CHARTING THE FUTURE

ClassNK

Technical Guide for Using Biofuels (Edition 1.1)

[English]



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Introduction

Recently, in the maritime industry, decarbonization has become a trend as a measure against global warming owing to the growing worldwide momentum for the realization of a decarbonized society. IMO adopted the "2023 IMO Strategy on Reduction of GHG Emissions from Ships" at MEPC 80 in July 2023, and revised the target upwardly to reach net-zero GHG emissions by around 2050 at the latest.

To achieve the target, in the maritime industry, the fuel shift is trying to be forwarded by conversion from conventional fossil fuels to alternative fuels with lower GHG emissions such as hydrogen, ammonia, and methanol. Meanwhile, the widespread availability of their alternative fuels may take a long time since there are challenges such as the development of safety utilization technology and the establishment of a supply chain. Therefore, biofuels are attracting attention as drop-in fuels usable in place of petroleum fuels without major modifications to existing marine diesel engines and machinery facilities.

Biofuels are renewable fuels produced from biological organisms (biomass) based on plants, and such fuels are said to be carbon neutral. This is because biofuels are processed and manufactured from plants, and the total amount CO_2 during plant growth may offset the amount of CO_2 emitted during combustion, i.e. total CO_2 emissions are considered to be zero. Up until now, GHG emissions have been evaluated based on the "Tank-to-Wake" approach considering only onboard emissions. In the meantime, usage of the "Well-to-Wake" approach, considering the origin of feedstock and the manufacturing process of fuels, is becoming a global standard in the evaluation methods of GHG emissions. The "Well-to-Wake" approach contributes to the reason biofuels are considered carbon neutral. Anyway, biofuels can be one of the potent measures to reduce net GHG emissions, especially for existing ships.

With such worldwide attention on biofuels, ClassNK has received a number of inquiries about the use of biofuels since about 2020. As for short or mid-term biofuel oil trials on board, no troubles have been reported as of December 2023. However, the risks associated with long-term use in the future are uncertain, and there is concern that some kind of trouble may occur due to differences from conventional petroleum fuel oils.

Therefore, this technical guide describes the characteristics of biofuels and the measures against possible issues that may occur when biofuels are used over a long period. The technical guide also introduces the relevant stipulation required by MARPOL and EU regulations and the future vision of biofuel use. It is to be noted that this technical guide mainly covers the biofuels intended for use in conventional marine diesel engines.

We hope that this technical guide will help in the use of biofuels.

Revision History

Version	Date	Part	Contents
1.0	December 2023	-	-
1.1	April 2024	Chapter 6	Addition of the new chapter

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Technical Guide for Using Biofuels

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Chapter 1 General

This chapter provides an overview of biofuels. In addition, the terminology and abbreviations used in this technical guide are summarized.

1.1 Terminology and Abbreviations

Table 1.1 lists the terminology and abbreviations used in this technical guide, while Table 1.2 lists the definitions or interpretations of this terminology.

Table 1.1 Terminology and Abbreviations

CII	Carbon Intensity Indicator
CO_2	Carbon Dioxide
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
EU	European Union
FAEE	Fatty Acid Ethyl Ester
FAME	Fatty Acid Methyl Ester
GHG	Greenhouse Gas
HVO	Hydrotreated Vegetable Oil
IMO	International Maritime Organization
IMO-DCS	IMO Data Collection System
ISO	International Organization for Standardization
MEPC	Marine Environment Protection Committee
NOx	Nitrogen Oxides
SVO	Straight Vegetable Oil
VLSFO	Very Low Sulphur Fuel Oil

Table 1.2 Definitions and Interpretations of Terminology

Biofuels	In the technical guide, this term mainly means fuels processed and manufactured primarily from plants.
Biofuel oils	In the technical guide, this term means biofuel oils such as SVO, FAME (FAEE) and HVO.
Blend oils	In this technical guide, this term means blends of biofuel oils with petroleum fuel oils.

Sludge	In this technical guide, this term collectively means solid contents that may block filters.
Polarity	This term means the property relevant to deviations of electric charges in molecules caused by electronegativity differences between the atoms in the molecules. In this technical guide, polar oils means oils that contain polar substances, and non-polar oils means oils that contain no of few polar substances.
Acid value	This value is an index relevant to the degree of oxidative deterioration for fats and oils, and is shown as the amount of potassium hydroxide necessary to neutralize free fatty acids in fats and oils.
Autoxidation	This term means a chemical reaction in which fats and oils are oxidized over time without influence due to external factors, such as light or heat, causing degradation.
Fatty acids	A kind of carboxylic acids (R-COOH) formed by the hydrolysis of fatty oils (triglycerides) and methyl esters, as described in Chapter 2 of this technical guide.
Higher/Lower fatty acids	Higher fatty acids means those fatty acids with relatively high carbon numbers and large molecular weights. Generally, these are fatty acids with a carbon number of ten or more. Lower fatty acids, on the other hand, means those with relatively low carbon numbers and small molecular weights.
Saturated/Unsaturated fatty acids	Unsaturated fatty acids means those with carbon double bonds (C=C), while saturated fatty acids means those without double bonds.
Residual oils	In this technical guide, this term means oils with properties equivalent to the RM grade fuel oils specified in ISO 8217. In the maritime industry, this is often referred to as HFO (Heavy Fuel Oil).
Distillate oils	In this technical guide, this term means oils with properties equivalent to the DM grade fuel oils specified in ISO 8217. In the maritime industry, this is often referred to as either MDO (Marine Diesel Oil) or MGO (Marine Gas Oil), depending on the property.

1.2 Outline of Biofuel Oils

Biofuel oils are mainly derived from vegetable oils. Thus, their properties vary widely depending on the raw feedstock used and the production/manufacturing methods adopted. As for biofuel oils considered usable for marine diesel engines, the examples are SVO, FAME (FAEE) and HVO, which are classified according to differences in production and manufacturing methods.

SVO is vegetable oil extracted from soybeans, rapeseed, palm, etc. or used cooking oil, FAME (FAEE) is the fuel produced by esterification of SVO or used cooking oils with methanol (ethanol), and HVO is fuel produced by hydrogenation of SVO. The schematic diagram of the reaction during

the production of these fuels is shown in Figure 1.1. While there are quality standards for HVO and FAME as automotive fuels, there are no quality standards for SVO. On the other hand, in terms of price, SVO is generally the lowest because of the raw feedstock used, followed by FAME and HVO, with the latter being the most expensive. Thus, it may be said that FAME provides a more favorable balance in terms of quality and price, which is why, as far as ClassNK recognizes, it is the most used biofuel in the maritime industry as of 2023. Furthermore, the safety provided by FAME is also attracting increasing attention.

Because of its low price and low GHG emissions during production, SVO may become more widely used. Likewise, due to its lower risk, HVO use may possibly increase. Therefore, understanding the fuel characteristics of the three types and the precautions associated with their usage are important aspect of fuel selection.

Currently, most biofuels are blended with petroleum fuels, such as residual oil and distillate oil. Generally, the term "B***" is used to represent the mixing ratio of biofuel with petroleum fuels. For example, B20 FAME is a fuel with 20% FAME content, and B100 SVO is pure SVO, i.e. a fuel with an SVO mixing ratio of 100%. The mixing ratio is often expressed in a volume ratio (%volume) or weight ratio (%mass). For example, on statutory certificates relevant to MARPOL Annex VI, volume ratio is used. (See Chapter 4 for details.)

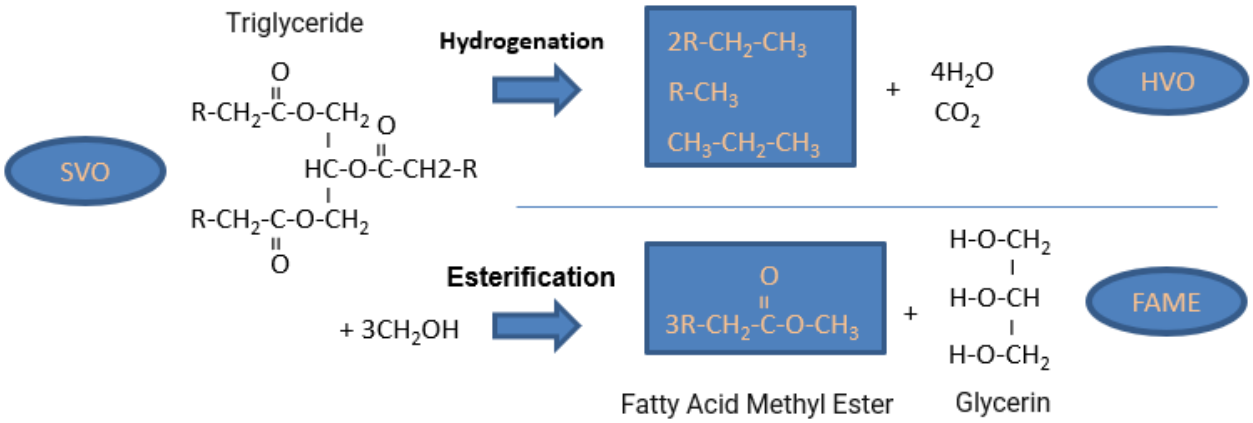


Fig. 1.1 Schematic of hydrogenation in the production of HVO and esterification in the production of FAME

Chapter 2 Characteristics of Biofuel Oils

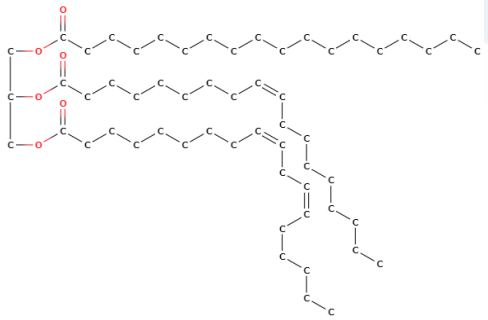
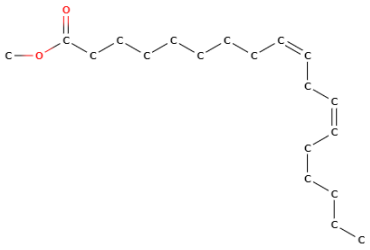
Understanding the differences between biofuel oils and conventional petroleum fuel oils is important. In this chapter, the significant characteristics, main chemical components and molecular structures of biofuel oils with those of petroleum distillate oils are firstly explained. Next, the phenomena associated with these biofuel characteristics are introduced.

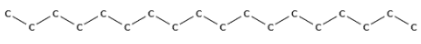
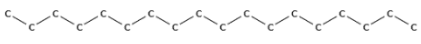
The purpose of this chapter is to deepen the understanding of SVO, FAME and HVO. In practice, biofuel oils are also assumed to be used as blended oils after blending with petroleum distillate oils or residual oils. For biofuel oil itself and blend oils, measures against potential concerns of such oils are introduced in Chapter 3.

2.1 Characteristics of Main Molecular Components

The main components of SVO, FAME and HVO and their characteristics are shown in Table 2.1. The typical molecular structures are illustrated in Table 2.1 to facilitate understanding of the characteristics. Molecular structures may vary depending on the variety of biofuel oil feedstock plants, while characteristic structures are basically common.

Table 2.1 Main Components and Characteristics of SVO, FAME and HVO

	SVO	FAME
Main Component	Triglycerides	Fatty Acid Methyl Ester
Molecular Structure (Typical example)		
Characteristics of Molecular Structure	• Carbon Double Bond (C=C) • Ester Bond (-COO-) • Large Molecular Structure • Polar Oils (Triglyceride's polarity is lower than FAME)	• Carbon Double Bond (C=C) • Ester Bond (-COO-) • Molecular weight like HVO/Distillate oil • Polar Oils

	HVO	Distillate oils (reference)
Main Component	Paraffinic Hydrocarbon (C: 15–18)	Paraffinic Hydrocarbon (C: 12–20)
Molecular Structure (Typical example)		
Characteristics of Molecular Structure	• Saturated Hydrocarbons (No Carbon Double Bond and No Ester Bond) • Non-Polar Oils	• Saturated Hydrocarbons (No Carbon Double Bond and No Ester Bond) • Non-Polar Oils

2.2 Phenomena Due to Molecular Characteristics

In light of the characteristics on molecular structure, Table 2.1 shows that HVO has properties similar to distillate oils, whereas SVO and FAME have the three characteristics Carbon double bond (C=C), Ester bond (-COO-) and Polarity. This section focuses on these characteristics and introduces possible phenomena.

2.2.1 Carbon Double Bonds (C=C)

This molecular structure causes two main phenomena. The first phenomenon is reaction with oxygen because the carbon double bond is less stable than single carbon bond. The double bond react with oxygen, causing polymerization and oxidation as time proceeds.

Regarding the polymerization, the kinematic viscosity increases as the polymerization proceeds as shown in Fig. 2.1.

As for the oxidation, higher fatty acids with weak acidity are formed, and then further oxidation of the higher fatty acids finally decomposes them into corrosive lower fatty acids. The following reference information relates to the autoxidation mechanism of fatty oils.

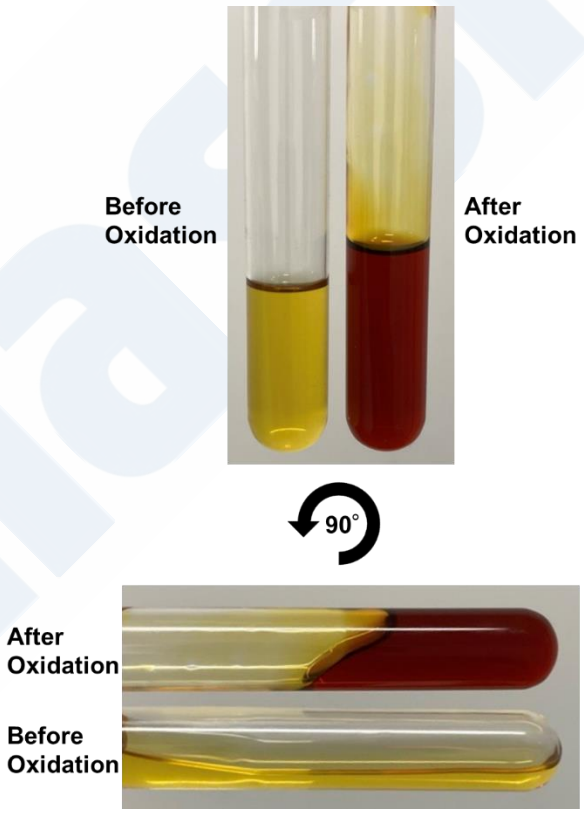


Fig. 2.1 Oxidation test results for B100FAME (150°C for 45 hours with air blowing)

<Reference>

Figure 2.2 shows an overview of autoxidation of fatty oils by illustrating the temporal process of chemical reaction associated with carbon double bonds.

Stage I: Hydro-peroxides (R-OOH) begin to be formed by the reaction of oxygen with carbon double bonds in triglycerides (SVO's main component) or FAME.

Stage II: Oxidation reaction is accelerated with the increased hydro-peroxide acting as a catalyst.

Stage III: Carbonyl compounds (aldehydes, ketones, lower fatty acids (formic acid and acetic acid), etc.) are increased due to the decomposition reaction of hydro-peroxide.

Stage IV: Molecular weight increases due to polymerization reaction of hydro-peroxide and molecules with unreacted carbon double bonds. As a result, kinetic viscosity increases.

In Stages III and IV, malodor can be given out since the carbonyl compounds are deemed odorous components by the food industry. The lower fatty acids contained in carbonyl compounds are corrosive acids, such as formic acid and acetic acid.

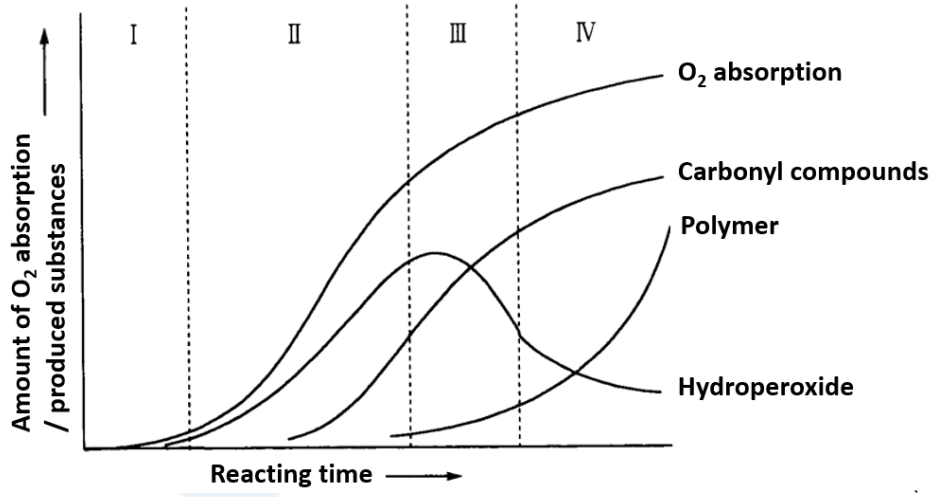


Fig. 2.2 Transition of product amount in autooxidation of fatty oils [1]

For the actual occurrence timing and time passage on autoxidation reaction, the exact prediction is difficult since the reaction depends on the biofuel-usage environment. For reference, research conducted by the University of Shiga Prefecture (Shiga, Japan) found that the acid value and the kinematic viscosity changed around ten months when storage experiments were conducted using soybean oil methyl ester (FAME) [2].

The second phenomenon is a decrease in the pour point, which is due to the twisted molecular structure caused by carbon double bonds. Since the twisted molecular structure weakens the intermolecular attractive force, such fuel oils tend to be less solidified even under lower temperature, i.e. their pour point tends to be lower. Biofuel oils have different numbers of double bonds depending on their feedstock, which affects the difference in pour points.

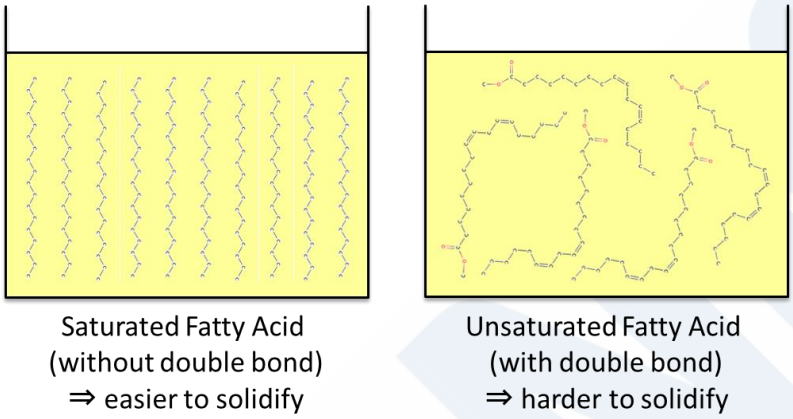


Fig. 2.3 Potential for solidification of saturated/unsaturated fatty acids

2.2.2 Ester Bonds (-COO-)

The weakly-acidic higher fatty acid (oleic acid, linoleic acid, etc.) is generated by hydrolysis of the ester bond in SVO and FAME. Furthermore, as a byproduct, glycerin is formed for SVO and methanol is formed for FAME.

Due to glycerin with high viscosity, the increase of kinetic viscosity can be caused. Methanol is volatile and can leave the oil or remain in the oil.

2.2.3 Polarity (Deviation of Electric Charge in Molecules)

Polarity is, therefore, largely related to solubility, and polar molecules basically tend to be more soluble in polar molecules, while hardly soluble in non-polar molecules. The most familiar polar oil is brake oil for cars and motorcycles. Perhaps, you have experienced the peeling-off of coatings or paint due to brake oil splashing onto the car's body. This is because the polarity of brake oil causes dissolution of the coating paint resin, which also has polarity.

SVO itself has almost no polarity, while FAME has polarity. Furthermore, as for the higher and lower fatty acids mentioned in 2.2.1 and 2.2.2, such substances tend to also have higher polarities than FAME. Generally, the ascending order of polarity on their materials is as follows: distillate oil < SVO (almost no polarity) < FAME < higher fatty acids (oleic acid, linoleic acid, etc.) < lower fatty acids (formic acid, acetic acid, etc.).

Therefore, biofuels may dissolve deposits that could not be dissolved by petroleum fuel oils, which phenomenon is known as cleaning effect.

As for the effect of biofuel oils on rubbers, since rubber molecules are polymerized, basically

fuel oils do not dissolve in rubbers. However, the interaction of rubber molecules and oils can cause swelling of rubbers. Oil-resistant rubbers such as NBR (nitrile butyl rubber) have polarity. Low or no polar oils, i.e. SVO itself and distillate oils, do not usually swell the NBR because such oils do not easily interact with NBR. In contrast, FAME and lower fatty acids, i.e. polar materials, can cause the NBR to swell because such oils interact with NBR [3]. Hence, anti-swelling measures are using high resistant rubbers for biofuel oils such as fluorine rubbers.

Chapter 3 Precautions and Measures for the Safe Usage of Biofuel Oils

Biofuel oils and their blend oils are expected to be used as drop-in fuels, while proper measures need to be taken regarding usage since such oils have some properties that are different from conventional petroleum fuel oils. Table 3.1 shows the measures necessary for biofuel oils and their blend oils. For the details of each measure, please refer to each section shown as item number in the table; for example, "(3.1.1)".

Table 3.1 Measures for Using Biofuel Oils or Their Blends with Distillate (DM-grade) / Residual (RM-grade) Oils

<table>
<tr><th></th><th>SVO + RM</th><th>SVO + DM
or
SVO</th><th>FAME + RM</th><th>FAME + DM
or
FAME</th><th>HVO + RM</th><th>HVO + DM
or
HVO</th></tr>
<tr><td rowspan="3">Measures necessary for machinery/ equipment</td><td colspan="5">Measures of manufacturer recommendations for machinery/equipment
(3.1.1)</td><td></td></tr>
<tr><td colspan="4">Swelling of rubber parts
in fuel piping system
(3.1.2)</td><td colspan="2">— — —</td></tr>
<tr><td colspan="4">Kinetic viscosity and density
changes
(3.1.3)</td><td colspan="2">— — —</td></tr>
<tr><td rowspan="5">Measures against sludge and fuel deterioration</td><td>Asphaltene sludge generation
(3.2.1)</td><td>— — —</td><td>Asphaltene sludge generation
(3.2.1)</td><td>— — —</td><td>Asphaltene sludge generation
(3.2.1)</td><td>— — —</td></tr>
<tr><td colspan="6">Microbe-derived sludge
(3.2.2)</td></tr>
<tr><td colspan="6">Solidification of biofuel oils
(3.2.3)</td></tr>
<tr><td colspan="4">Sludge due to cleaning effect
(3.2.4)</td><td colspan="2">— — —</td></tr>
<tr><td colspan="4">Oxidative polymerization
(3.2.5)</td><td colspan="2">— — —</td></tr>
<tr><td>Confirmation of fuel quality</td><td colspan="6">Confirmation of fuel quality with reference to existing standards
(3.3)</td></tr>
</table>

For precautions when using conventional petroleum fuel oils such as residue oil, please refer to the VLSFO Poster in Appendix III [4].

3.1 Measures Necessary for Machinery/Equipment

This section summarizes the measures necessary for machinery/equipment prior to the use of biofuel oils and their blend oils.

3.1.1 Measures of Manufacturer Recommendations for Machinery/Equipment (SVO, FAME, HVO)

Prior to use of biofuel oil or blends of biofuel oil, it is advised to ask the machinery/equipment's manufacturer about recommended measures. It is suggested that proper measures, such as replacement with biofuel-adaptable parts or change of maintenance frequencies, should be taken according to such recommendations.

At the inquiry to the manufacturers, by providing the information about the kinds and properties of biofuel oils in addition to the onboard storage duration, further suitable recommendations can be obtained from the manufacturer.

The subjects are mainly biofuel oil combustion equipment (diesel engines, boilers, incinerators, etc.) and fuel oil piping system equipment (fuel oil purifiers, pumps, valves, filters, strainers, heaters, etc.). The main measures necessary for such equipment are considered to be swelling measures for rubber parts and corrosion measures for combustion equipment parts. The next section introduces such measures.

3.1.2 Measures Against the Swelling of Rubber Parts in Fuel Piping Systems (SVO and FAME)

As mentioned above, rubber parts without swelling resistance may be used for the internal parts of equipment, flange gaskets of joint parts of fuel piping arrangements, sealing parts for the fittings of devices such as sensors, etc. Rubber fragility and strength reduction due to swelling can lead to fuel oil leaks from flange gaskets or the sealing parts themselves.

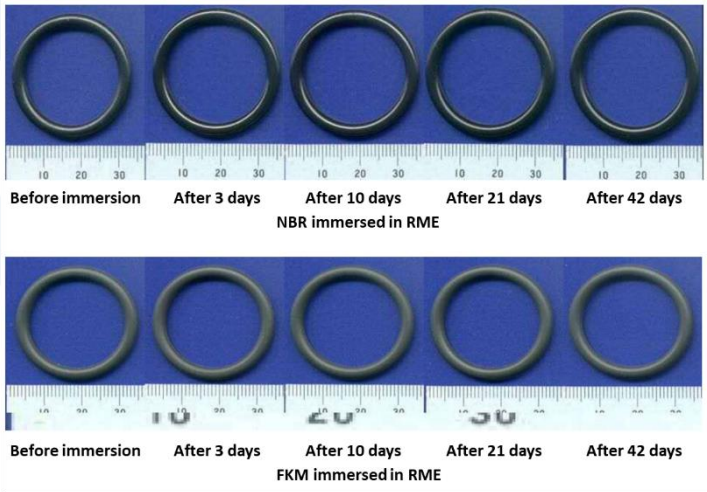


Fig. 3.1 Results of RME (FAME derived from rapeseed) immersion test of NBR (nitrile butyl rubber) and FKM (fluorine rubber) [5]

For safe use, it is recommended that the gaskets and sealing materials used in fuel piping system and their associated equipment should be regularly checked and replaced with swelling-resistant materials. The following reference information is for rubber parts that may need to be considered other than the ship's equipment.

<Reference>

Generally, bunkering hoses are made of butyl rubber with less swelling resistance to biofuel oils. Usually, bunkering hoses are not facility provided the by ship side. Nevertheless, if a degraded bunkering hose ruptures during bunkering, fuel oil may spill into the sea. In cases where permanent use of the hoses at bunkering of biofuel oils, attention may need to be paid to facilities provided by fuel supply sides.



Fig. 3.2 Bunkering hose and associated facilities

3.1.3 Measures Against Kinetic Viscosity and Density Changes (SVO and FAME)

The viscosity and density properties of SVO and FAME vary depending on the feedstock plants. Moreover, as is the case for residual oils, there is a wide variability in properties among the VLSFOs. In the case of blend oils, their properties may vary significantly at each bunkering.

If the fuel oil heating is not properly adjusted, combustion failure due to overheating or insufficient heating can be caused in combustion equipment, such as diesel engines, boilers and incinerators. For details of the measures to be taken, please refer to the poster [4] in Appendix III, as they are the same as those taken when using VLSFO.

3.2 Measures Against Sludge and Fuel Deterioration

At usage and storage of biofuel oils or blend oils, depending on the situation, it is important to take measures against:

1) Asphaltene sludge (In case of mixing with petroleum residue oils)
2) Microbe-derived sludge (In case of storage without heating)
3) Wax sludge, i.e. solidification of biofuel oils
4) Sludge due to cleaning effect of biofuel oils
5) Oxidative degradation of biofuel oils during storage, causing the kinematic viscosity change, the formation of viscous substances, etc.

3.2.1 Asphaltene Sludge Generation (Blend Oils with Residual Oils)

Generally, mixing with fuel oils of different properties increases the risk of asphaltene sludge generation. Especially when bunkering or switching tanks, it is inevitable that different fuel oils will mix in the tanks.

Since sludge can lead to the clogging of filters and sludge deposits in purifiers, proper measures are needed. For details, please refer to the poster in Appendix III [4] since the measures to be taken are the same as those for VLSFO usage.

3.2.2 Microbe-derived Sludge (SVO, FAME and HVO)

In fuel oil tanks, when three factors—suitable temperature (approx. 0-40°C), nutrient source (hydrocarbons), and moisture—are combined, microbes such as mold, bacteria, yeast, and actinomycete grow at the interface between fuel oil and water, and these microbes can form a slime-like sludge.

The clogging of filters and strainers due to sludge can cause fuel oil transfer problems. Since sludge due to microbes is not unique to biofuels, it has also been traditionally found in tanks for fuel oils that do not require heating, such as distillate oil (MDO/MGO).

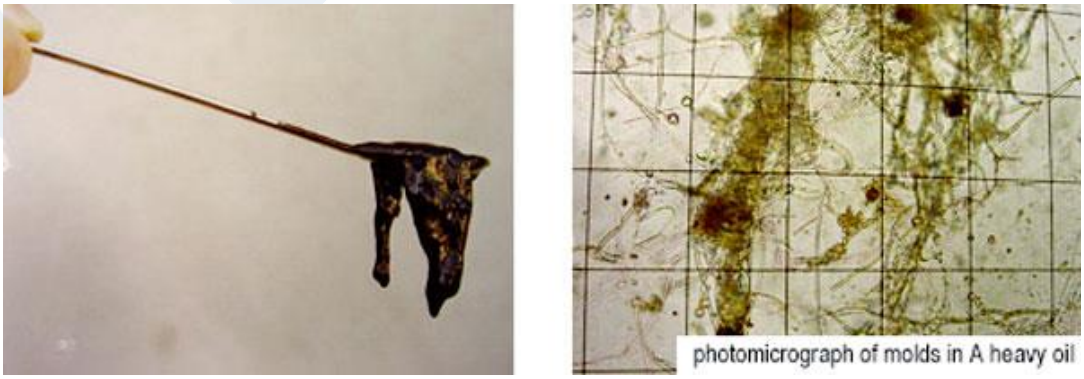


Fig. 3.3 Sludge caused by mold in marine distillate oils [6]

For safe use, it is important to check the kinetic viscosity and whether the tank heating is required. If tank heating becomes necessary due to high kinetic viscous fuel oils, such heating can help contribute to the restriction of sludge generation. On the hand, in the cases of low kinetic viscous fuel oils with no need for tank heating, it is important to take measures such as frequent drainage of water in tanks and use of fuel additives to inhibit microbe growth.

3.2.3 Solidification of Biofuel Oils (SVO, FAME and HVO)

As mentioned in 2.2.1, SVO and FAME tend to have a higher pour point in the cases where there are fewer carbon-double-bonds (unsaturated bonds) in the fats and oils. Moreover, some petroleum distillate and residue oils also have high pour points.

When fuel oil temperature drops below the pour point, the fuel oil cannot be transferred due to solidification. Hence, fuel oil heating may be necessary in the case of high pour point fuel oils even with low kinetic viscosities..

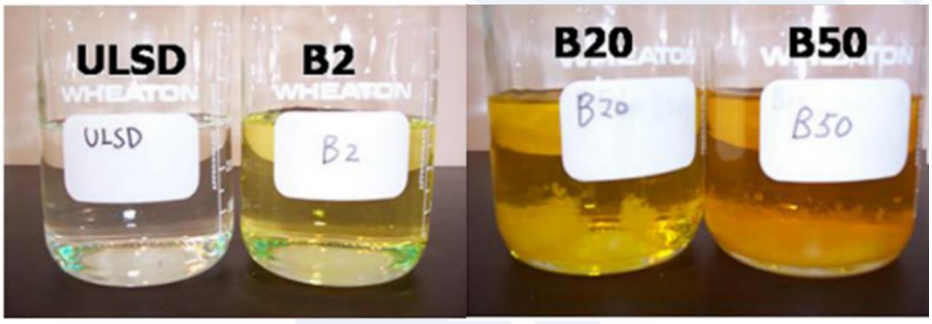


Fig.3.4 Wax sludge from distillate oil (ULSD) and blends with soybean FAME (B2, B20 and B50) after storage at 4°C for one day [7]

For safe use, it is important to obtain information on the pour points of the biofuel oils and blend oils to be used from fuel suppliers. In addition, it is necessary to check the conditions of tank heating facilities, while it is also important to request fuel suppliers to supply biofuel oils with sufficiently low pour points for the usage environment (sea water and ambient temperature in the navigation area) when planning to use tanks without heating facilities, such as distillate oil tanks, as biofuel storage tanks.

As for HVO, the main component after hydrogenation process is normal paraffin, and its pour point tends to be higher than petroleum distillate oils. In some cases, low-temperature fluidity may be improved by increasing the iso-paraffin ratio. However, since there is currently no marine fuel standard for HVO, it is important to obtain a property list and check the pour point when using HVO.

3.2.4 Sludge Due to Cleaning Effect (SVO and FAME)

As mentioned in 2.2.3, biofuel oils such as SVO and FAME have polar properties, and in case of using blend oils, it depends on the mixing ratio of SVO and FAME in the blend oil. Accordingly,

such biofuel oils may peel off the organic matter deposited in piping arrangements, tanks, etc., releasing the deposits into fuel oils where they eventually become sludge.

For safe use, it is important to operate purifiers at higher purification efficiency settings in anticipation of increased sludge formation and to frequently check filter and strainers condition as an early detection measure when switching to biofuel oils and storing such fuels in fuel oil tanks originally intended for petroleum oils.

3.2.5 Oxidative Degradation (SVO and FAME)

When using biofuel oils containing SVO or FAME, a short tank storage period contributes to preventing oxidation. As described in 2.2.1 and 2.2.2, increase of kinematic viscosity due to polymerization and oxidized substance is caused by hydrolysis reaction or oxidization of carbon-double-bonds (unsaturated bonds) in molecular structure.

Since contact between oxygen and biofuel oils is inevitable due to the respiratory effect from fuel tank vents, it is important to consume biofuel oils as quickly as possible since oxidization over time cannot be avoided.

Furthermore, for safe use, it is important to conduct oxidation stability tests appropriate for biofuel oils, such as the Rancimat method specified in JIS K 2390, EN 14112 or EN 15751, to confirm fuel oxidation stability in prior to usage.

3.3 Confirmation of Fuel Quality (SVO, FAME and HVO)

- Confirmation of Fuel Quality with Reference to Existing Standards (SVO, FAME and HVO)

When using biofuel oils or blend oils, it is important to confirm the fuel quality by referring to existing standards such as ISO 8217 standard values to reduce the risk of biofuel use.

In addition, since SVO and FAME react easily with oxygen as mentioned above, it is also important to check the oxidation stability using the Rancimat method, as described in 3.2.5. In general, oxidation stability tests are accelerated tests in which oxidation reactions of samples are artificially accelerated, and the speed of oxidation in the test is different from that in actual storage/use environments. Therefore, it is also important to recognize that it does not predict the period of safe storage.

Chapter 4 Regulations for Air Pollution Prevention and GHG Emissions Related to Biofuels

For onboard usage of biofuels, it is important to understand the international conventions and regulations relevant to biofuels and how they differ from those for from petroleum fuels. This chapter introduces the stipulations and their interpretations relevant to NOx emissions on MARPOL Annex VI, and the requirements and GHG reduction effects from the perspective of GHG reduction regulations in IMO and EU for biofuels.

4.1 Regulations Relevant to NOx emissions in MARPOL Annex VI for Biofuels

The use of biofuels is subject to requirements for the quality of fuel oils specified in Reg. 18.3 of MARPOL Annex VI in addition to requirements applicable to conventional petroleum fuel oils (e.g. flash point requirements of SOLAS, sulfur content requirements of Reg. 14, MARPOL Annex VI). Regarding the application of Reg. 18.3, fuel oil derived by petroleum refining is subject to the Reg. 18.3.1. Meanwhile, fuel oil derived by methods other than petroleum refining is subject to the Reg. 18.3.2; that is to say Reg.18.3.2.2 which specifies that “fuel oil...shall not cause an engine to exceed the applicable NOx emission limit...” is also applicable to such fuel oils.

Until June 2022, Reg. 18.3.2 had, in principle, been applied to biofuel oils, including blend oils with petroleum fuel oils, since such biofuels contain fuel oils obtained by methods other than petroleum refining.

In this regard, an unified interpretation (UI), which clarified the application of Reg. 18.3 to biofuels was approved at MEPC 78 in June 2022. Furthermore, amendments to this UI, which added synthetic fuels to the applicable scope, were approved at MEPC 79. A summary of this UI (paragraph 13 of MEPC.1/Circ.795/Rev.8) is given below.

1. A fuel oil which is a blend of not more than 30% by volume of biofuel or synthetic fuel should meet the requirements of Reg. 18.3.1, MARPOL Annex VI, i.e. such a fuel oil is not subject to Reg. 18.3.2.2 with respect to the wording “fuel oil...shall not cause an engine to exceed the applicable NOx emission limit...”.
2. A fuel oil which is a blend of more than 30% by volume of biofuel or synthetic fuel should meet the requirements of Reg. 18.3.2, MARPOL Annex VI. For application of Reg. 18.3.2.2 , the wording “fuel oil...shall not cause an engine to exceed the applicable NOx emission limit...” should be interpreted that as follows.
   (i) Where a marine diesel engine can operate on a biofuel or a synthetic fuel, or blends containing these fuels without changes to its NOx critical components or settings/operating values outside those as given by the engine’s approved NOx Technical File, such a fuel oil is permitted to be used without having to be assessed as required by

the Reg. 18.3.2.2.

(ii) Where a marine diesel engine can operate on a biofuel or a synthetic fuel, or blends containing these fuels with changes to its NOx critical components or settings/operating values outside those as given by the engine's approved NOx Technical File, such a fuel oil is required to be assessed as required by Reg. 18.3.2.2. For this assessment, an onboard simplified measurement method according to 6.3 of the NTC 2008 is available.

In this UI, a biofuel is defined as a fuel oil which is derived from biomass and includes, but is not limited to, the following:

(i) Processed used cooking oils,
(ii) FAME (Fatty Acid Methyl Esters),
(iii) FAEE (Fatty Acid Ethyl Esters),
(iv) SVO (Straight Vegetable Oils),
(v) HVO (Hydrotreated Vegetable Oils), and
(vi) BTL (Glycerol or other biomass to liquid type products).

Furthermore, a synthetic fuel is defined as a fuel oil made from synthetic or renewable sources similar in composition to petroleum distillate fuels.

Table 4.1 Summary of Unified Interpretation Relevant to Biofuels Approved at IMO MEPC.78

	NOx components, settings, operating value does NOT change outside the NOx Technical File	NOx components, settings, operating value changes outside the NOx Technical File
B0～B30 (Biofuel blend ratio≦30%)	Apply to Reg. 18.3.1 ⇒ Equivalent to petroleum fuel	Apply to Reg. 18.3.1 ⇒ Equivalent to petroleum fuel but NOx TF must be amended.
B31～B100 (Biofuel blend ratio＞30%)	Apply to Reg. 18.3.2 ⇒ Additional NOx evaluation is NOT required.	Apply to Reg. 18.3.2 ⇒ Additional NOx evaluation is required (to prove that emission does not exceed the limit.)

According to the UI, as long as the blending ratio of biofuels is 30%vol or less, the biofuels can be treated as being equivalent to conventional petroleum fuel oils with respect to MARPOL Annex VI. However, in cases where the blending ratio exceeds 30%vol, consultation with the engine manufacturer is recommended in order to confirm any need to change the NOx components or settings listed in the NOx Technical File, and any possibility of deviancy from operating values outside the allowance designated in the Technical File.

4.2 Requirements for Biofuels in Regulations for GHG Reduction

This section introduces requirements for biofuels, their GHG reduction effects, etc. from the perspective of the GHG reduction regulations specified by the IMO and EU.

4.2.1 IMO Regulations

-1 Interim guidance on the use of biofuels under regulations of IMO-DCS and CII

The IMO has been reviewing guidelines to evaluate GHG intensity (GHG emissions per unit of energy) comprehensively throughout the lifecycle of marine fuel, including their production, distribution, and onboard use. The guidelines were adopted at MEPC 80 as the "Guidelines for the lifecycle GHG intensity of ships' fuels (LCA Guidelines)", (Resolution MEPC.376(80)). However, the guidelines also highlight the need for further examination of certain issues, such as consideration of emissions resulting from land-use changes (e.g. conversion of forests to agricultural land) associated with the production of fuels derived from biomass, establishment of default values for GHG intensity, and development of guidance on third-party certification. Ongoing efforts to address these issues are planned so as to facilitate the practical implementation of the guidelines. Regarding biofuels, the "Interim guidance on the use of biofuels under Regs. 26, 27, and 28 of MARPOL Annex VI (DCS and CII)" (MEPC.1/Circ.905) was approved at MEPC 80 as an interim measure until the calculation method for the GHG emissions of biofuels is clarified in the aforementioned LCA Guidelines. This interim guidance specifies the following requirements.

(1) Biofuels that have been certified by an international certification scheme, meeting its sustainability criteria, and that provide a Well-to-Wake GHG emissions reduction of at least 65% compared to the Well-to-Wake emissions of fossil MGO of 94 [gCO_2eq/MJ], (i.e. not exceeding 33 [gCO_2eq/MJ],) according to that certification, may be assigned a CO_2 Emission Conversion Factor (Cf) equal to the value of the Well-to-Wake GHG emissions of the fuel according to the certificate (expressed in gCO_2eq/MJ) multiplied by its lower calorific value (LCV, expressed in MJ/g) for the purpose of IMO-DCS and CII.
(2) In any case, the value of Cf of biofuels cannot be less than 0.
(3) For blends, the Cf is calculated based on the weighted average of Cf for respective amount of fuels by energy.
(4) Biofuels that do not meet the conditions in (1) above should be assigned a Cf equal to the Cf of the equivalent fossil fuel type.

(Note)
- ✓ As the international certification scheme for sustainability, the interim guidance refers to the following sustainability certification schemes approved by ICAO

(International Civil Aviation Organization) and the CORSIA (Carbon Offsetting and Reduction Scheme for International Civil Aviation) sustainability criteria for CORSIA eligible fuels, which was developed by ICAO.

- International Sustainability and Carbon Certification (ISCC)
- Roundtable on Sustainable Biomaterials (RSB)

Therefore, in order to reflect the GHG reduction effects of biofuels on IMO-DCS and CII, it is necessary to use biofuels certified based on the certification schemes such as ISCC, RSB mentioned above.

※ ClassNK is preparing to become a certification body of the ISCC or other certification schemes to promote expansion of production and distribution of the sustainable biofuels. When the certification service of biofuels is started, we will inform the parties concerned of the service in a press release, etc.

✓ To reflect the GHG reduction effects of the biofuels on the verification of IMO-DCS and CII regulations, SEEMP Part II is required to be re-approved. After adding the biofuels into the section about fuels type used on the SEEMP Part II, please submit it to the Society via the ClassNK MRV Portal which is a verification tool for IMO-DCS/EU-MRV. Please also submit a copy of the document which shows the compliance with the sustainability for the biofuel (Proof of Sustainability as shown in Fig. 4.1 or similar documents) as well as a copy of Bunker Delivery Note.

-2 Calculation examples of Cf and CO_2 reduction effects when using biofuels based on the interim guidance

(1) Calculation of CO_2 Emission Conversion Factor (Cf)

Cf is calculated using the following formula as indicated in -1(1) above. The specifications of the biofuel used in this calculation are as shown in the "Sample Sheet" in Fig. 4.1.

$$Cf\ [gCO_2eq/g] = GHG\ Intensity\ [gCO_2eq/MJ] \times Lower\ Calorific\ Value\ [MJ/g]$$

(a) Example 1 (for an unblended biofuel: B100)

- Lower calorific value [MJ/g]

  809,930 [MJ] / 21.890×10^6 [g] = 0.037 [MJ/g]
- GHG intensity [gCO_2eq/MJ]

  14.9 [gCO_2eq/MJ] (< 33 [gCO_2eq/MJ])

Cf can be calculated as follows accordingly.

- Cf [gCO_2eq/g]
  14.9 × 0.037 = 0.551 [gCO_2eq/g]

(b) Example 2 (Blend oil B30: a blend of 21.890 [MT] of biofuel and 53.110 [MT] of VLSFO)

- Energy of biofuel [MJ]
  0.037 [MJ/gFuel] × 21.890×10^6 [g] = 809,930 [MJ]
- Energy of VLSFO [MJ]
  0.041 [MJ/gFuel] × 53.110×10^6 [g] = 2,177,510 [MJ]
  (The lower calorific value and Cf of VLSFO are based on the values of LFO stipulated in IMO Res. MEPC.364(79).)
- Energy ratio of biofuel and VLSFO
  809,930 / (809,930 + 2,177,510) : 2,177,510 / (809,930+ 2,177,510)
  = 0.271 : 0.729

Cf can be calculated as follows accordingly.

- Cf [gCO_2eq/g]
  0.271 × 0.551 + 0.729 × 3.151 = 2.446 [gCO_2eq/g]

Table 4.2 Values Used in Calculations and Corresponding Results

	Lower Calorific Value (LCV) [MJ/g]	Fuel Weight [g]	Energy Amount [MJ]	Ratio of Energy	Cf [gCO_2eq/g]	Cf of Blend (Weighted Average Based on Energy) [gCO_2eq/g]
Biofuel	0.037	21.890×10^6	809,930	0.271	0.551	0.149
VLSFO	0.041	53.110×10^6	2,177,510	0.729	3.151	2.297
Total (Blend oil)	-	75.000×10^6	2,987,440	1.000	-	**2.446**

(2) Reduction in CO_2 when using blend oil

By comparing the CO_2 emissions for the blend oil in "Example 2" of (1) above with the CO_2 emissions for an equivalent energy quantity of VLSFO only, the amount of CO_2 emission reduction and the reduction rate can be calculated.

- CO_2 emissions from the blend oil
  75.000×10^6 [g] × 2.446 [gCO_2eq/g] = 183.45×10^6 [gCO_2eq]
- Weight of VLSFO with the same energy quantity as the blend oil
  2,987,440 [MJ] / 0.041 [MJ/g] = 72.864×10^6 [g]
- CO_2 emissions from VLSFO
  72.864×10^6 [g] × 3.151 [gCO_2eq/g] = 229.59×10^6 [gCO_2eq]

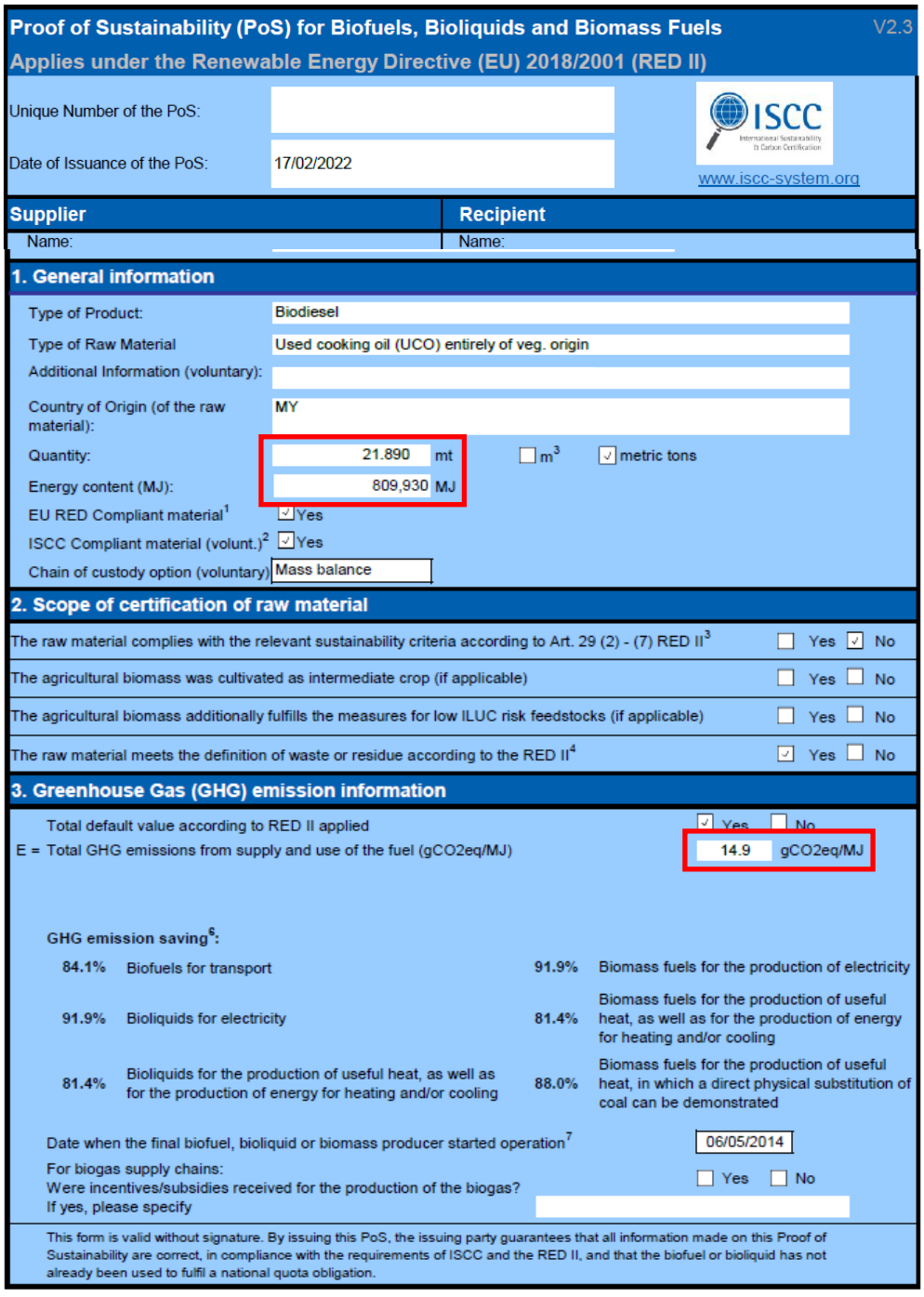
Reduction amount of CO_2(eq) and reduction rate can be calculated as follows accordingly.

- CO_2 reduction amount
  $229.59\times10^6 - 183.45\times10^6 = 46.14\times10^6$ [gCO_2eq]
- Reduction rate
  $46.14\times10^6 / 229.59\times10^6 \times 100 = 20.1\%$

As shown above, the CO_2 emissions are reduced by 46.14 [ton] compared to the case of using VLSFO only, resulting in a reduction rate of 20.1%.

Table 4.3 Values Used in Calculations and Corresponding Results

	Energy Amount [MJ]	Fuel Weight [g]	Cf [gCO_2eq/g]	CO_2 Emission Amount [g]
Blend oil	2,987,440	75.000×10^6	2.446	183.45×10^6
VLSFO only	2,987,440	72.864×10^6	3.151	229.59×10^6



Proof of Sustainability (PoS) for Biofuels, Bioliquids and Biomass Fuels V2.3

Applies under the Renewable Energy Directive (EU) 2018/2001 (RED II)

Unique Number of the PoS:

Date of Issuance of the PoS: 17/02/2022

ISCC International Sustainability & Carbon Certification

www.iscc-system.org

Supplier	Recipient
Name:	Name:

1. General information

Type of Product:	Biodiesel
Type of Raw Material	Used cooking oil (UCO) entirely of veg. origin
Additional Information (voluntary):	
Country of Origin (of the raw material):	MY
Quantity:	21.890 mt ☐ m^3 ☑ metric tons
Energy content (MJ):	809,930 MJ
EU RED Compliant material[1]	☑ Yes
ISCC Compliant material (volunt.)[2]	☑ Yes
Chain of custody option (voluntary)	Mass balance

2. Scope of certification of raw material

The raw material complies with the relevant sustainability criteria according to Art. 29 (2) - (7) RED II[3]	☐ Yes ☑ No
The agricultural biomass was cultivated as intermediate crop (if applicable)	☐ Yes ☐ No
The agricultural biomass additionally fulfills the measures for low ILUC risk feedstocks (if applicable)	☐ Yes ☐ No
The raw material meets the definition of waste or residue according to the RED II[4]	☑ Yes ☐ No

3. Greenhouse Gas (GHG) emission information

Total default value according to RED II applied ☑ Yes ☐ No

E = Total GHG emissions from supply and use of the fuel (gCO2eq/MJ) 14.9 gCO2eq/MJ

GHG emission saving[6]:

84.1%	Biofuels for transport	91.9%	Biomass fuels for the production of electricity
91.9%	Bioliquids for electricity	81.4%	Biomass fuels for the production of useful heat, as well as for the production of energy for heating and/or cooling
81.4%	Bioliquids for the production of useful heat, as well as for the production of energy for heating and/or cooling	88.0%	Biomass fuels for the production of useful heat, in which a direct physical substitution of coal can be demonstrated

Date when the final biofuel, bioliquid or biomass producer started operation[7] 06/05/2014

For biogas supply chains:
Were incentives/subsidies received for the production of the biogas? ☐ Yes ☐ No
If yes, please specify

This form is valid without signature. By issuing this PoS, the issuing party guarantees that all information made on this Proof of Sustainability are correct, in compliance with the requirements of ISCC and the RED II, and that the biofuel or bioliquid has not already been used to fulfil a national quota obligation.

Fig. 4.1 Sample Sheet for Biofuel (Proof of Sustainability: PoS)

4.2.2 Regulations of European Union (EU)

The EU has set a target of reducing GHG emissions by 55% or more from the 1990 level by 2030 with the aim of achieving net-zero emissions by 2050. In July 2021, a comprehensive climate change policy package "Fit for 55" was announced to achieve the 2030 target. This package included the expansion of the EU Emissions Trading System (EU-ETS), which is a carbon pricing mechanism, to the maritime sector and the introduction of the FuelEU Maritime regulations to promote decarbonization of onboard use of fuel. It was subsequently decided the EU-ETS would be introduced in the maritime sector starting from January 2024, while the FuelEU Maritime regulations would be introduced from January 2025. The requirements for biofuels in these regulations are outlined as follows.

-1 EU Directive for EU-ETS and EU-MRV Regulations

In the EU Directive for Emissions Trading System, it is required to conduct monitoring, reporting, and verification of GHG emissions from ships engaged in EU related voyages in accordance with the EU-MRV Regulations. The amendments to EU-MRV Regulations (Commission Delegated Regulation (EU) 2023/2776 amending Regulation (EU) 2015/757) includes the following requirements for calculating GHG emissions from ships using biofuels:

(1) Default emission factor for biofuels

Default values of the Emission Factor for CO_2, CH_4, and N_2O to be used when calculating GHG emissions for fuels are provided in Annex I, Part A (see Column 3~5 of Table 4.4 below). Using the Emission Factors and the quantity used for the respective biofuel, GHG emissions are calculated based on the following formula specified in the Annex I, Part A.

$$\mathrm{GHG_{MRV}} = \mathrm{CO_{2\,MRV}} + \mathrm{CH_{4\,MRV}} \times \mathrm{GWP_{CH_4}} + \mathrm{N_2O_{MRV}} \times \mathrm{GWP_{N_2O}}$$

$$\mathrm{CO_{2\,MRV}} = \sum_{i} (\mathrm{M_i} - \mathrm{M_{i,NC}}) \times \mathrm{EF_{CO_2,i}}$$

$$\mathrm{CH_{4\,MRV}} = \left[\sum_{i} (\mathrm{M_i} - \mathrm{M_{i,NC}}) \times \mathrm{EF_{CH_4,i}}\right] + \mathrm{CH_{4\,S}}$$

$$\mathrm{N_2O_{MRV}} = \sum_{i} (\mathrm{M_i} - \mathrm{M_{i,NC}}) \times \mathrm{EF_{N_2O,i}}$$

GHG_{MRV}	Greenhouse gas emissions to be reported under this Regulation, expressed in tonnes CO_2 equivalent, where 'CO_2 equivalent' means the metric measure used to compute the emissions from CO_2, CH_4 and N_2O on the basis of their global warming potential, by converting amounts of CH_4 and N_2O to the equivalent amount of carbon dioxide with the same global warming potential.
$CO_{2\,MRV}$	Total aggregated CO_2 emitted.
$CH_{4\,MRV}$	Total aggregated CH_4 emitted.
N_2O_{MRV}	Total aggregated N_2O emitted.
GWP_{CH_4}	Global warming potential of CH_4 over 100 years as referred to in the Annex to Commission Delegated Regulation (EU) 2020/1044. (GWP_{CH4}=28)
GWP_{N_2O}	Global warming potential of N_2O over 100 years as referred to in the Annex to Commission Delegated Regulation (EU) 2020/1044. (GWP_{N2O}=265)
i	Index corresponding to the fuels used on board the ship in the reporting period.
j	Index corresponding to emission sources on board the ship. For the purpose of this Regulation the sources considered include at least the main engines, auxiliary engines, gas turbines, boilers and inert gas generators.
M_i	Fuel consumption, as total mass of the specific fuel i used (total for all emission sources).
$M_{i,j}$	Fuel consumption, as mass of the specific fuel i used in emission source j.
C_j	Slippage coefficient as a percentage of the mass of the fuel i used by the emission source j [%]. C_j includes fugitive and slipped emissions. Fugitive and slipped emissions are emissions caused by the amount of fuel that does not reach the combustion chamber of the emission source or that is not consumed by the emission source because they are un-combusted, vented, or leaked from the system.
$M_{i,NC}$	Total mass of fuel i not combusted but released into the atmosphere. $M_{i,NC} = \sum_i \sum_j M_{i,j} \times C_j / 100$
CH_{4S}	Amount of CH_4 non combusted released into the atmosphere. For the purpose of determining such amount, companies shall apply the following formula: $CH_{4S} = M_{i,NC}$
$EF_{CO_2,i}$	Tank to Wake CO_2 emission factor by fuel i
$EF_{CH_4,i}$	Tank to Wake CH_4 emission factor by fuel i
$EF_{N_2O,i}$	Tank to Wake N_2O emission factor by fuel i

Table 4.4 Default Values for Emission Factors (EU-MRV)

1	2	3	4	5	6
Fuel Class	Type of Fuel	EF_{CO_2} $\left[\frac{gCO_2}{gFuel}\right]$	EF_{CH_4} $\left[\frac{gCH_4}{gFuel}\right]$	EF_{N_2O} $\left[\frac{gN_2O}{gFuel}\right]$	C_j As % of the mass of the fuel used by the emissions source
Biofuels	Ethanol	1.913	0.00005	0.00018	-
	Bio-diesel	2.834	0.00005	0.00018	-
	Hydrotreated Vegetable Oil (HVO)	3.115	0.00005	0.00018	-
	Liquified Bio-methane as	2.750	0	0.00011	3.1 for LNG Otto (dual fuel medium speed)

1	2	3	4	5	6
	transport fuel (Bio-LNG)				1.7 for LNG Otto (dual fuel slow speed)
					0.2 for LNG Diesel (dual fuel slow speed)
					2.6 for Lean-Burn Spark-Ignited (LBSI)
	Bio-methanol	1.375	0.00005	0.00018	-
	Other	3.115	0.00005	0.00018	-
	Bio-H_2	0	0	0 for Fuel Cells	-
				0.00018 for ICE	

(2) The cases where default emission factor is not applied

As indicated in the paragraph (1) above, default values of the emission factor for biofuels are generally used. However, Annex II, Part C specifies provisions for the "derogation from the general principle and use of emission factors pursuant to Article 14 Directive 2003/87/EC". According to these provisions, when using biofuels complying with the sustainability criteria and GHG emission saving criteria for the use of biomass established by Directive (EU) 2018/2001 (hereinafter referred to as the "Renewable Energy Directive"), the CO_2 emission factor (EF_{CO2}) of the biomass fraction is to be zero for the calculation of GHG emissions. In this case, it should be noted that the emission factors of CH_4 and N_2O (EF_{CH4} and EF_{N2O}) cannot be calculated as zero.

(Note)

- ✓ As for the CH_4 and N_2O emissions monitoring for the calculation of GHG emissions, as with CO_2 emissions, emissions of CH_4 and N_2O are calculated by multiplying emission factors (EF_{CH4} and EF_{N2O}) of each fuel by the amount of fuel used onboard, except using the direct GHG emissions measurement. These emissions are then converted into CO_2 equivalents by multiplying the Global Warming Potential (GWP). In the case of Bio-LNG, methane slip is also taken into account when calculating CH_4 emissions. Different rates for the methane slip are defined depending on the combustion system of the engine.

- ✓ When calculating emissions subject to the EU-ETS, CO_2 emissions (on a tank-to-wake basis) are calculated to be zero, provided that these biofuels meet the sustainability criteria and GHG emission reduction criteria set by the Renewable Energy Directive. In the case of blend oils, CO_2 emissions are to be zero only for the parts of the biofuels.

- ✓ EU has approved 15 certification schemes for biofuels under the Renewable Energy Directive, including ISCC EU and RSB EU RED (as of December 2023). Biofuels certified based on these schemes meet the above criteria.
  (Reference: https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/voluntary-schemes_en)

- ✓ When using biofuels, EU-MRV monitoring plan is required to be re-approved. After adding the biofuels into the section about fuels type used on the monitoring plan, please submit the plan to the Society via the ClassNK MRV Portal. Please also submit a copy of the document which shows the compliance with the sustainability criteria and GHG emission saving criteria of the Renewable Energy Directive for the biofuel (Proof of Sustainability as shown in Fig. 4.1 or similar materials) as well as a copy of Bunker Delivery Note.

-2 FuelEU Maritime Regulations

FuelEU Maritime is a regulation aimed at promoting decarbonization of fuels used in ships, comprising requirements that set an upper limit for the GHG intensity of fuels used in ships and request the use of on-shore power supply for container ships and passenger ships when being moored in ports of EU/EEA Member States.

The requirements for the GHG intensity of fuels set an upper limit for the annual average value of GHG emissions per energy unit (gCO_2eq/MJ) of fuels. The GHG intensity of each fuel is calculated for the Well-to-Tank and Tank-to-Wake parts, and an evaluation is made based on the combined value, known as the Well-to-Wake-based GHG intensity. The calculation method for GHG intensity is specified in Annex I of the FuelEU Maritime Regulations (Regulation (EU) 2023/1805), with default values of the Emission Factor for each fuel listed in Table of the Annex II. In the FuelEU Maritime Regulations, the GHG intensity of biofuels is evaluated based on the Renewable Energy Directive. The requirements for the calculation of GHG intensity for biofuels on a Well-to-Tank basis and Tank-to-Wake basis is outlined as follows:

(1) GHG intensity for Well-to-Tank

The GHG intensity for Well-to-Tank part is to be calculated using the following formula, which is specified in the Annex I of the FuelEU Maritime Regulations. The default values of the Emission Factor are specified in the Annex II (see Column 4 of Table 4.5 below). However, if the biofuels are certified under a scheme recognized European Commission in accordance with Article 30(5) and (6) of the Renewable Energy Directive, GHG intensity based on the measured values can be used.

(2) GHG intensity for Tank-to-Wake

The GHG intensity for Tank-to-Wake part is to be calculated using the following formula, which is specified in the Annex I of the FuelEU Maritime Regulations. The default values of the Emission Factor are specified in the Annex II (see Column 6~8 of Table 4.5 below). However, if the biofuels are certified by means of laboratory testing or direct emission measurements, GHG intensity based on the measured values can be used.

(3) Notwithstanding the requirements in paragraphs (1) and (2) above, if the biofuels do not comply with the sustainability criteria and GHG emissions saving criteria set out in the Renewable Energy Directive or that are produced from food and feed crops, the same emission factors as the least favorable fossil fuel pathway specified in the Annex II are to be used for calculating the GHG intensity.

$$\text{GHG intensity}\left[\frac{\text{gCO}_{2\text{eq}}}{\text{MJ}}\right] = \text{f}_{\text{wind}} \times (\text{WtT} + \text{TtW})$$

$$\text{WtT} = \frac{\sum_{\text{i}}^{\text{n fuel}} \text{M}_{\text{i}} \times \text{CO}_{2\text{eq WtT,i}} \times \text{LCV}_{\text{i}} + \sum_{\text{k}}^{\text{c}} \text{E}_{\text{k}} \times \text{CO}_{2\text{eq electricity,k}}}{\sum_{\text{i}}^{\text{n fuel}} \text{M}_{\text{i}} \times \text{LCV}_{\text{i}} \times \text{RWD}_{\text{i}} + \sum_{\text{k}}^{\text{c}} \text{E}_{\text{k}}}$$

$$\text{TtW} = \frac{\sum_{\text{i}}^{\text{n fuel}} \sum_{\text{j}}^{\text{m engine}} \text{M}_{\text{i,j}} \times \left[\left(1 - \frac{1}{100}\text{C}_{\text{slip j}}\right) \times \left(\text{CO}_{2\text{eq,TtW,i,j}}\right) + \left(\frac{1}{100}\text{C}_{\text{slip j}} \times \text{CO}_{2\text{eq TtW,slip,i,j}}\right)\right]}{\sum_{\text{i}}^{\text{n fuel}} \text{M}_{\text{i}} \times \text{LCV}_{\text{i}} \times \text{RWD}_{\text{i}} + \sum_{\text{k}}^{\text{c}} \text{E}_{\text{k}}}$$

i	Index corresponding to the fuel types delivered to the ship in the reporting period
j	Index corresponding to the fuel consumer units on board the ship. For the purpose of this Regulation the fuel consumer units considered are the main engine(s), auxiliary engine(s), boilers, fuel cells and waste incinerators
k	Index corresponding to the OPS connection points
n	Total number of fuel types delivered to the ship in the reporting period
c	Total number of OPS connection points
m	Total number of fuel consumer units
$M_{i,j}$	Mass of fuel i consumed by fuel consumer unit j [gFuel]
E_k	Electricity delivered to the ship per OPS connection point k [MJ]
$CO_{2eqWtT,i}$	WtT GHG emission factor of fuel i [gCO_{2eq}/MJ]
$CO_{2eq\ electricity,k}$	WtT GHG emission factor associated with the electricity delivered to the ship at berth per OPS connection point k [gCO_{2eq}/MJ] (For the purpose of this regulation, the term $\sum_k^c E_k \times CO_{2eq\ electricity,k}$ in the formula above is to be set to zero.)
LCV_i	Lower calorific value of fuel i [MJ/gFuel]
RWD_i	Where the fuel is of non-biological origin, a reward factor of 2 from 1 January 2025 to 31 December 2033 can be applied. Otherwise $RWD_i = 1$.
C_{slipj}	Non-combusted fuel coefficient as a percentage of the mass of the fuel i consumed by fuel consumer unit j [%]. C_{slip} includes fugitive and slipped emissions.
$C_{fCO2i,j}$, $C_{fCH4i,j}$, $C_{fN2Oi,j}$	TtW GHG emission factors by combusted fuel i in fuel consumer unit j [gGHG/gFuel]
$CO_{2eq,TtWi,j}$	TtW CO_2 equivalent emissions of combusted fuel i in fuel consumer unit j [gCO_{2eq}/gFuel] $\text{CO}_{2\text{eq TtW i,j}} = \left(\text{C}_{\text{fCO2,j}} \times \text{GWP}_{\text{CO2}} + \text{C}_{\text{fCH4,j}} \times \text{GWP}_{\text{CH4}} + \text{C}_{\text{fN2O,j}} \times \text{GWP}_{\text{N2O}}\right)_{\text{i}}$
$C_{sfCO2i,j}$, $C_{sfCH4i,j}$, $C_{sfN2Oi,j}$	TtW GHG emission factors by slipped fuel i towards fuel consumer unit j [gGHG/gFuel]

$CO_{2eq,TtWslipi,j}$	TtW CO_2 equivalent emissions of slipped fuel i towards fuel consumer unit j [$gCO_2eq/gFuel$] $CO_{2eq\ TtW\ slip\ i,j} = \left(C_{sfCO2,j} \times GWP_{CO2} + C_{sfCH4,j} \times GWP_{CH4} + C_{sfN2O,j} \times GWP_{N2O}\right)_i$ Where: $C_{sf\ CO2}$ and $C_{sf\ N2O} = 0$. $C_{sf\ CH4} = 1$.
GWP_{CO2}, GWP_{CH4}, GWP_{N2O}	CO_2, CH_4, N_2O Global Warming Potential over 100 years, which are defined in Directive (EU) 2018/2001, paragraph 4 of Part C of Annex V. （$GWP_{CO2} = 1$, $GWP_{CH4} = 25$, $GWP_{N2O} = 298$）
f_{wind}	Reward factor for wind-assisted propulsion $f_{wind} = 0.99$ ($P_{Wind}/P_{Prop} = 0.05$), 0.97 ($P_{Wind}/P_{Prop} = 0.1$), 0.95 ($P_{Wind}/P_{Prop} \geq 0.15$) Where: P_{Wind} is the available effective power of the wind-assisted propulsion systems and corresponds to $f_{eff} * P_{eff}$ as calculated in accordance with MEPC.1/Circ.896. P_{Prop} is the propulsion power of the ship and corresponds to P_{ME} as defined in the IMO Res. MEPC.364(79) and IMO Res. MEPC.333(76). Where shaft motor(s) are installed, $P_{Prop} = P_{ME} + P_{PTI(i),shaft}$.

Table 4.5 Default Values of Emission Factors (FuelEU Maritime)

1	2	3	4	5	6	7	8	9
			WtT	TtW				
Fuel Class	Pathway name	LCV $\left[\frac{MJ}{g}\right]$	$CO_{2eq\ WtT}$ $\left[\frac{gCO_{2eq}}{MJ}\right]$	Fuel Consumer Unit Class	$C_{f\ CO2}$ $\left[\frac{gCO_2}{gFuel}\right]$	$C_{f\ CH4}$ $\left[\frac{gCH_4}{gFuel}\right]$	$C_{f\ N2O}$ $\left[\frac{gN_2O}{gFuel}\right]$	C_{slip} As % of the mass of the fuel used by the engine
Biofuels	Ethanol Production Pathways of Directive (EU) 2018/2001	Value as set out in Annex III of Directive (EU) 2018/2001	$E - \frac{C_{f\ CO2}}{LCV}$	ALL ICEs	1.913	0.00005	0.00018	-
	Bio-diesel Production Pathways of Directive (EU) 2018/2001			ALL ICEs	2.834	0.00005	0.00018	-
	Hydrotreated Vegetable Oil (HVO) Production Pathways of Directive (EU) 2018/2001			ALL ICEs	3.115	0.00005	0.00018	-
	Liquefied Bio-methane as transport fuel (Bio-LNG) Production Pathways of Directive (EU) 2018/2001			LNG Otto (dual fuel medium speed)	2.750	0	0.00011	3.1
				LNG Otto (dual fuel slow speed)				1.7
				LNG Diesel (dual fuels)				0.2
				LBSI				2.6

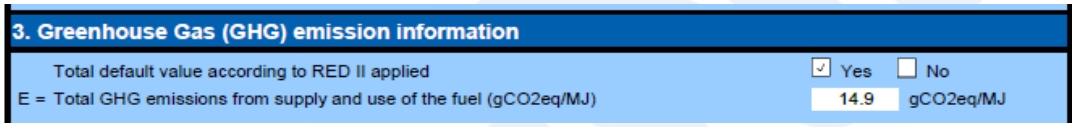
	Bio-methanol Production Pathways of Directive (EU) 2018/2001			ALL ICEs	1.375	0.00005	0.00018	-
	Other Production Pathways of Directive (EU) 2018/2001			ALL ICEs	3.115	0.00005	0.00018	-
	Bio-H2 Production Pathways of Directive (EU) 2018/2001	Value as set out in Annex III of Directive (EU) 2018/2001	N/A	Fuel Cells	0	0	0	-
				ICE	0	0	0.00018	
Fossil	HFO ISO 8217 Grades RME to RMK	0.0405	13.5	ALL ICEs	3.114	0.00005	0.00018	-
	LFO ISO 8217 Grades RMA to RMD	0.041	13.2	ALL ICEs	3.151	0.00005	0.00018	-
	MDO MGO ISO 8217 Grades DMX to DMB	0.0427	14.4	ALL ICEs	3.206	0.00005	0.00018	-
	LNG	0.0491	18.5	LNG Otto (dual fuel medium speed)	2.750	0	0.00011	3.1
				LNG Otto (dual fuel slow speed)				1.7
				LNG Diesel (dual fuel slow speed)				0.2
				LBSI				2.6
	LPG	0.046	7.8	ALL ICEs	3.030 Butane 3.000 Propane	0.00005	0.00018	N/A
	H2 (natural gas)	0.12	132	Fuel Cells	0	0	-	-
				ICE	0	0	0.00018	
	NH3	0.0186	121	Fuel Cells	0	0.00005	0.00018	N/A
				ICE	0	0.00005	0.00018	N/A
	Methanol (natural gas)	0.0199	31.3	ALL ICEs	1.375	0.00005	0.00018	-

(Note)

- ✓ The default value of Well-to-Tank (WtT) for liquid biofuels is calculated in accordance with the following formula using the value of GHG emissions (GHG intensity): E [gCO2eq/MJ], which is determined by the methodology of the Renewable Energy Directive (Directive (EU) 2018/2001) Annex V, Part C.

$$E - \frac{C_{f\,CO2}}{LCV}$$

The "E" value has been verified by a certification body of the biofuel and it is indicated in the document such as Proof of Sustainability (PoS) shown in Fig. 4.1. The FuelEU Maritime regulations require Bunker Delivery Note to be complemented with the information including "E" value and related evidence of compliance with the requirements set out in the Renewable Energy Directive.



- ✓ As with EU-ETS, when using biofuels, EU-MRV monitoring plan is required to be re-approved. After adding the biofuels into the section about fuels type used on the monitoring plan, please submit the plan to the Society via the ClassNK MRV Portal. Please also submit a copy of the document which shows the compliance with the sustainability criteria and GHG emission saving criteria of the Renewable Energy Directive for the biofuel (Proof of Sustainability as shown in Fig. 4.1 or similar materials) as well as a copy of Bunker Delivery Note.

◆ Management of GHG Emissions Using ClassNK ZETA

ClassNK has developed ClassNK ZETA (Zero Emission Transition Accelerator), a tool for managing GHG emissions, which has already been used on more than 5,000 ships (as of the end of 2023). This system is linked to ClassNK MRV Portal, a system that stores the data such as fuel consumption provided by ships. It is equipped with features for constantly monitoring GHG emissions and CII ratings of individual ships and entire fleets, as well as a function for simulating how GHG emissions and CII ratings would change by slow steaming, installing energy-saving devices, or switching fuels.

For biofuels, if the data such as fuel consumption is reported using the ClassNK MRV Portal, GHG emissions based on the methods in this section is automatically calculated, and the values can be confirmed by ClassNK ZETA.

ClassNK ZETA also has functions related to EU-ETS, allowing the users to display GHG emissions subject to EU-ETS for the entire fleet and individual ships, and to manage their own emission allowances.

In addition, we plan to introduce the functions for FuelEU Maritime Regulation, which will be introduced in 2025. ClassNK ZETA will in a future add the ability to calculate the GHG intensity required for FuelEU Maritime compliance and to manage fleet-wide compliance with the regulation.

Please utilize ClassNK ZETA for the management of GHG emissions for using biofuels.

ClassNK ZETA (Zero Emission Transition Accelerator) | ClassNK - English

ClassNK ZETA

Chapter 5 Scenarios for Achieving Goal of GHG Reduction by 2050

In July 2023, the IMO adopted its "2023 IMO Strategy on Reduction of GHG Emissions from Ships" (2023 IMO GHG Strategy). This updated strategy builds upon the initial strategy adopted back in 2018, now incorporating a net-zero GHG emission goal to be achieved by or around 2050. The 2023 IMO GHG Strategy sets the various numerical targets for reducing GHG emissions from international shipping and includes indicative checkpoints for achieving these reductions.

We considered a scenario where the expansion of biofuel use as an example of a scenario to achieve "20% to 30% reduction in GHG emissions by 2030 (compared to 2008)" on a Well-to-Wake basis which is one of the indicative checkpoints in the above numerical targets and published the details in a white paper titled "Pathway to Zero-Emission in International Shipping – Understanding the 2023 IMO GHG Strategy – ". The table shows the fuel mix as of 2030 in this scenario.

Table 5.1 Fuel Mix (Case of Achieving Indicative Checkpoint for 2030) [8]

	Fuel oil	LNG	Biodiesel	Total amount
Ship energy consumption	5.16 EJ (61%)	0.85 EJ (10%)	2.46 EJ (29%)	8.47 EJ (100%)
Life cycle GHG emissions (WtW)	473 mil. tons CO_{2eq}	71 mil. tons CO_{2eq}	37 mil. tons CO_{2eq}	581 mil. tons CO_{2eq} (20.5% reduction from 2008)
Indicative checkpoint for 2030	-	-	-	585 mil. tons CO_{2eq}

(Source: ClassNK estimations)

(Notes)
- The GHG intensity (WtW) of fuel oil is assumed to be 91.6 gCO_{2eq}/MJ, equivalent to HFO.
- The GHG intensity (WtW) of LNG is assumed to be 83.8 gCO_{2eq}/MJ.
- The GHG intensity (WtW) of biodiesel is assumed to be 15.0 gCO_{2eq}/MJ, equivalent to that derived from waste cooking oil.

By introducing a 29% biofuel (B-100) with a GHG intensity (Well-to-Wake) of 15.0 gCO_{2eq}/MJ for the energy consumption basis of fuel used in international shipping, the 2030 GHG emission reduction target (minimum 20% reduction compared to 2008) can be achieved. However, the required share of biofuel will vary greatly depending on the rate of increase in marine transport volume, the rate of improvement in energy efficiency of ships and other factors. Please refer to the aforementioned white paper for more details.

As stated above, biofuel can also play a role in achieving the indicative checkpoints of the 2023 IMO GHG reduction strategy. As for the GHG reduction effect of biofuel use, the "Interim guidance on the use of biofuels under Regs. 26, 27, and 28 of MARPOL Annex VI (DCS and CII)" has been approved by the IMO, and its GHG reduction effect has been recognized for biofuel that meets certain conditions. In the future, GHG intensity default values and other things will be developed through discussions on the LCA Guidelines, and practical evaluation methods related to the GHG reduction effects of biofuels will be developed as well.

In addition, according to a report published by the International Energy Agency (IEA) in 2023, one scenario for achieving net-zero global GHG emissions by 2050 is that the demand for biofuels in the maritime and aviation uses will gradually increase, while the demand for biofuels for road vehicles will decrease due to the decline of internal-combustion-engine vehicles, and that the share of biofuels in the maritime sector will increase to 19% in 2050 on an energy consumption basis.

Table 5.2 Scenarios for Fuel Mix Forecast to 2050 by the IEA [9]

Milestones	2022	2030	2035	2050
International shipping activity (trillion tonne-kilometers)	125	145	165	265
Share in final energy consumption				
Biofuels	0%	8%	13%	19%
Hydrogen	0%	4%	7%	19%
Ammonia	0%	6%	15%	44%
Methanol	0%	1%	1%	3%

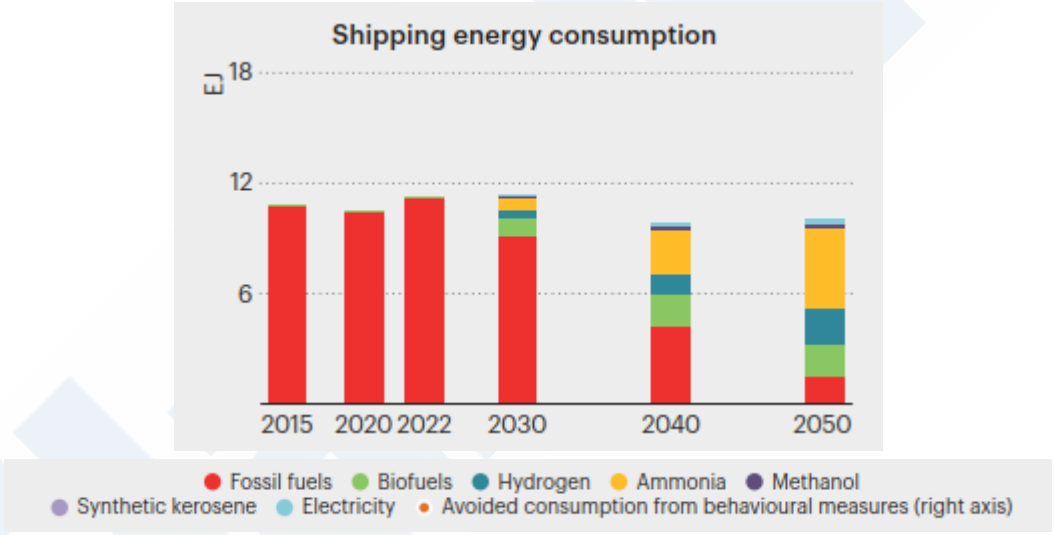


Fig 5.1 Scenarios for fuel mix forecast to 2050 by IEA [9]

Biofuels, depending on the type, are beneficial in that they can be used as drop-in fuels in conventional main diesel engines, and they also have low barriers to introduction for ships for which major specifications are difficult to change. Biofuels are, therefore, expected to play a major role in the transition toward net-zero GHG emissions, and their use is expected to expand, particularly for conventionally fueled ships.

Chapter 6 ClassNK Transition Support Services

Reduction of GHG emissions is being an urgent global issue. The shipping industry is under increasing pressure to reduce GHG emissions from ships, and environmental regulations in IMO and EU have been strengthened further. Decarbonization of ships requires a medium- to long-term approach, but the supply chain for zero-emission fuels, which is essential for reducing GHG emissions from ships, has not been sufficiently developed yet. For the time being, it is necessary to promote the transition to zero-emission by utilizing various means of reducing GHG emissions.

The technical guide focuses on biofuels only, which are expected to be a part of the transition to zero-emission, and compiles relevant information to aid ship operations. However, in order to comprehensively support the smooth transition to zero-emission, we have released the ClassNK Transition Support Services from the views of various GHG emission reduction measures. The following is an overview of the services.



Alternative fuels support (Ammonia / Methanol / LNG / LPG / Biofuel)

It is essential in the future to switch from conventional fuels to alternative fuels that are low or zero-emission fuels. We provide comprehensive support to customers at their discussing, designing, building, operating, and modifying for alternative fuel ships.



Fuel efficiency improvement support

Improving the fuel efficiency of ships is also important for reducing GHG emissions. The popular technologies for improving fuel efficiency include wind-assisted propulsion systems, air lubrication systems, energy-saving devices, propeller replacements, and voyage optimization systems and so on. We support customers from the estimation of fuel efficiency improvements to the introduction.



Shipboard CCS support

Corresponding to a growing interest to capture CO_2 in exhaust gas, development of shipboard CCS (Carbon Capture and Storage system) is underway. Based on the trends in shipboard CCS, we support customers in the introduction of shipboard CCS, including safety assessment in development and certification of the amount of CO_2 captured.



GHG emission management support

A framework for evaluating GHG emissions has been introduced in shipping industry, and the era of systematic management of GHG emissions in maritime transport has arrived.

We provide ClassNK MRV Portal, which is a certification tool for IMO-DCS and EU-MRV, to certify compliance with regulations and verify emissions during any period. In addition, we

provide ClassNK ZETA as well, which is a tool to visualize GHG emissions, as a service to certify GHG emissions in your fleet vessels. Furthermore, our services to support your carbon neutrality assessment and compliance with the Poseidon Principles are also available.

The ClassNK Transition Support Services aim to support your transition to zero-emissions through a variety of menus. Please refer to the following website for more information.

ClassNK Transition Support Services
URL: https://www.classnk.or.jp/hp/en/info_service/ghg/

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[9] International Energy Agency. "Net Zero Roadmap: A Global Pathway to Keep the 1.5℃ Goal in Reach", 2023.

Appendix I Field Survey Report on Biofuel Usage in Indonesia

[Background]

In Indonesia, biofuel oil usage is required by national policy. According to a government press release, the mixing ratio for biofuel oils used by the maritime industry is supposed to be B20 from September 2018, B30 from January 2020, and B35 from February 2023. In August 2023, ClassNK sent a team to visit shipping companies in Indonesia having experience in biofuel usage for several years to interview them about their perceptions and precautions regarding actual usage. The following is a report on the team's findings regarding biofuel usage in Indonesia.

[Interview Reports]

1. Distribution Situation of Biofuel Oil in Indonesia

- Biofuel oils in Indonesia were supplied by "Pertamina".
- Biofuel oils supplied for maritime sector were blends of MDO (Distillate oil) and FAME derived from palm oil. Thus, conventional pure MDO (Non-Biofuel 100%) was not generally available in Indonesia. Moreover, blend oils with HFO (Residual oil) were not supplied.
- Regarding the actual distribution situation as of July 2023, there were differences between areas. B35 was not necessarily distributed throughout all of Indonesia, and B30 seemed to still be used in some places at that time. According to information from Pertamina, it was said that the B35 had started to be supplied from June 2023.
- The future biofuel oil policy had not yet to be announced, but it was said that the preparations for B40 supply since 2024 had been underway. In the meantime, there was also information that B100 might be supplied.
- The price of biofuel oils seemed to depend on the market palm oil price, while the procurement price of B30 wavered about 1.1 to 1.6 times for HFO between January 2019 and June 2023. In addition, there seemed to be no government subsidy for biofuel oils supplied for maritime sector.

2. Status of Biofuel Oil Usage (Practical Example of Biofuel Oil Usage Hours)

- Domestic Ships (total operation time: About 8,000 hrs/year):
  - ✓ Biofuel Oils: About 40% of the total time (in port), otherwise VLSFO during navigation
- Tugboats (total operation time: About 4,000 hrs/year):
  - ✓ Only using biofuel oil in port
- Ocean-going ships
  - ✓ Main Engines: Using biofuel oils during start-up（Changing over to HFO or VLSFO)
  - ✓ Auxiliary engines: Only using biofuel oils (when bunkering in Indonesia)

3. Perceptions and Precautions on Biofuel Oil Usage

- Duration for Consumption
  - ✓ Within three months (on tugboats: consumed in two weeks)
- Stirring, Heating and Agitation (Practical Example)
  - ✓ Heating and circulation every two weeks (4 hrs, 60°C)
  - ✓ Circulation on every voyage and regular heating
- Sludge Formation
  - ✓ About 5% increase compared to MDO (equivalent to HFO)
  - ✓ Wax formation by blending the biofuel oil (bunkering in Indonesia) with the conventional MDO (bunkering in Singapore) ***1**
- FO Filter Blockage
  - ✓ About. 5% increase compared to MDO (equivalent to HFO)
  - ✓ Check every month or every two months (usually replaced every six months)
  - ✓ About half replacement interval (due to wax (above***1**))
- FO Leaks Due to Rubber Swelling/Degradation, Pipe Arrangement Corrosion, etc.
  - ✓ No particular problem
- Maintenance of Engine Parts
  - ✓ FO nozzle (seat): increasing tendency of repair/readjustment (compared to HFO)
  - ✓ FO injection pump (plunger & barrel) and FO nozzle: About half interval of replacement (due to wax (above***1**))
- Lubricant Oil (LO) for Engines
  - ✓ Type of LO: No change
  - ✓ Replacement interval: equivalent to petroleum oils
- Deposit Generation in Combustion Chambers
  - ✓ No particular problem
- Biofuel Oil Supplier Recommendations
  - ✓ Nothing in particular
- Use of Antioxidants
  - ✓ Not used

4. Other

- Bunkering Methods for Biofuels
  - ✓ Equivalent to HFO/MDO
- Operation Procedures in Engine Rooms for Biofuel Oils
  - ✓ Basically the same, except for more frequent checking of FO filters
- Facilities for Biofuel Oils Bunkering:
  - ✓ Bunkering by existing facilities (Information from Pertamina)

[Summary]

According to the results of interviews to shipping companies in Indonesia, it was said that biofuel oils can be basically used without trouble in cases where the oils are consumed before long-term storage. (In this interview, we heard the biofuel oils are usually consumed within three months.) In addition, precautions related to biofuel usage include regular stirring and heating, and more frequent checking of FO filters than conventional petroleum oils.

Despite a special case, in the event that biofuel oil (bunkered in Indonesia) was blended with the conventional MDO (bunkered in Singapore), there was a situation where the maintenance intervals had to be shortened by about half for the FO filter, pump (plunger and barrel), and nozzle due to wax formation. Thus, it is necessary to pay attention in the case of blending different kinds of fuel oils.

Appendix II Q&A

Q1.
If biofuels are used, can emission reductions be reflected in the EEDI/EEXI value?

A1.
The EEDI and EEXI are design energy efficiency indexes that only consider the onboard CO_2 emissions (Tank-to-Wake), in other words, neither the actual fuel types used in operation nor the CO_2 emissions from primary production to carriage of the fuel in a ship (Well-to-Tank) are taken into account. Therefore, the use of biofuels, which may contribute to the reduction of CO_2 emissions by absorbing it during plant growth, doesn't affect the EEDI and EEXI.

Q2.
Is a fuel suitability test in the presence of the surveyor required when using biofuels?

A2.
The fuel suitability tests in the presence of a surveyor may be required according to 2.3.1-1 (5)(e), Part B of the Rules for the Survey and Construction of Steel Ships, when ClassNK considers that the tests need to be conducted (e.g. in the cases of use of biofuel oil with properties significantly different from those of petroleum-based fuel oil normally used, or replacement to parts with different specifications).
If this is not the case, the witness of the surveyor may be voluntary. In the cases where you request, please contact the ClassNK Survey Department.
Our inspection items depend on your request, while the items would include a confirmation of the condition of relevant machinery and equipment after using biofuels, a check of the operation data when using biofuels, etc.

Q3.
What is the Reg. 18.3 of MARPOL Annex VI?

A3.
Regulation 18.3 of MARPOL Annex stipulates fuel oil quality. Regulation 18.3.1 applies to fuel oil derived from petroleum refining, whereas Reg.18.3.2 applies to fuel oil derived from methods other than petroleum refining. Moreover, Reg.18.3.2.2 further stipulates that the use of such fuel is not to cause ships to exceed the NOx limit values stipulated in Reg.13. Details on the handling of biofuel oil under this regulation can be found in 4.1 of the technical guide.

Q4.
Is it necessary to obtain an exemption from Reg. 18.3 of MARPOL Annex VI under Reg. 3.2 from the flag administration in order to use biofuel oils?

A4.
Unless otherwise instructed by the flag administration, it is not required to obtain an exemption for either temporary or permanent use (see 4.1 of the technical guide to find out whether compliance with Reg. 18.3.2.2 of MARPOL Annex VI is required).
In order to avoid any trouble, there is no objection to obtaining such permission from flag administrations, but doing so is left to the shipowner's discretion.

Q5.
What is the procedure for revising the NOx Technical File for main or auxiliary engines if it needs to be revised due to the use of biofuels?

A5.
The same revision procedure as usual can be used. If you are not sure whether a revision is necessary, ClassNK recommends that you should first consult with the engine's manufacturer.

Q6.
Regarding the mixing ratio of biofuels and petroleum fuels on board, what way is this to be presented to competent authorities, PSCs, etc.?

A6.
According to MEPC.1/Circ.795/Rev.8, it is stipulated that "The Product Name, as entered onto the bunker delivery note (BDN), should be of sufficient detail to identify whether, and to what extent, a biofuel or a synthetic fuel is blended into the product as supplied". Therefore, the BDN is useful to present the mixing ratio.

Appendix III [Poster] Issues After Starting to Use VLSFO (June 2021)

*If you would like to print the poster in actual size, you can download it from the following URL after logging in to My Page on the ClassNK website.

https://www.classnk.or.jp/account/en/Rules_Guidance/ssl/download.aspx?type=pdf&path=techpub/&file_name=VLSFO_e20210625

Issues after starting to use of VLSFO

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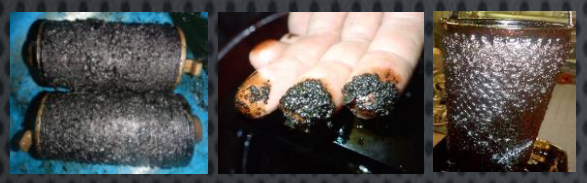
Sludge Problem and Engine Cylinder Problem

As the use of Very Low Sulphur Fuel Oil (VLSFO) has started to become more widespread, the frequency of these two problems has increased.
In addition, the properties of Very Low Sulfur Fuel (VLSFO) tend to be lighter properties (decrease in kinematic viscosity and density), higher pour points, and greater variation in properties than conventional 3.5% S HFO (like IFO 180 and IFO 380).
Based on these trends, we think that engineers should pay more attention to the mixing and heating of fuel oil so as to prevent sludge formation due to fuel oil compatibility and improper heating.
Although the causal relationship between engine cylinder problem and VLSFO has yet to be established.
In order to prevent cylinder problem, we also think that engineers are required to adjust cylinder lubrication setting appropriately according to the cylinder condition more than ever.

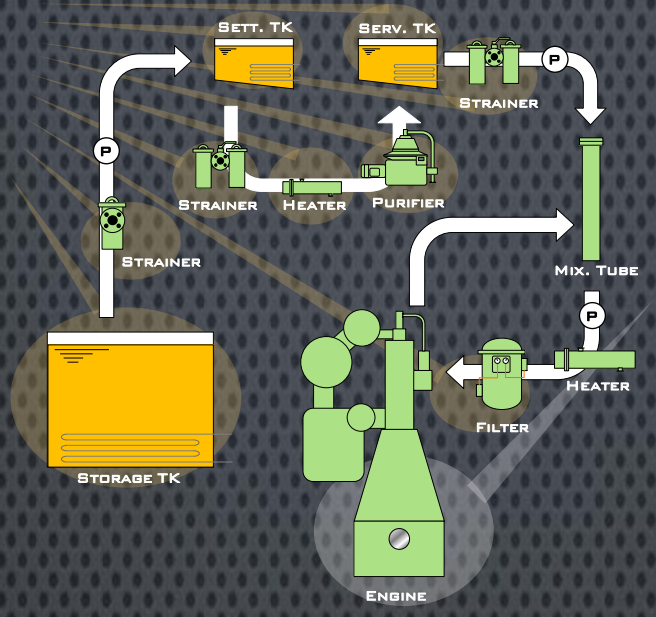
① Heavy sludge formation



Clay-like sludge accumulated in the purifier



Sludge stuck in the strainer & the filter



You may be forced to clean strainers and filters in a very short period of time. In the worst case, fuel oil pressure may drop and you may not be able to operate the engine.

✓Minimize fuel oil mixing
✓Beware of fuel oil over/underheating
✓Early detection of appropriate action



Piping blocked by sludge



Discarded cylinder liners

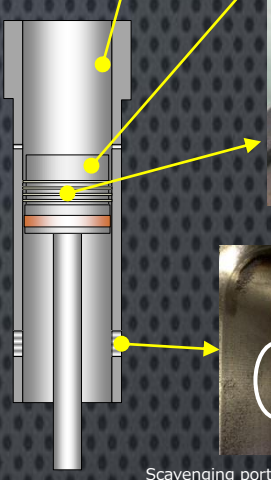
② Rings & Liners abnormal wear



Cylinder liner worn to the limit

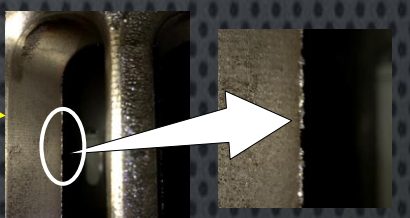


Deposit in the ring lands





Worn piston rings



Scavenging port burrs caused by cylinder liner abnormal wear

You may be forced to cut off a damaged cylinder during voyage. In the worst case, you may need to replace the rings, liners, and crowns of the engine.

✓ Early detection of appropriate action

Mitigate problems

Since their respective causes are not clear, it is difficult to completely eliminate each problem.
Therefore, itis important to minimize damage by taking measures for prevention of problems and early detection of abnormalities for each operational state.
The measures listed below are no different from those adopted when using a conventional 3.5% S HFO. However, as mentioned above, greater care must be taken when using VLSFO.
The below table summarizes the key measures for each operational state and each device. (Note that the below content does not completely cover all machinery operations.)

Refer to P2 ①
Refer to P2 ②

	Before Departure	Before Bunkering	During Bunkering	Before use	Use (Fuel change over)	Use (Consumption)
Storage TK		Stripping (①-1)	Spot tests (①-2)	Heating Check fuel properties (total sediment) (①-3)		
Strainer For Transfer Pump					Check the condition (①-7)	Check sludge accumulation (by monitoring the suction pressure of the pump, etc.) (①-10)
Settling TK				Lower tank level (①-6)	Heating adjustment (①-8)	
Strainer For Purifier					Check the condition (①-7)	Check sludge accumulation (by monitoring the suction pressure of the pump, etc.) (①-11)
Heater For Purifier				Check fuel properties (kinematic vis./pour point) (①-4)	Heating adjustment (①-8)	
Purifier				Check fuel properties (density) (①-5)	Purifier adjustment (①-9)	
Service TK				Lower tank level (①-6)	Heating adjustment (①-8)	
Strainer For Diesel Engines					Check the condition (①-7)	Check sludge accumulation (by monitoring the suction pressure of the pump, etc.) (①-12)
Heater For Diesel Engine				Check fuel properties (kinematic vis./pour point) (②-3)	Heating adjustment (①-8)	
Fine Filter For Diesel Engines					Check the condition (①-7)	Check sludge accumulation (by monitoring the in/out differential pressure of filters) (①-13)
Diesel Engine	Scavenge port inspections (②-1) Check the settings of the elect. Cyl. oil lubricator (②-2)					Check the each cyl. temp. of exh. gas, scav. air and jacket cool. water (②-4) Measurement of iron powder concentration in scavenging drain (②-6)

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1 Action against sludge problem

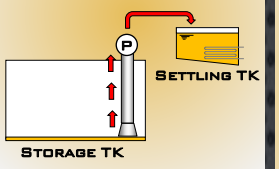
Generally, the type of sludge encountered is either asphaltene sludge due to fuel instability or wax sludge due to the characteristics of the wax component contained in the fuel.
Some ways to reduce the amount of sludge formation are as follows: avoid mixing as much as possible, heat to an appropriate temperature, and detect sludge formation at an early stage, such as when using 3.5% S HFO.

☞ : Prevent sludge formation
☞ : Early detection of sludge formation

Before Bunkering | **During Bunkering** | **Before use** | **Use (Fuel change over)** | **Use (Consumption)**

①－1 Stripping (storage tanks)

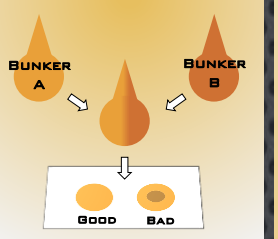
Minimize fuel oil mixing in storage tanks.



①－2 Spot tests

Check the possibility of sludge formation due to mixing when two fuel oils are unavoidably mixed in the storage tank.

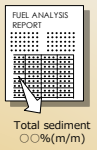
⊙Take actions to avoid sludge formation※1 according to spot test results.



①－3 Check fuel properties (Total sediment)

Check the stability of bunkered fuel oil.

⊙Take actions to avoid sludge formation※1 if the sediment value is close to the value (0.1%m/m) according to ISO 8217 standard.

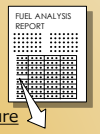


Total sediment
○○%(m/m)

①－4 Check fuel properties (Kinematic vis./Pour point)

Check the appropriate heating temperature for purifying the fuel oil according to the properties of the fuel oil.

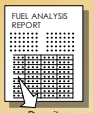
⊙Estimate the heating temperature to achieve the kinematic viscosity recommended by the purifier manufacturer. (See ②－3 for estimating temperatures) In addition, ⊙confirm the estimated heating temperature is high enough over the pour point.



Kinematic vis.
○○ (cSt)
Pour point
○○ (℃)

①－5 Check fuel properties (Density)

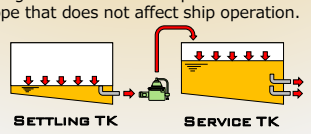
Check the density of the fuel for Selecting the gravity disc that suits the properties of the fuel oil.



Density
○○ (kg/m³)

①－6 Lower the level in tanks (Sett. tank/Serv. tank)

Avoid mixing with fuel oil transferred from storage tanks as much as possible within a scope that does not affect ship operation.



【Note that sludge formation is likely to occur during fuel change over.】

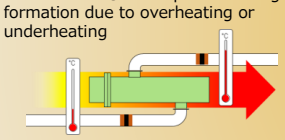
①－7 Check the condition of the filters and strainers

Check the condition before use to make it easier to detect any changes in its condition after use.



①－8 Heating adjustment (purifier line)

Heat the fuel oil to the temperature estimated in ①－4 to prevent sludge formation due to overheating or underheating



①－9 Purifier operation

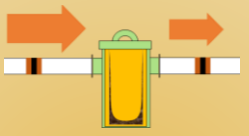
Select an appropriate gravity disc according to the heating temperature in ①—4 and the density in ①－5.
If heavy sludge formation is detected, adjust the separation efficiency (by reducing F.O flow rate, operating the purifiers in parallel) to prevent large amounts of sludge from accumulating in the purifier.



①－10 Check sludge accumulation (transfer line strainers)

Detect sludge formation at an early stage in the transfer line by monitoring the suction pressure of the transfer pump, etc.

If sludge accumulates in the strainer, ⊙check the kind of sludge.



If the sludge is liquefied by heating	If the sludge is NOT liquefied by heating
Consider raising the heating temperature as it may be a wax component.	Take actions to avoid sludge formation※1 as it may be asphaltene sludge

①－11 Check sludge accumulation (purifier line strainers)

Detect sludge formation at an early stage in the purifier line by monitoring the suction pressure of the purifier pump, etc.

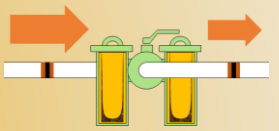
If sludge accumulates in the strainer, ⊙check the sludge separating condition of the purifier and ⊙the kind of the sludge in ①－10.



①－12 Check sludge accumulation (diesel engine strainers)

Detect sludge formation at an early stage in the fuel supply line by monitoring the suction pressure of the supply pump, etc. (Note that when changing over from VLSFO to MGO or vice versa, fuels with extremely different properties are mixed.)

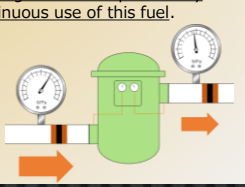
If sludge accumulates in the strainer, ⊙check ①－11 and judge whether the engine can be operated by continuous use of this fuel.



①－13 Check sludge accumulation in filters

Detect sludge formation at an early stage in the fuel circulation line by monitoring the in/out differential pressure of filters. ((Note that when changing over from VLSFO to MGO or vice versa, fuels with extremely different properties are mixed.)

If sludge accumulates in the filter, ⊙check ①－11,12 and judge whether the engine can be operated by continuous use of this fuel.



※1 There are no special measures against sludge formation by VLSFO. It is important to ensure that the measures taken so far are implemented.

2 Action against engine cylinder problem

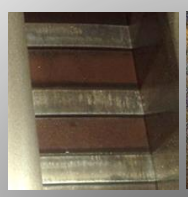
Many of the problems with engine piston ring and cylinder liner abnormal wear occur in 2-stroke diesel engines.
A causal relationship between VLSFO and damage has not yet to be established, but abnormal wear is basically due to poor lubrication.
The action to prevent poor lubrication is to adjust the lubrication rate to an appropriate level according to the cylinder conditions, as when using a 3.5% S HFO.

Before Departure | **Before use** | **Use (Fuel change over)** | **Use (Consumption ～ Use up)**

②－1 Scavenge port inspections

Check the condition of the piston, piston ring, and cylinder liner

If the condition has gotten worse since last inspection, ⊙determine if any action is required based on the engine manufacturer's service information, and ⊙check the condition of related parts and equipment※1 (operating conditions of fuel valves, cylinder lubrication systems, fuel oil heating devices, etc.). ⊙Based on these, consider increasing the lubrication rate※2.



Micro seizure



Deposits on piston lands

Related information issued by the manufacturer:

- MAN Energy Solutions (MAN ES): Service Letter SL2019-671/JAP
- Hitachi Zosen Corporation: Service Data HSD-B19103-R1
- Japan Engine Corporation (J-ENG) : UE Service Information USI-10022 Rev.3
- Winterthur Gas & Diesel (WinGD) : Guide for judging condition of relevant piston-running components (Version 5.0)
- IHI power systems : DU Service Information DUQ1-176E-1

②－2 Check the settings of the electronic cylinder oil lubricator

Check if the lubrication rate has dropped unexpectedly due to a mistake in the entering of set values

Check ⊙ if the input value is correct and ⊙ if the lubrication rate is appropriate.

MAN ES

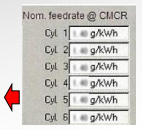


J-ENG



Correct?

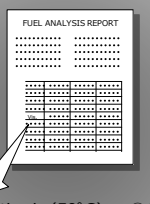
WinGD



②－3 Check fuel properties (Kinematic vis./Pour point)

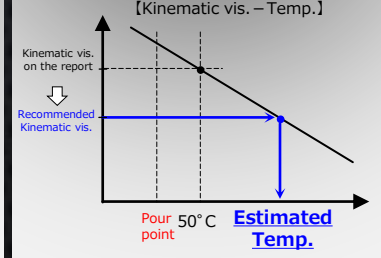
Check the appropriate engine inlet temperature according to the properties of the fuel oil.

⊙Estimate the heating temperature to achieve the kinematic viscosity recommended at the engine inlet by the manufacturer. In addition, confirm ⊙the estimated heating temperature is high enough over the pour point.



Kinematic vis.(50˚C) ⇒ ○○cSt
Pour point ⇒ ○○℃

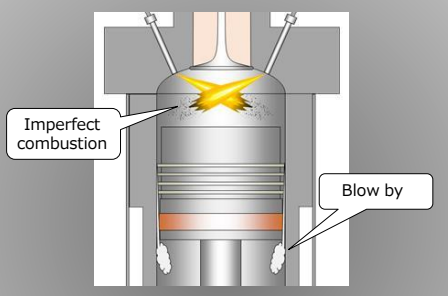
【Kinematic vis.－Temp.】



②－4 Check the temp. of exh. gas, scav. air, and cooling water for each cylinder

Detect abnormal wear of piston rings and cylinder liners at an early stage by monitoring the above-mentioned temperatures (Including temperature transition and deviation between cylinders).

If abnormality in the cylinder is detected, ⊙take action to protect the cylinder※1 (reduce engine load, increase cylinder lubrication rate, etc.) and ⊙check the condition of related parts and equipment※1 (operating conditions of fuel valves, cylinder lubrication systems, fuel oil heating devices, etc.).

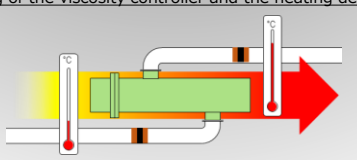


Abnormal cylinder liner wear is possible to affect Pmax / Pcomp and fuel efficiency.

②－5 Heating adjustment (engine inlet)

Ensure that the fuel oil is properly heated.
If the kinematic viscosity of the fuel oil is improperly adjusted, deposits in the combustion chamber may increase due to poor injection.

If the engine inlet temperature is not near the estimated temperature of ②－3 when the fuel change-over has been completed, ⊙check the operating conditions and setting of the viscosity controller and the heating device.

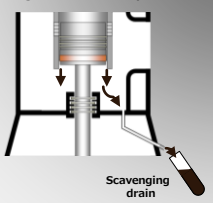


☞ **Check the temp. of exh. gas, scav. air, and cooling water for each cylinder (②－4)**

②－6 Scavenging Drain Analysis※3

Confirm that abnormal wear of the piston ring and the cylinder liner has not occurred when the main engine load has risen to the rated load during voyage.

If the iron contents is higher than the previous measurement or over the limit value specified by manufacturer, abnormal wear may start.
Therefore, ⊙ take action to protect the cylinder※1 (reduce the engine load, increase the cylinder lubrication rate, etc.) and ⊙check the condition of related parts and equipment※1(operating conditions of fuel valves, cylinder lubrication systems, fuel oil heating devices, etc.).





※1 There are no special measures against engine cylinder abnormal wear when using VLSFO. It is important to ensure that the measures taken so far are implemented.
※2 Engine manufacturers recommend using high BN cylinder oil depending on the engine condition.
※3 It is necessary to purchase an iron powder detector.

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