Superheated Steam Injection Technology for Heavy Oil Production

Science & Technology Management Department

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CHINA NATIONAL PETROLEUM CORPORATION

Superheated Steam Injection Technology leads to economic and efficient heavy oil development!

Contents

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 one of the largest refined oil products 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 10th 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 Superheated Steam Injection Technology for Heavy Oil Production is one of representatives for major innovations of CNPC.

CLEAN ENERGY SUPPLY FOR BETTER ENVIRONMENT

1 INTRODUCTION

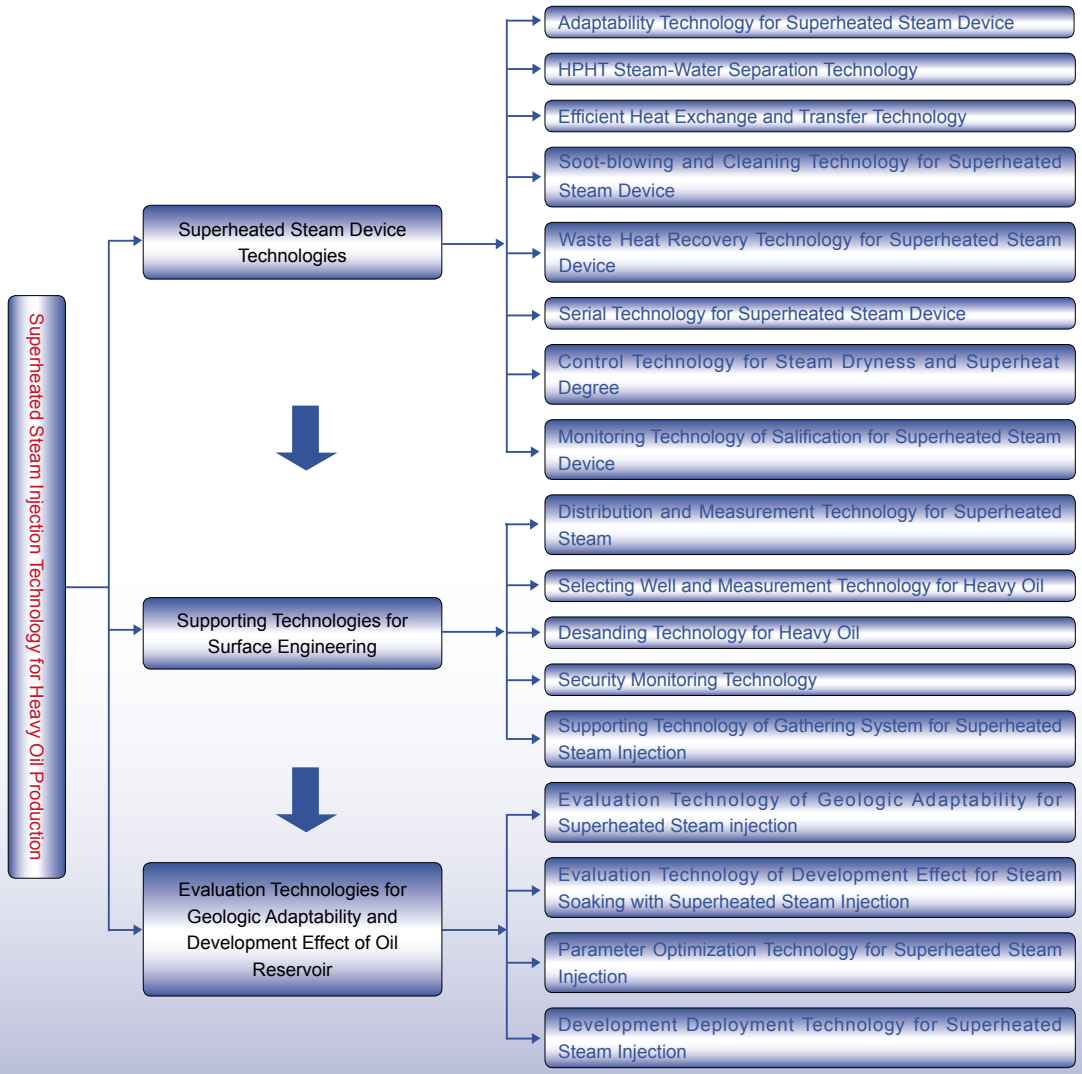
Since 1980s, CNPC has successively conducted thermal production experiments for heavy oil and obtained remarkable results. The steam injection technology is the main method of heavy oil development in China. In order to improve the dryness of steam injected and effect of thermal production, since 2004, the researchers of CNPC has made great efforts to scientific research and exploration, and finally developed the first superheated steam production device using wet steam produced by the ordinary boiler in the world, which has been put into operation successfully in Kenkyak Heavy Oil Field of Kazakhstan. The technology has broken through the internationally recognized forbidden zone, and has led to a whole set of superheated steam injection technologies for heavy oil production.

The international research on thermal production of heavy oil shows that the increasing dryness of the injected steam is helpful to improve the heavy oil recovery. In general, the case that the injected steam's dryness increases by 10% will lead to improve the heavy oil recovery by 3%, with remarkable economic benefits. The traditional thermal recovery boiler only adopts the ordinary boiler's softened water that is only softened but not demineralized and thus 20% of liquid water has to be preserved to dissolve and carry away salts. Therefore, the steam dryness of the outlet for the thermal production boiler is controlled within less than 80%, which makes the steam dryness that reaches the pipeline and target layer of oil reservoir is usually about 50%. This has seriously influenced the actual production effect.

The Superheated Steam Injection Technology for Heavy Oil Production of CNPC has been applied in many heavy oil fields and ultra-heavy oil fields at home and abroad, such as Kenkyak Heavy Oil Zones above Salt in Kazakhstan, Sinkiang Oilfield and Liaohe Oilfield, etc.

2 UNIQUE TECHNOLOGIES

The Superheated Steam Injection Technology for Heavy Oil Production includes three unique technologies—Superheated Steam Device Technologies, Supporting Technologies for Surface Engineering, Evaluation Technologies for Geologic Adaptability and Development Effect of Oil Reservoir.



2.1 Superheated Steam Device Technologies

It is a new-type thermal production equipment developed independently by CNPC according to the actual needs of heavy oil development.

- **Technical Features**

It produces the required superheated steam with the wet steam that is produced by the ordinary boiler's softened water which is softened but not demineralized.

- **Technical Parameters**

No.	Items		Parameters
1	Rated steam flow, t/h		9.2, 11.5, 23
2	Entrance steam dryness		75%-80%
3	Device exit temperature, °C		380-420
4	Designed pressure, MPa		6.3, 9.0, 18
5	Pressure drop of boiler pipe with rated flow, MPa		≤0.5
6	Fuel type		heavy oil, natural gas, oil and gas amphibious
7	Exhaust temperature °C	Incl. the air preheater	160
		Excl. the air preheater	380
8	Thermal efficiency	Incl. the air preheater	90%
		Excl. the air preheater	78.5%

2.1.1 Adaptability Evaluation Technology for Superheated Steam Device

The Adaptability Evaluation Technology for Superheated Steam Device is to evaluate comprehensively whether the softened water of ordinary boiler or the deeply softened heavy oil wastewater meets the water quality requirement of the device so as to ensure the safe and reliable operation of the device.

- **Technical Features**

The device's adaptive standard of water quality is developed by the qualification of the specific water quality.

- **Scope of Application**

It is fit for the inspection and evaluation when superheated steam devices operate with the wet saturated steam.

2.1.2 HPHT Steam-Water Separation Technology

HPHT Steam-Water Separation Technology refers to the technology that controls and separates HPHT wet saturated steam into steam and water effectively, and can avoid tube-burst caused by salification.

- **Technical Features**

It can realize efficient separation and control of steam-water two-phase flows with HPHT.

- **Scope of Application**

It is fit for the efficient separation of steam-water two-phase flows with HPHT.

The HPHT steam-water separator is applied in Kenkyak Oilfield of Kazakhstan.

2.1.3 Efficient Heat Exchange and Transfer Technology

The technology transfers efficiently the burning heat energy of fuel via the heating surface to the heated media by the reasonable design of the radiation, convection heating surface and fume flow chart.

- **Technical Features**

The technology can organize the smoke flow chart effectively, strengthen heat transfer and guarantee that the working temperature for heating surfaces does not exceed the safe working temperature of the pipes.

- **Scope of Application**

It is fit for the design and research on the efficient and direct heating device in oil and gas fields.

2.1.4 Soot-blowing and Cleaning Technology for Superheated Steam Device Using Oil

Compared with the device using gas, the Superheated Steam Device Using Oil is much easier to deposit soot on pipe walls, so the technology means to select the proper soot-blowing method and improve the furnace structure to meet the soot-blowing and cleaning requirements.

- **Technical Features**

In view of the characteristics of the mobile weak blast wave soot-blowing device, soot-blowing tubes are set in appropriate positions of the device and a cleaning hole is set in the furnace bottom to realize the blowing of each heating surface by means of the weak blast wave soot-blowing.

- **Scope of Application**

It is fit for the soot cleaning on furnace pipe walls of the heating device using oil.

2.1.5 Waste Heat Recovery Technology for Superheated Steam Device

It means to recover the waste heat of smoke by the recovery device to improve thermal efficiency.

- **Technical Features**

The heating combustion supporting air with waste heat can reduce the funnel temperature and improve thermal efficiency.

- **Scope of Application**

It is fit for the waste heat recovery for exhaust smoke.

Air Preheater

2.1.6 Serial Technology for Superheated Steam Device

The technology means to optimize the economic load and allocation plan of the device and form serial and standardized parameters according to the common rated parameters of the wet steam generator in the thermal recovery of heavy oil and the actual oilfield configuration mode.

2.1.7 Control Technology for Steam Dryness and Superheat Degree

The technology means to set the alert point in the evaporation and superheated parts to control the dryness of wet steam and the superheat degree of superheated steam that enter the device.

- **Technical Features**

The technology can effectively control the dryness of wet steam and the superheat degree of superheated steam that enter the device

Superheated Steam Device Using Gas in Sinkiang Oilfield (GW4000-ZQ/18-Q)

- **Scope of Application**

It is fit for the superheated steam device for thermal production of heavy oil.

2.1.8 Monitoring Technology of Salification for Superheated Steam Device

The technology means to monitor the salification by the steam parameter change in the furnace pipe according to the relationship between steam parameters and salification, thus avoiding or reducing tube-burst caused by salification.

- **Technical Features**

Auto cleaning can be done according to the salification in the furnace pipe.

- **Scope of Application**

It is fit for the salification monitoring and cleaning without stopping the operation of boiler for the pipelines of steam generator and the superheated steam device used for thermal recovery in oil and gas fields.

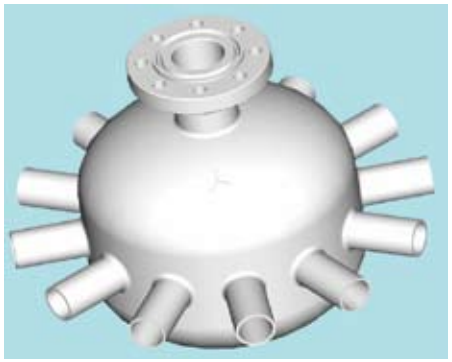
2.2 Supporting Technologies for Surface Engineering

2.2.1 Distribution and Measurement Technology for Superheated Steam

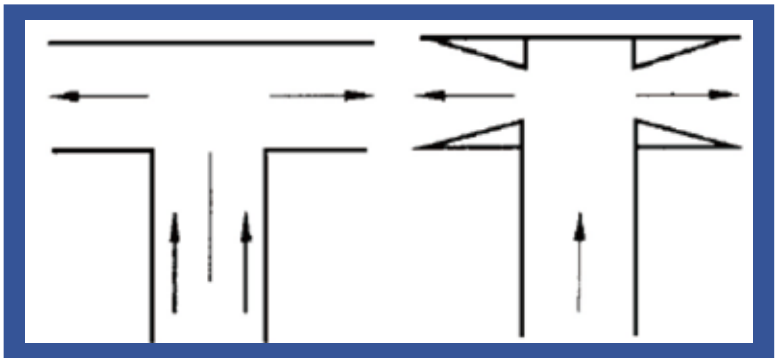
The technology means that when steam is injected to several heavy oil wells with only one set of device, some techniques are used to reduce the differences of steam injection flows caused by different injection parameters, thus realizing the scientific and demanded distribution of the superheated steam.

- **Technical Features**

a. It uses the injection-production syncretic mode to avoid the increasing cost caused by laying injection pipe and oil pipe respectively;



Sketch Map of Spherical Steam Distributor



Sketch Map of T-shape Steam Distributor

b. It uses the spherical distributor or T-shape pipe to distribute the superheated steam and uses the throttle valve to adjust and balance the steam injection quantity of each well;

c. The steam flow rate can be read and tested on-site, and the steam injection quantity, data storage, alarm and remote monitoring can be realized by RTU.

- **Scope of Application**

It is fit for the steam distribution and measurement of the superheated injection or wet steam injection in heavy oil production.

Sketch Map of Spherical Steam Distributor
Sketch Map of T-shape Steam Distributor

2.2.2 Selecting Well and Measurement Technology for Heavy Oil

The technology means to measure and select the produced liquid of heavy oil automatically.

- **Technical Indexes**

It can realize the unattended, automatic well selection and measurement.

Measuring accuracy: ≤1.5%.

- **Technical Features**

a. It can realize the unattended, automatic well selection and measurement by the combination of RTU and NC multi-port valve.

b. It ensures the gas-liquid separation by PID regulation technology of measuring distributor liquid level.

- **Scope of Application**

It is fit for the selected well measurement of the produced fluid for superheated injection or wet steam injection in heavy oil production.

Equipment in Multi-port Valve Room for Well Selection

2.2.3 High Temperature NC Multi-port Valve Technology

High Temperature NC Multi-port Valve is the main equipment for well selection and measurement of heavy oil, which is the special valve developed by CNPC researchers according to the actual requirements of oilfields.

- **Technical Features**

a. The material of sealing surface is produced with high-temperature resistance, oil resistance and anti-corrosion materials.

b. The valve can replace the current measurement pipe manifold and electric 3-way valve group, simplify the gathering and transportation process of metering station and realize the skid-mounted and unattended measurement.

- **Scope of Application**

It is fit for the automatic management of oilfield gathering and transportation and oil wells.

2.2.4 Desanding Technology for Heavy Oil

The technology means to clear sands in the produced fluid of heavy oil, thus avoiding the negative effects on its stable operation when sands get through the pipes, valves and other gathering equipment and preventing sands from reducing the service life of the equipment.

- **Technical Features**

a. It has high sand-removing effectiveness with low cost;

b. Its pressure drop: □100kPa.

- **Scope of Application**

It is fit for sand removal of the produced fluid of heavy oil.

Sand Removal Device for Heavy Oil

2.2.5 Security Monitoring Technology

The technology means to monitor and control the production process, and functionally it has two types: security monitoring technology with remote transfer and that without remote transfer.

Security Monitoring Technology with Remote Transfer

- **System Functions**

a. It includes the functions of data gathering, data processing, monitoring, alarm management, etc.

b. It has the features of high automation, simple operation and good man-machine interface, and can be remotely monitored.

- **Scope of Application**

The wireless signal transfer is not restricted in the oil/gas production fields.

Security Monitoring Technology without Remote Transfer—Upper Computer System

- **System Functions**

a. RTU's data can be read and the report can be output by the upper computer.

b. It is in charge of the production data query, system parameter conditions, database management, secondary development and routine maintaining for the whole automatic system.

- **Scope of Application**

It is fit for the oil and gas production field that needs security monitoring.

2.2.6 Supporting Technology of Gathering System for Superheated Steam Injection

The technology is for the selection of gas piping materials and piping insulation while the superheated steam is transported from the device to wellhead.

Gathering System of Superheated Steam Injection

- **Technical Features**

a. The superheated steam pipe of syncretic injection-production, economic and convenient to purchase, can meet the HPHT feature of superheated steam.

b. Heat preservation materials, economic and easy to construct, can meet the demand for pipe insulation

- **Scope of Application**

It is fit for the transportation and distribution of superheated steam.

2.3 Evaluation Technologies of Geologic Adaptability and Development Effect for Oil Reservoir

2.3.1 Evaluation Technology of Geologic Adaptability for Superheated Steam Injection

The technology means to establish the selection standard of reservoirs that is suitable for superheated steam injection by the methods of sublayer correlation and well log interpretation.

- **Technical Features**

a. It establishes the selection standard of reservoirs being suitable for superheated steam injection;

b. It sets suitable conditions and injection-production parameters of reservoirs for superheated steam injection;

c. It determines the selection criteria of ordinary heavy oil reservoirs for the development and deployment in superheated steam injection.

- **Scope of Application**

It is fit for the evaluation of geologic adaptability in the oil reservoir development.

2.3.2 Evaluation Technology of Development Effect for Steam Soaking with Superheated Steam Injection

The technology means to establish a comprehensive evaluation system for evaluating the development effect of superheated steam injection for heavy oil reservoirs and selecting the optimum well positions.

- **Technical Features**

a.It optimizes the geologic factor, development factor and steam injection parameters that influence the effect of superheated steam injection;

b.The value of each factor influencing the development effect of superheated steam injection is calculated with the method of fuzzy mathematics;

c.It forms a comprehensive evaluation system for the superheated steam injection, provides tools and approaches for increasing the development effect of superheated steam injection for heavy oil production.

- **Scope of Application**

It is fit for the development prediction and optimization of well positions for thermal recovery.

2.3.3 Parameter Optimization Technology for Superheated Steam Injection

The technology means to optimize the parameters of injection-production with the methods of statistics analysis, numerical simulation, etc. to realize the optimization and adjustment of the entire injection-production system.

- **Technical Features**

a. It optimizes steam injection parameters;

b. It determines the optimum steam injection parameters, reasonable steam-soak time, reasonable liquid production and incremental quantity of steam injection in the superheated steam huff and puff cycle, thus realizing the optimization and adjustment of the entire injection-production system.

- **Scope of Application**

It is fit for the optimization of parameters in superheated steam injection for heavy oil production.

2.3.4 Development & Deployment Technology for Superheated Steam Injection

The technology optimizes the superheated steam injection method, arranges thermal production solutions for pilot sites scientifically and provides a solid foundation for oil fields to raise the output.

- **Technical Features**

a.It selects the proper area to carry out the development in superheated steam injection;

b.It optimizes well spacing and injection-production parameters for superheated steam injection wells;

c.It determines and optimizes the deployment of development wells.

- **Scope of Application**

It is fit for the development & deployment in superheated steam injection.

3 TYPICAL CASES

3.1 Kenkyak Heavy oil field in Kazakhstan

From Oct. 2005 to Apr. 2010, the well number for superheated injection amounted to 209, the production of a single well increased 2-8t/d, the production cycle was 750 days, and the cyclic oil-steam ratio was 1.4. Moreover, the oilfield natural decline rate declined from 13% in 2008 to 8% in 2009; the production of steam stimulated wells (440t/d), with the well number accounting for 22% of that of the whole oilfield, shared 35 % of the oilfield's production. The total amount of the oilfield production was increased from 0.33 million tons before the use of superheated steam injection in 2006 to 0.47 million tons in 2009, which reached the highest production record in history. Aktobe Petroleum Company has determined the superheated steam injection as the main development method for heavy oil production in Kenkyak Oilfield.

3.2 Field Test of Injecting Superheated Steam for Heavy Oil Production in Sinkiang Oilfield

Sinkiang Oilfield Heavy Oil Development Company has started the superheated injection field test by using the first domestic superheated steam equipment since July 4, 2008. In July 2008, one of the equipment was applied in Block 97 of Sinkiang Oilfield, with experiments being performed for 6 times in 5 wells The recovery cycle was doubled as compared with that generated by the wet steam thermal production, and water production was more than the injected steam, which means that the water that had not been recovered in the last cycle was produced, so the oil production effect was much better than that brought by the conventional wet steam thermal production.

Superheated Injection Test Field in Kenkyak Oilfield of Kazakhstan

Test Field of Superheated Steam Injection for Heavy Oil Production in Sinkiang Oilfield

4 R&D EQUIPMENT

Direct Reading Spectrometer

Metallographic Microscope

Automatic Impact Test Enginery

The equipment relies on the Development Center of Science and Technology of Engineering Design Co., Ltd. of CNPC, Yanqing Electronic Laboratory and Process Simulation Laboratory, the manufacturing base of Jiangsu Shengang Boiler Co., Ltd., which have many sets of professional devices.

Direct Reading Spectrometer

Direct reading spectrometer can analyze nitrogen in steel, oxygen in copper and trace elements in non-ferrous metals, and does not need any instrument standardization for a long period in the continuous analysis.

Metallographic Microscope

It is used to examine semiconductor silicon wafer, mask board, LCD substrate, circuit boards, solid powder and various opaque industrial samples. It is also available for the inspection of biological samples and metallographic specimens, mineral samples and lithofacies samples.

Automatic Impact Test Enginery

It is used for testing the impact resistance of metal materials under dynamic load and judging the quality status of materials under dynamic load.

Large Heat Treatment Furnace

Large Heat Treatment Furnace

It is mainly used for the heat treatment of metal materials to control its performance by changing the material surface or internal metallurgical structure.

X-ray Fluorescence Detection Device

X-ray Fluorescence Detection Device

It is mainly used to detect the cracks or defects in metal materials or components.

Process Simulation Laboratory

Process Simulation Laboratory

It is mainly used in the wet saturated steam and superheated steam process simulation.

Electronic Laboratory

Electronic Laboratory

It is mainly used for the development of general automatic control system in oil and gas fields.

5 QUALIFICATION AND STANDARD

Based on the research and development environment for the superheated steam injection technology of heavy oil, CNPC has the qualifications of pressure vessel design, Grade “A” boiler manufacture and authentications of ISO9001 Quality Control System and ASME, etc.


中华人民共和国
特种设备设计许可证
Design License of Special Equipment
People's Republic of China
（压力容器）


中华人民共和国
特种设备制造许可证
Manufacture License of Special Equipment
People's Republic of China
（锅炉）


CERTIFICATE OF AUTHORIZATION
The American Society of Mechanical Engineers


（副本）
质量管理体系认证证书
北京道威尔石油天然气技术开发有限公司
CNAS
IAF
北京大陆航星质量认证中心


IQNet
CERTIFICATE
ISO 9001:2000 Standard

6 EXPERT TEAM

Lin Zonghu:(Famous heat engineering expert, Academician of China Engineering Academy, national expert with outstanding contribution, Professor and Ph.D. supervisor of Department of Thermal Engineering at Xi'an Jiaotong University, Director of Fluid Machinery Academic Committee of National Engineering Research Center)

He is mainly engaged in gas-liquid two phases, boiling heat transfer, multi-phase measurement research. He has published nearly 80 research papers and 13 monographs both at home and abroad. He was awarded the third prize of National Natural Science Award, the first prize of Technology Progress Award of the State Education Commission as well as 12 other provincial and ministerial-level science and technology awards, and obtained 4 Chinese patents.

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Liu Xilin:(Senior engineer, Ph.D. supervisor)

He is mainly engaged in oil production engineering. He has published 22 research papers in international and domestic journals and obtained 7 provincial and ministerial-level science and technology awards as well as 25 bureau-level achievement and management awards. Moreover, he has been appraised as one of the excellent scientific and technical workers of provincial, CNPC and bureau level for many times. Now he is a part-time professor of Daqing Petroleum Institute and Shenyang University.

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Fan Zifei:(Senior engineer, Member of American Society Petroleum Engineer, Member of Chinese Petroleum Society)

He has long been engaged in the oil and gas development research, development planning for oil and gas fields and obtained 1 second-prize of National Science and Technology Progress Award, 2 first-prizes and 3 second-prizes of CNPC's Science and Technology Progress Award. He has published more than 20 research papers in the core periodicals and magazines both at home and abroad.

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Zhang Xuelu:(Senior technical expert, senior engineer)

Mainly engaged in the production, ground engineering technology and management work, he has presided over and organized the research, experiment and promotion for new techniques of oil production. He has obtained 8 provincial and ministerial-level science and technology awards, 9 oilfield company-level scientific and technological achievement awards and 3 prizes of Excellent Paper Award, and obtained 10 patents. He has published 2 technical monographs and 6 research papers.

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Zhu Xinli:(Chief expert in major science and technology projects of CNPC's Engineering Design Limited Liability Company)

He has long been engaged in thermal energy engineering, exploiting heavy oil, etc. He has organized and carried out many designs and scientific researches, and assumed 5 CNPC scientific research projects. He has obtained 5 patents from the State Intellectual Property Office, 2 prizes of CNPC's Science and Technology Progress Award, one prize of Science and Technology Progress Award of China Petrochemical Industry Association. He has published more than 30 research papers and participated in the compilation of 2 monographs.

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