

ME-GI



2011

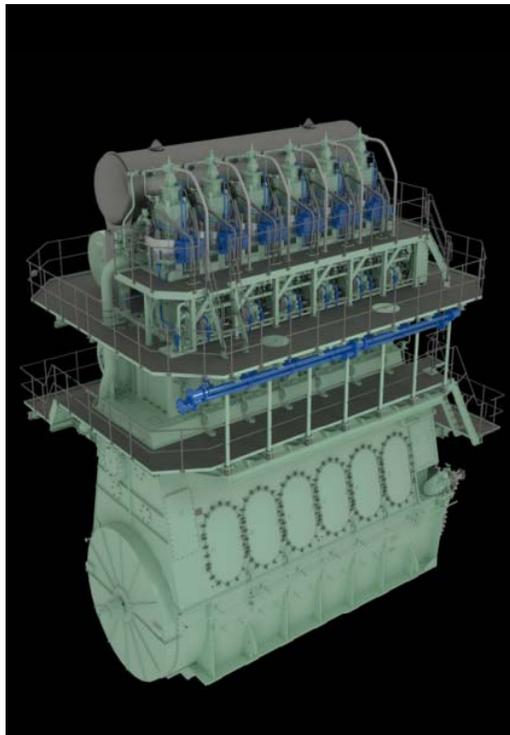
MAN Diesel & Turbo

ME-GI status January 2011

Niels B. Clausen

Low Speed Business Unit

ME-GI Concept



Motivation

Investment costs

- High powered unit
- Local production
- Easy installation

Operational costs

- Gas price vs. price of fuel oil
- Thermal and propulsive efficiency
- Reliability
- Overhaul intervals and overhaul cost
- Spare part cost

Emissions

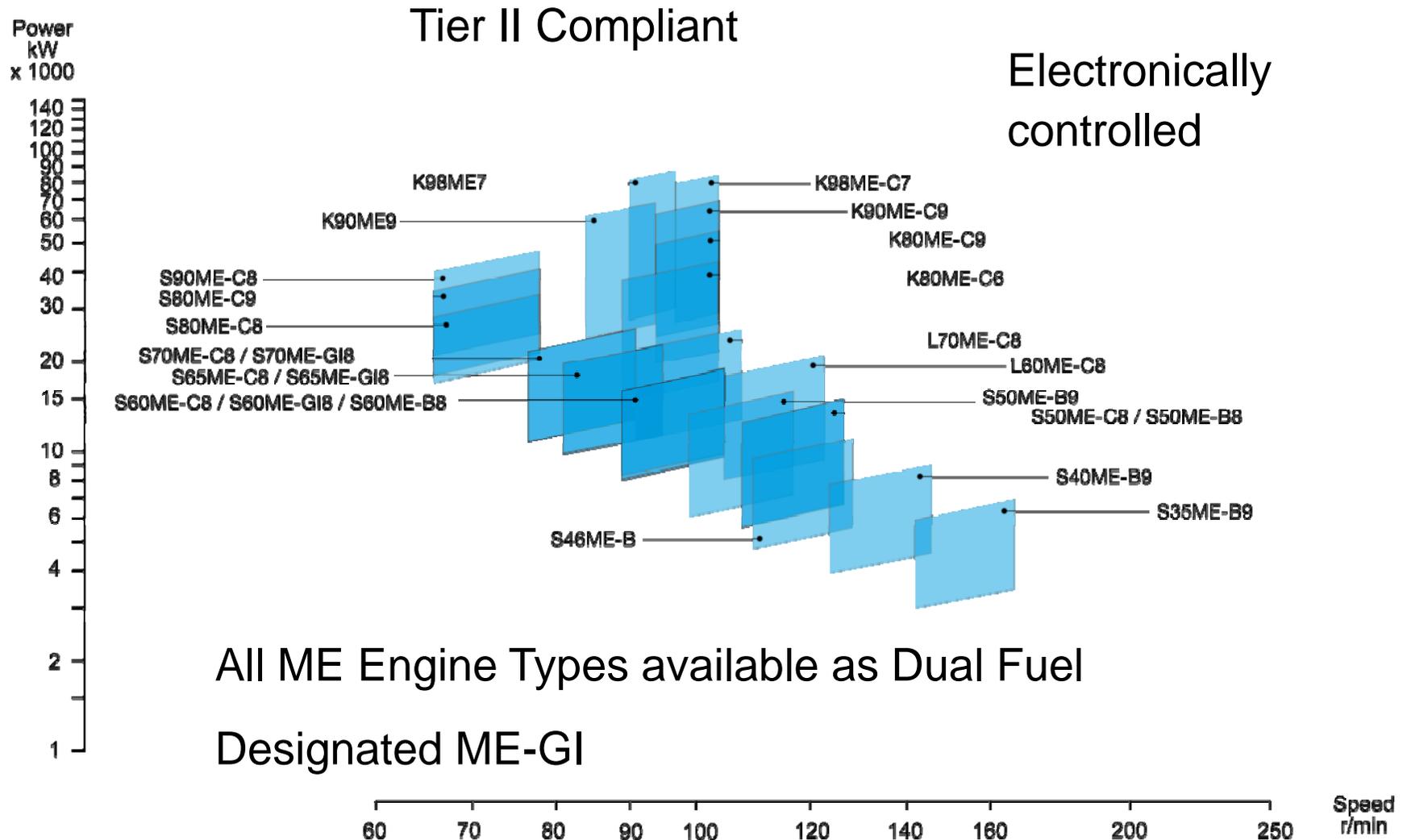
- GHG: CO₂ (EEDI) & Methane slip
- Tier II or Tier III NO_x compliant
- No sulphur in gas
- Reduced emission of particles

Other

- Gas spec. & gas and fuel oil flexibility
- Load acceptance
- Combined cycle efficiency (WHR)

Marine Engine Programme 2011

ME/ME-GI for Two-Stroke Propulsion



Dual Fuel High Pressure Gas Injection Engine S70ME-GI



Background

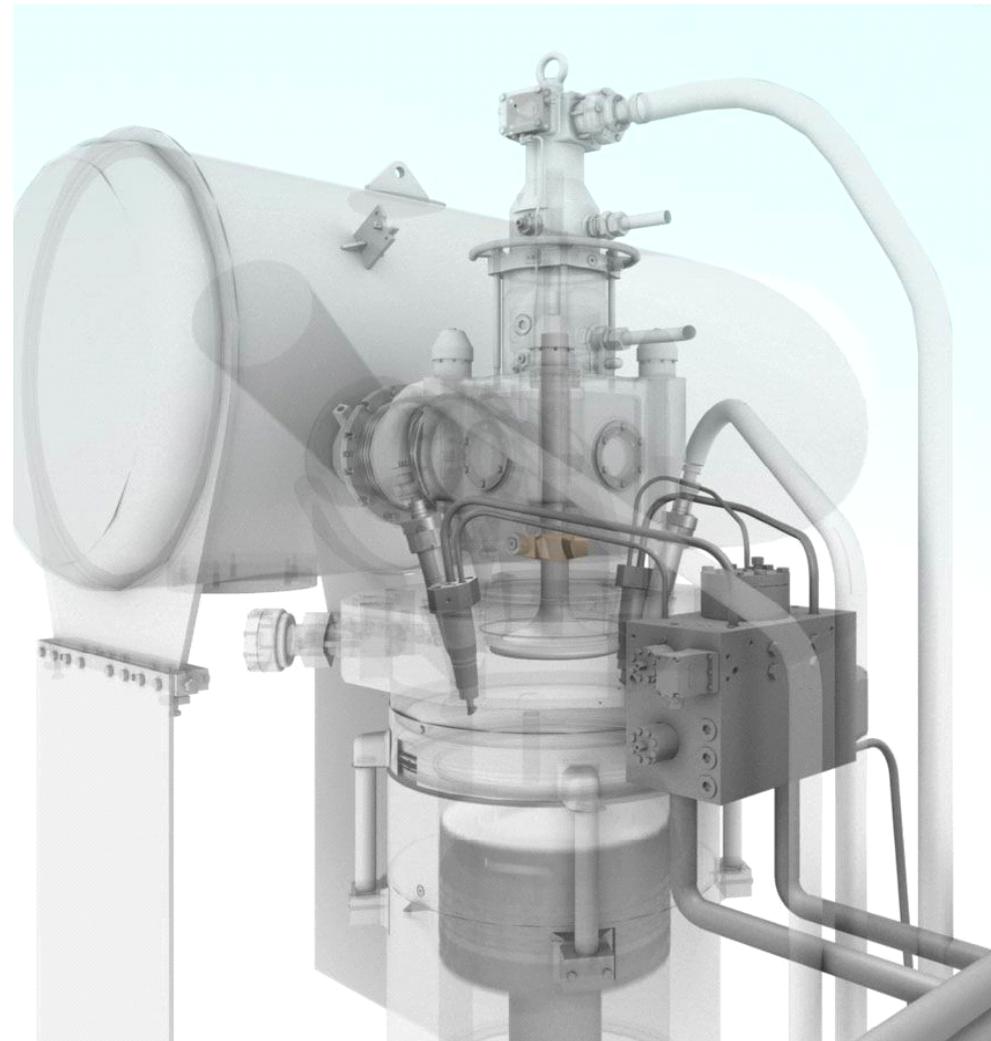
- Dual fuel experience since 1994
- Well-proven ME technology

New components

- Double wall gas pipes
- Gas Injections valves
- Large volume accumulators
- ELGI valves
- Control and safety system

Modified components

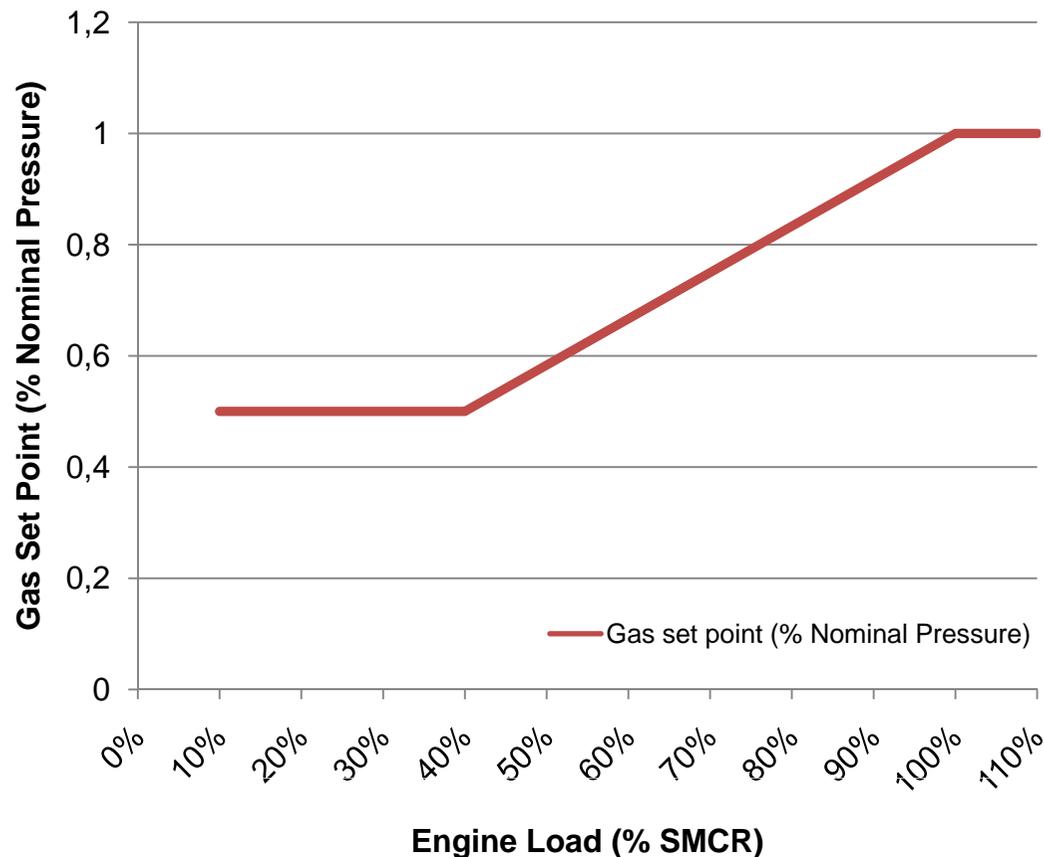
- Cylinder cover
- Exhaust receiver



ME-GI FGS Specification



Control of Gas Delivery Pressure



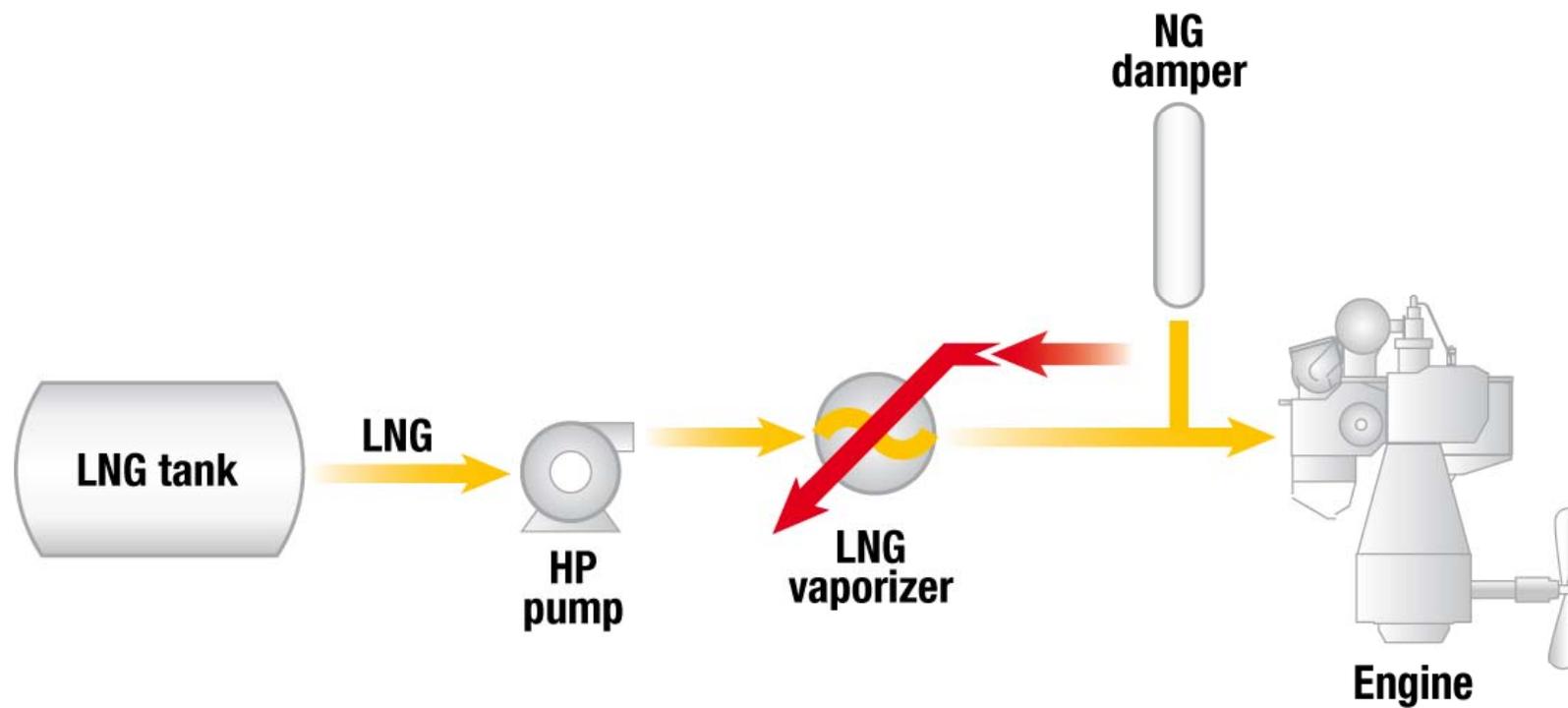
General Data for
Gas Delivery Condition:

Pressure:
Nominal at 100% load 300 bar
Max. value for design 315 bar
Set point tolerance (dynamic) $\pm 5\%$
Set point tolerance (static) $\pm 1\%$

Temperature:
 $45^{\circ}\text{C} \pm 10^{\circ}\text{C}$

Quality:
Condensate free, without oil/water
droplets or mist, similar to the
PNEUROP recommendation 6611
'Air Turbines'

ME-GI Fuel Gas Supply System for Container Ships



ME-GI Concept

Dual fuel operation modes



Fuel oil only mode:

- ❑ Operation profile as conventional engine

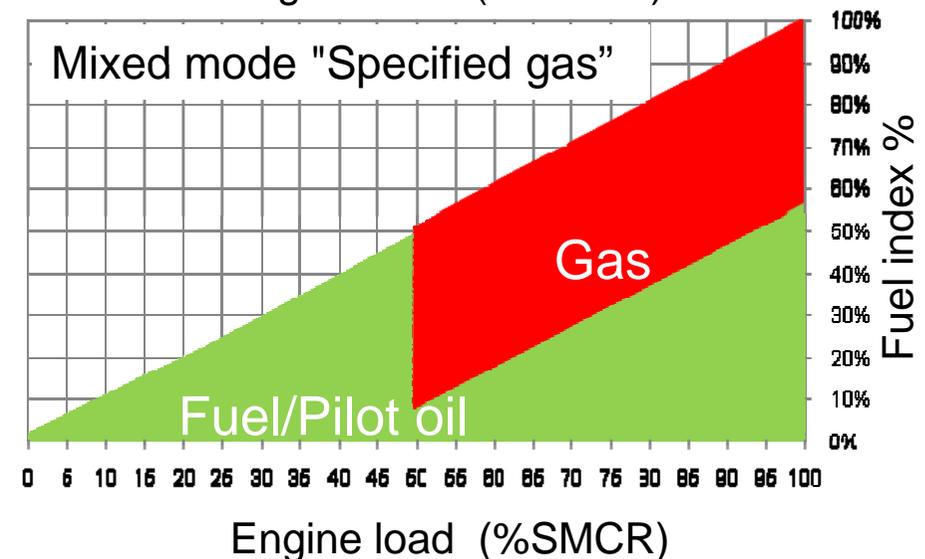
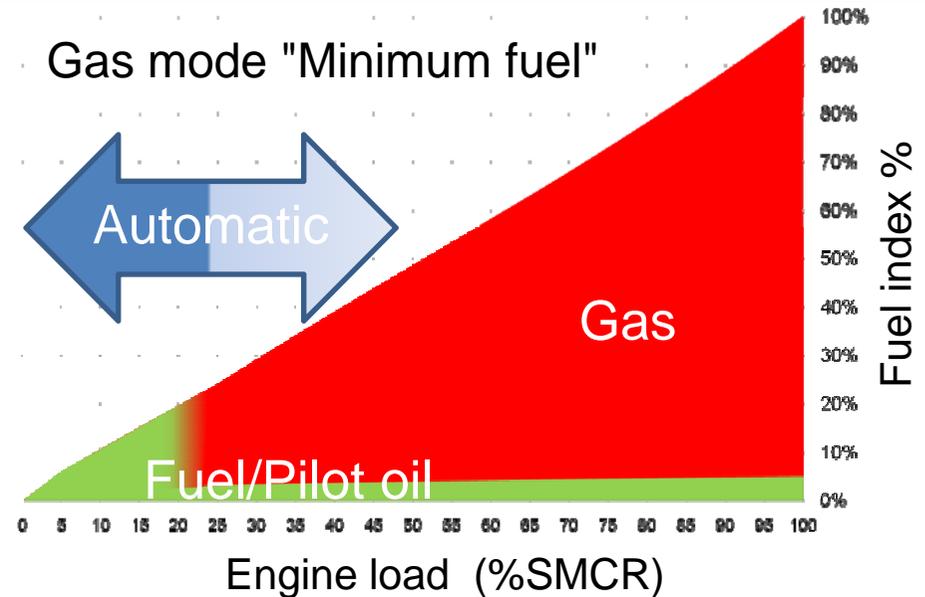
Gas fuel operation modes:

❑ Gas mode "Minimum fuel"

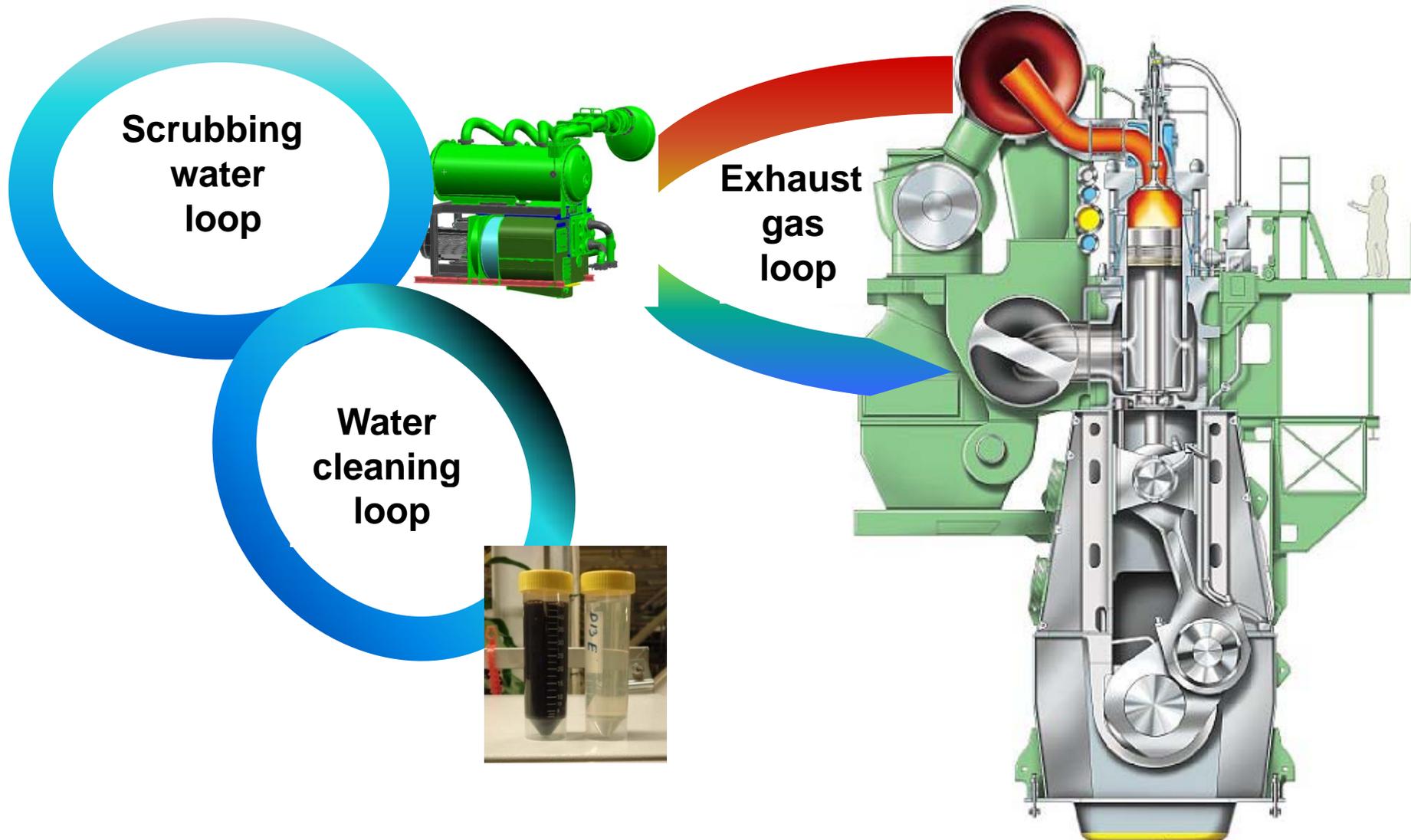
- Full operation profile
- Full load acceptance
- Full power range
- Load variation by gas injection
- Full pilot fuel oil flexibility
- Minimum pilot fuel used
- Increased pilot fuel at low loads
- Dynamic mix of gas and fuel oil

❑ Mixed mode "Specified gas"

- Full operation profile
- Gas fuel is specified on Gas MOP
- Load variation by fuel oil injection



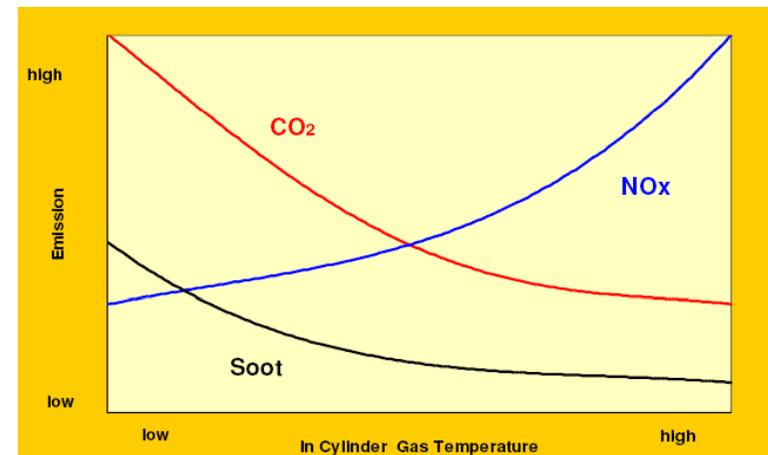
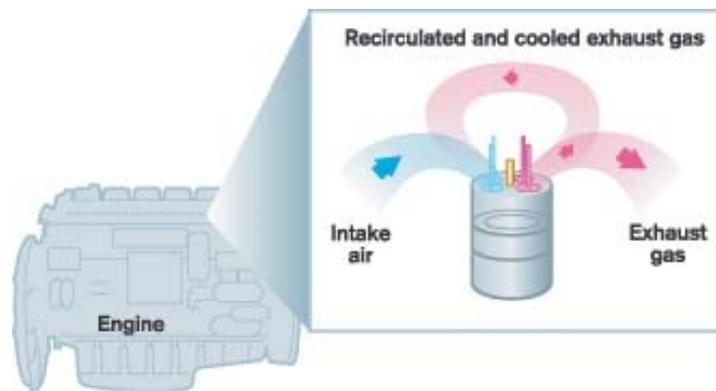
EGR is a Combination of Simple, Well-known Technologies



EGR basic principal



The principle of EGR:



Recirculation of exhaust gas increases heat capacity due to replacement of O₂ by CO₂ and lowers the O₂ content.

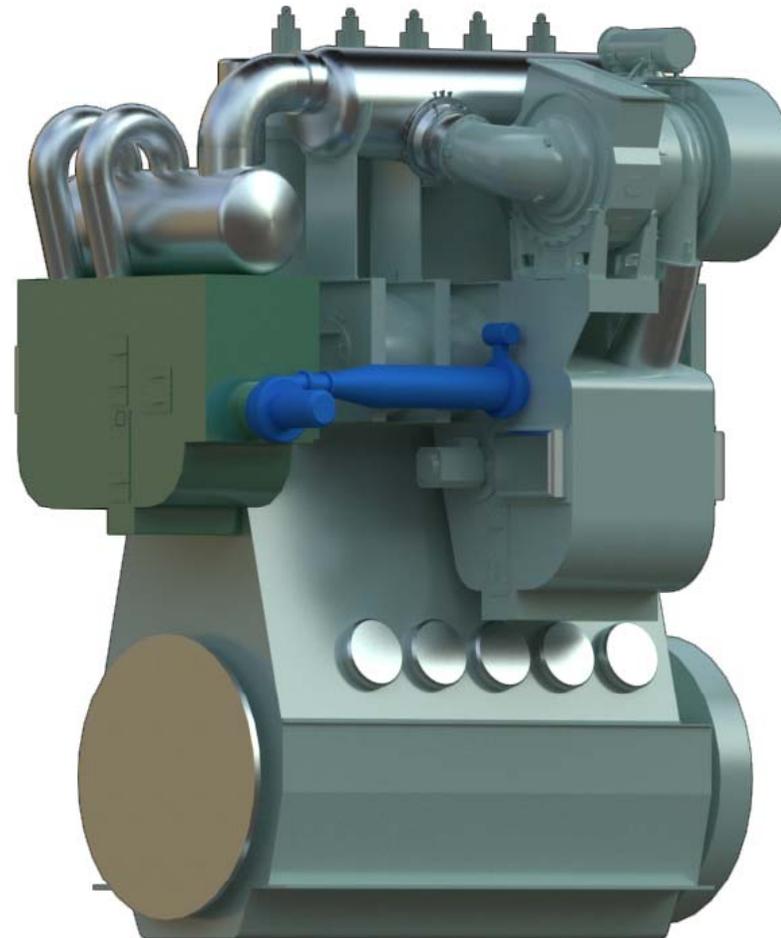
High heat capacity and low O₂ in scavenge air gives low combustion temperatures.

Low combustion temperatures gives low NO_x.

EGR in the Future

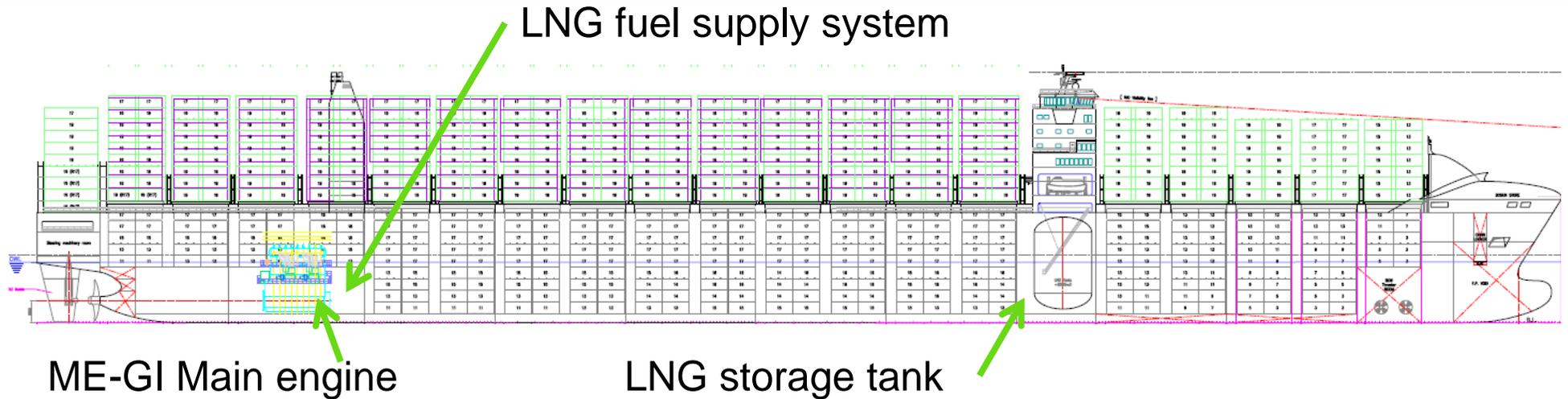


- Integration of EGR with the main engine
- Tier III compliance



Alternative Fuel for Container Ships

Tier 3 ME-GI Engine for LNG vs. Tier 2 HFO Engine



	Reduction with ME-GI	Reduction with ME-GI + WHR	Reduction with ME-GI + WHR + EGR
CO ₂ (gram per tonne mile)	↓ 23%	↓ 32%	↓ 31%
NO _x (gram per tonne mile)	↓ 13%	↓ 23%	↓ 82%
SO _x (gram per tonne mile)	↓ 94%	↓ 95%	↓ 96%
Energy (kJ)	↓ 0%	↓ 12%	↓ 11%
Particulate matter (gram per tonne mile)	↓ 37%	↓ 45%	↓ 61%

ME-GI Development plan

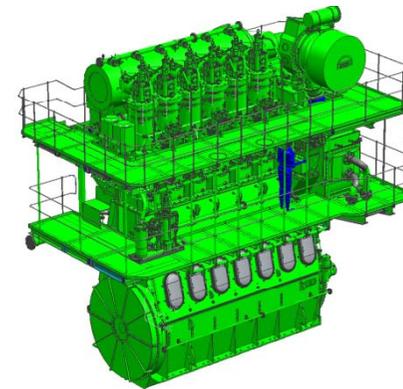


3) Test on R&D engine:

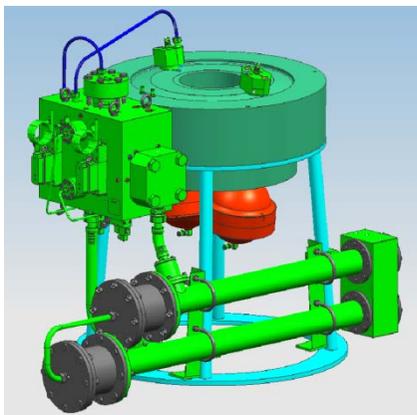


4) First production engine:

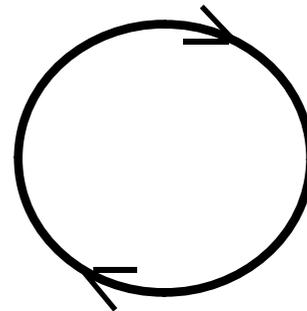
- Verification test and TAT



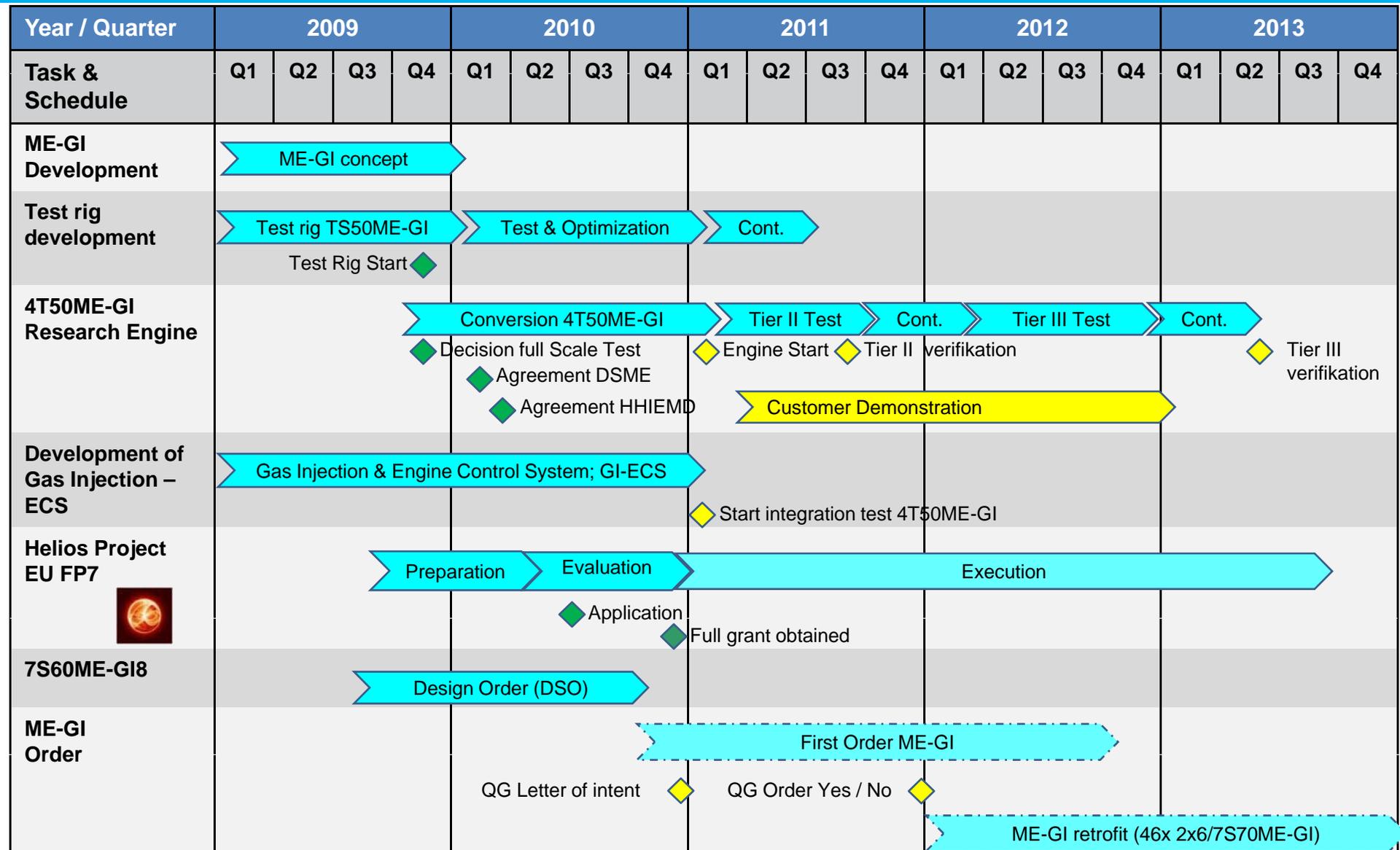
2) Test on gas rig:



1) Design and Calculation:



ME-GI Status January 2011 Development Plan



ME-GI Concept Updates

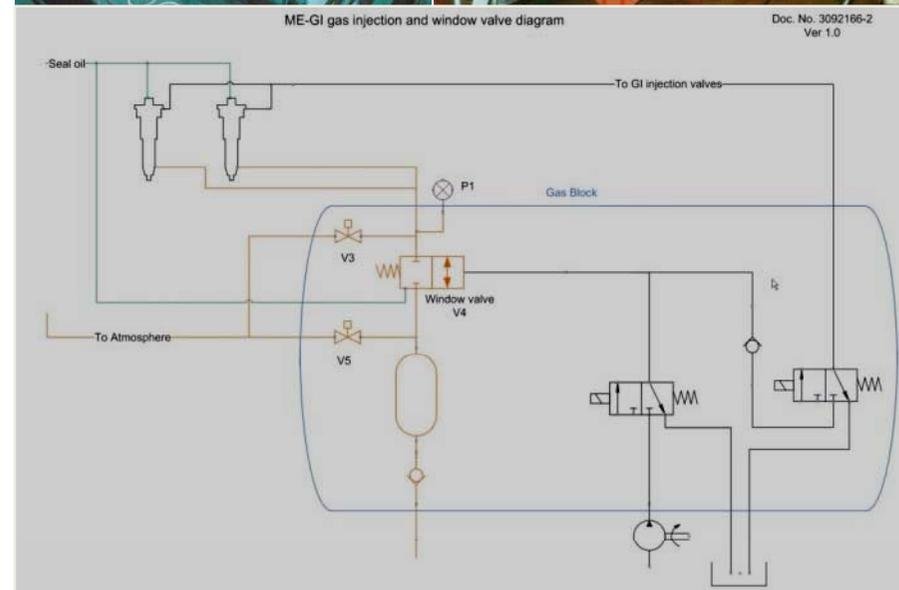


Product basis:

- ❑ 12K80MC-GI-S, Chiba (1994-2003)
- ❑ 6L55GFCA, Navion Viking, VOC System

ME-GI Concept updates

- ❑ Window function
- ❑ Leakage detection
- ❑ Safety concept / PMI-online
- ❑ Minimizing pilot oil
- ❑ Stable low load operation on gas
- ❑ Performance optimization
- ❑ Design review (reliability and cost)
- ❑ Application technology

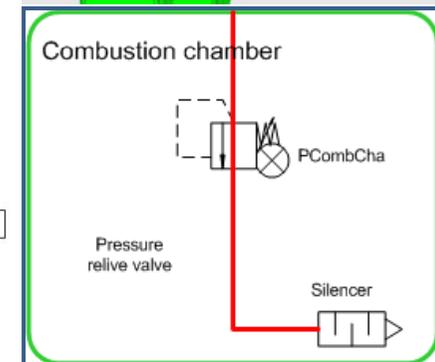
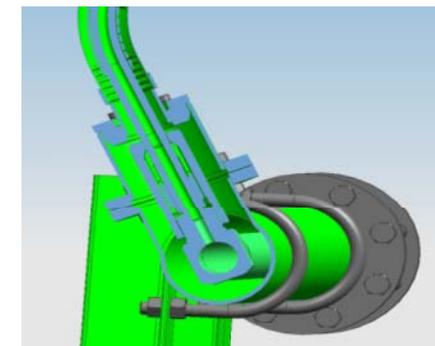
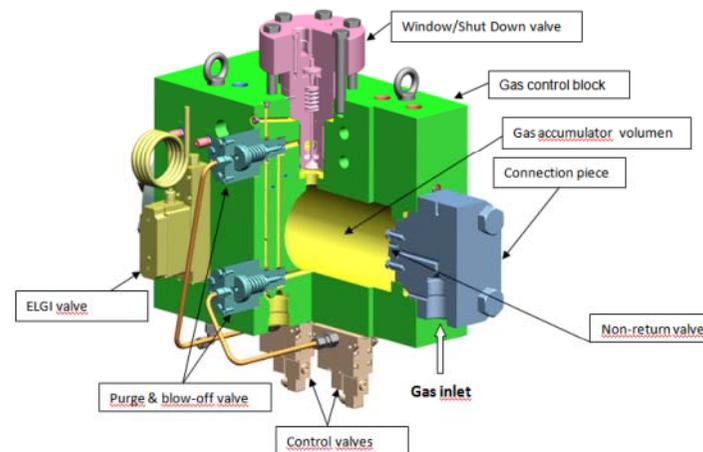
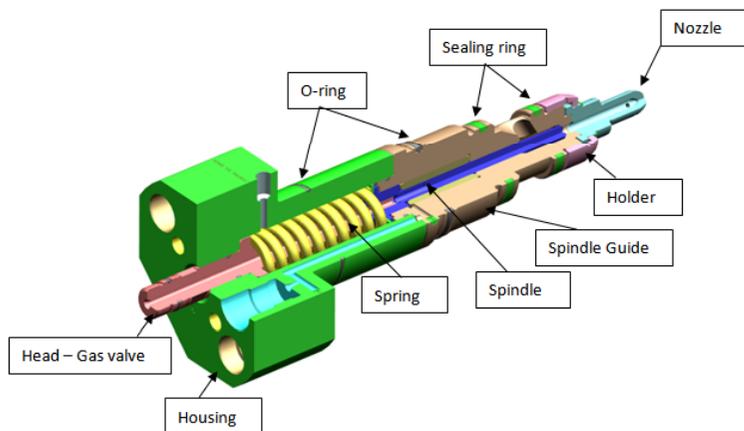
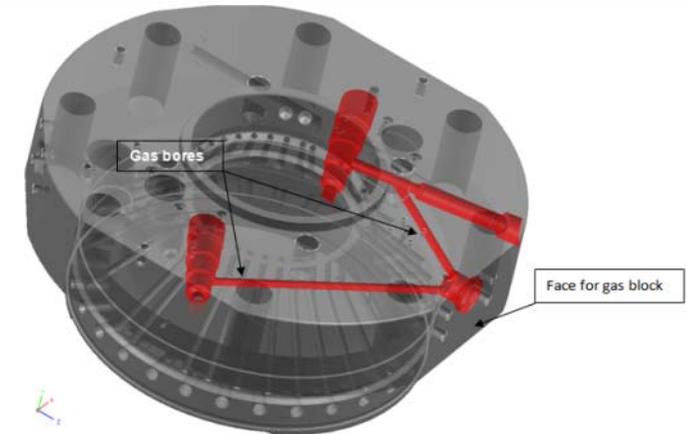


ME-GI Gas Test Rig

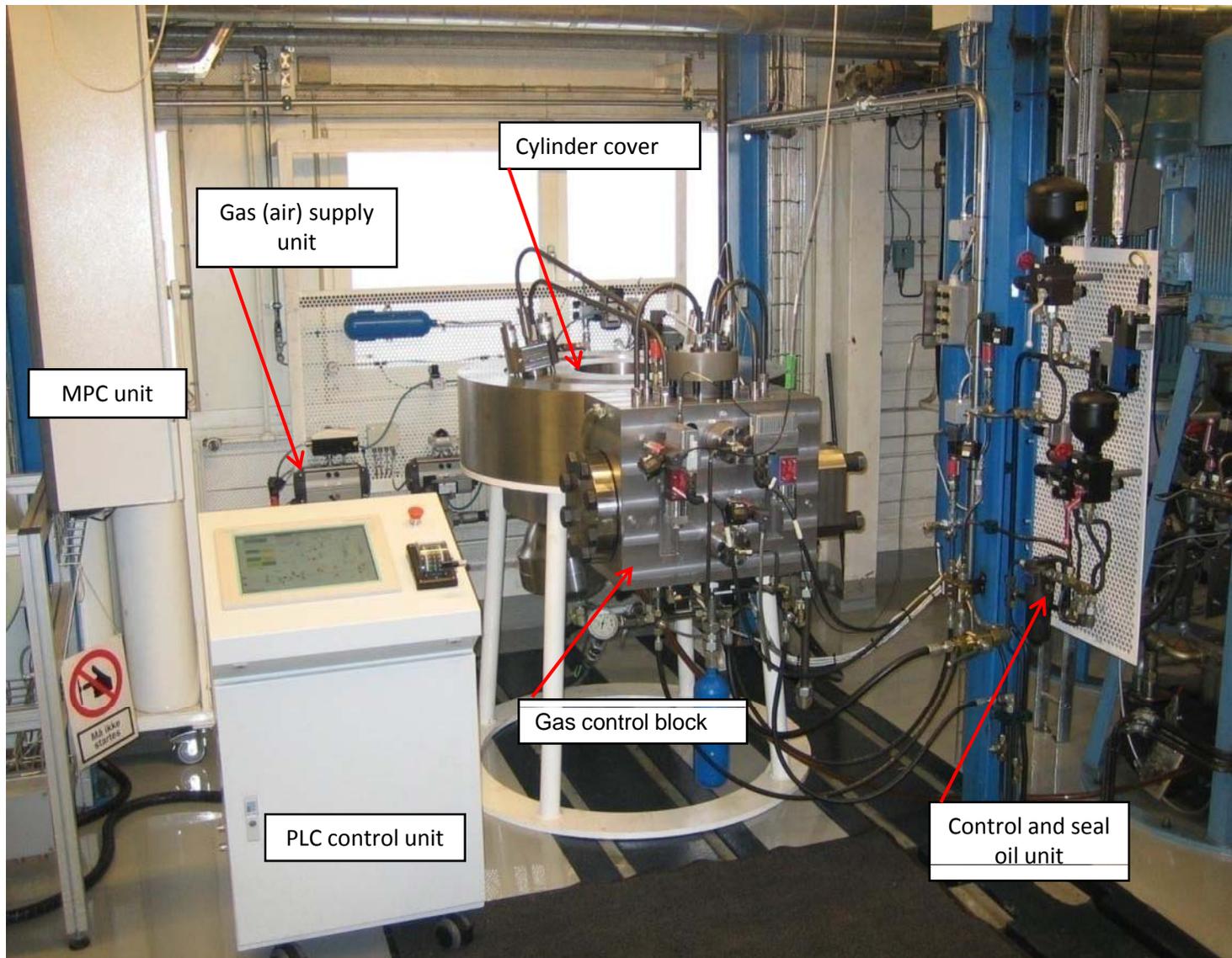


Design:

- ❑ Complete ME-GI engine components
 - S50ME cylinder cover
 - Gas injection valve and gas block
 - Pressurised “combustion chamber”
 - Double wall gas piping
- ❑ All necessary auxiliary systems installed and connected
- ❑ Operated on 300 bar compressed air



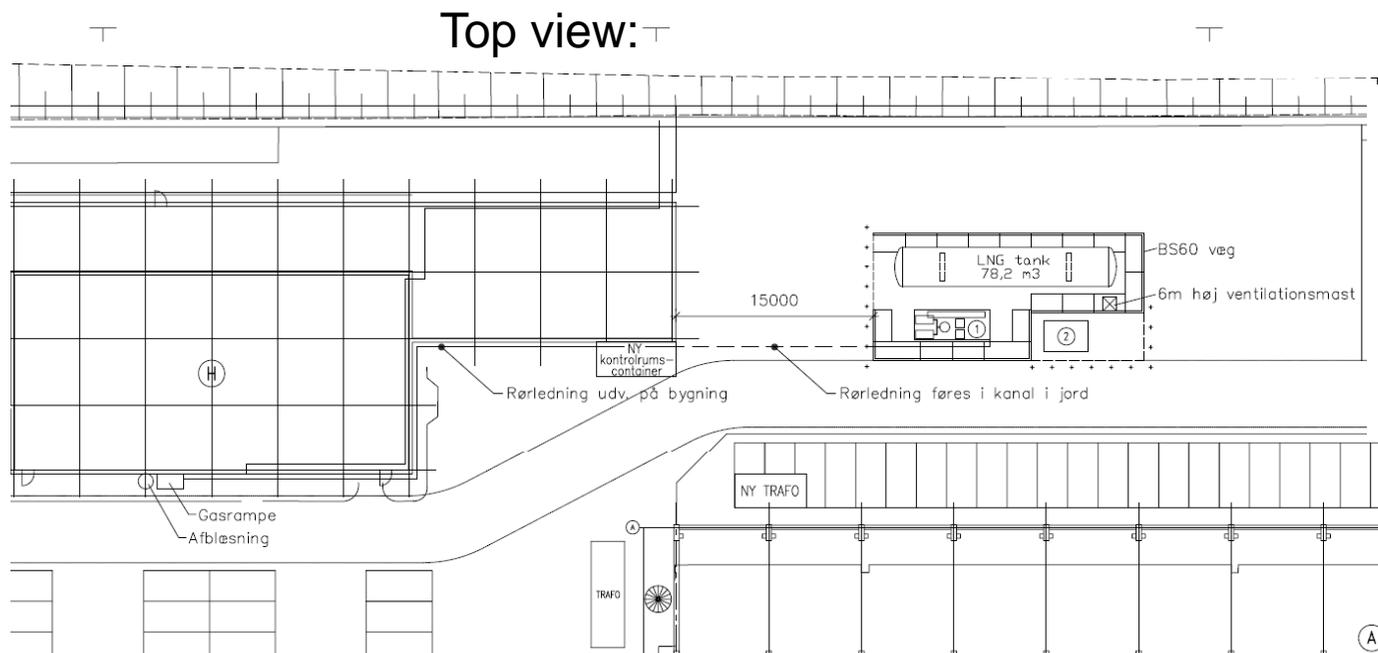
ME-GI Gas Test Rig



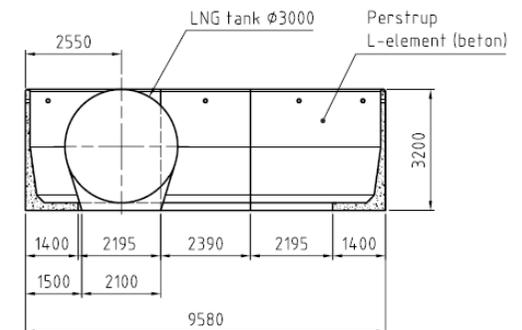
ME-GI FGS System Layout



- ❑ The FGS system will be installed in a distance of 15 meters from the T-module surrounded with concrete elements.
- ❑ All approvals from local authorities expected within February 2011.



Side view:



ME-GI FGS System photos



ME-GI Many Applications



ME-GI



2011

Thank you very much for your attention

Niels B. Clausen

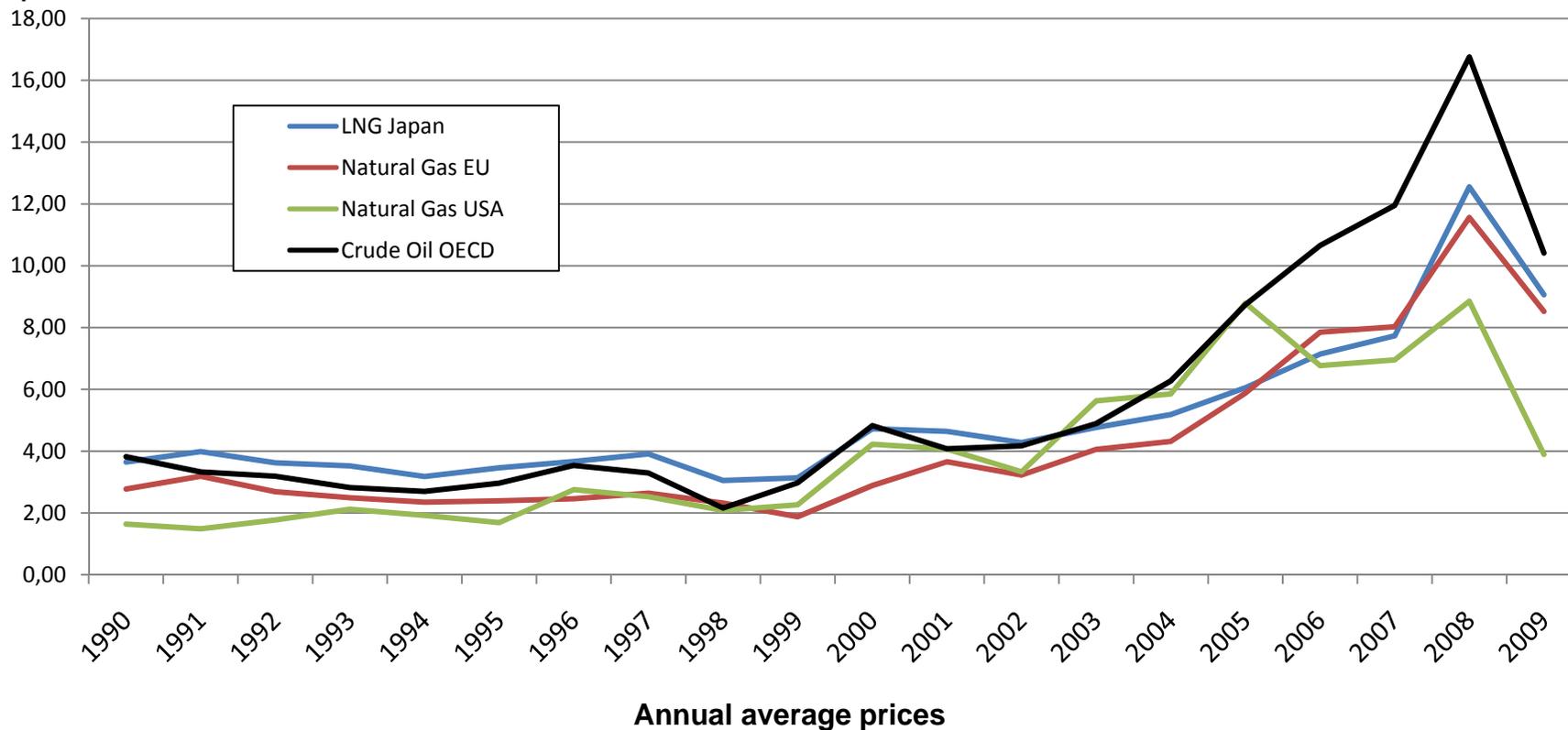
Low Speed Business Unit

Gas in general Natural Gas Prices



Natural Gas & Crude Prices (energy-equivalent basis)

US \$ per million BTU



Since beginning of 2000's Crude Oil is developing more expensive than Gas on an energy-equivalent basis

Source: BP Statistical Review of World Energy 2010

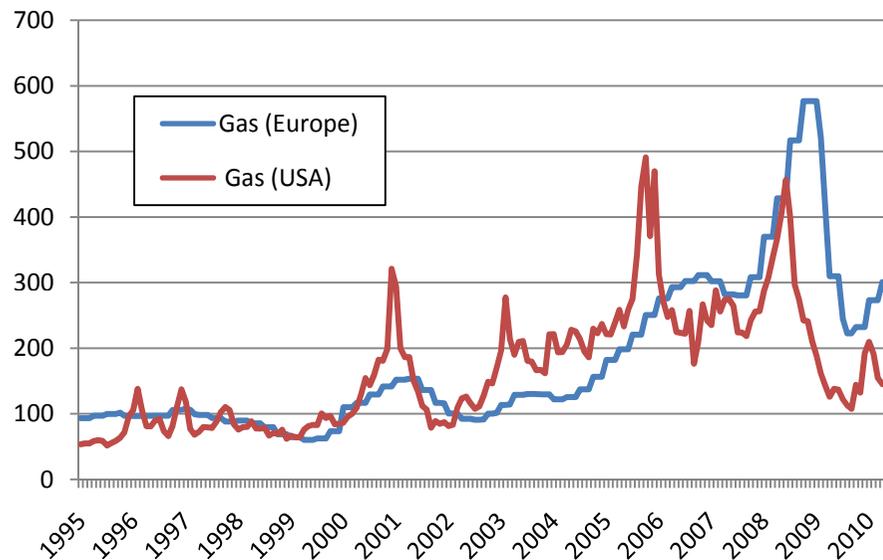
Gas in general

Natural Gas Prices

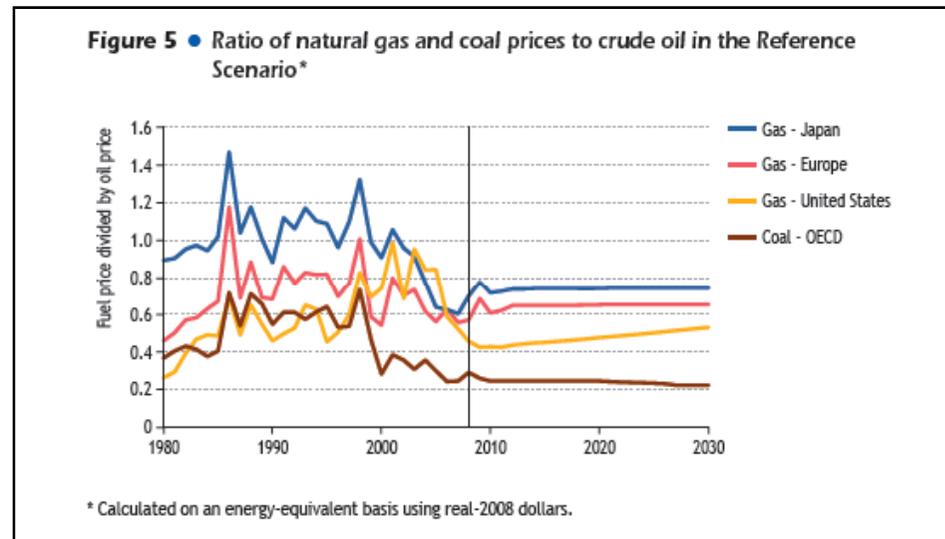


Natural Gas Prices

US \$/ 1000 cbm



Future Outlook



- Gas prices are expected to reach 2008 levels in 2015 again and will more than double up to 2030 compared to 2008 levels
- Nevertheless natural gas will stay **relatively cheaper than crude oil** (on an energy-equivalent basis)
- In the US, gas prices are expected to follow a path much more independent from oil prices and the abundance of relatively low-cost shale gas is expected to continue to exert downward pressure on US gas prices in the near term. Prices will rise relatively more than in Europe or Japan on the long-term as reserves of low-cost shale gas are depleted (but will stay well below European or Japanese prices!)

Source: IMF 2010, IEA 2009, GMM

ME-GI Concept Updates



Reduction of pilot oil:

- 5% pilot fuel at 100 % load
- Pilot fuel reduced proportional to RPM

- Further reduction of pilot fuel will be based on test results

	Pilot amount			
Load	ME/MC	ME-GI	ME-GI reduced pilot	difference
%	g/kWh*	g/kWh**	g/kWh**	%
100	170.6	9.0	9.0	0
75	166.7	11.8	10.7	-9
50	170	18.0	14.3	-21
25	178.4	40.8	25.7	-37

* Reference fuel LCV 42,700 kJ/kg at ISO conditions

** HFO: LCV:40.4MJ/kg, 86.6%C, 3 % S

LNG: LCV:50.0MJ/kg, 75.0%C, 0 % S

ME-GI Concept Updates



Reduced pilot oil impact on emission:

		CO2			NOx			SOx		
Load	SFOC	ME/MC	ME-GI	ME-GI reduced pilot	ME/MC	ME-GI	ME-GI reduced pilot	ME/MC	ME-GI	ME-GI reduced pilot
%	g/kWh*	g/kWh**	g/kWh**	g/kWh**	g/kWh**	g/kWh**	g/kWh**	g/kWh**	g/kWh**	g/kWh**
100	170.6	571.5	409.0	409.0	13.5	11.9	11.9	10.82	0.54	0.54
75	166.7	558.5	402.4	401.4	14.7	12.9	12.7	10.57	0.71	0.64
50	170	569.5	416.1	412.5	14.5	12.7	12.2	10.78	1.08	0.86
25	178.4	597.7	457.5	443.1	14.6	12.8	11.5	11.31	2.45	1.54
E3					14.3	12.6	12.4			

* Reference fuel LCV 42,700 kJ/kg at ISO conditions

** HFO: LCV:40.4MJ/kg, 86.6%C, 3 % S

LNG: LCV:50.0MJ/kg, 75.0%C, 0 % S



Increased operation range in GAS mode is developed:

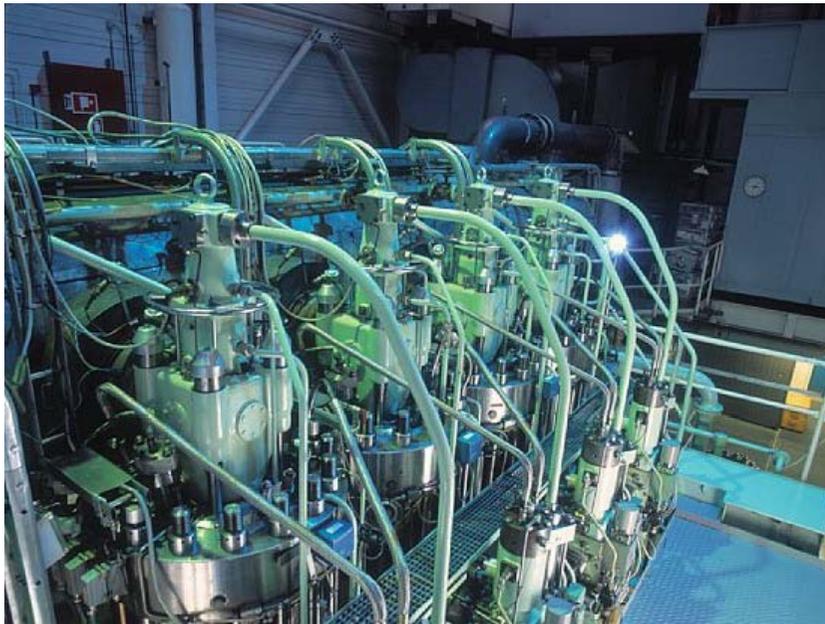
- ❑ Short time operation below 25 % load without leaving Gas mode
 - No venting of gas system needed in short term

- ❑ New “**fully automatic**“ **GAS standby state** at loads below 25 %
 - Engine continue in GAS mode
 - No venting of complete gas pipe needed
 - Gas operation resumes depending on load condition
 - Automatically controlled by ME-GI control system

EGR investigation and service test



**EGR investigation on 4T50ME-X:
7 MW diesel engine and >40% EGR**



**EGR service test on Alexander Maersk:
10 MW diesel engine and 20% EGR**



EGR investigation – test results



EGR investigation on 4T50ME-X – results with EGR and WIF

		Ref.	EGR TIER III	EGR Tier II	50% WIF (added)	50% WIF (added) + EGR	28% WIF (added)	28% WIF (added) + EGR
EGR rate	%	0	37	18	0	37	0	37
WIF-%	%	0	0	0	50	50	28	28
NO _x	g/kWh	17.4	3.4	12.3	10.4	1.3	13.5	2.0
CO	g/kWh	0.7	1.4	0.4	0.24	0.30	0.25	0.67
SFOC*	%	0	0.3	-2.6	2.4	3.9	0.4	2.5

Extreme EGR test - inspection

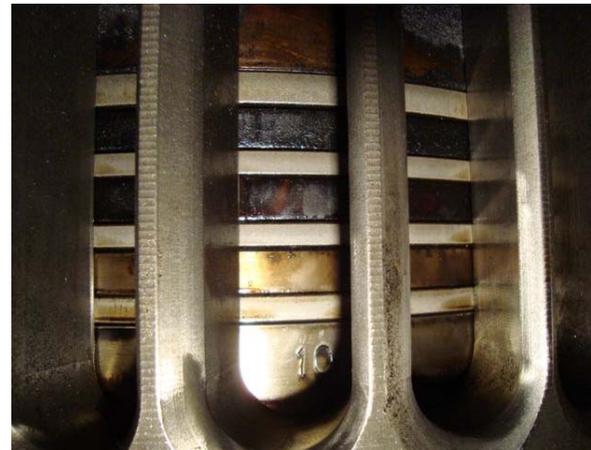


EGR test results 2009 – cylinder conditions: > 100 hours of extreme EGR test

Before – cylinder 1



After – cylinder 1



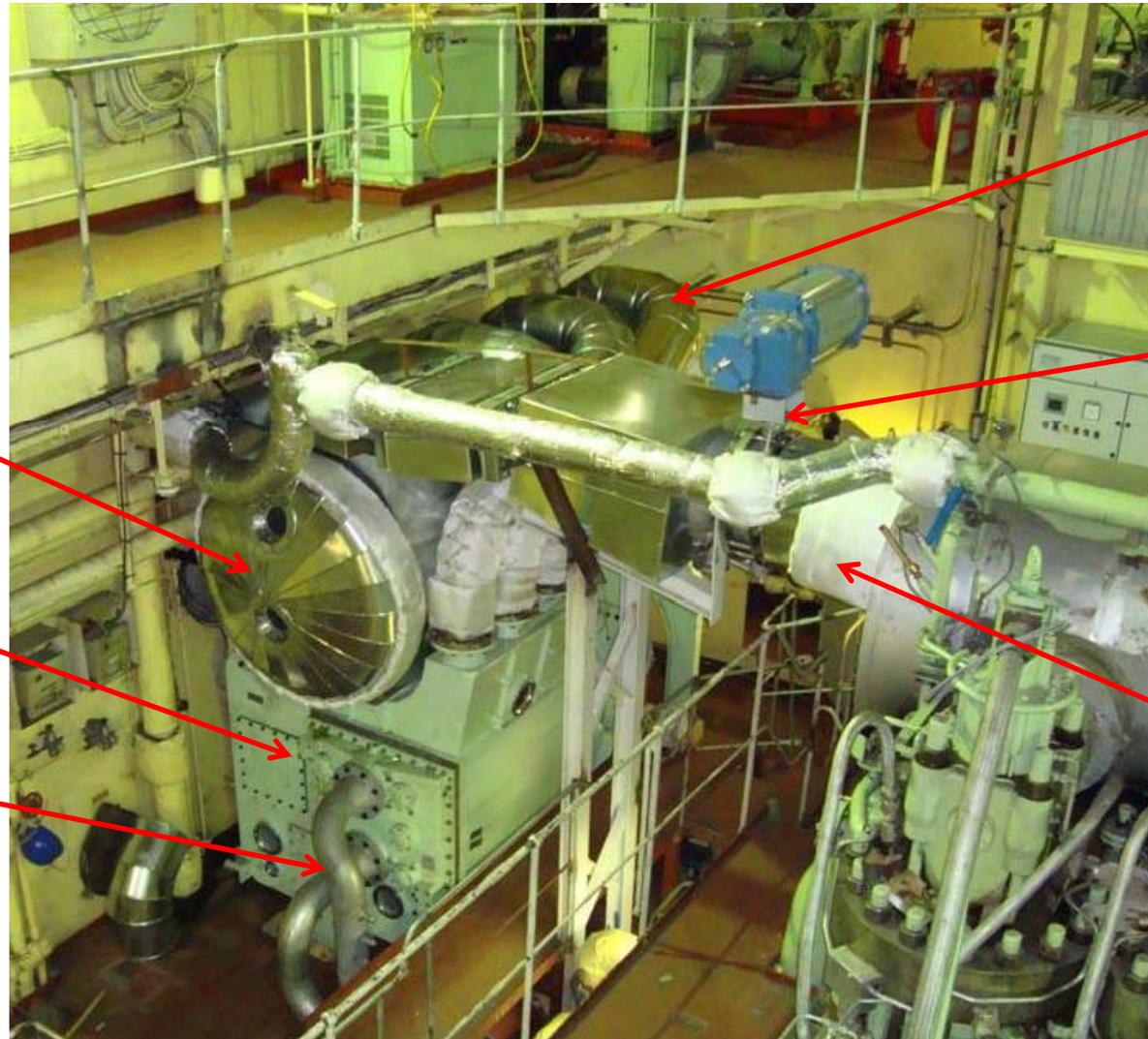
Before – cylinder 4



After – cylinder 4



EGR in Service on Alexander Maersk



EGR Gas pipes
- scrubber to cooler

EGR Shutdown
valve

EGR Gas
pipe/s
- exhaust receiver to scrubber

EGR Scrubber

EGR Cooler
& WMC
Cooling water pipes