Overview of Guidelines Issued by ClassNK during CY 2023

Research Institute, Research and Development Division

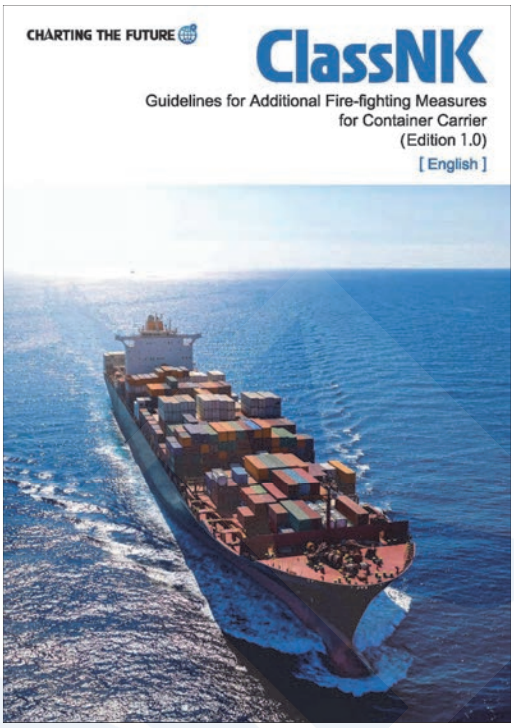
During calendar year 2023, ClassNK issued the 14 Guidelines shown in Table 1. This article presents the outlines of these Guidelines.

Table 1 Guidelines issued during CY 2023

Title	Languages	Date of issue	Contact
Guidelines for Additional Fire-fighting Measures for Container Carrier (Edition 1.0)	Japanese/ English	April 2023	Rule Development Dept.
Guidelines for Wind-Assisted Propulsion Systems for Ships (Edition 2.0)	Japanese/ English	April 2023	Technical Solution Dept.
Guidelines for Container Stowage and Securing Arrangements (Edition 3.1)	Japanese/ English	April 2023	Research Institute
Guidelines on Preventive Measures against Parametric Rolling (Edition 1.0)	Japanese/ English	April 2023	Research Institute
Guidelines for Electronic Logbooks (Edition 1.0)	Japanese/ English	May 2023	Rule Development Dept.
Guidelines for Direct Load Analysis and Strength Assessment (Edition 3.0)	Japanese/ English	June 2023	Rule Development Dept.
Guidelines for Shipboard CO_2 Capture and Storage Systems (Edition 1.1)	Japanese/ English	June 2023	Rule Development Dept.
Guideline for the Safe Transportation of Electric Vehicles (Edition 1.0)	Japanese/ English	August 2023	Material and Equipment Dept.

Title	Languages	Date of issue	Contact
Guidelines for Liquefied Hydrogen Carriers (Edition 2.0)	Japanese/ English	August 2023	Technical Solution Dept.
Guidelines for Fuel Cell Power Systems On Board Ships (Second Edition)	Japanese/ English	September 2023	Technical Solution Dept.
Guidelines for the Inventory of Hazardous Materials (Ver. 5.00)	Japanese/ English	October 2023	Ship Management Systems Dept.
Guidelines for Underwater Noise from Ships (Edition 1.0)	Japanese/ English	October 2023	Machinery Dept.
Guidelines for Cyber resilience of on-board systems and equipment (Edition 1.0)	Japanese/ English	November 2023	Maritime Education and Training Certification Dept., Machinery Dept.
Technical Guide for Using Biofuels (Edition 1.1)	Japanese/ English	December 2023	Machinery Dept.

Guidelines for Additional Fire-fighting Measures for Container Carrier (Edition 1.0)

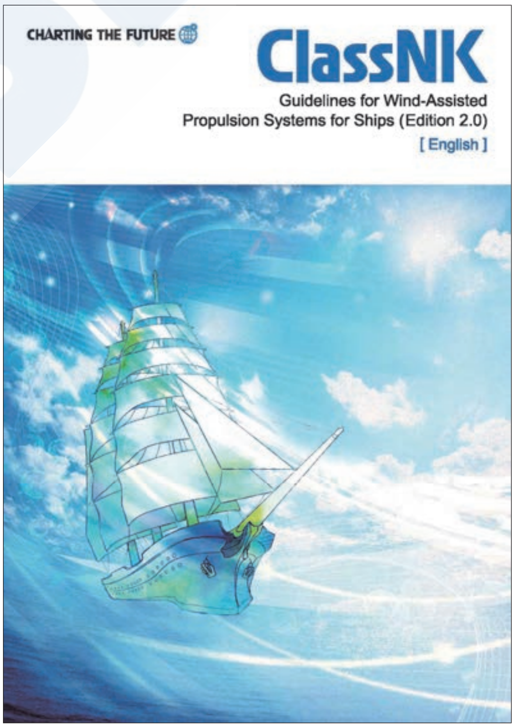


Accompanying the larger scale of container carriers in recent years, conventions have been revised to improve fire safety, but because multiple large fire accidents are still occurring, a review of international rules to further improve safety is under discussion in the IMO.

At MSC103 in May 2021, the IMO approved a new work plan to establish new requirements for fire safety measures on container carriers. In this plan, discussions on revision of the related requirements are to be completed by 2025, targeting issuance in January 2028.

There are also moves to respond voluntarily, in advance of discussions in the IMO, by some ship owners and ship management companies that operate container carriers. Therefore, the Society took the initiative in evaluating additional fire-fighting measures and issued “Guidelines for Additional Fire-fighting Measures for Container Carriers” to enable class notation representing those fire-fighting measures to the ship’s character of classification.

Guidelines for Wind-Assisted Propulsion Systems for Ships (Edition 2.0)



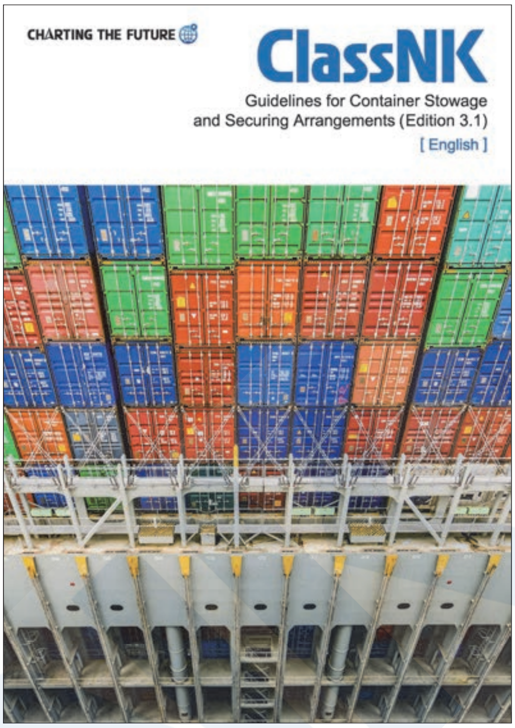
The safety of ships is guaranteed by international conventions, domestic laws, related regulations, etc., there are still no conventions applicable to Wind-Assisted Propulsion Systems (WAPS).

Therefore, ClassNK published the first edition of “Guidelines for Wind-Assisted Propulsion Systems for Ships” in 2019 and has performed drawing examinations and surveys related to the actual installation projects.

Reflecting the insights obtained from involvement in the actual installation projects, the guidelines are updated significantly to the second edition. The overall structure of the guidelines has been revised and organized into three parts: "Wind-Assisted Propulsion Systems", "Base Ships", and "Surveys", and requirements have been refined and clarified. The guidelines now provide a comprehensive overview of the points to be considered in designing WAPS and their installation on ships.

Also, the Guidelines will be successive updates planned, at the stage when actual results and knowledge concerning the adoption of WAPS have been accumulated.

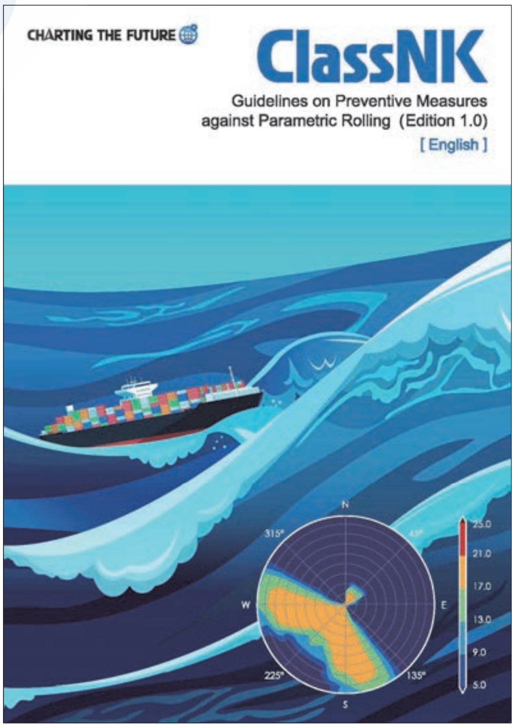
Guidelines for Container Stowage and Securing Arrangements (Edition 3.1)



To transport many containers at one time, container carriers are loaded with a large number of container stacks not only in holds, but also on deck. Container stacks are secured with securing devices, beginning with lashing rods that can withstand the loads associated with ship motion. Evaluations to determine whether the forces generated in containers and securing devices by ship motion exceed the allowable values are called “container securing strength calculations.”

Those calculations comprise evaluation of the design load and evaluation of lashing system deformation, including the lashing rods. In the Guidelines, design loads were revised by incorporating the results of the full revision of Part C in evaluations of ship motion and acceleration. In design load calculations, the Guidelines specified the use of encountered sea surface condition, considering ship behavior to avoid rough weather by weather routing, etc., based on the route and season. For evaluations of lashing system deformation, a solver that can perform calculations faithful to the phenomena with high speed and high accuracy was developed and is specified in the Guidelines. These revisions are expected to achieve safer and more economical maritime container transportation.

Guidelines on Preventive Measures against Parametric Rolling (Edition 1.0)



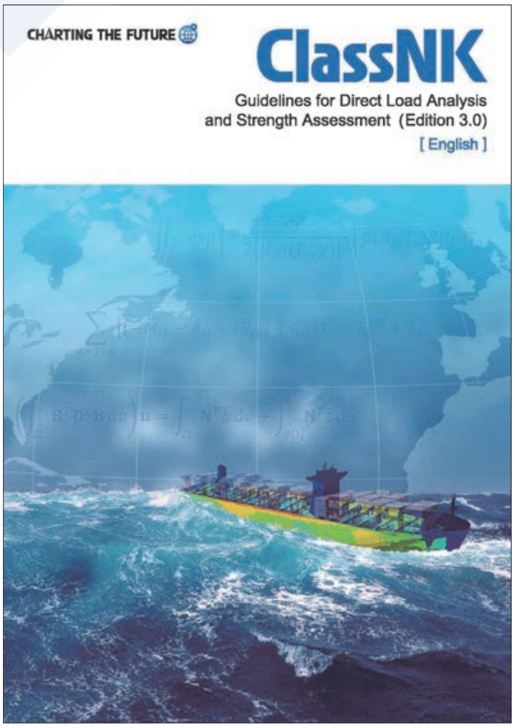
Parametric rolling, unlike synchronous rolling, is a rolling phenomenon caused by temporal changes in a ship’s righting moment, and can occur in a head sea or oblique sea. It occurs easily in fine ships such as containerships and car carriers. Particularly in recent years, cargo collapse accidents that are thought to have been caused by excessive rolling due to parametric rolling have occurred in large-scale containerships.

To promote wider use of measures to avoid and prevent excessive rolling due to parametric rolling, these Guidelines summarize the types of effective measures, functional requirements to be applied, and class notations to implement appropriate measures. Basic precautions for avoiding parametric rolling and the procedures for preparation of polar charts showing the parametric rolling region are also described.

Guidelines for Electronic Logbooks (Edition 1.0)

With recent progress in digital technology and digital devices such as tablets, various information that has been confirmed in paper form until now is being digitized, accelerating the overall transition to paperless business operations in society. Electronic logbooks describing important matters related to ship operation have also attracted attention in the maritime industry, and amendments allowing the use of electronic media for the record books for oil and ozone layer depleting substances required in the MARPOL Convention were adopted in May 2019. Since electronic logbooks have many advantages, not limited to the environmental aspect of paperless operation, but also in lightening the crew's recordkeeping workload by automatic inputting of data from nautical instruments and improving the quality of the contents of records, digitization is expected to spread to items other than the logbooks stipulated in the MARPOL Convention in the future. Against this background, the Society released these Guidelines, which summarize the general specifications for data retention and record management for electronic logbooks, as an approach for approving electronic logbooks used voluntarily on ships.

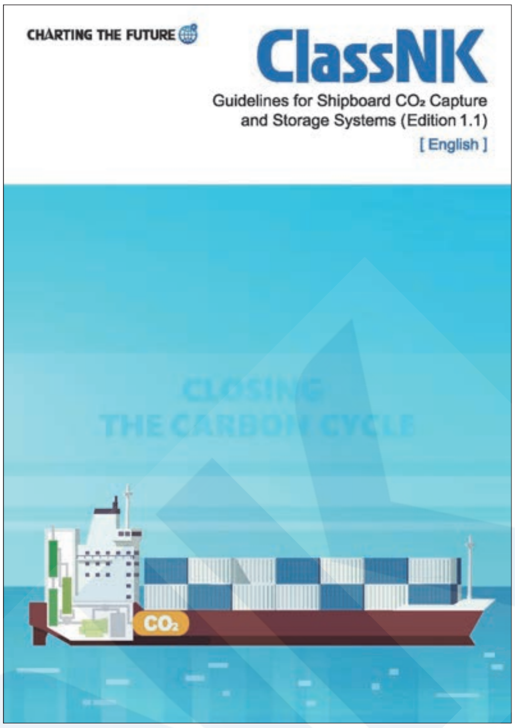
Guidelines for Direct Load Analysis and Strength Assessment (Edition 3.0)



"Guidelines for Direct Load Analysis and Strength Assessment Edition 1.0" specified the technique and related requirements of "Direct Load and Structural Analysis" for performing a structural analysis based on a direct load analysis that directly simulates the wave loads acting on a ship, and a ship structural strength assessment that accurately grasps the characteristics of the target ship. In 2022, the requirements for Direct Load and Structural Analysis were reviewed based on newly revised concepts related to structural strength assessment in Part C of *Rules for the Survey and Construction of Steel Ships* (released in July 2022), and Edition 2.0 was released.

At the end of 2022, Rev. 2 of IACS Recommendation No. 34 was released, specifying sea conditions in the North Atlantic analyzed using new technology. (IACS Recommendations are not compulsory.) Based on that revision, the Society recently released Edition 3.0, adding a summary of points to note when performing strength assessments based on the said sea conditions as reference.

Guidelines for Shipboard CO_2 Capture and Storage Systems (Edition 1.1)

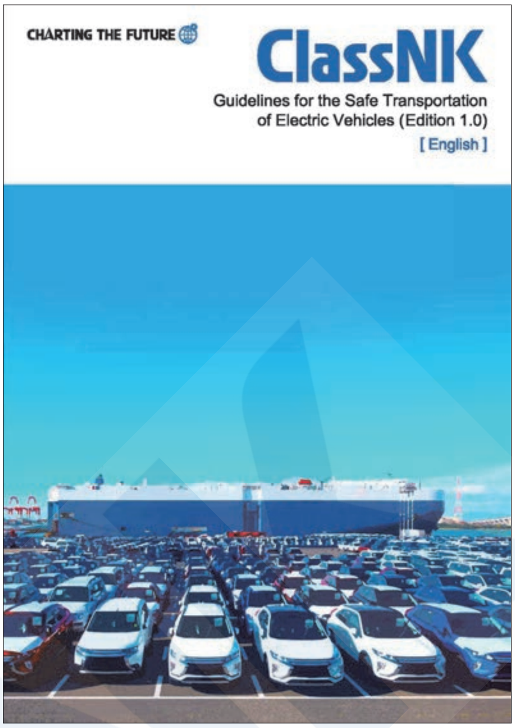


In recent years, ever stronger efforts have been made to reduce greenhouse gas (GHG) emissions from ships in the shipping industry. In particular, there is growing interest in shipboard CO_2 capture as a technology for reducing emissions of carbon dioxide (CO_2), which is said to have the largest impact among GHG.

Therefore, “Guidelines for Shipboard CO_2 Capture and Storage” was issued in April 2023 (Edition 1.0), summarizing the general concepts of CO_2 capture and storage systems (SCCS), safety requirements, the class notation equipped with SCCS, and the survey requirements for smooth Society approval of the installation of SCCS expected in the future, together with an Appendix on the additional energy requirements of SCCS, etc. Subsequently, the Guidelines were revised to clarify some content of the Appendix, and were released as Edition 1.1 in June of the same year.

The Guidelines specify the safety requirements for SCCS in two parts, Chapter 2, “CO_2 Capture Systems and Associated Equipment,” and Chapter 3, “CO_2 Storage Systems and Associated Equipment.” The content of Chapter 4, “Class Notation,” allows a flexible response to the actual situation by providing class notations that can be differentiated according to the installation condition of the respective equipment on ships, and class notations for cases where design was carried out envisioning future installation. The Appendix provides useful information for SCCS design, including a simple calculation method for the size of CO_2 absorber units, calculation of the additional energy required to operate the SCCS, the capacity of liquefied CO_2 storage tanks, etc.

Guidelines for the Safe Transportation of Electric Vehicles (Edition 1.0)



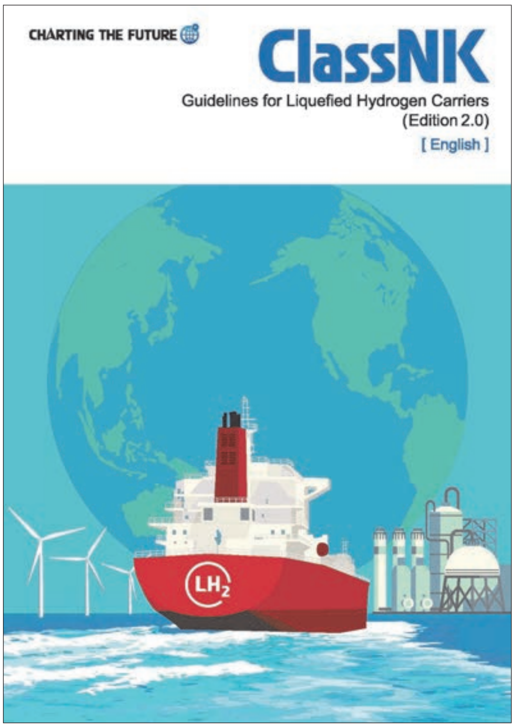
Accompanying the large increase in registered electric vehicles (EVs) worldwide, an increase in the number of EVs transported by car carriers is also foreseen. Since EVs are powered by electric energy stored in a lithium ion battery (LIB), if a fire breaks out from an LIB or fire spreads to an LIB, fire-fighting measures different from those used with gasoline-powered vehicles are necessary to extinguish EV fires.

The IMO has also begun discussions on fire safety measures for ships transporting new energy vehicles, including EVs, but those discussions are expected to extend over several years before rules are established.

On the other hand, since maritime transportation of EVs has already begun, ship companies are voluntarily studying and implementing fire safety measures.

Under these circumstances, the Society arranged the features and points to note concerning fires of EVs and issued “Guidelines for the Safe Transportation of Electric Vehicles,” showing the points which require attention in the fire-safety measures that are considered effective. This framework also allows voluntary assessment of fire measures by ship companies so that notations to the effect that a ship has taken measures that are considered effective can be affixed to the ship’s character of classification.

Guidelines for Liquefied Hydrogen Carriers (Edition 2.0)

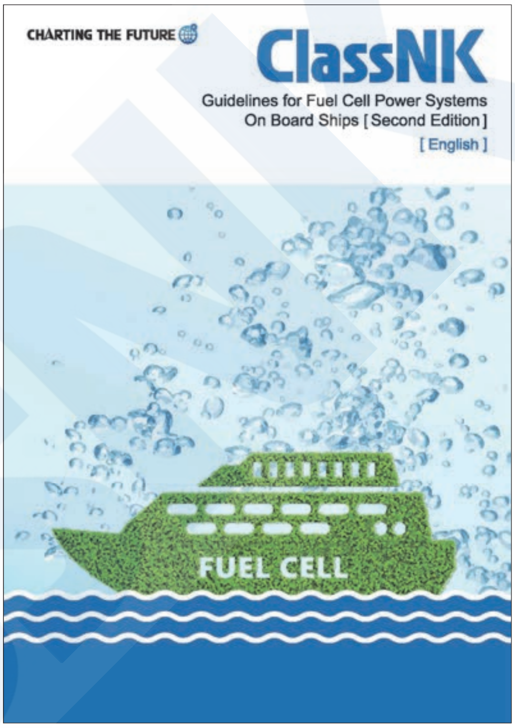


To construct a supply chain for hydrogen, which is expected to be a clean energy source in a decarbonized society, the development of liquefied hydrogen carriers that enable large-scale and efficient transportation is progressing actively.

IMO has worked on establishing safety requirements for liquefied hydrogen carriers that must keep cargo at an extremely low temperature of minus 253 degrees Celsius, and "Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk" was adopted in 2016. Based on the interim recommendations, ClassNK’s "Guidelines for Liquefied Hydrogen Carriers" published in 2017 set out specific requirements in consideration of related international standards and ClassNK’s R&D outcome. A design review and survey of the world's first liquefied hydrogen carrier, "Suiso Frontier," was based on these guidelines.

Incorporating insights from experience with the ship and reviews of other concepts currently under development, ClassNK has updated the guidelines to Edition 2.0. In this update, specific requirements were refined for clarity and rationality, and two sets of guidance assisting the process of risk assessment required for each project and the exploration of measures against potential hazards have been added, enhancing the practicality of the guidelines.

Guidelines for Fuel Cell Power Systems On Board Ships (Second Edition)



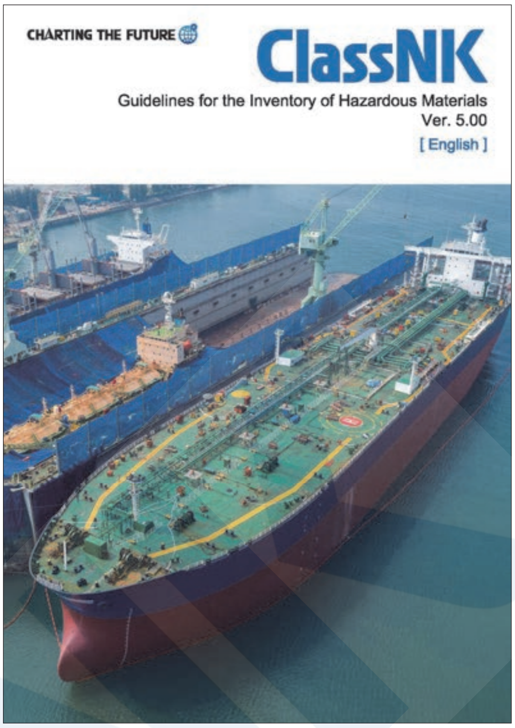
Fuel cells are power systems that use electrical energy obtained from the chemical reaction between hydrogen and oxygen. Notably, they do not emit CO_2 during electricity generation, positioning them as a potential solution to help reduce GHG emissions from shipping.

On the other hand, the use of fuel cells entails handling hydrogen, which has many physical properties distinct from conventional fuel gases. To ensure safety, it is critical to take sufficient measures. Discussions are currently underway at the IMO to amend the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code) to include provisions specific to fuel cells. At MSC105, the interim Guidelines for the safety of ships using fuel cell power installations were approved.

In this recent update, ClassNK has incorporated the contents of the IMO Interim Guidelines into its "Guidelines for Fuel Cell Power Systems On Board Ships (Second Edition)." These guidelines outline the latest safety measures for installing fuel cell power in vessels, including design principles for related equipment, fire safety, electrical systems, control, monitoring, and safety systems. The guidelines also set out requirements for a class notation for vessels that meet these provisions. Moreover, an annex detailing the examination requirements for fuel cell power systems, based on relevant IEC standards and regulations, has been added.

Guidelines for the Inventory of Hazardous Materials (Ver. 5.00)

With regard to Inventory of Hazardous Materials (IHM) required on Ship Recycling Convention, which will enter into force on 26 June 2025, RESOLUTION MEPC.379(80) "2023 GUIDELINE FOR THE DEVELOPMENT OF THE INVENTORY OF HAZARDOUS MATERIALS" have been adopted at MEPC80 in July 2023 as amendment to RESOLUTION MEPC.269(68). RESOLUTION MEPC.379(80) has been issued adding cybutryne to hazardous materials to be listed in the Inventory of Hazardous Materials (IHM) with respect to the restriction of the use of cybutryne as anti-fouling system (AFS) since January 2023 on AFS Convention. "Guidelines for the Inventory of Hazardous Materials (Ver.4.00)", issued in October 2019, has been updated as Ver.5.00 reflecting RESOLUTION MEPC.379(80).

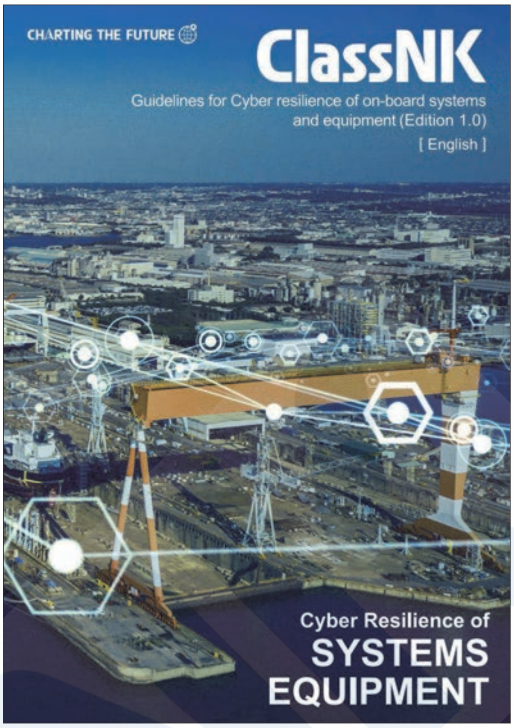


Guidelines for Underwater Noise from Ships (Edition 1.0)

In the early 2000s, stranding accidents of marine organisms such as dolphins and whales, which are assumed to be caused by underwater noise, occurred frequently, and research on the effect of underwater noise of ships on marine organisms was conducted. As a result of these investigations, the momentum for the introduction of underwater noise regulation increased internationally, and the International Maritime Organization (IMO) conducted activities for the introduction of underwater noise regulation, and adopted the non-mandatory guideline in March 2014. Since then, discussions to improve its effectiveness have increased, and a revised guideline was approved in July last year, including the preparation of a underwater noise management plan. In order to respond to such international trends, we have issued a guideline. This guideline specifies design requirements for underwater noise reduction, provisions for underwater noise measurement in accordance with ISO17208, and standards for assigning classification codes based on the results.

A brief explanation of the ClassNK Guidelines is presented at the end of this article.

Guidelines for Cyber resilience of on-board systems and equipment (Edition 1.0)



With the advent of IoT technologies in shipboard systems, the risk of ships falling victim to cyber-attacks is increasing. These attacks not only jeopardize the safety and reliability of ships but also pose a direct threat to human life and property at sea and the marine environment.

Therefore, IACS has studied the measures necessary to ensure the cybersecurity of ships. In April 2022, it issued new UR E26 and UR E27, which set out the measures as requirements. UR E26 covers ships, and UR E27 covers on-board systems and equipment. ClassNK has incorporated these into Part X of the *Rules for the Survey and Construction of Steel Ships* and will apply to ships contracted for construction on or after 1 July 2024.

The Guidelines are intended to assist manufacturers of marine systems and equipment, who are suppliers, intended to be covered by Chapter 4 of Part X incorporating UR E27. To this end, the Guidelines explain the technical details of cyber security and the Society's approval process..

Technical Guide for Using Biofuels (Edition 1.1)

Amid the growing momentum toward fuel transition for decarbonization, biofuels are gaining attention as carbon neutral fuels as feedstock plants absorb CO_2 from the atmosphere during their growth, and as drop-in fuels usable in place of petroleum fuels without major modifications to existing marine diesel engines or machinery. However, there are concerns about the potential risks associated with long-term use due to their limited practical experience and non-establishment of unified standards as marine fuel oils as of 2023.

The technical guide outlines the characteristics of biofuels, the potential issues arising from differences compared to conventional petroleum fuels, and precautions for safe use, such as measures related to machinery or against sludge. It also covers the stipulations and interpretations for biofuels under NOx and GHG reduction regulations, as well as future scenario for biofuels. In addition, it supplementally includes a hearing report on biofuel usage in Indonesia, as well as FAQ that is frequently asked from customers.

A brief explanation of the Technical Guide is presented at the end of this article.

Overview of Guidelines for Underwater Noise from Ships

Hirobumi KANEKO, Hikaru KAMIIRISA*

1. INTRODUCTION

In the first half of the 2000s, beaching incidents involving dolphins, whales and other forms of marine life occurred frequently. Because this phenomenon may be associated with underwater noise, research on the effects of underwater noise radiated by ships on marine life was carried out. The results of those studies heightened international momentum toward the introduction of underwater noise regulations. There were also moves in the International Maritime Organization (IMO) to introduce underwater noise regulations, and the non-mandatory guideline, Guidelines for the Reduction of Underwater Noise from Commercial Shipping to Address Adverse Impacts on Marine Life (MEPC.1/Circ. 833), was adopted by the 66th session of the IMO's Marine Environment Protection Committee (MEPC66) held in March 2014. Based on the direction formulated by the 76th session of the Committee (MEPC76) in March 2021, the work of reviewing and revising the Guidelines was begun, and the revised version of the Guidelines for the Reduction of Underwater Noise was approved at MEPC80 in July 2023. Based on these moves, ClassNK issued its own Guidelines for Underwater Noise from Ships (Edition 1.0) (hereinafter, referred to as the Guidelines) in October 2023.

This paper presents a technical overview of the relatively unfamiliar subject of underwater noise in the field of large-scale ocean-going commercial ships.

2. UNDERWATER NOISE

The main cause of underwater noise is the propellers and machinery and equipment installed on ships, and its level varies depending on the ship's hull form, structure and operating conditions, etc. In many cases, underwater noise is caused by propeller cavitation. Particularly in the case of large full type ships that require high-efficiency propellers and have highly nonuniform or non-homogeneous wake fields, it is thought that the underwater noise of the ship caused by propeller cavitation and radiated in the surrounding water is the dominant factor.

In this connection, the term "underwater noise level" means the sound pressure level (*dB*) given by the following equation.

$$L_p = 10\log\left(\frac{p}{p_0}\right)^2 \qquad (dB)$$

L_p: Sound pressure level, p_0: Reference sound pressure (= $1\mu Pa$)

The sound pressure level is converted to the level at a distance of 1 *m* from the noise source.

3. OVERVIEW OF THE *GUIDELINES*

The *Guidelines* comprise six chapters covering general provisions, submission of plans and documents, surveys, design requirements, underwater noise measurement, maintenance and operation. Among these, this paper presents a brief explanation of the design requirements and underwater noise measurement.

3.1 Design Requirements

This chapter of the *Guidelines* specifies the design requirements for underwater noise measurements for the ship hull, propellers, main and auxiliary engines, etc.

* Research Institute, Research and Development Division, ClassNK

3.1.1 Hull

To suppress cavitation, ship hull forms are to be designed so that the wake fields are as homogeneous as possible, the hull and propeller designs are to be adapted to each other, hull structures are to be optimized to reduce solid-borne noise and the excitation response of the hull, underwater noise reduction measures are to be harmonized with technical measures to reduce greenhouse gas (GHG) emissions, etc.

3.1.2 Propellers

The provisions for propellers include optimization of propeller load fluctuations in a wake flow designed to be as uniform as possible in order to reduce cavitation under normal operating conditions, model testing at cavitation test facilities using equipment such as a cavitation tunnel for optimizing propeller design, etc.

3.1.3 Main and Auxiliary Engines

Measures include appropriate vibration control measures such as resilient mounts, damping balancing, structural damping, etc. for equipment installed on board ships such as refrigeration plants, air compressors, etc., appropriate arrangement of onboard equipment, and optimization of foundation structures.

3.2 Underwater Noise Measurement

The *Guidelines* provides for acoustic measurement and evaluation in deep waters conforming to ISO 17208, where the effects of seabed acoustic reflection are limited.

3.2.1 Measurement site

Measurement site are to be selected in sea areas where the water depth is 150 m or more or more than 1.5 times the length of the ship, whichever is greater, and there is no traffic congestion.

3.2.2 Measurement Conditions

Measurements are, in principle, to be taken with the ship fully loaded during sea trials, under marine and meteorological conditions which will not affect the measurements at a BF scale of 4 or less and sea state of 2 or less, with engine power of 85 % of normal output.

3.2.3 Measurement Procedure

The Distance to the Closest Point of Approach (DCPA) to the hydrophones is to be 100 m or the ship’s length, whichever is greater. The tolerance of DCPA is not specified. The hydrophones used in the measurement are to omni-directional, and 3 hydrophones of the bottom-mounted type, floating buoy type, or a floating line system from a supporting vessel are to be used. Fig. 1 shows an example of the arrangement in the case of the bottom-mounted type.

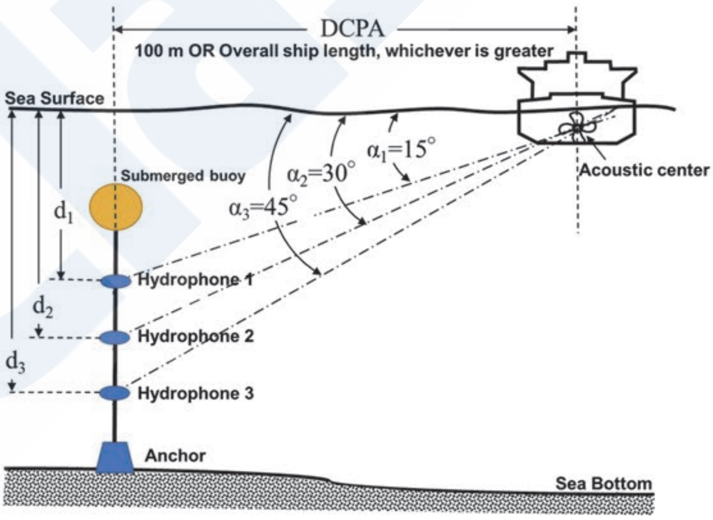


Fig. 1 Example of arrangement of bottom-mounted hydrophones

The measurement sections are to be the range of ±30 degrees from the center of the hydrophone, and the number of navigations and measurements is to be two times, with the hydrophone on the starboard side and the port side. Fig. 2 shows an example of the underwater noise measurement configuration in the test course.

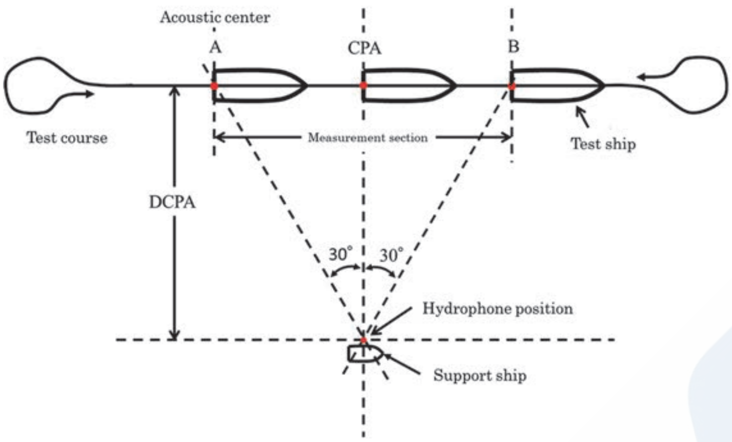


Fig. 2 Measurement configuration(test course and other matters)

3.2.4 Analysis Method

Narrow band spectrum analysis (every 1 Hz) and one-third octave band analysis are to be performed. The *Guidelines* also include provisions for processing of background noise, distance correction, correction of seabed reflection, etc.

3.2.5 Evaluation Criteria

The notation *Silent Underwater Noise-X* (abbreviated *SUN-X*) is noted to the class characters of ships adopting special measures for noise reduction in accordance with the *Guidelines*. *X* is based on the results of the Izu-Oshima underwater noise test conducted in cooperation with the Japan Ship Technology Research Association, and the notations *Silent Underwater Noise-Controlled* (*SUN-C*) and *Silent Underwater Noise-Advanced* (*SUN-A*) are noted in accordance with the determined reference noise levels(Fig. 3). For the detailed numerical values, please refer to the *Guidelines*.

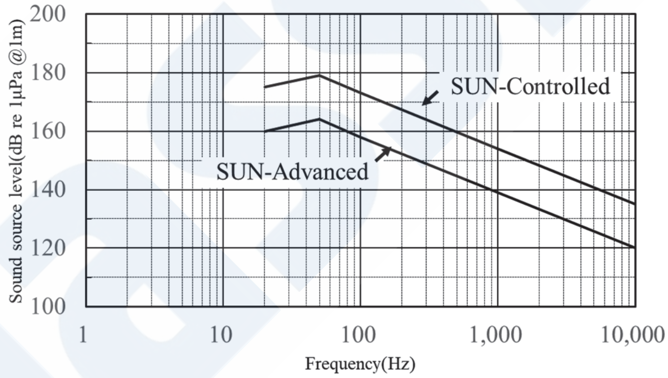


Fig. 3 Reference noise levels (1/3 octave band)

4. CONCLUSION

In recent years, underwater noise radiated from ships has also been considered one type of environmental pollution in the United States and Europe. This article has presented an overview of the ClassNK *Guidelines for Underwater Noise from Ships* (*Edition 1.0*), which corresponds to international regulatory moves to address this problem. It is our hope that this paper will contribute to resources for study by all stakeholders.

Discussions toward the next stage, including preparation of noise management plans by various types of ships to ensure the effectiveness of underwater noise reduction efforts, are already underway in the IMO. ClassNK will update the *Guidelines* when necessary, depending on developments in the IMO, and will also provide the corresponding services, etc. to clients.

Biofuel Oils as Marine Fuels

Takuya TOKURA*

1. INTRODUCTION

The trend toward decarbonization has accelerated worldwide in recent years due to concerns about global warming. Initiatives for decarbonization are also progressing in the maritime industry, and biofuel oils, which make it possible to reduce GHG emissions, are attracting attention for use in the existing oil-fueled ships as well as new oil-fueled ships that will likely continue to be built for some time. This paper presents a partial introduction to how biofuel oils will be used as marine fuels.

2. NEEDS FOR BIOFUEL OIL

In the International Maritime Organization (IMO), the 80th Session of the Marine Environment Protection Committee (MEPC 80) adopted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships in July 2023, which set a target of net-zero GHG emissions in international shipping by around 2050 at the latest. To achieve this target, a changeover from the conventional petroleum-derived fuel to alternative fuels is being considered, with a particular focus on hydrogen and ammonia, which do not emit CO_2 when used.

However, in order to achieve widespread adoption of these alternative fuels, many issues must be addressed, including development of the requisite technologies, construction of fuel supply chains, training of seamen and establishment of a regulatory framework. Considerable time will be required until alternative fuels are adopted, but today's rapidly-advancing global warming will not wait for adoption. Isn't there any means of reducing GHG emissions from existing ships fueled with petroleum-derived fuel oil?

One answer to that question is biofuel oils, which can be used without requiring significant modifications for ship machinery equipment.

2.1 GHG Emission Reduction by Biofuel Oils

The term "biofuel oil" refers mainly to SVO (Straight Vegetable Oil), FAME (Fatty Acid Methyl Ester), and HVO (Hydrotreated Vegetable Oil). SVO is extracted from the fruits and seeds of plants, while FAME and HVO are produced using SVO as a raw material. Like petroleum-derived fuels, all these biofuel oils emit CO_2 when used on ships. However, since the plants absorb CO_2 in the growth process, biofuel oils can be considered to have smaller GHG emissions than petroleum-derived fuels if evaluated by the CO_2 balance in the total process from production and transportation to consumption (use in fuel consumption machinery, such as diesel engines), that is, Well-to-Wake CO_2.

2.2 Motivation for Using Biofuel Oils

At present, ARA (abbreviation of Amsterdam-Rotterdam-Antwerp), Singapore supply bio-blend fuel oils, which are marine fuel oils made from biofuel oils and petroleum-derived fuel oils. In order to evaluate their GHG reduction effect, many bio-blend fuel oil suppliers have obtained ISCC EU Certification (a certification scheme that shows compliance with the requirements of the EU Renewable Energy Directive (EU RED II) for sustainable biofuel production).

The bio-blend fuel oils already in distribution at ARA are a blend of FAME and VLSFO (Very Low Sulfur Fuel Oil, an oil residue with a sulfur content of 0.5 mass%) with a ratio of 30 : 70 (commonly known as Bio-VLSFO), and a blend of FAME and MGO (abbreviation of Marine Gas Oil, indicates light oil) with a ratio of 30 : 70 (commonly called Bio-MGO or Bio-DMA). These fuels are termed B30. In Singapore, the biofuel already distributed is a blend of FAME and VLSFO with a ratio of 24 : 76, and is termed B24.

In this connection, do you know the supply price of the above-mentioned B30 bio-blend fuel oil? At the end of 2023, B30 was trading at a price more than about 1.5 times higher than that of VLSFO, and clearly lacked economic rationality, even

* Research Institute, Research and Development Division, ClassNK

though it is environmentally friendly. This suggests that the motivation for using this bio-blend fuel oil, in spite of its high cost, may be due to GHG emission regulations.

In particular, the emission trading system in the EU (EU-ETS) was also applied to the maritime industry beginning in January 2024, and requires verification of GHG emissions on voyages in which a ship calls on a port in the EU by an accredited verifier such as a ship classification society, etc., purchase of EU allowances (EUA) by the shipping company equivalent to those GHG emissions, and surrender (payment) of the EUAs to the Administering Authority. The penalties for non-conformance are severe; for example, if a shipping company forgets to report to the Administering Authority or otherwise fails to surrender the required amount of EUAs for 2 consecutive years or longer, it may be refused entry into ports in the EU/EEA member states [1].

To address this, one readily available method for reducing GHG emissions in order to meet these requirements is slow steaming (ship speed reduction) to reduce fuel consumption. Because fuel consumption is generally proportional to the square of speed, reducing a ship's speed by half will theoretically reduce fuel consumption to one-quarter. For this reason, many ships choose to operate slow steaming. However, it is difficult for the ships such as container carriers and car carriers to do this, because it is important to keep a set schedule. Therefore, the operators of these kinds of ships have expressed needs for bio-blend fuel oils, according to some surveys [2].

A Japanese version of the GHG emission trading system, GX-ETS, will begin in 2026, and in response, there are also expected to be domestic needs for bio-blend fuel oils in Japan.

3. PROPERTY CHARACTERISTICS OF BIO-BLEND FUEL OILS

When considering the use of bio-blend fuel oils as marine fuels, it is important to be aware of their characteristics. This chapter introduces the characteristics of the two base materials: biofuel oils, namely, their high pour point and easy oxidation (only for SVO and FAME), and VLSFO, specifically, the variations in physical properties of VLSFO, which is a petroleum-derived fuel [3] [4].

3.1 Characteristics of Biofuel Oils

As mentioned previously, biofuel oils are categorized as SVO, FAME, and HVO:

- SVO: Straight Vegetable Oil
  Mainly vegetable oil (includes UCO: Used Cooking Oil, i.e., waste cooking oil after use).
- FAME: Fatty Acid Methyl Ester
  Methyl ester-treated vegetable oil (produced by the reaction of SVO and methanol in the presence of an alkali catalyst).
- HVO: Hydrotreated Vegetable Oil
  Hydrotreated vegetable oil (produced by the reaction of SVO and hydrogen in the presence of a catalyst under high temperature and high pressure).

Fig. 1 shows photographs of these biofuel oil samples.

Although the mass of all the samples is the same (6 g), SVO has a smaller volume than the other two samples, and its color is also darker. By contrast, HVO has the largest volume and is almost colorless and transparent, while FAME has intermediate characteristics between the two. These characteristics of FAME are thought to occur because its molecular mass and density decrease due to methyl ester treatment in the production process, and as a result, its volume per unit mass increases in comparison with SVO, and its light transmittance increases in comparison with SVO because the impurities are removed in the treatment process. In the case of HVO, in addition to removal of impurities in the production process, the density of HVO decreases due to the smaller molecular mass and elimination of oxygen atoms by hydrogenation treatment, and as a result, its volume per unit mass is larger than that of FAME. The light transmittance of HVO is also increased by the elimination of unsaturated bonds in molecules by hydrogenation treatment, in addition to the removal of impurities by refining.

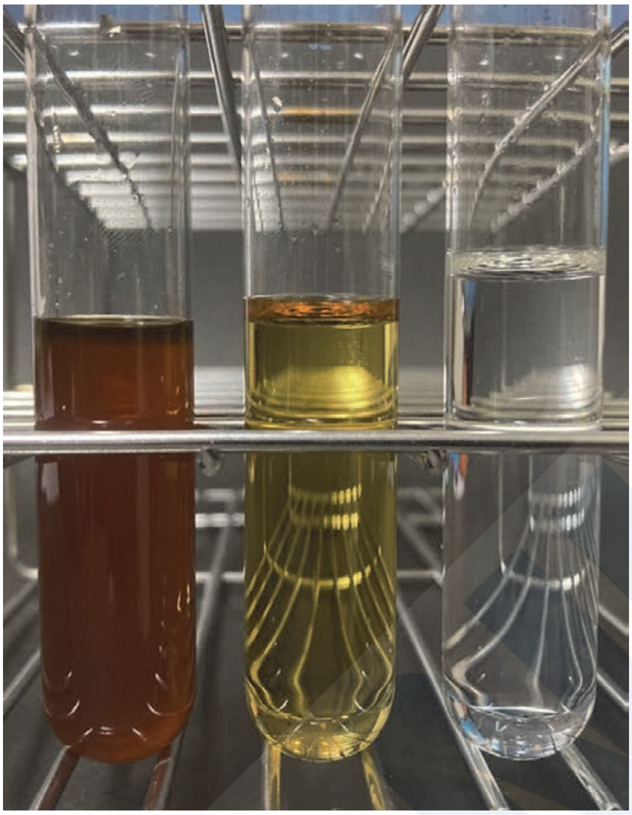


Fig. 1 Samples of biofuel oils
(all samples, 6g; from the left, SVO (UCO: Used Cooking Oil), FAME (UCOME: Used Cooking Oil Methyl Ester), and HVO)

Among these oils, HVO has properties similar to those of the distillate fuel oil such as MGO because the properties of vegetable oils (Oxygen atoms and unsaturated bonds in molecules) are eliminated by hydrogenation treatment.

On the other hand, SVO and FAME have a tendency to react readily with oxygen, which is a characteristic of vegetable oils. The easy oxidation of SVO and FAME is caused by the presence of carbon-carbon double bonds in their molecular structures. Therefore, if oxidation proceeds, lower fatty acids such as formic acid, acetic acid, etc. are eventually formed. Although these are weakly acidic, a corrosive environment for metals may form if they dissolve and concentrate in the drain water that accumulates at the bottom of a fuel tank. Additionally, both SVO and FAME are polar substances, and their polarity becomes stronger as oxidation proceeds. This polarity can cause swelling and strength reduction of nitrile rubber used in the seal parts of machinery.

In actuality, it may be possible to slow the oxidation reaction by adding an oxidation inhibitor (antioxidant) or mixing these biofuel oils with a petroleum-derived fuel. Nevertheless, when using SVO or FAME as a base material of the bio-blend fuel oil, the user should recognize the possibility that the above-mentioned phenomena may occur.

One characteristic related to all of these fuels, SVO, FAME and HVO, is low temperature fluidity. Although the fact that the molecular structures of SVO and FAME include carbon-carbon double bonds was noted above, if the oil contains few of the double bonds, oxidation tends to become more slowly, but the pour point (i.e., the temperature at which a substance loses its fluidity and solidifies) tends to become higher. The pour point of HVO will also increase if isomerization treatment to increase fluidity is not performed. Considering the possibility to lose its fluidity and solidify even at room temperature, users should be aware that the possibility of a high pour point is also a characteristic of bio-blend fuel oils.

3.2 Characteristics of VLSFO

Why introduce the characteristics of a petroleum-derived fuel? This is taken up here because the properties required in petroleum-derived fuels changed substantially as a result of strengthening of global regulations 4 years ago. In 2020, the regulations limiting the Sulphur content of marine fuels for ships were strengthened under the MARPOL Convention. To comply with those new regulations, many ships stopped using the High Sulfur Fuel Oil (HSFO; sulfur content: 3.5 mass%) until that time and began using VLSFO (sulfur content: 0.5 mass%).

Fig. 2 shows the property data for HSFO and VLSFO collected by the Society. It can be understood that the kinematic viscosity and density of VLSFO are significantly lower than those of HSFO. Fig. 3 shows the frequency distribution of each kinematic viscosity in Fig. 2.

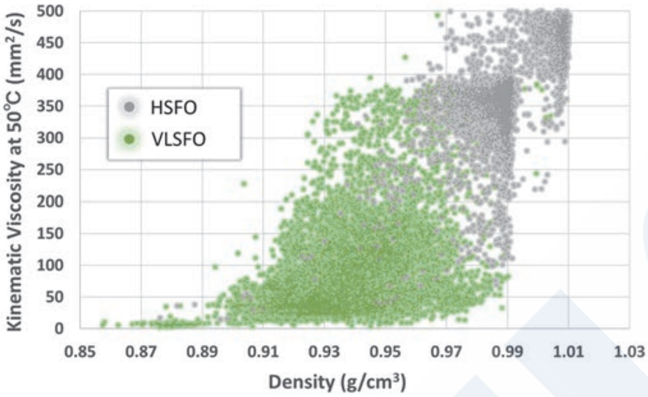


Fig. 2 Density-kinematic viscosity distribution of HSFO and VLSFO

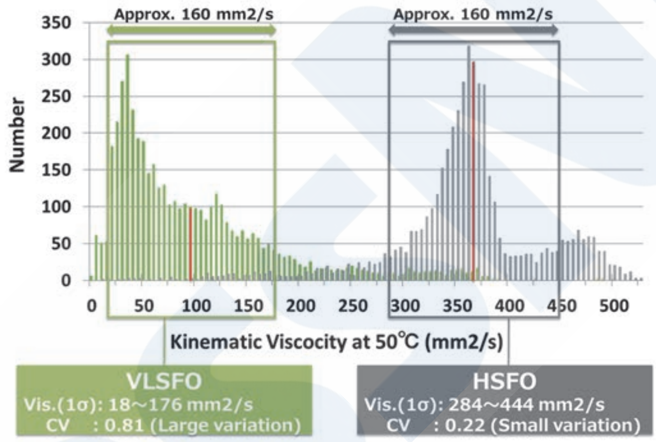


Fig. 3 Frequency distribution of each kinematic viscosity of HSFO and VLSFO

Approximately 70% of the kinematic viscosity values of both HSFO and VLSFO are distributed in a range of 160 mm^2/s, centering on the average value (this range represents ±1 standard deviation (±1σ) from the average). At a glance, there appears to be no difference in the variation. However, because the coefficient of variation (CV), which shows the variation of data, is 0.22 for HSFO but 0.81 for VLSFO, it can be understood that the variation of the kinematic viscosity of VLSFO is large. (In general, the value of CV is judged to be extremely large if the value exceeds 1.)

The variation of kinematic viscosity significantly impacts the work involved in operating a ship's machinery plant. ships have at least 4 heaters for fuel oil heating in the engine room, as well as piping trace heaters to maintain the fuel oil temperature in the fuel oil piping. The fuel oil is heated by maintaining a delicate heating balance of these multiple fuel oil heating devices. Because the temperature control of the individual devices is not linked, adjustments in the setting temperatures of the individual heater must be made by the crew. This is because of the complexity of the work, which includes trial-and-error adjustment of each of the heaters in order to find a new temperature balance when the heating temperature of the fuel oil changes significantly.

Marine heavy fuel oil must be heated to reduce its kinematic viscosity, which is too high to be used in ship's machinery plant. For example, the kinematic viscosity at the diesel engine inlet must be reduced to approximately 12 mm^2/s. Fig. 4 shows the heating temperature ranges for adjustment of HSFO and VLSFO to 12 mm^2/s for the kinematic viscosity range shown in Fig. 3.

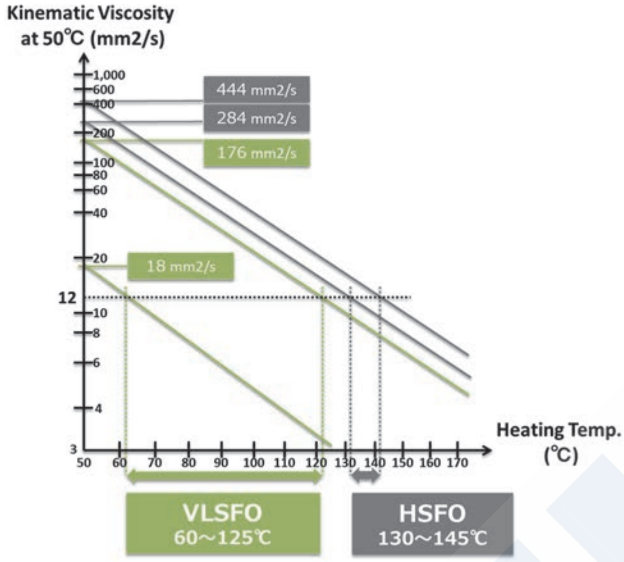


Fig. 4 Heating temperature ranges for HSFO and VLSFO

Although the heating temperature range of HSFO is narrow, at about 130 °C to 145 °C, the range for VLSFO is wide, from 60 °C to 125 °C. Thus, significant change in the heating temperature may be necessary when using VLSFO. Improper adjustment of the fuel oil heating temperature may result in problems in diesel engine operation due to abnormal combustion. Additionally, depending on the stability and pour point of VLSFO, asphaltene sludge may form in the fuel oil if heating is excessive, and wax sludge may form if heating is insufficient. If these types of sludge clog a filter, it will be impossible to adequately supply of fuel oil to the fuel consumption machineries, affecting its operation. Therefore, it is necessary to recognize that VLSFO requires careful temperature adjustment as one of its characteristic features.

4. MEASURES FOR USE OF BIO-BLEND FUEL OILS

Safety is the highest priority for ships. If a maritime accident occurs due to ship trouble, it not only endangers the lives of the seamen operating the ship, but also may have incalculable effects, such as marine pollution from an oil spill and disruption of maritime logistics due to the blockage of sea lanes.

To date, there have been no reports of trouble in actual ships using bio-blend fuel oils on a short- to medium-term basis. However, the risks of long-term use of the bio-blend fuel oils blended with SVO and FAME are unknown. Therefore, the following sections introduce responses for ship machinery for long-term use, measures for avoiding troublesome fuels, and measures for fuel storage and use [3].

4.1 Measures for Ship machinery

For long-term use of bio-blend fuel oils, the measures for each machinery consist mainly of countermeasures against the swelling of rubber and the corrosion of metals, which are characteristic problems mainly in the cases of SVO and FAME. The objects of these measures include seal parts made from nitrile rubber and metal parts in which a corrosive environment can occur. As measures for engines, boilers, purifiers, pumps, valves, filters and other machinery used to handle fuel oil, we recommend informing the respective manufacturers of the properties of the bio-blend fuel oil which the ship plans to use, the assumed fuel storage period, etc., and studying exchanges of parts and the length of the storage period based on the advice of the manufacturer concerned.

4.2 Measures for Avoiding Troublesome Fuels

The main measure for reducing the risk of using the fuel oils that may cause trouble is confirmation of fuel quality in accordance with ISO 8217, which is for conventional petroleum-derived fuel oils. If HVO which is equivalent to the distillate fuel oil such as MGO is used as a base material, conformance with ISO 8217 is considered sufficient. However, if SVO or FAME is to be used, in addition to conformance with the standard, it is also important to confirm the oxidation stability of the fuel, as the current ISO 8217 standard does not include provisions for evaluation of the ease of oxidation (oxidation stability). For this purpose, we recommend using the Rancimat method, which is specified in EN 14112, EN 15751, and other standards for automotive biofuels. In the Rancimat method, oxidation stability is evaluated by measuring the percentage of lower fatty acids generated in an aqueous solution by oxidation of SVO or FAME. If this test is performed a few days before bunkering, it may be possible to reduce the risk of purchasing bio-blend fuel oil that might cause problems, particularly when metal corrosion is a concern. Even if the above measures for machinery are considered sufficient, because machinery consists of metal components, this measure is important to minimize corrosion factors.

4.3 Measures for Fuel Storage and Use

During storage, oxidative degradation over time is unavoidable; that is, even assuming fuel oil of a certain quality is purchased, it will not maintain that quality permanently. This means it is important to consume bio-blend fuel oils in the short term. However, due to the operating conditions of ships, long-term storage may be unavoidable in some cases. Therefore, it is important to suppress oxidation during storage. According to Arrhenius's law, the rate of deterioration double when the storage temperature increases by 10 °C. For this reason, proper temperature control is recommended when using a bio-blend fuel oil containing the base materials such as SVO or FAME, which oxidize more easily than HVO, MGO, and VLSFO. The fuel oil heating temperature should not be excessive, as this will accelerate oxidation, and should not be reduced to the pour point to prevent solidification. (Another possible countermeasure to suppress oxidation is the addition of an oxidation inhibitor to the fuel oil.)

Suppression of microbial sludge is also important. Temperatures in the range of approximately 0 °C to 40 °C are a suitable environment for microorganisms, and if the three factors of temperature, a source of nutrition (hydrocarbons) and water are all present, mold, bacteria, yeast, actinomyces, and the like may propagate at the boundary between the fuel oil and water, resulting in the formation of slime-like or seaweed-like sludge. If this sludge blocks a fuel line filter, it will be impossible to provide an adequate supply of fuel oil to the oi consumption machinery. In addition, there is also a possibility that water in fuel tanks may create a corrosive environment for metals due to concentration of the water-soluble fatty acids formed by oxidation of SVO or FAME. Therefore, frequent removal of the drain water that accumulates at the bottom of fuel oil tanks in the engine room is recommended. (Another possible countermeasure for microbial sludge is the addition of a fungicide to the fuel oil to suppress microbial growth.)

4.4 Summary of Use Countermeasures

When using bio-blend fuel oil, it is important to pay attention to fuel oil temperature control, particularly as a countermeasure against variations in kinematic viscosity.

Moreover, because flow rate of fuel oil drain discharged from the various machinery is not large, there is a possibility that bio-blend fuel oil may accumulate in drain discharge lines for a long period of time, and forming a corrosive environment as oxidation proceeds. Since it is difficult to prevent this, we recommend checking the fuel oil drain lines of all machinery more carefully than before to enable early detection of corrosion.

5. CONCLUSION

The air transportation industry, like the maritime shipping industry, operates over long distances and is now studying SAF (Sustainable Aviation Fuel) using SVO as a raw material. Because both ships and aircraft have historically depended on oil fuels, which are easy to handle, liquid at ambient temperatures and pressures, and have high energy density, making the transition away from oil fuels not straightforward.

Although both bio-blend fuel oil and SAF are more expensive than petroleum-derived fuel oil and are expected to reduce GHG emissions, their supply is limited due to the availability of the raw material, SVO, making it difficult to secure the quantities needed by both industries. Consequently, the extent to which bio-blend fuel oils will be distributed in the maritime shipping industry remain uncertain. Furthermore, the primary motivation for using bio-blend fuel oil is international and regional regulations, and depending on the regulations and the price of bio-blend fuel oils, it may be more economically rational to bear the cost of purchasing GHG emissions allowances rather than reducing GHG emissions.

This potential conflict with the original intent of the regulations, which is to reduce GHG emissions, further contributes to the uncertainty in the distribution of bio-blend fuel oils.

Nevertheless, bio-blend fuel oils remain a limited means of reducing GHG emissions for the existing oil-fueled ships as well as new oil-fueled ships that will likely continue to be built for some time. Monitoring future regulatory developments and trends in the price of bio-blend fuel oils, advance preparations should be made envisioning long-term use, also assuming the possibility of full-scale distribution of bio-blend fuel oils.

REFERENCES

1) EU: FAQ – Maritime transport in EU Emissions Trading System, Sanctions and enforcement
2) Study Committee on Use of Biofuels in Ships, Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT): Results of Survey on the Possibility of Supplying Biofuels for Ships (Dec. 2023)
3) Nippon Kaiji Kyokai (ClassNK): Technical Guide for Using Biofuels (Dec. 2023)
4) T. Tokura et al.: Review of IMO 2020-Compliant Fuel Oil “VLSFO,” Symposium of the 93rd (2023) Marine Engineering Academic Conference (Japan Institute of Marine Engineering) (Sept. 2023)

ClassNK