# Emission Performance Study on Marine Propulsion Gas Engine

## 5th CIMAC CASCADES 2014

中国石油集团济柴动力总厂
CNPC JICHAI POWER EQUIPMENT COMPANY
2014/11/3

CNPC JPEC

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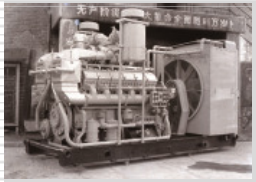
# Company Introduction-JPEC

CNPC JiChai power equipment company (JPEC) is CNPC's subsidiary, primarily produce engine and compressor for oil & gas field(CNPC),

Chinese National Petroleum Corp. (CNPC) is China's largest oil and gas producer and supplier.



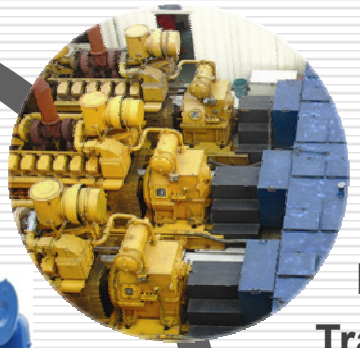
**1965** Z12V190B diesel engine was successfully developed for oil drilling industry in China.

**1988** The first gas engine with medium & large power in China was born in our company.

**2010** The company name is changed to CNPC JiChai Power Equipment Company.

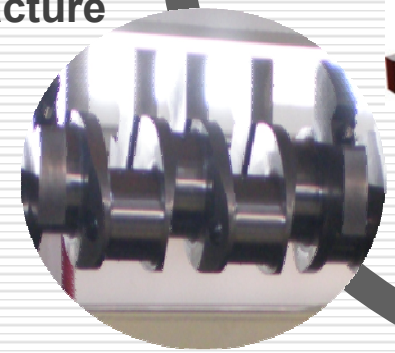
# Business distribution

Compressor



Hydraulic
Transmission

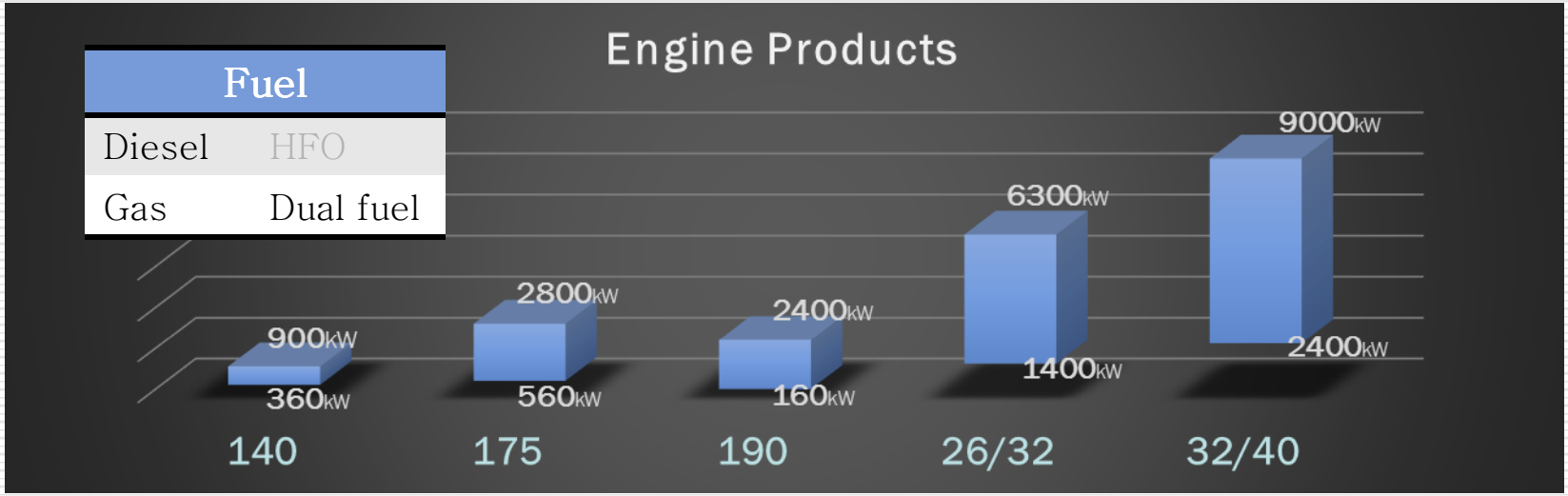
Engine

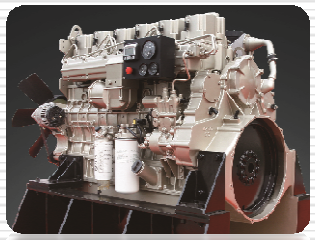


Remanufacture

Electric
Control

# Engine Products



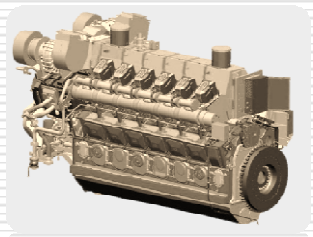



L6～V12

V8～20

L6，L8，V8，V12，V16

L6～V18



L6～V18

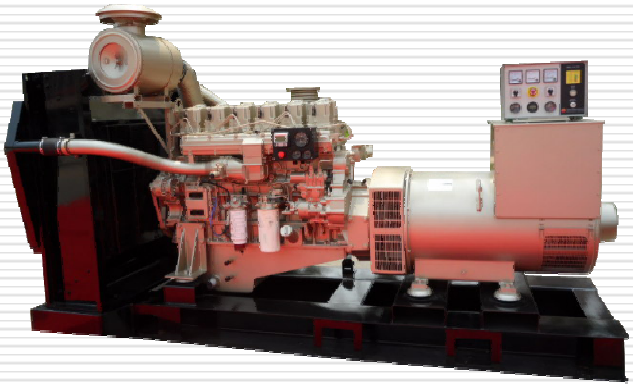


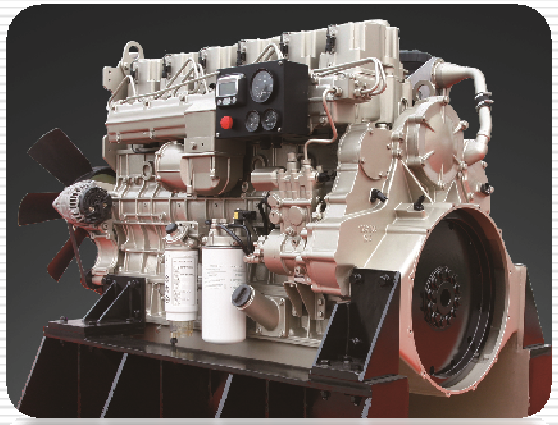
CNPC JPEC

# Engine Products

## 140 series

| Item | Parameters |
|---|---|
| bore | 140 mm |
| stroke | 165 mm |
| cylinders | L6, V8, V12 |
| speed | 1500 ~ 2100 rpm |
| power | 320 ~ 900 kW  71 ~ 76kW/cyl |
| fuel | Diesel & gas |
| fuel consump. | 205g/kW·h ;  10MJ/kW·h |
| emission | Euro3, Euro 5 |
| overhaul | 1200000km |

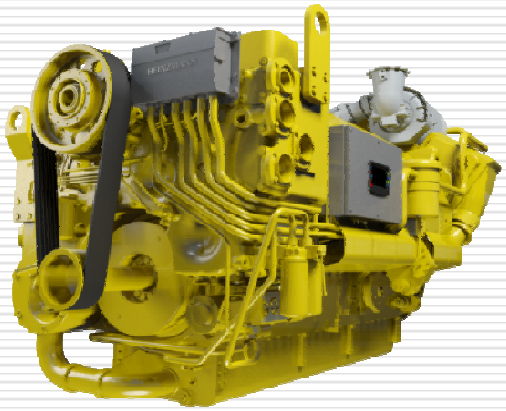




# Engine Products

## 175 series

| Item | Parameters |
|---|---|
| bore | 175 mm |
| stroke | 190 mm , 215mm |
| cylinders | V8 ~ V20 |
| speed | 1200 ~1800 rpm |
| power | 731 ~ 2742kW |
| fuel | Diesel & gas |
| fuel consump. | 195g/kW·h; 9.5MJ/kW·h |
| emission | Euro3, Euro 5 |
| overhaul | 35000h |



# Engine Products

## 190 series

| Item | Parameters |
|---|---|
| bore | 190 mm |
| stroke | 210 mm, 215mm, 255mm |
| cylinders | V8 ~ V20 |
| speed | 1000 ~1500 rpm |
| power | 300 ~2400kW |
| fuel | Diesel, gas, dual fuel |
| fuel consump. | 200g/kW·h 10.5MJ/kW·h |
| overhaul | 25000h |

# Engine Products

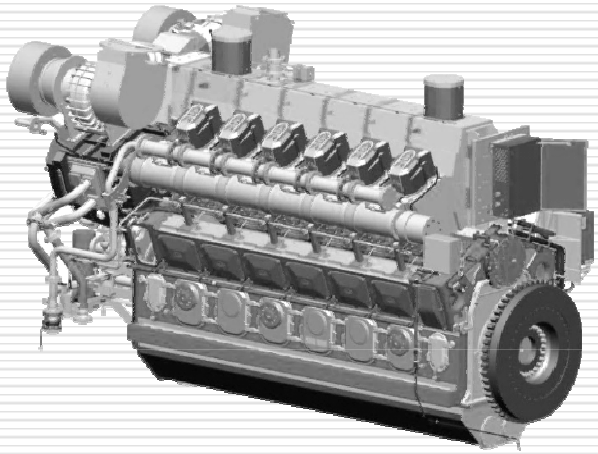
## 26/32 series

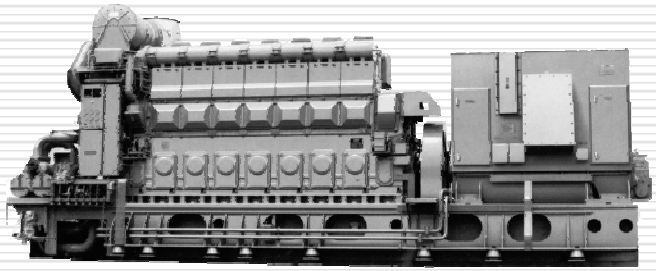
| Item | Parameters |
|---|---|
| bore | 260 mm |
| stroke | 320 mm |
| cylinders | L 6/8/9, V12/16/18 |
| speed | 900 ~1000 rpm |
| power | 1400 ~ 6300kW |
| fuel | MDO&MGO,HFO,Gas |
| fuel consump. | ≤184g/kW·h; 9.5MJ/kW·h |
| emission | IMO Ⅱ, Ⅲ |
| specific weight | 7kg/kW |
| overhaul | 45000h |

# Engine Products

## 32/40 series

| Item | Parameters |
|---|---|
| bore | 320 mm |
| stroke | 400 mm |
| cylinders | L6～ V18 |
| fuel | MDO, HFO, Gas |
| speed | 720 ～750 rpm |
| power | 3000 ～ 9000kW |
| fuel consump. | ≤181g/kW·h ; 9.0MJ/kW·h |
| specific weight | 10 kg/kW |
| overhaul | 50000h |





# Market-Oil & Gas

Oil drilling
300～1500kW

Compressor set
85～6000kW

Gen-set
200～9000kW

# Market- Marine

**Main products**: Diesel ,HFO , and Dual fuel engine. The products have passed the approvals of classification societies, such as CCS, BV, RS etc. and some type of Gas and dual fuel engine with CCS are running in this market.

**Power**： 300~9000kW

# Market- Power Generation

Oil& Gas field
200-9000kW

Ocean engineering power

Distributed energy system

# JPEC-GAS ENGINE

In China, Different type of fuel gas, such as NG, Coal mine methane, coke oven gas, landfill gas, mash gas, biogas and so on. And in different areas, the gas 'components is complex:

During the last 30 years, thousands of JPEC' s 190 series gas engines have been serving in the market, including pre-mixing type and port injection type.

**12V19ZLDT**
Premixing type

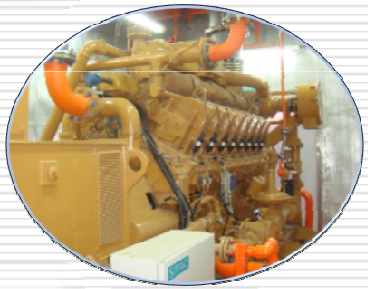
**G12V190ZLT**
Port injection

**H16V190T**
Premixing type

**AD12V190ZLBT1**
Port injection

# GAS ENGINE IN MARINE

JPEC – 16V190 gas engine with CCS is serving in offshore platform.



JPEC – LNG&Diesel duel fuel engine is serving HANCHUAN Ⅲ with CCS.

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# MARPOL 73/78

Marine engine

$NO_X$

ECAs

Emission control

Tier Ⅱ

Tier Ⅲ

2014

2016

$NO_X = 44 \times n^{-0.23}\ g/kW \cdot h$

$NO_X = 9 \times n^{-0.2}\ g/kW \cdot h$

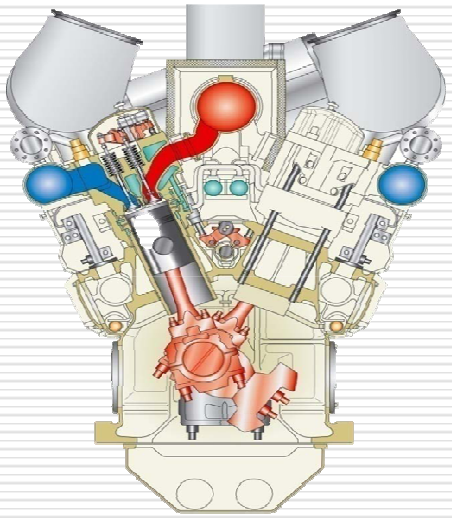
CNPC JPEC engine : 720～1000rpm $NO_X$<2.4 g/kW·h

Diesel

**Gas &duel fuel**

## Engine introduction

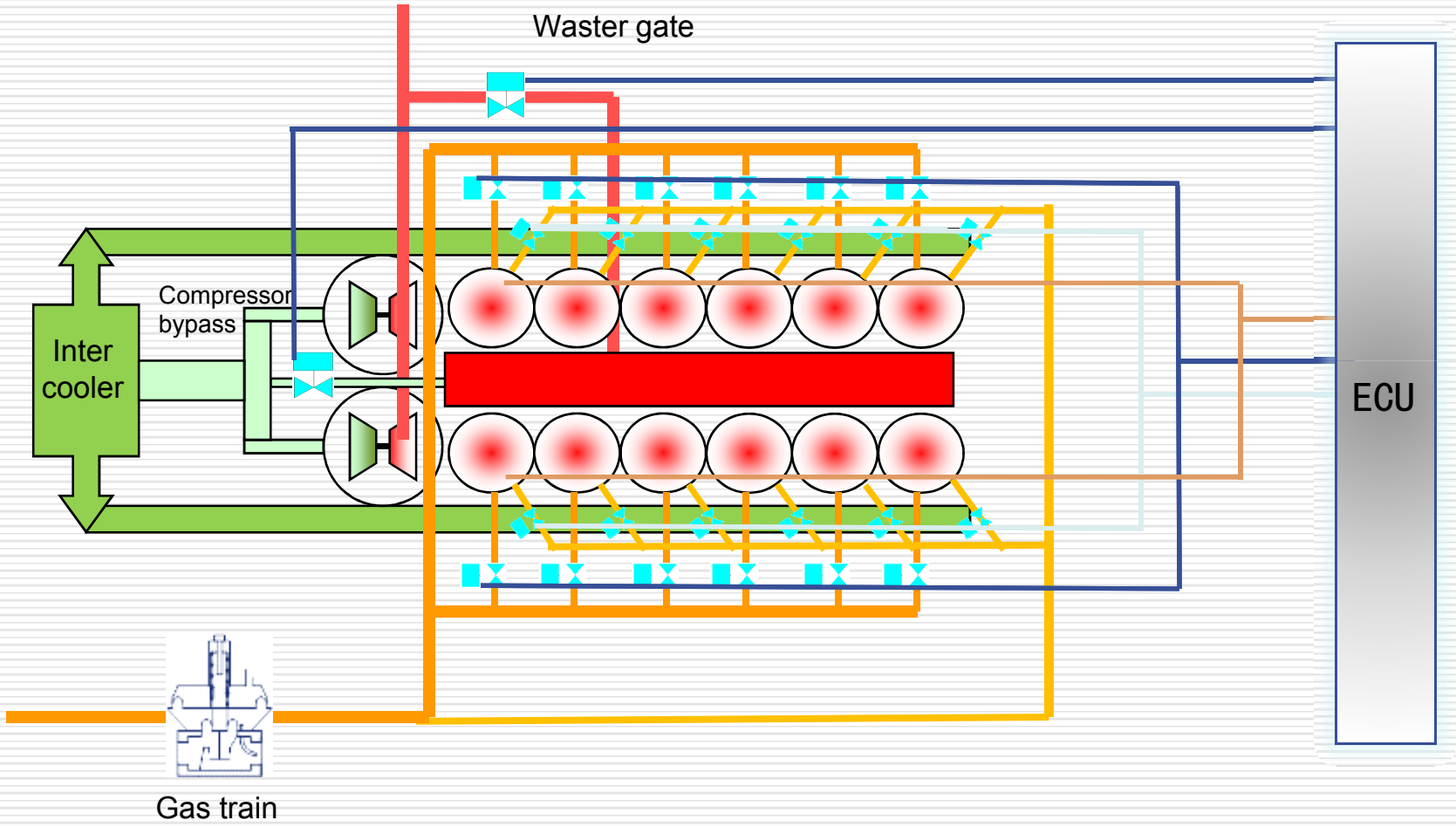
| Item | Parameters |
|---|---|
| Bore | 320 mm |
| Stroke | 400 mm |
| Rate speed | 750 rpm/720 rpm |
| Power/cyl. | 360 kW/cyl |
| Compression ratio | 11.5 |
| BMEP | 18 bar |
| Ignition | SI & pre chamber |
| Fuel | NG |
| emission | TIER III |



Lean burn

High efficiency

# Emission Performance Study on Marine Propulsion Gas Engine



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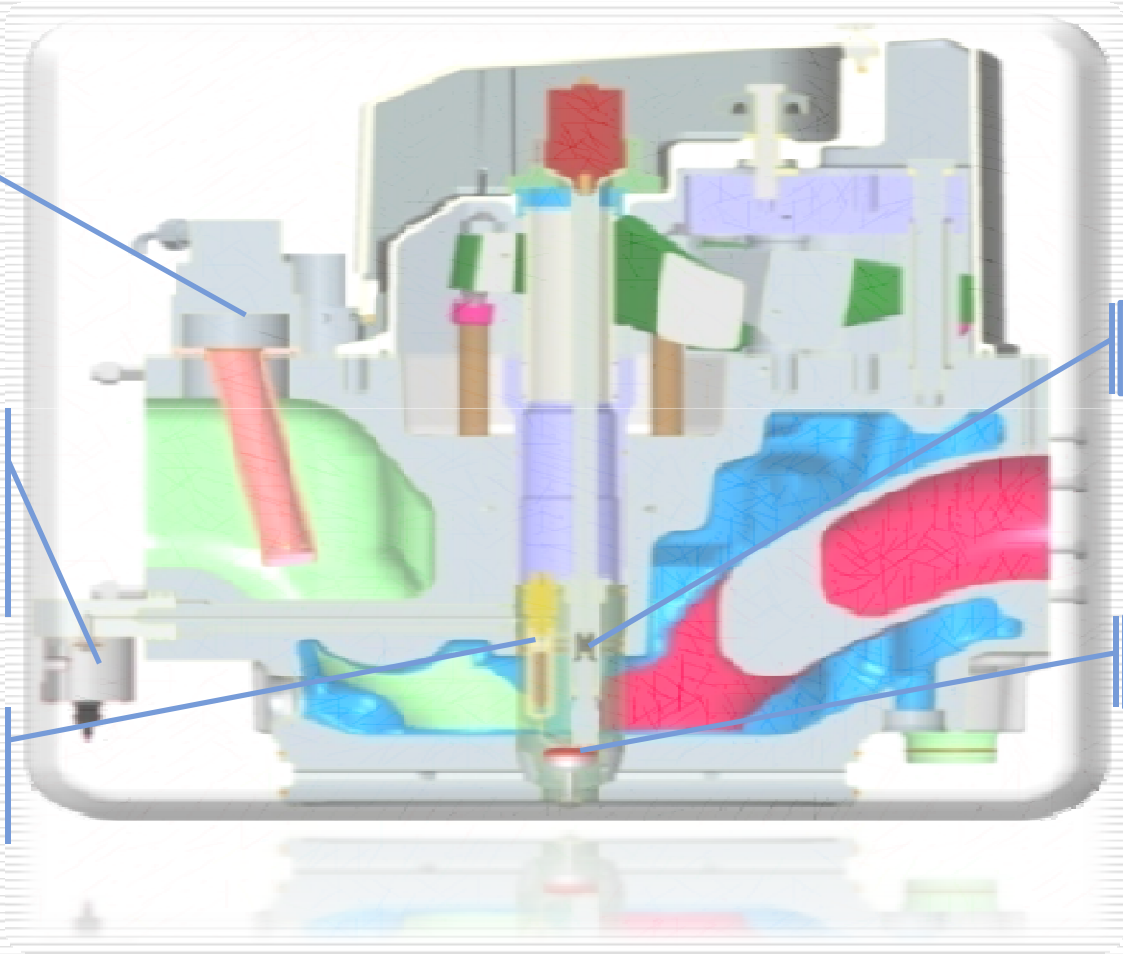
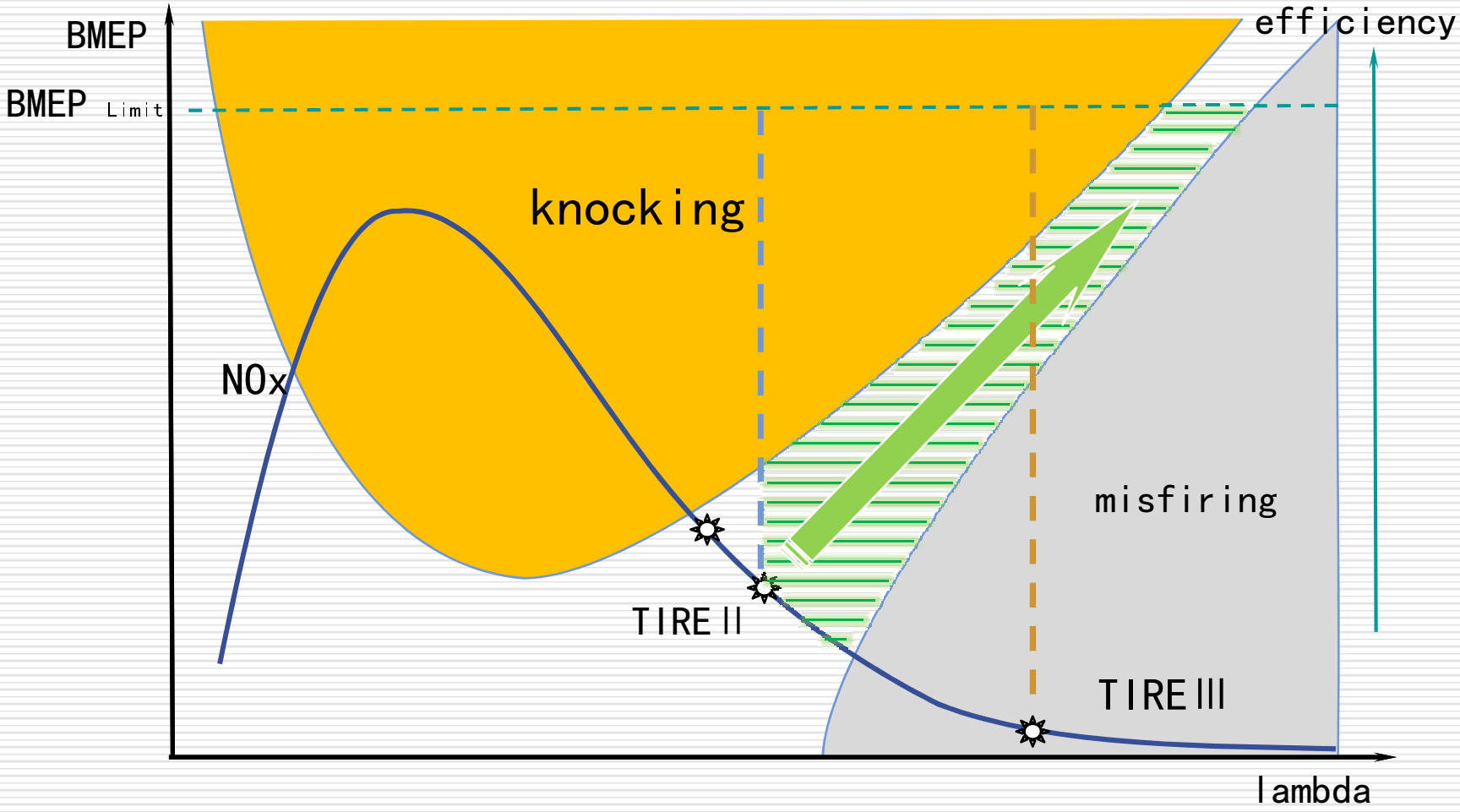


# Emission Performance Study



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# Emission Performance Study on Marine Propulsion Gas Engine

Contents of gas (Data corrected to 100%):

CNG

| | | |
|---|---|---|
| $N_2$ | 1.26 %Volume | 2.07 %Mass |
| $CH_4$ | 93.75 %Volume | 88.28 %Mass |
| $C_2H_4$ | 3.91 %Volume | 6.47 %Mass |
| $C_3H_6$ | 0.71 %Volume | 1.76 %Mass |
| $C_4H_{10}$ | 0.25 %Volume | 0.90 %Mass |
| $C_5H_{12}$ | 0.07 %Volume | 0.30 %Mass |
| $C_6H_{14}$ | 0.04 %Volume | 0.21 %Mass |

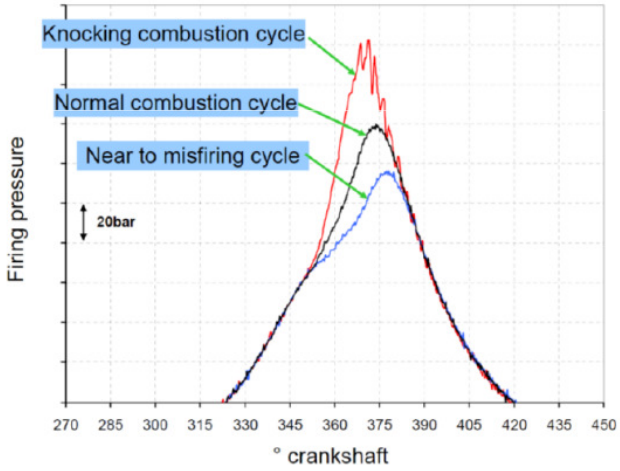
| | |
|---|---|
| *Methane number* | 80.4 |
| *Density (at a ,101.325kPa)* | 0.76116 kg/m3 |
| *Gas constant* | 487.35 J/K•kg |
| *Lover calorific value* | 48780.1 kJ/kg |
| *Molecular weight of the gas* | 17.0123 kg/kMol |
| *Stoichiometric air/fuel ratio* | 16.5147 kg Air/kg Gas |

# Emission Performance Study

Technical approach to Realize Low $NO_X$ in marine application:

Accurately control:

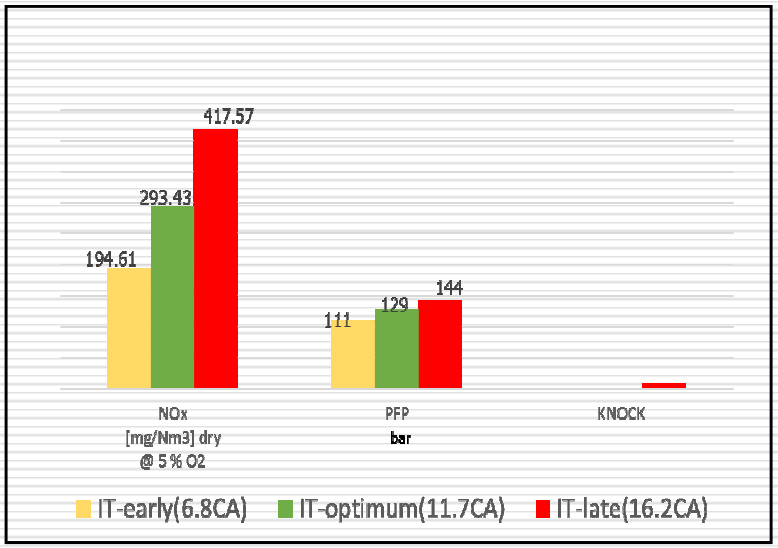
- Ignition timing
- Charge air temperature
- Charge air pressure
- Valve timing main gas
- Valve timing pre-chamber gas
- Load balance

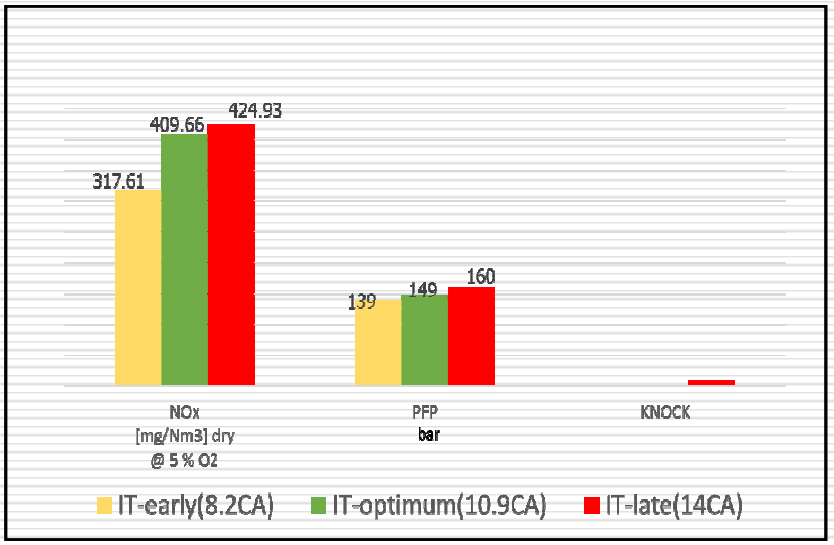


# Emission Performance Study on Marine Propulsion Gas Engine

## Different ignition timing test:

The ignition timing has a significant impact on efficiency, peak firing pressure, combustion stability, NOx-emissions :



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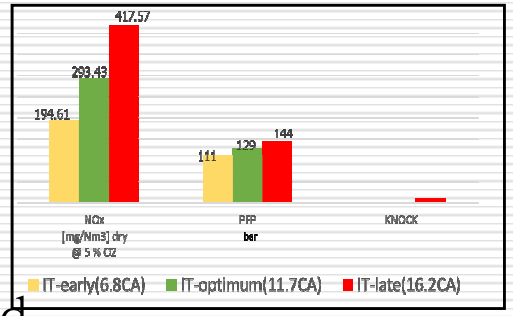



Different ignition timing test:

Early ignition timings result in a faster combustion with higher peak firing pressures and peak temperatures.

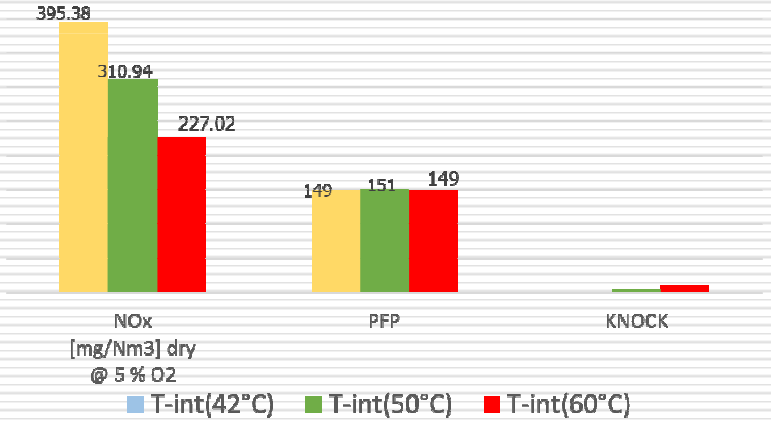
Late ignition timings result in a retarded combustion with lower engine efficiency, lower peak firing pressures and peak temperatures

This gas engine can operating as closely as possible to the knocking limit for reaching highest efficiency levels. Because of the knocking control system which monitors the combustion process on each cylinder.

# Emission Performance Study

Technical approach to Realize Low $NO_X$ :

- Ignition timing
- Charge air temperature
- Charge air pressure
- Valve timing main gas
- Valve timing pre-chamber gas
- Load balance



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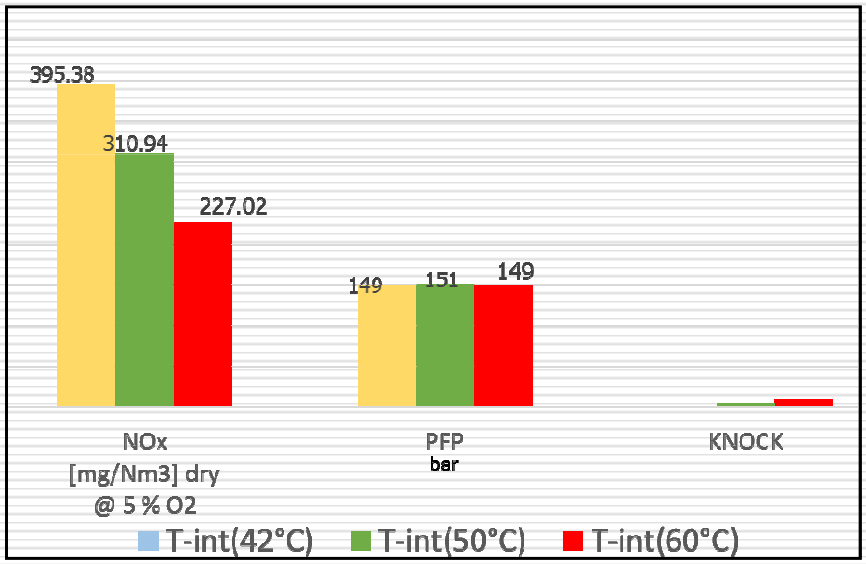
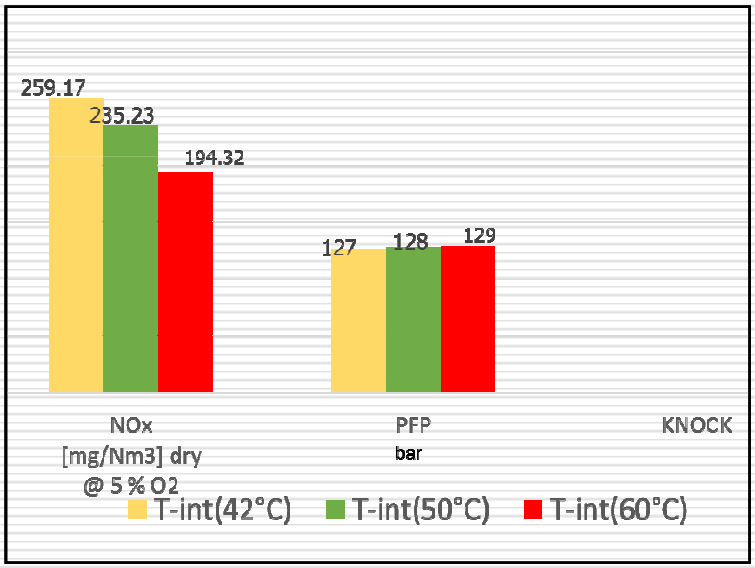
# Emission Performance Study on Marine Propulsion Gas Engine

## Different temperature of charge air test






CNPC JPEC

# Emission Performance Study

Technical approach to Realize Low $NO_X$ :

- Charge air pressure

  - The charge air pressure must increase by the engine's load increasing (keep the λ-value of the main chamber within the thermodynamically specified limit-values )
  - In marine application need control the charge air pressure is adjusted by a flap-controlled compressor bypass and a water gate:

# Emission Performance Study

Technical approach to Realize Low $NO_X$ :

➢ Valve timing main gas

With the ignition timing and charge air pressure, these are main driver for the λ and the mixture-homogeneity inside the combustion chamber of port injection gas engines

- To reach high-homogeneity levels inside the cylinders the timing of the gas admission must be adapted to the air flow during the inlet phase of the cylinder.
- the timing of the gas admission valves must be adjusted to create stratified combustion-mixtures.
- The timing of the main gas valves is also the key parameter for increasing/controlling the engine's load in dynamic load applications. Immediate load responses since the injection module (control of gas valves) is directly controlled by the speed governor which defines the amount of injected gas.

# Emission Performance Study

Technical approach to Realize Low $NO_X$ :

- Valve timing pre-chamber gas

The gas/air mixture in the pre-chamber should reach almost stoichiometric conditions to optimize the ignition stability. Since the main chamber of the engine is operated under very lean conditions the gas supply for the pre-chambers must compensate this gap of gas. The amount of injected pre-chamber gas was found to be very good about 1.8 % of the total cylinder gas charge.

# Emission Performance Study

Technical approach to Realize Low $NO_X$ :

- Load balance

Operating the engine near the knocking limit and closely to its mechanical limits requires an accurate balancing of the peak firing pressures of all cylinders. In the control concept of the engine initial balancing is realized by defined offsets for the exhaust temperature for individual cylinders and cylinder banks.

## E2 cycle test $NO_X$ emission result

| E2 CYCLE NOX EMISSION TEST DATA | | | | |
|---|---|---|---|---|
| speed | 100% | 100% | 100% | 100% |
| power | 100% | 75% | 50% | 25% |
| Weighting factor | 0.2 | 0.5 | 0.15 | 0.15 |
| mg/m$^3$ | 219.66 | 225.34 | 221.39 | 132.35 |
| g/kW•h | 0.572 | 0.608 | 0.646 | 0.470 |
| NOX Emission g/kW•h | | | 0.586g/kW•h | |

## E3 cycle test $NO_X$ emission result

| E3 CYCLE NOX EMISSION TEST DATA | | | | |
|---|---|---|---|---|
| speed | 100% | 91% | 80% | 63% |
| power | 100% | 75% | 50% | 25% |
| Weighting factor | 0.2 | 0.5 | 0.15 | 0.15 |
| mg/m$^3$ | 445.31 | 492.98 | 480 | 60 |
| g/kW•h | 0.98816 | 0.656411 | 4.7228 | 0.622 |
| NOX Emission g/kW•h | | | 1.4g/kW·h | |

## D2 cycle test $NO_X$ emission result

| D2 CYCLE NOX EMISSION TEST DATA | | | | | |
|---|---|---|---|---|---|
| speed | 100% | 100% | 100% | 100% | 100% |
| power | 100% | 75% | 50% | 25% | 10% |
| Weighting factor | 0.05 | 0.25 | 0.3 | 0.3 | 0.1 |
| mg/m^3 | 219.66 | 225.34 | 221.39 | 132.35 | 72.29 |
| g/kW•h | 0.572 | 0.608 | 0.646 | 0.470 | 0.397 |
| NOX Emission g/kW•h | | | | 0.6 g/kW·h | |

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# Summary

Test result shows:

- the engine efficiency reach 44% at rated power, Excess air ratio above 2.1, which leads to the low NOx emission
- NOx<1.4 g/kW·h : NOx emission has reached the requirements of marine application, even in ECAs.

Based on the results, the engine configuration and the engine management system's parameters is fixed.


Thank you!