



Yanmar's Innovation and New Product Development for “Beautiful Harmony with Global Environment”

Feb. 13, 2015

Development Department
Large Power Products Operations Division

YANMAR

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Development Concept

Concept

Boosting the "Life Cycle Value" for Customers

Beautiful Harmony with Global Environment

Policy

Strategic Approach to the Environment Regulation

**Reduce GHG
Optimized SCR for Engine
Noise & Vibration Technology
Flexible Fuel Strategy**

Innovative Improvement of Engine Performances

**Improvement of reliability
Reduce Maintenance Cost
Making to High power
Down sizing**

Challenge to the Ultra Low Fuel Consumption

**Cycle efficiency Improvement
Variable Technology
Electronic Fuel Injection**



Research and Development Organization

R&D



R&D Center



Kota Kinabalu



Firenze



Basic
Technology



Contract
Research

Development
Manufacture
Sales
Service



Products
And Service



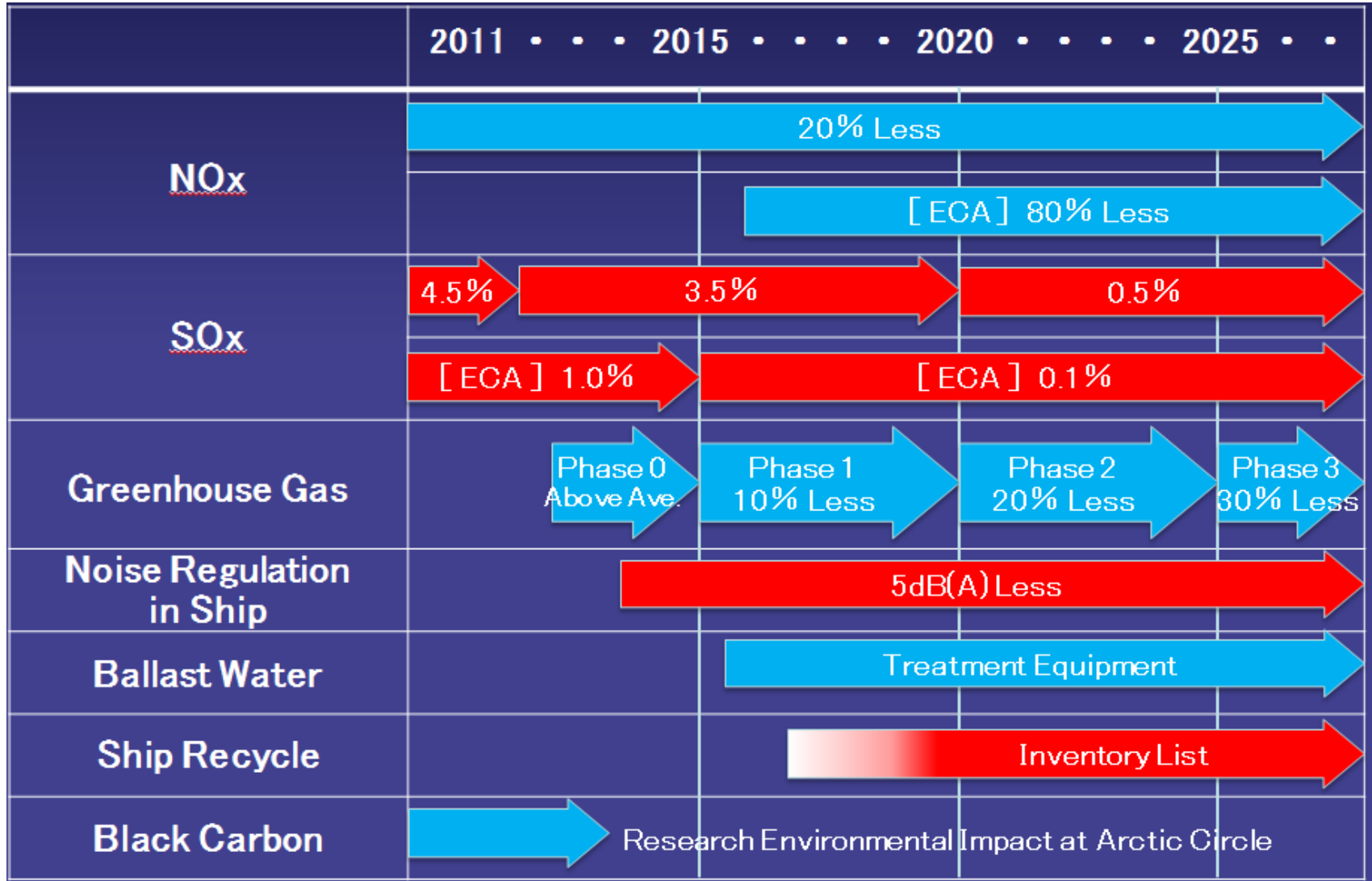
Voice of
Customer



Customer



Environmental Regulation Trend



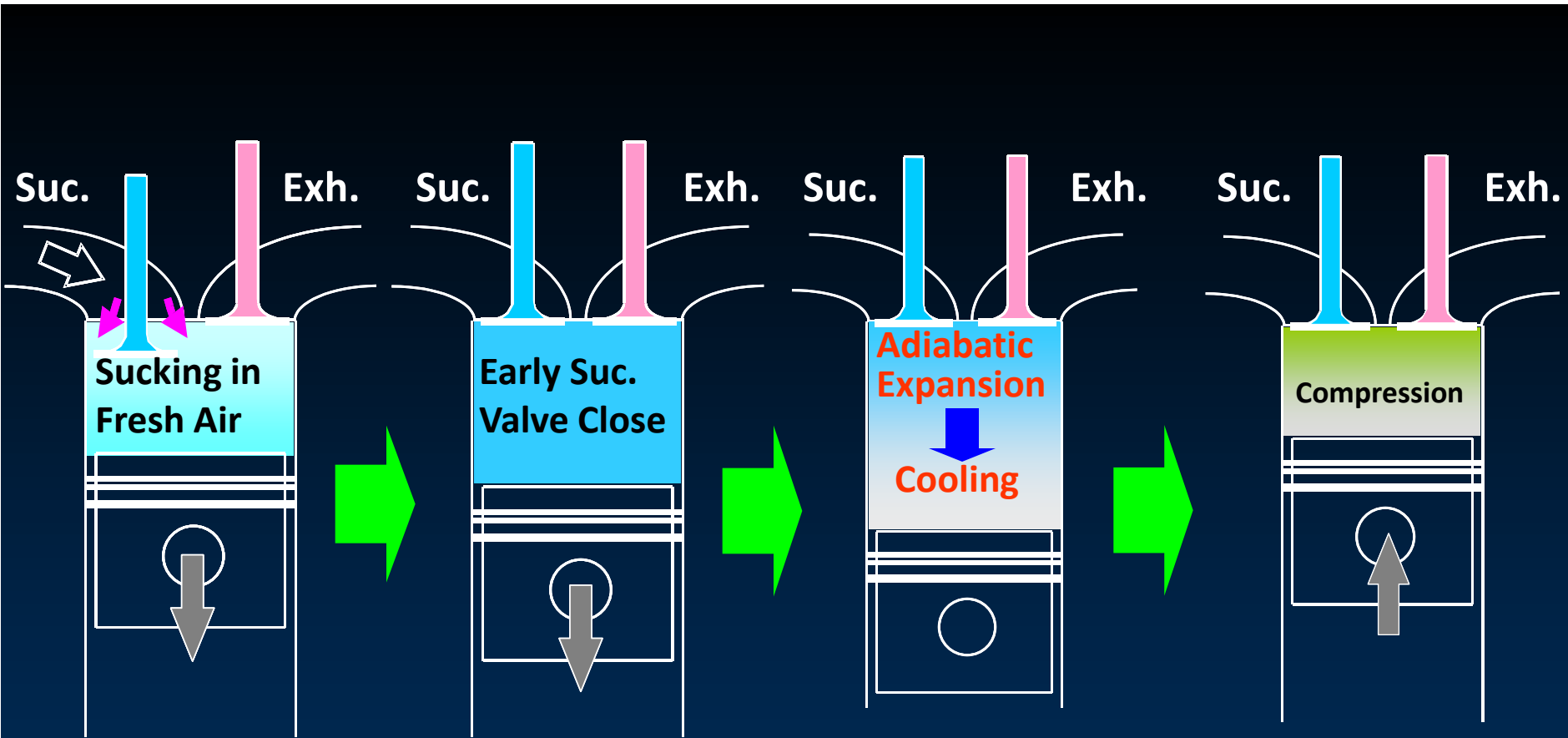
Technologies to Reduce Fuel Consumption

2-Stage Turbo Charging



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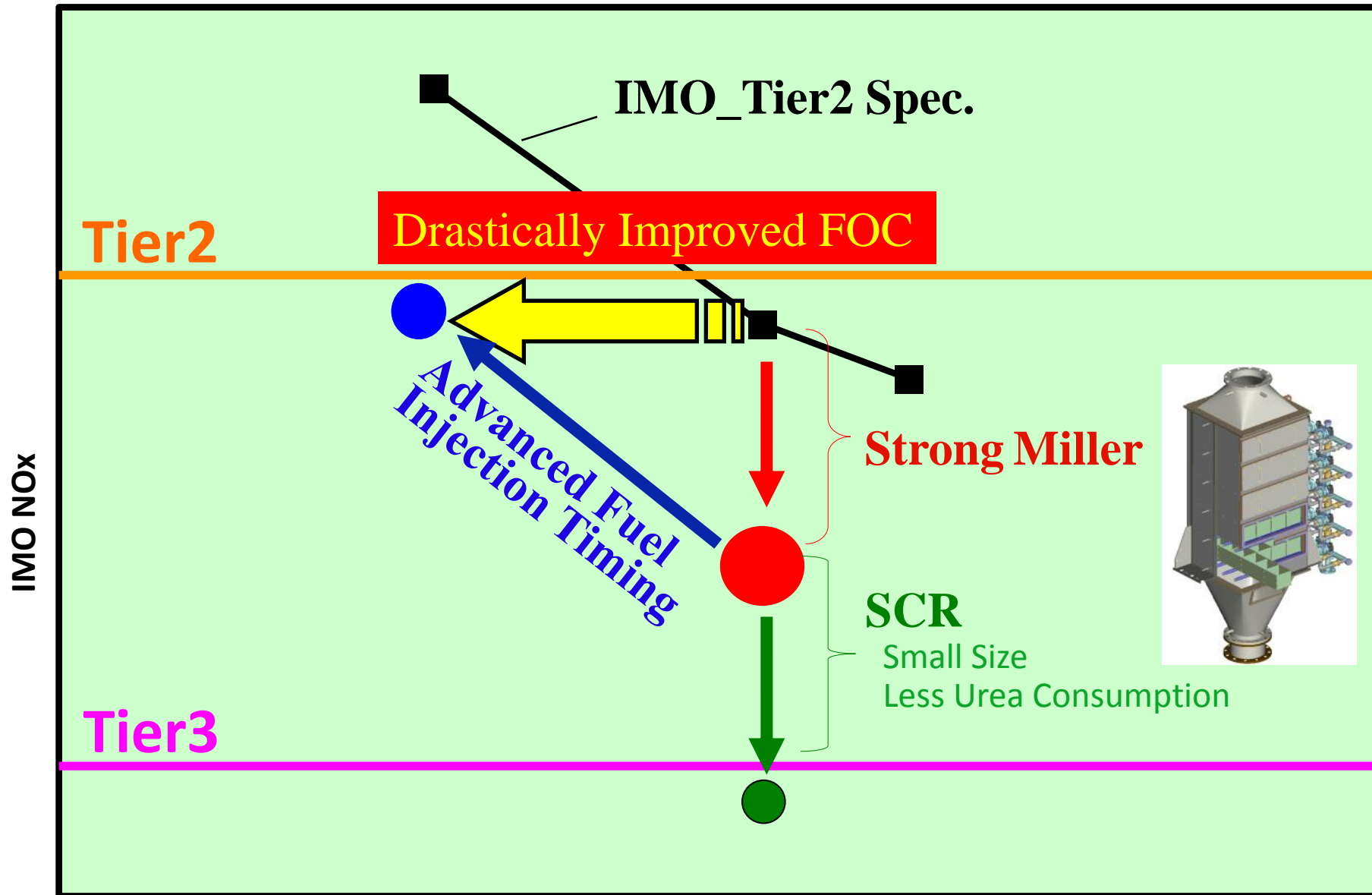
Miller Cycle : Early Suction Valve Close



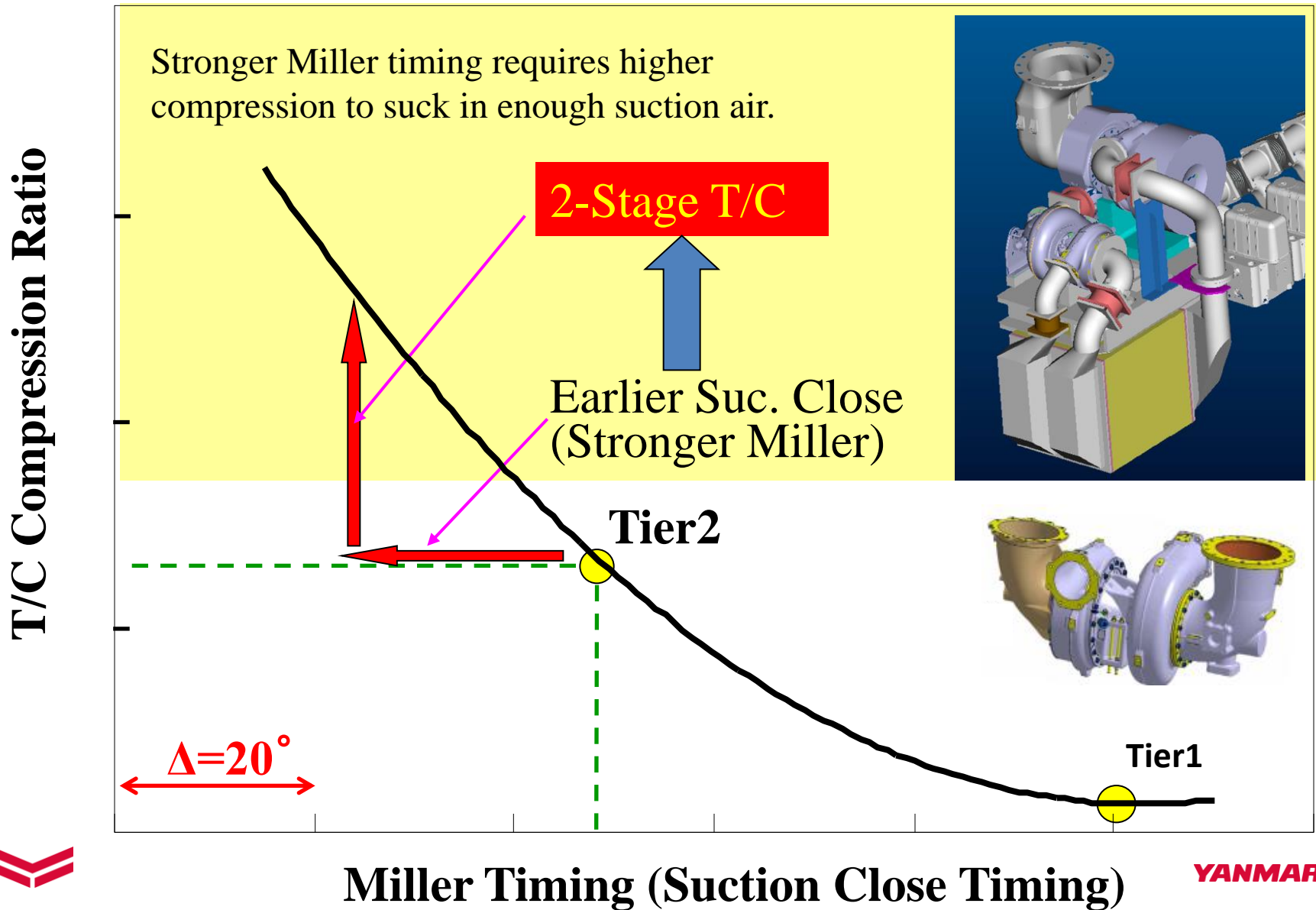
Decrease of Cylinder Air Temperature just before Combustion

Nox Reduction

The Great Effect of the Strong Miller Cycle

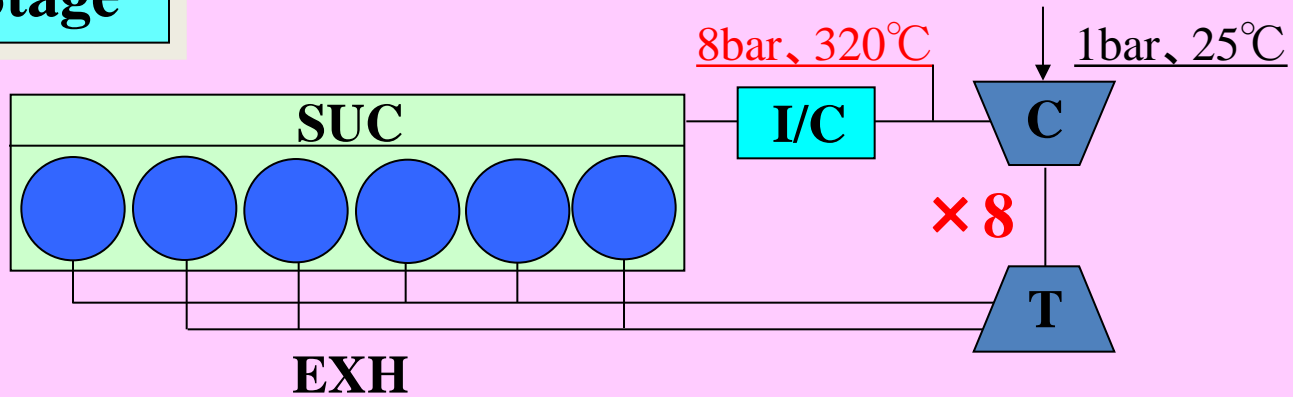


The Relationship between Miller timing and Required Compression Ratio

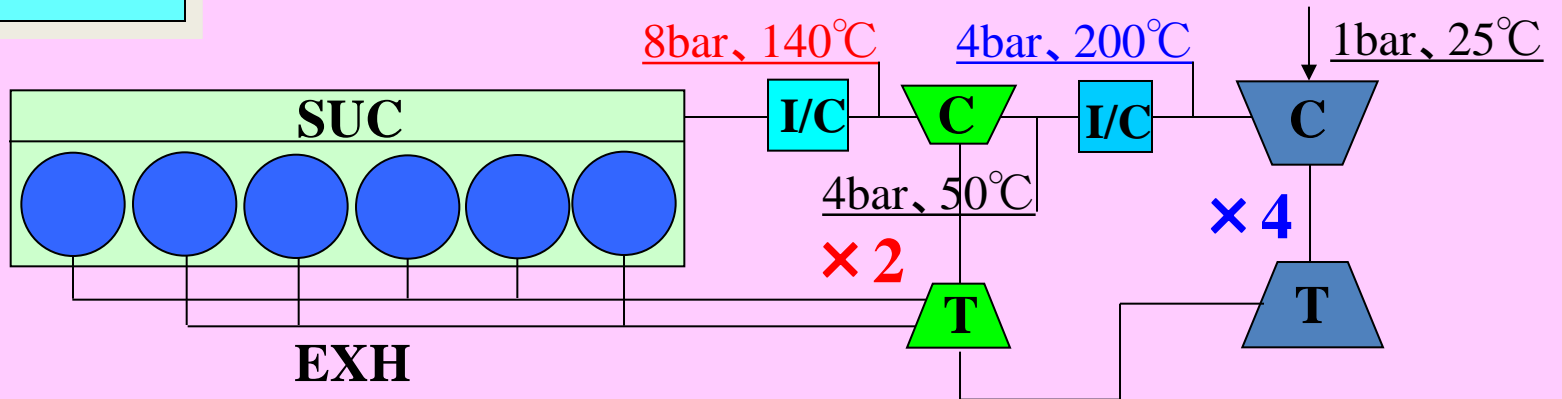


Turbo Charging System Layout

Single Stage



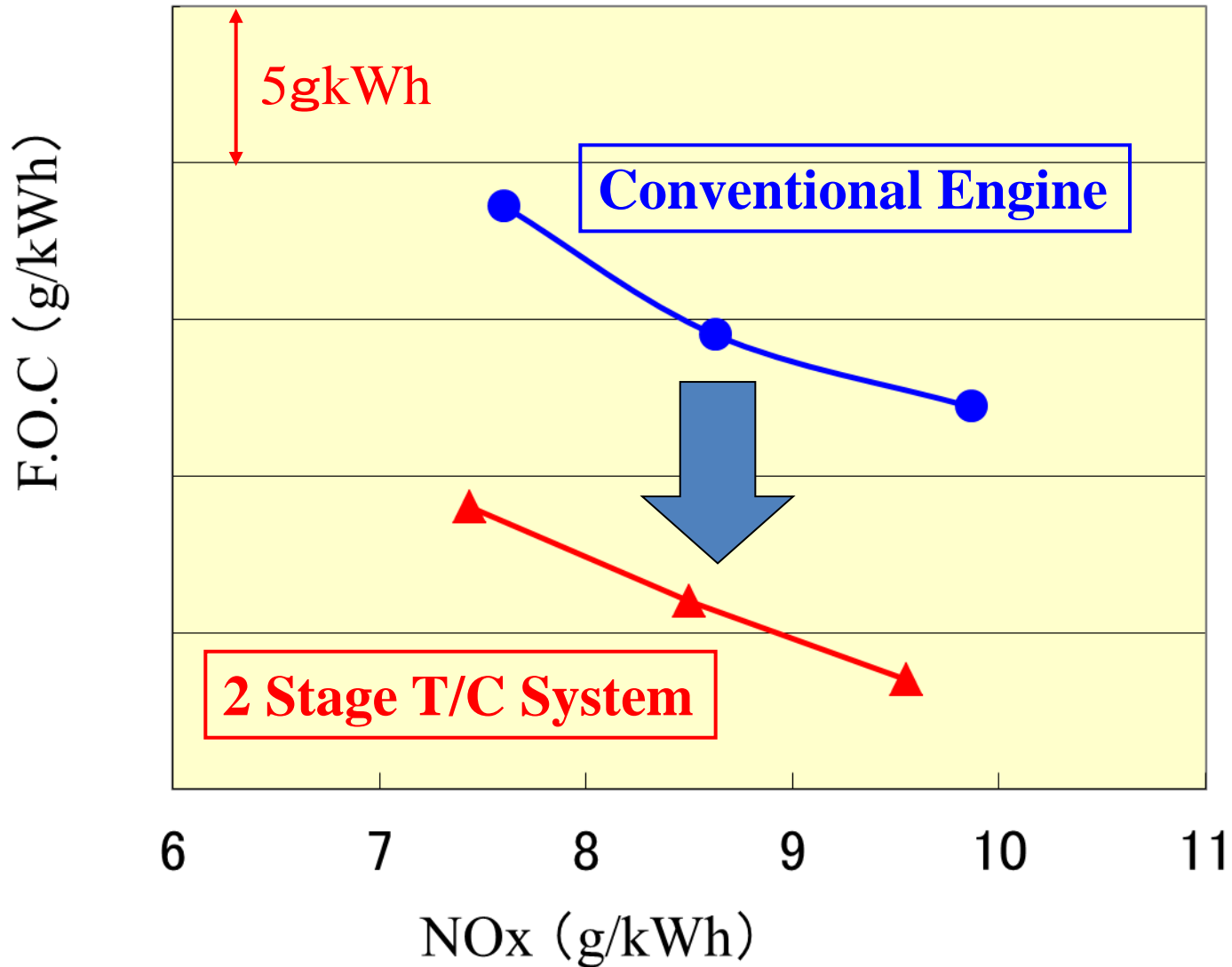
2 Stage T/C



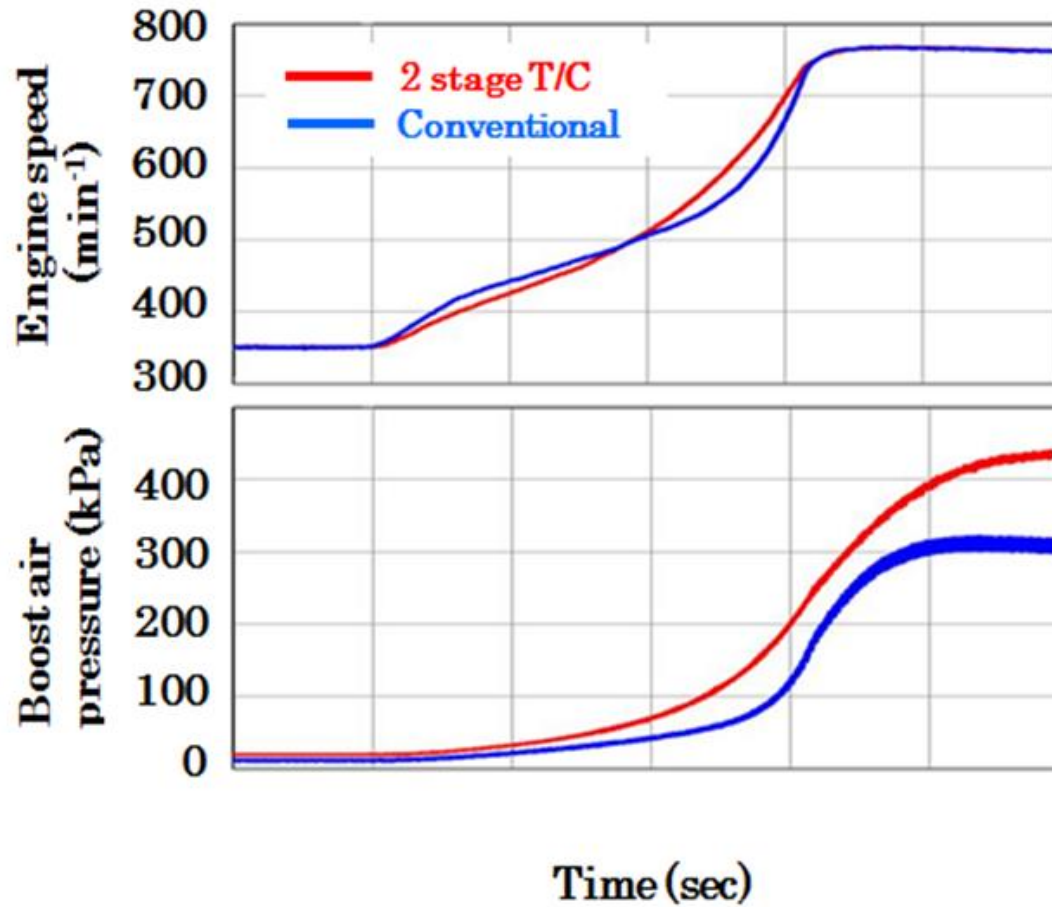
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Described Temperature, Pressure are example

Test Result (F.O.C – NO_x 75%Load)

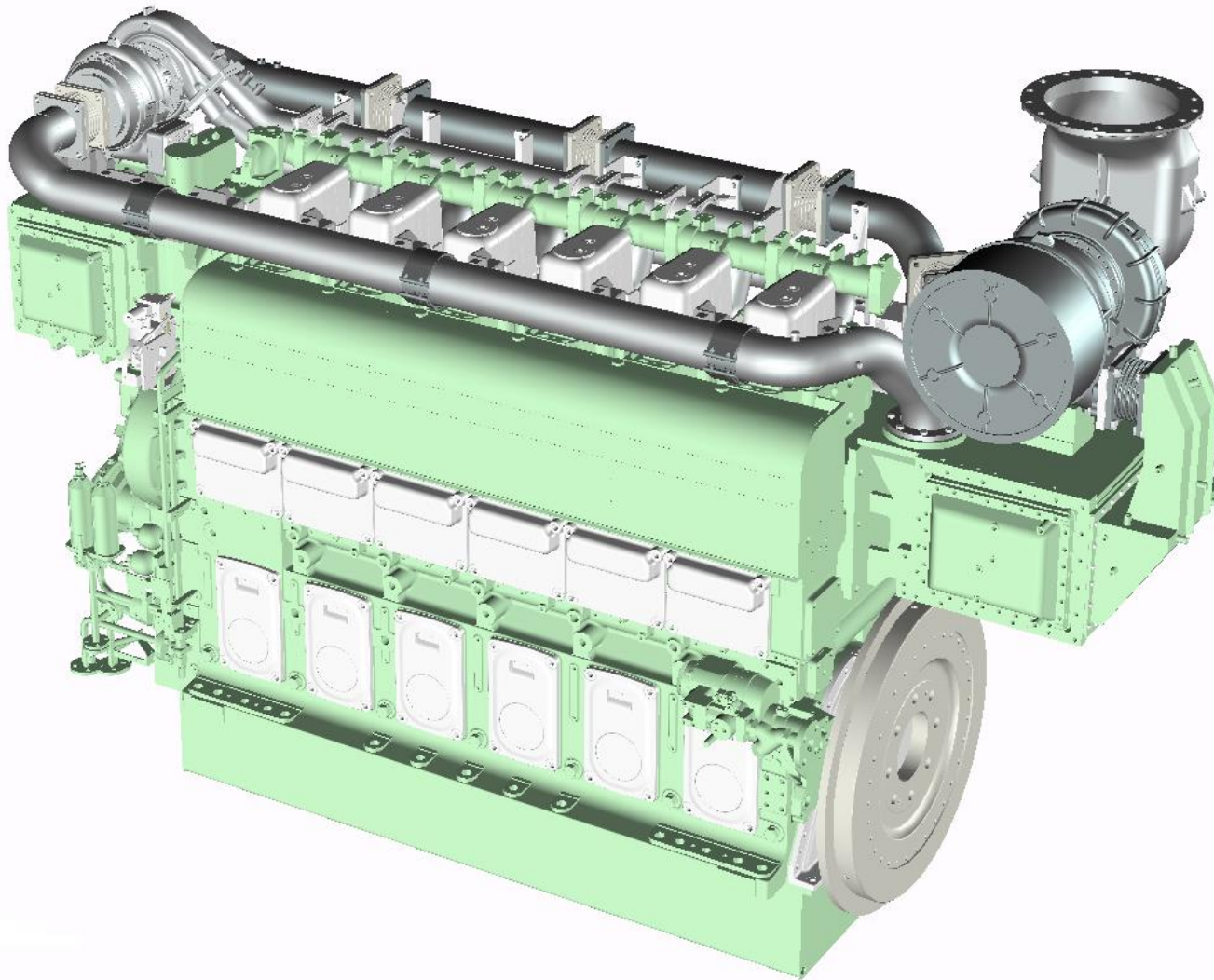


Performance in Acceleration



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2 Stage Turbocharging System to Reduce FOC



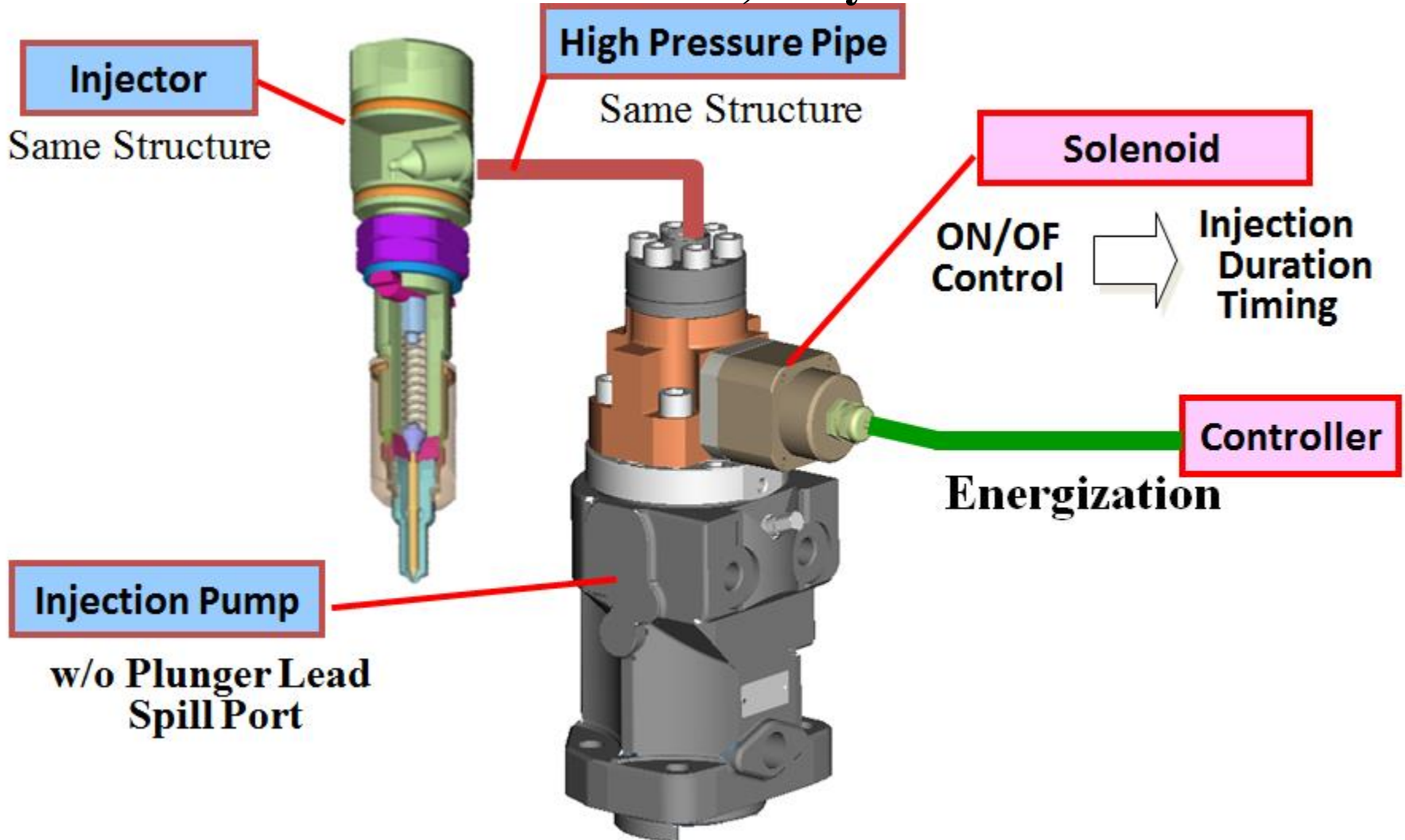
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Technologies to Reduce Fuel Consumption
Electronic Unit Pump System



Electronic Unit Pump System

Minor Modification from Conventional Engine
Minimum Electronic Device, Easy Maintenance



Main electronic control parts

Controller



Solenoid valve



Speed sensor



Phase sensor



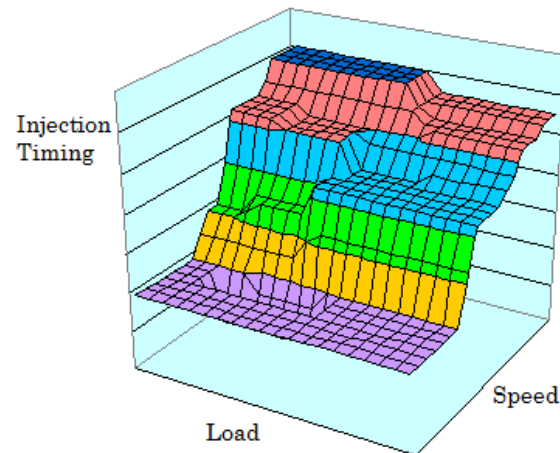
Wiring for control



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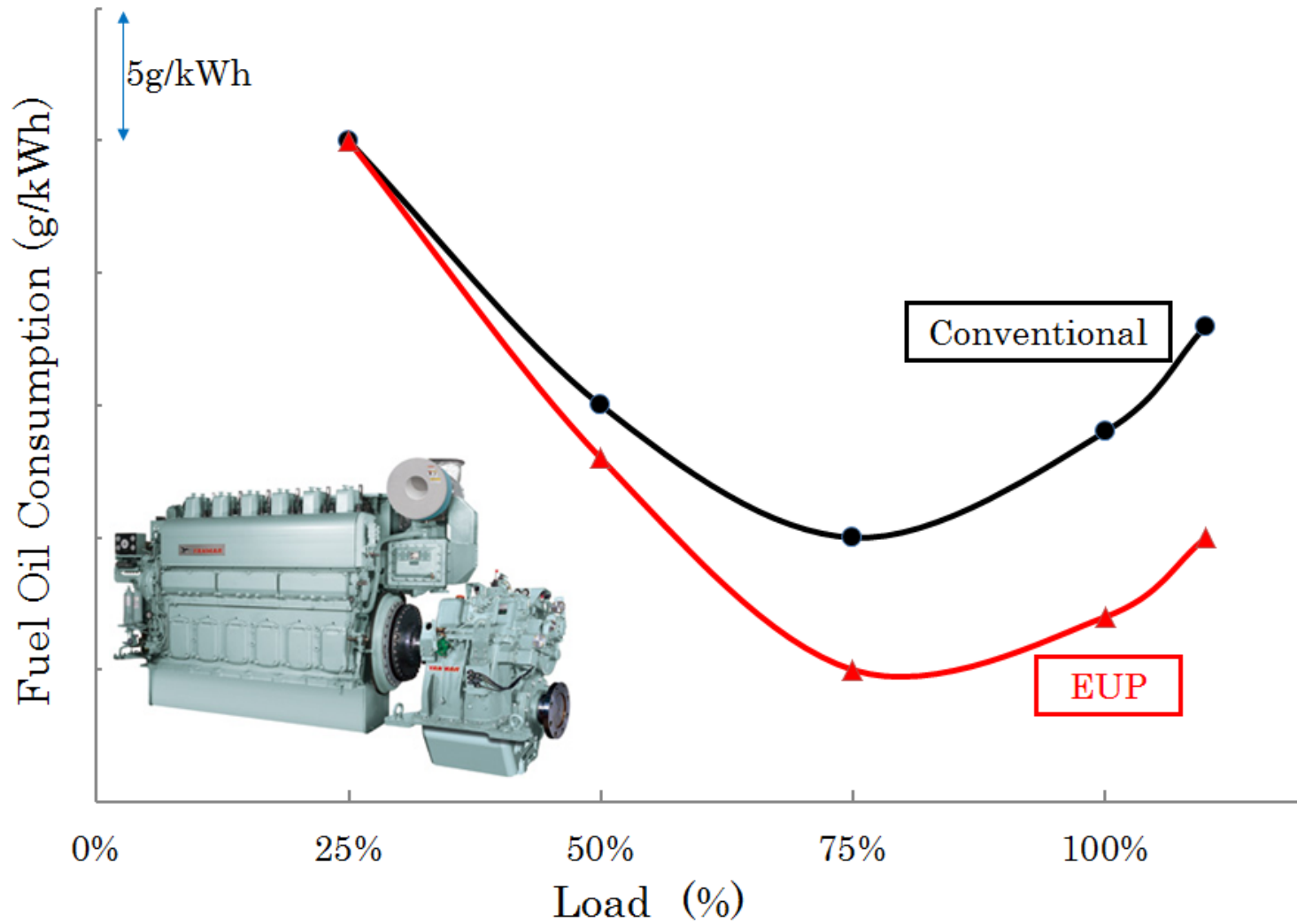
Merit of EUP System

- 1) *Further improvement of FOC-NOx trade-off*
- 2) *Smoke reduction (Start, Low load, Acceleration)*
- 3) *Ship handling improvement when ships come alongside the pier or leave the pier.*



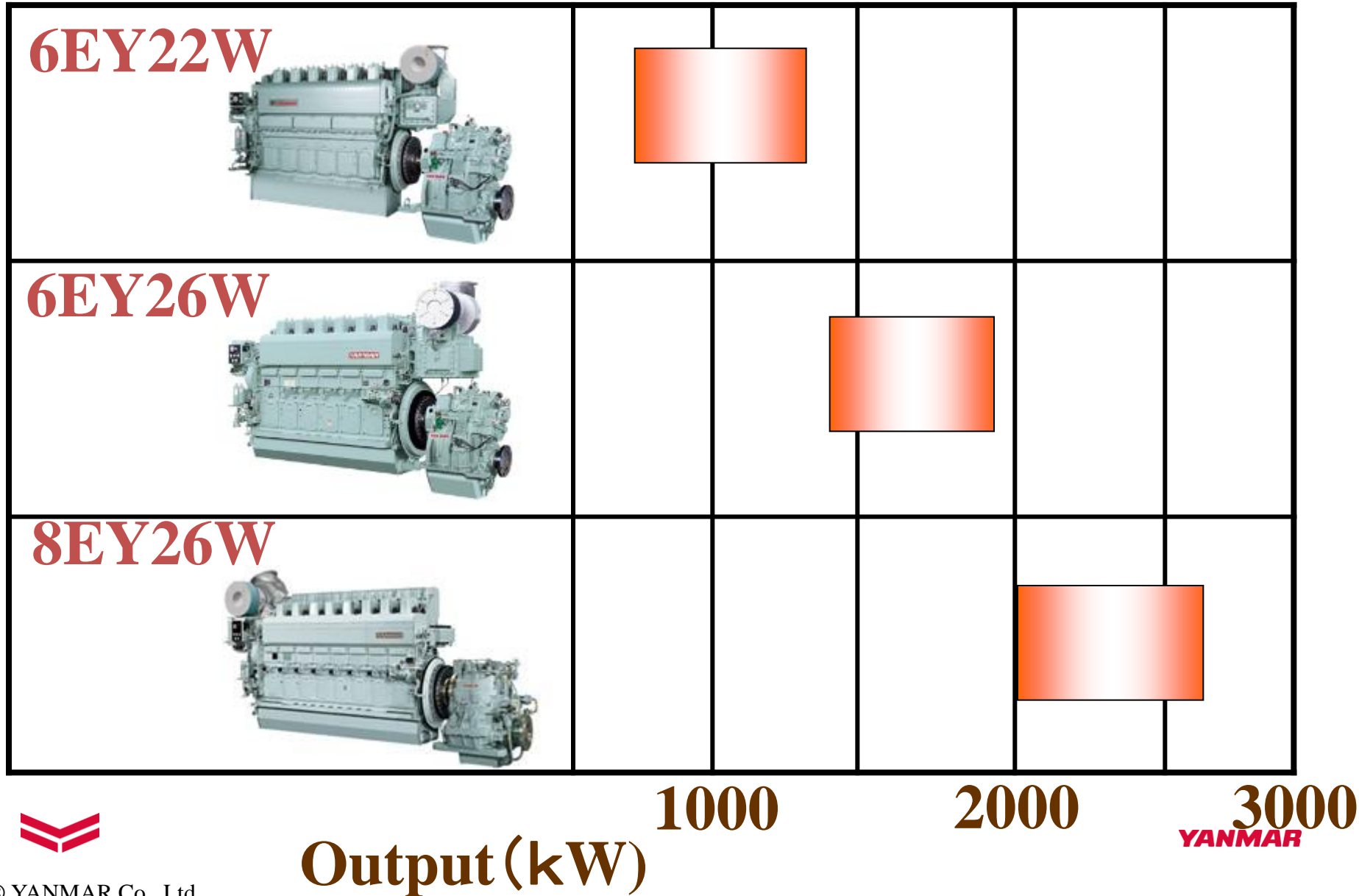
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Engine Performance Comparison



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Electronically Controlled Engine Line-Up



Development of Marine Gas Engine



Gas engine merit for ships

No	item	description	effect				Tasks to be solved
			NO _x	SO _x	PM	CO ₂	
1	SCR	NO _x deoxidation by the catalyst	◎	—	—	—	<ul style="list-style-type: none"> • Urea cost, maintenance • Prevention of ammonia leakage
2	Scrubber	Removing SO _x by seawater wash	△	◎	◎	—	<ul style="list-style-type: none"> • Purification of polluted seawater
3	EGR	Exhaust gas recirculation	○	—	×	×	<ul style="list-style-type: none"> • Engine durability • Efficiency drop recovering
4	Emulsion	Combustion temperature decrease by emulsion fuel	○	—	○	—	<ul style="list-style-type: none"> • Mass pure water production device • Engine durability
5	Gas engine	Operation by natural gas	◎	◎	◎	◎	<ul style="list-style-type: none"> • Fuel supply infrastructure • Fuel storage in ships



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

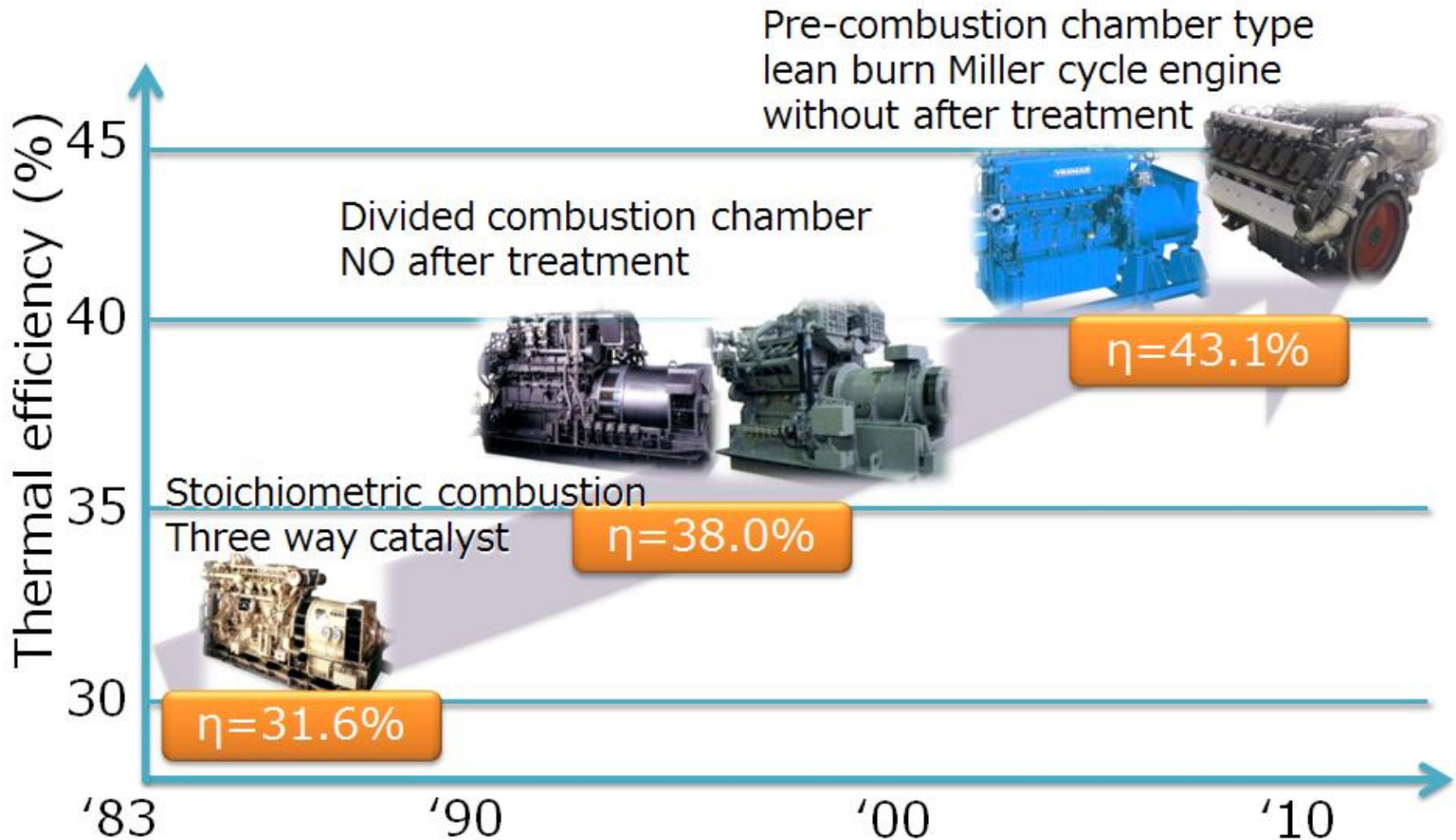
Remarks: ◎ excellent ○ good

△ not so bad × bad

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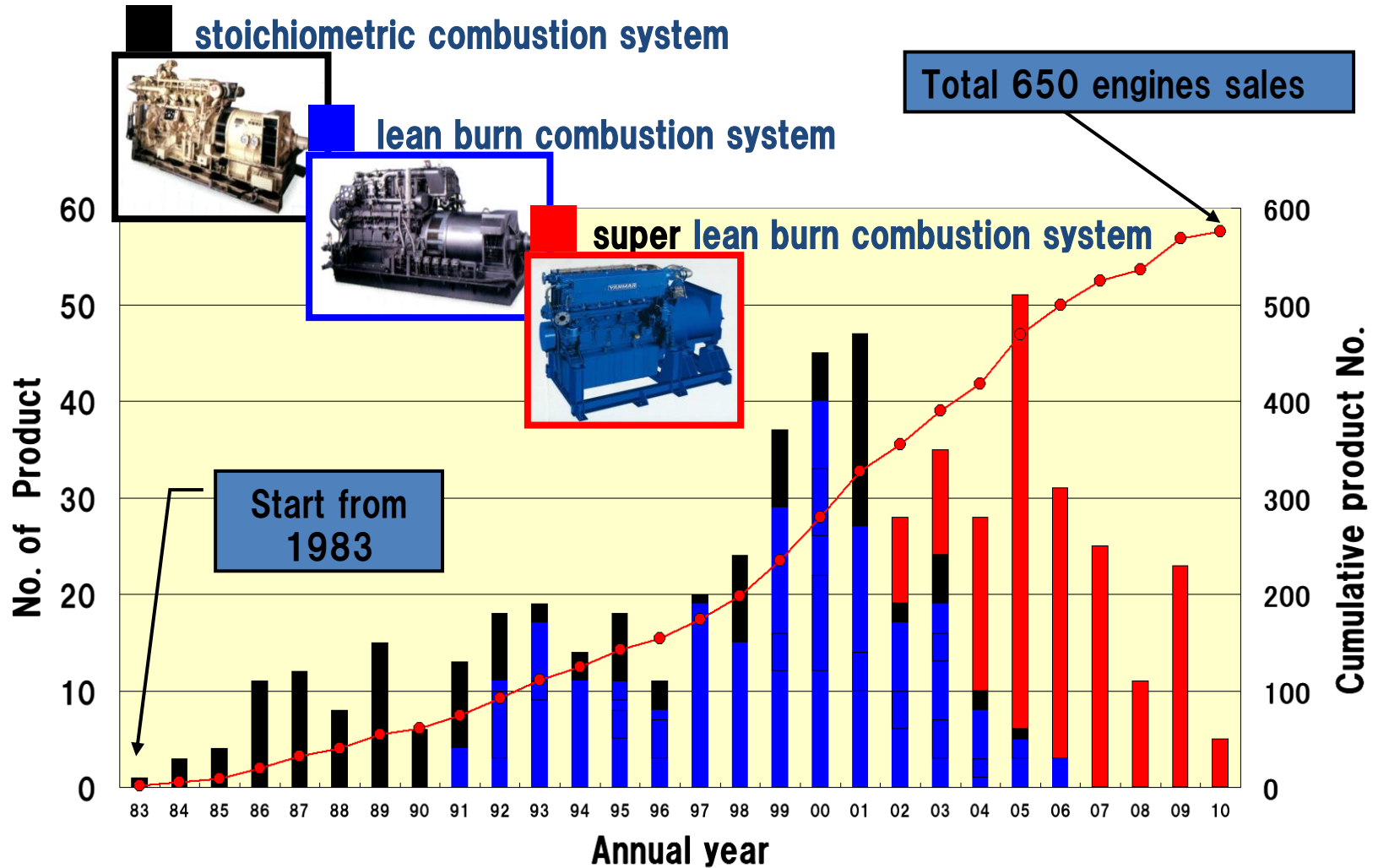


YANMAR gas engine history



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YANMAR gas engine history



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Development Policy of Marine Gas Engine

Base Engine

Established
Reliability & Durability



EY26 Marine Diesel Engine



Many actual achievement
in Land use Gas Engine



Pure Gas



6EY26DF



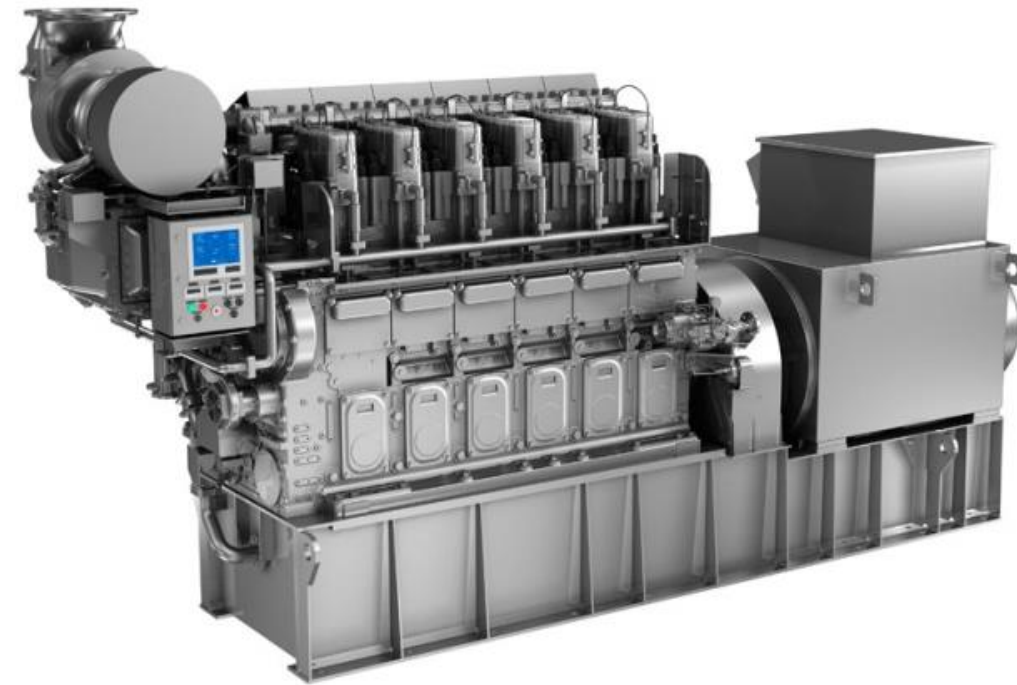
Dual Fuel



Pure Gas Engine



Specification



Engine name		6EYG26L
Engine type		4cycle water cooled
Cycle		Lean burn miller cycle
Ignition		Spark ignite
Bore	mm	260
Stroke	mm	385
Speed	min ⁻¹	720
Rated output	KW	1350
Fuel		Natural gas

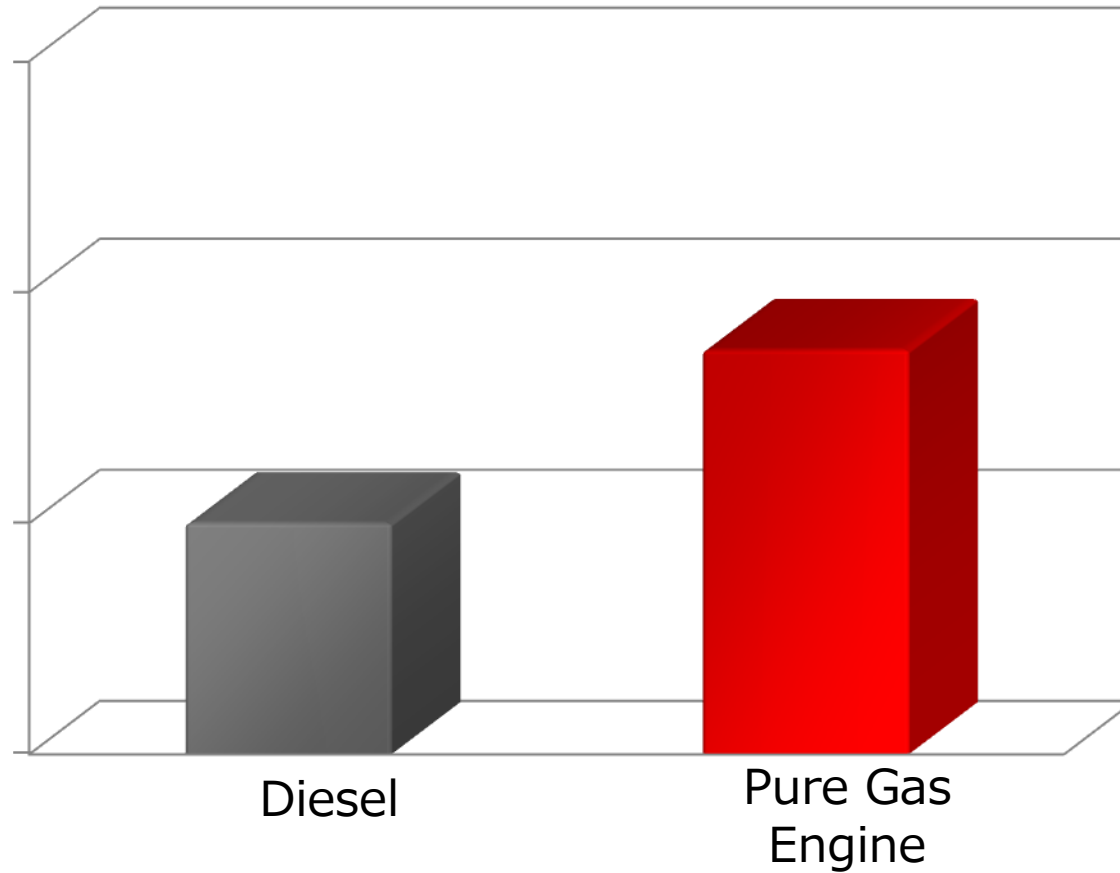


Marine gas engine profile (6EYG26)



Marine gas engine profile (6EYG26)

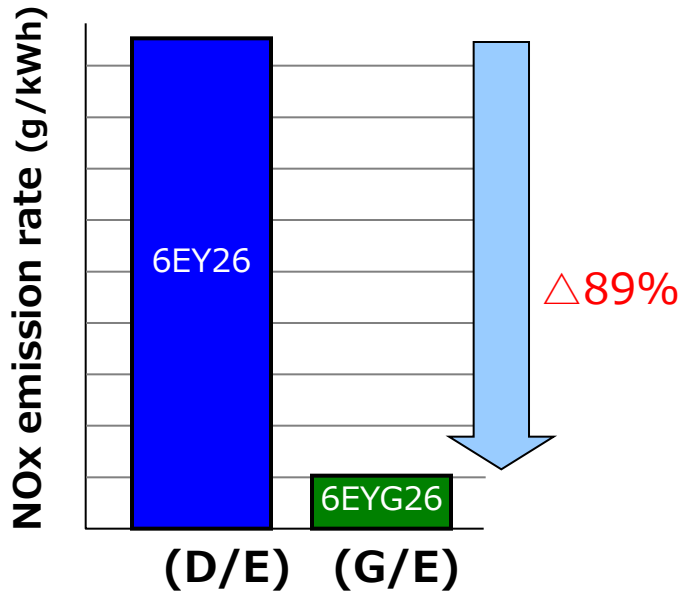
Thermal efficiency



Marine gas engine profile (6EYG26)

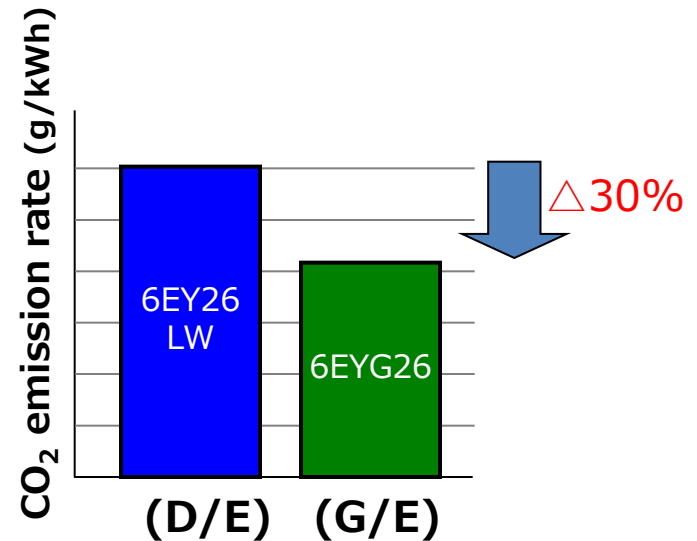
Exhaust gas characteristic

NO_x



Environmental impact material reduction of 89%

CO₂



GHG gas reduction of 30%



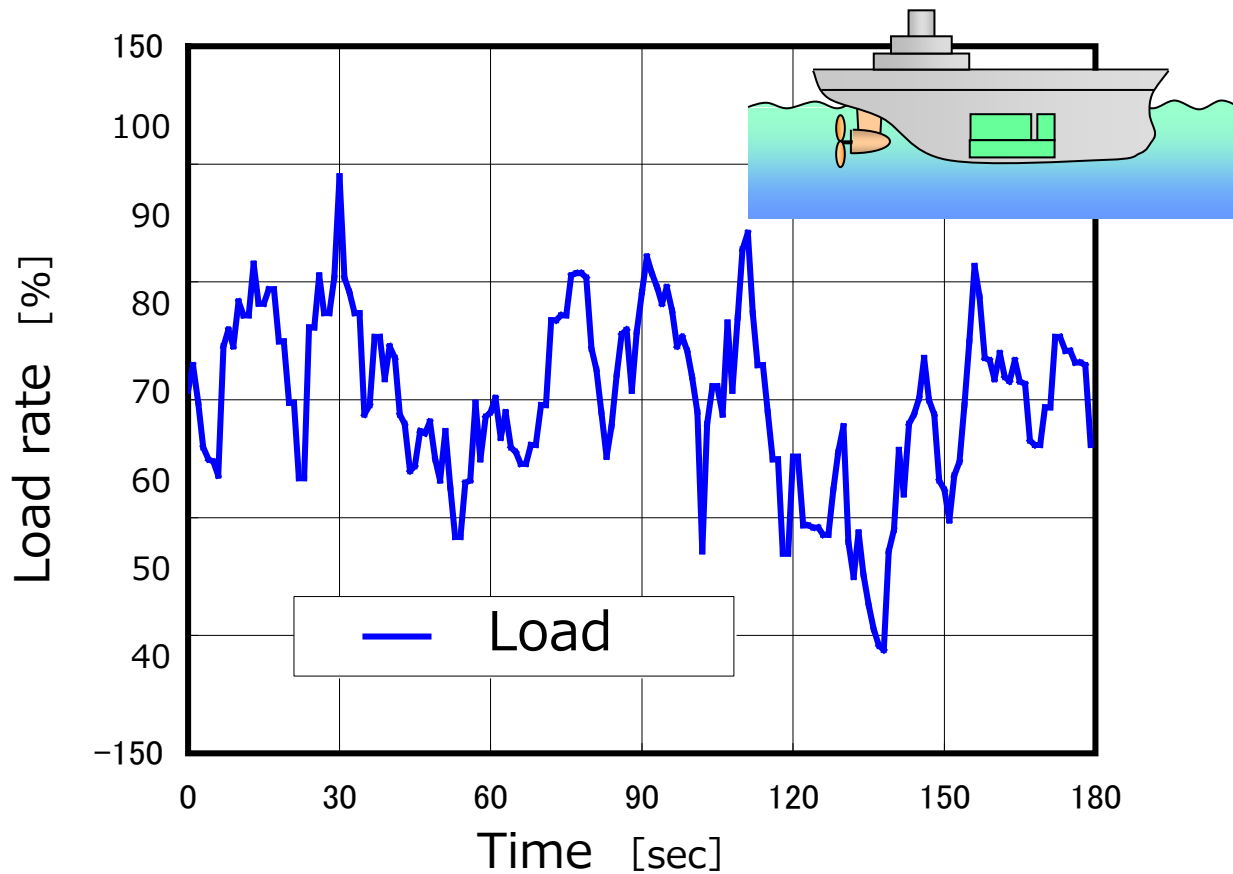
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Key technology development for marine gas engine

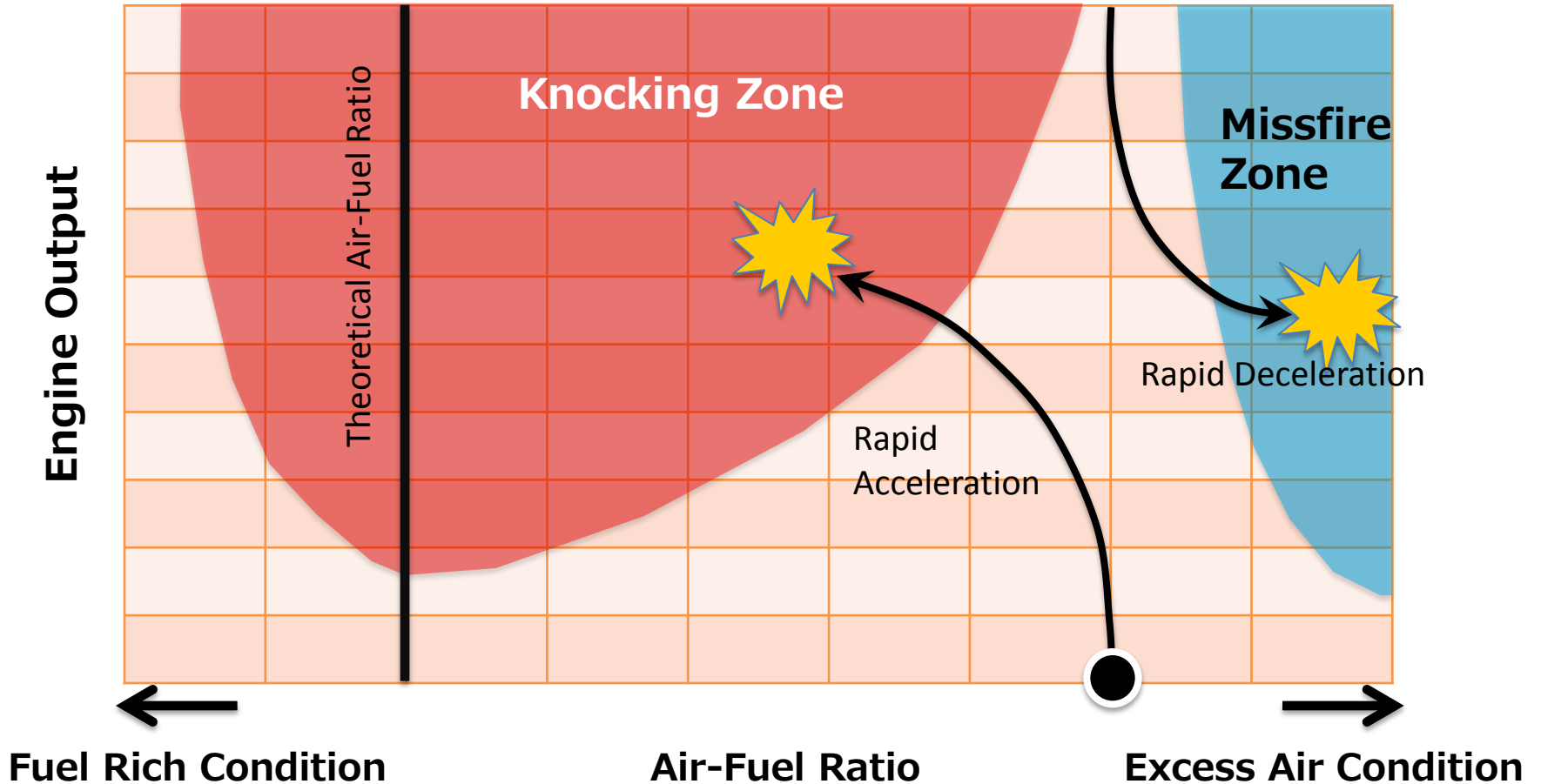
In gas engine, fuel gas is mixed with air in the intake port. The mixture concentration would vary when the load is varied.

The mixture concentration variation would strongly influence combustion stability.

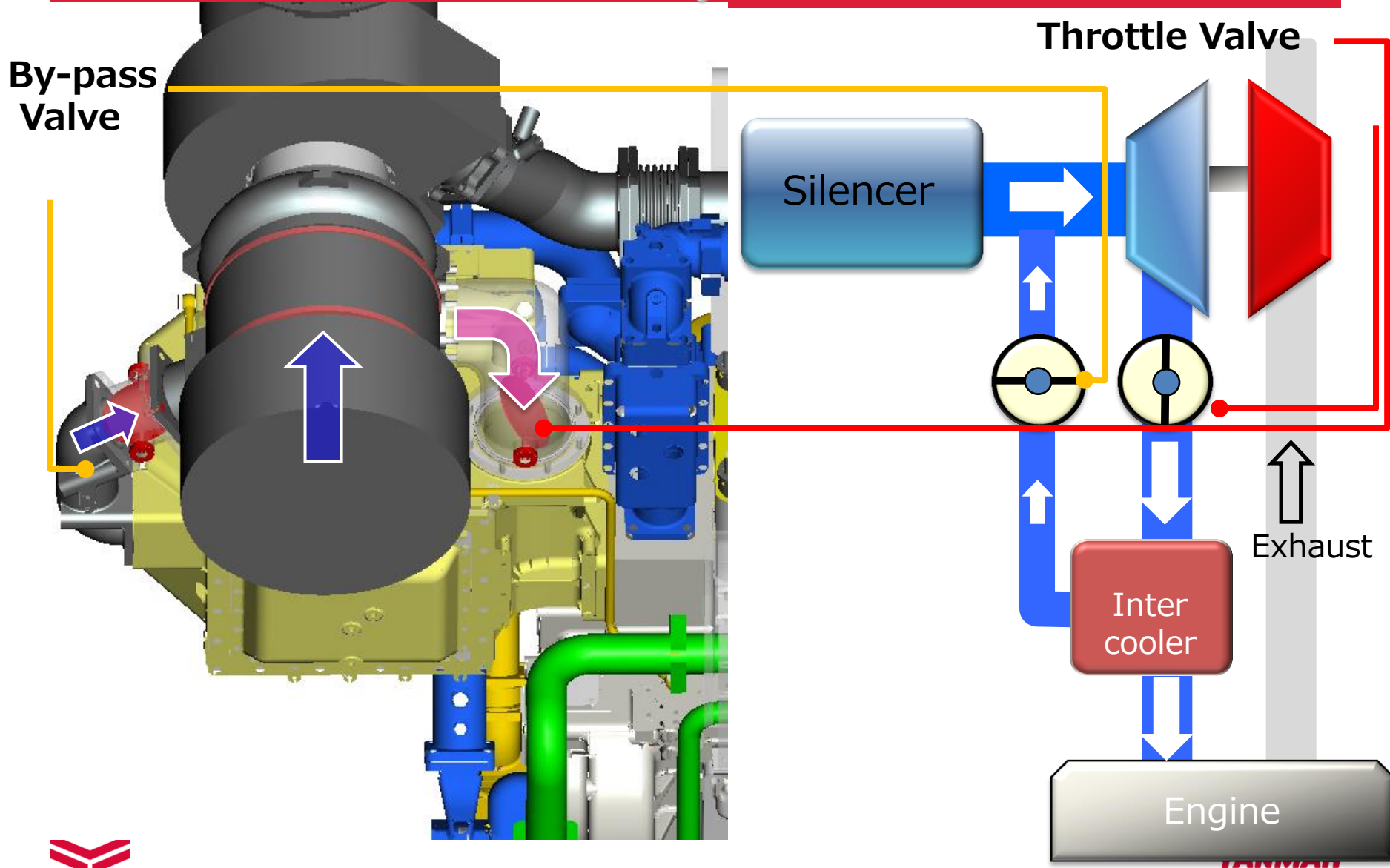
Yanmar developed the fuel mixture concentration control technology.



Combustion Characteristics of Gas Engine

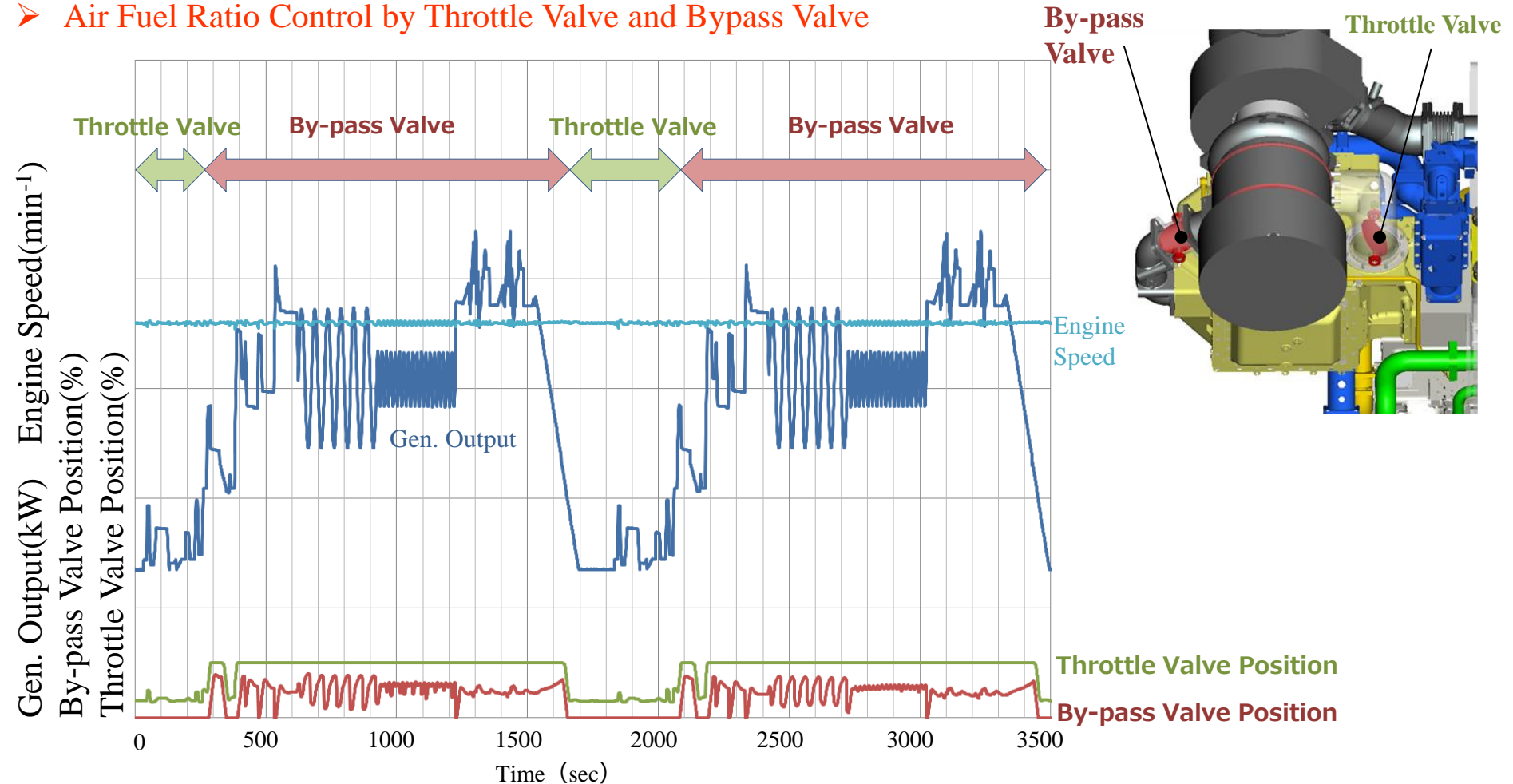


Air – Fuel Ratio Control System



Air – Fuel Ratio Control

➤ Air Fuel Ratio Control by Throttle Valve and Bypass Valve

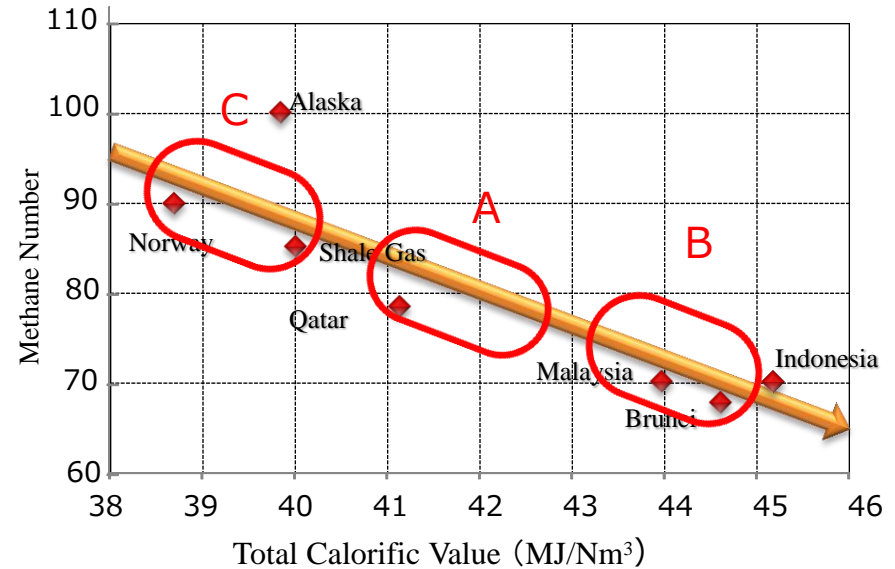
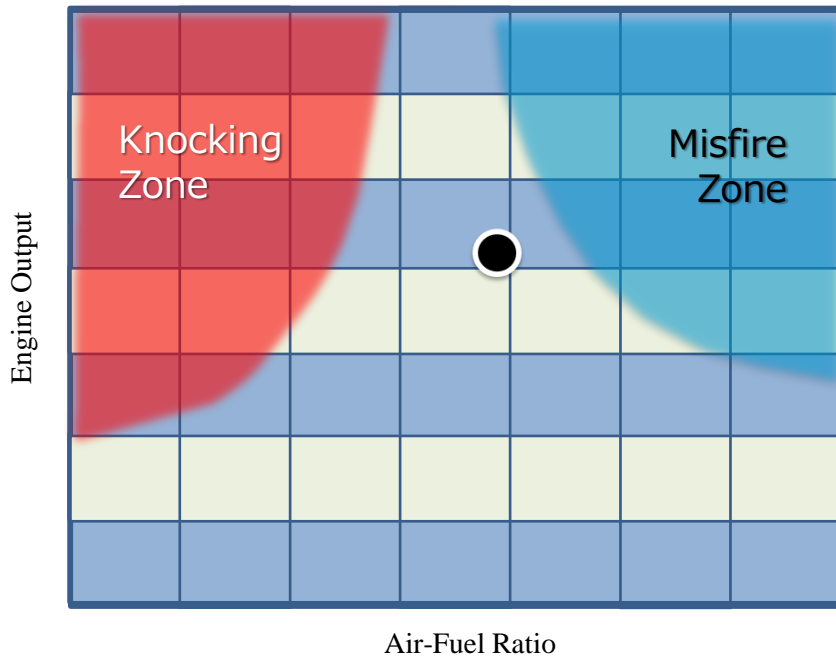


◆ Prompt Air Fuel Control at Load fluctuation

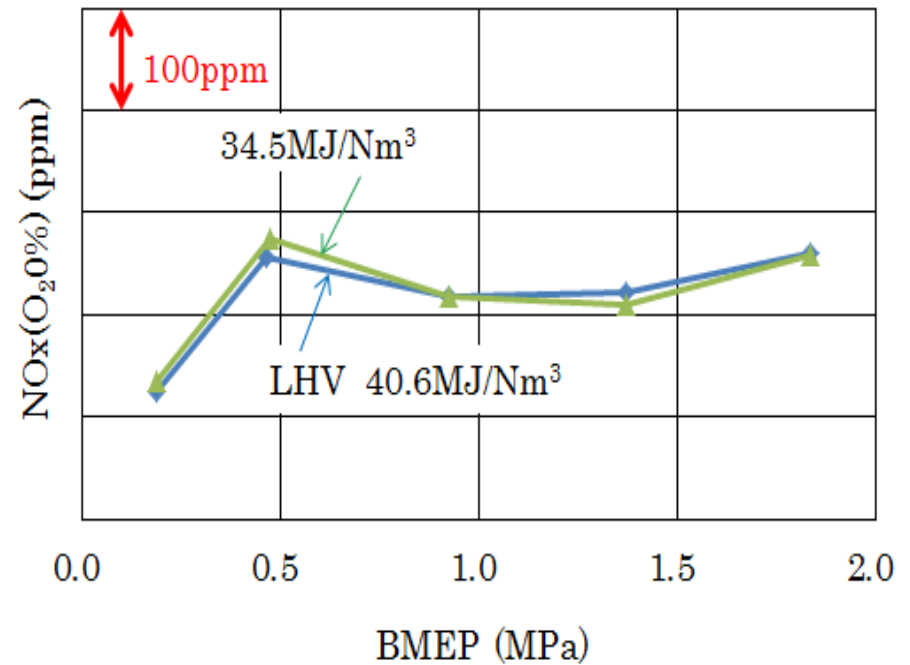
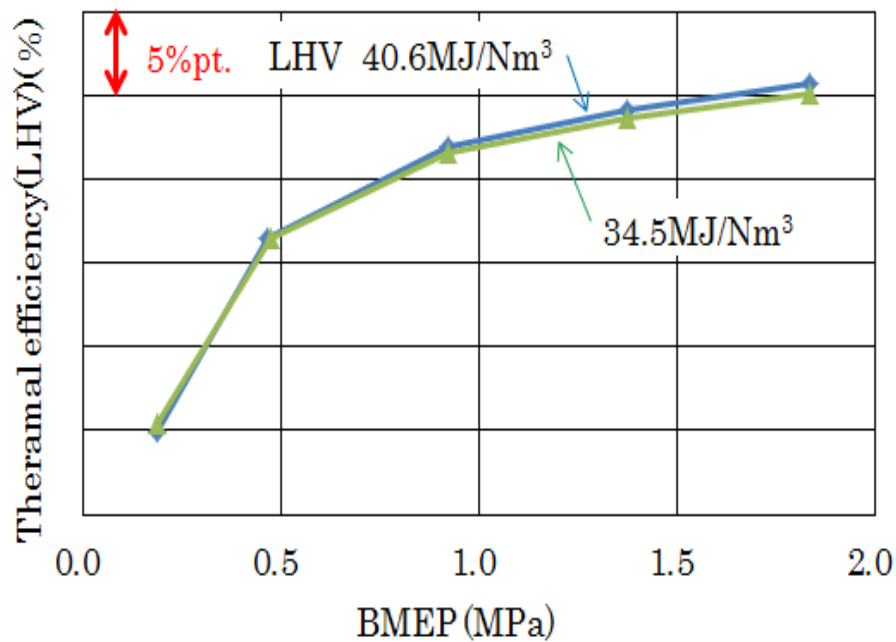


Technology to Compensate the NG Property Variation

➤ Air Fuel Ratio Control against the NG Property Variation



Effect of Fuel Calorie on Engine Performance



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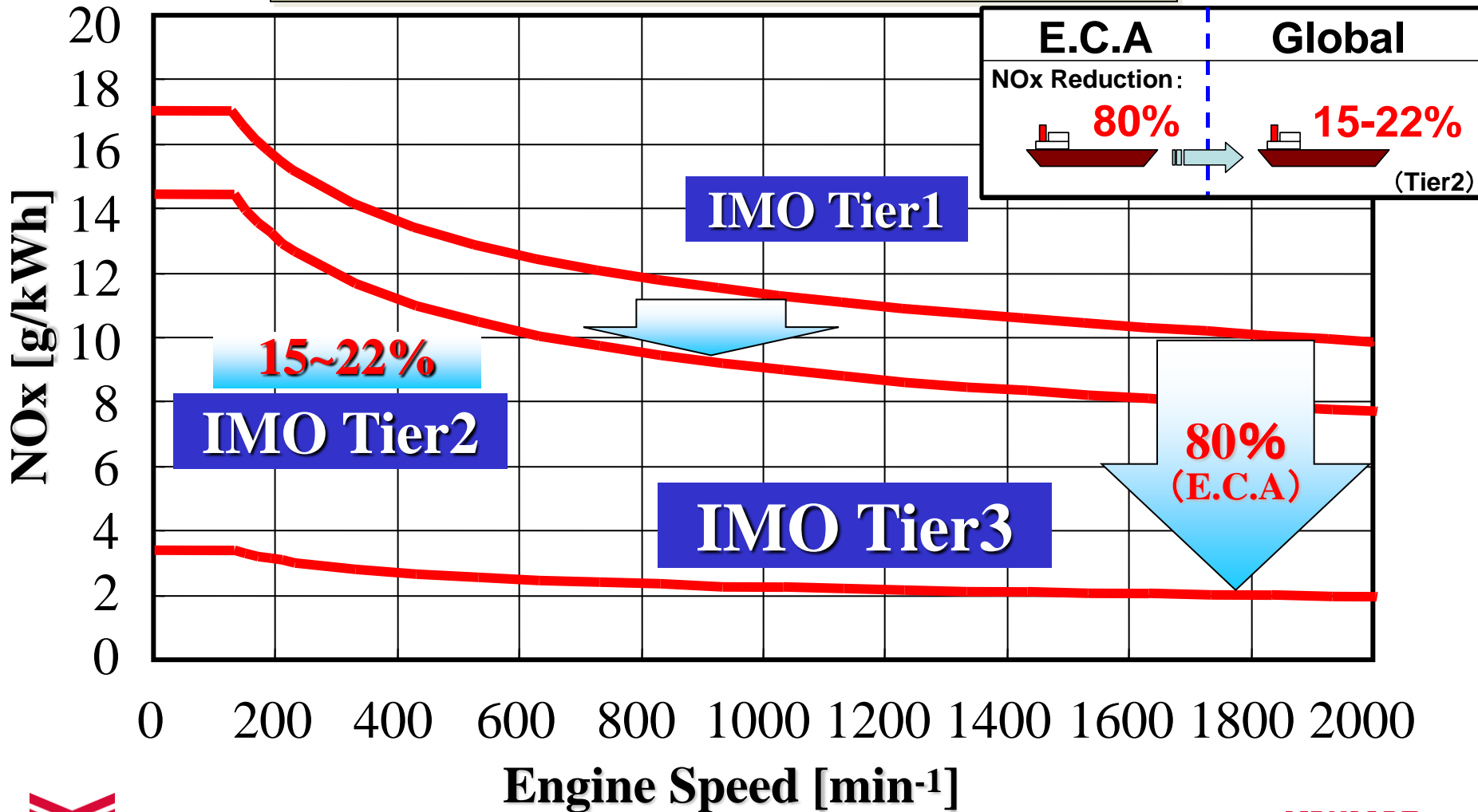
Development of Yanmar SCR System



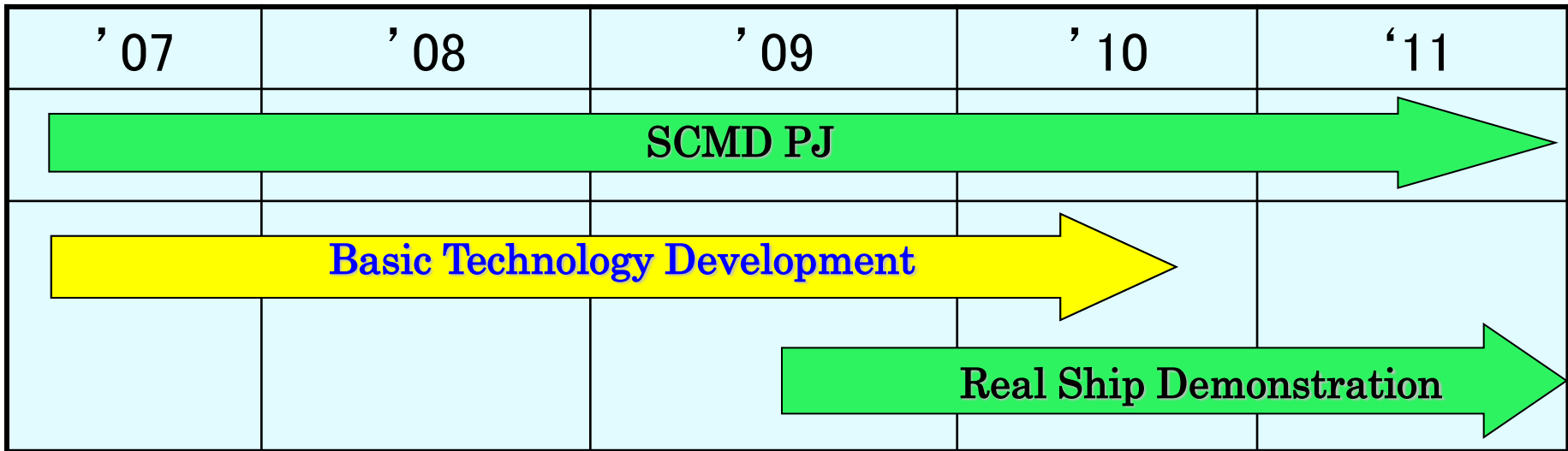
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IMO Regulation for NOx

(IMO Tier3 Apply from 2016)



Super Clean Marine Diesel PJ



Catalyst Rig Test



Real Engine Bench Test



Catalyst Rig Test Equipment



Rig Test
Model gas mixture unit
Water addition unit
Temperatures control unit
Reacting furnace
FT-IR



Optimum Catalyst Searching



Real Engine Bench Test



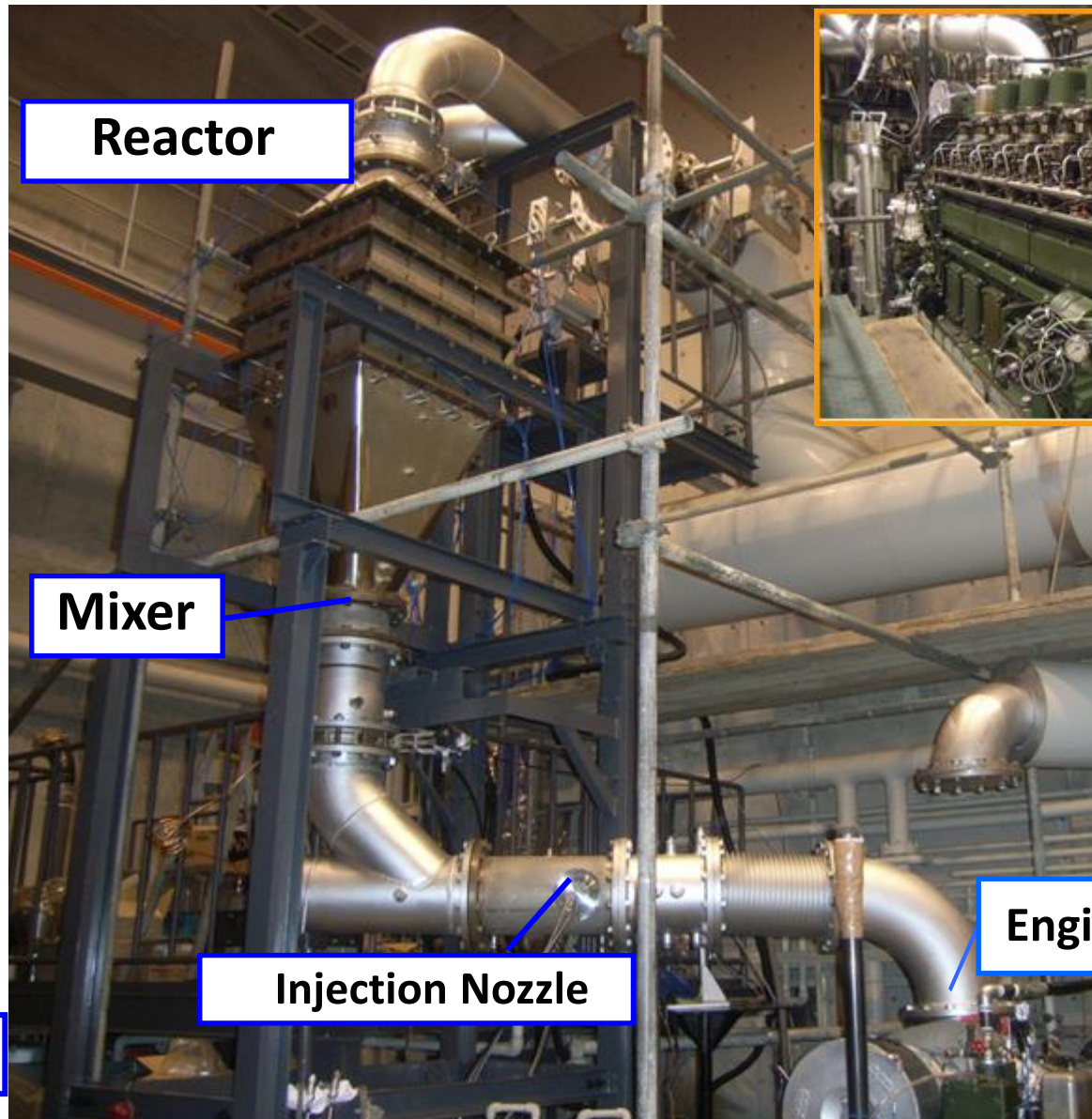
SCR System Bench Test (6EY18ALW+SCR)



**Urea Water
Supply Unit**



Controller



Reactor

Mixer

Injection Nozzle

Engine Outlet



6EY18AL



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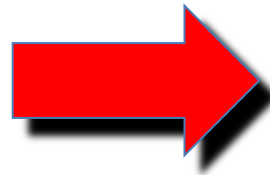
Reliability Improvement

Prevention of the Urea deposition

Inner wall of exhaust pipe

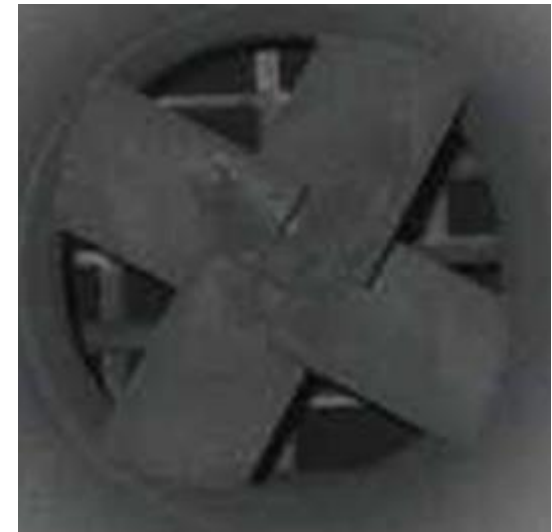
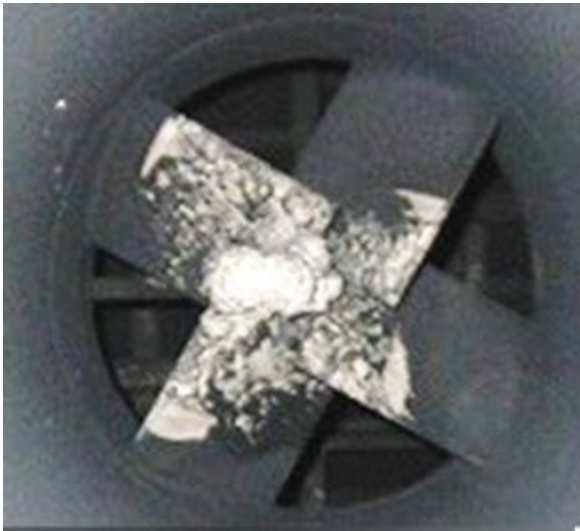


Air assist Injection



Adequate Temperature

Mixer

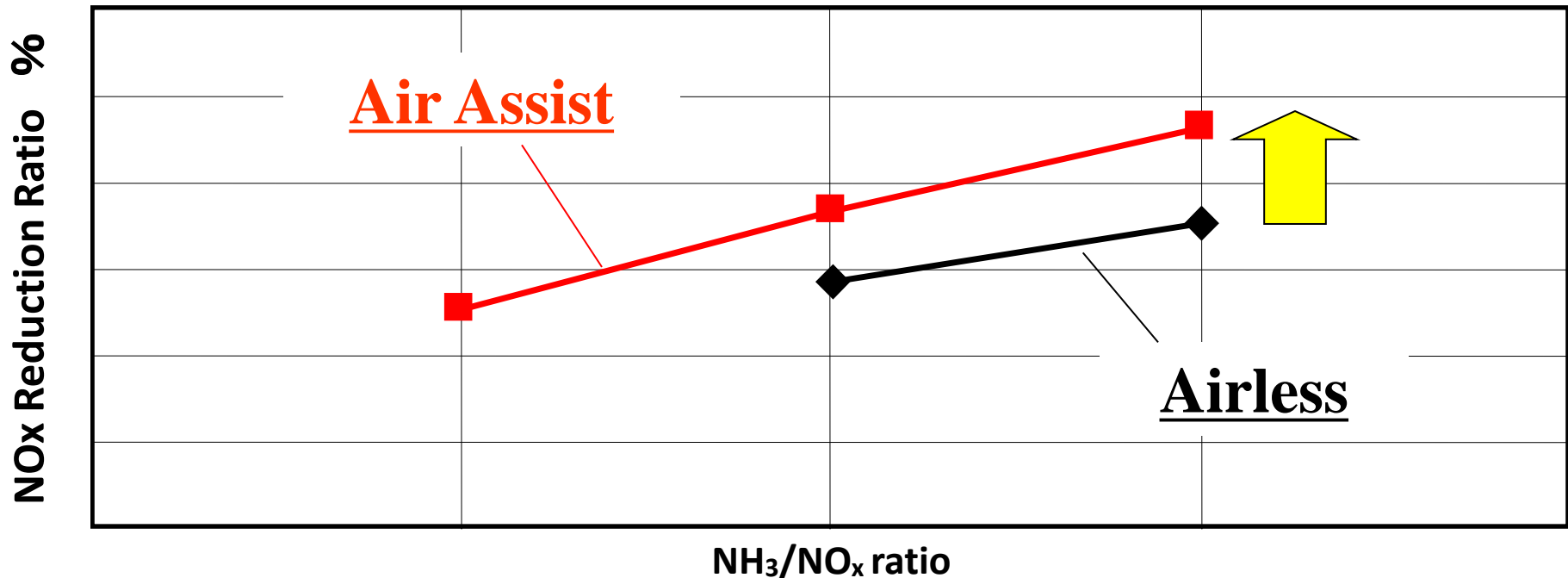


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Improvement of the NO_x Reduction efficiency

Test Results Example

(Urea Atomization ⇒ Promoted Decomposition to NH₃)



Air Assist Injection

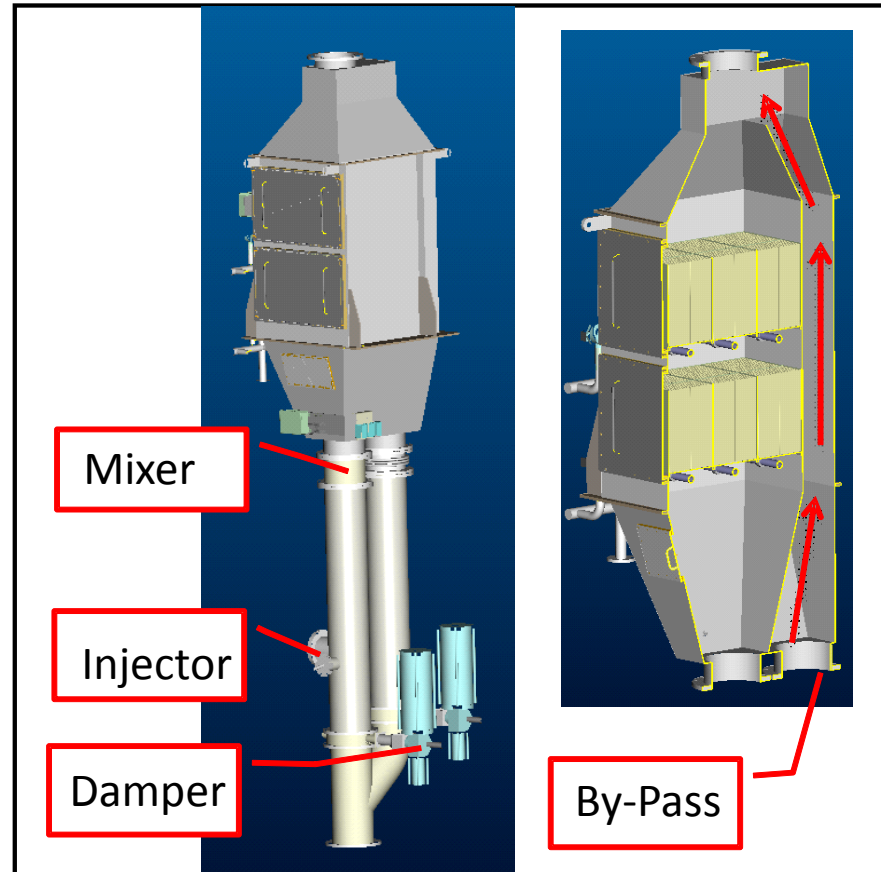
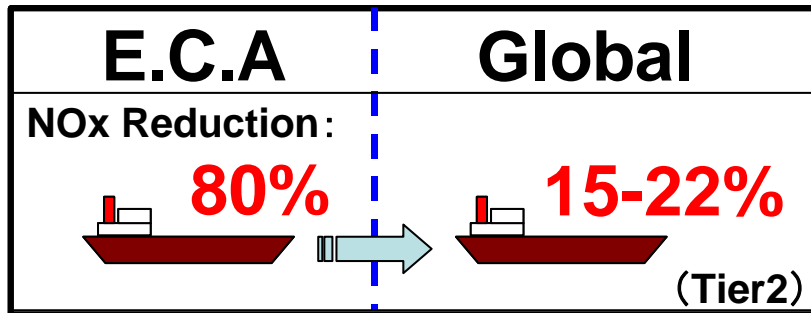
- Downstream Direction Injection ⇒ Spacelike Uniformity
- Continuous Injection ⇒ Timelike Uniformity



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Compact Structure

By-Pass Integrated Structure

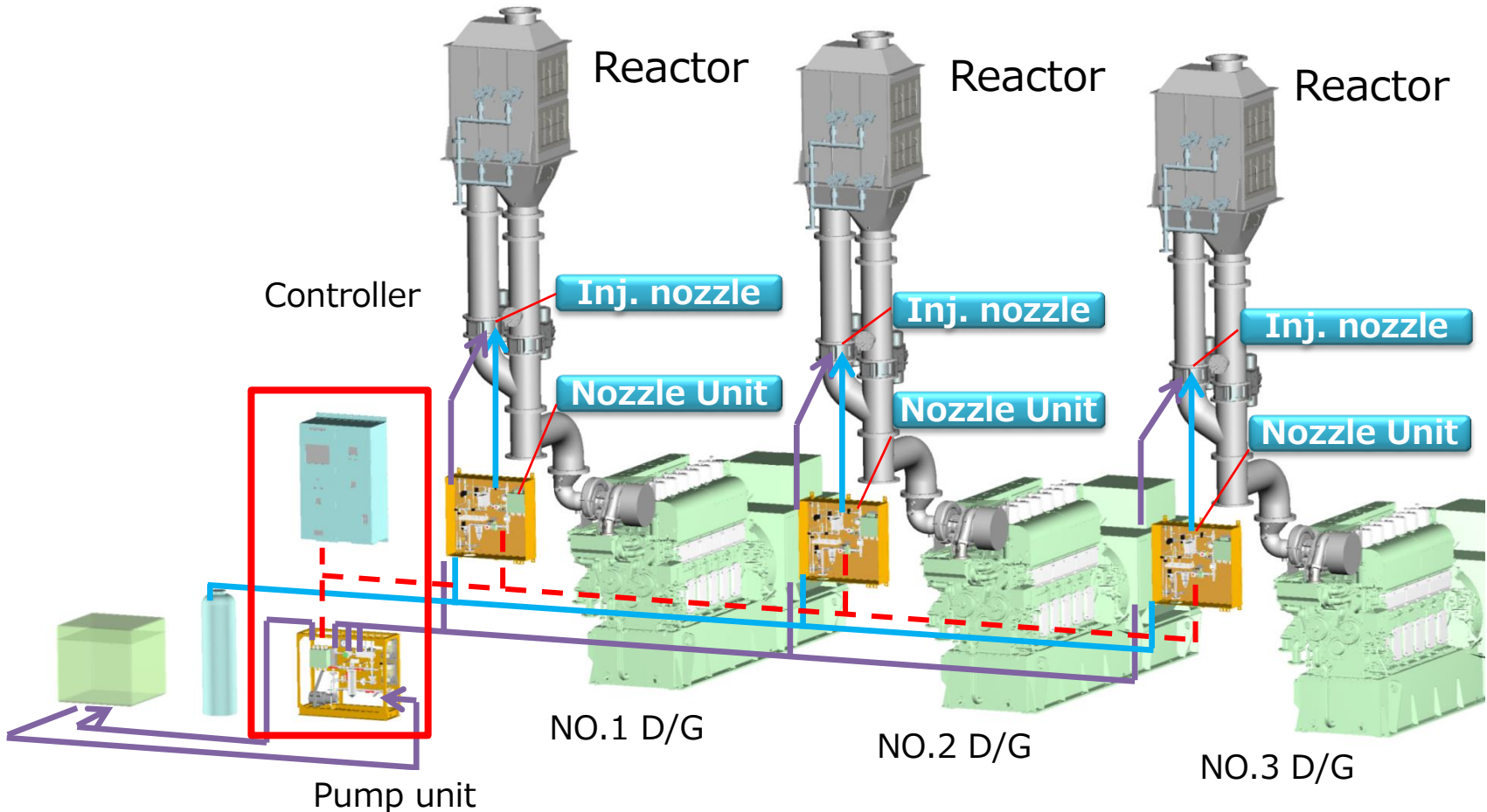


Easy Installation in Shipyard



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Optimum System for Plural Engines



The controller can controls urea water injection amounts for 4 engines.



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Bench Test of Total SCR System



NIPPON KAIJI KYOKAI

STATEMENT OF FACT

Form 130

Certificate No.: KB13MD00153

Engine Manufacture	Model Number	Serial Number	Test Cycle(s)	Rated Power (kW) and Speed (RPM)	NOx Reducing Device
Yanmar Co., Ltd.	6EY22LW	0262FMS	D2	880 kW 720 RPM	Selective Catalytic Reduction fitted

THIS IS TO CERTIFY:

- That, at the request of Yanmar Co., Ltd., Japan, NOx measurement for the above-mentioned marine diesel engine fitted with Selective Catalytic Reduction (SCR) was surveyed in accordance with Chapter 5 of NOx Technical Code 2008 at Yanmar Co., Ltd., Japan, on 29 May 2013, and
- That the NOx measurement result shows the following value less than the NOx Tier III emission limit of 2.4 g/kWh specified in paragraph 5.1.1, Regulation 13, MARPOL ANNEX VI.

NOx emission value: 1.9 (g/kWh)

Specification of the above-mentioned marine diesel engine fitted with SCR is as per the Drawing No. G5-09814-0020 and the document "Test Report", examined on 1 July 2013.

Issued at Tokyo on 1 July 2013


Y. Shibata
General Manager of Machinery Department
NIPPON KAIJI KYOKAI

This Report is issued subject to the condition that it is understood and agreed that neither the Society nor any of its Committees is under any circumstances whatever to be held responsible for any inaccuracy in any report or certificate issued by this Society or its Surveys or in any entry in the Record or other publication of the Society or for any error of judgment, default or negligence of its Officers, Surveyors or Agents.

97.11.10000 (K)



Urea Water Tank

6EY22LW

Reactor



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THANK YOU FOR YOUR ATTENTION.

