SNAMES ~ MAN DIESEL
Industry Nite

Brief Profile of Speakers:

Mr. Lars Bryndum

Director of Customer Support

Lars Bryndum, born 1949, received his M.Sc. in Mechanical Engineering from the Technical University of Denmark, Lyngby, in 1974.

After his graduation, Lars Bryndum worked five years at the Danish Maritime Institute, Copenhagen, where he was involved in ship propulsion and propeller design.

Lars Bryndum joined A/S Burmeister & Wain's Motor- og Maskinfabrik after 1971 A/S in 1979 and worked ten years with vibration aspects in the Research and Development department.

In 1990, he was transferred as a section manager to Two-stroke Design and in 1995, he was appointed to Senior Manager of Large Bore Engine Design.

In 2000, Lars Bryndum was appointed to Representative Director of MAN B&W Diesel in Korea and was the Managing Director of the office in Busan, Korea.

From 1 September 2006, Lars Bryndum has been Director in the department for Customer Support at the head office for two-stroke engines in Copenhagen, Denmark.

Mr. Stig Baungaard Jakobsen

Senior Manager of Two-Stroke Operations

Stig Baungaard Jakobsen holds a M.Sc. in Mechanical Engineering, obtained from the Technical University of Denmark in 1982.

Jakobsen joined MAN B&W Diesel's Two-stroke R&D Department in Copenhagen in 1982. He worked there as a vibration specialist until 1990 when he was appointed Manager of the Vibration Analysis Section.

In 1999, he subsequently became Manager of the Engine Development Section, followed by becoming Senior Manager of the New Design Department in 2001.

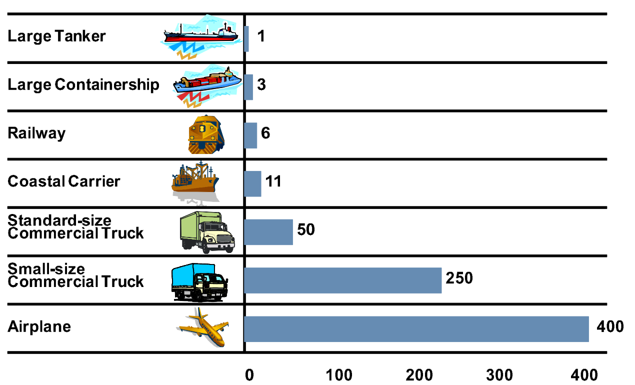
Three years later, Stig Baungaard Jakobsen was appointed Vice President of High Speed Diesel Engineering at MAN Diesel, Stockport, England and has been Senior Manager of MAN Diesel's Two-stroke Operation Department in Copenhagen since 2005.

Alternatives to Marine Diesel Engines?

- Fuel cells — Need development and clean fuel; Need frequency converters and el. motors.
- Sun and wind — Need development and back-up
- Nuclear power — Politically and economically not feasible

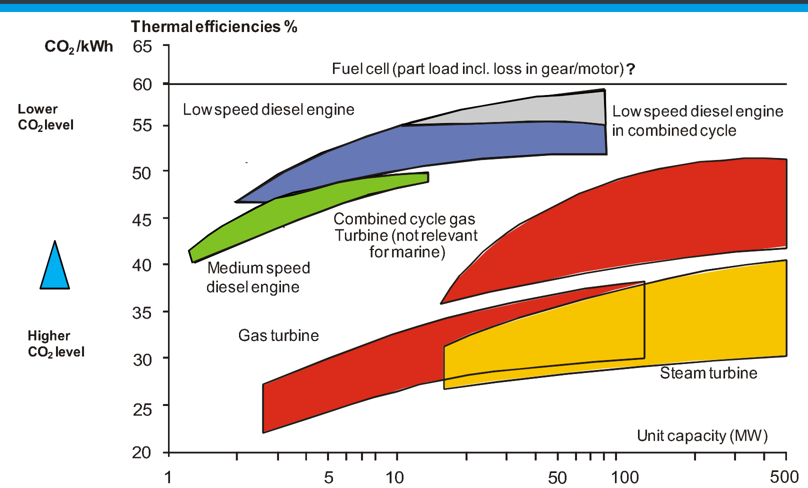
For a foreseeable future
Diesels will prevail ……
…… using cleaner and less fuels

CO_2 Emissions per Unit Load by Transport Mode

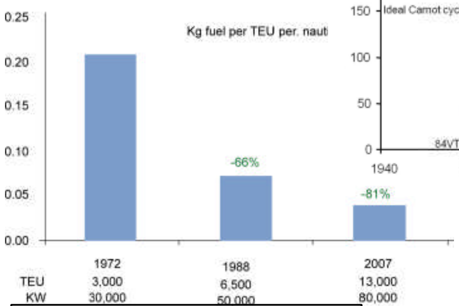


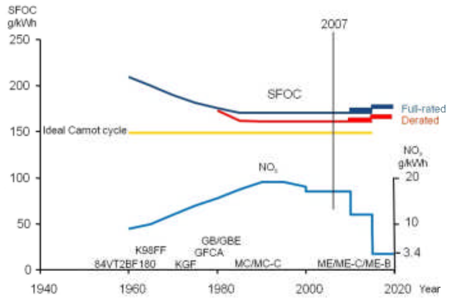
Source: Report on Research for CO2 Emission from Ships 2000 (SOF, Japan)
Interim Report by Transport Policy Council 2006 (MLIT, Japan)
Common Guideline for Calculation Method of CO2 Emission in Logistics (Issued on 2006 by METI and MLIT)

Typical Thermal Efficiency of Prime Movers



Larger Vessels Mean Lower Cost per TEU per Mile





Made possible with larger engines

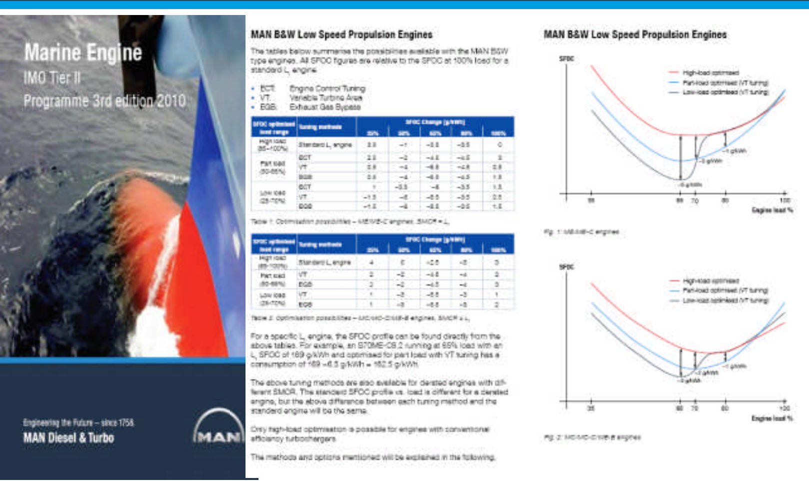
Alternative Diesel Fuels

Alternative fuels for two-stroke diesel engines.

- LNG
- Bio fuels
- Any hydrocarbon
- Hydrogen
- Orimulsion
- Coal slurry

- Syntetic fuels ??

Two-stroke Engine Programme 2010 3rd edition



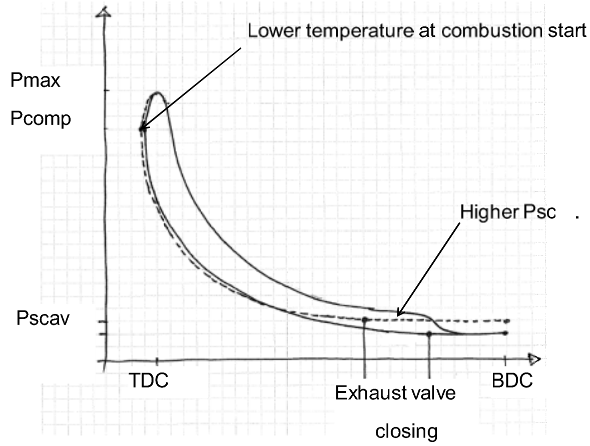
Dot 2 engines

Tier II Evolution continued

- Increased scavenge air pressure later closing of exhaust valve (enhanced Miller timing). Available with proven MAN Diesel &Turbo TCA turbochargers. New generation of ABB and MET turbocharger required.
- Reduced compression ratio
- Increased maximum combustion pressure
- Adjustments of compression volume
- Design changes on Pmax influenced components (mainly cylinder liner, piston, cover and crossheads)
- General outlines, dimensions, stroke, etc., have been kept unchanged.

S80ME-C8/9 = original Mk 8/9 engine complying with Tier I
S80ME-C8.1/9.1 = original Mk 8/9 engine complying with Tier II
S80ME-C8.2/9.2 = the new fuel-optimised version complying with Tier II

Enhanced Miller timing



SFOC Optimisation Methods – IMO Tier II Engines

1. SFOC optimised load ranges

High Load: 85% - 100% SMCR (standard tuned engine)

Part Load: 50% - 85% SMCR

Low Load: 25% - 70% SMCR

2. Engine tuning methods available for part load and low load optimisations

EGB: Exhaust Gas Bypass

VT: Variable Turbine Area

ECT: Engine Control Tuning (only for ME/ME-C)

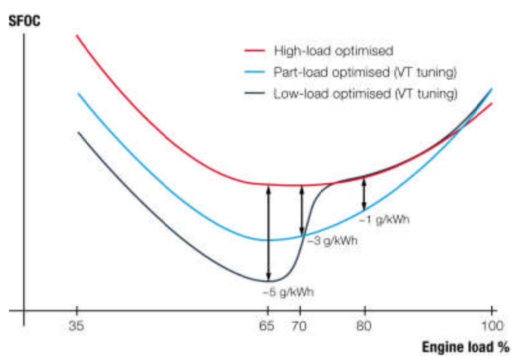
Only available for engines with high-effective turbocharger

3. Examples are shown for the below two engine types

6S80ME-C8.2 and **6S80MC-C8.2**

SFOC Optimisation Methods – IMO Tier II Engines

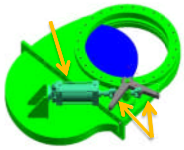
- ME / ME-C engines – example with VT:

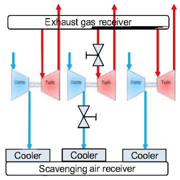


Engine Tuning Methods

Exhaust Gas By-pass, EGB

Turbocharger Cut-out

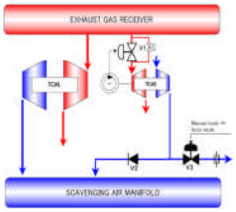




Turbocharger Variable Turbine Area, VTA

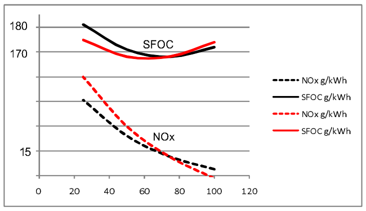
Engine Tuning Methods

Sequential Turbocharging

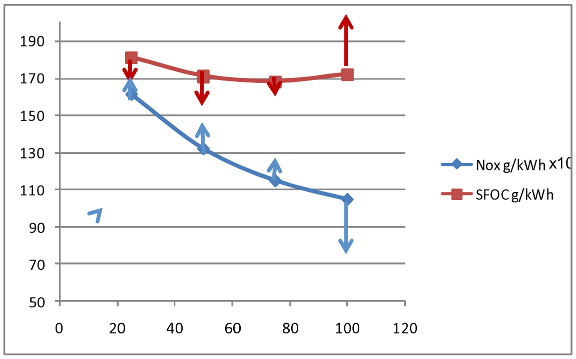


ECT Engine Control Tuning

SFOC-NO_x Balancing

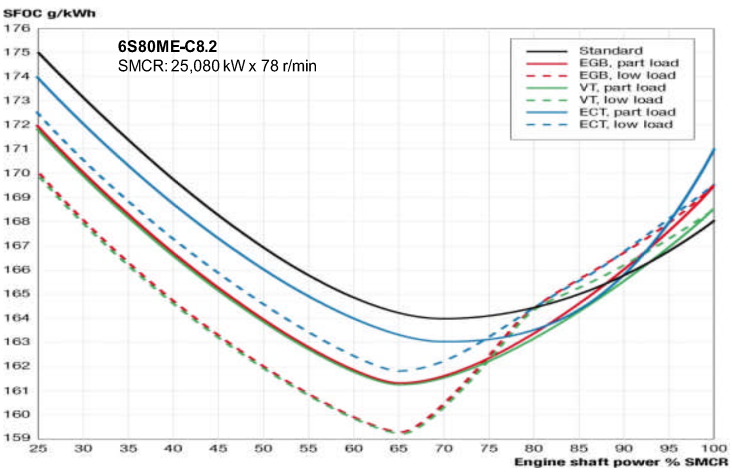


Low-load and part load tuning



E3 Cycle = **5%***NOx(25) + **11%***NOx(50) + **55%***NOx(75) + **29%***NOx(100) < **14,4 g/kWh**

SFOC Optimisation Methods – IMO Tier II Engines



SFOC Optimisation Methods – IMO Tier II Engines

Main engine 6S80ME-C8.2 IMO Tier II
SMCR = 25,080kW x 78r/min

Standard engine, high load optimised

Load Profile →

Engine load	% SMCR	35%	50%	65%	85%	100%	Total fuel consumptions
Engine power	kW	8,778	12,540	16,302	21,318	25,080	
SFOC Re LCV = 42,700 kJ/kg	g/kWh	171.4	167.0	164.3	165.0	168	
Fuel consumption	t/day	36.1	50.3	64.3	84.4	101.1	
Days in service	day/year	40	100	90	15	5	
Fuel consumption	t/year	1,444	5,030	5,787	1,266	506	14,033 t/year

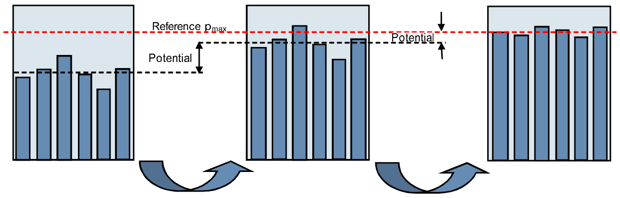
VT, low load optimised

Engine load	% SMCR	35%	50%	65%	85%	100%	Total fuel consumptions
Engine power	kW	8,778	12,540	16,302	21,318	25,080	
SFOC Re LCV = 42,700 kJ/kg	g/kWh	166.4	162.0	159.3	165.3	168.5	
Fuel consumption	t/day	35.0	48.8	62.3	84.6	101.4	
Days in service	day/year	40	100	90	15	5	
Fuel consumption	t/year	1,400	4,880	5,607	1,269	507	13,663 t/year
Fuel savings	t/year	44	150	180	-3	-1	370 t/year
Fuel savings	%/year	3.0	3.0	3.0	-0.2	-0.3	**2.6%/year**

Auto-tuning: Potential Fuel Reduction

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



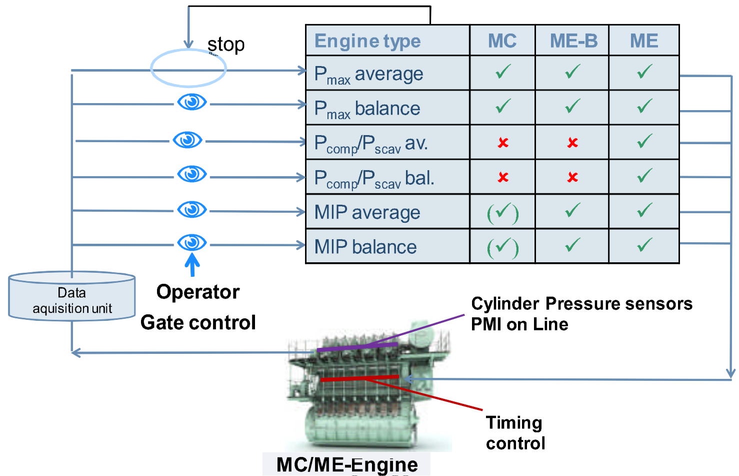
Pure p_{max} level increase
Potential 5-10 bar
Potential 1-2.5 G/kWh

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

Total potential 1.4 – 3.75 g/kWh

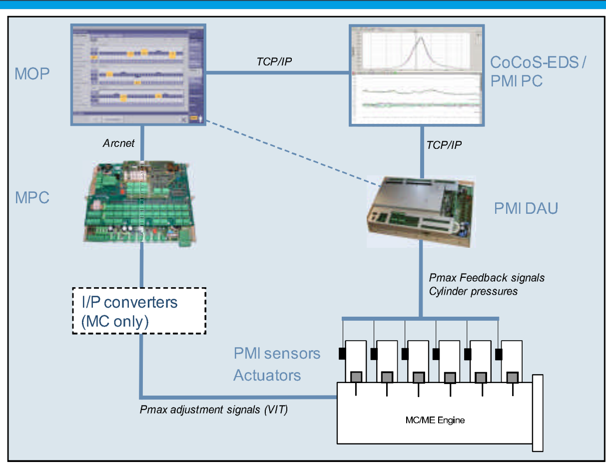
Gain even with engines already being operated within recommended limits

PMI Online + Auto-tuning

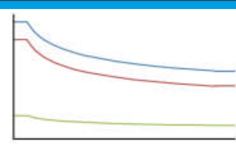


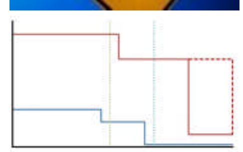
Engine type	MC	ME-B	ME
P_{max} average	✓	✓	✓
P_{max} balance	✓	✓	✓
P_{comp}/P_{scav} av.	×	×	✓
P_{comp}/P_{scav} bal.	×	×	✓
MIP average	(✓)	✓	✓
MIP balance	(✓)	✓	✓

Auto tuning: ME & MC engines



Flexible and Agile Two-Way Approach for Fulfilling IMO Tier III





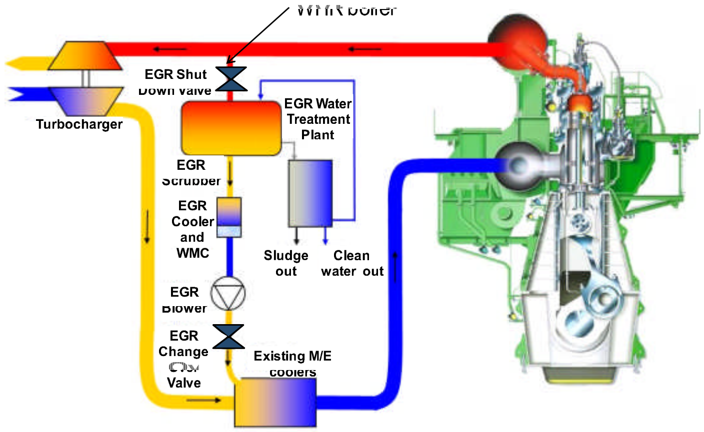
Tier III NO_x

- NO_x reduction with EGR (Exhaust Gas Recirculation)
- NO_x reduction with SCR (Selective Catalyst Reduction)

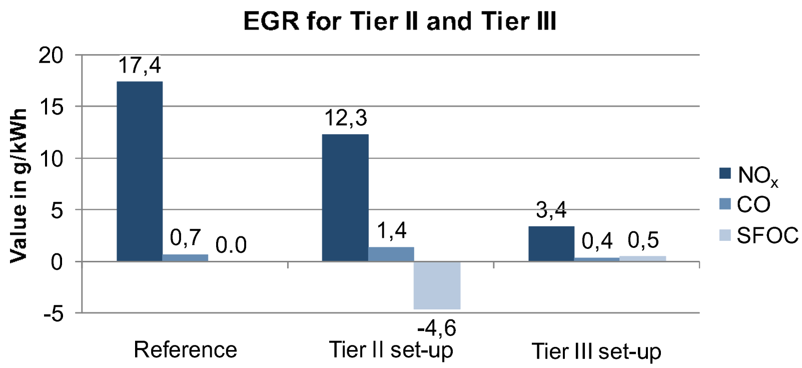
Tier III SO_x

- SO_x reduction with Exhaust Gas Scrubbers
- Engine operation on low sulphur fuels

EGR Principle for Two-stroke Engine Operating on HFO

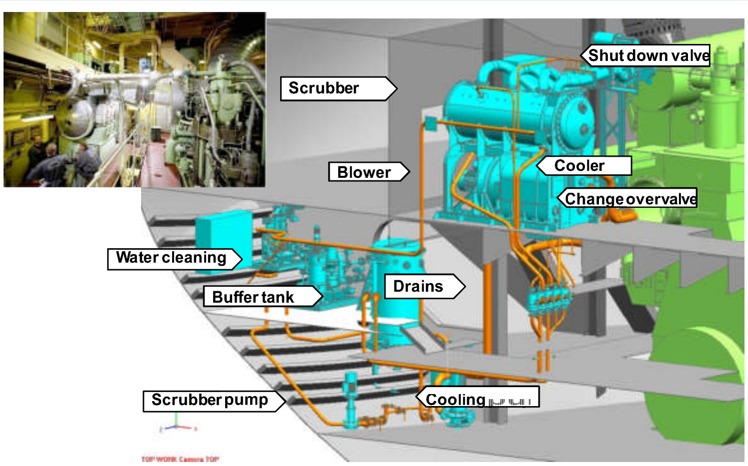


EGR for Tier II and Tier III

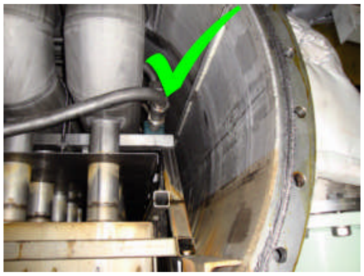


Power for EGR blower not included in SFOC values
Other emission parameters (PM, HC) nearly unchanged

Arrangement in Engine Room



System Inspection



Scrubber condition is fine

EGR cooler and WMC is fine

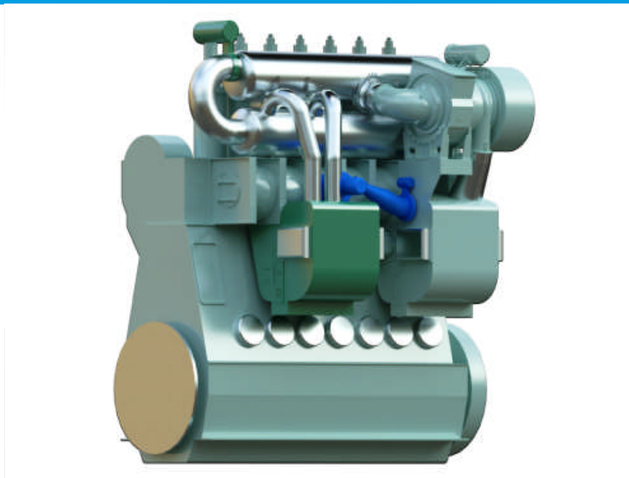
EGR Service Test Commissioning Conclusions

- EGR control system performed as planned
- Scrubber, blower and EGR cooler had sufficient capacity
- Pumps, drainers and buffer tank performed well
- Scrubber unit in perfect condition
- M/E coolers and WMC's looked fine – no deposits or corrosion
- NO_x reduction better than expected

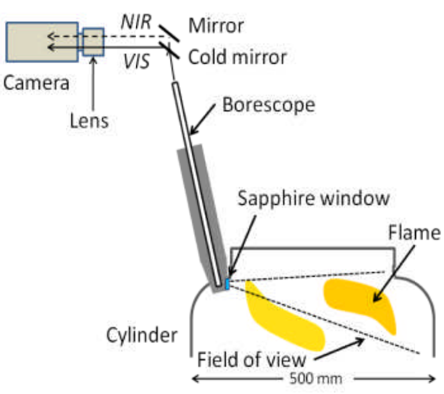
? Water Cleaning unit and PH dosing system not operating as expected

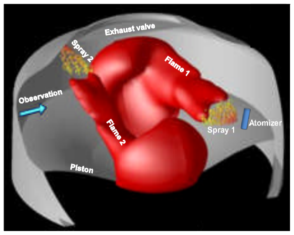
? Cylinder condition not confirmed, only due to too short operation time

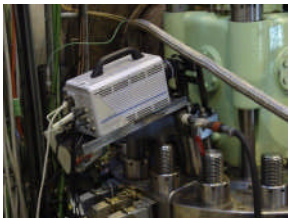
Integrated EGR



Photographing Combustion







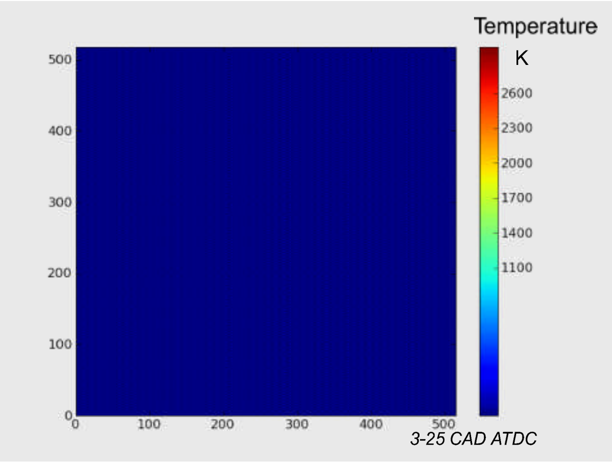
High Speed Imaging of Combustion

Recording with

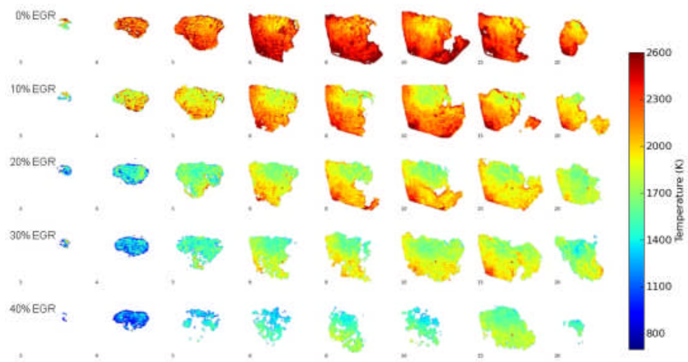
- 18,000 frames per seconds
- Shutter time 4μs

Combustion slowed down 600 times!

High Speed Imaging
Two-colour Pyrometry

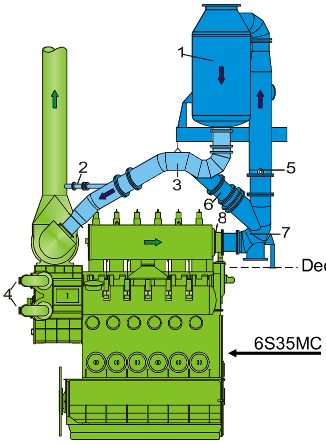


High Speed Imaging
Two-colour Pyrometry



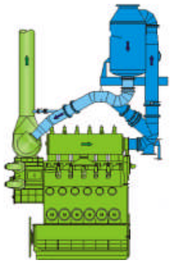
SCR Selective Catalytic Reactor

1. SCR reactor
2. Turbocharger bypass
3. Temperature sensor after SCR
4. Large motors for auxiliary blowers
5. Urea injector
6. SCR bypass
7. Temperature sensor before SCR
8. Additional flange in exhaust gas receiver



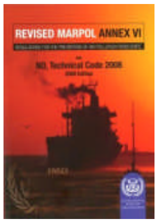
Objectives and Cooperation Partner

- Objectives
  - Develop commercial high-pressure SCR solutions
  - Meet Tier III requirements as only installed NO_x reducing technology
  - Applicable with MC, ME and ME-B engines
  - High "fuel tolerance"
- Three partners
  - MAN Diesel & Turbo Copenhagen
  - Engine builder
  - Catalyst manufacturer



Approved Methods for pre-2000 engines

- Upgrade from **Tier 0 to Tier I** (NOx)
- Engines installed on year **1990 to 2000** ships
  - Cyl displ. ≥90L & Engine power >5000kW
  - Approved Method available
- Regulation into force **1. July 2010**



The Approved Method is available when:

- The **designer** of the base engine to which the Approved Method applies, verifies that:
  - **engine rating** is not reduced by more than 1.0%
  - **Specific Fuel Oil Consumption** is not increased by more than 2.0%
  - **engine durability** and **reliability** is not adversely affected
- The **cost** of the Approved Method is not excessive

Approved Method

An Approved Method for an MAN B&W engine consists of a slide valve (with a newly developed low-NOx nozzle) and, in some cases, minor performance adjustments.

The application of an MAN B&W Approved Method will result in a range of benefits, among others:

- compliance with MARPOL Annex VI, Regulation 13, chapter 7
- unchanged or slightly improved fuel oil consumption
- reduced emissions of NOx, carbon monoxide, hydrocarbons and particulate matter
- improved low-load operation
- cleaner combustion chamber and exhaust gas ways.

The first engine type to receive an Approved Method is the S70MC. The S60MC and S50MC will follow during the second half of 2010.

Approved Method

It is the ship owner's obligation (when a vessel renewal survey is coming up following 1 July 2010) to verify whether an Approved Method has been released for his specific engine.

If an Approved Method is available, the ship owner shall introduce the Approved Method on board at the renewal survey.

If no Approved Method is available, the engine is in compliance, but the Class must amend the new IAPP that no Approved Method exists.

http://www.mandieselturbo.com/AM

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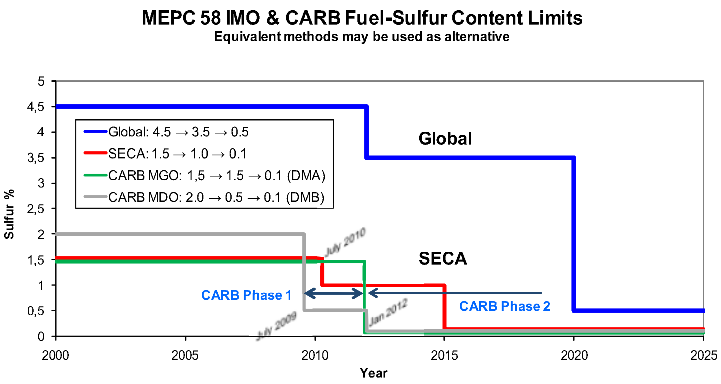
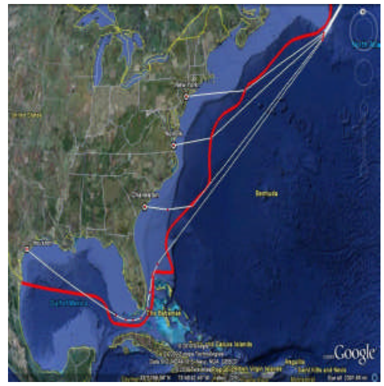
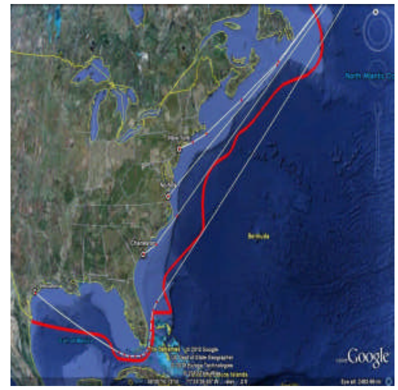
MEPC 58 Fuel-Sulfur Decision



CO2 versus SOx Emission or ECA evasion

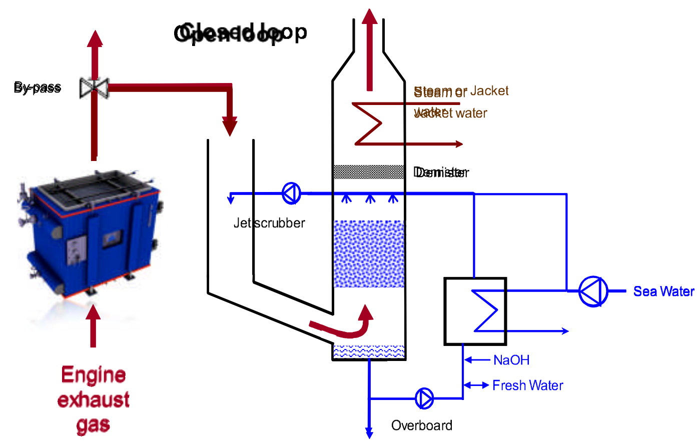




SOx Removal with Wet Scrubber

AALBORG INDUSTRIES

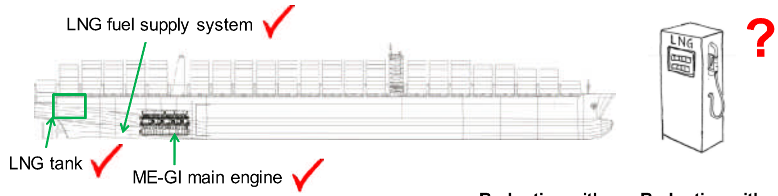
Scrubber Operation



Scrubber Retrofit

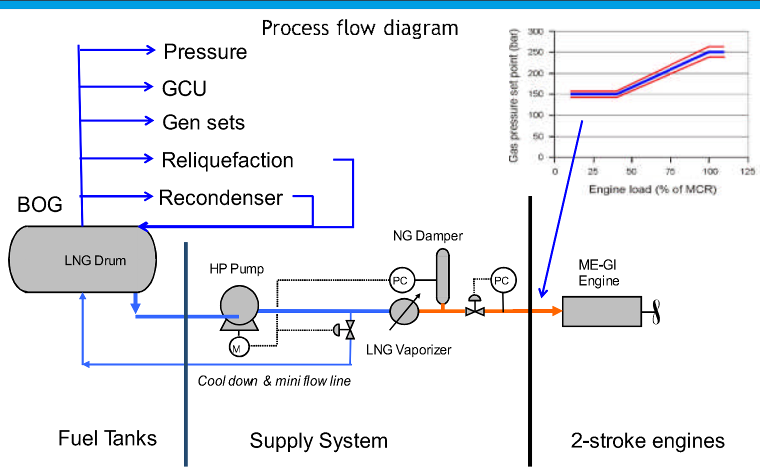
Before	During	After

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)	92%	92%	94%
Particulate matter (mg per m^3)	37%	37%	48%

LNG as Fuel for Marine Propulsion



ME-GI: Gas and Pilot Oil Injection

Background

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

New components

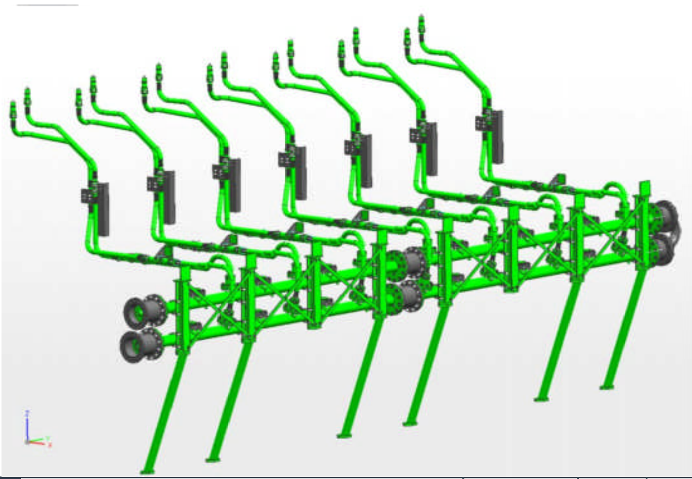
- Double wall gas pipes
- Gas Injections valves
- Large volume accumulators
- ELGI valves
- Control and safety system

Modified components

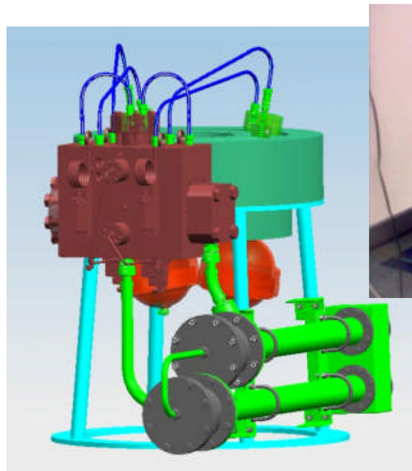
- Cylinder cover
- Exhaust receiver

4T50ME-GI ready for type approval test January 2011

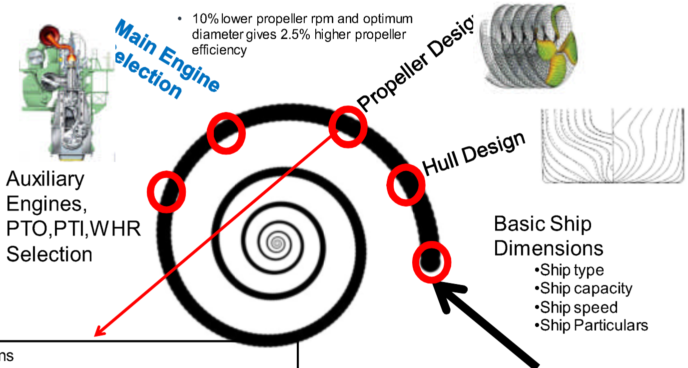
Gas-pipe-arrangement



Test Mock-up



Design Spiral

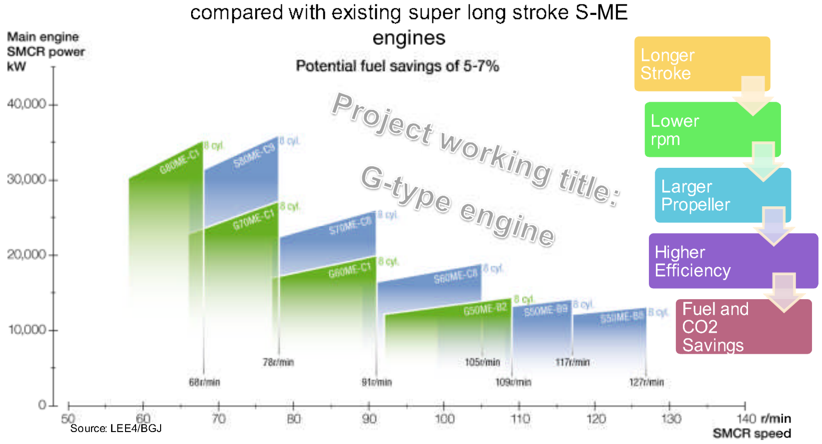


Concerns

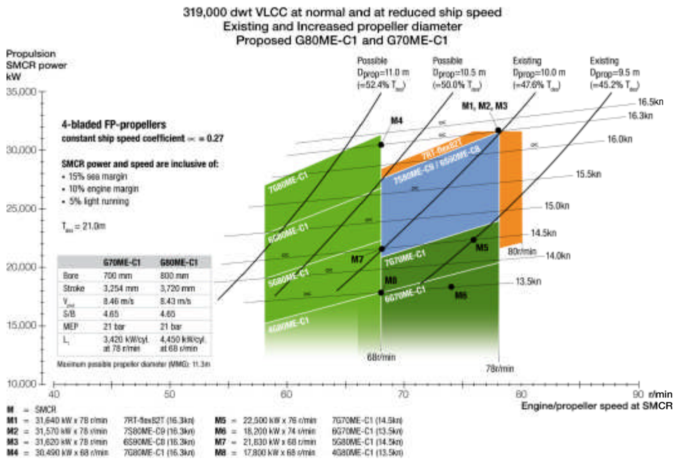
- Lubrication of stern tube bearing at very low rpm
- Insufficient submerged propeller in ballast condition
- Propeller tip clearence
- Width of bedplate aft end

G-ME Engines

Layout diagrams of proposed series of G-ME engines compared with existing super long stroke S-ME engines



Proposed G80ME-C1 and G70ME-C1 for VLCC (with reduced rpm)



Shipowner's Headache in the time to come

- Tier II or Tier III, 2015
- Operation pattern in known and future ECAs
- Economical service speed
- Fuel types and prices
- NO_x, SO_x and PM abating equipment
- Preparation beyond existing rules
- Resale price of vessel
- CO_2 energy efficiency considerations
- Low load layout
- Waste Heat Recovery
- And much more outside the engine room

Lars Bryndum
Director Customer Support
Low Speed Diesel Marine