FCCU Industrialized Complete Technologies

Science & Technology Management Department, CNPC

2015

CHINA NATIONAL PETROLEUM CORPORATION

FCCU Industrialized Complete Technologies :
Provide You with Comprehensive High-quality
Solutions to High-efficiency Conversion of Heavy Oil!

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 FCCU industrialized complete technologies is one of representatives for major innovations of CNPC.

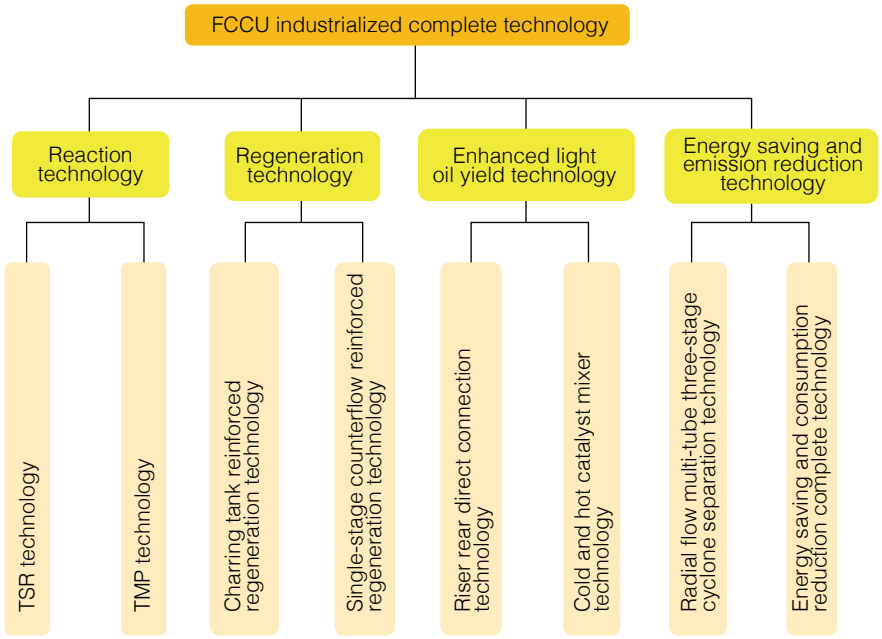
OFFERING ENERGY SOURCES, CREATING HARMONY

1 INTRODUCTION

FCCU is one of core units of a refinery. The FCC capacity accounts for about 40% of total primary processing capacity in China. About 70% gasoline, 30% diesel oil and 30% propylene come from FCCU, so FCC process is one of important means for heavy oil cracking.

Through several decades of accumulation, CNPC has gradually formed its specific FCCU industrialized complete technology series combining R&D, design and production, a series of core technologies, and more than 10 patents and technology secrets. Representative technologies include: two-stage riser FCC TSR technology, two-stage riser FCC TMP technology, regeneration technology, energy saving and emission reduction technology, etc. These technologies have advantages such as extensive adaptability to feedstock, high light oil yield, good product indexes, low energy consumption, small pollutant emission, etc.

In recent 10 years, these technologies have been popularized and applied in over 20 FCCUs of Daqing Petrochemical, Qingyang Petrochemical, Jinxi Petrochemical, etc. and have gained good effects and reputation.



2 CHARACTERISTIC TECHNOLOGIES

They include multiple of technologies involving gasoline and diesel oil enhancing, enhanced total liquid yield, TMP, reinforced regeneration, energy saving and consumption reduction, long-period running, etc. and can help a refinery maximize its product yield and quality and obtain the most economic and effective profitability.

2.1 Two-stage controlled FCC depth technology

2.1.1 TSR technology——two-stage riser FCC process

The TSR technology is fitted with two separate riser reactors to solve the problem involving deteriorated distribution of over-long products in riser and reaction competition of fresh feedstock and recycle stock in the same reactor. This can effectively prohibit excessive cracking, reduce coke yield, increase light oil product yield and improve light oil product quality. The technology can be used for new or reconstructed units with main target products being gasoline and diesel oil. Compared with conventional FCC technology, the TSR technology increases liquid yield somewhat; in addition, with the TSR technology, the ratio of diesel ratio to gasoline can be adjusted flexibly, diesel oil yield can be increased by about 5%, and economic benefits are remarkable.

2.1.2 TSR technology——two-stage riser FCC propylene yield increasing process

TMP is characterized by high propylene yield, low dry gas yield, high RON, low diesel oil density, high ethylene content (45%~50%) in dry gas, etc. TMP can be used to directly process various feedstocks such as VGO, atmospheric residue, vacuum residue, CGO, desulfurated residue, coking naphtha, etc. and can be used for new or reconstructed units with target products being mainly propylene and concurrently gasoline and diesel oil.

2.2 Charring reinforced regeneration technology

2.2.1 Charring tank reinforced regeneration technology

Greatly improve the charring efficiency during generation by optimizing a series of reinforced charring measures including main air distribution, catalyst distribution, fluidized rectification and other ways on the basis of traditional charring tank regeneration. Due to excellent performance and very good adaptability to catalytic feedstock, the technology can be used for new or reconstructed units and is applicable to various catalytic feedstocks. The technology is characterized by realization of complete regeneration of catalyst in charring tank, low regeneration temperature, small system catalyst inventory, maximal protection of catalyst activity, stable and reliable catalyst conveying system, no adjustment of main fan flow rate, power generation state of main fan set all the year, etc.

2.2.2 Single-stage counterflow reinforced regeneration technology

Single-stage counterflow regeneration is the completion of catalyst charring process at a time using

a fluidized bed regenerator. The charring efficiency in the generation process can be greatly improved by optimizing a series of reinforced charring measures including main air distribution, catalyst distribution, fluidized rectification, etc. The technology can be used for new or reconstructed units, has an extensive applicability scope and is especially applicable to the feedstock with high content of heavy metal vanadium. The regeneration temperature is no higher than 700°C, and the fixed carbon on regenerated catalyst can reach to -0.1wt%.

2.3 Single technology for reducing dry gas yield and increasing light oil yield

2.3.1 Riser rear direct connection technology

With the riser rear quick-separation and direct-connection technology, the retention time of oil and gas can be greatly shortened and secondary reaction can be reduced while avoiding settler coking. Compared with domestic and foreign like technologies, this technology has advantages such as no increase in additional steam consumption, no catalyst loss during commencement, shutdown and normal production, etc. and is one of technical means for heavy oil guarantee during long-period running of RFCC. The technology can be used for new or reconstructed units and is applicable to the FCCU with one or multiple risers.

2.3.2 Cold and hot catalyst mixer technology

The hot catalyst from a regenerative inclined pipe is mixed with the cold catalyst from an external cooler, which can achieve the purpose of reducing regenerated catalyst temperature very well. The technology can ensure uniform mixing of cold catalyst with hot catalyst, prevent the adverse impact of bias flow temperature difference on reaction and cause the temperature of the regenerated catalyst participating in reaction not to be limited by regenerated charring conditions. In addition, in cooperation with an advanced online mixing temperature control scheme, the technology can realize stepless regulation of regeneration severity participating in reaction. The technology is applicable to the FCCU with an external cooler. With the technology, dry gas yield can be reduced by 1% and light oil yield can be increased accordingly.

2.4 Environmental protection technology for reducing catalyst powder emission: radial flow multi-tube three-stage cyclone separation technology

The technology solves the problem on low comprehensive efficiency of a single tube of the conventional three-stage cyclone separator and greatly improves the comprehensive efficiency of a single tube. With the technology, the dust content at the three-stage cyclone outlet is lower than 90mg/Nm^3 on the premise of keeping three-stage pressure drop unchanged. The equipment can be applicable to various regenerative FCCUs.

2.5 Energy saving and consumption reduction complete technology

The corresponding energy saving complete technology has been developed by fully analyzing the composition of unit energy consumption starting with the three important aspects such as increasing the recycling ratio of coke combustion heat, increasing the recycling ratio of low temperature waste heat and reducing the energy consumption of product separation. After optimizing a unit using the energy saving and consumption reduction complete technology, the energy consumption of the unit can be generally reduced by 5~10kg standard oil/t catalytic feedstock. The technology can be completely or partially applied for new or reconstructed projects and reduce the unit's operation cost.

3 TYPICAL CASES

3.1 TSR technology application case

The technology has been used in long-period running of over ten FCCUs in China. Compared with conventional FCC technology, the TSR technology increases liquid yield somewhat. In addition, with the TSR technology, the ratio of diesel ratio to gasoline can be adjusted flexibly, diesel oil yield can be increased by about 5%, the cetane number of diesel oil can be increased by about 3 units, the alkene content in gasoline can be reduced to <30v%, and economic benefits are remarkable. Therefore, the technology has very good popularization value.

3.2 TMP technology application case

TMP technology has found industrial application in Hongrun Petrochemical 80×10^4t/a unit using VGO as the feedstock at the same of reprocessing of part coking naphtha of the coking unit. The designed indexes are as follows: propylene yield 19.82%, total liquid yield 78%, the sum of dry gas yield + coke yield 15.5%, and gasoline RON larger than 90. The technology can be used in reforming of coking naphtha while increasing propylene production so as to increase the octane number of coking naphtha.

3.3 Charring tank reinforced regeneration technology application case

The charring tank reinforced regeneration technology has been applied in Yumen Petrochemical 80×10^4t/a catalytic cracking revamping project. After revamping, the regeneration temperature has been decreased from 710 ℃ to lower than 690 ℃, thus greatly reducing catalyst damage caused by heavy metal vanadium. In addition, low regeneration temperature makes for increasing reaction catalyst-to-oil ratio, reducing dry gas yield and increasing light oil yield. After revamping, the catalyst consumption of the unit has been reduced from 2.2kg/t feedstock to 1kg/t feedstock, the dry gas yield has been decreased by 1 unit, and the light oil yield has been increased by 1~2 units.

3.4 Riser rear direct connection technology application case

The riser rear direct connection technology has been applied in Qingyang Petrochemical 160×10^4t/a two-stage riser catalytic cracking revamping project. After revamping, the retention time of oil and gas in the riser rear has been shortened greatly, thus reducing adverse secondary reaction. The oil and gas overflowing from coarse cyclone and top cyclone legs and the stripping oil and gas in the stripping section are directly led into the top cyclone from the gas tube at the bottom of the settler, thus eliminating the possibility of settler coking. Through revamping, the settler coking problem has been solved on the premise of not increasing steam, the dry gas yield has been reduced by 0.5%~1%, and the light oil yield has been increased by 0.5%~1%.

CNPC is armed with the advanced application system of computer network platform and real-time

4 SCIENTIFIC RESEARCH EQUIPMENT

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; 4. 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); 4. Rational layout and optimized operation of utility system (including models such as the heating furnace, steam turbine, gas turbine and refrigerating system)
Smart Plan P&ID	Smart PID design system centering on database and driven by rules
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.

to be continue

Designation	Category of Software
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	A combined cyclone separation filter	Utility model patent	ZL92238282.4
2	A regenerator oil-fired nozzle	Utility model patent	ZL01200325.5
3	A new oil slurry steam generator	Utility model patent	ZL200420098135.8
4	A propylene production unit with heavy oil	Utility model patent	ZL201020597213.4
5	An oil slurry filtering separation unit in catalyst cracking fractionating tower	Utility model patent	ZL201120503564.9
6	An improved catalytic cracking agent two-stage regeneration method and equipment	Invention patent	ZL201010279631.3
7	A conveying bed reaction riser	Utility model patent	ZL200820109735.8
8	A natural circulation waste heat boiler	Utility model patent	ZL201120430712.9
9	A MTO unit and method	Invention patent	201310154367.4
10	An alkene preparation method by alkane dehydrogenation	Invention patent	201210179765.7
11	A new anti-coking cyclone separation system applicable to multi-stage riser reactor	Utility model patent	201320346184.8
12	A simple separation method for division of catalytic cracking gasoline into light and heavy gasoline	Invention patent	201210097557.2

6 EXPERT TEAM

Hao Xiren

National investigation design master, expert enjoying the government special allowance, national young and middle-aged expert of outstanding contribution. He has taken charge of completing the R&D of key petrochemical science and technology research projects involving wax oil catalytic cracking, RFCC, catalytic cracking, etc. He has obtained 1 national science and technology advance prize, 2 national excellent design prizes, 6 provincial and ministerial science and technology advance prizes and 5 provincial and ministerial excellent design prizes. He has applied for 10 patents.

Tel: 0532-80950996

Email: haoxiren@cnpccei.cn

Xie Keqian

Senior technical expert. He has applied over 10 patents and proprietary technologies, most of which have been popularized and applied as FCCU core technologies. He has taken charge of designing, newly building and reconstructing over 40 sets of FCCUs, e.g. Maoming 2200 kt/a MIP unit, Guangxi Petrochemical 3500 kt/a RFCCU, Hohhot Petrochemical 2800 kt/a MIP unit, etc.

Tel: 0532-80950800

Email: xiekeqian@cnpccei.cn

Xia Zhiyuan

Senior engineer. He has been engaged in the design of petrochemical equipment. He has participated in completing the design of nearly 20 sets of FCCUs including Dalian 3500 kt/a RFCC, Hainan Dongfang 1200 kt/a DCC, etc. He has obtained multiple provincial and ministerial excellent design prizes.

Tel: 0532-80950299

Email: xiazhiyuan@cnpccei.cn

Wang Yang

Senior engineer. He is skilled in the engineering design of plan layout, operation, maintenance, fire safety, pipeline, etc. of FCCU and relevant process extension units. He has undertaken the design of dozens of sets of units including Dalian Petrochemical 3500 kt/a FCCU, Guangxi Petrochemical 3500 kt/a FCCU, Jilin Petrochemical 2000 kt/a TMP, etc. He has obtained 7 provincial and ministerial excellent engineering design, excellent investigation design and science and technology advance prizes.

Tel: 0532-80950912
Email: wangyang@cnpccei.cn

Gao Xionghou

Professor level senior engineer. He has been long engaged in R&D of petroleum refining catalysts and process. As an academic leader, he has undertaken over 40 major scientific research projects including national “973” plan projects, science and technology support plan projects, etc. and has obtained a large number of industrialization achievements which are of much significance at home and abroad. He has obtained 2 grade II national science and technology advance prizes and 18 provincial and ministerial science and technology achievements. 72 papers written by him have been published, including 13 SCI ones. 4 major series and 19 trademarks of new catalyst products have been developed, and totally 0.2 billion tons of heavy oil have been processed.

Tel: 0931-7961603
Email: gaoxionghou@cnpc.com.cn

Yang Chaohe

Professor, Ph.D. candidate supervisor, specially-invited expert of PetroChina Petrochemical Research Institute. He has been included in the “NCET” of the Ministry of Education.

Tel: 0532-86981169
Email: yangch@hdpu.edu.cn

Lu Chunxi

Professor, Ph.D. candidate supervisor, 973 chief scientist, professor of national key heavy oil laboratory, China University of Petroleum (Beijing); academic committee of key heavy oil processing laboratory, China Petrochemical Corporation. He has a long history of working at studying catalytic cracking fluidization engineering and equipment, and developed a catalytic cracking riser outlet (FSC, CSC, VQS, SVQS) innovative technology at the international advanced level. He has obtained Second Prizes 2 of the national technology progress awards (Ranks 1 and 3), 12 provincial science and technology achievements, including First Prizes 5.

Tel: 010-89733237
Email: lcxing@cup.edu.cn

CNPC
中国石油

技术依托单位联系人：

张　星　先生

电　话：0532-80950686

Email: zhangxing@cpeccei.cn

中国石油科技管理部联系人：

刁　顺／窦红波　先生

电　话：86-10-59986059/59982528

Email: sdiao@cnpc.com.cn/ douhb@cnpc.com.cn

Contact of the Technical Support Unit :

Mr. Zhang Xing

Tel: 0532-80950686

Email: zhangxing@cpeccei.cn

Contact of Science&Technology Management Department,CNPC :

Mr. Diao Shun/Dou Hongbo

Tel: 86-10-59986059/59982528

Email: sdiao@cnpc.com.cn/ douhb@cnpc.com.cn