Technical paper

Fuel and operational considerations for 2020

Fuel oil system: 1.5 KBSD single line
Fuel strategy: VLSFO

April 2019

Contents

1. Operational assumptions

Terminology

Marine Gas Oil [MGO]
Marine fuel that consist exclusively of distillates and fall with DMA/DMZ ISO 8217 categories

Marine Diesel Oil [MDO]
Marine fuels generally composed of various blends of distillates and small portion of Heavy Fuel Oils which falls within the DMB ISO 8217 category.

High Sulphur Fuel Oil [HSFO]
Fuel maximum sulphur contain of 3.5%

Very Low Sulphur Fuel Oil [VLSFO]
Fuel maximum sulphur contain of 0.5%

Ultra Low Sulphur Fuel Oil [ULSFO]
Fuel maximum sulphur contain of 0.1%

Reference to the fuel system P&ID for building our recommendation, we assume:

- The former HFO service tank is converted into a VLSFO service tank.
- The Diesel Oil service tank remains for MDO operation.
- The MGO service tank remains for MGO operation.

If your fuel implementation plan does not correspond to the above, we duly recommend that you contact one of our experts who will be willing to help evaluate the boiler operation in relation with your fuel implementation plan.

2. Deviation from tank management plan

Why is this important?

While MGO remains the most commonly used ECA area compliant fuel, fuel suppliers introducing new / blended residual fuel options.

The Alfa Laval fuel line has not been designed with these new emerging fuels in mind and it is important to understand some of the possible operational limitations if these fuels are stored in and used from the MGO and/or MDO service tanks.

What are the challenges?

- Residual Fuels might have higher viscosity than MGO or MDO and therefore require fuel heating in order to reach the specified viscosity at the burner inlet. When operating from the MGO or MDO tanks, the control system inhibits the steam tracing and the fuel oil heater.
- Efficiency of the Flushing during fuel change over sequences depend of the cleaning properties of the fuel, Residual Marine fuel might not have this cleaning characteristic.
- Fuel can not be heated in the ignition line, fuels with higher viscosity than specification could lead to ignition failure.

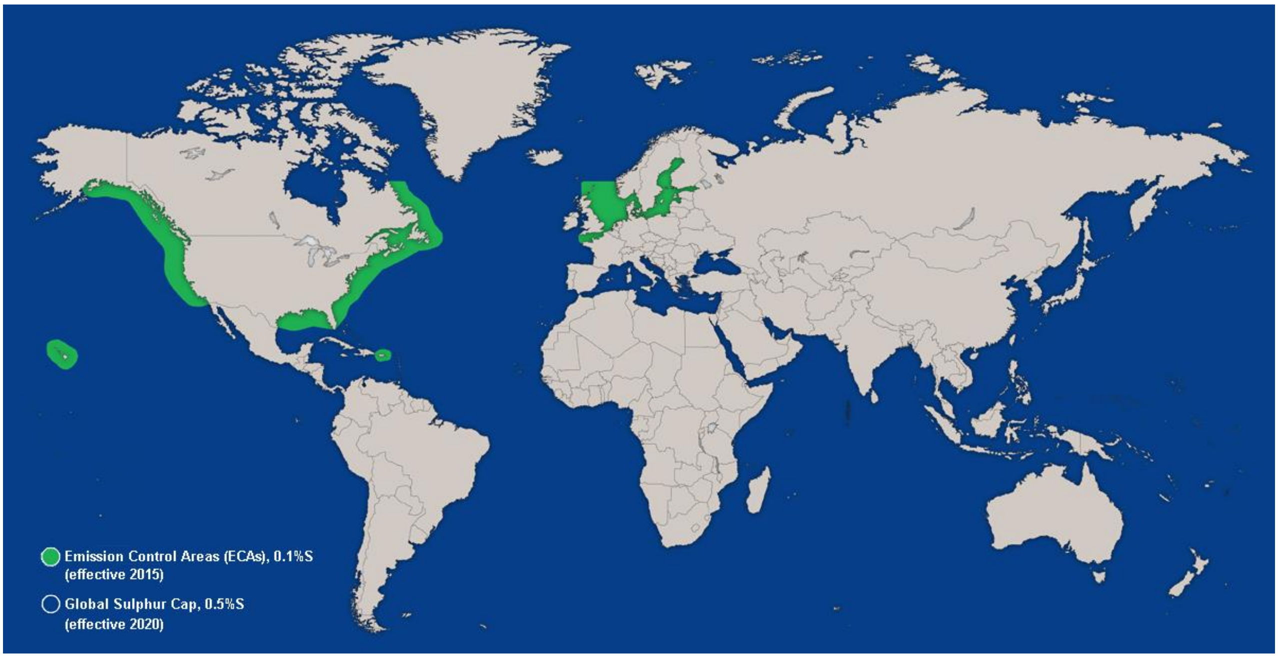
Conclusions

It is not recommended to operate Residual Marine Fuels from the MGO or MDO tanks

3. Sulphur contamination

Why is this important?

While the IMO 2020 Sulphur Cap regulations seek to impose tighter limitations on use of sulphur in fuels while sailing globally, it is the transition when sailing from a global cap area into an ECA area and the related fuel change over (change over from MDO/VLSFO to MGO) that is the most critical period to ensure compliance due to the potential for sulphur contamination.



Operation with residual fuels may lead to situation that leftovers from residual fuel in piping system will be dissolved when operation with distillate fuel started, this might lead situation that longer changeover period or alternative longer flushing is required to ensure used fuel sulphur content reaching required limits.

What are the challenges?

Provided:

- MGO is the compliant fuel for ECA area.
- MGO is operated from the MGO service tank (P&ID)

The potential fuel change over when entering in ECA area are:

- VLSFO to MGO
- MDO to MGO

Starting from VLSFO or MDO (The fuel line is filled with VLSFO or DO)

An Automatic flushing of the line with MGO is performed during the fuel changeover to MGO. The purpose of this flushing is to replace VLSFO or MDO in the fuel line with MGO, to remove all fuel residue and therefore avoid any sulphur contamination from the 0.50% sulphur fuel into the 0.10% sulphur fuel.

The flushing sequence duration is based on the following timer settings (please refer to the boiler instruction manual, flush sequence diagram)

- Flush Timer 2
- Flush Timer 4
- Flush Timer 7

High variation in the fuel specification expected and so it is not guaranteed that existing preset timer functions will be suitable to achieve a successful flushing sequence and potential sulphur contamination of the MGO (0.10%) fuel by VLSFO/MDO (0.50%) could lead to non-compliance in an ECA area.

Conclusions

With the implementation of VLSFO with various specifications, we duly recommend to re-adjust the timer settings to the time required to remove all the residual from the fuel line and therefore avoid any sulphur contamination of the MGO. We recommend to proceed with this re-adjustment before operation of any new fuel.

The timer settings should be adjusted by measuring the sulphur content in the MGO following the flush sequence. If the sulphur content in the MGO exceeds the regulation cap, the time setting should be prolonged until the sulphur content in the fuel line is reaches the required sulphur level. Test of fuel in the ring line is to be made by sampling from the test valve G466 at the mixing tube.

Before proceeding with any flushing sequence, mixability of the fuels should be confirmed by test, please refer to mixability section.

4. Density variation

Why is this important?

When performing a combustion setting during a commissioning or during a service on board, Alfa-Laval service engineers, are optimizing the combustion by adjusting the fuel flow and pressure and by adjusting the Air / Fuel Ratio. This can be illustrated by a combustion curve, max firing settings etc.

Record of the design data are available in the boiler manual. Below, an example of boiler manual with 3 x fuels operation.

Combustion process data

- Min. calorific value of marine gas oil: 42,200kJ/kg
- Min. viscosity of marine gas oil: 2 cSt. at 40 °C
- Max. viscosity of marine gas oil: 6 cSt. at 40 °C
- Density of marine gas oil: 850 kg/m^3 at 15 °C
- Min. calorific value of diesel oil: 42,200 kJ/kg
- Min. viscosity of diesel oil: 2 cSt. at 40 °C
- Max. viscosity of diesel oil: 11 cSt. at 40 °C
- Density of diesel oil: 900 kg/m^3 at 15 °C
- Min. calorific value of fuel oil: 40,200 kJ/kg
- Max. viscosity of fuel oil: 700 cSt. at 50 °C
- Density of fuel oil: 991 kg/m^3 at 15 °C
- Turn down ratio on fuel oil: 3:1
- Max. HFO viscosity before and at HFO pump and preheater: 380 cSt.
- Fuel oil viscosity at burner inlet: 14-16 cSt.
- Fuel oil temperature at burner inlet: 135-148 °C
- Air excess No. at 100% load: 1:3
- Flue gas temperature (clean boiler): 359 °C
- Air consumption at 100% load: 1,985 kg/h
- Flue gas flow (approx.): 2099 kg/h

Before 2020, fuel density, and calorific values were assumed to be stable per fuel type (HFO180, HFO380 etc), as well as across the different regions of the world, and across the different fuel suppliers, therefore providing a consistent basis to optimise combustion.

What are the challenges?

With the sulphur cap and the introduction of VLSFO, density variations are expected to increase between different fuels. Specifically, from 2020 with the introduction of 0.5% sulphur compliant fuel, the average fuel density (globally) should decrease compare to the 3.50% HFO. High density variations from the different VLSFO are also expected.

Boiler operation of a specific fuel from non-adapted combustion curve, would lead to sub-optimized combustion with risks of overheating, fouling, black smoke etc.

Conclusions:

We recommend to check any variation in the specification of fuel to be consumed from the VLSFO tank.

Density variation from the last combustion setting by Alfa Laval Aalborg service engineer		
	First action, insignificant density variation	Significant density variation
Steam atomizing burners	Careful observation of the flame shape and colour before and after bunkering. Careful observation of exhaust gas. Burner air/oil bias setting adjustment required in case of signs of sub-optimized combustion.	Combustion expected to be affected. **New combustion settings required.**

Fuel density is not the only parameter affecting the combustion settings. Careful observation should be maintained with corrective action undertaken in case of improper combustion.

Extract of instruction manual:
"If the heavy fuel oil bunker type is changed and the calorific value of the oil changes, the oil/air ratio should be checked and adjusted to obtain the correct combustion data."

5. Viscosity variation

Why is this important?

It is crucial for the burner/boiler system to burn fuels within a specified viscosity range. For example, viscosity at the KBSD burner inlet is specified at 15-20 cSt (please refer to the viscosity chart in your boiler manual).

Improper viscosity can lead to operational and safety issues due to bad atomization of the fuel.

What are the challenges?

From 2020 with the introduction of 0.5% sulphur compliant fuel, the average fuel viscosity should decrease (globally) compared to the 3.50% HFO. High viscosity variation from the different VLSFO is also expected.

Required viscosity is reached by heating the VLSFO through a steam heater and by maintaining the steam tracing. **The heating ‘set point’ is manually input by the crew** in the control system according to the viscosity chart found in the boiler instruction manual.

With greater variability in viscosity expected in future, a heavier reliance is placed on the crew to ensure this process is carried out correctly each and every time as adjustments to the heating set point and alarm/trip set points will be necessary.

In an extreme scenario heating fuel above the boiling point could lead to gasification with flame stability issues.

Conclusions:

It is a requirement to always test the fuel viscosity and to manually input the new heating set point and alarm/trip set point (high and low) in the control system in respect with the viscosity-temperature chart.

6. Service tank viscosity limits

Why is this important?

The specified minimum viscosity in the VLSFO service tank is 45cSt. This minimum is specified to ensure a proper operation of the steam heater, according to the heater/heating control design.

The specified maximum viscosity in the VLSFO service tank is 380cSt. This maximum is specified to insure pumpability of the fuel.

What are the challenges?

With greater variability in viscosity expected in future, appropriate fuel selection is crucial, in addition to there being a heavier reliance placed on the crew to ensure the correct service tank viscosity is maintained through heating, where possible.

Lower viscosity in the service tank could lead to instability in the heating control.

Higher viscosity in the tank can lead to clogging / pumping issues.

Conclusions:

We duly recommend to keep the viscosity in the service tank within the min to max range at all times.

7. Fuel compatibility / fuel changeover

This section is proposing calculation method for estimation of the volume of fuel flush back in the VLSFO service tank. This is proposed as information only; exact amount should be confirmed by measurement method.

Why is this important?

With this system design, several fuel change-over possibilities exist:

INITIAL / CHANGE TO	VLSFO	MDO	MGO
VLSFO		X	X
MDO	X		X
MGO	X	X	

With this single line design, the fuel change-over is achieved with **a complete flush of the fuel line**. The fuel mixture is flushed back in the VLSFO service tank. The duration of the flushing sequences is set by timers.

Confirmation of compatibility of fuels at the quantity flushed back is a pre-requisite to undertaking this process.

What are the challenges?

With new / emerging fuels with differing specifications, increased risk of non-compatibility exists if the correct case by case assessments on mixability are not undertaken prior to flushing.

Conclusions:

Before proceeding to any fuel change over, fuel compatibility shall be confirmed by appropriate test, considering the volume of fuel to be flushed back into the VLSFO tank and the compatibility of that specific mixture.

The following calculations are indicative of the volumes of flush back for various given scenarios

VLSFO to MGO change over:

The boiler is stopped, fuel line filled with VLSFO is flushed with MGO. The fuel mixture is flushed back in the VLSFO service tank.

The flushing sequence duration is condition by:

- Flush Timer 2 / FT2
- Flush Timer 4 / FT4
- Flush Timer 7 /FT7

In order to evaluate the quantity of MGO flush back in the VLSFO service tank, we recommend to apply of following calculation method:

V_{MGO}: The volume MGO flush back in the VLSFO settling tank [m³]

Q_{FO}: The Fuel Oil pump flow [m³/s]

T_{FT2}: Time of the flushing sequence FT2 [s]

T_{FT4}: Time of the flushing sequence FT4 [s]

T_{FT7}: Time of flushing sequence FT7 [s]

The estimated MGO volume mixed is given by

$$V_{MGO} = Q_{FO} \times (T_{FT2} + T_{FT7} + T_{FT4})$$

MDO to MGO change over:

The boiler is stopped, fuel line filled with MDO is flushed with MGO. The fuel mixture is flushed back in the VLSFO service tank.

The flushing sequence duration is condition by:

- Flush Timer 2 / FT2
- Flush Timer 4 / FT4
- Flush Timer 7 /FT7

In order to evaluate the quantity of MGO flush back in the VLSFO service tank, we recommend to apply of following calculation method:

V_{MGO}: The volume MGO flush back in the VLSFO settling tank

Q_{FO}: The Fuel Oil pump flow [m³]

T_{FT2}: Time of the flushing sequence FT2 [m³/s]

T_{FT4}: Time of the flushing sequence FT4 [s]

T_{FT7}: Time of flushing sequence FT7 [s]

The volume of MGO mixed is given by

$$V_{MGO} = Q_{FO} \times (T_{FT2} + T_{FT4} + T_{FT7})$$

The Volume of MDO flush back in the VLSFO Service tank is equivalent to the volume of the fuel line

<u>MGO to VLSFO change over:</u>

The boiler is stopped, fuel line filled with MGO is flushed with VLSFO. The fuel mixture is flushed back in the VLSFO service tank.

The Volume of MGO flush back in the VLSFO Service tank is equivalent to the volume of the fuel line.

<u>MDO to VLSFO change over:</u>

The boiler is stopped, fuel line is filled with MDO is flush with VLSFO. The fuel mixture is flushed back in the VLSFO service tank.

The Volume of MDO flush back in the VLSFO Service tank is equivalent to the volume of the fuel line.

<u>VLSFO to MDO change over:</u>

The boiler is stopped, fuel line filled with VLSFO is flushed with MDO. The fuel mixture is flushed back in the VLSFO service tank.

The flushing sequence duration is condition by:

- Flush Timer 2 / FT2
- Flush Timer 4 / FT4
- Flush Timer 7 /FT7

In order to evaluate the quantity of DO flush back in the VLSFO settling tank, we recommend to apply of following calculation method:

V_{DO}: The volume DO flush back in the VLSFO settling tank [m³]

Q_{FO}: The Fuel Oil pump flow [m³/s]

T_{FT2}: Time of the flushing sequence FT2 [s]

T_{FT4}: Time of the flushing sequence FT4 [s]

T_{FT7}: Time of flushing sequence FT7 [s]

The volume mixed is given by

$$\mathbf{V_{DO} = Q_{FO} \times (T_{FT2} + T_{FT4} + T_{FT7})}$$

<u>MGO to MDO change over:</u>

The boiler is stopped, fuel line filled with MGO is flush with MDO. The fuel mixture is flushed back in the VLSFO service tank.

The flushing sequence duration is condition by:

- Flush Timer 8 / FT8

In order to evaluate the quantity of MDO flush back in the VLSFO service tank, we recommend to apply of following calculation method:

V_{DO}: The volume MDO flush back in the VLSFO service tank

Q_{FO}: The Fuel Oil pump flow

T_{FT8}: Time of the flushing sequence FT8

The volume mixed is given by:

$$\mathbf{V_{DO} = (Q_{FO} \times T_{FT8})}$$

The Volume of MGO flush back in the VLSFO Service tank is equivalent to the volume of the fuel line.

8. Cat fines

Why is this important?

Cat Fines in the fuel can be harmful to the Boiler System in terms of causing damage and wear to pumps, filters, the burner and boiler pressure part itself. Existence of cat fines can also impact combustion optimisation.

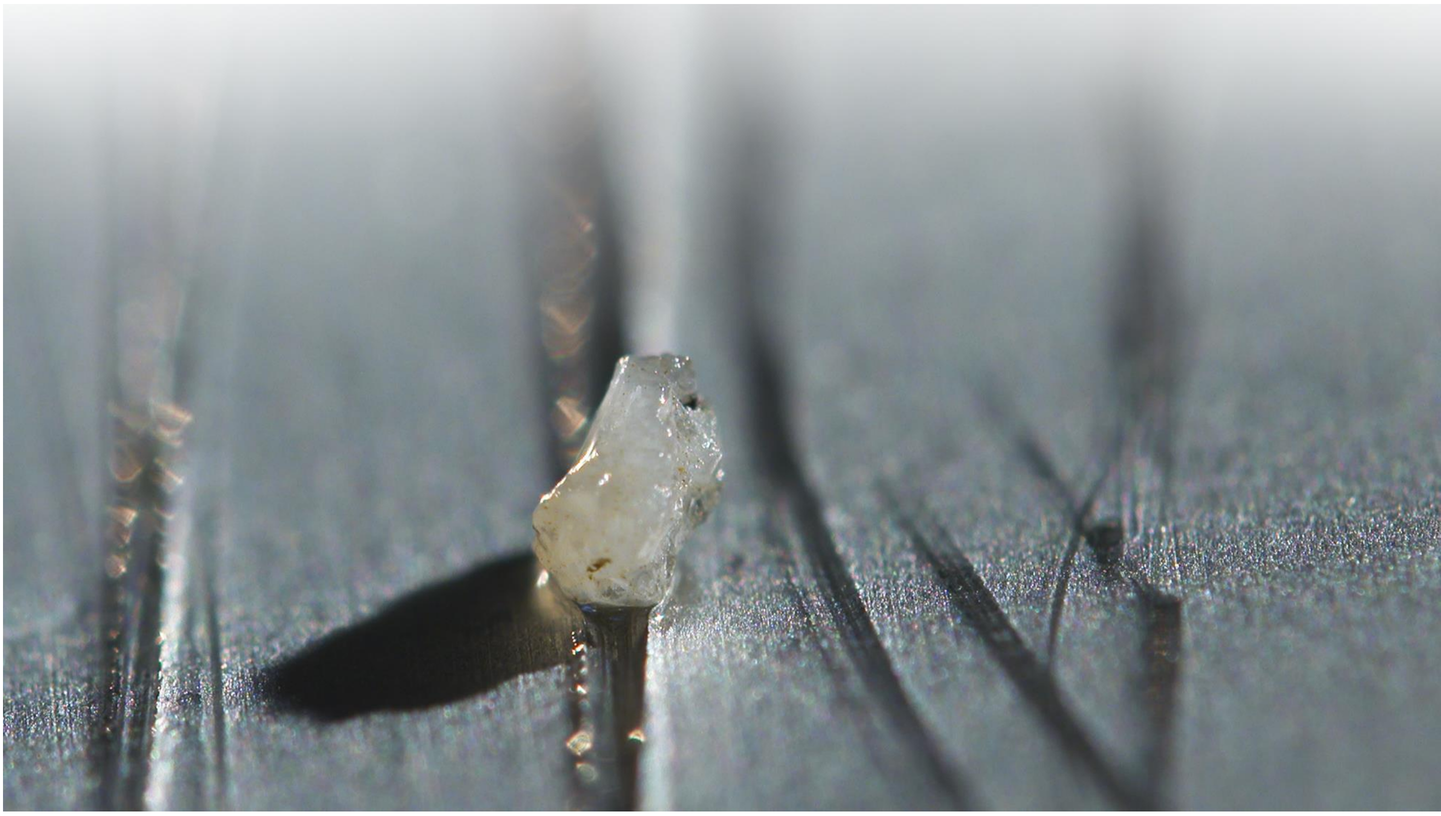
What are the challenges?

While a thorough understanding of new fuels entering the market is still to be achieved, experience to date suggests a possibility of an increase in cat fines due to the composition of these fuels.

Conclusions:

Recommendation for keeping the cat fines level as low as possible up to maximum cat fine level according to ISO 8217-2017.

Optimization of the separator plant might be considered.



9. Pour point

Why is this important?

Notice needs to be taken of fuel pour points in Service Tank and fuel line to ensure smooth flow of fuel and therefore operation of the system

What are the challenges?

While a thorough understanding of new fuels entering the market is still to be achieved, experience to date suggests an increase in variability of pour point temperatures, resulting in the need for a more vigilant approach to maintaining fuel temperatures through the system.

Conclusions:

We recommend maintaining the service tanks temperature 15°C above the pour point.

We recommend keping the fuel temperature in the fuel line 15°C above the pour point

The cooling unit temperature is initially designed for cooling the MGO (MGO operation) and therefore avoid too low viscosity.

This unit can be use as fuel temperature regulator (MGO operation) and heat up the MGO above the pour point. For this purpose, the LT cooling unit should be connected to the Low Temperature cooling system of the vessel.

Provided that the LT water temperature is at least 15°C above the pour point

It is recommended to adjust the set point of the low MGO temperature alarm from the default set point of 0°C to 10°C above the pour point.