Diesel engine fuels

all engines

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1 General for diesel engine fuels

This document is an excerpt from the WinGD operation manuals related to diesel engine fuels for large marine two-stroke engines.

The document includes data to the items that follow:

- Requirements for heavy fuel oil (HFO)
- Requirements for distillate fuel
- Requirements for bio-derived products and fatty acid methyl esters (FAME)
- Recommendations for ultra low sulphur fuel oils
- Recommendations for fuel additives
- Recommendations for non-standard fuels
- Procedures for fuel change-over.

NOTE: This is a temporary document to give the necessary data, as long as WinGD has not updated all operation manuals in the new SHIPDEX structure.

2 Diesel engine fuels

2.1 General

Almost all hydrocarbon residual, distillate and some renewable fuels can be burned in a diesel engine if applicable procedures are done. The type and quality of the fuel will have an effect on the frequency of overhauls and the work necessary to prepare the fuel. It is the primary economic considerations that according to the type, size and speed of the engine and its application, gives the fuel quality margins.

Gas oils and diesel oils (distillates) can be used in all WinGD engines with some limits. WinGD 2-stroke diesel engines are designed to operate on up to 700 mm²/s (cSt) at 50°C viscosity heavy fuel oil (ISO 8217:2017 RMK 700 grade) if sufficient fuel heating and treatment is done.

Heavy fuel oil must have treatment in an applicable fuel treatment plant on board. When bunkering, it is possible that the fuel suppliers will report only some of the values given in the Quality Specifications. Frequently, only the density and maximum viscosity is given. This makes the full understanding of the properties of the fuels very difficult, thus it is important to get a full certificate of analysis with each bunker.

The supplier must guarantee the stability of the fuel and thus the resistance to the formation of sludge. Also, the fuel must not have a corrosive effect on the injection equipment and must not contain used lubricating oil, chemical waste or other foreign matter.

Fuels from different bunkers must not be mixed because there is a risk that the fuels have different compositions. This can cause fouling of filters or too much sludge, which will overload the fuel preparation equipment. Fresh bunkers must always be put into empty tanks and not added to old bunkers.

2.2 Heavy fuel oil

Fuels used in marine diesel engines are blended using many different products from the petroleum refinery process that can include fuels such as HFO and gas oil. To get the necessary viscosity as specified by the supply specifications, the heavier oil stocks are blended with lighter, less viscous components. Modern refineries also apply a secondary conversion process, such as viscosity breaking (visbreaking) and catalytic cracking to get a higher yield of lighter products. The remaining products are mixed to get HFO.

Viscosity is usually used to identify diesel engine fuels. The viscosity is shown in mm^2/s, referred to as centistokes (cSt) and measured at 50°C. The fuels are classified in accordance with ISO 8217:2017 (Sixth Edition dated from March 2017).

Viscosity is not a quality criterion. To make an analysis of the fuel quality (to make sure that the fuel is applicable for use in a diesel engine), refer to the properties given in Table 1 - Specifications for HFO.

Very good supervision, engine maintenance and on board fuel treatment equipment is necessary, especially when the properties of the fuel in use is near the permitted maximum and minimum limits. Poor quality fuels or insufficient or inadequate preparation can give problems in handling and/or combustion. Thus higher maintenance requirements, shorter service intervals and possibly shorter service life of various components of the equipment can be possible.

In Table 1 - Specifications for HFO, the values in the column Bunker limit (ISO 8217:2017 RMK700) show the minimum quality of heavy fuel as supplied and bunkered to the ship/installation. Good operation results come from commercially available fuels that are in the ISO 8217:2017 limits. But the use of fuel with lower metal, ash and carbon contents and a lower density can have a positive effect on overhaul periods. This can improve combustion and exhaust gas composition and can decrease the wear.

The fuel as bunkered must be processed before it goes into the engine. It is recommended that you refer to the related specifications of WinGD for the design of the fuel treatment plant. The minimum separator capacity is 1.2 x CMCR x BSFC / 1000 (liters/hour), which is related to 0.21 l/kW. The fuel treatment must remove sludge and decrease catalyst fines and water to the recommended engine inlet limits.

Unwanted substances such as used oil or chemical waste must not be added to the fuel (refer to ISO 8217:2017). These unwanted substances can cause damage to the fuel system components, to the fuel injection equipment, to pistons, piston rings or cylinder liners. Contamination of the turbocharger, the exhaust system or the boiler can also occur because of poor fuel quality. Thus WinGD recommends a sample of the bunkered fuel is tested by a laboratory. If the analysis shows, that the fuel does not obey the specifications, you must do the related procedures.

The specifications of the fuel quality at the engine inlet uses the latest ISO 8217:2017 specification, refer to Table 1 - Specifications for HFO. You can get the ISO standards from the ISO Central Secretariat, Geneva, Switzerland (www.iso.ch).

Tab 1 Specifications for HFO

Parameter	Bunker limit	At engine inlet	Unit	Test method
Kinematic viscosity at 50°C	Maximum 700	13 to 17 [1] (not related to temperature)	mm^2/s [cSt] [2]	ISO 3104
Density at 15°C	Maximum 1010 [3]	Maximum 1010	kg/m^3	ISO 3675/12185
CCAI	Maximum 870	Maximum 870	-	Calculated
Sulphur [4]	Statutory specifica-tions	Maximum 3.5	mass %	ISO 8754/14596
Flash point	Minimum 60	Minimum 60	°C	ISO 2719
Hydrogen sulphide [5]	Maximum 2.0	Maximum 2.0	mg/kg [ppm]	IP 570
Acid number	Maximum 2.5	Maximum 2.5	mg KOH/g	ASTM D 664
Total sediment, aged	Maximum 0.1	Maximum 0.1	mass %	ISO 10307-2
Carbon residue: mi-cro method	Maximum 20	Maximum 20	mass %	ISO 10370
Pour point (upper) [6]	Maximum 30	Maximum 30	°C	ISO 3016
Water	Maximum 0.5	Maximum 0.2	volume %	ISO 3733
Ash	Maximum 0.15	Maximum 0.15	mass %	ISO 6245
Vanadium	Maximum 450	Maximum 450	mg/kg [ppm]	ISO 14597/IP501/ IP470
Sodium	Maximum 100	Maximum 30	mg/kg [ppm]	IP501/IP470
Aluminum plus Sili-con	Maximum 60	Maximum 15	mg/kg [ppm]	ISO 10478/IP501/ IP470
Used lubricating oils (ULO) must not be present: Calcium (Ca) and zinc (Zn)	ULO shows if: Ca>30 and Zn>15 or Ca>30 and P>15	Do no use if: Ca>30 and Zn>15 or Ca>30 and P>15	mg/kg [ppm]	IP501 or IP470 or IP500

1 For Generation X, X-DF and RT-flex engines, the fuel viscosity at the engine inlet must be in the range between 10 mm^2/s and 20 mm^2/s, but WinGD recommends a fuel viscosity at the engine inlet in the range between 13 mm^2/s and 17 mm^2/s. The maximum permitted temperature is 150°C.

2 1 mm^2/s = 1 cSt (Centistoke)

3 The maximum density limit is 991 kg/m^3 if the fuel treatment plant cannot remove water from high-density fuel.

4 In ISO 8217:2017 sulphur limits are not given for HFO. Sulphur limits are related to statutory specifications.

5 The hydrogen sulphide limit is applicable from 1st July 2012.

6 Purchasers must make sure that the equipment on board can always keep the fuel at a temperature above the pour point, specially in cold climates.

It is very important that the fuel is fit for purpose in the related engine application.

NOTE: From 1st January 2015 fuel with less than 0.1% sulphur content must be used in Emission Control Areas (ECA). As an alternative you can burn LNG (Liquefied Natural Gas) or in some areas you can use SO_X scrubbers to decrease the content of sulphur oxides in the exhaust gas.

NOTE: Related to the MARPOL annex VI the maximum permitted sulphur content in fuel is 3.5%.

- LSFO (Low Sulphur Fuel Oil) has a maximum of 1.0% sulphur content
- VLSFO (Very Low Sulphur Fuel Oil) has a maximum of 0.5% sulphur content
- ULSFO (Ultra Low Sulphur Fuel Oil) has a maximum of 0.1% sulphur content.

NOTE: From 1st January 2020 fuel with less than 0.5% sulphur content must be used outside of ECA zones. As an alternative you can burn LNG or in some areas you can use SO_X scrubbers to decrease the content of sulphur oxides in the exhaust gas.

2.3 Data about heavy fuel oil specifications

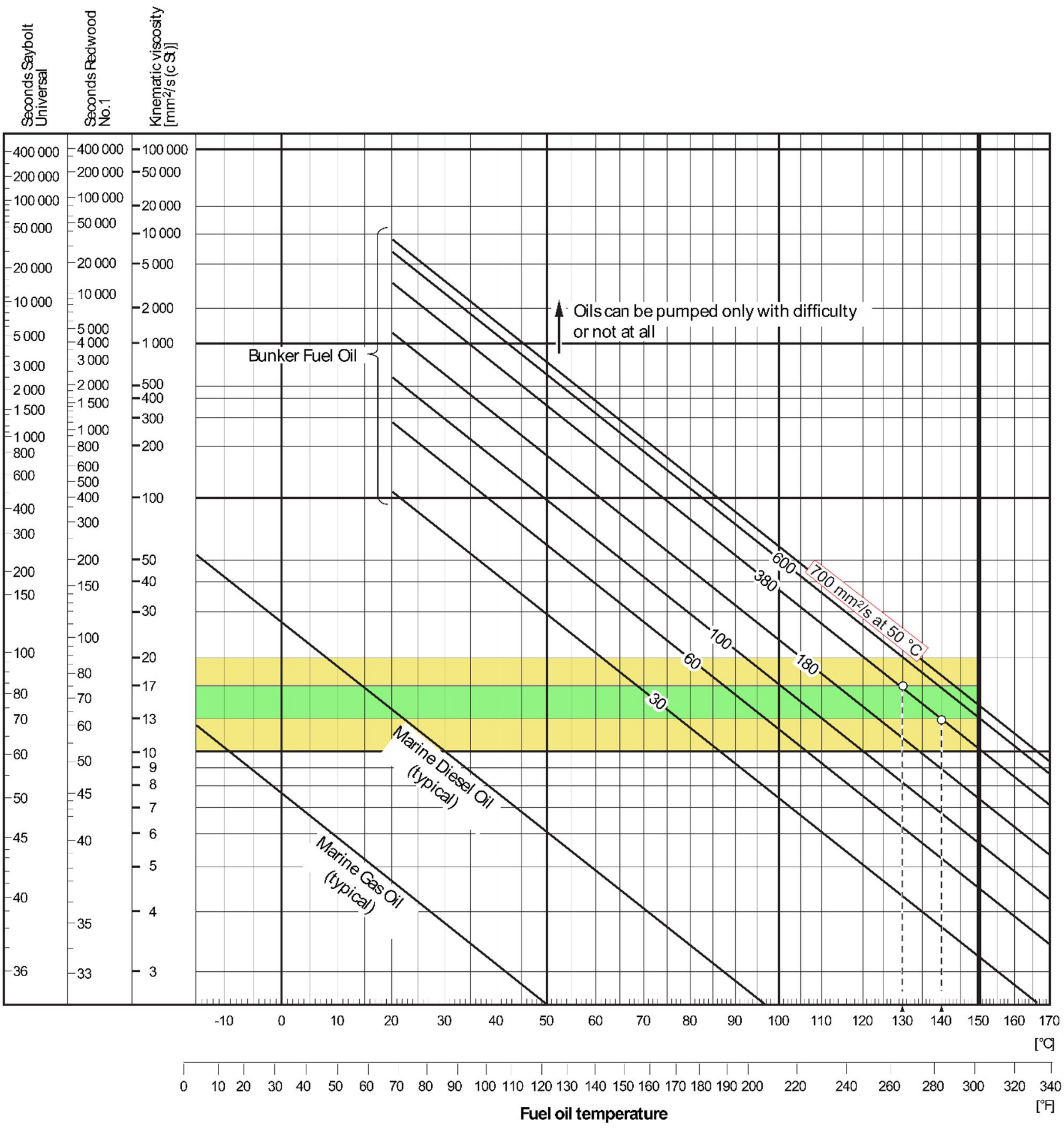
The paragraphs that follow give more data about the specifications for HFO.

2.3.1 Viscosity

WinGD recommends a viscosity range at the engine inlet between 13 mm^2/s (cSt) and 17 mm^2/s (cSt). You get the necessary temperature for a given nominal viscosity from the data in Figure 1.

The maximum permitted viscosity of the fuel that can be used in an engine installation is related to the heating and fuel preparation facilities available. The flow rate and the temperature of the fuel that flows through the separators must be adjusted in relation to the viscosity to get good separation. The temperature of the fuel must not be increased to more than 150°C to get the recommended viscosity at the engine inlet. This is because the fuel can start to decompose, form particles and the temperature can be above the flash point.

Fig 1 Viscosity / Temperature diagram



Recommended viscosity range for Generation X, X-DF and RT-flex engines

Required viscosity range for Generation X, X-DF and RT-flex engines

00099

2.3.2 Density

The composition of the fuel gives the density. A high density shows a high aromatic content. It is not always possible to use conventional methods to measure the density at 15°C. Thus, the measurement is made at a higher temperature and then converted and adjusted to the reference temperature. Usually the maximum density of fuel is 1010.0 kg/m^3 related to the ISO 8217:2017 RMK specifications. If you use a fuel with a density higher than 991.0 kg/m^3, you must make sure that an equipment is available on board that can treat such fuels.

2.3.3 Calculated Carbon Aromaticity Index (CCAI)

The ignition and combustion properties of the fuel in a diesel engine are related to the specific engine design, load profile and fuel properties.

The CCAI is a calculated value of the ignition properties or ignition delay of the fuel related to the viscosity and density. The CCAI gives no indication of the combustion properties. The CCAI limit is useful to examine fuels with unusual density-viscosity relations.

2.3.4 Sulphur

Sulphur limits are not specified in ISO 8217:2017 because statutory specifications put a limit on this value. WinGD 2-stroke engines are designed to operate with high and low sulphur fuels, if:

- You select the alkalinity (base number (BN)) of the cylinder oil in relation to the sulphur content of the fuel in use.
- You use the necessary equipment related to the statutory specifications.

2.3.5 Flash point

The flash point is an important safety and fire hazard parameter for diesel fuels. Fuel is always a fire hazard. There can be flammable vapors in the air space above the remaining fuel in the tanks. Take care if you increase the temperature of the remaining fuel above the flash point, as flammable vapor can occur.

2.3.6 Hydrogen sulphide (H_2S)

Hydrogen Sulphide (H_2S) is a very toxic gas and exposure to high concentrations is dangerous and can kill you. Be careful when tanks or fuel lines are opened because there can be H_2S vapor. At low concentrations H_2S smells almost the same as rotten eggs. You cannot sense H_2S at moderate concentrations. H_2S causes nausea and dizziness.

2.3.7 Acid number

Fuels with high acid numbers can cause damages to fuel injection systems. Most fuels have a low acid number, which is not dangerous, but an acid number above 2.5 mg KOH/g, can cause problems. Some naphthenic fuels can have an acid number of more than 2.5 mg KOH/g, but still be permitted. Only a full laboratory analysis can measure the strong acid number.

2.3.8 Sediment, Carbon and Asphaltenes

High quantities of sediment, carbon and asphaltenes decrease the ignition and combustion quality of the fuel. These materials also increase wear and damage to engine components. Asphaltenes also have an effect on the stability of blended fuels and can cause too much sludge in the separators and filters. If the blended fuel is not stable, particles can collect on the bottom of the tank.

To keep risks to a minimum, make sure that bunkers from different suppliers and sources are not mixed in the storage tanks on board. Also be careful when HFO is blended on board to decrease the viscosity. Paraffinic distillate, when added to an HFO of low stability, can cause the asphaltenes to collect, which causes heavy sludge.

HFO can contain up to 14% asphaltenes and will not cause ignition and combustion problems in 2-stroke engines if the fuel preparation equipment is adjusted correctly.

2.3.9 Pour Point

The operation temperature of the fuel must be kept between approximately 5°C and 10°C above the pour point to make sure that the fuel can flow easily.

2.3.10 Water

The separator and the correct configuration of drains in the settling and service tanks are used to decrease the water quantity in the fuel. A complete removal of water is highly recommended to decrease the quantity of hydrophilic catalytic fines (cat fines) and sodium in the fuel. Sodium is not a natural oil component, but diesel engine fuel often has sea water contamination, which has sodium. A content of 1.0% sea water in the fuel is related to 100 ppm sodium.

To get a good separation effect, the flow rate and temperature of the fuel must be adjusted in relation to the viscosity. For high-viscosity fuels the separation temperature must be increased, and the flow rate must be decreased in relation to the nominal capacity of the separator. For the recommended data to operate the separator, refer to the documentation of the manufacturer.

2.3.11 Ash and Trace Metals

Fuels with a low content of ash, vanadium, sodium, aluminum, silicon, calcium, phosphorous and zinc are recommended. High quantities of these materials can increase mechanical wear, high-temperature corrosion and particles in the turbocharger, exhaust system and boilers.

- **Vanadium and Sodium**

  Sodium compounds decrease the melting point of vanadium oxide and sulphate salts, especially when the vanadium to sodium ratio is 3:1 or higher. High sodium quantities (as well as lithium and potassium) at the engine inlet can cause damage to the turbocharger, exhaust system and boilers. Ash modifiers can correct the effect of high-temperature corrosion and particles.

- **Aluminum and Silicon**

  Aluminum (Al) and silicon (Si) in the fuel are an indication of catalytic fines. These are particles of hard oxides (round particles of material almost the same as porcelain) which cause high abrasive wear to pistons, piston rings and cylinder liners. Catalytic fines are used as a catalyst in some processes in petroleum refining and can be found in diesel engine fuels. The most dangerous catalytic fines are between 10 microns and 20 microns.

- **Catalytic fines**

  Catalytic fines cause cylinder liners to become worn. Catalytic fines are attached to water droplets and are very difficult to remove from the fuel. With correct treatment in the fuel separator, the aluminum and silicon content of 60 ppm (mg/kg) can be decreased to 15 ppm (mg/kg), which is thought to be satisfactory. For satisfactory separation, a fuel temperature as close as possible to 98°C is recommended. A decreased fuel flow rate through the separator gives a better separation. This is because the fuel stays in the separator for a longer period. Also obey the instructions of the equipment manufacturer.

  Catalytic fines can collect in the sediment of the fuel tank from other bunkers. During bad weather conditions, the movement of the ship mixes the sediment into the fuel. Thus, it is better to think that all fuels contain catalytic fines, although it is possible that a fuel analysis can show a different result. Thus do also regular procedures to remove sludge and catalytic fines from the fuel that is in the settling tank and the service tanks.

2.3.12 Used Lubricating Oil and Chemical Waste

Used lubricating oils and chemical waste must not be mixed into the fuel. If you do so, the fuel would not be stable because the base oil is very paraffinic and can cause too much sludge. Most used lubricating oil is from the crankcase, thus large quantities of calcium, zinc, phosphorous and other additives and wear metals can cause contamination. The limits in ISO 8217:2017 and the WinGD specifications make sure that no used lubricating oil is in the fuel.

Chemical waste (eg polymers, styrene and other chemical substances) must not be added to the fuel. These materials can cause the fuel to become too thick, to become almost solid and thus can cause blocked filters. They can also cause corrosive attacks and damage to the fuel injection system.

2.4 Distillate Fuel Specifications

Since 2015 more frequently distillate fuels are used in 2-stroke engines to obey the new ECA rules. Distillate fuels are easier to operate than residual fuel, but caution is necessary for some problems.

In ISO 8217:2017 there are specified the DMX, DMA, DMZ and DMB grades and the new DFA, DFZ and DFB grades with a maximum fatty acid methyl ester (FAME) content of 7.0 volume %. The WinGD specifications use the DMB grade which is the highest viscosity grade, refer to Table 2 - Specifications for distillate fuels. The DMX grade is not applicable for use in 2-stroke engines because of its low flash point and viscosity.

Tab 2 Specifications for distillate fuels

Parameter	Bunker limit	At engine inlet	Unit	Test method
Kinematic viscosity at 40°C	Maximum 11.0 Minimum 2.0	Minimum 2.0 (not related to temperature)	mm^2/s [cSt] [1]	ISO 3104
Density at 15°C	Maximum 900	Maximum 900	kg/m^3	ISO 3675/12185
Cetane index	Minimum 35	Minimum 35	-	ISO 4264
Sulphur [2]	Maximum 1.5	Maximum 1.5	mass %	ISO 8754/14596
Flash point	Minimum 60	Minimum 60	°C	ISO 2719
Hydrogen sulphide [3]	Maximum 2.0	Maximum 2.0	mg/kg [ppm]	IP 570

Parameter	Bunker limit	At engine inlet	Unit	Test method
Acid number	Maximum 0.5	Maximum 0.5	mg KOH/g	ASTM D 664
Total sediment by hot filtration	Maximum 0.1	Maximum 0.1 [4]	mass %	ISO 10307-1
Oxidation stability	Maximum 25	Maximum 25 [5]	g/m^3	ISO 12205
Fatty acid methyl ester (FAME)	-	-	volume %	ASTM D7963 or IP 579
Carbon residue: micro method on 10% volume distillation residue	Maximum 0.3	-	mass %	ISO 10370
Carbon residue: micro method	Maximum 0.3	Maximum 0.3	mass %	ISO 10370
Pour point (upper) winter [6]	Maximum 0	Maximum 0	°C	ISO 3016
Pour point (upper) summer	Maximum 6	Maximum 6	°C	ISO 3016
Cloud point winter	-	-	°C	ISO 3015
Cloud point summer	-	-	°C	ISO 3015
Cold filter plugging point winter	-	-	°C	IP 309 or IP 612
Cold filter plugging point summer	-	-	°C	IP 309 or IP 612
Water	Maximum 0.3	Maximum 0.2	volume %	ISO 3733
Ash	Maximum 0.01	Maximum 0.01	mass %	ISO 6245
Lubricity, corrected wear scar diameter (WSD) at 60°C [7]	Maximum 520	Maximum 520	µm	-

1 1 mm^2/s = 1 cSt (Centistoke)

2 The purchaser must specify the maximum sulphur content in accordance with the usual statutory specifications.

3 The hydrogen sulphide limit is applicable from 1 July 2012.

4 If the sample is not clear and bright, it is necessary to do the total sediment by hot filtration and the water tests.

5 If the sample is not clear and bright, you cannot do this test. Thus it is not possible to see the compliance with the limit.

6 Purchasers must make sure that the pour point is sufficient for the equipment on board, specially for operation in cold climates.

7 This parameter is applicable to fuels with a sulphur content of less than 0.05 mass %.

2.5 Data about distillate fuel specifications

The paragraphs that follow give more data about the specifications for distillate fuels.

2.5.1 Viscosity

For distillate fuel a minimum viscosity of 2.0 mm^2/s (cSt) at the engine inlet is necessary. A lower viscosity can cause too much leakage in the fuel system.

Operators must be careful during the change-over procedure from distillate to residual fuel and back to make sure of problem free operation. Refer to the related fuel change-over procedures in the Operation Manual.

In some conditions, it is possible that you cannot get the minimum viscosity of 2.0 mm^2/s (cSt) at the engine inlet. In such conditions, a fuel cooling system is necessary to make sure that the inlet to the engine has the minimum viscosity.

2.5.2 Lubricity

ISO 8217:2017 specifies a maximum lubricity wear scar diameter (WSD) of 520 μm to make sure that the fuel has sufficient lubricity. This prevents quick wear of the fuel system components.

2.5.3 Density

The distillate density is related to the composition of the fuel. A high density indicates a high aromatic quantity.

2.5.4 Cetane index

The ignition and combustion properties of a distillate fuel in a diesel engine is related to the specific engine design, load profile and fuel properties. The Cetane Index is a calculated value of the ignition quality of the fuel related to the distillation and density. The density and the temperature when 10%, 50% and 90% of the fuel is distilled, gives the Cetane Index. This has no effect on the fuel combustion properties.

2.5.5 Sulphur

Sulphur limits are specified in ISO 8217:2017 for distillate fuels, but statutory specifications must be obeyed. The alkalinity (BN) of the cylinder oil must be selected in relation to the sulphur content of the fuel in use.

Indications for the selection of the BN of the cylinder oil in relation to the sulphur content of the fuel are found in the related specifications.

2.5.6 Acid number

Fuels with high acid numbers can cause damage to fuel injection systems. Most fuels have a low acid number, which is not dangerous, but an acid number above 2.5 mg KOH/g can cause damage.

2.5.7 Flash Point

The flash point is an important safety and fire hazard parameter for diesel fuels. Fuel is always a fire hazard because there can be flammable vapors in the air space above the remaining fuel in the tanks.

2.5.8 Hydrogen sulphide (H_2S)

Hydrogen Sulphide (H_2S) is a very toxic gas and exposure to high concentrations is dangerous and can kill you. Be careful when tanks or fuel lines are opened because there can be H_2S vapor. At low concentrations H_2S smells almost the same as bad eggs. You cannot sense H_2S at moderate concentrations. H_2S causes nausea and dizziness.

2.5.9 Sediment

High quantities of sediment, carbon and asphaltenes decrease the ignition and combustion quality of the fuel and increase wear and damage to engine components. High sediment quantities can cause filters to block, or frequent discharge from filter systems that have automatic cleaning. For more data about mixtures, refer to Para 2.3.8.

2.5.10 Pour point

The operation temperature of the fuel must be kept between approximately 5°C and 10°C above the pour point to make sure that the fuel flows easily. It is possible that in very cold conditions, there could be problems for distillate fuel.

2.5.11 Water

The quantity of water in distillate fuel can be decreased as follows:

- Let the fuel settle in the service tanks.
- Use a separator to remove water from the fuel.

2.5.12 Ash and trace metals

Distillate fuels must have low quantities of ash, vanadium, sodium, aluminum, silicon, calcium, phosphorous and zinc related to residual fuels. High quantities of these materials increase mechanical wear, high-temperature corrosion and particles in the turbocharger, exhaust system and the boilers.

2.5.13 Used lubricating oil and other contamination

Lubricating oils and chemical waste must not be mixed into the distillate fuel. Lubricating oil can cause water to stay because of the large quantity of detergent. Additive materials such as calcium, magnesium, zinc and phosphorous could increase the ash content to more than that given in the specification.

Chemical waste must not be added to distillate fuel. These materials can have the effects that follow:

- Can cause the fuel to become too thick and thus can cause a blockage of the filters
- Can cause damage to fuel injection systems
- Can cause a blockage of the fuel pump plungers or injectors.

2.5.14 Cloud point and cold filter plugging point

Before you bunker fuel, make sure that the pour point, the cloud point and the cold filter plugging point (also known as cold flow characteristics) are correct for your ship’s design and voyage. There could be problems with wax deposits in the storage tanks and in the separators, or with clogged filters.

2.6 Bio-derived products and fatty acid methyl esters

Such components can be found in diesel engine fuels and can cause a decrease of greenhouse gases and SO_x emissions. Most bio-fuel components in the diesel fuel are Fatty Acid Methyl Esters (FAME), which come from a special chemical treatment of natural plant oils. These components are mandatory in automotive and agricultural diesel in some countries. FAME is specified in ISO 14214 and ASTM D 6751.

FAME has good ignition properties and very good lubrication and environmental properties, but FAME has also known negative properties as follows:

- Possible oxidation and thus long term storage problems
- A chemical attraction to water and nutrient for microbial growth
- Unsatisfactory low temperature properties
- FAME material particles can appear on exposed surfaces and filter elements.

If you use FAME as a fuel, make sure that the on-board storage, handling, treatment, service and machinery systems can be used with such a product.

2.7 Ultra low sulphur fuel oils

Some fuel suppliers are selling ultra low sulphur fuel oils (ULSFO, sometimes also referred to as hybrid fuels) as an alternative to distillate fuels to obey the ECA rules.

Many of these products obey the specifications for residual fuel related to ISO 8217:2017, but they are different to heavy fuel oil (HFO) in properties like sulphur content, compatibility, stability viscosity, density and pour point. Do the same procedures for ULSFO as for HFO related to storage, heating and separation.

The use of ULSFO is under the full responsibility of the operating company. WinGD recommends to speak to the fuel supplier.

2.8 Fuel Additives

WinGD does not recommend the use of fuel additives. Additives are not necessary for fuels that obey the ISO 8217:2017 standard or for fuels that WinGD has recommended.

If you think that it is necessary to use additives, WinGD recommends to speak to the fuel supplier and to the additive supplier. They can give you the related results of the use of additives. If you use additives for some causes, you assume full responsibility. Existing No Objection Letters done by Wärtsilä Switzerland Ltd. are no longer applicable and have no more support by WinGD.

NOTE: WinGD does not accept liability or responsibility for the performance or potential damage caused by the use of such additives.

2.9 Non-standard fuels

If it is necessary to use non-standard fuels (fuels that are not in the related list from WinGD), speak to or send a message to WinGD before use.

NOTE: WinGD does not accept liability or responsibility for the performance or potential damage caused by the use of non-standard fuels.

3 Change-over the diesel fuel - general

When you change from heavy fuel oil (HFO) to marine diesel oil (MDO) or back, you must keep the thermal stresses of the related fuel components as low as possible. Thermal stress occurs because of the large temperature changes. Too fast change of the temperature can cause damage to the fuel pump plungers and can cause leakages in the fuel pipes.

During the change-over procedure the temperature of the fuel must not change more than 2°C each minute. This prevents damage to the system, specially when you do the procedure frequently. The small change rate is also because of the large difference of viscosity between HFO and MDO/ MGO.

You can do a change-over of the fuel only when the engine is running. While the engine has stopped, there is no fuel flow through the fuel rail. In this situation a change-over is not possible.

3.1 Automatic fuel change-over

WinGD recommends the installation and use of an automatic fuel change-over system to prevent problems during the change-over procedure.

- This system decreases the thermal load of the related fuel components (eg fuel pump plungers).
- The safety functions decrease the risk of damage because of thermal loads.
- You can do the change-over procedure at a load of up to 100% CMCR.
- The time period for automatic change-over is less than that of a manual change-over.

3.2 Manual fuel change-over

When you do a manual change-over of the fuel, you must make sure that the change-over is safe. Refer to the related procedures.

Make sure that during the procedures HFO never can flow into the MDO tank and pipe system.

NOTE: WinGD recommends to do a manual change-over only, if an automatic change-over system is not installed or if the automatic change-over system is unserviceable.

3.3 Recommended viscosity at the inlet of the fuel pumps

For the temperature necessary to make sure that the fuel upstream of the inlet to the fuel pumps is at the correct viscosity, refer to the Viscosity / Temperature Diagram in section 2 Diesel engine fuels. The viscosity for MDO must not be less than 2 cSt.

A viscosimeter measures the viscosity and thus controls the temperature of the fuel.

Make sure that you monitor the viscosity and the temperature of the fuel.

3.4 Cylinder oil

When you do a change-over of the fuel, you must make sure that you change to the correct cylinder oil at the same time. This prevents damage of the piston running system because of an incorrect BN. For more data refer to the related procedures.

3.4.1 Engine with iCAT

If the engine has an iCAT system (integrated Cylinder lubricant Auto Transfer system), WinGD recommends as follows, when you change-over the fuel:

- If the iCAT system is in auto mode, the iCAT system automatically changes-over the cylinder oil at the correct time.
- If the iCAT system is in manual control (no iCAT functionality mode), you have to manually change-over the cylinder oil at the same time as the diesel fuel change-over.

3.4.2 Engine without iCAT

If the engine has no iCAT system (integrated Cylinder lubricant Auto Transfer system), WinGD recommends to monitor the change-over of the cylinder oil. Do a calculation of the cylinder lubricant quantity and make sure that you know the cylinder lubricating feed rate, refer to Figure 2.

1. Make sure that you know the cylinder lubricant quantity that is between the change-over valve and the lubricating quills including the measurement tube.
2. Calculate the related lead time that the cylinder oil has to get to the lubricating quills.
3. Use this lead time to have the correct timing for the change-over of the cylinder oil.

NOTE: When you change from MDO to HFO, WinGD recommends to start the change-over of the cylinder oil from low BN to high BN already inside the ECA zone. This prevents operation with high sulphur fuel and low BN cylinder oil.

Fig 2 Cylinder lubricant quantity

Cylinder lubricant quantity in piping and measuring tank:

Volume piping: $\sum V = \sum \frac{d^2 * \pi}{4} * l$ $[V] = m^3$ $[d] = m$ $[l] = m$

Mass: $m = \rho * V$ $[m] = kg$ $[\rho] = \frac{kg}{m^3}$ $[V] = m^3$

The density of the cylinder lubricant can be found in the technical data sheet. If not available, an average value of 920 $\frac{kg}{m^3}$ is suitable for this purpose.

Total mass: *Mass of cylinder oil in measuring tank [kg]*
+
Mass of cylinder oil in piping [kg]

Lead time until new lubricant is in use:

$$consumption = \frac{effective\ feed\ rate * current\ power\ output}{1000}$$

$$lead\ time = \frac{total\ mass}{consumption} \qquad [lead\ time] = h \quad [m] = kg$$

$$[consumption] = \frac{kg}{h} \quad [effective\ feed\ rate] = \frac{g}{kWh} \quad [current\ power\ output] = kW$$

00595

4 Change-over from HFO to MDO manually

Periodicity

Description	
Unscheduled	
Duration for performing Preliminary requirements	0.0 man-hours
Duration for performing the Procedure	2.0 man-hours
Duration for performing the Requirements after job completion	0.0 man-hours

Personnel

Description	Specialization	QTY
Engine crew	Intermediate	1

Support equipment

Description	Part No.	CSN	QTY
None			

Supplies

Description	QTY
None	

Spare Parts

Description	Part No.	CSN	QTY
None			

SAFETY PRECAUTIONS

- None

PRELIMINARY OPERATIONS

- WinGD recommends to do a manual change-over only, if an automatic change-over system is not installed or if the automatic change-over system is unserviceable.

PROCEDURE

1 Make a full time schedule for the change-over to obey the ECA rules.

2 If you operate the engine with MDO for a long period, you must change the cylinder oil to the applicable BN at the related time, refer to section 3 Change-over the diesel fuel - general.

3 Set to OFF the trace heating of the fuel pipes and fuel rail approximately one hour before the change-over. The correct time is related to the pipe diameter and the waste heat in the system.

4 Set the viscosimeter to 17 cSt to decrease the temperature of the fuel.

5 Set to OFF all heating sources in the system (eg fuel heaters) some minutes before the change-over.

6 Decrease the load of the engine to max. 50% CMCR. The decrease of the engine power is related to the total quantity of fuel that flows in the system, eg the larger the mixing tank, the less decrease in load is necessary.

7 Follow the instructions of the plant to slowly change-over the fuel supply from HFO to MDO. Make sure that you decrease the fuel temperature a maximum of 2°C each minute.

8 If the temperature changes too much, wait until the fuel temperature is stable. Then you can continue the procedure. Try to decrease the temperature as linearly as possible.

9 When the temperature of the fuel is near the applicable value, you can start the cooler slowly to give a linear and smooth temperature change at minimum viscosity.

NOTE: The viscosity of the fuel must not be less than 2 cSt.

10 Do a check of the temperature, viscosity and pressure of the supplied fuel.

11 If the temperature, viscosity, or pressure is not correct, find the cause and repair the fault.

12 If you have to collect the MDO from the leakage and return pipes, do as follows:

12.1 Wait until the system is completely flushed with MDO.

NOTE: This prevents contamination of the MDO with HFO.

12.2 If also a MDO leakage tank is installed, move the 3-way valve in the pipe from the outlet of the fuel leakage fuel pump and injection control to the MDO leakage tank.

12.3 If the fuel return of the pressure control valve goes into the HFO service tank, set the valve positions to have the fuel return go into the MDO service tank.

13 If you have to stop the engine, wait until the change-over procedure is fully completed.

NOTE: This prevents problems during the subsequent engine start because of a mixture of HFO and MDO in the system.

CLOSE UP

- None

5 Change-over from MDO to HFO manually

Periodicity

Description	
Unscheduled	
Duration for performing Preliminary requirements	0.0 man-hours
Duration for performing the Procedure	2.0 man-hours
Duration for performing the Requirements after job completion	0.0 man-hours

Personnel

Description	Specialization	QTY
Engine crew	Intermediate	1

Support equipment

Description	Part No.	CSN	QTY
None			

Supplies

Description	QTY
None	

Spare Parts

Description	Part No.	CSN	QTY
None			

SAFETY PRECAUTIONS

- None

PRELIMINARY OPERATIONS

- WinGD recommends to do a manual change-over only, if an automatic change-over system is not installed or if the automatic change-over system is unserviceable.

PROCEDURE

1 Make a full time schedule for the change-over to obey the ECA rules.

2 Make sure that you have changed the cylinder oil to the applicable BN, refer to section 3 Change-over the diesel fuel - general.

3 Set to ON the trace heating of the fuel pipes and fuel rail.

4 If the engine room is cold, after a minimum of one hour make sure to get correct heating.

5 Make sure that HFO cannot flow into the MDO system.

- **5.1** If also a MDO leakage tank is installed, move the 3-way valve in the pipe from the outlet of the fuel leakage fuel pump and injection control to the HFO leakage tank.
- **5.2** If the fuel return of the pressure control valve goes into the MDO service tank, set the valve positions to have the fuel return go into the HFO service tank.

6 Close all covers on the rail unit.

7 Decrease the load of the engine to max. 75% CMCR. The decrease of the engine power is related to the total quantity of fuel that flows in the system, eg the larger the mixing tank, the less decrease in load is necessary.

8 Set the viscosimeter to 13 cSt to increase the temperature of the fuel.

NOTE: The viscosimeter controls the end-heater, which keeps the fuel temperature at the necessary viscosity.

9 Follow the instructions of the plant to slowly change-over the fuel supply from MDO to HFO. Make sure that you increase the fuel temperature a maximum of 2°C each minute.

NOTE: Sudden temperature changes can stop the movement of the fuel pump plungers.

10 If the temperature changes too much, wait until the fuel temperature is stable. Then you can continue the procedure.

11 Do a check of the temperature, viscosity and pressure of the supplied fuel.

12 If the temperature, viscosity, or pressure is not correct, find the cause and repair the fault.

13 If you have to stop the engine, wait until the change-over procedure is fully completed.

NOTE: This prevents problems during the subsequent engine start because of a mixture of HFO and MDO in the system.

CLOSE UP

- None