WIN GD
Winterthur Gas & Diesel

Concept Guidance Distillate Fuels

Impact on the engine installation and ship system design

Revision-D, October 2019

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Table of Contents

1 Introduction 5
2 Fuel oil viscosity 6
3 Fuel oil system 6
3.1 Fuel oil storage tanks 6
3.2 Fuel oil and MDO/MGO drain tank 8
3.3 Fuel oil pumps 9
3.3.1 Pumps for HFO and MDO/MGO fuel system 9
3.3.2 Pump for the MDO/MGO only or MGO only fuel system 9
3.4 MDO/MGO heat exchanger 9
3.4.1 MDO/MGO heat exchanger position and arrangement options 10
3.4.2 Heat exchanging methods 10
3.4.3 Heat exchanger heat dissipation 11
4 Fuel changeover procedure 12
4.1 Automatic fuel changeover 12
4.2 Manual fuel changeover 12
5 Cylinder lubrication 12
5.1 Arrangement of the cylinder lubricating oil system 13
5.2 Blending on board 13
6 SCR application and operation 13
Appendix A : Cylinder LO system with iCAT 14
Appendix B : Cylinder LO system with 3-way changeover valve 15

List of Figures

Figure 3-1: Option 1 – Two (2) dedicated settling tanks for each type of HFO 7
Figure 3-2: Option 2 – Two (2) common settling tanks for different types of HFO 7
Figure 3-3: Option 3 – One (1) dedicate settling tank for each type of HFO 8
Figure 3-4: Fuel oil drain tank arrangement 9
Figure 3-5: System proposal – fuel system with fuel oil cooler at different positions 10
Figure 3-6: Schematic illustration of fuel oil temperature at mixing unit and before cooler 11
Figure 6-1: Cylinder LO System with iCAT 14
Figure 6-2: Cylinder LO System without iCAT 15

List of Tables

Table 1-1: Fuel oil terminology with regards of Sulphur content 5
Table 3-1: Fuel oil settling tank and service tank requirement 6
Table 3-2: Options of settling tanks arrangement for HFO 6

Abbreviation

BN	Base Number
BOB	Blending On Board
BSFC	Break Specific Fuel Consumption
CIMAC	International Council on Combustion Engines (Abb. Of French name)
CMCR	Contracted Maximal Continuous Rate
DM	Distillate Marine fuel
ECAs	Emission Control Areas
FAME	Fatty Acid Methyl Esters
FO	Fuel Oil
HFO	Heavy Fuel Oil
HSFO	Fuel Oil with High Sulphur content
iCAT	Integrated Cylinder Lubrication Automatic Transfer
IMO	International Maritime Organization
ISO	International Organization for Standardization
LO	Lubricating Oil
MDO	Marine Diesel Oil
ME	Main Engine, particularly refer to WinGD 2-stroke engine
MIDS	Marine Installation Drawing Set for WinGD engines
MGO	Marine Gas Oil
NECA	NO_X Emission Control Area
RM	Residual Marine fuel oil
SCR	Selective Catalytic Reduction systems
SECA	Sulphur Emission Control Area
ULSFO	Fuel Oil with Ultra-Low Sulphur content
VLSFO	Fuel Oil with Very-Low Sulphur content
WinGD	Winterthur Gas & Diesel Ltd.

1 Introduction

WinGD (Winterthur Gas & Diesel Ltd. Co.) allows its 2-stroke engines to be operated on all fuels specified under the ISO standard 8217:2017. This concept guidance mainly focusses on application possibilities and treatment of distillate fuels used in RT-flex, X and X-DF 2-stroke engines.
According to ISO 8217:2017 standard, distillate fuels are categorized as DMX, DMA/DMZ (also called MGO) and DMB (also called MDO). DMZ is equivalent to DMA, but DMZ has a higher minimum viscosity limit. DMX is emergency fuel with a lower flash point, e.g. for use in emergency generator or lifeboat, coming with additional storage precautions and therefore usually not used in marine diesel engines.
The ISO 8217:2017 specification allows a Fatty Acid Methyl Esters (FAME) content of up to 7% for DFA, DFZ and DFB. WinGD has so far not received any negative feedback from operators using DFA, DFZ and DFB. Care must be taken to the storage and handling of such fuels.
Since the exhaust gas emission limits is getting stricter, there is increased demand on distillate fuels as an alternative or supplement to heavy fuel oils for engine operation. For WinGD DF engines, the demand of a pure MGO or MDO/MGO fuel system in combination with the gas fuel system is increasing as well. This document gives guidance for pure MGO or MDO/MGO fuel system.
The latest limit on the emissions of SO_x, equivalent to Sulphur (S) content in the fuel following the “Marpol 73/78 Annex VI” is as listed below:

Restricted Sulphur content worldwide:
- 3.50% from 1st January 2012
- 0.50% from 1st January 2020

Restricted Sulphur content in Europe ECAs:
- 0.10% from 1st January 2015

Restricted Sulphur content in the USA ECAs:
- 0.10% for MGO and MDO from 1st January 2014

Restricted Sulphur content in the domestic ECAs – China & Hong Kong:
- 0.50% for all ships at berth in core ports from 1st January 2017
- 0.50% for all ships enters domestic ECA from 1st October 2018

Following the proposal from the IMO and the CIMAC, WinGD has defined a fuel oil terminology based on the Sulphur (S) content in WinGD relevant documents.
- ULSFO DM: distillate marine fuel oil with Sulphur content not higher than 0.10%.
- VLSFO DM: distillate marine fuel oil with Sulphur content between 0.10% and 0.50%.
- DM: distillate marine fuel oil with Sulphur content higher than 0.50%.
- ULSFO RM: residual marine fuel oil with Sulphur content not higher than 0.10%.
- VLSFO RM: residual marine fuel oil with Sulphur content between 0.10% and 0.50%.
- LSFO RM: residual marine fuel oil with Sulphur content between 0.50% and 1.00%.
- HSFO RM: residual marine fuel oil with Sulphur content higher than 1.00%.

To clarify the relation of the types of marine fuels (based on the fuel viscosities, properties and the Sulphur content), WinGD provide following table for overview:

Table 1-1: Fuel oil terminology with regards of Sulphur content

Sulphur Content	HFO	MDO (DMB)	MGO (DMA & DMZ)
S ≤ 0.10%	ULSFO RM	ULSFO DM	
0.10% ≤ S ≤ 0.50%	VLSFO RM	VLSFO DM	
0.50% ≤ S ≤ 1.0%	LSFO RM	DM	
S > 1.00%	HSFO RM	DMB (S ≤ 1.50%)	N.A.

2 Fuel oil viscosity

When operating on HFO, WinGD recommends a fuel oil viscosity at the engine inlet is 13 – 17 cSt, though the extended range of 10 – 20 cSt is permissible.
For MGO and MDO a nominal lower viscosity grade of minimum 2 cSt must be kept. To adjust this low viscosity grade, the installation of a viscometer with a high accuracy at low viscosities may be necessary.

3 Fuel oil system

The arrangement of a complete pressurised fuel oil system for the HFO or multiple fuel oils, including the fuel oil treatment and tank arrangement, is shown as proposal in the Marine Installation Drawing Set (MIDS).
Due to the increased demand on pure MGO or pure MDO/MGO fuel systems, WinGD will provide proposals of system arrangements for dedicated pure MGO or pure MDO/MGO fuel system. The MIDS will be updated in stages.

3.1 Fuel oil storage tanks

It is mandatory to design at least one dedicated service tank for each type of HFO, MDO and MGO to ensure the fuel is immediately available when the specific fuel is required for the ME operation.
For MGO there is no need for a settling tank installation and for MDO one settling tank is sufficient in most cases.

Table 3-1: Fuel oil settling tank and service tank requirement

Tank requirement	HFO	MDO	MGO
Service tank	Two	One	One
Settling tank	3 options	One common tank	No need

For HFO there are three options of settling tank arrangement. These are compared with the installation costs and the treatment system performance:

Table 3-2: Options of settling tanks arrangement for HFO

Options	Fuel treatment performance	Installation cost
Two (2) dedicated settling tanks for each type of HFO (refer to Figure 3-1)	Optimum for fuel settling efficiency; optimum for fuel type changing	High
Two (2) common settling tanks for different types of HFO (refer to Figure 3-2)	Limited fuel settling efficiency; risk of fuel mixing during fuel type change	Low
One (1) dedicated settling tank for each type of HFO (refer to Figure 3-3)	Limited fuel settling efficiency, not recommended for 2020 fuels	Low

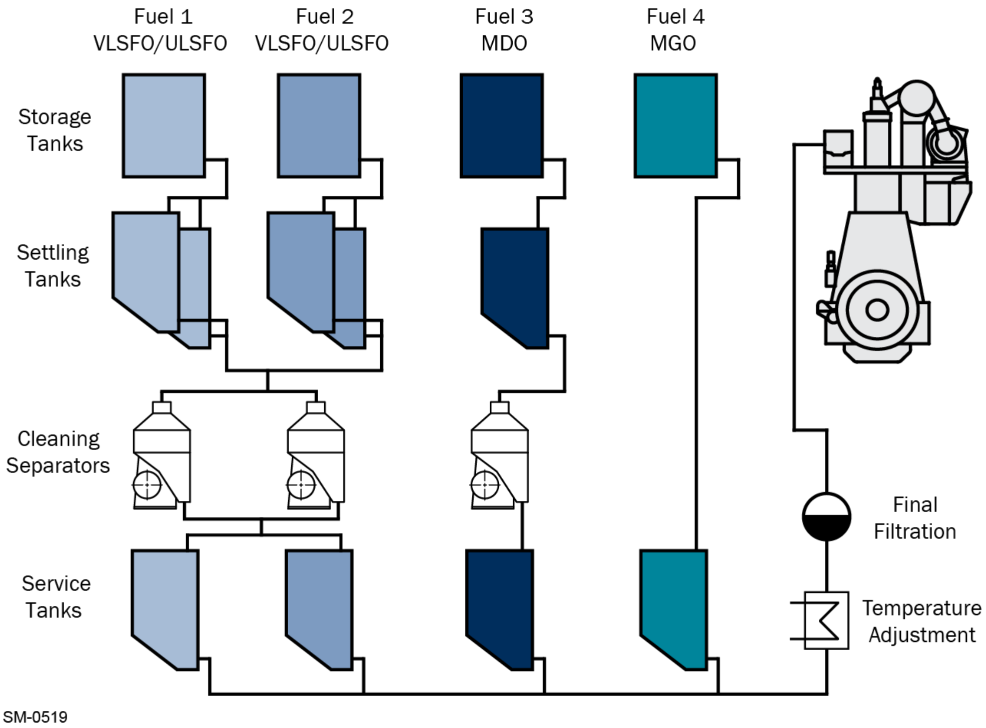

Figure 3-1: Option 1 – Two (2) dedicated settling tanks for each type of HFO

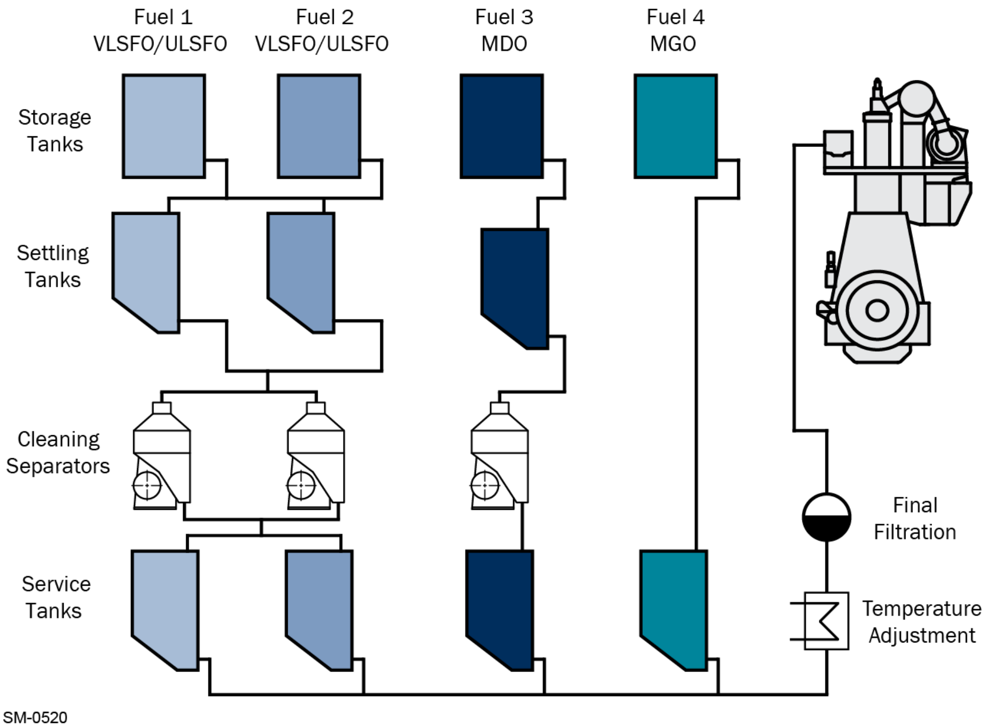

Figure 3-2: Option 2 – Two (2) common settling tanks for different types of HFO

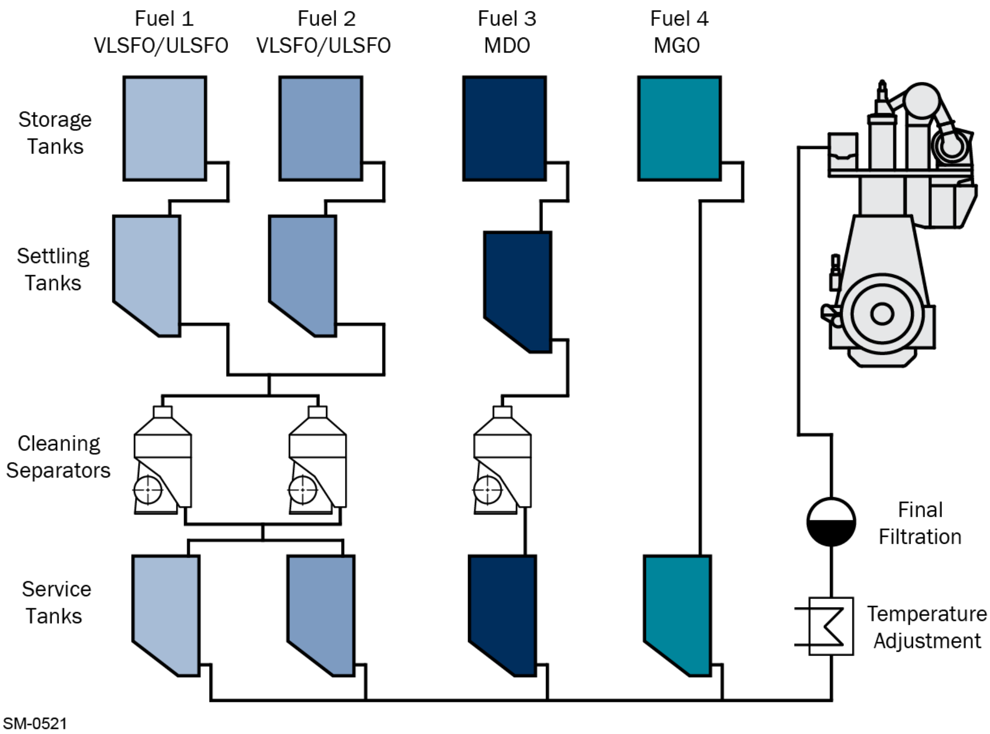

Figure 3-3: Option 3 – One (1) dedicate settling tank for each type of HFO

Remark on the tank design:

- The tanks should have an inclined bottom for easier separation of cat fines and other solid particles from the fuel. Bottom drains need to be installed.
- An overflow pipe from the bottom of the service tank back to the settling tank should be installed to enable recirculation.
- For the WinGD DF engines with gas fuel and the pure MGO solution, the fuel oil purification system can be much simplified or obsoleted because the MGO is a clean fuel and requires no particle separation before combustion.

3.2 Fuel oil and MDO/MGO drain tank

To comply with the stricter environmental rules, engine operation on distillate fuels (e.g. MDO/MGO) is more frequently required, which means that the periods in this operating mode are getting longer. MDO/MGO has a significantly lower viscosity than HFO. Therefore, during engine operation on MDO/MGO a considerable increase in clean MDO/MGO in the pressureless fuel oil return (from the fuel pumps and fuel injection control unit) has been observed by the ship operators. It is estimated that the quantity from the pressureless fuel oil return can be up to 10 times higher with MDO/MGO operation than with HFO operation.

For cost saving purpose, it is not recommended to mix a considerable amount of this MDO/MGO with the HFO within the pressureless fuel oil return. Therefore, WinGD recommend the use of a separated MDO/MGO drain tank to collect the MDO/MGO from the pressureless fuel oil return, for reuse when the vessel is in long-term operation on MDO/MGO.

For this, a three-way valve must be installed to switch between the common FO drain tank (collecting HFO or HFO mixed with MDO/MGO) and the MDO/MGO drain tank (please refer to Figure 3-4).

Before the collection of MDO/MGO into the dedicated drain tank the system must be practically HFO free, so must be thoroughly flushed by MDO/MGO before switching the three-way valve.
The duration of the whole changeover procedure depends on a variety of operating conditions (e.g. fuel quality, engine power, system size and arrangement) and can't be specified by an absolute figure. If it is not indicated in the automatic changeover unit, the times required for fuel changeover valve and system flushing need to be calculated, as the fuel supply changeover procedure can only be completed once the fuel in the circulation line is completely replaced.

NOTE	The switch over to the MDO/MGO drain tank should aim to take place once less than 1% of HFO fuel is remaining in circulation line.

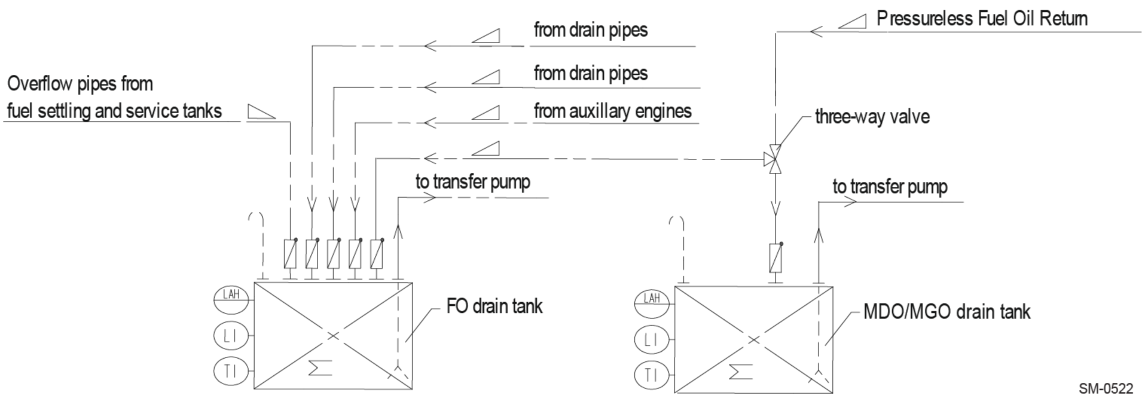

Figure 3-4: Fuel oil drain tank arrangement

3.3 Fuel oil pumps

3.3.1 Pumps for HFO and MDO/MGO fuel system

For the conventional fuel supply system, the feed pump, booster pump, mixing unit, viscometer, fuel oil heat exchanger and end-heater are necessary for HFO and MDO/MGO. In addition, a dedicated fuel supply circuit with feed pump together with cooler and filter for the pilot fuel is needed for the DF engines.
The feed and booster pump capacities should be specified for the lower fuel oil viscosity, which normally corresponds to the MDO/MGO grade (2 – 11 cSt at 40 °C). As nominal pump capacity decreases with lower fuel viscosities, this must be considered when determining the capacities of the feed and booster pump.

3.3.2 Pump for the MDO/MGO only or MGO only fuel system

For the MDO/MGO only or the MGO only fuel supply system, only one fuel feed pump is needed. The delivery head of this pump shall equal to the total delivery head of the conventional feed and booster pump. The flow capacity of the fuel feed pump shall equal the conventional booster pump. The dedicated pilot fuel supply circuit is not needed. The supply of pilot fuel can be provided by the main fuel oil supply system.

3.4 MDO/MGO heat exchanger

The MDO/MGO heat exchanger is used to adjust the MDO/MGO temperature to ensure the required viscosity grade of min. 2 cSt at engine inlet.

3.4.1 MDO/MGO heat exchanger position and arrangement options

WinGD recommend that a MDO/MGO heat exchanger is installed after the high-pressure booster pump (and before the viscometer which regulates the fuel oil end-heater), as referred to as *‘10 (Opt. 1)’* in
Figure 3-5.
This will ensure that the MDO/MGO viscosity remains within limits, even when the fuel oil end-heater is not completely by-passed and shut-off.
If this arrangement does not provide the correct operation fuel oil viscosity for the booster pumps, an **alternative** or **additional** MDO/MGO heat exchanger position should be considered in front of the booster pumps as referred to as *‘11 (Opt. 2)’* in
Figure 3-5 .
There is also an option of an additional MDO/MGO heat exchanger, referred to as *‘12 (Opt. 3)’* in Figure 3-5, if the feed pump also requires supplementary changes to viscosity.

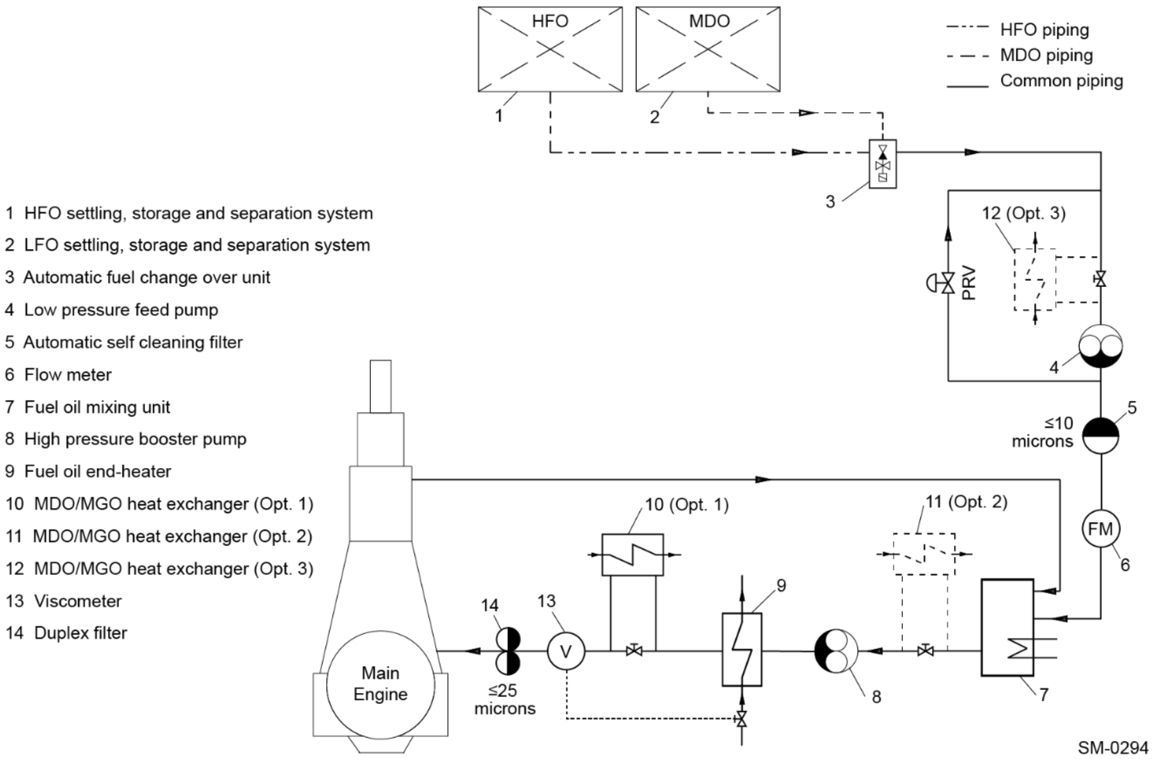

Figure 3-5: System proposal – fuel system with fuel oil cooler at different positions

3.4.2 Heat exchanging methods

WinGD recommend the direct heat exchange method for the fuel oil by applying tubular or plate type of heat exchanger, using cooling water from the low-temperature circuit as coolant (LT water of 25 °C – 36 °C).
This solution is recommended for the following reasons:

- Heat dissipation capacity is sufficient to fulfil the viscosity requirements, if fuels according to ISO 8217:2017 are in use.
- Automatic temperature control, i.e. no additional temperature control is needed.
- No additional pump and separate cooling medium is required.

Other cooling methods such as cooling by seawater are not recommended due to the increased system complexity and unnecessary additional cost. Cooling by chilled water is not required for fuels in accordance to ISO 8217:2017, but maybe applicable if at risk of using off-specification fuels.

3.4.3 Heat exchanger heat dissipation

The MDO/MGO heat exchanger heat dissipation (Q) is determined by the following formula:

$$Q = \frac{0.34 \times BSFC \times P \times (T_1 - T_2 + 25.65)}{10^6} \quad (3\text{-}1)$$

Where:

Q [kW]	= heat exchanger heat dissipation at 100% engine load
BSFC [g/kWh]	= specific fuel consumption at design conditions and 100% engine load
P [kW]	= engine power at 100% CMCR
T_1 [°C]	= temperature of distillate fuel supplied to engine
T_2 [°C]	= temperature of distillate fuel at engine inlet

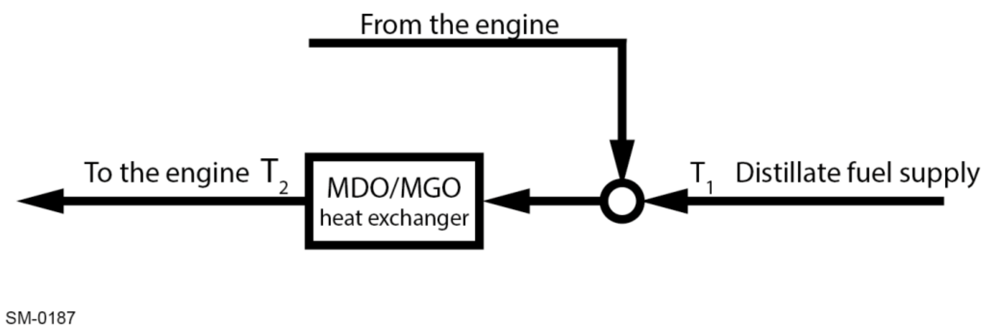

Figure 3-6: Schematic illustration of fuel oil temperature at mixing unit and before cooler

Example for 8X52DF

Design conditions at 100% CMCR: P = 7440 kW, BSFC = 182.3 g/kWh
Distillate fuel: DMA, viscosity 2 cSt at 40 °C, supply temperature T_1 = 45 °C
Target: viscosity of 2.5 cSt at engine inlet, therefore, DMA oil needs to be cooled down to 28 °C

$$Q = \frac{0.34 \times 182.3 \times 7440 \times (45 - 28 + 25.65)}{10^6} = 19.7\ [kW]$$

Therefore, the cooler with a capacity of about 20 kW should be selected for this vessel.

4 Fuel changeover procedure

When changing over from HFO to MDO/MGO and vice versa, thermal shock to the engine fuel injection system (injection pumps, piping, etc.) due to temperature decrease and temperature increase respectively must be prevented. Sudden temperature changes may lead to seizing of the fuel pump plungers, which may directly affect the manoeuvrability of the ship or result in fuel pipe leakage with the risk of fire.
Therefore, when changing over from one fuel type to another, the temperature gradient of 2 °C/min should not be exceeded and must be monitored in addition to the required viscosity grade (min. 2 cSt for MDO/MGO).

4.1 Automatic fuel changeover

The automatic fuel changeover unit is shown in WinGD's system proposal drawing in the MIDS. The automatic fuel changeover unit comprises the following advantages:

- The unit enables a fully automatic changeover from HFO to MDO/MGO and vice versa even at 100% CMCR engine load.
- The changeover time can be significantly reduced, making MDO/MGO saving possible.
- The required maximum temperature gradient of 2 °C/min can be easily maintained during changeover by internal monitoring devices and a controlled cooler, if cooler control function is integrated in the changeover unit.
- The risk of damage by abrupt temperature changes is limited due to integrated safeguard functions.
- With an advanced automatic fuel changeover unit, the end of changeover (including flushing time) is supervised to ensure compliance with SECA requirements.

A detailed description of the fuel changeover procedure is given in the relevant product document of the fuel changeover unit.

4.2 Manual fuel changeover

The manual fuel changeover is done by means of a simple three-way valve. This solution is acceptable only if the operator, i.e. normally the crew, can take well consideration of following points:

- Depending on the current oil level in the fuel oil service tanks, pressure fluctuations due to varying static pressure need to be compensated at the inlet of the three-way valve.
- The fuel changeover must only be done at engine loads below 75% to avoid exceeding the temperature gradient of 2 °C/min.
- The changeover procedure is strongly influenced by the volume of fuel in the system. A large fuel volume enhances reduction of the temperature gradient, but on the other hand prolongs the process.
  Generally, the period during which the different types of fuel are present together must be kept as short as possible to avoid incompatibility problems.
- To keep a minimum viscosity of 2 cSt it must be ensured that MDO/MGO is not heated up too much (e.g. by the pumps).

5 Cylinder lubrication

To prevent the build-up of deposits, originating from non-neutralised hard calcium carbonate deposits, the use of cylinder lubricating oil of different Base Number (BN) values is necessary.
More detailed description of the adjustment of the BN level in relation to the fuel type, engine load and feed rate is given in the WinGD document: "Lubricants", as provided on www.wingd.com

5.1 Arrangement of the cylinder lubricating oil system

The arrangement of the cylinder lubricating oil system with two storage and two service tanks, for operation with high and low BN oil is shown in the MIDS.
The periodical feeding of the LO into the cylinder (following the piston running pace) leads to the pulsating flow of the cylinder lubricating oil from the service tank to the ME. Such pulsating LO flow makes it difficult to measure the flow with a conventional flow meter. Therefore, a flow meter with sufficient accuracy and anti-pulsating ability shall be selected if a flow meter is required.
As an alternative design to the cylinder LO consumption monitoring, a separated small measuring tank can be installed downstream of the LO service tank, as shown in the MIDS drawing. This provides an indication of cylinder LO consumption within several hours or days instead of an instant flow measurement by the flow meter.
The minimum static height requirement of the cylinder LO service tank to the ME inlet is specified in the MIDS drawing for each engine type. This requirement must be complied to ensure proper LO supply to the ME.
For any engines equipped with the integrated Cylinder Lubrication Automatic Transfer (iCAT) system, the changeover of the LOs with different BN can be automatically done by the iCAT system. Refer to Appendix A.
For the engines without iCAT system, the changeover of the LO with different BN shall be done by a manual or remote switch of the 3-way changeover valve. This must be installed as close as possible to the engine inlet. Refer to Appendix B.

5.2 Blending on board

Blending On Board (BOB) provides a flexible solution for adjusting the BN grade of the cylinder lubricating oil when operating with fuels of different sulphur contents at different engine loads. The basic function is to keep the cylinder constantly lubricating at the optimum oil feed rate, without interruption under any engine operational conditions, while simultaneously adjusting the content of the additives to cover the range from 40 BN to 120 BN. For WinGD engines with iCAT system, BOB is not needed.

6 SCR application and operation

To comply with the IMO Tier III regulations for NO_x emission control areas (NECA), the engine can be equipped with an exhaust gas treatment system, e.g. High- or Low-Pressure SCR (HP-SCR/LP-SCR). Depending on the design of the SCR, it may only be operated if the fuel sulphur content meets the requirement of the SCR system supplier. Information about the permissible fuel sulphur content must be provided by the SCR system supplier. In general, LP-SCR systems cannot operate with a fuel sulphur content level above 0.5%, while HP-SCR systems may be designed for up to 3.5% sulphur content.
To ensure the required fuel sulphur content, a fuel changeover (including system flushing) might be needed as described in section 4.

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Appendix A : Cylinder LO system with iCAT

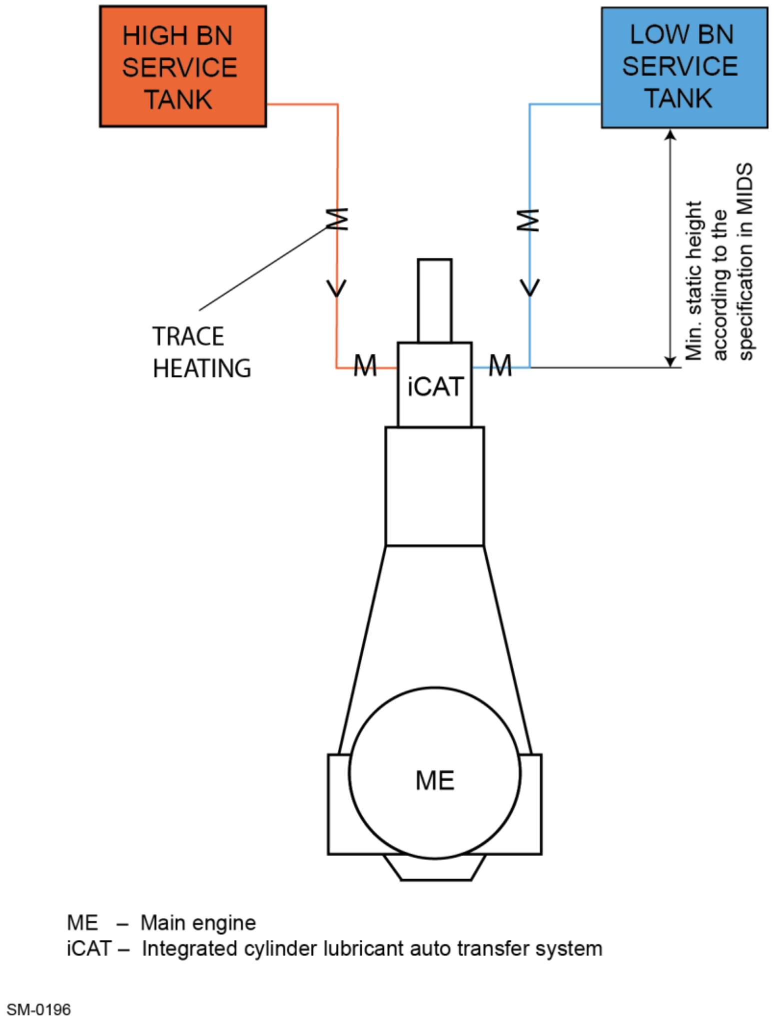

Figure 6-1: Cylinder LO System with iCAT

Appendix B : Cylinder LO system with 3-way changeover valve

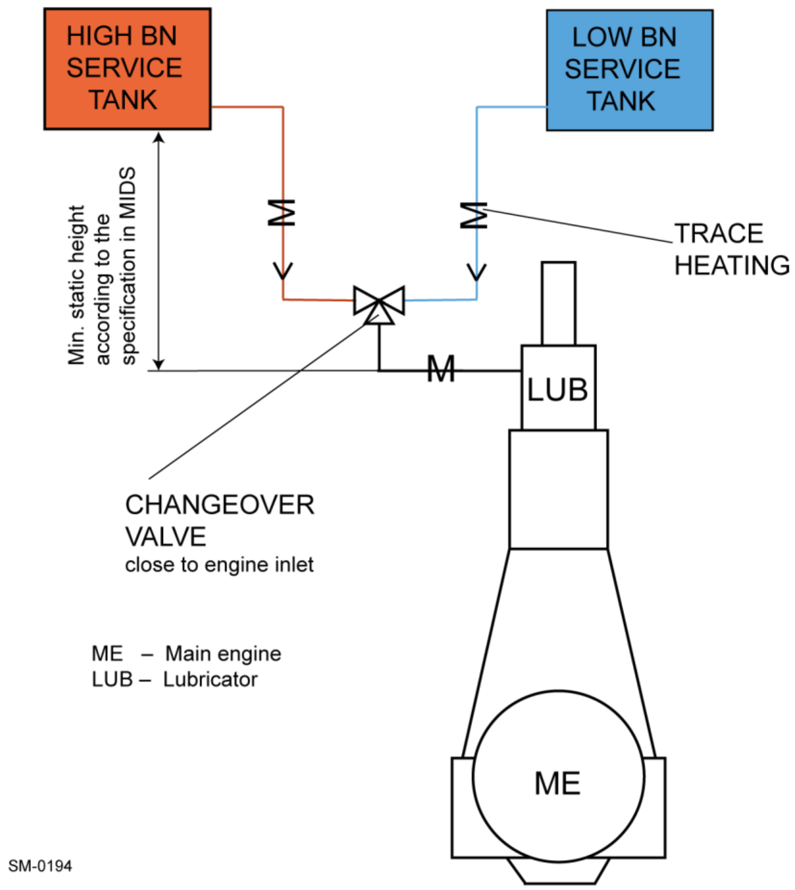

Figure 6-2: Cylinder LO System without iCAT

CONCEPT-GUIDANCE - WinGD-2S - OPERATION-ON- DISTILLATE-FUELS

TRACK CHANGES

DATE	SUBJECT	DESCRIPTION
2016-10-25	DOCUMENT	First web upload
2019-10-10	107.428.377	new revision