



H₂S High-sulfur Gas Drilling and Completion Technology

Science & Technology Management Department

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CHINA NATIONAL PETROLEUM CORPORATION

*A Golden Key to Safety Drilling of
“Three-high” Gas Fields!*



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HTHP High-sulfur Gas Drilling and Completion Technology(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 reorganized 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 2012 CNPC produced 110 million tons of crude oil and 79.82 billion cubic meters of natural gas, while crude processing volume reached 191 million tons. The total revenue of RMB 2,690 billion with a profit of RMB139.1 billion had been achieved the same year.

CNPC was ranked 4th among the world's largest 50 oil companies and 6th in Fortune Global 500 in 2012.

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.

HTHP High-sulfur Gas Drilling and Completion Technology is one of representatives for major innovations of CNPC.

CLEAN ENERGY SUPPLY FOR BETTER ENVIRONMENT

1

INTRODUCTION

Since 1959, CNPC has independently studied and developed the unique engineering technologies of the industrial leading level for “three-high” gas fields and has obtained plenty of achievements in the drilling and completion field of gas fields. Through over 50 years of exploration and practice, CNPC

has successfully solved the difficult problems about drilling and completion technologies for “three-high” gas fields in Sichuan Basin, Xinjiang Tarim Basin, etc. and has realized highly effective and safe development of “three-high” gas fields.



2

UNIQUE TECHNOLOGY

2.1 “Three-high” Gas Well Drilling Technology Series

The main technologies applicable to complex formations including horizontal well trajectory control technology for high and steep structures, well control technology, wellhead control and recovery technology for out-of-control wells, etc. have been formed to increase drilling speed.

Well Control Technology

Well Control Technology can provide the relative technologies for formation pressure prediction, well control design, well control operation, conventional overflow treatment and treatment of complex conditions including full empty well, blowout and leakage in the same layer, etc.. CNPC has abundant experiences in treating complex well control problems involving “three-high” wells and it can also provide various models of well control matching equipment for “three-high” wells. The main technical indexes of the equipment reach API standards.



On site treatment of blowout of sour oil and gas well

Wellhead Control and Recovery Technology for Out-of-control Wells

CNPC has world-class professional land oil and gas well emergency rescue teams, rescue equipment and technologies and once participated in rescue of large oil and gas wells including those in Kuwait, Osman-2 well in Turkmenistan, etc., which well heads were successfully recovered and effectively controlled. CNPC can provide customers with recovery operations and relevant technical consultancy after blowout out-of-control or ignition of large oil and gas wells.



2.2 Comprehensive Technology Series for Drilling (Completion) Fluids and Leakage Prevention and Control for Deep and Ultra-Deep Wells

The comprehensive technologies for drilling (completion) fluids and leakage prevention and control for deep and ultra-deep wells that meet the requirements of drilling of “three-high” gas wells have been formed according to the features of “three-

high” gas wells, for the purpose of increasing drilling speed and reducing complex accident loss.

Drilling Fluid Technology for Deep and Ultra-deep Wells

CNPC has an expert team of abundant experiences in drilling fluids for deep and ultra-deep wells and perfect laboratories and can provide the most appropriate integrated services involving drilling (completion) fluid system design and operation according to different geologic features.

The deep and ultra-deep drilling (completion) fluid systems that have found mature applications and have won good market credit include:

- High temperature drilling (completion) fluid;
- Ultra-high density drilling (completion) fluid;
- Drilling (completion) fluid resistant to pollution of gypsum salt and acid gas;
- Drilling (completion) fluid for slim hole wells, high-inclination wells and horizontal wells



2.3 “Three-high” Gas Well Completion and Production Test Technology Series

The “three-high” gas well completion and production test technologies are intended to effectively recognize reservoir characteristics and obtain fluid properties by optimizing completion methods, developing special tools, equipment and matching string structures and optimizing the surface design according to the features of “three-high” gas wells such as high pressure, high temperature and high H₂S content.

The “three-high” gas well completion and production test technologies including test and

workover engineering design, formation test and sulfur-resistant surface test and metering technology.

Sulfur-resistant Surface Test and Metering Technology

By separating and metering formation fluids and recording the data including wellhead pressure, temperature, etc., some important reservoir parameters are obtained, including formation fluid properties, stable production of oil, gas and water, GOR, compressibility coefficient, etc. The surface test and metering technology is an important technical means for reservoir evaluation in the exploration process.



105MPa high sulfur-resistant two-phase flow and three-phase flow surface metering equipment

According to the features of reservoirs in “three-high” gas wells, 105MPa sulfur-resistant surface equipment is used to separate and meter sulfur-containing formation fluids and obtain the important parameters such as formation fluid properties, production, etc. The surface test and metering technology is an important technical means for reservoir evaluation in the exploration process.

The “three-high” gas well test technology has found mature applications and won good market credit, and the technology parameters are as follows:

- ◆ Maximum shut-in wellhead pressure, 107.85MPa;
- ◆ Maximum wellhead test flowing pressure, 87.03MPa;
- ◆ Maximum formation temperature, 192°C ;
- ◆ Maximum bottom hole operation pressure, 210MPa;
- ◆ Maximum formation pressure, 135.29MPa;
- ◆ Maximum H₂S content, 551g/m³;
- ◆ Maximum production test interval depth, 7448m.

The success ratio of the “three-high” gas well test technology reaches 98% and meets the requirements of high sour gas well tests with the depth of 8000m, the bottom hole temperature of 200°C and the formation pressure of ≤ 140MPa.

3

TYPICAL CASES

3.1 Blowout out-of-control treatment of well LH2

When the well was drilled to 4418.5m, overflow occurred, the shut-in casing pressure reached 26MPa, the semi-blind ram preventer was pierced and leaked (formation pressure 68MPa) and then the wellhead was out of control, gas flows were ejected to 25m high (gas production $206.46 \times 10^4 \text{m}^3/\text{d}$) and the drilling tools in the well were of brittle failure due to H_2S (H_2S content $6.15\text{g}/\text{m}^3$). Surface manifolds were used in open flowing and pressure relief. A drilling tool lifting device was connected at the wellhead to lift the drilling tools, the blind ram preventer was closed to control the wellhead, the core of the semi-blind ram was replaced, the annular

preventer was changed, and a new single-ram preventer was installed. After that, the empty well killing was succeeded.

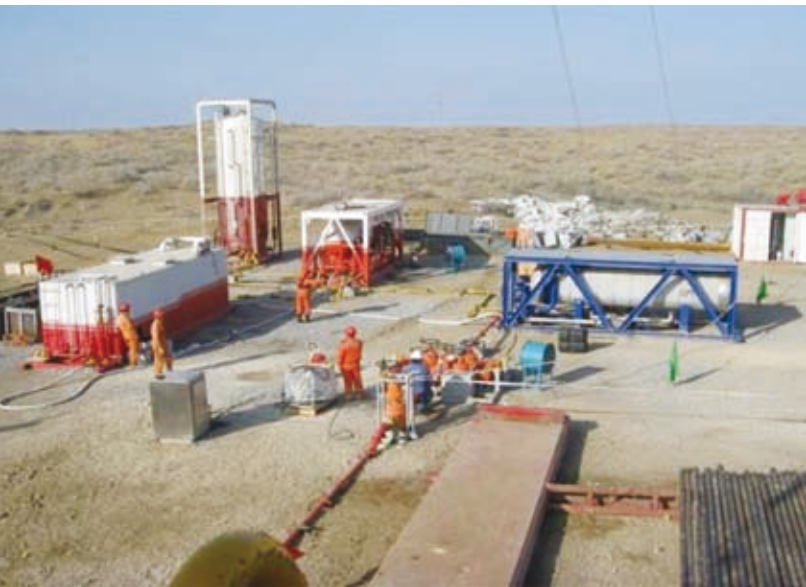
3.2 Osman-3 Well Rescue

Osman-3 well in Turkmenistan was of blowout and on fire on Oct. 28, 2006. The equipment at the well site was burned out, the blowout flow rate reached $500 \sim 1000 \times 10^4 \text{m}^3/\text{d}$, and the H_2S content in the ejected natural gas was up to as high as $23000\text{mg}/\text{L}$. Heat radiation was extremely strong at the rescue site and personnel within the scope of 50m were difficult to approach it. The well on fire was successfully controlled after two months of strenuous efforts.



3.3 Applications of “Three-high” Gas Well Completion and Production Test Technologies

Surface test and metering operations were performed in Ordovician strata of well ZG6 on ZG-5 lithologic trap in 1# slope break belt of Tazhong low uplift of the central uplift in Tarim basin. The test interval was 5934.50~6172.73m, the gas production, oil production and formation water production during the test were 15442m³/d, 64.8m³/d and 2.52m³/d respectively, and the H₂S content in natural gas was larger than 400000mg/L (converted into 551g/cm³). The well has the highest sulfur concentration in Tarim oilfield at present.



4 R&D EQUIPMENT

CNPC has national key laboratories with excellent equipment and advanced technologies.

CNPC has developed bottom hole pressure monitoring systems and data monitoring and control systems while drilling and realized the localization of key MPD (managed pressure drilling) equipment. CNPC has developed special rescue equipment including remote jet ignition devices, remote hydraulic sandblasting cutting devices with a single sprayer and dual pipes, rescue casing heads, special remote wellhead rush installation devices, etc. CNPC has introduced the world advanced equipment including Land Rover 60 fire snow cannons, special remote excavators and bulldozers resistant to high temperature and radiation, etc. and has formed complete and advanced rescue equipment series used to cope with various complex blowout out-of-control accidents.



仪器保养台架

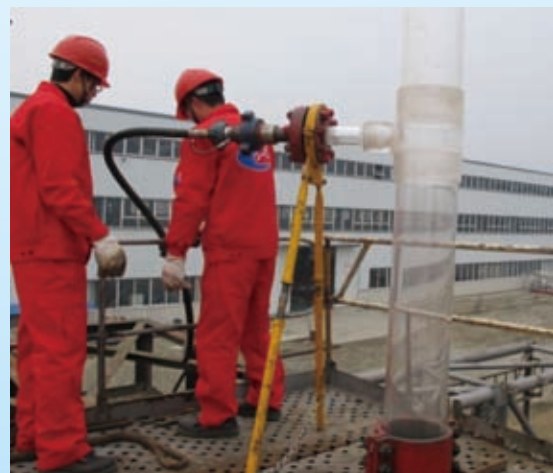
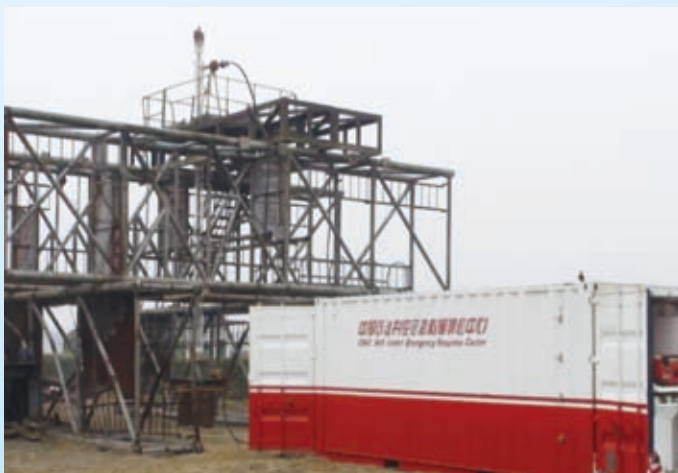


仪器维修台架



仪器校验台架

Horizontal well instrument verification and maintenance center



Freezing and temporary plugging test platform



Wellhead reconstruction equipment



Sandblasting cutting equipment



HTHP test platform for downhole tools



Indoor well control simulator

CNPC has a gas analysis and evaluation laboratory and a sour oil and gas field material and corrosion laboratory, CNPC is accordingly recognized as gas product quality supervision and inspection center of the petroleum industry and China's technical management unit of ISO/TC193. The sour oil and gas field material and corrosion laboratory can be used to conduct static corrosion tests in HTHP and

high-corrosion environments (70MPa and 350°C) and flowing corrosion tests by simulating downhole and surface environments of oil and gas wells as well as multiple corrosion tests and evaluations involving sulfide stress cracking, stress corrosion cracking, etc. of metallic materials, nonmetals and corrosion inhibitors for downhole and surface gathering and transportation.



Gas analysis and evaluation laboratory



Sour oil and gas field material and corrosion laboratory

5 QUALIFICATIONS & STANDARDS

5.1 Qualifications

CNPC has passed ISO 9001:2000 quality management system certification and IADC international well control training qualification certification. CNPC has the national sour field material corrosion detection and metering acceptance certificate, the special equipment detection and inspection organization acceptance certificate, etc.



Comprehensive study quality management system of gas development



Metering qualification certificate



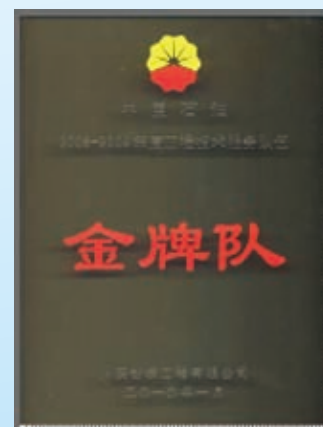
ISO 9001:2000 quality management system certification of well drilling, well control, fire fighting technique, oil & gas test and equipment, development and engineering technical services



Drilling design qualification certificate



Well control training qualification certificate



“Three-high” formation test operation certificate

5.2 Standards & Patents

Standards

No.	Standard No.	Standard name	Description of standard adoption
1	GB/T20972.1—2007	Materials for Oil and Gas Production in H ₂ S Environment of Oil and Natural Gas Industry - Part 1: General Principles for Selecting Crack Resistant Materials	Equivalent adoption of ISO 15156-1:2001
2	GB/T20972.2—2008	Materials for Oil and Gas Production in H ₂ S Environment of Oil and Natural Gas Industry - Part 2: Use of Cracking Resistant Carbon Steel, Low Alloy Steel and Cast Iron	Modified adoption of ISO 15156-2:2003
3	GB/T20972.3—2008	Materials for Oil and Gas Production in H ₂ S Environment of Oil and Natural Gas Industry - Part 3: Cracking Resistant and Corrosion Resistant Alloy (CRA) and Other Alloys	Modified adoption of ISO 15156-3:2003
4	GB/T 4157—2006	Laboratory testing of metals for resistance of specific forms environmental cracking in H ₂ S environments	Modified adoption of NACE TM 0177:1996
5	AQ2016—2008	Specification for ignition time of out of control on wellhead of natural gas well involving hydrogen sulfide	Referring to EUB Directive 071 and ID 2001-5
6	AQ2017—2008	Classification method of public hazard levels for natural gas well involving hydrogen sulfide	Referring to EUB Directive 056, ID97-06 and ID81-03
7	AQ2018—2008	Specification for public safety protection distance of natural gas wells involving hydrogen sulfide	Referring to EUB Directive 056, ID97-06 and ID81-03
8	SY/T5087—2005	Recommended Methods for Safety Drilling in Sour Wells	Non-equivalent adoption of API RP49:2001
9	SY/T6610—2005	Recommended Practice for Oil and Gas Well Servicing and Workover Operations Involving Hydrogen Sulfide	
10	SY/T6616—2005	Specification for well-control equipments arrangement, installation and operation of oil and gas well involving sulfide	
11	SY/T6137—2005	Recommended Practices for Oil and Gas Producing and Gas Processing Plant Operations involving Hydrogen Sulfide	
12	SY/T6277—2005	Regulations on H ₂ S Monitoring and Personnel Safety Protection in Sour Oil and Gas Fields	

Patents

- A test device for direct reading of downhole data crossing test valves (ZL20072200804485.5)
- Mechanical load calculation software for production test strings (SR2010SR055952)
- A wireless acquisition and monitoring device for surface test data of oil and gas wells (ZL200720080629.7)
- A pipe string sand remover (ZL200720080285.X)
- A wireless transmission pressure acquisition system (ZL200820063331.X)
- A wireless transmission temperature acquisition system (ZL200820063330.5)

6

EXPERT
TEAM

CNPC has a skilled and experienced gas drilling and completion expert team and can provide high quality technical solutions to different customers.



Luo Pingya Oilfield chemistry expert, education expert, Academician of the Chinese Engineering Academy. He has long been engaging in teaching and scientific research in the field of oil and gas exploration and development. He has studied and developed drilling and completion technologies for reservoir protection. The “shielding type temporary plugging” series technologies successfully developed by him have been widely applied in the country. He was once awarded with grade I national excellent teaching achievement prize and grade II national science and technology advance prize.

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Wu Xianzhu Senior technical expert. He has long been engaging in the study of drilling engineering and drilling technology and has obtained 2 national patents. He was once awarded with grade II science and technology advance prize of the State Education Commission and grade II national science and technology advance prize.

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Sun Haifang Senior technical expert. He has long been engaging in the study of ultra-deep horizontal wells, geosteering horizontal wells with ultra-thin reservoirs, etc. He has obtained 6 national authorization patents.

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Yang Lingrui Senior technical expert. He has long been engaging in the study of well control technologies in drilling and rescue and fire extinguishing technologies for oil and gas wells. He was awarded with 1 grade I prize of CNPC and 1 grade II prize of CNPC and obtained 2 national utility model patents and 1 appearance design patent.

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Ma Zongjin He has long been engaging in the study of drilling technologies, well control technologies in drilling and rescue and fire extinguishing technologies for oil and gas wells. He was awarded with 1 grade II national employee technology innovation prize, 1 grade I technology innovation of CNPC and 1 grade II technology innovation of CNPC and obtained 1 national utility model patent.

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Han Liexiang Technical expert. He is of great attainments in drilling technologies and well control technologies and especially vertical drilling technologies. He formulated and revised 2 industrial standards. Over 10 papers published.

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