



BH-WEI Drilling Fluid

Science & Technology Management Department, CNPC

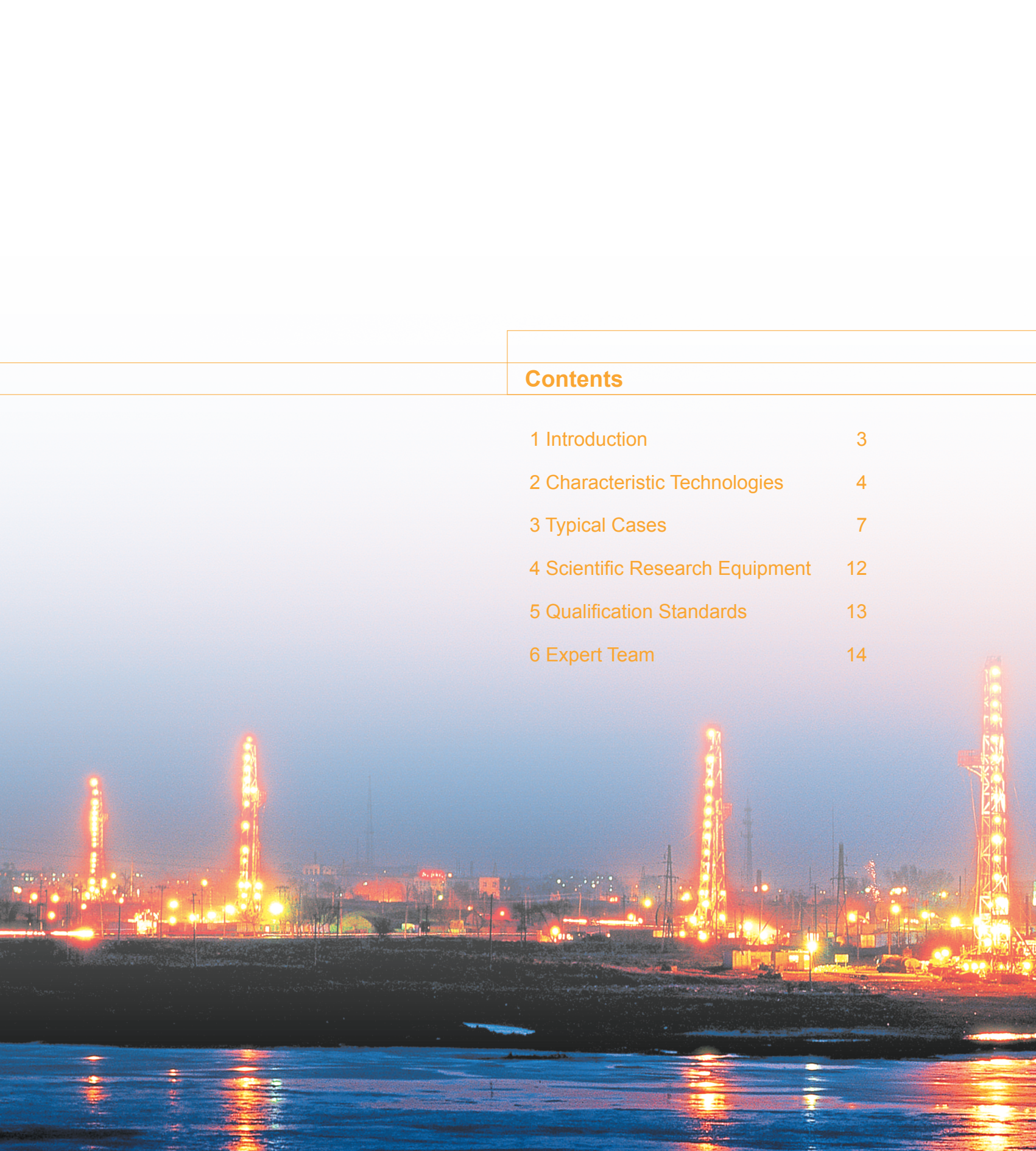
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CHINA NATIONAL PETROLEUM CORPORATION

*Optimal Drilling: Protecting Reservoirs,
Caring for the Environment,
Selecting BH-WEI Drilling Fluid!*





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CNPC

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 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 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 **BH-WEI drilling fluid** is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

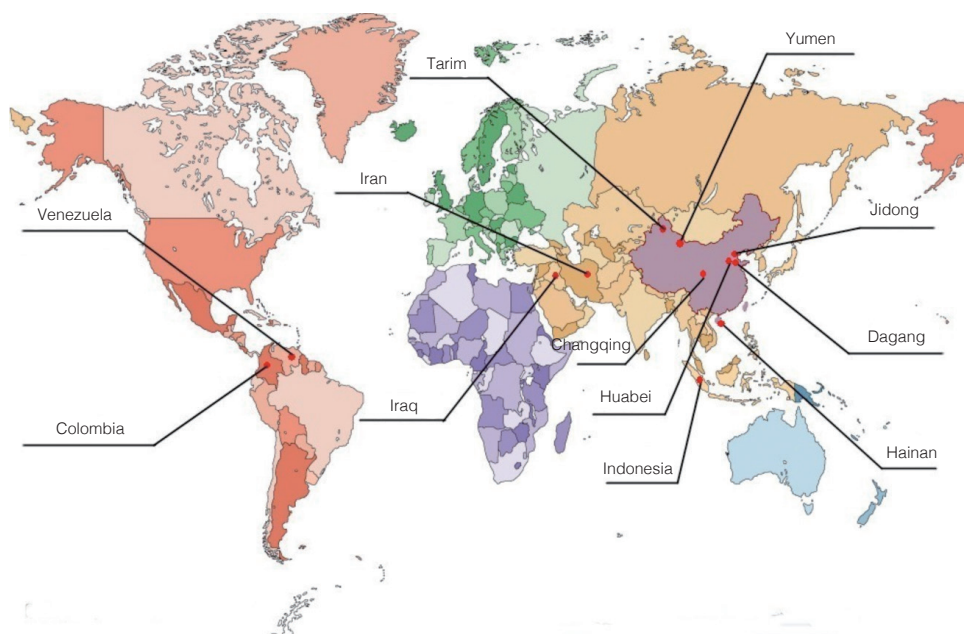
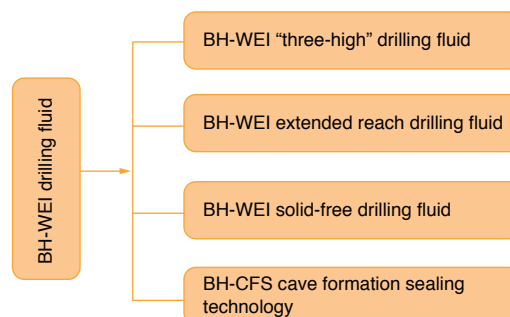
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INTRODUCTION

“BH-WEI drilling fluid” mainly aims at drilling operations in HTHP gypsum mudstone formations and horizontal well reservoirs in different regions as well as special complex formation wells, complex structure wells, deep wells and ultra-deep wells in environment sensitive regions and can realize integration of drilling fluid and complete fluid. BH-WEI drilling fluid can be recycled and is characterized by low comprehensive cost, reservoir protection, environment protection, safety drilling and scientific drilling.

According to the property features of BH-WEI drilling fluid and different technical service needs, the following technologies have been formed: BH-WEI “three-high” drilling fluid technology, BH-

WEI extended reach drilling fluid technology, BH-WEI solid-free drilling fluid technology and BH-CFS(BH-Cave Formation Sealing Technology). The technologies are widely applied in domestic markets such as Tarim oilfield, Dagang oilfield, Jidong oilfield, etc., and international markets such as Indonesia, Iraq, Venezuela, etc.



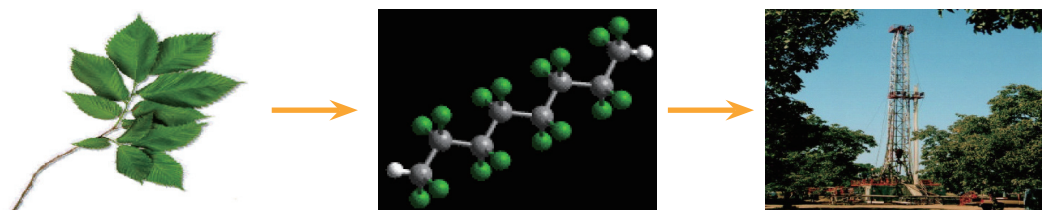
2 CHARACTERISTIC TECHNOLOGIES

2.1 BH-WEI “three-high” drilling fluid

BH-WEI “three-high” drilling fluid is a high performance water base drilling fluid system which is formed using high density inhibitive composite organic brine as the base fluid in cooperation with other additives. The drilling fluid is intended mainly to solve the technical problem on drilling fluid in complex formations involving large section salt gypsum, gypsum mudstone, high temperature, high pressure, etc.

Technical characteristics:

- ◆ Resistant to 220°C temperature; resistant to salt gypsum; density up to 2.60g/cm³;
- ◆ Bentonite-free mud preparation;
- ◆ Low solid content;
- ◆ Strong inhibitive anti-sloughing capacity;
- ◆ Good high temperature rheological property;
- ◆ Good reservoir protection effect; permeability recovery value $\geq 85\%$;
- ◆ Small corrosion; N80 steel corrosion rate 0.011mm/a in saturated brine;
- ◆ Environmentally friendly; the value of EC50 in both main additive and system formula of drilling fluid is larger than 30000mg/L.

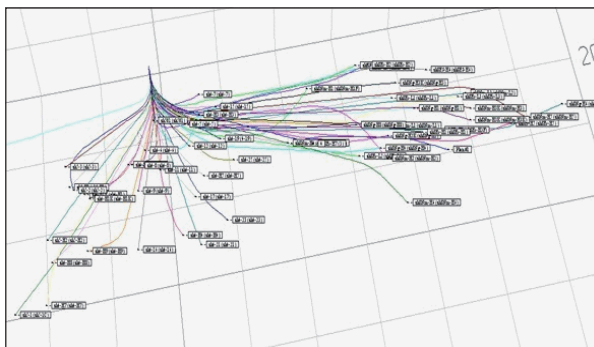


2.2 BH-WEI extended reach drilling fluid

BH-WEI extended reach drilling fluid technology is a drilling fluid technology which uses high performance water base drilling fluid system as the support and technical software prediction and monitoring as the means and is intended mainly to solve the technical problems involving large scope and extended reach well wall stability, hole purification, lubrication, anti-sticking, etc.

Technical characteristics:

- ◆ Drilling parameter design, tracking and guidance through simulation with software;
- ◆ Strong inhibitive and explosion-proof capacity;
- ◆ Good lubrication and anti-sticking effect; site well mud $K_f < 0.06$;
- ◆ Good suspension and sand carrying effect; $YP/PV \geq 0.5$;
- ◆ Good reservoir protection effect; permeability recovery value $\geq 85\%$.

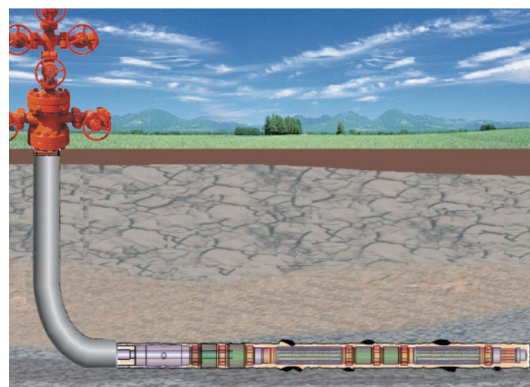


2.3 BH-WEI solid-free drilling fluid

BH-WEI solid-free drilling fluid is a drilling fluid system which is formed using high solubility soluble salt as the weighting agent in cooperation with other additives and used specially in construction of reservoir intervals of horizontal wells. With the open hole mud replacement technology and the drilling fluid, reservoir operations in horizontal wells without intermediate casing have been performed successfully; the technical problem on reservoir protection in horizontal wells has been solved; screen completion and on-stream without acid cleaning have been realized.

Technical characteristics:

- ◆ Drilling fluid density $1.03 \sim 1.55 \text{ g/cm}^3$ adjustable;
- ◆ No inert solid; strong inhibitive property;
- ◆ Permeability recovery value $> 90\%$;
- ◆ Low OWC tension;
- ◆ Integration of drilling fluid and completion fluid;
- ◆ Completion procedure reduction, low comprehensive cost.

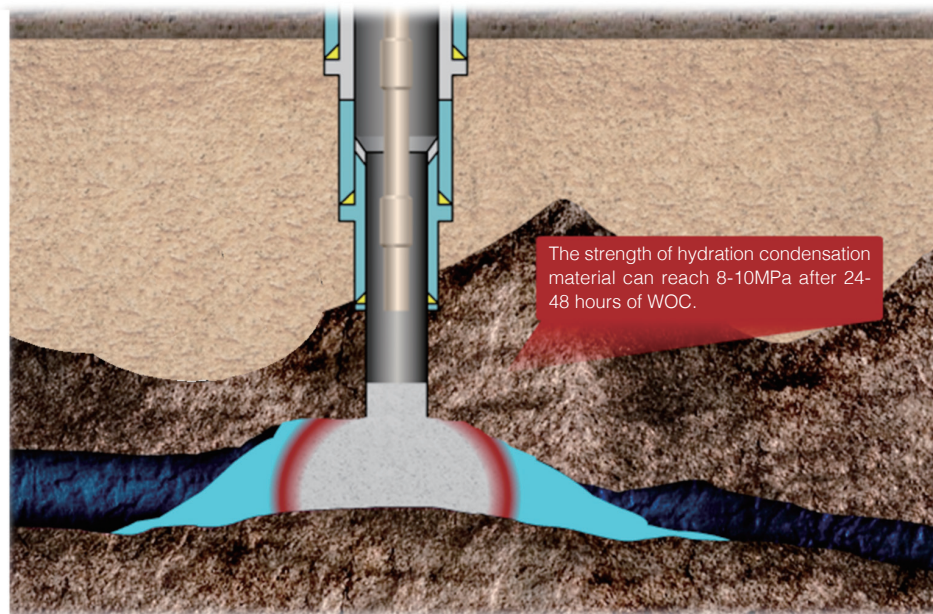


2.4 BH-CFS cave formation sealing technology

BH-CFS cave formation sealing technology is the static gelling fluid sealing technology composed of gelling sealing fluid and supporting fluid and is used mainly to solve drilling fluid lost return phenomena during serious leakage and drilling in limestone buried hill caves and large fractures.

Technical characteristics:

- ◆ Supporting fluid: isolate formation water from gelling sealing fluid and prevent sealing fluid from being diluted by formation water;
- ◆ Static gelling sealing fluid: flocculate with supporting fluid and form mixed gel plug with high static gelling shearing force at the interface, so that gel (fluid) doesn't collapse easily and a high steep slope sealing wall is formed;
- ◆ Balanced pressure displacement process: after leakage stoppage operation completion, hydrated condensates are in pressure balance state at the cave inlet and can neither leak into the deep part of the cave nor return into well bore above the cave;
- ◆ Applicable to various drilling fluid systems and different water qualities in different regions: add special flow type conditioning agent and lost circulation additive in common drilling fluid (water base) to prepare gelling sealing fluid and then carry out leakage stoppage;
- ◆ Resistant to 160 °C temperature; meeting the requirements of leakage stoppage in brine formations.



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TYPICAL CASES

(1) BH-WEI “three-high” drilling fluid was used in well WB-1 in Tali, Xinjiang, realizing “zero accident, zero leakage and problem and zero drilling fluid discharge”.

Well WB-1 is a risk exploration well in Kashgar piedmont region in Xinjiang. The well includes multiple sets of variable-thickness mudstone, salt rock, gypsum salt and gypsum mudstone formations; the upper part of the well is hydrated and dispersed extremely easily and causes serious mud making phenomena; hard and fragile mud shales in the deep part flake off and collapse easily, and salt rocks and gypsum mudstones easily lead to creep deformation and diameter shrinkage; the formation pressure is high and the designed density is up to 2.25g/cm^3 .

In the operation period from Aug. 15, 2010 to Dec. 27, 2012, BH-WEI “three-high” drilling fluid was used, realizing “zero accident, zero leakage and problem and zero drilling fluid discharge” for the well and eliminating hidden pollution discharge trouble. 5 times of electrical logging of the well succeeded at a time. The mid completion depth was 6677m, the open hole length 2045m, and the soaking time nearly 390d. 740m salt gypsum and gypsum mudstone complex formations were continuously penetrated; borehole wall was stable; operation was favorable. The cores from salt gypsum formations were integral, and the average hole diameter enlargement ratio was 7.4%.

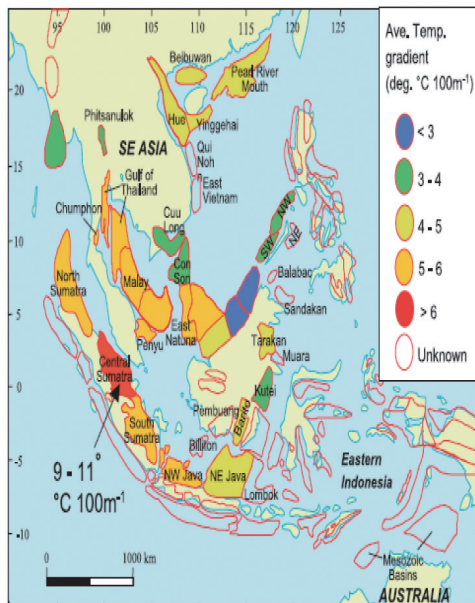


(2) BH-WEI “three-high” drilling fluid helped find the best oil and gas show of the block from well Madederop 1 in Madura Island, Indonesia.

Well Madederop 1 is a high risk key preparatory well in the northwest of Madura Island, Indonesia. The well is a directional well spudded four times. The inclination is 39°, the designed depth 2581.35m/2194.56m, the actual TD 2686.81m/2274.42m, and the well construction period 147 days. Kujung lower formation for the fourth spudding is a special formation where complex accidents occurred in all adjacent wells. The formation is characterized by easy occurrence of borehole wall instability, kick, blowout, lost circulation and sticking. The water for mud preparation used the wastewater in the pit and was treated by MI

SWACO. The Cl^- content was 1000mg/L, the Ca^{2+} content 120mg/L, the pH value 6.8, and the H_2S concentration 5~20ppm. The drilling fluid had pungent smell, and the highest H_2S concentration in the water pit was 200ppm.

During the fourth spudding, BH-WEI “three-high” drilling fluid was used to the TD, and no accident occurred. The oil and gas field was discovered at the same of successful drilling completion. 47 sections of fluorescent shows (totally 114.68m) were found in this well, including 46 sections (111.32m) found during the fourth spudding. In addition, the best oil and gas show of the block was found in Kujung formation. Completion electric logging was performed to bottom hole at a time, and the hole diameter enlargement ratio was only 4.7%.

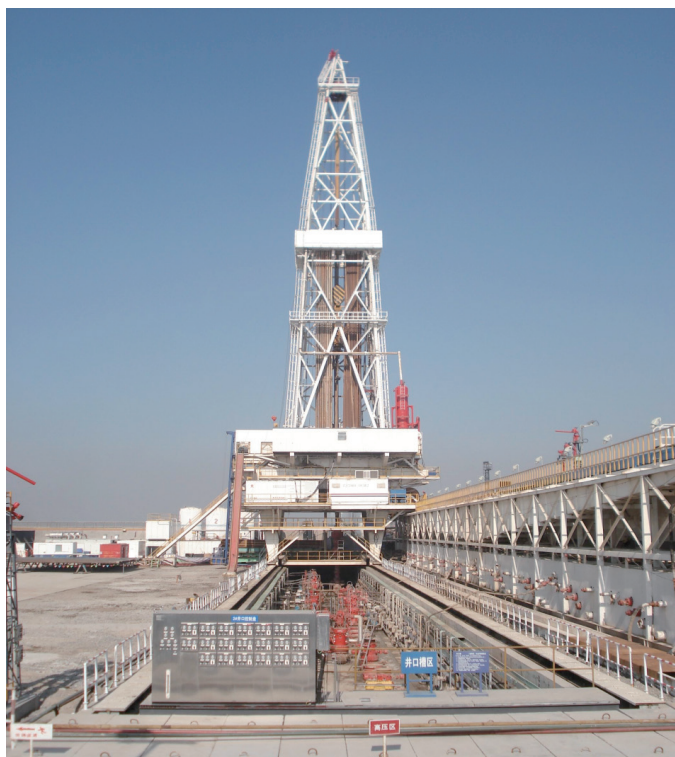


(3) The smallest casing friction record created with BH-WEI extended reach drilling fluid in well ZH8Nm-L9.

Well ZH8Nm-L9 is a shallow extended reach horizontal well in Chenghai area I of Dagang oilfield. The kick-off point of the well is 80m, the TVD 1075m, the inclined depth 3868m, the displacement 3231.22m, the maximum inclination 89.6°, and the ratio of the horizontal displacement to the vertical depth 3.01. The strata of the well all are Minghuazhen mudstones and are characterized by bad diagenesis, serious dispersibility and mud making phenomena and easy diameter shrinkage, blockage and sticking. The directional kick-off point is shallow and

the horizontal section length is 2400m. Downhole friction was large, thus easily leading to difficult slide steering and blockage and sticking during casing running.

In the operation period from Apr. 20, 2013 to May 4, 2013, BH-WEI extended reach drilling fluid was used, no safety accident occurred, there was no backing pressure during directional operation, and tripping was smooth. Especially the measured and calculated friction during simulation of completion and casing running reached 0.08. The smallest friction record has been created since operation in Chenghai area I. This has ensured successful screen running at a time.

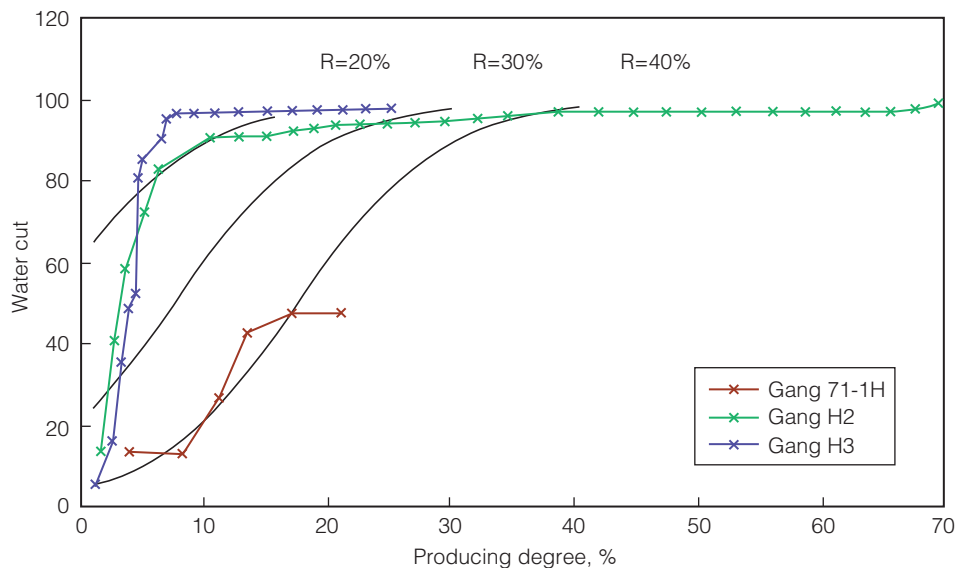


(4) Acid cleaning-free technical services for well Gang-71-1H with BH-WEI solid-free drilling fluid.

Well Gang-71-1H is a horizontal development well in Tangjiahe region in Dagang oilfield. The TD of the well is 2319m, the bottom hole displacement 894.73m, and the maximum inclination 92.4°. To increase the ultimate recovery ratio of the well, BH-WEI solid-free drilling fluid was used from Oct. 15, 2009 to Oct. 18, 2009. After entering the window, the original drilling fluid was directly replaced with this drilling fluid in the open hole section, thus reducing a layer of casing run in hole. After completion, the

drilling fluid was directly used as the completion fluid for production test without acid cleaning, thereby improving production operation time efficiency and reducing secondary pollution to reservoirs caused by non-thorough acid cleaning.

In the test production stage of the well, an 8mm choke was used, with the daily oil production of 57.78t and the daily gas production of 1700m³. Under the same geologic conditions, the recovery ratio was increased by 200%, the oil discovery time was shortened by 55%, the single-well oil production was increased by 13.7 times, and the permeability recovery value reached 92.16%.



Relation curve of water cut vs. producing degree of comparable wells in xx oilfield

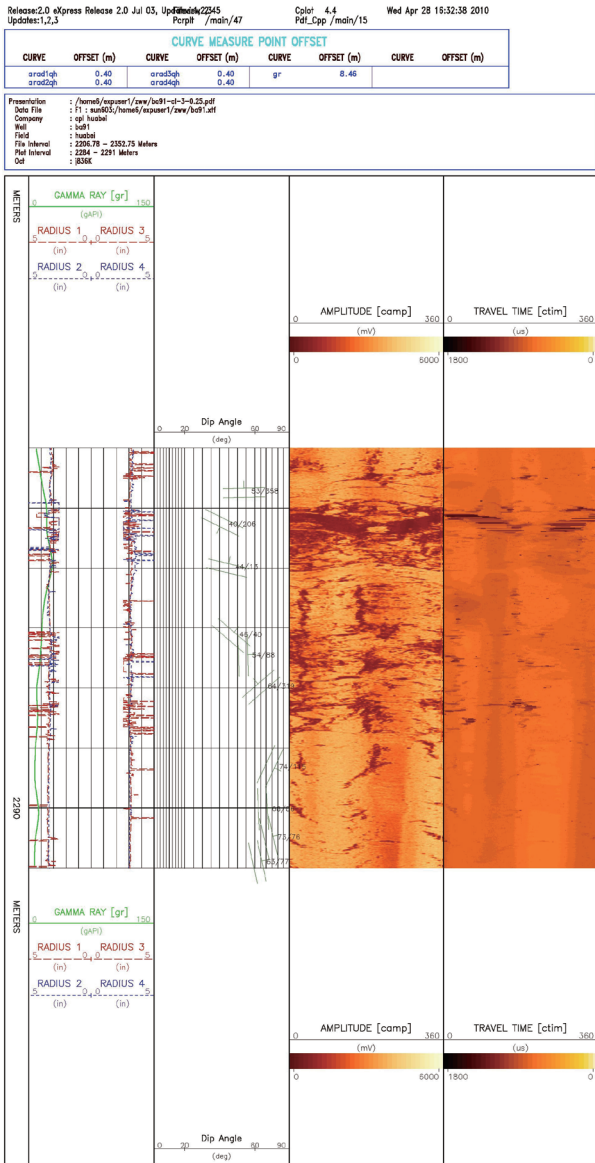
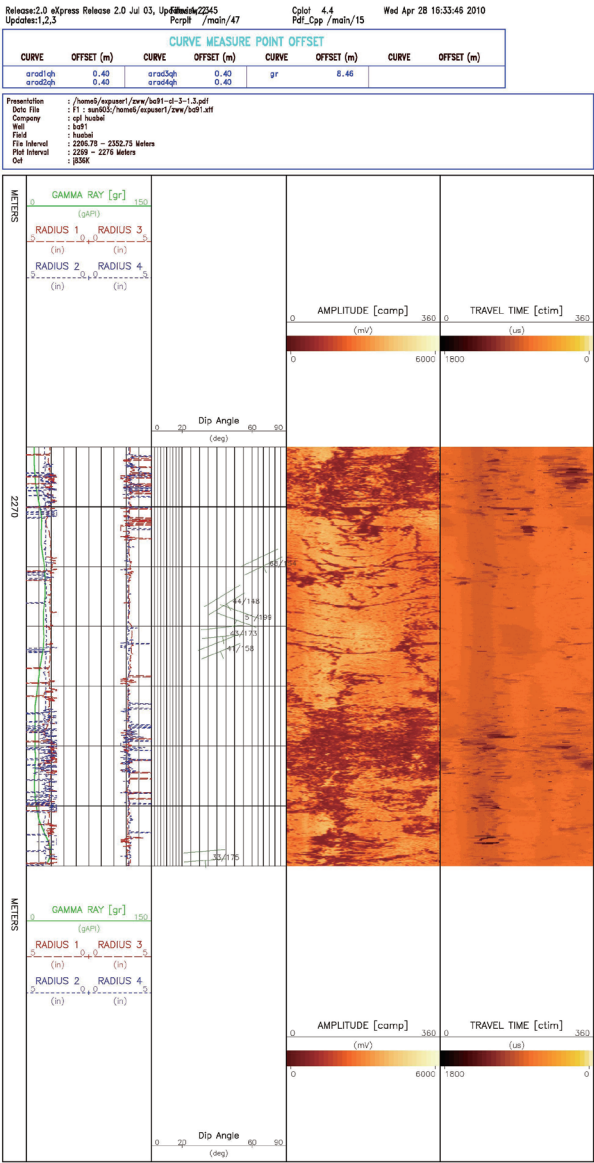
(5) Technical services for well Ba-91 with BH-CFS cave formation sealing technology.

Well Ba-91 is a preparatory well on Ba-35 buried hill high part of Ertaijie Longhuzhuang structural belt in Baxian sag. On Mar. 12, 2010, the well was drilled to 2237m, lost circulation occurred, and lost returns were found at the wellhead. The well was still drilled to 2350m, and the cumulative loss was 3299m³. After

no return was found at the wellhead through many times of leakage stoppage, a decision was made on ascertaining downhole conditions through logging and then carrying out leakage stoppage. According to the logging result, the well had a 0.6m thick cave at 2239.5m, a 0.95m thick cave at 2253.05m and a 0.8m thick cave at 2258.3m and multiple fractures. The static gelling cement slurry sealing method was

used: firstly inject the supporting slurry with high structural viscosity to function in supporting; then add prepad fluid. Then static gelling cement slurry was injected as solidified fluid, so that the plug surface was controlled to be at around 120m above the first leakage zone. The plug surface was probed

at 1940m after 48h. When drilling to the original well depth, the drilling fluid at the wellhead returned normally. BH-CFS cave formation sealing technology was used in leakage stoppage operation, and 3 large leakage caves and multiple large leakage fractures were successfully plugged.



4 SCIENTIFIC RESEARCH EQUIPMENT



R&D and testing of drilling fluid additives

CNPC has perfect drilling fluid system (drilling fluid additive) R&D and technical service systems, professional drilling fluid experiment buildings and over 260 pieces (sets) of domestic and foreign advanced instruments and equipment.



Malvern zeta potential particle size analyzer Zetasizer Nano



Brookfield viscosimeter DV-II+Pro



Haake rotational rheometer RS6000



Waters high-performance liquid chromatograph HPLC 2650

5 QUALIFICATION STANDARDS

CNPC has multiple qualification certifications in R&D of drilling fluid and drilling fluid additives with proprietary intellectual property rights and has formed a large number of industrial and professional technical specifications and obtained 6 patents.



6

EXPERT TEAM



Luo Pingya

Academician of the Chinese Engineering Academy. He has organized and completed “Continued Engineering Education in Reservoir Protection Technology”, proposed the theory of high temperature water base mud for deep wells, worked out series high temperature water base mud matching technologies for deep wells and amphoteric ion polymer mud systems and studied and developed reservoir protection drilling and completion technologies. The “shielding type temporary plugging” series technologies successfully developed by him have been widely applied in China.

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Huang Daquan

Professor level senior engineer. He has been long engaged in R&D of drilling fluid additives and study, popularization and management of new technologies. He has successively taken charge of multiple scientific research projects such as “Research on High-inclination and Extended Reach Drilling Fluid Technology”, “R&D of High Temperature Resistant Oil-in-Water Drilling Fluid Technology”, “Drilling Fluid Technology for Chemical Borehole Wall Reinforcement and Reservoir Protection and Its Industrial Application”, etc.

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Zhang Minli

Senior engineer. He has been long engaged in application of site drilling and drilling fluid technologies and study, popularization and management of new technologies. He has successively taken charge of multiple scientific research projects such as “Study and Application of Drilling Fluid Technology for Deep and Ultra-deep Wells”, “Study and Application of BH-WEI Drilling Fluid Technology”, “Borehole Wall Stability Mechanism Analysis and Countermeasure Research In TZ40 Block”, etc.

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**Zhao Fuxiang**

Professor level senior engineer. He is engaged in drilling technology, drilling fluid and cementing technology research work. He has successively taken charge of multiple scientific research projects such as “Research on Matching Drilling Technologies for Deep and Ultra-deep Wells”, “Research on Cave Formation Sealing Technology”, “Research on Releasing Stuck Agent”, “WSI-O₂ Type CO₂ Corrosion Inhibitor”, etc.

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Senior engineer. He is engaged in drilling fluid technology research and popularization and management of new technologies. He has successively taken charge of multiple scientific research projects such as “Popularization and Application of Drilling Fluid Technology for Reservoir Protection”, “Research on Drilling Fluid Technology for Extended Reach Wells”, “Research on High Temperature and High Density Oil Base Drilling Fluid Technology”, etc.

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**Dong Dianbin**

Senior engineer. He is engaged in drilling fluid technology research, new technology popularization and site technology management in the international market. He has successively taken charge of multiple scientific research projects such as “Study and Application of Saturated Brine Resistant Drilling Fluid Technology”, “Drilling Fluid Technology Applicable to High Pressure Salt Gypsum Formations in Halfaya Oilfield”, etc.

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