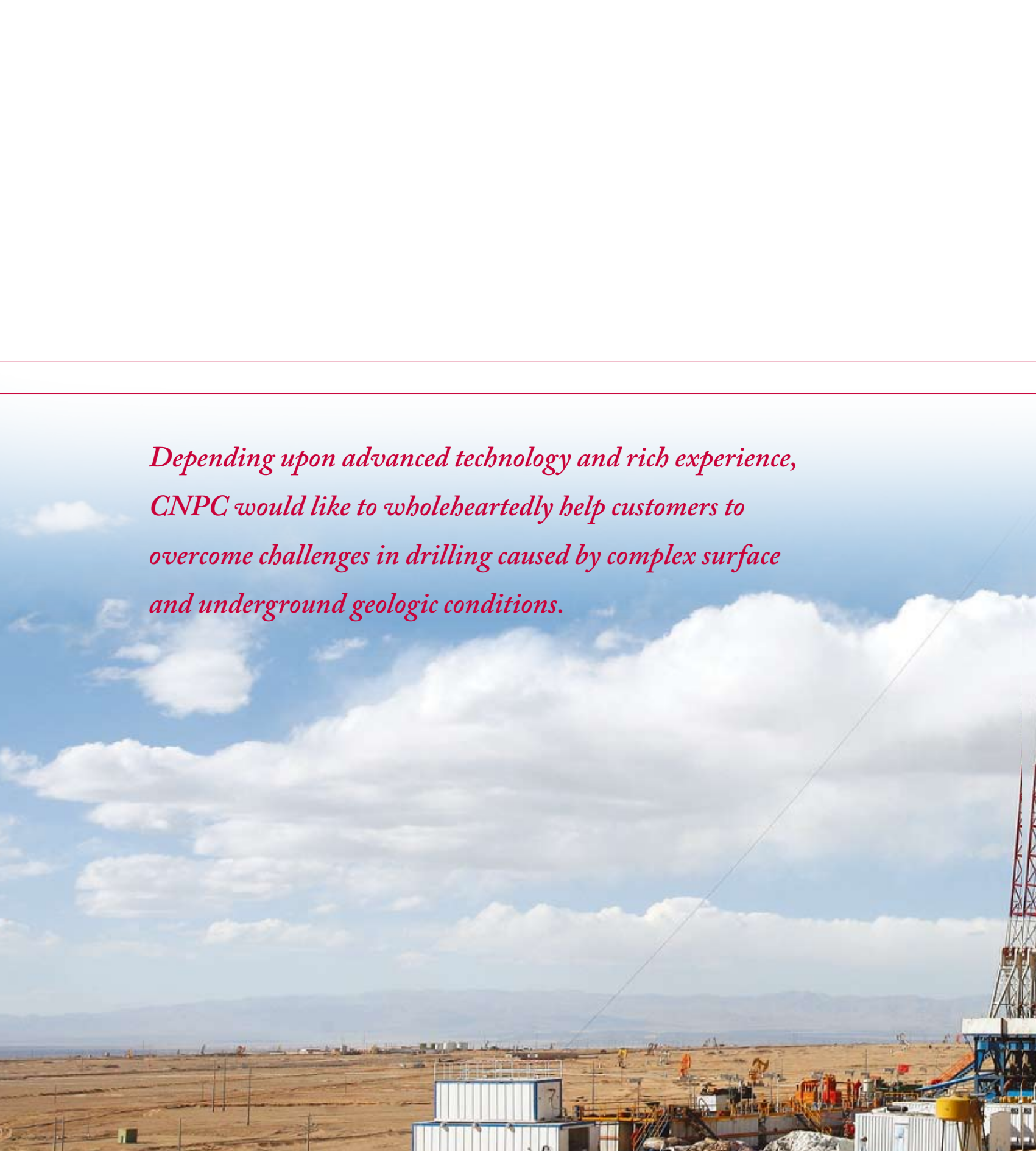
Drilling Technology

Science & Technology Management Department

2011

CHINA NATIONAL PETROLEUM CORPORATION

Depending upon advanced technology and rich experience, CNPC would like to wholeheartedly help customers to overcome challenges in drilling caused by complex surface and underground geologic conditions.



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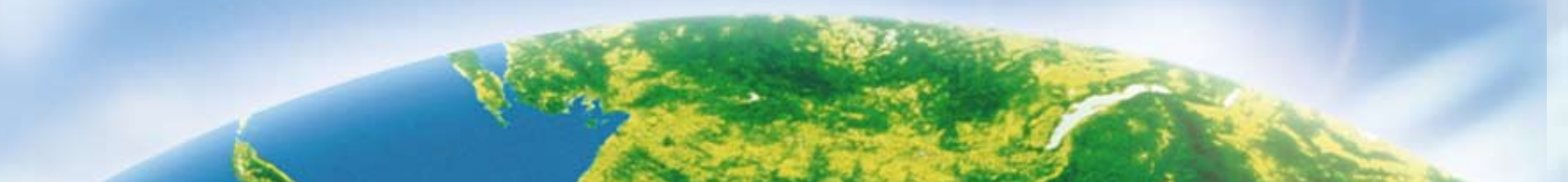
China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. As an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integration of upstream and downstream operations, internal 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 of refined oil produts 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 RMB172.7billion 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.

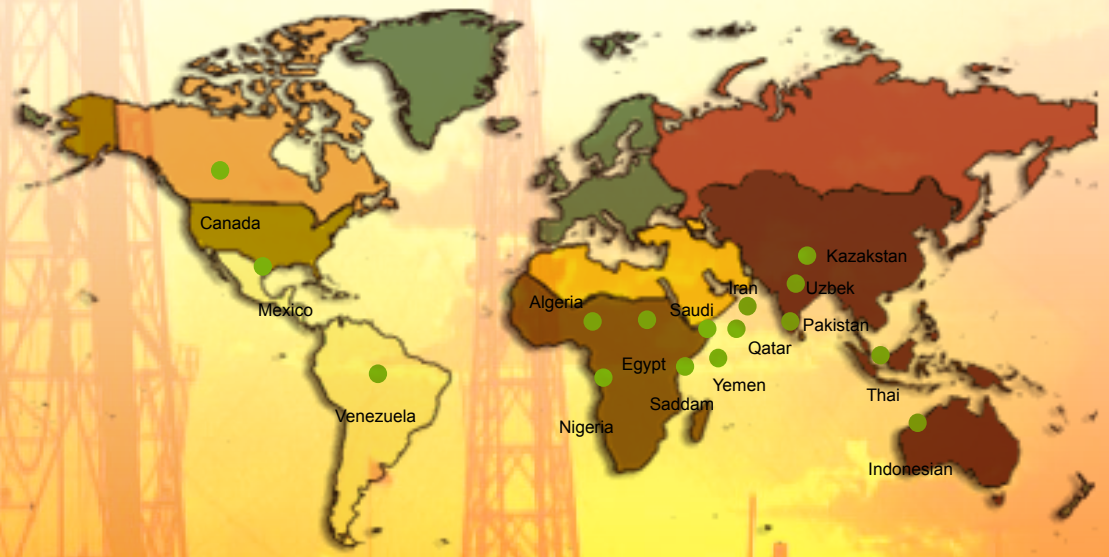
The Drilling Technology is just one of the representatives for major innovations of CNPC.



1 INTRODUCTION

CNPC has devoted itself to exploration and practice for drilling engineering & technology and become an outstanding operator and explorer in the industry, possessing qualified R & D talents and professional personnel in drilling as well as a complete portfolio of equipments, tools and instruments for oil/gas drilling. For overseas opwrations, CNPC has provided drilling service in 29 countries and regions, in Middle East, South America, Middle and Southeast Asia.

The eternal goal pursued by CNPC is to improve drilling safety and drilling rate, reduce cost and enhance exploration & development benefits by full means of drilling. CNPC intends to share the advanced and practical drilling technologies & experience with the whole world, providing the most excellent services to our customers and creating more wealth.



2 SPECIALTY TECHNOLOGIES

2.1 Technologies for Deep and Ultra-deep Well Drilling & Completion

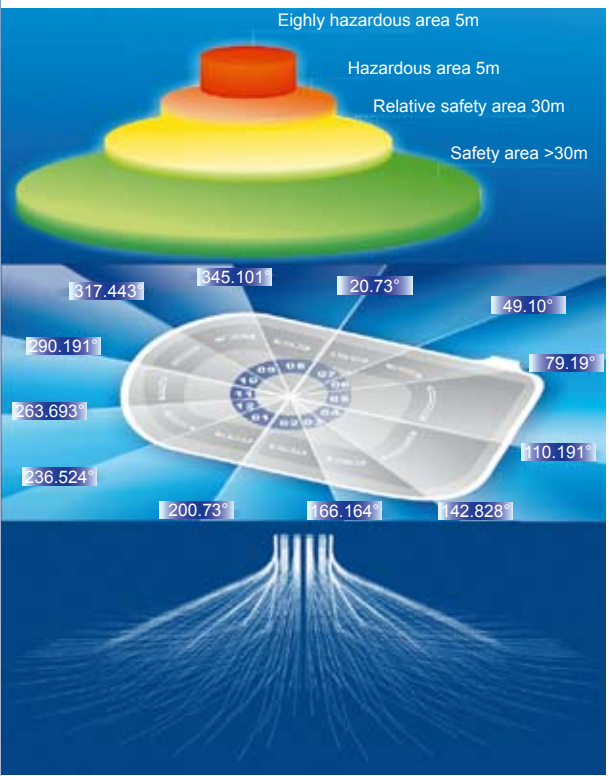
Generally speaking, a deep well refers to a well with a depth ranging from 4,500m to 6,000m, while an ultra-deep well refers to that with a depth over 6,000m. CNPC has developed a series of drilling equipments and tools suitable for deep and ultra-deep wells, including ZJ120/9000DB™ 12,000m A.C. variable frequency drilling rigs, DQ120BSC™ 9000kN top driven drilling system, 1,617kW drilling pump/high pressure manifold system, and drilling tools such as 4,410kW winch, disc brake and electronic driller system, which meet the current demand for drilling in blocks with complicated geological conditions by means of a number of approaches such as high pressure jetting drilling, customized bit design and high efficiency deviation control. The solutions featuring in high drilling rate and low cost are provided to the customers.

Meanwhile, CNPC provides services such as pressure prediction, monitoring and test of complicated formation, analysis of sidewall stability in highly steep structures, fragile formations and massive salt horizons, as well as technical services of drilling fluids with strong capability for inhibition, strong shut off and high-efficiency loss control.

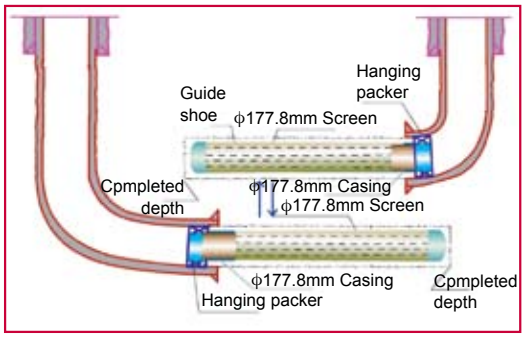
2.2 Technologies for Directional and Horizontal Well Drilling & Completion

Directional Drilling Technology is to drill according to the designed deviation and orientation and reach the target layer. A horizontal well is a directional well with the well track to extend for a certain length when the wellbore trajectory gets horizontal. CNPC has developed TrajectoryControl© software for well track control,wireless measurement while drilling system CGMWD™, near bit geosteering drilling system, CGDS NB™ and measurement/control instruments and tools for all types of screw drills, so as to provide drilling and completion services in multilateral wells, extended reach horizontal wells, re-entry sidetracking, stepwise horizontal wells in stringers, SAGD horizontal wells and horizontal wells in ultra-shallow layers as well as the solutions for welltrack control of closely spacing cluster wells.

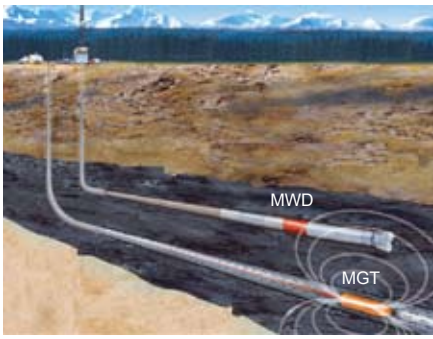
Stepwise horizontal well



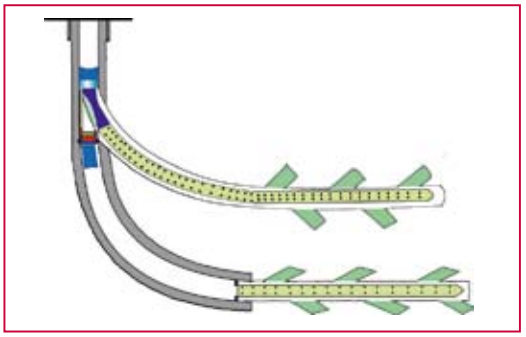
Well track contril of cluster wells with closely spacong



SAGD paired paralel



Horizontal well

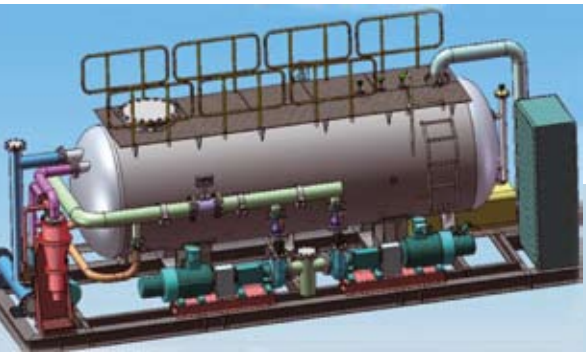


Multilateral well

Near bit geosteering drilling system

Field test of booster

LK-30/2.5QZ air compressor



Four phase separator

2.3 Technologies for Underbalanced Well Drilling & Completion

Underbalanced drilling refers to drilling operation with a circulation pressure of drilling fluid at bottom hole lower than the porous pressure in the formation, allowing the fluid from major reservoir to flow into wellbore and circulate to surface, with effective control on the surface. It facilitates the discovery and protection of reservoir, the increase among oil/gas production, recovery ratio and drilling rate. It can be applied to the exploration and development of reservoirs with low pressure, water sensitivity, natural fractures and special lithology.

CNPC owns well-qualified drilling crews dedicated in underbalanced drilling. With advanced concepts and technologies, a set of underbalanced equipments have been designed and manufactured, such as rotary BOP, air compressors, boosters and snubbing tools. Also, a software for optimal design of underbalanced drilling——Opti-Underbalance® has been developed. Integrated technologies and services can be realized for liquid underbalanced drilling, gas drilling (pure gas, mist, foam and aerated drilling) and systematic underbalanced drilling.

Rotary BOP

2.3.1 Liquid Underbalanced Drilling.

Liquid Underbalanced Drilling Technology is to use all types of liquid drilling fluids or mud caps to fulfill underbalanced drilling.

The service of liquid underbalanced drilling includes:

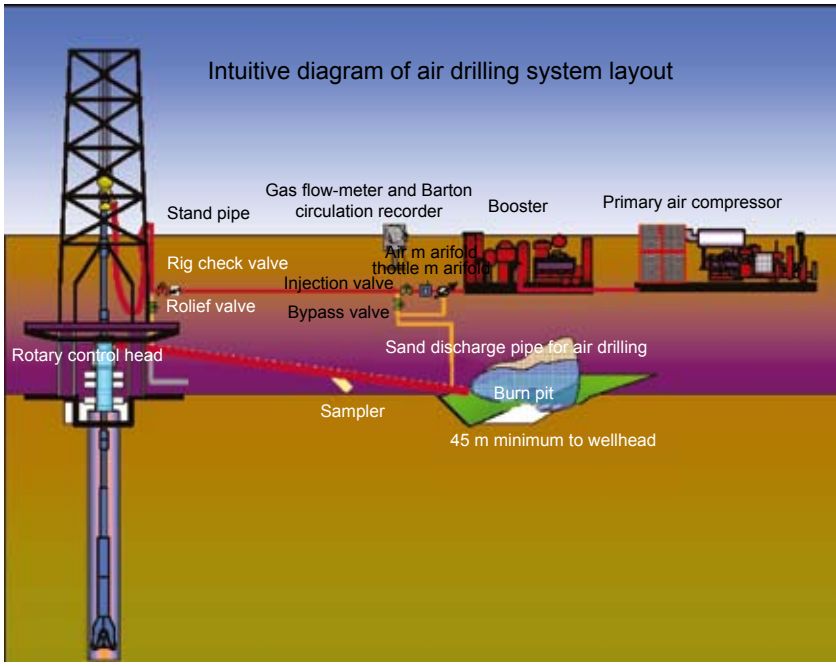
• Underbalanced drilling with drilling fiuid of water in oil or oil in water.

• Underbalanced drilling with drilling fluid of water or brine.

• Underbalanced drilling with conventional drilling fluid.

• Underbalanced drilling with density reducer drilling fluid in.

2.3.2 Gas drilling.



Intuitive diagram of air drilling system layout

Air hammer

Air drilling

Mist drilling

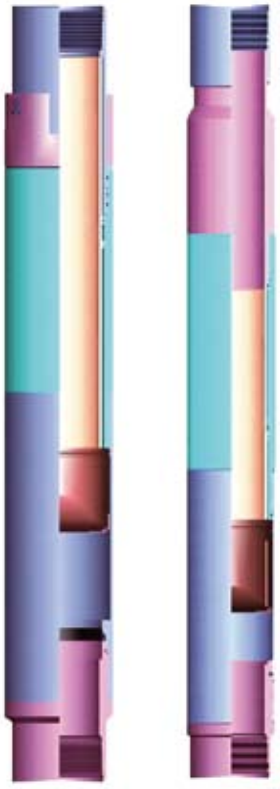
Foam drilling

2.3.3 Whole-process Underbalanced Drilling

The Whole-process Underbalanced Drilling technology is to fulfill under-balanced operations in drilling, tripping, coring, logging and well completion by means of special equipments, tools and technologies. Since the under-balance operations are realized completely from drilling to well completion, oil/gas reservoirs can be protected well.

Snubbing device (60t)

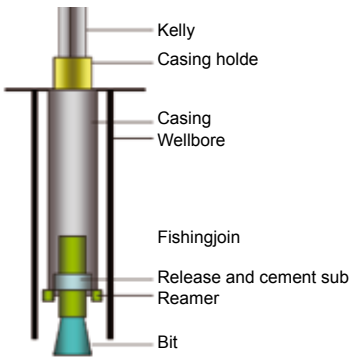
Impermeable expandable screen



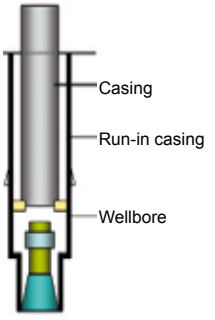
Downhole casing valve

2.4 Systematic Technologies for Casing Drilling

Casing Drilling Technology is to realize bit rotation and drilling by using casing string instead of drilling string to apply torque and weight on bit, and the casing string remains in the borehole for well completion after drilling is completed, which is primarily used for exploration and development of mid-shallow wells. CNPC is capable of providing services for single trip casing drilling™ and multiple trip casing drilling™ with changeable bit.

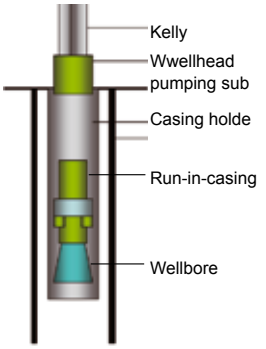


(1) Surface casing
(int ermediate casing) drilling

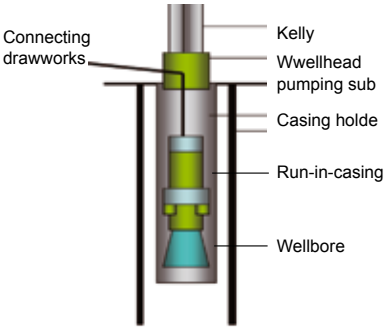


(2) Termination of production
casing drilling

Single trip surface casing drilling



Pump in the drilling bit during the process



Fish the bit

Multiple trips casing drilling

2.5 Drilling Fluid and Additive Technologies

Drilling fluid is used to clean bottom hole, carry the cuttings to the surface, and maintain the normal drilling operation. It acts as the “blood” of drilling.

2.5.1 Specialty drilling fluid systems.

Drilling fluid system for bit cleaning and ROP increase.

Drilling fluid system with high temperature resistance(240˚C).

• Saturated brine drilling fluid system for halite-anhydrite formation.

• Drilling fluid system for reservoir protection through dual membrane synergistic blocking.

• Membrane forming water-base drilling fluid system for sidewall protection against sloughing & sidewall stabilization.

• High density drilling fluid system for high pressure formation.

• Amine drilling fluid system for inhibition of mudstone/shale hydration/swelling.

2.5.2 Specialty additives.

Totally, 398 types of 18 categories of drilling fluid additives are available to CNPC for satisfing customer’s demands in drilling of various oil/gas wells, including RH-4 bit balling preventive cleaning agent, KSZJ faster drilling additive, GBH high temperature protective agent, BTM semi-permeable membrane additive, CMJ isolation membrane additive and JYM ultra-low permeable additive and so on.

Specialty additives

Cementing site

2.6 Cementing Technologies

In cementing, a casing string with certain dimension is run into the borehole and fixed on the sidewall by cement slurry which is injected around the string. So sidewall sloughing can be avoided.

CNPC is up to the world advanced level in the research, development and application of cementing materials as well as the cementing technologies for complicated formations. With more than 80 categories of well cementing additives developed independently, CNPC has provided cementing services under various harsh conditions in dozens of countries over four continents worldwide. Following cementing services, additives and cementing tools are available to satisfy the demands of customers:

2.6.1 Cementing services.

• Cementing in deep and ultra-deep wells (high temperature, high density).

• Cementing in horizontal wells and sidetracked horizontal wells.

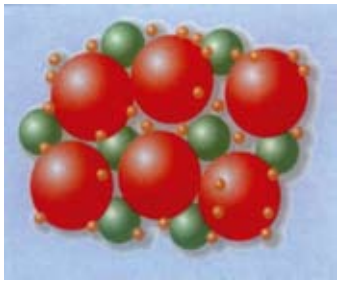
• Cementing in slim holes.

• Cementing in long open hole intervals prone to loss circulation, with low pressure.

• Cementing in adjustment wells.

Slurry prepared by MTC and cured cement slat

High density cement slurry and cement slat



Model for linear accumulation of cement slurry with low density and high strength

Cross-section of 1.50g/cm^3 and 1.30g/cm^3 low density and high strength cement

2.6.2 Additives.

• Additive for MTC (Mud to Cement) cementing.

• Additive for foamed cement.

• Additive for cement slurry in high temperature deep wells.

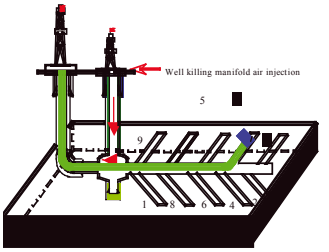
• Additive for cement slurry with low density and high strength.

• Additive for salt-resisting cement slurry.

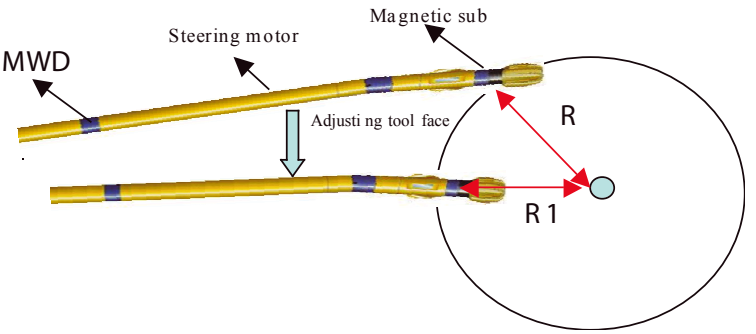
• Additive for latex cement slurry.

2.7 Systmatic Technologies for CBM Well Drilling & Completion

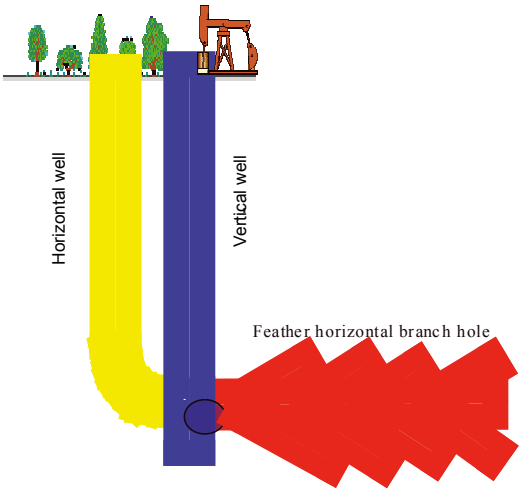
In view of the problems of CBM recovery such as low single well productivity and high cost, CNPC has spared no effort in exploring and research, developing a series of unique CBM drilling tools and software, including SMTS spiral magnetic induction system™, SSQM-1 wire line coring™ and CBM-DAS design software™ etc. Integrated CBM drilling and well completion engineering/ technical services can be provided, such as vertical drilling with low cost and high reliability, drilling/completion of multilateral horizontal wells and CBM well cementing.

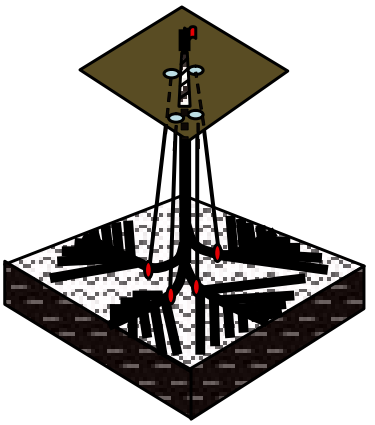


CBM multilateral horizontal well



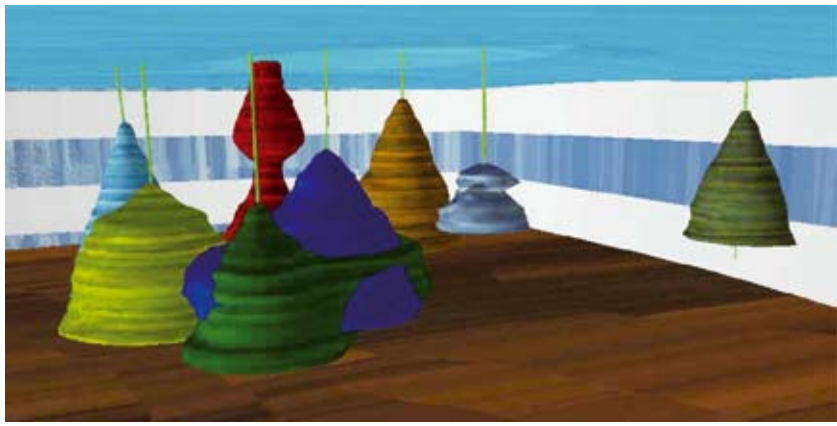
SMTS spiral magnetic induction system



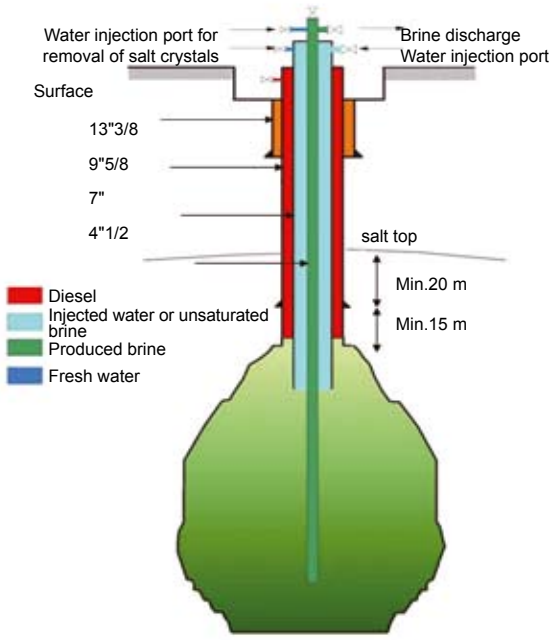


2.8 Systematic Technologies for Underground Storage Construction and Engineering

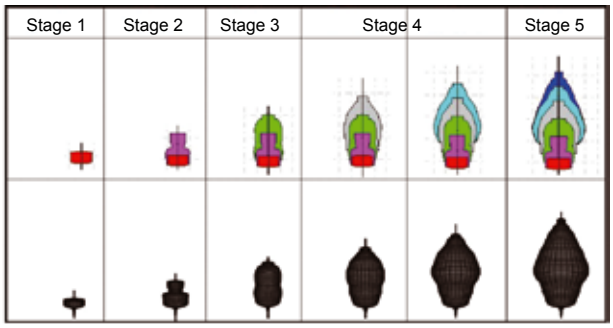
The underground storages include underground gas storages in depleted gas (oil) reservoirs, underground gas (oil) storages in salt cavern, and underground gas storages in aquifer, etc. CNPC has developed a number of products such as 3D simulation software® for underground gas storage construction in multi-bedded salt cavern, multi-functional tools for quick solution mining of underground gas storages in salt cavern™, SSID-3 multishot oil(gas)/water interfacial analyzer™ and drilling & completion design



software for underground gas storages™. As a result, a series of technologies are developed, including the storage construction technologies in depleted oil/gas reservoir, aquifer and salt cavern, the pressure test for cavity sealing, sonar test and analysis, and the technology for stimulation analysis of safety operation of gas storages. A complete portfolio of technical services for underground storage engineering can be provided, including drilling and completion of underground storages, injection/production, blocking of existing wells, solution mining in salt cavern, gas injection and brine expelling, analysis and evaluation of solution cavity stability, upgrading and utilization of existing solution cavity.



Sketch map of solution mining for salt cavern gas storage



Sketch map of behavior developing of cavity in salt cavern

2.9 CNPC's proprietary technologies

Totally, 1,445 patents have been granted to the drilling sector of CNPC, including 195 invention patents.

Typical patents on drilling technologies
• Rotary head device in top driven drilling system.
• Braking tongs for auto-compensation gap in disc brake.
• Auxiliary brake in magnetic rheid drilling rig.
• Hydraulically expandable liner hanger.
• Near bit resistivity MWD technique and device.
• Wireless electromagnetic short transmission device.
• Technique and device for receiving and test of mud pressure pulse signals.
• Whipstock for casing sidetracking.
• Technique for whole process under-balanced drilling.
• Seating casing specially used for casing drilling.
• Cationic drilling fluid.
• HTHP core filtration meter.
• Machining technique of slotted screen.
• CBM wireline coring tool.
• Cavity pressure test method for gas storage in salt cavern.
• Jetting tool for solution mining.

3 TYPICAL CASES

3.1 Drilling in ultra-deep well Moshen-1.

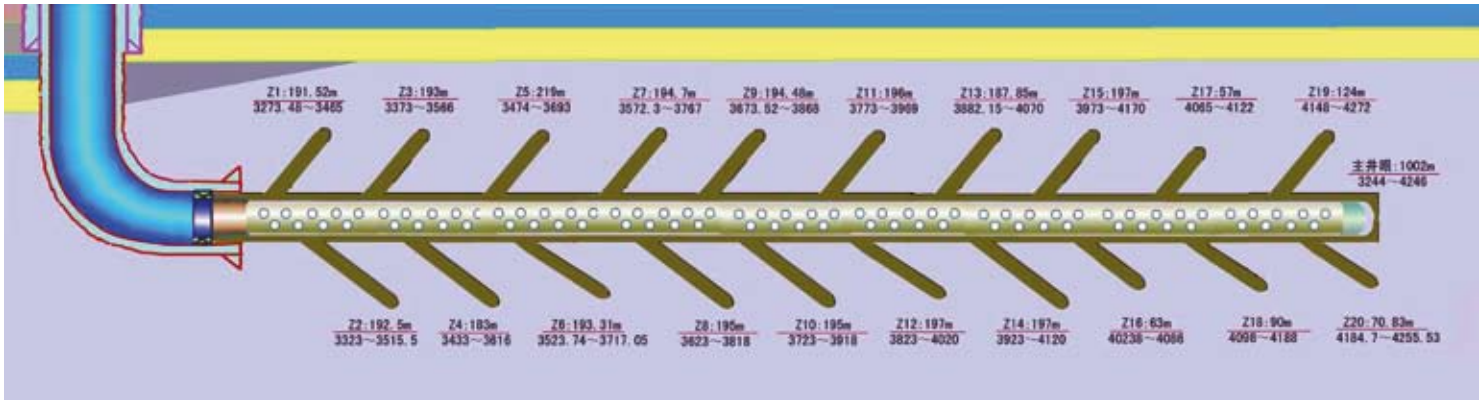
Well Moshen-1 is located in Mosowan area of central Junggar Basin, Xinjiang Uygur Autonomous, with features of high temperature and high pressure, high risk, difficult to be drilled. Drilling has been completed at the depth of 7,500m. It is an ultra-deep exploration well of CNPC.

Following equipments and systems have been used during drilling of Well Moshen-1: the first 9,000m A.C. variable frequency ultra-deep drilling rig which is developed independently in China, China-made 6,750 kN top drive with independent intellectual property, 4,000 hp single shaft winch, 2,200 hp drilling pump and high-temperature high-density water-base drilling fluid system. Successful drilling in this well demonstrates the world advanced level of CNPC's engineering technologies for ultra-deep drilling.

3.2 Application of horizontal drilling.

Well Jing-52-HIZ completed by CNPC has a complicated structure, and it is composed of 20 laterals. Its trunk wellbore has a footage of 4,246m. In the horizontal section, the trunk wellbore is 1,002m long; the footage of 20 fishbone laterals is 3,332m. The total footage is 7,578m, including 4,560m drilled in the buried hill. The trunk wellbore in the buried hill was completed by screen and the fishbone laterals were open hole completed.

In Xinjiang Oilfield, the shallowest horizontal well hqHW-001 was drilled successfully, with a vertical depth of only 126m. From directional drilling to precisely sidetracking into the window, it took only 20 hours and the problem of casing running in shallow horizontal wells was solved by using the



circulation pressuring device developed by CNPC.

3.3 Application of gas drilling in Longgang area.

Well Longgang-1 is a venture exploratory well drilled by CNPC in 2006. Gas drilling technologies were applied to raise the drilling rate, leading to the discovery of Longgang Gas field in the same year. As a result, significant geological discovery was fulfilled to speed up the development of unproued gas resources in the field and its productivity was established.

By means of scaled application of gas drilling, the exploration and development have been accelerated and the drilling rate has been increased. In 2007, 11 wells were drilled by gas drilling in Longgang area. The average drilling cycle was 187.1 days, 323 days less than that of conventional drilling technologies. As a result, a large oil/gas field was discovered in the upper Jurassic Formation in the area.

3.4 Application of casing drilling in Jilin Oilfield.

Well Dong-26-23.21 is located in Fuyu III structure, Jilin Oilfield, with a designed TD of 452m. The ordinary 5½" casing was used for casing drilling.

On 26th June 2008, the casing drilling technology developed by CNPC independently was applied to Well Dong-26-23.21 and the targets of short construction cycle and reducing drilling cost were

fulfilled (drilling cost savied by 10%-15%). Good results were obtained for reservoir protection.

3.5 Application of high temperature drilling fluid in Well Changshen-5.

As a venture exploratory well in the southern Songliao Basin, Well Changshen-5 is now the deepest well in Jilin Oilfield, with a designed TD of 5,400m at a bottom hole temperature of 22°C. The technical difficulties encountered for the drilling fluid used in drilling of the deep interval in Well Changshen-5 are mainly as follows.

(1) the most difficult problem in this well is the high geothermal gradient in the area, thermal stability of drilling fluid with high temperature, especially thermal stability at elevated temperature for a long time.

(2) for such a long open hole section and complicated formation, it is hard to compromise among sidewall stability, well control/killing and loss circulation control/blocking.

In Jilin Oilfield Company, high temperature water base drilling fluid was used for drilling of the deep interval of Well Changshen-5. Field application shows that the high temperature water base drilling fluid has successfully tackled the difficulties as mentioned above and satisfactory results have been obtained.

3.6 Application of cementing technologies with low density for long open hole interval to be isolated in Well Changshen-5.

In low density cementing and isolation of a long open hole interval, some problems exist, including the difficulty to control over cement thickening time, tendency of midway thickening, long thickening time, insufficient strength of set cement as a result of low density of cement slurry, long cement interval, formation prone to loss circulation and contamination, high displacement pressure, convenience to be bridged due to high filtration, low displacement efficiency and poor cementing quality.

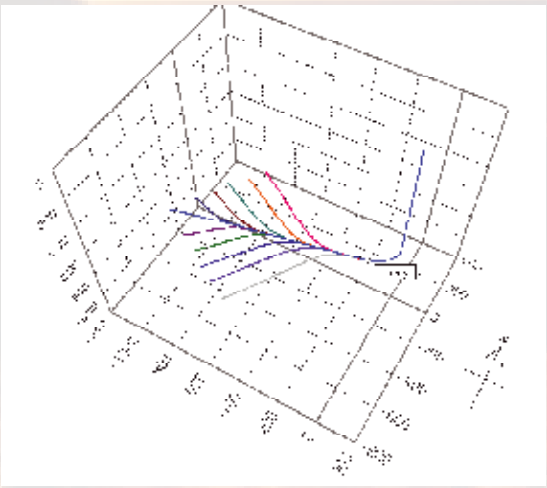
In Well Changshen-5, the 5,320m production casing was set and it was required to return the cement slurry to the wellhead. The open hole interval for the production casing was 1,950m long, the interval to be cemented and isolated at the first stage was 2,470m long and 2,850m long at the second stage. There was a large temperature differential between these two intervals (as at 77°C and 88°C respectively). At the first stage, latex cement slurry was used for cementing, a high-strength low-density (1.40-1.45g/cm^3) latex cement slurry for the upper

part and a latex cement slurry (1.83-1.88g/cm^3) for the lower part. 97.68% of the isolated interval is of high quality and the cementing over the whole well interval is acceptable.

3.7 Application of CBM drilling in Well Wu M1-1.

Well Wu M1-1 is a well pattern located at the southern slope of Ningwu Basin. It is composed of a multilateral horizontal well and a vertical gas producer.

In Well Wu M1-1, a trunk horizontal wellbore and 10 horizontal laterals were drilled actually, with a total footage of 7,993 m, drilled depth in the coal bed of 5,939m, coal bed encountering rate of 95%, drilling cycle of 49.58 days and an average ROP of 10.56 m/h. For this well, the trunk horizontal measured TD, vertical TD and coal bed encountering rate are high, up to the top level in China.



Sketch map of wellbore trajectory of Well Wu M1-1

3.8 Application of underground storage construction and engineering technology in Dagang area.

Dagang underground gas storage is the first underground natural gas storage in China, it is also an important part of Shaanxi-Beijing Gas Pipeline Project. Jintan salt cavern underground gas storage is the first one for gas storage in underground salt cavern, also an important part of the West-East Gas Pipeline Project.

At the end of 2008, the construction of a group gas storages have been completed in six depleted gas reservoirs, including Dazhangtuo, Ban-876, north high of Banzhong, south high of Banzhong, Ban-808 and Ban-828, with a preliminary capacity up to several BCM. In Jintan, the modification and utilization of six existing solution cavities have been completed in salt cavern and the first peak shaving has been finished for the gas storage. In addition, 15 new cavities have been drilled, with a maximum cavity volume up to 11×10^4 m^3.

4 R&D EQUIPMENT

CNPC owns more than 300 sets of various large lab instruments, apparatuses and equipments, such as multifunctional testers, SEM fatigue testers, tri-axial rock testers, HTHP thickening testers, liquid chromatography unit and tension testers for need in drilling R & D, with a newness factor of 0.8,

There are a number of drilling research institutes in CNPC, including a drilling research institute directly affiliated to CNPC, 12 regional drilling research institutes, a directly affiliated pipe research institute and a state engineering laboratory of oil/gas drilling technology.

The state engineering laboratory of oil/gas drilling technology is a CNPC affiliated national engineering lab, consisting of ten professional labs, three testing platforms, a product test & fabrication center and a center for commercialization test, manufacturing and inspection of petroleum drilling related products.

■ Ten professional labs

- Downhole measurement control lab;
- Lab on drilling fluid and reservoir protection;
- Managed pressure drilling lab;
- Lab on rock mechanics and sidewall stability;
- Lab on rock breaking and high pressure water jetting;
- Lab on drilling & well completion techniques;
- Drilling machinery & equipment lab;
- Lab on under-balanced drilling /gas drilling;
- Cementing lab;
- Offshore drilling lab.

SEM fatigue tester

Torsion tester

Multifunctional tester

Horizontal tension tester

- Three testing platforms
  - Simulation test platform for whole drilling process;
  - Test platform for drilling and well completion in complicated deep wells;
  - Test platform for drilling equipment and tools.
- A center for product commercialization test, manufacture and inspection.
- A center for commercialization test, manufacture and inspection of petroleum drilling related products.

Liquid chromatography unit

Tri-axial rock tester I

Tri-axial rock tester II

Tri-axial rock tester III

Thickening tester

5 QUALIFICATION AND STANDARDS

中国合格评定国家认可委员会
实验室认可证书
（No. CNAS L3386）

计量认证合格证书

资质认定
计量认证证书


CPAC
质量管理体系认证证书
GB/T19001-2000 idt ISO9001:2000
CNAS
IAF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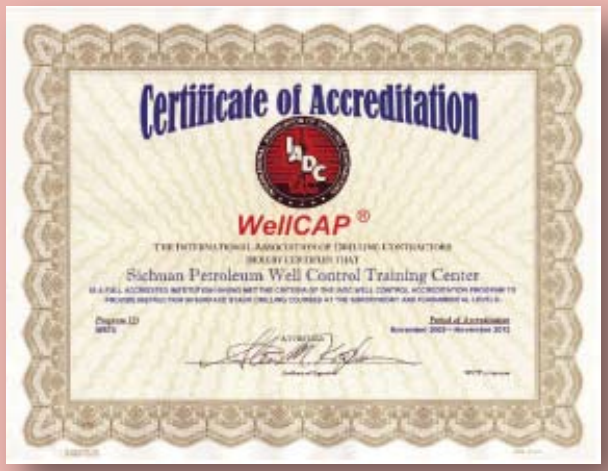
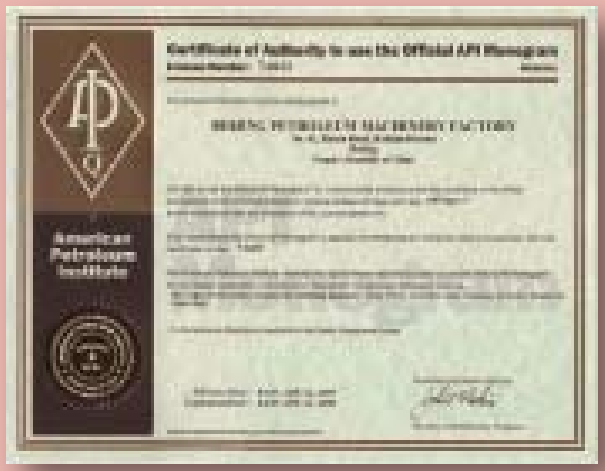

Certificate of Accreditation
IADC
WellCAP®
Sichuan Petroleum Well Control Training Center


American Petroleum Institute

6 SPECIALISTS

Sun Ning Drilling engineering expert. He was in charge of or participated in a lot of major projects such as drilling with optimized parameters, drilling of directional and cluster wells, horizontal drilling, sidetracked horizontal drilling, deep/ultra-deep drilling, gas drilling, and top driven drilling system.

Su Yinao Drilling engineering expert and academician of Chinese Academy of Engineering. He has been engaged for a long time in the research and application of drilling engineering technologies, and has many top-level internationally inventive achievements in his study on drilling mechanics, trajectory control and downhole tools, of which systems have been established in production and significant economic results are gained. He has proposed a novel research field in Downhole Control Engineering and is in charge of a series of leading research works such as geological steering. He has 23 patents granted, 7 works and more than 200 papers have been published.

Zhou Laifang Senior expert on drilling technologies. In 2007, he was granted with an EMBA as a major of global energy management in Huston University. As a visiting scholar in Willanmus Company in the U.S., he had a study on under-balanced technologies. For a long time, he has been engaged in research on drilling technologies as oriented primarily in the theory and technology on drilling and well completion of oil/gas wells.

Xu Shuqian Senior expert on drilling technologies. He is good at research and application of cement and additives for oil well cementing, cementing and well completion technologies, directional & horizontal drilling technologies and under-balanced drilling technologies. He was in charge of the preparation of several drilling programs for one-million-ton level new oilfields.

Zou Ye Senior expert on drilling technologies. He has been engaged in drilling operation, R & D as well as introduction and application of new technologies for more than 20 years. He has undertaken many R & D projects and new technology application.

Wu Xianzhu Senior expert on drilling technologies. He was in charge of several projects for research and application such as gas drilling and under-balanced drilling, organized and supervised the rescue activities in hash blowing out wells, including wells Du-1, Xin-851, Luojia-16H and Aosiman Well 3 in Turkmenistan, minimizing the loss.

Yun Zhishen Senior expert on drilling technologies. For a long time, he has been engaged in the research and application of drilling technologies in directional and horizontal wells, with ten more technical papers published.

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中国石油

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