property: 20g(50~800Hz)

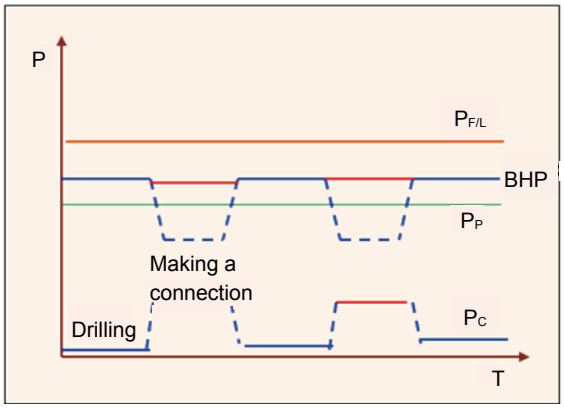
3 CHARACTERISTIC TECHNOLOGIES

Multiple characteristic technologies have been formed, including bottom hole constant pressure drilling technology, micro-flow control drilling technology, precise pressure control underbalanced drilling technology and mud cap drilling technology under pressure, etc.

Bottom hole constant pressure drilling technology

According to the bottom hole pressure value acquired in real time, automatically regulate wellhead casing pressure and backpressure compensation pressure to balance bottom hole pressure with the closed loop pressure control algorithm software. The technology can control bottom hole pressure within the predetermined range in real time and provide continuous bottom hole pressure control under different operating conditions, thus making bottom hole pressure control at narrow safety density window become more reliable.



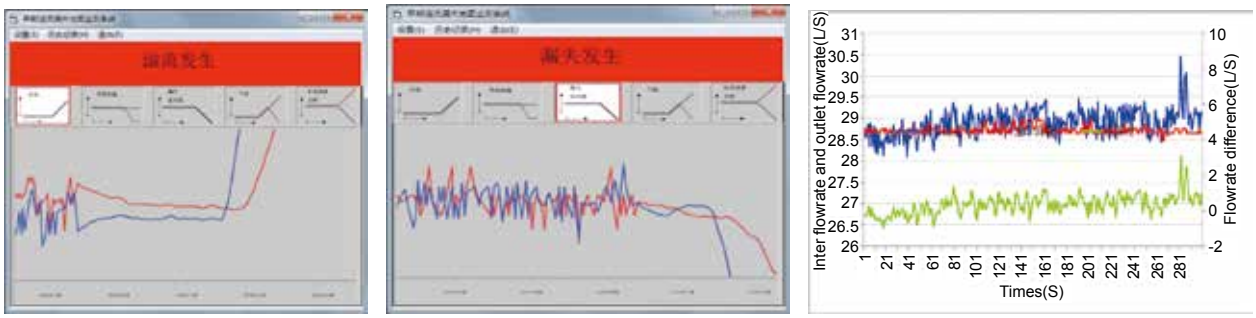


- Bottom hole pressure control accuracy during drilling: ±0.25MPa
- Bottom hole pressure control accuracy during tripping: ±0.35MPa

Patent No.: PCT/CN2011/001867, ZL201120357728.1

Micro-flow control drilling technology

Through real time monitoring of engineering parameters such as wellhead inlet flow rate, wellhead outlet flow rate, standpipe pressure, casing pressure, etc., monitor and control the variation of the fluid volume entering or flowing out of well bore to be within a very small scope, and keep bottom hole pressure within a safety density window. The technology can be used under high temperature reservoir conditions and has wide applicability.



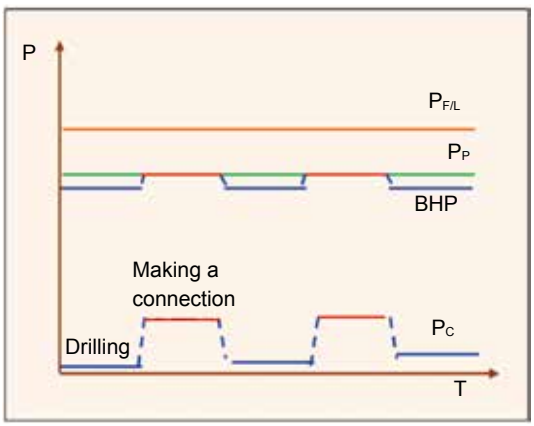
Micro-flow control drilling monitoring software interface

- Not limited by formation temperature;
- Finding overflow/ lost circulation in advance;
- The monitoring value of the minimum cumulative flow rate of overflow/lost circulation is 0.1L.

Precise pressure control underbalanced drilling technology

Based on the precise MPD equipment and technology concept, accurately control wellhead backpressure in real time during underbalanced drilling; ensure that the bottom hole pressure and under-pressure values during underbalanced drilling are the designed target values; can timely find and protect reservoirs and realize safety drilling.

- The under-pressure value can be controlled to be 0~5MPa under underbalanced drilling conditions.



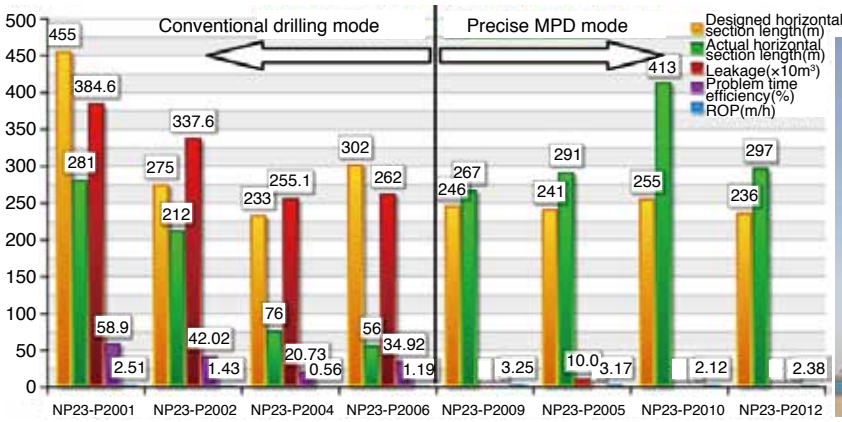
4 TYPICAL CASES

CQMPD-1 precise MPD system has been applied in 11 wells in Jidong Nanpu oilfield and Southwest oil and gas field, thus effectively solving the difficult problem on safety drilling in formations with narrow density window and forcefully promoting the pace of exploration and development.

(1) Application of the precise MPD system in Nanpu-2 buried hill structure in Jidong oilfield

Ordovician reservoir fractures in Nanpu-2 buried hill structure in Jidong oilfield are developed and the density window is narrow. The average leakage quantity of each of drilled wells is 3000m3. It is difficult to drill to the designed geologic target and there are high well control risks.

CQMPD-1 precise MPD system was used in the 5 wells such as NP23-P2009, NP23-P2005, NP23-P2010, NP23-P2012 and NP23-P2016 to precisely control bottom hole pressure, thus drilling to the designed geologic targets without leakage and problem and effectively solving the drilling problem "coexistence of overflow and leakage". The single-well average leakage quantity was reduced by 3000 m^3, the nonproductive time was reduced by 20%~58%, the ROP was increased by 13%~25%, and the actual footage in horizontal sections was 8%~62% larger than the designed footage.



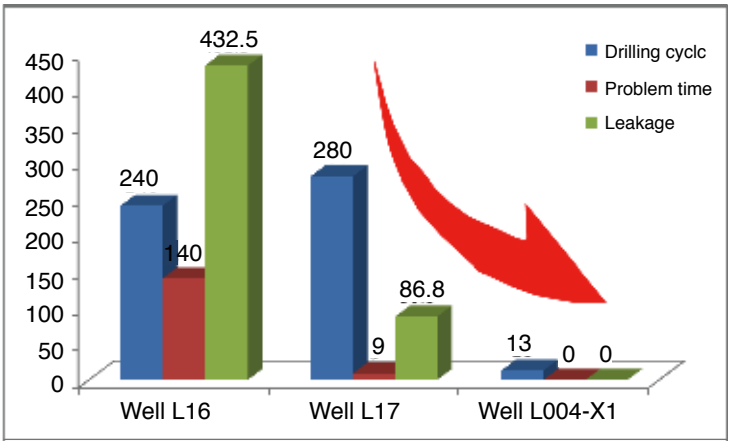
Comparison of precise MPD drilling application effects in Nanpu-2 structure

NP23-P2009 operation site

(2) Application of the precise MPD system in Jiulongshan structure in Sichuan basin

The reservoirs in Jiulongshan structure in Sichuan basin are fracture-pore formations, where coexistence of blowout and leakage easily occurs during conventional drilling and the problem treatment time is long. The conventional drilling mode was used to drill the adjacent well of the structure to the target formation, so that drilling fluid was seriously lost by over 1800m^3 and the nonproductive time of treating downhole overflow and leakage of a single well was over 140h.

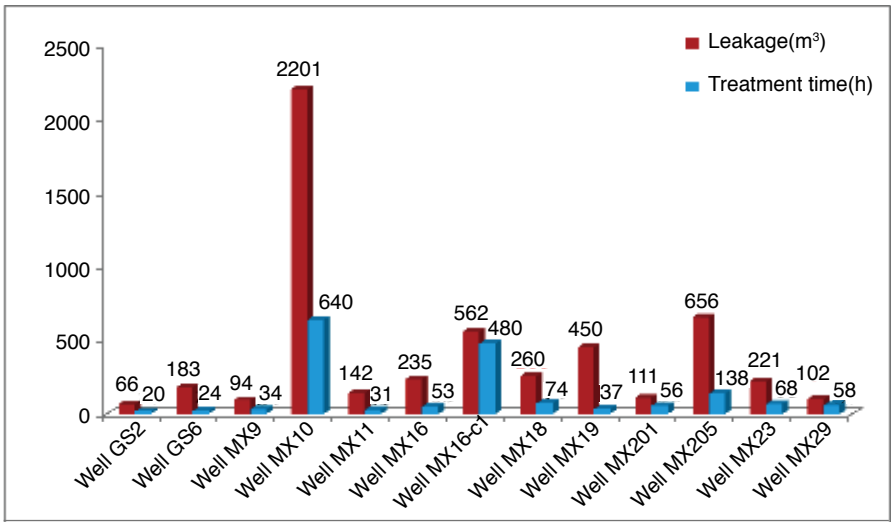
After using CQMPD-1 precise MPD system, the nonproductive time of the target formation well L004-X1 was 83% less than that of the adjacent well, and the designed well depth was reached favorably.



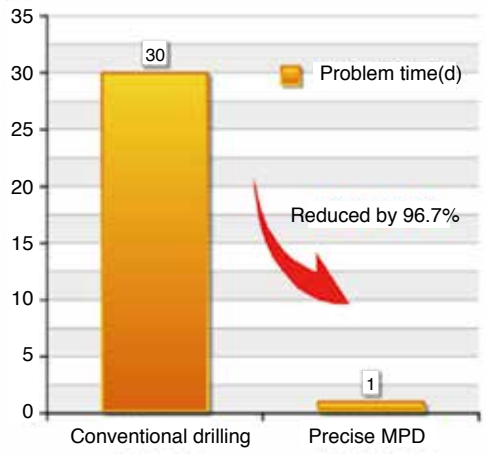
Comparison chart of precise MPD technology application effects

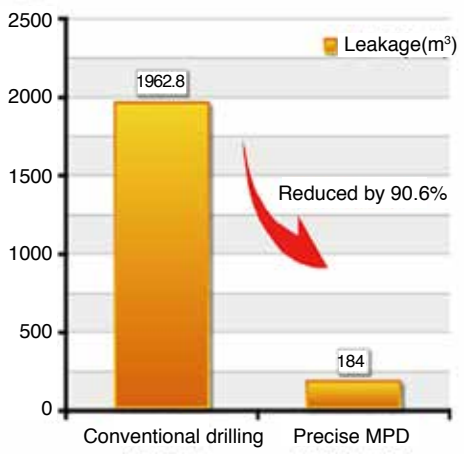
(3) Application of the precise MPD system in Moxi-Gaoshiti structure in Sichuan basin

The formation pressure coefficient in Jia-2 Member~Qiongzhusi Member in Moxi-Gaoshiti structure is high (1.60~2.0), the gas production is high, and fractures are developed. During conventional drilling in the structure, the phenomenon "coexistence of blowout and leakage" often occurs, the treatment difficulty is large, and the treatment period is long.



During the fourth spudding of well GS-19, a ϕ 215.9mm bit was used with 2.15g/cm^3 drilling fluid. When drilling from 2865m to 4013.69m, high pressure fracture formations were encountered, overflow and leakage occurred alternately, and drilling couldn't be performed using the treatment modes such as conventional leakage stoppage, cement plugging, etc. Afterwards, 2.30g/cm^3 drilling fluid was used in precise MPD operations in Qixia Fm.~Baota Fm., and the wellhead pressure and ECB were controlled to be 2.2~5.5MPa and 2.38~2.41g/cm^3 respectively, thus solving the difficult problem "coexistence of blowout and leakage". The well was still drilled by 216.6m while keeping micro-leakage, operation safety was guaranteed, and the mid completion depth was reached favorably.





5 SCIENTIFIC RESEARCH EQUIPMENT

CNPC has a precise MPD test base. The base is fitted with special commissioning equipment, full-scale well control simulation well and precise MPD 3D simulation laboratory and can be used to perform precise MPD 3D simulation training. In addition, CNPC has precise MPD hydraulic calculation software, which can be used to design precise MPD hydraulic parameters.

Full-scale well control simulation well

Wellhead rotary control device test equipment

MPD 3D simulation laboratory

MPD hydraulic calculation software

6 QUALIFICATION STANDARDS

Enterprise Qualification

CNPC has passed ISO9001:2000 quality management system certification, HSE certification and IADC international well control training qualification certification.


Certificate of Authority to use the Official API Monogram

License Number: 16RCD-0007

CCDC DRILLING & PRODUCTION TECHNOLOGY RESEARCH INSTITUTE
Section 2
South Zhongshan Rd.
Guanghan, Sichuan
People's Republic of China

API Spec 16RCD

16RCD-0007

American Petroleum Institute

The scope of this license includes the following product: Rotating Control Device

QMS Exclusions: No Exclusions Identified as Applicable

Effective Date: DECEMBER 6, 2013
Expiration Date: DECEMBER 6, 2016

Rotary control device API qualification


bsc

质量管理体系认证证书

CERTIFICATE OF CONFORMITY OF QUALITY MANAGEMENT SYSTEM CERTIFICATION

Certificate 03112Q20555R4M

This is to certify the quality management system of
CCDC DRILLING&PRODUCTION ENGINEERING TECHNOLOGY RESEARCH INSTITUTE
Add: South Section 2,Zhongshan Avenue,Guanghan City,Deyang City, Sichuan Province,China
is in conformity with
GB/T19001-2008 / ISO9001:2008 standard
This certificate is valid to the following product(s)/service

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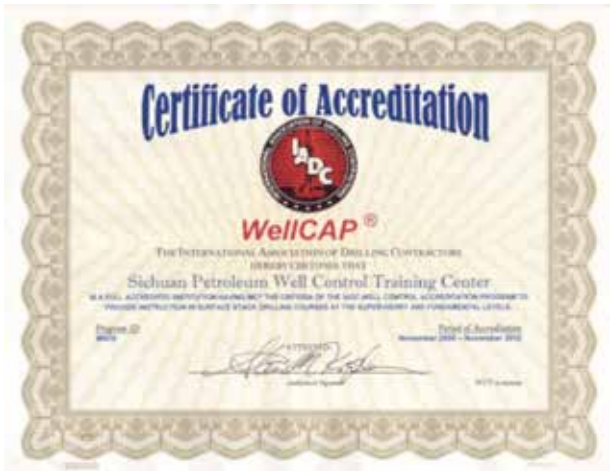
钻井、井控、灭火技术、油气井测试及装备的设计、开发和工程技术服务

Equipment design,development and technical service regards drilling,well control,fire fighting and oil-gas well testing

CNAS IAF

Drilling engineering service quality management system ISO9001 certificate


Certificate of Accreditation

IADC

WellCAP

Sichuan Petroleum Well Control Training Center

IADC well control training qualification certificate


CPAD

中国石油健康安全环境管理体系认证证书

证 明

HSE quality certificate

Specifications and patents

Specifications

5 enterprise specifications for precise MPD system have been formulated:

(1) Enterprise specification for precise MPD system

(2) Operating regulations for PWD system

(3) Operating regulations for automatic choke control system

(4) Operating regulations for backpressure compensation system

(5) Operating regulations for monitoring and control system

Patents

10 national patents have been obtained, including 2 invention patents (1 international invention patent) and 8 utility model patents.

No.	Patent name	Patent type	Patent authorization No.
1	Well bore pressure model prediction system control method	Invention patent	ZL201110332763.2
2	Well bore pressure model prediction system control method	Invention patent	PCT/CN2011/001867
3	Closed loop precise MPD system	Utility model patent	ZL201120357728.1
4	A precise MPD monitoring system for oil and gas wells	Utility model patent	ZL201120357735.1
5	An electrical throttling device for petroleum drilling	Utility model patent	ZL201120357729.6
6	Electrically controlled automatic choke system for oil and gas wells	Utility model patent	ZL201120357734.7
7	Backpressure compensation device	Utility model patent	ZL201120357725.8
8	A self-contained local circulation system	Utility model patent	ZL201120357731.3
9	A wellhead pressure suction device	Utility model patent	ZL201120357732.8
10	A transportation device for PWD pressure measuring equipment while drilling	Utility model patent	ZL201120357724.3

7 EXPERT TEAM

CNPC has a skilled and experienced precise MPD expert team and can provide a set of solutions to safe and quick drilling in complex formations of deep wells.

Wu Xianzhu Professor level senior engineer, technical expert of CNPC. He has over 20 years of experience in drilling technology research and field work and is skilled in well control, problem treatment and precise MPD. Over 40 papers written by him have been published.
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Sun Haifang Professor level senior engineer, technical expert of CNPC. He has been long engaged in R&D and application of new drilling technologies involving directional drilling, underbalanced drilling, precise MPD, etc. Over 20 academic papers written by him have been published.
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Han Liexiang Professor level senior engineer, technical expert of CNPC. He has been engaged in R&D and application of new drilling technologies involving optimal and quick drilling, deviation control, underbalanced drilling, precise MPD, etc. for many years. Over 20 papers written by him have been published.
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Wei Wu Professor level senior engineer. He has been engaged in scientific research and management of underbalanced drilling, gas drilling, precise MPD, etc. for many years. 13 academic papers written by him have been published.
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Xiao Xinyu Senior engineer, technical expert. He has been engaged in underbalanced drilling, full-process underbalanced drilling and precise MPD for many years. Over 10 academic papers written by him have been published.
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Xiao Runde Senior engineer, technical expert. He has been engaged in scientific research on underbalanced drilling/precise MPD equipment and technology for many years. Over 12 papers written by him have been published.
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