1. Introduction

In many respects, distillate fuel differs from heavy fuel. It is a product rather than a waste material, and is of much better quality. Its specifications are well documented, including combustion characteristics, and are much tighter than for heavy fuels.

According to ISO 8217:2005, distillate fuels are categorized as DMX, DMA, DMB and DMC. Category DMA is also called marine gas oil or MGO, and DMB is often called marine diesel oil or MDO.

DMX is emergency fuel with a lower flashpoint, coming with additional storage precautions. Due to the low flashpoint, this fuel would not normally be used in marine diesel engines.

DMA and DMB are the most common distillate fuels and have guaranteed good combustion characteristics due to the specified cetane index, whereas DMC-fuel contains up to 15% HFO and has no cetane index prescribed.

Wärtsilä Switzerland allows for its engines to be operated on all fuels supplied under the ISO 8217 specification. Distillate fuels can be safely used, when the manufacturers’ recommendations are followed. They are summarized in this article.

2. Fuel injection pump

The mechanical fuel injection pumps used on the latest Wärtsila 2 stroke engines have evolved over many years, however, the basic operating principle has remained the same. The valve controlled pump allows for precise injection due to the accurate start and end of the injection. The fuel pump plunger clearance has no direct effect on the pump timing and the sealing takes place along the length of the plunger. Due to this, the clearance between the barrel and plunger can be optimized and is generally greater than would be found on a jerk type pump. As the barrel has no spill port the circumferential fuel oil distribution remains constant and no lateral thrust is applied to the plunger. Fuel pump seizures are seldom encountered. The leakage of fuel increases during the injection phase (referred to as the effective injection stroke) i.e. when the pressure increases. This would be higher at increased engine loads. The relationship between the engine load and effective delivery stroke is shown in Fig. 1 (the effect of the V.I.T. is shown in this diagram where the timing is advanced at 75% load).

Fig. 1: Effective delivery stroke.

A certain quantity of fuel oil leakage through the pump is required to act as a lubricant.

The latest electronic engines utilize a jerk type pump. These do have a helix on the plunger. This is to control the volume
delivered and has no timing function. Again the barrel and plunger clearance is optimized.

3. Minimum fuel viscosity

The current recommendation for fuel viscosity at the fuel injector is 13 to 17 cSt when operating on HFO. In order to achieve this viscosity, heavy fuel needs to be heated to 100-140 °C. However, this viscosity level cannot be achieved with MDO and MGO, unless the fuel is cooled. Experience has however shown that viscosities for grades DMA and DMB distillate fuels, as detailed in table 1 of the ISO 8217:2005 specification, have no adverse affect on the operation of the fuel system components.

However, a nominal lower viscosity level of 2 cSt at the fuel pump is recommended. To achieve this level, a cooler may be required, depending on the actual maximum fuel temperature reached. With low ambient engine room temperatures and heat losses through radiation from the relevant fuel tank, cooling may not be required. The ability of current viscosity controllers to operate stably at these low viscosity levels needs to be considered as well.

Considering all marine diesel engines, low viscosity values raise two main points of concern. The first concern is an alteration in fuel pump timing, due to increased leakage between the plunger helix and spill port. This is not an issue on Wärtsilä 2-stroke engines, as the pump timing is controlled by valves.

The second concern is the lubrication function of the fuel oil between the barrel and plunger. Providing the fuel meets the specification laid in ISO8217:2005, no additional measures are required. Both concerns will be discussed in more detail in the next chapters.

4. Lubricity

Sulfur has a natural lubricating effect, even at levels down to 100 ppm (0.01 wt%) there is still sufficient lubricity. When fuel with lower sulfur content is blended, usually a lubricity additive is added to compensate for the lack of sulfur.

In the rare case that a fuel with no sulfur and no lubricity additives enters the marine market and is used in a Wärtsilä 2-stroke engine, it is unlikely to cause problems with the fuel pump lubrication.

The relatively large clearances between fuel pump barrel and plunger make Wärtsilä 2-stroke fuel pumps rather insensitive to problems with fuels of low lubricity. These arguments are valid both for mechanical and electronically controlled fuel injection.

5. Fuel pump leakage

Distillate fuel has a lower density than heavy fuel which, on average, is not fully compensated for by the higher calorific value. This results in a net reduction in the calorific values by volume [1]. As the fuel pumps are volume controlled, this will lead to an increase in the load indicator position. However, much more important for observed higher load indicator positions when running on distillate fuel, is the fuel pump leakage.

The fuel pump leakage has different effects for mechanically versus electronically controlled engines, so these are handled separately here.

5.1 Mechanically controlled (RTA-type engine)

When burning distillate fuels or fuels with very low viscosities, increased leakage will occur through the fuel pump barrels and plungers and suction and spill valve push rods. The rate of leakage may differ depending on the clearance between the components resulting from wear. If all drains are clear, the leaked fuel is collected and drained from the fuel pump intermediate space and therefore cannot enter the lubricating oil, as shown in Fig. 2.

![Fig. 2: RTA fuel pump section.](image-url)
installations limit the engine load due to the governor torque and/or scavenged air limiters. If an installation is to be run on low viscosity fuels for any length of time this may require adjustments of the governor. Care should however be taken to ensure the maximum crankshaft torque is not exceeded when reverting to the standard fuel.

As the timing of Wärtsilä RTA 2-stroke engine fuel pumps is valve controlled, no countermeasures are required to adapt the fuel pump timing with regards to increased leakage through the fuel pumps.

5.2 Electronically controlled engines (RTflex type)
As the fuel injection operating principle of the RT-flex engines differs from the RTA engines, other considerations apply.
When the engine is at standstill the fuel circulation is only through the fuel pumps and not the rail unit. Due to this the fuel cannot be changed over at this point.

![RT-flex fuel pump section.](image)

The increased oil leakage through the fuel pumps may result in a higher actuator position. This does not have a timing effect and is only to adjust the volume control. The fuel pump has a segregated drain space with o-rings. Ensure the o-rings are in a good condition, see Fig. 3. The leakage oil is drained from the engine through drain pipes. It is necessary to ensure these drains are clear. When the engine is run on gas oil and the fuel change over is complete, allow for any residual heavy oil to be drained. Once complete, ensure the steam or electrical trace heating is switched off. Ensure this is switched on again for HFO use.

Increased leakage may occur in the rail unit assembly, including the injection control units (ICU). This fuel oil leakage is through a separate drain system which has flow sensors fitted. Again all drain pipes and bores should be clear and the steam or electrical trace heating is switched off for long term low viscosity fuel use.
With the increased leakage through the rail unit the fuel pressure drop may increase when the engine is at standstill. This may lead to a slight increase in the starting air consumption when maneuvering.

6. Combustion characteristics

When using low viscosity fuel, improved combustion would be experienced. This can result in high peak pressures which may have a negative effect on the reliability of the piston rings and other combustion space components.

For every fuel change it is recommended to check the maximum pressures of each cylinder, certainly when switching from heavy to distillate fuel or vice versa. When switching from heavy to distillate fuel, the timing sometimes needs to be retarded to get the maximum pressure back to normal again. On all RTA, RLA/B and some RMD-M engines, the Fuel Quality Setting (FQS) can be used to retard the timing. On all other older R type engines, the timing has to be retarded by adjusting the fuel pump cams.

The pressure rise differs by both engine type and the rating. The original shop- and/or sea trial data should be used for reference values and information. This procedure needs to be carried out for each batch of fuel irrespective of the grade and is helpful in optimizing the engine performance.

For electronically controlled “Flex” engine types, the injection timing is controlled by the crank position, and will not be affected by low viscosity fuels.

The combustion of standard RMG380 was compared with standard MDO on the RTX-3, which is a 4RT-Flex58TB engine type. The HFO had an Estimated Cetane Number (ECN) of 18, the MDO (regular Swiss heating oil) cetane number exceeded 40.

The FIA test cell measured a big difference in heat release
between the two fuels, see Fig. 4.

![Fig. 4: FIA ROHR curves of MDO (dotted red line) and HFO](image)

Despite the large differences indicated by the FIA, the RTX-3 engine hardly noticed this (see Fig. 5).

![Fig. 5: RTX-3 ROHR curves of MDO (dotted red line) and HFO](image)

Without changing injection timing, the maximum pressures measured were similar (within 1% variation). However, at low load operation, a significantly lower pressure was measured with heavy fuel. The short injection time at low load does make the poorer combustion (longer combustion period) noticeable.

The cleaner combustion of distillate fuel at low load operation results in less fouling and is a clear advantage of distillate fuel.

### 7. Cylinder oil selection

For operation on fuels, distillate or residual with a sulfur content lower than 1.5%, the cylinder oil feed rate and base number (BN) should be low. This is in order to prevent the build-up of deposits originating from un-neutralized hard calcium carbonate deposits. (See Fig.6).

![Fig.6 Calcium carbonate deposits on a piston crown.](image)

Because hardly any soot and other particulate materials are generated when operating on distillate fuel, the lowest achieved feed rate and lowest BN should be chosen. When selecting the lower feed rate values the condition of the piston rings and liner need to be taken into account.

With pulse lubrication a cylinder oil feed rate of 0.8 g/kW.hr (0.6 g/BHP.hr) is recommended; lower feed rates are achievable as experience has shown. At such low feed rates the piston assembly remains clean and improves the overall piston running reliability.

When optimizing the cylinder oil feed rate a liner wall temperature monitoring system such as MAPEX is a useful tool in determining the cylinder oil film stability.

The cylinder lubrication is load-dependent and the feed rate is determined by both the engine speed and load indicator position. With an increased load indicator position, resulting from the use of distillate fuel as mentioned above, an increase in the cylinder oil feed rate is to be expected. This is not a desired effect. If the engine is to be run on low viscosity fuels for any length of time, the operator should consider adjusting the feed rate to compensate for this increase. The ultimate indication of the feed rate is the mass of cylinder oil consumed over a reference time period. For this purpose an accurate engine power is also required. A torsion meter is required for this as the load indicator is no longer an accurate indication of the engine power. This applies to the use of the load indicator versus engine speed graph to determine the engine power.
8. Fuel change over

When changing from HFO to MDO or MGO a temperature gradient of 15°C/min is recommended, the change over should be at a reduced engine load. The actual time required will depend on the fuel system volume, the fuel piping insulation effectiveness, the engine load (and hence consumption) and the actual fuel system layout. The change-over time needs to be kept as short as possible to prevent excessive mixing of various fuel grades. If possible a compatibility test should be carried out when receiving various fuel bunkers, to see if any incompatibility problems may arise. The intentional mixing of fuels to lower or raise the fuel temperature is not recommended.

When changing from one fuel type to another consideration should be given to the vessel’s location. It is not, for example, recommended to do this in critical areas such as busy shipping lanes, unless experience has been gained and all considerations mentioned in this article have been taken into account.


It is recommended that any distillate fuels bunkered are treated as any marine fuel would be, i.e. the fuel should be filtered and separated as per the relevant equipment supplier’s instructions. While the quality of distillate fuels are by their nature superior to residual fuels, contamination may be introduced during the fuel supply chain or handling aboard the vessel. Depending on the relevant vessel’s trading pattern it could be that distillate fuels would only be used for a relatively short time, both for the main propulsion engine and the auxiliary engines. Depending on the quantity of distillate fuel bunkered, care should be taken with the medium to long term storage of the fuel.

10. Conclusion.

Based on experienced gained on various Wartsila 2 stroke engines over many years it can be said that few countermeasures are required to operate the engines reliably using residual fuels. In fact the use of residual fuel has definite benefits with regards to the combustion process and general condition of the piston assembly, in particular the reduction of combustion deposits. While an engine is expected to be run on various fuels reliably consideration should be given to the selection of lubricants and the auxiliary plant in general. The best practice is to inspect the piston assemblies when feasible thereby detecting any deterioration referred to.

References


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