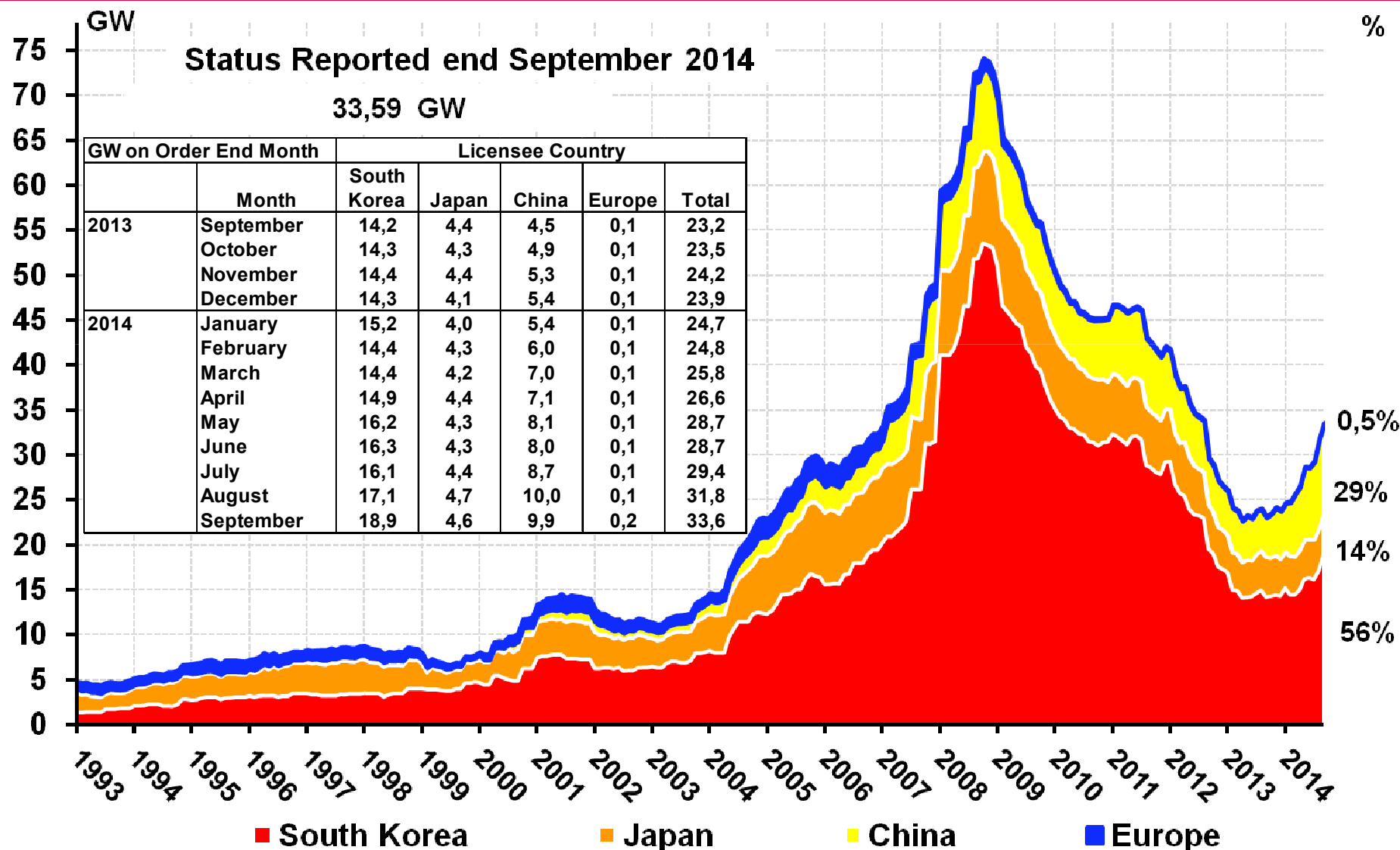




The 2 stroke Dual Fuel ME-GI Engine **A robust gas combustion solution**

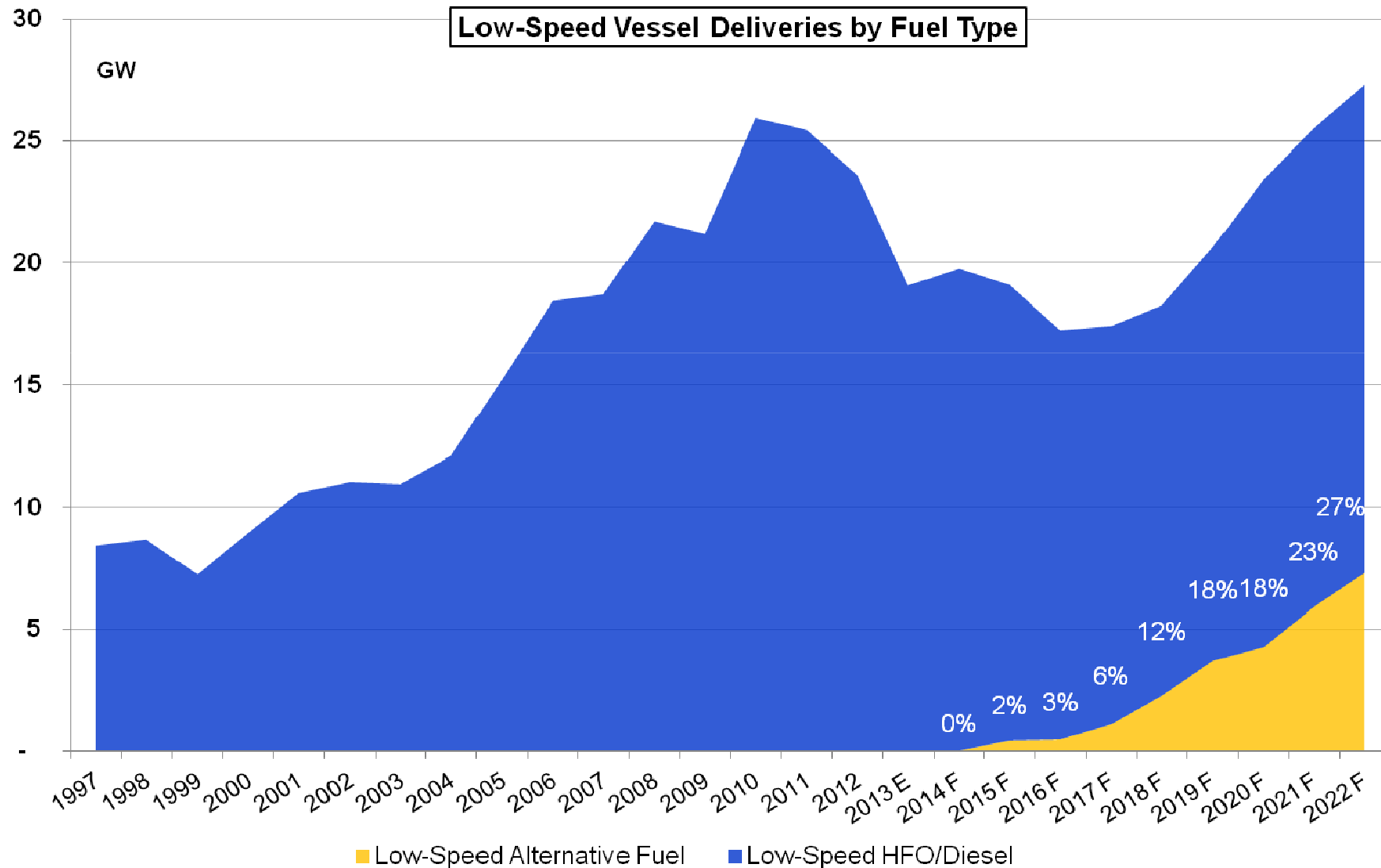
Rene Sejer Laursen
MAN Diesel & Turbo
E mail: ReneS.Laursen@man.eu

The Licensees Reported Order Book Low Speed



Alternative Fuel Penetration

Gas & Alcohols

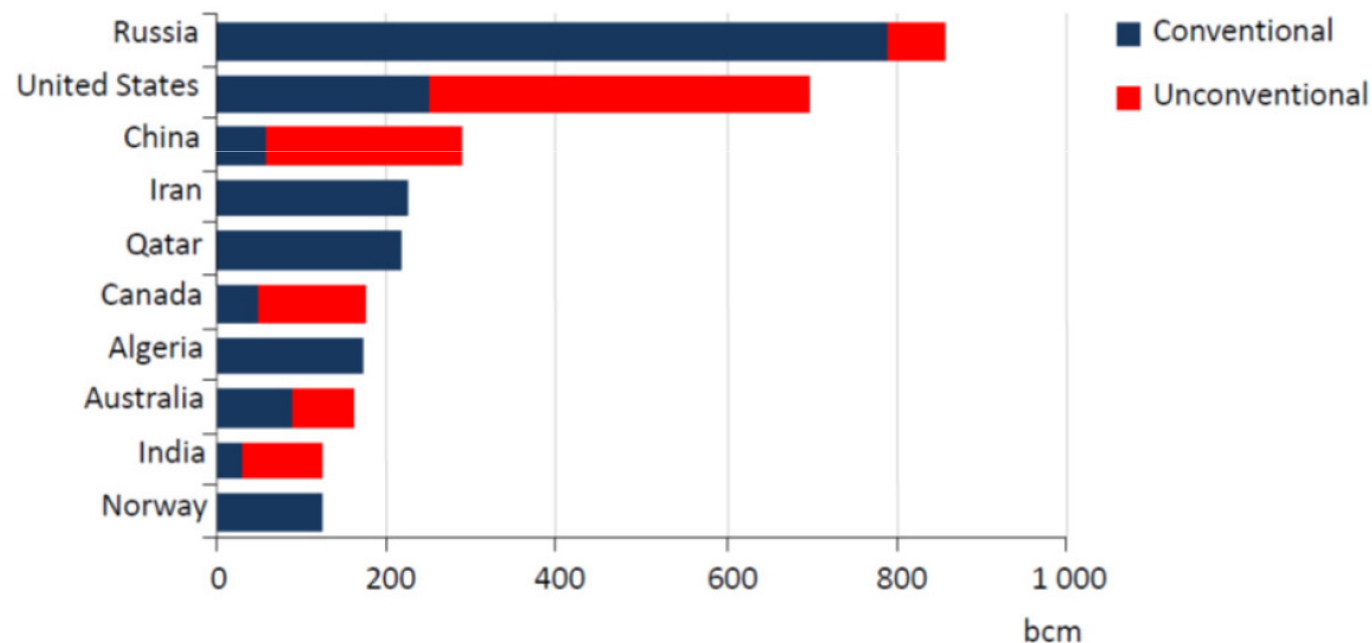


The US shale gas revolution, also China and Canada expect to contribute



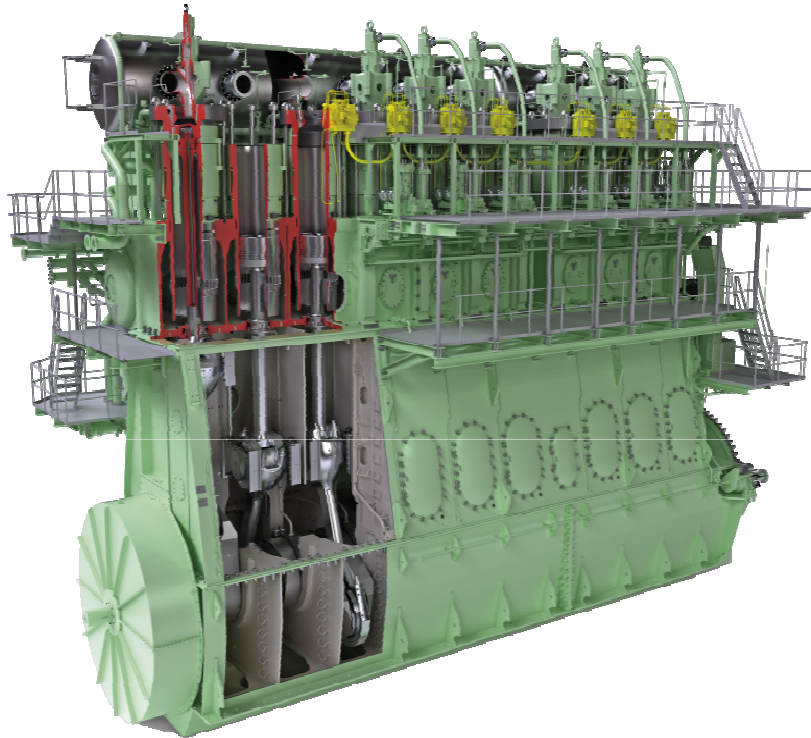
Note: The shale gas contains both methane gas, ethane gas, propane and butane.

Figure 2: The largest gas producers in the world in 2035



Source: IEA WEO 2011

Two-Stroke Dual Fuel Diesel Engines



- 56 x ME-GI for Natural Gas
- 9 x ME-LGI for Methanol
- 3 x ME-GI for Ethane Gas

ME-GI & ME-LGI – Dual Fuel Done Right
68 sets ordered already

MAN Diesel ME-GI

ME-GI = dual fuel done right!



Teekay 173kcum LNGC– World's first fuel efficient LNGC (2 x 5G70ME-GI)



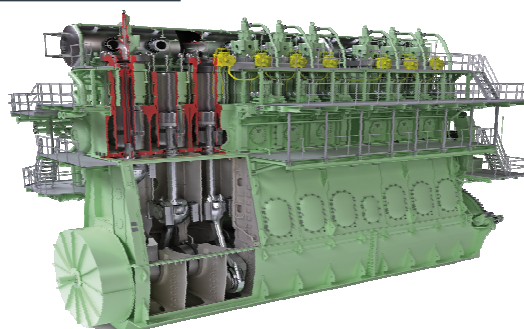
Tote Containership– World's first dual fuel containership (8L70ME-GI)



Brodosplit –World's first international DF containership (8S50ME-GI)



**Matson Containership-
World's largest dual fuel engine (7S90ME-GI)**

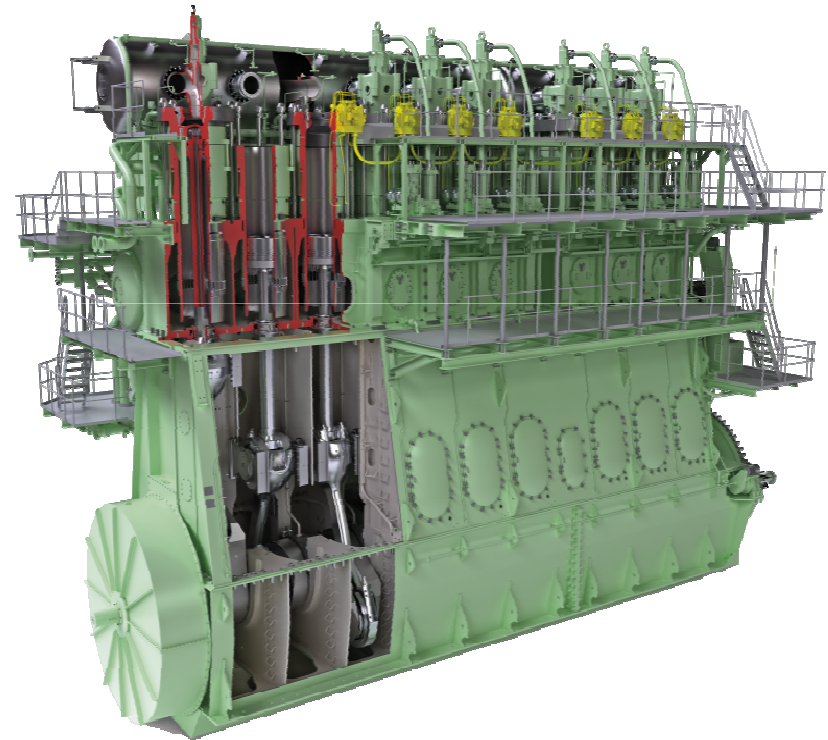


Why the ME-GI Engine?



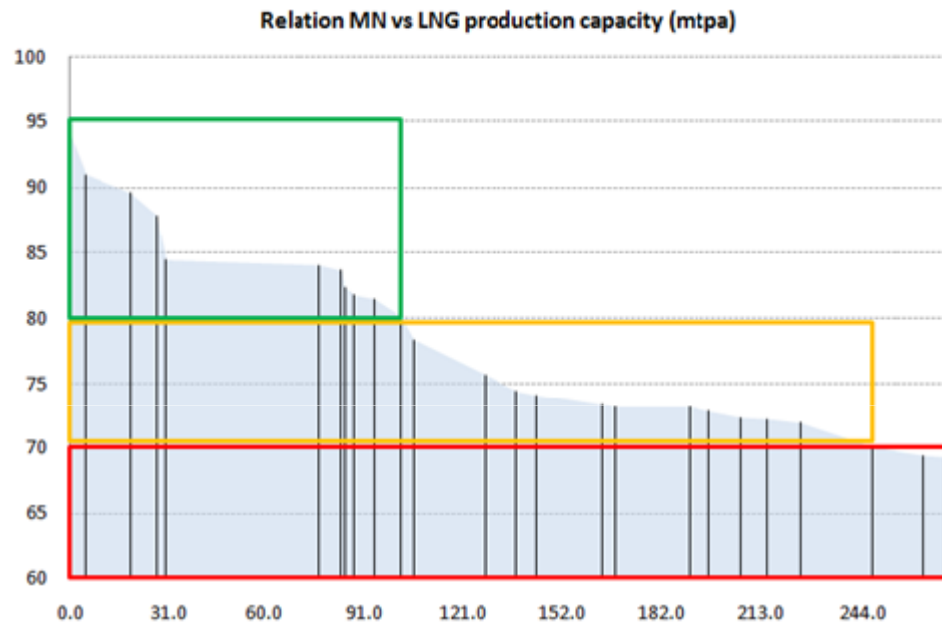
The ME-GI is derived from the industry's standard MC and ME engine.

- Proven design, **>20,000** engines in service.
- **Diesel cycle** high fuel efficiency **~50%** versus much lower for other engine types.
- High fuel flexibility – burn ***all*** gas grades ***without derating***. ***Burns all fuel types***.
- High **reliability** – same as fuel engines.
- ***No derating*** because of ***knocking*** danger.
- ***Negligible methane slip***.
- ***Only demonstrated AND ordered 2 stroke dual fuel engine***.
- ***A robust gas combustion – unchanged load respons – unaffected by ambient conditon***



LNG Production Quality

Variation in MN vs. production capacity



MN Range (AVL)	Global LNG Production (mtpa)	% of Total LNG produced
0 - 70	26	10 %
70 - 75	118.3	43 %
75 - 80	26.1	10 %
80 - 100	102.8	38 %
0 -100	273.15	100 %

- The greatest production is seen at lower methane numbers
 - An engine with a min MN spec (AVL) of 80 can use only 38% of global supply
 - An engine with a min MN spec (AVL) of 70 can use 90% of global supply
- An engine with no MN requirement, like **the ME-GI can use all LNG qualities**

Source: Shell International

Port to Port Operation

Rough weather conditions



Measurements from LNG tanker in service:

- Rolling ship with twin engine
- Propeller torque variations
- Wind speed: Up to 18 m/s.
- Waves: 9.5 metres from portside aft on ship



First ME-GI Order

For two 3,100 TEU LNG-powered containerships



Vessel technical specifications

Length Overall:	764 ft.
Breadth:	106 ft. (Panamax)
Depth:	60 ft.
Draft:	34 ft.
Speed:	22.0 kts

Propulsion plant

Main Engine Type:	Dual Fuel Slow Speed (x1)
Main Engine Model:	MAN 8L70ME-C8.2-GI
Main Engine MCR:	25,191 kW x 104.0 rpm
Main Engine NCR:	21,412 kW x 98.5 rpm
Aux Engine Type:	Dual Fuel Gensets 3 x 9L28/32

Scheduled delivery for the first ship: Q4 2015 / Scheduled delivery for the second ship: Q1 2016

ACD 18398, FAT MOM/Test data for TOTE H6496 HP Pump Skid



First engine delivered June 2014

8L70ME-GI for TOTE

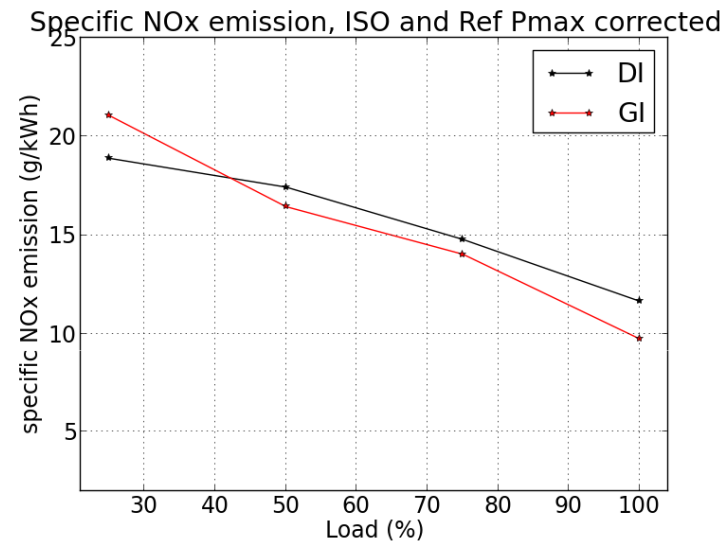
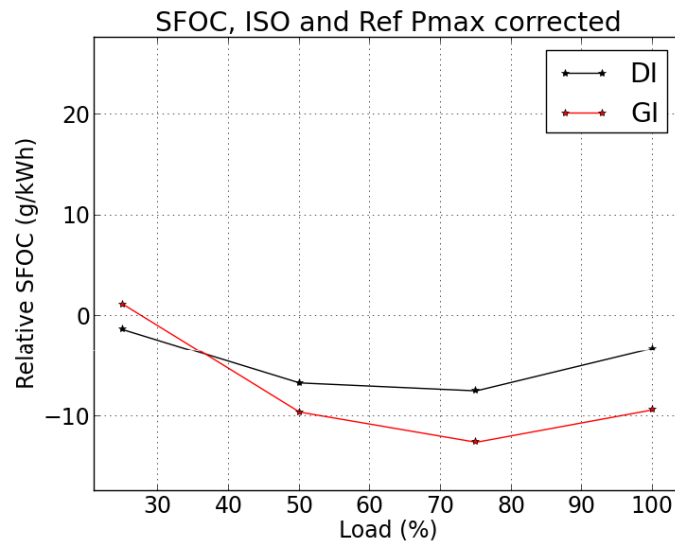


Conclusions on the FAT test results done at Doosan:

- ME-GI concept available and confirmed
- Performance and emissions overall meet expectations
- Operation of the pilot fuel injection confirmed to 3.4% Guaranteed 5%
- Operation on low load on gas confirmed to 10% Guaranteed 15%
- Service: Q4 2015

GI Latest Performance Results

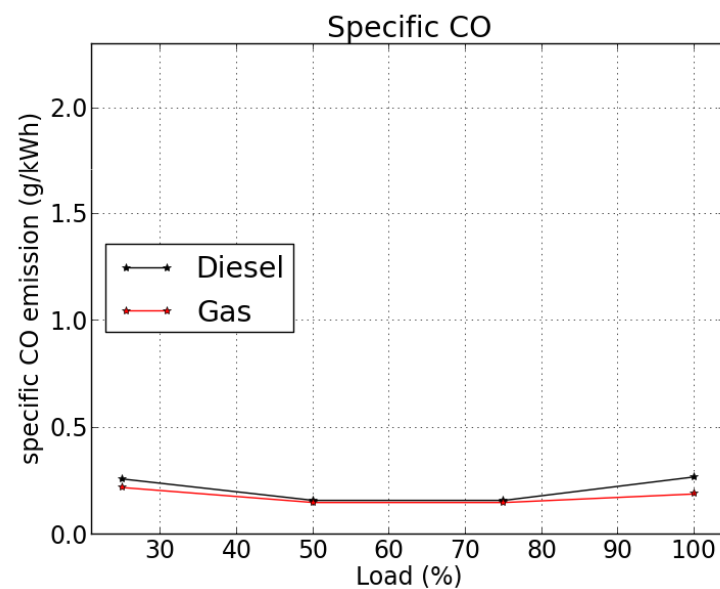
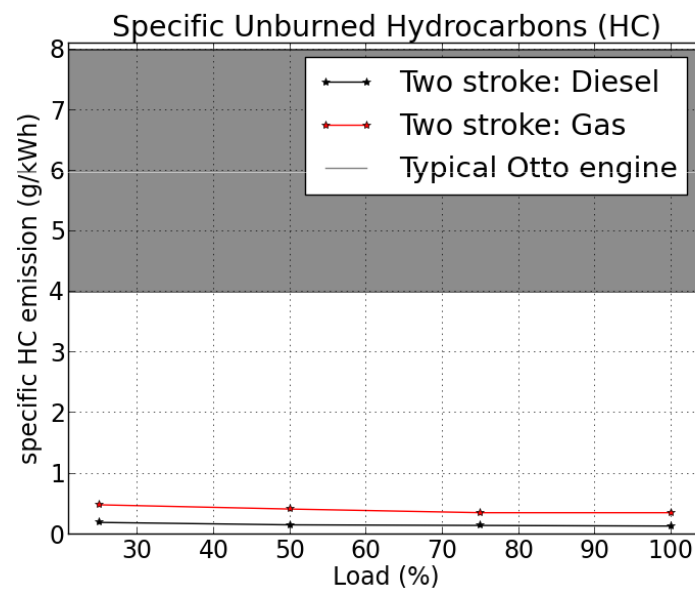
Gas versus Diesel: SFOC



Test #	Diesel atomizer	Gas atomizer	Δ SFOC [g/kWh]	Δ Nox [g/kWh]
DI	GI-4	--	0	0
GI	GI-4	GI-21	- 4,8	- 1.0

GI Latest Performance Results

Gas versus Diesel: Emissions



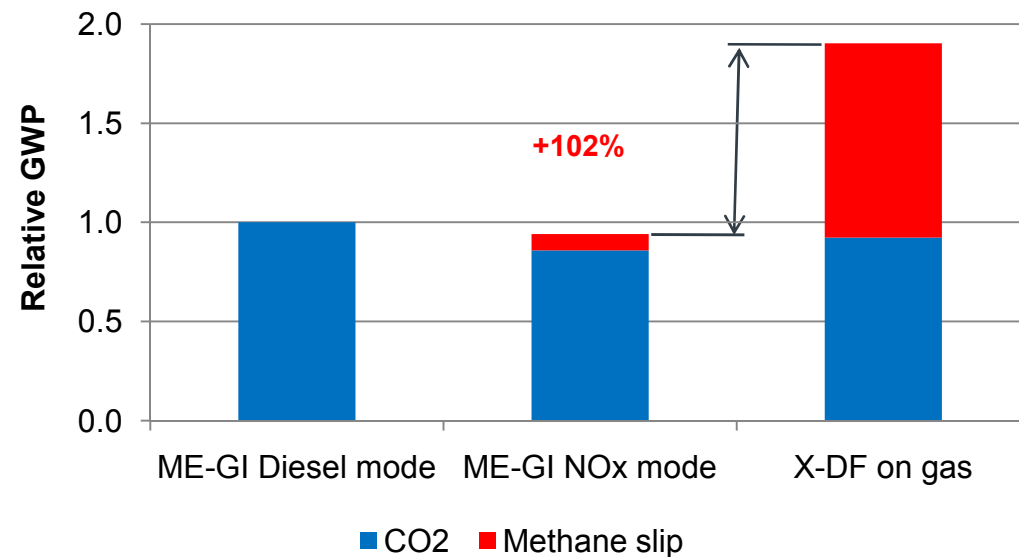
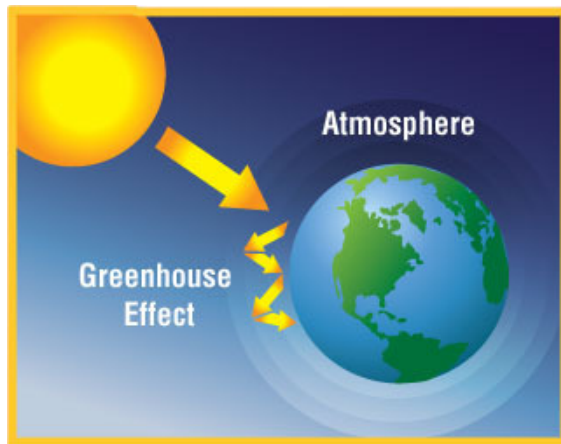
*Source: Nielsen, J. B., Stenersen, D., "Emission factors for CH₄, NO_x, particulates and black carbon for domestic shipping in Norway", MARINTEK report, MT22 A10-199, Klima og Forurensningsdirektoratet, Norway (2010)

Global Warming Potential, 20 Years

ME-GI vs X-DF



Global Warming Potential, GWP20



GWP (Global Warming Potential in CO₂ equivalents), values from the latest two IPCC reports and for the two most commonly used timeframes:

	GWP 20 years	GWP 100 years
2007 IPCC	72	25
2013 IPCC	86	34

IPCC: Intergovernmental Panel on Climate Change

Specific emission (g/kWh)	CO ₂	Methane
ME-GI Diesel mode	526.4	0.0
ME-GI NOx mode	452.4	0.5
4-stroke DFDE on gas	485.7	6.0

http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml and <http://www.ipcc.ch/report/ar5/wg1/>

ME-GI Gas Fuel Mode

Port to port in dual fuel mode



Fuel oil only mode

- Operation profile as conventional engine

Dual fuel operation mode

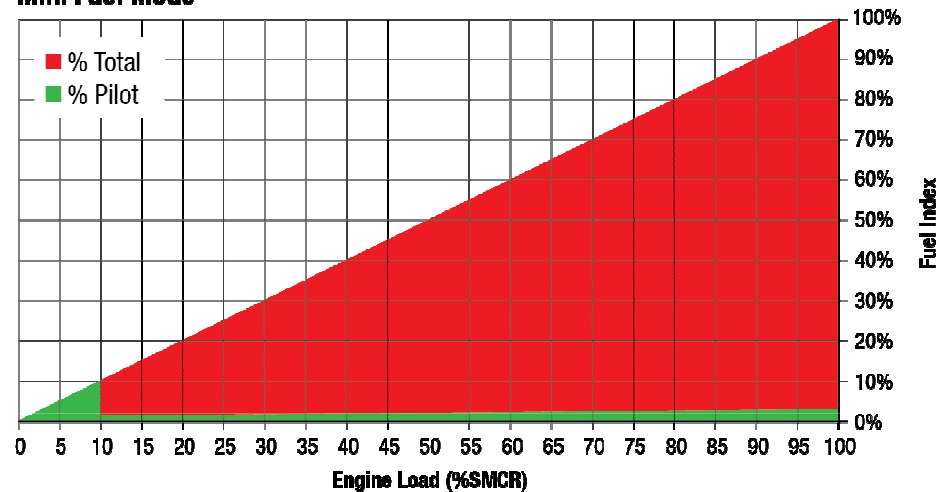
- No fuel slip
- No knocking problems
- Insensitive to gas fuel
- Unchanged load response

News:

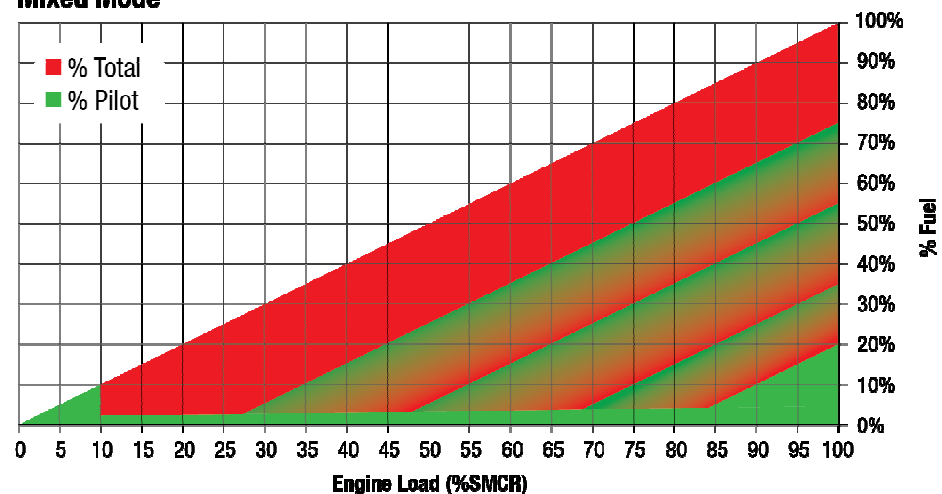
Reduced pilot oil amount 5% → 3%

Reduced load on gas → 10% load

Min. Fuel Mode

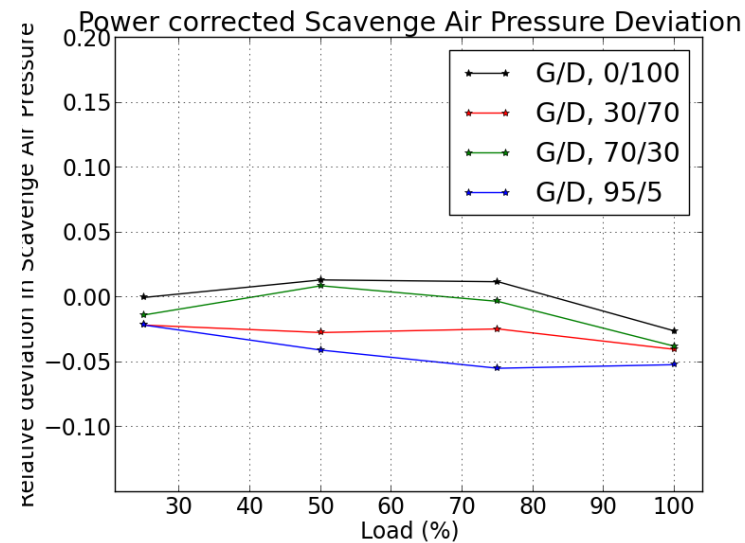
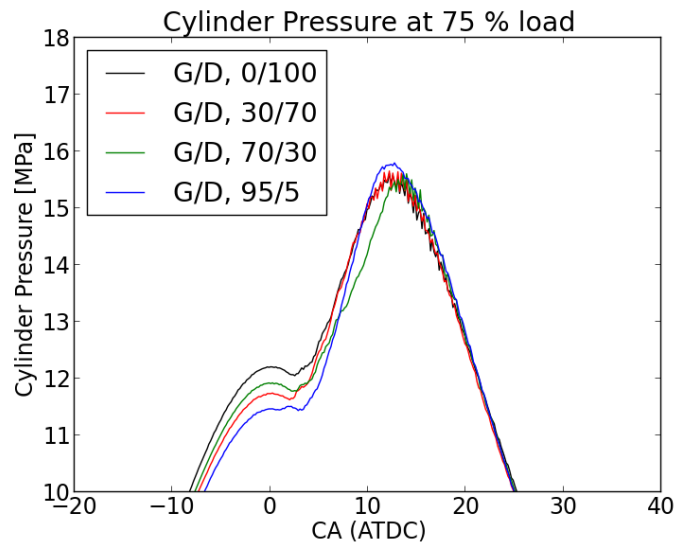
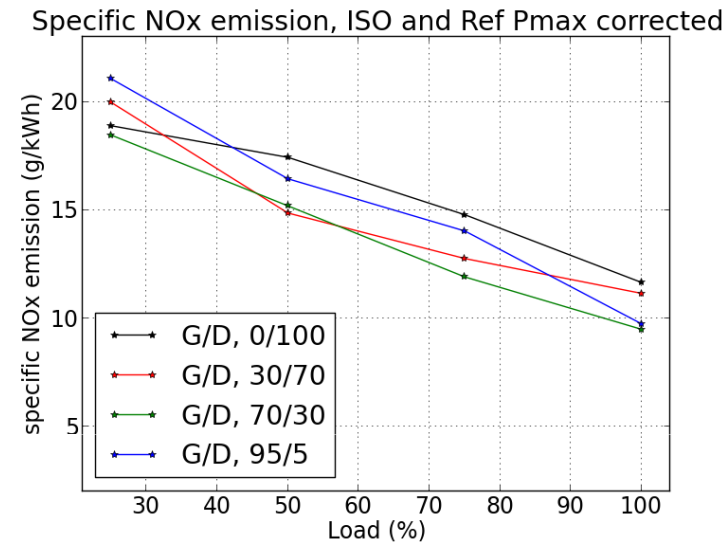
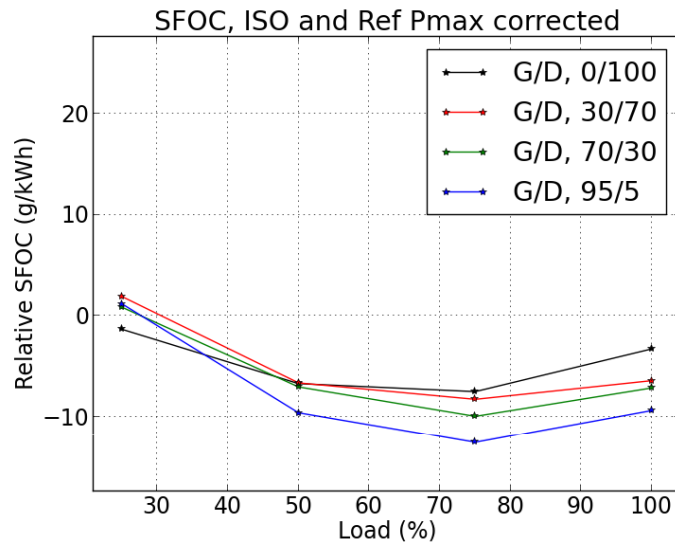


Mixed Mode



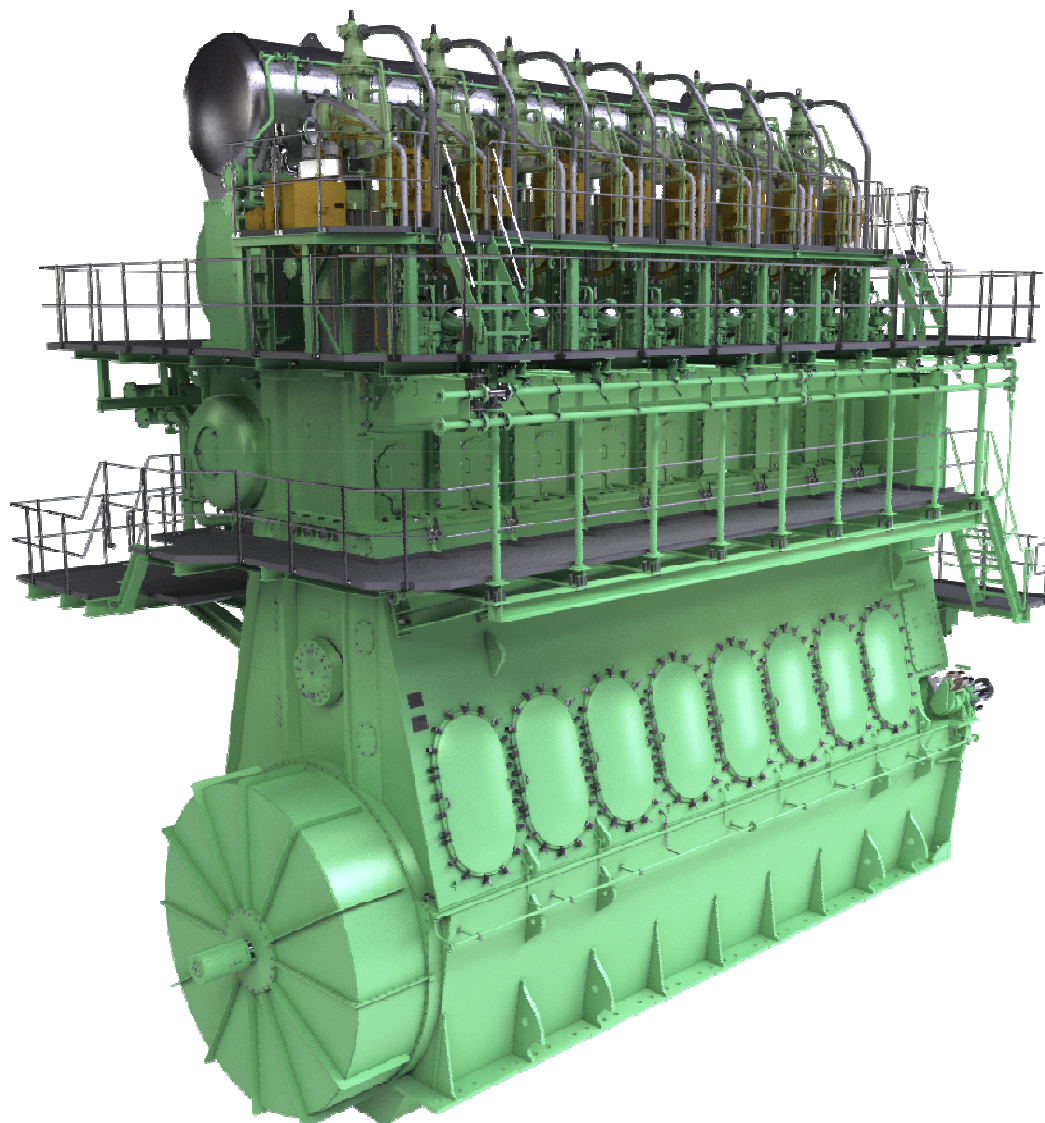
GI Latest Performance Results

Specified Dual Fuel Operation: Performance



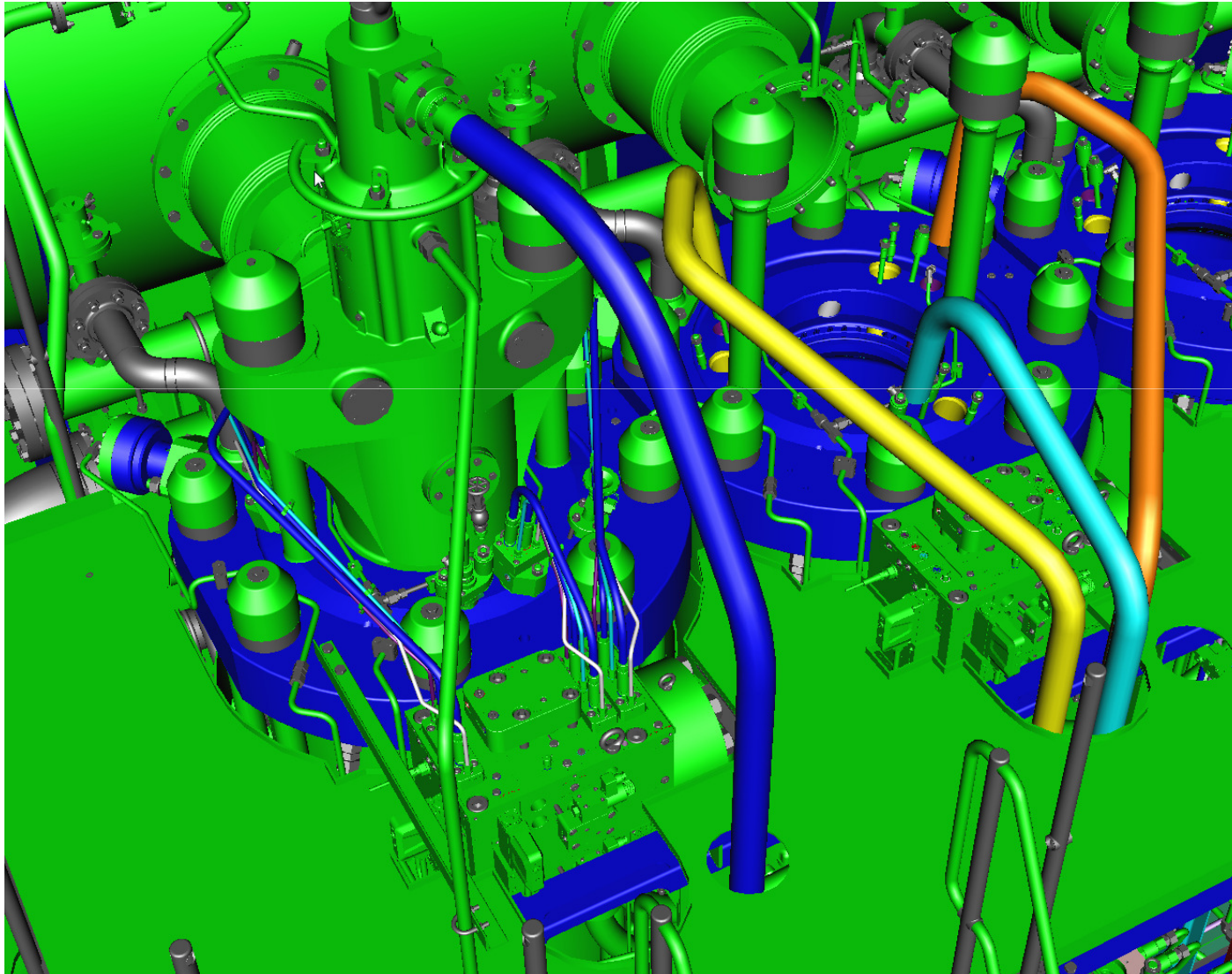
Dual Fuel engine design

ME-GI /ME-LGI



GI Latest Design Status

Cylinder Cover & Gas Block

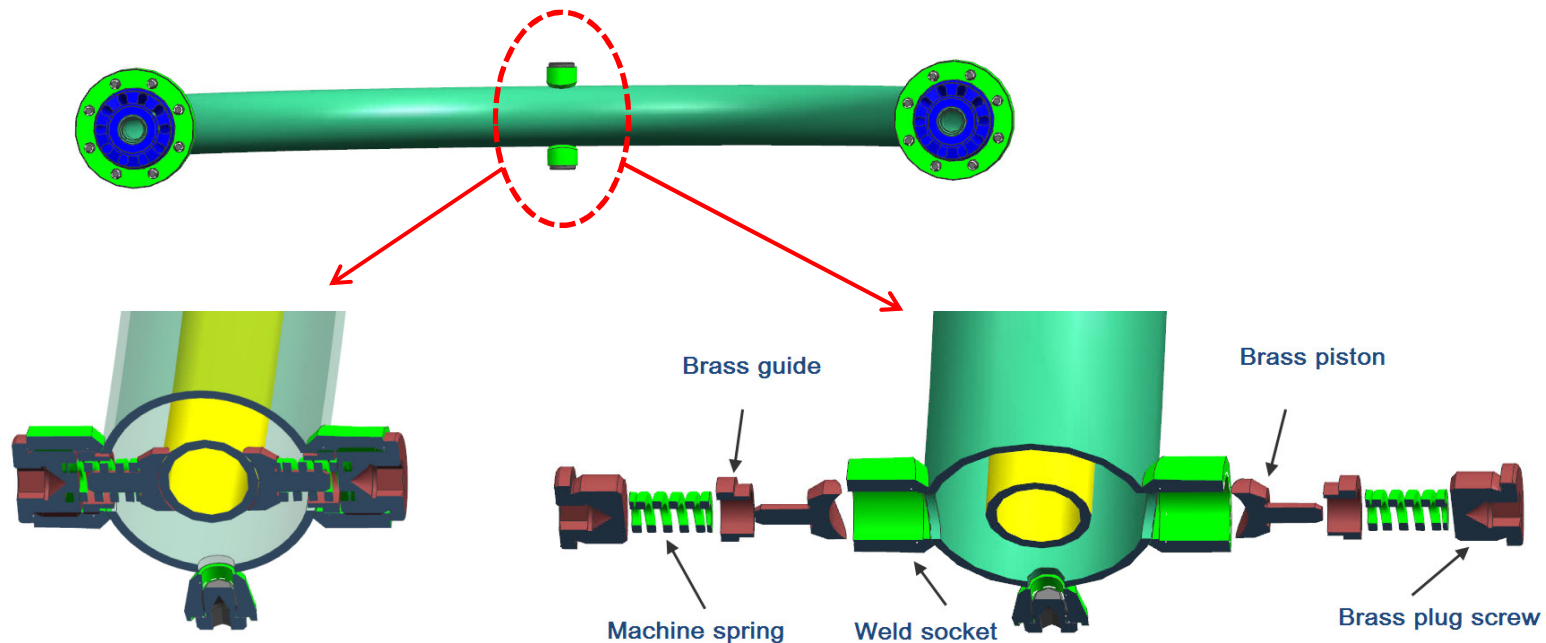


GI Latest Design Status

Chain Pipe, Inner Support



- Good vibration damping properties due to the transverse supports
- Vertical flexibility by the springs design
- The wear parts can be replaced and checked from the outside
- No wear and stress added to the inner pipe due to the brass piston

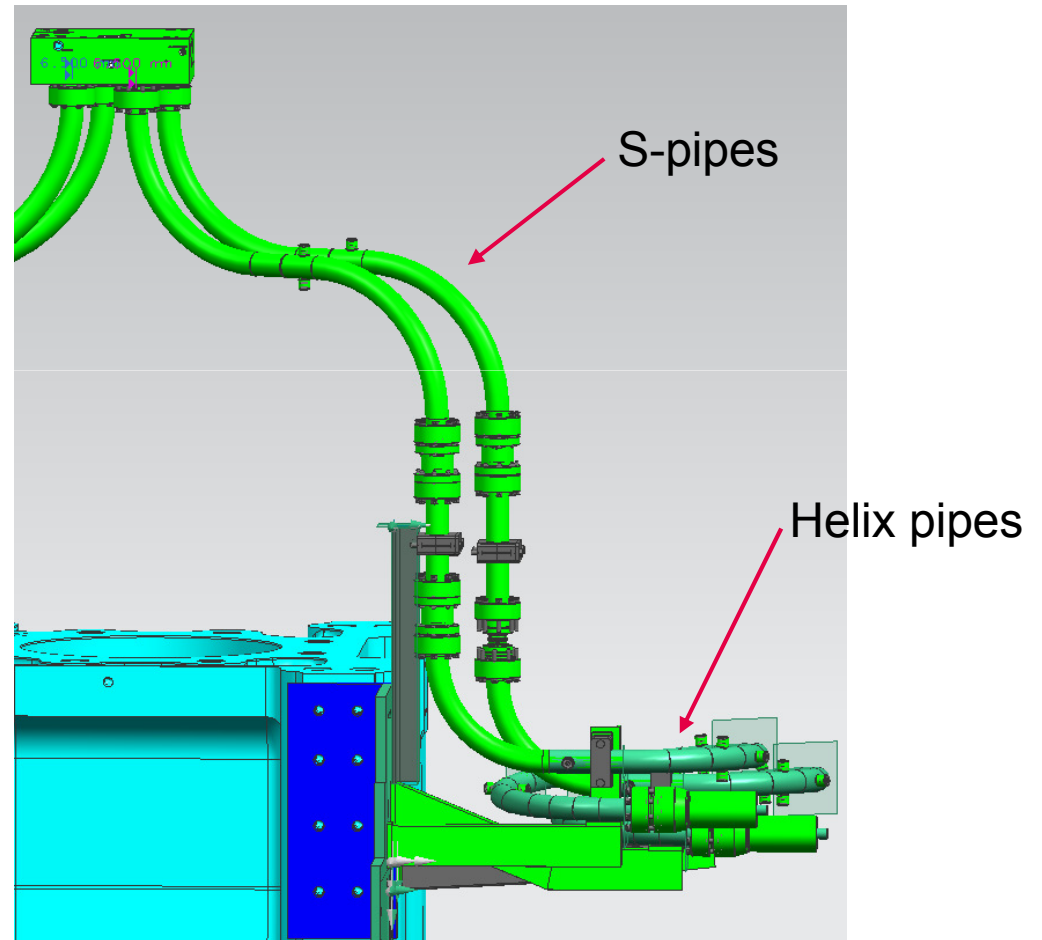
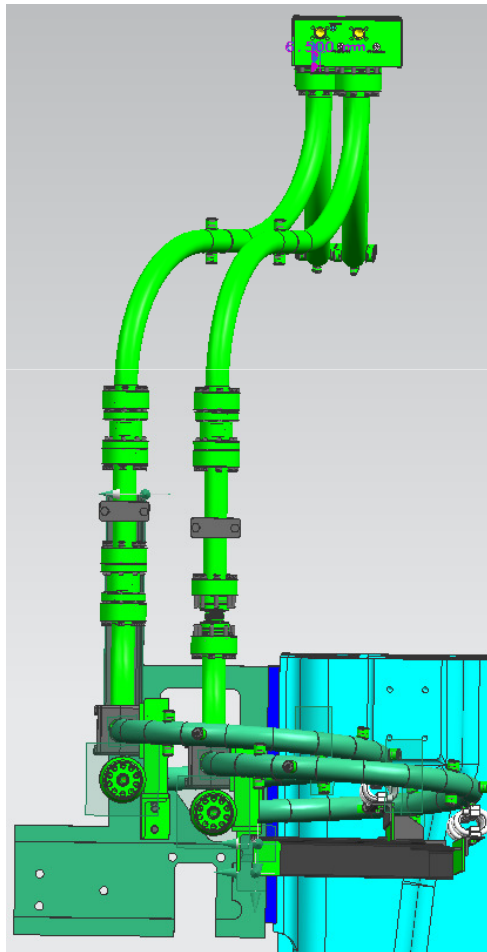


GI Latest Design Status

S-Pipes & Helix Pipes



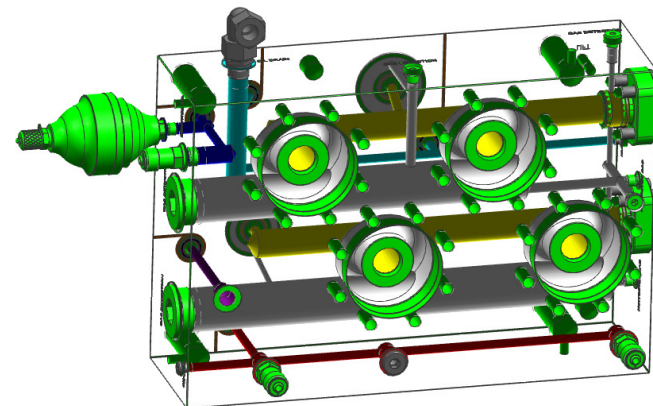
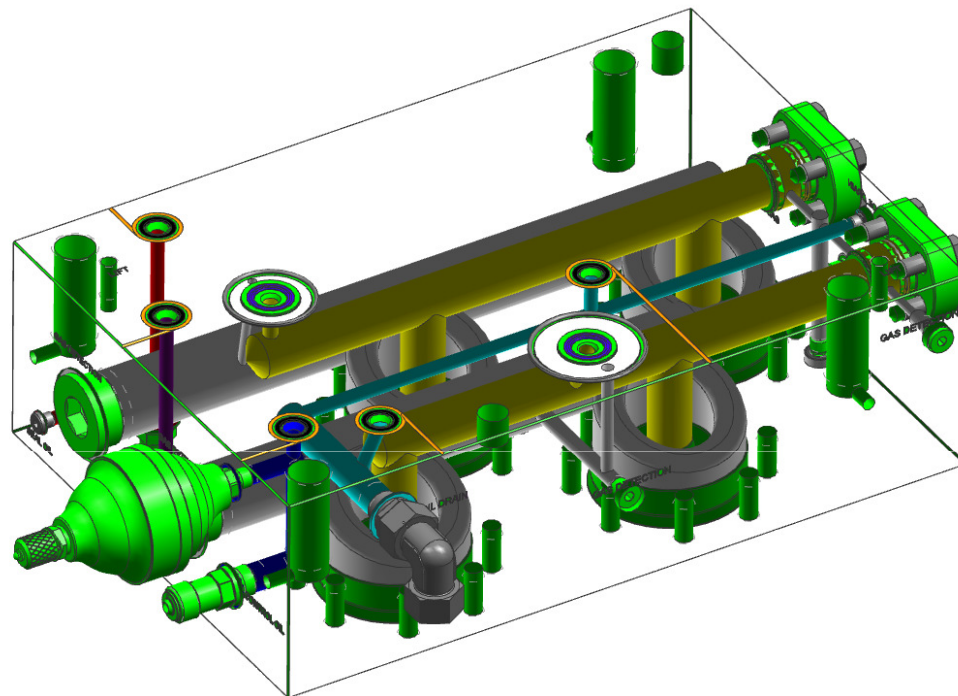
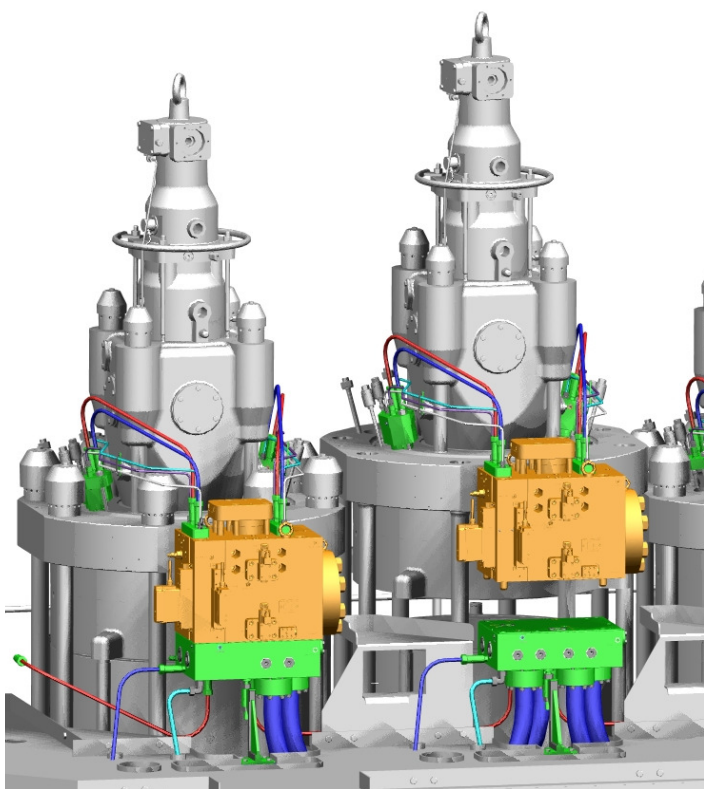
- Connection to ship installation via flexible pipe



ME-GI Adaptor block



Adaptor block incl. chain
pipes, remains the on
engine in overhaul

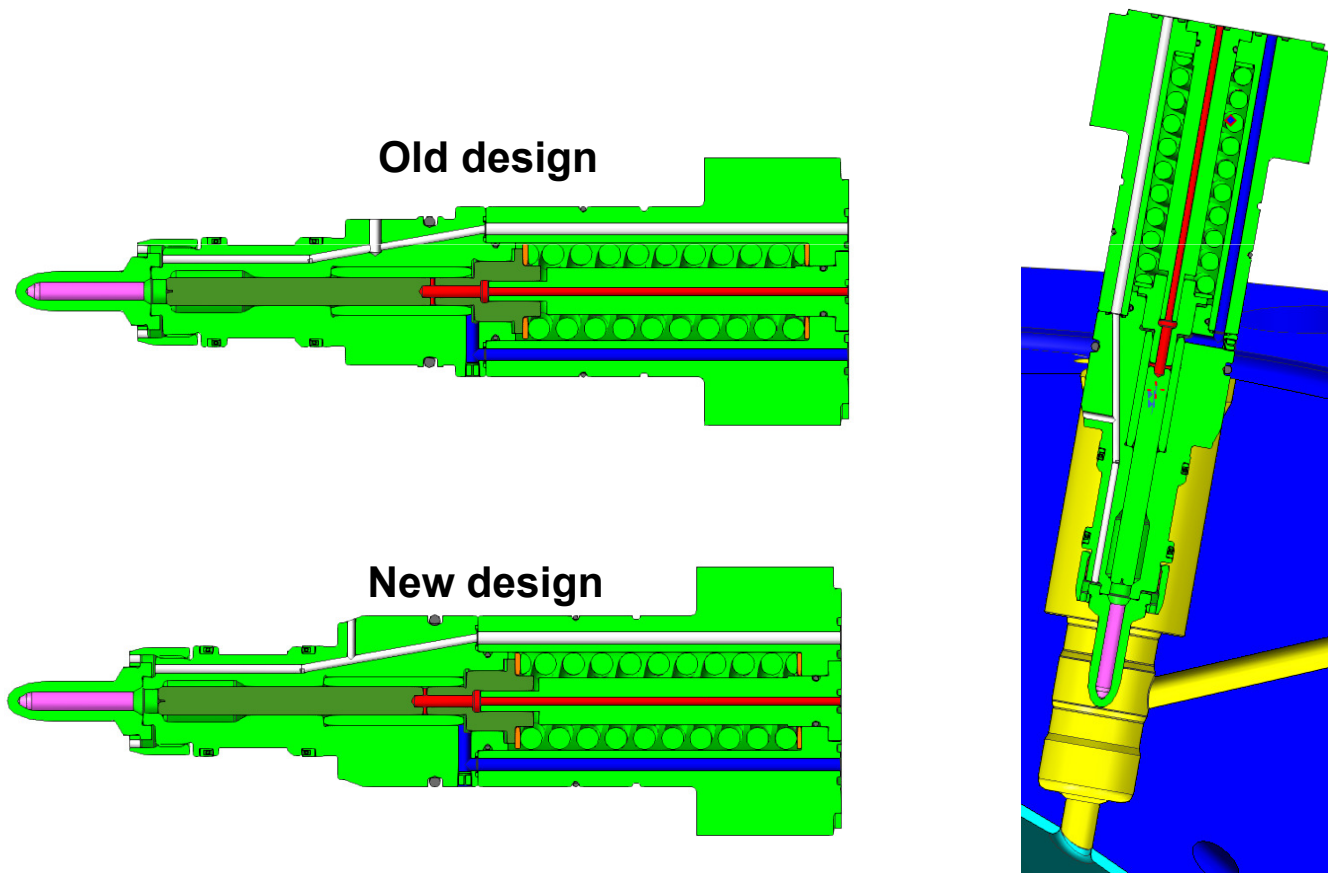


GI Latest Design Status

Gas Injection Valve

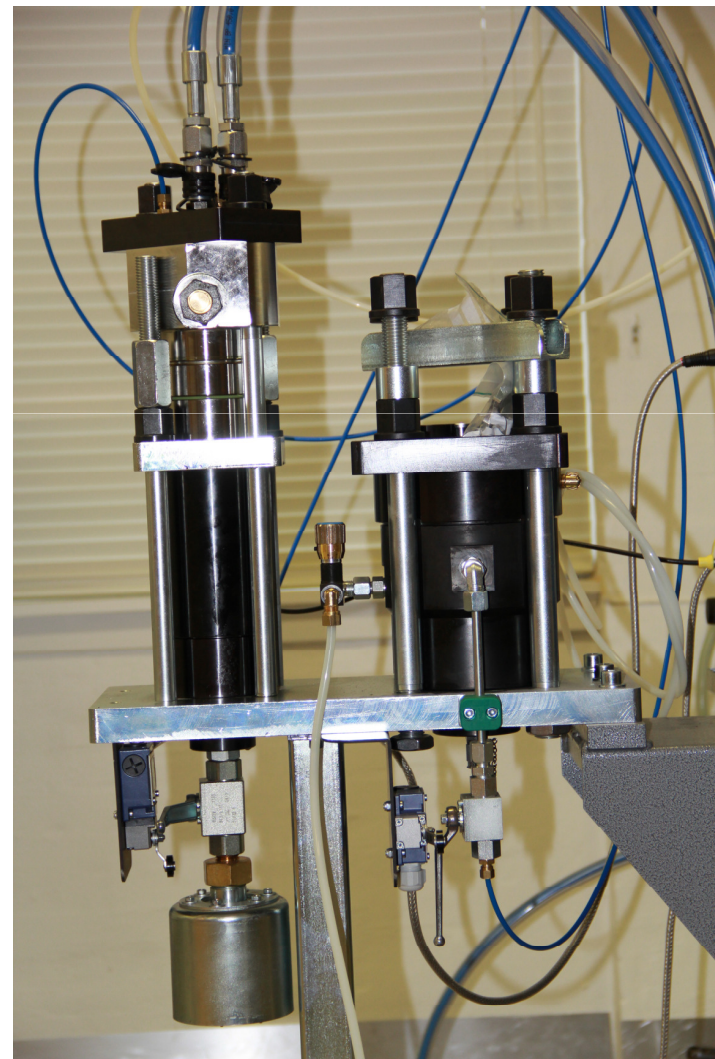
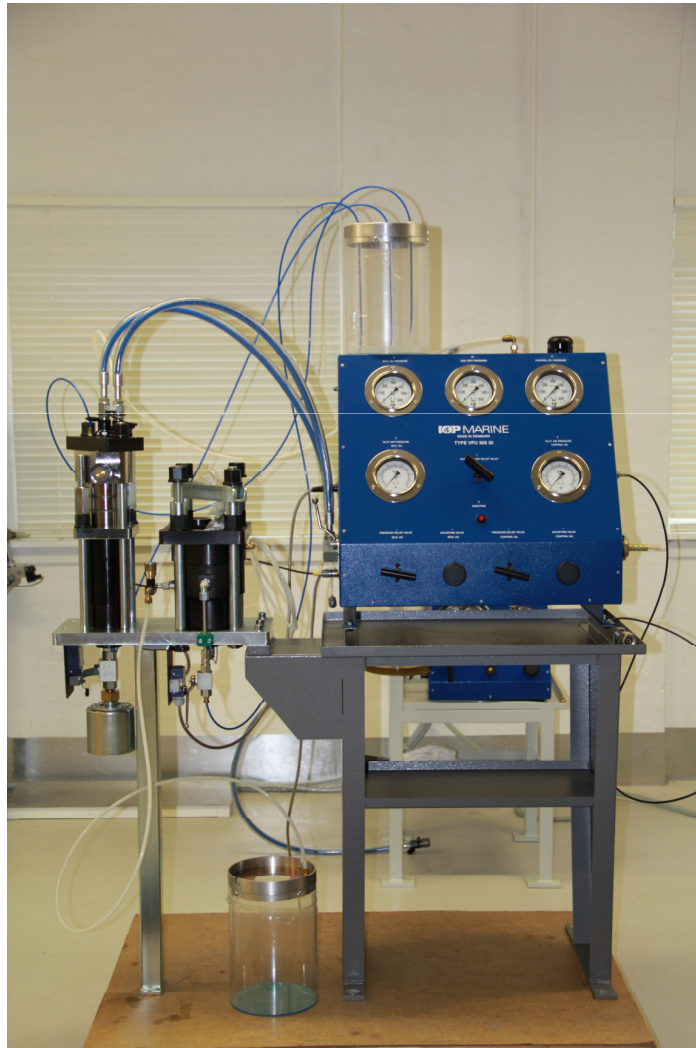


- Outside geometry of spindle guide is updated to improve guidance during mounting
- Possible contact between spindle guide and cylinder cover is avoided



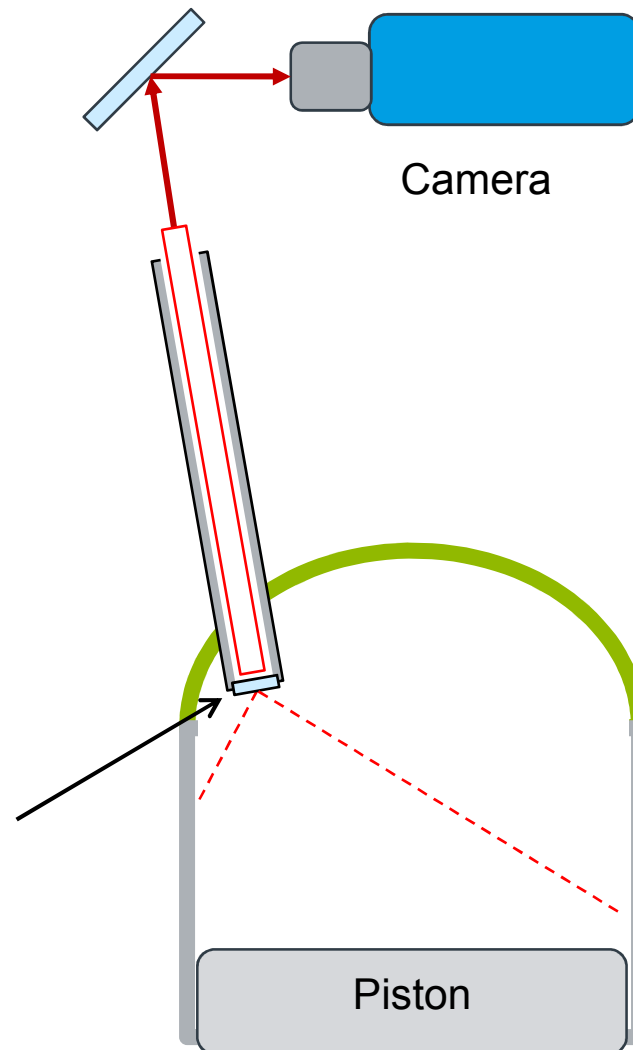
Gastester

Test of gas injection valve and window valve



Fuel Injection and Ignition

High-speed movie of pre-injection light

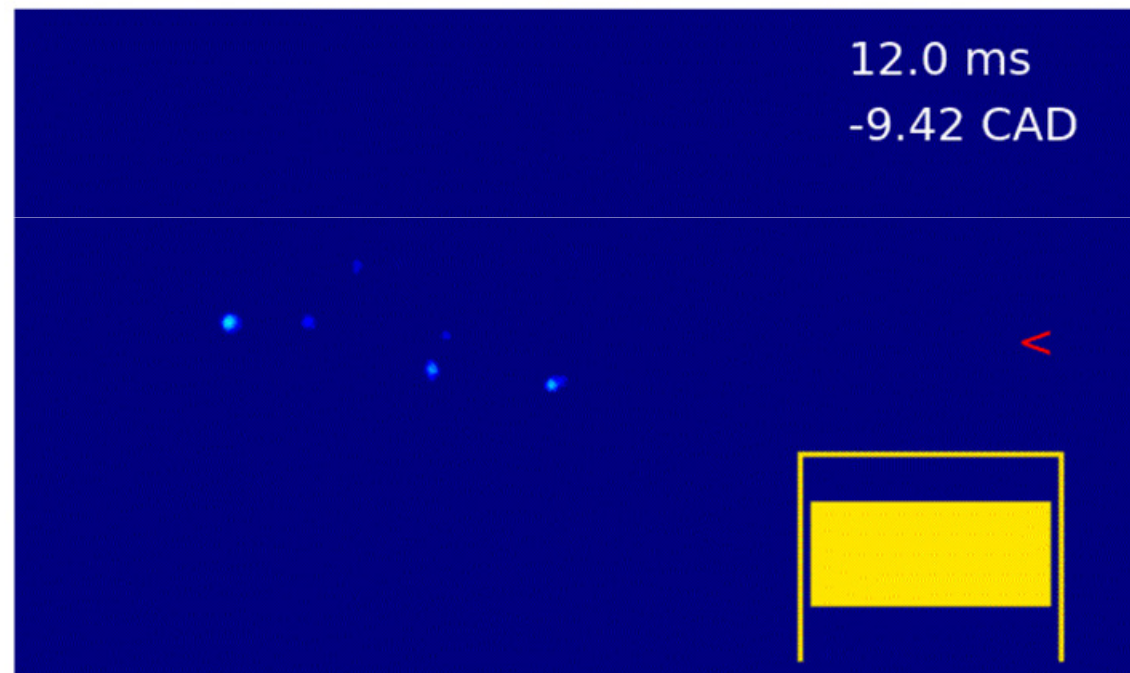
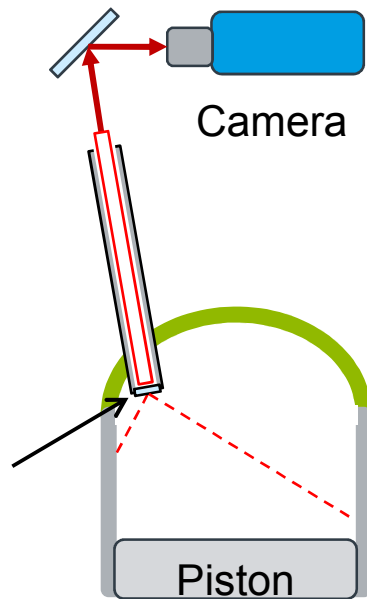


Fuel Injection and Ignition

High-speed movie of pre-injection light



-15 to +5 CAD

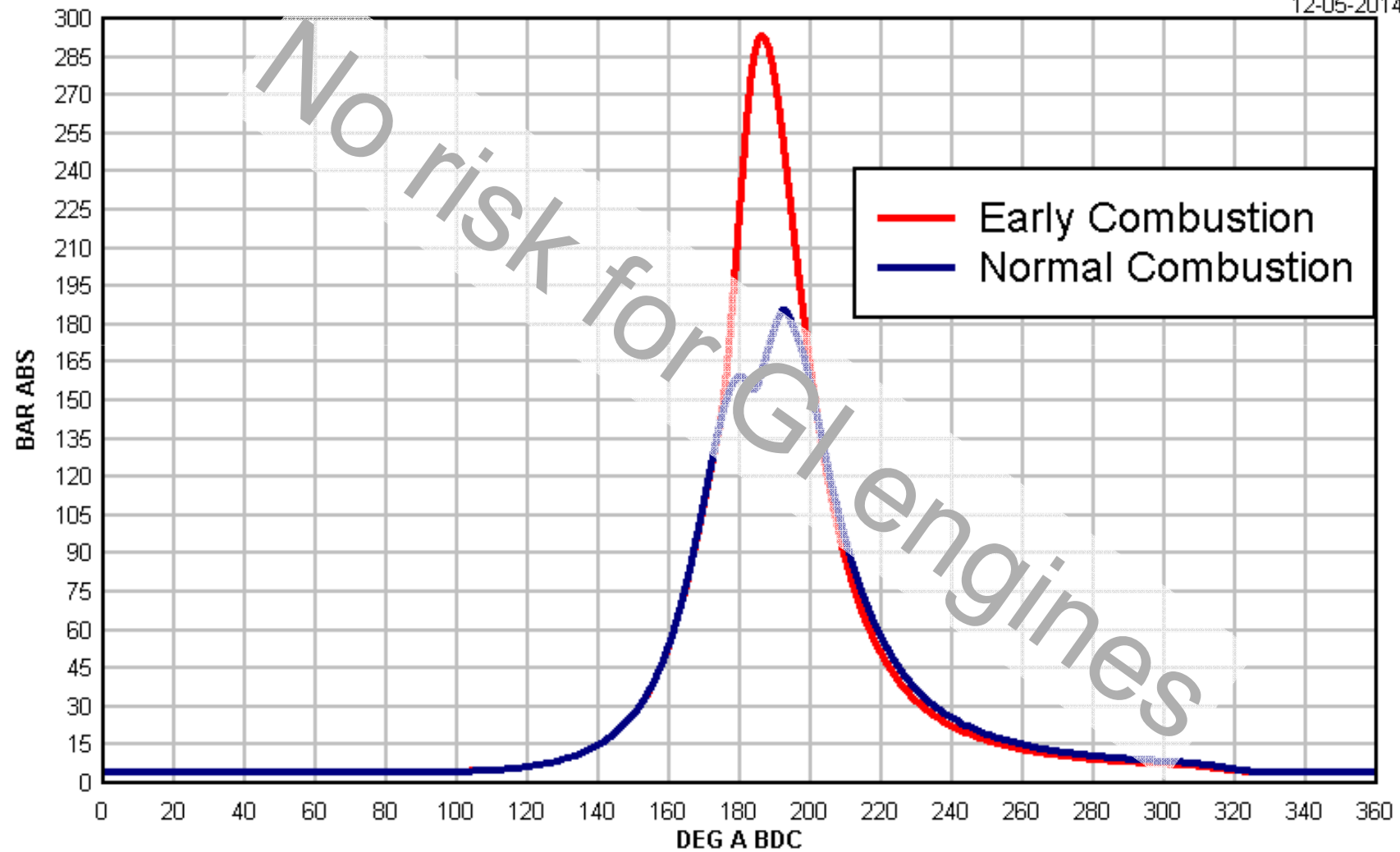


GI versus DF

Consequences of normal and early injection



12-05-2014



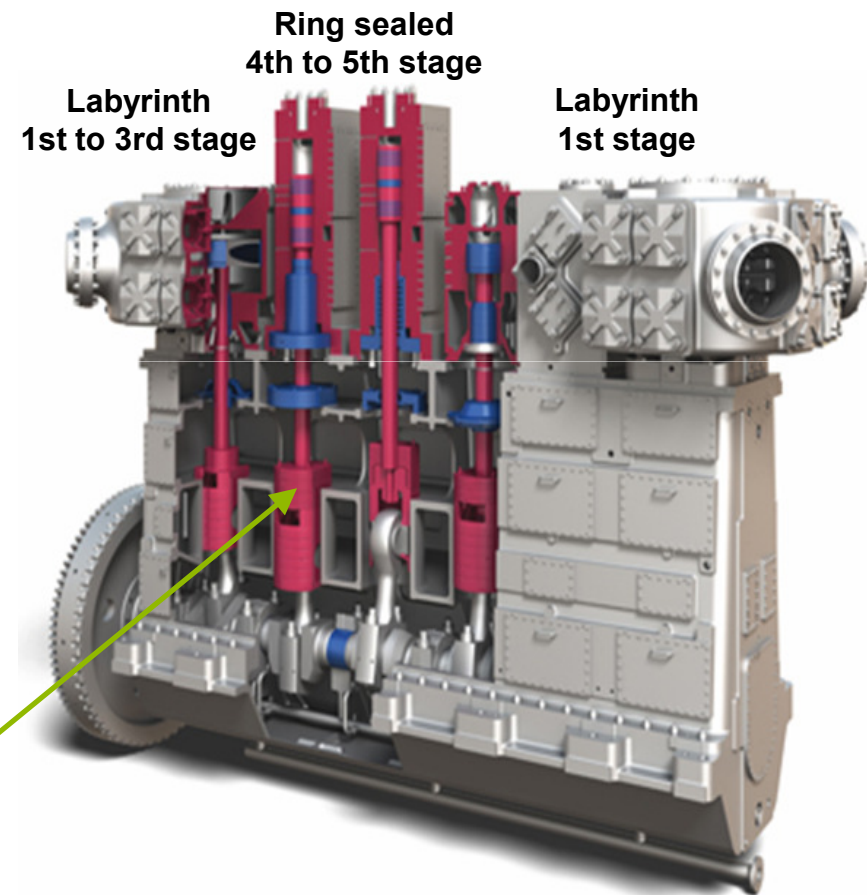
08-cyl-pres.dpl1

Burckhardt Laby®-GI

Fuel gas compressor type 6LP250-5S



- Combining LNG BOG and high pressure process compression technology
- Optimal selection of compressor sealing system
- Fully balanced, single casing, slow speed vertical frame design
- Gas-tight compressor casing



Balancing weights



Laby-GI: Golar Freeze Operating Data

Availability – Reliability

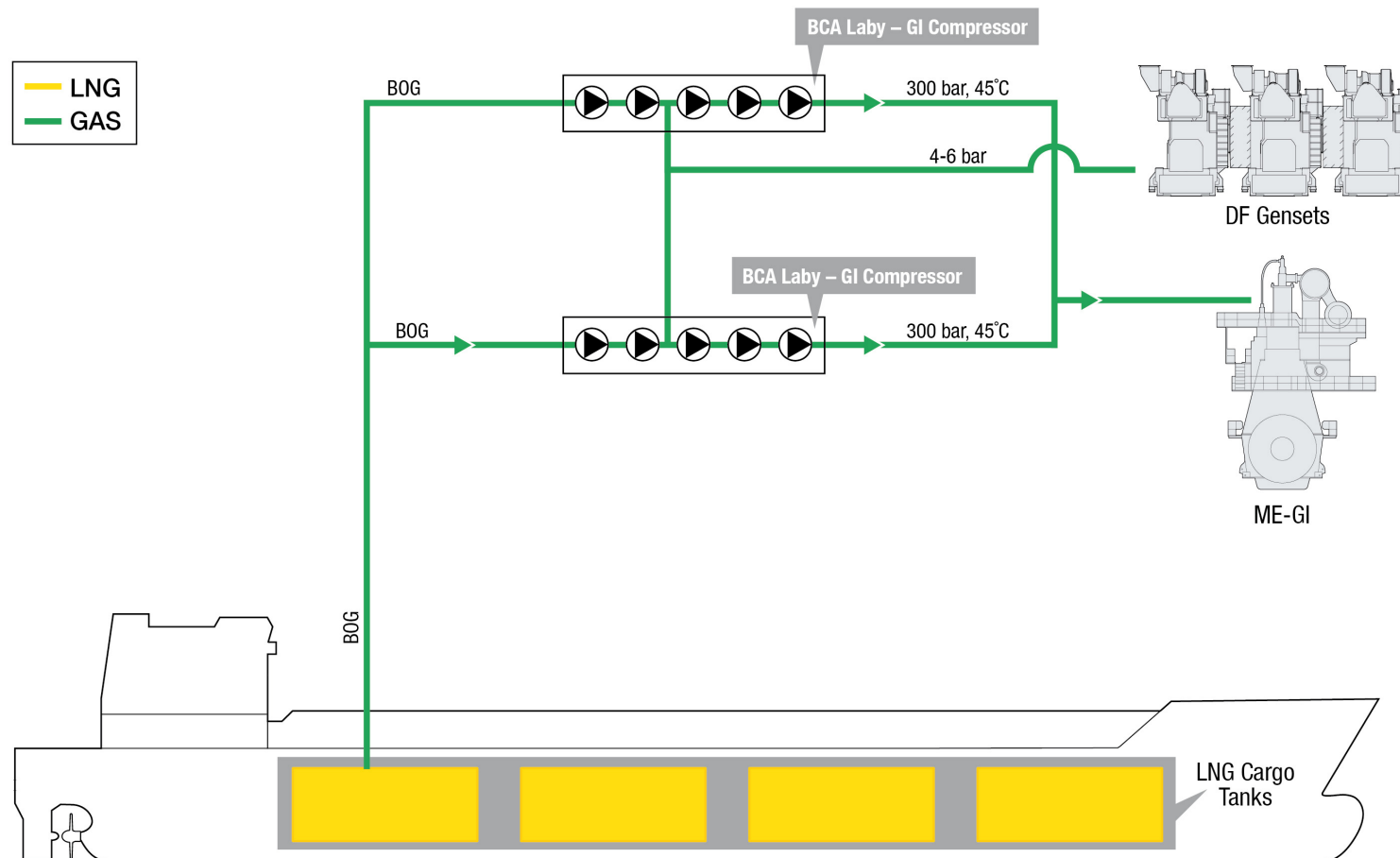


Period from 05.11.2012 to 05.11.2013

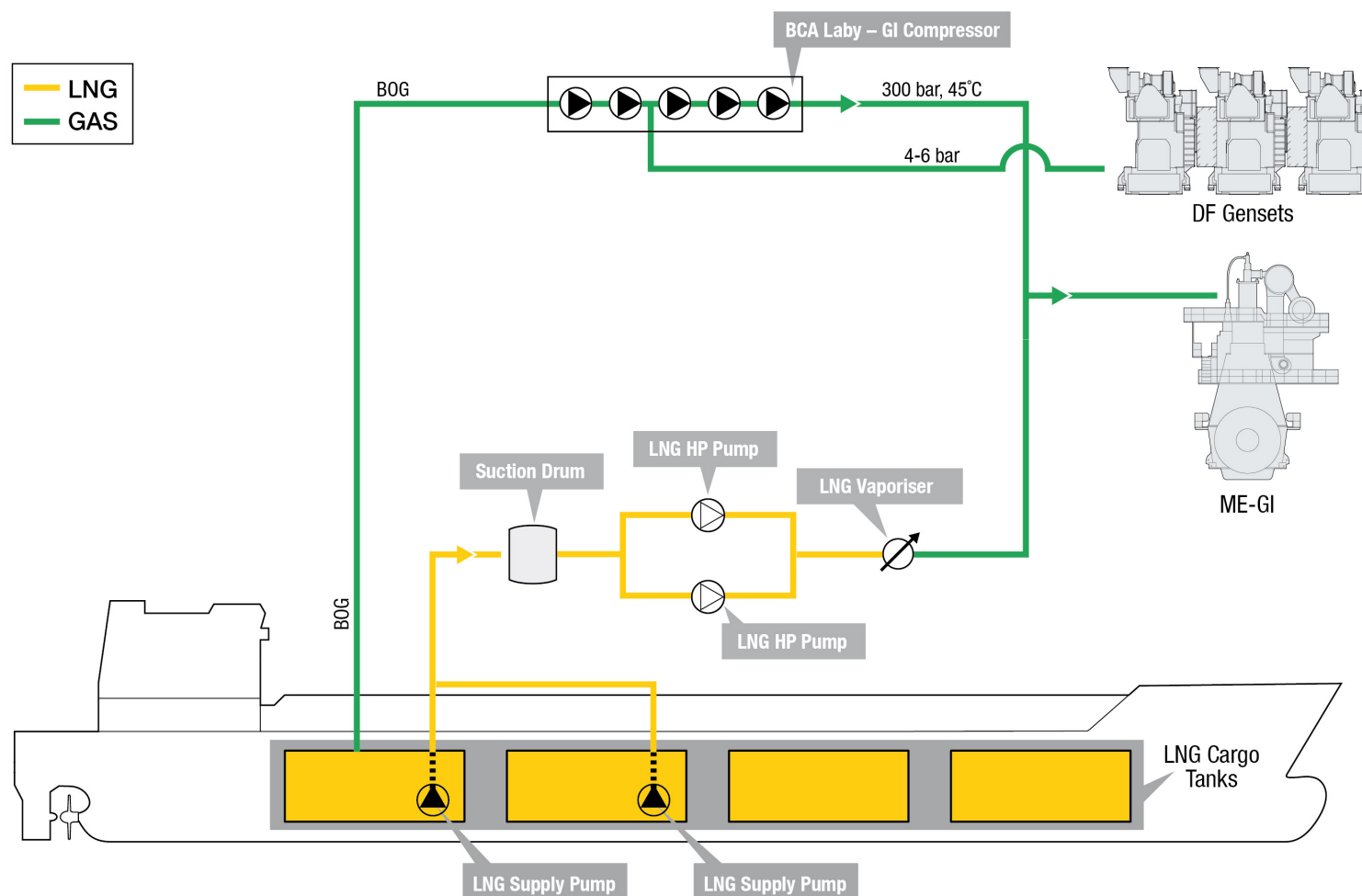
- Total running hours per year (or per 8,700 hrs. period):
Total 5,517 hrs., 15.12 hrs./day
- Total hours standstill/not running:
Total 3,243 hrs., 8.88 hrs./day
- Total hours shut down for regular maintenance:
Approx. 120 hrs*, 5 days
- Total hours shut down due to unforeseen problems:
NIL *Overhaul after 3 years of operation

Availability $8,760 - 120 / 8,760 = 98.6\%$
Reliability $8,760 - 0 / 8,760 = 100\%$

The compressor solution. 2 x 50% Laby-GI compressors - sufficient

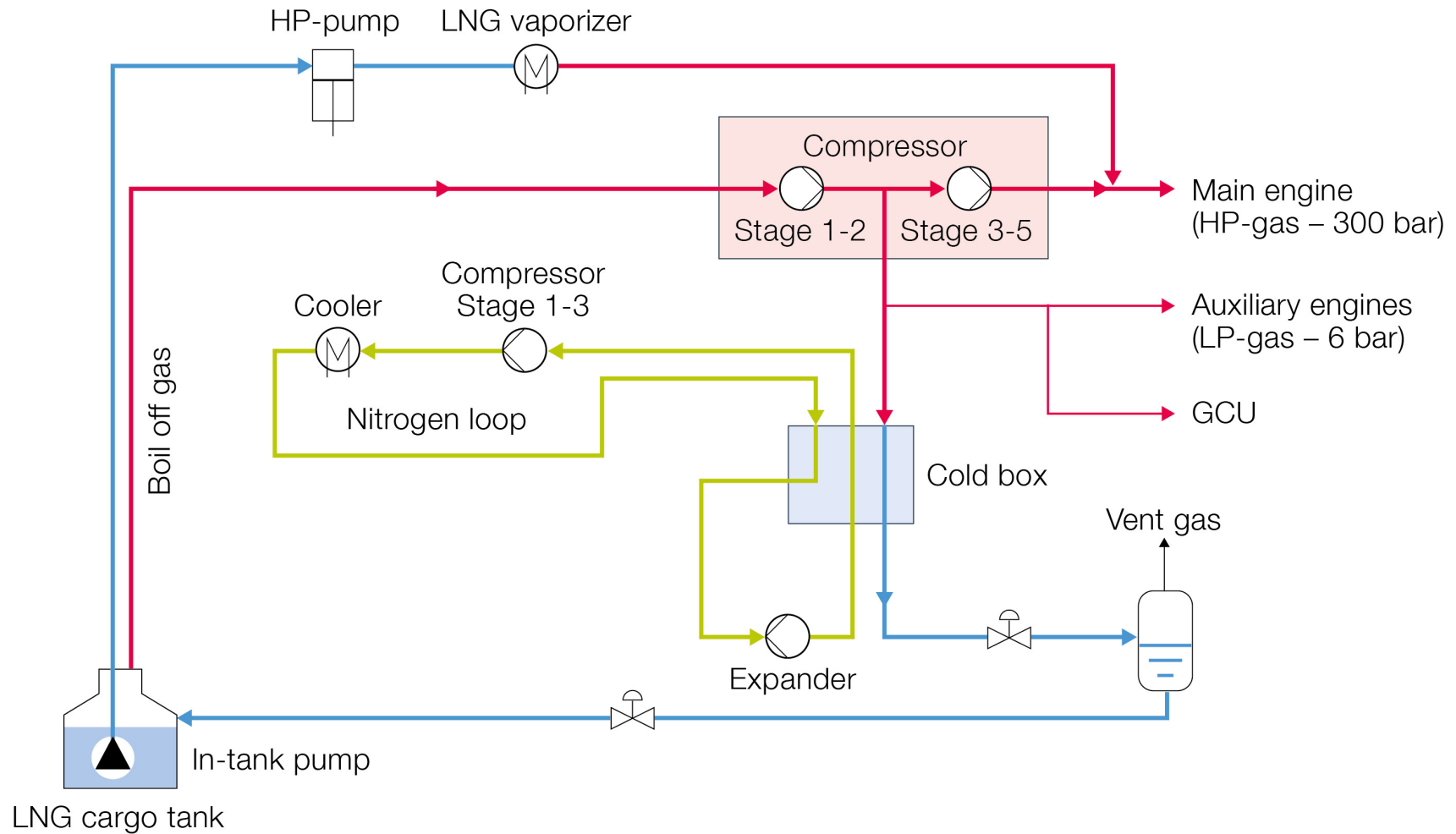


1 x 100% Laby-GI compressors - sufficient 2 x 100% HP cryogenic pumps



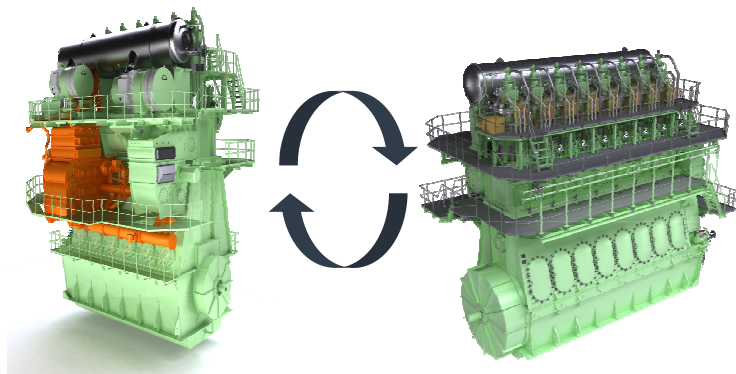
BOG Reliquefaction System (LNGRS)

HP-Compressor and HP-pump



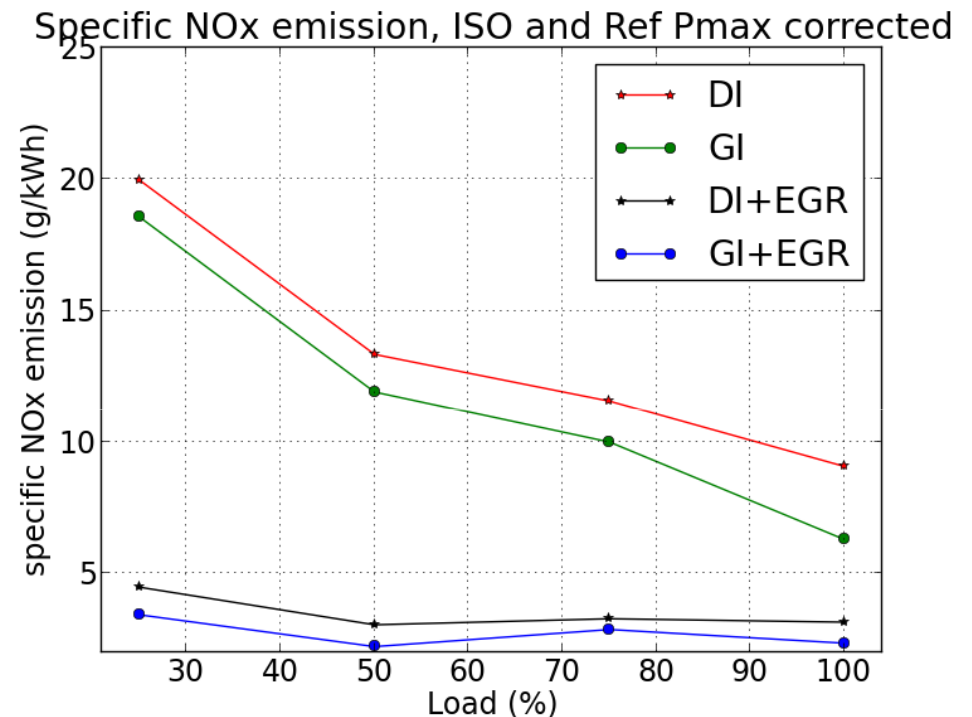
New Engine Platforms

Test results research engine



Test on research engine:

- ME-GI engine reacts as expected during EGR operation
- **NO_x reduction is below Tier III level on both fuel oil and gas operation**
- SGC same or better than operation on MDO/HFO with EGR



Why do LNG carriers need either a SCR or an EGR to meet tier III?



Operating dual fuel engines on gas requires that gas is available, but this is not always the case for LNG carriers.

- When the charter requires to empty the LNG tanks.
- When the ships are going to Dockyard / Repairyard.
 - When the gas system is failing

EGR/SCR gives full fuel flexibility in Tier III areas, and avoid the need for towing boats.

**Using Low Sulphur HFO is also possible.
Lately we have learned that full redundancy in fuel choice is required.**

Do You Have Any Questions?



Rene Sejer Laursen

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