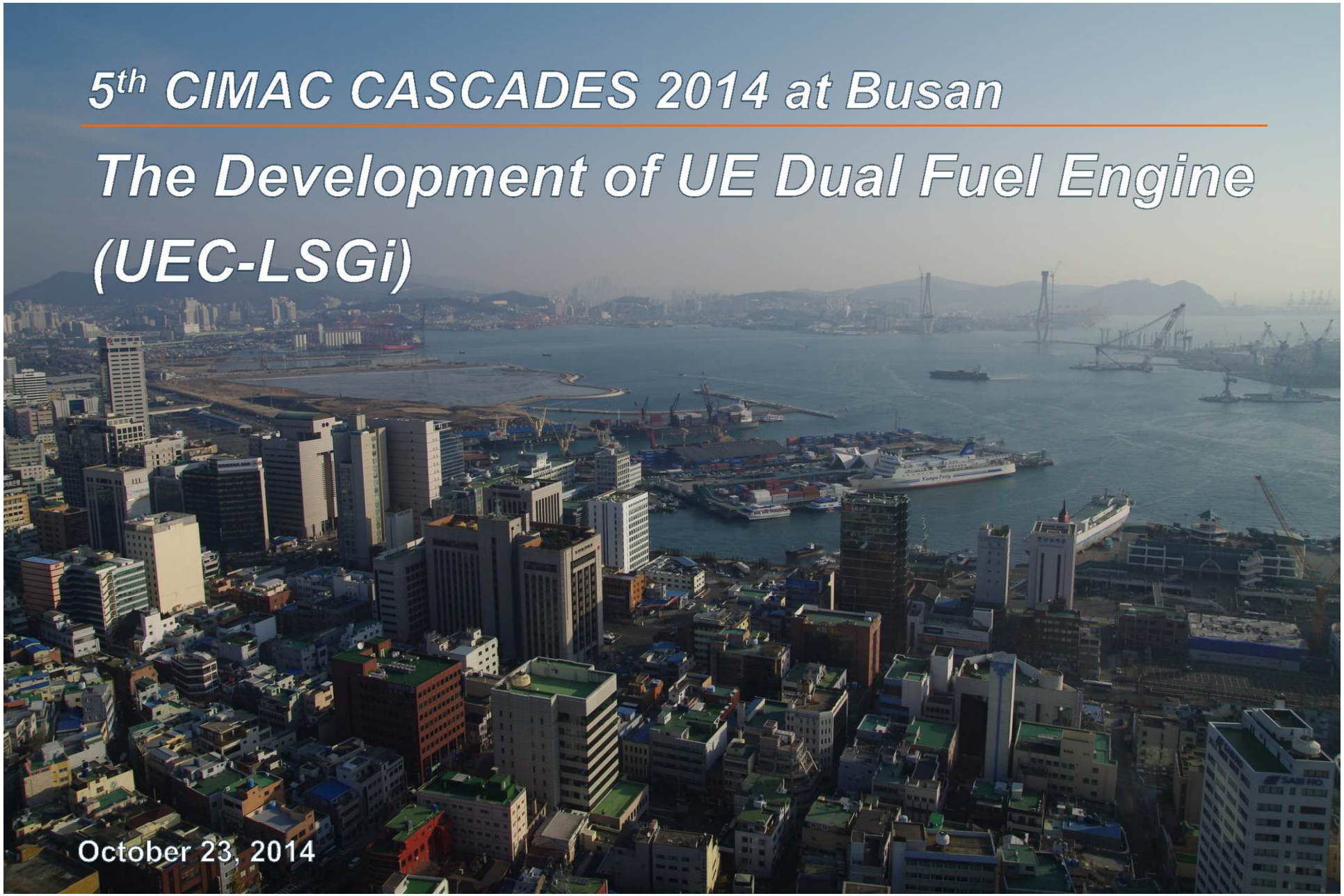


WFS-0712

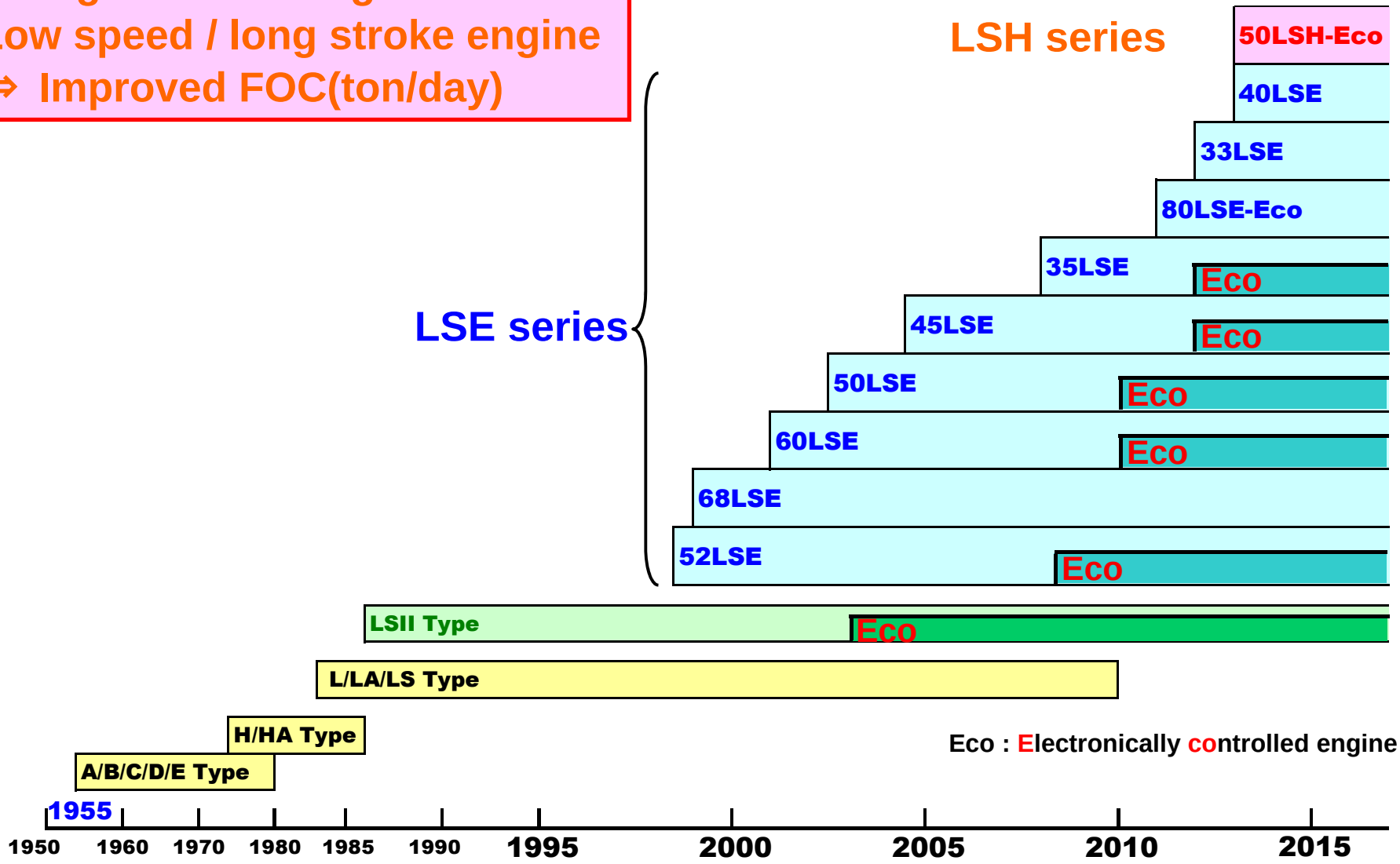
MITSUBISHI HEAVY INDUSTRIES MARINE MACHINERY & ENGINE CO., LTD.

MHI MITSUBISHI HEAVY INDUSTRIES / GROUP

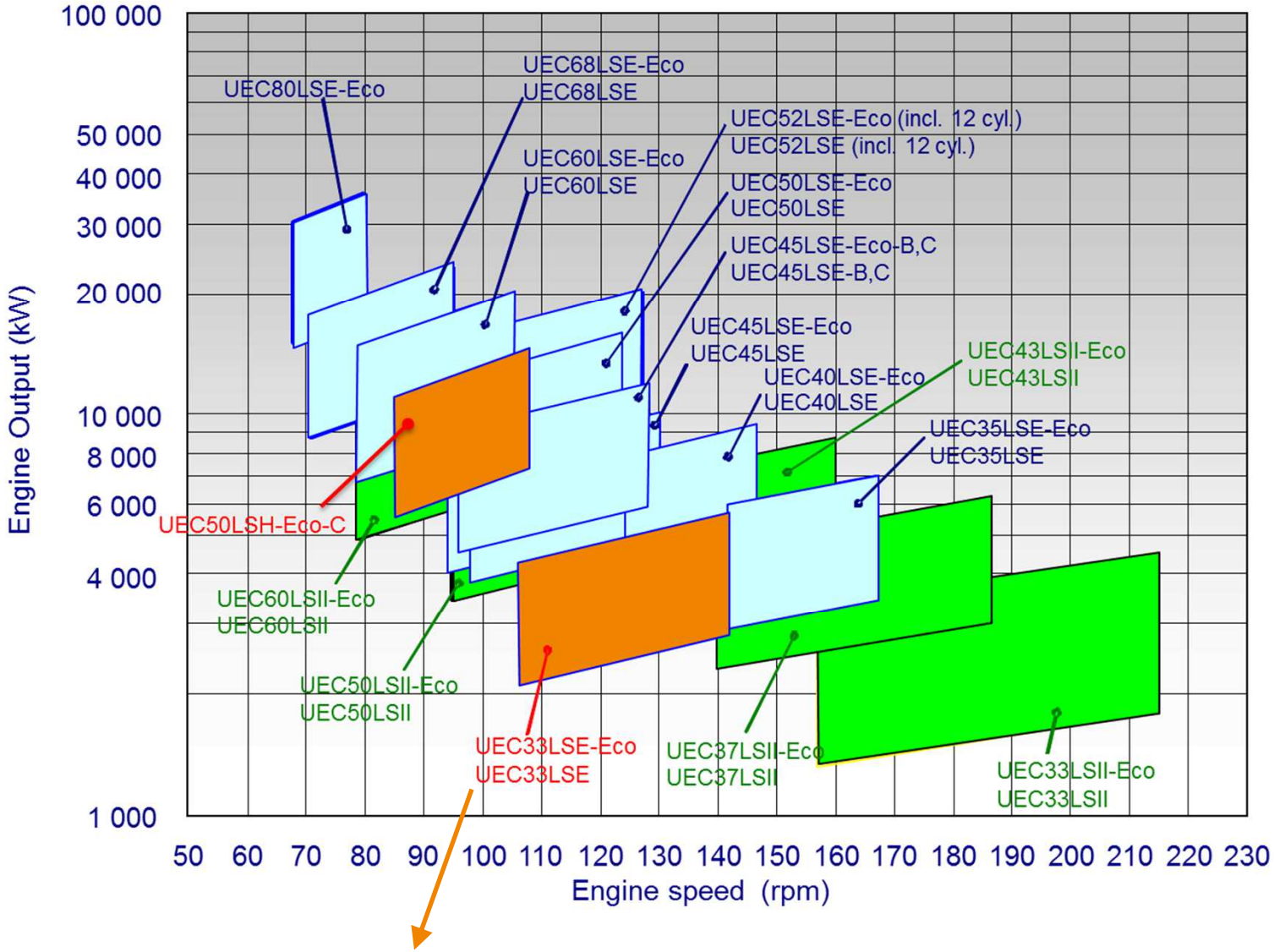
Contents

Development History of UE

New generation engine :
Low speed / long stroke engine
⇒ Improved FOC(ton/day)



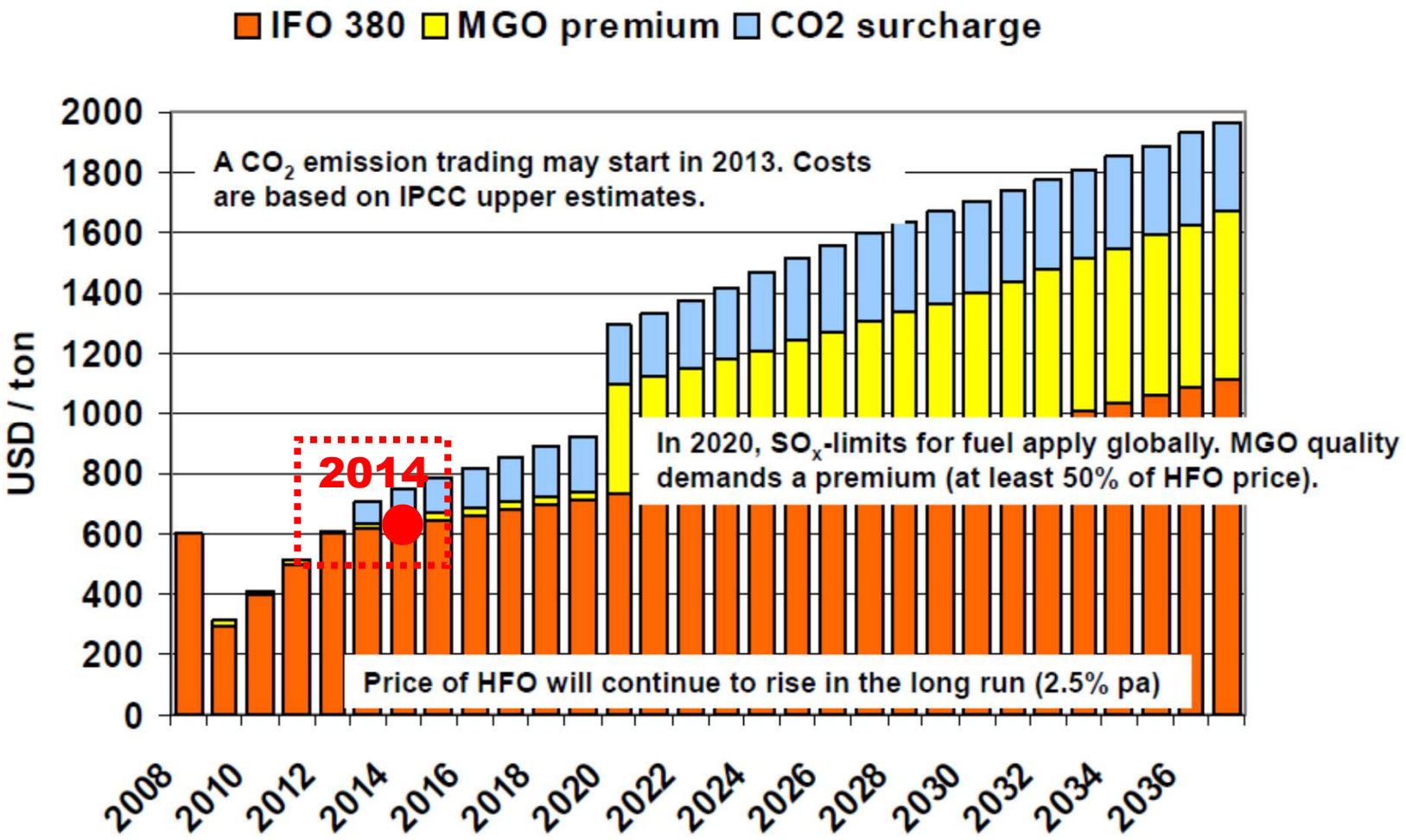
Rating Map of UE



We are developing longer-stroke UE engine from small/middle bore size.

Contents

Trend of Fuel (Fuel Price Estimation)

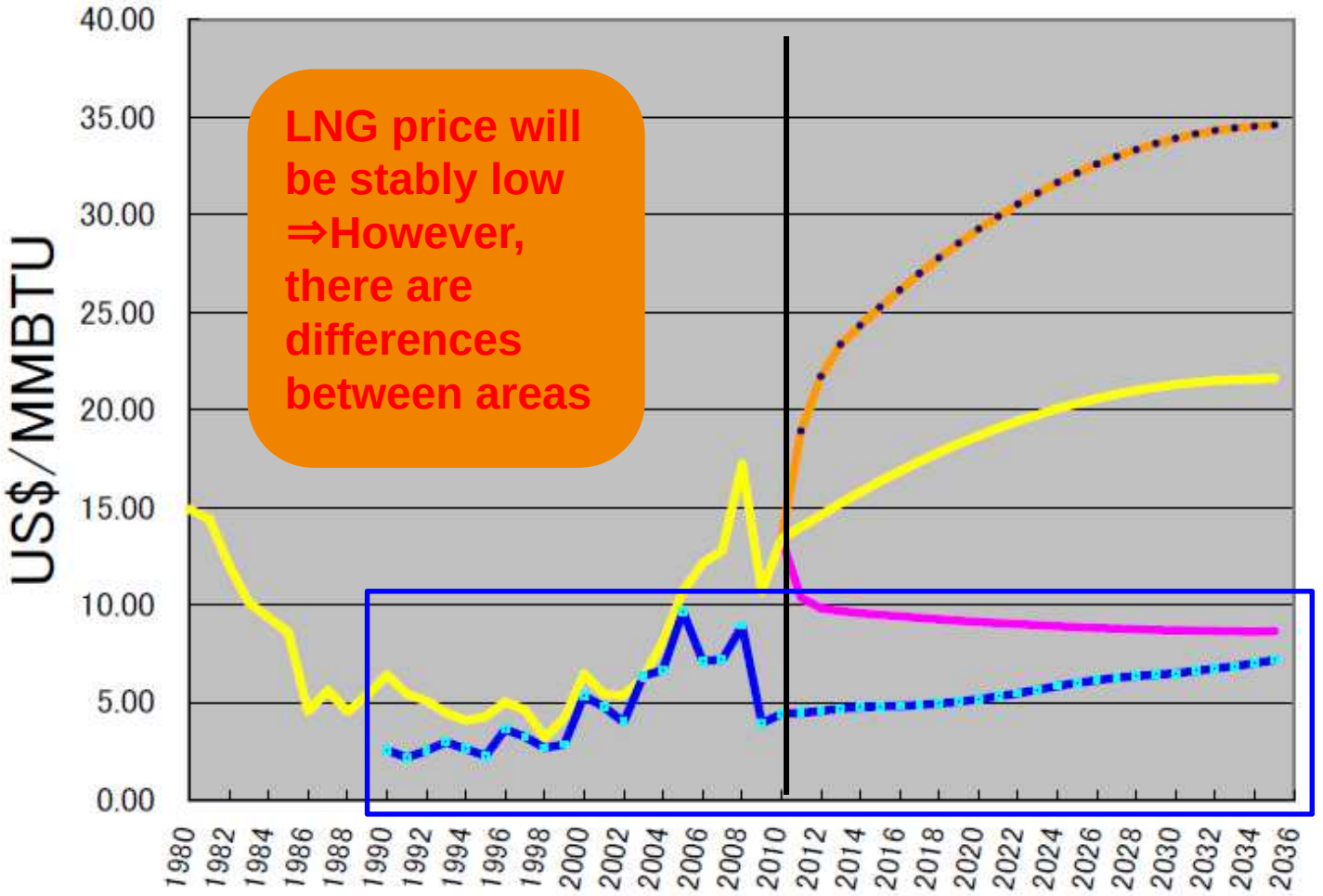


Energy-saving technology is essential due to the fuel price rising.
(“2,000 USD/ton” age will come.)

Reference: GL research

Trend of Fuel (Oil-Gas Price Estimation)

Trend and estimation of natural gas and oil price（USEIA 2011)

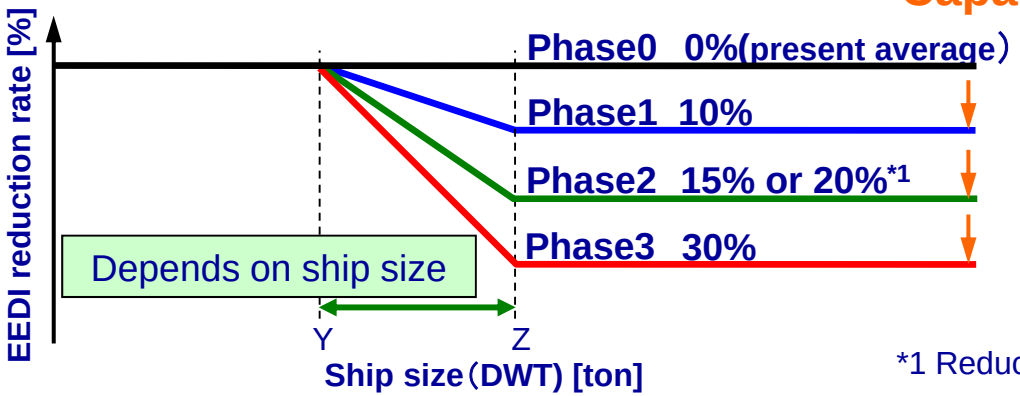


Reference：S&T seminar

EEDI regulation

EEDI (Energy Efficiency Design Index): Theoretical transport efficiency

$$\text{EEDI [g/(ton x mile)]} = \frac{\overbrace{\text{Specific CO2 content of relevant fuel x SFC [g/kWh] x Power [kW]}}^{\text{CO}_2\text{ emission [g/h]}}}{\underbrace{\text{DWT [ton] x Speed [mile/h]}}_{\text{Capacity [ton x mile/h]}}}$$



EEDI limitation will go up gradually after 1/1/2015

*1 Reduction rate depends on vessel type

Ship type	Ship size (DWT)	EEDI reduction rate			
		Phase0	Phase1	Phase2	Phase3
		2013/1/1 ~	2015/1/1 ~	2020/1/1 ~	2025/1/1 ~
Bulk Carrier	20,000(Z) ~	0	10	20	30
Container ship	15,000(Z) ~	0	10	20	30
General cargo ship	15,000(Z) ~	0	10	15	30
LNG carrier	10,000(Z) ~	0	10	15	30
Ro-ro cargo	10,000(Z) ~	0	5	15	30

EEDI

EEDI (Energy Efficiency Design Index): Theoretical transport efficiency

CO_2 emission [g/h]

EEDI [g/(ton x mile)] = Specific CO2 content of relevant fuel x SFC [g/kWh] x power [kW] / DWT [ton] x speed [mile/h]

Capacity [ton x mile/h]

Energy saving technology

M/E | D/G | Shaft motor | Electric | Machinery

$$= \frac{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right) + \left(\left(\prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)}\right) - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE} - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}**\right)}{f_i \cdot f_c \cdot Capacity \cdot f_w \cdot V_{ref}}$$

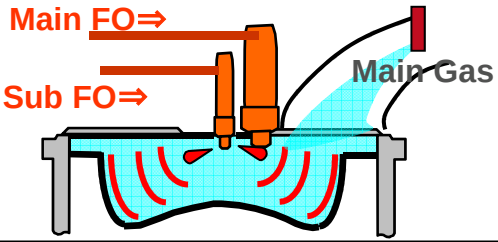
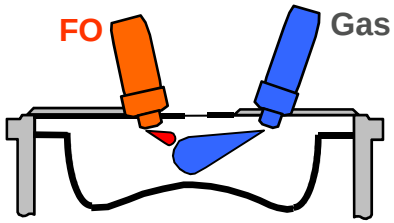
- f_i: Capacity factor (Ice-class etc.)
- f_c: Cubic capacity correction factor (Chemical tanker etc.)
- f_w: Weather factor
- V_{ref}: Ship speed

⇒ **EEDI reduction possibilities;**

- Speed reduction
- Optimizing vessel & propeller
- Air lubricating system
- De-rated engine
- Waste heat recovery
- Gas fueled engine
- Renewable energy etc.

Contents

Comparison of DF System

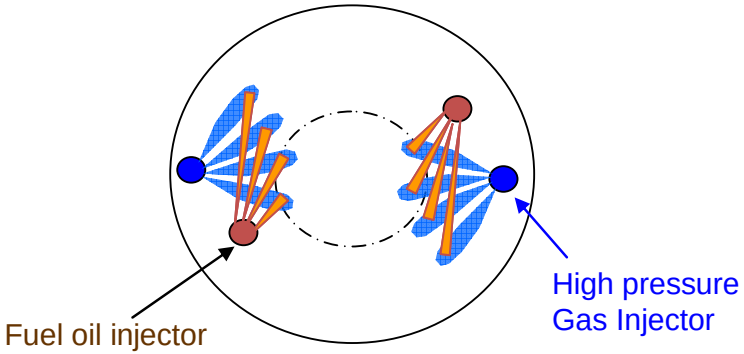
	Premixed DF	Gas Injection DF
		
Merit	・Low gas supply pressure (5-10bar) ・Lower NOx	・Robust combustion to fuel gas composition ambient condition etc. ・No methane slips ・Same performance as Oil mode (efficiency, gas temp. etc.)
Demerit	・Sensitive combustion to fuel gas composition ambient condition etc. ⇒ Load restriction (2 cycle) ・Lower efficiency in Oil mode ・Methane slip (1-2% of fuel gas) ・More time to switch from Oil to Gas	・High gas supply pressure (250 ~ 300bar) ・Higher NOx than premixed DF but lower than Oil mode

Outline of UEC-LSGi (Concept)

➢ Dual fuel（Gas & Oil）2cycle diesel engine

- Multi-fuel operation of Gas(SOx-free) and Oil

➢ Direct injection combustion（GI system）



- High combustion stability through all load range
  - ⇒ Free from knocking
    (No restriction of ambient and operating condition)
  - ⇒ No influence of gas composition (methane number)

- No unburned fuel gas and No methane slip
  - ⇒ Lower Greenhouse Effect than other types of gas engines

Outline of UEC-LSGi (Concept)

- Flexible and optimum operation both with Gas and Oil supported by full electrically controlled engine based on UEC Eco-engine

- Secure designs for high pressure gas
  - advanced combustion diagnosis
  - reliable leak gas detection and inert gas purge system

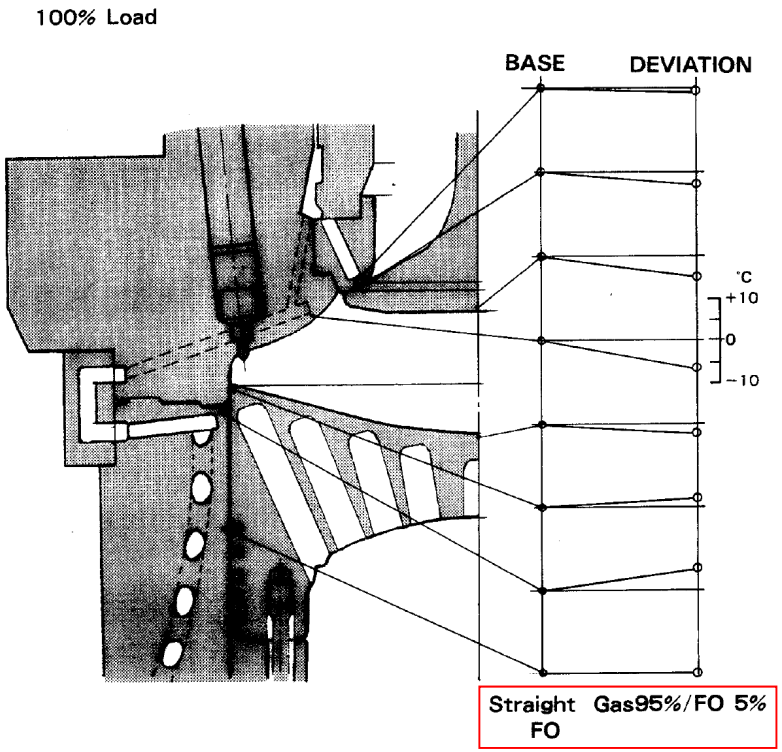
- Simple and high reliability designs

- Equivalent engine performance (comparing with Oil)
  ⇒ Retrofit is also available.

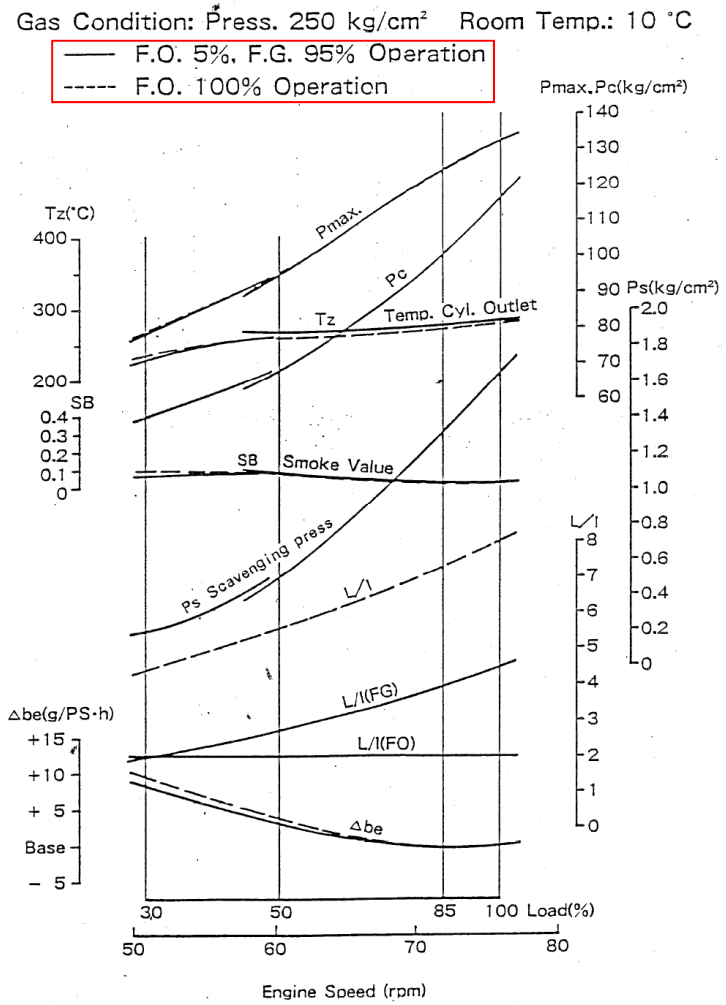
- NOx Tier-III regulation
  ⇒ with SCR or EGR

Outline of UEC-LSGi (Engine Performance)

Gas combustion technology was already studied and evaluated in 1986 by using the RTA84M-DF, which was designed by MHI's own technology.



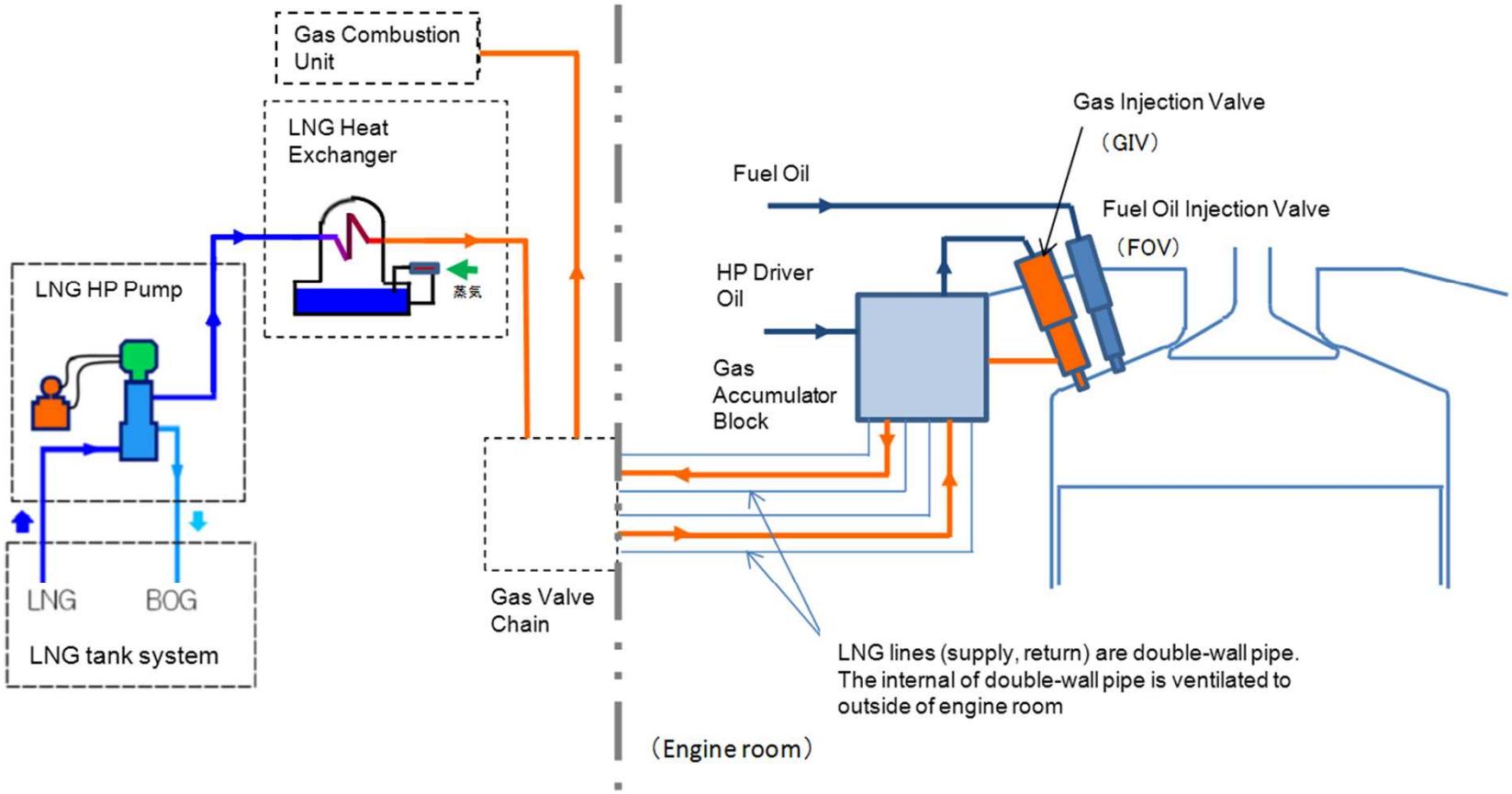
Combustion chamber Temperature



Engine performance

Outline of UEC-LSGi

<System outline of UEC-LSGi>

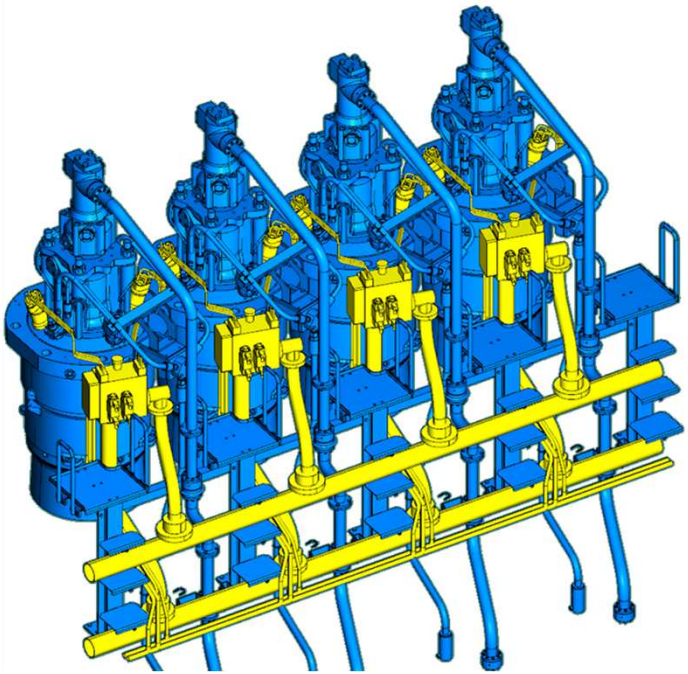


- **Consist of LNG HP supply, HP driver oil line and Ventilation/Safety system**

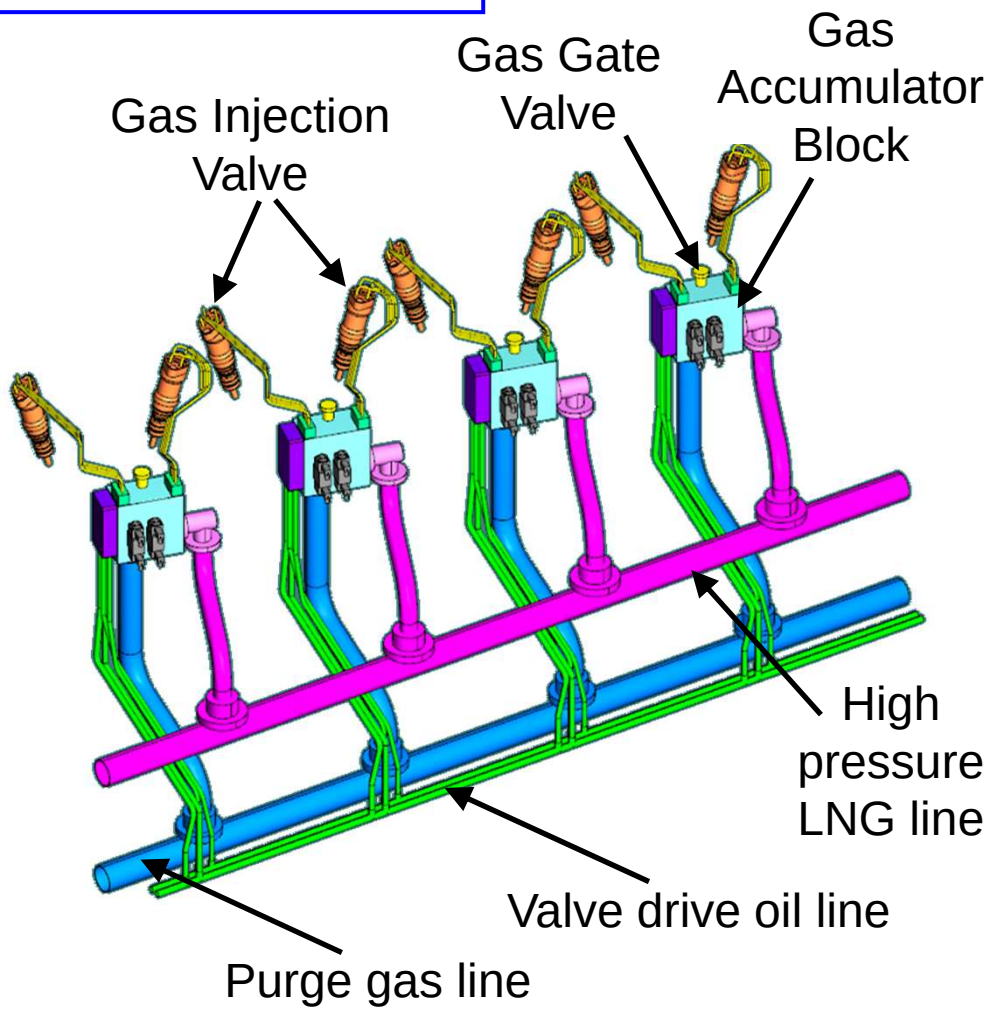
Outline of UEC-LSGi (Design Development)

Plan for 4UE-X3

Blue parts: Diesel origin
Yellow parts: Gas addition

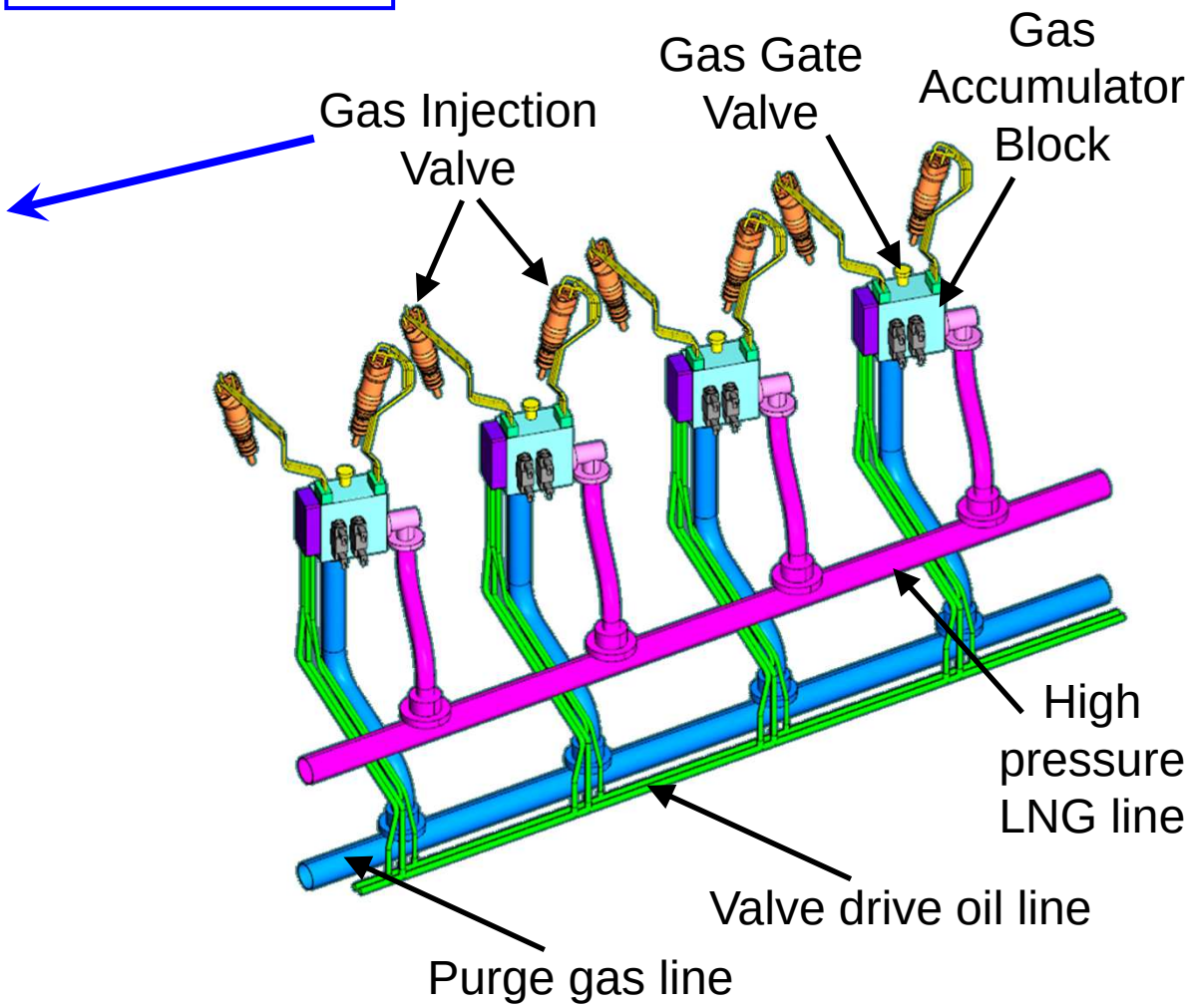


Gas parts overview



Development of UEC-LSGi (Gas Injection Valve)

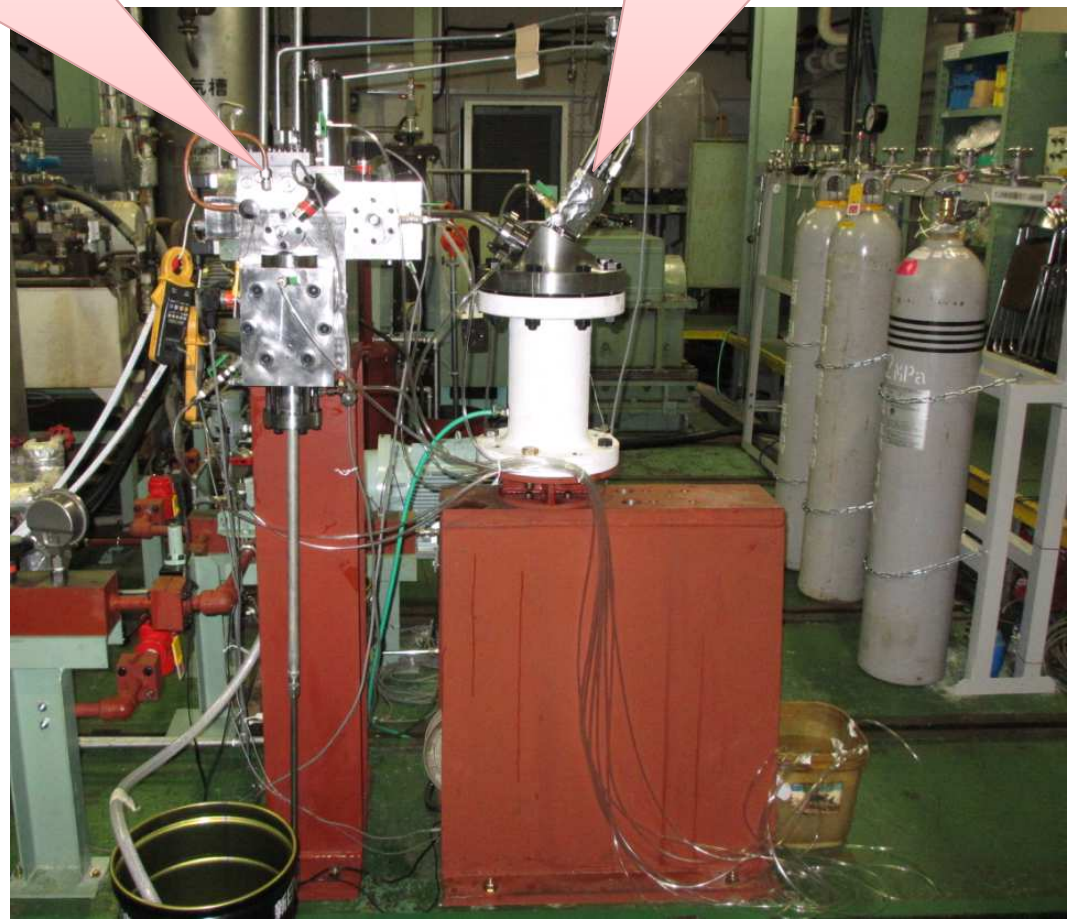
GIV overview



Development of UEC-LSGi (Test bench of Gas Injection Valve)

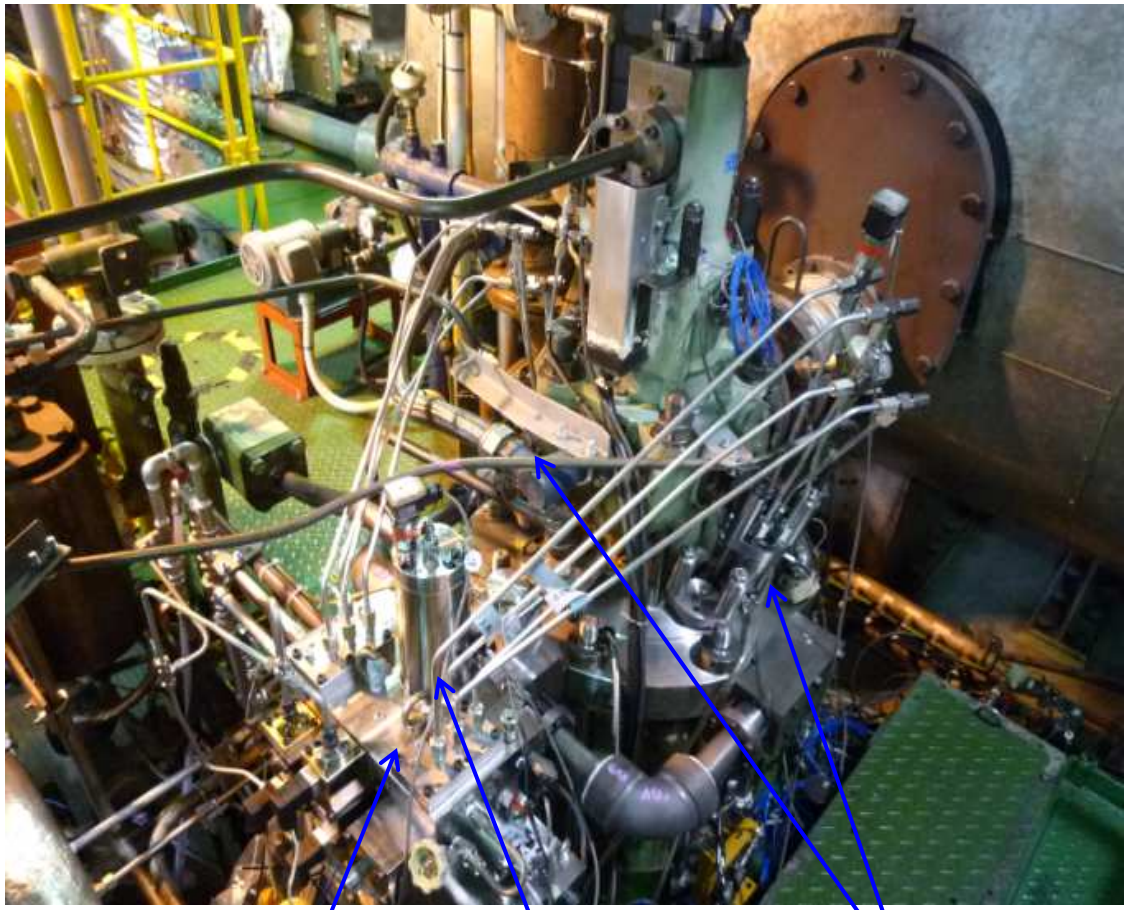
Gas Accumulator Block（GAB）

Gas Injection Valve（GIV）



Contents

UEC-LSGi（Dual Fuel Engine）



Gas Accumulator Block
（GAB）

Gas Gate Valve（GGV）

Gas Injection Valve
（GIV）

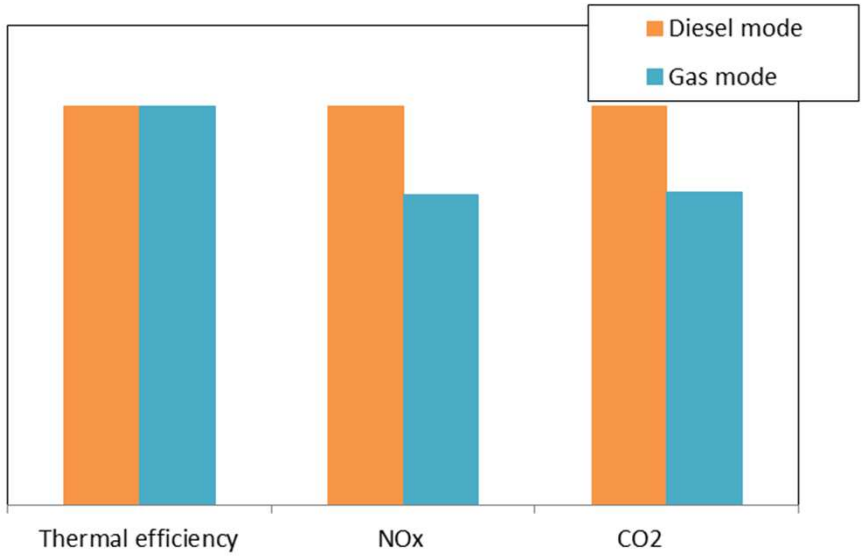
GIV

GGV

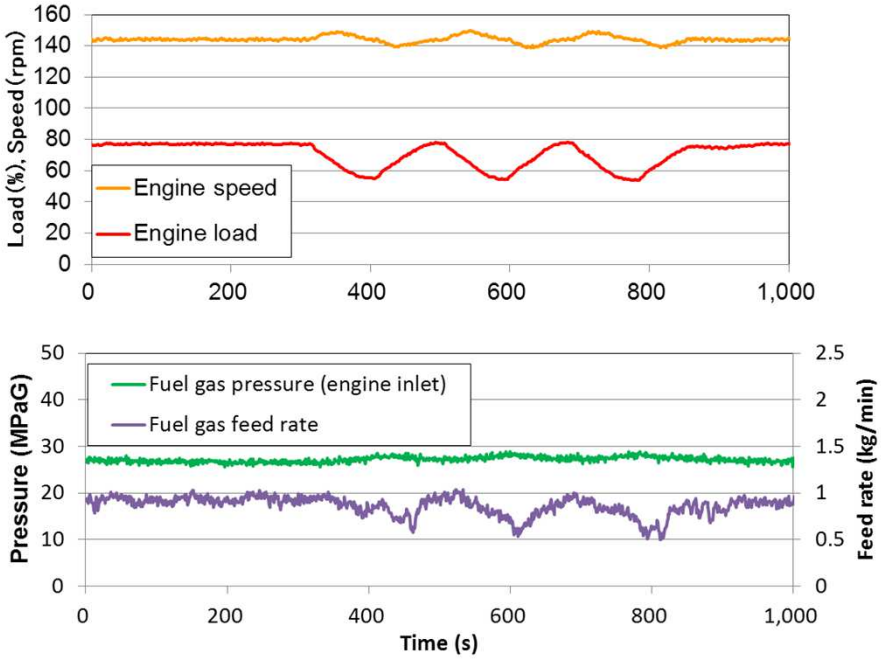
Combustion test(220h) and valve durability test (6,000h) have already finished !!

UEC-LSGi Test Result (Performance)

<Static performance>



<Dynamic performance>



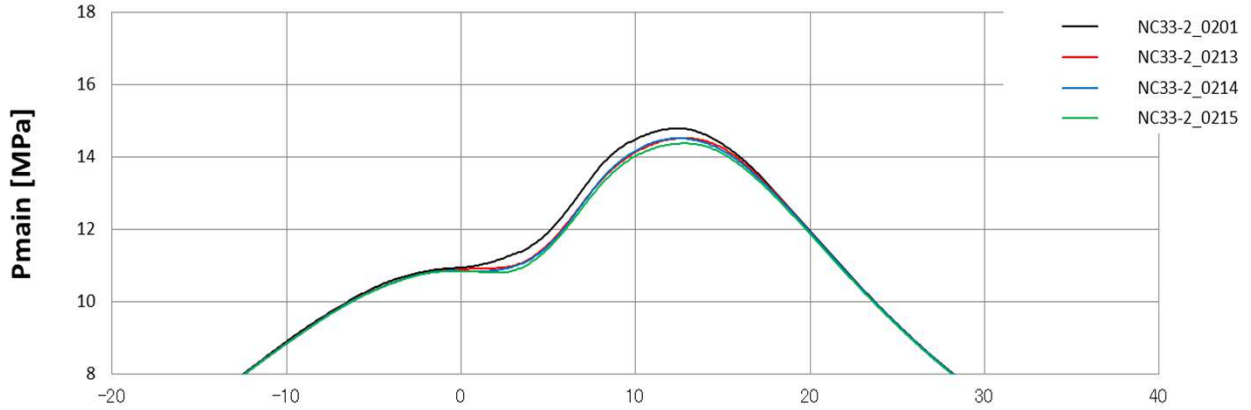
＜Summary＞

- At 75% load, thermal efficiency is almost same, NOx and CO_2 are slightly reduced. (between Diesel mode and Gas mode)
- Adequate response for load variation (60% ~ 80%) considering the rough weather condition

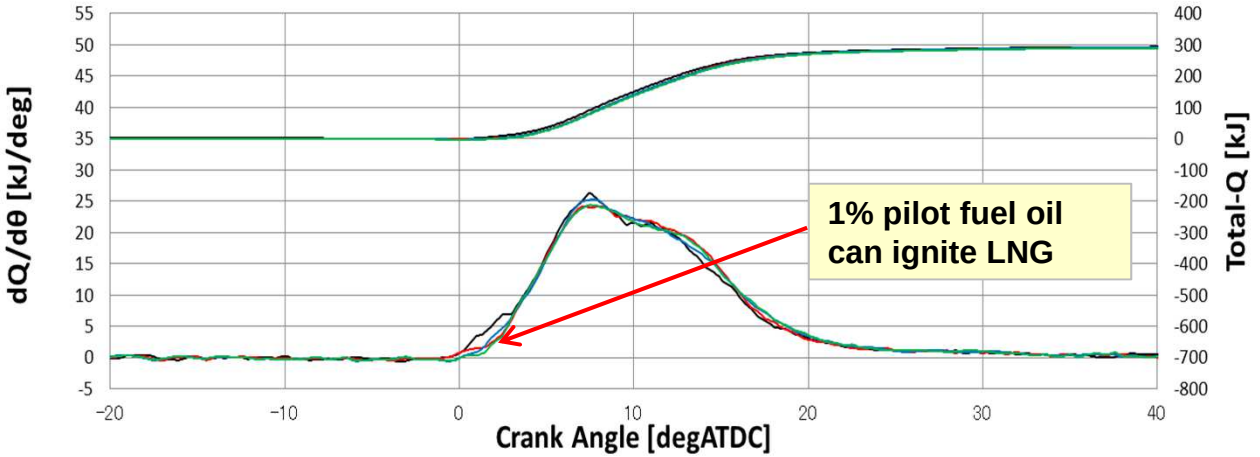
⇒Now under developing, commercial engine will be marketed in 2017.

UEC-LSGi Test Result

<Crank Angle vs. Cylinder Pressure>

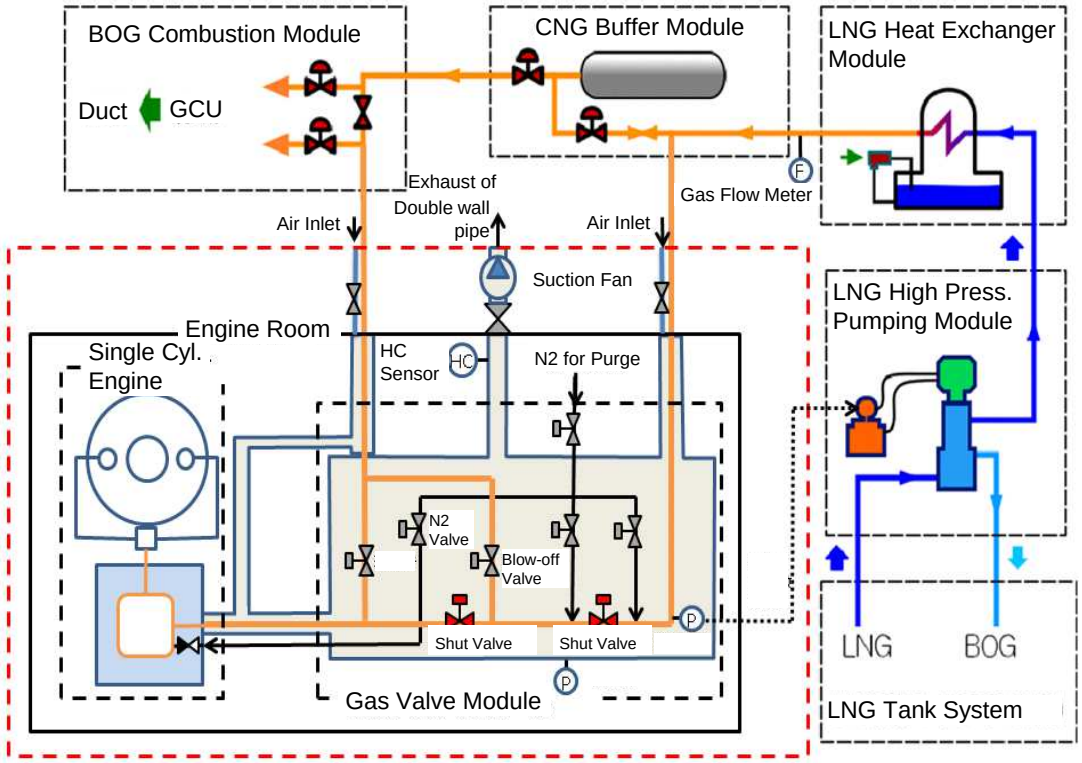


<Crank Angle vs. Heat Release>



⇒We confirmed the ability of Gas mode operation at 1% pilot fuel oil, now durability is under evaluation.

UEC-LSGi High Pressure LNG Supply System



High Pressure LNG Supply System (Test Plant)

LNG High Pressure Pump, Heat Exchanger

Valve Module

Contents

Summary of UEC-LSGi development

- **According to rising fuel oil price, there are possibilities that LNG's competitive advantage will rise up relatively.**

- **We are developing Gas Injection Dual Fuel system utilizing knowledge of fuel oil diesel engine and past test results.**

- **GI system has merits that equivalent engine performance comparing with fuel oil diesel engine and no methane slip. For compliance with TierⅢ, EGR or SCR will be combined.**

- **Mitsubishi's UEC-LSGi can perform stable combustion, emission decreased and good dynamic characteristic.**
  ⇒ Aiming for higher performance gas injection system, under developing and evaluating further

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PROJECT MEET

Thank you for your attention!!