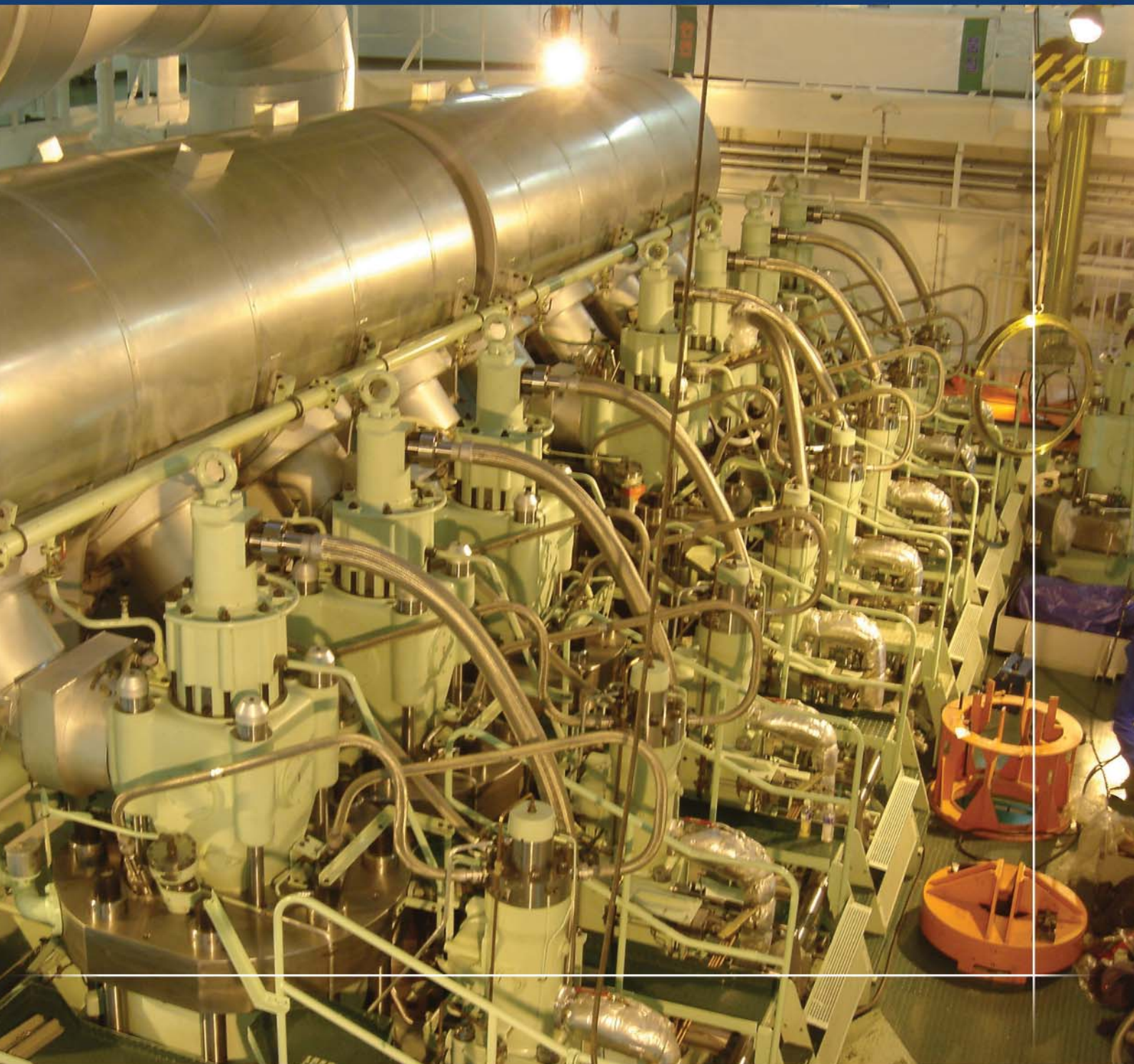


Fuel Switching Advisory Notice



Our Mission

The mission of ABS is to serve the public interest as well as the needs of our clients by promoting the security of life, property and the natural environment primarily through the development and verification of standards for the design, construction and operational maintenance of marine-related facilities.

Quality & Environmental Policy

It is the policy of ABS to be responsive to the individual and collective needs of our clients as well as those of the public at large, to provide quality services in support of our mission, and to provide our services consistent with international standards developed to avoid, reduce or control pollution to the environment.

All of our client commitments, supporting actions, and services delivered must be recognized as expressions of Quality. We pledge to monitor our performance as an on-going activity and to strive for continuous improvement.

We commit to operate consistent with applicable environmental legislation and regulations and to provide a framework for establishing and reviewing environmental objectives and targets.



Fuel Switching Advisory Notice

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Disclaimer

This ABS Advisory Notice is not intended to be a comprehensive analysis of all the issues applicable to operating marine engines and machinery on low sulfur, low viscosity fuels for every ship. It is issued by ABS for informational and guidance purposes only and each ship should have its machinery plant assessed by competent persons to determine what issues may specifically apply and what risks may be involved in switching between fuels of different properties.

Introduction

Ship-sourced emissions are receiving increased scrutiny from the International Maritime Organization (IMO), government environmental agencies, public health advocates and non-governmental environmental groups. The goal of these groups is to reduce the harmful effects of ship emissions on air quality. Initial regulations have been oriented towards reducing harmful emissions in coastal and port areas with a focus on the release of sulfur oxide (SOx) and nitrogen oxide (NOx) compounds and particulate matter (PM).

SOx compounds can be reduced directly by lowering the percent of sulfur in fuel oil. NOx compounds are not affected significantly by the type of fuel burned but can be reduced by controlling the combustion process. Regulations are also addressing the reduction of particulate emissions, which can be achieved by burning cleaner distillate fuels as opposed to residual fuels, such as traditional heavy fuel oils, and by reducing sulfur content since some particulates are sulfur compounds. To achieve these goals the use of low sulfur distillate fuel is becoming mandatory in a growing number of coastal and port areas.

Because fuel is a major component of vessel operating costs, most ship machinery plants have been designed to operate primarily using lower cost heavy fuel oil (HFO) with provision for occasional

operation using marine diesel oil (MDO), particularly when maneuvering. For some smaller diesel engined ships and most high speed ships, such as fast ferries, MDO is the primary fuel used. Use of heavy fuels and some types of MDO will be progressively restricted under the pending emission regulatory regimes. Ships will have to operate either using clean distillate fuel, marine gas oil (MGO), or use an effective emissions scrubbing system in order to meet the low sulfur fuel requirements when trading in areas where strict emission limits are in effect.

Since most machinery plants were not designed to operate using MGO, there are many potential difficulties that can arise during the fuel switching process and during sustained operation. These stem from the effects of the low sulfur and low viscosity characteristics of MGO on machinery plants designed for HFO. These may also affect plants designed for MDO operation but to a less significant degree than HFO plants.

This ABS Advisory has been prepared to provide guidance to shipowners, operators and builders about how the new requirements requiring switching to MGO operation may affect the operation, safety and design of ships. For most ships, switching to MGO fuel is not easily achieved as, apart from the physical modification of the plant, the changeover must be subject to careful procedures if it is to be handled safely.



I. Background

The primary international regulatory mechanism for controlling ship emissions is Annex VI, Regulations for the Prevention of Air Pollution from Ships, of the MARPOL Convention. Since the harmful effects of SO_x emissions from ships have been known for many years, measures have been taken under MARPOL to regulate the sulfur content in fuel. This has resulted in a gradual lowering of sulfur in residual fuels from 6 percent in the 1970s to a maximum of 4.5 percent in the current MARPOL Annex VI regulations as determined by the ISO standard for marine fuels. Currently, actual average sulfur levels are in the range of 2 to 3.5 percent.

In response to the desire of some countries to reduce SO_x emissions from ships in their coastal waters, Annex VI permits the establishment of SO_x Emission Control Areas (SECA). IMO has subsequently replaced the SECA designation with ECA (Emission Control Area), since it implies control of more emission components than only those associated with sulfur compounds. To date, ECAs have been established that cover the entire Baltic Sea, most of the North Sea and the English Channel and several more areas have been proposed for consideration. At present, fuel with a maximum of 1.5 percent sulfur must be used in an ECA.

Some coastal areas, countries and regions, such as the state of California and the EU, as described in Section III of this Advisory, are placing even stricter controls on ship emissions in coastal areas and in port. They are implementing new regulations outside the IMO since these localities feel there is a health and environmental urgency to controlling ship-sourced emissions. In some ports, there is also a goal to stop all emissions from ships at the dock by requiring the use of shore power while the ship is alongside (commonly referred to as “cold ironing” or “alternate marine power”).

Even so, it continues to be recognized that the IMO is still the most effective forum for addressing air pollution from ships on a worldwide basis. As part of this process countries are now submitting to the IMO requests to have their coastal waters declared an Emission Control Area (ECA). As described in Section II of the Advisory, the US and Canada have submitted a proposal to have the coastal waters of both countries out to 200 NM, except for Arctic regions, designated as an ECA. Such action may

prompt other countries and the EU to consider submitting proposed ECAs along their coastal areas and adjacent seas to IMO for adoption.

II. IMO Regulations & Status

Annex VI Sulfur Limits

Annex VI of MARPOL, Regulations for the Prevention of Air Pollution from Ships, contains the international regulations that globally control the harmful emissions from ships. It took effect on 19 May 2005. It represents worldwide acceptance that harmful emissions from ships should be further decreased in a progressive manner as the capability to do so is developed. 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). It is applicable from 1 July 2010. The revisions adopted include progressive reduction in SO_x emissions from ships, progressive reductions in NO_x emissions from marine engines and revised criteria for Emission Control Areas (ECAs).



Relevant to fuel switching, the allowed sulfur content of fuels in non-ECAs for use on ships is to be decreased over the coming years per the schedule contained in the revised Regulation 14 of Annex VI as follows:

- 4.5 percent sulfur prior to 1 January 2012
- 3.5 percent sulfur on and after 1 January 2012
- 0.5 percent sulfur on and after 1 January 2020
- A review provision is included in Regulation 14 that shall be completed by 2018 to determine if availability of fuel oil to meet the 0.5 percent sulfur limit in 2020 can be expected. If not, then the possibility is given to delay the effective date until as late as 1 January 2025.

SECAs & ECAs

Regulation 14 of Annex VI contains provisions for nations to apply to the IMO for designation of areas where harmful emissions from ships can be specially limited. In the original Annex VI this applied to SO_x emissions only and the areas were designated as SO_x Emission Control Areas (SECAs). The IMO has approved two such areas: the Baltic Sea and the North Sea and English Channel as defined in Regulation 14 (3) (a) of the original Annex VI. In the revised Regulation 14, effective 1 July 2010, other harmful emissions including particulate emissions and NO_x emissions can be limited. These areas are now designated as Emission Controls Areas (ECAs). Appendix III of the Revised MARPOL Annex VI lists the Criteria and Procedures for Designation of Emission Control Areas. The existing SECAs are now designated as ECAs. For a ship operating in an ECA the following sulfur limits apply:



SO_x Emission Control Areas

- 1.5 percent sulfur prior to 1 July 2010
- 1 percent sulfur on and after 1 July 2010
- 0.1 percent sulfur on and after 1 January 2015

Other areas of the world are interested in having an ECA designated for their coastal waters (see earlier). The key requirements of the proposed US/Canada ECA are as follows:

- 1 percent sulfur on and after 1 January 2012 (expected)
- 0.1 percent sulfur on and after 1 January 2015
- NO_x Limit: Effective 1 January 2016, all new ships must have NO_x emissions in compliance with Tier III requirements per Regulation 13 of Annex VI.

It is expected that ships that operate in an ECA will be able to use low sulfur heavy fuel, assuming heavy fuel with sulfur content below 1 percent is available, up until the 2015 implementation of the 0.1 percent sulfur limit. Regulation 14 requires suppliers of any fuel to be used in an ECA to document its sulfur content in accordance with Regulation 18. Such fuel shall be segregated from higher sulfur content fuel. Ships shall carry on board a written procedure showing how the fuel oil changeover is to be accomplished, allowing sufficient time for the fuel system to be flushed of all non-compliant fuel.

The date, time and place of the changeover when entering and leaving the ECA plus the volume of low sulfur fuel in each tank at such time shall be logged. For the lower sulfur limits coming into effect 1 January 2015, currently only MGO type fuels are available that can meet the required low sulfur content. All vessels that transit through the ECA will therefore need to have capability to operate on MGO for the entire time the vessel is in the ECA.

Exhaust gas cleaning systems are an alternate means of satisfying the requirements of the ECA by removing the harmful substances directly from the exhaust gas and allowing the use of regular fuels. They are discussed in Section VIII of this Advisory.

Bunker Delivery Notes & 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 requires that parties to MARPOL Annex VI shall take reasonable steps to promote the availability of fuels which comply with the Annex. It also lays out



Chart of Proposed US/Canada ECA

the steps that can be taken by regulatory agencies and actions that can be taken by a ship if such fuel is found not to be available. 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.

Per paragraphs 8.1 and 8.2 of the revised Regulation 18, each Bunker Delivery Note shall be accompanied by a representative sample of the fuel oil delivered. 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.

If the sample is required to be analyzed 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 check and confirm the seal number against the sample label on the test record. A detailed sampling and verification procedure shall be followed by the laboratory as described in Appendix VI.

III. Other Regional, National & Local Regulations

Besides regulations issued by the IMO, regions, countries and the state of California have implemented fuel content and emission regulations or are in the final process of adopting them.

EU In-port Regulations

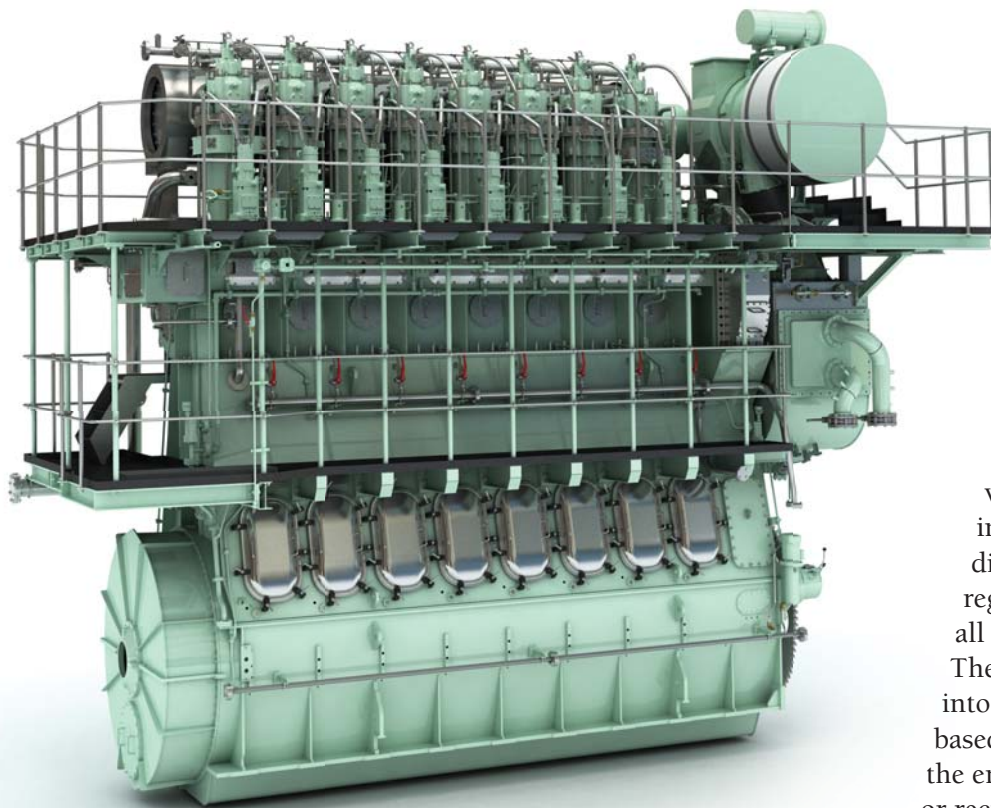
The EU has implemented regulations relating to the sulfur content of fuels used in its ports. Under Article 4b of the EU Council Directive 1999/32/EC of 26 April 1999 relating to a reduction in the sulfur content of certain liquid fuels and amending Directive 93/12/EEC, as amended, the following sulfur limit is applied:

- Sulfur Limit: 0.1 percent sulfur for marine fuels
- Effective Date: 1 January 2010
- Applies to all types of marine fuels used by ships at berth in EU ports unless an approved emission abatement technology is employed or shore power is available. Also applies to both main and auxiliary boilers.

Following representations from shipowner associations regarding their inability to meet the 1 January 2010 effective date due to the unavailability of sufficient parts for the modification of existing engines, insufficient trained personnel to effect the modifications, and taking into account the safety considerations associated with fuel switching for non-modified engines, on 21 December 2009 the EU Commission issued a recommendation to EU Member States. The recommendation 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 non-complying ships.

The Commission also intends to take action to allow LNG carriers to use mixtures of fuels resulting in emissions of sulfur dioxide equal to or lower than required by the Directive.





generally MDO is currently not available with such low sulfur content so ships will effectively be using MGO only during Phase II.

US EPA Regulations

For new US flag vessels, the US EPA has implemented national diesel engine emission regulations applicable to all regions of the country. These regulations have come into effect over several years based on the size and use of the engine (e.g. commercial or recreational use). There are three categories of engines based on per-cylinder displacement.

Category 1 engines are those with displacements of less than 5 liters per cylinder, Category 2 engines have displacements between 5 and less than 30 liters per cylinder, and Category 3 engines have displacements of 30 liters per cylinder or more.

Under the EPA regulations, Category 1 and 2 engines have phased in limits in 4 tiers. All new Category 1 and 2 engines must now be at least Tier 2 compliant on US flag vessels. The EPA Tier 2 limits are similar to Tier II limits of Annex VI for NO_x, but also regulate hydrocarbon (HC), particulate matter (PM) and carbon monoxide (CO). Each engine subject to the regulations shall be provided with an EPA issued certificate provided by the maker indicating it meets the required standards and the fuel type for which it is certified.

It is expected engines can only meet these regulations by using MGO unless an exhaust gas cleaning system is used. Since low sulfur MGO will be used in these engines, a side effect is that SO_x emissions will also be reduced, even though not directly addressed in the regulations.

These regulations apply to all engines built after the effective date, for a particular engine size, that are installed on US flag ships, regardless of whether they are in US waters or not, as it is illegal to have any equipment or connections on board that allows the operator to connect a fuel to the engine for which the engine is not certified.

Despite the recommendation, it remained up to each EU/EEA Member State to decide whether and how they choose to respond to the EU Recommendation.

California Air Resources Board Regulations

The California Air Resources Board (CARB), under its authority to regulate emissions within the state, has implemented regulations in two phases pertaining to the sulfur content limits and types of fuels that can be used in California waters, as follows:

- Phase I Effective Date: 1 July 2009
- Phase I Allowed Sulfur Limits and Fuel Types: Marine Diesel Oil (ISO 8217, DMB Grade) with a limit of 0.5 percent sulfur, Marine Gas Oil (ISO 8217, DMA Grade) with a limit of 1.5 percent sulfur. Note that heavy fuel usage is not permitted, even if low sulfur fuel, so as to reduce particulate emissions
- Phase II Effective Date: 1 January 2012
- Phase II Allowed Sulfur Limits and Fuel Types: MDO (ISO 8217, DMB Grade) or MGO (ISO 8217, DMA Grade) with a limit of 0.1 percent sulfur
- Boundary Limit: All California waters within 24 NM of the California baseline (coastal boundary as defined in the regulation)
- Applies to all types of marine fuels used by ships. Applies to auxiliary boilers, but not to main propulsion boilers

Even though the California regulations allow use of MDO, even under the Phase II regulations,

EPA Tier 3 limits for Category 1 engines are being implemented over the time period of 2009 through 2014 depending on the displacement of the engine. For Category 2 engines Tier 3 regulations become effective 1 January 2013 for engines less than 15 liters/cylinder, and 1 January 2014 for engine up to 30 liters/cylinder.

New Category 3 engines are presently required by EPA to meet Tier 1 limits, which are identical to the MARPOL Tier I limits. EPA has established Tier 2 and Tier 3 limits for Category 3 engines that will limit NO_x emissions similar to MARPOL, but will also limit HC and CO emissions. Tier 2 requirements must be met by all new engines beginning in 2011 and Tier 3 limits in 2016.

EPA is finalizing a change to the diesel fuel program that will allow for the production and sale of 0.1 percent sulfur fuel for use in Category 3 marine vessels. In addition, the new fuel requirements will generally forbid the production and sale of marine fuel oil above 0.1 percent sulfur for use in most US waters, unless the vessel employs alternative devices, procedures, or compliance methods that achieve equivalent emission reductions.

IV. Marine Fuels

Fuel Standards

There are internationally recognized standards that define the characteristics of fuel oils and what they can contain so that they will be suitable for use on board ships. The most widely used standard is ISO 8217 with the latest edition issued in 2005. Other standards exist such as those issued by the Europe-based International Council on Combustion Engines (CIMAC), the British standard BS6843-1:1996 and the US standard ASTM D-975.

Frequently, the type of fuel that can be supplied to a ship is restricted to a fuel that meets a specific designation in one of the standards, usually from the ISO-8217 standard. The most commonly used HFO types are IFO180 and IFO380, where the number indicates the maximum viscosity in centiStokes (cSt) at 50°C. The highest viscosity fuel per ISO 8217 is HFO 700, but even though many ships have fuel systems designed to operate up to this viscosity, it is rarely actually used.

In the ISO standard, within each viscosity class of fuel, there are subcategories, such as RME 180, RMF 180 and RMH 380, RMK 380, etc. The fuels with a lower last letter have lower density and fewer impurities (and would generally cost more).

Sulfur content in the IFO180 and 380 fuels is currently restricted to 4.5 percent per Annex VI of MARPOL and this limit will progressively reduce per the changing limits over time contained in the new Annex VI.

In reality, most fuels available today have lower sulfur content. In some areas of the world, heavy fuels with a sulfur content of less than 1.5 percent are available to meet the current standard applied in ECAs. These fuels are referred to as low sulfur heavy fuel oil (LSHFO). For some LSHFO the low sulfur content occurs naturally because the source crude oil is a sweet crude (low sulfur). For others, the fuel has gone through a desulfurization processes to achieve the required sulfur level.

The marine distillate fuel designations per ISO 8217 are DMX, DMA, DMB and DMC. DMX fuel is a gas oil type fuel with low flash point (minimum 43°C). It is used only in special applications on ships since, for safety reasons, fuel with a minimum flashpoint of 60°C is the standard. All the other marine distillate fuels have a minimum flashpoint of 60°C. DMC is also not widely used as it is similar to DMB but with higher density and more impurities and so there is little demand for it. MDO is normally understood to mean fuel that meets the DMB standard and MGO is understood to mean fuel that meets the DMA standard.

The ASTM D-975 standard impacts distillate fuels available in North America since most distillate fuels are consumed by automotive and land based engines and fuels sold into that market are prepared to meet one of the ASTM standard designations. The same fuels are sold to the marine market as meeting the closest ISO standard. The most commonly used fuel made to an ASTM standard used on ships is No. 2 Diesel oil, which is similar to ISO 8217 Grade DMA. There are currently three standards for sulfur content in No. 2 Diesel, S15, S500 and S5000, where the number indicates the sulfur content in parts per million. In percentages, the sulfur contents are 0.0015 percent (also known as ultra low sulfur diesel (ULSD)), 0.05 percent (low sulfur diesel) and 0.5 percent (regular diesel), respectively.



Sulfur & Viscosity Ranges

The new restrictions on sulfur content affect the types of fuels that can be used on ships and thus it is helpful to understand what are 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 1.

An update of ISO-8217 is underway and is expected to be published in mid 2010. In the update the minimum viscosity of DMA and DMB will be harmonized at 2.00 cSt at 40°C and DMC will be reclassified as a residual fuel.

Ultra Low Sulfur Diesel Oil

There is a growing worldwide movement to require the use of ultra low sulfur diesel fuel. Initially this requirement has been applied to automotive use and now is being applied to non-road and marine engines. Around the world ULSD has varying definitions, typical sulfur contents are 15 parts per million (ppm) (0.0015 percent) (US/Canada), 10 ppm (Europe, Australia, New Zealand) or 50 ppm in some other countries. As the use of ULSD becomes widespread ashore, refineries will increasingly only produce ULSD and sell it to the marine market, since it does not pay to refine the small quantities of fuel sold to the marine market to a different standard.

The reason for the push to require ULSD is that its use permits the application of new emission control technologies that will permit substantially lower particulate matter and NO_x emissions from diesel engines. Its use will also lead to a reduction in SO_x emissions from engines.

There are several issues that arise with the usage of ULSD that are well recognized. One is that ULSD fuel has low lubricity because the process that reduces the sulfur also reduces its lubricating properties. This will affect pumps and components in the fuel system. To prevent excessively low lubricity in diesel fuel, minimum lubricity standards for fuels were adopted by ASTM in 2005. The refining process also reduces the aromatic content and density of the fuel, resulting in a minor decrease in its energy content on a volumetric basis on the order of 1 percent.

Since automotive engines will be using ULSD fuel exclusively, the engines and fuel system components can be designed based on its characteristics. The situation is different for marine engines because they are typically designed to normally operate on higher viscosity fuels with higher lubricity. This means operating these engines occasionally on ULSD fuel has more potential for adverse impact. Designing fuel systems and engines to operate on both normal marine fuels and ULSD is a challenge to engine designers and marine engineers and could reduce the power and efficiency of engines in the future.

Fuel Quality Requirements for Propulsion & Auxiliary Diesels

Makers of diesel engines normally set a range of viscosities over which the engine can be operated. These include a minimum and maximum viscosity that apply to the fuel at the fuel injection pumps in running condition. For heavy fuels with high viscosity, the required viscosity is achieved by heating the fuel. For distillate fuels, the fuel at

Table 1 – Sulfur and Viscosity Limits and Ranges for Typical Fuels

Fuel Type ¹	Viscosity (cSt) (at 50°C for IFO and 40°C for Distillate Fuels)			Sulfur Content (%)	
	Minimum	Maximum	Typical Range ²	Maximum	Typical Range ³
IFO180	–	180	–	4.5%	1% - 3.5%
IFO380	–	380	–	4.5%	1% - 3.5%
DMB	–	11	2.5 - 6	2%	0.03% - 1.3%
DMA	1.5	6	2 - 4	1.5%	0.01% - 1%
ULSD	1.9	4.1	–	0.0015%	–

1. Fuel designations and limits are based on ISO 8217 standard except ULSD, which is based on ASTM D975 standard.

2. Typical Range data is taken from CARB presentation dated 5 March 2008, ref. 4

3. Typical Range data is taken from BunkerWorld.com Worldwide Fuel Quality Reports dated 10 December 2009, ref. 13



ambient temperature normally has a viscosity within the specified limits. Low sulfur fuels tend to have viscosity near or at the lower limits of allowed viscosity and the main issue becomes whether they are below the lower limit considering the temperature of the fuel at the injection pumps.

Typical minimum viscosity levels for various engine types are listed below. Engine makers should be consulted for limits applicable to any specific engine as the minimum viscosity limits do vary between engine makers and engine types from the same maker.

- Slow Speed Diesel Engines (cross head type with rated speed of less than 400 rpm): 2 cSt is typical minimum fuel viscosity.
- Medium Speed Diesel Engines (trunk piston type with rated speed of 400 rpm to less than 1400 rpm): 1.8 to 3.0 cSt is minimum viscosity depending on make and type.
- High Speed Diesel Engines (trunk piston type with rated speed of 1400 rpm and above): 1.4 to 1.5 cSt is minimum viscosity depending if the engine is designed for DMX fuel (1.4 cSt min) as well as DMA fuel (1.5 cSt min).

It is important to note these minimum viscosities are the values at the fuel injection pumps at the actual fuel temperature and not the nominal viscosity at standard conditions such as 40°C. Since low sulfur fuels have viscosities close to the permitted minimums as indicated in Table 1, the temperature of the fuel needs to be controlled. If, for example, DMA fuel with viscosity at the lower end of the permitted range of 2 cSt at 40°C, is used in a slow speed diesel, the fuel temperature at the engine needs to be kept below 40°C at all times.

There are many circumstances when the fuel can easily be above this temperature, such as during and just after changeover from HFO usage, during warm weather and from the heating that occurs during recirculation of fuel through a hot engine and back to the mixing tank. In the past this has not been an issue for several reasons. Ships normally used heavy fuel from “pier to pier” and only occasionally changed to marine diesel oil (MDO) for short periods of time. Furthermore, normally available MDO had a viscosity at 40°C (standard condition) that was sufficiently above 2 cSt over the typical range of temperatures found at the injection pumps and the viscosity remained above 2 cSt even when the temperature exceeded 40°C.

In the future, when ships operate in ECAs under the upcoming very low sulfur requirements, there can potentially be days of operation using DMA fuel. Commonly DMA is available with a viscosity close to the minimum value of 2 cSt at 40°C and thus any fuel temperature rise above 40°C will result in fuel with too low a viscosity at the engine with potentially harmful effects as discussed in the next section.

V. Effects of Low Sulfur Fuels on Operation

Potential Effects of Low Viscosity, Low Sulfur Fuel on Diesel Engines

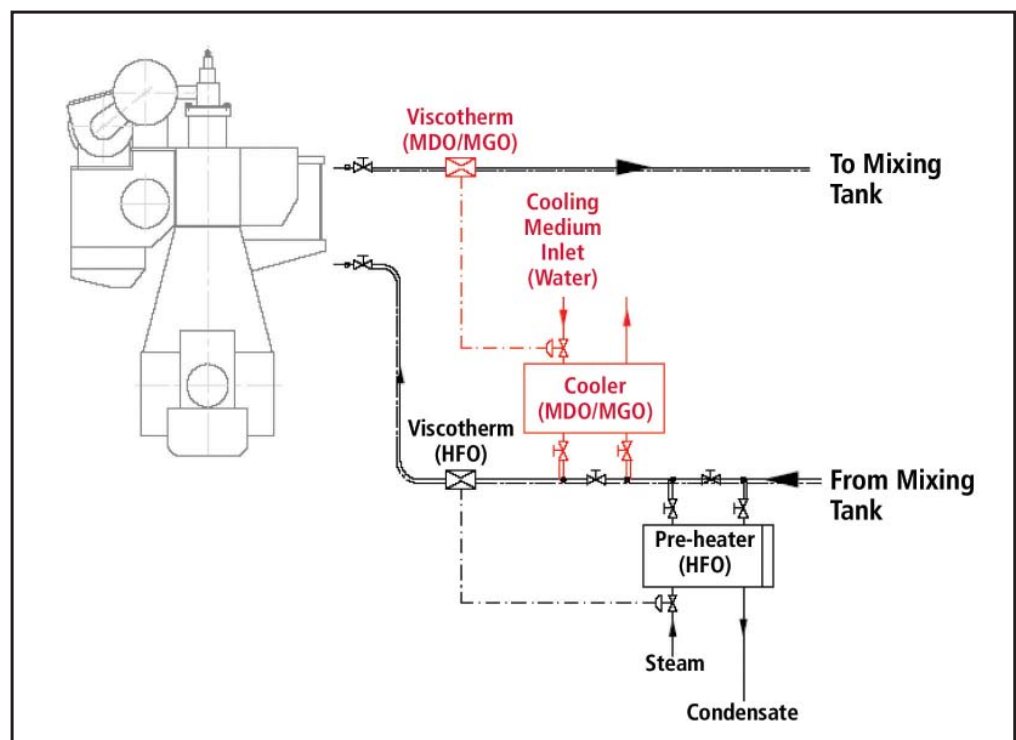
Use of low sulfur, low viscosity fuel has the potential for several harmful effects on diesel engines as discussed in the following paragraphs.

Low Viscosity: The potential effects of fuel with too low a viscosity either because of purchase of incorrect fuel or too high fuel temperature are as follows:

1. Reduced effectiveness as a lubricant. The lower viscosity will reduce the film thickness between the fuel pump plunger and casing and in the fuel valves leading to excessive wear and possible sticking, causing failure of the fuel pump. Special fuel injection pumps may be available that are more suitable for this type of fuel, such as tungsten carbide coated pumps, or a fuel pump lubrication system could be installed. Any new types of fuel injection equipment installed to address lubrication issues shall be certified by the engine maker to maintain engine compliance with emission standards and may require re-certification of engines.

2. Loss of capacity in fuel supply and circulation pumps due to low viscosity fuel leaking around pump rotors, preventing the ship from achieving full power.
3. Leakage of fuel through the fuel pump barrel and plunger and suction and spill valve push rods on slow speed engines. This leakage may result in a higher load indication position of the fuel rack and may require adjustment of the governor for sustained operation on low viscosity fuel.
4. An existing purification system may not be suitable for low viscosity, low density fuels. MGO purification is not always required, but is sometimes recommended. To do so may require the installation of a separate MGO purifier and a separate piping system to maintain fuel segregation.
5. When operating on low viscosity MGO, one way to keep viscosity above the minimum value of 2 cSt (or whatever is the specified minimum by the engine manufacturer) at the engine fuel injection pumps is to install a fuel cooler that will 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 this temperature. A fuel cooler that uses the central FW cooling as the cooling medium may not be adequate as the cooling water normally has a set point temperature of 36°C to 38°C and may not provide sufficient cooling if the fuel has to be kept below 40°C. In this case, adding a chiller unit to the cooler can lower the fuel temperature down to about 20°C to 25°C and will be effective in raising the viscosity above the required minimum. There are several locations where the cooler can be installed

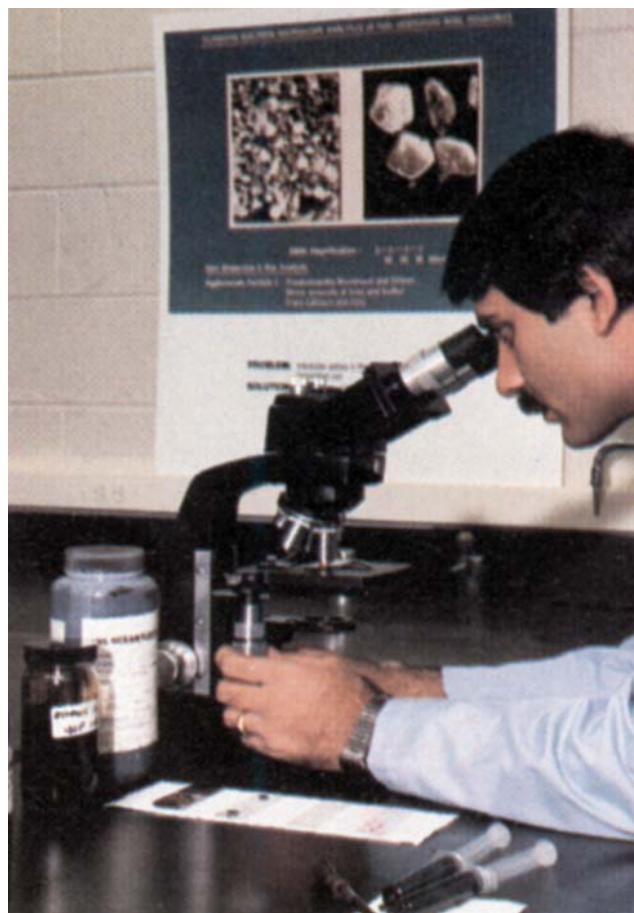
in the fuel service system. One arrangement is to install the cooler in the return line from the engine to the mixing tank to take out the heat added to the fuel during the recirculation through the engine. This type is effective if the fuel source is at the correct temperature and it is only necessary to reduce fuel heating from the returned fuel to the mixing tank. This type 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 first. An alternative fuel cooler location is in the fuel supply pipe to the engine. In this arrangement the temperature of the fuel to the engine is directly controlled and it is more effective in cooling the fuel down below 40°C since there is no heat from the fuel source and pumps added back after the cooler. Temperature of the fuel out of the cooler can be controlled if a means of adjusting the cooling medium flow (by a temperature sensor in the fuel outlet line) is provided. In this way fuel temperature can gradually be brought to the desired temperature during fuel switching. Abrupt lowering of the fuel temperature should be avoided. Diesel oil coolers for boilers are similar in concept to those for diesel engines. See Figure below for a typical cooler installation with the cooler in the fuel supply line.



Possible Fuel Cooler Arrangement

Low Sulfur: The potential effects of fuel with very low sulfur content are as follows:

1. Lube oil BN (Base Number) does not match the acidity of the fuel. This especially applies to slow speed engines which have cylinder lubrication. Because of the higher levels of acid formed on the cylinder liner when using traditional heavy fuel oil with sulfur content of 2 percent or higher, ships with slow speed engines normally operate with cylinder oils with BN of about 70. However, this BN is inappropriate for low sulfur fuels with sulfur content of less than 1.5 percent and, in particular, for ULSD with sulfur content of 15 ppm. For extended operation with low sulfur fuel and 70 BN cylinder oil there is a danger of hard calcium deposits forming on the cylinder liners. The reason for this is that alkaline compounds such as calcium salts are used to neutralize the sulfuric acid formed on the liner when using high sulfur fuels and, if there is excessive alkaline compound compared to the amount of acid, deposits of the alkaline compound will occur. The hard deposits can lead to bore polishing, liner lacquering and sudden severe wear of the liner. For short term operation on low sulfur fuel (several days to one week) continued operation with 70 BN cylinder oil is generally accepted by engine manufacturers provided cylinder oil lubrication rates are kept at minimum levels. For longer term operation with low sulfur fuel, change to a lower BN 40 or BN 50 oil is recommended. Long term operation on very low sulfur level fuels requires careful matching of the cylinder oil, including alkaline compounds, and detergent levels to the actual operating conditions of the engine. Engine manufacturers should be consulted if this type of operation is planned. If an engine is changed to low BN cylinder oil and then operated with high sulfur fuel the risk exists of excessive acid formation and rapid cylinder liner wear. For trunk piston engines it is also important to carefully select the correct lube oil if operation with both HFO and ULSD is desired. In the case of truly extended operation on dual fuels, a drain/refill system or a set of engines with one oil type and another set with the other oil type may be necessary.
2. The more complex refining of low sulfur fuel, including the desulfurization process, can lead to fuels with poor ignition and combustion characteristics. This particularly affects medium and high speed diesel engines which are more sensitive to this quality. Studies are underway to understand this phenomenon better.



Lack of Lubricity: Low sulfur fuels, particularly ULSD fuel, can have low lubricity. The reason for this is that sulfur in chemical combination with other components of fuel oil has a lubricating effect. Lack of lubricity can further promote sticking and seizing of fuel pumps caused by low viscosity. The ISO 12156-1 standard offers a test method for fuel lubricity and fuel suppliers can be requested to carry out this test. If the test results are outside commonly used limits, i.e. 460 to 520 microns, fuel suppliers can be requested to add a lubricity additive. Consideration must be given, however, to the effects of the additive on engine emissions.

Low Density: Low sulfur, low viscosity fuels typically have low density when compared to heavy fuel oils. This will result in less energy per volume of fuel and thus will require more fuel volume to be supplied to the engine to maintain equivalent power. This can be a problem with 4 stroke engines where the difference in output per unit volume of fuel delivered to the engine can be on the order of 6 to 15 percent when also considering the increased leakage in fuel pumps. Engine governors and automation need to be able to adjust to the changes in fuel rack position and governor settings. This situation is aggravated on older engines with worn injector pumps.

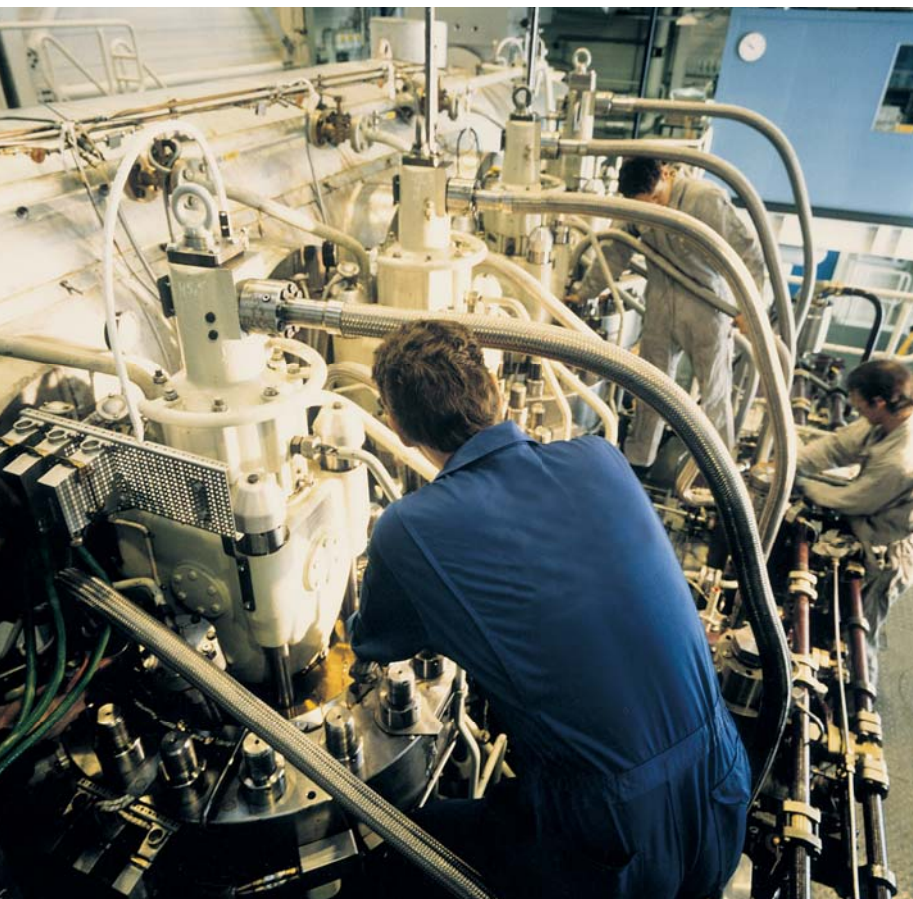
Incompatibility of Fuels: Mixing two types of fuels can lead to risk of incompatibility between the two fuels, particularly when mixing heavy fuel and low sulfur distillate fuels. If incompatibility does occur, it may result in clogging of fuel filters and separators and sticking of fuel injection pumps, all of which can lead to loss of power or even shut down of the propulsion plant, putting the ship at risk. Compatibility problems can be caused by differences in the mixed fuels' stability reserves. HFO fuels typically have high aromatic levels and contain asphaltenes. If the stability level of the HFO is low there can be difficulties when mixing with more paraffinic, low sulfur fuels and as a consequence the asphaltenes can precipitate out of the blend as heavy sludge, causing clogging. Compatibility test kits are available that can be used when bunkering both HFO and low sulfur fuel.

Low Sulfur Heavy Fuel Oils: Where sulfur levels are required to be 1 to 1.5 percent low sulfur heavy fuels (LSHFO) may be available in some areas. In the past these were commonly made from low sulfur crude oils, but it is possible for refineries to install desulfurization units to achieve the low sulfur content. These units are expensive and this method may not achieve wide use. If LSHFO is created by a desulfurization unit, fuel

aromaticity may be decreased which can result in lower stability reserves and lower fuel stability. A consequence of this happening is increased fuel incompatibility problems when mixing with regular HFO during fuel changeover. The low sulfur processing can also lead to additional quality problems such as ignition and combustion difficulties and increased catalytic fines levels. In addition, when LSHFO is carried on board for use in an ECA, it is required by MARPOL Annex VI be stored and purified separately from regular HFO. This can require piping changes to the fuel transfer and purification system.

Potential Effects of Low Viscosity, Low Sulfur Fuel on Boilers

Boilers have been identified as the most at-risk component on board ships when switching from HFO to low sulfur diesel oil (such as 0.1 percent sulfur diesel oil or ULSD). The reason is that the fuel supply systems, burners and combustion controls all need to be adjusted when switching fuels on boilers designed to primarily operate using HFO. The risk exists that furnace explosions can occur causing damage to the boiler and potentially a fire hazard to the ship, plus the risk of increased smoking causing air pollution and thus contravening the purpose of the switch to low sulfur diesel to reduce harmful emissions.



Special procedures apply to propulsion boilers, primarily used in LNG ships today, where there is clean boil-off gas available as a fuel. The issues that arise with those types of boilers should be specially considered by the owner, class and regulatory agencies.

Commonly used on ships are small boilers used for ship auxiliary steam production and medium size boilers used to additionally supply steam for tank heating and cargo pump operation on tankers.

Thermal Oil Heaters have similar fuel systems and burners as auxiliary boilers and the same concerns exist for them. Even though most boilers are designed to operate on marine diesel oil as a standby to heavy fuel, they are generally not designed to operate for sustained periods of time or at full capacity on the low viscosity, low sulfur fuels now being required. Some of the issues that arise with boilers when operating for

sustained periods of time on this type of fuel are as follows:

1. Burner system fuel supply pumps need to be designed to operate with the low viscosity and low density of low sulfur fuels. For example, Aalborg, a major boiler supplier, designs its fuel pumps for minimum viscosity of 4.5 cSt, which is higher than the normal viscosity of MGO of 2 to 4 cSt. To operate with lower viscosity fuel, pumps would need to be modified or a second pump provided that is optimized for low viscosity. The lower density of the low sulfur fuel may require adjustment of fuel supply controls that are volume based.
2. Burners need to be adjusted or replaced to be suitable for operation with low viscosity fuels. Depending on the type of burner, i.e. pressure jet burner, rotary cup burner, steam atomizing burner, different effects can happen. A lower viscosity fuel will cause an increase in fuel input through the burners and potentially cause excessive smoke. For rotary cup burners the higher heat radiation from the higher fuel input can cause coking of the burners unless special heat shields are in place. For steam atomizing burners the high temperature of the steam will lower the viscosity of the low sulfur fuel excessively and may cause over-firing and compressed air atomizing or special steam atomizing lances may be required. With steam atomizing there is also an issue when parallel tubes are used for the steam and unheated diesel fuel as the temperature gradient can cause distortion of the fuel tubes. The easier evaporation of lighter fuels can also cause accidental ignition in case of a missing flame or ignition source. In addition, burner automation and controls need to be adjusted to suit low viscosity, low sulfur fuels.
3. Boiler control systems should be adjusted to provide for pre and post-purge sequences to clear the furnace of flammable fuel vapors from the evaporated light fuels in case of flame failure or boiler shut down.
4. Fuel preheaters and fuel heat tracing need to be bypassed or shutoff to stop heating of the low sulfur fuels to prevent further reduction in viscosity. Care should be taken to avoid pumping MGO through heated fuel pipes and consideration given to installing separate MGO pipes. Fuel pumps that continuously circulate fuel during boiler standby condition, a necessary requirement when using high viscosity heavy fuel, should have the control system changed to stop the fuel pumps when the boilers are not being fired. The

recirculation can heat the fuel and thus cause the viscosity to decrease to an unacceptable level. Use of fuel coolers should be considered to keep fuel cool enough to achieve required viscosity levels.

5. Additional flame scanners may be required. Two scanners for the main flame supervision may be needed because of the different spectral emission ranges of heavy fuel and low sulfur diesel oil. An additional, separate scanner is useful to detect the operation of the ignition burner, if provided, since flame out of the ignition burner can lead to explosive accidental ignition.
6. Because of the integrated and specialized nature of boiler burners and controls it is recommended that each boiler fuel and burner system be checked for feasibility of operation on low sulfur, low viscosity fuel oil and any required modifications be implemented prior to its use. Only skilled and experienced persons, preferably authorized by the manufacturer, should be used for such checking. Proper fuel switching procedures should be prepared and the crew trained in their implementation with the importance of safety highlighted. Any changes or modifications to the fuel and burner systems will require class review.
7. For LNG vessels with propulsion boilers that can burn gas, the following should be considered:
 - a. Where low load firing operation, particularly under maneuvering conditions with large and rapid load changes, without use of pilot fuel is proposed, and if such operation has not been assumed in the original boiler design system, it is recommended that a safety assessment be made for each operational case in



order to ascertain safe operation. The assessment should include, among other considerations, boiler management system and combustion controls suitability for low load firing operation and flame scanner type and positioning to detect failure at low load firing operations.

- b. Fuel systems which were designed to use HFO will need to be modified to use MGO. The reason MGO is not to be used in these vessels without proper modifications include the following:
 - need to maintain uninterrupted fuel to the propulsion boilers,
 - risks of failures to fuel pumps and valves,
 - risks of unintentional fuel evaporation,
 - problems with steam atomizing with MGO (including distortion of the tubes),
 - the need to change burner management and flame supervision systems to include MGO operation.

8. Besides information received from manufacturers, a good source for further information on the above issues are the ABS Notes on Use of Low Sulfur Marine Fuel for Boilers (ref. 2). It also contains ABS requirements regarding operating boilers on MGO.

VI. Operating with Dual Fuels: HFO & Distillate

Ever since the era of costly fuels began in the 1970s, ships have generally been designed to operate primarily on low cost heavy fuels with marine diesel oil (MDO) used sometimes for smaller auxiliary engines and for long term shutdown. The Unifuel concept, where all primary machinery operates on the same HFO, was widely adopted as fuel prices increased in recent years. However, the low sulfur and low particulate emission regulations now coming into effect will require sustained operation on distillate. As discussed in the previous section, machinery plants designed for heavy fuel operation cannot be assumed suitable for operation on a sustained basis on marine gas oil (MGO) as is. 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. It is also important to prepare fuel changeover and operating procedures covering this range of fuels. Without these efforts there

is real danger of damage to auxiliary machinery, engines and boilers and their components, lack of required power being available and possible loss of propulsion or generating power at critical times during vessel maneuvering, placing the ship and the environment at risk.

This section of the Advisory discusses some of the key items that should be considered and addressed in a fuel switching procedure. An approved exhaust gas cleaning system is permitted by some of the regulations as an alternative to using the mandated fuel types. This option is discussed in more detail in section VIII of this Advisory.

The most commonly occurring issues that arise in switching over to operation on marine gas oil (MGO) are highlighted below, including the recommendations and requirements of ABS.

For new designs, consideration should be given to incorporating electronic fuel control and direct fuel injection combustion systems allowing the engines to burn a wide variety of fuels more efficiently, resulting in more power, cleaner emissions and increased fuel economy.

It should also be noted that consideration ought to be given to MARPOL Annex VI compliance when modifying anything that affects the combustion process. Any new components installed should have been tested to demonstrate their suitability as allowable alternative NOx components or settings of that particular engine group or family. The engine maker should confirm that the modification was covered by the configurations used during engine emission testing of the engine. Otherwise additional testing may be required.

ABS Suggestions for Fuel Switching

As guidance to ship owners and operators ABS has issued two Fuel Switching Compliance Notes, one for engines (ref. 1) and one for boilers (ref. 2). In the Notes it is suggested that all owners whose vessels are intended to operate in areas where low sulfur fuel is required should carry out the following measures.

1. Prepare an evaluation and risk analysis including consultation with manufacturers that outlines the issues and risks involved with operating the ship on low sulfur fuel. This analysis should cover the entire fuel system and its components, engines, boilers and control systems. Using only the engine or boiler maker advice on their equipment may not be sufficient as other components in

the system may have issues that need to be addressed. It may be advisable to consult with specialized persons in this field. Check for any service or maintenance requirements that are recommended when using MGO. A copy of the report should be maintained on board for reference by any interested party.

2. 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.
3. Consult with fuel suppliers to select and receive proper MGO on board (with viscosity at or above the minimum suitable for the machinery on board).
4. System seals, gaskets, flanges and other fittings should be carefully maintained since fuel seepage and leakage may occur from the low viscosity MGO.
5. System purifiers, filters and strainers should be maintained.
6. Control systems including alarms, transmitters, indicators, etc., should be checked and made operational.
7. Crew training (initial and periodic) should be conducted. An assessment of their training needs should be kept up to date.
8. Cylinder lubrication should be carefully



9. Any fuel switching should be completed before entering ports or restricted waters to prevent risks to the ship in case of malfunction during the fuel switching.

As a service to owners wanting documentary proof they operate in compliance with the new regulations ABS is prepared to issue Statement of Fact (SOF) certificates. These will require survey by an ABS Surveyor and ABS will verify that the vessel has dedicated low sulfur fuel storage tanks, fuel piping systems suitable for its use that maintain segregation from other fuels and has operational procedures in hand for its use. Refer to the ABS Notes for further guidance on this matter or contact the applicable ABS Divisional Technical office or Assistant Chief Surveyor office.

ABS Requirements Applicable to Fuel Switching

ABS has specific requirements that apply to the fuel switching process and any modifications made to fuel and engine components. If there are any questions please contact the applicable ABS Technical office or Assistant Chief Surveyor office.

1. If the design evaluation carried out for the operation on MGO 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.
2. The design evaluation should 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, engine start and other relevant issues. The analysis should cover fuel switching to and from HFO and MGO, 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 engine and fire and explosions. Please refer to the two ABS Notes on Use of Low Sulfur Marine Fuel (ref. 1 and 2) for more details on what is required in the analysis.
3. Any design modifications should be in compliance with original manufacturer's recommendations whenever possible. A competent entity other than the manufacturer 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 fuel pumps 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.

Guidance for Fuel Switching Procedures

The issues related to fuel switching are unique to each ship and its condition so there are no universal procedures that can be applied to all or even most ships. 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 procedure or manual be developed by competent and experienced persons for any ship that will transit in 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 the new MARPOL Annex VI, Regulation 14 (6) for ships entering and leaving an ECA.

Operating crew should be well trained in how to use the procedure and aware of any safety issues that can arise and how to respond to these. Any new crew members joining a ship should be trained prior to their 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, such as in the state of California, it is best to carry this out before the ship enters crowded and restrained channels and port areas or where there is higher risk of grounding or collision. Where operation on low sulfur is only required after vessel docking in port, such as currently in the EU, then fuel switching can safely be carried out in port while alongside or in anchorage.

The following are important steps and issues that should be considered in the preparation of a fuel switching procedure.

1. Carry out an assessment of the fuel system on board the ship by competent persons and determine what needs to be done to operate safely and effectively on low sulfur fuel.
2. Consider the fuel storage, settling and service tank arrangement. This will determine if fuel switching can be done by segregating 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 storage, settling and service tanks. Most ships built after 1998, because of new 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 when the low sulfur fuel is

MDO or MGO, but not when the low sulfur fuel is LSHFO. However, as allowable sulfur limits are progressively decreasing it is becoming more likely the low sulfur fuel will be MGO so the fact that the second service tank is for diesel oil is an advantage. It is beneficial to also have separate settling tanks to fully maintain fuel segregation at all times if LSHFO is used. 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 supply pumps for the engine or boiler. The switching verification process is also much simpler with a segregated system as the time for the valve changeover can be easily recorded and the time to flush the fuel system with the new fuel requires only a few hours at most.

3. A ship which does not have a tank arrangement that permits segregation of fuel beyond the storage tanks will have to develop procedures for fuel mixing. One way to do this is to reduce the level in the settling tank to about 20 percent before filling with the alternate fuel. With this arrangement, up to several days of operation may be needed before entering an ECA to reduce the sulfur level in the mixed fuel to the required level. This can lead to high consumption of expensive low sulfur fuel so consideration should be made to installing a segregated fuel system on any ship that regularly trades in areas where low sulfur fuel is required.
4. Prior to commencement of fuel switching it is generally recommended to reduce ship power to the level indicated in the fuel switching procedure. Typically this is a power level of 30 percent to 70 percent MCR, depending on the specifics of the propulsion plant.
5. 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, such as the commonly used rate of 2°C/minute. As an example of how to determine the time for fuel switching, if a ship is using HFO heated to about 150°C prior to the fuel injection pumps and switching to MGO at 40°C the temperature difference is about 110°C. Under these conditions and considering a 2°C/minute permitted rate of change, the fuel switching process should take a minimum of 55

minutes to complete safely. Consider using longer than minimum time to prevent short term rapid temperature changes during the process, which may not consist of a smooth, even temperature change. There are several difficulties that can occur in controlling the rate of temperature change to extend out the time as desired.

- a. Many ships carry out fuel switching by manually changing over a single 3 way valve. This immediately changes the fuel source and 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 MGO can lead to overheating the MGO causing a rapid loss of viscosity and possible gassing in the fuel system. Too rapid change from unheated MGO 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. If desired to do fuel switching at higher power levels, the fuel switching system may have to be modified, including the possible installation of an automated fuel changeover system that changes the fuel in a timed and regulated manner. Such



automated systems are now being offered by some engine makers and by fuel system equipment suppliers.

- b. 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 diesel oil is completed the heat supply needs to be turned off and any heat tracing should also be turned off during the switching when changing to low viscosity fuel.
 - c. When switching from heated HFO to MGO, engine components and fuel in the mixing tank will retain heat during the switching process and as the still hot fuel mix becomes more pure MGO there is real danger of “gassing” occurring at the booster pumps causing the engine to stop. Fuel temperature should be closely monitored during this process and components given sufficient time to cool down before running on pure MGO. This is where fuel coolers can be of value.
6. Compatibility of the mixed fuels is an issue as discussed in the section on Marine Fuels. During the fuel switching process, fuel filters, strainers and mixing tank should be carefully checked for evidence of clogging and excessive sludge forming. This is one reason that fuel switching is best done ahead of time in open waters clear of hazards.
 7. If a fuel cooler is installed, turn it on and open the valves to the cooler carefully while closely monitoring the temperature of the fuel to prevent an excessive rate of cool down. When changing from cooled MGO to heated HFO, the cooler can usually be bypassed and shut off at the start of the process.
 8. Purifiers should be adjusted to suit the new fuel. Make sure the suction and return pipes go to the correct tanks. If operating on MGO, a separate purifier may be in operation.
 9. If there is fuel valve injector cooling on the engine, this may need to be turned off or on during fuel switching. After switching to MGO, fuel valve cooling may not be needed and if this is the case it should be turned off to prevent over cooling of the fuel if the



- engine will be operated for extended periods of time on MGO. If cooling was turned off, it should be turned on again when switching to heated HFO fuel. Consult with the engine manufacturer regarding this item.
10. Monitor temperatures of the engine and its components to check that they are maintained at normal service temperatures. Adjust or re-set engine control equipment such as control valves, temperature sensors, viscosity controller, etc., as needed, to account for the new fuel type, where this not done automatically. As experience is gained 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 MGO. During initial fuel switches, added vigilance is needed to spot potential problems before they become serious. Fuel switching procedures should be adjusted to account for identified problems.
 11. 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.
 12. If sustained operation (more than 5 to 7 days) on a fuel with a large difference in sulfur content is planned, engine makers typically recommend that the cylinder oil type used in slow speed diesels be changed to the appropriate one for the sulfur content of the fuel being used. See Section V of this Advisory for more discussion on this issue.

VII. Ship Design Issues to Deal with ECAs

Meeting the requirements for sustained operation on low sulfur, low viscosity fuels will have two major impacts on the design of ships besides the impact on the engines and boilers themselves. One is on the required storage capacity of distillate fuel and the other is on the fuel piping system and equipment to be able to segregate and handle two quite different types of fuels with different viscosities, densities and handling temperatures. New ships can be designed specifically to incorporate the needed features. However, many of the new emission requirements will apply to all ships and so existing ships may require modification as well. This section will discuss how these changes impact the design and arrangement of the ship.

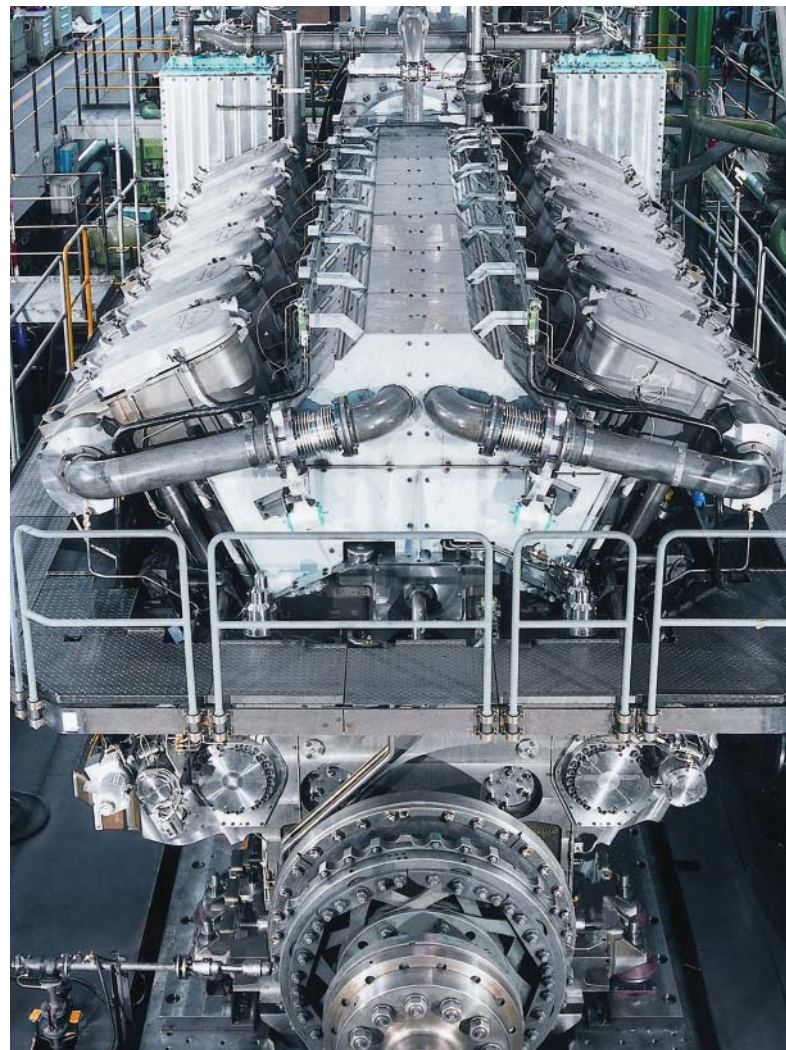
Intended voyage routes will determine the length of the voyage that will be within an ECA and some alteration in a ship's route planning may be justified to limit the length of transit in an ECA. Because of the size of the ECAs (particularly those proposed for the US and Canada), regardless of route planning, it is expected there will be multiple days of operation with distillate fuel including time to fuel switch, time at sea in the ECA, time maneuvering in port and time at the pier. The amount of distillate fuel required for transiting the ECA and operation in port (if not using shore power) must be estimated and compared to available capacity of distillate fuel storage tanks, service tanks and purifier capacity.

See Tables 2 and 3 below for typical distillate fuel capacities for existing tankers, containerships and bulk carriers and possible operating days and range in an ECA. Most ships are now designed to use MDO as the distillate fuel. As the requirement to use 0.1 percent low sulfur fuel comes into effect, this can currently only be met by using MGO. Most ship owners do not want to carry three types of fuel on the ship, so once there is a need to operate on MGO they will carry only MGO in the distillate fuel tanks. This means for all times when HFO is not used, the ship needs to be prepared to use MGO.

Whether existing ships have adequate distillate fuel capacity depends on where the ship is going. For example, for the 24 NM zone off the California coast and the EU requirement for low sulfur fuel usage in port, or even to reach

many ports in the North Sea/English Channel ECA, many ships may have adequate existing distillate tank capacity. This should be checked for any ship planning to enter one of these areas.

For transiting to ports in the Baltic Sea ECA from the Atlantic Ocean, considering the vessel has to operate in both the North Sea/English Channel ECA and Baltic Sea ECA, and for transiting through the proposed US/Canada ECA, it is likely the required capacity of distillate fuel will exceed the available capacity. This can be illustrated by considering a typical trans-Atlantic round trip voyage to Houston, Texas. The ship will first encounter the ECA off the US East Coast. On the most direct great circle route the entry could be north of Cape Hatteras. From the entry point the ship would have to transit south along the US East Coast, around the tip of Florida and across the Gulf of Mexico to Houston and back again for a similar return trip. This voyage is about 1,750 NM each way for a total of over 3,500 NM depending on where the ECA is entered/left. During the entire time in the ECA the vessel must operate on low sulfur diesel. Coastwise voyages up and down the US East Coast and the



US West Coast could similarly be on the order of 750 to 1,000 NM each way. Voyages to Baltic Sea ports are of similar distance within ECAs.

Designers and owners of new ships should carefully assess where the ship is intended to trade and anticipate the distances to be traveled in ECAs and expect that additional ECAs will be adopted in the future. For this reason much larger capacity for distillate fuel storage than was traditional in the past should be included in any new ship designed for possible trading in areas where ECAs will be in effect. A separate fuel bunkering and transfer piping system should be provided for the distillate fuel.

For existing ships with inadequate distillate capacity and as supplemental capacity for new ships, HFO fuel tanks can be changed over to distillate fuel or designed for dual use, either

HFO or distillate. Particularly when planning to fill a tank previously filled with HFO with MGO, adequate safeguards should be in place to segregate the MGO from HFO contamination (such as separate fuel suction/fill connection to the tank for HFO or MGO). After emptying HFO from a tank to be converted to MGO, thorough cleaning of the tank and any piping used with both fuels should be carried out before bunkering MGO.

The second area affected by operation on low sulfur fuel is the design of the fuel system. Since it is required to document that the correct fuel is used throughout the period of time a ship operates in a sulfur content regulated area, it is best to have the low sulfur fuel segregated at all times from out of compliance fuel. Keeping this segregation right up to the fuel supply pumps to the engines or boiler burners allows for the

Table 2 – Typical Ship Fuel Tank Arrangements

Ship Type/Size	HFO		MDO	
	Description	m ³	Description	m ³
2,500 TEU Feeder Containership	6 HFO stor + 1 Sett + 1 Serv	3,200	1 DO Stor + 1 Serv	300
6,000 TEU Post-Panamax Containership	10 HFO stor + 2 Sett + 2 Serv	8,000	2 DO Stor + 1 Serv	400
9,000 TEU Post-Panamax Containership	12 HFO stor + 2 Sett + 2 Serv	10,000	2 DO Stor + 1 Serv	800
50,000 DWT Panamax Tanker	2 HFO stor + 1 Sett + 1 Serv	1,500	1 DO Stor + 1 Serv	150
110,000 DWT Aframax Tanker	4 HFO stor + 1 Sett + 1 Serv	3,000	1 DO Stor + 1 Serv	250
160,000 DWT Suezmax Tanker	4 HFO stor + 1 Sett + 1 Serv	4,000	1 DO Stor + 1 Serv	350
300,000 DWT VLCC Tanker	4 HFO stor + 2 Sett + 2 Serv	5,500	1 DO Stor + 1 Serv	450
35,000 DWT Bulk Carrier	4 HFO stor + 1 Sett + 1 Serv	1,500	1 DO Stor + 1 Serv	100
Capesize Bulk Carrier	4 HFO stor + 1 Sett + 1 Serv	4,000	2 DO Stor + 1 Serv	350

Table 3 – At Sea Cruising Range when Using Distillate Fuel for ME & AE

Ship Type/Size	Days	Naut. Miles
2,500 TEU Feedership	2.6	1,300
4,000 TEU Panamax Containership	1.9	1,100
6,000 TEU Post-Panamax Containership	1.7	1,000
9,000 TEU Post-Panamax Containership	1.8	1,100
Panamax Tanker	3.3	1,200
Aframax Tanker	3.5	1,300
Suezmax Tanker	3.6	1,300
VLCC	3.3	1,200
35,000 DWT Handy Size Bulk Carrier	3.3	1,100
Capesize Bulk Carrier	3.5	1,200

quickest fuel switching and easiest determination of the time when the fuel switch was completed (outside the ECA). It also allows better demonstration the fuel was uncontaminated and met the required sulfur level since only the sulfur level as bunkered need be considered, without any consideration of effects of mixing beyond the short period of time for switching.

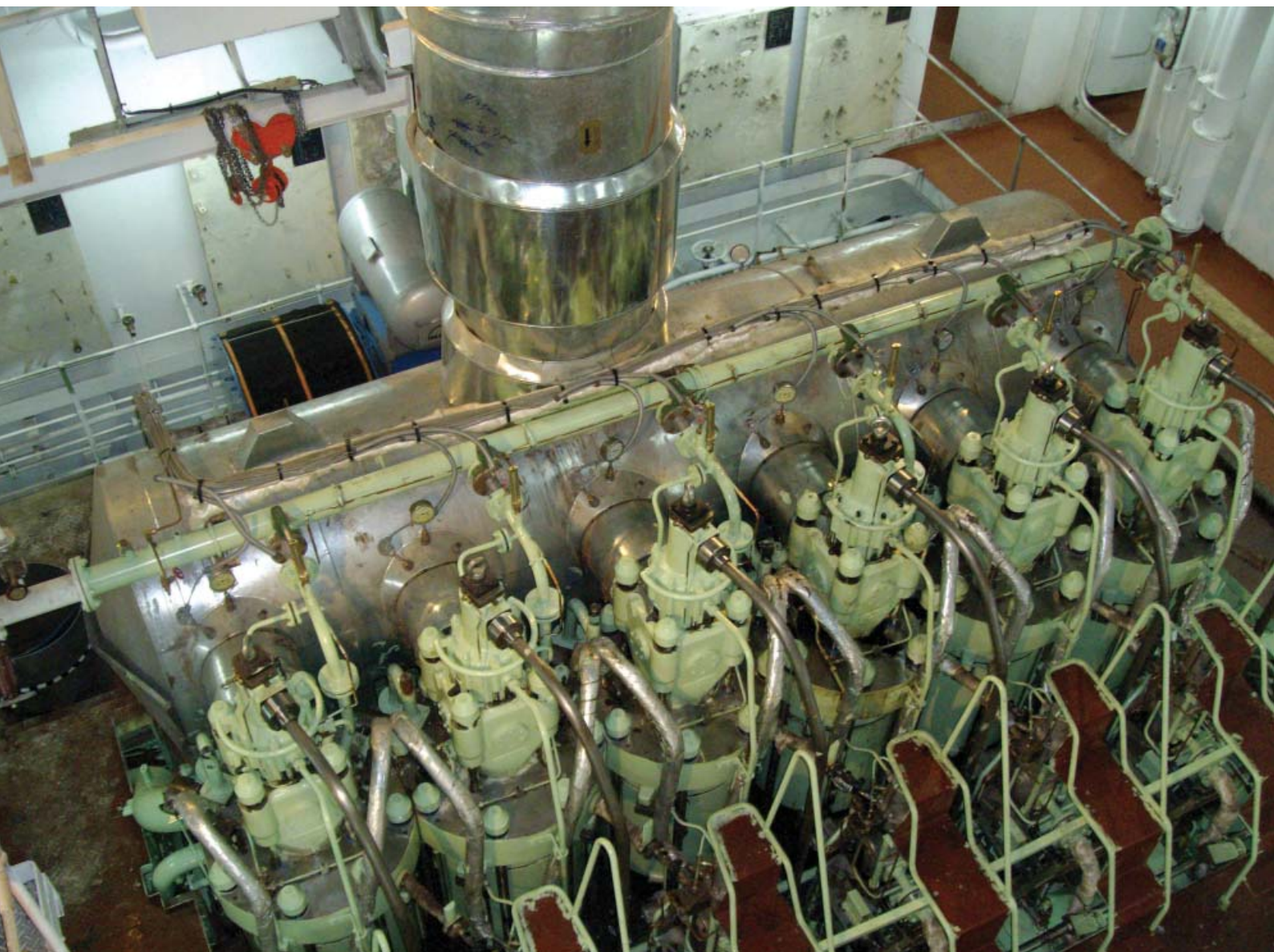
For use of LSHFO, the design of a segregated HFO system is quite well known and has been carried out on many ships. It provides for a common HFO bunkering, transfer and purification system, but has separate LSHFO storage, settling and service tanks. The LSHFO service tank has a separate supply pipe to the changeover valve in the fuel supply system to the engine or boiler.

For dual fuel operation with distillate as the second fuel, the following recommendations for designing fuel systems should be considered to make switching easier to carry out and provide more certainty as to when a switch has been completed.

1. Provide for separate fill connection and pipes for distillate fuel.
2. Provide for separate transfer pipes and pump for distillate fuel.
3. Provide for separate settling tank

(optional if only MGO is carried as distillate) and service tank for distillate fuel. For sustained periods of operation on distillate consider to install two service tanks so there is the ability to change service tanks in case one becomes contaminated.

4. Provide for a separate purification system, including a separate purifier, for distillate fuel which can take suction from the settling tank (or storage tank if no settling tank is provided) and from the service tank and return to the service tank.
5. Provide for a fuel cooler (preferably a chilled type down to 20°C to 25°C) so the ship can operate on low viscosity distillate in warm weather conditions and better control the temperature of the fuel to the engine or boiler.
6. Install an automated fuel changeover valve or system that can provide for timed changeover of fuel from one type to another so that temperature shock and out of viscosity fuel during switching can be avoided. This applies to both diesel engine and to boiler fuel supply systems.
7. In consultation with boiler manufacturers, provide for required equipment and controls for boilers to operate safely on low viscosity fuel.



VIII. Exhaust Gas Cleaning Systems

An alternate method of achieving reduced SO_x emissions (and NO_x and particulate emissions) that is permitted by most emission control regulations (not in California) is to install a system that removes the harmful substances from the exhaust system and allows the use of regular fuels. IMO adopted Resolution MEPC.184(59) which contains the 2009 Guidelines for Exhaust Gas Cleaning Systems and recommends to Flag Administrations to adopt this guideline for approving such systems.

Before any system is planned for or installed on board a ship, it should be checked with the ship's Flag Administration as to what requirements are being applied for exhaust cleaning system approval. It should also be confirmed what are the permitted SO_x discharge levels as these can

vary depending on which ECAs are to be entered and what Tier of emission standard is being applied. Proposed systems are to be tested in the factory and receive type approval and then tested again after installation on board to confirm required emission levels are met as installed.

Either continuous monitoring of exhaust gas output should be provided or daily spot check carried out. Wash water discharge needs to be processed to remove harmful substances and then monitored that it meets applicable water discharge standards, particularly in port and near coastal areas. Residues removed from the wash water prior to overboard discharge should be disposed of properly on land.

The most common type of Exhaust Cleaning System is a scrubber that uses direct contact of the exhaust with the scrubbing liquid (sea water

or a caustic solution of sea water) to absorb SO_x or chemically convert SO_x to a salt solution. Such a scrubber is similar to the units provided on tankers for scrubbing the exhaust gas to generate inert gas for cargo tanks. The scrubber also cools the exhaust gas.

One problem with the cooling effect is that, if another exhaust cleaning system is to be used for lowering NO_x levels, such as a selective catalytic reduction (SCR) unit, this requires the exhaust gas to be hot to function properly. The SO_x must be removed from the exhaust prior to the passing through the SCR unit as the SO_x will react with the ammonia that has to be added to the exhaust

gas and form a coating on the catalyst elements that will prevent them from working until being thoroughly cleaned.

If both types of cleaning systems are installed it may require the exhaust gas to be reheated. Resolving these types of problems and the cost for installation, operation and maintenance are reasons why exhaust cleaning systems have not been widely installed as yet. As fuel prices rise and the emission requirements that mandate use of high cost MGO come into effect over large areas, there may be greater motivation by ship owners to install exhaust cleaning systems that permit the continued use of lower cost HFO.

References and Suggested Further Reading

1. ABS, Notes on the Use of Low Sulphur Marine Fuel for Main and Auxiliary Engines, Revision 4, 13 January 2010.
2. ABS, Notes on the Use of Low Sulphur Marine Fuel for Boilers, Revision 3, 16 December 2009.
3. California Air Resources Board, 25 June 2009, Marine Notice 2009-4, Advisory for Owners or Operators of Ocean-Going Vessels visiting California Ports, Regulation on Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline.
4. California Air Resources Board, 5 March 2008, Worldwide Marine Diesel Distillate Fuels, Properties – DNV 2007 Data.
5. US Code of Federal Regulations, 2005, Title 40 Ch I, Part 94.8 Exhaust Emission Standards.
6. US Code of Federal Regulations, 2007, Title 40 Ch I, Part 1042 Control of Emissions from New and In-Use Marine Compression-Ignition Engines and Vessels.
7. European Marine Safety Agency (EMSA), 15 October 2009, Technical Meeting Report EMSA Technical Meeting on the use of 0.1% sulphur content fuel at berth.
8. International Maritime Organization (IMO), 10 October 2008, Resolution MEPC.176(58), Annex 13.
9. American Petroleum Institute, API Technical Issues Workgroup, 3 June 2009, Technical Considerations of Fuel Switching Practices.
10. Wartsila, 20 November 2009, Low Sulphur Guidelines, Revision III, Warstila Diesel.
11. Aabo, Kjeld, August 2005, Operation on Low-Sulphur Fuels Two Stroke Diesels, Edition 3, MAN B&W Diesel A/S.
12. Aalborg Industries, January 2009, Changing from HFO to MDO or MGO, Aalborg Solutions, No. 12.
13. Bunkerworld Fuel Quality Reports, 10 December 2009, Bunkerworld.com.
14. Wikipedia, 10 December 2009, Ultra Low Sulfur Diesel.

ABS Guidance for Operating in a Low Sulfur World

The European Union (EU) and California 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 the engine and other associated machinery/equipment capabilities to operate with low sulfur fuel.

ABS has prepared the following guidance to assist owners, operators, shipyards and designers in identifying potential design and operational issues, risks and ABS requirements which may be applicable under these new operational conditions.

Regulations

1. Article 4b of EU COUNCIL DIRECTIVE 1999/32/EC of 26 April 1999 relating to a reduction in the sulfur content of certain liquid fuels and amending Directive 93/12/EEC, as amended, introduces 0.1% sulfur limit (m/m) for marine fuel.
 - a. **Effective Date:** 1 January 2010
 - b. **Applies 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 available.
2. California Air Resources Board (CARB)
 - a. **Effective Dates:**

Phase I: in force since 1 July 2009 [MGO (ISO 8217, DMA Grade) at or below 1.5%S or MDO (ISO 8217, DMB Grade) at or below 0.5%S]

Phase II: 1 January 2012 [MGO (ISO 8217, DMA Grade) or MDO (ISO 8217, DMB Grade) at or below 0.1%S]

Note: MGO = Marine Gas Oil; MDO = Marine Diesel Oil
 - b. **Applies to:** All types of marine fuel used by ships within California Waters (within 24NM of the California baseline). "Baseline" means the mean low water line along the California coast, as shown on the following National Oceanic and Atmospheric Administration (NOAA) Nautical Charts as authored by the NOAA office of Coast Survey, which are incorporated in CARB by reference:
 - Chart 18600, Trinidad Head to Cape Blanco (January 2002);
 - Chart 18620, Point Arena to Trinidad Head (June 2002);
 - Chart 18640, San Francisco to Point Arena (August 2005);
 - Chart 18680, Point Sur to San Francisco (June 2005);
 - Chart 18700, Point Conception to Point Sur (July 2003);
 - Chart 18720, Point Dume to Purisima Point (August 2008);
 - Chart 18740, San Diego to Santa Rosa Island (April 2005).
 - Chart 18720, Point Dume to Purisima Point (August 2008); and
 - Chart 18740, San Diego to Santa Rosa Island (April 2005).

All engines and boilers are affected by the above Regulations and it will be mandatory to operate the engines and boilers on the low sulfur marine fuel with the sulfur content and effective dates as indicated in the respective Regulations noted above. As for boilers, the EU Directive applies to main and auxiliary boilers, while the CARB Regulations apply to only the auxiliary boilers (i.e., non-propulsion).

ABS Issuance of a Statement of Fact Certificate

ABS requires each owner/operator to conduct a design evaluation of each ship for low sulfur fuel operation by systematically assessing the related systems taking into consideration (but not to be limited to) the identified potential risks in the following ABS Notes as applicable to the specific systems and take necessary actions, as appropriate, to establish safeguards.

Owners and operators are reminded that all modifications to engines, boilers and associated fuel oil piping and control systems, together with the results of the above mentioned design evaluation, are required to be submitted to ABS for approval so that class and statutory certification can be maintained. Where the owner is satisfied that modifications to the vessel's installed equipment and systems are not required, it is recommended that the results of the design evaluation that has been conducted be maintained on board.

In all cases it is expected that operating procedures, including guidance for switching between fuel types, will be provided on board by owners/operators. As this is a safety issue, availability of the proper operating guidance may be verified during ISM audits.

Regarding survey, ABS is prepared to issue a Statement of Fact (SOF) Certificate(s) as follows:

1. ABS surveyor will verify fitting of and report on the following:

- a. The vessel is fitted with dedicated low sulfur fuel oil storage tank(s) with a capacity of xx m³ fitted between fr. and fr. port/starboard side.
 - b. The fuel oil piping system is arranged to allow main engine(s), auxiliary engines and boiler(s) to operate on low sulfur fuel.
 - c. The structure, piping and control systems are in accordance with ABS-approved drawings (dwg. no., rev. 0, ddmmmyyy).
 - d. Operational procedures for fuel-change-over are provided on board the vessel (doc. no., rev. 0, ddmmmyyy).
 - e. Operating procedures for using low sulfur fuel in engines and boilers are provided on board the vessel (doc. no., rev. 0, ddmmmyyy).
2. For vessels equipped to operate in a cold ironing condition in port through the shore-power connection installation, the surveyor will verify and report that “the vessel is arranged with a shore-power system as per drawing number, revision and date.”
 3. Issuance of a Statement of Fact for the installation of exhaust gas scrubber/emission abatement technologies will be considered on a case-by-case basis, with details to be submitted to an ABS engineering review office for review prior to surveyor issuance of the statement of fact report. The Statement of Fact will report on what the surveyor has surveyed.

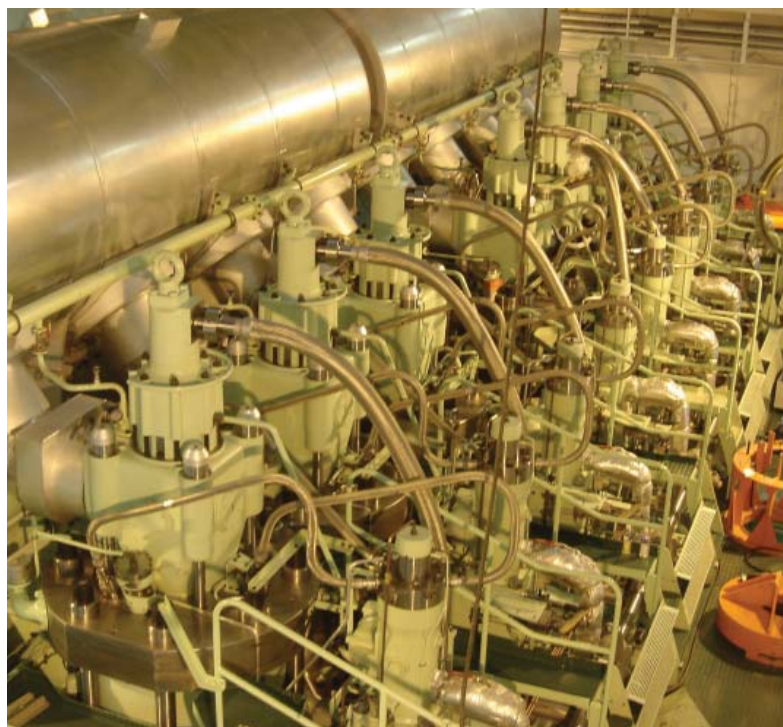
Questions regarding engineering submittal requirements should be submitted to the nearest ABS Divisional Engineering Office. Divisional Survey Offices may be contacted for questions pertaining to survey.

ABS Guidance

If operation within affected areas is intended and the vessel is not designed to operate on low sulfur fuels, some modifications to the vessel's installed equipment and systems may need to be carried out and owners should evaluate the potential risks associated with such operation.

To assist operators in their evaluations, ABS has prepared two Notes which identify a list of potential risks (this list is not exhaustive) associated with such operation.

ABS Notes are developed with a view to assist owners, operators, shipyards and designers as



appropriate. ABS emphasizes that these Notes are to be used for guidance purposes only.

The following suggestions are provided for information purposes only and are not intended to replace any applicable local, national or international safety, operational or material requirements. It is recognized that safe operation of the vessel is the owner's responsibility.

The requirements in the ABS Rules cover the general requirements for piping, automation and electrical that apply to systems and equipment used for low sulfur fuels, for example MGO (0.1%S by m/m) as fuel for engines.

Attention is drawn to the previously mentioned regulations relating to a reduction in the sulfur content of certain liquid fuels and the USCG Marine Safety Alert 03-09, dated 16 June 2009, regarding the switching of fuel oil from residual fuel to distillate fuels in order to reduce emissions.

EU Commission Recommendation on the Safe Use of Low Sulfur Fuel by Ships at Berth in EU Ports

On 21 December 2009, the EU Commission recommended to EU Member States, when enforcing the requirement that ships at berth in EU ports use marine fuels with a sulfur content not exceeding 0.1% by mass from 1 January 2010, to consider the existence of detailed evidence of the steps taken by ships to achieve safe compliance with the Directive. EU Member States may consider the existence of an “approved retrofit plan” when assessing penalties for non-complying ships. The Commission also intends to take action to allow LNG carriers to use mixtures of fuels resulting in emissions of sulfur dioxide equal to or lower than required by the Directive.

Use of Low Sulfur Marine Fuel for Main and Auxiliary Diesel Engines

ABS is aware that as a consequence of the EU regulations, 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, ABS considers 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 (i.e., low sulfur marine fuel oil) needs to be followed in order to maintain engine and equipment safety and availability. ABS does caution that ABS is not an engine or system design expert, so this information should be used in working with such experts, not in place of such expertise.

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, involving the engine manufacturer or another entity recognized by the engine manufacturer to be responsible for the overall arrangement including any needed design adjustments may be a prudent course of action.

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 (0.1%S fuels). 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, consideration might 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 (including capacity) 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 locks 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, 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 in accordance with a specific formula. If low sulfur fuels are used predominantly, low-BN cylinder oil is generally recommended by manufacturers, either BN40 or BN50 oil as compared to the typical BN70 cylinder lubricating oil used with HFO. Where frequent fuel oil changes are necessary due to the vessel's trading pattern, it is recommended that a second grade of cylinder lubricating oil with a lower base number (BN) than the first 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 re-adjustment made if necessary.
- t. During the change-over process it may be necessary to re-set or re-adjust 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.

- u. "Cat fines" are substances like silicon and aluminum compounds which are required as catalysts in the refining process known as catalytic cracking (cat cracking). This process takes place in special cracking towers at a temperature of around 500°C. After the conversion, there may be a large quantity of catalyst fines (cat fines) in both the residues of the cracking towers and the distilled crude oil products.

These cat fines have a negative impact on the end products. They vary both in size and hardness. The fines are also extremely abrasive. Since the heavier fuels go through less refining they will have less cat fines. The low sulfur fuels often contain higher levels of cat fines.

The usual procedure to reduce cat fines includes settling out oil in the storage tanks, regular draining of tanks, purification (centrifuge) and other suitable treatment.

If the cat fines are not reduced to an acceptable limit, the scouring action of these fines can cause extremely rapid wear or damage to certain engine moving parts or components, particularly items such as fuel pumps, injectors, piston rings and liners with potentially severe consequences or total failure.

ABS Suggestions

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. Their training needs assessments should be kept up to date.
9. Fuel change-over should be completed well before entering the Regulated California Waters.
10. Cylinder lubrication consumption should be carefully monitored since a high consumption may be indicative of liner lacquering.

ABS Requirements to be Satisfied

1. General
 - a. Where modifications are identified, 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 only for consideration 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.

Use of Marine Low Sulfur Fuel for Boilers

All engines (main and auxiliary engines) and boilers are affected by the new low sulfur regulations. (As for boilers, please note that the EU Directive 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, certain ABS class requirements would apply. These ABS Requirements are identified separately from the ABS Suggestions to provide clarity.

ABS Suggestions

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' opinions regarding 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. ABS considers that 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 locks 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. Photo cells 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 to 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 it was originally designed to handle MGO). It may be necessary to install completely different and new types of 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. In addition to the above, it is suggested that 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. Their training needs 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, ABS would recommend that a safety assessment 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.



(Photo credit:
Aalborg Industries)

- 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, ABS recommends that safety assessments 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 will need to be modified to use MGO. The reasons MGO is not to be used in the fuel oil systems in these vessels without modifications include the following:
- 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.



ABS 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 owners and operators (or separate entities if employed) are required to evaluate the boiler operation with low sulfur fuel by systematically assessing related systems taking into consideration (but not limited to) these 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.





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