WG7 ‚Fuels'
Status report,

Council meeting,

The world's leading designer of Two Stroke Diesel Engines

Copenhagen, Denmark.

Design of Two-Stroke Engines

Production of Spare Parts

PrimeServ Academy

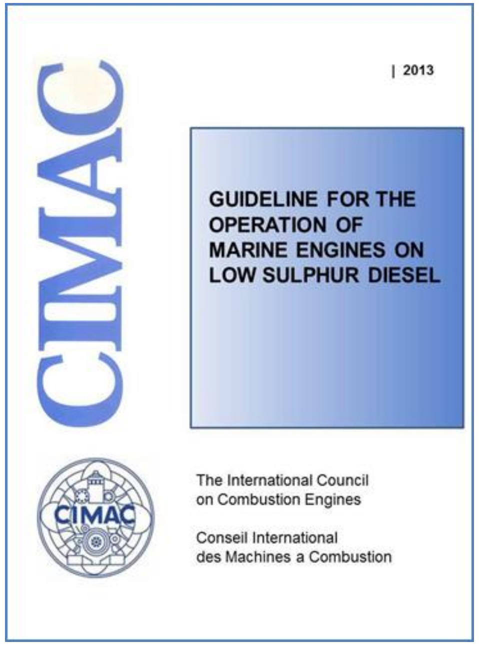
R&D Center

Diesel House

Employees CPH 1,300 (DK about 2,000)

WG7 ‚Fuels‘

- 35 members
  - 15 on waiting list
- Represented stakeholders
  - Refiners, Suppliers, OEMs, Ship Operators, Fuel Testing Labs, Classification Societies and others
- Co-operation with
  - All CIMAC WGs in case of common topics
  - ISO8217 fuels group (very close relationship)
- Latest Publications
  - Guideline providing answers to FAQ from ISO 8217:2017 (Mar 2017)
  - Guideline on the Interpretation of Marine Fuel Analysis Test Results (Feb 2016)
  - Guideline on Filter Treatment of Residual Fuel oil (Dec 2015)
  - Position paper: New 0.10% sulphur marine (ECA) fuels (June 2015)
  - Guideline: Cold flow properties of marine fuel oils (Jan 2015)



WG7 ‚Fuels'

Recent and upcoming meetings

- No 76: Apr 2017, Switzerland
- No 77: Sep 2017, Frankfurt
- No 78: Apr 2018, Copenhagen
- No 79: Sep 2018, Philadelphia, US
- No 80: Mar 2019, Oslo or Lisbon

Current activities, subgroups

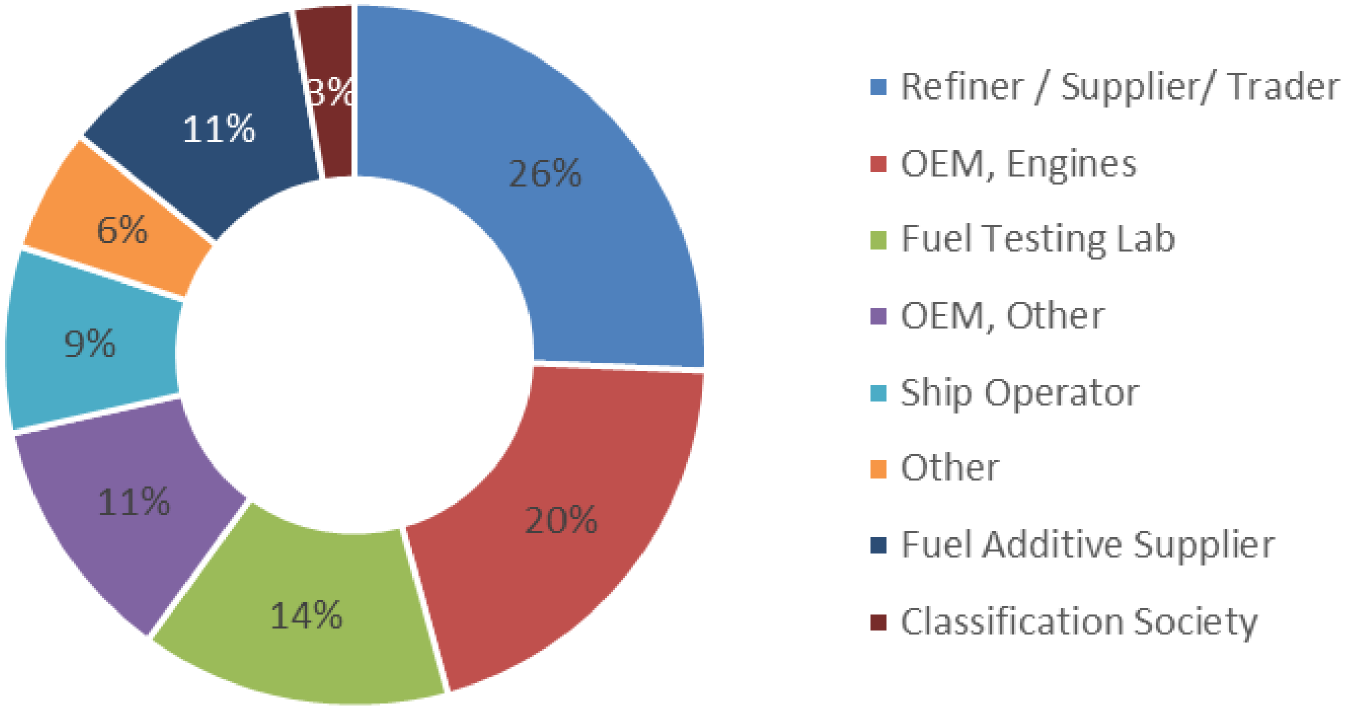
<u>High priority SGs</u>

SG 1-1 CFR (centrifuges and efficiency)
SG4 Guideline on stability/compatibility
SG5 LNG quality
SG6 Ignition/Combustion, 2020 fuels
SG9 "How to order and use 2020 fuels"

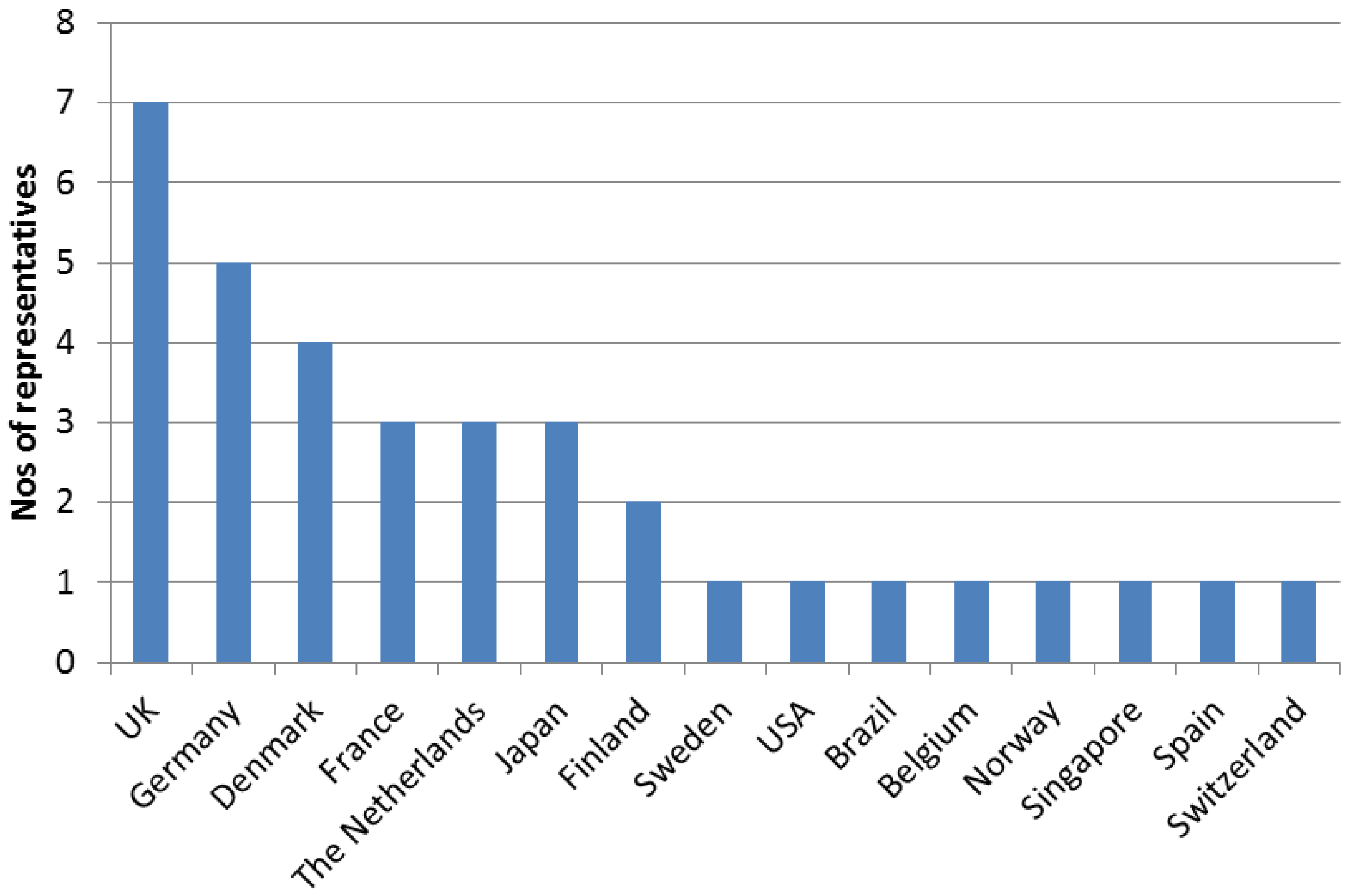
<u>Low priority SGs</u>

SG 1-2 Separators
SG 3 pH / Corrositivity
SG 7 Emulsion fuels
SG10 Niche fuels

Representation in WG7 by sector



Representation in WG7 by country



CIMAC WG7 Fuels and ISO 8217 committee

CIMAC WG7 Fuels	ISO 8217
Recommendation	Standard
Short lead time	Long lead time
High flexibility	Limited flexibility

- Participant overlap between groups
- WG7 and ISO 8217 support each other
- Rational use of resources – avoid duplication of work

How is CIMAC WG7 ‚Fuels' preparing for 2020 ?

Definitions:

- Ultra low sulphur fuel oil (ULSFO), max 0.10% S
- Very low sulphur fuel oil (VLSFO), max 0.50% S
- Low sulphur fuel oil (LSFO), max 1.00% S
- High sulphur fuel oil (HSFO), above 1.00% S

- LS MGO – max 0.10% S (no heating required)
- HS MGO – above 0.10% S (no heating required)

How is CIMAC WG7 ‚Fuels‘ preparing for 2020 ?

- Close cooperation with ISO 8217
- Assist ISO 8217 taking on some of the investigative work
- Prepare guidelines related to 2020 fuels. Currently two on the agenda:
  - Guideline: Stability / Compatibility
  - Guideline: How to order and use 2020 fuels?
- Investigate if there are other onboard and/or lab measurements available/needed to ensure safe operation on the VLSFO

- Represented in IMO “Joint Industry Guidance for 0.50%S Marine Fuel”

MAN B&W 2-stroke Engines

Residual
ME/MC

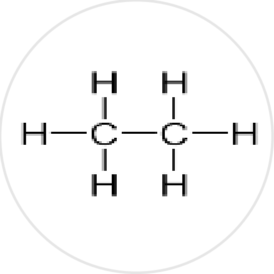
Distillates
ME/MC

ULSFO
ME/MC

Methane
ME-GI/MEGA

Methanol
ME-LGIM

LPG
ME-LGIP



Ethane
ME-GIE

Biofuel
(2nd+3rd gen.)
ME/MC

MAN Energy Solutions supports all

MAN B&W Multifuel Engines

New fuels - emissions

	NO_x	SO_x	PM	CO_2
LNG	20-30%	90-99%	90%	24%
LPG	10-15%	90-100%	90%	13-18%
Methanol	30-50%	90-97%	90%	15%
Ethane	30-50%	90-97%	90%	15%

- Compared with Tier II engines on HFO
- Based on estimates
- Tier III can be met with EGR, PIFIW or SCR

Today - The Dual Fuel success

4 x World's first duel fuel driven ships equipped with MAN B&W engines

World's first LNG driven ocean going ship

Owner: TOTE

Ship type: Container ship, 3,100 Teu

Capacity: Dual Fuel engine type: 8L70ME-C8.2-GI

Engine delivered in 2012

World's first methanol driven ocean going ship

Owner: MOL

Ship type: Methanol carrier, 50,000 dwt.

Dual fuel engine type: 7S50ME-B9.3-LGIM

Engine delivered in 2013

World's first ethane driven ocean going ship

Owner: Hartmann Schifffahrt

Ship type: LEG Carrier, 36,000 M^3

Dual Fuel engine type: 7G50ME-GIE

Engine delivered in 2014

World's first LPG driven ocean going ship

Owner: Exmar

Ship type: VLGC, 80,000 M^3

Dual Fuel engine type: 6G60ME-LGIP

Not yet in service

MAN B&W 2-stroke Engines

Residual
ME/MC

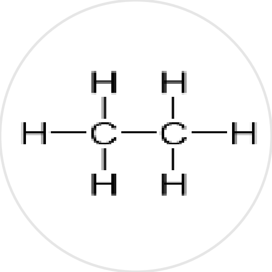
Distillates
ME/MC

ULSFO
ME/MC

Methane
ME-GI/MEGA

Methanol
ME-LGIM

LPG
ME-LGIP



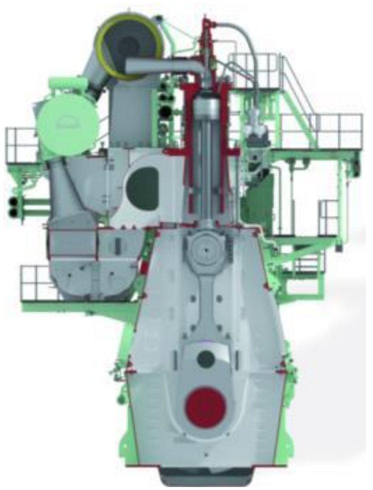
Ethane
ME-GIE

Biofuel
(2^{nd}+3^{rd} gen.)
ME/MC

MAN Energy Solutions supports all

What Fuel will be used in 2020 and beyond?

Compliant fuel		High sulphur fuel
MC/ME/-C engine Single Fuel: 0.10%S fuel, 0.50%S fuel	ME-GI/ME-LGI engine Dual Fuel: LNG, Ethane, LPG, MeOH	MC/ME/-C engine 0 – 5%S fuels: HFO/MDO + Scrubber



ULSFO < 0.1% Sulphur but what about level of Cat fines for VLSFO < 0.5% ?

	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F	Supplier G	Supplier H	Supplier I
Density (kg/m3 @ 15 C)	895-915	910	857	868	932	845	868	928	870-930
Viscosity (cSt @ 40 or 50 C)	40-75 (40ºC)	65 (50ºC)	17.6 (50ºC)	8.8	22.6 (50ºC)	8.8	8.5 (50ºC)	40C: 45-65. 50C 30-40	8-25 (50ºC)
Sulphur (% m/m)	0.1	0.095	0.08	0.05	0.1	0.03	0.09	0.1	<0.1
Pour Point (C)	15-30	20	<-12	-12	30	21	27	20-25	18-21
Flash Point (C)	>70	60	>200	72	90	>70	>70	70	60-80
Water (% v/v)	0.05	0.1	<0.2	0.004	<0.05	0.01	0.05	0.2	0.05-0.1
Acid Number (mg KOH/g)	<0.1	2.5	0.3	0.27	0.06	0.04		2.5	0.1-0.2
Al+Si (ppm m/m)	<0,3	17	<15	?	34	<1	<3	10-20	12-15
Lubricity (µm)	<320	520	-	410	-	326	-	-	-
CCAI	795-810	860	762	-	-	765	789	790-800	790-810

What may / will happen in 2020?

Key parameters for 0.50% Marine Fuel Oil blending will be:

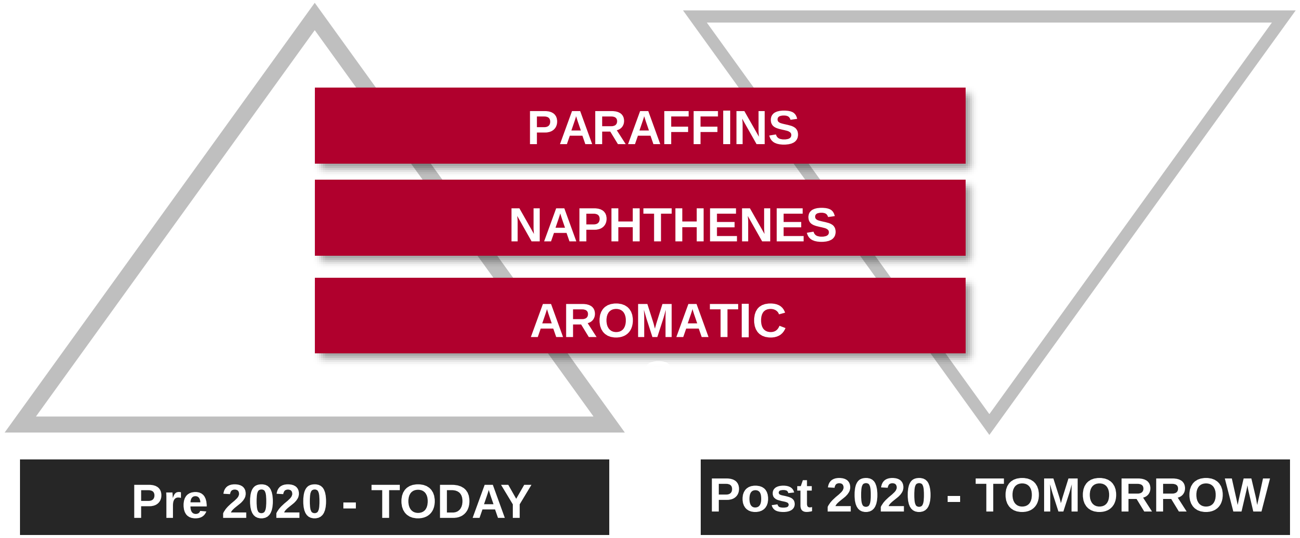
Stability (Total Sediment)
- Paraffinic vs Cracked blend components

Pour Point
- ULSFO /VLSFO close to PP limits

Acidity
- Sweet crude sources with high AN (e.g. DOBA)

Viscosity
- No minimum limit in ISO 8217, Table 2

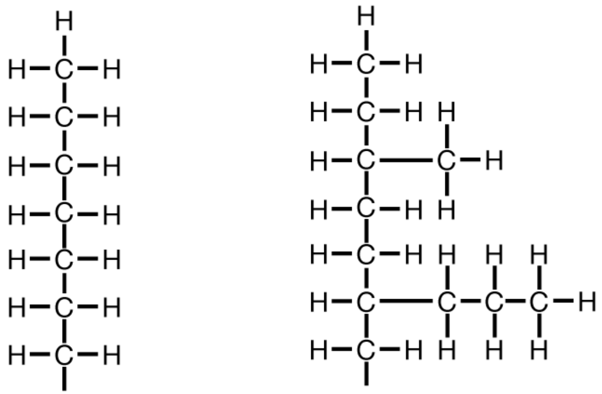
CCAI
- Larger difference between viscosity and density



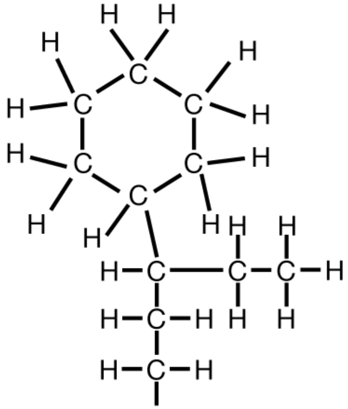
Ref: KBC/Mel Larson

Fuel Stability and Fuel Incompatibility

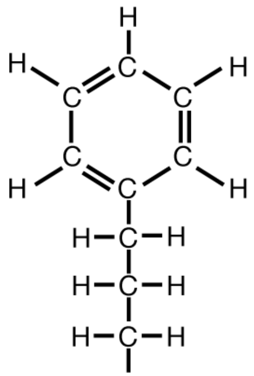
Fuel components



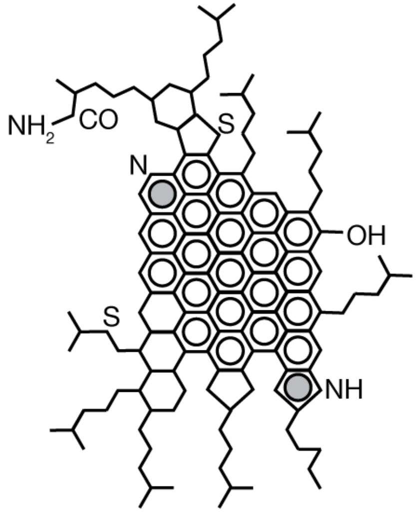
Paraffins



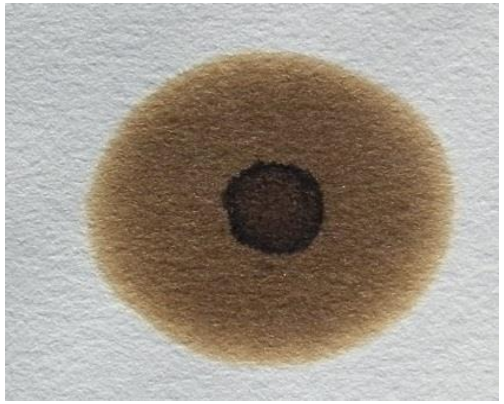
Naphtenes



Aromatics



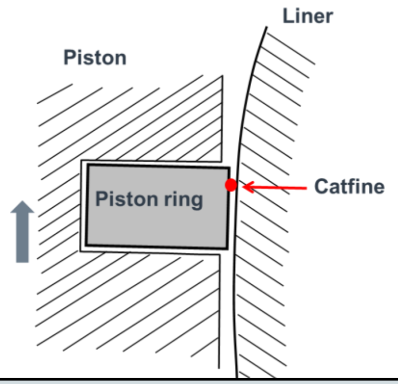
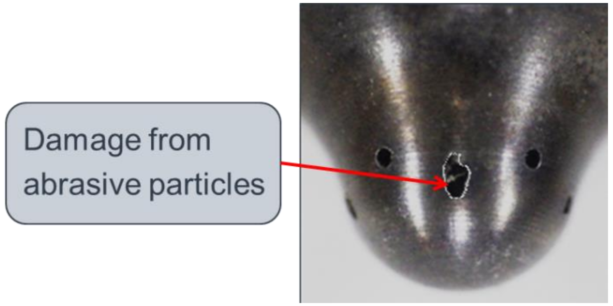
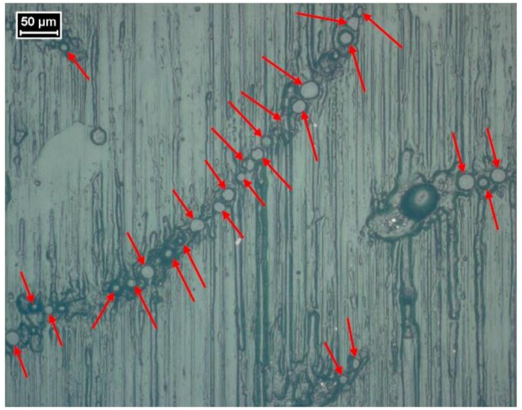
Asphalthene



Incompatible fuel blend

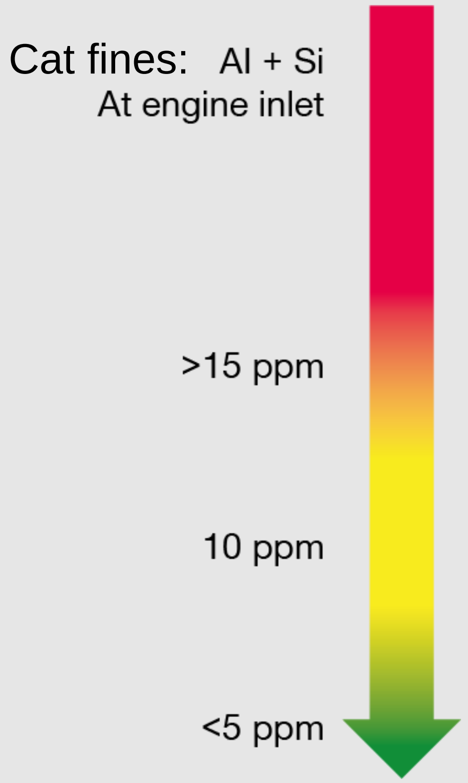
Compatible fuel blend

Overview of damages
Found in two-stroke engines and small four-stroke Gensets

Damages found in two-stroke engines	Damages found in small four-stroke Gensets
Wear in combustion chamber parts	Wear in fuel equipment
	
Resulting in high wear	Resulting in poor combustion
	

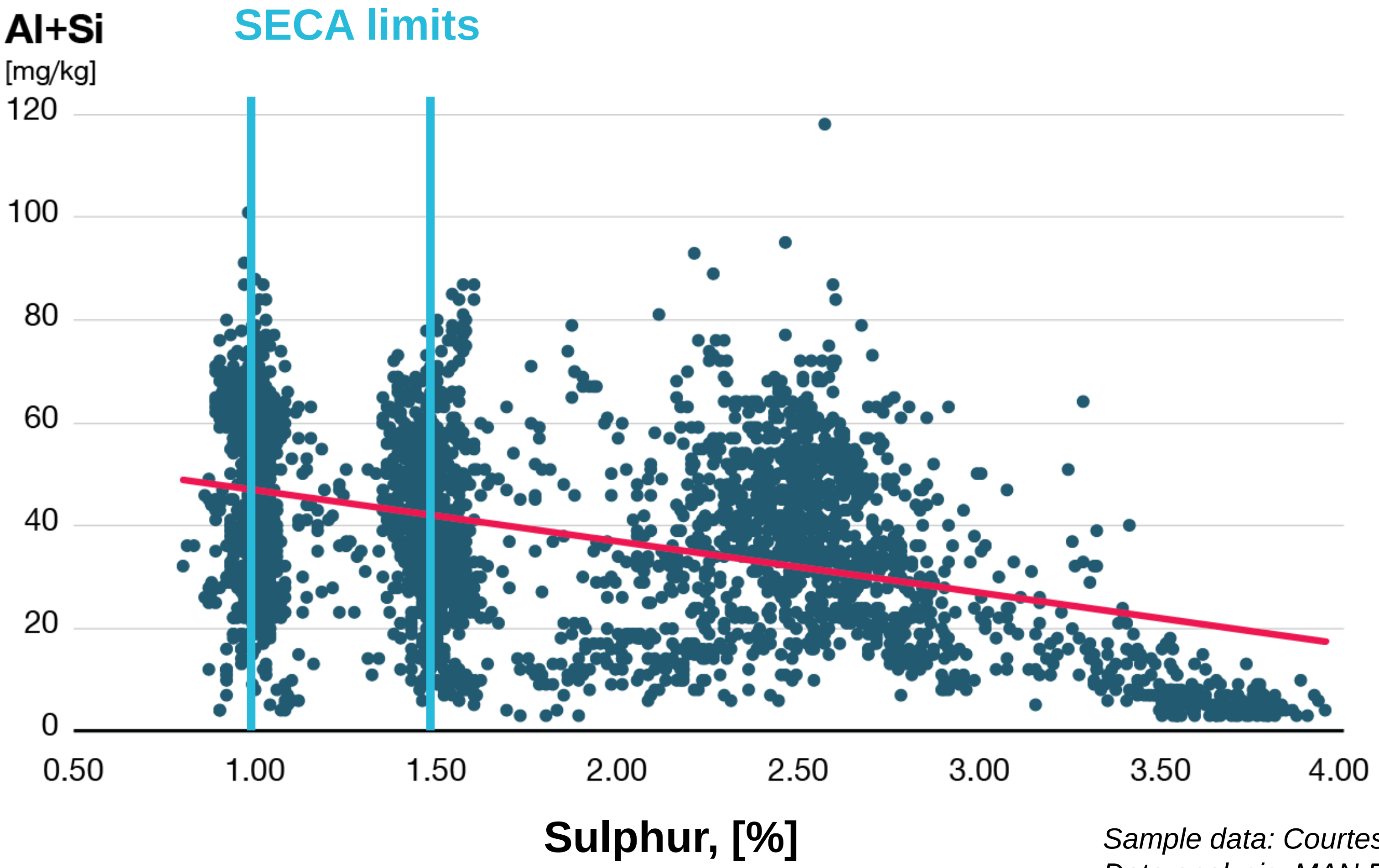
Cat fines

Cat fines cause wear in the engines



Limits for cat fines content at engine inlet

Cat fines in fuel bunker samples from 2010



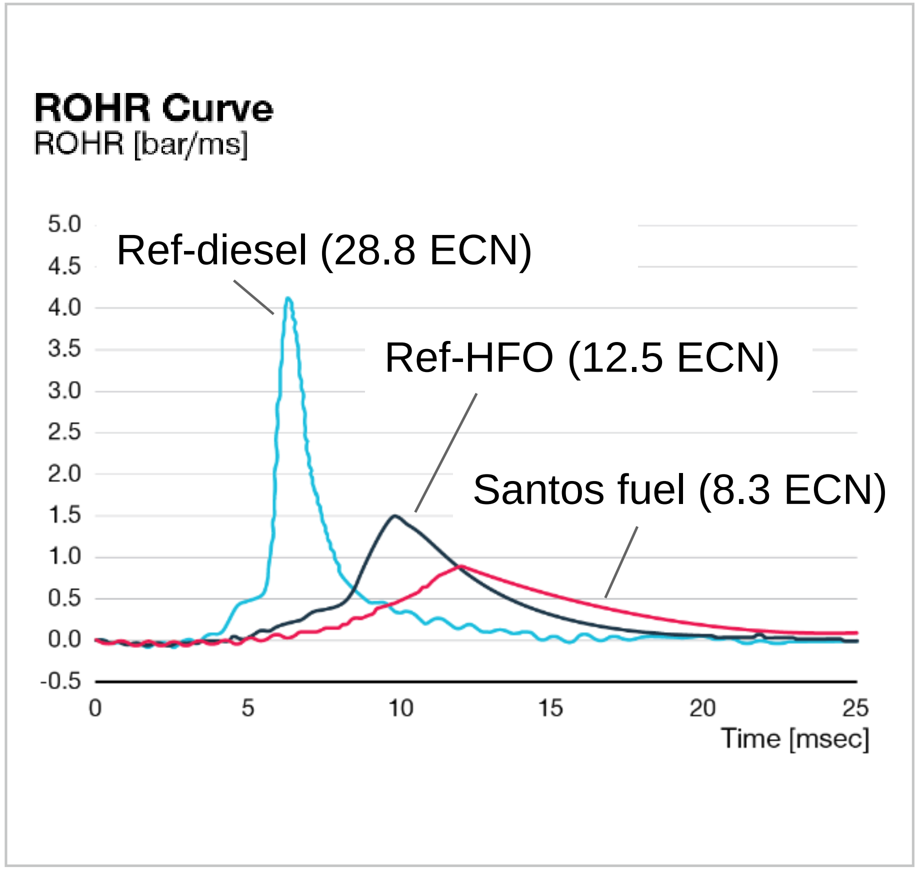
Sample data: Courtesy: VPS
Data analysis: MAN ES

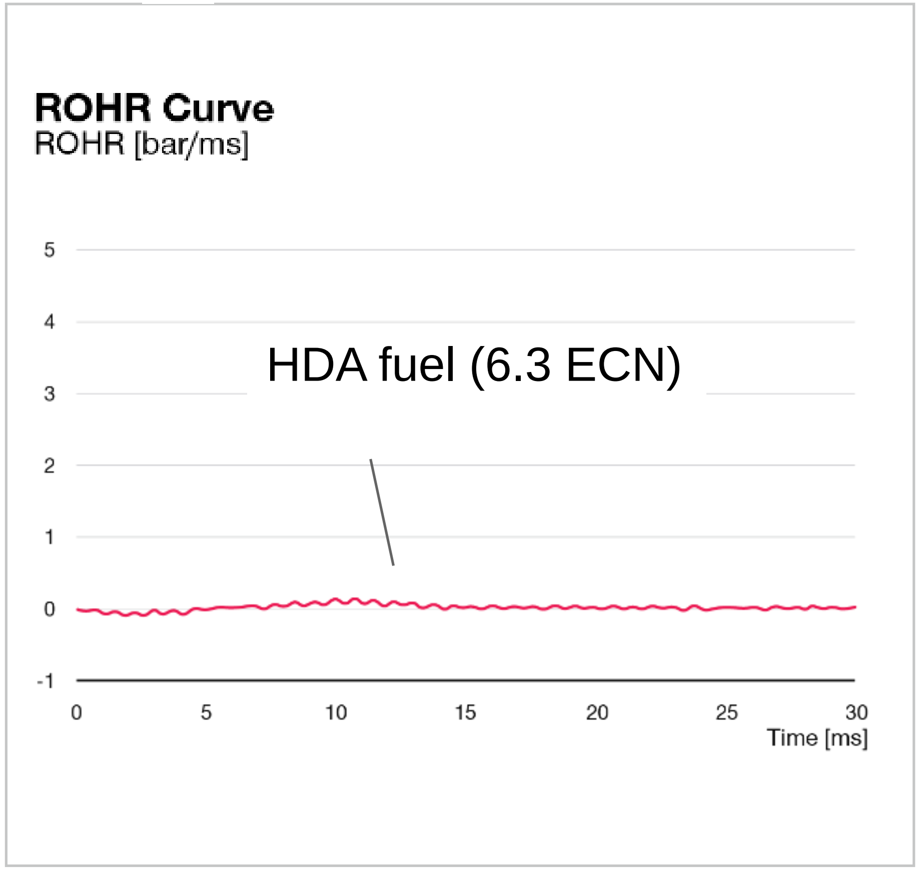
Cold flow properties - wax

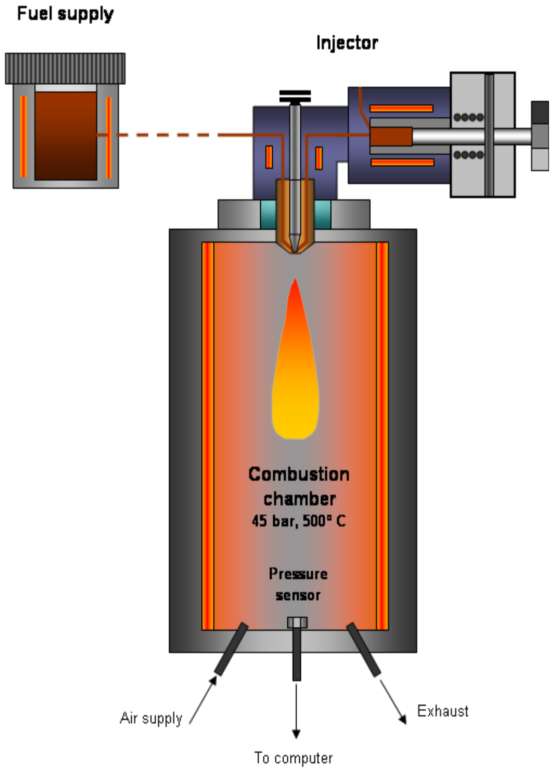
VeriFuel
Understanding Marine Fuel

Combustion test – Lab test

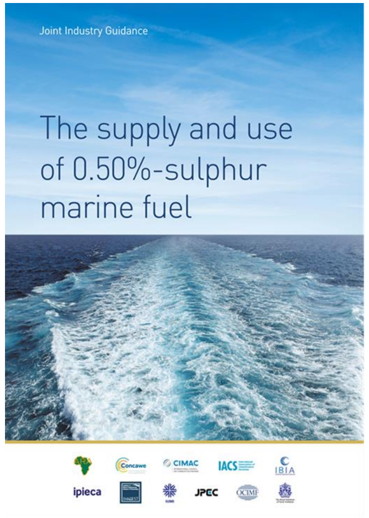
FIA test IP 541: Constant volume combustion chamber method







Latest Publications about the coming fuels 2020



Joint Industry Project

ISO 8217 PAS

ISO/TC 28/SC 4 N 1047

ISO/TC 28/SC 4
Classifications and specifications

Email of secretary:
Secretariat: AFNOR (France)

Result of Voting DPAS ISO PAS 23263

Document type: Summary of voting

Date of document: 2019-08-18

Expected action: INFO

Background: Dear members,

Please find here attached the result of voting for DPAS ballot for ISO/AWI PAS 23263. The draft is approved with 100% of P-members voting for publication.

The file of comments will be transmitted to WG6 in charge for treatment before finalizing the draft for publication.

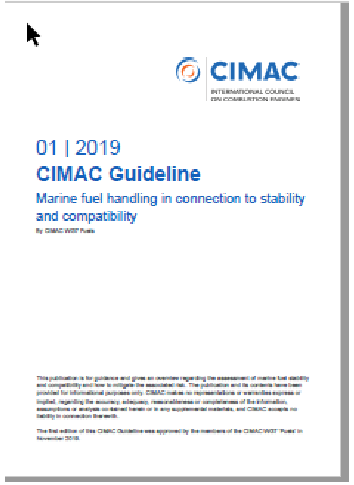
Regards,

ISO/TC28/SC4 secretariat
Manuel LOPES

Committee URL: https://isotc.iso.org/livelink/livelink/open/tc28sc4

Concawe

CIMAC WG 7



CIMAC Guideline

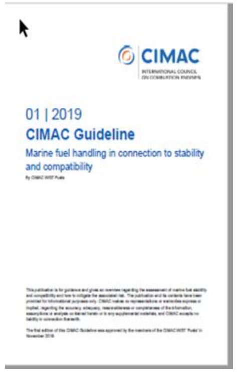
Several test methods to evaluate fuel stability exist have been highlighted in this paper, however, their applicability and accuracy varies.

Only one method (ASTM D4740) is available as providing a useful onboard screening tool for compatibility between two fuels of which one must be of a residual (RM) nature. Fuels which are actually compatible may be deemed less compatible or incompatible by the method.

The most effective way to determine a fuel's stability or compatibility between two or more fuels, is using test methods that can only be applied in a controlled laboratory setting.

The test method ISO 10307-2 Potential Total Sediment (TSP) is used as the definition for a stable fuel in ISO 8217:2017 when the TSP is below 0.10% m/m.

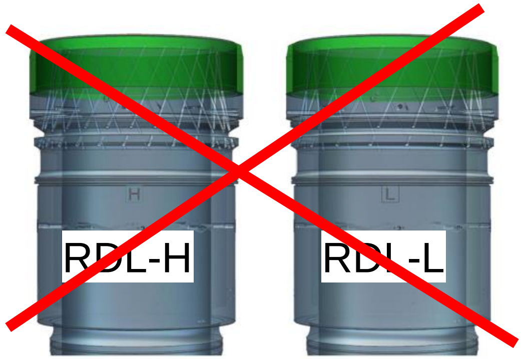
The three test methods: ASTM D7157, D7112 and D7060 with the prediction model offer a tool to evaluate the degree of compatibility of fuels without the need to test the fuels mixed together.


CIMAC
01 | 2019
CIMAC Guideline
Marine fuel handling in connection to stability and compatibility

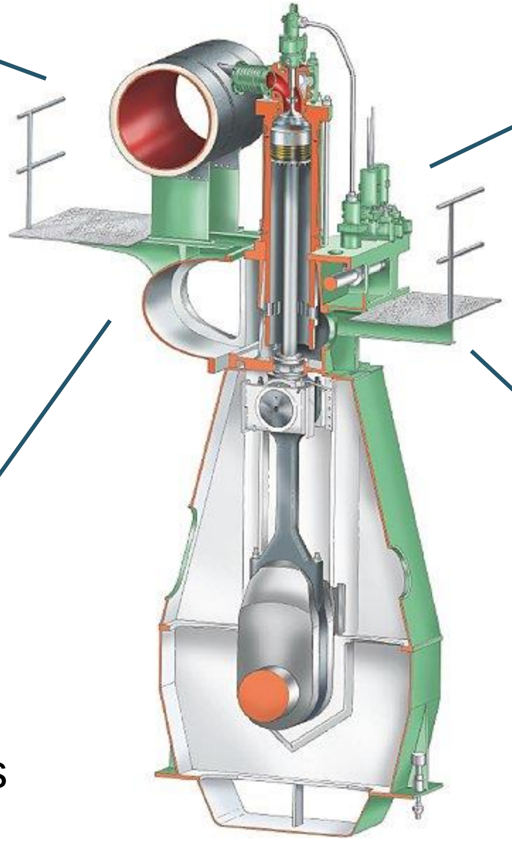
Public

Engine updates – for 0.50% S fuel

What to consider?

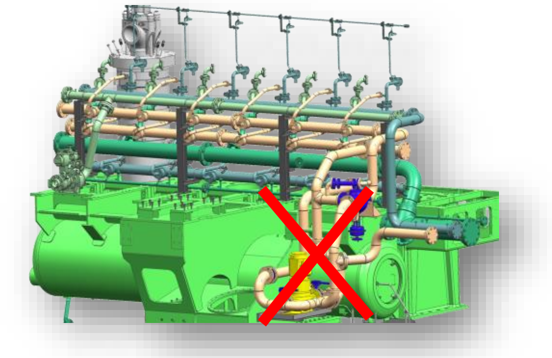


Piston rings:
Full cermet coated ring-pack



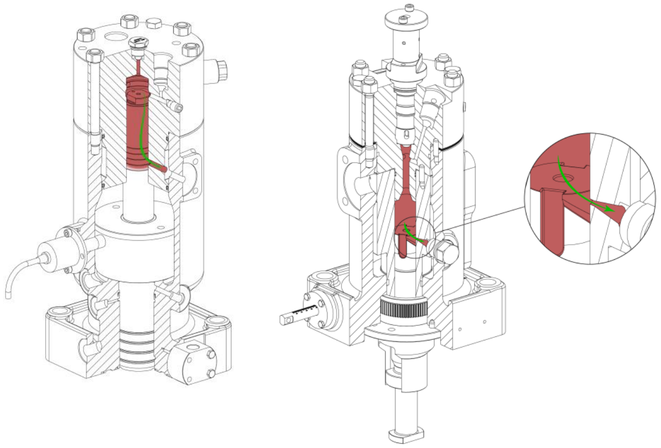
Liner cooling:
- Reduced temp.: 80 C
- No LDCL
- No RDL

LDCL



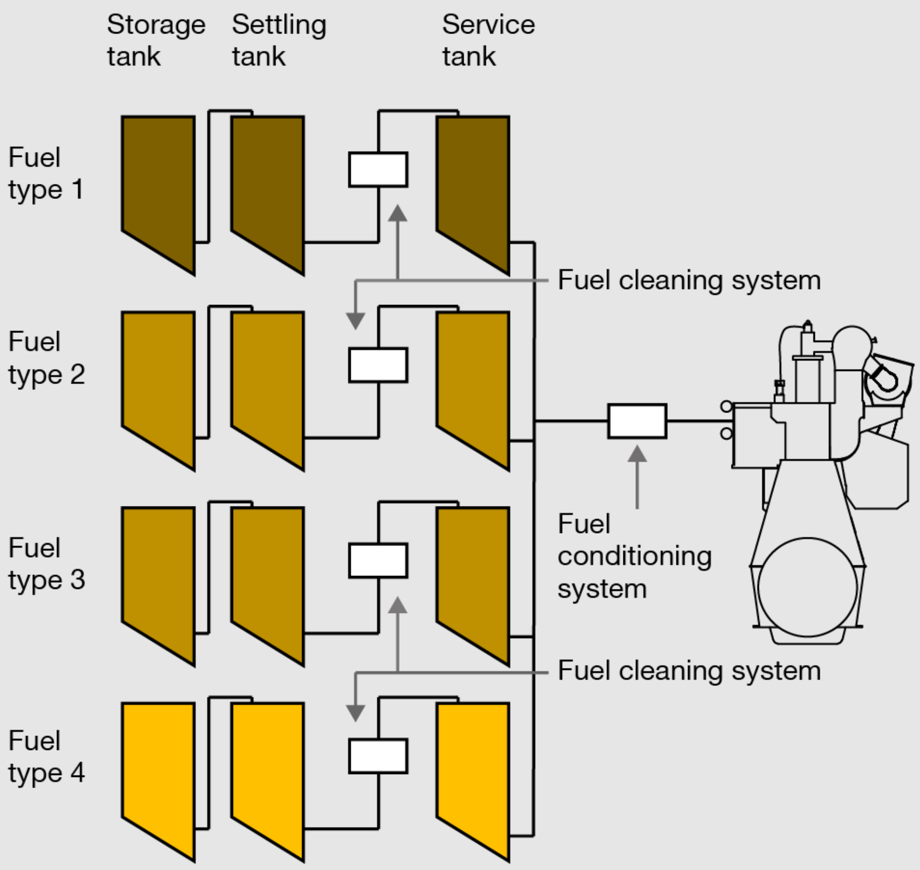
Cylinder oil:
- 40 BN
- No deposits

High-pressure fuel pumps:
- Low viscosity fuel
- High viscosity fuel
- Change-over

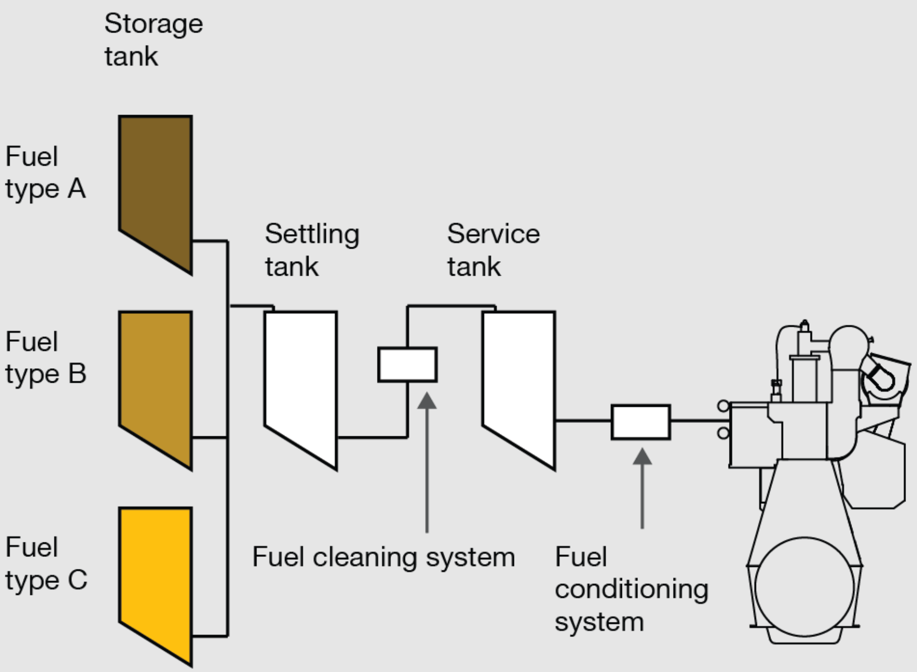


Fuel system – schematic examples

Flexible fuel system

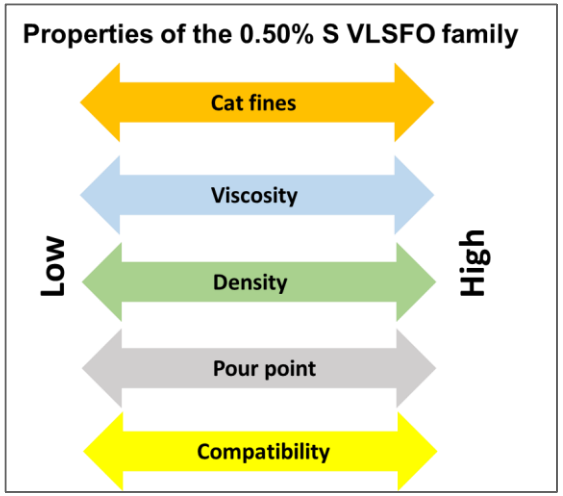


Simple fuel system

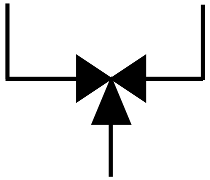


Summary: 0.50% S fuels

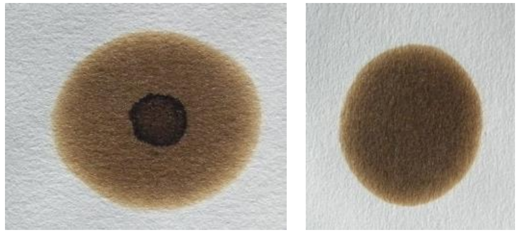
What to consider – for the ship?



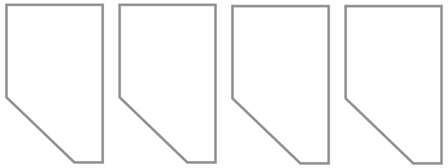
Fuel change-over



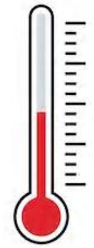
Compatibility of mixed fuels



Fuel tank system considerations

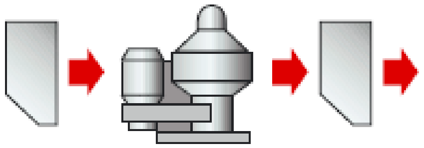


Temperature

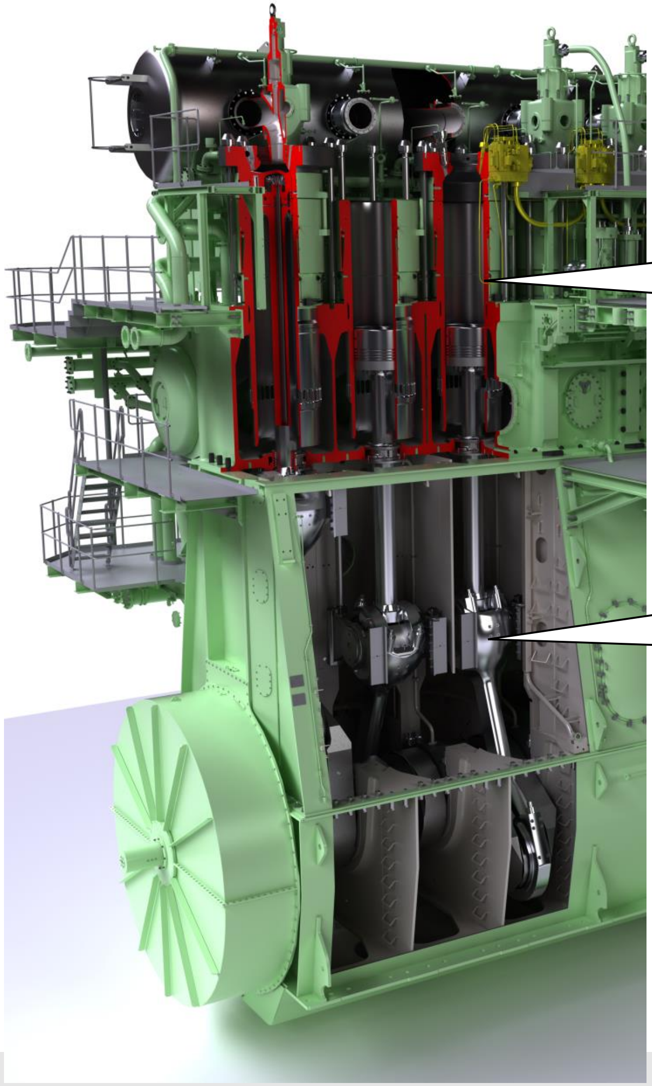


Viscosity

Clean the fuel



Lube Oils



Cylinder oil
SAE50
BN = 15-100

System oil
SAE30
BN = 5-6

Key properties for cylinder lube oil:

- Lubricate, decrease friction
- Neutralize sufficiently
- Provide a gas-seal between rings and liner
- Keep parts clean:
    - Avoid coke formation (thermal stability of the base oil)
    - Remove coke, additives, impurities and wear particles from liner and piston ring area

MAN B&W Multifuel Engines

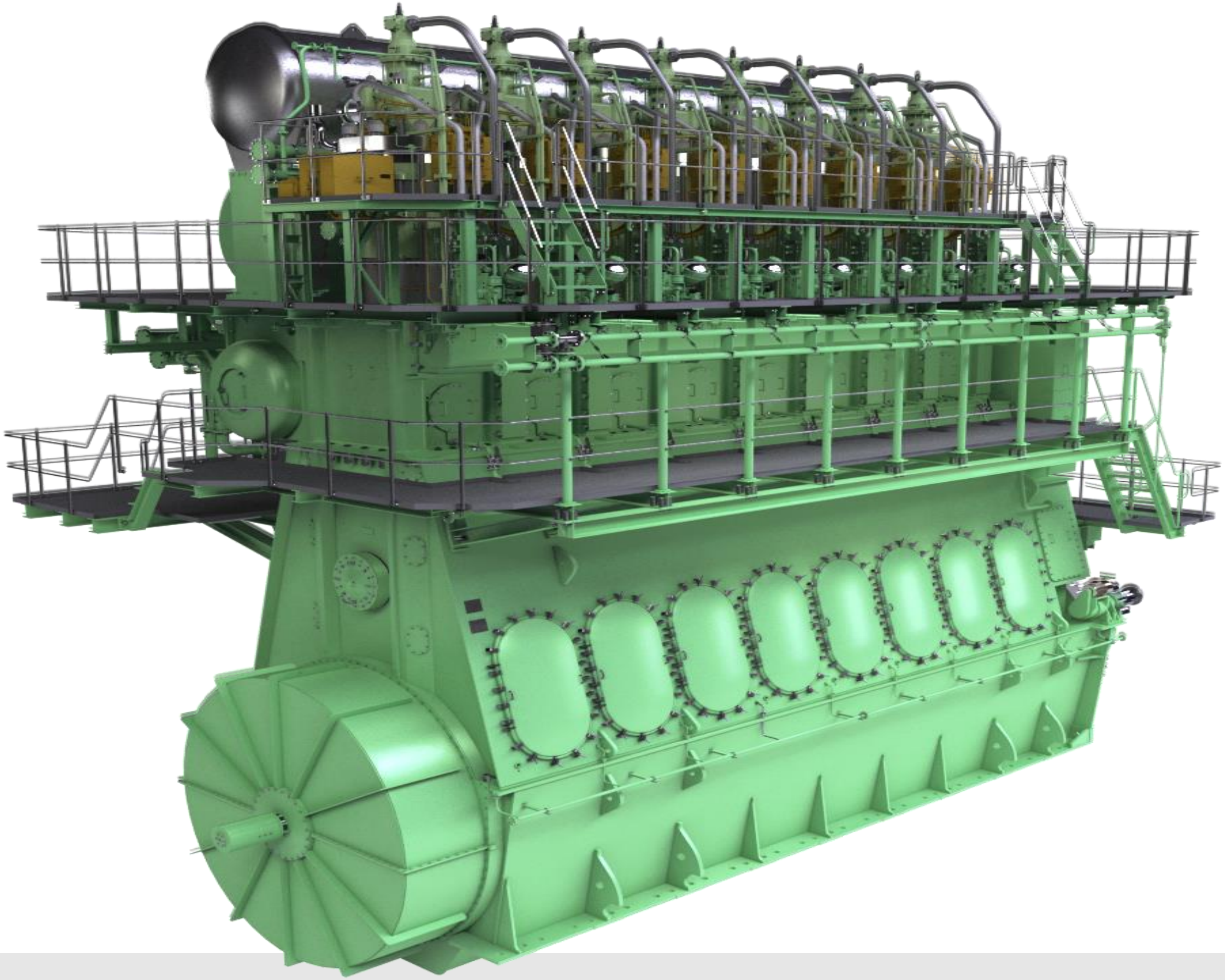
New fuels - emissions

	NO_x	SO_x	PM	CO_2
LNG	20-30%	90-99%	90%	24%
LPG	10-15%	90-100%	90%	13-18%
Methanol	30-50%	90-97%	90%	5%
Ethane	30-50%	90-97%	90%	15%

- Compared with Tier II engines on HFO
- Based on estimates
- Tier III can be met with EGR, PIFIW or SCR

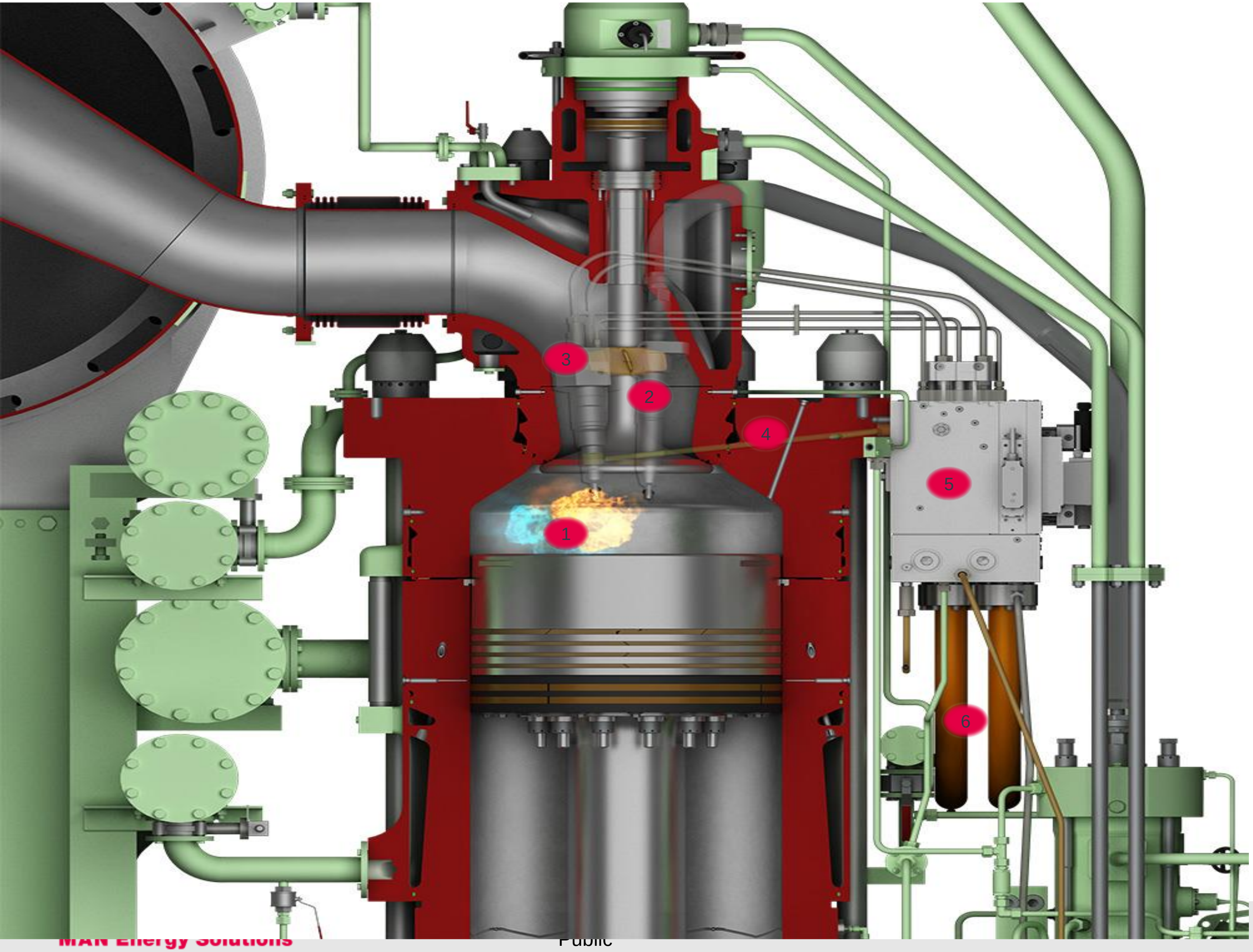
ME-GI engine

GI components



ME-GI Concept

Combustion Concept



1. Direct injection of pilot oil and gas

   Yellow = pilot oil
   Blue = gas

2. Conventional slide fuel valve
3. Gas fuel valve
4. Gas distribution channel
5. Gas block
6. Gas chain link double-walled pipes

ME-GI / ME-LGI Gas Fuel Mode

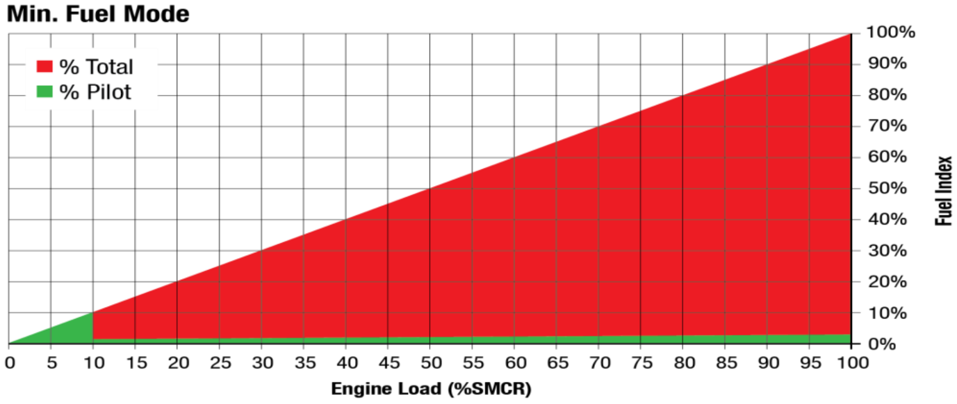
Port to port in dual fuel mode

Fuel oil only mode

- Operation profile as conventional engine

Dual fuel operation mode

- No fuel slip
- No knocking problems
- Insensitive to gas fuel (methane number)
- Unchanged load response



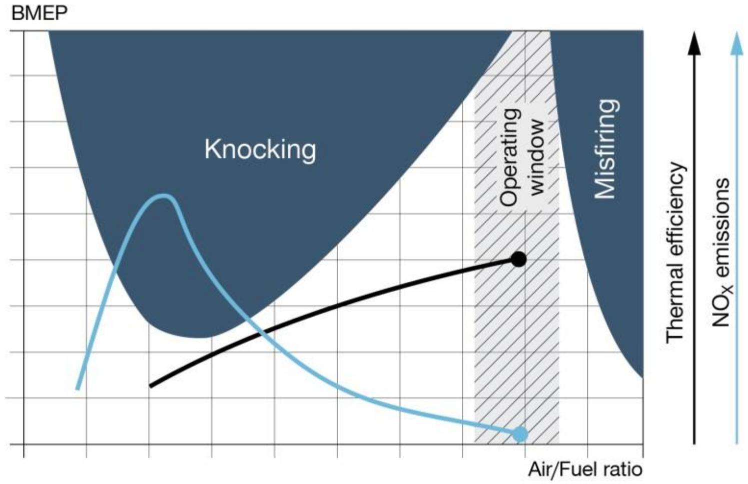
News:

- Pilot oil amount 3% → 1% (ME-GI Mk.2)
- Load on gas → 10% load

ME-GA

Pre-mixed Engine Concept

Confidential

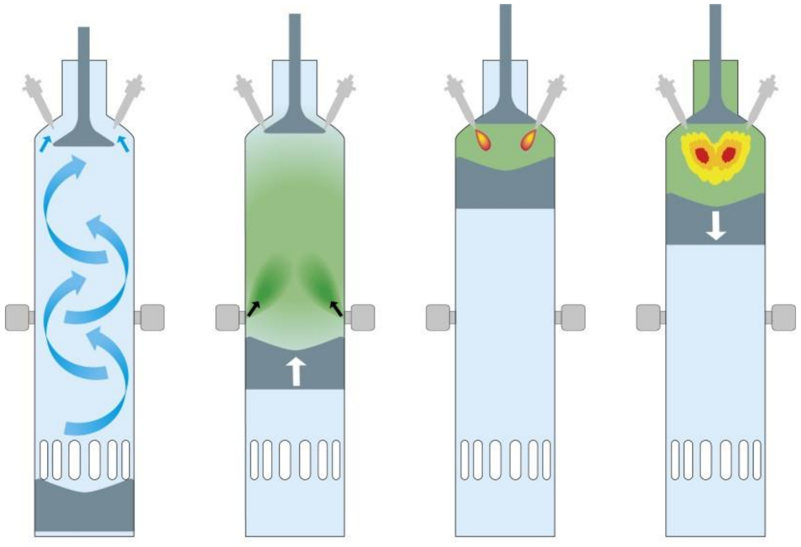


Advantages

- Low CAPEX due to low gas supply pressure (<16 bar)
- For LNGCs the BOG compressor of piston type is avoided
- Pre-mixed combustion → Lower NO_x
- TIER III compliant in gas mode

Challenges in the development

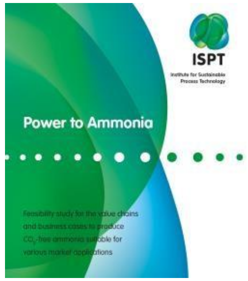
- Narrow operating window necessary to avoid pre-ignition, knocking limits and misfire
- Reduced compression ratio, MEP and thermal efficiency
- Gas quality limitations (Methane number)
- Methane slip increased



Ammonia has better power density than Hydrogen

Does not have to be kept at extremely low temperatures or under high pressure to be stored

Technology	Pressure	Temperature	Density (Gje/m3)	P-to-X Efficiency	Safety
Liquid H2	Ambient	-254	4.8	68%	Explosive, Cryogenic
Pressurized H2	700	Ambient	2.8	76%	Explosive, very high pressure
CH4	Ambient	-163	11.4	56%	Explosive, Cryogenic
MeOH (CH3OH)	Ambient	Ambient	8.2	54%	Toxity, but much industrial experience
NH3	Ambient	-33	6.8	65%	Toxity, but much industrial experience



CO2 sourcing (for CH4 or MeOH) requires a carbon capture unit at the power plant, with the additional disadvantage of decreasing round trip efficiency and not capturing all CO2 produced. (ISPT, P2A, 2017, p.31)

Source: Institute for Sustainable Process Technology, Power-to-Ammonia, 2017, p. 31, Power-to-X (P-to-X) efficiency represent the amount of energy maintained when power is converted to the end-product. Losses in an engine in following use is not included. This is a SGRE Estimate based on ISPT data. The estimate has been made by assuming the X-products are converted back into power with an energy loss of 50%.

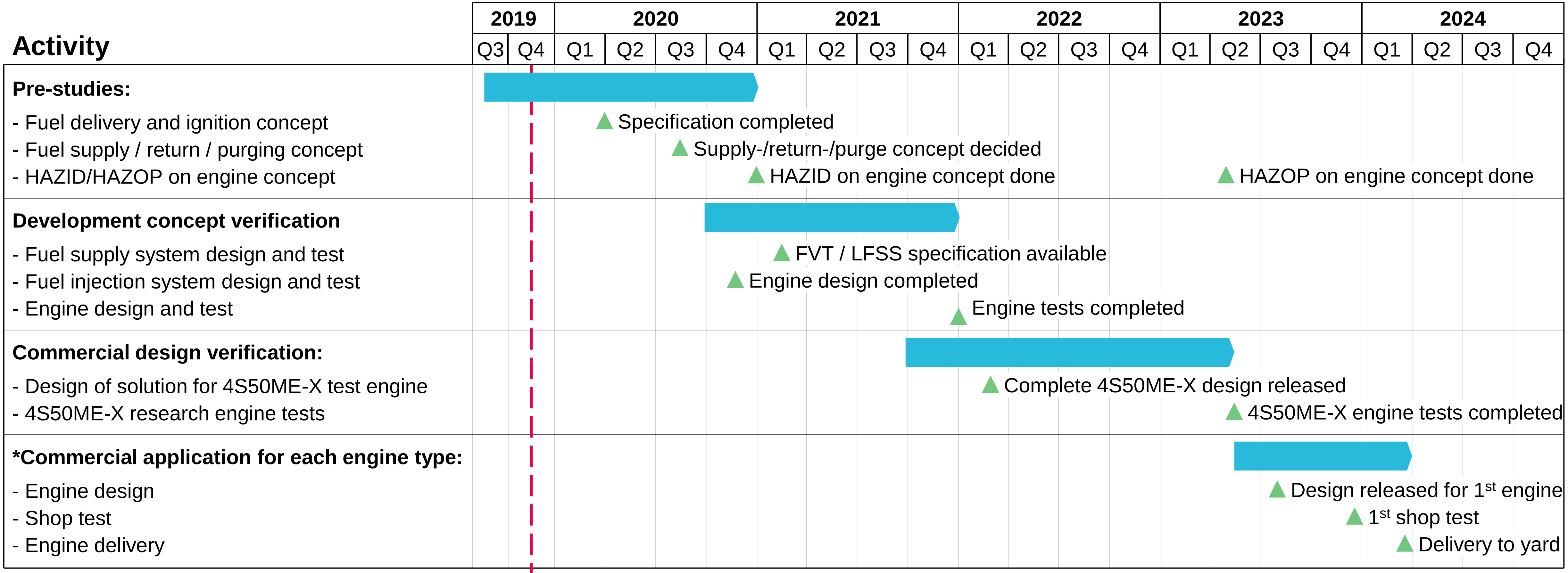
Ammonia as green fuel produced with renewable energy

SIEMENS Gamesa
RENEWABLE ENERGY

NH3 advantages as green fuel

- No carbon. Clean combustion without CO2 or carbon
- Can be produced 100% by electrical energy
- Can easily be reformed to H2 and N2
- Can be stored with high energy density at < 20 bar
- Low risk of fire. Relatively specific ratio of NH3 and air (15-25%) is required to sustain combustion

Ammonia Development Project – Road Map



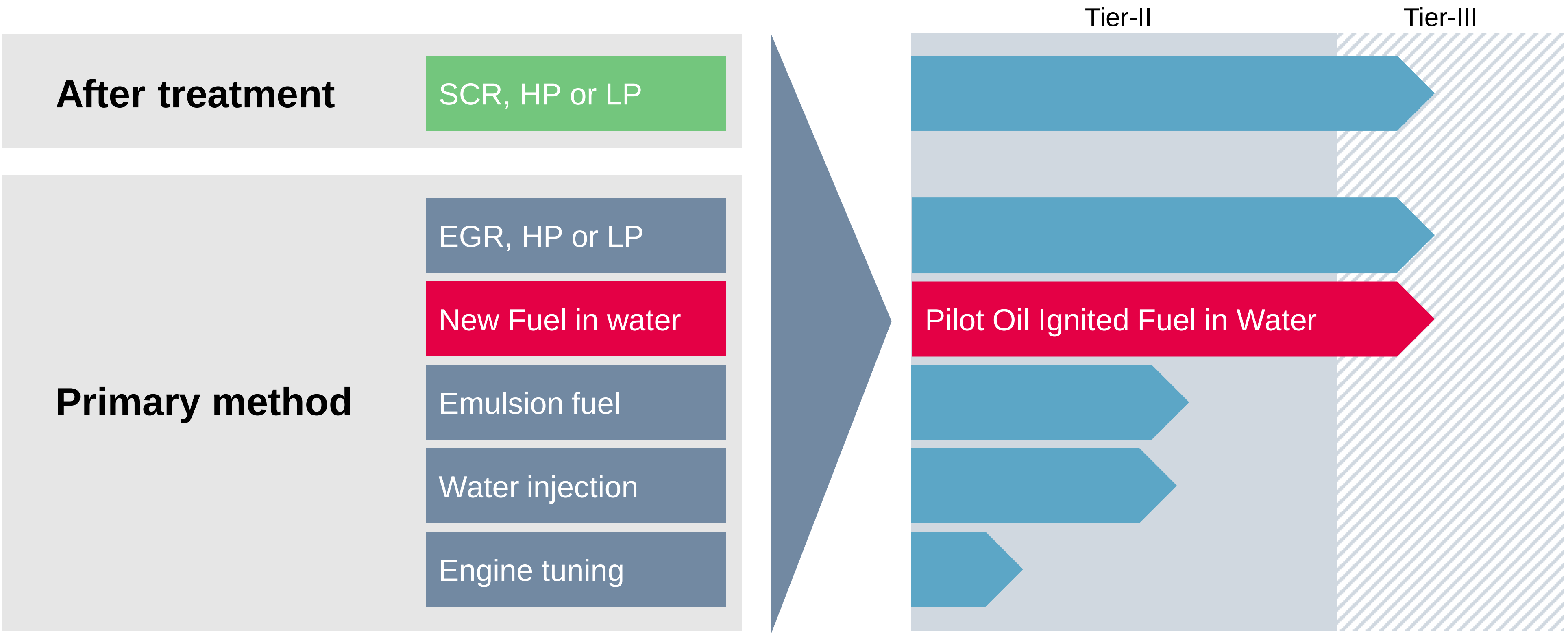
*Commercial application schedule is depending on order

Date of issue: 08. Nov 2019

NO_x Reduction Technologies

New Pilot Oil Ignited Fuel in Water, (PI FiW)

Available methods | **Possible NO_x emission levels**



SCR: Selective Catalytic Reduction System; **EGR:** Exhaust Gas Recirculation System

Combination of Methods also being pursued

Development of PI FIW Tier III engine

Conclusion on PI-FIW

Low-sulphur fuel design: Max. 0.10%S

High-sulphur fuel: Max. 3.5%S

EGR
On-Engine

SCR
High-Pressure

SCR
Low-Pressure

Methanol

Water addition
Dual Fuel technology

Water/Fuel

Water addition
Dual Fuel technology

Disclaimer

All data provided in this document is non-binding.
This data serves informational purposes only and is especially not guaranteed in any way.
Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

MAN Energy Solutions
Future in the making

Thank you very much!

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