Natural Gas Engine Technologies

Science & Technology Management Department

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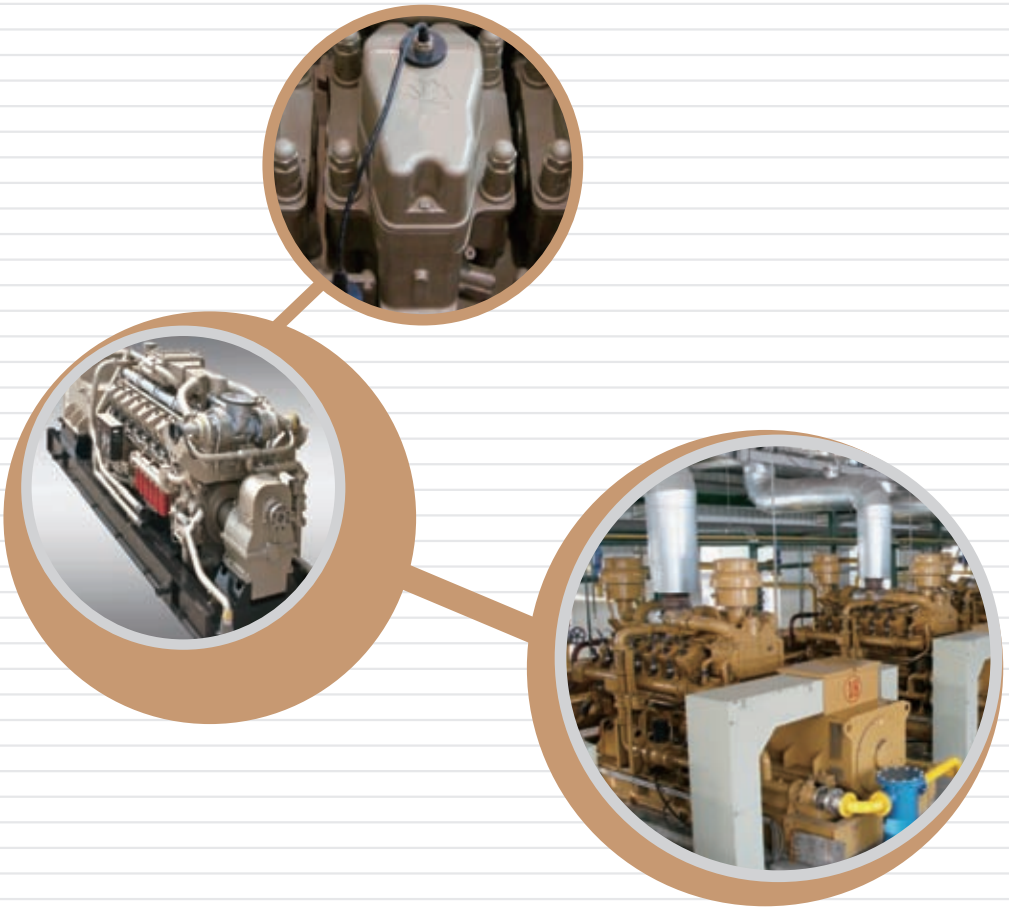


CHINA NATIONAL PETROLEUM CORPORATION

Natural Gas Engine Technologies ——

Green, Powerful and Efficient!

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 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.

Natural Gas Engine Technologies is one of representatives for major innovations of CNPC.

CLEAN ENERGY SUPPLY FOR BETTER ENVIRONMENT

1 INTRODUCTION

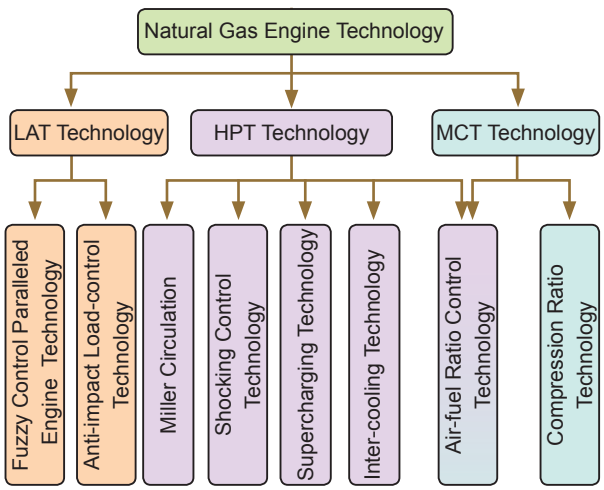
Along with the ever-increasing development of the society, the environmental pollution and energy consumption have become more and more severe. So energy-saving and emission reduction has been the major objective of engine research and development.

As an efficient, clean and cheap fuel, natural gas used for engines can not only solve the power problem in gas-rich regions and dynamic issues for other facilities, but, compared with diesel engine, have advantages in reducing emission of pollutants and reducing costs.

The main component of natural gas is Methane (CH_4), it is gaseous under normal temperatures and is a recognized green and clean energy, having exceptional advantages in the main social streams of energy-saving and emission reduction and low-carbon development.

As the natural gas engine market share continues to improve, the natural gas engine technologies are developing rapidly. In order to improve the engine performance and meet the demand for various purposes, we have developed a series of technologies in terms of increasing the engine power, inhibiting knocking and reducing thermal load, etc. and have successfully developed various natural gas engines and generator sets, which are widely used in various fields. The gas engines with professional design and perfect control system have shown favorable economical efficiency, dynamic properties and low emission performance.

With the increasing maturation and development pace of nature gas technologies, the application of natural gas engines is becoming more and more extensive. The natural gas engines will surely play a very important role in building a green, internationalized and sustainable CNPC.



>>>190 Series Natural Gas Engine

External-mix Natural Gas Engine

Internal-mix Natural Gas Engine

Model	4190ZLT1-2	6190ZLT-2	12V190DT2-2	12V190ZDT-2	G12V190ZLT-2	G12V190ZLT	12V190ZLT
Type	Four-stroke, Water-cooling, Supercharged and Mid-cooling, Spark-plug Ignition, External-mix				Four-stroke, Water-cooling, Supercharged and Mid-cooling, Spark-plug Ignition, Internal-mix		
Number of Liners and Arrangement	Four-liner-in-line	Six-liner-in-line	12V, 60° V model		12V, 60° V model		
Liner Diameter x Stroke	190mm×210mm				190mm×210mm		
Rated HP	165kW	270kW	450kW	550kW	600kW	800kW	800kW
Rated RPM	1000r/min				1000r/min	1500r/min	1500r/min
Compression	10 : 1	8 : 1	9 : 1	8 : 1	10 : 1		
Heat Consumption Rate	11.4MJ/(kW·h)				9.8MJ/(kW·h)		
Engine Oil Consumption Rate	≤ 1.63g/(kW·h)				≤ 1.6g/(kW·h)		
Diversion	Counterclockwise (for output terminal)				Counterclockwise (for output terminal)		
Starting Method	Electric Motor				Electric Motor		
Lubricating Method	Force and Splash Lubrication				Force and Splash Lubrication		

Closed-loop Electrically-controlled Natural Gas Engine

3000/6000 Series Natural Gas Engines

Model	G12V190ZLDT	G12V190ZLDT1	G12V190ZLDT-2	G12V190ZLDT1-2	AD12V190ZLT2	H12V190ZLT	H16V190ZLT-2
Type	Four-stroke, Water-cooling, Supercharged and Mid-cooling, Spark-plug Ignition, External-mix				Four-stroke, Water-cooling, Supercharged and Mid-cooling, Spark-plug Ignition, External-mix		
Number of Liners and Arrangement	12V, 60° V model				12V, 60° V model		16V, 60° V model
Liner Diameter x Stroke	190mm×210mm				190mm×215mm		
Rated HP	600kW		550kW		1100kW	1500kW	1200kW
Rated RPM	1500r/min		1000r/min		1500r/min	1500r/min	1000r/min
Compression	12 : 1				12 : 1		10 : 1
Heat Consumption Rate	11MJ/(kW·h)				9.5MJ/(kW·h)		
Engine Oil Consumption Rate	≤ 1.6g/(kW·h)				≤ 1.0g/(kW·h)		
Diversion	Counterclockwise (for output terminal)				Counterclockwise (for output terminal)		
Starting Method	Electric Motor				Electric Motor		
Lubricating Method	Force and Splash Lubrication				Force and Splash Lubrication		

2 UNIQUE TECHNOLOGIES

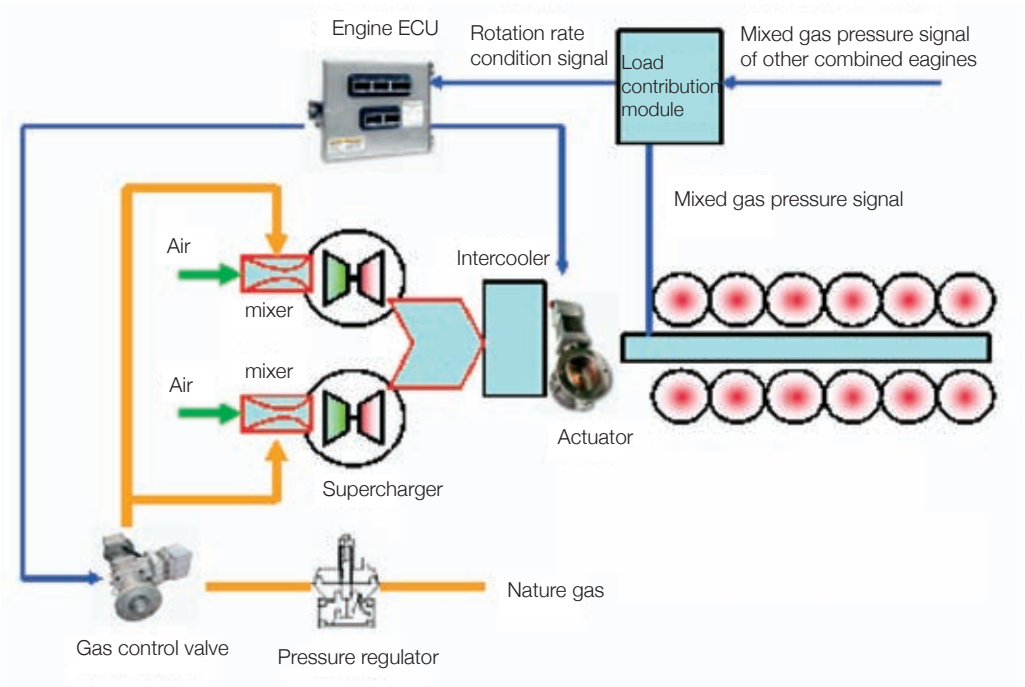
2.1 Load Adaptiveness Technology (LAT)

By monitoring the engine operating parameters, assessing the operating status of the engine and adjusting the control parameters so as to adapt to the engine control technology with varied load.

(1) Realized the automatic load distribution for mechanically paralleled gas engines;

(2) Can automatically distinguish the load changing rate;

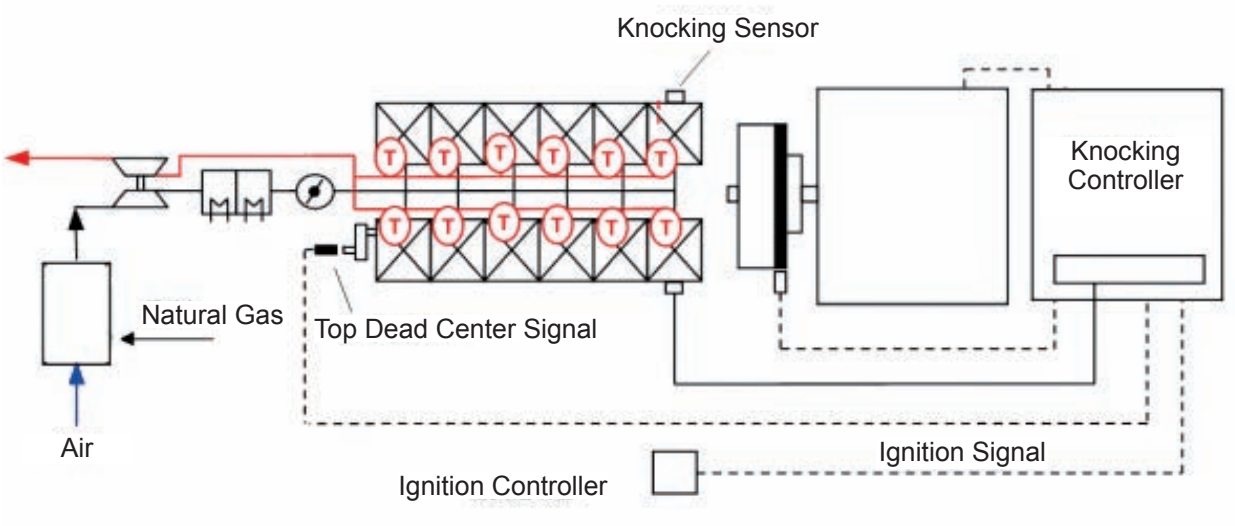
(3) Suitable for applications of varied load under complex working conditions.



2.2 High Performance Technology (HPT)

This technology optimizes the design of the engine air intake, combustion and valve system, which protects the engine while ensuring efficiency and low emission and also controlling knockings.

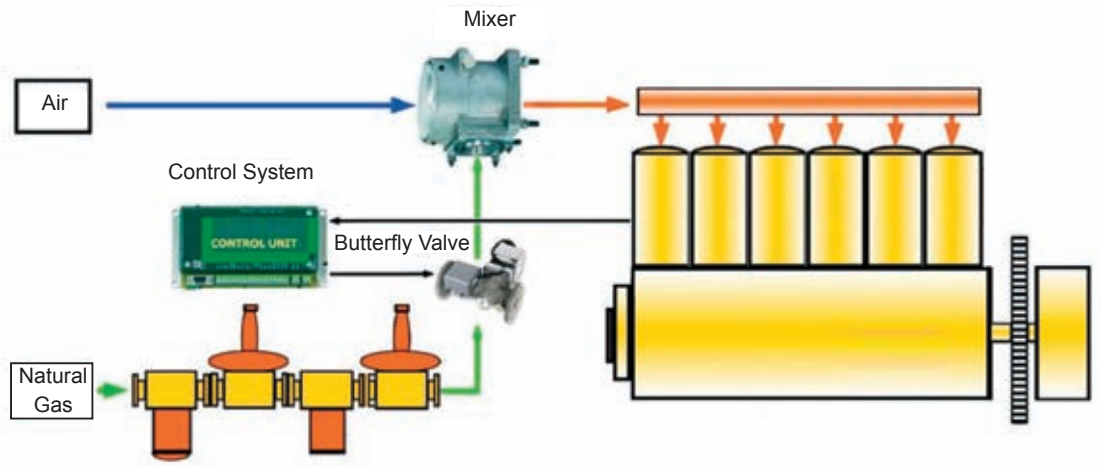
(1) Improve the thermal efficiency of the engine, and also reduce the engine's thermal load and emission;
(2) Control air-fuel ratio by controlling air or natural gas flow rates;
(3) Can control knockings and protect the engine;
(4) Applicable to gas engines with high dynamic indicators and low emission.



2.3 Multi-gas Combustion Technology (MCT)

This technology optimizes the design of the engine according to the difference of various fuel properties, so that the engine can adapt to various fuels, and also ensures the economic efficiency, dynamic property and emission performance of the engine.

So the engine can use various inflammable gases as fuel.



3 TYPICAL CASES

West-east Natural Gas Transmission Project

In 2005, Ji'nan Diesel participated in the construction of west-east gas transmission project, providing reliable generating equipments for 9 main line boosting stations and 22 branch line stations, which played an important role in guaranteeing the safety of gas transmission and power supply.

Fushan Oilfield

In 2010, in Fushan Oilfield in South China Sea, the industrial test for natural gas engine used for drilling was conducted successfully, which was the first to use natural gas engine as drilling power in the world.

Oil Production Platform of CNOOC

In 2010, the 1000kW gas generator set was first successfully used on the drilling platform in Chengbei Oilfield, opening a new application area for large power gas engines and filling the gap of domestic gas generator set application on drilling platforms.

6MW Natural Gas Power Plant, Niger

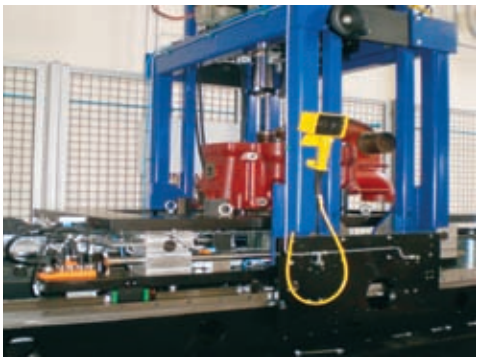
The muting island power plant project of 6MW gas engine conducted in Niger in 2011 can meet harsh environments like desert, high temperature, strong sandstorms, etc.

4 R&D EQUIPMENT

Product Experimental Equipment

The B&K PULSE7.0 Vibration Noise Testing System (Denmark)

AVL422 Air Leakage Gauge



AVL FTB2000plus Cylinder Head Air Passage Test Bed

The HORIBA Partial Flow Grain Sampling System MDLT-1302TMA (Japan)

AVL415S Filter-type Smokemeter

The new lab is equipped with the AVL FTB2000plus air passage property test bed, the engine parts performance and reliability test bed and the diesel engine with common-rail fuel system test bed, which can achieve automatic acquisition and data storage for multi-mode operation of internal combustion engines. In addition, some main testing instruments are introduced like dynamometer, fuel consumption meter, emission tester, combustion analyzer, noise and vibration measurement analyzer, etc, which can test various functions of single-cylinder engines to 6000kW internal combustion engines.

Metering and Physical and Chemical Testing Equipment

Full-automatic Oil Viscosity Measuring Gauge

Large Three-coordinate Measuring Machine

The Metering Center has established the highest enterprise measuring standard, equipped with large three-coordinate measuring machine, laser interferometer, high-precision industrial CT and axle-type all-purpose tester, which can undertake the precision testing of geometric error, temperature, force value and electric parameters.

The Physical and Chemical Center is equipped with more 40 sets of various physical and chemical testing equipments, which can undertake comprehensive physical and chemical analysis to components of materials, oils and gases. The comprehensive metering and physical and chemical testing means plays a vital role in product inspection and quality control.

5 QUALIFICATIONS AND STANDARDS

CNPC is a sponsor of the branch of the National Standardization Technical Committee and the National Standard-setting Unit, has a national-level technical center and holds relevant qualifications like quality management system certification, environment management system certification, CE certification, China CCS certification, Bureau Veritas (BV) certification, etc. and has established a number of national standards, of which there are 8 items relating to gas engine standards, and has obtained 5 national patents.

Qualifications

Standards

- JB/T10629-2006 Gas Engines General Requirements and Test Methods
- Q/CNPC-JC39004-2010 Safety Operation Specifications for Skidded Equipment of Gas Engine for Drilling Rigs
- SY/T5641-2009 Natural Gas Engine for Oil and Gas Industry
- GB/T22343-2008 Natural Gas internal combustion Generating Set for the Petroleum Industry
- GB/T29487-2013 Medium/high-power Gas Generating Set
- GB/T29488-2013 Medium/high-power Marsh Gas Generating Set
- GB/T23506-2009 The Natural Gas Power Set for Oil Production Drilling Site
- SY/T6728-2008 Diesel/Natural Gas Dual Fuel Engine for Oil and Gas Industry

Patents

- Air-fuel Ratio Control System for Gas Engine
  Patent No.: ZL201220075616.1
- An Air Intake Diverter of Engine
  Patent No.: ZL201220075625.0
- Low Density Mine Gas Engine Control System
  Patent No.: 200920225480.6
- Gas Engine Compound System
  Patent No. 201020663808.5
- Fuel Gas Supply System for Engines using Fuel of Diesel and Natural Gas
  Patent No.: 200920246298.9

6 EXPERT TEAM

Li Shusheng Senior technical specialist, the vice chairman of China Internal Combustion Engine Society, deputy secretary general of Shandong Internal Combustion Engine Society, expert committee member of China Internal Combustion Engine Industry Standard, expert committee member of China National Standard Commission, etc. He was in charge of formulating and revising 5 standards, has obtained 20 national patents. Dozens of papers and 4 works published.
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Qin Jianping He has long been involved in engine design and development; hosted a number of scientific research projects.
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Wang Lingjin Senior technical expert, member of CNPC Petroleum Quality Reliability Specialized Committee, member of power standardization of work department of national petroleum drilling standard committee. He has undertaken a number of major scientific research projects of national level and group corporation level and achieved a great deal in technical development and promotion of new technologies in terms of gasification and water transport, gas engine for well drilling, marsh engineering, etc. He has obtained 6 national patents. Dozens of academic papers and I work published.
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Wang Zhigang senior engineer. He has long been involved in the electric design of generator sets, the design of power plant and automatic control and has taken charge of the overall design of Niger FPF gas power station project and hosted or participated in the compiling of three national and industrial standards.
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Yang Jiacheng Technical expert. He has participated in the development of dozens of engine models and obtained 2 national patents. 6 papers published.
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Sun Jie Technical expert. She has long been engaged in the development of engines, and has undertaken duel fuel engines for well drilling and the development of multiple new products for west-east gas transportation power plants, and has organized the establishment of 8 national and industrial standards, a number of papers published.
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