



White paper



## MARPOL Annex VI fuel strategies and their influence on combustion in boilers

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## Intro

In 2004, MARPOL Annex VI Regulations for the Prevention of Air Pollution from Ships were adopted and in regulation 14 of the annex a stepwise reduction of permissible SOx emissions was agreed upon. From 1 January 2020 the global sulphur cap will be 0.5% m/m, while the previously adopted limit of 0.1% m/m in Emission Control Areas will remain in force.

Complying with the regulation will affect the maritime industry to a great extent, as vessels will need to find ways to reduce their SOx emissions.

There are several strategies owners/managers can choose to achieve the necessary reduction. Even though the boiler will be only a small part of the overall decision, most strategies will affect the boiler's operation.

This document aims to provide information on the effects of the various strategies on boiler operation. It does not, however, provide arguments to assist owners/managers in making a choice between the fuel strategies available.

## Overview

A ship owner has several fuel strategies to choose from for reducing SOx emissions. Likewise, there are a number of factors to consider in the decision. The availability of different fuels, the cargo space that needs to be sacrificed to store fuels, the capital investment related to new equipment and the price expectations for the various fuels are all factors that will influence the choice.

In general, there are two main strategies available, each of which involves several options in turn. An owner/manager can either switch to a compliant fuel or continue using a high-sulphur fuel (such as HFO) and remove the sulphur from the exhaust gases before they are emitted into the atmosphere (by means of a scrubber).

When it comes to compliant fuels, there are various options open to the owner/manager. Low-sulphur MGO is available in the market and is the easiest to implement, as it requires almost no investment in capital equipment. Another option is switching to LNG as the main fuel. The handling of LNG is different from that of HFO, so a relatively high capital equipment investment is needed to ensure that the LNG can be used in the engines and boilers on

board. Since 2010, oil majors have been developing fuels that have the properties of HFO but also a low sulphur content. These ULSHFO vary greatly from supplier to supplier, but they provide an opportunity. There are also alternative fuels such as ethanol and methanol, among others, but as these are currently in an experimental stage they will not be included in this document.

The remainder of this document will examine the effect on boilers of the following options:

- Exhaust gas cleaning (scrubbers)
- Changing to LNG as main fuel
- Continuous firing with MGO
- Firing with LSHFO/ULSHFO in combination with MGO



## Exhaust gas cleaning

One way to fulfil the emission requirements after 2020 is to clean the exhaust gases before they are emitted into the atmosphere. This can be done with scrubbers. The technique of scrubbing has been in place for many years, but it has mainly been used to produce inert gas from boiler exhaust gases. The same process is used in today's exhaust gas cleaning (EGC) systems, but the scrubber systems have been scaled up to enable the handling of much larger gas amounts.

The scrubbing can be done with the washing water system operated in open loop, closed loop or a hybrid of these two arrangements. The exact details of EGC systems are not a part of this document.

In addition, the owner/manager has the possibility to choose a scrubber only for the main engine exhaust or a multiple-inlet scrubber to which the auxiliary engines and boiler(s) can also be connected.

In the first case, the owner/manager will need to choose a different solution to control the emissions of the auxiliary engines and boiler(s). This could be any of the previously mentioned main solutions involving the use of a low-sulphur fuel.

If the owner/manager decides to install a multiple-inlet scrubber, the boiler will be affected by the increased back pressure of the scrubber. The amount of back pressure will depend on the design of the scrubber.

Most boilers and burner systems can be modified to compensate for the calculated back pressure of the scrubber. For retrofit solutions to overcome the increased back pressure, it is possible to install a retrofit package for the boiler that is tailor-made for the boiler/scrubber combination.



## LNG as main fuel

Using LNG as fuel will solve many of the emission problems, but it also poses several operational challenges, such as storage and bunkering infrastructure.

Boilers can operate very well on LNG. However, individual gas firing studies may conclude that steam output will be reduced. Due to the high explosiveness there are also some precautions to be taken.

First of all, the fuel lines have to be double-wall piping with a gas detection system in the space between the two walls. This is to ensure there are no gas leaks into the atmosphere and to sound an alarm in the event that gas is detected in the void space.

Another crucial component is the gas valve train, where the gas pressure and flow are regulated. Extraction air fans, gas detectors and other pieces of equipment are needed for safe and reliable operation of the system.

For newbuild vessels, there is no problem in specifying the fuel and having boilers delivered with the correct components. However, detailed engineering studies are needed along with the additional LNG handling equipment.

Retrofitting is a possibility, and if a vessel is converted to use LNG as fuel for the main engine it is only a investment to upgrade the burner for LNG operation as well. The most important issue will be the availability of space for the gas valve unit, extraction air fans and gas detectors. The burner itself will also need to be upgraded or replaced, as well as the control panel. In most cases, the forced-draught (FD) fan can be reused.

When using LNG as fuel, the flame properties will be different from an HFO or MGO flame. A gas flame has less radiation heat transfer, which means a boiler designed for fuel oil is not always ideal for burning gas. A boiler study will be able to determine if the capacity of the boiler can be maintained at the same rating.

Aside from the upgrading of the oil-fired boiler(s) to LNG operations, the exhaust gas boilers connected to the main engine and auxiliary engine(s), as well as the associated equipment, must be subject to a design review for the revised exhaust gas temperatures and amounts. This will provide assurance of heat transfer and establish the new estimated levels of heat recovery.

A further study will be required to determine the total steam balance. A lower bunker heating requirement is countered by an increased heat required to evaporate the LNG.

## Continuous firing with MGO

Firing a boiler with MGO is not a problem, as long as the correct safety precautions have been taken.

Most boilers were originally designed for operation on HFO with MDO as a start-up fuel (from dead ship). Nowadays there is not much MDO available; hence, MGO is considered the secondary fuel for boilers. MGO has a much lower flashpoint than HFO, which can lead to some issues when using MGO on a continuous basis.

### Flashpoint

Due to the low flashpoint of MGO, it is very important to ensure that no gases form in the furnace or in the pipelines.

Preventing fuel entering the hot furnace without a flame present is the first safety consideration. Ensuring that all valves are in good operational condition is very important. In the unforeseen event that unburned fuel enters the hot furnace, gases will form and create a potential risk of explosion.

Purging of the gases is therefore the most important consideration when using MGO as main fuel. The purging of the furnace is normal for all fuels. But when it is fired with MGO, a post-purge is required. In other words, the furnace must be purged after the flame has been stopped.

In the normal start/stop cycle, this is not very difficult and requires only that the forced-draught (FD) fan continues operating even after the flame has been extinguished. Ideally, the FD damper should move to fully open position at that time. The same can be achieved after a forced shutdown of the boiler, e.g. shutdown activated by an alarm.

In the event that the burner stops due to a blackout, purging of the boiler must be ensured either by forcing the FD damper into a fully open position or by locking it in the last position before the blackout. The natural draught in the boiler will ensure that the furnace space is purged to the maximum possible extent. After power has been restored, it is recommended to purge the furnace for one additional cycle before introducing a flame into it. This must be done manually.

NOTE: It is common knowledge that the furnace needs to be purged before any ignition. With MGO, it is even more important to ensure that in emergency firing mode (bypass of the automation) operators do

not start the burner without taking the purging time into consideration. Especially after misfiring, it is of extreme importance to perform proper purging of the furnace with the FD damper in fully open position.

It is equally important that no gasification of the fuel takes place in the piping system leading to the burner. This means precautions need to be taken to protect against any potential heat sources increasing the temperature of the fuel to above the flashpoint.

There are three areas of concern:

### • Circulation pump

In most fuel systems, the circulation pump is oversized to ensure sufficient oil supply to the burners. This results in a large amount of fuel going through the pump. As the pump is a gear pump, the pump's friction will heat up the fuel within the pump. When the surplus fuel is circulated over a smaller circuit, this can potentially increase the fuel temperature to above the flashpoint.

### • Burner

In the case of a steam-atomizing burner, the design of the lance should be such that the steam heats the fuel to the minimum during operation. When the burner is idle, the burner should not be filled with oil.

### • Fuel line

Care needs to be taken to ensure that no heating source is present near the fuel.





## Cold flow properties

If the ship is operating in winter conditions, some operational issues may arise – especially as modern MGOs contain increasing amounts of wax. When it comes to the cold flow properties of MGO, there are three parameters to observe carefully:

- **Cloud point (CP)**

CP is the temperature at which dissolved particles precipitate and form a cloudy appearance (wax). At this temperature, wax crystals will start to form in the fuel.

- **Pour point (PP)**

PP is the lowest temperature at which fuel will flow. It thus determines the temperature below which the fuel will become immovable. At a lower temperature, the oil will no longer be pumpable and will solidify.

- **Cold filter plugging point (CFPP)**

CP is the lowest temperature at which fuel will pass through a filter under specified conditions. It is a relative indication of where filterability problems may start to occur. Such problems can lead to restrictions of fuel flow to various equipment.

When bunkering MGO, the pour point and the cold filtering point of the fuel should be carefully monitored. If the fuel temperature falls below either of them, it is imperative to heat the fuel to a temperature above these points with a safety margin included.

## Combustion

MGO has a lower density and a higher calorific value than HFO, which affects the combustion curve.

There will be no problem with the flame if the correct adjustment of the combustion curve is implemented during commissioning of the boiler.

MGO does, however, burn with a different light spectrum and care needs to be taken that the correct flame detection equipment is used. If an ignition burner that operates on MGO is used, precautions need to be taken to prevent fuel from entering the furnace. A flame eye on the ignition burner will both shut down the fuel supply to the ignition burner and prevent the main oil valves from opening.

## Viscosity

Due to the low viscosity of MGO, extra care needs to be taken with the tightness of shut-off valves. Furthermore, the circulation pumps should be MGO-ready (also taking into account the reduced lubrication capabilities of the MGO).

## NOTE

In the case of newly built vessels (ordered after 2010), these precautions have been taken into account. For other vessels that have yet to be retrofitted, the above will lead to some adjustments in the system.



## LSHF0/ULSHFO

As expected, refineries have reacted to the market demand and some of the major suppliers have introduced low-sulphur and ultra-low-sulphur HFO (LSHF0/ULSHFO). These fuels are obtained by blending HFO with lighter (low-sulphur) distillates to create blends that have low sulphur content but high viscosity.

The main issue with LSHF0/ULSHFO is that the consistency of the fuel is not very high. This means it is not known how fuels from different suppliers (or bunkering ports) will react with each other.

Poor consistency will also result in combustion that is not optimal for all fuels, so special attention must be taken to ensure that the fouling of the boiler is not excessive. If the fuel leads to excessive fouling, the burner/combustion needs to be adjusted. Specialized experts should be considered if the crew on board is not able to do this themselves.

When these fuels are used in combination with MGO, it is recommended to consider separate day tanks and even to continue with the changeover procedures introduced in 2009/2010, with the ideal solution being separate fuel lines to the burners for MGO and other fuels.

LSHF0/ULSHFO is also known to contain wax and other impurities. Some of these waxes will form if the temperature becomes too low. This process is not reversible, which means the fuel will need to be kept at temperature (including the bunkers).

Especially for hybrid fuels, it is very important to study the bunker note carefully. The OEM should always be contacted if there is any question as to whether the fuels will cause problems for the boilers.

## Conclusion

In preparing to comply with emission limits in 2020 and beyond, the boiler will only partly influence fuel strategy decisions. However, each strategy will have consequences for the boiler. Due attention must therefore be paid to the combustion in the boiler.

Ultimately, the decisions for the boilers should be made in consultation with the OEM of the boiler/burner.