

# **DREMWD CBM Drilling Geosteering System**

Science & Technology Management Department, CNPC

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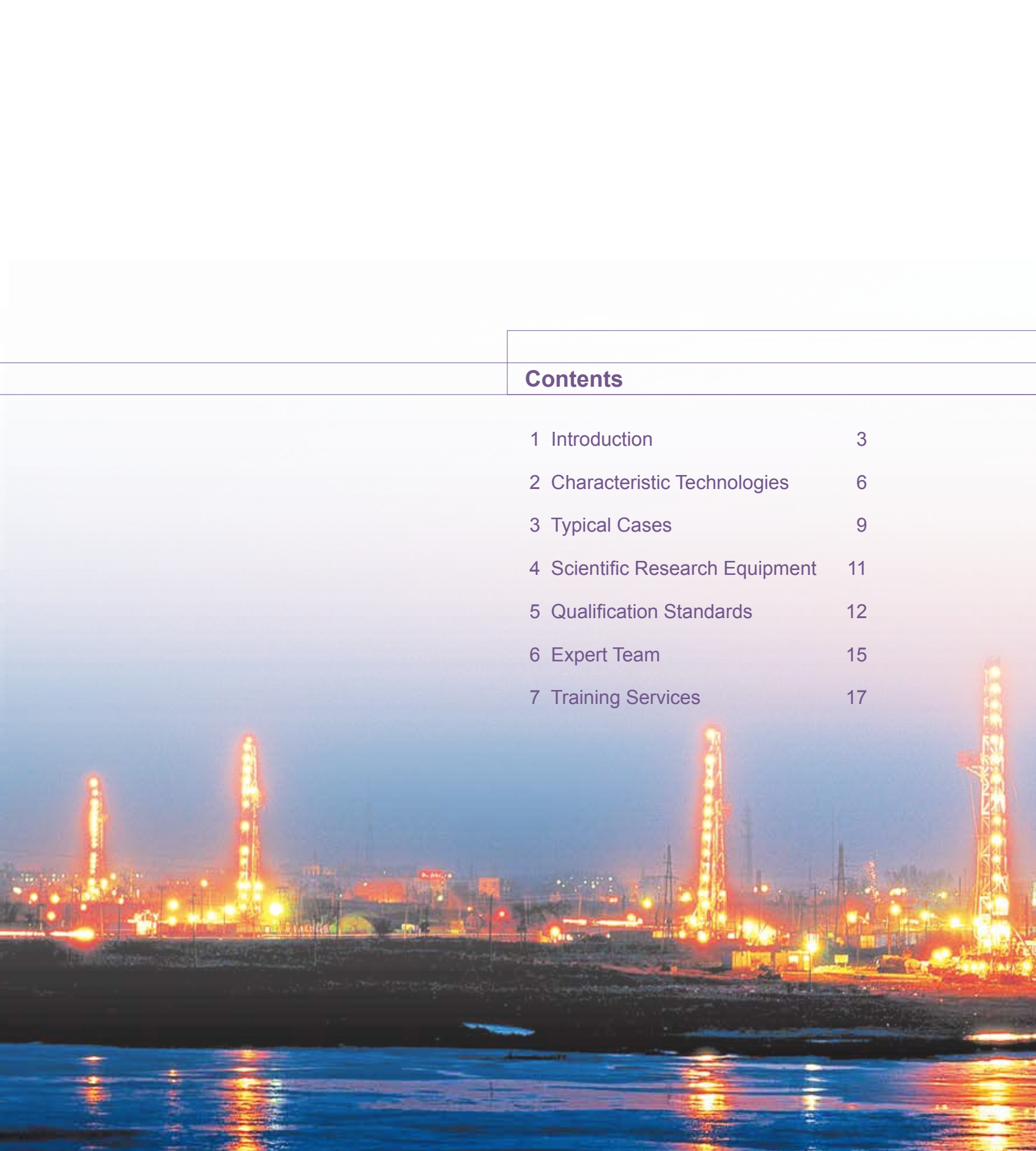


CHINA NATIONAL PETROLEUM CORPORATION

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*DREWD Remote Intersection: Realizes  
Accurate Steering of CBM Development!*





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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.

**DREMWD CBM Drilling Geosteering System** is one of representatives for major innovations of CNPC.

## OFFERING ENERGY SOURCES, CREATING HARMONY



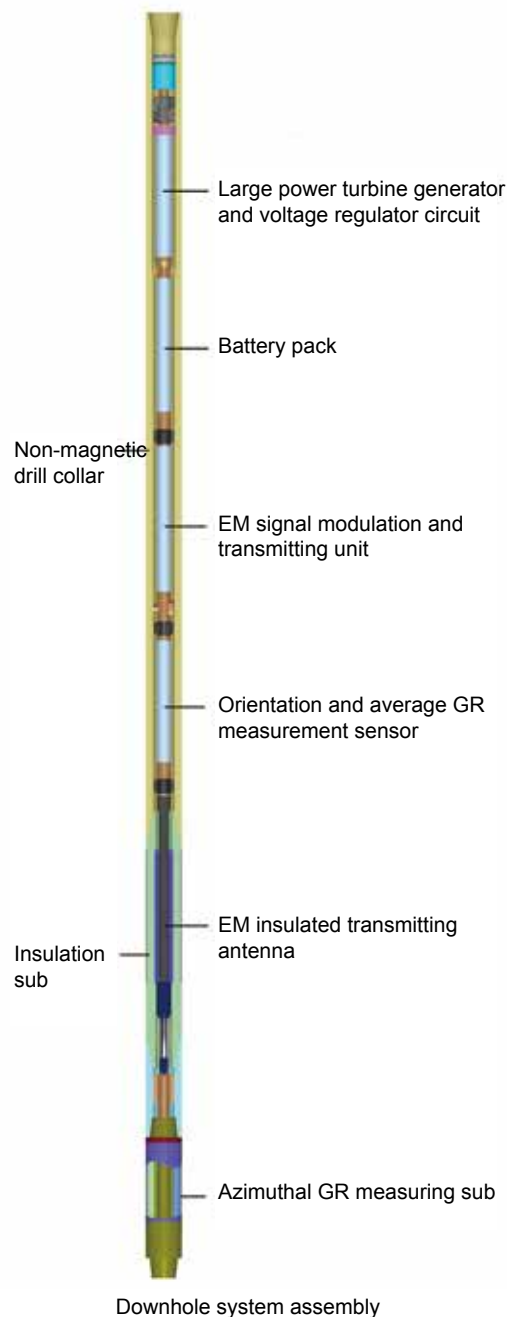
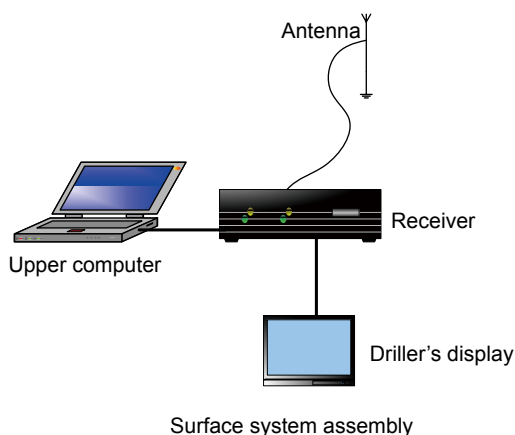
# 1

## INTRODUCTION

CBM drilling requires high-efficiency and low-cost MWD and geosteering tools to meet the economic demand of scale development of CBM.

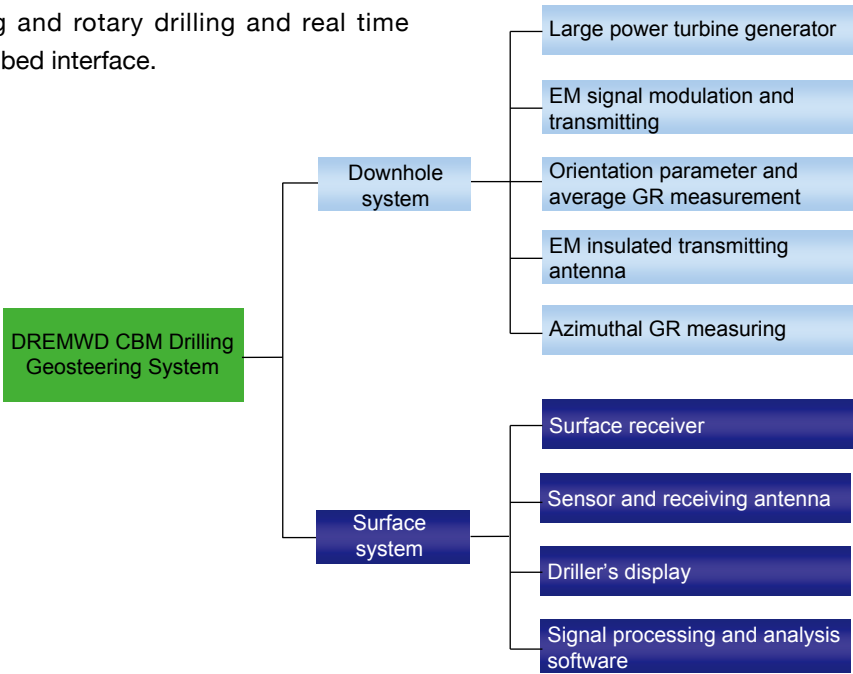
The CBM drilling (electromagnetic transmission channel) geosteering system (hereinafter abbreviated to DREMWD system) of CNPC has advantages including extensive application medium range, quick signal transmission rate, low field application failure rate, etc. as well as real time measurement function of well trajectory and geologic parameters, and ensures that the actual hole penetrates through coal beds and obtains the best position. The DREMWD system increases drilled ratio to the greatest extent possible and is a powerful tool for CBM drilling geosteering.

The DREMWD system consists of two major parts such as downhole part and surface part. The system has two major functions such as MWD and real time transmission and can measure the engineering parameters such as inclination, azimuth, tool face angle, etc. as well as orientation and average GR geologic parameters while drilling. The data transmission rate of the system is 3.5~11bit/s, and the well depth of relay-free transmission is no less than 2500m. The system has two major technical advantages: (1) the system uses downhole large power



(6000W) generator technology, low-frequency self-adaptive signal emitter and unique data modulation and detection technology, the relay-free transmission depth capacity is strong and the data uploading rate is high; (2) the GR dynamic MWD technology is used, which can realize real time azimuth measurement in sliding drilling and rotary drilling and real time judgment of coal bed interface.

The DREMWD system has been industrialized and has three specifications such as 6<sup>3</sup>/<sub>4</sub>in, 4<sup>3</sup>/<sub>4</sub>in and 3<sup>1</sup>/<sub>2</sub>in. The system has been popularized and applied in Zhengzhuang block in Shanxi and Hannan block in Shanxi, etc., and has obtained good effects.



DREMWD 系统技术指标

|  |   |
|--|---|
| Nominal size   | 3 <sup>1</sup> / <sub>2</sub> " , 4 <sup>3</sup> / <sub>4</sub> " , 6 <sup>3</sup> / <sub>4</sub> " |
| Orientation parameter measurement range and accuracy | 0°~180° ±0.1°, 0°~360° ±0.5°, 0°~360° ±0.5°   |
| GR measurement range and accuracy                    | 0 ~ 250API±3%FS (Double natural GR sensor)  |
| Data transmission rate                               | 3.5 ~ 11bit/s   |
| Relay-free transmission well depth                   | > 2500m   |
| Working pressure and temperature                     | 100MPa, 125℃  |
| Generator output power                               | 100 ~ 600W  |
| Mud/gas displacement                                 | 5 ~ 50L/s, 30 ~ 100m <sup>3</sup> /min  |



Part of downhole measurement tools and surface devices



Generator, directional probe, EM signal transmitting unit, drill collar insulation transmitting antenna, azimuthal GR sub, etc



Surface signal receiver, upper computer and driller's display



DREMWD system at the product release site

# 2

## CHARACTERISTIC TECHNOLOGIES

### 2.1 Design and manufacturing technology for downhole insulated electric dipole transmitting antenna

- The downhole insulated electric dipole transmitting antenna is the core component for establishing EM transmission channels.
- Composed of insulated drill collar type dipole and two-segment conventional nonmagnetic drill collar.
- The difficulty is meeting the requirements of both drill collar insulation (resisting torsional degree over 20kNm) and ensuring strength and resisting erosion.

- 1 enterprise technology secret (DRJSMM2011001) and 6 utility model patents obtained.



### 2.2 Downhole large power turbine generator technology

- The turbine generator consists of diversion stator, driving rotor, contactless magnetic coupler, body, filtering voltage regulator circuit, etc.
- The maximum output of a single generator is 600W; over 2 generators can be used in groups.
- Applicable to drilling circulation media such as conventional mud, aerated or foam mud, gas,

etc.

- Provide sufficient electric energy to downhole instruments and EM signal transmitting, increase relay-free uploading depth of downhole signals, and have the potential of further increasing relay-free uploading depth.
- 1 enterprise technology secret (DRJSMM2011002), 1 invention patent (ZL2008101146325) and 7 utility model patents obtained.



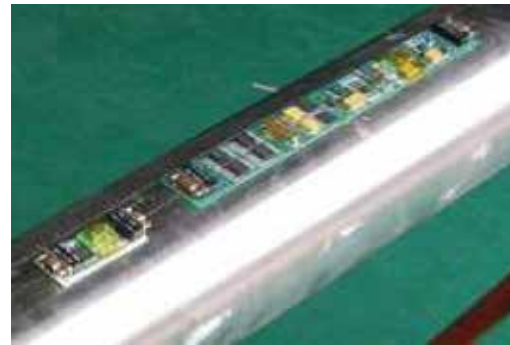
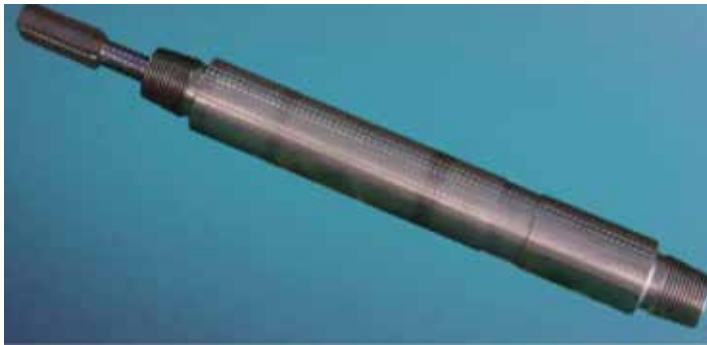


### 2.3 Downhole rotary dynamic azimuthal GR MWD technology and device

- The device consists of mainly GR and roll angle sensor, signal processing circuit, etc.
- Measure the upper and lower GR values in reverse and identical directions with the gravity field in real time; judge reservoir interface and

determine the position of hole in reservoirs; ensure that a bit runs in reservoirs all the time and remarkably increase the drilled ratio of reservoirs.

- 1 enterprise technology secret (DRJSMM 2011006), 1 invention patent (ZL200810114633X) and 2 utility model patents obtained.



### 2.4 Downhole low-frequency signal self-adaptive transmitting technology and device

- Low frequency signals are transmitted, thus reducing high-frequency EM signal attenuation caused by formations and increasing EM signal transmission depth;
- The voltage of the EM signal transmitted by the device can vary with the resistivity of the drilled formation. When drilling high resistivity formation, high voltage signals are transmitted; when

drilling low resistivity formation, high current signals are transmitted. The device adapts to a wide formation resistivity variation range, thus remarkably improving EM signal transmitting efficiency;

- The unique coding structure can minimize code length, thus increasing data uploading rate;
- 2 enterprise technology secrets (DRJSMM 2011003, DRJSMM2011004), 2 invention patents (ZL2008101146344, ZL2008101148176) and 2 utility model patents obtained.

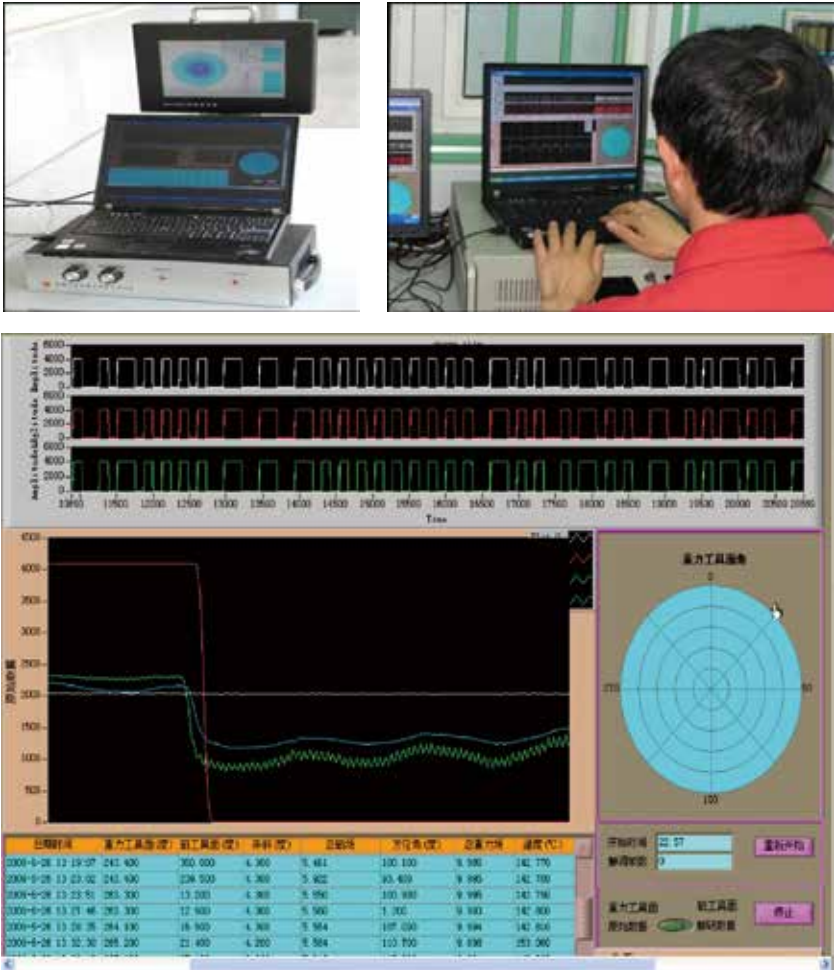


2.5 Surface feeble signal detection technology and device

- The device consists of mainly surface receiving antenna, signal receiver, upper computer and driller's display;
- What is unique lies in the fact that the surface receiving antenna uses the double models

including voltage field and current field for detection and collaborative work, thereby remarkably increasing the capacity of weak signal detection and decoding;

- 1 enterprise technology secret (DRJSMM2011005) and 4 utility model patents (ZL201020985700) obtained.



# 3

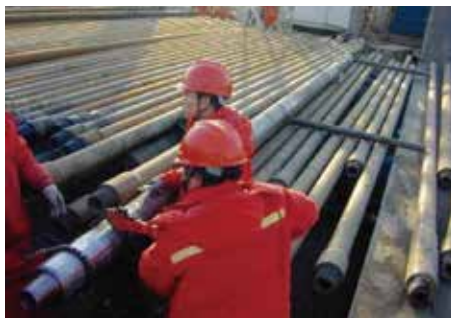
## TYPICAL CASES

### 3.1 The footage of well Z4P8H was 1491m within one round trip, thus reducing drilling time by 17h.

From Apr. 30, 2012 to May 5, 2014, 4.75in DREMWD CBM drilling geosteering system was successfully applied in well Z4P-8H in Shanxi. The well is a CBM multi-branch horizontal well in Zhengzhuang block of Qinshui CBM field in the south slope of Qinshui basin. Due to complex formations and short construction period, it was required to minimize POOH times and improve drilling efficiency during operation. The whole-section geosteering operation of one main hole and two branches was completed each time of RIH with the DREMWD system, with the continuous working time of 112h and the total horizontal section footage of 1491m. Compared with conventional mud pulse MWD system, the DREMWD system saves drilling time by 15%.



Downhole tool tripping out of wellhead



System test before RIH

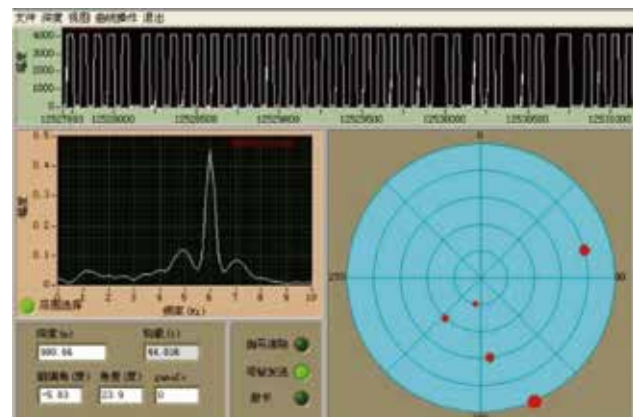
### 3.2 99% drilled ratio of thin coal reservoirs in well HLP1H

In Jun. 2012, 4.75in DREMWD CBM drilling geosteering system was used to complete field operation of HLP1H CBM horizontal well in Shanxi. Due to thin coal beds, it was required to ensure high drilled ratio of coal beds, and geosteering operation was difficult. During drilling, the azimuthal

GR measurement sub was connected at the bottom of the downhole tool and directly with PDM, and the GR measurement point was 5.6m from the bit, thus ensuring real time judgment of upper and lower boundaries of coal beds. The DREMWD system worked stably and was run in hole continuously for 6 times to complete the geosteering operation in the horizontal section, with the cumulative footage of 1185m and the drilled ratio of coal beds up to 99%.



Tool RIH



Surface system signal processing and display interface



# 4 SCIENTIFIC RESEARCH EQUIPMENT

National engineering laboratory for oil and gas drilling technology, CNPC key drilling engineering laboratory and large experiment equipment and instrument detection equipment with world advanced

level provide good test environment and scientific research equipment support to R&D of DREMWD CBM drilling geosteering system.



Full-scale drill collar insulation medium high-temperature test chamber



"Triaxial co-vibration + temperature" composite test system



Impact test system



Triaxial position and velocity rotary table



Triaxial nonmagnetic simulation rotary table

# 5

## QUALIFICATION STANDARDS

### Qualification

CNPC Drilling Research Institute passed ISO9001 quality management system certification in 2011 and is qualified in oil, natural gas and CBM drilling engineering technology and equipment development and service.



### Standards

Strictly carry out relevant API standards, national standards, industrial standards, enterprise standards, etc. during technology and equipment development and service.



### Enterprise technology secrets and patents

DREMWD CBM drilling geosteering system has 16 enterprise technology secrets, 4 national invention patents and 21 utility model patents.

## List of enterprise technology secrets and national patents

| No.                            | Name of technology secrets and patents  | Identification No. and patent No. |
|--------------------------------|---|-----------------------------------|
| Enterprise technology secrets  |   |                                   |
| 1                              | Design and manufacturing technology for downhole insulated electric dipole transmitting antenna | DRJSMM2011001                     |
| 2                              | Large power (600W) downhole generator technology applicable to drilling circulation media       | DRJSMM2011002                     |
| 3                              | Downhole low-frequency signal transmitting technology   | DRJSMM2011003                     |
| 4                              | Self-adaptive regulating circuit applicable to formation resistivity variation                  | DRJSMM2011004                     |
| 5                              | Surface weak signal receiving technology  | DRJSMM2011005                     |
| 6                              | Downhole rotary dynamic azimuthal GR MWD technology   | DRJSMM2011006                     |
| 7                              | Manufacturing technology for insulating wear layer of insulating dipole                         | DRJSMM2011007                     |
| 8                              | Surface receiver signal filtering and amplification, DSP digital filtering circuit              | DRJSMM2011008                     |
| 9                              | Filtering, voltage stabilizing and conversion control circuit of generator                      | DRJSMM2011009                     |
| 10                             | EM emission guide rod structure   | DRJSMM2011010                     |
| 11                             | Sensor interface and signal modulation circuit  | DRJSMM2011011                     |
| 12                             | Gas and liquid driven turbine design method   | DRJSMM2011012                     |
| 13                             | Surface weak signal power spectrum demodulation technology                                      | DRJSMM2011013                     |
| 14                             | Generator magnetic coupling technology design and manufacturing technology                      | DRJSMM2011014                     |
| 15                             | Surface current field receiving antenna   | DRJSMM2011015                     |
| 16                             | Electric energy distribution and control technology for downhole power supply system            | DRJSMM2011016                     |
| National invention patents     |   |                                   |
| 1                              | A coding and decoding method for downhole information transmission                              | ZL2008101146344                   |
| 2                              | A self-adaptive downhole information transmission method and system                             | ZL2008101148176                   |
| 3                              | A near-bit geosteering detection system   | ZL200810114633X                   |
| 4                              | A downhole power generation device  | ZL2008101146325                   |
| National utility model patents |   |                                   |
| 1                              | A downhole wireless EM transmitting device  | ZL2008201085079                   |
| 2                              | An insulated dipole wireless transmitting antenna while drilling                                | ZL2008201086461                   |
| 3                              | A high speed transmission and transmitting device for measurement while drilling                | ZL2010202985823                   |
| 4                              | A calculation system for EM MWD tool  | ZL2012205056974                   |
| 5                              | An insulation sub for EM MWD system   | ZL2012205601311                   |
| 6                              | Downhole measurement information transmission system  | ZL2012206174573                   |
| 7                              | An AC generator set for downhole MWD  | ZL200820108505X                   |
| 8                              | Liquid driven turbine for downhole generator  | ZL2008201080840                   |
| 9                              | A turbine generator for gas drilling  | ZL2010202980618                   |
| 10                             | A downhole turbine generator system   | ZL2012201043602                   |
| 11                             | A downhole generator set  | ZL2012203609643                   |
| 12                             | Downhole generator for drilling instruments   | ZL2012202680275                   |
| 13                             | A downhole generator set  | ZL2012203613827                   |
| 14                             | An electrical connection device for measurement while drilling                                  | ZL2011204767391                   |

to be continue

| No. | Name of technology secrets and patents                                  | Identification No. and patent No. |
|-----|---|-----------------------------------|
| 15  | A direct insertion structure for downhole instrument sub while drilling | ZL2012200602021                   |
| 16  | A transmitting coil and magnetic core for measurement while drilling    | ZL2008201085115                   |
| 17  | A downhole wireless EM signal transmitting device while drilling        | ZL2008201085149                   |
| 18  | A current field receiving antenna device for measurement while drilling | ZL2008201085064                   |
| 19  | A surface signal downloading system                                     | ZL2008101085134                   |
| 20  | A surface signal receiving instrument for EM measurement while drilling | ZL2010202985700                   |
| 21  | A downhole two-way data transmission system                             | ZL2012202770943                   |



Identification certificates of part technology secrets



Invention patent certificates



# 6

## EXPERT TEAM



**Su Yinao**

Oil and gas drilling engineering expert, Academician of the Chinese Engineering Academy, Ph.D. candidate supervisor. He has been long engaged in the study and application of drilling technology. His multiple research achievements in drilling mechanics, trajectory control, downhole instruments and tools, etc. reach the international advanced level.

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**Sheng Limin**

Professor level senior engineer, Ph.D. candidate supervisor. He has been long engaged in R&D of MWD and steering control technology and equipment for oil and gas drilling. He has obtained multiple national, provincial and ministerial science and technology prizes.

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**Li Lin**

Professor level senior engineer. He has been long engaged in the study of MWD and downhole information transmission channel technologies and instruments for oil and gas drilling. He has obtained multiple national, provincial and ministerial science and technology prizes.

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**Deng Le**

Professor level senior engineer. He has been long engaged in R&D of MWD instruments and automatic steering control tools for oil and gas drilling. He has obtained multiple national, provincial and ministerial science and technology prizes.

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**Wang Jiajin**

Senior engineer, winner of the Twelfth China Youth Science and Technology Prize. He has obtained multiple research achievements in geosteering drilling, comprehensive processing of MWD information, surface software development, etc. as well as national and ministerial science and technology prizes.

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**Peng Liexin**

Senior engineer. He has obtained multiple scientific research achievements in petroleum instruments and meters, wireless communication, measurement and control, automatic control technology, etc. Dozens of papers written by him have been published.

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# 7

## TRAINING SERVICES

CNPC provides high quality training and services to DREMWD CBM drilling geosteering system users:

- Provide system operation and routine maintenance technology services via telephone, network, etc.;
- Provide detailed system operation manuals and maintenance manuals (Chinese and English versions);
- Provide users with technical training and site guidance;
- Ensure long-term supply of conventional components and consumables;
- Timely reply to questions provided by users (within 24h);
- If users encounter insurmountable hardware problems during use, the system can be returned for repair and assistance in solution.



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