MARINE FUEL OIL ADVISORY 2018

ABS

TABLE OF CONTENTS

INTRODUCTION

Ship-sourced emissions have received increased scrutiny from the International Maritime Organization (IMO), government environmental agencies, public health advocates and non-governmental environmental groups. The goal of these entities is to reduce ship emissions to improve air quality. Initial regulations have been geared toward reducing SOx and NOx emissions in areas where shipping crosses paths with people, such as coastal and port areas. The IMO's upcoming 2020 Global Sulfur Cap will expand emissions requirements further, tightening limits on SOx emissions in waters outside of coastal zones.

To comply with the various regulations, vessels will need to adopt different approaches to control emissions. SOx emissions are based on the level of sulfur content in the fuel used and can be controlled using low sulfur fuel oil or alternate technology such as an exhaust gas cleaning system. An additional benefit of reducing SOx emissions is a decrease in the levels of particulate matter (PM), a pollutant regulated by the U.S. Environmental Protection Agency (EPA). To control NOx emissions new ships, based on their construction date, are required to use Tier II compliant engines outside Emission Control Areas (ECAs) and Tier III compliant engines within ECAs. Where these emission limits cannot be met by the engine itself, using either exhaust gas recirculation (EGR) or selective catalytic reduction (SCR) technologies may be explored.

As the 2020 Global Sulfur Cap deadline for compliance approaches, it is vital that industry understands the available fuel options and the impacts on their fleets. This Advisory provides in-depth technical guidance covering a range of topics, from engine considerations to fuel properties to operational risks. Using this Advisory to understand the implications of different marine fuels, owners and operators can make smarter decisions on the future of their fleets.

BACKGROUND

The primary international regulatory mechanism for controlling ship emissions is IMO MARPOL Annex VI, Regulations for the Prevention of Air Pollution from Ships. The regulation limits fuels with a sulfur content of up to 0.10% to be used within the Emission Control Areas (ECAs) from 1 January 2015 and a sulfur content of up to 0.50% to be used globally from 1 January 2020. As defined in Regulation 2.9 of Annex VI, SOx emission controls apply to all fuel oil used in combustion equipment and devices onboard unless an approved exhaust gas cleaning system, such as a scrubber system, is installed. Alternatively, vessels may choose to utilize low sulfur content Marine Gas Oil (MGO) or 0.10% Heavy Fuel Oil (HFO) specifically developed for use in ECAs.

Most of the existing marine engines and other fuel burning equipment in operation were specifically designed to burn HFO or Marine Diesel Oil (MDO). Design modifications and operational adjustments may be necessary for engines and equipment to use alternative fuels. Appendix 1 and 2 contain additional information.

Fuels utilized by marine diesel engines are highly finished petroleum-based products combined with chemical additives. Many of the fuel and oil properties, such as specific energy content, ignition quality and specific gravity are related to the hydrocarbon composition. Complete and incomplete combustion of fuel in the diesel engine results in the formation of a complex mixture of gaseous and particulate exhaust. During combustion, sulfur compounds in the fuel are predominantly oxidized to sulfur dioxide (SO_2) and some sulfur trioxide (SO_3) commonly known as SOx.

PM is a complex mixture of extremely small particles and liquid droplets that consist of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. The PM that exists in the emission stream has been shown to affect the heart and lungs and cause serious health effects in exposed persons.

The amount of SOx and PM in the exhaust stream can be significantly reduced by burning cleaner, low sulfur fuel oils, e.g. Marine Gas Oil (MGO), and low sulfur (0.10%-0.50%) Heavy Fuel Oil. To achieve a reduction of SOx and PM in the environment, the use of low sulfur fuel will be mandatory globally in 2020 unless alternative technology such as an Exhaust Gas Cleaning System is being used. NOx compounds are not affected significantly by the type of fuel burned but they can be reduced by controlling the combustion process.

ABS first published a Fuel Switching Advisory Notice in March 2010, which was revised in 2014 with significant updates and new guidance to shipowners, operators and builders to identify the potential risks of fuel switching and best practices. This new Marine Fuel Oil Advisory has been developed considering the requirements of the upcoming IMO global sulfur cap 2020. The major components of the previous Fuel Switching Advisory were incorporated into this new document. This document will provide guidance to ship owners, operators and builders on different aspects of marine fuel oils, specifically addressing fuel specifications, quality, and key considerations prior to or during use. The information in this document will help industry comply with 2020 requirements.

SECTION 1 – INTERNATIONAL REQUIREMENTS

MARPOL Annex VI took effect on 19 May 2005. It represents worldwide acknowledgement that harmful emissions from ships should be decreased as the ability to do so develops. As a consequence, the IMO Marine Environment Protection Committee (MEPC) 58th Session in October 2008, adopted a Revised MARPOL Annex VI – Resolution MEPC.176(58), applicable from 1 July 2010. The revisions adopted include progressive reductions of SOx emissions from ships, progressive reductions of NOx emissions from marine engines and revised criteria for ECAs. As a result of the IMO's Marine Environment Protection Committee meeting held in October 2016 (MEPC 70), a marine fuel sulfur cap of 0.50% effective 1 January 2020 was confirmed. Under this global sulfur limit, ships will have to use marine fuels with a sulfur content of no more than 0.50% (the current limit is 3.5%) unless using approved equivalent methods under regulation 4.1 of MARPOL Annex VI, such as an exhaust gas cleaning system (EGCS).

Furthermore in the MEPC 72th session in April 2018, the committee approved amendments to regulation 14 of MARPOL Annex VI and the form of the Supplement to the IAPP Certificate concerning the prohibition of the carriage of non-compliant fuel oil for combustion purposes with a sulfur content exceeding 0.50%. This action was taken with a view to adoption at MEPC 73. Exemptions for ships equipped with an equivalent arrangement were also approved.

The Resolution provides controls specific to operation inside ECAs established to limit the emission of SOx and particulate matter (SECAs) and those applicable outside such areas and are primarily achieved by limiting the maximum sulfur content of the fuel oils used onboard. These fuel oil sulfur limits (expressed in terms of % m/m, that is by weight) are subject to a series of step changes over the years, as shown in Table 1 and Table 2.

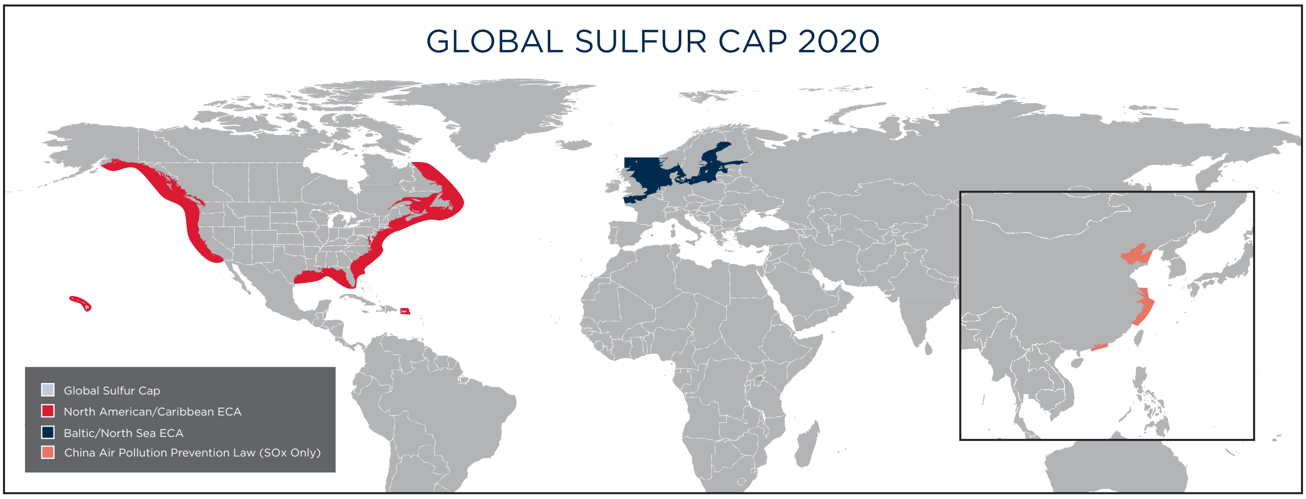

Table 1: MARPOL Annex VI, Regulation 14 – Global SOx Compliance Dates

Compliance Date	Sulfur Limit in Fuel (% m/m)
1 January 2000	4.5%
1 July 2012	3.5%
1 January 2020	0.50%

Table 2: MARPOL Annex VI, Regulation 14 – Emission Control Area Compliance Dates

Compliance Date	Sulfur Limit in Fuel (% m/m)
1 January 2000	1.5%
1 July 2012	1.0%
1 January 2015	0.10%

Note: There are currently two SOx Emission Control Areas (Baltic Sea and North Sea) and two designated Emission Control Areas (North American and US Caribbean Sea) which control both SOx and NOx.

SECAS AND ECAS

Regulation 14 of Annex VI contains provisions for nations to apply to the IMO for designation of special areas to further reduce harmful emissions from ships operating in their coastal waters. The first two ECAs approved by the IMO, known as SECAs, were the Baltic Sea and the North Sea (including the English Channel), as shown in Figure 1. The IMO then approved two more ECAs: the North American and US Caribbean Sea, as shown in Figure 2 and Figure 3 respectively. These ECAs include SOx emissions restrictions in addition to NOx Tier III emission restrictions. NOx Tier III emissions restriction was enforced from 1 January 2016 in these two ECAs. It should be noted that MARPOL Annex VI does not specifically limit PM but PM is reduced by regulating the sulfate portion of PM formation through the fuel sulfur content requirements of Regulation 14 to Annex VI.

During MEPC 71, the IMO adopted Resolution MEPC.286(71), amendments to MARPOL Annex VI, introducing two new NOx Emission Control Areas (ECAs). These two new NOx ECAs which were previously known as SECAs – the Baltic Sea and the North Sea – will be enforced for ships constructed (keel laying) on or after 1 January 2021, or existing ships which replace an engine with "non-identical" engines, or install an "additional" engine on or after that date.

The IMO Annex VI regulation 14, Special Areas are identified in Table 3.

Figure 1: Baltic and North Sea/English Channel ECA

Figure 2: The North American ECA 200 nautical miles offshore US and Canada, including Hawaii, St. Lawrence Waterway and the Great Lakes

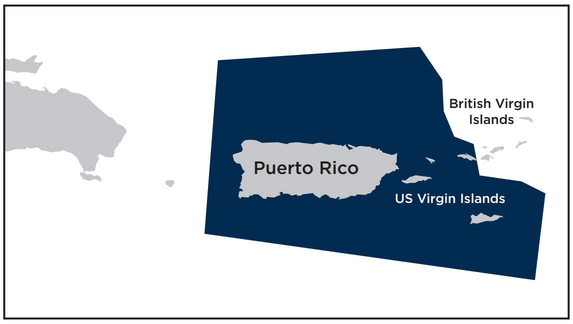

Figure 3: The United States Caribbean Sea ECA

Table 3: Annex VI Prevention of Air Pollution by Ships (Emission Control Areas)

Annex VI Special Area	Adopted	Entry into Force Date	Effective Date
Baltic Sea (SOx)	26 September 1997	19 May 2005	19 May 2006
North Sea (SOx)	22 July 2005 (Resolution MEPC.132(53))	22 November 2006	22 May 2007
North American (SOx and PM)	26 March 2010 (Resolution MEPC.190(60))	1 August 2011	1 August 2012
US Caribbean Sea (SOx and PM)	15 July 2011 (Resolution MEPC.202(62))	1 January 2013	1 January 2014

Beginning 1 January 2015, ships that operate in an ECA are required to use low sulfur fuel with a sulfur content no greater than 0.10%. To meet these requirements, vessels must use distillate fuel (e.g. MGO) or 0.10% Heavy Fuel Oil. Alternatively, ships can use higher sulfur HFO if operating with an approved exhaust gas cleaning system (EGCS) also known as a scrubber.

To satisfy the lower 0.10% sulfur content in ECA's, some vessels switch to lower sulfur fuels as the approach the area. In such cases, the ship shall carry on board a written procedure showing how the fuel oil changeover is to be accomplished, ensuring sufficient time will be allotted for the fuel system to be flushed of all noncompliant fuel prior to entering the ECA. The date, time and place of the fuel changeover and the volume of low sulfur fuel in each tank shall be logged when entering and leaving the ECA. The crew must be trained to carry out the fuel management and fuel switching procedure. An example Fuel Oil Management Plan template is included as Appendix 3.

BUNKER DELIVERY NOTES AND SAMPLING

Regulation 18, as revised by MEPC.176(58), with an effective date of 1 July 2010, contains the latest requirements for fuel oil availability and quality. It states that parties to MARPOL Annex VI shall take reasonable steps to promote the availability of fuels which comply with the Annex. In the event a compliant fuel oil cannot be obtained, Regulation 18 of MARPOL Annex VI currently provides that a Party to MARPOL Annex VI can request evidence outlining the attempts made to obtain the compliant fuel, including attempts made to locate alternative sources. When a ship is visiting a port where the operator cannot purchase compliant fuel oil due to non-availability, the operator is to notify the ship's Administration and the next destination port authority; the Administration shall notify IMO of the non-availability of compliant fuel oil. The Pollution Prevention and Response (PPR) Sub-committee and the Marine Environment Protection Committee (MEPC) are developing a standardized system for reporting fuel oil non-availability which may be used to record a ship's inability to obtain compliant fuel.

Vessels that are unable to find compliant low sulfur fuel oil prior to entering the North American ECA are required to file a report with the US Environmental Protection Agency (EPA) and authorities at the relevant destination port using the EPA's Fuel Oil Non-Availability Report (FONAR).

A vessel unable to obtain compliant low sulfur fuel oil prior to entering the Baltic and North Sea SECAs must provide evidence that it attempted to purchase compliant fuel oil in accordance with its voyage plan and that, despite best efforts, no such fuel oil was available. If a ship provides the above information, the competent authority shall take into account all relevant circumstances, and the evidence presented, to determine the appropriate action to take, including not taking control measures (see MEPC.1/Circ.637).


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Regulation 14 requires suppliers of any fuel intended for use in an ECA to document the sulfur content in accordance with Regulation 18. Lower sulfur content fuel shall be segregated from higher sulfur content fuel.

Paragraph 3 of the revised Regulation 18 gives specific requirements for the quality and contents of fuel oils. Per paragraphs 5 and 6, each ship shall receive and retain on board for three years a bunker delivery note from the fuel supplier containing the details of the fuel supplied. The form of the bunker delivery note shall follow the sample provided in Appendix V of the Revised MARPOL Annex VI which was revised and adopted in the 71th session of the IMO's Marine Environment Protection Committee. The Resolution MEPC. 286(71) amendments to the MARPOL Annex VI bunker delivery note (BDN) contains the supplier's declaration about the product not exceeding specific sulfur limits. Delivery notes should also be accompanied by product Material Safety Data Sheets (MSDS).

Per paragraphs 8.1 and 8.2 of Regulation 18, each bunker delivery note shall be accompanied by a representative sample of the fuel oil delivered. This sample is to be collected from the ship's bunker manifold, not the supply barge. The sample shall be sealed and signed by the supplier's representative and the Master or officer in charge of the bunker operation on completion of bunkering. It shall be retained under the ship's control for a period of not less than 12 months. It is necessary that oversight by the ship is applied both to the bunker delivery note and the representative fuel oil sample. When the bunker delivery note or the representative sample lacks information demonstrating compliance with the relevant requirements, documentation must be prepared for the ship's Flag State Administration and copies submitted to the bunkering port authorities and the bunker supplier, and a further copy retained onboard with any relevant commercial documentation (Resolution MEPC.181(59)).

If the stated sulfur content of the sample requires analysis, it shall be done in accordance with the verification procedure set forth in Appendix VI of the Revised MARPOL Annex VI. The analysis shall verify the sulfur content of the supplied fuel oil. Samples shall remain sealed until opened at the laboratory, which shall confirm chain of custody. A detailed sampling and verification procedure shall be followed by the laboratory.

SECTION 2 – REGIONAL, NATIONAL AND LOCAL REQUIREMENTS

In addition to regulations issued by the IMO, regions, countries and the State of California have implemented fuel content and emission regulations. These regulations will remain valid after 2020 IMO low sulfur enforcement.

The European Union (EU) and California Air Resources Board (CARB) have adopted regulations requiring the use of low sulfur marine fuels in designated areas. These regulations require owners to assess their operations within the affected regions and evaluate engine's and associated machinery/equipment's ability to operate with low sulfur fuel. It should be noted that both main and auxiliary boilers fall under the requirements of the EU Directive.

EU IN-PORT REGULATIONS

EU Commission Regulation Article 4b of the EU Council Directive 1999/32/EC, dated 26 April 1999, denotes a reduction in the sulfur content of certain liquid fuels and amends EU Directive 93/12/EEC. As amended, it introduces a 0.10 percent sulfur limit (m/m) for marine fuel at berth. The regulation was further amended with EU Directive 2005/33/EC dated 6 July 2005, effective date 1 January 2010, and then with EU Directive 2016/802/EU of 11 May 2016.

These directives apply to all types of marine fuel used by ships at berth for more than two hours in EU ports unless an approved emission abatement technology is employed or shore power is used. Vessels using boilers burning HFO or MDO to power steam-driven cargo pumps are impacted by the EU Directive and are required to burn low sulfur content fuel while in port.

EU COMMISSION RECOMMENDATION

As a result of information from shipowner associations reporting an inability to meet the EU in-port regulations due to the unavailability of parts required to modify engines, insufficient trained personnel to carry out the modifications, and the safety considerations associated with fuel switching for non-modified engines, the EU Commission issued a recommendation to EU Member States (2009/1020/EU) on the safe implementation of the use of low sulfur fuel by ships at berth in Community ports. The EU recommendation, dated 21 December 2009, urged that, when enforcing the requirement, Member States should consider the existence of detailed evidence of the steps taken by ships to achieve safe compliance with the Directive. The Member States may consider the existence of an approved retrofit plan when assessing penalties for noncomplying ships.

EU COMMISSION DECISION ON LNG CARRIERS

Recognizing that many liquefied natural gas (LNG) carriers use a mixture of boil off gas (BOG) and HFO, the Commission took action to allow such mixtures provided the resulting emissions of sulfur dioxide is demonstrated to be equal to or lower than required by the EU Directive. The Commission Decision 2010/769/EU, dated 13 December 2010, established a technological abatement method for LNG carriers to run on a mixture of boil-off gas and marine fuel while at berth as an alternative to use of low sulfur marine fuels meeting the requirements of Article 4b of the Council Directive 1999/32/EC, as amended by Directive 2016/802/EU. The calculation criteria for this alternative technological abatement method are set out in the Annex of the Commission Decision 2010/769/EU. Further in a letter to the European Community Shipowners' Associations (ECSA) dated 6 June 2014, the Commission clarified that provided *"the HFO pilot fuel used in the mixture has sulfur content in mass equal or lower than 0.50%, the requirements of Article 4c of the Directive are complied with and the abatement method in question shall be allowed in SECAs as an alternative compliance option with Directive 2012/33/EU."*

CALIFORNIA AIR RESOURCES BOARD (CARB) REGULATIONS

The California "Fuel Sulfur and Other Operation Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline" (also known as the Ocean Going Vessel (OGV) Fuel Regulation), in force since July 2009, was designed to provide significant air quality benefits by requiring the use of cleaner, low sulfur marine distillate fuel in ship main engines, auxiliary engines and auxiliary boilers. The OGV Fuel Regulation does not apply to propulsion boilers.

Amendments were made to align California's OGV Fuel requirements with the North American ECA, including the implementation of the 1.0% sulfur limit effective 1 August 2012. The original regulation required the use of 0.10 percent sulfur distillate fuel, beginning 1 January 2012, but was amended on 23 June 2011, extending the effective date for Phase II by two years, to 1 January 2014 (See Table 4 where DMA and DMB are marine distillate fuel designations).

Table 4: CARB Fuel Requirements for Ocean-Going Vessels (OGV)

Fuel Requirement	Effective Date	ARB's California OGV Fuel Requirement Sulfur Content Limit
Phase I	January 1, 2000	Marine Gas Oil (DMA) at or below 1.50% sulfur; or Marine Diesel Oil (DMB) at or below 0.50% sulfur
	August 1, 2012	Marine Gas Oil (DMA) at or below 1.0% sulfur; or Marine Diesel Oil (DMB) at or below 0.50% sulfur
Phase II	January 1, 2014	Marine Gas Oil (DMA) at or below 0.10% sulfur; or Marine Diesel Oil (DMB) at or below 0.10% sulfur

Operators must comply with both the California OGV Fuel Regulations and the North American ECA requirements. All engines and boilers, except main propulsion boilers, are affected by the above regulations and it is mandatory to operate engines and auxiliary boilers on low sulfur marine fuel with a sulfur content indicated in the respective regulations noted above.

Originally, all California waters within 24 nautical miles of the California baseline were affected by the OGV Fuel Regulation. Then, in June 2011, the regulatory boundary in Southern California was amended to also include the region 24 nautical miles from each of the Channel Islands. The boundary was also changed to align more closely with the California baseline denoted by the 2007 National Oceanic and Atmospheric Administration (NOAA) charts. The current restricted area is illustrated in Figure 4. Even though the California regulations allow use of MDO under both Phase I and Phase II, MDO is currently not available with sufficiently low sulfur content, and thus ships will effectively be using MGO to satisfy the low sulfur distillate fuel requirement during Phase II.

The CARB OGV Fuel regulations do not include provisions for the use of equivalent arrangements (i.e. EGCS/Scrubber) or the use of low sulfur residual fuels which includes 0.10% Heavy Fuel Oil known as ECA compliant fuel oil. In this regard, the CARB Marine Notice 2014-1, dated August 2014 authorized a temporary "Research Exemption" which was revised and ended on 31 December 2017 as per CARB Marine Notice 2017-1, dated August 2017.

CARB allows vessel to operate in California waters using only 0.10% sulfur distillate fuel oil. Using 0.10% Heavy Fuel Oil or scrubbers is prohibited and is not a compliance option under the California Oceangoing Vessel Fuel Regulations.

The CARB Marine Notice 2017-1 dated August 2017 provides an exemption for research projects which is very limited and only allows for the temporary use of noncomplying fuel (e.g. high sulfur Heavy Fuel Oil) when necessary for a research project. For example, a research project could involve the emissions testing of a new scrubber design with high sulfur fuel. Then the use of the scrubber with high sulfur fuel would only be allowed for the duration of the actual emissions testing. The vessel is required to use the low sulfur distillate fuel (even if the scrubber performed well) after completion of the test. It is to be noted that the research work will require rigorous emissions testing protocols, and a research report is to be provided to CARB which will be also available to the public.

To help ships avoid loss of propulsion from fuel switching and the accompanying potential of spilling oil from collision or grounding, the State of California Office of Spill Prevention and Response published a practical guideline for vessels intending to enter the

Figure 4: California's Ocean Going Vessel Regulatory Zone

Emission Control Area for the first time. According to the document, “Preventing Loss of Propulsion after Fuel Switch to Low Sulfur Distillate Fuel Oil,” the vessel’s crew should conduct a “trial” fuel switch by practicing a full switch to low sulfur distillate fuel within 45 days prior to entering regulated California waters for the first time. The vessel’s crew should also operate main and auxiliary engines no less than four (4) hours on low sulfur fuel oil. This will help crew members identify any specific change over operational issues or problems.

The guidelines also strongly advised the following be conducted 45 days prior to entry into regulated California waters:

- Operate main engine from the engine control room.
- Operate main engine from engine side (local).

Crew should become familiar with “Failure to Start” procedures while maneuvering and establish corrective protocols for “Failure to Start” incidents.

While underway, after fuel switching is completed, the Master should ensure one of the Senior Engine Room Officers is in the engine control room while the vessel sails through pilotage waters and is:

- Able to operate the main engine from the engine control room.
- Able to operate the main engine from engine side (Local).

Provisions for a safety exemption is included in California Code of Regulations, title 13, section 2299.2, subsection (c)(5), and title 17,section 93118.2, subsection (c)(5). The safety exemption provides the Master of the vessel with an exemption from the regulation in situations where compliance would endanger the safety of the vessel, its crew, its cargo or its passengers due to severe weather conditions, equipment failure, fuel contamination, or other extraordinary reasons beyond the Master’s reasonable control.

CALIFORNIA AT-BERTH OCEAN-GOING VESSELS REGULATION

California Code of Regulation (CCR), Section 93118.3 addresses Airborne Toxic Control Measures for Auxiliary Diesel Engines Operated on Ocean-Going Vessels (OGV) Berthed at a California Port.

The purpose is to reduce oxides of nitrogen (NOx) and diesel particulate matter (PM) emissions from the operation of auxiliary engines on container vessels, passenger vessels, and refrigerated cargo vessels while these vessels are docked at berth at a California port. The CCR mandates that any OGV (in addition to above three types) if equipped to use high voltage shore power then the vessel is required to perform ‘Cold Ironing’ while visiting any California port. This reduces emissions by limiting the time during which auxiliary diesel engines are operated on the regulated vessels while such vessels are docked at-berth in a California port. Vessels visiting terminals are permitted to use one or more control techniques including electric power from the utility grid, electrical power from sources that are not part of an utility’s electrical grid (distributed generation), or alternative control technologies that achieve equivalent emission reductions.

The California At-Berth OGV Regulation ultimately requires a fleet operator to reduce at-berth emissions from its vessels’ auxiliary engines. Fleet means a number of vessels owned/operated by an entity that visits a specific California port as per following criteria:

- A fleet composed solely of container or refrigerated cargo vessels that visits the same California port 25 times or more in a calendar year; and
- A fleet composed solely of passenger vessels that visits the same California port 5 times or more in a calendar year.

A reduced onboard power generation option was implemented from 1 January 2014 and the requirement changes to next levels on 1 January 2017 and 1 January 2020 respectively where ship operators’ are to use high voltage shore power to perform ‘Cold Ironing’. This reduced power generation includes percent of a fleet’s visit to a port and the percentage reduction of on board power generation from the fleet’s baseline power generation. Beginning 1 January 2017, this value became 70 percent and beginning 1 January 2020, it increases to 80 percent.

Table 5: California At-Berth OGV Regulation Compliance Schedule

Requirements	Percentage of fleet’s visits to port required to meet operational time limits	Percentage reduction of AE power generation from fleet’s baseline
2014	50%	50%
2017	70%	70%
2020	80%	80%

US EPA REGULATIONS

Air emission regulations in the US for marine applications are available at 40 CFR Parts 94, 1042 and 1043. The regulations in the Parts 94 and 1042 contain provisions that affect both engine manufacturers for NOx compliance where these engines installed on vessels reflagged to become U.S. vessels. The regulations in Part 1043 include MARPOL Annex VI regulations which are applicable to both U.S. and foreign flagged vessels. Table 2 of the Part 1043.60 specifically covers the fuel oil sulfur limits in accordance with the requirements of the regulation 14 of MARPOL Annex VI. Besides NOx and SOx limits, US CFR also limits hydrocarbons (HC), PM and carbon monoxide (CO) from the engine emissions which are primarily applicable for U.S. flagged vessels.

THE PEOPLE'S REPUBLIC OF CHINA REGULATIONS

China has also developed local air emissions regulations, the Marine Emission Control Area Plan, applicable to the Pearl River Delta, Yangtze River Delta and Bohai Rim Area (see Figure 5) under the "The People's Republic of China Air Pollution Prevention Law". The regulations apply to ships navigating, at berth and operating within the ECA that extend up to 12 nautical miles from the coastline. The special administrative regions, Hong Kong and Macau, are excluded from this Plan. Military vessels, sports boats and fishing vessels are exempt from this regulation.

Figure 5: China ECA

This regulation applies a phased date approach that initially focuses on the application of international requirements and the control of emissions from ships at berth for more than two hours. The use of alternatives such as shore power connections or EGCS is permitted. Emission control requirements include:

- Beginning January 1, 2018, ships at berth in all ports within the ECA are to use fuel with ≤0.50% sulfur content.
- Starting January 1, 2019, ships operating within the ECA are to use fuel with ≤0.50% sulfur content.
- Before December 31, 2019, an assessment of the effectiveness is to be made for the above-mentioned measures, and a decision will be made whether or not to conduct the actions below:
  - Ships operating within the ECA to use fuel with ≤0.10% sulfur content
  - Expand the ECA
  - Other further action
- Ships can use shore power connection, clean energy, exhaust after-treatment or take alternative equivalent measures for emission control.

HONG KONG SPECIAL ADMINISTRATIVE REGION OF THE PRC REGULATIONS

As of July 1, 2015, the Air Pollution Control (Ocean Going Vessels) (Fuel at Berth) Regulation, requires ocean-going vessels to use compliant fuels while berthing in Hong Kong. Compliant fuels, defined by the regulation, are marine fuels with a sulfur content of ≤0.50%, liquefied natural gas and any other fuels approved by the air pollution control authority.

The Regulation requires vessels to:

- Switch to compliant fuel within one hour of arriving at their berth and burn compliant fuel until one hour prior to departure
- Record dates and times of vessel's arrival, departure and of commencement and completion of fuel change-over operations as soon as practicable after each occurrence
- Keep records onboard the vessel for a period of at least three years, readily available for inspection at all reasonable times

Approved technologies such as SOx EGCS may be used subject to their capability of achieving a reduction of sulfur dioxide, which could be considered at least as effective as the use of low-sulfur marine fuel. Ocean going vessels installed with such approved technologies may be exempt from switching to one of the compliant fuels. Written applications for exemptions on the basis of the use of approved technologies must be made to the authorities at least 14 days before the date on which the vessel intends to make its first exempted call at Hong Kong.

Additional information may be obtained from "Air Pollution Control (Ocean Going Vessels) (Fuel at Berth) Regulation" Chapter 311AA, gazette Number E.R. 2 of 2015.

SECTION 3 – MARINE FUELS

There are internationally recognized standards that define key characteristics of fuel oils and their components denoting suitability for use on board ships. However, there are important considerations that may not be covered in these standards.

FUEL STANDARDS

The most widely used fuel standard in marine industry is ISO 8217 with the latest edition issued in 2017. Other existing standards are the Europe-based International Council on Combustion Engines (CIMAC), the British Standard BS6843-1:1996 and the American Society for Testing and Materials (ASTM) D-975. Frequently, vessels are designed to use fuel from a specific designation of one of the standards, usually from ISO 8217.

However, the current edition of ISO 8217 does not include requirements for 0.10% Heavy Fuel Oil, commonly known as ECA fuel.

The ISO 8217 standard specifies the requirements of fuels for use in marine diesel engines, boilers and stationary diesel engines for marine applications. It specifies seven categories of distillate fuels and six categories of residual fuels. The ISO defines fuel as hydrocarbons from petroleum crude oil, oil sands and shale, synthetic or renewable sources, similar in composition to petroleum distillate fuels including blends of some distillate fuel with the fatty acid methyl ester (FAME) component as permitted. ISO 8217 provides the detailed specifications of distillate (DM) grades, distillate FAME (DF) grades and also residual (RM) grade marine fuel oils.

The current ISO 8217:2017 (Sixth edition), with the addition of a new class of distillates FAME (DF) allowing for bio-fuel blends, introduced a new reporting requirement on cold flow properties for winter grade distillates (cloud point and cold filter plugging point), and a change of the scope to allow for inclusion of hydrocarbons from synthetic or renewable sources. Also, there are substantial amendments to the general requirements where sulfur limits were reduced for several distillate grades and a number of informative annexes (i.e. sulfur content, flash point, catalyst fines and precision and interpretation of test results) were deleted; however the key information is available within the body of the document and in referenced industry publications.

A revised ISO 8217 standard will not be issued prior to 2020. However, it is likely that the ISO 8217 technical committee (ISO TC28/SC4/WG6) will provide an interim solution by publishing a publicly available specification (PAS) in early 2019. Such a PAS, which is an intermediate specification published prior to a full International Standard, would be valid for up to three years, after which it may be extended for up to another three years or withdrawn. The PAS, or elements of it, could be adopted as part of the next full ISO 8217 revision. It is expected that the PAS requirements will be developed such that they maintain consistency between the ISO standard and implementation of the 0.50% sulfur limit.

At present no universally accepted standard has been developed to define the properties of the 0.50% Heavy Fuel Oil. Furthermore, it is anticipated that in addition to the oil majors, regional suppliers will emerge to supply the market needs, potentially creating fuel oil which vary between suppliers. They may be based on Vacuum Gas Oil (VGO), or blends incorporating various heavy and light refinery product streams, including residual fuel oils and middle distillates. A future edition of ISO 8217 is expected to provide marine fuel producers with a standard fuel specification.

The distillate fuels are categorized as DMX, DMA, DFA, DMZ, DFZ, DMB and DFB while residual fuels are characterized as RMA, RMB, RMD, RME, RMG and RMK. The ISO 8217 standard covers the fuel characteristics limits of viscosity, density, cetane index/CCAI, sulfur, flash point, hydrogen sulfide, acid number, total sediment, carbon residue, cloud point, pour point, cold filter plugging point, appearance, water, ash, lubricity, vanadium, sodium, aluminium plus silicon (cat fine), calcium and zinc. Most of these characteristics are

applicable for both type of oils, except a few are applicable either for distillate or residual fuels as denoted in Table 1 and 2 of ISO 8217.

FUEL TYPES

The new restrictions on sulfur content determine the types of fuels that can be used on ships, and thus it is helpful to understand the maximum/minimum values and typical ranges of sulfur content and viscosity for the standard fuels used on ships. Typical data is given in Table 6.

Table 6: Typical Parameters of Marine Fuel

Fuel Types	ISO Category	Viscosity (cSt) (at 50°C for Residual and 40°C for Distillate Fuels)		Sulfur Content (%)
		Minimum	Maximum	
Heavy Fuel Oil (HFO)	Residual (RMA – RMK)*	10	700	1.0 – 3.5
Marine Diesel Oil (MDO)	Distillate (DMB)	2	11	0.10 – 1.5
Marine Gas Oil (MGO, Low Sulfur Distillate Fuel)	Distillate (DMA and DMZ)	2	4	0.10 – 1.0
0.10% Heavy Fuel Oil (HFO, ECA Fuel)	Not standardized	9	67	0.10
0.50% Heavy Fuel Oil (HFO, Global Fuel)	Not standardized	No requirements defined	No requirements defined	0.50

*RMA-RMK: RMA, RMB, RMD, RME, RMG and RMK

MARINE GAS OIL (LOW SULFUR DISTILLATE FUEL)

Distillate fuels are components of crude oil that evaporate in fractional distillation and are then condensed into liquid fractions. Marine Gas Oil (MGO) describes marine fuels that consist exclusively of distillates and falls within the DMA category. Marine Gas Oil usually consists of a blend of various distillates. Marine Gas Oil is similar to diesel fuel, but has a higher density. MGO is based on the lighter distillates and has a low viscosity so as to operate at a controlled temperature. Emissions from MGO contains significantly less particulate matter and soot as well as possessing low sulfur emissions.

Marine Diesel Oil (MDO) is generally composed of various blends of distillates and a small portion of Heavy Fuel Oil which falls within the DMB category. Diesel is a middle distillate and a predominantly mineral fuel but MDO is similar to diesel fuel with a higher density. Unlike Heavy Fuel Oil, Marine Diesel Oil does not have to be heated during storage. The different blending ratios of Marine Diesel Oil can be controlled directly by processes in the refinery or by blending ready-made marine fuels.

Distillate fuels are produced with varying degrees of sulfur content, though the maximum permissible sulfur content of MGO lies below that of Heavy Fuel Oil. The DMA category has a maximum sulfur limit of 1.0% but 0.10% sulfur content MGO is available for marine use. The DMB category has a maximum sulfur limit of 1.5% but ranging between 0.10%-1.5% sulfur content MDO is available for marine use.

0.10% HEAVY FUEL OIL (ECA FUEL)

Various marine fuel suppliers have developed new low sulfur fuel oils which are specially designed to help marine operators comply with 0.10% sulfur limits. These new fuel oils contain low sulfur like MGO but have a higher flash point and viscosity. These are known as 0.10% Heavy Fuel Oil or ECA fuel oils or hybrid fuel oils. Examples of these fuels are listed in Table 7.

Table 7: 0.10% Heavy Fuel Oil

	Shell ULSFO	ExxonMobil HDME 50	ExxonMobil AFME 200	LUKOIL	CEP SA	BP	Phillips 66
Density (kg/m³)	790-910	900-915	917	886	868	845.4	855.2
Viscosity (cSt)	10-60	30-45	67	16	8.8	8.8	8.6
Micro Carbon (MCR) (mass %)	2	<0.30	<10	0.1	0.1	0.1	0.04
Sulfur (mass %)	<0.1	<0.10	<0.10	0.07	0.05	0.03	0.06
Pour Point (deg. C)	18	6-12	6-15	18	-12	21	-12
Flash Point (deg. C)	>60	<70	<70	165	72	>70	79
Water (vol. %)	0.05	0.05	<0.5	0.05	0.004	0.01	0
Acid Number (mg KOH/g)	<0.5	<0.1	<0.1	0.5	0.27	0.04	NA
Vanadium (mg/kg)	2	<1	1	1	NA	<1	<0.10
Al+Si (mg/kg)	12-20	<5	<10	2	NA	<1	2
Lubricity (microns)	NA	<320	NA	270	410	326	NA
CCAI	800	795-810	799	793	NA	765	NA

These fuels simplify fuel changeover procedures necessary to enter areas with emissions control requirements and eliminate the need to install a cooler or chiller. However, new ECA low sulfur fuels have not yet been categorized according to ISO 8217, therefore before use the ship operator should consult the engine manufacturer to ensure use of these fuels will not affect the engine warranty. A vessel owner may request certification or confirmation from the engine manufacturer or fuel supplier that these fuels can be used. Some of these new fuels have a high pour point and, in low ambient temperatures, wax crystals might form. Since these fuels are highly paraffinic, compatibility with existing bunkers needs to be considered.

0.50% HEAVY FUEL OIL (GLOBAL FUEL)

With the implementation in 2020 of the global 0.50% sulfur cap requirement for marine fuels, there is an anticipated surge in demand for low sulfur RM (residual) and DM (distillate) type fuels coming into the market. In addition, it is expected that ships may be required to manage different fuel formations based on fuel availability in different geographic locations. As a result, it is anticipated that a wide mix of different types of fuels will be used to meet the new 0.50% sulfur cap.

The sulfur content of crude oil varies significantly in different parts of the world, ranging from 0.1% to 4.1%. The translation of sulfur content in crude to residual bunker fuel in general ranges from a factor of 2 to 3 which means a light sweet crude having a minimum sulfur content of 0.4% would translate to a residual bunker fuel sulfur content of minimum 0.8% to 1.3%. Hence to meet the IMO regulations the refiners have to either treat the fuel or blend it with ultra-low sulfur fuel oil. Other options to obtain a 0.50% sulfur content fuel include blending with hydro-treated residuals, heavy fractions from hydro-crackers and lighter hydro-treated fractions.

SECTION 4 – 2020 FUEL CONSIDERATIONS AND IMPACT ON OPERATIONS

COMPLIANCE OPTIONS

The regulations outlined in Sections 1 and 2 offer multiple pathways for compliance with the global 2020 requirements. These choices allow the vessel operator to address the requirement though either fuel selection or sulfur mitigation technologies. The options are:

a) Marine Gas Oil (Low Sulfur Distillate Fuel)

b) 0.10% Heavy Fuel Oil (ECA Fuel)

c) 0.50% Heavy Fuel Oil (Global Fuel) (may be blended, specification not known)

d) Exhaust Gas Cleaning System (EGCS) with Heavy Fuel Oil

e) LNG

f) Alternative fuels e.g. LPG, ethane, methanol, CNG, bio-fuel, solar power and fuel cells

Options with 0.10% sulfur are most applicable for the vessels which will be operated near ECAs and with frequent transitions into and out of ECA areas, in order to avoid frequent fuel switchover.

Additional alternate fuels such as those listed in options e) and f) have limitations. LNG fuel can help ship owners and operators meet emissions regulations for both carbon and sulfur, but has high capital cost and requires supporting bunkering infrastructure.

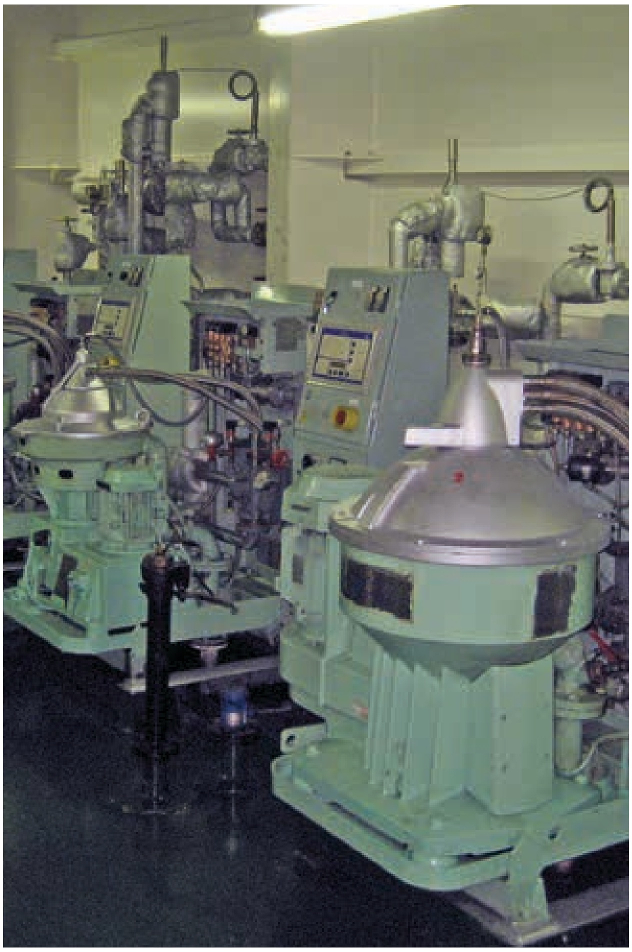
Based on the above, it is anticipated that a majority of the world fleet operating outside ECAs will operate on 0.50% sulfur fuel oil. With existing fuel available, some vessels will operate on high-sulfur HFO and remove the SOx by using an EGCS.

KEY CONSIDERATIONS OF 0.50% HEAVY FUEL OIL

Compatibility: While each individual fuel oil should be delivered as a stable product, compatibility of one fuel oil with another cannot be readily predicted without testing. Generally, fuels of the same viscosity grade with similar densities are likely to be compatible; however, it is advised to avoid mixing fuel from different sources or to mix Heavy Fuel Oil with Distillate Fuel Oil. Also, instability can be introduced during the blending process and as a result of commingling incompatible bunkers on board vessels. Vessel owners should prepare for increased bunker segregation in line with standard procedures to minimize the associated risks and work closely with their bunker suppliers to purchase compatible fuels.

The experience from the establishment of ECAs indicates that proper ship machinery operations should be sufficiently capable of addressing the concerns regarding combustion of the 0.50% Heavy Fuel Oil.

These fuels are expected to be more aligned with currently available low sulfur Heavy Fuel Oil, having a lower viscosity than the existing heavy fuel oil grades. There may however be increased stability and compatibility risks if not handled correctly. Clear knowledge of the ordered product will assist the crew in carrying out the necessary adjustments to the fuel system set up for safe storage, handling, effective treatment and use of the fuels on board.



Precautions should be taken by ship crews to minimize incompatibility by avoiding mixing bunker fuels from different sources, choosing a fuel with similar viscosity and density, and avoiding the mixing of low sulfur Heavy Fuel Oil with distillate fuel oil. When bunkering a compliant fuel, the operator needs to ensure it is going into a clean tank. If two fuels are incompatible then the mixing will have asphaltenic material suspension from previous fuel which will be precipitated as sludge with a tendency to heavily load the fuel oil filters therefore reducing the rate of fuel flow.

Overall, the new 0.50% sulfur limit creates higher risks of fuel incompatibility as more blended fuels are introduced.

Stability: Fuel oils are produced on the basis of widely varying crude oils and refinery processes. There is a potential for a fuel to change conditions in storage in certain circumstances. Bulk fuel stored for long periods can become unstable because the asphaltenes can precipitate out of solution, causing the formation of sludge. The 'break up' is dependent on the nature of the liquid hydrocarbons in which the asphaltenes are suspended. Once a fuel has chemically broken down there is no way to satisfactorily reverse the process. Precipitated asphaltenes cannot be redissolved.

Cat fines: These are created as a result of catalytic cracking during the crude oil refining process, during which tiny fragments of the catalyst material become entrained in the refined and residue products. These cat fines are typically a combination of aluminum and silicon and are very hard, abrasive particles, capable of causing severe wear to engines. The size of cat fines varies generally from sub-micron up to about 30 microns. The typical acceptable cat fines limit rages from 7 to 15mg/kg depending on engine manufacturers' recommendation.

Cat fines exist in fuel oil even after being purified and conditioned, and are the cause of gradual engine wear. However, if excessive amounts of cat fines are introduced into the engine, they can cause significant damage to sensitive engine components such as fuel pumps and fuel injection valves as well as cylinder liners and piston rings. Ultimately cat fines can cause significant damage or even total failure of the engine.

The extent of these entrained cat fines is regulated through the fuel oil standards which identify the maximum amount (PPM or mg/kg of silicon and aluminum) allowed in the fuel oil. For example, in the sixth edition of ISO 8217:2017, the maximum amount of combined silicon and aluminum in RMG heavy fuel oil is not to exceed 60 mg/kg. Furthermore, HFO typically has a combined silicon and aluminium concentration of around 30 mg/kg. ISO 8217:2010 reduced the limit values of cat fines to a level that ensures a minimal risk of abrasive wear assuming adequate fuel pre-treatment by maintaining the centrifugal purifier inlet temperature at a constant value, usually 95-98 degrees Celsius and assuming the fuel-cleaning system (tanks, centrifugal and filters) operate under optimum conditions. Moreover, appropriate fuel temperature should be maintained in the settling tank to aid settling and water content removal. Settling tanks are to drain at regular intervals throughout the period of operation using high cat fine content fuel. Cat fines are to be reduced as much as possible by the fuel centrifuge and, as a guideline, the level should not exceed 15 mg/kg after the centrifuge.

Consequently, even though the expected 0.50% Heavy Fuel Oil will fall within ISO 8217 specifications, efficient fuel pre-treatment is important in order to limit cat fines.

Combustion Characteristics: The ignition characteristic of a residual fuel is determined by the Calculated Carbon Aromaticity Index (CCAI) specified in ISO 8217. The CCAI is an indication of ignition performance in order to avoid fuels with an uncharacteristic density-viscosity relationship. The ignition and combustion characteristics of a residual fuel in a diesel engine is dependent on the particular type, design, operating and engine condition, load profile and the chemical properties of the fuel oil. In engine applications where the ignition quality is particularly critical, a basis for suppliers and purchasers of residual fuels to agree on tighter ignition quality characteristics. While residual fuels blending at or close to the maximum density, the CCAI limit can restrict the combination of density and viscosity.

The CCAI is determined from the density and viscosity of a residual fuel and while it does not provide information related to the combustion characteristics of residual fuel, it does provide an indication of the ignition delay. CCAI has been included in order to avoid residual fuel oils with uncharacteristic density viscosity relationships, which can lead to an extended ignition delay. New fuels should have their CCAI verified in line with the pending ISO PAS specifications.

Density: Density is related to the fuel quality because fuels derived from extensive refinery processing are left with a higher carbon content, are more aromatic and thus heavier. Therefore, fuels with a high density are also high in carbon residue and asphaltenes. It is expected that the 0.50% Heavy fuel Oil density will be as per the pending ISO PAS specification.

Flash Point: The flash point limit is set as a safeguard against fire. SOLAS and ISO 8217 requires a fuel flash point not less than 60 deg. C and minimum flash point of any fuel carried in the tanks of a ship should maintain this limit. There is no permissible negative tolerance. This applies to any fuel onboard the vessel with an exception of fuel for lifeboats which can be distillate DMX grade with a flash point min of 43 deg.C. We know the current 0.10% Heavy Fuel Oil (also known as ECA fuel) offered by different oil companies are maintaining flash point limit as per ISO 8217 specifications even though these fuels do not fall within any standard. It is expected that flash point of new fuels will be not less than 60 degrees Celsius as per current SOLAS limit and also mentioned in ISO 8217.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Pour Point: The pour point indicates the minimum temperature at which the fuel should be stored and pumped. Temperatures below the pour point results in wax formation. Some of the hybrid/blended 0.10% Heavy Fuel Oil has relatively higher pour point and need to keep heated to avoid wax formation.

Viscosity: Viscosity is a measure of the fluidity of the product at a certain temperature. The viscosity of a fuel decreases with increasing temperature. The viscosity at the moment the fuel leaves the injectors must be within the limits prescribed by the engine manufacturer to obtain an optimal spray pattern. Viscosity outside manufacturers' specifications at the injectors will lead to poor combustion, deposit formation and energy loss. The viscosity of the fuel must be such that the required injection viscosity can be reached by the ship's preheating system.

For heavy fuels with high viscosity, the required operating viscosity is achieved by heating the fuel to lower the viscosity. For distillate fuels, the fuel at ambient temperature normally has a viscosity within the specified limits. Low sulfur fuels tend to have viscosities near or at the lower limits of allowed viscosity. Considering the increased fuel temperature at the injection pumps, the main concern is that the fuel viscosity may fall below the lower allowable limit. Since low sulfur distillate fuels have viscosities close to the permitted minimums, the temperature of the fuel needs to be controlled. The viscosity is not considered as a major concern for the 0.50% Heavy Fuel Oil which is expected to be a heated fuel oil with relatively higher viscosity.

Tank cleaning: This is very important and key to avoid compatibility and stability issues while transitioning to 0.50% Heavy Fuel Oil (Global Fuel) from Heavy Fuel Oil (HFO). There is a high risk of undetected residue of non-compliant fuels remaining in tanks when switching from a HFO to a Global Fuel. If there is a fraction of the HFO left in the tank then it will contaminate the new product and will become non-compliant. Therefore, the tank and piping system should be fully flushed, clearing out all last remnants of HFO before filling it with a lower sulfur fuel. This cleaning process takes time and cannot be carried out while the ship is in operation. Many shipowners or operators are not aware of the risks associated with residual fuel contamination, and are unlikely to choose this method due to economic and time constraints. However, appropriate tank cleaning is a must to avoid noncompliance and keep equipment running efficiently.

Sampling: When bunkering, a sample blend can be tested to ensure the fuel mix is compatible. This can be performed through sediment or spot testing. The sediment test is generally carried out in the fuel testing laboratory while the simple spot test is conducted onboard.

Table 8: Summary of the items to consider based on the different fuel types

Fuel Issue	Heavy Fuel Oil (Residual)	Marine Gas Oil (Distillate)	0.10% Heavy Fuel Oil (ECA Fuel)	0.50% Heavy Fuel Oil (Global Fuel)
Incompatibility	None	None; Fuel must however be segregated from HFO and follow appropriate fuel changeover procedures	None	Attention needed as specifications may differ based on the geographical locations
Instability	None	None	Possible	Attention needed when fuels are mixed
Cat FInes	Limits defined in ISO 8217	Limits defined in ISO 8217	Possible; does not fall within ISO 8217	Possible; risks if Cat fines more than ISO 8217 unless same will be specified in the pending ISO Publicly Available Standard for 0.50% sulfur fuel oil
Combustion Characteristics	Exists as per ISO 8217	Addressed under Cetane index within ISO 8217	Calculated Carbon Aromaticity Index varies; generally below HFO; Not yet standardized by ISO 8217	If Calculated Carbon Aromaticity Index varies too much may give poor ignition performance
Flash Point	Exists as per ISO 8217	Exists as per ISO 8217	Mostly falls within ISO 8217 specifications; not yet standardized	Possible; risks if flash point goes below 60 deg. C and not verified after blending by supplier
Pour Point	Exists as per ISO 8217	Exists as per ISO 8217	Mostly falls within ISO 8217 specifications; not yet standardized	Possible; risks if pour point is too high and not verified after blending by supplier

OPERATIONAL CHALLENGES OF 2020 SULFUR CAP

The change from high sulfur fuels to 0.50% Heavy Fuel Oil in order to meet the global sulfur limits is significant. The following are operational challenges and items to consider associated with achieving compliance:

- Segregation of fuel oil tanks with integral piping systems will be necessary. Attention will be needed to avoid cross contamination, with an increased awareness of the fuel being used and the associated implications.
- New fuels will depend on local refinery configurations; the quality of which may vary considerably on a regional basis until specific guidelines/standards are provided by ISO. In order to avoid incompatibility, fuels from different suppliers should be kept separate and not mixed without testing.
- Blended fuel oil may be more paraffinic and may pose an increased risk of incompatibility with conventional residual fuels. Viscosity of the new fuels is expected to be lower than conventional residual fuel grades such as RMG or RMK, but higher than DMA or MGO.
- Density of new fuels is expected to be lower than conventional residual fuels; as a result centrifuges will require readjustment or recalibration.
- New fuels may require heating for delivery purposes and may need to be kept in heated tanks. If the Pour point is high and fuels are not heated, there is a potential for wax formation.
- The new fuels should be processed in a similar way as a Heavy Fuel Oil, purified prior to use in main and auxiliary engines. Purifiers should be correctly set up for the viscosity of the new fuel with care taken when comingling new fuel with Heavy Fuel Oil to avoid any issues that may occur due to the cleaning effect on any residues in the settling and service tanks.
- When the fuel starts to feed through the fuel service system, additional back-flushing of the fuel auto-filter can be expected because of the cleaning effect. Careful monitoring of all fuel filters is recommended.

- A vessel with only one settling tank should consider stopping the purifier and draining any remaining oil to the overflow tank before refilling with 0.50% Heavy Fuel Oil. Ships with two settling tanks and two service tanks will have greater flexibility and the option of cleaning tanks or draining, opening and inspecting before filling.
- The fuel should be heated to the appropriate temperature to achieve the correct injection viscosity according to the engine builder guidelines.
- The fuel temperature at the main engine and auxiliary engines can be lower than at the purifiers. A temperature of 75°C will enable sufficient lubricity. It is not recommended to allow excessive heating at the main engine as lubricity may be reduced. The temperature in the system should not be allowed to drop below 70°C or as recommended by the OEM and fuel supplier.
- When 0.50% Heavy Fuel Oil is to be used in an auxiliary boiler burner, the low fuel temperature trip may need to be adjusted to suit the lower temperature requirement for the new fuel. The temperature setting for the fuel heater should be reduced as per the OEM and fuel supplier recommendation.
- Two stroke engines should use cylinder lube oil of low BN (15 to 40) when operating on these low sulfur fuels. Even for four stroke engines for long term operation, the system oil BN should be lower. Operators should follow their OEM recommended guidelines for the appropriate lubricants to be used with their engines.
- The 0.50% HFO fuels may not fit into current Table 1 or Table 2 of ISO 8217, but expected that ISO will provide Publicly Available Specification (PAS) a standard which is under development in coordination with other stakeholders to address this new fuel specification.
- While writing the fuel clause in the Charter Party and also with Insurance agencies, full information on the fuel should be provided to avoid any dispute.
- The specific technical and operational challenges of the fuel have to be clearly addressed and advice obtained from OEM to ensure safe and problem free operation.
- Most ships should have addressed the concerns earlier outlined through increasing the awareness of the crews through training and practice.
- In addition a risk assessment should be conducted which will identify additional measures such as increased frequency of maintenance checks, reduced service life estimates and other such steps.
- In line with good practice, the impact should be assessed for each vessel. In particular, the engine manuals should be consulted regarding any restrictions associated with engine operating parameters

OWNER AND OPERATOR PREPARATIONS FOR 2020

- Work with fuel suppliers prior to 2020 to ensure fuel type and specification so the vessel will be suitable to use compliant fuel in time.
- Prepare to enter 'term contracts' rather than 'spot contracts', particularly in the period just after 01 January 2020.
- Develop onboard plans for fuel segregation, mixing and compatibility testing as there will be increased levels of compatibility issues between fuels.
- Create a transition plan, both shore side and onboard so that the transition goes smoothly.
- Plan for tank cleaning and contract tank cleaning services.
- Prepare budget considering increased capital and operating expenses.

IMPACT ON SHIP DESIGN

Meeting the requirements for sustained operation on low sulfur, low viscosity fuels will have two major impacts on the design of ships, in addition to impacts on the engines and boilers themselves. One is on the required storage capacity of low sulfur fuel and the other is on the fuel piping system and equipment to segregate and handle different types of fuels with different viscosities, densities and handling temperatures. New ships can be designed specifically to incorporate the required features. Table 9 shows the fuel tankage arrangements recently provided for various ship types. However, based on geographical trading pattern emission requirements may apply to many ships including existing ships that require modifications as well.

Table 9: Fuel Tankage Arrangement

Ship Type/Size	HFO		LSHFO		MDO/MGO		LNG Fuel	
	Description	m^3	Description	m^3	Description	m^3	Description	m^3
2,500 TEU Containership (Dual Fuel)	2 x Storage 1 x Settling 2 x Service	2,000			1 x Storage 1 x Service	1,300	2 x Storage	2,400
3,700 TEU Containership (Dual Fuel)	2 x Storage 1 x Settling 1 x Service	2,200			2 x Storage 1 x Settling 1 x Service	1,100	2 x Storage	3,600
3,000 TEU Containership w/RoRo (Dual fuel)	2 x Storage 2 x Settling 2 x Service	2,400			3 x Storage 1 x Settling 1 x Service	2,300	1 x Storage	2,300
4,500 TEU Containership	6 x Storage 1 x Settling 1 x Service	4,000	1 x Storage 1 x Settling 1 x Service	700	MDO 1 x Storage 1 x Service MGO 1 x Storage 1 x Service	MDO: 150 MGO: 100		
9,200 TEU Containership	3 x Storage 1 x Settling 1 x Service	5,000	1 x Storage 1 x Settling 1 x Service	2,000	MDO 1 x Storage 1 x Service MGO 1 x Storage 1 x Service	MDO: 300 MGO: 200		
13,000 TEU Containership	5 x Storage 1 x Settling 1 x Service	8,500	1 x Storage 1 x Settling 1 x Service	2,000	MDO 1 x Storage 1 x Settling 1 x Service MGO 1 x Storage 1 x Service	MDO: 400 MGO: 300		
20,000 TEU Containership	6 x Storage 1 x Settling 1 x Service	12,300	2 x Storage 1 x Settling 1 x Service	2,000	1 x Storage 1 x Settling 1 x Service	600		
50,000 DWT Panamax Tanker	3 x Storage 1 x Settling 1 x Service	1,200	1 x Storage 1 x Settling 1 x Service	300	MDO 1 x Storage 1 x Service MGO 1 x Storage 1 x Service	MDO:150 MGO:150		

Ship Type/Size	HFO		LSHFO		MDO/MGO		LNG Fuel	
	Description	m³	Description	m³	Description	m³	Description	m³
115,000 DWT Aframax Tanker	3 x Storage 1 x Settling 1 x Service	2,000	1 x Storage 1 x Settling 1 x Service	1,000	MDO 1 x Storage 1 x Service MGO 1 x Storage 1 x Service	MDO: 150 MGO: 200		
160,000 DWT Suezmax Tanker	3 x Storage 1 x Settling 1 x Service	2,500	1 x Storage 1 x Settling 1 x Service	1,500	MDO 1 x Storage 1 x Settling 1 x Service MGO 1 x Storage 1 x Service	MDO: 200 MGO: 250		
158,000 DWT Suezmax Tanker (With SOx Scrubber)	3 x Storage 1 x Settling 1 x Service	2,800			3 x Storage 1 x Service	1,100		
320,000 DWT VLCC Tanker	3 x Storage 1 x Settling 1 x Service	5,000	1 x Storage 1 x Settling 1 x Service	2,000	MDO 1 x Storage 1 x Service MGO 1 x Storage 1 x Service	MDO: 300 MGO: 500		
320,000 DWT VLCC Tanker (With SOx Scrubber)	3 x Storage 1 x Settling 1 x Service	4,000	1 x Storage 1 x Settling 1 x Service	1,400	2 x Storage 1 x Service	700		
35,000 DWT Bulk Carrier	4 x Storage 1 x Settling 1 x Service	1,300	1 x Storage 1 x Settling 1 x Service	250	MDO 1 x Storage 1 x Settling 1 x Service MGO 1 x Storage 1 x Service	MDO: 100 MGO: 100		
181,000 DWT Bulk Carrier	3 x Storage 1 x Settling 1 x Service	3,500	1 x Storage 1 x Settling 1 x Service	1,200	MDO 1 x Storage 1 x Service MGO 1 x Storage 1 x Service	MDO: 300 MGO: 400		

SECTION 5 – FUEL SWITCHING

Fuel oil switching from high sulfur HFO to low sulfur distillate fuel oil is challenging and appropriate procedure is to be used to avoid loss of propulsion from thermal shock. Also, changeover is to be completed prior to entering regulated waters (e.g. ECA, California water) to avoid non-compliance. Fuel changeover from high sulfur HFO to low sulfur HFO is not difficult because both are heated fuel oils but changeover from HFO to distillate is to be carried out very carefully. It is likely that from 2020 the changeover may become very simple if ships changeovers from 0.50% Heavy Fuel Oil to 0.10% Heavy Fuel Oil unless where mandatory changeover is required to 0.10% Marine Gas Oil (Distillate Fuel) specifically while entering regulated California water. Low and extra low sulfur content in fuels has many potential negative effects on diesel engines and boilers primarily due to its lower viscosity and few other concerns.

It is important to check the suitability of each component in the fuel system and the combustion system of each engine and boiler for the range of fuels expected to be used by the vessel. It is also important to prepare fuel changeover and operating procedures for the vessel based on the modified fuel system design. Without these efforts there is real potential to damage to auxiliary machinery, engines, boilers and their components. Other possible risks include a deficiency of required power, leading to a possible loss of propulsion or the inability to generate power at critical times during vessel maneuvering, placing the ship and the environment at risk.

For new design vessels, consideration should be given to incorporating electronic fuel control and direct fuel injection combustion systems, which allow engines to burn a wide variety of fuels more efficiently, resulting in better power generation, cleaner emissions and increased fuel economy.

Consideration should be given to compliance with MARPOL Annex VI when modifying anything that affects the combustion process of a marine engine. The engine maker should confirm that the modification was included in the configurations used during engine emission testing. Otherwise additional testing may be required.

FUEL SWITCHING CONSIDERATIONS

This section of the Advisory discusses some of the key items that should be addressed in a fuel switching procedure. The most common issues that arise in switching over to operation on MGO are noted below, including recommendations and requirements from ABS.

As guidance to shipowners and operators, ABS has issued two Fuel Switching Compliance Notes, one for engines and one for boilers (see Appendix I and II respectively). The Notes suggest that all vessels operating in areas where low sulfur fuel is required should carry out the measures below.

- Prepare an evaluation and risk analysis including consultation with manufacturers to outline the issues and risks of using low sulfur distillate fuel. This analysis should cover the entire fuel system and its components, engines, boilers and control systems. It is recommended that, in addition to the engine or boiler maker's advice, issues related to other components in the system should also be addressed by individuals specializing in specific systems or sub-systems. Check for any service or maintenance requirements that are recommended when using MGO. A copy of the risk analysis report should be maintained on board for reference by any interested party.


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- Prepare a detailed fuel switching procedure (or manual) in consultation with engine/machinery makers and place it on board. Include any required inspections or maintenance schedules. Properly train crew in the procedures. As this is a safety issue, a copy of this procedure should be retained on board, and its availability may be verified during ISM audits.
- Consult with fuel suppliers to select MGO (with viscosity at or above the minimum required for the machinery on board). Independent fuel oil testing is recommended.
- System seals, gaskets, flanges and other fittings should be carefully examined and maintained to correct any fuel seepage and leakage. Fine spray particles from such leakage may pose a severe fire safety risk.
- Maintain fuel oil purifiers, filters and strainers.
- Check and maintain control systems including alarms, transmitters, and indicators.
- Conduct crew training (initial and periodic).
- Monitor cylinder lubrication carefully to identify any increases in lube oil consumption, which may be caused by liner lacquering. Periodic testing of in-use lubricating oils can give early indications of unusual wear.
- Concerns with steam atomizing with MGO (including distortion of the tubes) should be assessed with the manufacturer and corrected. For burners having parallel tubes for steam and fuel oil, due to the lower temperature of MGO, tubes conveying MGO can distort due to temperature gradients.
- Ensure the burner management and flame supervision systems safely include MGO operation.
- Complete fuel switching prior to entering a port or restricted water to satisfy regulations and reduce risks.

ABS is prepared to issue Statement of Fact (SOF) certificates as a service to owners wanting documentary proof they operate in compliance with the air emissions regulations. After inspection by an ABS surveyor, ABS will verify that the vessel has dedicated low sulfur fuel (e.g. MGO) storage tanks, fuel piping systems suitable for low sulfur distillate use that maintain segregation from other fuels and has operational procedures on hand (See Appendix 3).

FUEL SWITCHING REQUIREMENTS

ABS has specific requirements that apply to the fuel switching process and any modifications made to fuel systems and diesel engine components.

Owners and operators are required to evaluate the engine and associated machinery and equipment using low sulfur fuel. This evaluation should be a systematic assessment of related systems taking into consideration the potential risks identified in the design and operational review. Appropriate measures based on the assessment results must then be taken. The vessel owner is responsible for the vessel and its safe operation. It is recommended that the engine manufacturer or another entity recognized by the engine manufacturer be employed to carry out the design evaluation and oversee any modifications.

The evaluation is to consider, under all normal and abnormal modes of operation, the following, including (but not limited to) whether the vessel:

- Is fitted with dedicated low sulfur fuel oil storage tank(s), fuel oil piping system is arranged to support low sulfur fuel supplies for the main engine, auxiliary engines, and boiler etc.
- Is optimized for fuel switch over from Heavy Fuel Oil to low sulfur distillate, low viscosity fuel
- Is optimized for fuel switch over from low sulfur distillate, low viscosity fuel to Heavy Fuel Oil
- Is capable of maneuvering in congested waters or a channel while switching between fuels
- Machineries are capable of operation on low sulfur fuel during long idle times
- Lube oil is standardized for Heavy Fuel Oil operation and whether the engines are allowed to operate on low sulfur fuel for a specified duration using that lube oil
- May start any engine at berth or anchorage using low sulfur fuel

A detailed fuel changeover procedure (or manual) is to be developed by the vessel owner or operator in consultation with the engine and/or machinery manufacturers and placed on board. If the engines are capable of operating on low sulfur marine fuel such as MGO, although they were originally designed to operate on HFO and/or MDO, this fuel changeover procedure (or manual) shall be maintained.

Manufacturers and associated systems providers are to be consulted to determine whether or not their existing fuel systems/arrangements require modifications or additional safeguards for the intended fuels. Engine manufacturers are to be consulted regarding any service or maintenance requirements when operating on low sulfur fuel. A fuel system and component inspection and maintenance schedule is recommended:

- System seals, gaskets, flanges, purifiers, filters and strainers and other fittings are to be carefully maintained since fuel seepage and leakage may occur from the use of MGO in systems which have previously used HFO and/or MDO.
- Control systems including pressure and temperature alarms, flow indicators, and filter differential pressure transmitters are to be properly calibrated and kept operational.
- Crew training (initial and periodic) is to be conducted.

Cylinder lubrication consumption is to be carefully monitored since a high consumption may indicate liner lacquering. HFO and low sulfur fuels should be tested by a reputable fuel oil testing laboratory to provide data that can be used to assess risks when switching fuels to the engine. The laboratory results can also provide information to help operational optimization and may result in reduced fuel use. If the design evaluation carried out for the operation on low sulfur fuel identifies any modifications to the ship and its machinery, the report shall be submitted, together with modification plans and data, to the applicable ABS Technical office.

The design evaluation is to identify potential hazard scenarios associated with aspects of the proposed modifications. Issues to be considered are the fuel switching process, fuel properties and processing, fuel compatibilities, concerns regarding engine starting on low sulfur fuels and other relevant issues. The analysis is to cover fuel switching to and from HFO and low sulfur fuel, issues that arise with maneuvering while switching over, long idle times and starting engines in port. Potential hazards include, but are not limited to, loss of propulsion, blackouts, failure to start engines, fire and explosions. Please refer to the ABS Notes on Use of Low Sulfur Marine Fuel for Engines and Boilers (Appendix 1 and 2) for more details on analysis requirements.

All design modifications are to be in compliance with original manufacturer's recommendations whenever possible. A competent 3rd party can be used for design modifications provided that the entity is recognized by the original manufacturer and/or is willing to undertake the full responsibility for the modified design. Any modifications to existing installations including piping systems, control systems, equipment and fittings will be subject to ABS review and approval for design assessment and survey. Any new pumps in the fuel system are required to be ABS certified. All modifications shall be carried out in accordance with the approved drawings and details to the satisfaction of the attending surveyor.

Low sulfur fuel (i.e., MGO) tanks and systems are to be arranged to facilitate fuel changeover. Sufficient capacity for the intended operation must be carefully considered and planned. While not specifically mandated, installation of dedicated low sulfur fuel service tanks may be necessary. HFO and low sulfur fuel piping systems (including pipe fittings and equipment) are to be arranged so as to carry out effective flushing of HFO from the system.

FUEL SWITCHING PROCEDURES

The issues related to fuel switching are unique to each ship and its condition. However, there are certain general principles and procedures that apply to most ships and understanding these will be helpful in developing the fuel switching procedure for any specific ship. It is highly recommended that a well thought out fuel switching procedure or manual (onboard procedure and checklist) be developed by competent and experienced persons for any ship that will transit waters that require the use of low sulfur fuel so that the fuel switching can be carried out safely with no risk to the crew, ship or environment. This is a requirement of MARPOL Annex VI, Regulation 14 (6) for ships entering and leaving an ECA.

Operating crew are to be well trained in how to use the procedure and aware of any safety issues that can arise and how to respond to them. All new crew members joining a ship are to be trained prior to participating in the fuel switching process. The proper implementation of fuel switching and reliable operation of the propulsion

machinery through the time of the switching and while operating on the low sulfur fuel is of great importance because the requirement to operate on low sulfur fuels is generally applicable to ports and coastal waters where there is the greatest risk to the ship and environment from loss or reduction in a ship's propulsion power.

Where fuel switching is required for operation in coastal waters, it is recommended the vessel carry out the changeover operation in safe navigable waters prior to entering crowded and restricted channels and port areas or areas where there is a higher risk of grounding or collision. The vessel operator shall follow the ship's onboard procedure and checklist to safely perform the changeover. Where operation on lower sulfur fuel is only required after vessel docking in port, such as current EU requirements (0.10% fuel "at berth"), then fuel switching can safely be carried out in port while alongside or in anchorage.

The following are important steps and issues that are to be considered in the preparation of a fuel switching procedure, as one or more of these events could lead to unexpected shut down of the main or auxiliary engine(s):

- A competent person is to carry out an assessment of the fuel system on board the ship and determine the requirements for safe and effective operation on low sulfur fuel.
- The arrangements of fuel storage, settling and service tanks are to be considered in the fuel switching procedure. This will determine whether fuel switching can be done by segregating the systems or by mixing fuels. Segregating fuels is the preferred method as it allows much quicker switching and there is less potential for compatibility issues. Segregation can be carried out on ships that have separate fuel lines between fuel storage, settling and service tanks.

  Most ships built after 1998, because of SOLAS requirements, have double service tanks and more than two storage tanks, so the possibility for segregation exists. In many cases the second service tank is a diesel fuel tank and not a heavy fuel tank. This works well to accommodate low sulfur fuel MDO or MGO.

  Having separate, segregated fuel systems greatly simplifies the switching process and reduces the risks and crew effort as the switching is done by changing over the valve or valves that supply fuel to the fuel service pumps for the engine or boiler. The switching verification process is also much simpler with a segregated system because the time for the valve changeover can be easily recorded and the time to flush the fuel system with the new fuel is significantly reduced.
- There is a concern that thermal shock may be caused during fuel changeover from HFO to low sulfur distillate fuel because heated HFO has been delivered to the engines and the distillate low sulfur fuel replacing the HFO is unheated. Thermal shock may be caused if the changeover time is too short. Switching fuels is to be carried out very carefully, by maintaining a steady drop in temperature, reducing the engine load, and slowly by-passing the fuel oil heater prior to beginning the fuel changeover. The fuel temperature must be lowered slowly (about 2°C per minute) to prevent thermal shock to the fuel system.

  When changing engine operation from HFO to distillate rapidly; an uneven temperature change could cause thermal shock, creating uncontrolled clearance adaptation which can lead to sticking or scuffing of the high pressure fuel injection components or complete fuel pump seizure.
- Prolonged engine operation with an incompatible crankcase or cylinder lubricating oil could result in accelerated piston ring/liner wear. Alkaline compounds such as calcium salts are used to neutralize the sulfuric acid formed on the liner when using high sulfur fuels. If the pH of the lubricating oil does not match the fuel used in the engine, alkaline crystals may build on the liner. This can cause a loss of sufficient oil film thickness, bore polishing, liner lacquering and sudden severe wear of the liner.

DIESEL ENGINES

During the changeover process it may be necessary to re-set or re-adjust various equipment (such as control valves, temperature sensors, and viscosity meter/controllers) employed in the monitoring and control systems, unless this is accomplished automatically. Where manually adjusted, changes should be conducted in accordance with the engine maker's recommendations.

Control of Viscosity: When operating on low viscosity low sulfur fuels, one way to keep viscosity above the minimum value for delivery at the engine fuel injection pumps is to install a fuel cooler to keep the fuel temperature below 40°C. This is especially true for operation in summer and tropical conditions since ambient temperature in the engine room and fuel tanks can be above 40°C. A fuel cooler that uses the central freshwater (FW) cooling system as the cooling medium may not provide adequate cooling as the cooling water normally has a set point temperature of 36°C to 38°C. In this case, adding a chiller unit to the cooler can lower the fuel temperature to about 20°C to 25°C and will be effective in maintaining the viscosity above the required minimum.

There are several locations where the cooler can be installed in the fuel service system. One location is in the fuel return line between the engine and the mixing tank. This removes the heat added to the fuel during circulation through the engine. This cooler location is effective if the fuel source (tank) is at the required temperature and it is only necessary to reduce heat from the fuel returned to the mixing tank. It also allows the fuel supplied to the engine to be gradually lowered in temperature since the cooled fuel is mixed with the warmer fuel in the mixing tank rather than introducing cooled fuel directly to the engine. An alternative fuel cooler location is in the fuel supply pipe prior to the engine. In this arrangement the temperature of the fuel to the engine is directly controlled and it is more effective at cooling the fuel below 40°C because it removes heat introduced from the engine return, the fuel source and service pumps in the fuel system.

The temperature of the fuel out of the cooler can be controlled if a means of adjusting the cooling medium flow (i.e., by a temperature sensor in the fuel outlet line) is provided. In this way the fuel can gradually be brought to the desired temperature during fuel switching. Abrupt lowering of the fuel temperature should be avoided. Fuel oil coolers for boilers are similar in concept to those for diesel engines.

Procedures for Switching with Fuel Mixing: A ship lacking a tank arrangement permitting segregation of fuel beyond the storage tanks must develop procedures for fuel mixing. One method is to reduce the level in the settling tank to about 20 percent before filling with the alternate fuel. This arrangement may require up to several days of operation and several dilutions to reduce the sulfur level in the mixed fuel to the required level before entering an ECA. This can lead to high consumption of expensive low sulfur fuel, so consideration should be made to install a segregated fuel system on any ship that regularly operates in areas where low sulfur fuel is required. It is important to ensure compatibility of any fuels prior to mixing.

Reducing Ship Power: Prior to commencement of fuel switching it is generally recommended to reduce ship power to the specific level indicated in the vessel's fuel switching procedure. Typically this is 25% to 40% maximum continuous rating (MCR), depending on the specifics of the propulsion plant.

Thermal Shock Avoidance while Switching Fuels: Avoiding thermal shock to the fuel system is one of the critical elements to be considered in a fuel switching procedure. Engine makers normally offer guidance on the maximum allowed rate of temperature change in fuel systems. A commonly stated rate is that of 2°C per minute.

For example, if a ship is using HFO heated to about 150°C prior to the fuel booster pumps and switching to MGO at 40°C, the temperature difference is about 110°C. Under these conditions and considering a 2°C per minute permitted rate of change, the fuel switching process should take a minimum of 55 minutes to complete safely. Consider using longer than the minimum time to prevent short term rapid temperature changes during the process. There are several important factors that should be taken into consideration in controlling the rate of temperature change during change over.

Manually Fuel Switching: Many ships carry out fuel switching by manually changing over a single three-way valve. This immediately changes the fuel source. If the fuel switching is done at high power levels, the fuel change is carried out in a relatively short period of time as the fuel circulates at a high rate through the mixing tank. Rapid change from HFO to distillate can lead to overheating the low sulfur fuel, causing a rapid loss of viscosity and possible gassing in the fuel system. Too rapid of a change from unheated low sulfur fuel to HFO can lead to excessive cooling of the HFO and excessive viscosity at the fuel injectors, again causing loss of power and possible shutdown.

If a single changeover valve is provided, it is recommended to carry out fuel switching with the engine at low power levels so the fuel change will occur gradually enough to remain within the temperature rate of change limits. Fuel switching is not to be carried out at higher power levels and it is recommended that an automated fuel changeover system that changes the fuel in a timed and regulated manner be installed. Such automated systems are now offered by some engine makers and by fuel system equipment suppliers.

Fuel Pump Considerations: With the introduction of low sulfur fuel oil such as MGO into the fuel system, the existing HFO service pumps may lose suction because of reduced fuel oil viscosity and lubricity. Due to less lubrication, overheating of the existing HFO pumps (if they are not designed to handle distillate) may occur. Therefore, it may be necessary to install different types of pumps to handle low viscosity fuel. For ships contracted for construction on or after 1 July 2013, IACS UI 255 provides guidance for fuel service pump arrangements required to maintain normal operation of propulsion machinery for compliance with SOLAS II-I/26.3.4.

Also, excessive wear within the fuel injection pump can result from the lower lubricating properties of 0.10% sulfur fuels. This could necessitate replacement of the existing injection pump with a new fuel pump. Engine fuel injection pumps may be replaced with special pumps (e.g. tungsten carbide-coated fuel injection pumps).

Consideration should be given to incorporating electronic fuel control and direct fuel injection combustion systems into the design for new engine systems. This allows engines to burn fuel more efficiently, resulting in better power generation, cleaner emissions and increased fuel economy.

Consideration must be given to MARPOL Annex VI compliance when modifying any part of the combustion process. It may be necessary for an engine manufacturer to install some specific components for operation on certain fuel grades or for certain operational requirements. In such instances, these components require testing to demonstrate their suitability as allowable alternatives NOx sensitive components (included in NOx Technical File) or settings of that particular engine group or family. In essence, the engine manufacturer must confirm that the modification was covered by the configurations used during emission testing of the engine. Otherwise additional testing may be needed. ABS does not anticipate any major effects when techniques such as a coating or surface treatment are adopted to resolve the fuel injection pump lubricity issues. However, the ignition quality of the different fuel types may demand a different fuel oil injection system, including a new setting for injection timing. This could result in major modifications requiring recertification of the engines.

If new pumps are installed in the fuel system, they are required to be certified by the attending surveyor at the manufacturer's plant as required by 4-6-1/7.3.1 of the ABS Rules.

Fuel Heating: Fuel heaters and pipe heat tracing should be turned off or on in a controlled manner during the fuel switching process. Most ships have a viscosity control system that controls the heat supply to the fuel preheaters located in the fuel supply system. This system will adjust the heat supply to the preheaters as the fuel viscosity changes during the fuel switch. However, when the change to low viscosity fuel oil is completed, the heat supply must be turned off, along with any heat tracing.

Gassing: When switching from heated HFO to low sulfur fuel, engine components and fuel in the mixing tank will retain heat. As the tank of hot fuel continues to be replaced by low sulfur, low viscosity fuel, there is real danger of the fuel heating to a point that it will flash in the booster pumps. This "gassing" of fuel will prevent fuel delivery to the engine, causing a shut-down condition. The fuel temperature should be closely monitored during the switchover process and components should be given sufficient time to cool before the fuel system is completely flushed by low sulfur fuel. Use of fuel coolers can be of value to avoid the gassing of low viscosity fuel.

Fuel Compatibility: Compatibility of the mixed fuels is an issue and is discussed in Section 4. During the fuel switching process, fuel filters, strainers and the mixing tank should be carefully checked for evidence of clogging and excessive sludge formation. This is one reason why fuel switching is best done ahead of time in open waters clear of hazards.

Purifier Operation: For extended operation on low sulfur fuel, purifiers may be adjusted to suit the new fuel. The purifier suction and return are to be checked to make sure the pipes lead to the correct tank(s). If operating


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on low sulfur fuel, a separate purifier may be used for continued purification of the HFO and low sulfur fuel tanks. In general, the purification of a fuel such as MGO may not be required. However, some engine makers may recommend purification. In that case, the purifier operational details are to be in accordance with the purifier maker's instructions and recommendations.

The usual procedure to reduce cat fines includes settling out oil in the storage tanks, regularly draining the residue of tanks, purification (centrifuge) and other suitable treatment. Testing can reveal the amount and the size of the cat fines, enabling the vessel to adjust its purification process to the specific fuel need. There are also optimized onboard cleaning systems and automatic tank and separator systems on the market that help maximize cat fine removal. ABS recommends contacting the engine manufacturer for more details.

ABS recommends vessel owners/ operators take the following actions to prevent failure due to fuel quality:

- Check engine manufacturer's maximum recommended cat fines concentration
- Optimize the use of separators, purifiers and clarifiers
- Verify that cleaning systems can remove increased concentrations of cat fines which may occur in heavy weather
- Consult engine manufacturers regarding the use of additional fine mesh filter(s)
- Use a homogenizer immediately upstream of a separator, purifier, or clarifier
- Use an electronic, inline cat fine monitoring system
- Use separate fuel service and booster pumps for low sulfur fuel oil operation
- Add a fuel oil cooler/chiller to control viscosity
- Use a separate piping arrangement with fuel change over mechanism
- Use appropriate BN lubrication oil for extended operation with low sulfur fuels
- Modify electronic control system for both engines and boiler
- Modify or change-out boiler burners
- Operations in cold areas may cause wax in distillates to solidify and may need MGO heating arrangement

Intelligent fuel oil testing also provides information on other specific parameters useful in optimizing the combustion efficiency such as calorific value, water content and ignition point and/or delay. These values should be routinely scrutinized in order to optimize combustion and minimize costs.

Fuel Injector Cooling: If an engine is equipped with fuel injector cooling, it may need to be turned off or on during fuel switching. When the engine is operating on unheated low sulfur fuel, fuel injector cooling may not be needed and should be turned off to prevent over cooling if the engine is to be operated for an extended period of time. If injector cooling has been secured, it should be turned on when the engine is returned to operation with heated HFO. The engine manufacturer should be consulted regarding this item.

Temperature Monitoring: Temperatures of the engine and its components must be continually monitored to ensure they are maintained at normal service temperatures. Adjustment or resetting of engine control equipment such as control valves, temperature sensors, or viscosity controller may be needed, to account for the new fuel type, if not done automatically. As crew members gain experience with fuel switching there will be better understanding of what needs to be adjusted and monitored during the switching process and during sustained operation with low sulfur fuel. During fuel switches, vigilance is needed to spot potential problems before they become serious. Fuel switching procedures should be adjusted to account for identified problems.

Powering Up: Once the propulsion and generating plant are stabilized on the new fuel and all components are at normal service temperatures, the propulsion plant should be able to be brought back to normal power and the vessel can proceed into restricted and port areas.

Considerations for Lube Oil: If sustained operation (more than five to seven days) is planned on a fuel with a sulfur content greatly different from the fuel the vessel typically uses, slow-speed diesel engine makers recommend that the cylinder oil be changed to accommodate the sulfur content of the fuel being used.

Lubricating oil with high levels of alkaline additives is recommended by many manufacturers for use with high sulfur fuels. Therefore, a lower total base number (TBN) crankcase oil for medium speed engines (i.e., trunk-type) or cylinder lube oil for slow speed engines (cross-head type) should be selected if a low sulfur fuel is going to be used permanently or for a prolonged period of time.

BOILERS

If a boiler has been originally designed to burn only HFO or MDO, there are several points that should be considered when changing fuels. Usually, during initial flashing and when the furnace temperatures are low (particularly after repair), the boilers can use small amounts of MGO. However, they cannot sustain use of MGO during normal operations and meet steam demand without modifications.

Boiler explosions can occur due to incorrect operations. For example, when the boiler furnace is not properly purged before ignition, a high pressure of fuel gas may build up in the burner due to flame failure and when the control system is malfunctioning or disconnected. Unburned fuel may be admitted to a hot furnace following flame failure, leading to an explosion.

Systems providing fuel atomization may have to be reassessed because steam atomization may not be suitable for MGO due to the possibility of fuel vaporization before exiting the burner tip. This could lead to flame instability, improper combustion and, possibly, flame extinguishment. Equipment manufacturers should be consulted to determine the necessary safeguards.

Use of MGO may cause coke deposits on rotary cup types of burners. Protective heat shields are necessary to prevent coke build up. The changeover process should consider solubility of asphaltenes (i.e., fuel compatibility). Existing burners designed for HFO and/or MDO may have to be modified, or require new types of burner assemblies accommodating both HFO and MGO. The existing piping used to transport heated HFO from the service pump to the boiler may not be suitable to transport MGO, since there is a concern that MGO flowing through hot piping may vaporize, creating vapor lock, causing irregular fuel flow towards the burner and resulting in flame extinction.

Therefore, MGO is not to be delivered through heated pipes to the burner. Consideration should be given to provide dedicated MGO delivery piping and accessories. The burning of MGO may also necessitate swift and effective flame failure detection. Boiler/equipment manufacturers should be consulted for specific recommendations. To avoid vaporization by heating MGO in the piping system, heat tracing of the fuel pipes should be turned off or the heaters should be bypassed and/ or switched off.

If a boiler is designed to burn HFO instead of MGO, a flame failure may occur when the fuel is changed over to MGO because the photocells may lack the color spectrum necessary for MGO. Equipment and/or machinery manufacturers should be consulted for specific recommendations based on applications. Also, safety features should be developed or considered to promptly and effectively deal with flame failures and all of the possible ramifications of a flame failure. For example, flame supervision may have to be complemented with another flame scanner due to the different properties of HFO and MGO flames, such as flame length.

Existing HFO service pumps may have difficulties with suction of the lighter oil because of viscosity.

Also, HFO has better lubrication properties than MGO. Accordingly, overheating of the existing HFO service pumps due to lack of lubrication, may result (unless the pump was originally designed to handle low viscosity fuel). It may be necessary to install completely different service pumps and associated valves to handle MGO.

HFO has a higher density and a lower calorific value than MGO. The fuel supply control system is therefore to be adjusted to supply an adequate volume of low density low sulfur fuel oil to maintain equivalent steam generation. This will cause an increase in burner fuel throughput and will potentially cause excessive smoke due to the change in the fuel air ratio. The fuel to air ratio will be too rich for safe combustion and must be adjusted.

A detailed, boiler-specific, fuel changeover operation manual is to be readily available for the operating crew on board.

In addition, it is suggested that vessel owners and operators consider the following:

- Establishment of a fuel system inspection and maintenance schedule
- System pressure and temperature alarms, flow indicators, and filter differential pressure transmitters, should all be operational
- Maintenance of system seals, gaskets, flanges, fittings, brackets and supports
- Detailed system diagram(s) should be available
- Initial and periodic crew training should be conducted and their training needs assessments should be kept up to date

When a low-load firing operation without a pilot fuel (i.e., burning only MGO) is proposed, and if such operation has not been assumed in the original boiler system design, ABS recommends a safety assessment be made for each individual operational case in order to ascertain safe operations.

This should include, among other considerations, the following:

- A boiler management system and combustion control that is suitable for intended low-load firing operation
- Flame scanner type and positioning suitable to detect failure at low-load firing operations

When boilers are used for propulsion, maneuvering conditions may demand large and rapid load changes. Therefore, if the boiler is in operation without a pilot fuel, under maneuvering conditions, and such operation has not been assumed in the original boiler system design, ABS recommends safety assessments be made for each individual operational case to ascertain its safety and feasibility.

Fuel oil systems in LNG ships with steam turbine propulsion are designed for HFO in combination with the boil off from the cargo. Therefore, fuel oil systems in these vessels will need to be modified to use MGO. MGO is not to be used in the fuel oil systems in these vessels without modifications for the following reasons:

- It is important that the fuel supply remain uninterrupted for propulsion boilers
- There is a risk of failure in fuel service pumps and associated valves
- There is a risk of unintentional fuel oil evaporation
- Steam atomizing in burners having concentric type fuel injectors can overheat MGO
- Atomizing burners with parallel tubes for steam and fuel oil can distort due to the temperature gradient between unheated MGO and steam
- The design of the burner management system (BMS) and flame supervision is based on HFO

APPENDIX 1 – USE OF LOW SULFUR MARINE FUEL FOR MAIN AND AUXILIARY DIESEL ENGINES

As a consequence of the EU regulations (EU Directive 2005/33/EC dated 6 July 2005, effective date 1 January 2010, and then with EU Directive 2012/33/EU of 21 November 2012.), main engines, auxiliary engines and boilers will be required to operate on low sulfur fuels (unless under Regulation 1, an approved exhaust gas scrubber/treatment system is fitted or shore-power is made available, i.e., cold ironing) which will likely be Marine Gas Oil (MGO). Please note that many of these engines and equipment (e.g. boilers) were specifically designed to operate on Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO). Thus design modifications and operational adjustments may be necessary to some of these engines and equipment.

In addition, where these engines and equipment are capable of operating on MGO, though originally designed to operate on HFO, a well-designed and efficient change-over procedure to and from MGO needs to be followed in order to maintain engine and equipment safety and availability. Input from engine specialists should be obtained.

In light of the regulations and with a view to assist the owners, operators, shipyards and designers as appropriate, ABS highlights certain issues (design and operational), makes the following suggestions, and specifies the requirements that are to be satisfied for ABS classification purposes. It is important to recognize that many systems are directly supplied by the engine manufacturer. In modern engines, typically the engine control is integrated with an outside sourced control system. As such, may be a prudent course of action to involve the engine manufacturer or another entity recognized by the engine manufacturer to be responsible for the overall arrangement including any needed design adjustments.

DESIGN AND OPERATIONAL ISSUES

1. Design Issues
   a. New fuel pump: With the introduction of low sulfur fuel oil such as MGO into the fuel system, the existing HFO pumps may have difficulties with suction of the light gas oil (MGO) because of reduced fuel oil viscosity and lubricity. Accordingly, due to lack of lubrication, this may eventually result in overheating of the existing HFO pumps (if not designed to handle MGO). Therefore, it may be necessary to install different types of pumps to deal with MGO.
   b. Excessive wear within the fuel pump can result from the lower lubricating properties of MGO (0.10% sulfur fuel). This could also necessitate replacement of the existing HFO pump with a new fuel pump. This includes fuel injection pumps which may necessitate replacement with a special pump (e.g. tungsten carbide coated fuel injection pump).
   c. For new designs, it may be appropriate to incorporate electronic fuel control and direct fuel injection combustion systems into the engine systems allowing the engines to burn fuel more efficiently, resulting in more power, cleaner emissions, and increased fuel economy.
   d. Consideration must be given to MARPOL Annex VI compliance when modifying anything that affects the combustion process. It may be necessary for an engine manufacturer to install some specific components for operation on certain fuel grades or for certain operational requirements. In such instances, these components must have been covered by testing to demonstrate their suitability as allowable alternative NOx components or settings of that particular engine group or family. In essence, the engine manufacturer must confirm that the modification was covered by the configurations used during emission testing of the engine. Otherwise additional testing may be needed.

      ABS does not anticipate any major effects when techniques such as a coating or surface treatment are adopted to resolve the fuel pump lubricity issues. However, the differences in ignition quality of the different fuel types may demand a different fuel oil injection system, including a new setting for injection timing. This could result in major modifications requiring re-certification of the engines.
   e. It is to be noted that MGO with a minimum viscosity of 1.5 cSt at 40°C (ISO 8217) requires approximately 22°C to keep the limit to 2 cSt. Maintaining the fuel oil temperature in the required range may be difficult with existing systems. The consequence of not doing so may be "sticking" of fuel system components. Thus, to maintain a minimum viscosity of 2 cSt it may be necessary to install a new cooler together with appropriate controls in the design of the modified fuel oil system.
   f. For the lowest viscosity MGOs, a cooler may not be sufficient. In such cases, it may be necessary to include in the design a "chiller" (along with appropriate controls), which removes heat through vapor-compression or an absorption refrigeration cycle.

g. In some industries, additives have been used to improve lubrication and mitigate the viscosity issue. Fuel suppliers, engine and pump suppliers should be consulted.

h. MGO tanks and systems should be arranged to facilitate effective change-over. Sufficient capacity for the intended operation should be carefully considered and planned. While not specifically mandated, installation of dedicated MGO service tanks may be necessary due to operational considerations.

i. HFO and MGO piping systems (including pipe fittings and equipment) should be arranged so as to carry out effective flushing of HFO from the system.

j. Low-BN cylinder oil tank(s) may also be needed. See item (p) in Operational Issues.

2. Operational Issues

k. There exists a concern during a fuel change-over from HFO to low sulfur fuel such as MGO because the pipes and other parts of the fuel oil pumping system are heated when using HFO. MGO flowing through the same hot piping may vaporize creating vapor lock and causing irregular fuel flow to injectors resulting in engine stoppage. Therefore, MGO is not to be used through heated pipes to engines.

l. Sticking/scuffing of high pressure fuel oil injection components: When changing engine operation from HFO to MGO, rapid or uneven temperature change could cause thermal shock creating uncontrolled clearance adaptation which can lead to sticking or scuffing of the fuel valves, fuel pump plungers, or suction valves, or fuel pump seizure.

m. Accelerated piston ring and liner wear: Prolonged engine operation with incompatible crankcase or cylinder lubricating oil could result in accelerated piston ring/liner wear.

n. There may be a loss of sufficient oil film thickness due to liner lacquering.

o. One or more of the above events in items (l), (m) or (n) could lead to unexpected shut down of the main or auxiliary engine(s).

p. Lubricating oil with high levels of alkaline additives, i.e., high-BN (base number) oil is recommended by many manufacturers for use with high sulfur fuels. Therefore, a lower TBN (total base number) crankcase oil for medium speed engines (i.e., trunk-type) or cylinder lube oil for slow speed engines (cross-head type) should be selected if a low sulfur fuel (MDO or MGO) is going to be used permanently or for a prolonged period of time.

q. In addition to selecting lower TBN lubricating oil with the use of low sulfur fuel oil, it may also be necessary to adjust the cylinder lubrication feed rate to match the total alkaline content of the cylinder oil with that in the fuel oil according to a specific formula.


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If low sulfur fuels are used predominantly, low-BN cylinder oil is generally recommended by manufacturers, (either BN40 or BN50) as compared to the typical BN70 cylinder lubricating oil used with HFO. Where frequent fuel oil changes are necessary due to the vessel's routes, it is recommended that a second grade of cylinder lubricating oil with a lower base number (BN) be considered.

r. In general, the purification of MGO may not be required. However, some engine makers may recommend purification. In that case, the purifier operational details should be in accordance with the purifier maker's instructions and recommendations.

s. During engine operation with MGO, since the engine jacket cooling water temperature can be lower than that with the engine operating with HFO, the fresh water generator system should be checked, temperature carefully monitored and readjustment made if necessary.

t. During the changeover process it may be necessary to reset or readjust various equipment (such as control valves, temperature sensors, viscosity meter/controller etc.) employed in the monitoring and control systems, unless this is accomplished automatically. Where manually adjusted, this should be in accordance with the engine maker's recommendations.

CONSIDERATIONS

Owners/operators are required to evaluate the engine and other associated machinery and equipment operation with low sulfur fuel by systematically assessing related systems taking into consideration (but not limited to) the potential risks identified in the Design and Operational Issues (items (a) through (u) as applicable), and see that appropriate measures are to be taken. The vessel owner is responsible for the vessel and its safe operation. It is recommended that the engine manufacturer or another entity recognized by the engine manufacturer be employed to carry out the design evaluation and oversee any modifications.

1. A detailed fuel change-over procedure (or manual) should be developed by the vessel owner/operator in consultation with the engine and/or machinery manufacturers and placed on board.

   If the engines are capable of operating on low sulfur marine fuel such as MGO, although they were originally designed to operate on HFO/MDO, this fuel change-over procedure (or manual) should still be developed and placed on board.
2. Fuel oil suppliers should be consulted to select and receive proper MGO on board.
3. Manufacturers and associated systems providers should be consulted to determine whether or not their existing fuel systems/arrangements require modifications or additional safeguards for the intended fuels.
4. Engine manufacturers should be consulted regarding any service or maintenance requirements when operating on MGO (i.e., low sulfur fuel). A fuel system/component inspection and maintenance schedule should be established.
5. System seals, gaskets, flanges and other fittings should be carefully maintained since fuel seepage and leakage may occur from the use of MGO in systems which have previously used HFO/MDO.
6. System purifiers, filters and strainers should be maintained.
7. Control systems including pressure and temperature alarms, flow indicators, filter differential pressure transmitters etc., should all be operational.
8. Crew training (initial and periodic) should be conducted. Training assessments should be kept up-to-date.
9. Fuel change-over should be completed well before entering regulated waters.
10. Cylinder lubrication consumption should be carefully monitored since a high consumption may be indicative of liner lacquering.

REQUIREMENTS

1. General
   a. Details of all modifications together with the aforementioned design evaluation are required to be submitted to ABS for approval.
   b. Where the owner is satisfied that modifications to the vessel's installed equipment and systems are not required, it is recommended that the design evaluation be maintained on board. As this is a safety issue, the analysis substantiating the safe operation with low sulfur fuel is to be available during ISM audits as evidence that safe operation has been considered.
   c. The design evaluation is to consider under all normal and abnormal modes of operation, including (but not limited to) the following:
      - Switch over to low sulfur, low viscosity fuel

- Switch over to HFO from MGO
- Maneuvering in congested waters or harbors while switching over
- Long idle times
- Starting engine at berth or anchorage

2. For modified systems, ABS requires the following:
    a. Design modifications, if any, are to be carried out by the original manufacturer or a competent entity that will be responsible for the modified design.
    b. Any modification to existing installations (including piping arrangements, control systems, equipment and other fittings) will be subject to ABS review and approval for both design assessment and survey. Accordingly, the details of the modifications considering the recommendations are required to be submitted to an ABS technical office for review of general piping (such as pipe materials suitability, pressure and fittings), automation and controls systems and other safety requirements in accordance with the applicable Rules. A copy of the design evaluation in conjunction with the modifications is to be submitted to ABS for approval.
    c. If new fuel oil pumps are installed, they are required to be certified by the attending surveyor at the manufacturer's plant as required by 4-6-1/7.3.1 of the Rules.
    d. All modifications are to be carried out in accordance with approved drawings and details to the satisfaction of the attending surveyor.

APPENDIX 2 – USE OF MARINE LOW SULFUR FUEL FOR BOILERS

Engines (main and auxiliary) and boilers are affected by the new low sulfur regulations. (As for boilers, please note that the EU Directive (2005/33/EC) applies to main and auxiliary boilers, while the CARB Regulations apply only to the auxiliary boilers, i.e., non-propulsion boilers.) This section addresses those issues that are associated with boilers operating on low sulfur marine fuel.

In modern boilers, typically the control is integrated with an outside sourced control system. As such, starting with the boiler and control manufacturer and involving a person or outside consultant to be responsible for the overall arrangement including any needed design adjustments may be a prudent course of action. It is to be noted that where boilers and equipment are not originally designed to burn lighter types of fuels such as MGO, existing installations of boilers, burners/equipment and fuel systems may need to be modified as a consequence of the mentioned legislation. For such modified systems, ABS class requirements would apply. These ABS Requirements are identified separately from the ABS Suggestions to provide clarity.

CONSIDERATIONS

1. Owners and operators are required to evaluate the boiler and other associated machinery/equipment operation with low sulfur fuel by systematically assessing the related potential risks involved. ABS recommends that vessel owners and operators consult with the boiler manufacturer and associated systems provider(s) or other competent designer recognized by the boiler manufacturer or designer to determine whether or not their existing fuel systems/arrangements require modifications or additional safeguards regarding the intended use of MGO fuels. This should also include obtaining the manufacturers' fuel switching guidance or procedures, if applicable, particularly where the plant was not originally designed for use of MGO.
    a. Where the owner is satisfied that modifications to the vessel's installed equipment and systems are not required, it is recommended that the risk analysis be maintained on board. As this is a safety issue, the analysis substantiating the safe operation with low sulfur fuel is to be available only for consideration during ISM audits as evidence that safe operation has been considered.
2. LNG carriers and oil carriers, where boilers burning HFO/MDO are used to power steam-driven cargo pumps, will also be affected by the new EU Directive and CARB requirements requiring the burning of low sulfur content fuel while in port.
3. Where a boiler has been originally designed to burn only HFO/MDO, the following points should be noted:
    a. Usually during initial flashing from cold when furnace temperatures are low (particularly after repair) the boilers can use small amounts of MGO but cannot sustain use of MGO during normal operation to meet the normal steam demand without modifications.
    b. Boiler explosions can take place due to incorrect operations. For example, if the boiler furnace is not properly purged before ignition (i.e., pre-ignition purge), when there is a high pressure of fuel gas built up in the burner due to flame failure, and when the control system is malfunctioning or disconnected.
    c. Unburned fuel may be admitted to a hot furnace following flame failure. This could result in an explosion in the furnace, as a source of ignition within the furnace could exist.
    d. Systems providing fuel atomization may have to be re-assessed because steam atomization may not be suitable owing to vaporization of MGO fuel before exiting the burner tip. This could lead to flame instability, improper combustion, and possibly flame extinguishment. Equipment manufacturers should be consulted to determine the necessary safeguards.
    e. Use of MGO may cause coke deposits on rotary cup types of burners. Protective heat shields are necessary to prevent coke build up. The change-over process should consider solubility of asphaltenes (i.e., fuel compatibility).
    f. Existing burners designed for HFO/MDO may have to be modified or new types of burner assemblies accommodating both HFO and MGO may be necessary.
    g. The existing piping used to transport heated HFO from the pump to the boiler may not be suitable to transport MGO, since:
        - MGO needs to be delivered at ambient temperature (storage tank temperature), and
        - There exists a concern that MGO flowing through hot piping may vaporize creating vapor lock and causing irregular fuel flow towards the burner resulting in flame extinction.

Therefore, MGO is not to be delivered through heated pipes to the burner. Consideration should be given to dedicated MGO delivery piping and accessories. The burning of MGO may also necessitate speedy and effective flame failure detection. Boiler/equipment manufacturers should be consulted for specific recommendations in this regard.

h. To avoid vaporization by heating of MGO in the piping system, heat tracing of fuel pipes should be turned off or heaters bypassed and/or switched off.

i. Flame stability should be considered. Where a boiler is designed to burn HFO instead of MGO, a flame failure may occur when the fuel is changed over to MGO. Photocells may not have the color spectrum necessary for MGOs. Equipment and/or machinery manufacturers should be consulted for specific recommendations based on applications. Also, safety features too promptly and effectively deal with flame failures, and all of the possible ramifications of a flame failure, need to be developed/considered. For example, flame supervision may have to be complemented with another flame scanner due to different properties of HFO and MGO flames such as flame length.

j. Existing HFO pumps may have difficulties with suction of the light oil (MGO) because of viscosity (HFO is more viscous than MGO). Also, HFO has better lubrication properties than MGO. Accordingly, due to lack of lubrication, this may eventually result in overheating of the existing HFO pumps (unless they were originally designed to handle MGO). It may be necessary to install new pumps and associated valves to handle MGO.

k. HFO has a higher density and a lower calorific value than MGO. Therefore, if the original burner setting for HFO is not changed before using MGO to control the amount of fuel injected into the burner, increased smoke emissions may result from boiler uptake. Further, fuel/air ratio, governed by fuel pressure only, will be too rich for safe combustion.

l. A detailed fuel change-over operation manual should be readily available for the operating crew on board.

m. Vessel owners and operators consider the following:

- A fuel system inspection and maintenance schedule should be established.
- System pressure and temperature alarms, flow indicators, filter differential pressure transmitters, etc., should all be operational.
- System seals, gaskets, flanges, fittings, brackets and supports need to be maintained.
- A detailed system diagram should be available.
- Initial and periodic crew training should be conducted. Training assessments should be kept up-to-date.

n. Where a low-load firing operation without a pilot (i.e., burning only gas) is proposed, and if such operation has not been assumed in the original boiler system design, a safety assessment should be made for each individual operational case in order to ascertain safe operations. This should include, amongst other considerations, the following:

- Boiler management system and combustion control that is suitable for intended low-load firing operation.
- Flame scanner type and positioning that are suitable to detect failure at low-load firing operations.

o. It should be noted that when boilers are used for propulsion, maneuvering conditions may demand large and rapid load changes. Therefore, if boiler operation without a pilot under maneuvering conditions is proposed and such operation has not been assumed in the original boiler system design, safety assessments should be made for each individual operational case in order to ascertain the feasibility of such an operation.

p. The fuel oil systems in LNG ships with steam turbine propulsion are designed for HFO in combination with the boil-off from the cargo. Therefore, fuel oil systems in these vessels must be modified to use MGO. MGO is not to be used in the fuel oil systems in these vessels without modifications since:

- It is important that the fuel supply remain uninterrupted for propulsion boilers.
- Risk of failures in fuel pumps and valves.
- Unintentional fuel oil evaporation risks.
- For burners having concentric type fuel injectors, steam atomizing can heat up MGO.
- For burners having parallel tubes for steam and fuel oil, due to the lower temperature of MGO, tubes conveying MGO can distort due to temperature gradients.
- The design of the burner management system (BMS) and flame supervision is based on HFO.

REQUIREMENTS

For modified systems, ABS requires the following:

1. For boilers which have not been originally designed to continuously burn MGO, it may be necessary to carry out modifications to the existing fuel oil piping arrangements including the burner management and associated control systems. The boiler operation with low sulfur fuel should be evaluated by systematically assessing related systems taking into consideration the potential risks identified in ABS Suggestions 3 (a) through (p) as applicable, and appropriate measures are to be taken for safe operation of the boilers. Where modifications are identified, details of all modifications together with the aforementioned design evaluation are required to be submitted to ABS for approval.
2. Design modifications, if any, are to be carried out by the original manufacturer or a competent entity that is considered responsible for the modified design.
3. Any modification to existing boiler installations (including piping arrangements and control systems) will be subject to ABS review and approval for both design assessment and survey. Accordingly, the details of the modifications considering the above suggestions are required to be submitted to an ABS technical office for review of general piping (such as pipe materials suitability, pressure and fittings), automation and controls systems and other safety requirements in accordance with the applicable Rules.
4. All modifications are to be carried out in accordance with approved drawings/details to the satisfaction of the attending surveyor.

APPENDIX 3 – FUEL OIL MANAGEMENT PLAN

A Fuel Oil Management Plan template, is available at:
http://ww2.eagle.org/content/dam/eagle/forms/fomp-review.docx

LIST OF ACRONYMS

ABS	American Bureau of Shipping
ACC	Automatic Centralized Control
ACCU	Automatic Centralized Control Unmanned
Al	Aluminium
ASTM	American Society for Testing and Materials
BDN	Bunker Delivery Note
BN	Base Number
BOG	Boil Off Gas
CARB	California Air Resources Board
CCAI	Calculated Carbon Aromaticity Index
CCR	California Code of Regulation
CFR	Code of Federal Regulation
CIMAC	International Council on Combustion Engines
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DMX, DMA, DMZ, DMB, DFA, DFZ, DFB	Distillate Grade ISO Fuel Oil Categories
ECA	Emission Control Area
ECSA	European Community Shipowners' Associations
EGCS	Exhaust Gas Cleaning System
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
EU	European Union
FAME	Fatty Acid Methyl Ester
FONAR	Fuel Oil Non-Availability Report
HFO	Heavy Fuel Oil
HSQE	Health, Safety, Quality and Environmental
IAPP	International Air Pollution Prevention
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
ISM	International Safety Management
ISO	International Standard
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LSHFO	Low Sulfur Heavy Fuel Oil
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine Diesel Oil
MEPC	Marine Environment Protection Committee
MGO	Marine Gas Oil
NOx	Nitrogen Oxide
OGV	Ocean Going Vessel
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
PPR	Pollution Prevention and Response
PRC	People's Republic of China
RMA, RMB, RMD, RME, RMG, RMK	Residual Grade ISO Fuel Oil Categories
SAR PRC	Special Administrative Region of the People's Republic of China
SCR	Selective Catalytic Reduction
SECA	Sulfur Emission Control Areas
Si	Silicon
SO_2	Sulfur Dioxide
SO_3	Sulfur Trioxide
SOLAS	Safety of Life at Sea
SOx	Sulfur Oxide
TBN	Total Base Number
VGO	Vacuum Gas Oil

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