System Engineering Concept Guidance

OPERATION ON DISTILLATE FUELS – IMPACT ON THE INSTALLATION

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Substitute for:												PC	Q-Code	X	X	X	X	X

Modif	-	7-77.747	08.12.2009	A	EAAD083852	29.05.2012	B	EAAD086137	01.09.2015	C	EAAD086866	26.07.2016
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WIN GD Winterthur Gas & Diesel

Product: **W-2S**

Concept Guidance Distillate Fuels
Installation Aspects

Made	20.11.2009	M.Lüthi	Main Drw.	Page 1 / 15	Material ID **107.428.377.500**
Chkd	30.11.2009	C.Van Gijssel	Design Group	Drawing ID **107.428.377**	Rev **C**
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1 Introduction

WinGD (Winterthur Gas & Diesel Ltd.) allows for its engines to be operated on all fuels supplied under the ISO standard 8217, 2012 (table 1of this document).
The present concept guidance mainly focuses on application possibilities and treatment of distillate fuels in RTA, RT-flex and W-X 2-stroke engines.
According to ISO 8217, 2012 standard, distillate fuels are categorized as DMX, DMA/DMZ (also called MGO) and DMB (also called MDO). DMZ is equivalent to DMA, but has a higher minimum viscosity limit than DMA. DMX is emergency fuel with a lower flash point, coming with additional storage precautions and therefore usually not used in marine diesel engines.
The increasing demand for distillate fuels as an alternative or supplement to heavy fuel oils for engine operation is directly connected to exhaust gas emission limits getting stricter.
Since the emissions of SOx are related to the sulphur (S) in the fuel its content is restricted according to "Marpol 73/78 Annex VI" as follows:

<u>Restricted sulphur content worldwide</u>:

- 3.50% from 1 January 2012
- 0.50% from 1 January 2020

<u>Restricted sulphur content in ECA areas</u>:

- 1.00% from 1 July 2010
- 0.10% from 1 January 2015

<u>Restricted sulphur content in the California area</u>:

- 1.00% for MGO (DMA, DMZ) and 0.5% for MDO (DMB) from 1 August 2012
- 0.10% for MGO and MDO from 1 January 2014

2 Fuel oil viscosity

WinGD´s current recommendation for the fuel oil viscosity at engine inlet when operating on HFO is 13 to 17cSt for RTA/RT-flex/W-X engines, though for RT-flex/W-X engines also values above respectively below this recommendation within the extended range 10-20cSt are permissible when operating on HFO.
For MGO and MDO a nominal lower viscosity grade of minimum 2cSt has to 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 pressurized fuel oil system for various fuel oil qualities, including fuel oil treatment and tank arrangement, is shown as proposal in the Marine Installation Drawing Set (MIDS) and in figure 5 of this document.

3.1 Fuel oil storage tanks

Depending on the used fuel oil types the following tank arrangements are possible:

- Cost-down solution with lower installation costs, but limited HFO/LSHFO treatment performance:

HFO	1 settling tank + 1 service tank
LSHFO	1 settling tank + 1 service tank
MDO/MGO	1 settling tank + 1 service tank

- Optimum solution with an improved LSHFO treatment performance, but additional installation costs:

HFO	2 settling tanks + 1 service tank
LSHFO	2 settling tanks + 1 service tank
MDO/MGO	1 settling tank + 1 service tank

- Compromise solution, as shown in MIDS and figure 5, with good HFO treatment performance and lower LSHFO treatment performance:

HFO & LSFO combined	2 settling tanks
HFO	1 service tank
LSHFO	1 service tank
MDO/MGO	1 settling tank + 1 service tank

Remark on the fuel oil storage tank design:

- The tanks should have an inclined bottom for easier separation of cat fines and other solid particles from the fuel.
- An overflow pipe from the bottom of the service tank back to the settling tank should be installed to enable re-circulation.

3.2 Fuel oil drain and leakage collection tank

In regard to stricter environmental rules, engine operation on distillate fuels (e.g. MDO/MGO) is more frequently required, which means that the particular 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 leakage from the fuel pumps and fuel injection control unit has been observed by ship operators on vessels in service (leakage rate with MDO/MGO operation can be up to 10 times higher than with HFO operation).

From an economical point of view the draining of this huge amount of clean MDO/MGO into the common drain tank and mixing with HFO is not recommended. Therefore, when long-term operation on MDO/MGO is planned WinGD highly recommends that a separate FO leakage tank is installed to collect clean MGO/MDO for re-use. To enable switching between the common fuel oil drain tank (collection of pure HFO respectively of MDO/MGO blended with HFO) and the clean FO leakage tank (collection of pure MDO/MGO) a three-way valve needs to be installed on system side in the drain line from fuel pumps and injection control unit (please refer to figure **1**).

Before switching the three-way valve to enable MDO/MGO draining into the clean FO leakage tank the system must be practically 100% HFO free.

For that purpose the piping system must be thoroughly flushed by MDO/MGO circulation after the change-over from HFO to MDO/MGO has been initiated. The duration of the whole change-over procedure depends on a variety of operating conditions (e.g. fuel quality, system size and ambient conditions) and cannot be specified by an absolute figure. The actual required change-over respectively flushing time needs either to be calculated (manual fuel change-over), or is indicated as output of the automatic change-over unit control box (automatic fuel change-over), provided such a device is applied as recommended by WinGD (Pos. 012 in figure 5).

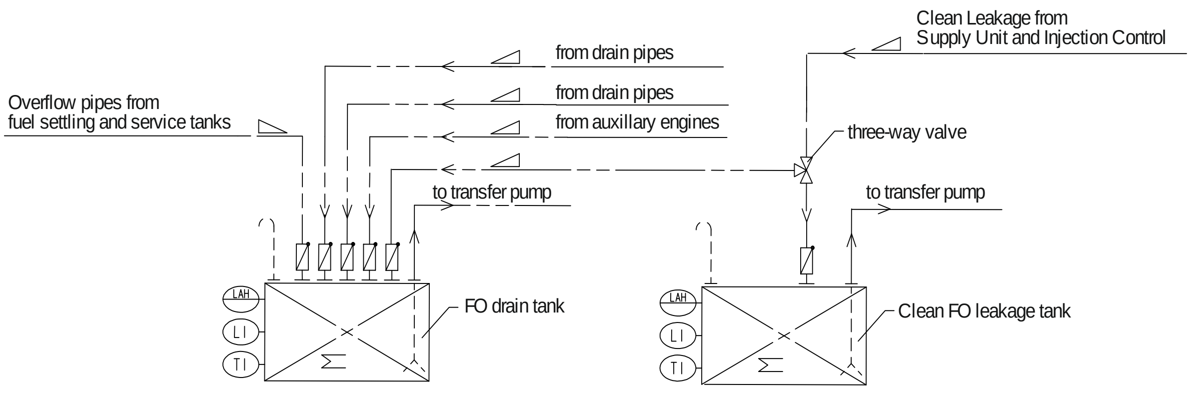

Figure 1**: Fuel oil drain / leakage tank arrangement**

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3.3 Fuel oil pumps

The feed and booster pump capacities should be specified for the lower fuel oil viscosity, which normally corresponds to the MDO/MGO grade (2 – 11cSt at 40°C). As nominal pump capacities will decrease with lower fuel viscosities, this has to be considered when determining the capacities of the feed and booster pumps.

3.4 Fuel oil cooler

The fuel oil cooler is used to cool down MDO/MGO to reach the required viscosity grade of min. 2cSt at engine inlet.

3.4.1 Cooler position

WinGD recommends the installation of the fuel oil cooler after the booster pumps before the viscometer (ref. 1 in figure 2), since an installation in this position protects the engine in case the pre-heater is not completely by-passed and off.

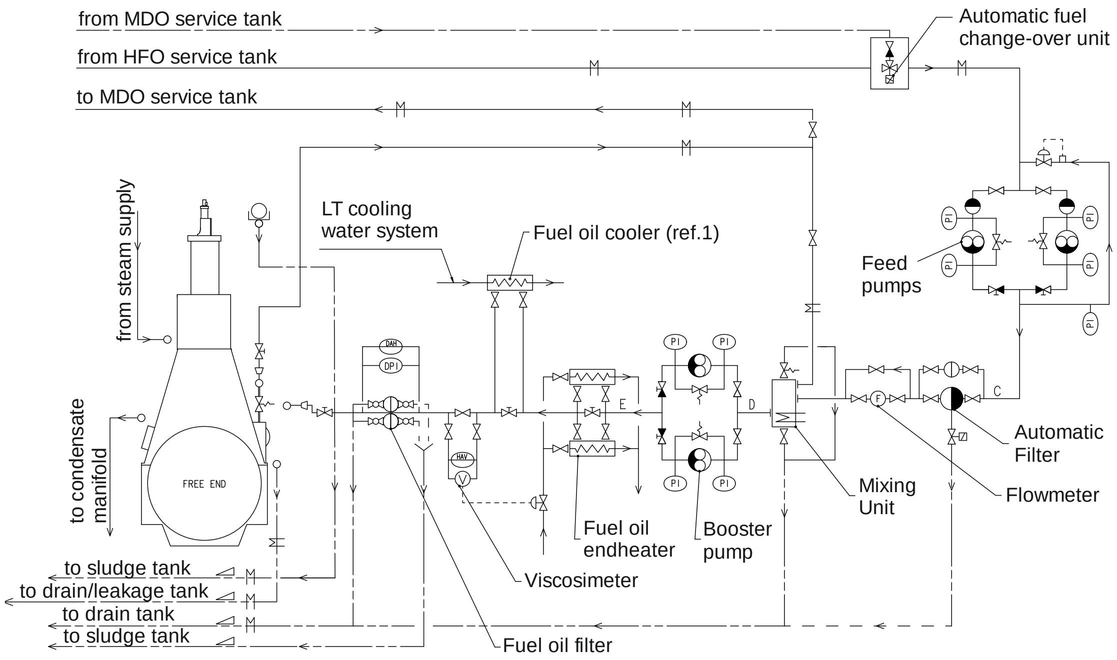

Figure 2: System proposal - fuel oil system with fuel oil cooler after booster pumps

In case the pumps require for proper operation a particular fuel oil viscosity grade that cannot be achieved with the above mentioned cooler arrangement, the installation of cooler in alternative or additional positions needs to be considered.
In this regard, an optional respectively additional fuel oil cooler can be installed also before the booster pumps (ref. 2 in figure 3) and if required complemented by an optional cooler before the feed pumps (ref. 3 in figure 3).

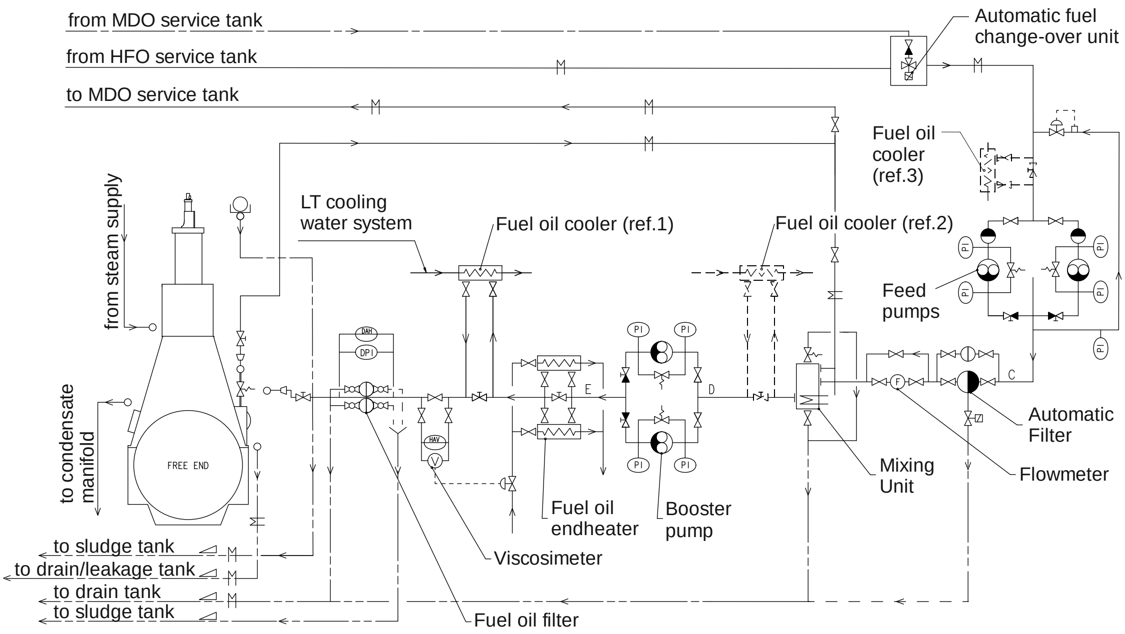

Figure 3: System proposal - fuel oil system with fuel oil cooler before booster pumps

3.4.2 Cooling methods

Depending on the required heat dissipation different cooling methods are applicable.

- Direct cooling with plate coolers, using 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 ISO 8217 fuel oil specifications.
  - ➢ Automatic temperature control.
  - ➢ No additional pump and separate cooling medium is required.

- Direct cooling with plate coolers, using seawater as coolant.

  If this solution is applied the following needs to be considered:

  - ➢ Double walled coolers with titanium plates are required to avoid leakages (requirement by Class).

- Indirect cooling with chiller, cooling down freshwater with a refrigerant and in turn the fuel oil.

  Usually not needed and not applied for the following reasons:

  - ➢ Heat dissipation capacity by direct cooling with plate coolers is sufficient to fulfil the ISO 8217 fuel oil specifications.
  - ➢ Requirement for additional pumps and separate cooling medium.

3.4.3 Cooler heat dissipation

The cooler heat dissipation (Q) is determined by the following formula:

$$Q = m \times cp \times DT\,[kW]$$

Q	[kW]	Heat dissipation
m	[kg/s]	Mass of the distillate fuel passing the cooler
cp	[kJ/kg °C]	Specific heat capacity of the distillate fuel
cp	[kJ/kg °C]	2.0 - 2.2
DT	[°C]	T1´ - T2
T1´	[°C]	Temperature at the cooler inlet
T2	[°C]	Temperature at the cooler outlet

The temperature (T1´) results from the mixing of the fuel amount returning from the engine (temperature Tr) and the distillate fuel supply to the engine (temperature T1). The distillate fuel amount corresponds to the actual fuel consumption.
The temperature difference (Tr - T2) corresponds to the fuel temperature increase across the engine injection system (please refer to figure 4 below).

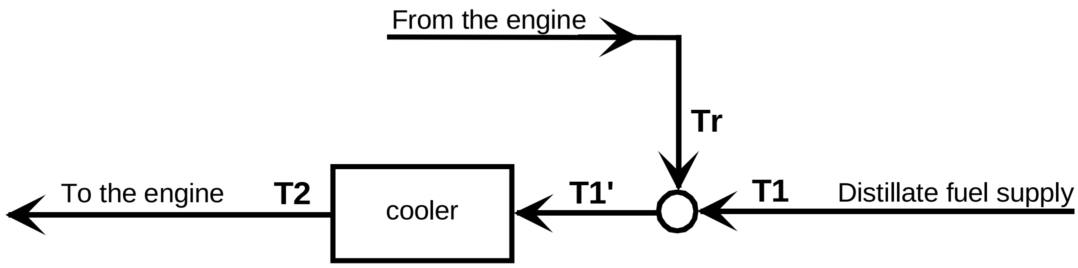

Figure 4: Cooling principle

The required heat dissipation at 100% engine load by taking into account the temperature increase across the engine can be calculated with the following formula:

<u>For RTA engines</u>

$$Q = \frac{[BSFC \times P \times (DT + 12)]}{1.34 \times 10^6}$$

<u>For RT-flex/W-X engines</u>

$$Q = \frac{[BSFC \times P \times (DT + 6)]}{1.34 \times 10^6}$$

Q	[kW]	Cooler 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
DT	[°C]	T1´ - T2
T1´	[°C]	Temperature of the distillate fuel supply
T2	[°C]	Distillate fuel temperature required at engine inlet

The temperature at cooler inlet (= mixing temperature T1´) at 100% engine load can be calculated by the following formula:

For RTA engines

$$T1' = 0.455 \times T1 + 0.545 \times T2 + 5.46 [C°]$$

For RT-flex engines / W-X engines

$$T1' = 0.455 \times T1 + 0.545 \times T2 + 2.73 [C°]$$

Example with W-X engine W7X82

Design conditions: P = 33250 kW, BSFC = 166 g/kWh
Distillate fuel: DMA, viscosity 2cSt at 40°C, supply temperature T1 = 45°C
Target: viscosity of 2.5cSt at engine inlet
Approach: DMA is cooled down to 28°C

$$Q = \frac{[166 \times 33250 \times ((38.5 - 28) + 6)]}{1.34 \times 10^6} = 68KW$$

$$T1' = 0.455 \times 45 + 0.545 \times 28 + 2.73 = 38.5°C$$

Example with RTA engine 12RTA96C-B

Design conditions: P = 68640 kW, BSFC = 180 g/kWh
Distillate fuel: DMA, viscosity 2cSt at 40°C, supply temperature T1 = 45°C
Target: viscosity of 2.5cSt at engine inlet
Approach: DMA is cooled down to 28°C

$$Q = \frac{[180 \times 68640 \times ((41.2 - 28) + 6)]}{1.34 \times 10^6} = 232KW$$

$$T1' = 0.455 \times 45 + 0.545 \times 28 + 5.46 = 41.2°C$$

4 Fuel change-over 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 has to be prevented. Sudden temperature changes may lead to seizing of the fuel pump plungers, which may directly affect the maneuverability of the ship or result in fuel pipe leakage with a 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 has to be monitored in addition to the required viscosity grade (min. 2cSt for MDO/MGO).

4.1 Automatic fuel change-over

The automatic fuel change-over requires the installation of an automatic fuel change-over unit as it is shown in the system proposal in MIDS and figure 5 of this document.
The automatic fuel change-over unit comprises the following advantages:

- The unit enables a fully automatic change-over from HFO to MDO/MGO and vice versa even at 100% CMCR engine load.
- The change-over time can be significantly reduced, i.e. saving in MDO/MGO is possible.
- The required maximum temperature gradient of 2°C/min can be easily maintained during change-over by internal monitoring devices and controlled cooler.
- The risk of damage by abrupt temperature changes is limited due to integrated safeguard functions.
- The end of change-over including flushing is supervised to ensure compliance with SECA rules.

A detailed description of the fuel change-over procedure is given in the relevant product documentation of the fuel change-over unit.

4.2 Manual fuel change-over

The manual fuel change-over is done by means of a simple three-way valve.
By application of this method for fuel change-over the following points have to be taken in consideration:

- Pressure fluctuations due to varying static pressure, depending on the current oil level in the tank, need to be compensated at the inlet of the three-way valve.
- The fuel change-over should only be done at engine loads below 75% to avoid exceeding the temperature gradient of 2°C/min.

- The change-over procedure is strongly influenced by the fuel volume currently available 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 has to be kept as short as possible to avoid incompatibility problems.
- To keep a min. viscosity grade of 2cSt it has to 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 oils of different BN values is necessary. For operation on fuels with sulphur content in the range from 0.5 to 1.5%, the cylinder oil feed rate should be low and have a grade of 40BN. Since 1 January 2015 the legal requirements for ECA areas are to operate on fuels with a sulphur content of less than 0.10% mass. This require the use of cylinder lubricating oil in the range from 15 to 25 BN.
Prior to changing over to distillate fuels the cylinder oil should be switched over to allow for the higher BN oil to be flushed through. The time for this to be achieved depends on the layout of the piping system and the tanks involved, and in particular on the volume. The use of low BN oil with a fuel with higher sulphur content during this relatively short change-over period will not have an adverse effect on the liner and piston ring wear rates, provided that the change-over occurs quickly.
A more detailed description of the adjustment of the BN level in relation to engine load and feed rate is given in the Technical Bulletin `RT-161, Cylinder lubrication´ and in the Technical Bulletin `RT-138, Lubricating oils´.

5.1 Arrangement of the cylinder lubricating oil system

The arrangement of a cylinder lubricating oil system with two storage and two service tanks for operation with high and low BN oil is shown in the marine installation drawing set (MIDS) and in figure 6 of this document.
The cylinder LO service tank with metering device provides the possibility to supervise the cylinder LO consumption of the engine. Alternatively, if the cylinder LO service tank is omitted, i.e. the engine is fed directly from the cylinder LO storage tank, the storage tank has to be located at the same minimum installation height as specified for the service tank in MIDS, respectively a certain level higher if additional elements are installed in the supply line to the engine (e.g. a flowmeter) to compensate the pressure drop created. The change-over from one oil quality to another occurs by means of a three-way valve, which has to be fitted as close as possible to the engine inlet, to avoid a too long time delay in oil delivery due to the oil volumes contained in the supply pipes when changing over. The three-way valve can be either manually or remotely operated.

Application of heating coils in the service- and storage tanks has to be considered just as an option. It is recommended to install trace heating (preferable electric heating devices) in the supply lines to engine inlet. Experience has shown that even with just 5-6 meters distance to the cylinder LO tank, the temperature from tank to engine could drop to about engine room temperature, i.e. in winter condition down to almost 0°C.
Therefore the installation of heating coils just in the service tank is in most cases not sufficient to obtain sufficiently warm cylinder LO at engine inlet and has to be considered just as supplement to the trace heating in the supply lines.

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 on fuels with differing sulphur contents at different engine loads. The basic function is to keep the cylinder lubricating oil feed rate constantly at the optimum, without interruption under all engine operational conditions, while simultaneously adjusting the content of the additives to cover the range from 40 BN to 120 BN. More detailed information about the installation and operation of the BOB system is given in the relevant product documentation.

6 SCR application and operation

To comply with the IMO Tier III regulations for NOx emission control areas (NECA), the engine may be equipped with an exhaust gas treatment system, e.g. high- or low-pressure SCR.
Depending on the design of the SCR it may only be operated if the sulphur content of the fuel in use meets the requirement of the system supplier. Typically MDO/MGO with a sulphur content of 0.1% must be considered. Information about the permissible fuel sulphur content as well as the corresponding respectively required cylinder lubricating oil quality must be requested in advance from the system supplier to make sure the system works properly and avoid any damage.
Usually it is required to change over from 100% HFO to 100% MDO/MGO before starting the SCR system. 100% MDO/MGO means that the whole piping system is practically HFO free. For that purpose the piping system must be thoroughly flushed by MDO/MGO circulation after the fuel change-over from HFO to MDO/MGO has been initiated. The duration of the whole change-over procedure depends on a variety of operating conditions (e.g. fuel quality, system size and ambient conditions) and cannot be specified by an absolute figure. The actual required change-over respectively flushing time needs either to be calculated (manual fuel change-over), or is indicated as output of the automatic change-over unit control box (automatic fuel change-over), provided such a device is applied as recommended by WinGD (Pos. 012 in figure 5).

7 Enclosures

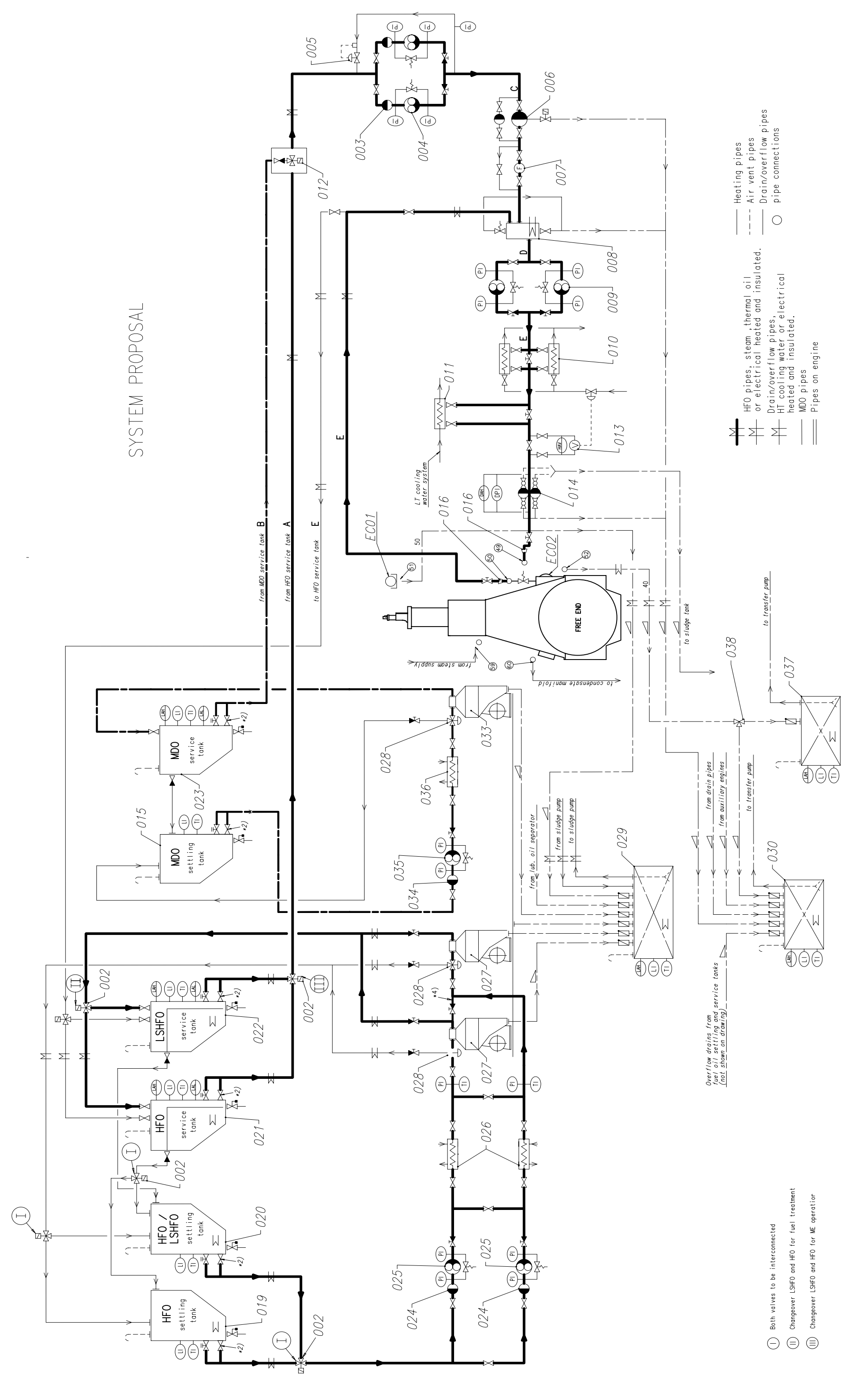

Figure 5: System proposal of fuel oil system

Substitute for:											PC	Q-Code	X	X	X	X	X
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Fuel oil system components

001. Main engine
002. Three-way valve, manually or remotely operated
003. Fuel oil suction filter, heated (trace heating acceptable)
004. Low- pressure feed pump
005. Pressure regulating valve [1]
006. Automatic self-cleaning filter, 10 micron, heated (trace heating acceptable)
007. Flowmeter
008. Mixing unit, heated and insulated (according to separate drawing)
009. High-pressure booster pump
010. Fuel oil end-heater
011. Fuel oil cooler
012. Automatic fuel change-over unit
013. Viscometer
014. Fuel oil filter, 60 micron, heated (trace heating acceptable)
015. MDO settling tank
016. Pipe reduction
019. HFO settling tank, heated and insulated
020. LSHFO settling tank, heated and insulated
021. HFO service tank, heated and insulated
022. LSHFO settling tank, heated and insulated
023. MDO service tank
024. Suction filter
025. HFO/LSHFO separator supply pump, with safety valve [2]
026. HFO/LSHFO pre-heater
027. Self-cleaning HFO/LSHFO separator [3]
028. Three-way valve, diaphragm operated
029. Sludge tank
030. Fuel oil drain tank
033. Self-cleaning MDO separator [3]
034. Separator supply pump, with safety valve [2]
035. MDO suction filter
036. MDO pre-heater
037. Clean FO leakage tank
038. Three-way valve

1 The return pipe may also be led to the HFO service tank

2 Pump may be omitted if integrated in the separator

3 Separator capacity related to viscosity in accordance with instructions of separator manufacturer according to certified flow rate layout.

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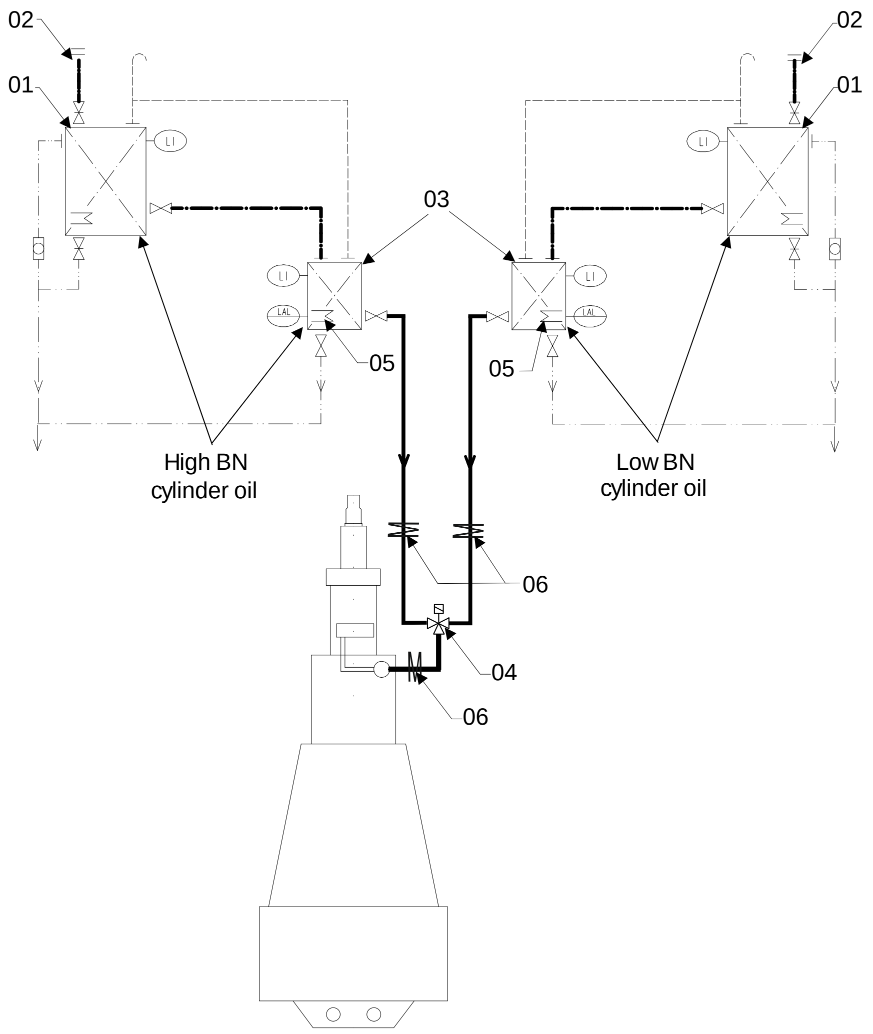

Figure 6: Cylinder lubricating oil system

01.	Cylinder lubricating oil storage tanks
02.	Deck connection
03.	Cylinder lubricating oil service tanks
04.	Three-way valve, manually or remotely operated
05.	Heating coil (optional)
06.	Trace heating

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PC | Q-Code | X | X | X | X | X

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Characteristic	Unit	Limit	DMX	DMA	DMZ	DMB
Kinematic viscosity at 40°C [a]	mm^2/s	max	5.500	6.000	6.000	11.00
	mm^2/s	min	1.400	2.000	3.000	2.000
Density at 15°C	kg/m^3	max	-	890.0	890.0	900.0
Cetane index	-	max	45	40	40	35
Sulphur [b]	mass %	max	1.00	1.50	1.50	2.00
Flash point	°C	min	43.0	60.0	60.0	60.0
Hydrogen sulphide	mg/kg	max	2.00	2.00	2.00	2.00
Acid Number	mgKOH/g	max	0.5	0.5	0.5	0.50
Total sediment by hot filtration	mass %	max	-	-	-	0.10 [d]
Oxidation stability	g/m^3	max	25	25	25	25 [e]
Carbon residue: micro method on the 10% volume distillation residue	mass %	max	0.3	0.3	0.3	-
Carbon residue: micro method	mass %	max	-	-	-	0.30
Cloud point	°C	max	-16	-	-	-
Upper pour point [c], winter	°C	max	-	-6	-6	0
Upper pour point [c], summer	°C	max	-	0	0	6
Appearance	-	-	Clear & Bright [h]			[d,e,f]
Water	volume %	max	-	-	-	0.30 [d]
Ash	mass %	max	0.010	0.010	0.010	0.010
Lubricity, corrected wear scar diameter (WSD 1,4) at 60°C [h]	µm	max	520	520	520	520 [g]

a	1 mm^2/s=1cST
b	Notwithstanding the limits given, the purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations. See Annex C of ISO 8217.
c	Purchasers should ensure that this pour point is suitable for the equipment on board, especially if the ship operates in cold climates.
d	If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required, see 7.4 and 7.6 of ISO 8217.
e	If the sample is not clear and bright, the test cannot be undertaken and hence the oxidation stability limit shall not apply.
f	If the sample is not clear and bright, the test cannot be undertaken and hence the lubricity limit shall not apply.
g	This requirement is applicable to fuels with a sulphur content below 500 mg/kg (0,050 mass %).
h	If the sample is dyed and not transparent, then the water limit and test method as given in 7.6 of ISO 8217 shall apply.

Table 1: Distillate fuel oil specification according to ISO 8217, 5th edition, 2012

CONCEPT-GUIDANCE_WinGD-2S_OPERATION-ON- DISTILLATE-FUELS

TRACK CHANGES

DATE	SUBJECT	DESCRIPTION
2016-10-25	GUIDANCE	First web upload