“IMO 2020: VLSFO and On-Board Testing Strategy”

White Paper

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Table of Contents

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1. Introduction

Since introduction of IMO 2020 regulations and new formulations of marine fuel oils – very low sulphur fuel oils (VLSFOs) - with 0.50 % sulphur requirement, the international marine fuel market has rather quickly adjusted to production and distribution of new fuel oil batches. Despite the continuing efforts to diversify marine fuels and to substitute traditional fuel oil with alternative fuels such as marine gas oil/ marine diesel oil, liquid natural gas (LNG), biofuels known as FAME (fatty acid methyl ether) as well as current consideration of production of sulphur-free hydrogen-based fuels such as methanol and ammonia[1], VLSFO will remain one of the principal marine fuels for international shipping in the coming decades.

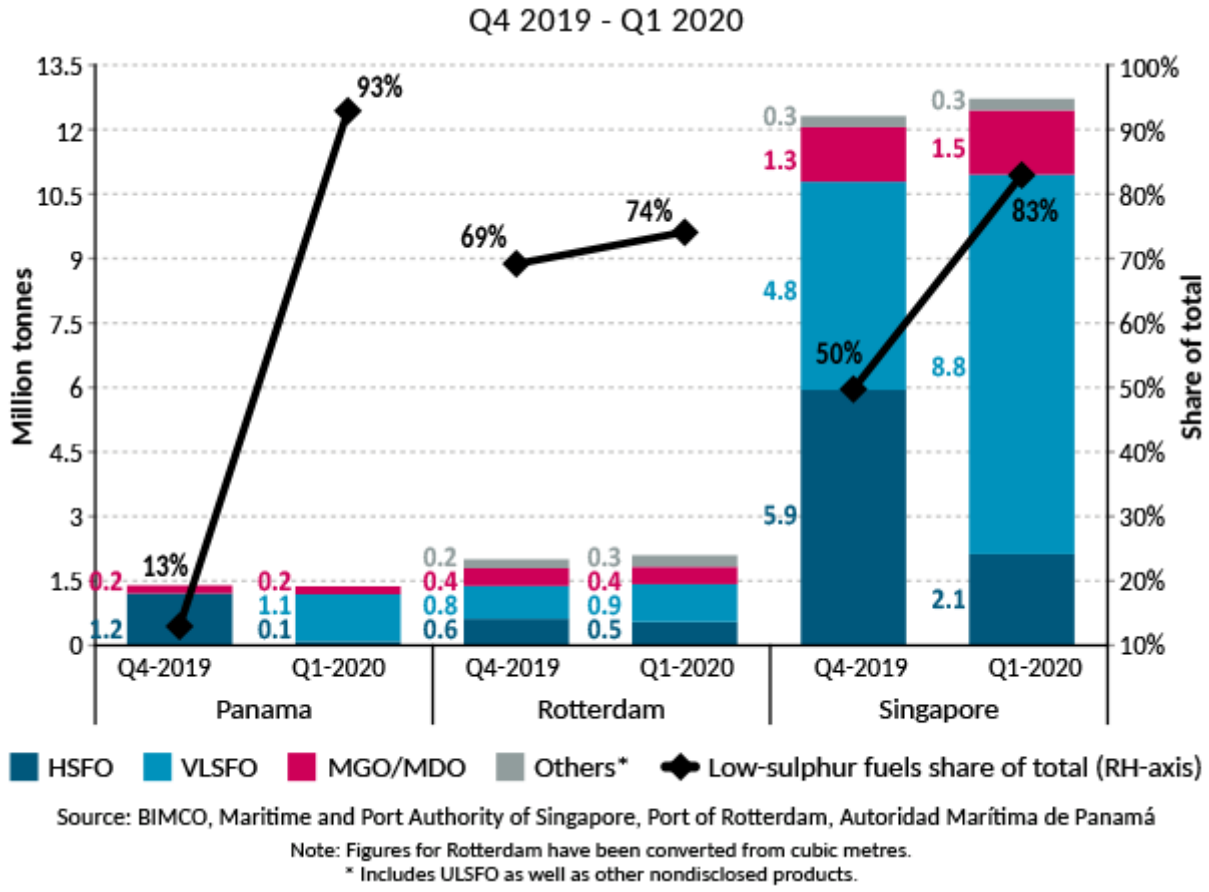

Fig. 1. Bunker Sales in Major Bunkering Hubs[2]

[1] "Flexibility Key to Enabling Shipping's Transition to Future Fuels". Wärtsilä Corporation, News, 15 May 2020.
https://www.wartsila.com/media/news/15-05-2020-flexibility-key-to-enabling-shipping-s-transition-to-future-fuels-2823479

[2] "The Collapse of the Oil and Bunker Fuel Markets in early 2020", Peter Sand, 7 May 2020, BIMCO.
https://www.bimco.org/news/market_analysis/2020/20200507_the_collapse_of_the_oil_and_bunker

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In this sense, the international shipping industry has to effectively deal with various challenging issues related to very low sulphur fuel oil quality. Regarding huge differences in compositional structures of new VLSFO batches even within the same fuel grade specified in ISO 8217:2017, depending on such factors as geographical origin and a source of formulation of marine fuel blend as such, multiple problems are regarded as of concern.

Early data analysis on 2020 Marine Fuels Quality published by Marine Environment Protection Committee (MEPC) summarizes general characteristics of VLSFOs pointing out that these fuels tend to be more paraffinic in nature than conventional HSFO types; they have a lower viscosity, density, lower micro carbon residue (MCR) and Calculated Carbon Aromaticity Index (CCAI), higher net specific energy and a higher pour point.[3] The important issue with catalyst fines (Al+Si) remains relevant also with regard to new VLSFOs as shown in the table below.

Table 1: Average of RM Fuel Oil Characteristics, 2020 vs. 2018[4]

	2020 RM VLSFO	2018 RM HSFO
Viscosity at 50°C, cSt	**105**	**355**
Density, kg/m3	**936**	**988**
MCR, mass%	**5.4**	**13.9**
Net Spec Energy, MJ/kg	**41.7**	**40.3**
CCAI	**813**	**848**
Al+Si, mg/kg	**18.2**	**22.3**
Sulphur, mass%	**0.45**	**2.61**

It is necessary to note that all the data presented above refer only to the limited period of time of data collection and assessment, namely January to June 2020. The available statistical reports show several problematic points with regard to VLSFOs that have to be further carefully observed in order to receive a more profound understanding of major differences as well as similarities to HSFOs.

In the meantime, appropriate monitoring of crucial fuel oil properties and adequate management on board a vessel is essential to provide proper functioning of the engine system. Equally important is the application of regular on-board testing to early detect any off-specification characteristics of VLSFOs but also incompatibilities

[3] "Air Pollution Prevention. Review of 2020 Marine Fuels Quality. Submitted by ISO". MPEC 76/5, 29 January 2021, p.4

[4] Same source, p. 2

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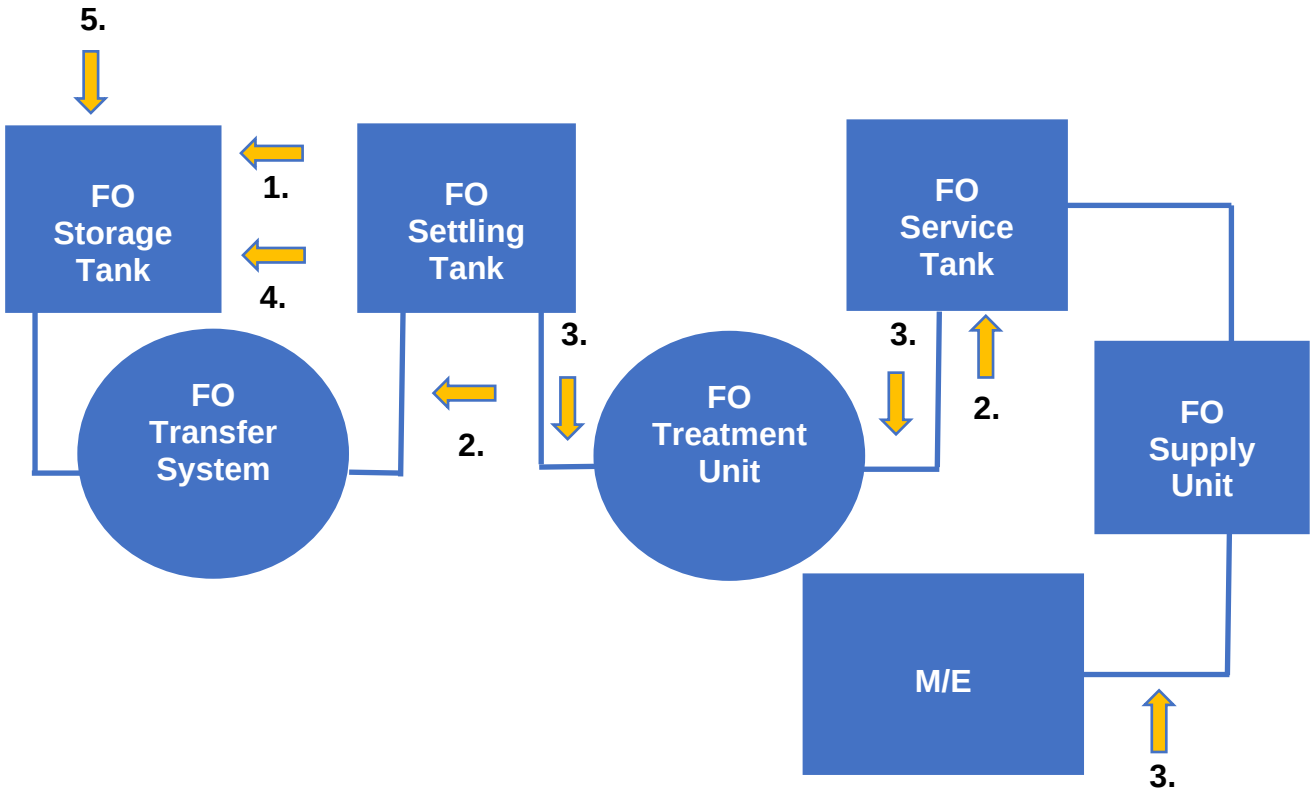
between fuels and as a constituent part of on-board fuel oil handling and treatment strategy.

Due to the extended range of the problematic issues with VLSFOs quality, this White Paper will be only focused on few important parameters, namely stability and compatibility, catalyst fines (Al+Si), viscosity and CCAI as well as flash point.

Particular attention will be paid to Martechnic®'s portable test equipment as a reliable solution in supporting on-board fuel testing strategy in order to effectively manage new VLSFO batches. The graphic below (see Fig. 2) depicts the main reasonable testing points for selected parameters Martechnic® regards as crucial for effective management of fuel oil quality on board a vessel. Each parameter will be considered in detail in separate chapters.



1. Stability
2. Compatibility prior transfer
2. Compatibility if not fully drained before filling
3. Cat Fines before/after FO Treatment Unit
3. Cat Fines before M/E
4. Viscosity
5. Flash Point

Fig. 2. Recommended Regular On-Board Testing of Crucial Fuel Oil Parameters in Marine Fuel Oil Tanks

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2. Stability and Compatibility of VLSFOs

The marine fuel delivered on board a vessel should be in compliance with stability requirement stipulated in ISO 8217:2017 and it is responsibility of the supplier to ensure that the end product is homogenous and stable as well as its stability reserve is sufficient[5].

Various types of VLSFOs can be predominately paraffinic or aromatic in nature, depending on their initial formulation and the way of production. The predominantly aromatic VLSFOs tend to be more stable. In the contrary, VLSFOs with high paraffinic content have tendency to be or to become more unstable. Once VLSFO has become unstable, it cannot be further used as the precipitated asphaltenes lead to excessive sludge concentration in fuel oil tanks (storage, settling and service tanks) and can cause blockage of separators (fuel oil purification system), filters, fuel injection equipment and fuel pipes.

As the consequences of unstable VLSFO represent a major problem for the ship's crew operating a vessel, it is important to check stability of the marine fuel oil before bunkering and to allocate a separate storage tank for it in the first step (see Fig 2, p.5). Application of quick and easy on-board testing with portable test equipment can provide immediate confirmation whether the VLSFO supplied on board a vessel corresponds to ISO 8217:2017 specifications and is stable.

Moreover, during prolonged sea voyages on-site testing can help to reveal potential stability problems and ongoing changes of compositional structure of VLSFO resulting from temperature and pressure fluctuations as well as oxidization over time.

According to recently available statistical information, the stability problem and sedimentation issues with regard to VLSFOs have noticeably increased in comparison to conventional HSFO.[6]

Table 2. Total Sediment: Comparison between 2020 RM VLSFO and 2018 RM HSFO[7]

TSA, mass%		**2020 RM VLSFO**		
	TSA < 0.05	0.05 ≤ TSA ≤ 0.10	0.10 < TSA ≤ 0.15	TSA > 0.15
% of samples	93.5	5.0	0.7	0.8

TSA, mass%		**2018 RM HSFO**		
	TSA < 0.05	0.05 ≤ TSA ≤ 0.10	0.10 < TSA ≤ 0.15	TSA > 0.15
% of samples	94.0	5.8	0.09	0.14

[5] "Guidance on Best Practice for Fuel Oil Suppliers for Assuring the Quality of Fuel Oil Delivered to Ships". IMO MEPC.1/Circ.875/Add.1, 9 November 2018, Annex, p.3

[6] "Air Pollution Prevention. Review of 2020 Marine Fuels Quality. Submitted by ISO". MPEC 76/5, 29 January 2021, p. 4

[7] Same source, p.3

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As currently the sedimentation problem of VLSFOs is under investigation, it is important to follow the guidelines and provide adequate fuel oil quality management practices with regard to VLSFO storage conditions and storage time combined with onboard testing strategy.

Compatibility issue of VLSFOs refers to the scope of onboard fuel management practices and their proper application by the ship's crew. An important point to mention is that even though two fuel oils are confirmed individually as stable according to ISO 8217:2017 stability criteria, they might be incompatible when blended on board a vessel. Due to differences in the compositional structures of new VLSFO types, mixing a VLSFO with predominantly aromatic fuel oil with a high-paraffinic VLSFO can result in incompatibility, i.e., precipitation of asphaltenes and formation of sludge. Moreover, incompatibility can also occur between batches of the same product.

In practice it is not always possible to prevent mixing of different fuel oils as a storage tank might not be fully emptied and contain the leftover fuel. Besides, depending on the fuel tank arrangement system of a vessel different bunker fuels might get mixed in the fuel transfer, settling, service tanks and supply circuits despite all the efforts to minimize commingling throughout the fuel system, when or for example during fuel switching when entering and leaving ECAs.[8] In this regard, it is essential to always check on VLSFOs compatibility prior to proceeding with mixing new VLSFO batch with leftover fuel or comingling two VLSFOs (even when originally stored separately in different storage tanks) in fuel oil pipelines, settling and then service tanks (see Fig 2, p.5).

[8] "Joint Industry Guidance: the Supply and Use of 0.50% - Sulphur Marine Fuel Oil". P.23/ https://www.concawe.eu/wp-content/uploads/Joint-Industry-Guidance-on-the-supply-and-use-of-0.50-sulphur-marine-fuel.pdf

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2.1. Testing Stability and Compatibility on Board a Vessel

On-site testing for stability and compatibility is regarded as a simple and valuable approach to manage various VLSFO batches effectively on board a vessel.

Martechnic® offers on-site compatibility and stability tests with portable test kit “COMPA DENS CHECK” guided by ASTM D4740-04 (2014). The test kit helps to directly determine whether the delivered bunker fuel is stable and/or compatible with the fuel oil previously stored in a storage tank before starting bunkering it on board a vessel. Besides, quick verification of stability and compatibility parameters during sea voyages can be performed at any time when potential comingling of two fuels is under consideration. Availability of nearly immediate test results contributes to effective decision-making.

Fig. 3. Test Kit “COMPA DENS CHECK”

As paraffinic fuels are more problematic to blend with other fuel oils, it might be useful to check various options of blending (e.g., 90/10, 80/20, 60/40 etc.), keeping the paraffinic VLSFO ratio in low percentage (e.g., 10%) and aromatic fuel oil in high percentage (e.g., 90%). However, if the tested mix indicated compatibility and stability directly after blending, it might become unstable later in a tank. In this case regular on-site stability testing with “COMPA DENS CHECK” can help to identify occurring stability issues at the right time.

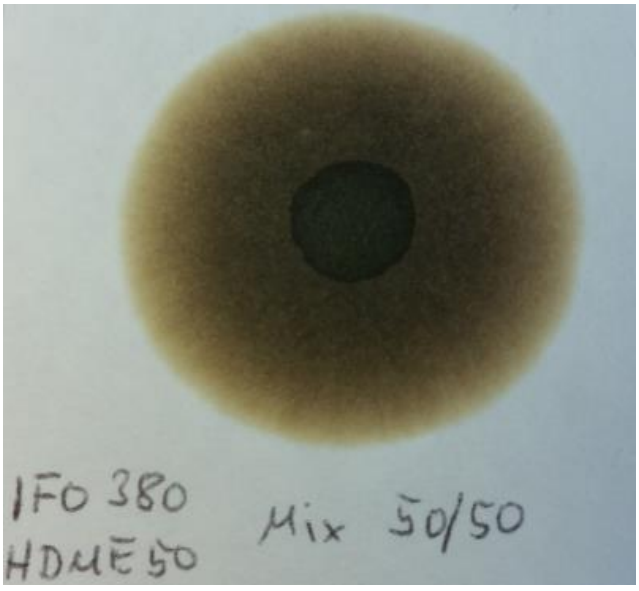

Fig. 4. Example of Incompatibility between Two Fuels

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3. Catalyst Fines and New VLSFO Blends

Cat fines (Al and Si compounds) are hard abrasive particles that remain in fuel oil as a by-product resulting from the catalytic cracking technology or fluid catalytic cracking (FCC) used in the intensive refining and blending process to reduce the sulphur content. New formulations of marine fuel oil with different compositional structures are considered to contain increased amounts of cat fines in comparison to HSFO types. And, in particular, heavy cycle oils (slurry oils) may presumably be at risk of containing higher levels of cat fines.

When cat fines are present in big quantities in VLSFO or of a large size and if they find their way to the engine, they can substantially damage the components of the engine system such as fuel pumps, injection valves, cylinder liners, pistons and piston rings.

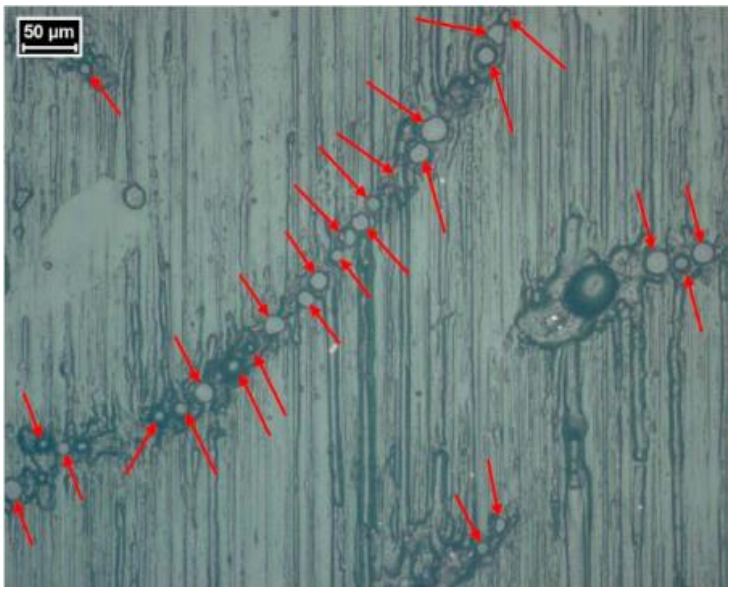

Fig. 5. Example of Cat Fines Embedded into a Cylinder Liner Surface[9]

In compliance with the international specifications, cat fines concentration in bunker fuel delivered on board a vessel should not exceed the maximum permissible level of 60 mg/kg (ppm).[10] On-board fuel oil treatment and separator systems are aimed at cleaning a fuel oil and reducing the cat fines concentration by at least 80-85% to internationally recommended 15 mg/kg (ppm) or even lower before a fuel oil enters the engine system. The efficiency of on-board filters including their appropriate size is also of crucial importance as a last possible measure to further decrease the cat fines concentration.

[9] "PAPER No.51: Onboard Fuel Oil Cleaning, the ever neglected process How to restrain increasing Cat-fine damages in two-stroke Marine Engines". CIMAC., CIMAC Congress 2013, Shanghai, p.3

[10] "Petroleum Products – Fuels (Class F) – Specifications for Marine Fuels". International Standard. ISO 8217:2017, Sixth Edition, 2017-03, p.11

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Nevertheless, in practice despite the on-board fuel oil treatment efforts, cat fines may remain in the fuel oil if the separators do not perform in a sufficient manner and/or service tanks bottoms are not properly cleaned or a filtration system is not efficient, i.e., the mesh size of the filters is too large and smaller cat fines particles cannot be removed.

Consequently, all these possible limitations of on-board fuel oil treatment imply the necessity of adoption of on-board testing strategy. It is essential to regularly assess cat fines content with on-board testing before and after fuel oil treatment in separator system with additional cat fines monitoring measures prior to the main engine (M/E) (see Fig. 2, p. 5).

Cat fines concentration varies noticeably through different VLSFO types and grades. This tendency is clearly observable in the early survey jointly carried out by BIMCO, ICS, Intercargo and Intertanko from 24 February until 6 May 2020. If some respondents refer to the increased cat fines concentrations in a VLSFO used on a board a vessel (31% of all respondents experienced operational issues due to increased amounts of cat fines)[11], meanwhile other participants do not attribute the problem of increased wear and tear of piston rings and cylinder liners to cat fines per se, but mention operational problems with on-board purification system and application of a new VLSFO as well as the necessity to make changes in filter system from mesh size of 25 micron to 10-micron.[12] It can be assumed that the experiences made with increased cat fines concentration in VLSFOs are highly dependent on particular types and/or grades supplied and used for engine system operation.

In any case, regardless of a VLSFO type/ grade to be used, a good on-board VLSFO quality management is essential and on-board trend monitoring of cat fines concentration with portable testing equipment is cost-effective method for providing continuous smooth operation of the engine system.

[11] "2020 Fuel Oil Quality and Safety Survey". BIMCO, International Chamber of Shipping, Intercargo and Intertanko. Pp.4, 34, 36, 37, 38

[12] Same source, pp.35, 36, 60

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3.1. On-Board Testing for Early Identification and Management of Cat Fines Problems

The test kit “MT CAT FINES CHECK” has been designed by Martechnic® as a part of on-board pre-consumption fuel oil analysis for easy, quick and accurate determination of cat fines concentrations in heavy fuel oil. Regular verification of cat fines amounts is recommended before and after on-board handling and treatment measures in fuel oil treatment unit as well as prior to using the fuel oil for engine operation (see Fig. 2, p.5).

Fig. 6. Test Kit “MT CAT FINES CHECK”

This “double-check” strategy helps to regularly estimate the cleaning efficiency of the separators as it is their crucial role to reduce cat fines content to the lowest extent possible before the engine inlet.

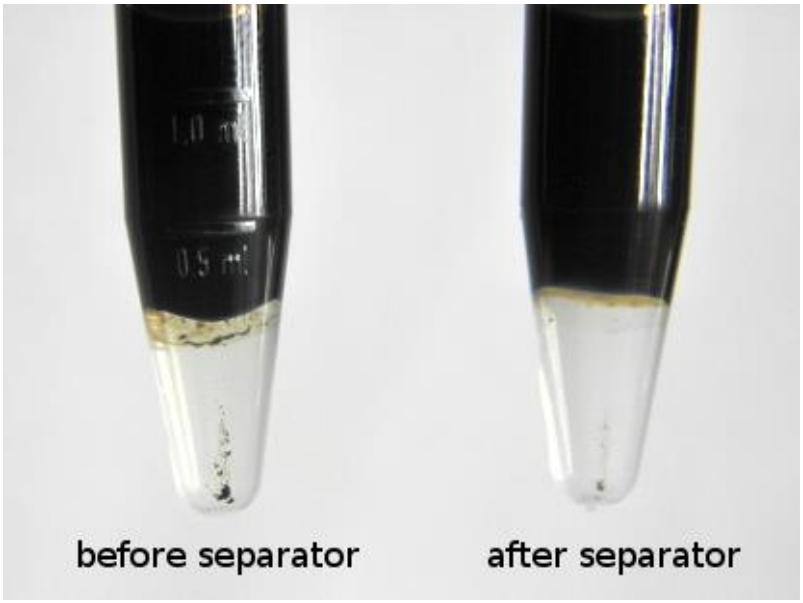

Fig. 7. Difference in Cat Fines Concentration before and after VLSFO Treatment in Separators

As the test kit is simple to use and no special training is required, the ship’s operators can easily employ it for cat fines verification on board a vessel. Regular on-board monitoring of cat fines concentrations can substantially reduce the risk of experiencing engine wear and tear problems related to cat fines and their possible abnormal levels in new formulations of VLSFOs.

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4. Viscosity of VLSFOs: Effective On-Board Management

Viscosity is probably the most variable parameter in the compositional structure of different VLSFO types in comparison to conventional high-sulphur fuel oils. A fuel type/ grade can show a very low viscosity or, in contrast, high viscosity number depending on particular blend components used for VLSFO formulation, geographical location and supplier.

Table 3. Viscosity: Comparison between 2020 RM VLSFO and 2018 RM HSFO[13]

Viscosity, V 50°C, cSt	**2020 RM VLSFO**					
	V ≤ 10	10 < V ≤ 20	20 < V ≤ 80	80 < V ≤ 180	180 < V ≤ 380	V > 380
% of samples	1.6	4.9	44	36	13	<0.5

Viscosity, V 50°C, cSt	**2018 RM HSFO**					
	V ≤ 10	10 < V ≤ 20	20 < V ≤ 80	80 < V ≤ 180	180 < V ≤ 380	V > 380
% of samples	< 0.1	< 0.1	0.6	04. Aug	73	22

It is necessary to note that ISO 8217:2017 does not specify any minimum limit of viscosity for new types of VLSFOs for bunker fuel suppliers. The highly fluctuating viscosity property with a general tendency to lower viscosity of VLSFOs may require closer monitoring and appropriate management on board a vessel. In addition, low viscosity VLSFOs may have tendency to destabilize more easily, whereas deviating viscosity of fuels could also provide an indication of incompatibility issues.

In this context, it might be helpful to regularly check viscosity of VLSFO with on-board testing equipment upon delivery to maintain correct temperature in storage tanks (see Fig. 2, p.5) and make necessary adjustments of the on-board handling and pre-treatment mechanisms, e.g., fuel purification system and transfer temperatures, to avoid possible problems before the fuel oil will be injected into the engine.

Another important concern is determining and controlling the acceptable temperature of low viscosity VLSFOs to achieve the correct injection temperature within the recommended levels. In contrast to high viscosity HSFOs, low viscosity VLSFOs may require less or no additional heating (in addition to storage or transport temperature). Increased pour point of VLSFOs with very low viscosity values can be also regarded as unusual feature. Therefore, it is important to carefully verify injection temperature in accordance with the requirements of the engine manufactures to provide adequate functioning of the engine system.

[13] "Air Pollution Prevention. Review of 2020 Marine Fuels Quality. Submitted by ISO". MPEC 76/5, 29 January 2021, p.3

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4.1. Regular Viscosity and Density Measurement with the Test Device “VISCO DENS PLUS”

Fig. 8 Test Device “VISCO DENS PLUS”

Effective on-board management of various types/ grades of VLSFOs can be conducted by applying on-board test device “VISCO DENS PLUS” to directly verify viscosity and density values of the delivered bunker fuel in just one quick test. The significant advantage of the test device is the capability to apply the same test tube at three different temperatures (40℃, 50℃ and 80℃). The determination of oil density in the first step allows more precise indication of viscosity value.

Regular viscosity measurements with VISCO DENS PLUS in storage tanks (see Fig. 2, p. 5) can help to confirm the corresponding values measured through on-board capillary viscosimeter or to immediately detect possible deviations and to make necessary adjustments at the right time.

Moreover, the test device can be applied to determine the Calculated Carbon Aromaticity Index (CCAI) of VLSFOs. Based on the measured viscosity and density values, the VISCO DENS PLUS will calculate the CCAI automatically. As CCAI is a crucial indicator for assessment of ignition performance of bunker fuels, it might be important to verify this parameter with regard to VLSFOs and their broad range of viscosity and density properties. On-site early detection of uncharacteristic combination of viscosity and density parameters (e.g., high density and lower viscosity) will help to avoid complications with the engine operation.

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5. Flash Point of VLSFOs

In accordance with international guidelines and safety measures stipulated in the International Convention for the Safety of Life at Sea (SOLAS) and ISO 8217:2017, the flash point of marine fuels delivered on a board a vessel must be at least 60°C. And the supplier of VLSFO is responsible for delivering a compliant fuel oil with this strict flash point requirement.

However, the general observation of various VLSFO formulations so far has resulted in the identification of a number of cases with the flash point values measured under the minimum limit specification of 60°C.[14] The decreased flash point of VLSFOs can be possibly due to the various components used for fuel oil refining and blending processes. As low flash point can be dangerous and represent a fire hazard, it is crucial to check its value when transferring the supplied fuel oil into a storage tank. It can also happen that the VLSFO with the initially compliant flash point can become off-specification if the flash point has been significantly shifted during storage time.

On-board flash point verification with portable testing equipment may help to identify possibly hazardous liquids in due course. The test device FLASH POINT CHECK enables ship operators to determine the flash point of the delivered marine fuels directly on site (see Fig. 2, p. 5) and provides immediate confirmation whether the flash point meet the minimum requirement of 60°C. The flash point is measured with the closed cup method taking into account ISO 2719 DIN EN 22719 and ASTM D-93.

Fig. 9. Test Device "FLASH POINT CHECK"

[14] "Global: UK P&I Club Issues Guidance Following "Significant Uptick" in Low-Flashpoint Fuels". Bunkerspot, Rhys Berry, 24 September 2020. / https://www.bunkerspot.com/global/51401-global-uk-p-i-club-issues-guidance-following-significant-uptick-in-low-flashpoint-fuels

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6. Conclusion

The first experiences with new formulations of VLSFOs can be summarized as controversial. Chemical composition of VLSFOs that are still remaining of experimental character differs greatly across various types/grades and can present several potential problems.

As predominantly paraffinic blends have been recently prevailing, the increased cases of unstable/ incompatible fuel oils have been registered. Moreover, in comparison to conventional HSFO, VLSFOs show clearly tendency to higher sedimentation and sludge formations. It can be assumed that new VLSFOs are more susceptible to temperature and pressure stresses and oxidization over time as well as their compatibility with other fuels tends to be more limited. Therefore, the crucial task is to provide adequate fuel oil quality management practices and to test VLSFOs for stability and/ or compatibility with portable on-board testing equipment at regular intervals in order to identify possible problems prior to using fuel oil for engine system operation.

Catalyst fines and their highly damaging levels in particular types/ grades of VLSFO blends remain of concern to shipping industry. Due to their abrasive nature and increased risk of wear and tear of engine system components, it is essential for the ship's operators to monitor cat fines concentrations before and after the fuel oil treatment in separators and prior to engine by using on-board testing equipment. Only regular on-site verification can provide confidence that cat fines levels are at their minimum possible, separator system is working flawlessly and a VLSFO can be injected into the engine system.

Low viscosity VLSFOs, and especially with unusual high pour point, should be properly managed to keep appropriate temperature in storage tanks in order to prevent possible fuel destabilization issues. Moreover, immediate identification of problematic low sulphur fuels with decreased flash point by testing on board will enable to safely operate a vessel in accordance with international regulations.

Overall, it can be concluded that VLSFOs require further careful examination in order to get profound understanding of their specifications. Reliable on-board testing strategy, proper fuel handling and treatment are the principal appropriate tools to manage effectively the quality of new marine fuel types, to protect the engine and to improve maintenance intervals.

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References

1. “Petroleum Products – Fuels (Class F) – Specifications for Marine Fuels”. International Standard. ISO 8217:2017, Sixth Edition, 2017-03.
2. “Guidance on Best Practice for Fuel Oil Suppliers for Assuring the Quality of Fuel Oil Delivered to Ships”. IMO, MEPC.1/Circ.875/Add.1, 9 November 2018, Annex.
3. “Air Pollution Prevention. Review of 2020 Marine Fuels Quality. Submitted by ISO”. MPEC 76/5, 29 January 2021.
4. “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”. ISO /PAS 23263:2019, First Edition 2019-09.
5. “Guidance on Best Practice for Fuel Oil Suppliers for Assuring the Quality of Fuel Oil Delivered to Ships”. IMO MEPC.1/Circ.875/Add.1, 9 November 2018, Annex.
6. “Joint Industry Guidance: the Supply and Use of 0.50% - Sulphur Marine Fuel Oil”. https://www.concawe.eu/wp-content/uploads/Joint-Industry-Guidance-on-the-supply-and-use-of-0.50-sulphur-marine-fuel.pdf (April 2021)
7. “CIMAC Guideline Marine Fuel Handling in Connection to Stability and Compatibility“. CIMAC WG7 Fuels 2019-01 (1st edition). https://www.cimac.com/cms/upload/Publication_Press/WG_Publications/CIMAC_WG07_Guideline_Stability_and_Compatibility_Nov_2019.pdf (April 2021)
8. “PAPER No.51: Onboard Fuel Oil Cleaning, the ever neglected process How to restrain increasing Cat-fine damages in two-stroke Marine Engines”. CIMAC., CIMAC Congress 2013, Shanghai.
9. “2020 Fuel Oil Quality and Safety Survey”. BIMCO, International Chamber of Shipping, Intercargo and Intertanko.
10. FUJCON 2021: Sulphur Off-Specs in Bunker Fuel Samples More Than Doubled on Year in 2021, Observes VPS. 24 March, 2021. https://www.manifoldtimes.com/news/fujcon-2021-sulphur-off-specs-in-bunker-fuel-samples-more-than-doubled-on-year-in-2021-observes-vps/ (April 2021)
11. “The Collapse of the Oil and Bunker Fuel Markets in early 2020”, Peter Sand, 7 May 2020, BIMCO. https://www.bimco.org/news/market_analysis/2020/20200507_the_collapse_of_the_oil_and_bunker (May 2021)
12. “Flexibility Key to Enabling Shipping‘s Transition to Future Fuels”. Wärtsilä Corporation, News, 15 May 2020. https://www.wartsila.com/media/news/15-05-2020-flexibility-key-to-enabling-shipping-s-transition-to-future-fuels-2823479 (April 2021)
13. Global: UK P&I Club Issues Guidance Following “Significant Uptick” in Low-Flashpoint Fuels”. Bunkerspot, Rhys Berry, 24 September 2020. https://www.bunkerspot.com/global/51401-global-uk-p-i-club-issues-guidance-following-significant-uptick-in-low-flashpoint-fuels (May 2021)