Industrialized Complete Technology for Atmospheric and Vacuum Distillation Units

Science & Technology Management Department, CNPC

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CHINA NATIONAL PETROLEUM CORPORATION

Industrialized Complete Technology for Atmospheric and Vacuum Distillation Units can Builds Sustainable Green Refineries for You!

Contents

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 reorgnized to become an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integrations of upstream and downstream operations, internal and external trade, production and marketing. CNPC's business covers six main sectors: oil and gas operations, petroleum engineering service, petroleum engineering construction, petroleum equipment manufacturing, financial services and new energy development. In 2014 CNPC produced 113.67 million tons of crude oil and 95.46 billion cubic meters of natural gas, while crude processing volume reached 150.2 million tons. The total revenue of RMB 2,730 billion with a profit of RMB173.4 billion had been achieved the same year.

CNPC was ranked 3th among the world's largest 50 oil companies and 4th in Fortune Global 500 in 2014.

CNPC strictly follows by the combined strategies of increasing resource capacity, expanding market shares and consolidating the international role, and persists in regarding technical innovation as a key framework to advance technological progress. To develop its core businesses, focuses will be placed on the solutions of key bottleneck technologies and key proprietary technologies. Thanks to continuously improving of the technical innovation system, optimizing the configuration of technological resources and strengthening the construction of strong talent teams, CNPC's technological creativity has been considerably upgraded. Consequently, a large number of technologies have been developed independently, with its own intellectual property.

The industrialized complete technology for atmospheric and vacuum distillation units is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

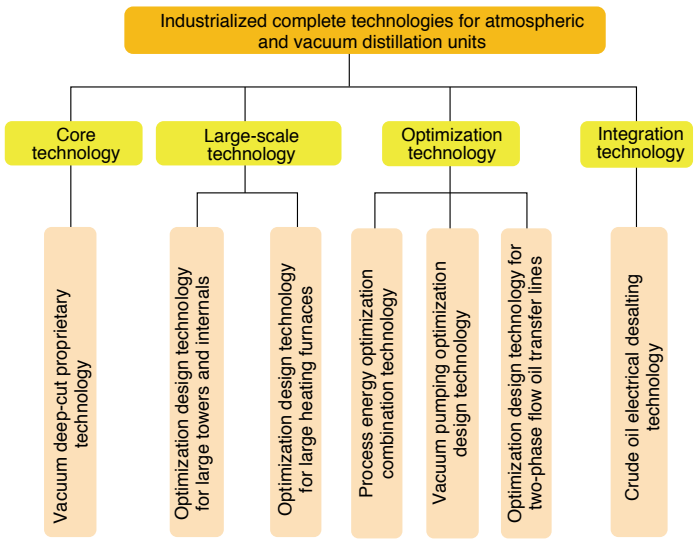
1 INTRODUCTION

The atmospheric and vacuum distillation unit is the first working procedure of a refinery for crude oil processing and its “leading” unit and provides feedstock to downstream secondary processing units. The processing capacity of the atmospheric and vacuum distillation unit represents the processing scale of the refinery, directly affects the production situation of downstream secondary processing units and the whole refinery, and plays a decisive role.

CNPC’s industrialized complete technology for atmospheric and vacuum distillation units includes multiple of characteristic complete technologies such as process energy optimization combination complete technology, vacuum deep-cut complete technology, crude oil electrical desalting and dewatering technology, optimization design technology for large towers and internals, vacuum pumping optimization design complete technology, etc., and has over 20 patents. They have been successfully used in over 40 oil refining enterprises at home and abroad.

CNPC has powerful expert teams, has trained a large number of excellent professional talents and can provide customers with economic, safe, green, environmentally friendly and internationally standardized engineering design and first-class services.

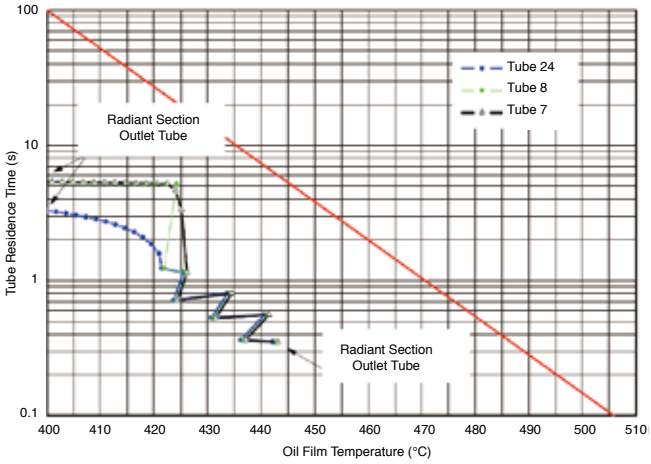
Business distribution map



2 CHARACTERISTIC TECHNOLOGIES

2.1 Characteristic design technology series

The industrialized complete technology for atmospheric and vacuum distillation units includes multiple characteristic complete technologies such as process energy optimization combination complete technology, vacuum deep-cut proprietary complete technology, crude oil electrical desalting and dewatering technology, optimization design technology for large towers and internals, vacuum pumping optimization design complete technology, etc.



Research diagram of deep-cut heating furnace coking

2.1.1 Vacuum deep-cut

With the vacuum deep-cut technology, the cut point of vacuum residue in conventional crude oil can reach to 570~620 ℃ , the content of nickel + vanadium in heavy VGO is less than 3μg/g(wt), the content of carbon residue is less than 1%(wt), the asphaltene content is less than 0.5%(wt), and the production period can reach over 4 years. The technology has been successfully applied in the design of multiple sets of atmospheric and vacuum distillation units. At present, these units run stably. The processed feedstock of Jilin Petrochemical 600×10^4t/a atmospheric and vacuum distillation unit is the mixed crude oil of Russia crude oil with Daqing crude oil, the TBP cut point of vacuum residue reaches over 565 ℃ , the wax oil yield is high, and the product quality is acceptable.

2.1.2 Optimization design technology for large towers and internals

With the technology, the attainable efficiency, pressure drop, operation elasticity and operation stability of small distillation towers can be realized by regulating and controlling the uniformity of gas and liquid flow in large towers. The technology can be used in the optimization design of internals of atmospheric towers and vacuum towers for atmospheric and vacuum distillation units of large refineries. With the technology, the ASTM D86 95% point of atmospheric side-cut diesel oil distillate of a large atmospheric and vacuum distillation unit is less than 365 ℃ , and the flash point is higher than 55℃ ; the content of <350℃ distillates in atmospheric residue is lower than 5%; the indexes such as carbon residue, heavy metal content, chroma and other datas of VGO all meet requirements; the content of light components in residuum reaches the designed index value. Atmospheric and vacuum operation elasticity can meet the requirement of 60%~120% and the operation period can last 4 years.

2.1.3 Optimization design technology for large heating furnaces

The technology involves furnace type optimization selection and optimization design of furnace tubes, combustion systems, waste heat recovery systems, etc. The technology can be used in optimization design of structures and waste heat recovery systems of atmospheric furnaces and vacuum furnaces for atmospheric and vacuum distillation units of large refineries.

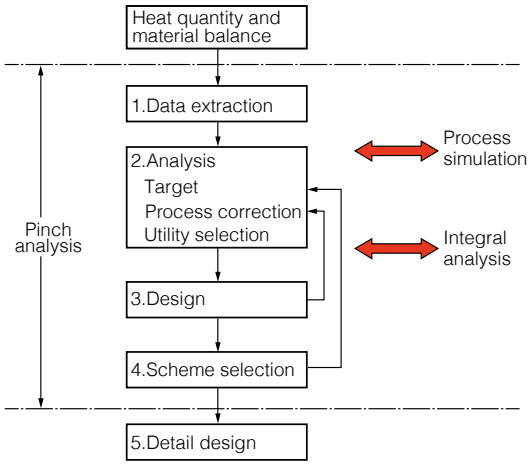
Large atmospheric furnace

Large vacuum furnace

2.1.4 Process energy optimization combination technology

The technology is used in energy optimization design of new atmospheric and vacuum distillation units, energy consumption analysis of atmospheric and vacuum distillation units which have run and energy optimization modification scheme design of atmospheric and vacuum distillation unit modification projects and can realize heat recovery of atmospheric and vacuum distillation units and the optimization of heat exchange network cost.

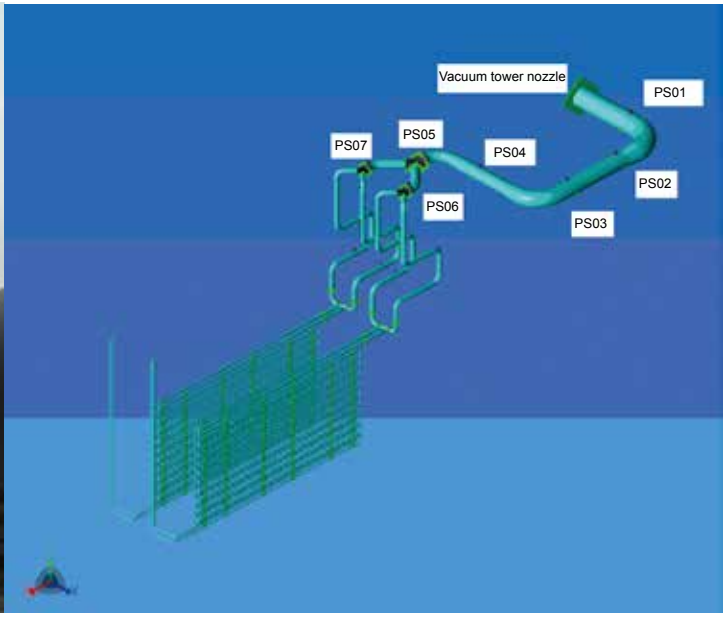
The pinch technology is used in optimization design of atmospheric towers and vacuum towers. On the premise of ensuring the quality and yield of products, optimize intermediate section heat extraction and try to provide more high temperature level heat sources to heat exchange network. Determine the heat extraction percent and heat extraction temperature level in each intermediate section of atmospheric towers and vacuum towers using advanced computer simulation software, find out the pinch temperature difference which causes the total cost to be the lowest, and reasonably select the heat exchanger type. Optimize and integrate the energy consumption of all units and can reduce 10%~15% unit energy consumption.



Process energy optimization combination flow chart

2.1.5 Vacuum pumping optimization design technology

Carry out optimization design of vacuum tower operating pressure on the premise of ensuring product quality; carry out regression of the vacuum pumping system calculation model according to crude oil type and vacuum furnace outlet temperature, and then determine vacuum pumping system load; optimize each stage of compression ratio of the vacuum pumping system. The energy consumption reaches international advanced level. The technology can be used in optimization design of the vacuum furnace vacuum pumping system of fuel type and lubricating oil type atmospheric and vacuum distillation units.



Vacuum oil transfer line layout optimization

2.1.6 Optimization design technology for two-phase flow oil transfer lines

Vacuum furnace tube, oil transfer line, vacuum tower feed distributor and vacuum tower's other internals are analyzed and designed as a whole. By preventing furnace tube coking, controlling oil and gas flow velocity of oil transfer line, analyzing piping system stress and optimizing oil and gas separation in the flash section of vacuum tower, find the best fluid flow pattern in the oil transfer line and the reasonable key point pressure and design the oil transfer line system suitable for deep-cut operating mode. The technology can be used in optimization design of atmospheric oil transfer lines and vacuum oil transfer lines of atmospheric and vacuum distillation units.

2.1.7 Crude oil electrical desalting technology

The technology includes AC electrical desalting, AC and DC electrical desalting, high speed electrical desalting, etc. According to different crude oil properties, determine appropriate operating temperature through evaluation; use appropriate deemulsifiers or ultrasonic demulsification technology and reasonably design the process flow.

Each atmospheric and vacuum distillation unit is fitted with an electrical desalting system. The technology can reduce HCl corrosion to atmospheric and vacuum distillation units and the destructive effect on downstream unit catalysts; in addition, low oil content in discharged water reduces the load of wastewater treatment sites.

3 TYPICAL CASES

3.1 Application of vacuum deep-cut technology

Jilin Petrochemical 600×10^4t/a atmospheric and vacuum distillation unit was designed with the vacuum deep-cut complete technology and was successfully put into production at a time on Oct. 11, 2010. The unit consists of heat exchange, electrical desalting, primary tower, atmospheric furnace, atmospheric tower system, vacuum furnace, vacuum tower system, light hydrocarbon recovery system, three-injection system, etc. With the technology, the cut point of vacuum residue can reach to 565℃ , the content of nickel+ vanadium in heavy VGO is less than 3μg/g(wt), the content of carbon residue is less than 1%(wt), and the asphaltene content is less than 0.5%(wt). The vacuum oil transfer line of the unit is operated stably. The load of the vacuum pumping system is 5%~10% lower than that of a domestic like unit. The heat exchange final temperature calibration data of the unit reaches 314℃ . As of the date of commence of the unit, the yield and quality of all products are acceptable, the unit runs stably continuously, and the energy consumption calibration data is 10.128kg standard oil/t crude oil (including 0.79kg standard oil/t crude oil of the light hydrocarbon recovery part).

3.2 Application of 1000×10^{4}t/a atmospheric and vacuum distillation unit complete technology

Sichuan Petrochemical 1000×10^{4}t/a atmospheric and vacuum distillation unit is designed to process Southern Xinjiang crude oil/Northern Xinjiang Crude oil and KZ crude oil. The unit has large scale and good adaptability to crude oil. The unit has been optimized through process energy optimization combination, two-phase flow oil transfer line design, vacuum pumping optimization design, large heating furnace optimization design, crude oil electrical desalting technology, etc. The unit was successfully put into production at a time on Jan. 16, 2014. The yield and quality of all products are acceptable; the unit runs stably continuously, the energy consumption of the unit is 5%~10% lower than that of a domestic like unit.

4 SCIENTIFIC RESEARCH EQUIPMENT

CNPC is armed with the advanced application system of computer network platform and real-time and efficient network communication system, which are widely used in design and management. Moreover, it provides over 100 kinds of engineering design software such as PIMS, PRO II, AspenPlus and PDMS to meet the demands of different owners at home and abroad.

Designation	Category of Software
PIMS	An optimal management system of factory plan, also a powerful user-friendly software package of economic planning for process industry. It adopts the Linear Programming (LP) technology to optimize the operation plan of process industry enterprises. It can be used in: 1. Optimization of operational plan; 2. Logistics and supply chain management; 3. Technical evaluation; Capacity estimation and production expansion study of each unit in factories
Pro/II、Aspen plus、Aspen Hysys	Large general process simulation software for production unit design, steady simulation and optimization
Aspen Energy Analyzer	Computing software of pinch technology based on process combination and integration. It uses the site operation data or the process simulation computation data as input to design the process flow with the minimum energy consumption and lowest operation cost in chemical plants and refineries. Typical applications are as follows: 1. Process integration plan design for energy conservation reconstruction of old plants; 2. “Debottleneck” analysis for production capacity expansion of old plants; 3. Design analysis for energy recovery system (e.g. heat exchanger network). Rational layout and optimized operation of utility system (including models such as the heating furnace, steam turbine, gas turbine and refrigerating system)
Smart Plant P&ID	Smart PID design system centering on database and driven by rules

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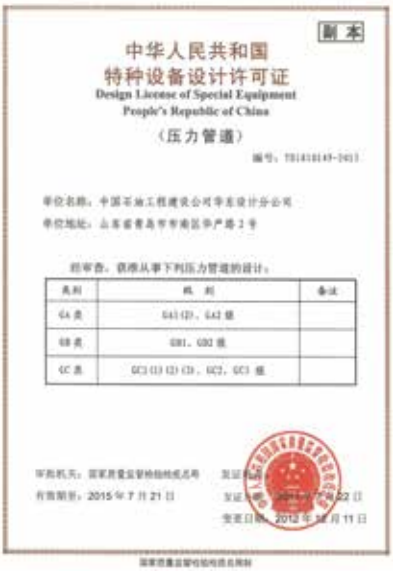
Designation	Category of Software
Dynsim	Dynsim is a full-featured and mature dynamic process simulation system based on precise calculation; it provides accurate and reliable calculation results by using the mechanism based technology and precise thermodynamic data to solve the most difficult problems of dynamic simulation encountered in engineering analysis, control system checking and operator training system, etc.
PDS、PDMS	As a three-dimensional plant layout and design management system, the software has the following main features: 1. The full-scale 3D entity modeling; 2. Applying the network to perform real-time collaborative design of multiple disciplines and simulate real spot environment, thus allowing multiple professional groups to carry out collaborative design to establish a detailed 3D digital factory model and every designer at any time during design process to check what the other designers are doing; 3. In the process of interactive design, PDMS can automatically perform real-time 3D collision check among components and various professional design products, ensuring the accuracy of design results on the whole; 4. The separate database structure allows all the components and equipment information to be stored in the parameterized component library and equipment library, instead of the third party's database; 5. The open development environment facilitates the output of drawings meeting traditional industry standard
CAESAR Ⅱ	CAESAR Ⅱ is professional software for pressure piping stress analysis. It can be used for both static analysis and dynamic analysis. It can provide users with complete international general specifications concerning pipeline design conveniently
HTRI、HTFS	A kind of software used for calculation of heat transfer of heat exchanger and burning furnace and other relevant calculations
Flare-Net	Used for steady-state design, calculation and debottleneck of flare system
PFR FRNC-5PC	Heating furnace simulation and structure design
ANSYS	Equipment stress analysis
STADD/CHINA2006	Steel structure computation
P3E/C	Project program management
Project Wise	Document management
POWERON	General contracting management

5 QUALIFICATION STANDARDS

5.1 Qualification

CNPC possesses Class A qualifications in engineering audit, engineering investigation (geotechnical engineering, engineering surveying) and engineering cost consultation. Besides, CNPC holds the qualifications in pipeline design and the design of pressure vessels of 15 types in categories Ⅰ, Ⅱ and Ⅲ.



5.2 Standard

All kinds of domestic and foreign standard specifications are known well and, the design standards proposed by owners are followed strictly.

Standards established by CNPC as chief compiler or complier member:

Standard number	Standard name/planned project name	chief complier/ complier member
GB/T9112—2010	Type and parameters of steel pipe flange	complier member
GB/T9125—2010	Fasteners for pipe flange connection	complier member
GB/T9124—2010	Technical specification of steel pipe flange	complier member
GB/T 13402—2010	Large-diameter steel pipe flange	complier member
HG/T20653—1011	Technical specification for chemical water treatment design in chemical enterprises	complier member
Q/SY1303—2010	General principles for anti-seepage treatment design in petrochemical enterprises	chief complier
CNPC DOC. (2005) No.519	Installation project expense standard in petroleum construction	complier member
Q/SY 1373—2011	Rules for compiling chapters concerning energy conservation in preliminary design of refining and petrochemical projects of fixed assets investment	chief complier
Q/SY 1579—2013	Rules for compiling chapters concerning water conservation in preliminary design of refining and petrochemical projects of fixed assets investment	chief complier
Q/SY 1064—2010	General rules for compiling sections(chapters) concerning energy and water conservation-feasibility study and preliminary design of fixed assets investment projects	complier member
Q/SY 1577—2013	Rules for making assessment report concerning energy conservation of refining projects of fixed assets investment	chief complier
GB/T 17185—1997	Steel flange fittings	complier member
GB/T19326—2003	Socket welded, thread and butt welded steel side tube base	complier member
GB/T17186.1	Calculation method of pipe flange connection strength Method A	
JB/T1762—2012	Stop valve and check valve for LNG	complier member
Q/SY2012—106	Technical requirements for prevention and control of water pollution under accident condition	complier member

5.3 Patent technologies

No.	Patent name	Patent type	Application No. or patent No.
1	Baffle type crude oil electrical desalting and dewatering equipment	Utility model patent	ZL 201120436206.0
2	Equipment for preventing vibration of heat exchangers and pipelines in the heat exchange network of an atmospheric and vacuum distillation unit	Utility model patent	ZL 201120503692.3
3	Bracket combination structure of the intermediate furnace tube of a cylindrical tube heating furnace	Utility model patent	ZL 200520084780.9
4	Asphalt heating kettle of butane deasphalting unit with small processing capacity	Utility model patent	ZL 200720190562.2
5	A double-cylindrical radial chamber heating furnace	Utility model patent	ZL 201120018908.7
6	A single-row single-face biradial nest tube vacuum deep-cut vacuum furnace	Utility model patent	ZL 201120018906.8
7	A heating furnace with guide plate	Utility model patent	ZL 201120272933.8
8	A double-step double-face radial tube type heating furnace	Utility model patent	ZL 201120274457.3
9	Fume sampling port of heating furnace of refinery unit	Utility model patent	ZL 201120430801.3
10	Vertical furnace tube location sleeve of heating furnace of refinery unit	Utility model patent	ZL 201120430710.X
11	Down-fired U-tube box type heating furnace	Utility model patent	ZL 201120430713.3
12	Eccentric reducer flanged collecting tube for heating furnace of refinery unit	Utility model patent	ZL 201120431043.7
13	A heating furnace tube hanger	Utility model patent	ZL 201320101169.7
14	A welding structure for bottom head and skirt of large vessel	Invention patent	ZL200310121385.9
15	Externally adjustable welded seal high-pressure heat exchanger	Utility model patent	ZL 200720169438.8

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No.	Patent name	Patent type	Application No. or patent No.
16	Flexible welded seal ring for heat exchanger	Utility model patent	ZL 200920222890.5
17	Flexible sealing plug	Utility model patent	ZL201220024285.9
18	A spiral twisted flat tube heat exchanger	Utility model patent	ZL 201120476306.6
19	Folded baffle plate for spiral baffle heat exchanger	Utility model patent	ZL 201020176895.1
20	Anti-plugging liquid distributor for fractionating tower	Utility model patent	ZL 201220484159.1
21	Support beam	Utility model patent	ZL 201220704905.3
22	Anti-plugging liquid distributor for fractionating tower	Utility model patent	CN 201220484159
23	A baffle plate for baffle electrical desalting and dewatering equipment	Utility model patent	CN 201110033151
24	Support beam	Utility model patent	CN 201220704905
25	Equipment for preventing vibration of heat exchangers and pipelines in the heat exchange network of an atmospheric and vacuum distillation unit	Utility model patent	CN 201120503692

6 EXPERT TEAM

Dong Fuchun

Senior technical expert, senior engineer, expert enjoying the government special allowance. He has taken charge of completing the design of multiple sets of atmospheric and vacuum distillation units including 500×10^4t/a and 1000×10^4t/a ones. The key technical research projects completed under the direction of him including tower internals, DC electrical desalting and dewatering technology, vacuum tower top high vacuum vacuating technology, etc. these have filled up the technology gap in China. He has obtained 3 provincial and ministerial science and technology advance prizes.

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Liu Dengfeng

Senior technical expert, senior engineer. He is skilled in engineering design of atmospheric and vacuum distillation units, development and application of relevant technologies, whole-refinery overall processing flow design and design project management. He has taken charge of designing and completing multiple units including Sichuan Petrochemical 1000×10^4t/a atmospheric and vacuum distillation unit, Jilin Petrochemical 600×10^4t/a atmospheric and vacuum distillation unit (vacuum deep-cut), Changqing Petrochemical 500×104t/a atmospheric and vacuum distillation unit, Huabei Petrochemical 500×10^4t/a atmospheric and vacuum distillation unit, etc. He has obtained 1 national excellent design prize and 4 provincial and ministerial excellent engineering design and science and technology advance prizes.

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Han Bing

Senior technical expert, senior engineer. She is skilled in engineering design of atmospheric and vacuum distillation units as well as development and application of relevant technologies. She has taken charge of designing and completing multiple units including Guangxi Petrochemical 1000×10^4t/a atmospheric and vacuum distillation unit, Ningxia Petrochemical 500×10^4t/a atmospheric and vacuum distillation unit, Dagang Petrochemical 500×10^4t/a atmospheric and vacuum distillation unit, etc. She has obtained 1 national engineering design excellent computer software prize and 4 provincial and ministerial excellent engineering design and science and technology advance prizes.

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Wang Xuelian

Senior technical expert, senior engineer. She is engaged mainly in process design of atmospheric and vacuum distillation units, viscosity breaking units, gas fractionation units, etc. She has obtained 5 provincial and ministerial excellent design prizes. 5 papers written by her have been published.

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Xiao Wenli

Technical expert, senior engineer. She is skilled in design and technology development of nonstandard equipment of atmospheric and vacuum distillation units. She has completed the design and examination of main equipment of multiple sets of refinery units including Guangxi Petrochemical 1000×10⁴t/a atmospheric and vacuum distillation unit, Sichuan Petrochemical 1000×10⁴t/a atmospheric and vacuum distillation unit, Jilin Petrochemical 600×10⁴t/a atmospheric and vacuum distillation unit, etc. She has obtained 3 provincial and ministerial excellent engineering design prizes. She has 1 utility model patent. Over 3 professional papers written by her have been published in petrochemical equipment journals.

Song Jiwei

Senior engineer, national registered oil and natural gas engineer, pressure pipeline approver. He is skilled in layout optimization of oil refining and chemical units and integral optimization design of rotary equipment piping systems and large diameter high temperature pipelines. He has taken charge of completing the engineering design of over 80 sets of units including Guangxi Petrochemical 1000×10⁴t/a atmospheric and vacuum distillation unit, Sichuan Petrochemical 1000×10⁴t/a atmospheric and vacuum distillation unit, Huabei Petrochemical 500×10⁴t/a atmospheric and vacuum distillation unit, Changqing Petrochemical 500×10⁴t/a atmospheric and vacuum distillation unit, etc. He has obtained 1 national excellent engineering design silver prize, 5 grade Ⅰ provincial and ministerial excellent engineering design and science and technology advance prizes and 2 grade Ⅱ provincial and ministerial excellent engineering design and science and technology advance prizes.

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Hu Yuchen

Senior technical expert, senior engineer, registered automatic system engineer. He is skilled in type selection and design of automatic control systems and instruments for atmospheric and vacuum distillation units. As the professional principal, he has completed the design of multiple units including Sichuan Petrochemical 1000×10^4t/a atmospheric and vacuum distillation unit, Huabei Petrochemical 500×10^4t/a atmospheric and vacuum distillation unit, Sudan Khartoum Refinery 250×10^4t/a atmospheric and vacuum distillation unit, etc. He has participated in technology control of $500\sim1000\times10^4$t/a atmospheric and vacuum distillation units of Guangxi Petrochemical, Guangdong Petrochemical, Qingyang Petrochemical, Ningxia Petrochemical, Hohhot Petrochemical, etc. He once obtained 4 provincial and ministerial excellent engineering design prizes.

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Dou Shishan

Senior technical expert, researcher. He is skilled in engineering design of large heating furnaces and application and development of relevant technologies and especially has abundant and mature experience in the design of HTHP critical hydrogen heating furnaces of process units and atmospheric and vacuum heating furnaces of 1000×10^4 t/a refinery units. He has taken charge of designing the heating furnaces for multiple sets of large units including Guangxi Petrochemical 10Mt/a refinery unit, Guangdong Petrochemical 20Mt/a refinery unit, etc. He has obtained 1 CNPC excellent engineering design prize, 1 excellent engineering design prize of China Petroleum and Chemical Society and multiple company's excellent engineering design prizes.

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