Global 0.5% Sulphur Cap 2020

CIMAC Circle

Marintec, December 5th 2019

Today’s Panelists

Monique Vermeire
Fuel Technologist
Marine and Powergen

Yan Yantao
Vice General manager and
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Director New Technologies
Sales & Promotion Two-Stroke Marine

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Manager of Efficiency and
Technology department

Paolo Tonon
Senior Vice President
Head of Global Product Group

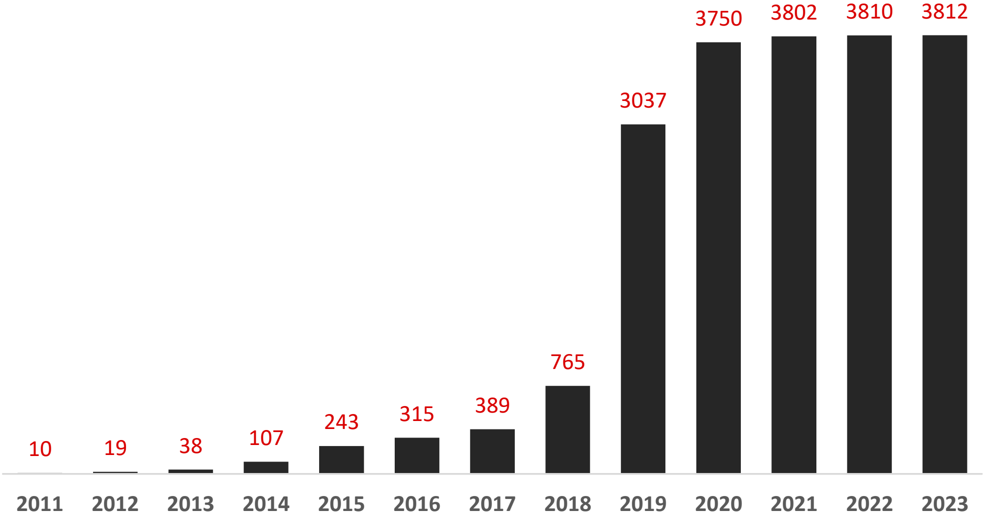
Global Sulphur Cap

Key Dates in 2020

- 1 January 2020
  - Mandatory use of low-sulphur (0.50%) fuel globally, unless
  - Alternative technology such as Exhaust Gas Cleaning System (scrubber) is being used
- 1 March 2020
  - Global carriage ban for HSFO in fuel tanks, unless
  - Scrubbers are being used

Scrubbers Update
December 2019

Total number of ships with scrubbers (in operation and on order)



Costal states and ports with stricter local regulations or complete prohibition of scrubber washwater discharges

Scrubber deliveries spike in 2020 – More than 80% (in GT) of the global merchant fleet will rely on compliant fuels

Source: DNV GL Alternative Fuel Insight – Dec 2019

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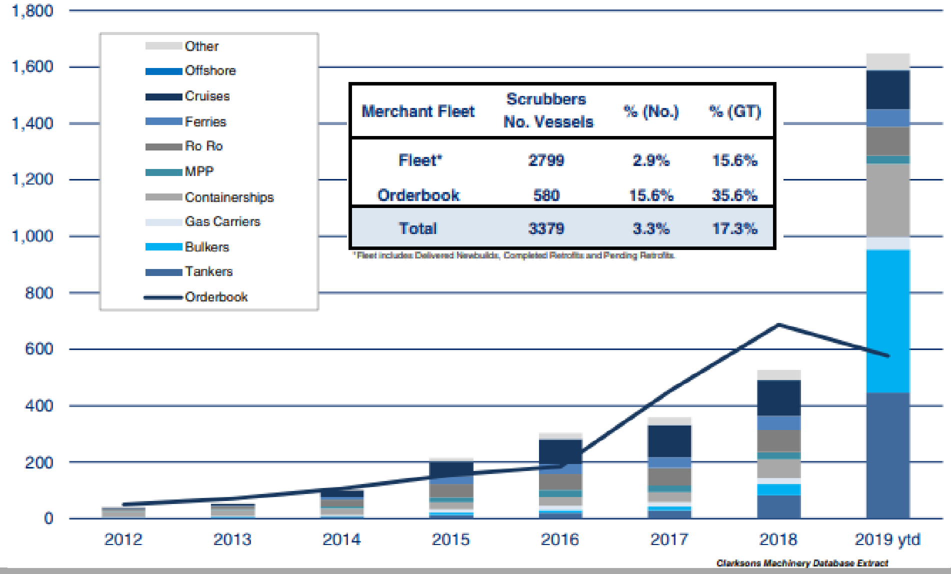
INTERNATIONAL COUNCIL ON COMBUSTION ENGINES

Scrubbers Update
December 2019

Exhaust Scrubbers – Total Equipped Merchant Vessels



Merchant Fleet	Scrubbers No. Vessels	% (No.)	% (GT)
Fleet*	2799	2.9%	15.6%
Orderbook	580	15.6%	35.6%
Total	3379	3.3%	17.3%

*Fleet includes Delivered Newbuilds, Completed Retrofits and Pending Retrofits.

Costal states and ports with stricter local regulations or complete prohibition of scrubber washwater discharges

Scrubber deliveries spike in 2020 – More than 80% (in GT) of the global merchant fleet will rely on compliant fuels

Source: Clarksons Emission Abatement Systems Report – Nov 2019

Low-Sulphur Fuels

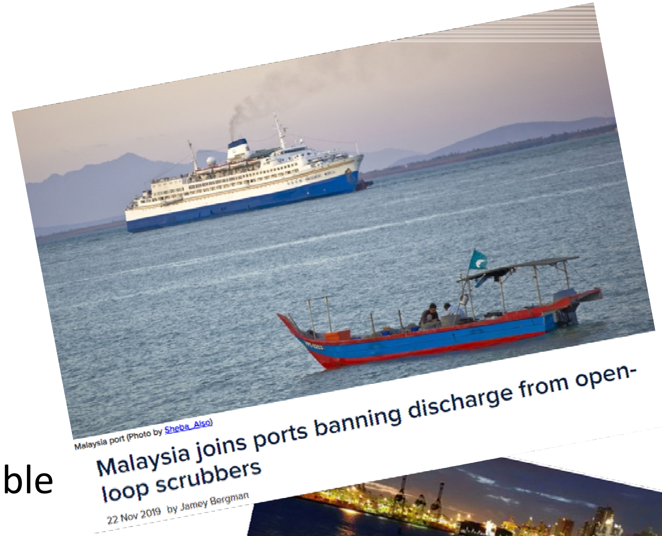
Main steps to prepare vessels for a switchover from HSFO

- Risk assessment and mitigation plan
- Tank cleaning
  - Manually, by chemical additives or by flushing with MGO/VLSFO
  - In dry-dock or during service
  - Thorough flushing of complete fuel piping system (bunkering, transfer & supply)
  - Sludge management, storage and proper disposal
- Fuel oil system modifications (e.g. separators upgrade) if deemed necessary
- Procurement of compliant fuel
- Execution of changeover plan to compliant fuel

Global Sulphur Cap implementation

What comes after 1 January 2020?

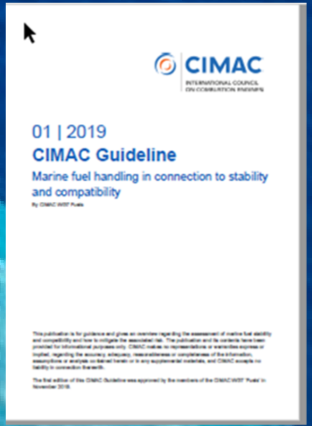
- Marine fuels price development, especially the gap between HSFO and compliant fuels
- Open loop scrubbers
  - Potential for more bans by coastal states and ports
  - Future acceptance by legislators and public opinion questionable
- Stability and compatibility of compliant fuels
  - Blending practices by fuel traders
  - Fuel properties such as flash point, lubricity and cat fines
- Availability of LSFO (or HSFO) in certain ports and associated delays
- Enforcement of the Global Sulphur Cap and measures against non-compliance



MAN Energy Solutions
Future in the making

CIMAC Circle Marintec, Shanghai,2019

Fuels 2020 seen from WG 7 point of view.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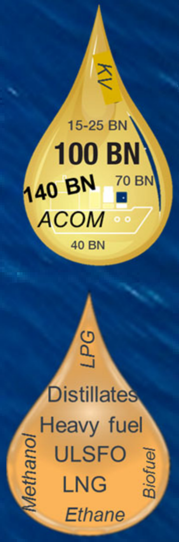
CIMAC Guideline
Marine fuel handling in connection to stability and compatibility



Kjeld Aabo
Director New Technologies
Sales and Promotion Two stroke Marine
Member of WG ISO 8217 & Chairman CIMAC Fuels

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

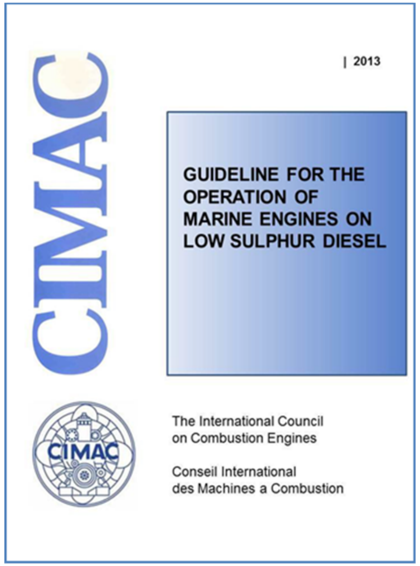
Diesel House

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

WG7 ‚Fuels'

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, Lisbon
- No 81: Oct. 2019, Oslo

Current activities, subgroups

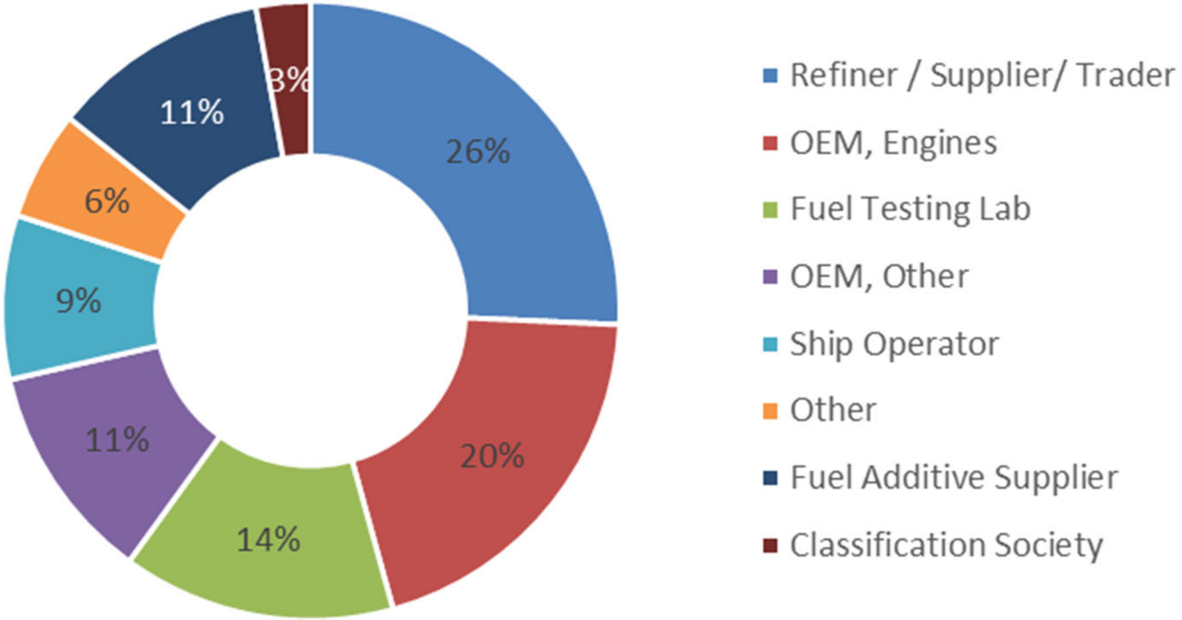
High priority SGs

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"

Low priority SGs

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

Representation in WG7 by sector



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"

Conclusion from IMO meeting regarding CO2 reduction

CIMAC
INTERNATIONAL COUNCIL ON COMBUSTION ENGINES

This has been agreed

- A minimum reduction in carbon intensity per transport work of 40% by 2030 compared to 2008 with the aim of reaching 70% by 2050
- A reduction in greenhouse gas emissions from ocean shipping by at least 50% by 2050 compared to 2008

First, focus will be on reduction of **methane** and **VOC** emissions. Later, focus will be on carbon free fuels, such as biofuels, hydrogen, ammonia and methanol

Fuel sulphur regulation

- For all ships

1 Jan. 2019: Max. 0.50% S
1 Jan. 2020: Sailing: 0.50%S
Berthing: 0.10%S
Hainan Island waters: 0.10%S

MAN B&W 2-stroke Engines

Residual
ME/MC

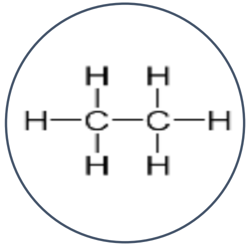
Distillates
ME/MC

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

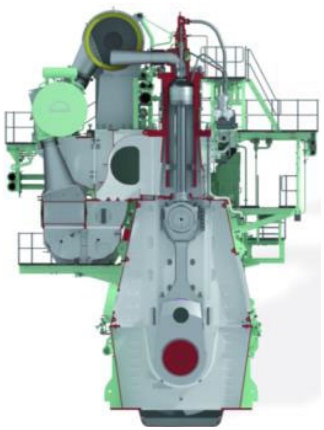
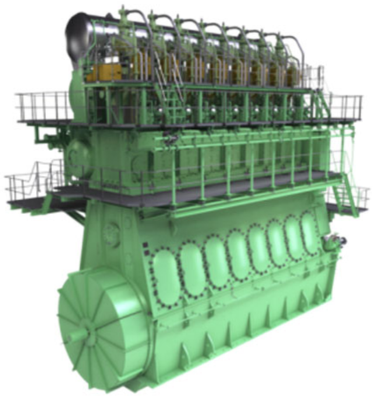
MAN B&W Multifuel Engines

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

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% ?

CIMAC
INTERNATIONAL COUNCIL ON COMBUSTION ENGINES

	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

2020 Fuels
What may / will happen in 2020?

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

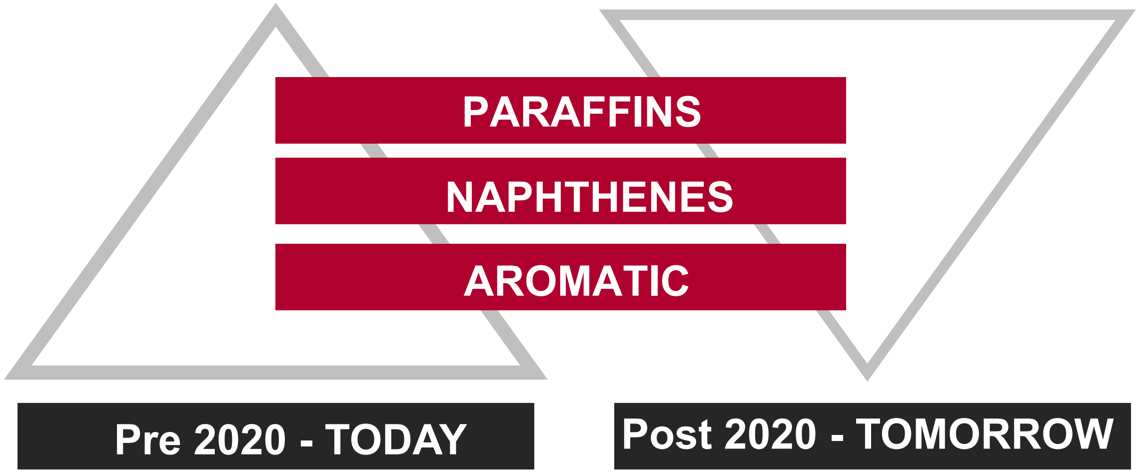
Stability (Total Sediment)
- Paraffinic vs Cracked blend components

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

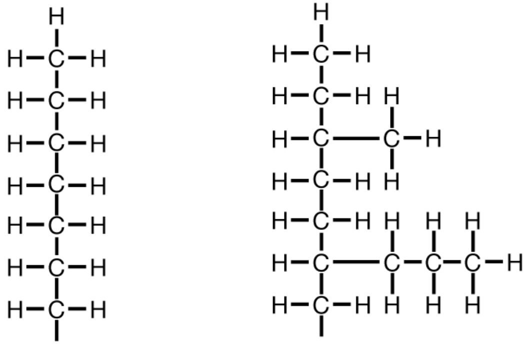


Ref: KBC/Mel Larson

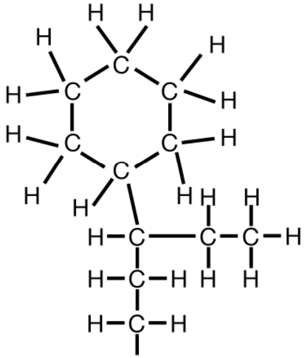
VeriFuel
Understanding Marine Fuel

Fuel Stability and Fuel Incompatibility

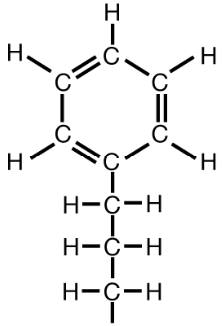
- Fuel components



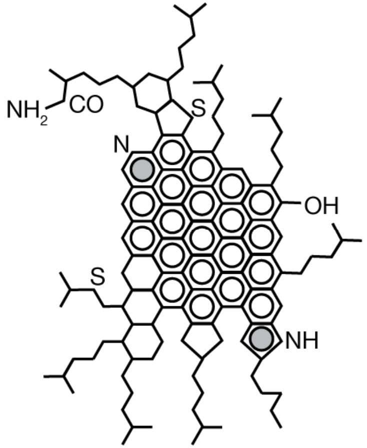
Paraffins



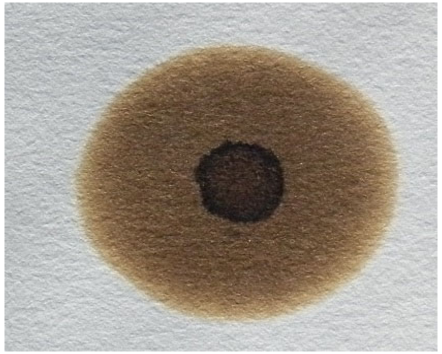
Naphtenes



Aromatics



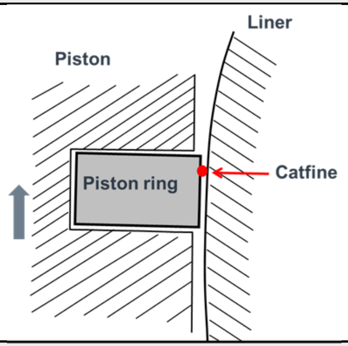
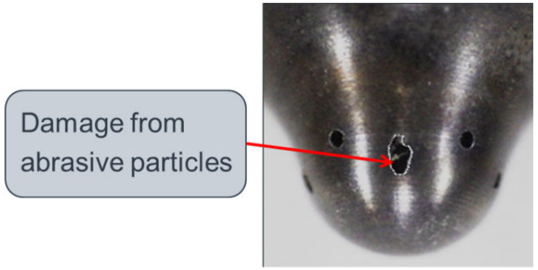
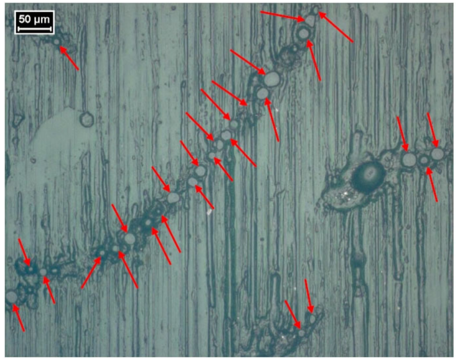
Asphalthene



Incompatible fuel blend

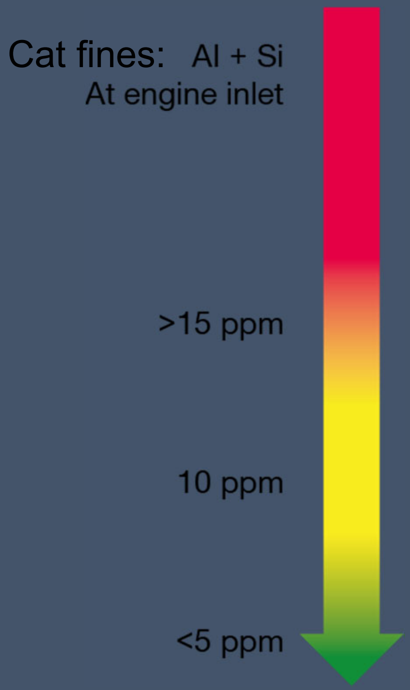
Compatible fuel blend

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
	

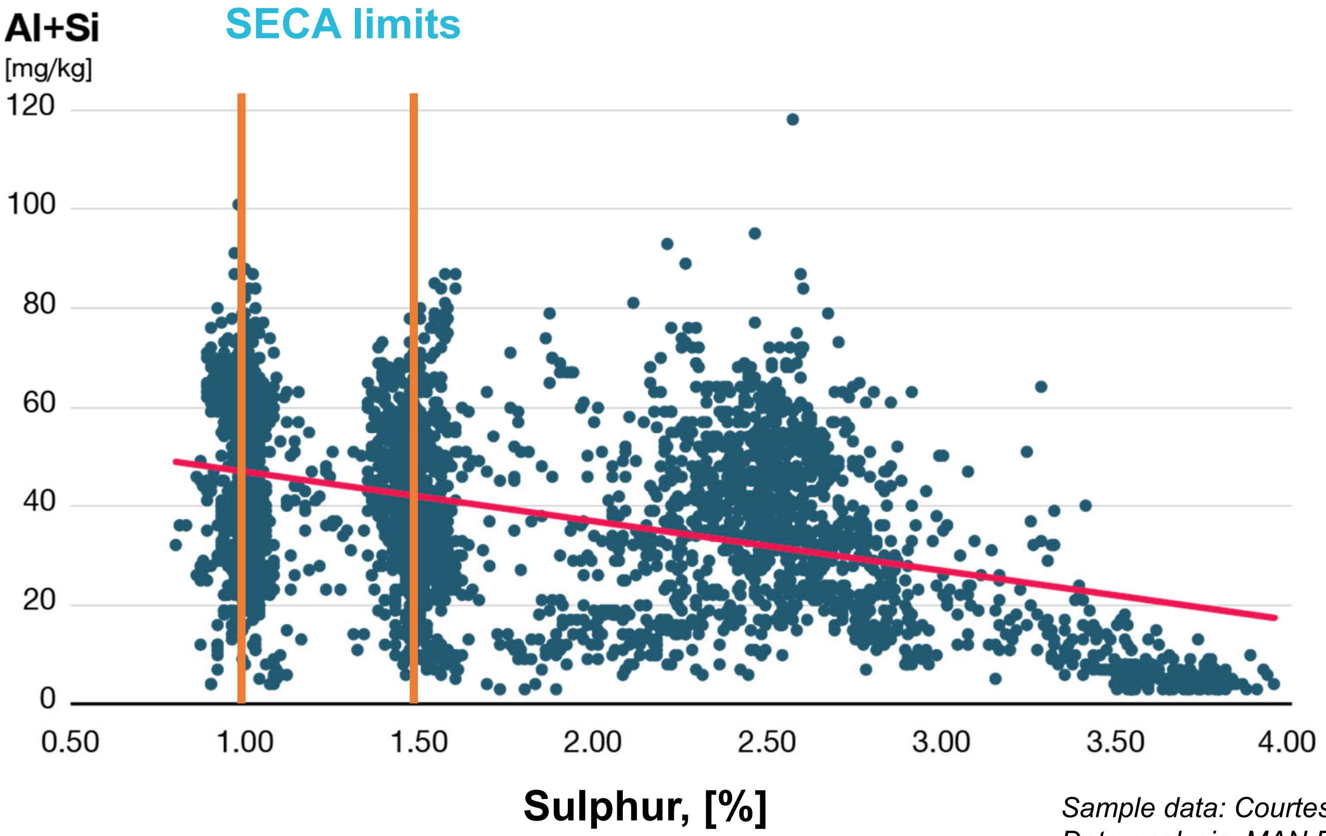
Cat fines

- Cat fines cause wear in the engines



Limits for cat fines content at engine inlet

Cat fines in fuel bunker samples from 2010

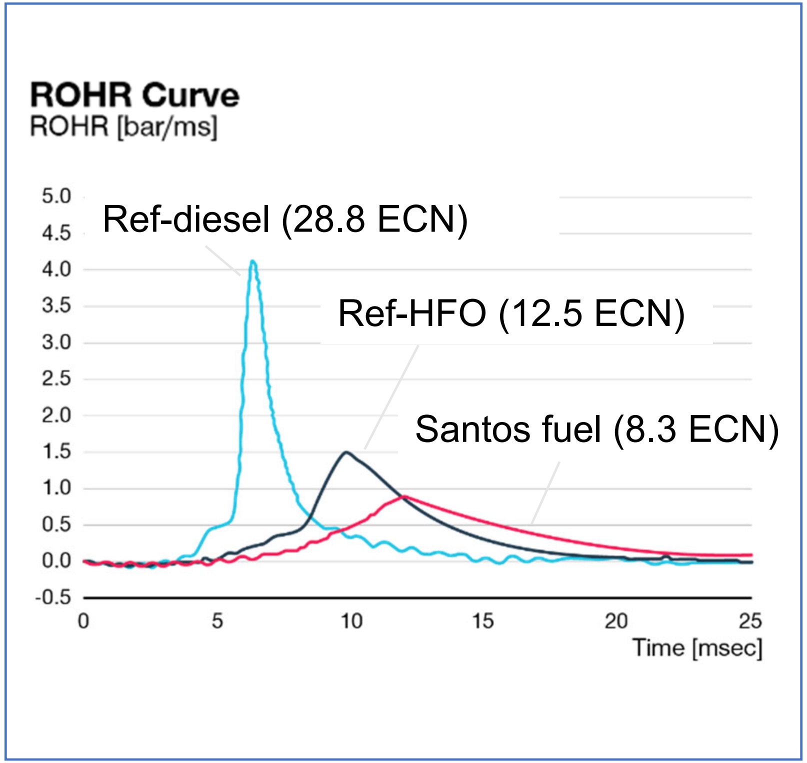


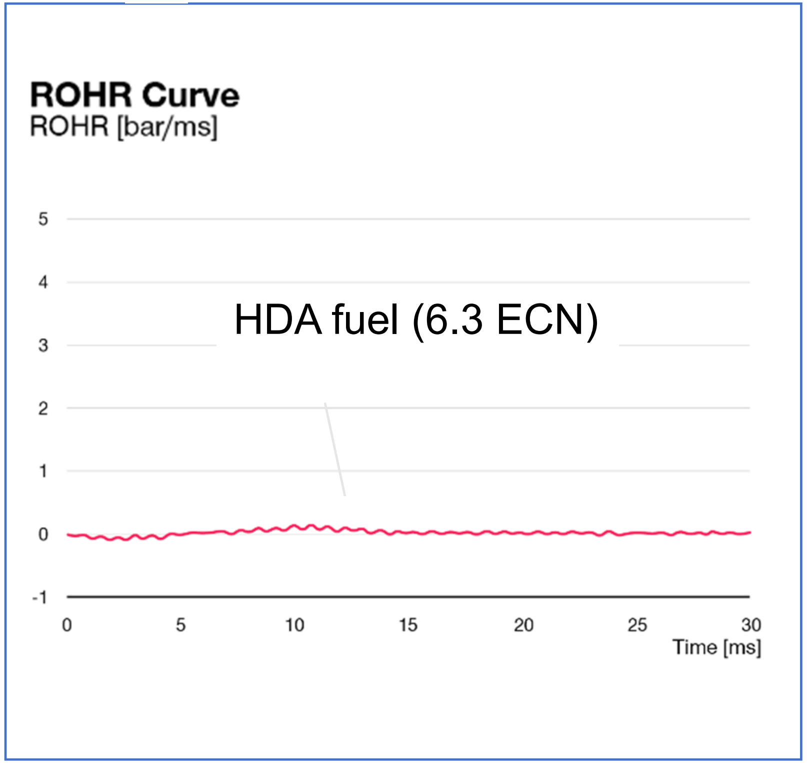
Sample data: Courtesy: VPS
Data analysis: MAN ES

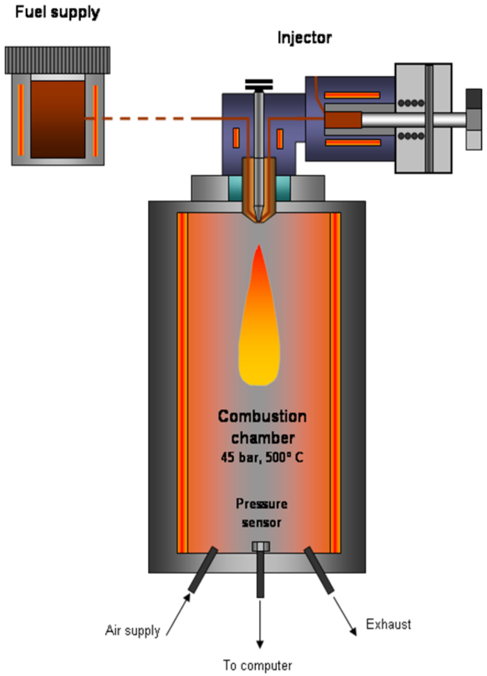
2020 Fuels
Cold flow properties - wax

Combustion test – Lab test

- FIA test IP 541: Constant volume combustion chamber method







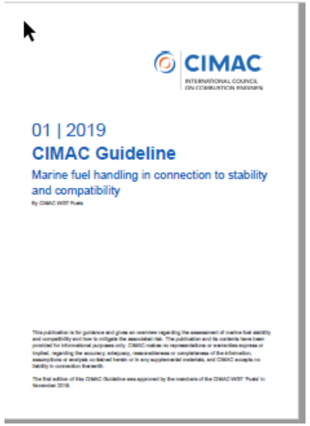
Latest Publications about the coming fuels 2020

Joint Industry Project

ISO 8217 PAS

Concawe

CIMAC WG 7



CIMAC Guideline

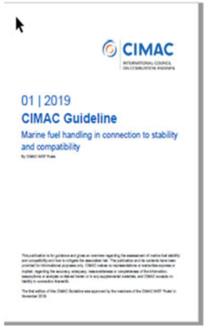
Several test methods to evaluate fuel stability exist have been highlighted in this paper, however, their applicability and accuracy varies.

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.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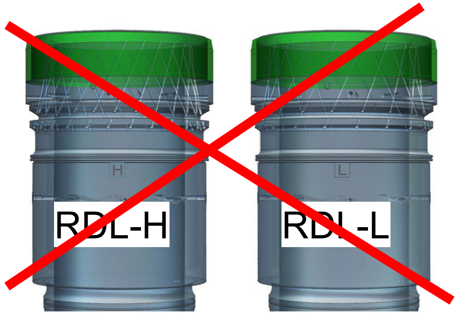
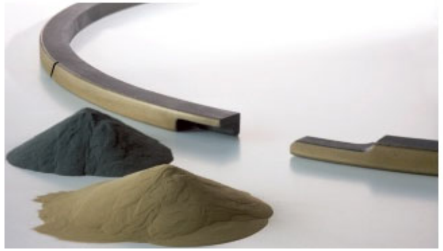
Marine fuel handling in connection to stability and compatibility

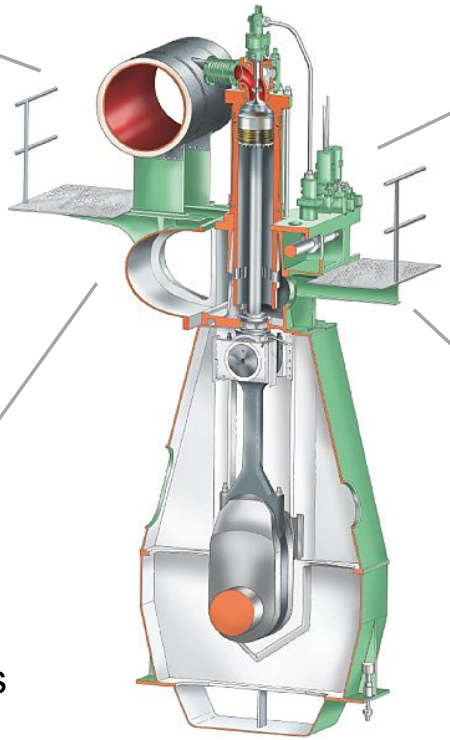
Engine updates – for 0.50% S fuel

- What to consider?



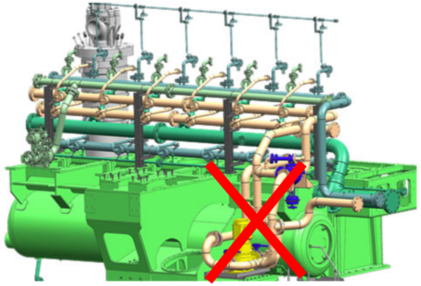
Piston rings:
Full cermet coated ring-pack





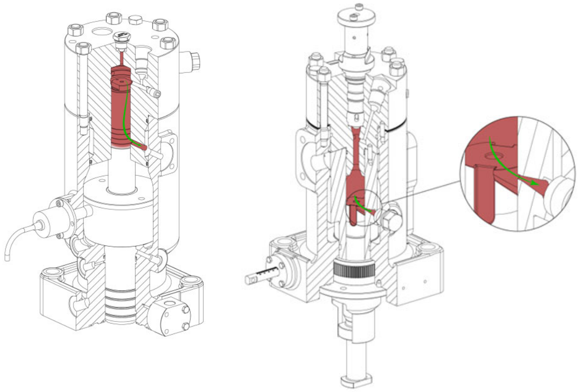
Liner cooling:
- Reduced temp.: 80 C
- No LDCL
- No RDL

LDCL

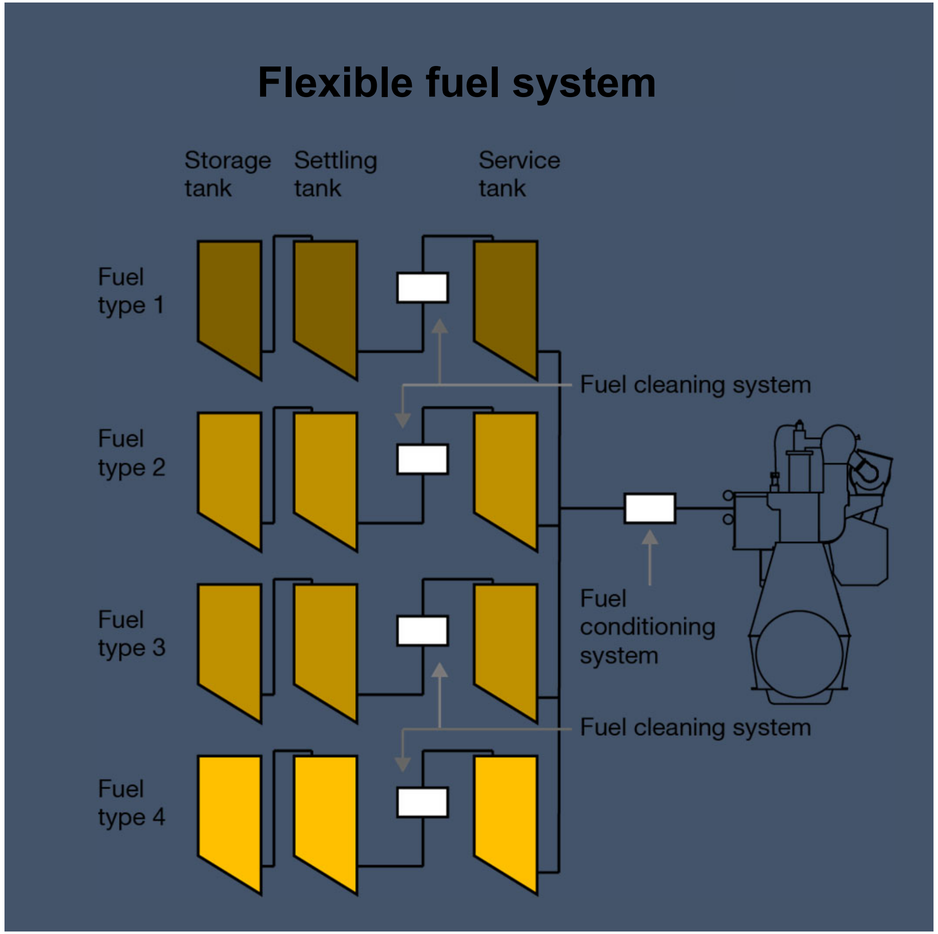


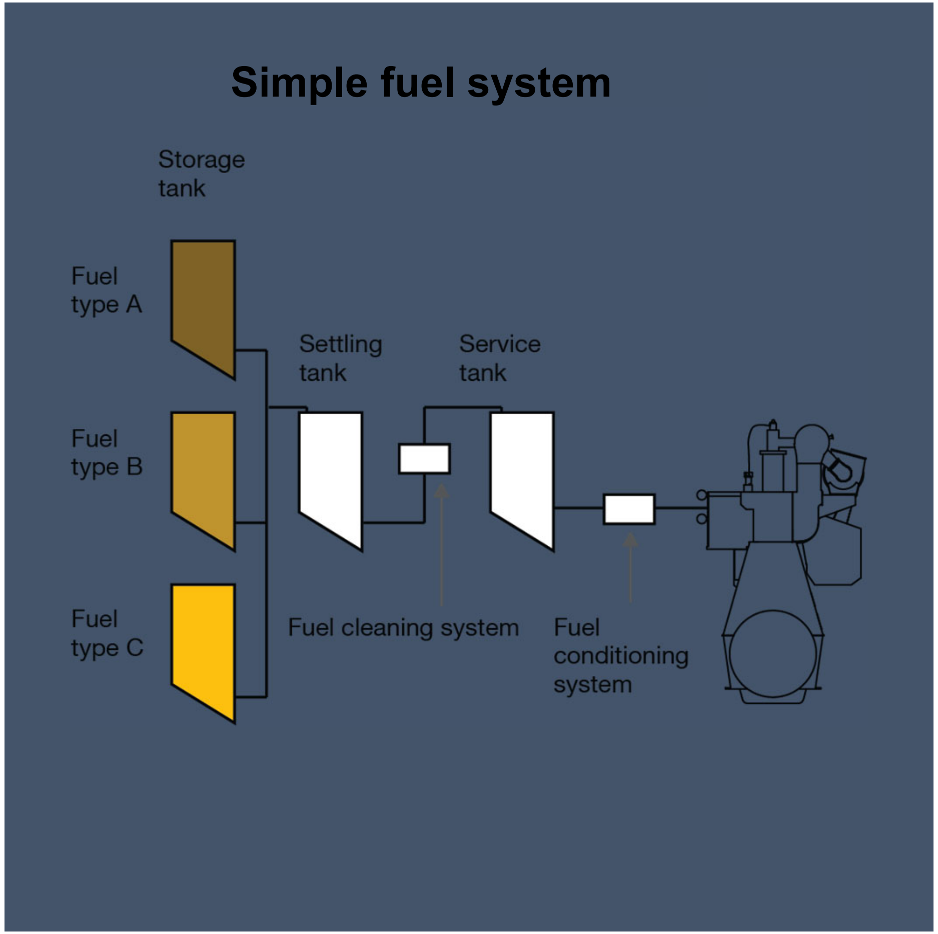
Cylinder oil:
- 40 BN
- No deposits

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



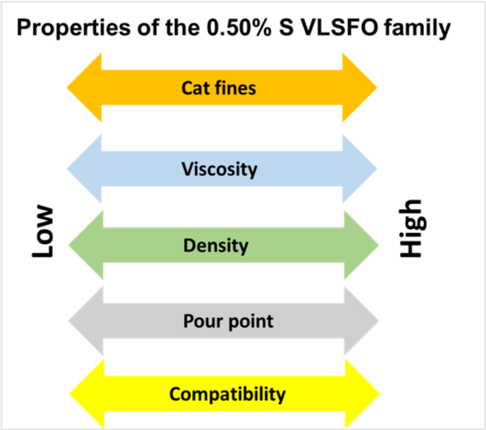
Fuel system – schematic examples

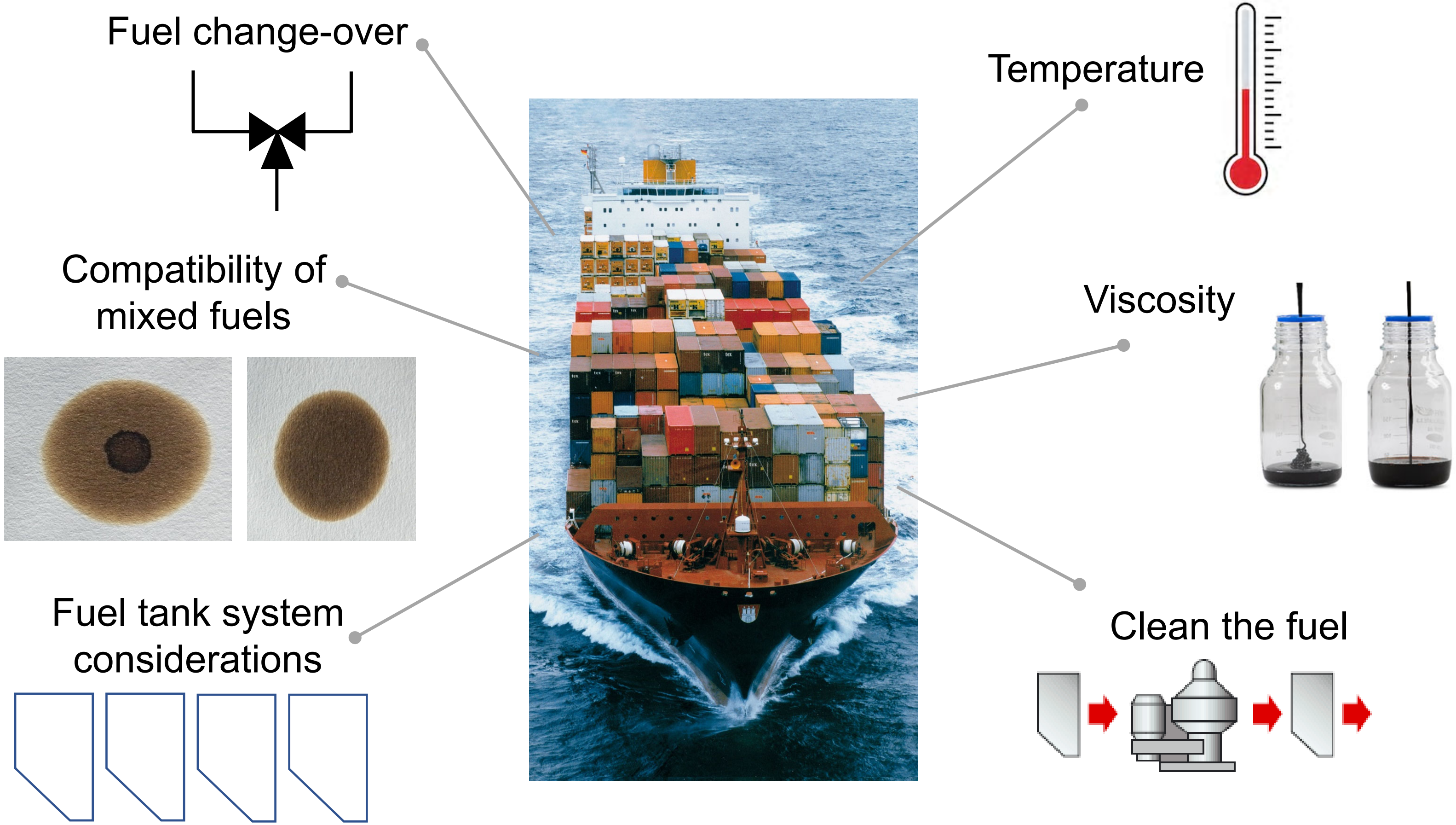




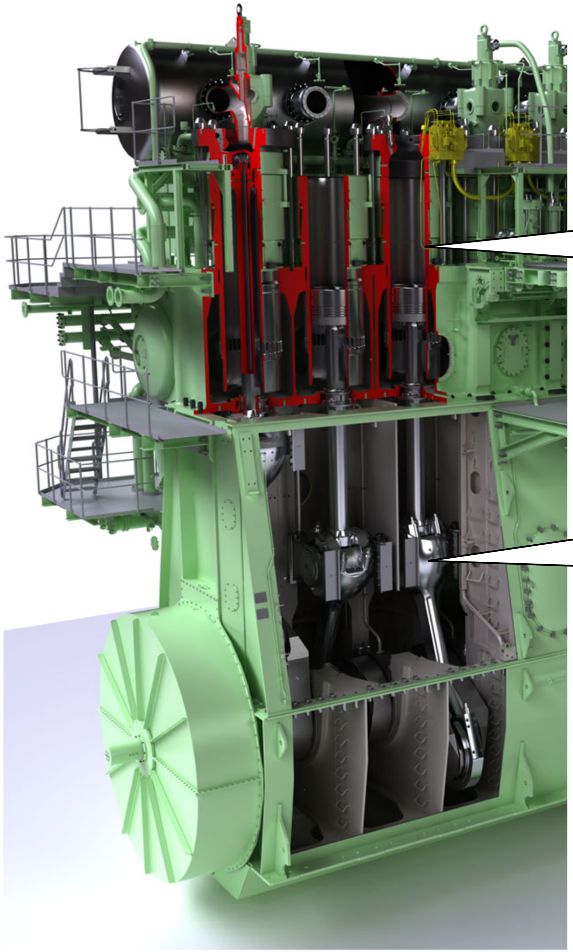
Summary: 0.50% S fuels

- What to consider – for the ship?





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

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.

IMO 2020 from a fuel’s specification perspective

CIMAC Circle
Marintec, Shanghai

5 December 2019

Presented by ISO/ TC28/ SC4/ WG6 Convenor
Monique Vermeire

Pre-2020 marine fuel specifications

- ISO 8217 is regularly being revised based on users' experience of fuels available on the market & keeps pace with the requirements of a rapidly shifting marine industry
  - Is sufficiently detailed, technically balanced and realistic
  - Considers ship machinery developments, regulatory requirements, fuel availability, health and safety of ship and crew, testing methods
    - E.g. 2017 edition: introduction of reporting of CP and CFPP

- Fuels as delivered are not fit for use : ISO 8217 specifies the requirements for fuels for use in marine diesel engines and boilers, prior to conventional onboard treatment
- All fuels supplied are "blended"

Post 1 January 2020 marine fuel specifications

- Fuel blending driven by S content, other characteristics will follow

- Diverse new range of RM and DM fuels enter in the market
  - Some RM fuels can be more paraffinic, less aromatic

- ISO 8217 applies to all fuel oils, including 0,10 and 0,50 % S fuels

- Development of ISO/PAS 23263:2019
  - To be used in conjunction with ISO 8217:2017 but can also be used with earlier editions
  - No additional specifications, no new tables

- Full revision of ISO 8217 after 2020

ISO/PAS 23263:2019

- **Petroleum products — Fuels (class F) — Considerations for fuel suppliers and users regarding marine fuel quality in view of the implementation of maximum 0,50 % sulfur in 2020**
  - Interim solution to respond to an urgent market need: addresses technical considerations that might apply to 0,50 % S max. marine fuels
  - Published: September 2019

Contents

Page

ISO/PAS 23263:2019

General considerations for 0,50% S marine fuels

Considerations that apply to **ALL 0,50% S max fuels**

- Regulatory requirements: sulphur and flash point
  - Supplier's responsibility to deliver fuel that meets sulphur and flash point requirement
- Application of ISO 8217:2017
  - ISO/PAS23263:2019 to be used in conjunction with ISO 8217:2017 but can also be used with earlier editions
- Fuel purchasers shall continue to order fuel as they did before 1 January 2020

ISO/PAS 23263:2019
Specific considerations for 0,50% S marine fuels

Considerations that may apply to **particular 0,50 mass % S fuels**

Included in ISO 8217

- Kinematic viscosity
- Cold flow properties: Cloud point, CFPP, PP
- Stability: total sediment aged of 0,10 % m/m max.
- CCAI
- Catalyst fines

Concern on potential incompatibility of fuels:

- suppliers can not guarantee compatibility without testing
- CONCAWE sponsored ISO/TC 28/SC 4/WG6 study to evaluate testing methodologies to obtain indication of degree of compatibility between marine fuels without having to mix the fuels

ISO/PAS 23263:2019
Specific considerations for 0,50% S marine fuels

- Cold flow properties: Cloud point, CFPP (distillates); Pour point
  - can be managed onboard
    - consider area where ship will operate & inform supplier when negotiating fuel stem
    - review heating capabilities of (distillate) tanks
    - fuel storage temperature : typically 10°C above PP, but high CFPP and CP can still cause filter blockage
- Kinematic viscosity: wider variation even within same grade; check BDN !
- Stability:
  - resistance of the fuel to precipitate asphaltenic sludge
  - can be upset by : thermal stress, adding paraffinic material, reducing aromatics, mixing with other (stable) fuel
  - total sediment aged (thermal ageing) of 0,10 % m/m max

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Specific considerations for 0,50% S marine fuels

- Compatibility: a measure of how stable a mixture is of two or more different components in a given ratio

- Compatibility: not guaranteed by fuel supplier
  - apply best practice of complete segregation or controlled commingling
  - ASTM D4740 “spot test” not always reliable: waxy nature of fuels can give a “high“ spot rating but fuels are stable

- Incompatibility: tendency to form organic sediment when commingling fuel oils, leading to filter clogging, purification problems, ….

- Incompatibility is NOT NEW !

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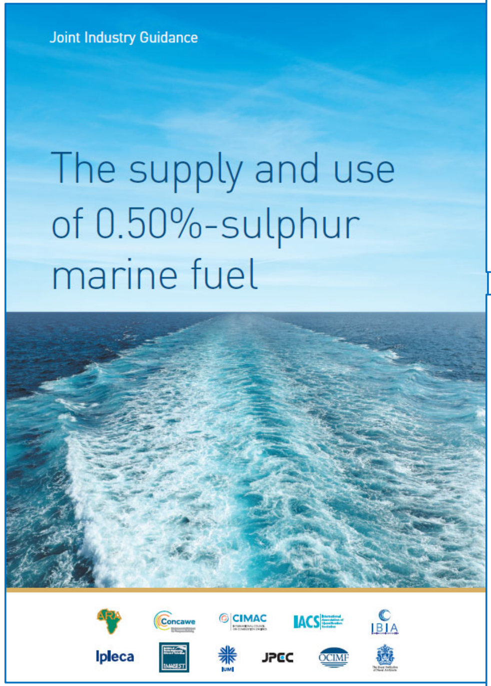
Specific considerations for 0,50% S marine fuels

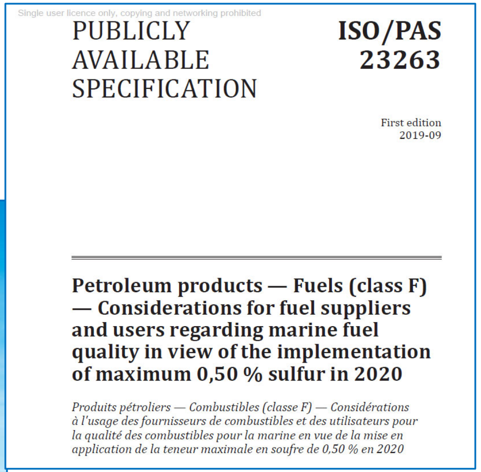
- Incompatibility can be mitigated by segregation of fuels, but some mixing onboard can not be avoided

- Forward planning, reduce ROB as much as possible

- Supplier might be able to provide information that may help to evaluate potential risk for incompatibility

- Guidance in ISO/PAS,CIMAC and JIG

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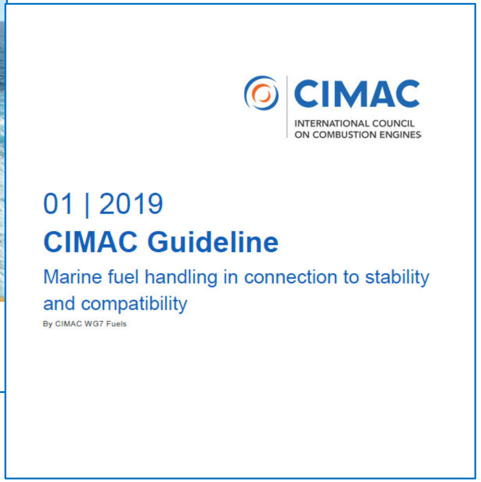
PUBLICLY AVAILABLE SPECIFICATION

ISO/PAS 23263

First edition
2019-09

Petroleum products — Fuels (class F) — Considerations for fuel suppliers and users regarding marine fuel quality in view of the implementation of maximum 0,50 % sulfur in 2020

Produits pétroliers — Combustibles (classe F) — Considérations à l'usage des fournisseurs de combustibles et des utilisateurs pour la qualité des combustibles pour la marine en vue de la mise en application de la teneur maximale en soufre de 0,50 % en 2020


CIMAC
INTERNATIONAL COUNCIL ON COMBUSTION ENGINES

01 | 2019

CIMAC Guideline

Marine fuel handling in connection to stability and compatibility

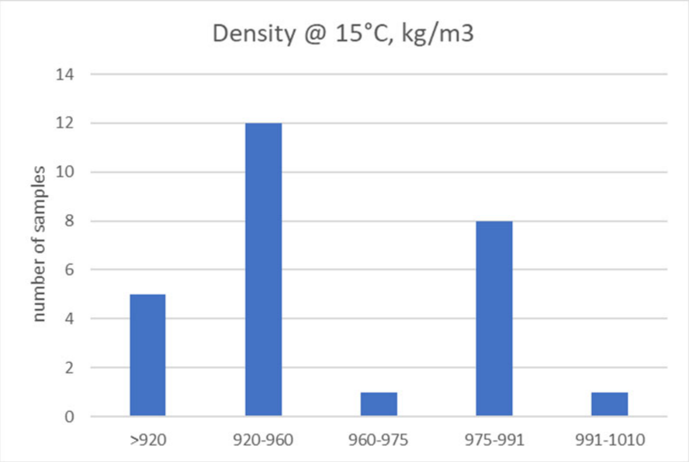
By CIMAC WG7 Fuels

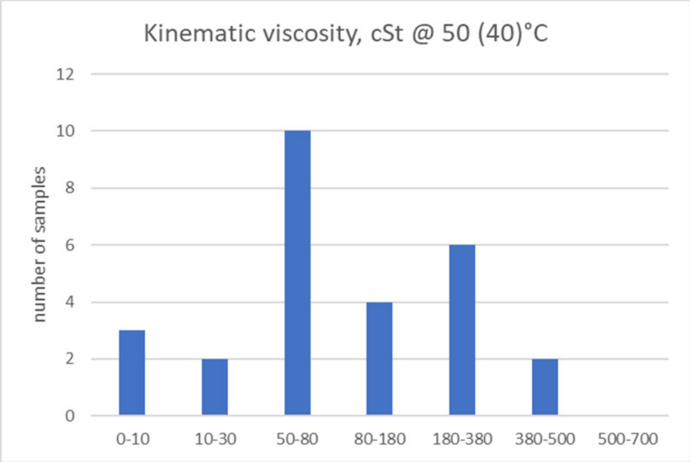
ISO/CONCAWE study

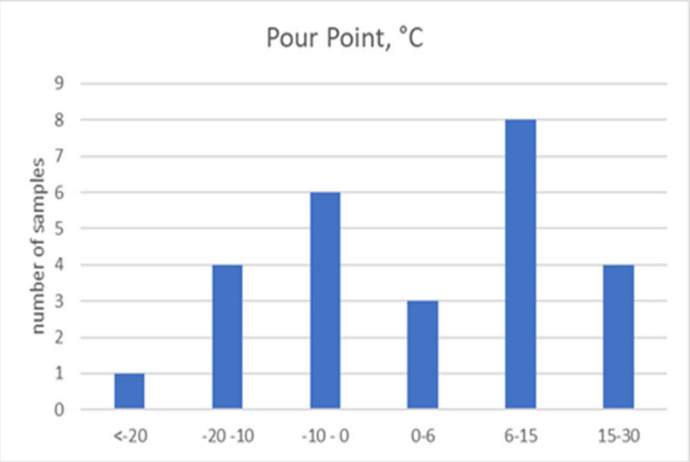
investigation whether test methods currently only routinely used by refiners, can provide additional information on the stability and guidance on potential instability of different fuel formulations and blends thereof

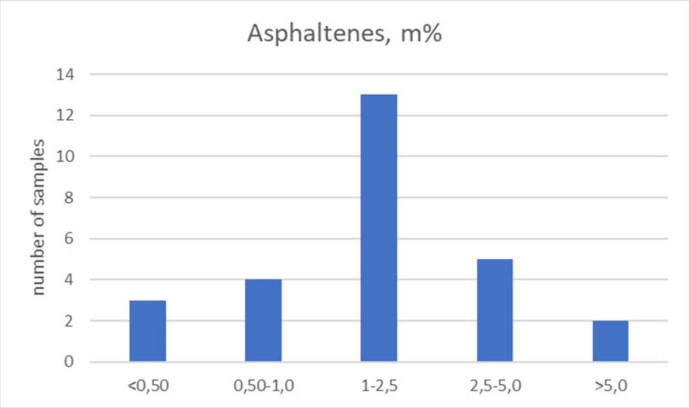
- Test program conducted on a limited fuel set (52 samples, including 27 VLSFO)
- All samples (ULSFO, VLSFO, LSFO, HSFO) tested according to ISO 8217
- 3 Additional test methods (ASTM D7157, D7112, D7060) evaluated:
    - Measurement of parameters related to:
        - ability of fuel oil matrix to maintain asphaltenes dispersed
        - capacity of the asphaltenes to remain dispersed
    - Parameters of the individual fuels to be commingled can be used to obtain indication on degree of compatibility of the fuels

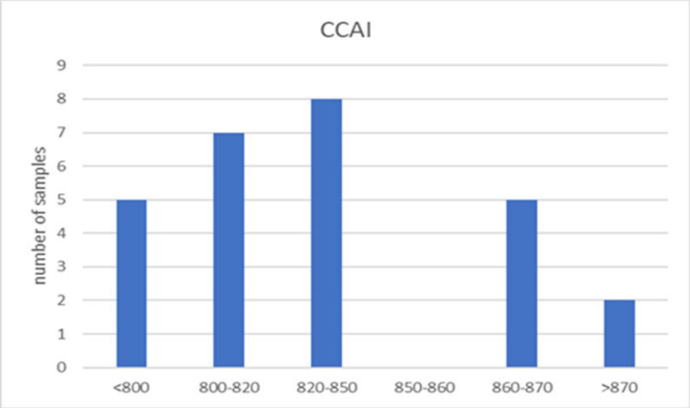
ISO/CONCAWE study: VLSFO typical test data











ISO/CONCAWE study
Compatibility prediction model

Blending model parameters which can be used to obtain guidance on compatibility of fuels:

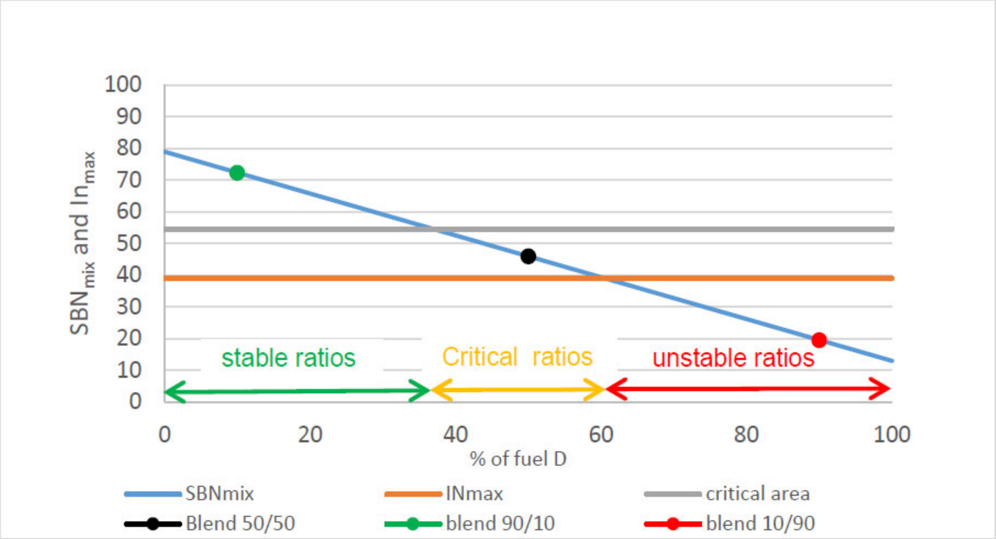
- ASTM D7158 and D7112
  - SBN: Solubility blending number: measure of the oil's ability to keep asphaltenes in solution
  - IN: Insolubility number: measure of the degree of asphaltenes insolubility
    - A higher number indicates a higher risk for asphaltenes precipitation
- ASTM D7060
  - Po: the solvency/peptization power of the fuel oil carrier
  - FR_{max} represent the capacity of the asphaltenes to remain dispersed

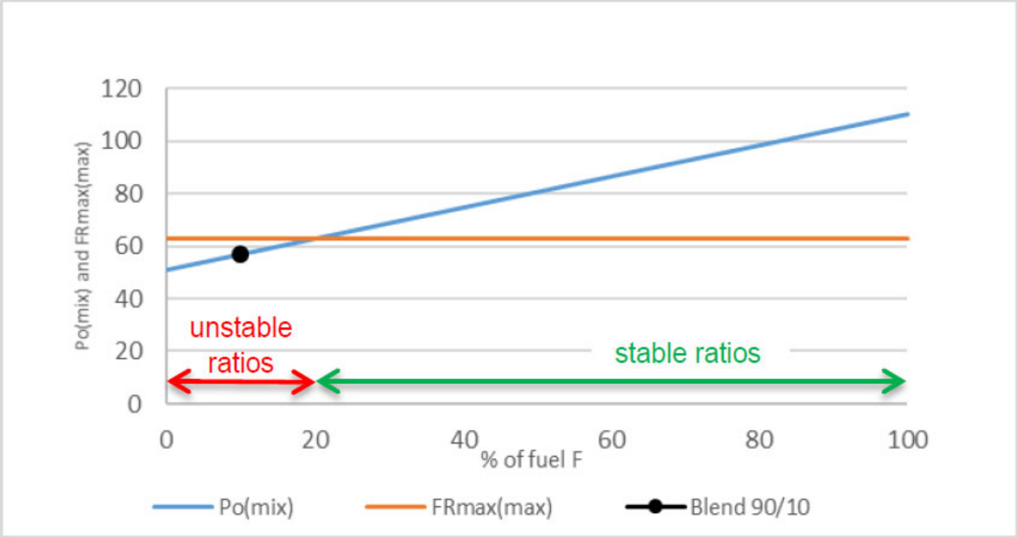
ISO/CONCAWE study

Compatibility prediction model: examples

Fuel	SBN	IN
Fuel C	79	39
Fuel D	13	24
Blend of Fuel C and Fuel D; Ratio 10/90	SBN_{mix} = (0,10 x 79) + (0,90 x 13) = 19,6	IN_{max} = 39 1.4 x IN_{max} = 54.6

Fuel	FR_{max}	Po
Fuel E	27	51
Fuel F	63	110
Blend of Fuel E and Fuel F; ratio 90/10	$FR_{max(max)}$ = 63	$Po_{(mix)}$ = (0,90 x 51 + 0,10 x 110) = 56,9

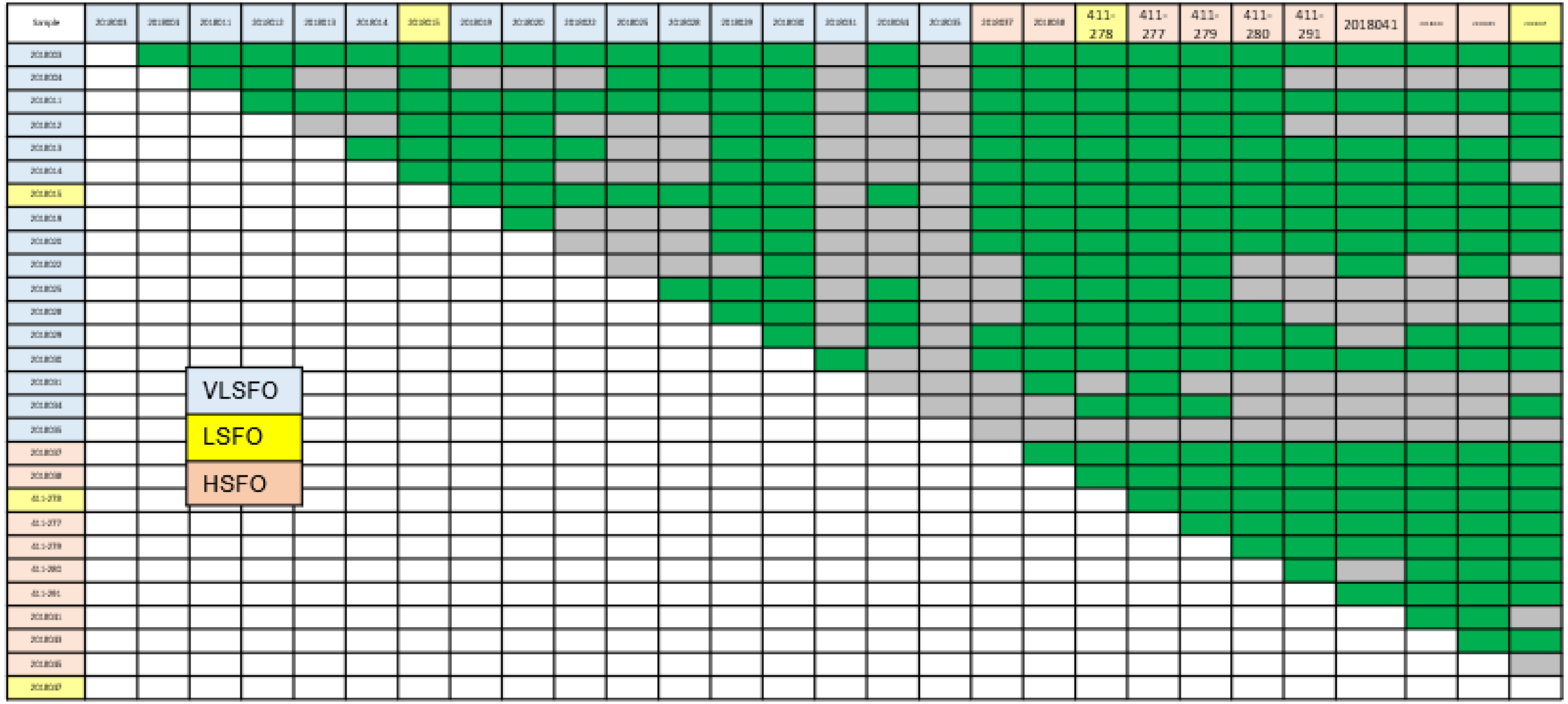




Source: CIMAC Guideline 01/2019

ISO/CONCAWE study

- Example compatibility prediction model:
  - Green shaded cells: compatible over the entire 0-100 % commingling range
  - Grey shaded cells: compatible at specific commingling ratio



ISO/CONCAWE study
Prediction methodology accuracy

TSP ≤ 0.10 mass %	TSA ≤ 0.10 mass %	Stable
0.08 ≤ TSP ≤ 0.10 mass %	TSA > 0.10 mass %	Borderline. Just on spec according to TSP but TSA is high
TSP > 0.10 mass %		Unstable

Source: CONCAWE report 19-11

ASTM D7157 (Rofa) prediction		Actual blend stability based on TSP and TSA		
		Stable	Borderline	Unstable
Predicted classification	Stable	16	2	1
	Borderline	10	0	3
	Unstable	2	0	1
ASTM D7112 (Porla) Prediction		**Actual blend stability based on TSP and TSA**		
		Stable	Borderline	Unstable
Predicted classification	Stable	13	1	1
	Borderline	14	1	2
	Unstable	1	0	2
ASTM D7060 (Zematra) prediction		**Actual blend stability based on TSP and TSA**		
		Stable	Borderline	Unstable
Predicted classification	Stable	18	2	0
	Unstable	6	0	4

ISO/CONCAWE study

- Prediction methodologies (3) predict 65-69% of all possible fuel combinations to give stable blends whatever the mixing ratio is
    - ±50% of the possible fuel combinations that are predicted to be always stable whatever the mixing ratio is, are common for all 3 test methods

- Prediction methodology can only be applied to fuels that have been tested with the same test method; some methods include a margin for error factor

- Recommendation to use TSP (Potential Total Sediment) to guarantee total sediment aged of a fuel meets specification of 0,10 % mass max.

Test methods for stability/ compatibility evaluation

Test method	Reference	Applicability		
		Stability	Compatibility= stability of mixture	Prediction of compatibility without testing
Total sediment (TSE, TSP, TSA)	ISO 10307 (IP 375/390, ASTM D4870)	✓	✓	x
Spot test[1]	ASTM D4740	✓	✓	x
S-value	ASTM D7157	✓	✓	✓
P-value	ASTM D7112	✓	✓	✓
P-ratio	ASTM D7060	✓	✓	✓

[1] Waxier asphaltenes-free products can incorrectly give high spot rating

In summary: be prepared for 2020

- Be aware of the potential variability in fuel’s viscosity, density, cold flow properties before using the fuel
- Potential safety and fuel related issues alerted for do exist today and are being managed
- Proper planning, onboard fuel management and training of ship’s crew and technical staff will help to overcome technical challenges
- Many guidelines, publications to help the industry through this transition