Svenskt Marinetekniskt Forum

2011

MAN Diesel & Turbo

LNG as fuel

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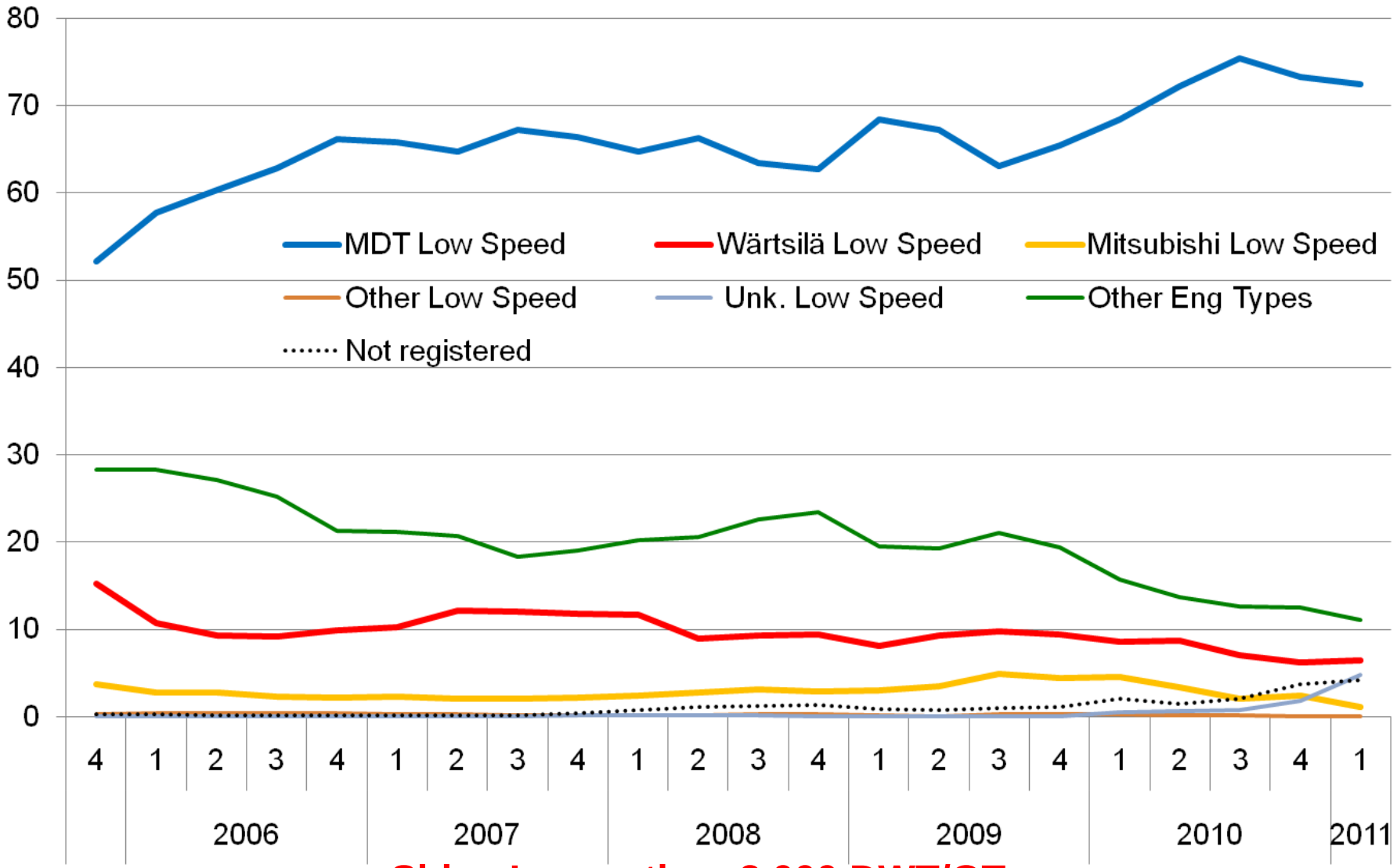
Agenda

0945	**1015**	Kaffe
		Föreläsning MAN B&W ME-GI
1015	**1145**	motorn
1145	**1245**	Lunch
		Visning av produktionen samt promenad till
1245	**1400**	Test centre
		Visning och testkörning av
1400	**1500**	motorn
		Transport till Diesel
1500	**1515**	House
		Kaffe, körning av motorn (om möjligt live körning,
1515	**1645**	annars video)
		Buss Diesel House -
1645	**2030**	Göteborg

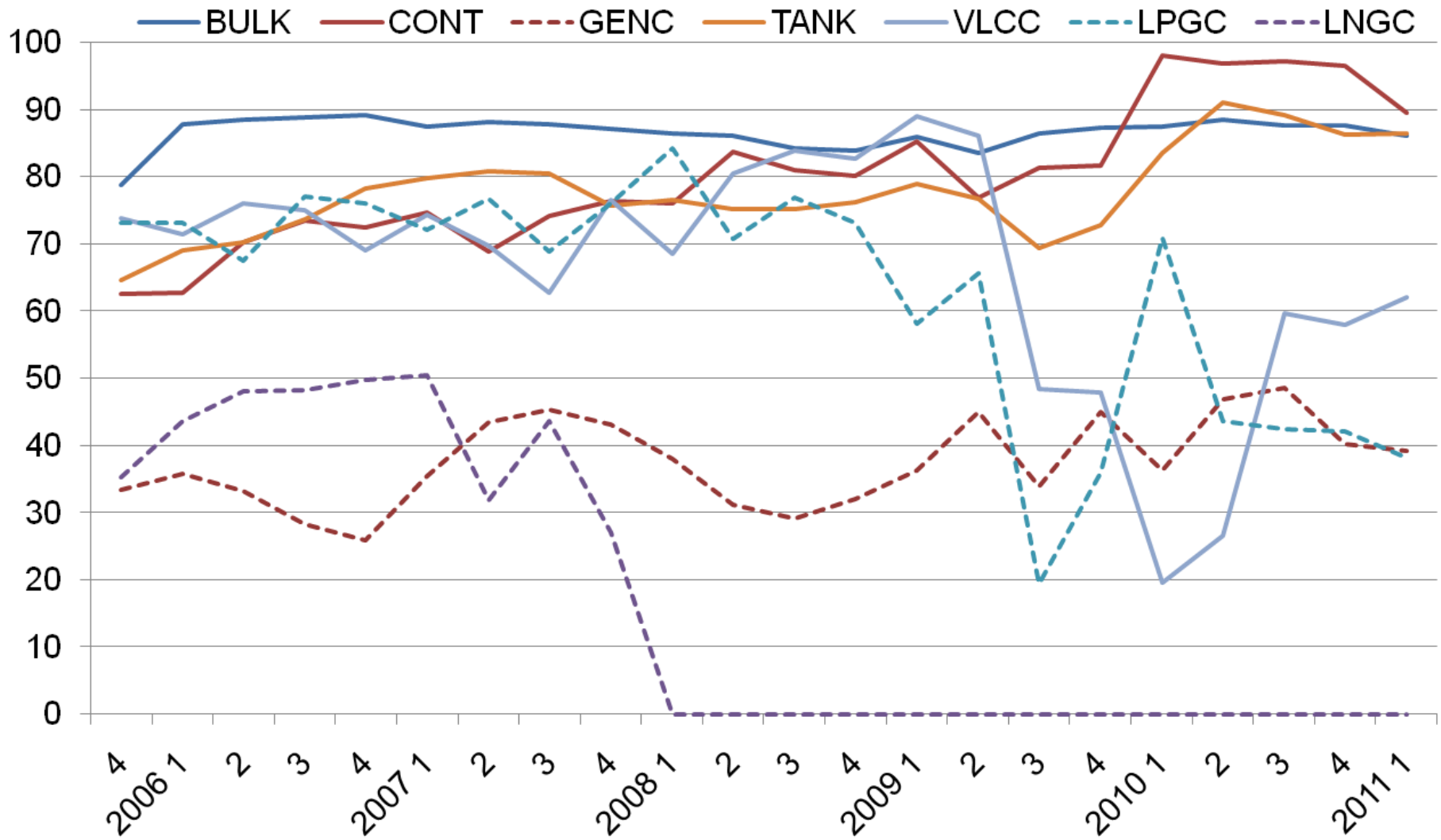
Market Shares
Contracting Four Quarter Moving



Ships Larger than 2,000 DWT/GT

Updated end February 2011 Source: IHS Fairplay

Market Shares Contracting Four Quarter Moving
MAN B&W Propulsion Engines

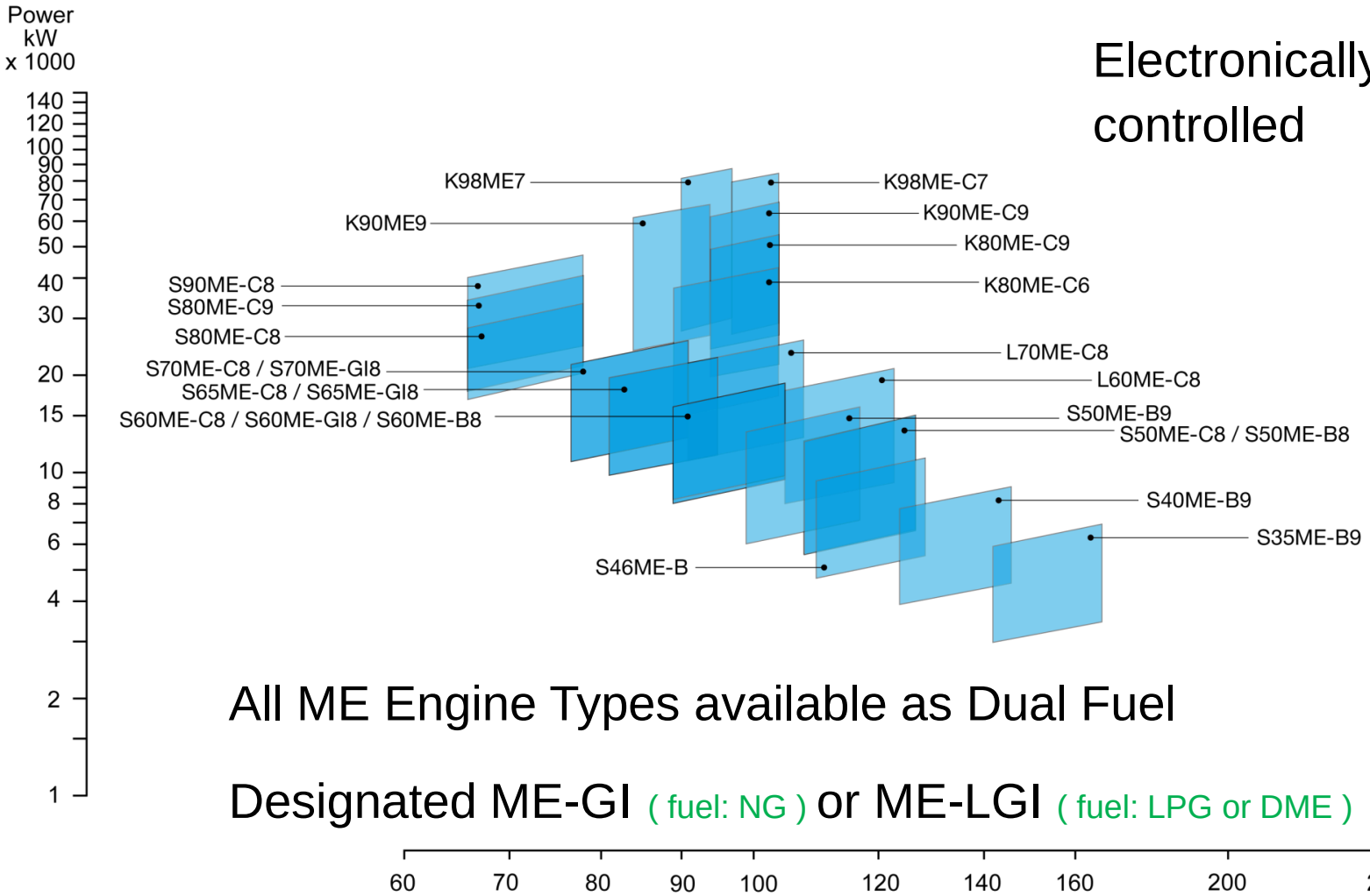


Ships Larger than 2,000 DWT/GT

Updated end February 2011 Source: IHS Fairplay

Marine Engine Programme 2010
Prefered for Tier II Compliance

Two-stroke Propulsion

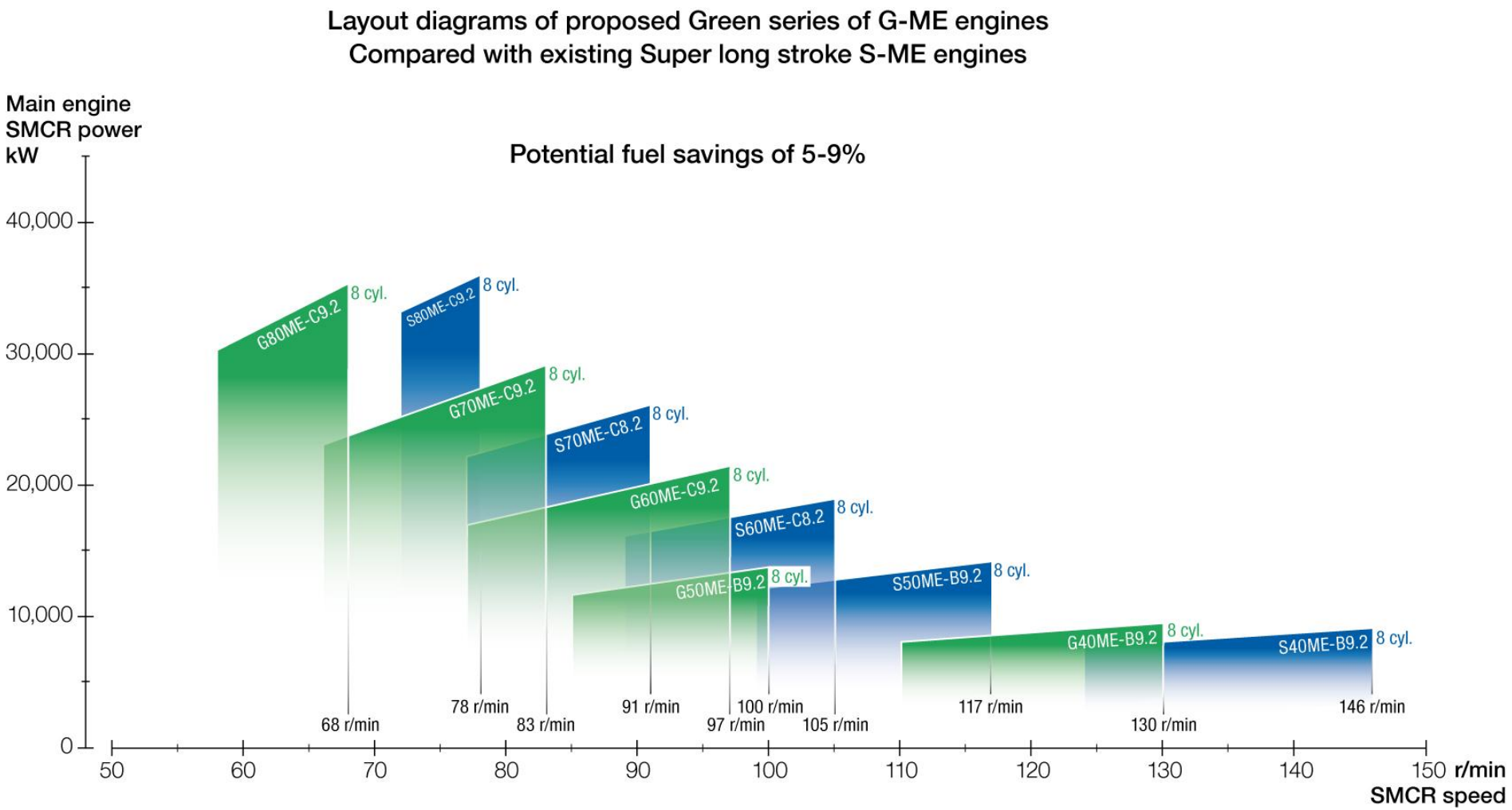


Electronically controlled

All ME Engine Types available as Dual Fuel

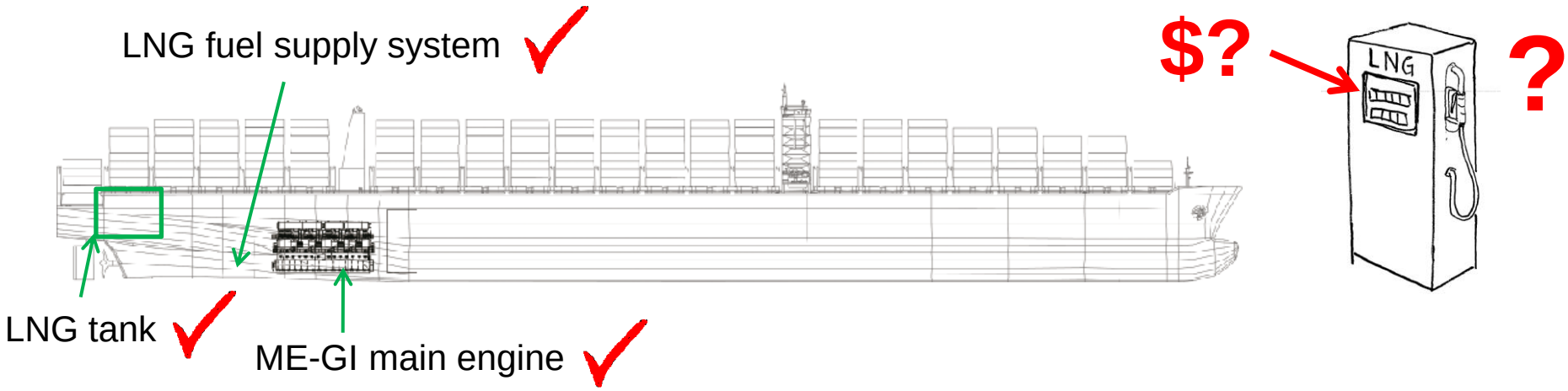
Designated ME-GI (fuel: NG) or ME-LGI (fuel: LPG or DME)

New G-engine type of engine
Also available as dual fuel



ME-GI
Many Applications

LNG has Become HOT as Future Fuel

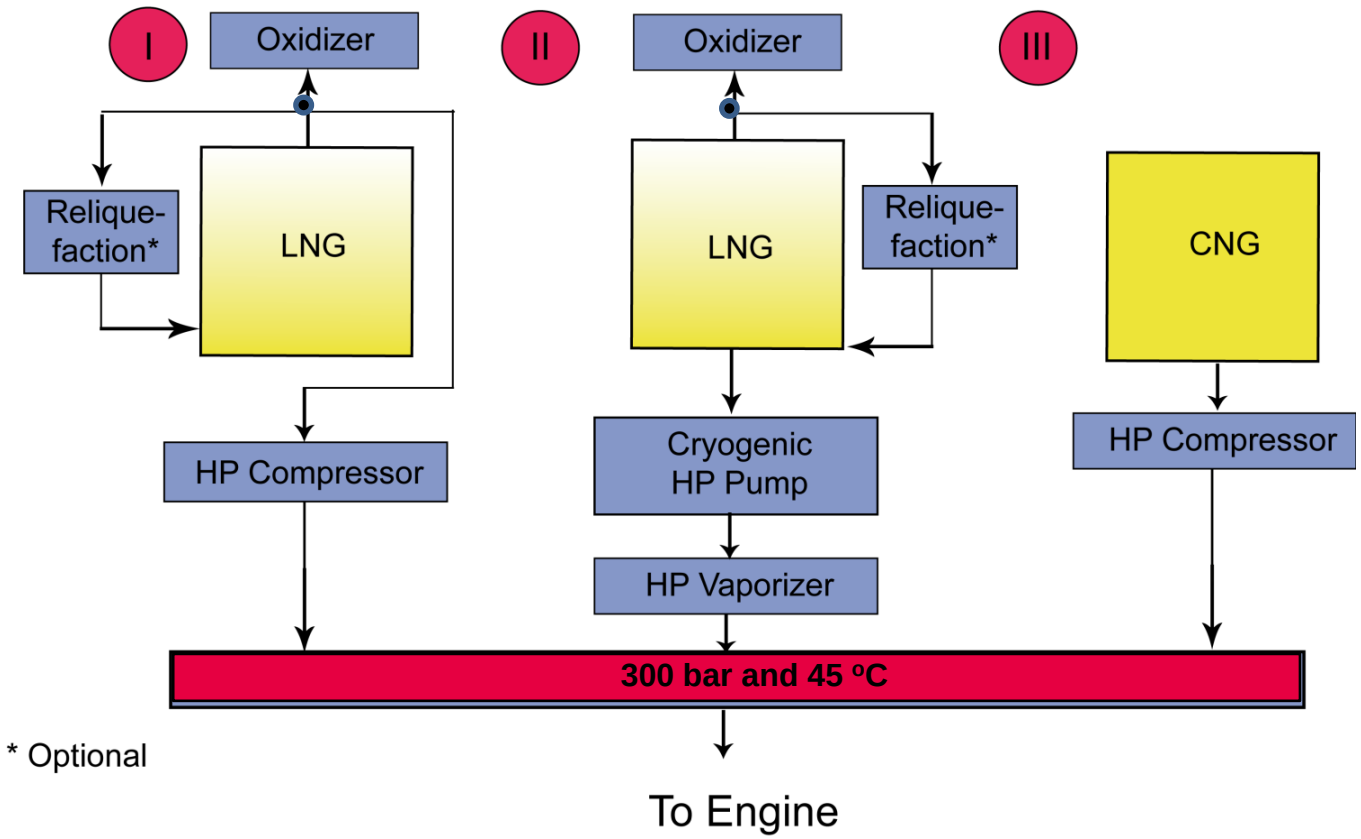


	Reduction with ME-GI	Reduction with ME-GI + WHR	Reduction with ME-GI + WHR+EGR
CO_2 (gram per tonne mile)	23%	35%	33%
NO_x (gram per tonne mile)	13%	13%	80%
SO_x (gram per tonne mile)	95%	95%	97%
Particulate matter (mg per m^3)	37%	37%	48%

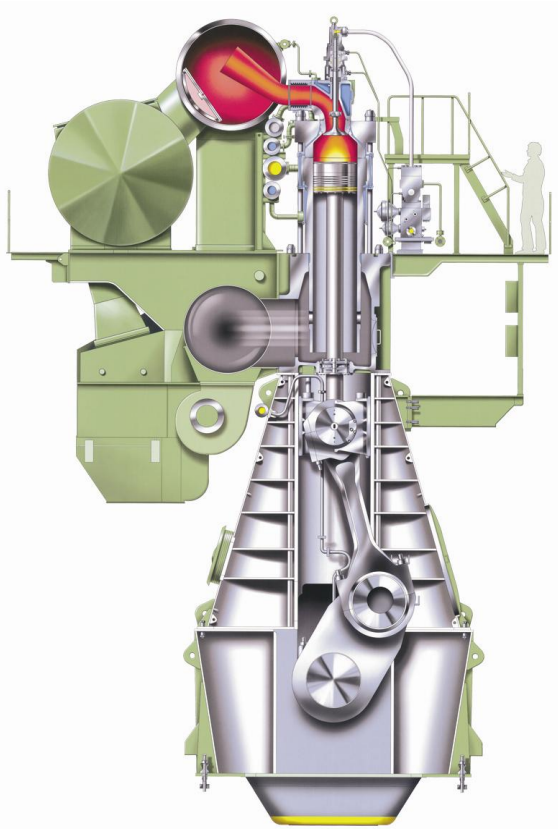
Coming LNG Terminals Around the Baltic Region

Zeus Virtual Energy Library - Liquefied Natural Gas (LNG)

ME-GI
From Gas Tank to Engine



ME – GI Engine

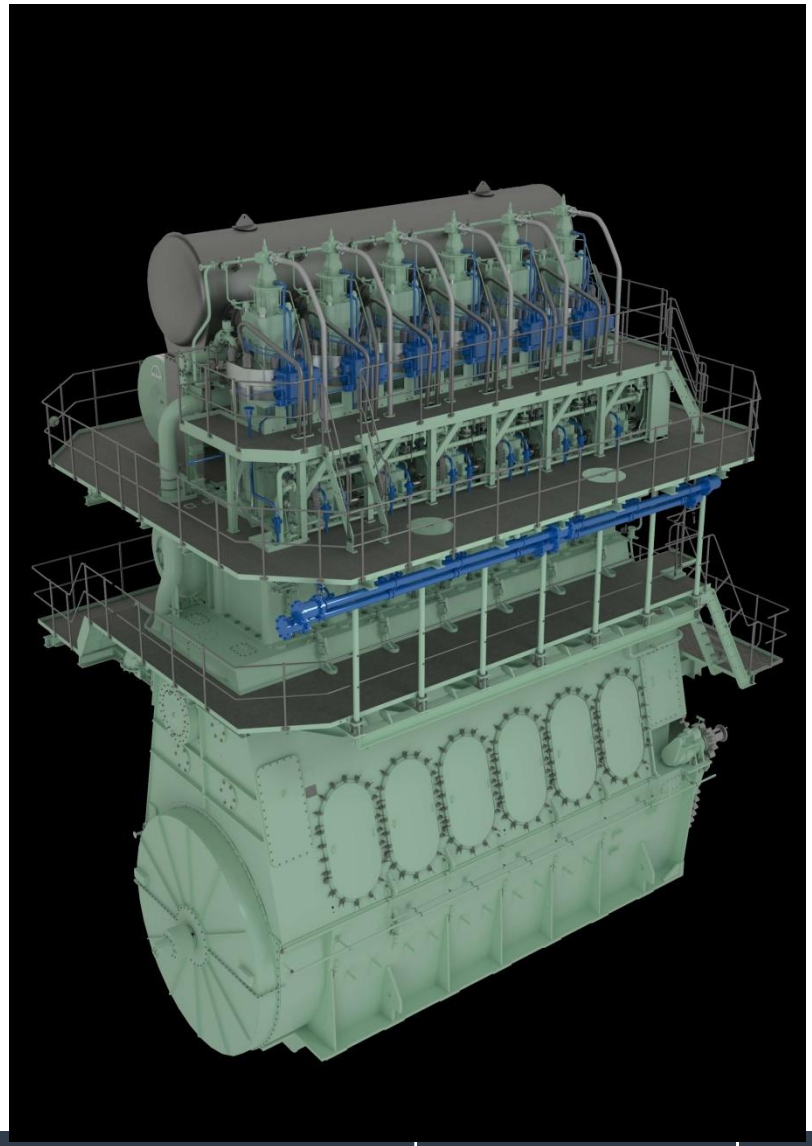


MAN B&W ME-GI/ME-LGI Engines Powered by NG, HFO, MDO and LPG

Simple modifications enable two-stroke gas injection

Proven engine design

· High fuel efficiency 50%
· High fuel flexibility
· High reliability



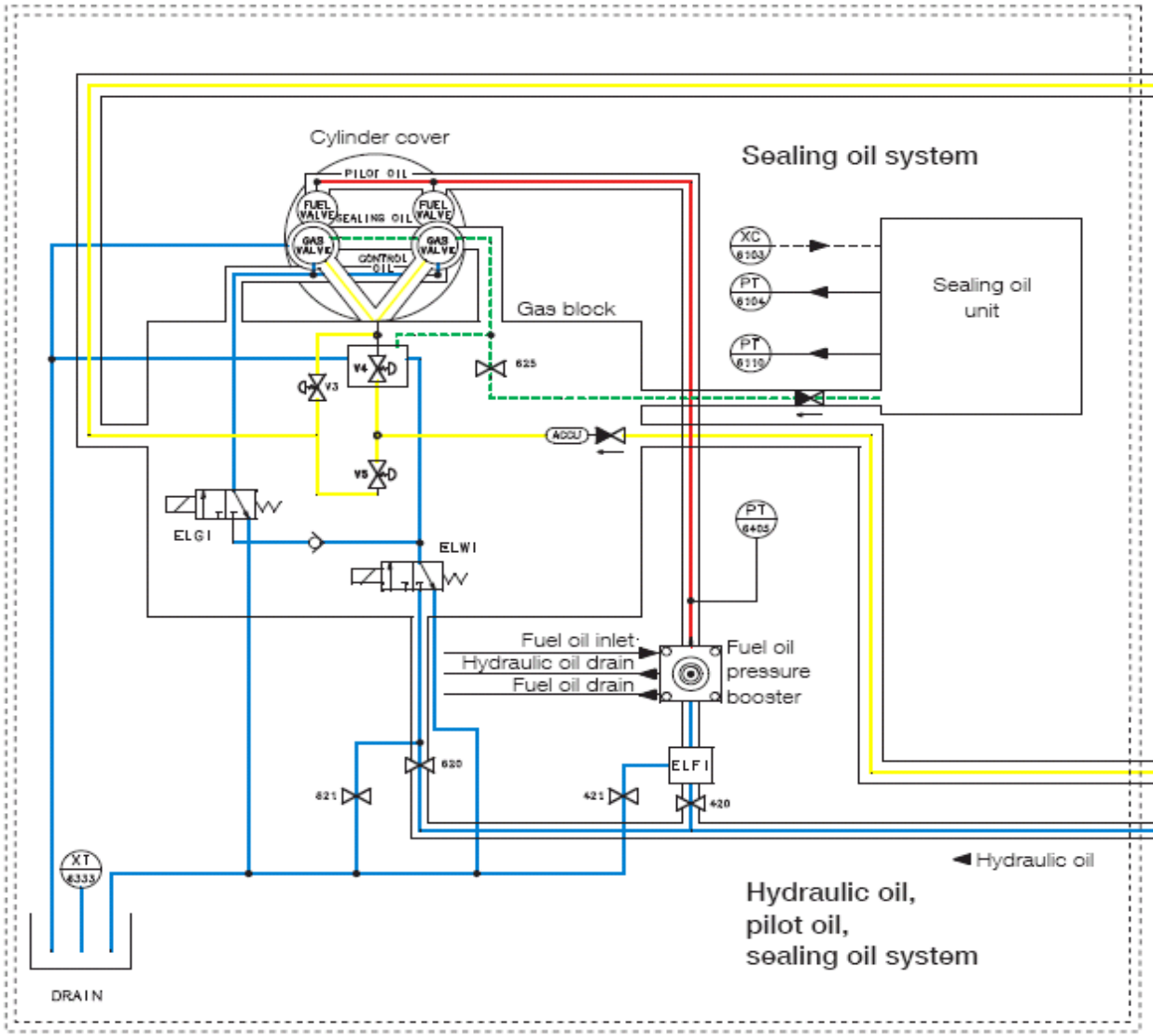
ME-GI Concept
Fuel Injection System

Product basis:

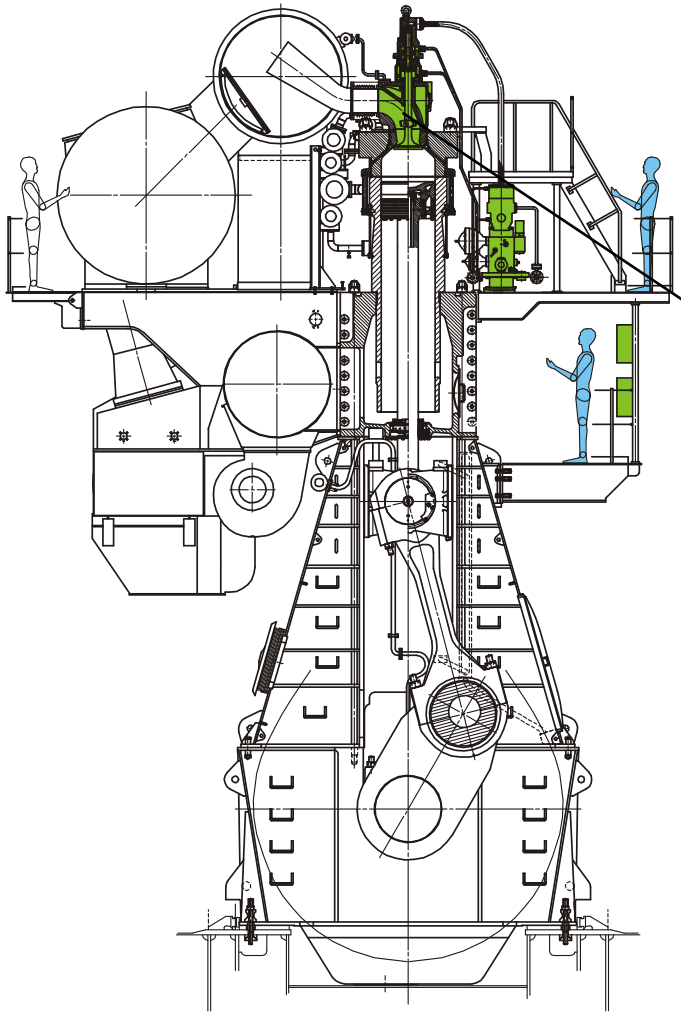
- 12K80MC-GI-S, Chiba (1994-2003)
- 6L55GFCA, Navion Viking, VOC System

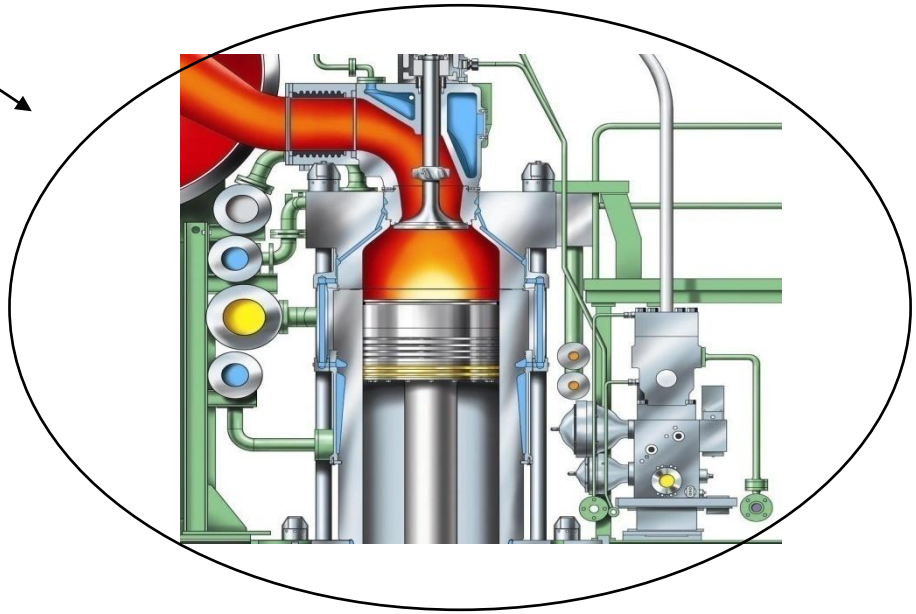
ME-GI Concept NEW!

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



New components





From ME → ME-GI

Dual Fuel High Pressure Gas Injection Engine ME-GI/ME-LGI

Background

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

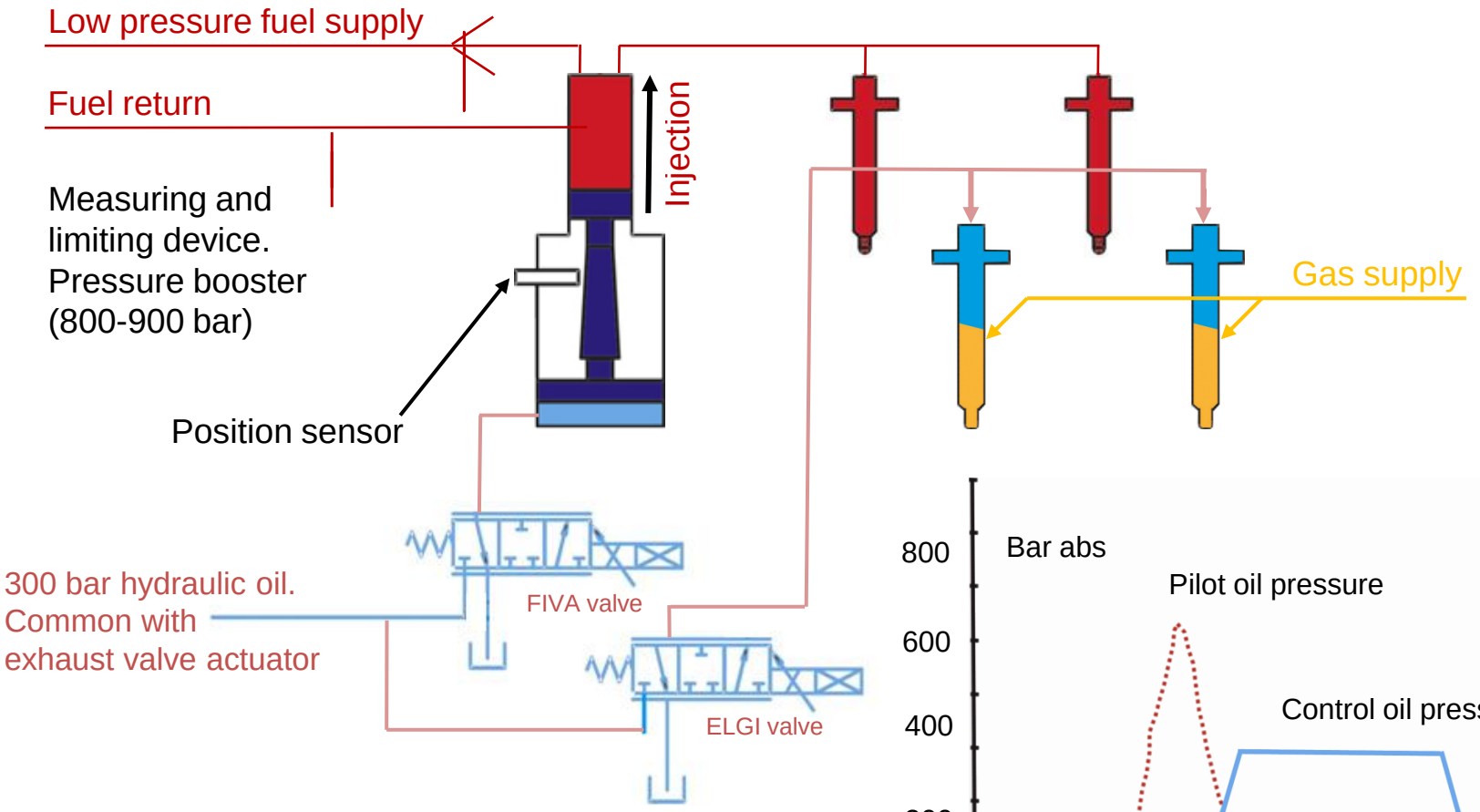
New components

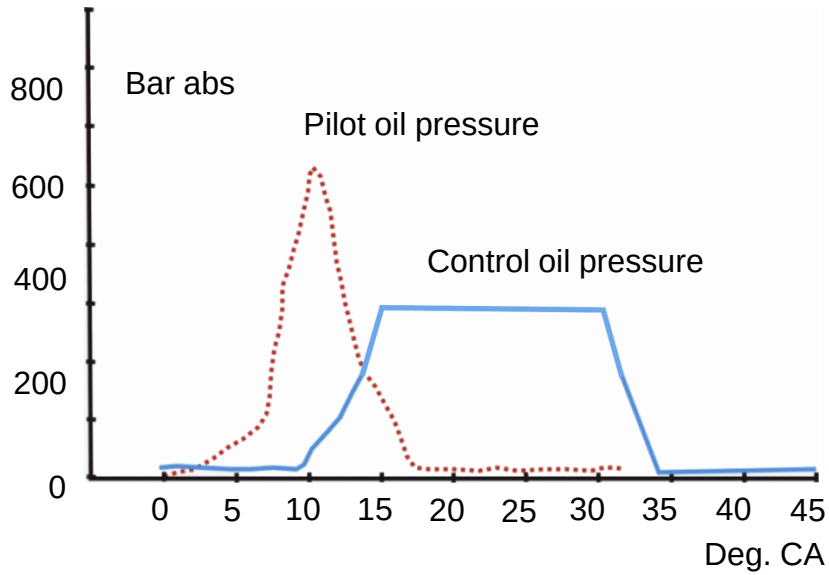
- Double wall gas pipes
- Gas Injections valves
- Large volume accumulators
- ELGI valves
- Control and safety system

Modified components

- Cylinder cove

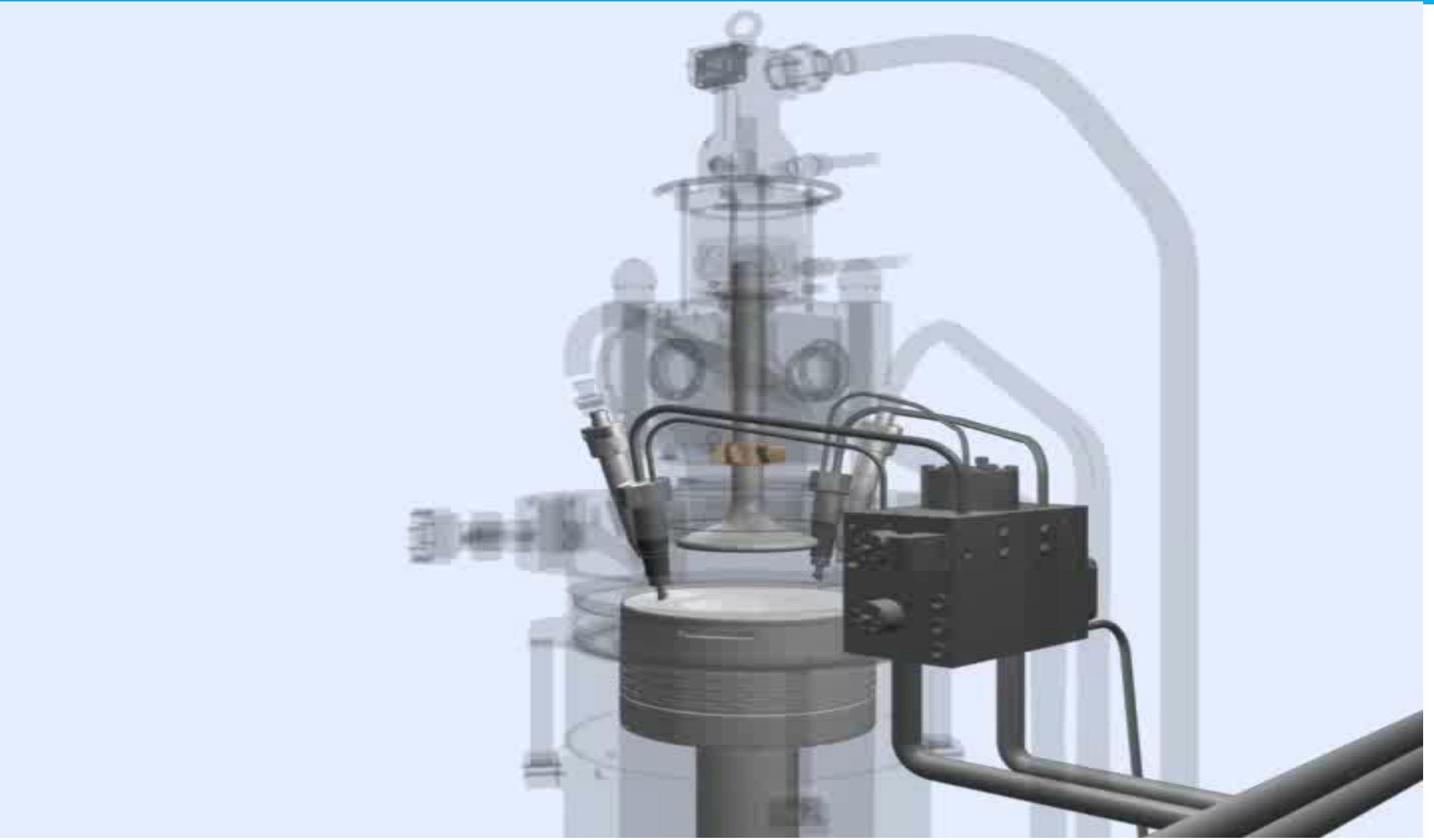
ME-GI Concept
Fuel Injection System



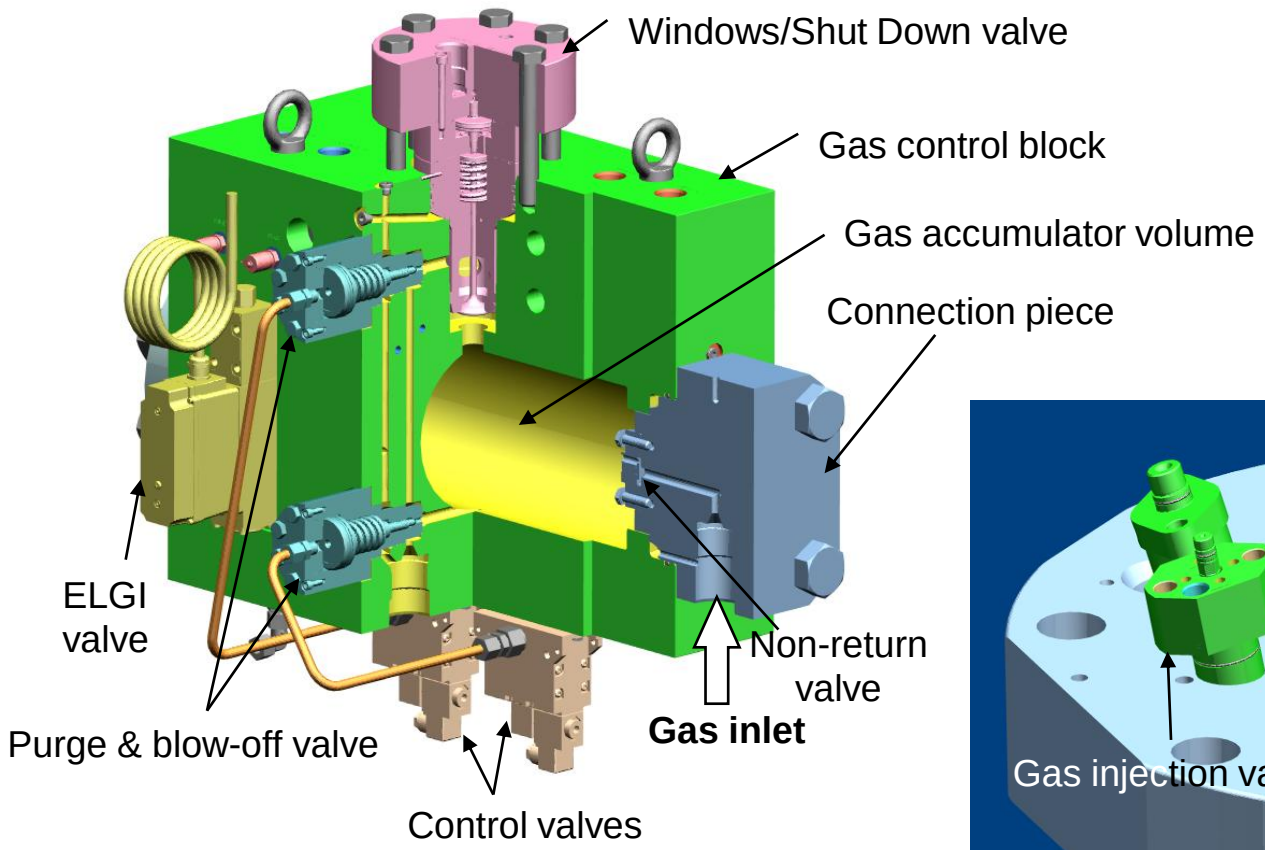


The system provides:
Pressure, timing, rate shaping,
main, pre- & post-injection

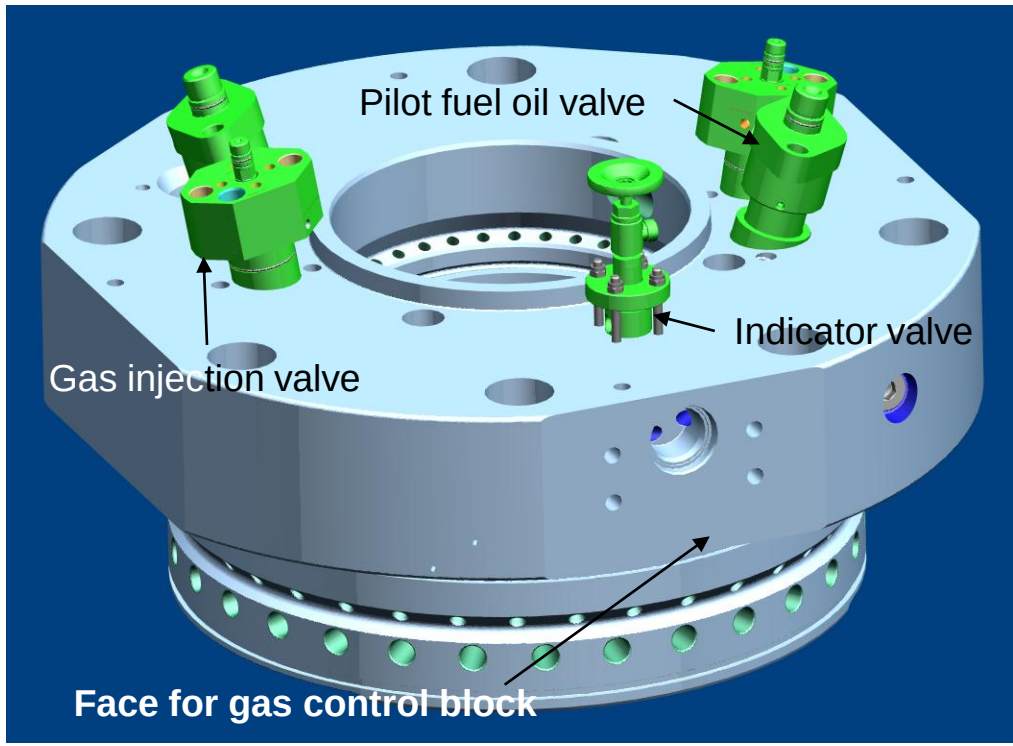
ME-GI Concept
Gas and Pilot Oil Injection



ME-GI – Mechanical Design



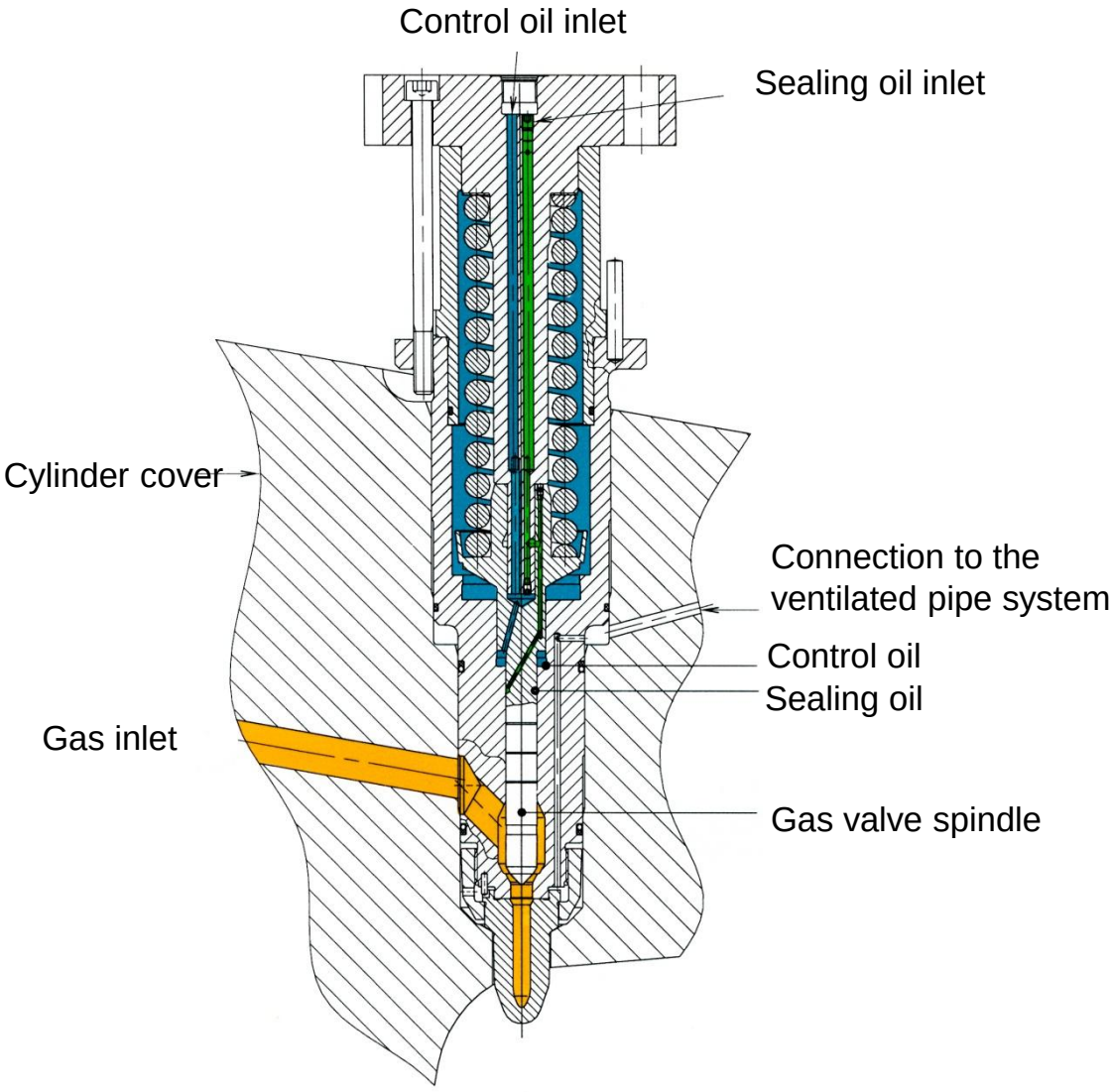
Design Specification of 7S60ME-C8-GI finished summer 2010



Same design used for gas test rig in Copenhagen and on our test engine Q4, 2010

Gas Injection Valve
(a pilot oil and a gas injection valve)

Gas injection valve

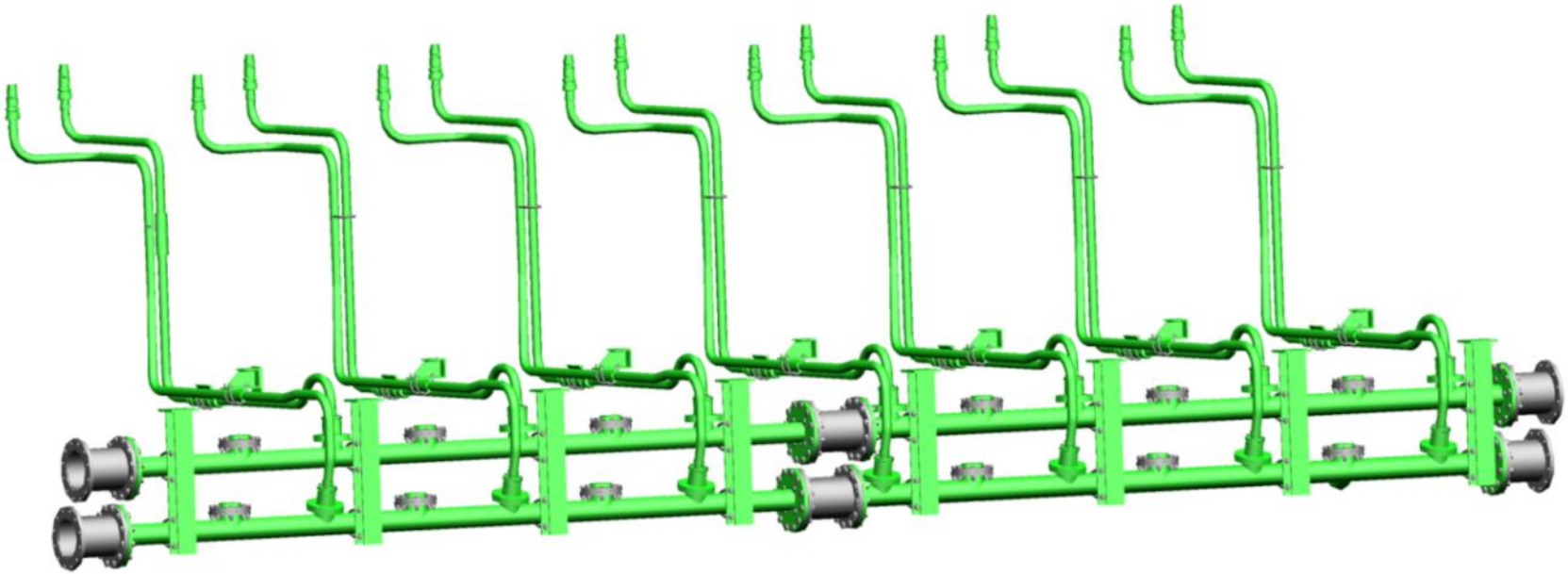


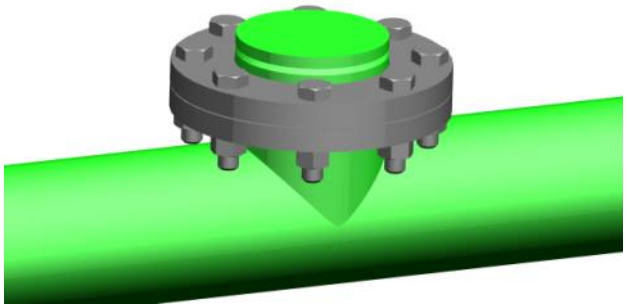
ME-GI
Service Tests

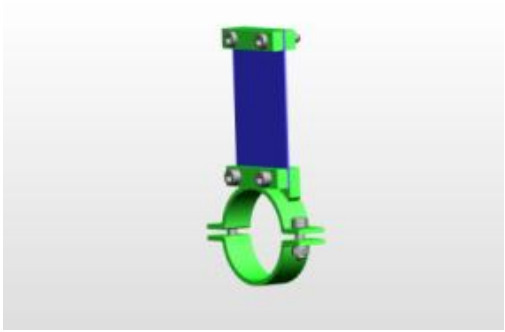
Gas injection valve temperature/deposit resistance: Test carried out in order to evaluate gas injection valve condition during long term HFO operation. Gas injection valve showed excellent condition after 1600 hours testing, installed on a 7S50MC, without deposits or thermal overload. Next inspection will take place after 6000 hours. Same result is expected.

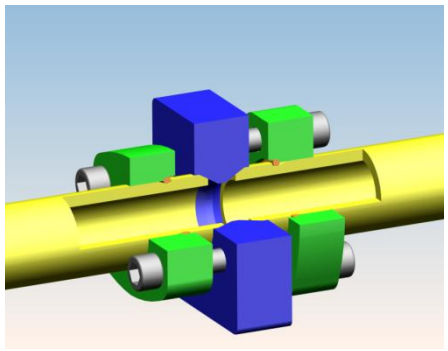
Gas injection nozzle

The double wall pipe
Support & Flange connection

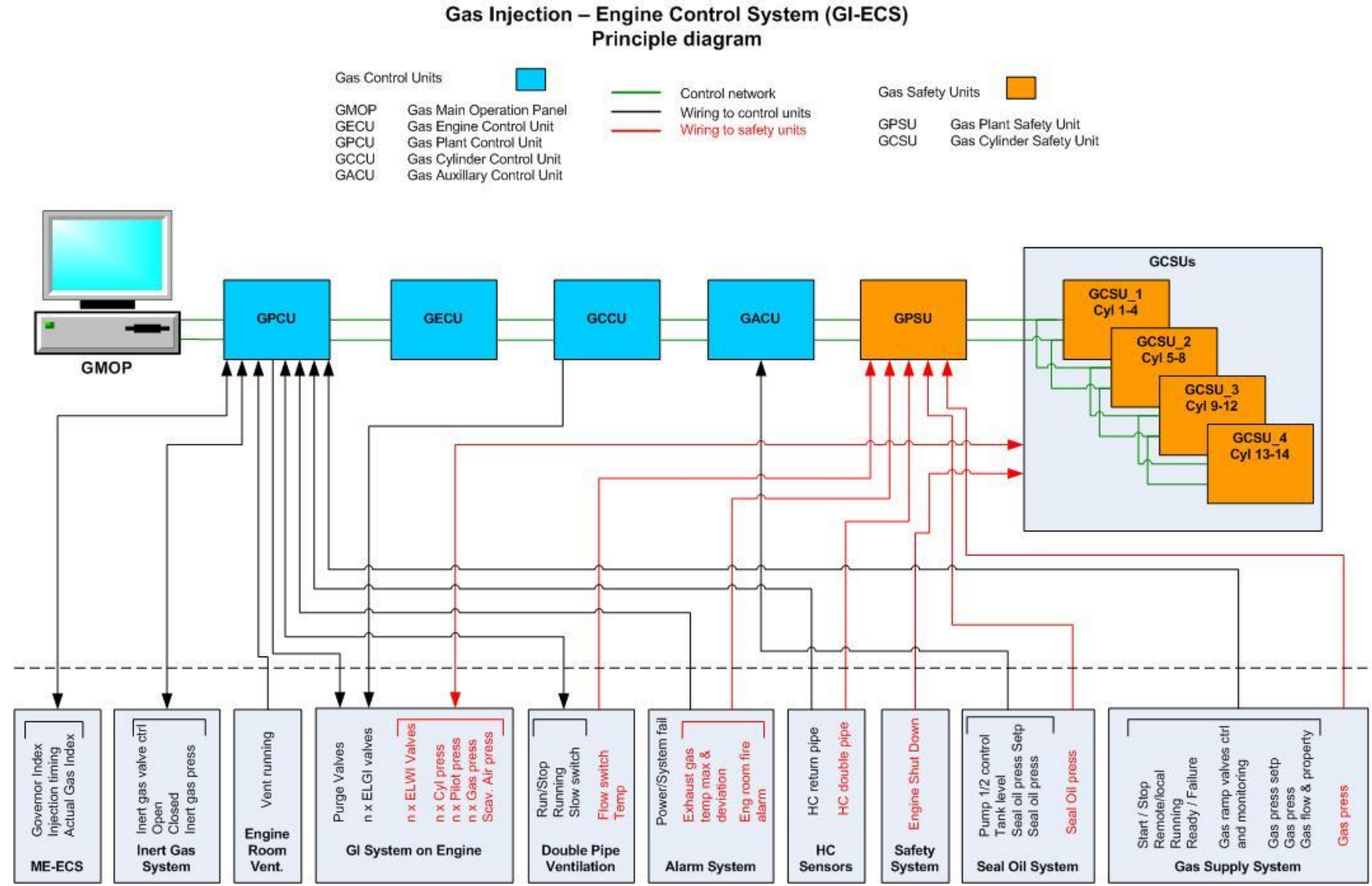








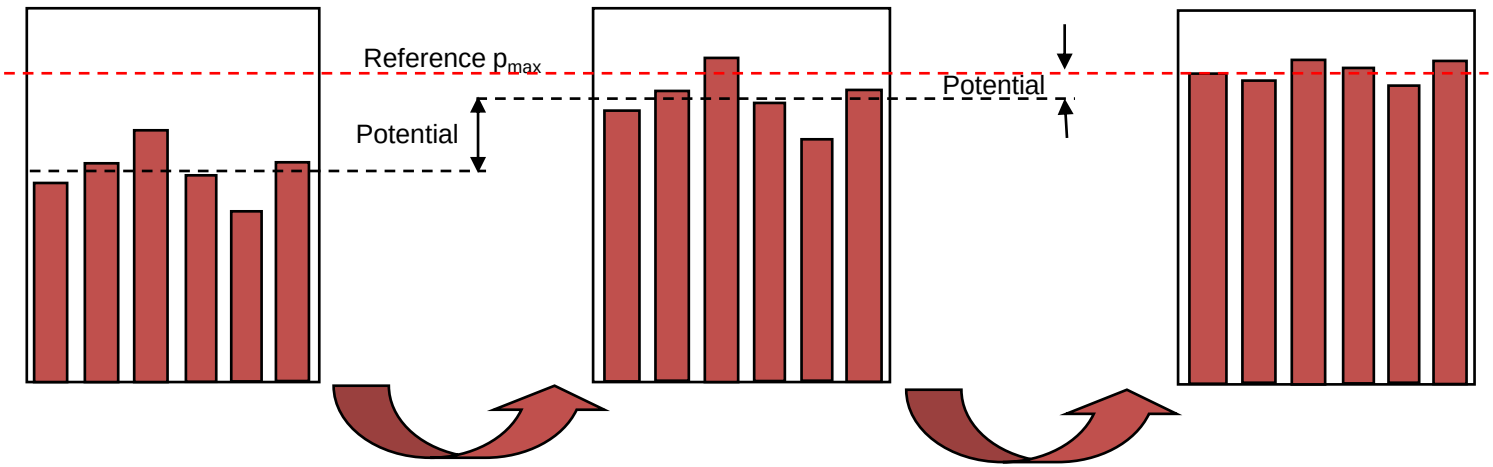
ME-GI/ME-LGI
Gas Injection - Engine Control Syst.



Auto-tuning: Potential Fuel Reduction. Additional benefit free of charge.

Reduction in fuel oil consumption / CO_2 emission

1 bar increase in average p_{max} => 0.20-0.25 g/kWh decrease in fuel oil consumption



Pure p_{max} level increase
Potential 5-10 bar
Potential 1-2.5 G/kWh

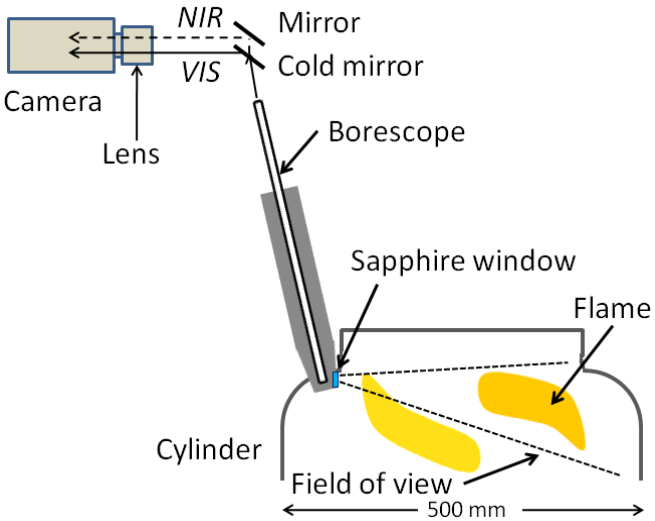
Balancing + p_{max} level increase
Potential additional 2-5 bar

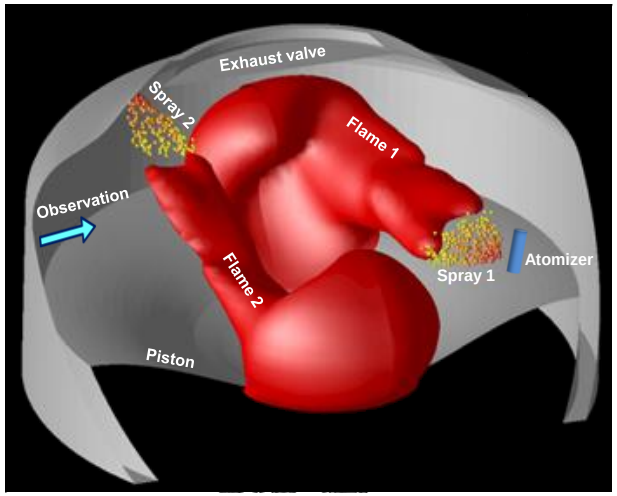
Total potential 1.4 – 3.75 g/kWh

Gain even with engines already being operated within recommended limits

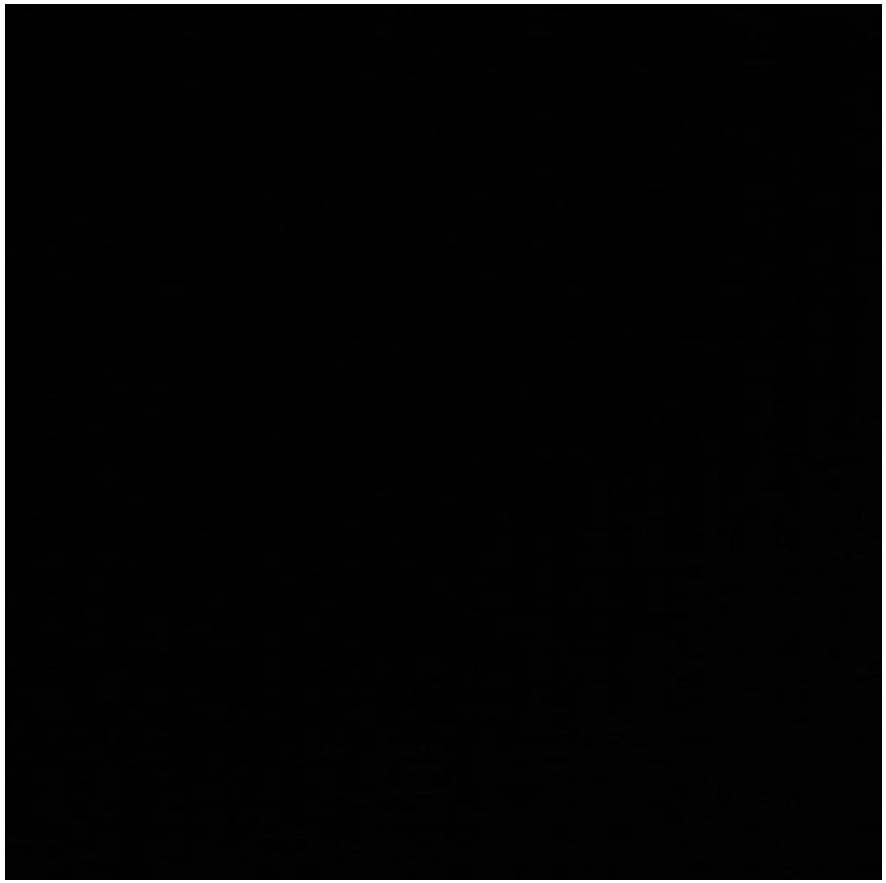
ME-GI
User Interface

Visualization with light sensor and high speed imaging





Movie: pilot approx. 3.4% of MCR fuel/stroke



Fuel nozzle 2 cut-off during imaging to enhance the view of the flame from nozzle 1

ME-GI/ME-LGI Concept

Fuel oil only mode:

- Operation profile as conventional standard engine

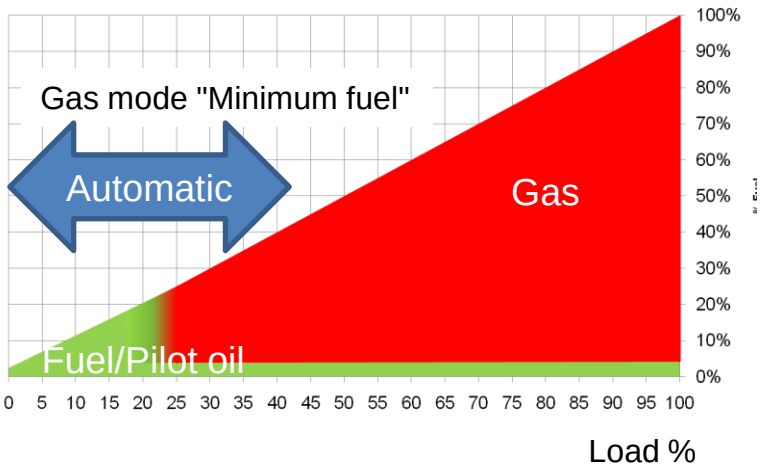
Dual fuel operation modes:

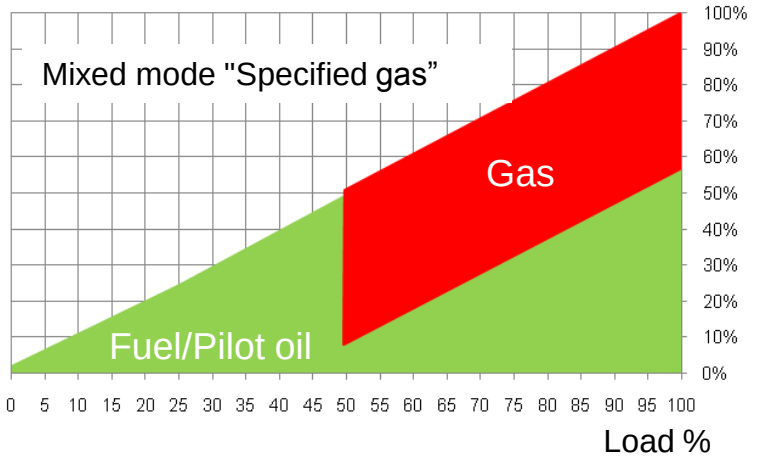
Gas mode “Minimum fuel”

- Full operation profile available
- Full load acceptance available
- Full power range available
- Load variation is governed by gas injection
- Pilot fuel can be MDO, MGO or HFO
- Minimum pilot fuel used at load > 25 % (5 => 3 %)
- Increased pilot fuel at loads < 25% load
- Dynamic mix. of gas and fuel at loads < 25% load

Mixed mode “Specified gas”

- Full operation profile available
- Amount of gas fuel is specified on Gas MOP
- Load variation is governed by fuel oil injection

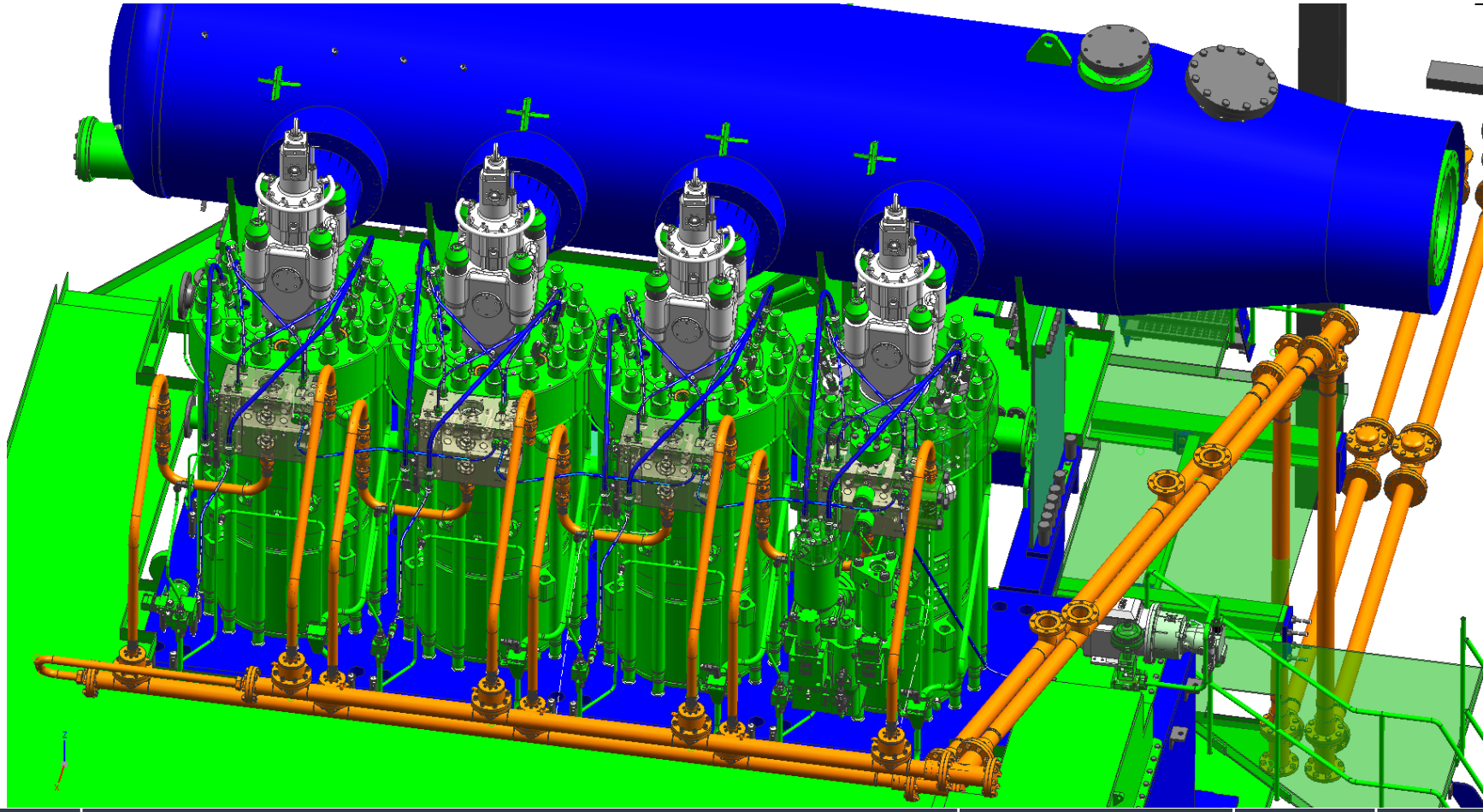




ME-GI
4T50ME-GI-X Design

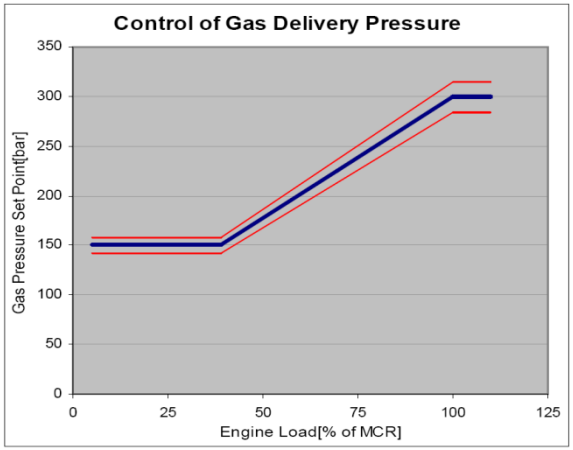
Gas installation on 4T50ME-GI-X:

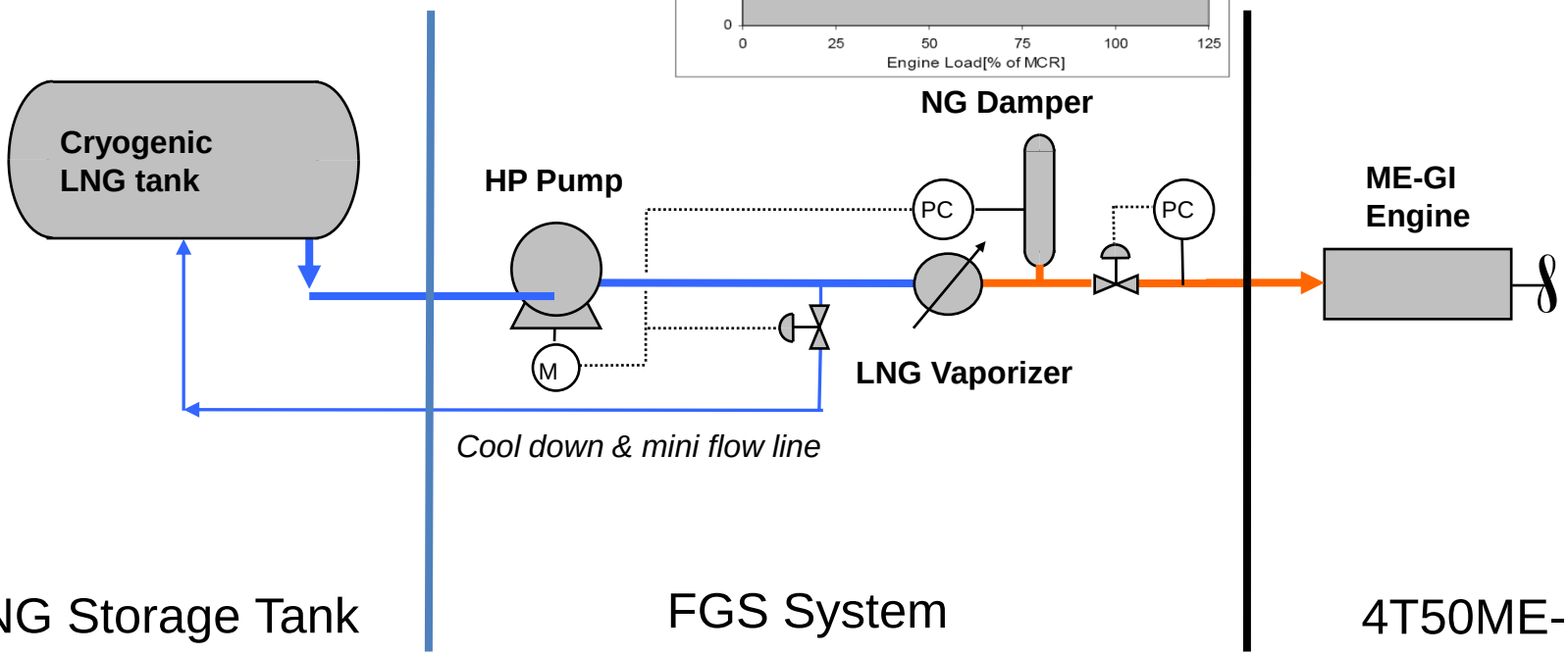
- ME-GI Components designed and delivered



ME-GI
Fuel Gas Supply System (Cryostar)

Process flow diagram





HP Pump from Cryostar

ME-GI Engine

Example of the power consumption for a LNG pump

Engine type: 8S90ME-C8.2-GI Output : 45.760 kW

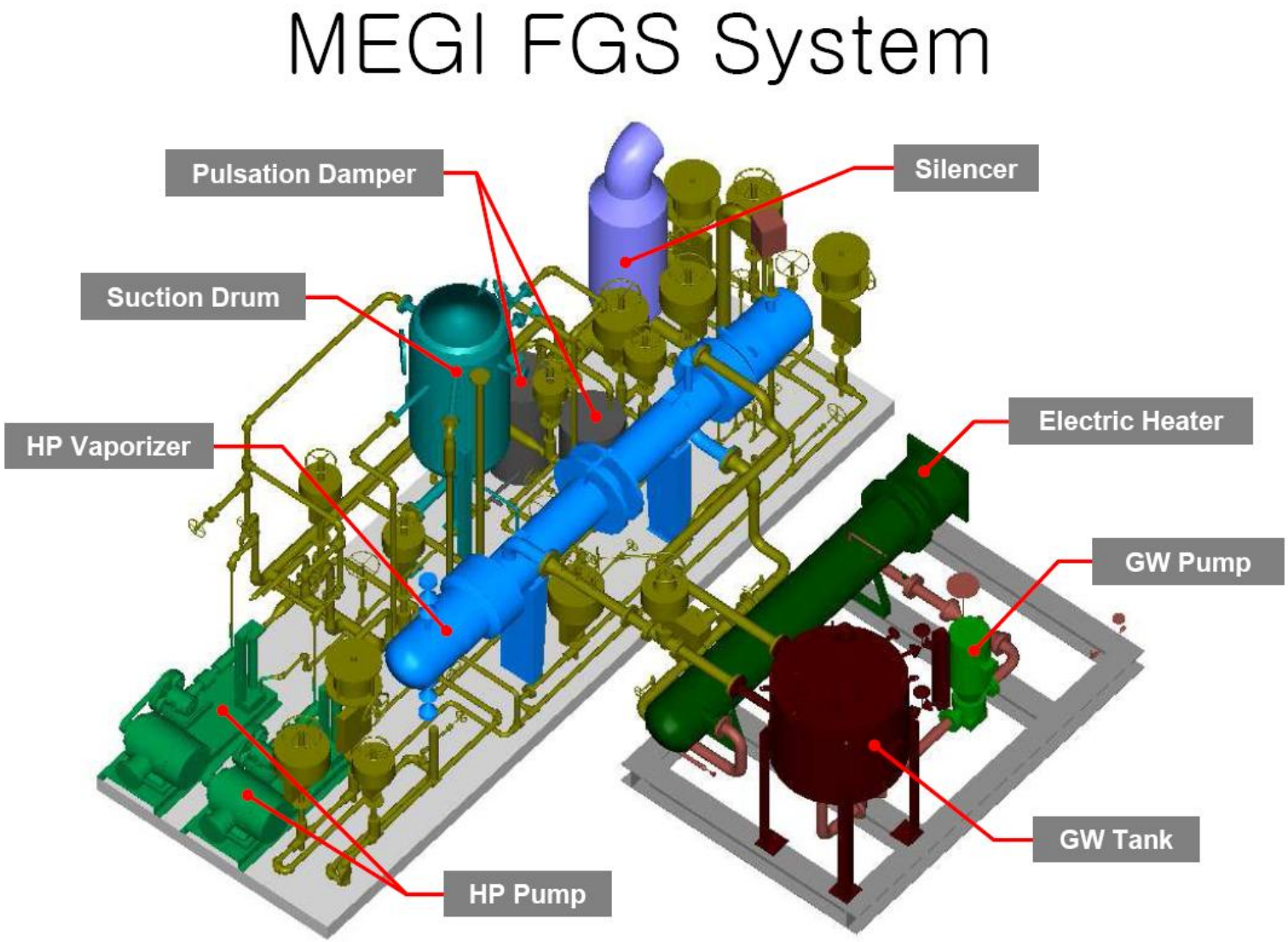
LNG Flow is based on 100% load and a LCV value of 50.000 kJ/kg

HP fuel gas supply

LNG Flow	HPP
5587 kg/h	200 kW

Less than 0,5% efficiency reduction

ME-GI
FGS System Layout from DSME

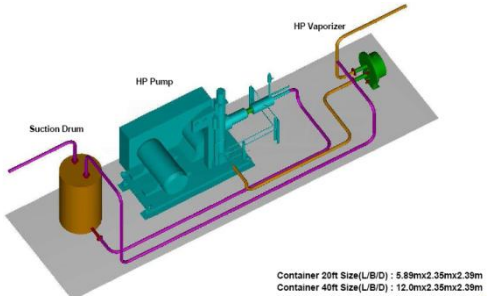


ME-GI
FGS System photos

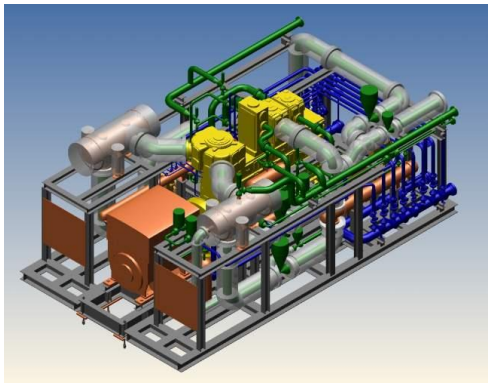
5 Different Gas Supply Systems available.

Cryostar
LNG Pump System

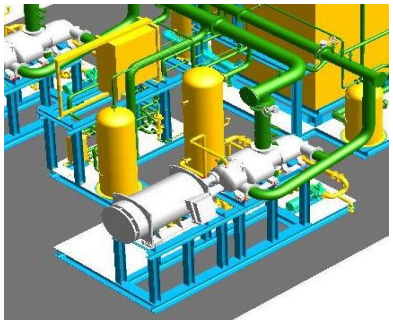
DSME
LNG Tank & Pump System



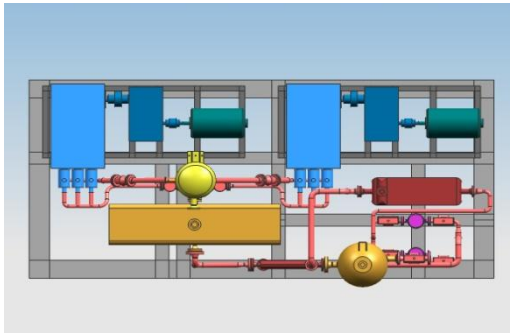
Burckhardt Compression
Laby-GI Compressor



TGE
LNG Tank & Pump System

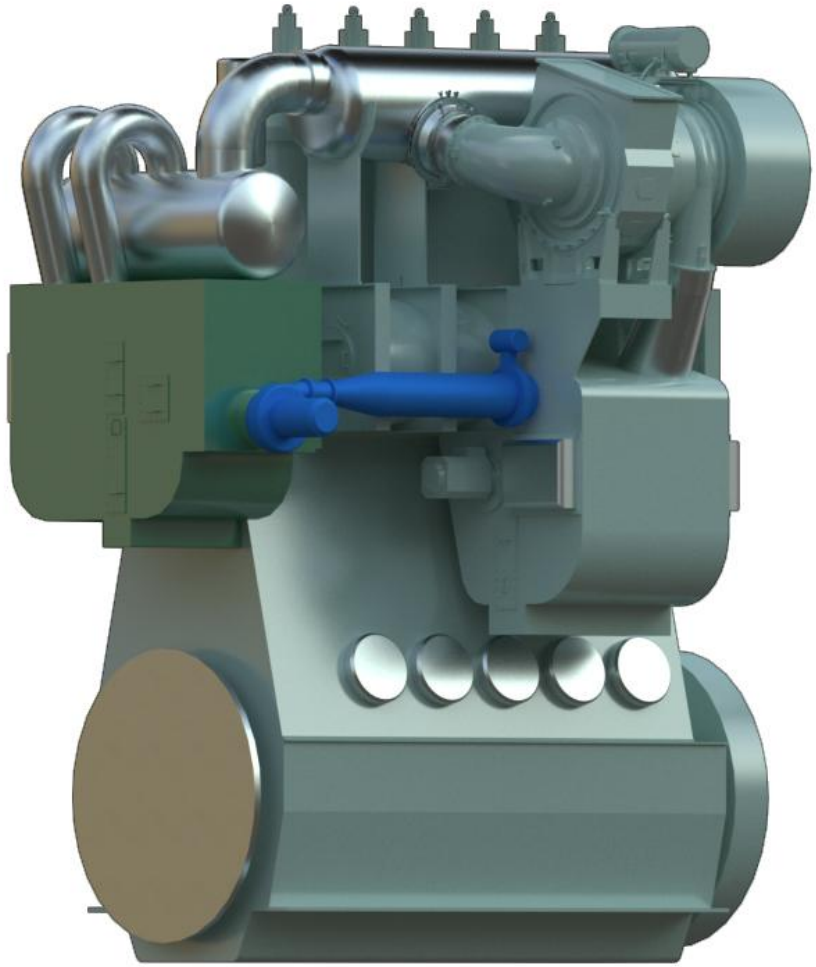


Hamworthy Gas System
LNG Tank & Pump System

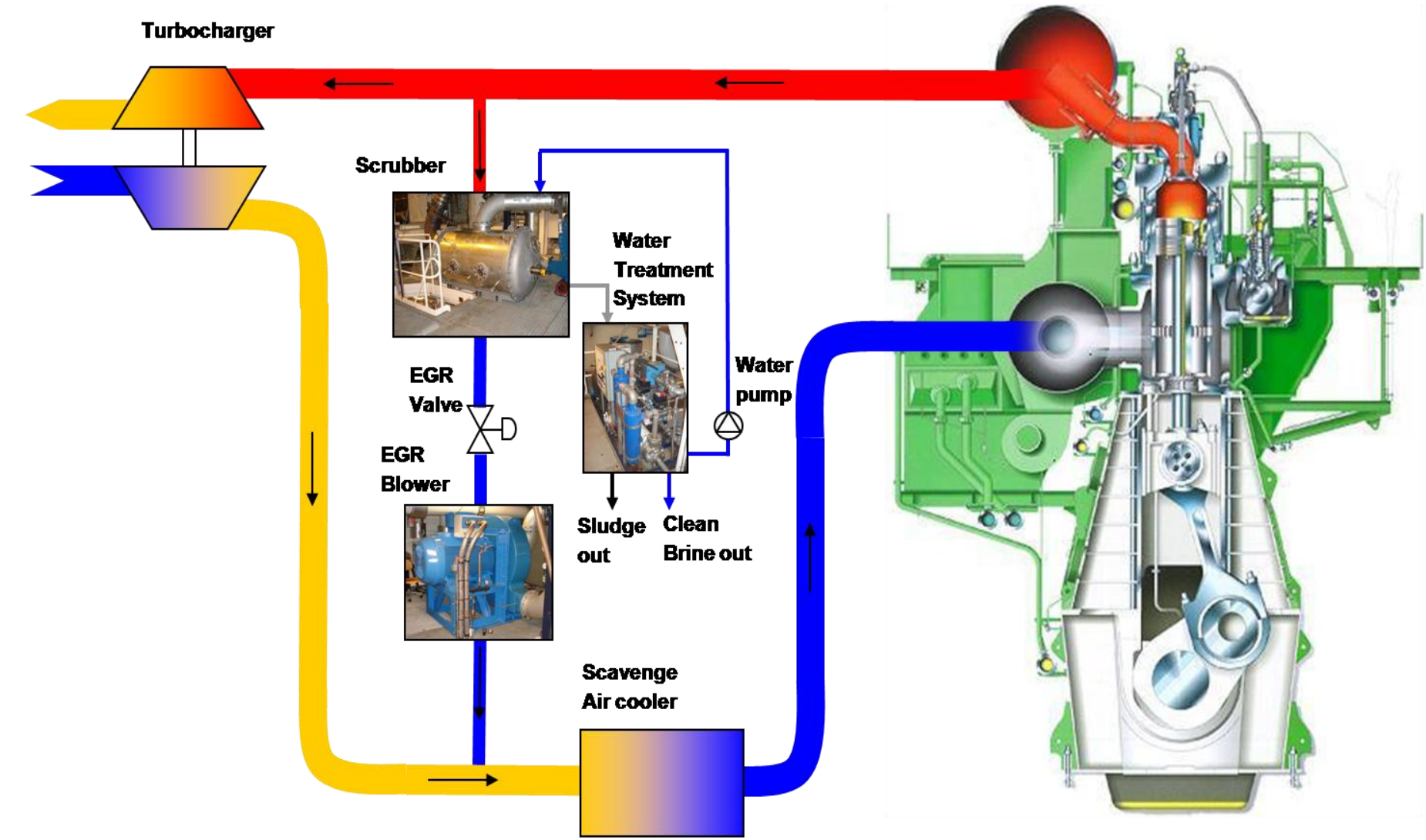


ME-GI
Tier III – EGR (Exhaust Gas Recirculation)

Engine
Integration

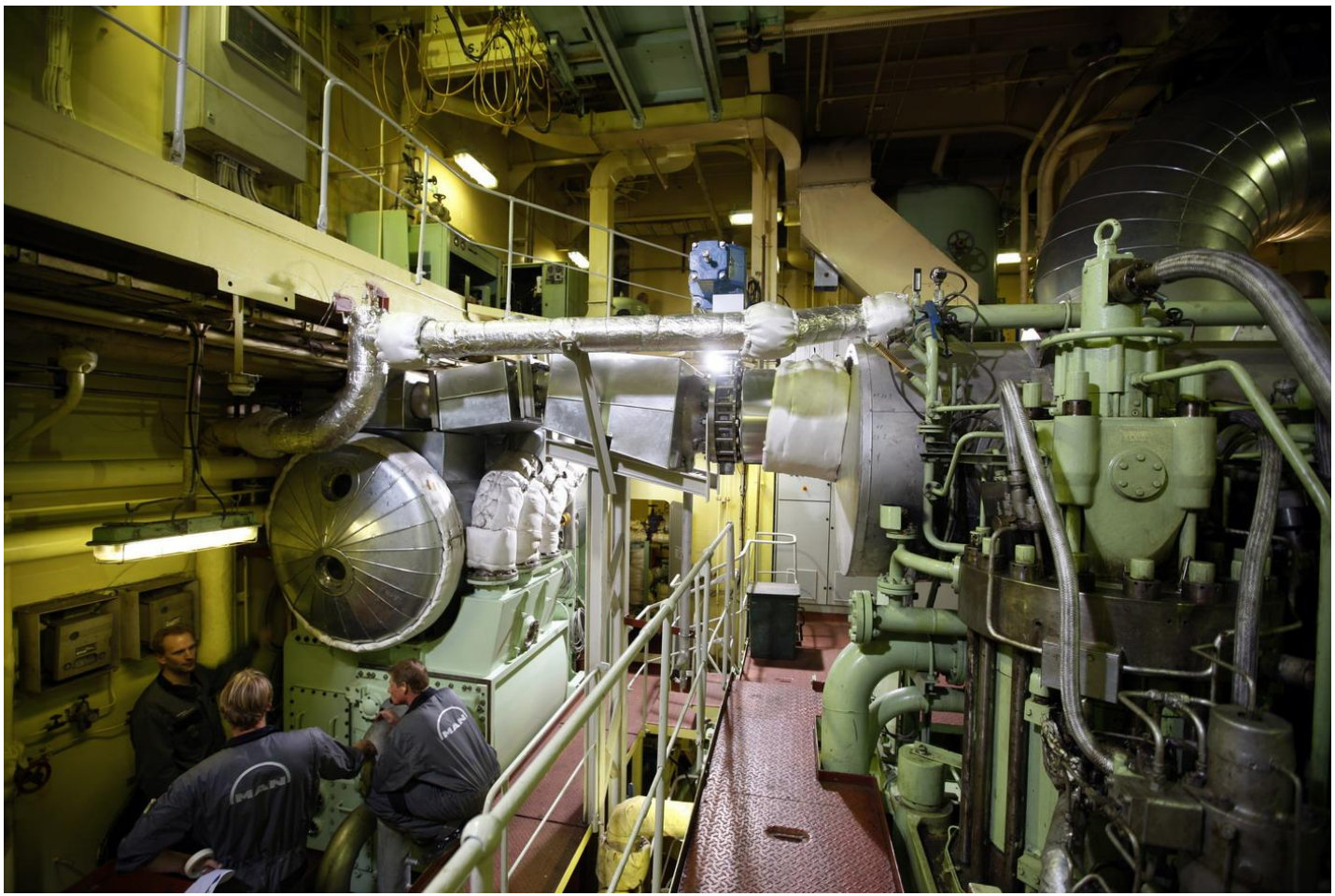


Tier III
EGR – Exhaust Gas Recirculation



ME-GI
Tier III – EGR (Exhaust Gas Recirculation)

EGR service test on Alexander Maersk – installation



Installed EGR unit – scrubber, cooler and blower

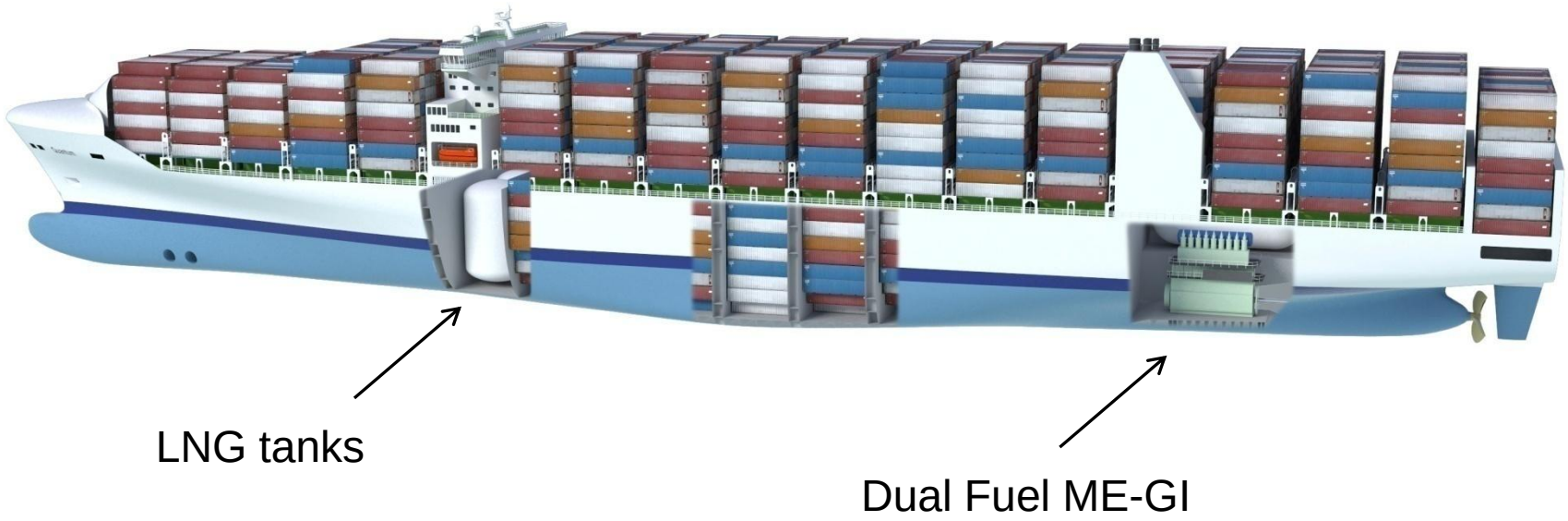
ME-GI Tier III solution
EGR operating cost

- ME-GI Tier III solution : Fuel Optimised Main Engine

Fuel optimised engine – NOx 21.0 g/kWh							
Area	NOx request g/kWh	NOx reduction g/kWh	NOx reduction %	EGR % %	SFOCgain g/kWh	SFOCpenalty g/kWh	SFOCchange g/kWh
ECA – Tier III	3.30	17.60	84%	42%	3.30	2.10	-1.20
Non ECA - Tier II	14.40	6.60	31%	16%	3.30	0.79	-2.51

- Also requires extra electrical power consumption, additional maintenance, and possibly a small amount of NaOH, depending on the sulphur content of the fuel.
- For operation on GAS the NOx emission is in comparison to HFO approx 15% lower . The EGR recycle and SFOC figures will therefore become better than shown in the table. Actual figures will be measured during the scheduled ME-GI test.
- For operation on GAS the sulphur content is zero except for the sulphur coming from the pilot oil. Consumption of the NaOH is therefore neglectable.

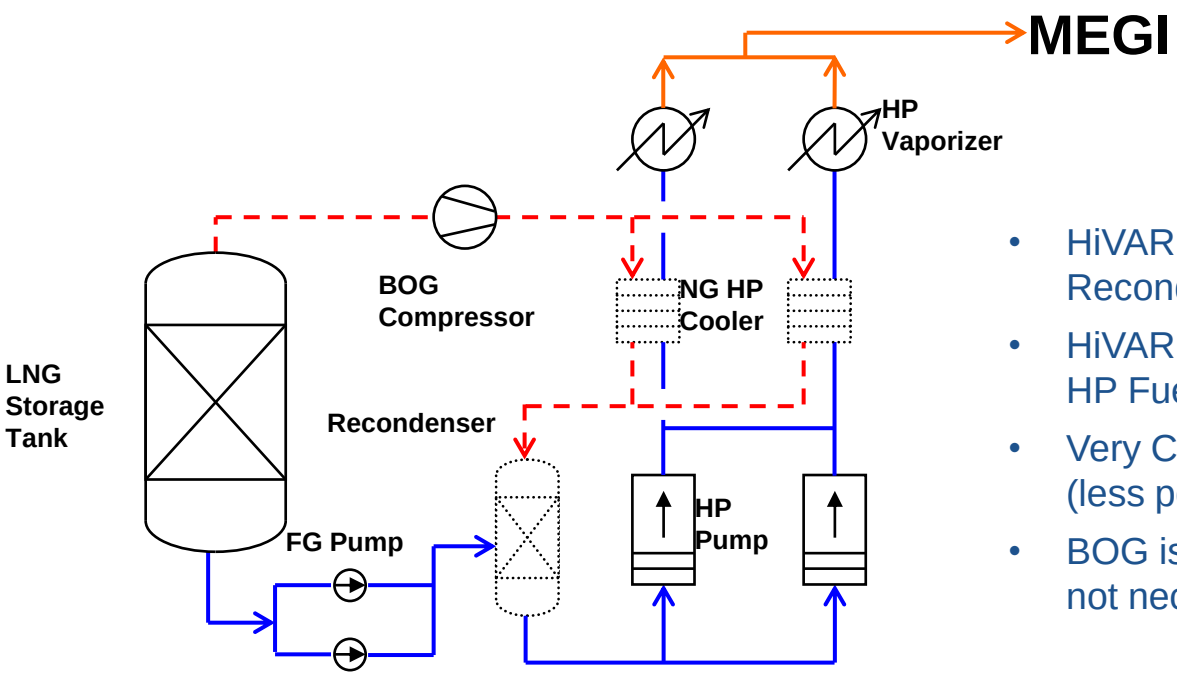
9000 teu Gas Fuelled Container Ship
DNV & MDT Quantum 9000 Teu project



Low pressure tank
Fuel Gas Supply System – HiVAR
Solution from DSME

Schematic Diagram - HiVAR

DSME Patent



- HiVAR comprises HP Pump, Vaporizer and Recondenser
- HiVAR is Efficient and Cost-effective solution for HP Fuel Gas Supply.
- Very Competitive compared with HP Compressor (less power, less capital cost)
- BOG is Recondensed. (Reliquefaction plant is not necessary)

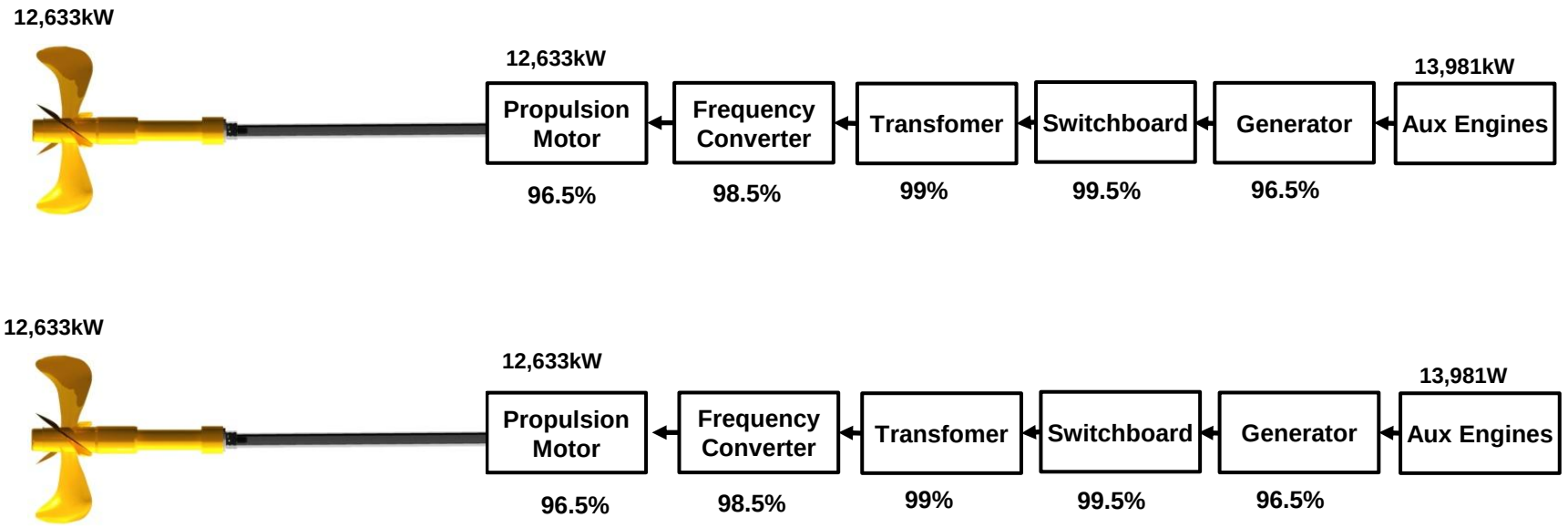
❖ HiVAR: High Pressure Pump, Vaporizer and Recondenser

170,000m³ LNG Tanker

Propulsion Power Demand

DFDE Solution

- Power requirement at propeller = 25,265 / 2 = 12,633kW



- Engine power requirement including transmission losses = 2x 13,981kW (includes losses at 100% load as shown)

Propulsion Power Demand

ME-GI Solution

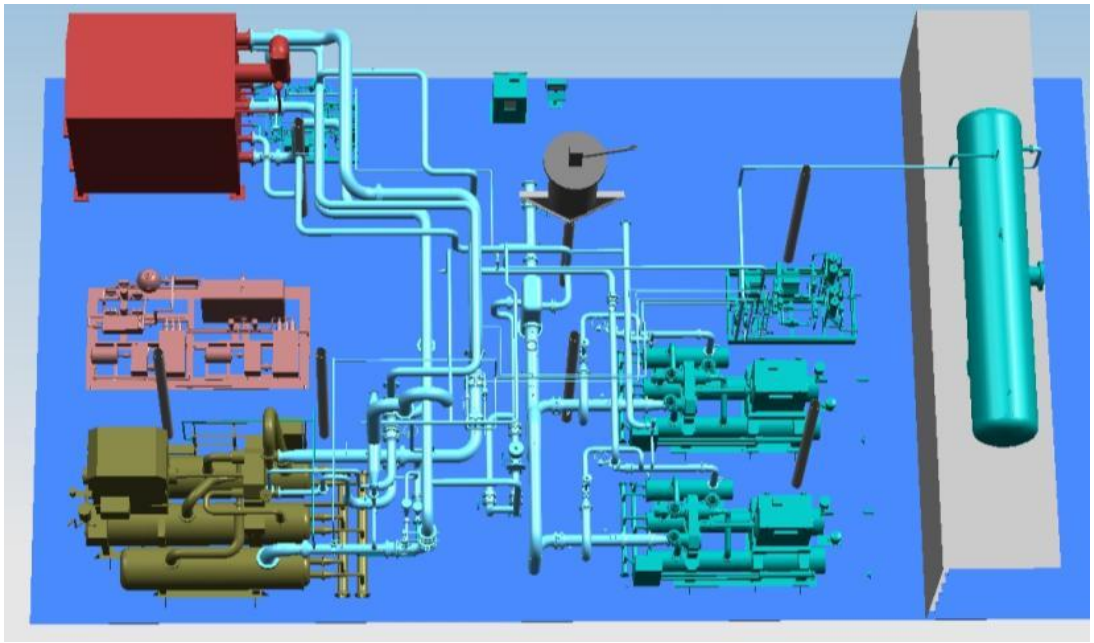
- Power requirement at each propeller = 25,265 / 2 = 12,633kW

- DF Gensets with ME-GI Main engines 2x 5S70ME-C8.2-GI
- Engine power requirement for propulsion = 2x 12,760kW (including 1% shaft loss)

LNG Carrier with fulll fuel flexibility

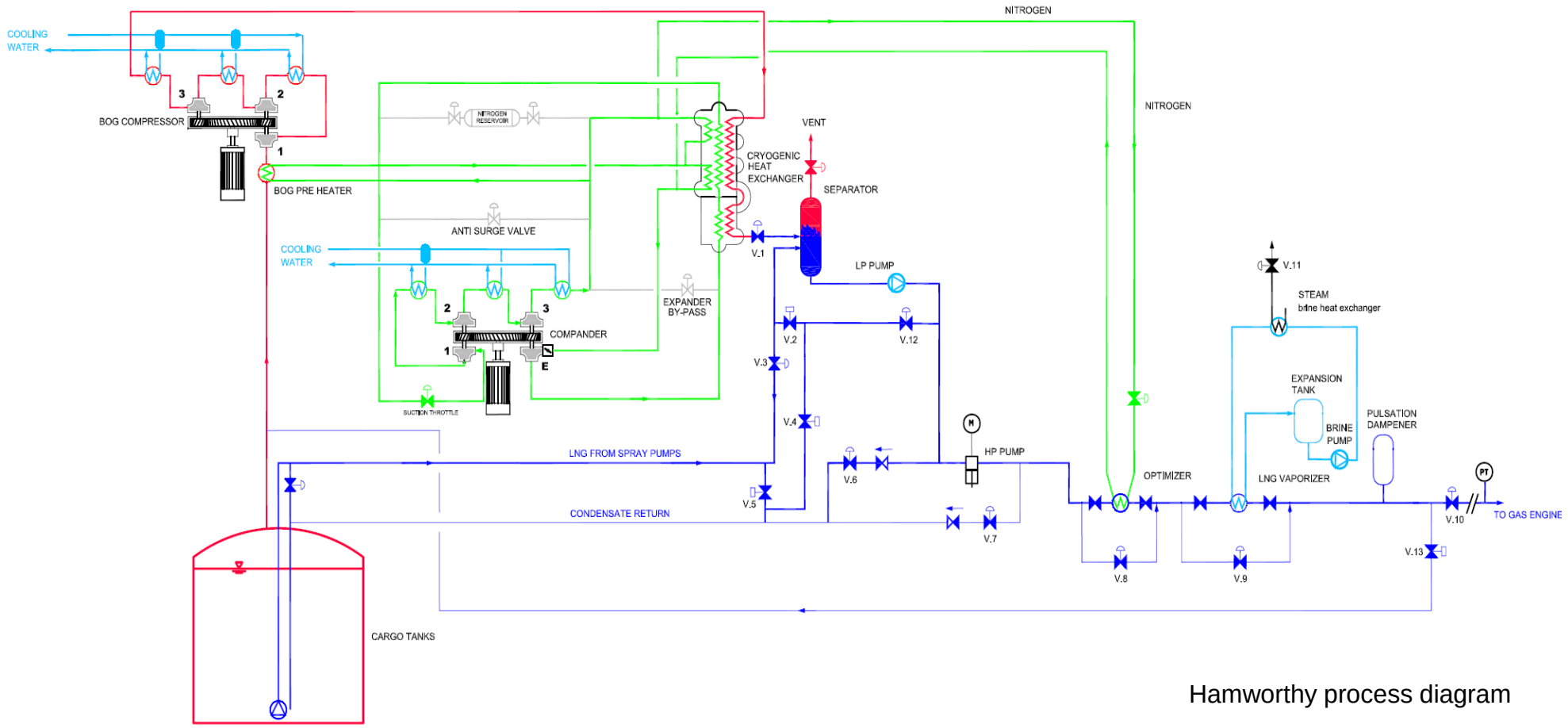
Hybrid System (Cryogenic pump + BOG compressor)

- BOG 3 stage compressor with 100% reliquification capacity
- Cryogenic heat exchanger
- N2 compander
- Separator
- Low pressure pump
- High pressure cryogenic pump
- Optimiser
- Vaporiser
- Brine heater
- Brine pump



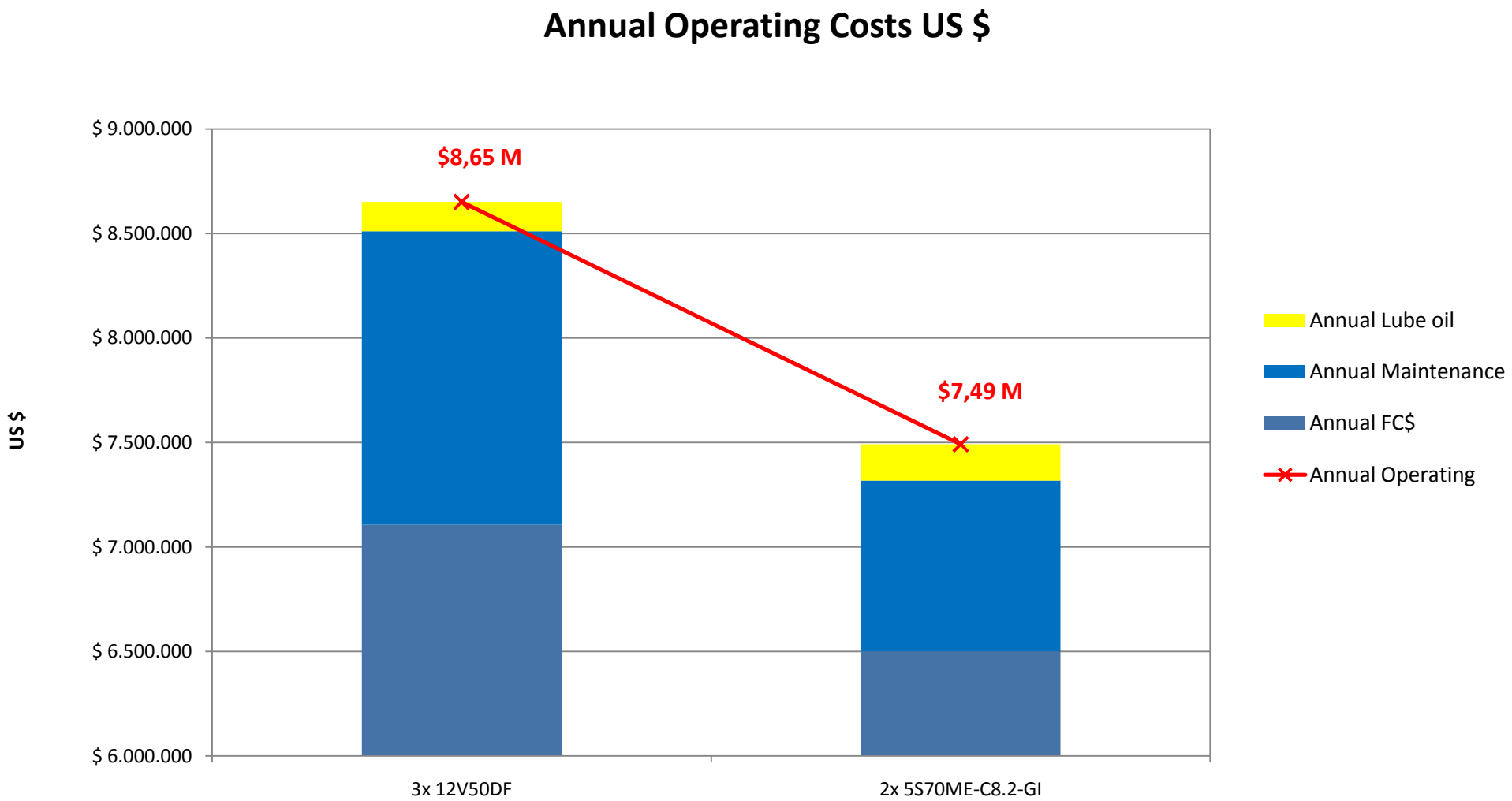
LNG Carrier with fulll fuel flexibility

Fuel Gas Supply System (BOG compressor & LNG pump)



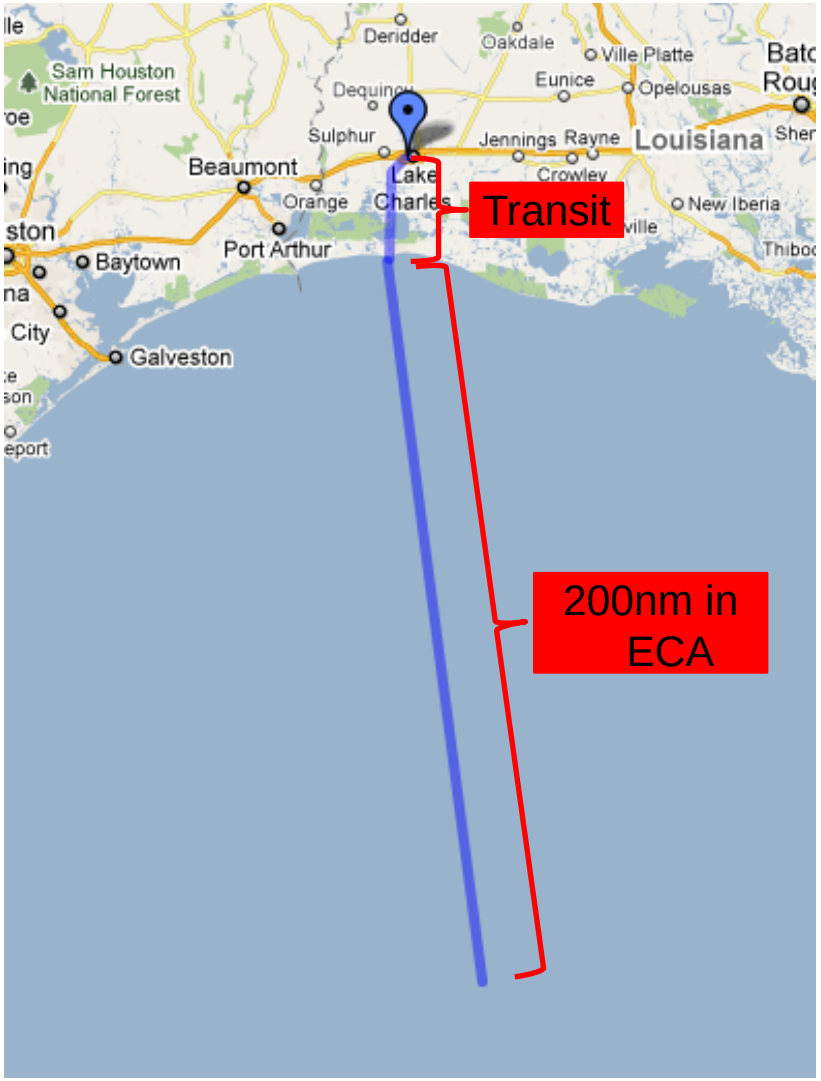
Hamworthy process diagram

Shipowner Considerations



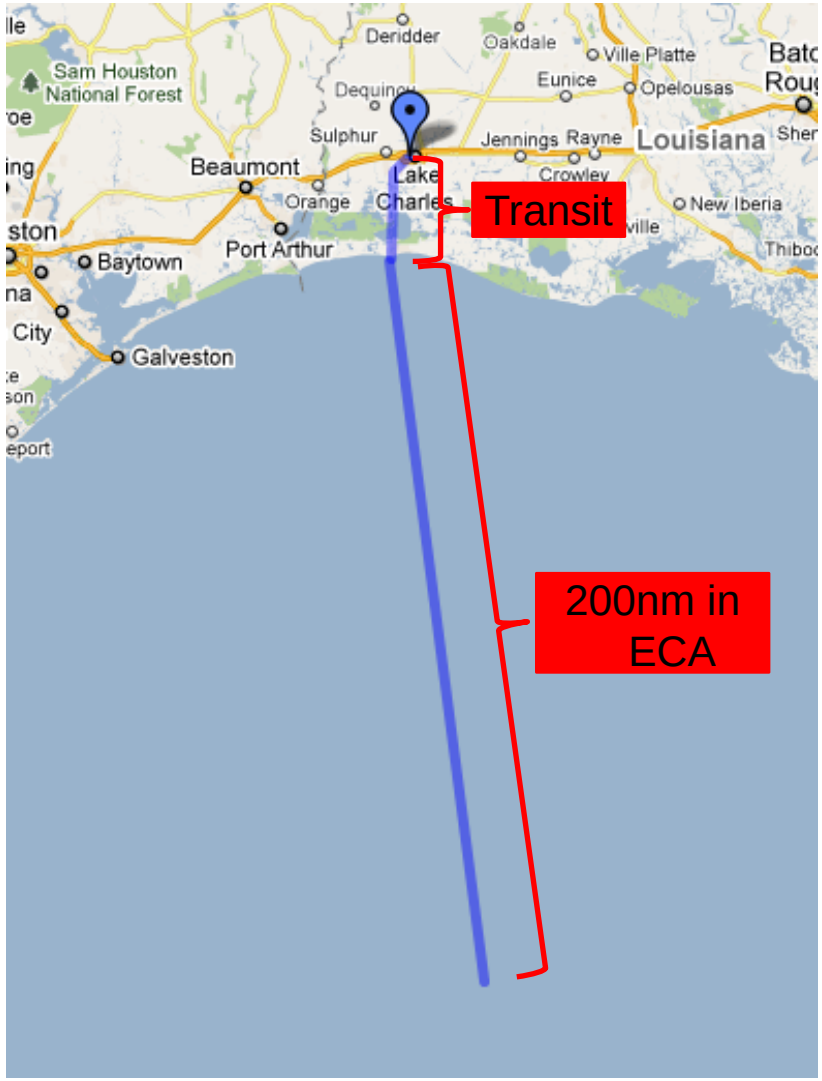
Shipowner Considerations

- Fuel prices & consumption
- Maintenance
- Lube oil
- Emission Control Area (NOx)
  - ME-GI requires EGR operation for NOx compliance in :
    i. Transit – 50km x2 at 5kn = 17.5hrs
    ii. ECA – 370km x2 at 18kn = 22.2hrs
  - Assume 4x per year…

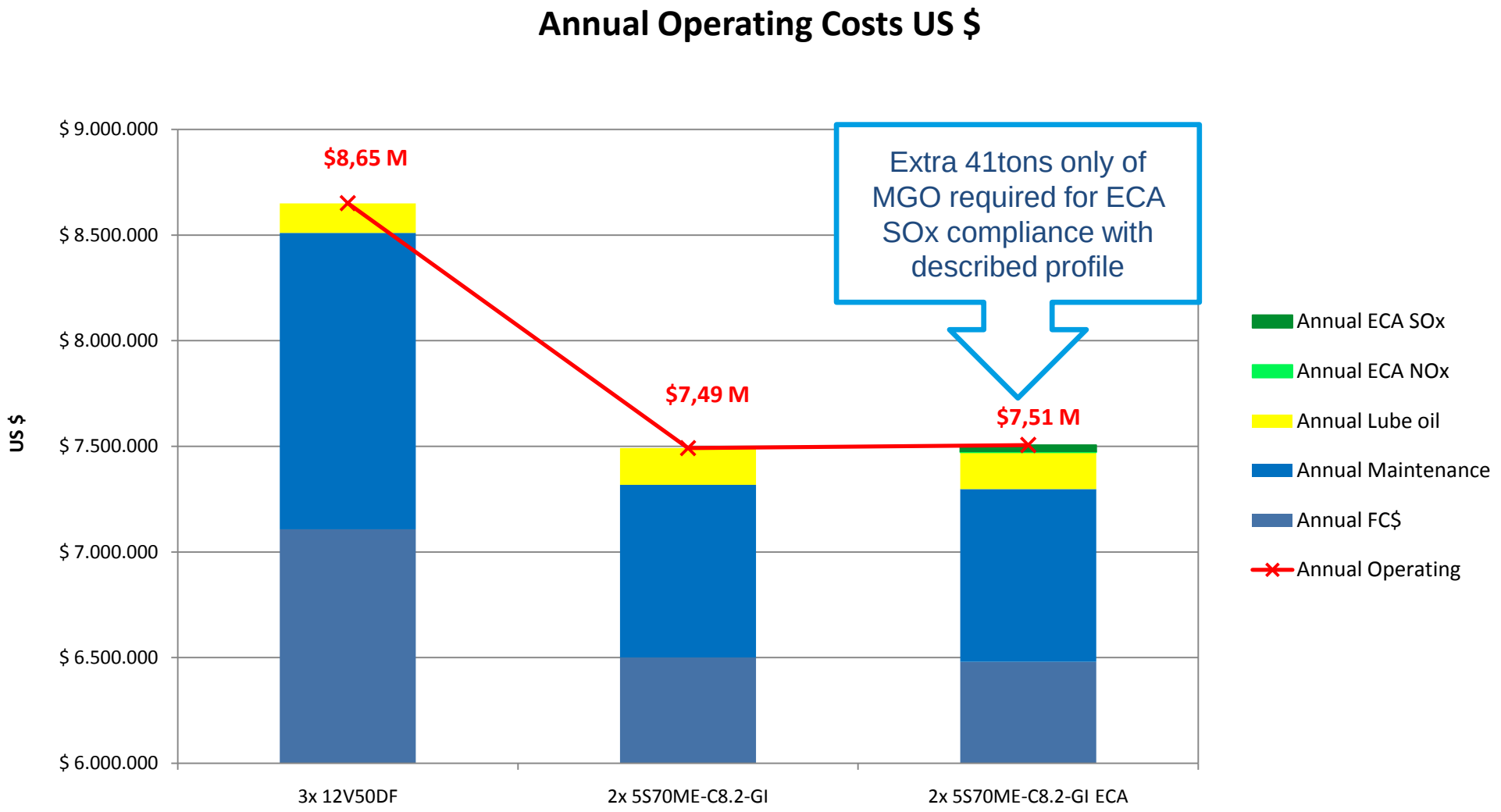


Shipowner Considerations

- Fuel prices & consumption
- Maintenance
- Lube oil
- Emission Control Area (SOx)
  - ME-GI requires MGO for SOx compliance in:
    i. Transit (MGO only)– 50km x2 at 5kn = 17.5hrs
    ii. ECA (MGO as pilot oil) – 370km x2 at 18kn = 22.2hrs
  - Assume 4x per year…



Shipowner Considerations



Shipowner Considerations

- Fuel prices & consumption
- Maintenance
- Lube oil
- Emission Control Area (NOx)
- Emission Control Area (SOx)

- First Cost (USD)

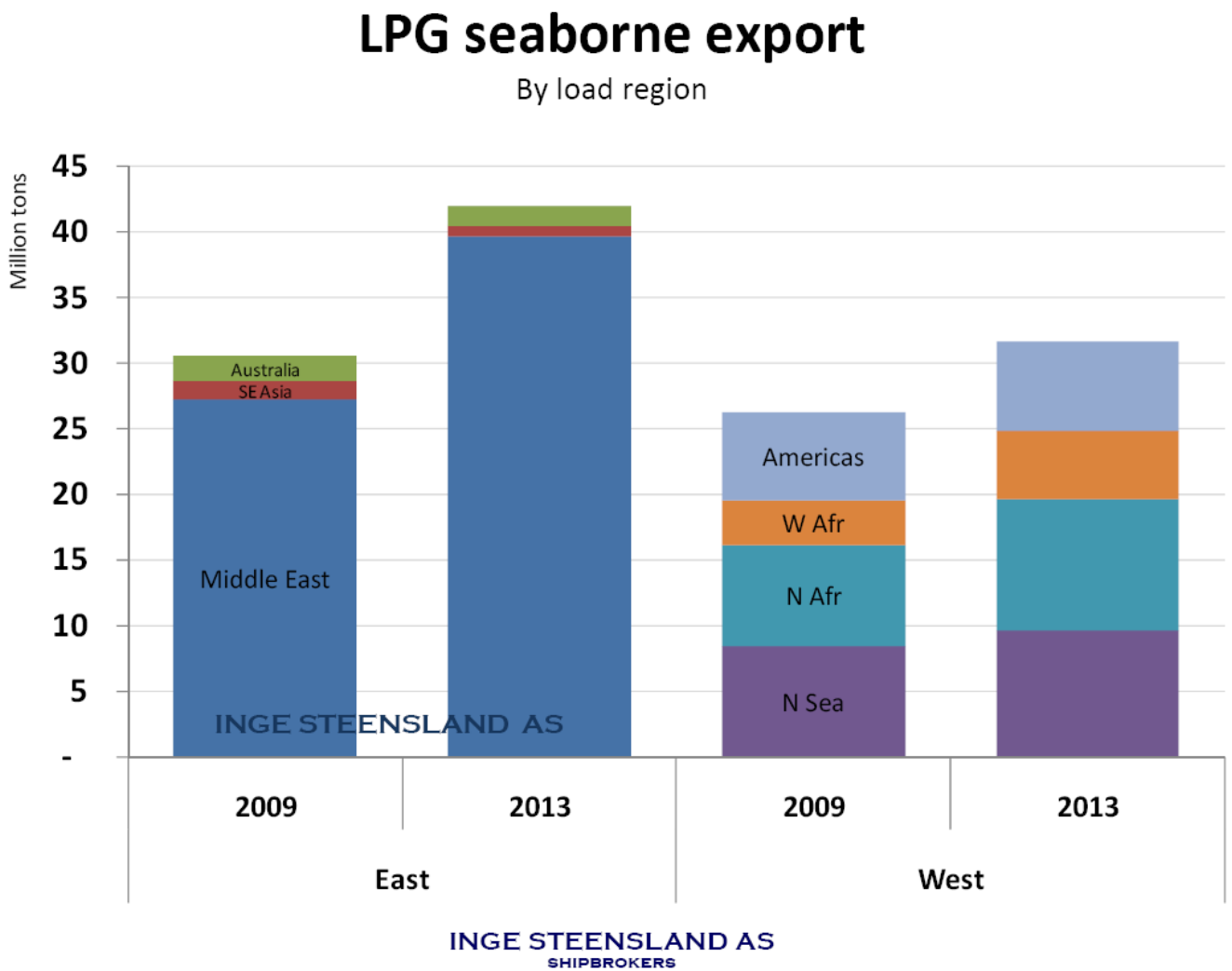
	3x 12V50DF	2x 5S70ME-C8.2-GI
Main Engine	-	7.8M
Gensets	18.9M	6.5M
EGR	-	1.1M
Electrical systems	10M	-
100% Reliquification	11.5M	11.5M
Fuel Gas Supply system (tanks not included)	~3M	3.8M
Total budget price USD	**$43.4M**	**$30.7M**
CPP (option)	+1M	
Gearbox (option)	+1.5M	
Redundancy (option)	+6.6M	+2M
SCR (option)	~+1M	

ME-LGI engine powered by LPG

550 bar at
35 °C

LPG is a by-product of LNG production, so

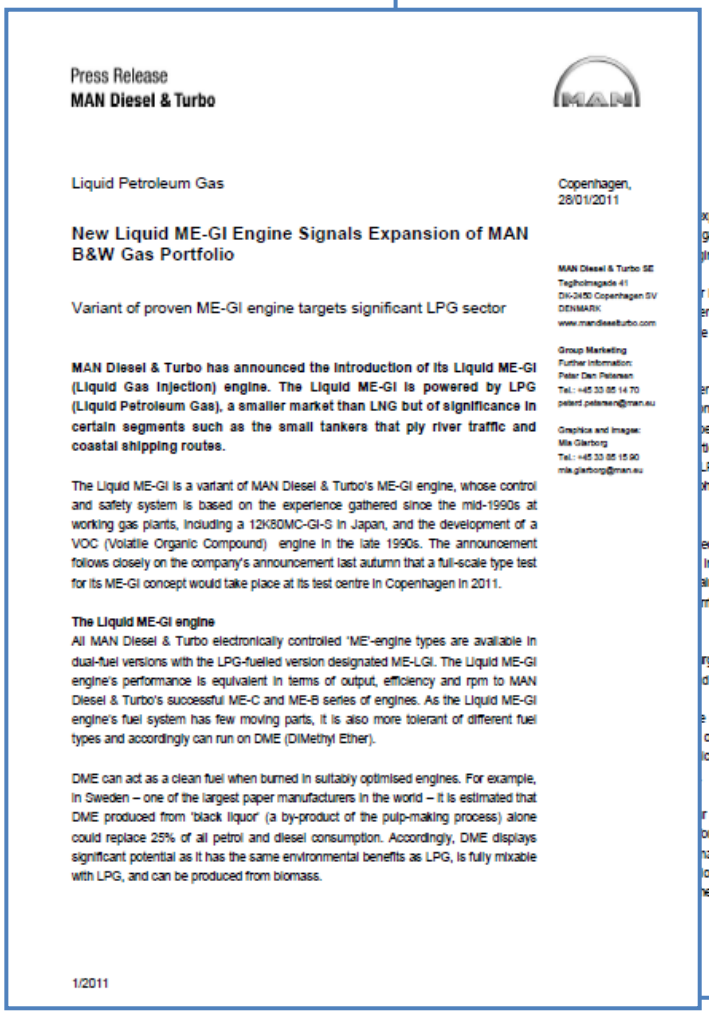
LPG production is not driven by demand



30% Increase of LPG production is expected in 2013.

How will this affect the LPG price?

Press Release
LOI for a DME fuelled ME-LGI engine



Press Release
MAN Diesel & Turbo

Liquid Petroleum Gas

Copenhagen,
26/01/2011

New Liquid ME-GI Engine Signals Expansion of MAN B&W Gas Portfolio

Variant of proven ME-GI engine targets significant LPG sector

MAN Diesel & Turbo has announced the introduction of its Liquid ME-GI (Liquid Gas Injection) engine. The Liquid ME-GI is powered by LPG (Liquid Petroleum Gas), a smaller market than LNG but of significance in certain segments such as the small tankers that ply river traffic and coastal shipping routes.

The Liquid ME-GI is a variant of MAN Diesel & Turbo's ME-GI engine, whose control and safety system is based on the experience gathered since the mid-1990s at working gas plants, including a 12K80MC-GI-S in Japan, and the development of a VOC (Volatile Organic Compound) engine in the late 1990s. The announcement follows closely on the company's announcement last autumn that a full-scale type test for its ME-GI concept would take place at its test centre in Copenhagen in 2011.

The Liquid ME-GI engine
All MAN Diesel & Turbo electronically controlled 'ME'-engine types are available in dual-fuel versions with the LPG-fuelled version designated ME-LGI. The Liquid ME-GI engine's performance is equivalent in terms of output, efficiency and rpm to MAN Diesel & Turbo's successful ME-C and ME-B series of engines. As the Liquid ME-GI engine's fuel system has few moving parts, it is also more tolerant of different fuel types and accordingly can run on DME (DIMethyl Ether).

DME can act as a clean fuel when burned in suitably optimised engines. For example, in Sweden – one of the largest paper manufacturers in the world – it is estimated that DME produced from 'black liquor' (a by-product of the pulp-making process) alone could replace 25% of all petrol and diesel consumption. Accordingly, DME displays significant potential as it has the same environmental benefits as LPG, is fully mixable with LPG, and can be produced from biomass.

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1/2011

xperience safe and reliable running with
gas valves and gas pipes are smaller but
ine.

r injection all the way from tank to engine
enerate the required pressure, comprising
e from a large number of suppliers within

engines are superior in fuel efficiency,
nomy. By introducing LPG as fuel to the
enefits can be obtained, especially with
rticulate matter. NO_x emission reductions
LPG operation is combined with either an
hur levels are naturally minimal.

ed Promotions and Sales, MAN Diesel &
in the Liquid ME-GI engine as operators
already have several interesting projects
rmer newbuilding where we have signed a

rg by FKAB, Sweden's largest marine-
d construction.

e logistics problems that LNG has at this
over almost all the planet. Furthermore,
ich makes LPG auxiliary systems less

r gas-engine series stems from the many
or the Liquid ME-GI's increased flexibility
harine transportation. The addition of the
o means that MAN Diesel & Turbo now
hensive array of prime-mover solutions all

opment of the Liquid ME-GI engine to have a
ture."

el in the car industry for many years. The
SO_x and particulate emissions has also
terest in investigating fuel alternatives and
mpared with MDO. Consequently, there are
sing LPG in coastal areas and on inland
n can also be retrofitted to small-bore MAN
ers, carriers, container vessels and RoRo

crease in LNG production. This will cultivate
el on ships in general since gas is expected
s for a significant period of time, a price
parison with other types of low-sulphur fuel.
te additional LPG as LPG is a by-product of
ditional benefit, LPG production is not driven
existing LPG price level and make it more

he future, establishing bunkering facilities,
s is costly, time-consuming and subject to
urrently have an LNG network in place for
e Norway, and realistically, the widespread
e away.

hed fuel that enjoys a mature, global supply
mparatively minor safety issues.

n as bunkering stations as all have onboard
less demanding and less expensive to run
ip to ship loading of LPG is not considered

are already running on LPG as the

es and a low-carbon, low-polluting
tural gas, it is usually manufactured
il or gas streams as they emerge

from which most LPG is derived —
d to the LPG derived from cracking
that is virtually untapped and has

performance
rable to ME-C and ME-B engines
dent on current gas prices,
rable to alternative low-sulphur
nged
Fulfils Tier-II requirements
Can meet Tier-III with EGR/SCR installation
95% reduction in SO_x compared with other fuels
nged during gas operation
lled for Copenhagen test engine
eration during full load
le
ped by Hamworthy
ly LPG and DME; likely methanol
anol in the future

Liquid Gas Supply Station
Guiding Specification for LPG, DME etc.

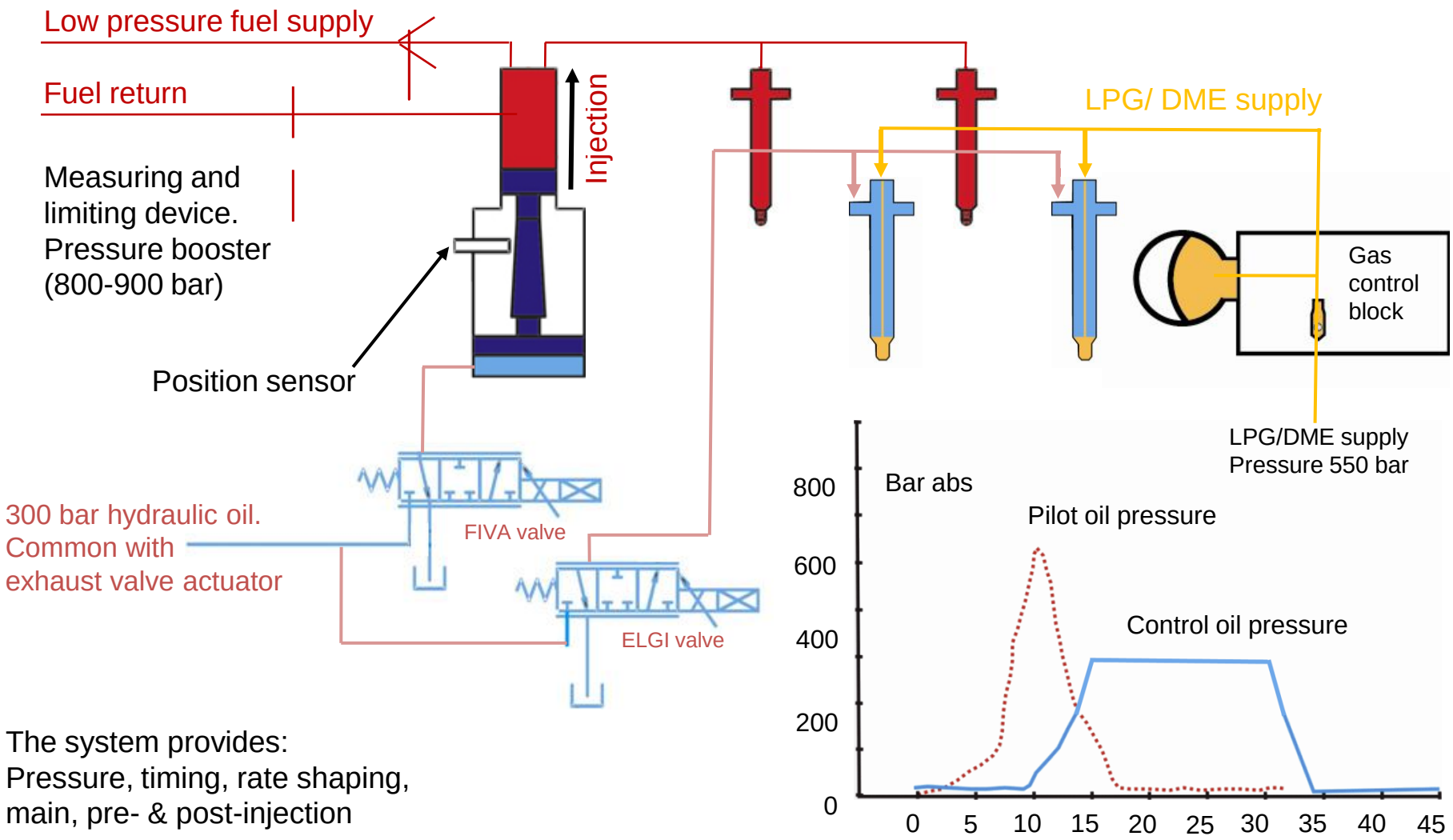
General Data for
Liquid Gas Delivery Condition:

Pressure:
Nominal 550 bar
Max. value 600 bar
Pulsation limit 3 bar
Set point tolerance 5%

Temperature:
Approx. 25°C -> 55°C / tolerance 10 °C

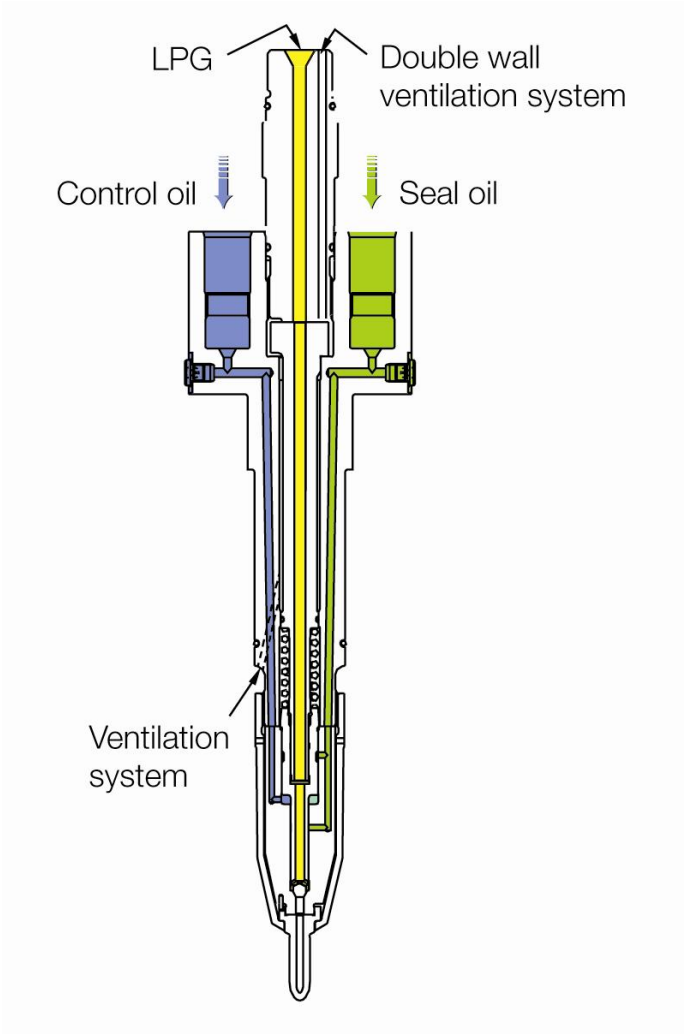
L/70020-5.0/0299

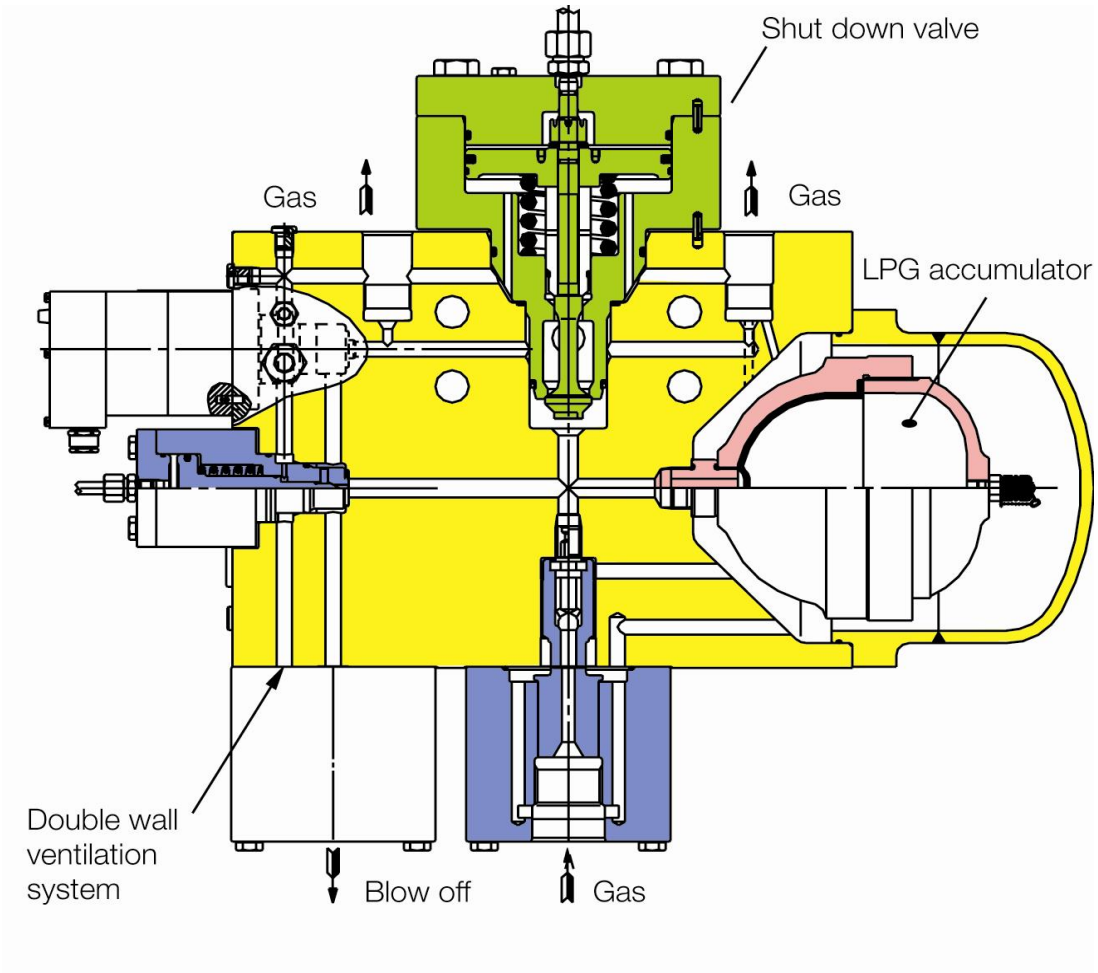
ME-LGI Injection system for LPG or DME operation



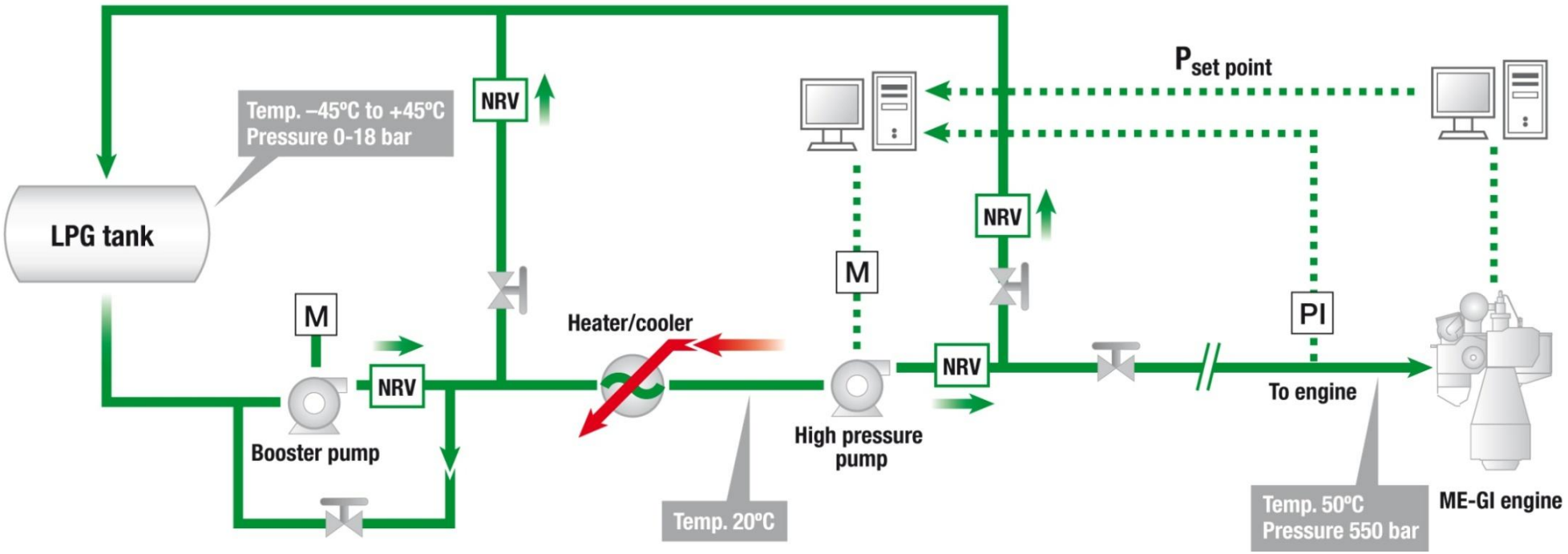
The system provides:
Pressure, timing, rate shaping, main, pre- & post-injection

Gas Injection Valve & Valve Block incl. accumulator

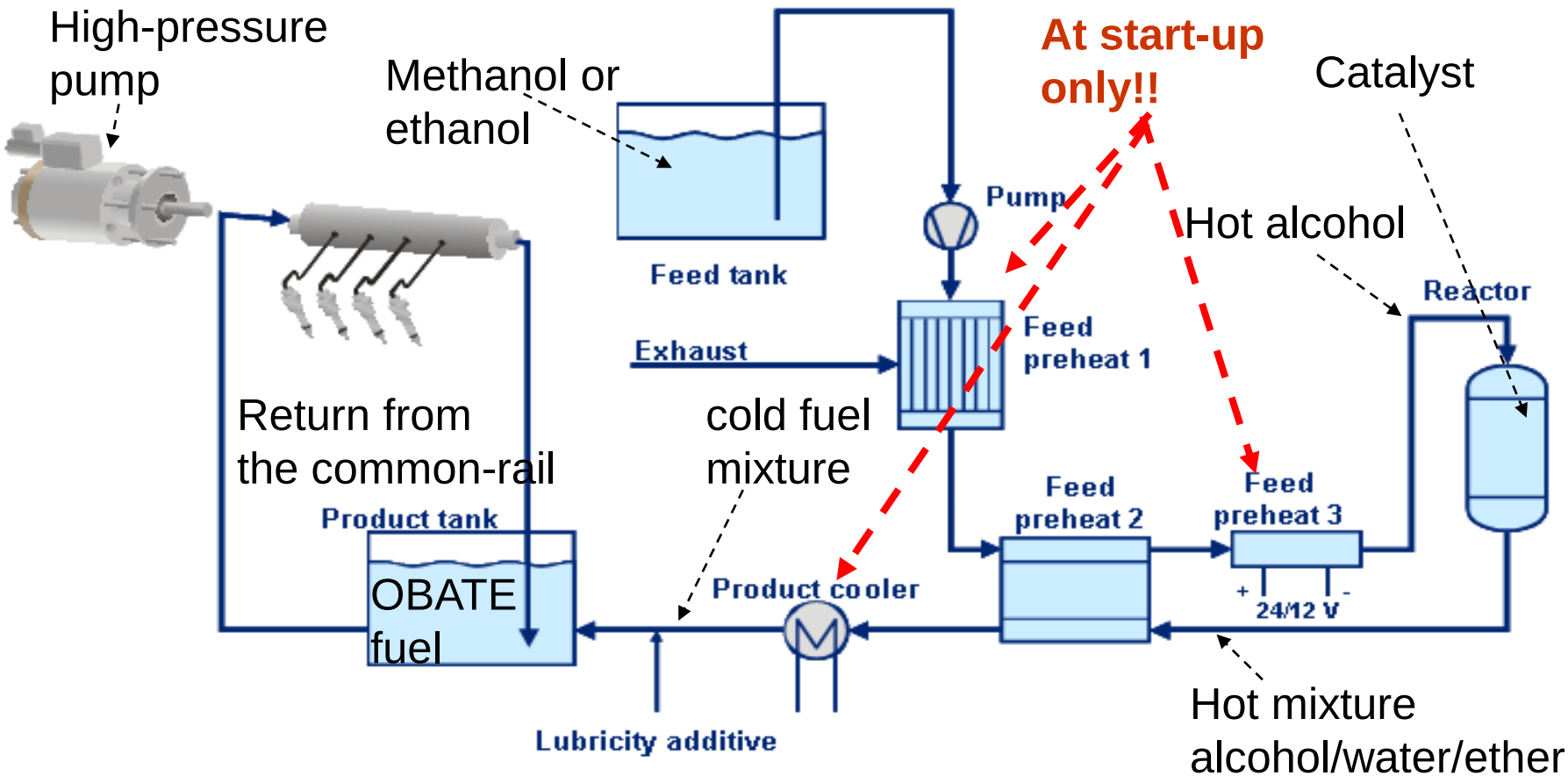




Gas Ssupply System from HGS Using LPG as Fuel



On Board auto-thermal process



$$2CH_3OH \Leftrightarrow CH_3OCH_3 + H_2O$$

The process is auto-thermal: the OBATE fuel has the same heating value than the original fuel!!

Conclusion ME-GI for short sea operation

❑ Over all efficiency.	☺ Equal
❑ Operational cost	☺ Better with gas price of today
❑ Reliability	☺ *Unchanged*
❑ Emission	☺ *Fulfilling Tier II /alt. Tier III with EGR/SCR*
❑ Emission	☺ *95% reduction on SOx*
❑ Load response	☺ *Unchanged during gas operation*
❑ Pilot oil amount	😐 *Improved during coming test*
❑ Gas operation	☺ Gas operation during full load
❑ Auto Tuning	☺ Available
❑ Gas Supply system	☺ 5 different solutions available
❑ Power range	☺ Down to below 3 MW.

ME-GI

2011

Thank you for your kind attention

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