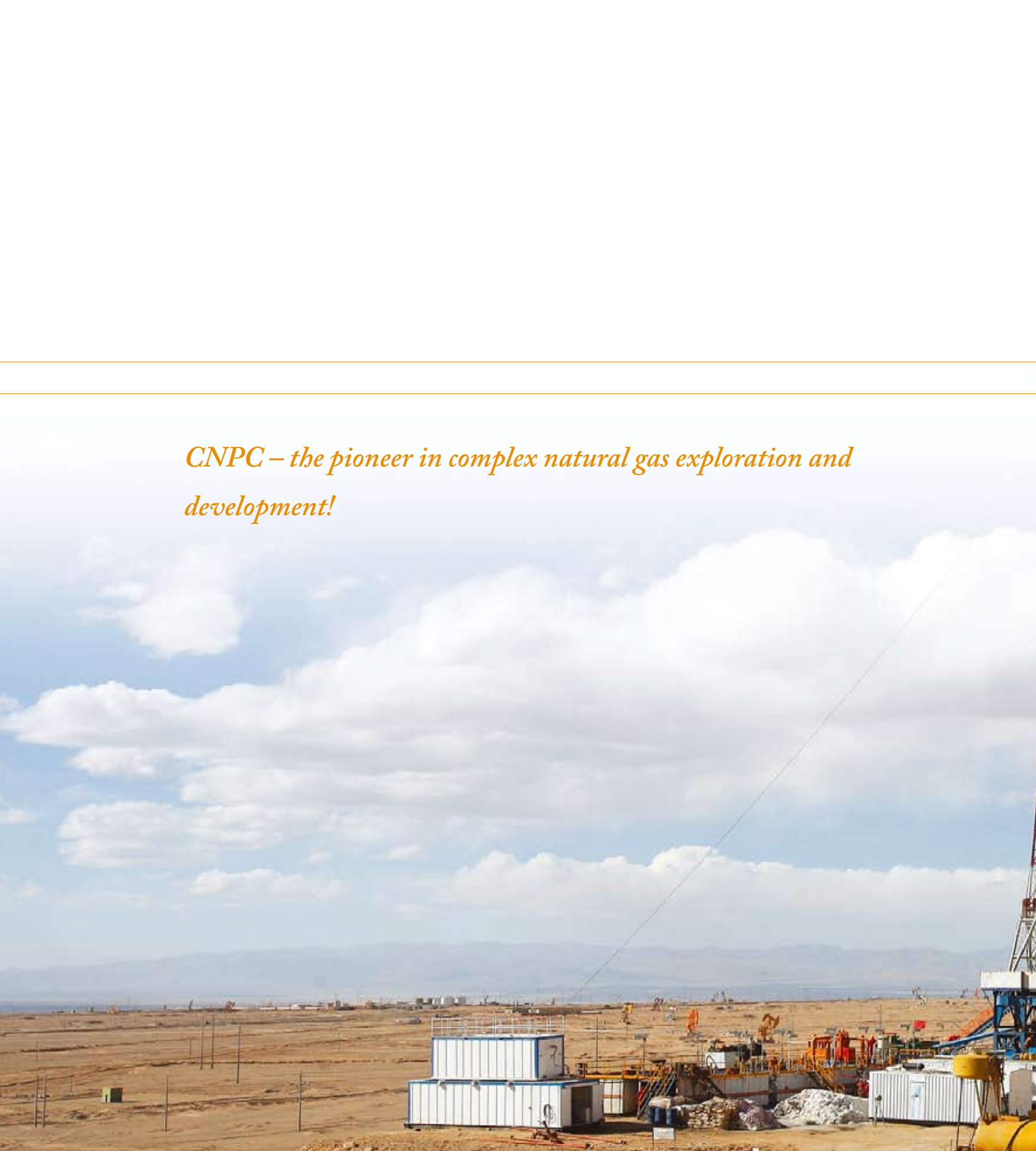
Gas Exploration and Development Technology

Science & Technology Management Department

2011

CHINA NATIONAL PETROLEUM CORPORATION

CNPC – the pioneer in complex natural gas exploration and development!



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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 RMB172.7 billion 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 Natural Gas Exploration and Development Technology is one of the representatives for major innovations of CNPC.

1 INTRODUCTION

CNPC has been engaged in onshore and offshore gas exploration and development for more than 50 years. It has now developed 25 unique technological series in five major sectors including gas exploration, drilling (completion) engineering, gas reservoir engineering, gas recovery engineering, and surface engineering. CNPC has fulfilled successful exploration in such complicated natural gas reservoirs as abnormally high-pressure gas reservoir, high sulfur gas reservoir, water-bearing gas reservoir, extra-low permeability gas reservoir, carbonate gas reservoir, loose sand gas reservoir, and vulcanite gas reservoir.

CNPC's gas exploration and development technologies have been widely used in both domestic and overseas gas development sectors; providing technical service for internationally well-known oil companies including Shell, Total, Texaco, and other oil companies in Central and South Asia.

2 UNIQUE TECHNOLOGIES

Gas Exploration

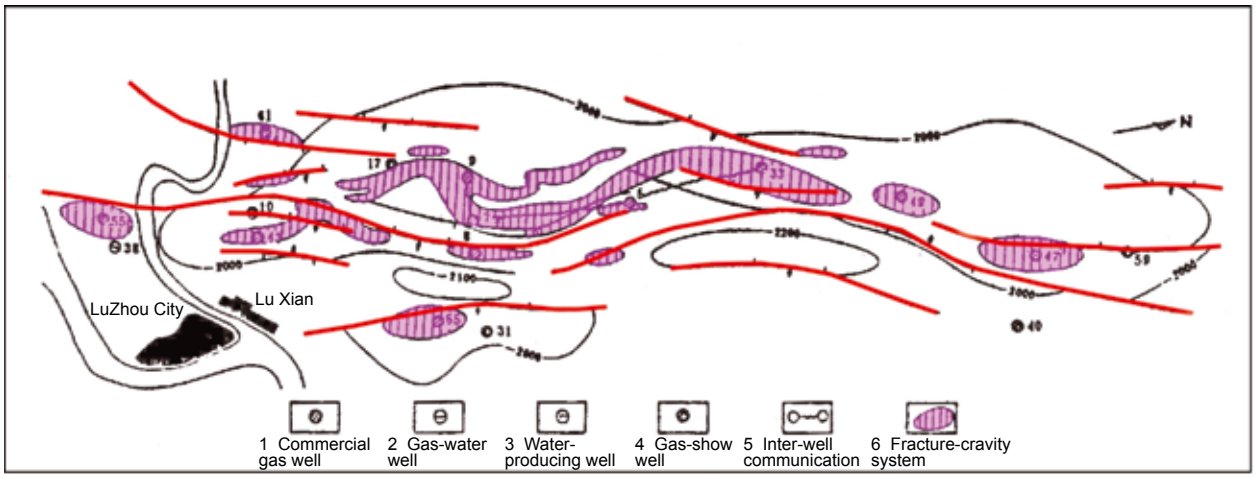
Combined with the theories of multiple disciplines and multiple technologies, the gas exploration technology refers to the comprehensive evaluation based on the geology, seismic, well log and drilling data from the geobody, which can be used as the guidance to discover natural gas reservoirs. The distinctive gas geology theories, exploration technologies and advanced software and hardware equipments CNPC had can provide integrated technological services and solutions for gas field exploration, particularly in comprehensive evaluation of gas fields, seismic exploration in complicated areas and comprehensive well logging evaluation.

2.1.1 Comprehensive geological evaluation of gas reservoirs

Comprehensive geological evaluation of gas reservoirs refers to the analysis and evaluation of gas reservoirs in respect of oil generation, formation, migration, accumulation, and preservation, including trap identification and evaluation, reservoir evaluation, and gas reservoir fluid evaluation.

2.1.1.1 Trap identification and evaluation under complex geological conditions

Complex geological conditions includes huge elevation difference, unfavorable reception and imaging of seismic reflection data, complicated underground structure, fault/fracture development, extreme nonuniformity of reservoirs and diversified traps. In addition to the technndogies of trap identification and evaluation for general purpose, CNPC has applied its distinctive technologies and approaches to the traps that extremely difficult to be explored. So a number of gas fields were discovered.

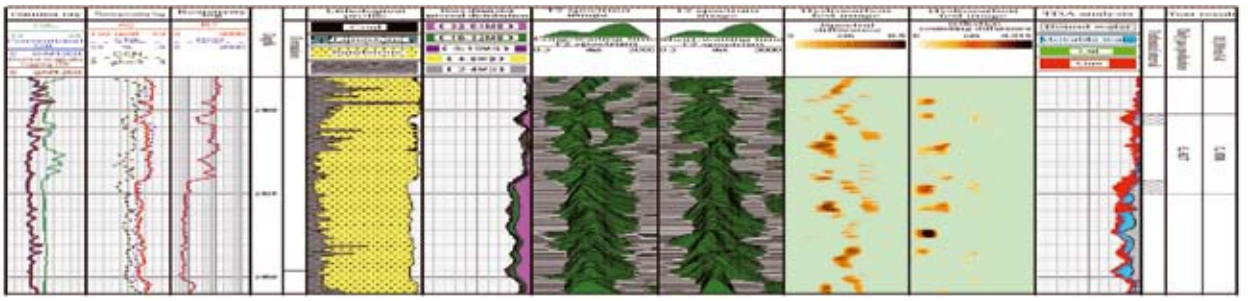


Distribution of series fracture-cavity system of Yangxin in Yanggaosi Gas Reservoir

2.1.1.2 Reservoir evaluation

Reservoir evaluation refers to quantitative or semi-quantitative evaluation of reservoir characteristics, including fracture-cavity, physical properties, vertical and horizontal distribution of formations, and other major controlling factors, by using experimental and analytical technologies, rock thin section analysis in combination with geophysical methods and well logging evaluation technologies.

2.1.1.3 Gas reservoir fluid evaluation



Profile of Xujia River intereted by gas reservoir fluid evaluation

Gas reservoir fluid evaluation refers to the evaluation of fluid property, water-gas relationship, fluid distribution by means of well logging and testing techniques,etc. CNPC has the technologies to determine the fluid property of reservoirs with low porosity and low permeability sandstone, and complex carbonate rock, as well as predict the fluid distribution, providing critical reference for gas reservoir development.

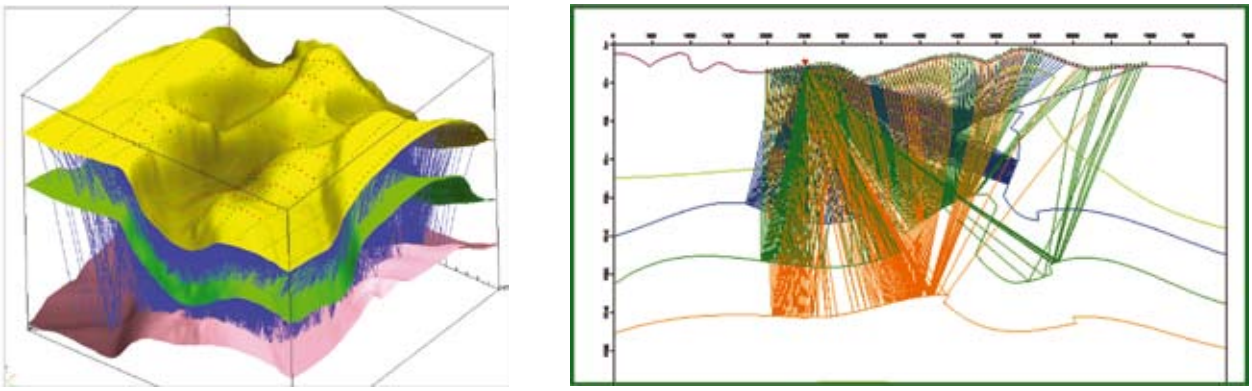
2.1.2 Seismic Exploration Technologies for Complex areas

2.1.2.1 Seismic acquisition technologies for complex areas

Seismic acquisition site in complex area

The seismic acquisition technology for complex areas means to acquire seismic reflection data by using specially designed software, small drilling devices and artificial technologies for seismic wavelets exciting and receiving under complicated surface or subsurface geological conditions. CNPC now owns a series of seismic acquisition, processing, and interpretation technologies as well as software. The advanced 408XL acquisition equipment can provide integrated seismic exploration service in complicated areas.

2.1.2.2 Imaging technology for steeply dipping complex structure

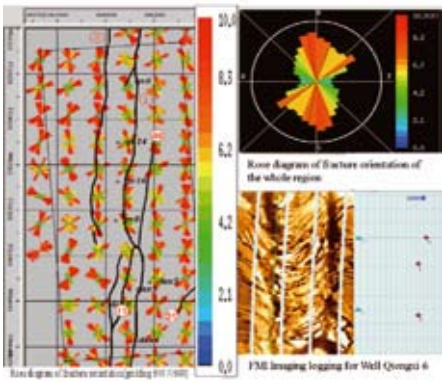


Imaging interpretation profile of steeply dipping complex structure

The imaging technology for steeply dipping complex structure refers to the technology used for accurate homing of seismic wave field under complex mountainous surface and underground steeply dipping structure, by means of advanced computer hardware and data processing software, as well as such supporting methods as static correction, velocity analysis, and migration imaging. CNPC's patented processing software and the advanced external Omega and Geocluster processing software, combined with the cutting edge parallel processing computer cluster, can provide integrated imaging solution to high-steep complex structure.

2.1.2.3 Complex reservoir prediction and description

Technology of complex reservoir prediction and reservoir description can be used for complex reservoir prediction, fluid identification, and fracture monitoring, through analyzing the seismic wave by the organic combination of geological data, seismic data and well logging data, as well as the use of seismic interpretation and professional processing software, and 3D visualization. With world-leading professional software, such as Landmark and Jason, CNPC is able to provide full technical services covering complex reservoir prediction and description.



Rose diagram of fracture orientation

2.1.2.4 Multi-component seismic exploration

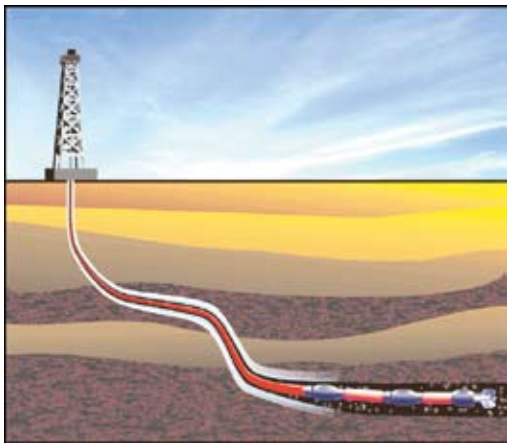
The multi-component seismic exploration technology refers to the technology used for improving structure and reservoir imaging, identifying lithology and fluid, detecting reservoir fracture, and evaluating reservoir directly. This technology uses multi-type seismic wave data, such as longitudinal or transverse wave excitation, multi-component geophone receiving, and the comprehensive use of longitudinal wave, transverse wave, and converted wave. CNPC's patented technology and software for processing and interpreting multiwave, combined with international DSU3, VectorSeis 3-component digital geophone and VectorVista, Promc processing software, can provide integrated multi-component seismic exploration service.

2.1.2.5 Well-to-seismic integrated exploration

The well-to-seismic technology is an innovative seismic exploration technology that combined acquisition, processing, and interpretation of both surface seismic data and borehole seismic data. The hardware is the digital wellbore VSP acquisition equipment manufactured by British AVALON Company and the software uses VSP processing systems branded Univers and promax, which can provide completed technical service for well-to-seismic integrated exploration of acqusition, processing and interpretation.

2.1.3 Comprehensive well logging evaluation technologies

Comprehensive well logging evaluation is to make a comprehensive analysis of reservoirs and structures nearby wells using logging data. During the long-term exploration activities, CNPC has formed the logging data processing technology for "three-highs" (high pressure, high temperature, and high sulphur) gas wells, horizontal wells, and ultradeep wells, under balanced drilling. The comprehensive evaluation technology with high reliability has been developed in particular for fine description of aeolotropic carbonate rocks, low porosity and low permeability clastic rocks, and high-steep structures.



horizontal wellbore logging acquisition

Jirui well log interpretation and processing system

2.2 Drilling and Completion

CNPC has several unique technologies, including the drilling (completion) engineering technology, the well control technology, the drilling (completion) fluid and circulation lost prevention technology, the under balanced drilling/completion technology, the gas drilling technology, the directional well and horizontal well drilling technology, the coring technology, the oil/gas well test technology, the emergency treatment and rescue technology, and the cementing technology.

2.2.1 Drilling and Completion for Deep and Ultradeep Wells

Drilling and completion technologies for deep and ultradeep wells are designed aiming at the difficulties of safe and rapid drilling and completion for wells with a depth above 5,000m under complex geologic conditions of high-sweep structure, complex lithology and anomalous pressure, etc. CNPC can provide complete drilling engineering solutions for gasfields and the designs and operation technology for single wells.

Drilling design and interpretation system for deep and ultra-deep wells

2.2.2 Underbalanced drilling technologies

Full underbalanced drilling technologies are used to maintain the bottom hole pressure (BHP) lower than pore pressure of drilled formations by optimizing drilling fluid systems and construction plans. CNPC has developed supporting equipment of underbalanced drilling by introduction and independent development, including fail safe heads, restricting control systems and data acquisition and processing systems, has owned advanced analysis software of underbalanced drilling hydraulics, including Signa and DrillBench. CNPC is able to conduct underbalanced drilling design and technical consulting, provide complete underbalanced drilling, logging and completion services.

10.5MPa fail safe head

Snubbing unit

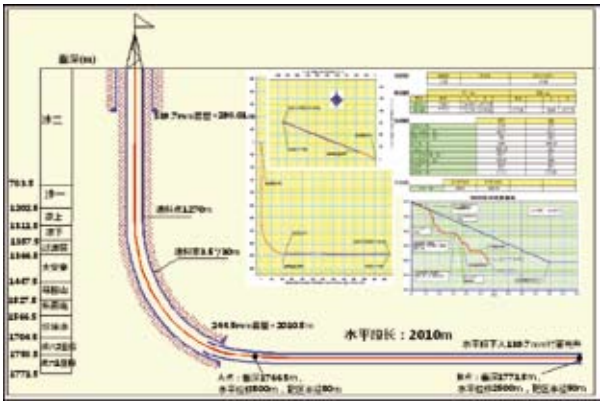
Vacuum degasser

2.2.3 Gas drilling technologies

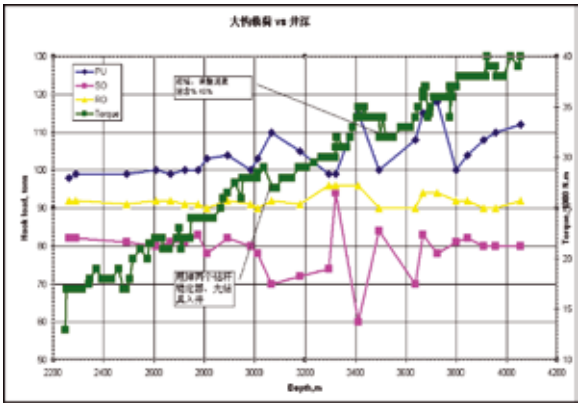
The gas drilling technology means to use gas or gas/fluid double-phase as a drilling circulation medium to prevent oil/gas layer pollution and protect oil/gas layers, significantly improving drilling velocity and controlling severe circulation loss. According to different formations and subsurface conditions, CNPC has developed a series of gas drilling technologies, including the technology of formation suitability evaluation, the technology of downhole explosion monitoring and control, the packed hole technology and the multi-medium (including dry gas, pulverization, foam and gasification) gas drilling technology. These technologies can provide effective methods to the development of low permeability gas reservoir and improve penetration rate.

2.2.4 Drilling technologies for directional well and horizontal well

Directional drilling precisely penetrates the target geological areas along the designed trajectory by using special bottom hole assembly (BHA) and well track measurement tools, and extends for a certain displacement in the target area according to the geological and engineering designs. CNPC possesses the technology of well path MWD for deep HT directional wells, the well path control technology for horizontal wells in which mud loss and formation caving are likely to occur, the technology of geo-steering drilling in carbonation formation, the underbalanced horizontal drilling technology and the drilling technology of horizontal wells with gas.



Drilling section of horizontal wells



Drilling design of directional well

2.2.5 Drilling coring technologies

As to the standardization and seriation of the coring tools, CNPC has developed its unique coring technology which has been applied in the oilfields of more than 20 nations abroad.

2.2.6 Cementing technologies

For different geological and working conditions, CNPC has developed a series of cementing technologies. Peculiarly, on the aspects of cement operations in complex geological conditions and in wells of HT, HP and high H_2S content, CNPC has relatively strong technological advantages and service capabilities.

Working site of cementing operation

2.2.7 Well control and oil/gas well emergency and fire extinguishing technologies

According to the drilling and completion safety issue under various complicated geological conditions, CNPC has developed a set of well control technologies, built up safety monitoring systems of well control devices, and compiled well control industry standards. In the aspect of oil/gas well fire extinguishing and emergency rescuing, CNPC has advanced oil/gas fire extinguishing equipments and professional fire teams. In addition, a series of technologies to deal with oil/gas well blowout and fire under complicated conditions have been summarized, and CNPC had successfully handled lot of well blowout and fire accidents in Kuwait, Turkmenistan, Pakistan and Indonesia.

Fire extinguishing in 6 oil wells in Hainan-2 platform in Liaohe oilfield, 1999

Kuwait oil well fire extinguishing site in 1991

2.2.8 Oil/gas well test technologies

Aiming at solving the gas well test problems under high temperature, high pressure and high sulfur content, CNPC has developed several advanced oil/gas well test equipments, including APR full opening anti-sulfur test devices and 10MPa anti-sulfur horizontal three-phase/two-phase separators. Sulfurous oil/gas well surface metering and safety monitoring, high temperature high pressure sulfurous deep well DST test and high production high sulfur content gas well permanent completion packer can provide important basis for long-term safety in high temperature, high pressure and high sulfur content gas fields.

2.2.9 Drilling fluid and sealing technologies

CNPC has a series of technologies for deep well drilling fluid, high density drilling fluid, reservoir protection drilling fluid, MEG drilling fluid, oil base drilling fluid and drilling cutting treatment, organic salt debris free drilling fluid and comprehensive sealing. They are superior in solving serious problems in formation mud making, formation collapse, drilling fluid pollution prevention (salt, H_2S and CO_2 pollution, etc.), high temperature high density drilling fluid rheological property control, low permeability reservoir protection and severe circulation loss.

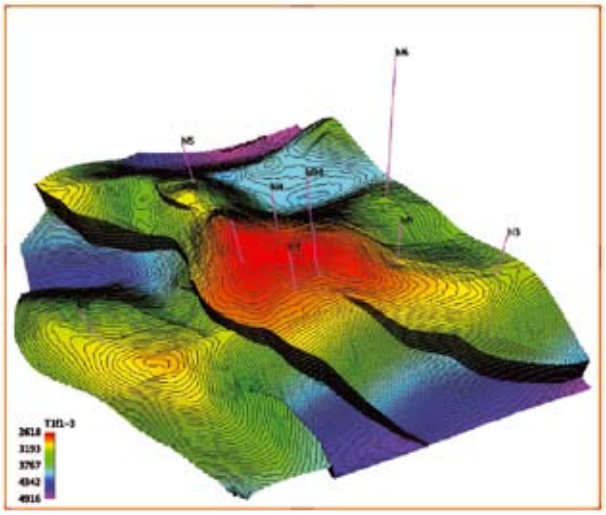
2.3 Gas Reservoir Engineering

Gas reservoir engineering is mainly to study and analyze the mechanism of dynamic changes of gas reservoirs for grasping the development status of gas wells and gas reservoirs, and is able to deepen the understanding of exploitation characteristics of gas wells and gas reservoirs and rules by the geological modeling technology, the well testing technology and the numerical simulation technology. On the basis, established the appropriate methods for tracking analysis, simulation and optimization control in the whole development course for realizing the rational development of gas reservoirs.

CNPC has established distinctive technologies such as fine reservoir description of complicated gas reservoirs, dynamic prediction of water breakthrough in fracture, analysis of low velocity non-Darcy flow, numerical simulation tracking analysis of gas reservoir development, numerical simulation and development plan optimization for different types of gas reservoirs, which can provide high efficiency resolvent for gas reservoir engineering.

2.3.1 Fine gas reservoir description technologies

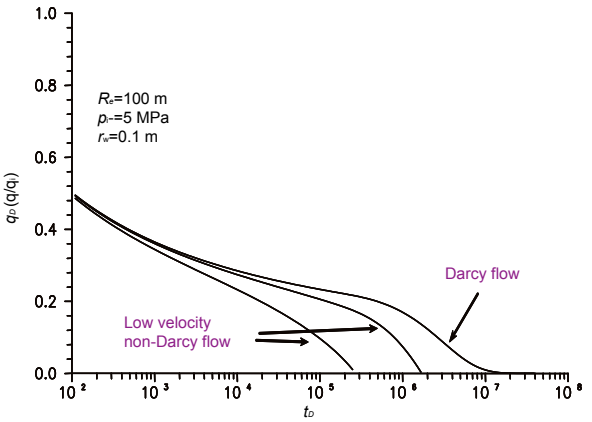
Fine gas reservoir description is a comprehensive study of multidisciplinary integration based on geological research. It is the basis of management and study of gas reservoir development. CNPC has successfully developed a series of fine gas reservoir technologies, which are composed of static analysis technologies, such as fine formation and reservoir correlation, fine seismic processing and interpretation, fracture characterization and fine gas reservoir geological modeling, as well as dynamic characterization technologies such as well test analysis and numerical simulation. CNPC has Petrel and RMS geological modeling software, and can provide fine gas reservoir characterization technological service and solution to improve the accuracy of structure, reservoir and remaining reserve characterization.



Geological modeling structure model of fine gas reservoir

2.3.2 Engineering technologies for special gas reservoirs

Unconventional gas reservoir represents the gas reservoirs with water cut, high sulfur content, ultra-low permeability, condensate bearing, high heterogeneity and multi-pay. CNPC has formed special technologies in special gas well test analysis, numerical value tracking for gas reservoir development, numerical simulation and development plan optimization. CNPC also has several softwares for advanced well test interpretation, numerical test, dynamic analysis and numerical simulation, such as PanSystem, PanMesh, Saphir, Weltest, MatBal, Topaze, WellFlo, F.A.S.T, ReO, Eclipse, Vip and SimBest□etc, and can provide high-quality gas reservoir engineering solutions, including special gas reservoir test analysis, productivity evaluation, and performance analysis and development plan optimization.



Natural production decline analysis of ultra-low permeability gas reservoir

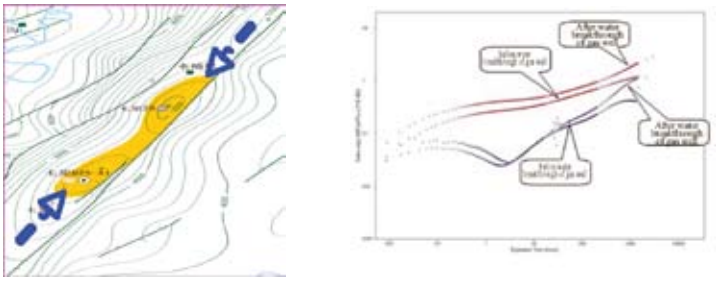
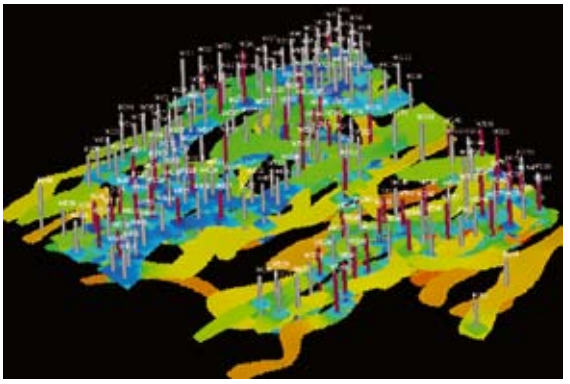
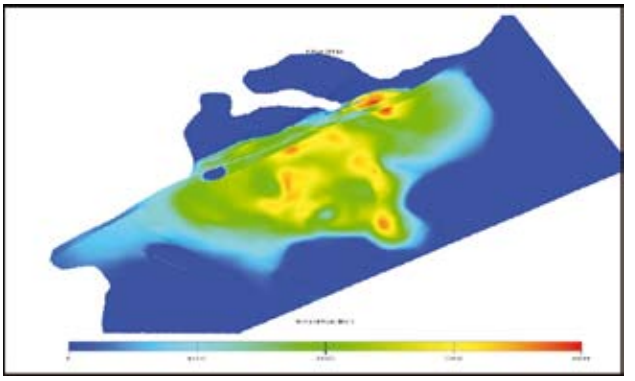


Diagram of water invasion predication and water invasion direction diagnose



Reserve distribution of fracture-pore dual medium gas reservoir



Matrix reserve abundance of fracture-pore dual media gas reservoir

2.3.3. Experiment evaluation technologies for gas reservoir formation and development

The experiment evaluation for gas reservoir formation and development is an effective means to grasp the gas reservoir characteristics and gas reservoir development. CNPC has formed series of experiment evaluation technologies, including study on the mechanism of hydrocarbon generation and expulsion of high mature or post mature source rock, the non-Darcy flow parameters measurement of extra-low permeability core, mechanism description of water break-through in fracture, phase analysis of natural gas with sulfur, and related experiment instrument and matching equipment.

Relative permeability and electric property parameter measuring system

2.4 Gas Recovery Engineering

Gas recovery engineering consists of gas well completion, testing, production test, commissioning, stimulation, down-hole operation and workover. It is an important means to develop gas fields efficiently. CNPC has advanced operation equipment, specialized tools and software, particularly enjoying unique technical advantages in well completion of high temperature, high pressure gas reservoirs with high sulfur content, stimulation of carbonate gas reservoirs and clastic rock gas reservoirs with low permeability, drainage & gas recovery of gas reservoirs with aquifers, low pressure well workover, and experimental evaluation, and can provide systematic design of gas recovery engineering plans and technical services.

2.4.1 Completion Technologies for High Sour Gas Reservoir

The Completion Technology for High Sour Gas Reservoir refers to a series of techniques applicable to gas wells with high hydrogen sulfide and carbon dioxide contents. It is developed via study on in-situ stress, wellbore stability and corrosion mechanism. The technology includes optimization of completion approaches and completion strings, gas well testing combined “perforation, acidization and testing”, provision of permanent packers which can stand 70MPa pressure and matching tools, and permanent pressure & temperature monitoring systems. The anti-corrosion technique using corrosion resistant alloy or carbon steel plus inhibiter to prolong the life of down-hole strings is also part of the completion technology.

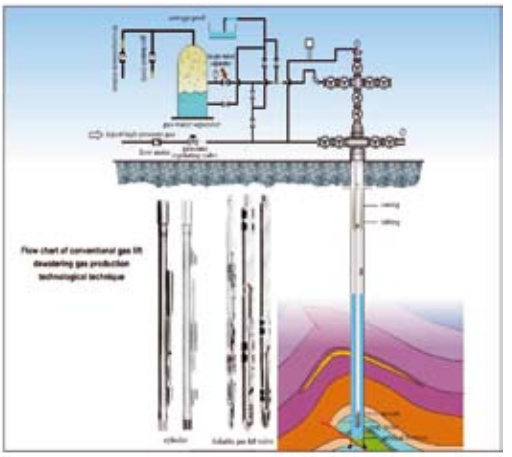
2.4.2 Stimulation Technologies for Gas Reservoir

The Gas Reservoir Stimulation Technologies mainly include hydraulic fracturing and acidizing (acid-fracturing) technologies. CNPC has various stimulation related software such as 3D acid-fracturing simulating and design software for carbonate reservoirs, alternating pump injection and closed acidizing design software (2D and 3D), FracproPT (a fracturing design software), Wingoher (a real 3D hydraulic fracturing simulating software), Stimpro (a matrix acidizing design software), Acidguide (an expert system of matrix acidizing) and various kinds of fracturing and acidizing additives. It can provide complete gas reservoir stimulation technical services and solutions, as well as many other technical services including multi-level alternating injection + closed acidizing, ultra-large sand fracturing, separate zone fracturing with packers, staged fracturing in horizontal wells, multi-layer fracturing without moving strings, and coiled tubing acidizing, etc.

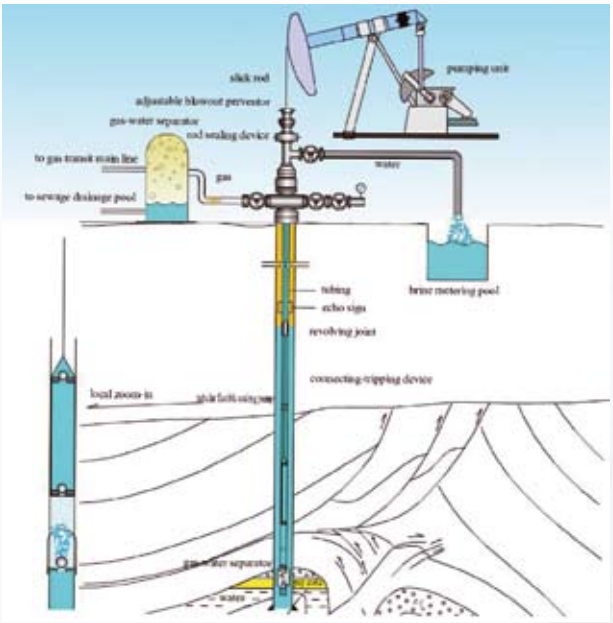
Stimulation operation site

2.4.3 Gas Recovery Technologies

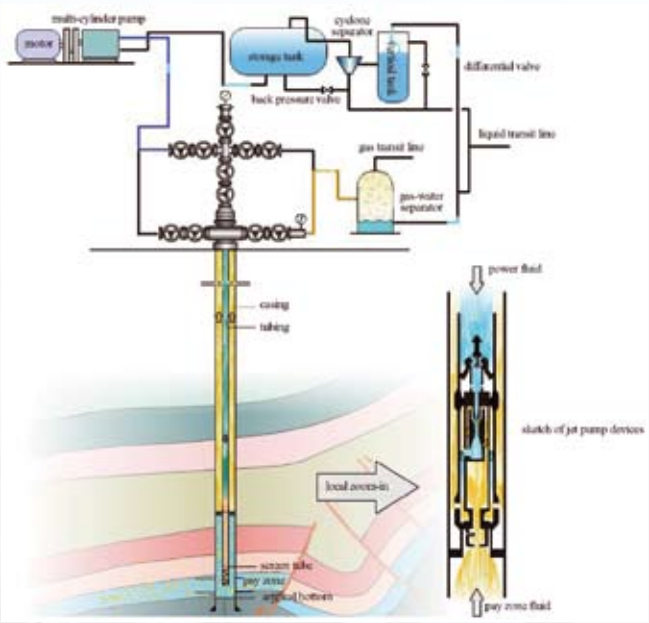
The Gas Recovery Technologies refer to a series of technologies used in the process of gas production. CNPC has developed unique drainage & gas recovery technology, downhole choke technology and testing technology for wells with high sulfur content. It possesses various software, such as gas production engineer software package, downhole choke and hydrate prevention software, and dewatering gas-production technique optimization software, as well as specialized tools and equipment, and is able to provide comprehensive technology design and field operation services for producing gas reservoirs and enhancing gas recovery efficiently.



Flow chart of drainage & gas production by conventional gas lift



Work flow of drainage and gas production by pumping



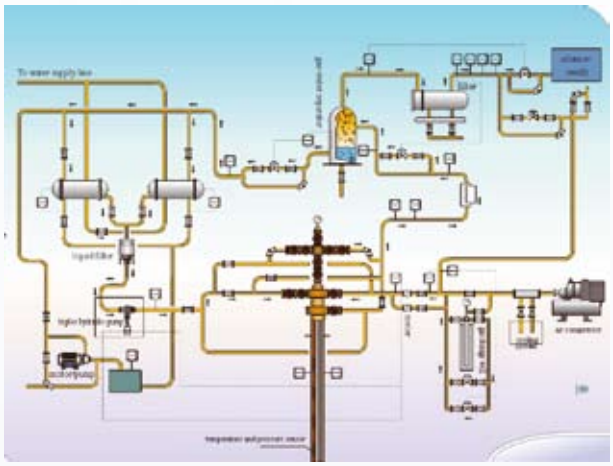
Workflow of drainage gas production by ejector

2.4.4 In-house gas recovery engineering evaluation and pilot test technology

In-house gas engineering evaluation technology is to use advanced experiment equipment to simulate field operation condition, perform experiment and analytical evaluation, which can provide basis for optimizing the gas engineering plan and material in use, reduce the risk of field test, and accelerate the development and completion of new gas production technologies, new process and new equipment, as well as improve technology application.

Full view of the simulating experimental system for gas production

CNPC has advanced experiment system for gas recovery simulation, gas lift simulation experiment bench, electric submersible pump experiment bench, cable test and maintenance devices, hydraulic pressure slick line well test truck and other equipments. Meanwhile, CNPC introduced overseas devices and equipments, such as advanced high temperature high pressure core displacement system and dynamic acid filtration meter, which can provide technological evaluation and acidization fracturing evaluation service for gas production.



Flow chart of the simulating experimental well of gas recovery technology

2.5 Surface Engineering

Gas surface engineering refers to gathering, processing and storage & transmission of gas produced from gas wells, primarily consisting of a number of production links such as gas throttling & depressurization, heat exchange, separation, metering, dehydration, boosting, purification, processing and sales transmission.

CNPC possesses a portfolio of techniques for gas gathering and processing to assist customers in fulfilling safety and clean development of conventional gas fields, gas-condensate fields, highly H_2S gas fields and ultra-low permeability gas fields.

(1) Wet and dry sour gas transmission technology.
(2) Design and construction of large gas purification plants.
(3) Liquid oxidation/reduction and solid desulfurization of mid-low sulfur content natural gas.
(4) Material evaluation and selection technology.
(5) Corrosion evaluation and protection technology.
(6) Desulfurization solvent, sulfur recovery catalyst and anti-corrosion agent series.
(7) Natural gas analysis and test technology.

2.5.1 Internal Gathering Technology for Highly Corrosive, High Pressure Gas and Condensate Gas Fields

The Internal Gas Gathering Technology means to gather gas from different gas wells by pipelines and then transport it to gas processing plants to perform processing, according to the gas property, development plans and specific surface conditions.

2.5.1.1 Sour Gas Gathering Technology

The Sour Gas Gathering Technology has effectively solved problems in hydrate formation, selection of material for making pipelines, anti-corrosion, waste water transportation and treatment.

(1) Dry gas transmission: It is to dehydrate gas in gas fields before transporting it to processing plants by pipelines. It is suitable for central desulfurization of several gas fields and long-distance sour gas transmission. By using this technology, CNPC has successfully developed the sour gas field in Sichuan Datianchi, Dachigan and Qilixia structure zone.

Datianchi dewatering station

(2) Wet gas transmission: After gas/water separation metering in an individual well or gathering station, the technology is to transport gas by pipelines to processing plants and then perform desulfurization and dehydration. It is suitable for single gas field and short-distance sour gas transmission. Sour gas fields in Sichuan Wolonghe, Zhongba, Moxi, Weiyuan all use this method.

2.5.1.2 Condensate Gas Field Gathering Technology

Gas gathering pipeline of gas/liquid miscible transportation system in Yingmai-7 filed

Liquid plug collector at the entrance of processing plant

The Condensate Gas Field Gathering Technology mainly uses single well or multi-well cluster to gather gas, uses wellhead 2nd-order throttle to reduce pressure and transports gas to central processing plants by closing gas/liquid miscible transportation pipelines. For the produced gas with hold up liquid, liquid plug collectors should be installed at the end of gas gathering pipelines. In the central processing plants, CNPC uses J-T valves to realize flow restriction and cooling, low temperature separation, dehydration and hydrocarbon separation, injects hydrate resistant in advance to prevent gas hydrate formation, and applies normal pressure distillation method to perform stable processing of condensate. These technologies effectively avoid waste water and waste gas generation during the production process and some wells in remote areas do not need any field office anymore. By using these technologies, CNPC has successfully developed Kela-2, Tazhong and Yingmai-7 gas fields.

2.5.1.3 Optimization of Surface Gathering Technology for Low Permeability Gas Field

Based on the low production, large well number and rapid pressure drop of low permeability gas fields, CNPC used the optimized and simplified gathering technology to reduce the cost and realize efficient recovery.

(1) Use downhole throttle to prevent hydrate formation.

(2) Use single well concatenation, multiwell cluster gas gathering systems to reduce pipeline length.

(3) Central separation and turnaround metering in gathering stations and export to processing plants for further treatment.

Changqing Sulige Gas Field and Sichuan Guang'an Gas Field have successfully applied these technologies and had gained good results.

Gas-liquid separation skid

2.5.2 Natural Gas Purification and Processing Technologies

To reach the required standard of product gas, the Gas Purification Technology is used to remove H_2S, CO_2 and water from gas for better quality. CNPC owns a series of technologies in gas desulfurization, dehydration, decarbonization, sulfur recovery, tail gas treatment, liquefied sulfur degasification and can provide integrated technological plans and service.

Central processing plant in Kela-2 gas field

Chongqing gas purification plant

2.5.3 Anti-corrosion Technology for Sour Gas Field

CNPC has spared no efforts to the study and practice of the corrosion and protection technology during the gas exploration and development and had accumulated rich experience and practical technologies that can help customers to realize safe, environmental and economical sour gas field development.

(1) Fluid corrosiveness and anti-corrosion property evaluation of materials.

(2) Anti-corrosion agent development and application evaluation.

(3) Anti-corrosion plan design.

(4) Field corrosion monitoring and diagnosis.

(5) Corrosion database and other supporting technologies.

HTHP dynamic corrosion evaluation device

CT series solid desulfurization agent

CT series sulfur recovery catalyst

2.5.4 Gas Analytical Test, Metering and Standardization Technologies

Gas analytical test, metering and standardization means technologies and standardization of measuring methods, sampling, metering, experiment and analytical methods from production (wellhead) to users. CNPC notonly has developed a whole set of gas analysis and test technologies represented by gas component analysis and sulfide analysis, but also builtup national flow metering standard devices, completed national, industry and company level natural gas standard system, and manufactured several kinds of national 1st degree and 2nd degree standard materials.

3 TYPICAL CASES

3.1 Carbonate fracture-cavity or fracture-pore gas reservoir exploration

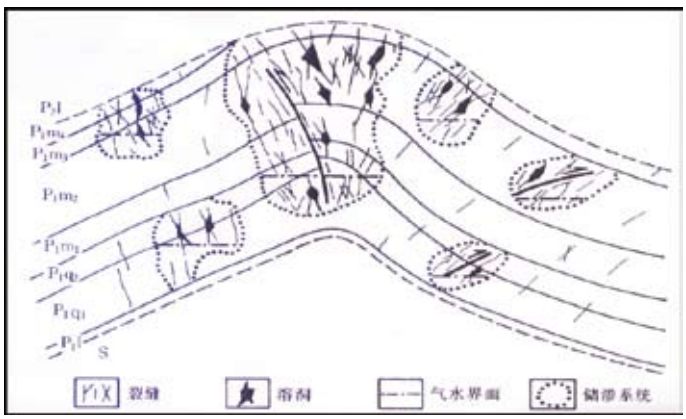
According to the characteristics of fracture-cavity and fracture-pore gas reservoirs, CNPC has developed various technologies for different exploration targets. The penetration rate of fracture-cavity reservoirs is over 90% and the success rate is higher than 75%.

(1) “Three-optimizes”. Optimize favorable structure type, optimize favorable structure zone and optimize favorable fault type.

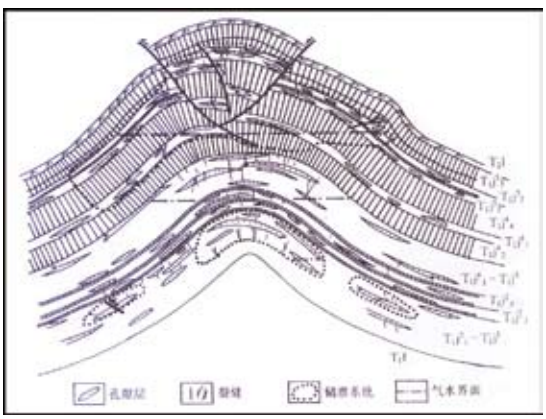
(2) “Three calculations”. Structure curvature calculation, fault associated fracture calculation and structure filtering calculation.

(3) “Four processings”. Forward modeling, high resolution, Seis-log (or G-log), pattern recognition or P-G index.

(4) “Comprehensive evaluation”. Comprehensively analyzes the above optimization, calculation and processing data and recalculate reserves (fault anticline method) to optimize fracture-cavity system with large reserves.



Reservoir pattern of lower Permian dense limestone fracture-cavity

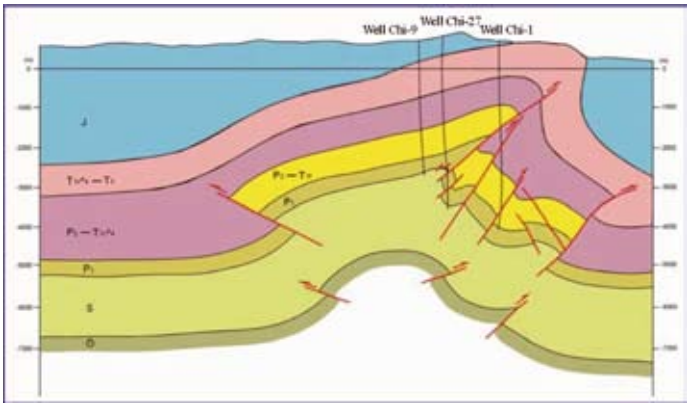


Reservoir pattern of lower Triassic evaporative platform fracture-pore carbonate

3.2 Exploration of gas reservoir in high-steep complex structures

Based on the forming mechanism of high steep structures in eastern Sichuan Basin and combined with strong fold, large dipping angle and complicated subsurface structure, CNPC used several kinds of highly steep structure exploration technologies and made great breakthrough. A group of mid-large sized gas fields featuring varied types were discovered and they became the major gas production area of Sichuan oil/gas fields.

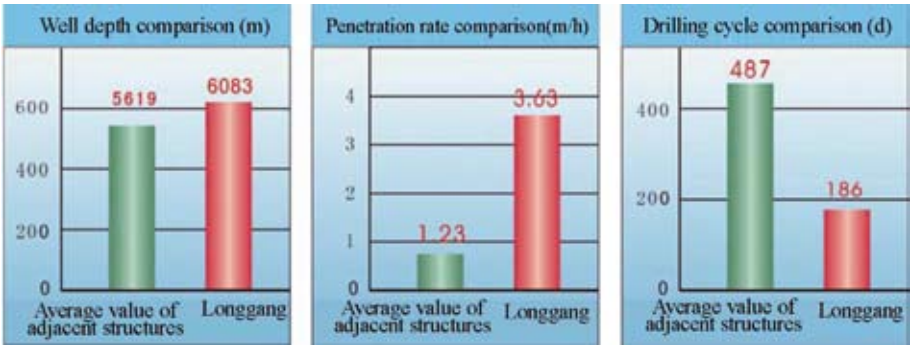
Field outcrop of high-steep structure in eastern Sichuan Basin



Geological interpretation profile of Dachigan structure

3.3 Deep and Ultra-deep Well Drilling Technology in Sichuan Basin

According to the deep formation and a series of problems, CNPC applied Deep and Ultra-deep Well Drilling Technology in Sichuan Basin to improve the penetration rate. The use of gas drilling and Dina drill with PDC drilling bit can improve the penetration rate twice and the drilling cycle can be shortened by 50%.

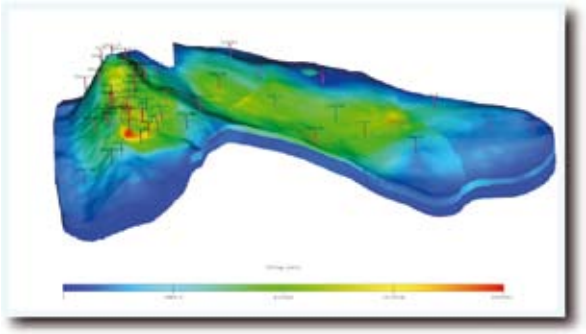


Comparison of actual drilling between 35 wells drilled and 7 adjacent wells in Longgang

3.4 Gas reservoir development in Ultra-low permeability clastic rocks

Low permeability gas reservoirs are widely distributed in different areas and formations, which are often water bearing, strongly heterogeneous and multi-layered. All these properties restrict the efficient development of them. The development of ultra-low clastic rock gas reservoirs is even more difficult.

The reservoir permeability of Mid-Triassic Xujiahe Formation clastic rock in Sichuan Basin is often lower than 0.1md. Based on the low permeability, strong heterogeneity, low productivity and complicated water/gas contact, CNPC applied the Fine Gas Reservoir Characterization Technology, the Special Gas Well Test Technology and the Numerical Tracing and Analysis Technology to determine the effective reservoir distribution, water/gas distribution, gas well productivity and the controlling factors. CNPC selected gas accumulation blocks, optimized well deployment and used Well Cluster and Downhole Flow Restriction Technologies to optimize surface process and reduce the cost. This made the single well stimulation ratio of 5-20 and realized rational and efficient development of gas reservoirs.



Distribution of remaining reserves at Guang'an Xu-6 Fm. gas reservoir

3.5 Sulfur Gas Field Development

3.5.1 Anti-corrosion technologies help to realize safe development of sulfur gas reservoirs

Lei-3 gas reservoir in Zhongba Gas Field in Sichuan contains high sour gas, with H_2S of 4.9%-7.11%, CO_2 of 4.16%-4.69% and Cl^- of 1000-51766mg/L. Depending on Sour Gas Field Development Technologies, CNPC has maintained safety gas production for nearly 30 years.

Corrosion test devices in the high sulfur gas field

3.5.2 Purification technology in sulfur gas reservoirs

Due to the high carbon-sulfur ratio and the existence of organic sulfur in sulfur recovery process in some areas, CNPC used the technologies of Desulfurization Purification, Selective Oxidation Catalysis, Organic Sulfur Hydrolysis Catalysis to improve the selectivity of desulfurization solutions, anti-foaminess and anti-oxidation performance, and improve the performance of sulfur recovery catalyst. The H_2S content was lowered significantly and the energy consumption was reduced a lot. The practical use indicates that the self-developed CT8-5 formula type solution has good performance and the performance of lean solution with H_2S and CO_2 content is better than that of similar products. Selective Desulfurization and Super Kraus Sulfur Recovery technologies can ensure normal devices operation. The H_2S content in purified gas is normally 5-10mg/m^3, and the sulfur recovery rate can reach 99%.

Gas purification plant (using CT8-5 selective desulfurization solvent)

3.6 Water-bearing gas reservoir development

During the development of water-bearing gas reservoirs, subsurface water will break into gas reservoirs when the formation pressure drops gradually. It will form dead gas area and result in wellbore liquid loading, which will seriously affect gas well production and gas reservoir recovery rate. Most gas reservoirs are water bearing, which means that it will be affected by formation water invasion to different extent.

The Water Drainage Gas Production Technology is an important technology for water bearing gas reservoir development. Since 2000, the average number of wells that uses water drainage gas production in Sichuan Basin is about 300. The stimulation gas accounts for 6%-8% of the annual gas production, which means that the water bearing gas reservoir development efficiency is significant.

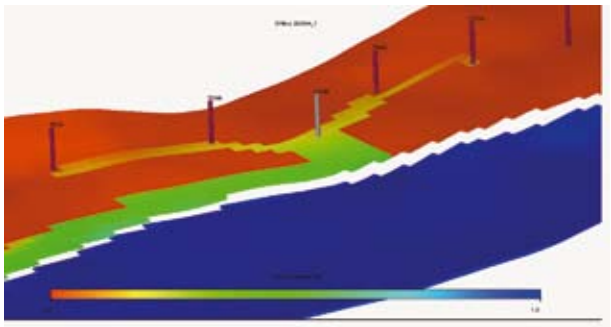
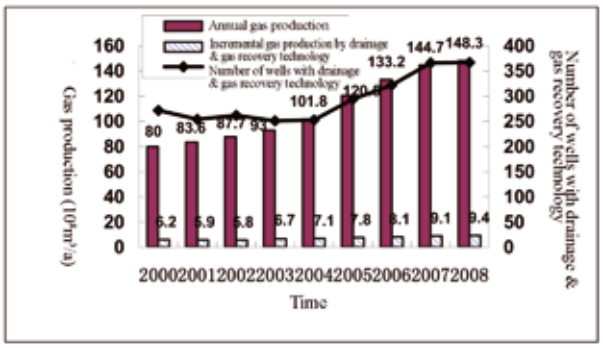


Diagram of fracture water breakthrough mechanism



Drainage & gas recovery application effect in Sichuan Basin

3.7 Fire extinguishing and rescuing of large-scale well blowout in Well Osman-3, Turkmenistan

On October 28th 2006, strong blowout happened in Well Osman-3 in Turkmenistan when drilling to 4,577m. The drilling rig was completely burned out and one derrick monkey was dead. The daily blowout gas volume exceeded 5 million cubic meters. The H_2S content reached 34.5g/m^3, and the well belonged to high production high pressure and high sulfur content gas well. CNPC emergency team fought fire, and overcame several difficulties of insufficient water, changing wind direction and severely-destroyed well head, and finally fulfilled this difficult emergency rescuing operation.

Emergency rescue site of Well Osman-3 in Turkmenistan

4 SCIENTIFIC RESEARCH EQUIPMENT

CNPC is well-equipped and has advanced key laboratories, thus can provide various technological services, including geophysical exploration, gas reservoir evaluation, drilling and completion, downhole operation, gas recovery engineering, natural gas purification and surface gathering engineering research and development, experimental analysis and evaluation, engineering consultancy, design and construction etc.

In natural gas exploration, CNPC has 408 XL and 408 UL seismic devices and advanced seismic data interpretation and processing systems, various well logging work station and logging software etc.

High pressure permea meter

In gas reservoir engineering, CNPC has self-developed and import advanced experimental analysis equipment and analysis software, such as dense rock permeability meter, HP-40 multifunctional Helium porosity meter, full-diameter core permeability meter, sulfurous core depositional experiment devices, extended pattern helium porosity meter, UPY-1000 solid density meter, NMR device and PVT phase device etc.

(1) Carbonate reservoir acidization laboratory: the current technologies include fracturing acidization technology selection, fluid performance evaluation, fracturing acidization additive product quality check, reservoir sensitivity analysis, proppant performance evaluation, rock mechanical property and crustal stress in-house test.

(2) The gas recovery engineering laboratory owns the only full-diameter gas recovery engineering simulation well, which can perform water/gas two-phase flow modeling experiment, gas recovery engineering evaluation experiment and tool/device performance experiment.

Gas recovery engineering modeling well

(3) The gas purification laboratory mainly performs sulfur recovery and waste gas treatment, solid desulfurization, complex iron desulfurization and alkylol amine desulfurization experiment analysis and evaluation.

(4) The gas analysis and test laboratory is the oil/gas industry product quality research and test center and ISO/TC193 domestic technology specialized unit.

(5) The material and corrosion laboratory for sour gas field can simulate 70MPa, 350ºC downhole condition and surface environment in sour gas fields and perform high temperature, high pressure and high corrosiveness static and flow corrosion test, and perform other sulfide stress fracturing, stress corrosion fracturing and other corrosion test and evaluation on downhole and surface gathering metal materials.

Solid desulfurization experiment device

Hydrogen desulfurization experiment device

High temperature and high pressure H_2S modeling device

5 QUALIFICATION AND STANDARD

5.1 Qualifications

CNPC has passed IADC international well control training qualification and coring API qualification. The surface engineering technology has national A level qualification in engineering design, engineering investigation, engineering monitoring and engineering consultancy. It possesses a national long-pipeline testing center, which has national pressure pipeline testing certificate and state-certified laboratory certificate, testing organization-certified certificates, national sour gas field material corrosion testing and measuring certificate, special equipment testing and inspection organization approval, large flow metering station measuring certificate and other relevant certification.


Certificate of Accreditation

WellCAP ®

THE INTERNATIONAL ASSOCIATION OF DRILLING CONTRACTORS
HEREBY CERTIFIES THAT

Sichuan Petroleum Well Control Training Center

IS A FULL ACCREDITED INSTITUTION HAVING MET THE CRITERIA OF THE IADC WELL CONTROL ACCREDITATION PROGRAM TO PROVIDE INSTRUCTION IN SURFACE STACK DRILLING COURSES AT THE SUPERVISORY AND FUNDAMENTAL LEVELS.

Program ID
WS70

Period of Accreditation
November 2009 – November 2012

IADC international well control training certificate


中华人民共和国
特种设备检验检测机构核准证

Special equipment testing and inspection organization approval

Well control device quality monitoring and testing center certificate

Engineering design certificate

Sour gas field material corrosion inspection and metering certificate

Development laboratory metering certificate

Natural gas analysis and test laboratory recognized certificate

5.2 Standards

CNPC can provide full series of technological service and always keep improving based on API and other international industry standards, making its technologies and devices upgraded immediately for better linkage with the international industry.

6 SPECIALISTS

Dai Jinxing: Academician of China Academy of Science, natural gas geology and geochemistry expert, devoted to gas/oil geology and geochemistry research. He is in charge of several National Key Scientific and Technological Projects about gas. He had proposed the coalbed hydrocarbon generation mode, various gas reservoir identification methods, gas accumulation mode and mid-large gas field accumulation rationale.

Chen Gengsheng: Gas exploration expert. He is in charge of several risky exploration projects in various blocks (basins) and made great achievements; He is good at combining oil/gas geology theory, new technologies and new methods with exploration practice. He has rich cooperation experience with international oil companies in oil/gas exploration and acquainted with oil/gas geology and development.

Huang Xianping: Gas exploration expert. He has worked long in gas exploration and development research and scientific management in Sichuan Basin, and has accumulated rich experience in scientific research and project management. He has taken charge of several key scientific research projects.

Li Yalin: Gas expert and SEG member. He has 22 years of experience in highly steep complicated structure imaging and interpretation, complicated oil/gas reservoir prediction and oil/gas reservoir characterization, multi-component seismic exploration technology research and field operation.

Song Jiarong: Gas exploration expert. He has worked long in gas/oil geological research and development study and has rich experience in marine carbonate rock oil/gas accumulation and foreland basin lithologic oil/gas reservoir study and has gained significant success.

Qi Baoquan: Well logging expert. He has 20 years of well log interpretation experience and is good at image logging, NMR logging data application and carbonate reservoir well log evaluation.

Han Liexiang: Drilling expert. He has accomplished a lot in drilling technology and well control technology, especially in vertical well drilling technology. He takes charge in compilation and amending of several industry standards.

Xu Feng: Cementing expert. He has 22 years of cementing experience and field operation experience. He is a technological expert in deep and ultra-deep well cementing, “three-high” well cementing and complicated geological condition cementing and has 2 national patents.

Zhong Bing: Gas engineering expert. He has rich experience in gas field development and had taken charge of over 40 scientific projects, including national and CNPC gas field development plan compilation, gas field research and gas field development field test.

Feng Xi: Gas engineering expert. He has worked in gas engineering research for 24 years and he is good at complicated gas reservoir, gas well development dynamic mechanism and performance analysis research. He has made several innovative achievements in low rate non-Darcy flow performance analysis of ultra-low permeability gas reservoirs, local water invasion performance analysis of fracture-pore types and early stage performance analysis of high sulfur content gas reservoirs.

Ma Faming: Gas development expert. He has more than 20 years of gas development experience and has organized completion, workover, producing test and stimulation operation in over 300 wells. He took the lead to edit several gas standards and two works including “Gas Production Engineering”.

Huang Liming: Corrosion prevention expert, NACE and SPE member, Associate Director of China National Natural Gas Technical Committee of Standardization Secretariat. He has 22 years of experience in corrosion prevention and acidization technological research and has participated in editing two works.

Jiang Fang: Corrosion prevention expert, Chinese Cankerous and Protection Society director, NACE China Chapter committee member. He has worked long in oil/gas field material and corrosion research and design. He is the chief editor of 6 national and industry standards.

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