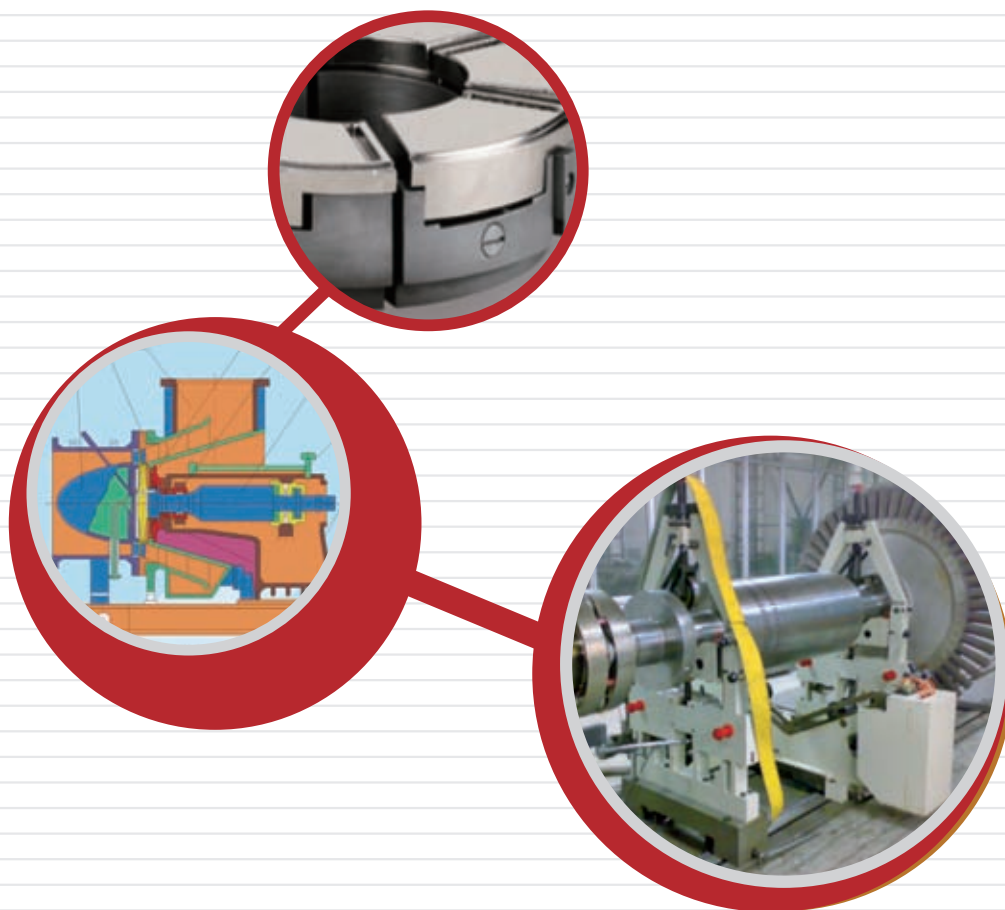


Superpower Flue Gas Turbine

Science & Technology Management Department

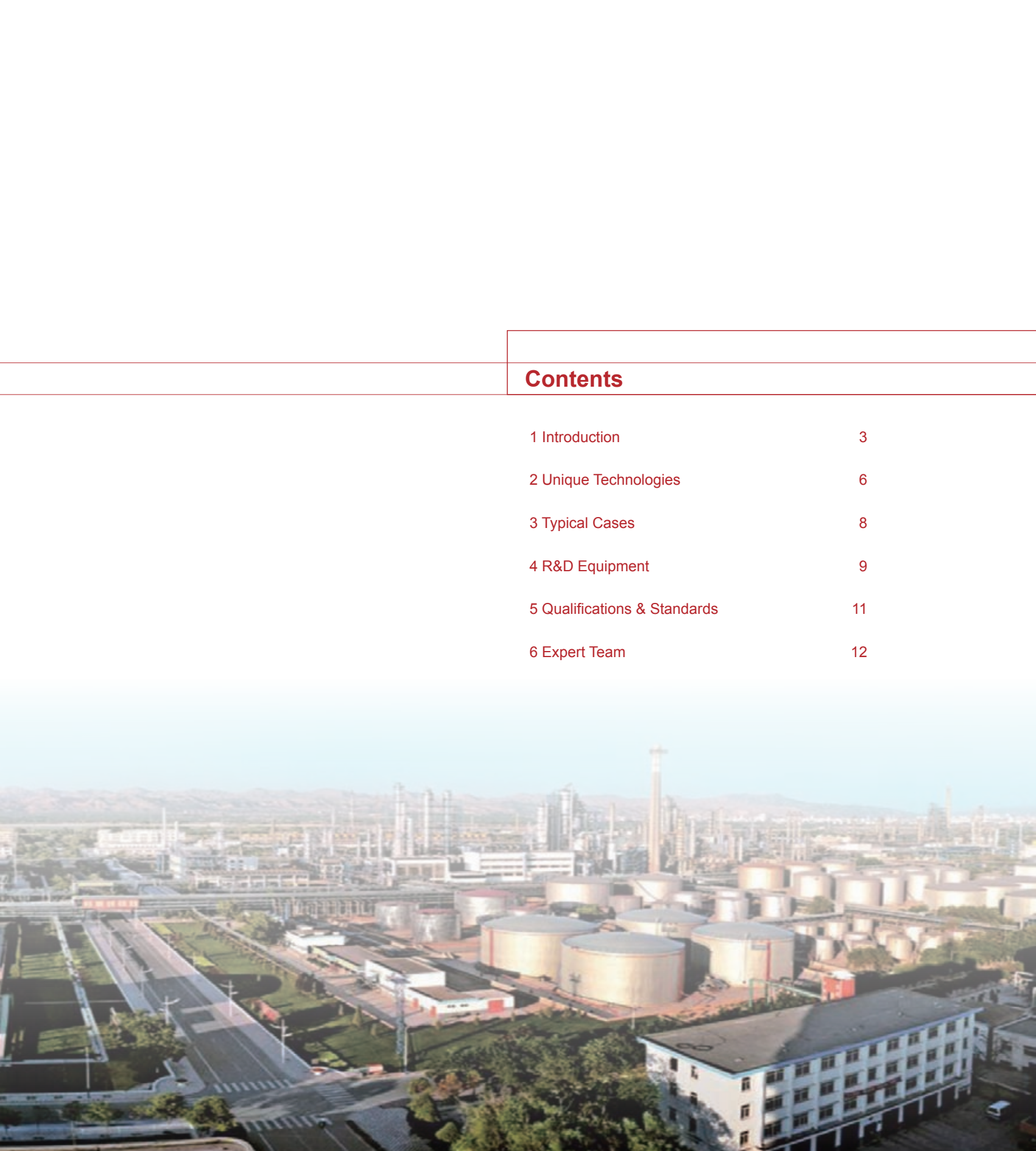
■ 2013



CHINA NATIONAL PETROLEUM CORPORATION

*Energy-conservation and Emission-reduction
to Boost Low-carbon Development*





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China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. On July 1998, with the implementation of the Institutional reform of the State Council, CNPC was reorganized to become an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integrations of upstream and downstream operations, internal and external trade, production and marketing. CNPC's business covers six main sectors: oil and gas operations, petroleum engineering service, petroleum engineering construction, petroleum equipment manufacturing, financial services and new energy development. In 2012 CNPC produced 110 million tons of crude oil and 79.82 billion cubic meters of natural gas, while crude processing volume reached 191 million tons. The total revenue of RMB 2,690 billion with a profit of RMB139.1 billion had been achieved the same year.

CNPC was ranked 4th among the world's largest 50 oil companies and 6th in Fortune Global 500 in 2012.

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.

Superpower Flue Gas Turbine is one of representatives for major innovations of CNPC.

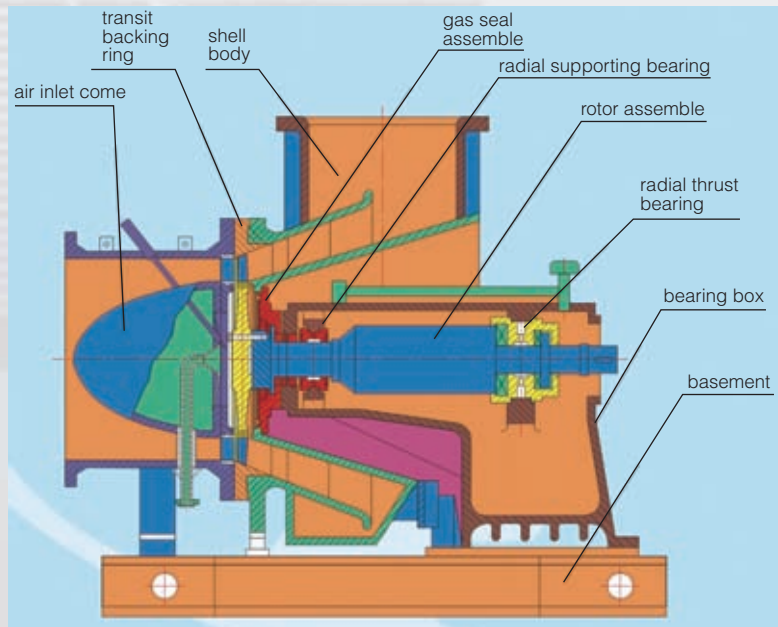
CLEAN ENERGY SUPPLY FOR BETTER ENVIRONMENT

1

INTRODUCTION

- ◆ Since 2000, the ten-million-ton refinery has become the new benchmark in China's petrochemical industry, and the 30,000kW flue gas turbine used by large catalytic cracking unit, as its supporting device, was also included in the list of National Major Technical Equipment Development Projects over the "Tenth Five-Year Plan" Period.
- ◆ In August 2003, the first 30,000kW superpower flue gas turbine was put into operation in Lanzhou, with power up to 32,800kW, making China the second country that manufactures and applies 30,000kW superpower flue gas turbine after USA.
- ◆ By the end of 2011, a total of 14 units of YL Series Superpower Flue Gas turbine were sold, with installed power up to 30×10^4 kW, which uses hot industrial exhaust to generate electric power of 24×10^8 kW·h/year, with energy-saving benefit up to 1.2 billion Yuan per year. Moreover, it generates huger benefits by saving coal and reducing exhaust (e.g. CO₂).

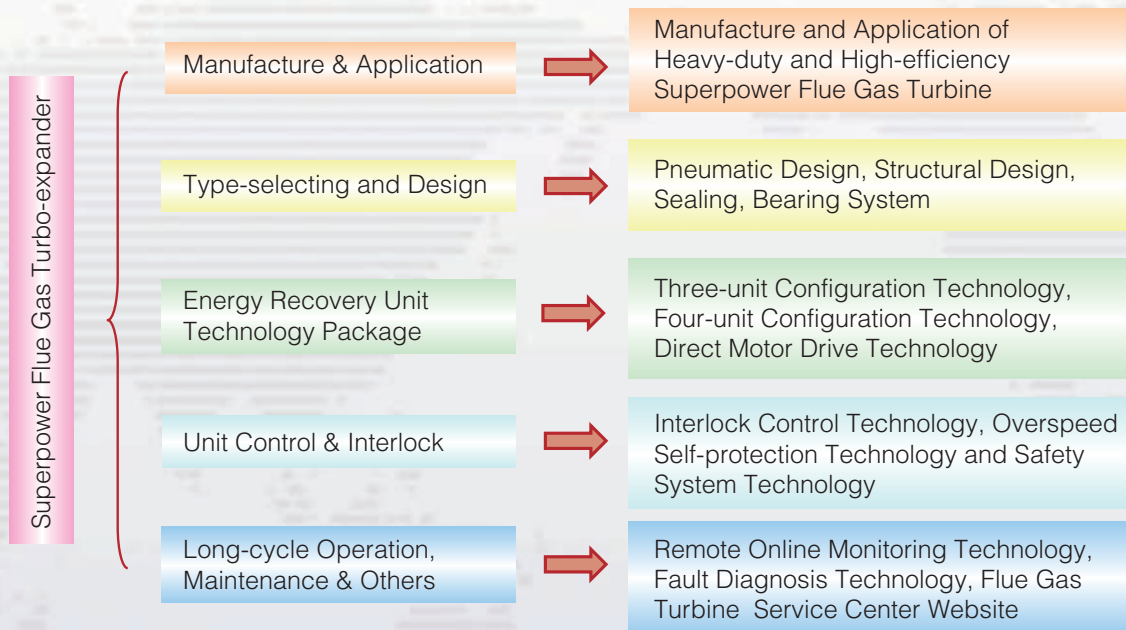
Main Structure



net: 45~60t

Overall Technology

- ◆ The catalytic cracking unit is the most essential production facility for refineries as well as the major equipment for energy consumption and exhaust emission.
- ◆ By use of the hot industrial exhaust from the regenerator of the catalytic cracking unit, the Flue Gas Turbine drives the turbine to act, which can then drive other equipment to run or generator to produce electric power.



Rationale of Energy Recovery from Catalytic Cracking Unit

- ◆ Energy recovery rationale: After flue gas flows from the regenerator, the three-stage cyclone separator further separates catalyst particles from the gas; then the flue gas passes through the adjusting butterfly valve into the flue gas turbo-expander to act and drive main air blower or electric generator directly; the exhaust discharged then enters the heat recovery boiler to produce steam.



In China, there are many fields that need exhaust heat emission reduction and heat recovery.



The catalytic cracking unit, nitric acid production unit, coal gasification unit and other units in the petrochemical industry can all employ the Flue Gas Turbine for heat recovery.



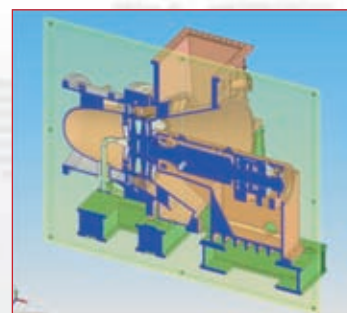
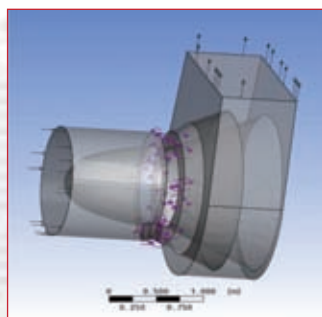
A 30,000kW flue gas turbine can generate electric power of $2.4 \times 10^8 \text{ kW} \cdot \text{h/year}$ worth around 120 million Yuan, save coal by $5.3 \times 10^4 \text{ t/year}$, and reduce CO_2 emission by $13.78 \times 10^4 \text{ t/year}$, SO_2 emission by 450t /year and nitrogen oxides emission by 392t/year.



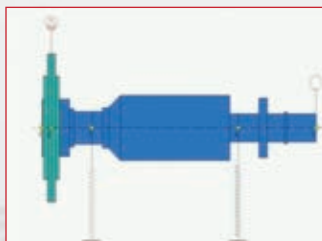
The Flue Gas Turbine will extend presence to metallurgy, power, fertilizer, cement, garbage disposal and other sectors.

2.1 “Fully Rigid” Structural Design Technology

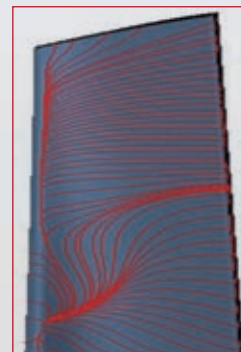
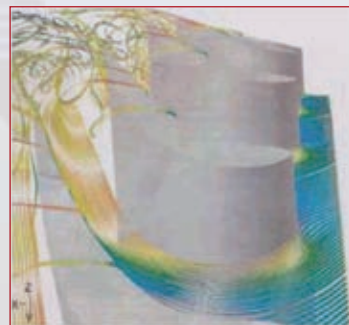
- ◆ The Flue Gas Turbine adopts a fully rigid frame, thus effectively addressing deformation from external forces , thermal stress, etc.



- ◆ The rotor adopts a fully-rigid single-stage cantilever, which prevents flexible deformation in high-speed rotation and thus ensures long-cycle operation of the unit.

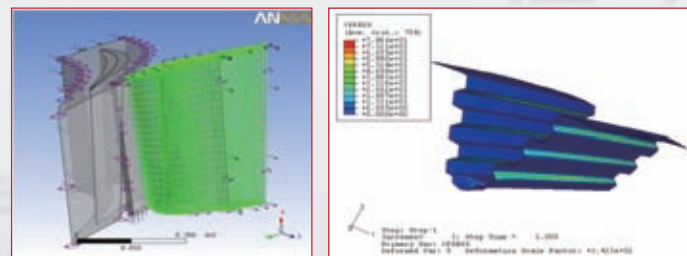
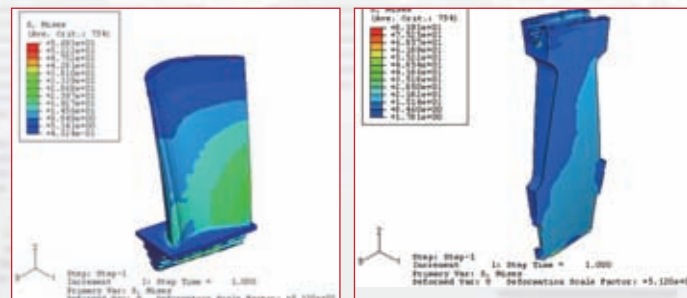


- ◆ The key areas of flow field are given intensive processing so that secondary flows and solid particles can be tracked. Through optimization and improvement, the first flow rate is controlled, secondary flows reduced and the rigidity of flow passage components enhanced.



2.2 Digital Modeling & Optimized Design Technology

- ◆ Via the finite element software ANSYS, the grid technology is applied in modeling.
- ◆ Numerical methods are used to solve stress distribution models of key heat-resistant components under centrifugal force, thermal stress and solid particle erosion.
- ◆ Optimized design makes each section with equal strength.
- ◆ The software Abquse is applied to eliminate contact stress concentration of key components.



2.3 Dynamic Behavior Simulation Analysis

- ◆ Damped and undamped critical rotating analysis;
- ◆ Natural frequency, oil film bearing and sealing properties of rotor – bearing – support at undamping;
- ◆ Natural frequency and sealing properties of rotor – bearing- support at damping;
- ◆ Special dynamic balance test system for response authentication;
- ◆ Impact analysis of interaction of catalyst particles and turbine vanes on the rotor.



3

TYPICAL CASES

In August 2003, the first Superpower Flue Gas Turbine YL33000A was put into operation on the 300×10^4 t catalytic cracking unit at the oil refinery of Lanzhou Petrochemical Company, CNPC, with all its performance indicators and main design up to the world's advanced level. It runs well till now.



By the end of 2011, the YL33000A Flue Gas Turbo-expander ran for more than 64,000h in total and recovered energy worth over 1.2 billion Yuan.

Over 200 units of the YL Series Flue Gas Turbine were sold, with total power above 180×10^4 kW. Among them, 14 units were superpower flue gas turbine, with total power up to 30×10^4 kW.

The products have made presence in refining enterprises across China. "Where there is a refinery, there is a flue gas turbine".

4

R&D EQUIPMENT

4.1 Research Equipment

CNPC has 79 units or sets of major research equipment, including imported data processing projector, coordinate measuring machine, mechanical performance test facilities, metallographic test facilities, spectral analysis facilities and metering facilities. It has also equipped with flue gas turbine and special valve test beds.



Germany-made Data Processing Projector ST1000



America-made Coordinate Measuring Machine HERA-20-10-10



20t Rotor Dynamic Balance Test Machine



3200kW Flue Gas Turbine Test Bed

4.2 Manufacturing Equipment

CNPC has over 800 units or sets of major manufacturing equipment, including large NC lathe, large horizontal boring machine, large double housing planer, large plano-milling machine, kinds of drilling machines, NC equipment, large special facilities, ordinary facilities, etc.



Imported processing Center workplace



NC Lathe CK61150



NC Machining Workplace



Large Parts Machining Workplace

5 QUALIFICATIONS & STANDARDS

5.1 International QMS Certificates

The quality management system of YL Series Superpower Flue Gas Turbine strictly follows GB/T 19001—2000, idtISO 9001-2000 and U.S. API Q1.



5.2 Product Standard & Environmental Assessment Certificate

CNPC took the lead to draft and implement the industry standard HG/T 3650-1999 Flue Gas Turbine Technical Specification, and its products have passed the HSEMS certification.



5.3 Patents

Name of patent	Name of patent	Country	No.
An Anti-heat Radiation Device for Bearing Housing of Flue Gas Turbine	Patent for utility model	China	ZL 2005 2 0127028.8
Heat Run Test Bed for Flue Gas Turbine	Patent for utility model	China	ZL 2005 2 0129836.8



6

EXPERT TEAM



Li Kexiong Professor-level senior engineer, senior technical expert and expert granted the State Council Special Allowance. He has presided over many research projects, such as the national major technical equipment project “30,000kW Superpower Flue Gas Turbine”, and transformed research results into products. Further, he has obtained 7 national patents and 15 papers published.
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Dong Jianxin Professor and doctoral supervisor of Beijing University of Science and Technology. He is mainly engaged in high-temperature alloy, anti-heat & anti-erosion alloy, special steel, material simulation and optimized design. He has undertaken major projects and surface projects of National Science Foundation of China, “863” Project, “973” Project, international cooperation projects, etc.
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