Marine Gas Engine Development

October 15. 2015

Development Department

Large Power Products Operations Business

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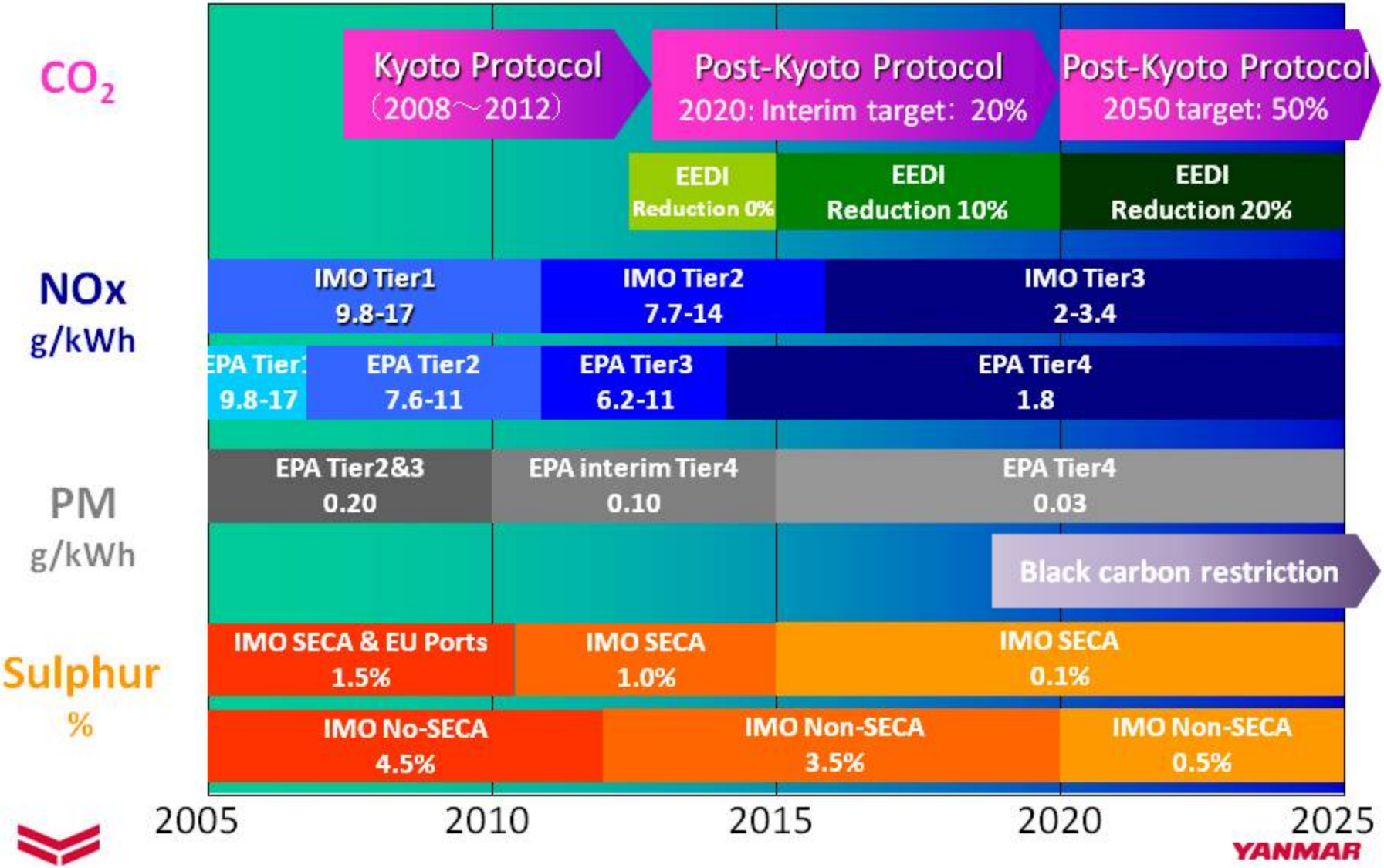
Environmental Impact Material and GHG Reduction Schedule



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Gas Engine Merit for Ships

No	item	description	effect				Tasks to be solved
			NOx	SOx	PM	CO_2	
1	SCR	NOx deoxidation by the catalyst	◎	—	—	—	・Urea cost, maintenance ・Prevention of ammonia leakage
2	Scrubber	Removing SOx by seawater wash	△	◎	◎	—	・Purification of polluted seawater
3	EGR	Exhaust gas recirculation	○	—	×	×	・Engine durability ・Efficiency drop recovering
4	Emulsion	Combustion temperature decrease by emulsion fuel	○	—	○	—	・Mass pure water production device ・Engine durability
5	Gas engine	Operation by natural gas	◎	◎	◎	◎	・Fuel supply infrastructure ・Fuel storage in ships

Gas engine is the most effective solution to reduce all exhaust emissions simultaneously.

Remarks: ◎ excellent ○ good
△ not so bad × bad

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Development Policy of Marine Gas Engine

Base Engine

EY26 Marine Diesel Engine

Pure Gas

Supported by THE NIPPON FOUNDATION

Dual Fuel

6EYG26L
Pure Gas Engine

Marine Gas Engine

Pure Gas Engine EYG26L

- Electric propulsion marine main Engine
- Auxiliary equipment

Model	6EYG26L
Combustion system	Pre-chamber lean barn miller cycle
Ignition system	Spark ignited
Fuel gas	Natural gas (36.0～40.6 MJ/N㎥)
Exhaust volume	122.6L (6-ϕ280mm × 385mm)
Output	1350kWm ／ 720min^{-1} 1280kWe
NOx	1.3 g/kWh
CO_2	429 g/kWh

Advantage

- ◇ Superior thermal efficiency
- ◇ Low emission
- ◇ Simple structure and clean combustion

Technical issues

- ◇ Strength of load fluctuation
- ◇ Changes in fuel composition

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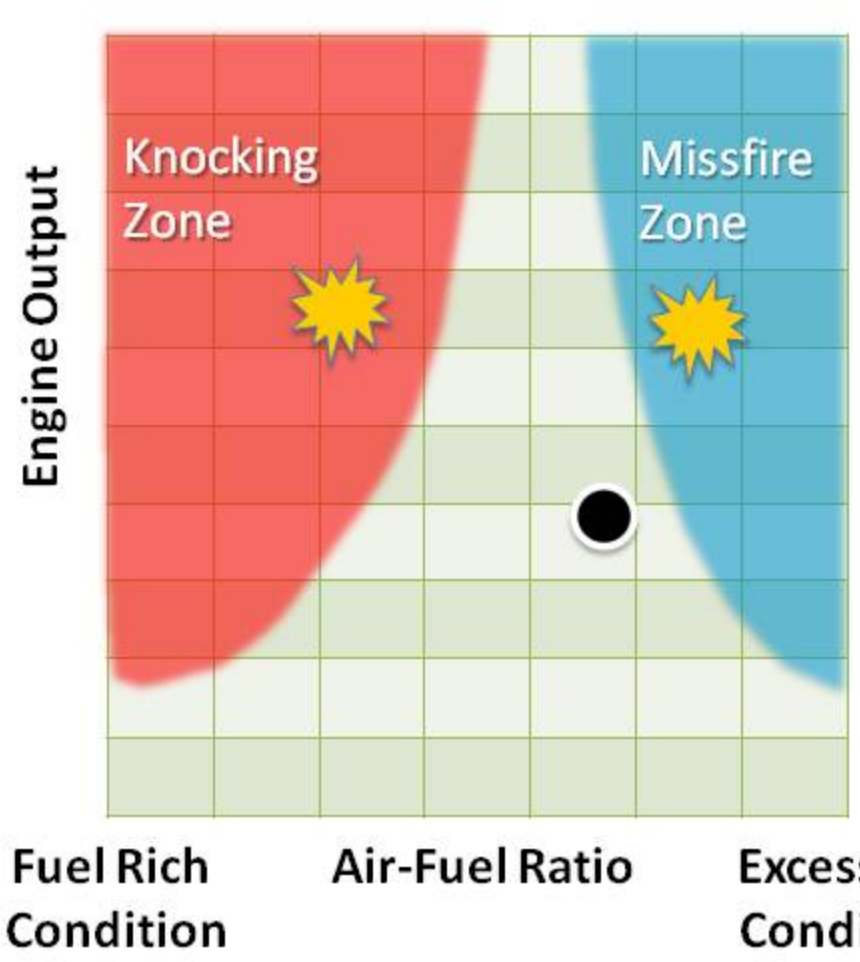
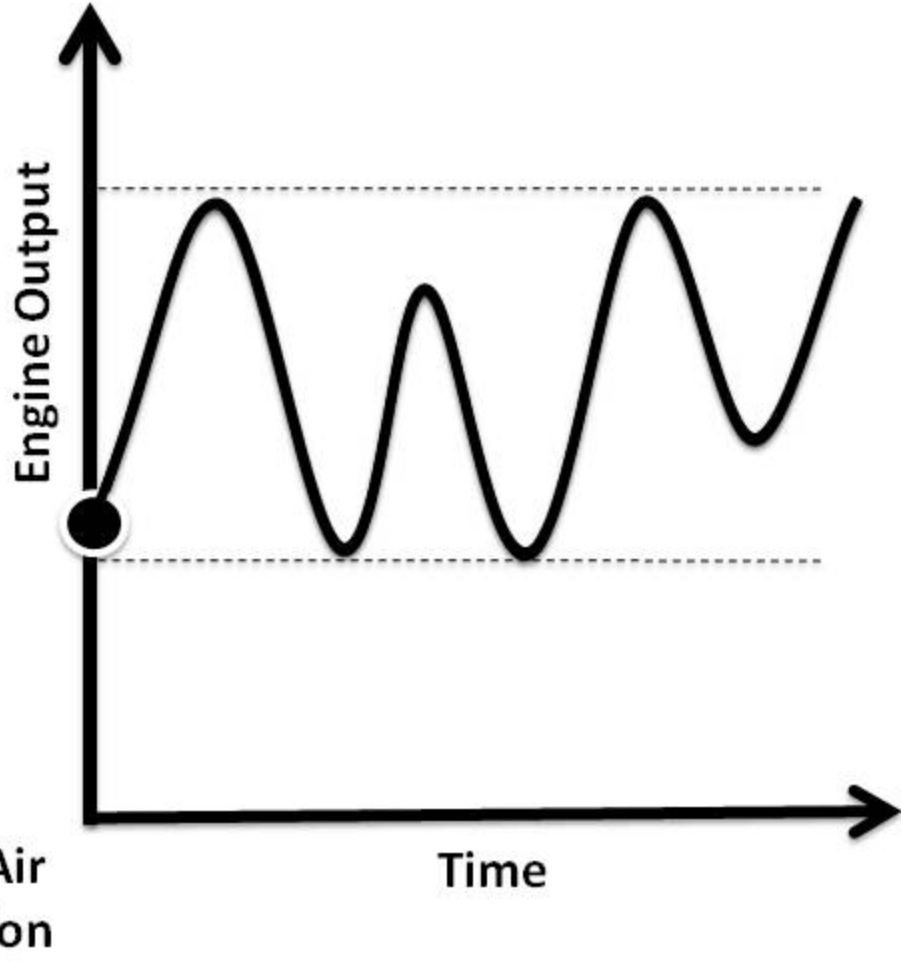
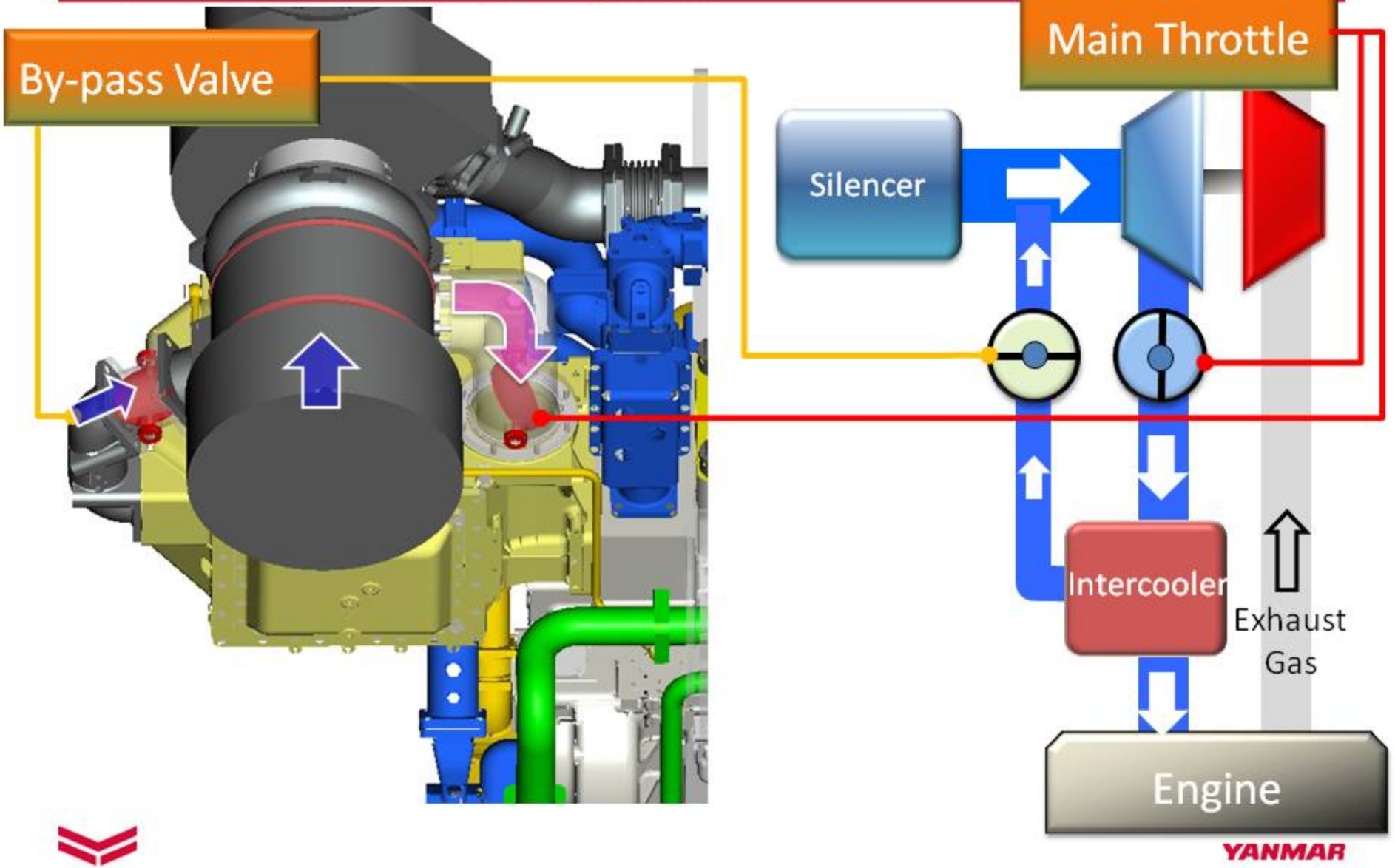
Marine Gas Engine Technology: Transient Load Changing



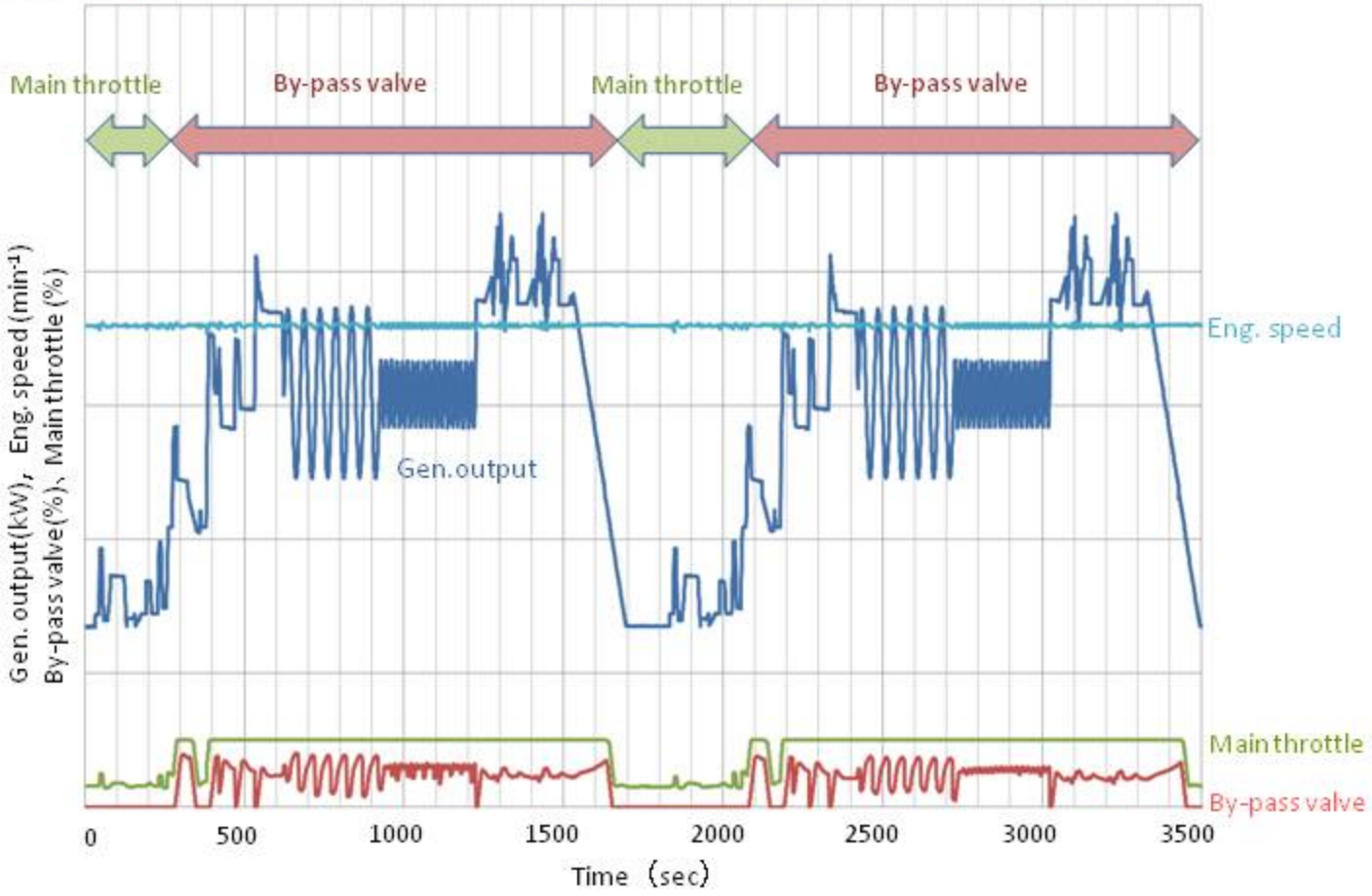


Air-Fuel Ratio Control System



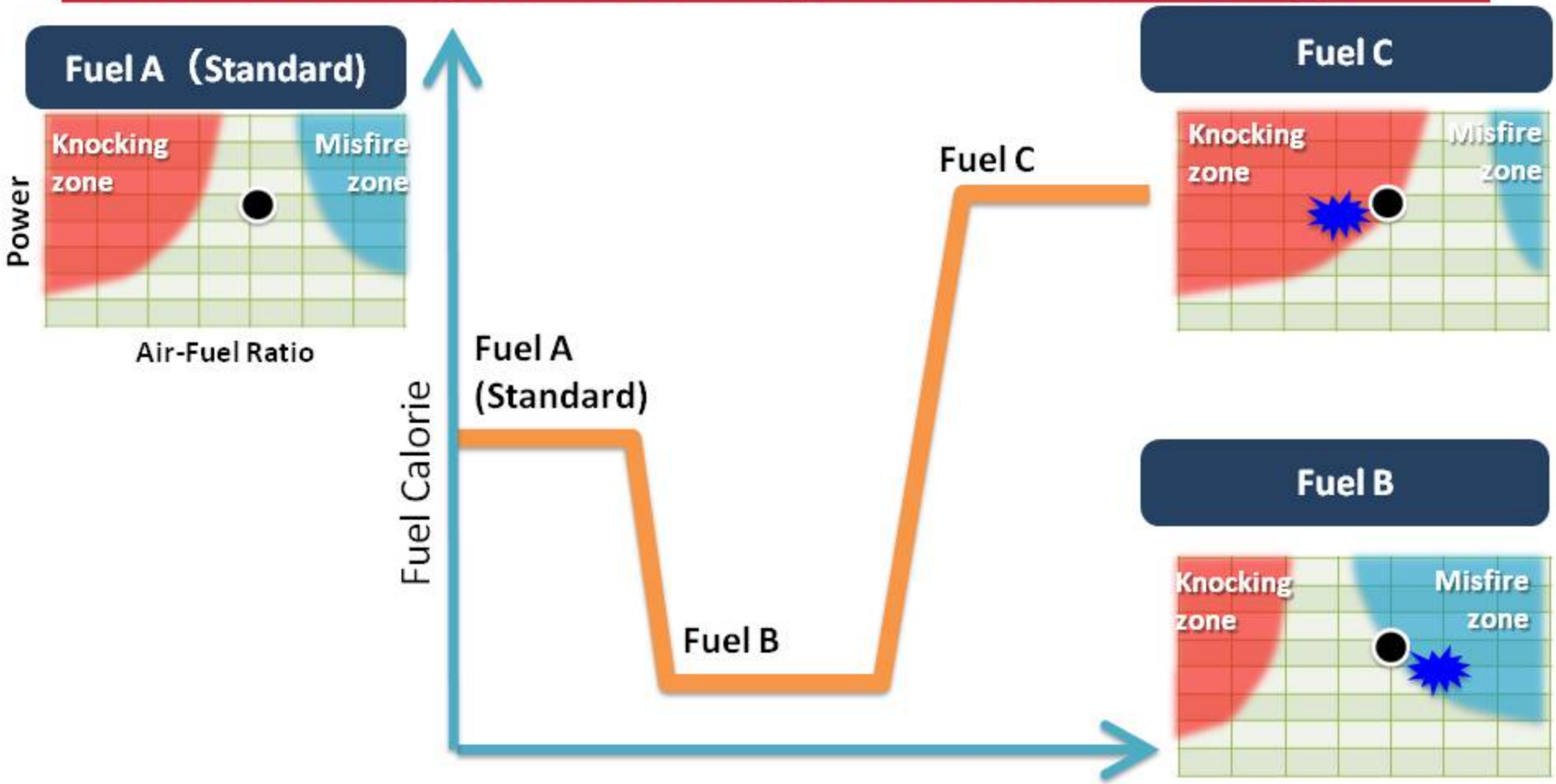
Air-Fuel Ratio Control

- A/F control result by main throttle and By-pass valve



- The air-fuel ratio control against the load fluctuation is performed quickly.

Marine Gas Engine Technology: Fuel Calorie change



- The Air-Fuel ratio is changed by fuel calorie variation.

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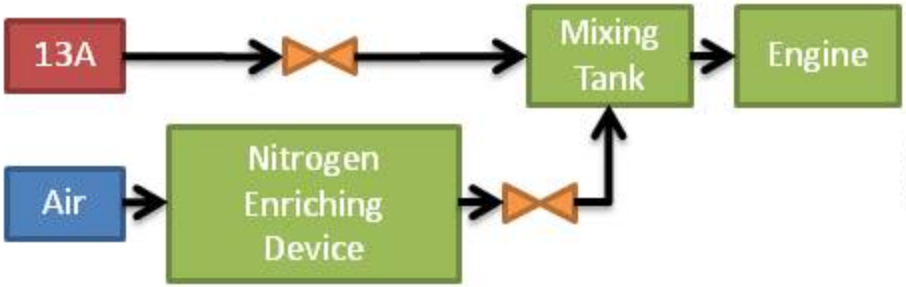
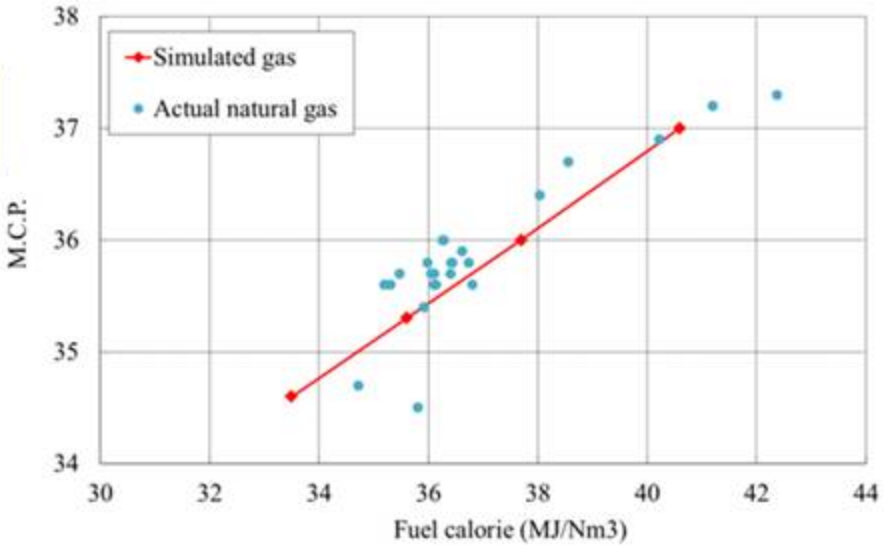
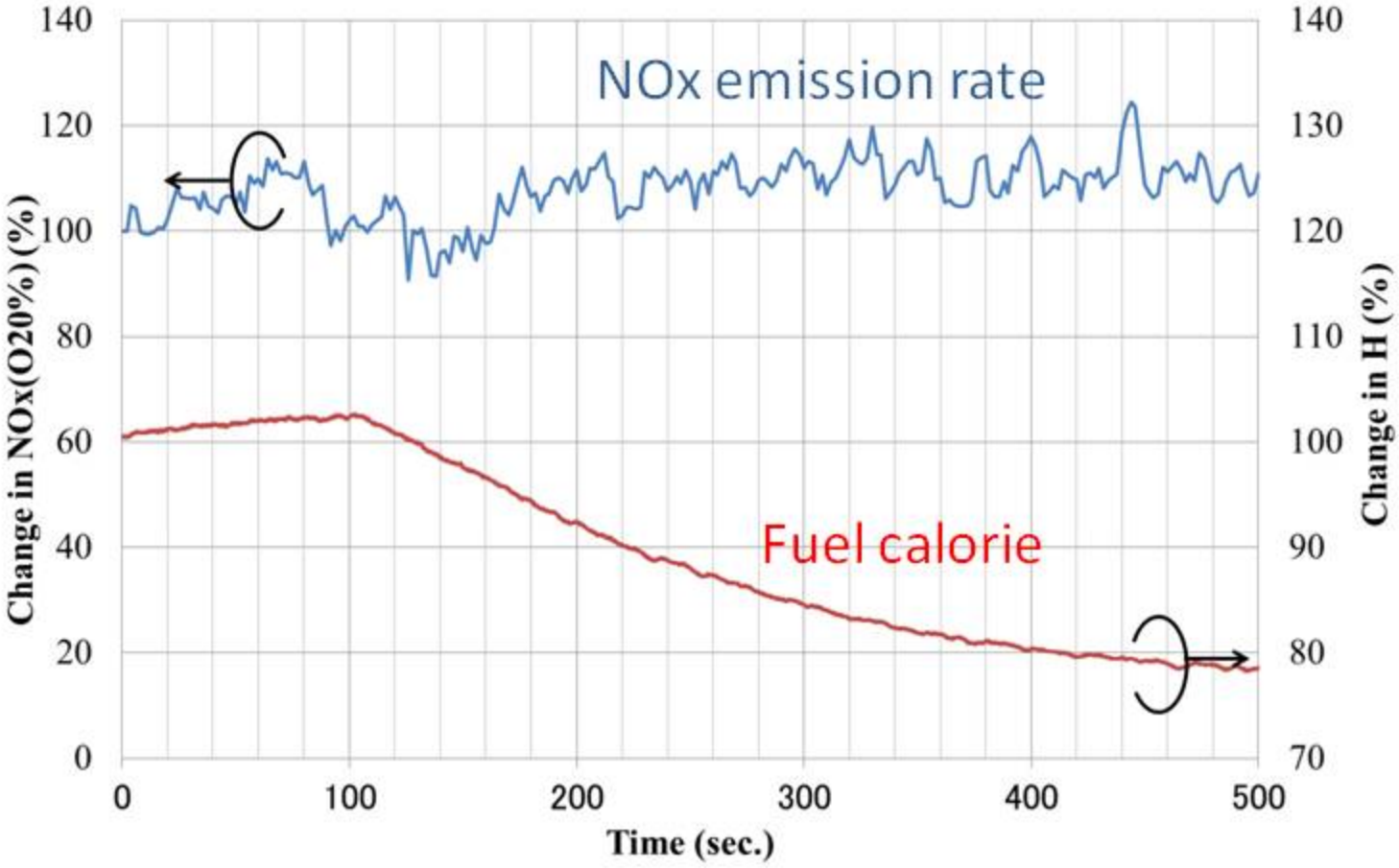
Fuel calorie control system





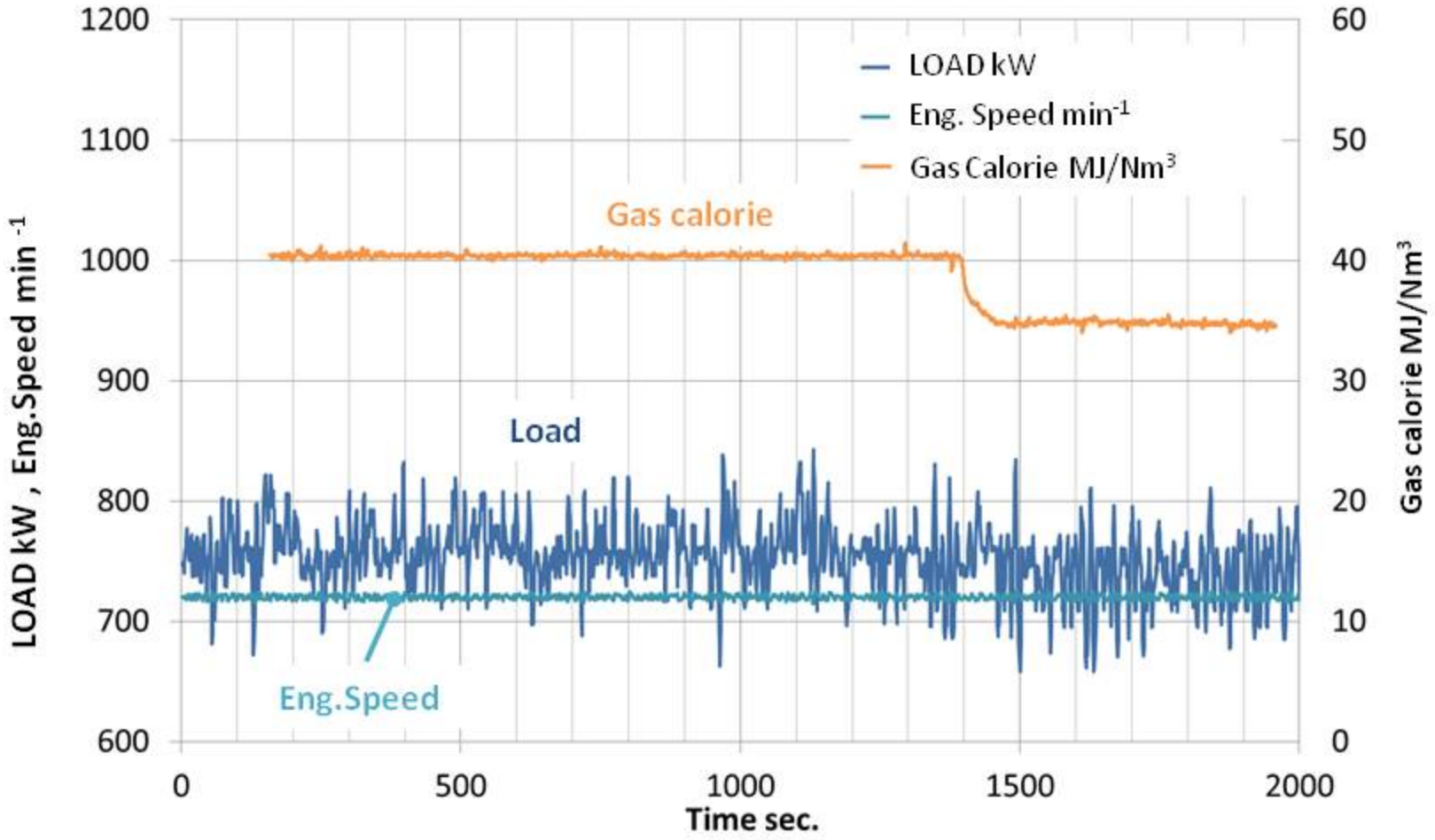
M.C.P. (Maximum Combustion Potential)
: Indicator of the combustion velocity

NOx Emissions in Case of Changing Fuel Calorie



- The air-fuel ratio control by the load fluctuation prediction
- Controlling the air-fuel ratio by the gas calorie change

Demonstration test results in gas calorie change



- The air-fuel ratio control by the load fluctuation prediction
- Controlling the air-fuel ratio by the gas calorie change

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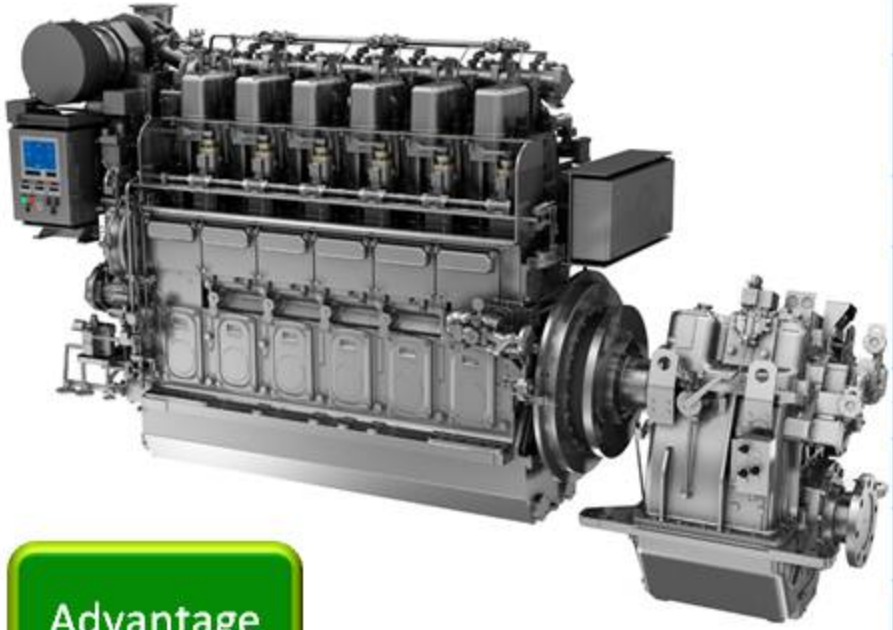
6EY26DF
Dual fuel Engine

Marine gas engine

Dual fuel eng. EY26DF (1530 kWm)

- Main propulsion engine
- Ocean-going vessels auxiliary



Model	6EY26DF
Combustion system	Lean barn miller cycle
Ignition system	Micro pilot injection
Fuel gas	Natural gas (36.0～40.6 MJ/N㎥) MDO
Exhaust volume	122.6L (6-ϕ280mm × 385mm)
Output	1530kWm ／ 750min^{-1}
NOx	< 2.0 g/kWh
CO_2	25% reduction （vs diesel ratio）

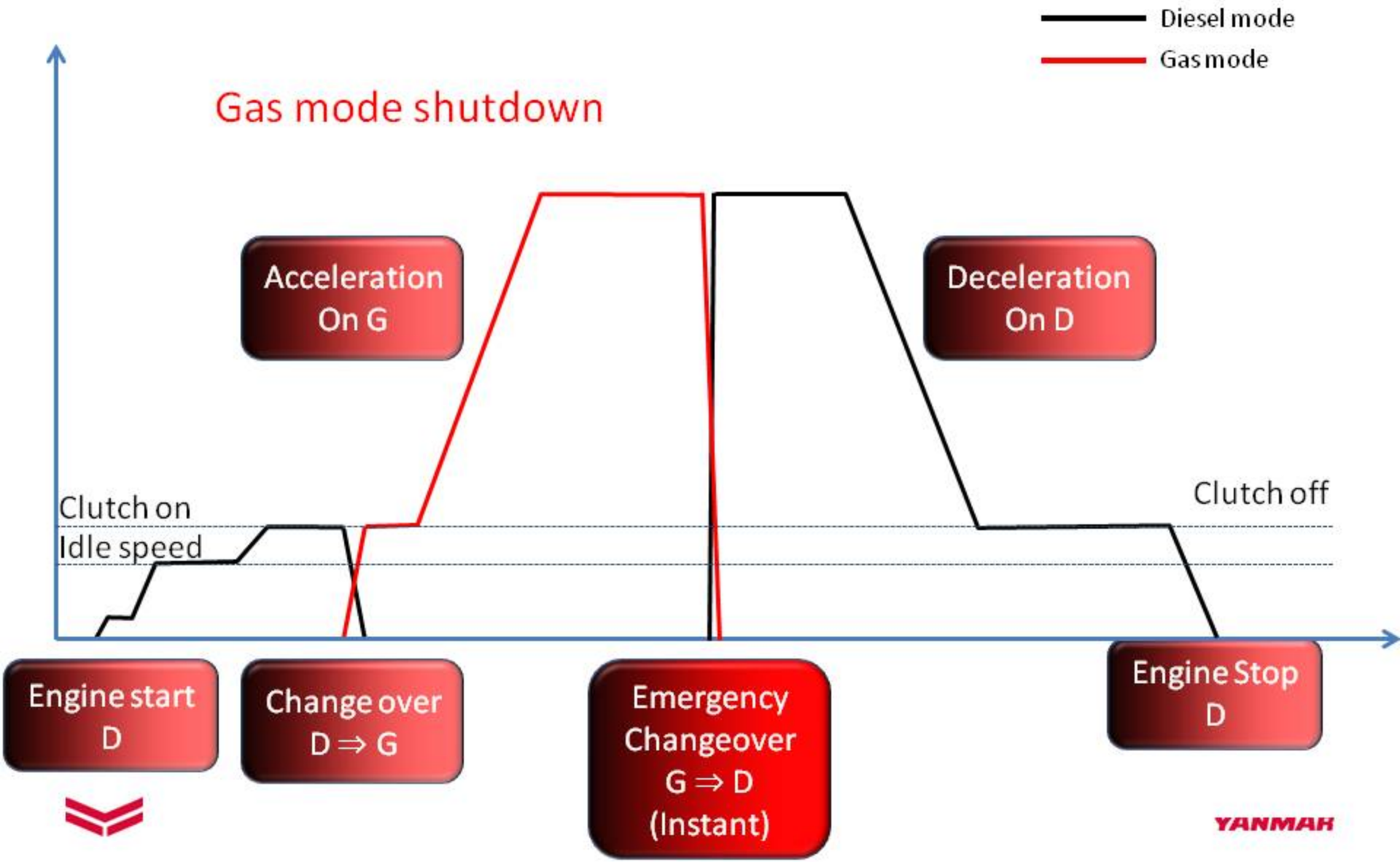
Advantage

- ◇ The flexibility for the use fuel
- ◇ Redundancy due to dual fuel
- ◇ The high output by the micro-pilot ignition

Technical issues

- ◇ Fuel changeover control(Backup)
- ◇ Acceleration as main propulsion engine

6EY26DF Operation Schedule



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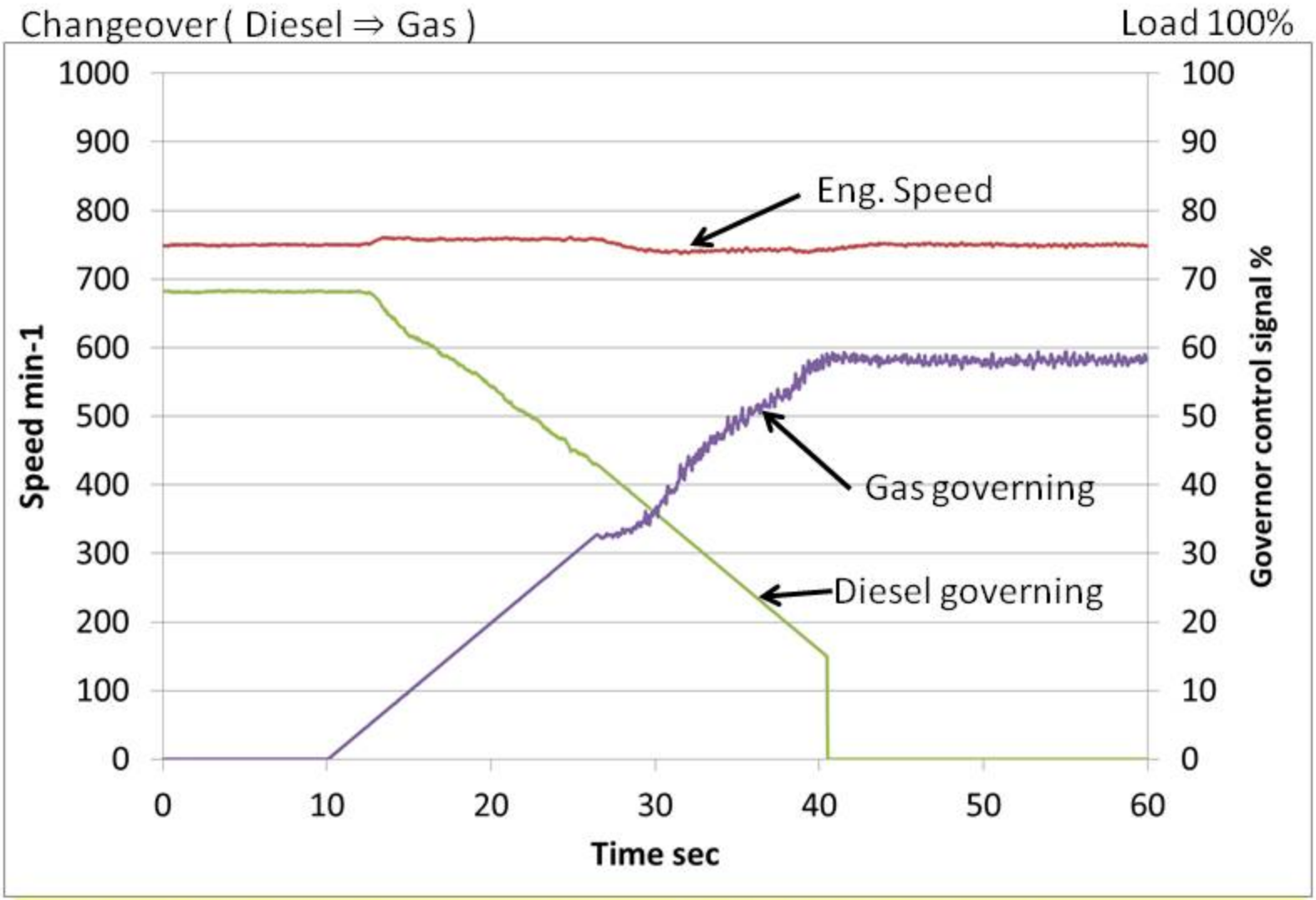
Demonstration test results in Change-over with Load



➢ Smooth change-over with no fluctuation of the Eng. Speed.

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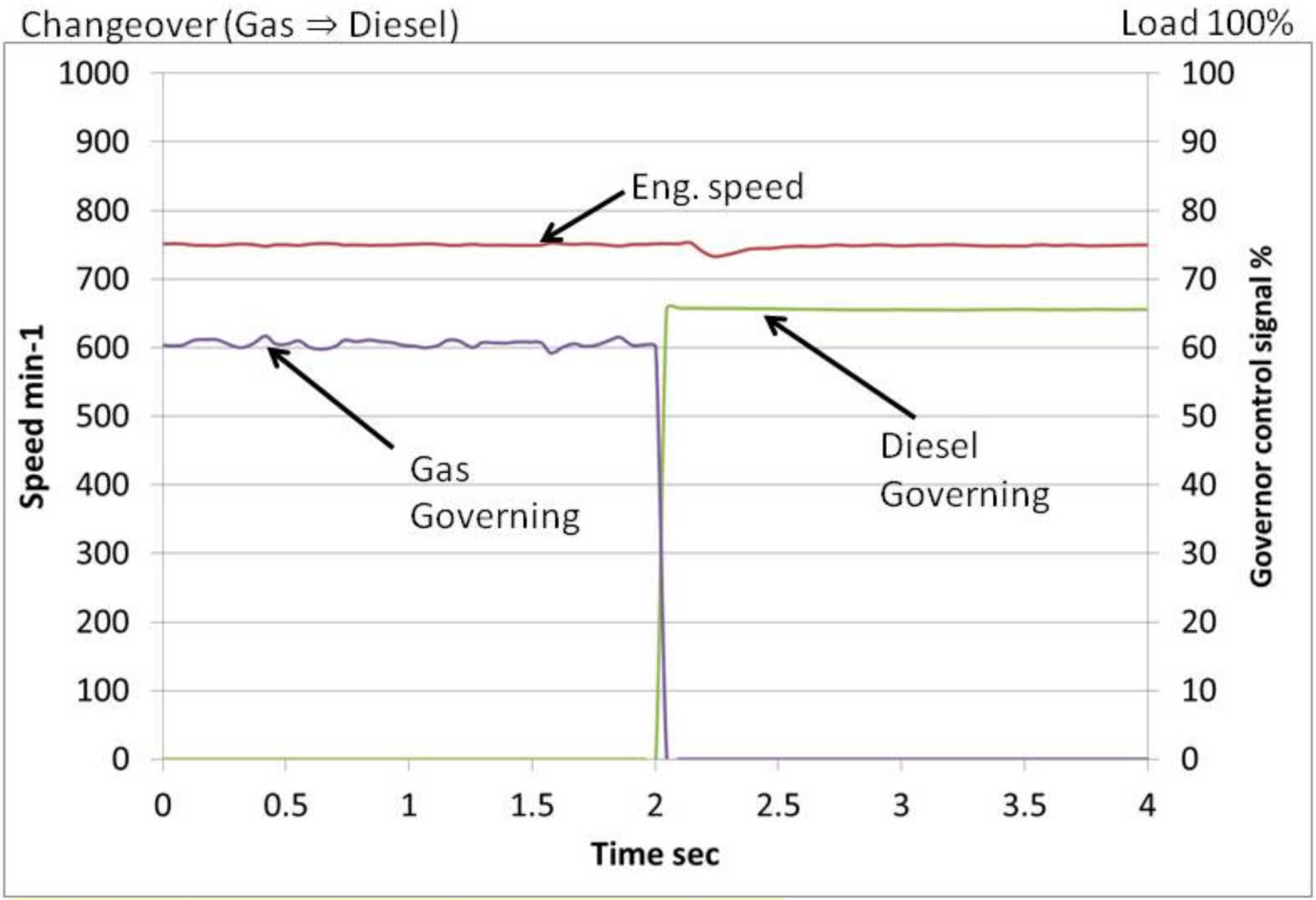
Demonstration test results in Change-over for Safety Action



- The changeover is performed instantly.

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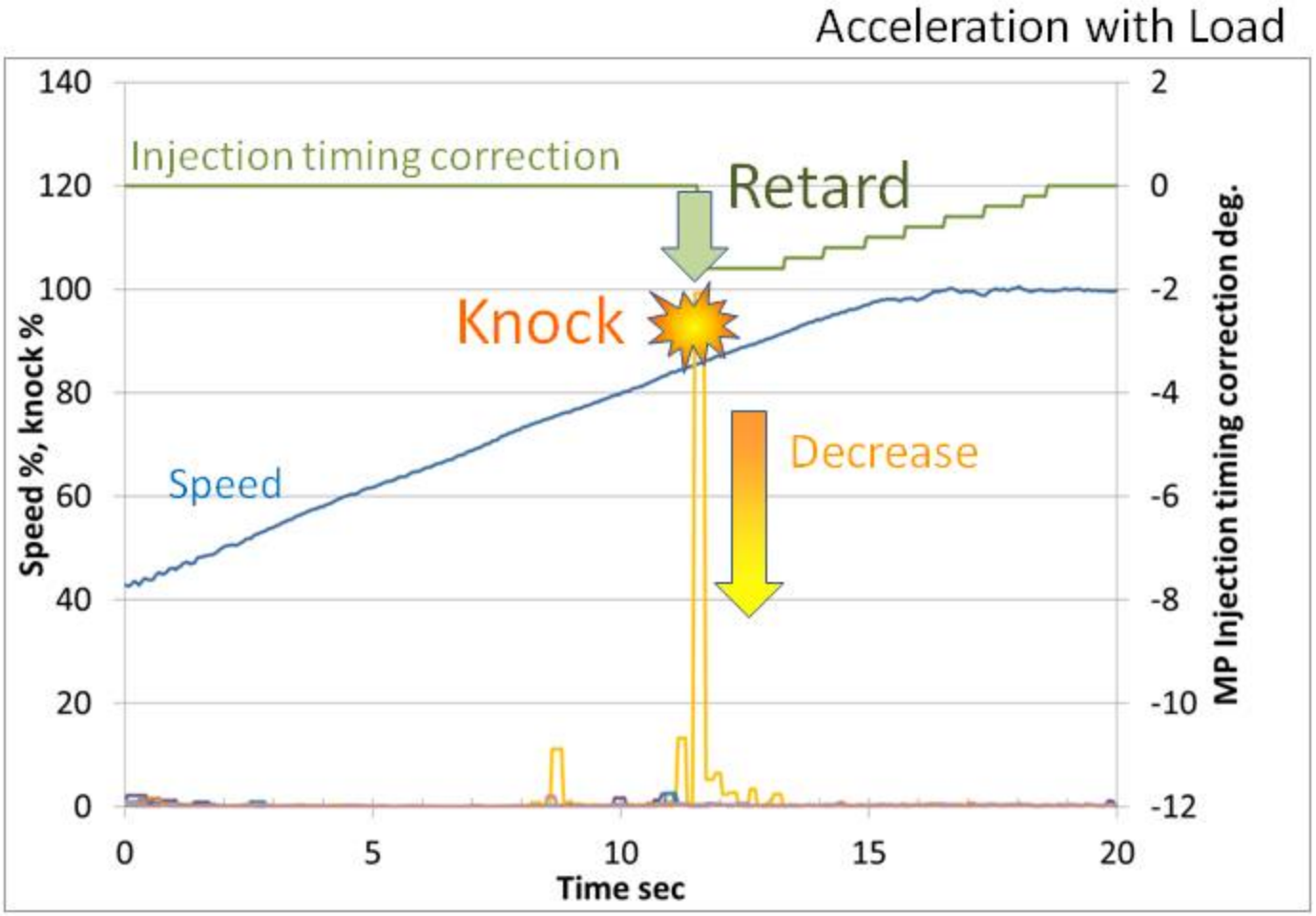
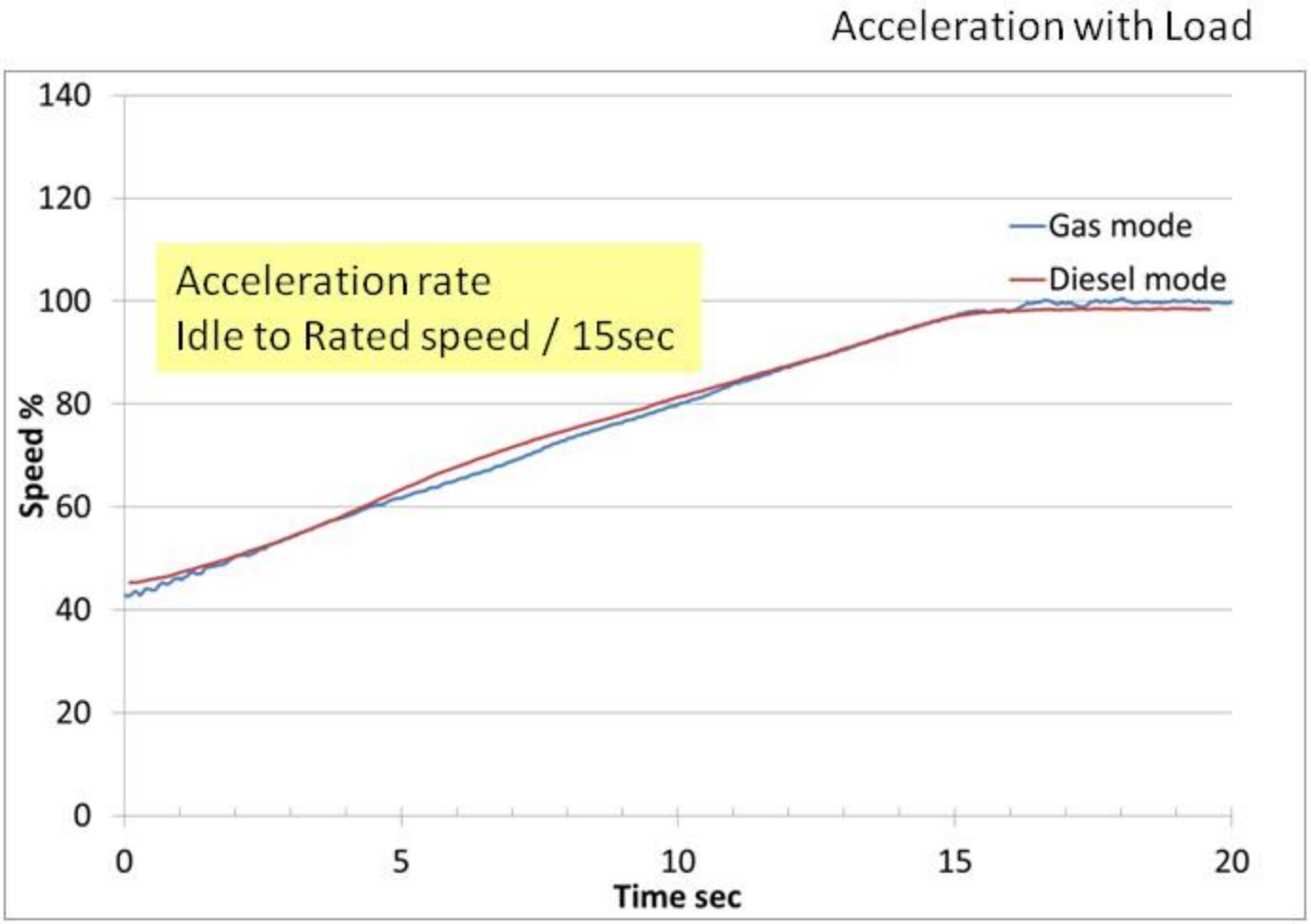
Demonstration test results in Avoid Knocking



- When the knock is detected, the injection timing is retarded instantaneously.
- The knock is lost and the engine can be accelerated.

Diesel & Gas test result in Acceleration Performance



➢ The Gas mode acceleration performance is same as the Diesel mode.

Summary

- Yanmar developed the marine gas engine and the dual fuel engine for corresponding to exhaust emissions regulations in the future.
- The adoption of a new lambda control technology enabled the correspondence of the load variation and the calorie variation.
- The engine can avoid knocking instantly by automatic injection retard. And it can continue on the gas mode operation.
- The engine can change from the gas mode to the diesel mode in case of the gas mode failure in instantly. Then the engine can continue operation.