MariEMS Learning Material – Hull and Propeller Condition

This is the sixth compilation by Professor Dr Reza Ziarati on the work of the EU funded Erasmus + MariEMS' partners and material researched by Chief Engineer Mohammed Haque. The material is composed from Chapter 11 of the learning material.

11. Fuel Management

11.1 Introduction

Fuel quality has significant impact on engines' and boilers reliability and performance. When ordering a fuel, qualities in terms of grade of fuel, its specification, calorific value and suitability for engines and boilers need to be considered. It is well known that higher density fuels and higher water and sulphur contents all reduced calorific value that represents the energy content of fuel. Also, high sulphur contributes to undesirable air emissions of SOx and high metallic impurities put the engines and boilers at risk.

The limits for fuel quality parameter as set out in International marine fuel standard, ISO 8217, are based on the understanding that the fuel will be treated on-board the vessel to meet specific requirements for particulars of engines and boilers fitted on-board the vessel. On-board treatment systems are therefore vital in ensuring that fuel is purified effectively in order to ensure it complies with the necessary specifications of the relevant combustion system.

This section covers aspects of fuel management which includes bunkering, fuel quality analysis, storage and treatment. It starts at bunkering point and ends at the point where fuel is supplied to various combustion systems including engines, boilers, etc.

11.2 Fuel Oil Procurement and Bunkering

The first major step in fuel management is to ensure that the right quality of fuel is ordered for the vessel. While requesting bunkers for a specific vessel, any limitations of ship's machinery capabilities, limitations on storage, operation profile, trading area for environmental compliance and giving enough time to get analysis before the fuel is put into use, should be considered.

The on-board fuel management starts first with the bunkering operation. During the bunker operation, safe handling and pollution prevention controls measures, correct measurements before, during and after bunker operations, loading in empty tanks (to avoid mixing of incompatible fuels) and collection of representative samples are the most critical issues. Quantity (by weight) of fuel bunkered should be established and recorded along with the on-board storage locations, and tracked to ensure selection of good subsequent heating or purification characteristics.

Quantity calculations aside, taking representative sample(s) of the fuel delivered to the vessel is regulatory requirements as well as of paramount technical and commercial importance for safety of engines and boilers. Without adherence to correct sampling procedures, which give real insight into the quality of fuel loaded by the vessel, the analysis results provided may be flawed. Analysis of fully representative samples of each bunker batch serves as first line of defence against poor quality fuels. Such an analysis should be performed in order to assure the quality of fuel supplied and to identify potential problems at the earliest opportunity which helps to identify mitigating actions/claims that may arise due to the supply of poor quality fuels.

11.3 Fuel Quality and Quantity Assurance

Bunkers come in a wide variety of quality levels and to meet the international quality standards (ISO 8217) and statutory requirements (mainly sulphur), the marine residual fuels are generally blended by manufacturers or suppliers with different components. Using better quality fuel and /or a higher grade of fuel can lead to an improvement in engine efficiency, safety of combustion systems and / or prevent degradation. On the other hand, to meet the regulatory requirement to reduce the sulphur level in bunker fuel, more and more refinery processes and also blend components are being used which could results in an increase in the levels of highly abrasive particles of Aluminium and Silicon (also called catalytic fines) or fuel's chemical stability over the long term. This has also raised concerns about the ignition and combustion quality of fuels along with the issues related to the stability and compatibility of the fuels.

Thus, analysis of the representative sample(s) of the bunkered fuels should be carried out to ensure:

- Appropriate storage, handling and treatment actions are taken beyond bunkering up to consumption.
- The use of fuel in a most safe and efficient way.
- Compliance to environmental legislation.
- Maximise combustion performance.
- Appropriate actions are taken to avoid any adverse effects and mitigating disputes.
- Reduce commercial, technical and operational risks associated with using varying quality fuels.

The same applies to quantity measurement as discussed in **Section 11.5**.

11.4 Fuel Storage and Transfer

It is important that all precautions to be made to try to avoid co-mingling (i.e. loading on top of each other) of different batches of fuels. Incompatible fuels are the most common problem with the bunker fuel mixing that leads to clogged filters and in the worst-case scenarios, complete paralysis of the fuel system lines as shown in **Figure 11.4.1**. This also helps in case the fuel supplied is of undesired quality then co-mingling makes it difficult to de-bunker the fuel if such situation arises.

Figure 11.4.1 - Clogged fuel pipes due to very poor quality fuels

If due to bunker planning and/or operational reasons mixing of the fuels is unavoidable then this should be done after performing the compatibility test between the fuels to be mixed that would indicate their stability after mixing. Ideally such a test should be carried out under lab conditions however this test can be carried out on-board the vessel as illustrated in **Figure 11.4.2**.

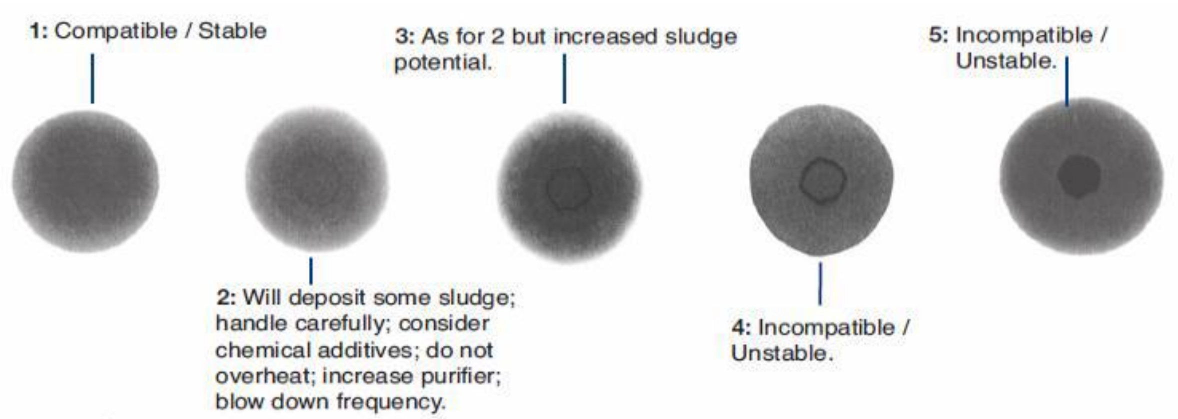

Figure 11.4.2 – Compatibility test procedure [ExxonMobil]

Fuel should be consumed in a first in, first out fashion. Avoid carrying or use fuels that are over a few months old. The longer a fuel is kept on-board, the chances of sediments in the fuel to drop out and stratification of the fuels increase. This then leads to more potential for filter clogging and other fuel issues and problems. Fuel that cannot be used for any reasons should be de-bunkered off the ship as soon as possible in consultation with vessel's technical superintendent.

11.5 Bunker Measurements

Bunker measurement is normally carried out before and after bunkering by the chief engineer or his/her representative to ensure that the actual quantity of lifted bunkers is accurate. The method of measurements includes:

- **Manual gauging of all the fuel tanks before and after bunkers:** This together with making corrections for the trim/heel of the vessel gives the volume of the fuel in the tanks which is then subtracted from the pre-bunker readings. Using the fuel volume, temperature and the density of the fuel as provided by the fuel supplier and by applying correction factor for the observed temperature, the weight of the fuel is calculated. This calculation is based on the understanding that the density of the fuel given by the supplier is correct and that there is no excess water in the fuel. This weight is adjusted accordingly upon receipt of the analysis of the bunker drip sample if density of the fuel varies considerably from the reported values or the amount of water in the fuel is excessive.
- **Use of the mass flow meters:** Based on the performance of the available technologies, Coriolis mass flow meters are advocated to be a good choice for mass flow metering of the fuel during bunkering because of the direct mass measurement by this device. Manufacturers claim that such measurements are not affected by fuel temperature, pressure, and composition. Meter size and location of the meter plays an important role therefore proper installation and operation practices are critical for these meters.

Of the above methods, the use of Coriolis flow meters is still being investigated and tested in the field to ensure optimal performance and benefit these types of flow meters. Currently, option 1 above that involves fuel inventory check is the common practice in industry.

11.6 Fuel Consumption Measurement and Reporting

Fuel consumption of main engines, auxiliary engines and boilers is normally measured and recorded on a daily basis. These are recorded in the engine logbook and reported to the company through noon reports and voyage reports. Method of daily fuel consumption measurement is done as follows:

- By the use of mass flow meters fitted for main engines, auxiliary engines and for the boilers.
- By manual gauging of the tanks and measuring the amount of fuels transferred to the specific machinery type.

Accuracy of fuel flow meters is of great importance. For energy efficiency monitoring, the vessel should be able to accurately measure the amount of fuel consumed on-board by the main consumers. This includes a thorough understanding of the fuel system and the placement of accurate fuel flow meters on the system, which must have a reasonable accuracy. Furthermore, the fuel oil temperature at the flow meters should be measured and related correction made from normally measured volumetric flow rate to mass flow rate. It is best if the accuracy of the fuel flow meters is regularly verified.

11.7 Fuel Oil Treatment – Settling and Purification

11.7.1 Settling tank(s)

The role of settling tank is to separate heavy residues and water from the fuel through the natural settling process. In this way, these items are expected to settle gradually at the bottom of the settling tank. To provide best performance:

- Settling tank temperature should normally be maintained between 60-70C for HFO to reduce the density and viscosity of the fuel to facilitate gravitational separation.
- Transfer of fuel to the settling tank to be controlled automatically to top up in small quantities at frequent intervals. This is to help minimise the temperature drop and quantity of dirty/unsettled fuel in the tank immediately after the transfer.
- It is important to drain off water and sludge at the settling tank bottom drains at regular intervals. Frequent / low volume – "flash blowing" is the most effective way of removing settled contaminants.
- Some settling tanks are fitted with high and low outlets. In normal service conditions, it is always preferable to use the lower outlet to minimise the space available for sludge accumulation and give early warning of contamination issues. The high outlet should only be used when there are major issues such as when the tank is subject to a significant water contamination.

11.7.2 Fuel purification Purifiers are almost invariably used in ships. The main task of purifiers is to separate water and other impurities from fuel. The purification process is based on centrifugal motion principle and the fact that materials with different densities will be subject to different centrifugal forces and thereby will separate from each other. Figure 11.7.2 shows the typical arrangement of fuel oil purifiers on board ships.

Figure 11.7.2 – Typical purifier systems on-board

The efficiency of a centrifugal separator is affected by several factors such as composition of the fuel (nature, quantity and size of undesired components), unstable process fluid dynamics (homogenisation of the fuel before the separators, turbulence within the fuel, poor temperature stability of the process fluid), cleanliness of the separator (the gap between individual discs in the disc stack, fouling of the clean fuel centripetal pump, fouling of the control water system or sliding bowl parts) and general operation (separator throughput, incorrect discharge interval).

For good purifier performance, the following operating controls should be observed:

- Operate purifiers / clarifiers in an optimum manner with purification level dependent on contaminant levels.
- Where applicable, ensure correct gravity disc fitted to purifiers. Manual de-sludge cycle time should be set with regard to fuel contaminant levels.
- In order to optimise the volume available within the bowl the interface line should be as close to the edge of the separating disc as possible.

Sludge (oil residue) is considered to be the residual waste oil products generated during the normal operation of a ship, such as those resulting from the purification of fuel or lubricating oil for main or auxiliary machinery, separated waste from oil filtering equipment, waste oil collected in drip trays and waste hydraulic and lubricating oils.

Excessive sludge from the fuel oil system such as purifiers is a parameter that reduces the fuel efficiency of the ship via increased fuel waste. As a result, the monitoring of the fleet’s sludge production in relation to the fuel consumption, with the aim of promptly identifying cases where corrective actions are needed is quite important. Some ships will benefit from use of fuel homogenisers to reduce sludge.

11.8 Fuel Viscosity Control

For use of fuels in engines it is very important to ensure that the fuel is heated to the correct temperature to maintain the required injection viscosity at the engine inlet. Incorrect injection viscosity results in poor atomisation which affects the efficiency by which the fuel is burnt.

Figure 11.8.1 shows the fuel oil steam heater for control of fuel oil temperature. The arrangement of viscosity controller and fuel filters are shown in **Figure 11.8.2**.

Figure 11.8.1 – Typical fuel oil heaters

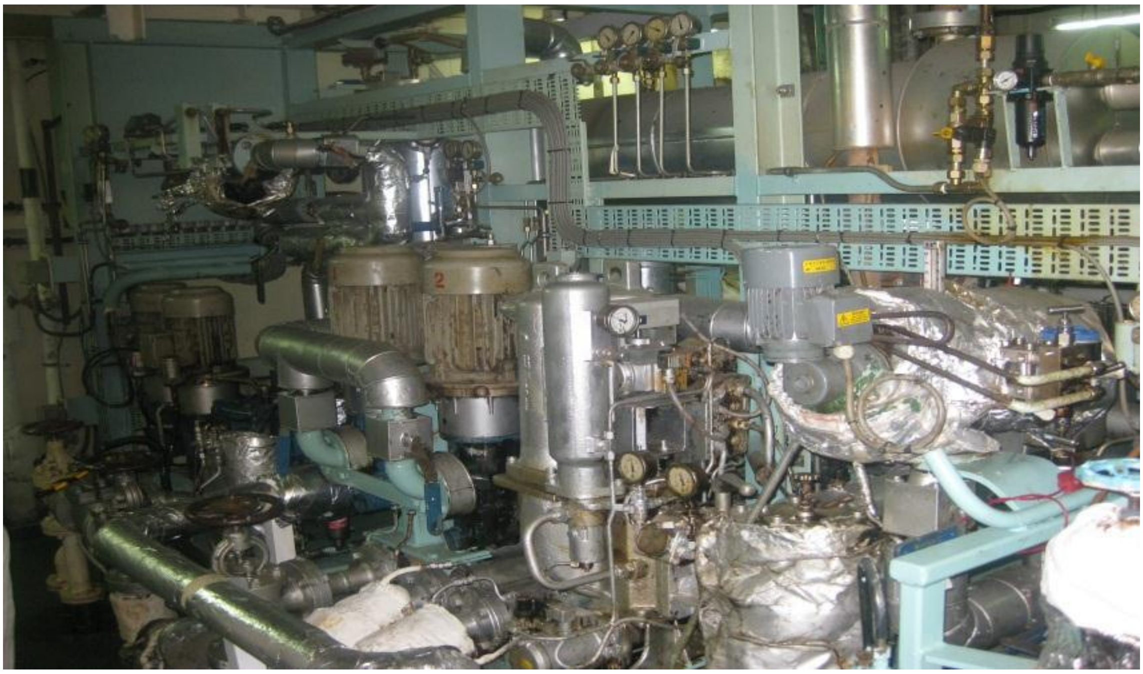

Figure 11.8.2 – Viscosity controller and fine filter units

It is best to put the viscosity controller on auto viscosity control mode than on the fixed temperature control mode. The correct function of the viscosity controller should be ascertained specifically when changing over from high viscosity fuels to low viscosity fuels and vice versa.

Due to the complex nature of marine residual fuels, it is difficult to predict the ignition and combustion performance of two fuels even if their standard quality parameters are the same. Poor quality fuels may lead to significant damages to the engine (see **Figure 11.8.3**). In view of this, it is good practice to monitor the engine's cylinder combustion performance through available diagnostic tools on-board, particularly at the start of the use of a new bunker. In case of any issues with the ignition / combustion of the fuels, appropriate actions should be taken to keep the engine parameters within the specified limits. Engines fitted with VIT (Variable Injection Timing) or similar arrangements can be adjusted accordingly to enhance the ignition / combustion efficiency.

Figure 11.8.3 – Damage to engine piston and cylinder liner [Gard 2014]

11.9 Fuel Oil Additives

Fuel additives are chemical compounds formulated to enhance the quality and efficiency of the fuels used. Environmental legislation to reduce emissions and improve fuel economy is having a significant impact on fuel formulations and engine system design. As a result of low sulphur regulations, the composition, long term stability, lubricity, combustion quality, etc. of fuels are evolving due to either desulphurisation of heavy fuel oil or blending. Fuel contaminations with bio-related products mixed with fuels adds a new dimension to fuel's long term stability.

Standard types of additives are metal deactivators, corrosion inhibitors, oxygenates and antioxidants. Fuel additive suppliers advocate them as delivering flexible and advanced solutions to the ever-changing fuel market environment and fuel quality issues. Over many years, additive products have demonstrated benefits in some specific areas of marine applications.

The fuel additive technology could provide benefits for marine fuels mainly in areas of enhancing the fuel combustion and preventing the formation of particulates (combustion enhancing additives). Same additives also help prevent fouling of exhaust systems and economisers as well as provide a cleaner combustion system altogether. Therefore, it may be stated that additives have proven records with regard to:

- Improvement of fuel combustion and reduction of particulate matter and visible smoke.
- Overcoming soot build-up in the exhaust system, thus ensuring the efficiency of exhaust system including economiser via keeping them clean, foul free with a reduction in risk of fire.
- Reduction and inhibition of deposit build-up on piston rings, injector nozzles and valves.
- Reduction and prevention of cylinder liner lacquering build-up.
- Protection against fuel pump and injector needle seizures commonly associated with ultra-low sulphur fuels.
- Extension of engine maintenance intervals and less engine downtime; saving both time and money.

The impact of fuel additives on engine fuel efficiency has not been proven despite some significant claims made by some suppliers. However, in view of the better combustion efficiency and cleaner engine and exhaust system, some improvement in engine thermal efficiency is expected; but not significant.

Various fuel oil additives are available on the market. Use of additives, being chemicals, should take place with care and after full testing and consultation with engine manufacturers. Also, right dosage at well-defined periods should be observed. Also, treatment of fuel oil should be carried out in accordance with manufacturer's advice so as to ensure optimum performance from the combustion of fuel.

11.10 Energy Efficiency Measures

There is a number of energy efficiency measures directly related to fuel management aspect. These measures include:

- Vessels should carry the most economical amount of bunker in inventory. Carrying too much bunker fuel is not energy efficient as they have weight and any transport of extra weight will cause extra fuel consumption.
- Energy is also used for temperature control of fuel and its transfer. To ensure energy efficient storage and transfer, fuel temperature in storage tanks needs to be controlled to lowest temperature feasible in order to retain it in a fluid condition and also suitable for transfer. In the latter case it is only the fuel to be transferred which is to be heated. Steam heating and trace heating should only be applied as required and not be left running unnecessarily.
- Ensure tank fittings (manhole covers, vent pipes, etc.) do not allow water, cargo or other material to get into the fuel. Ensure heating coils are tight.
- Ensure that tank wall condition is in good order thus avoiding corrosion or other material being entrained with the fuel which then has to be removed.
- Maintain settling tanks at a temperature which will enable the purifier heaters to achieve the required treatment temperature.
- When a service tank is not in use it is not necessary to maintain usual high temperatures.
- Heater controls should be checked to ensure correct operation. Accumulations on heater elements should be minimised.

- Periodically verify that the viscosity controller is working correctly.
- Monitor fuel oil sludge levels and ensure that sludge levels are not high due to poor maintenance of the purifiers. As advocated, homogenisers can be used to reduce the sludge levels.
- Fuel measurement and metering is the first step for subsequent performance analysis of various engines and boilers. The more accurately fuel consumption is measured and reported, the more will be the chances for identifying inefficiencies and making improvements.

Although all aspects of fuel management have a close association with energy efficiency, most of the ship-board activities are done to safeguard the engines and boilers from damage. Therefore, fuel management for safety of assets marries well with its aspects of energy saving and there is no conflict between the two objectives.

11.11 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. "IMO train the trainer course material", developed by WMU, 2013.
2. ExxonMobile Newsletter, "Fuel stability and compatibility - best practise top tips" http://www.exxonmobil.com/MarineLubes-En/learning-and-resources_voyager-newsletter_2015_may.aspx Viewed Nov 2016.
3. Dimitrios V. Giannakouros, "Technical Aspects of Identifying and Managing Bunker Problems", Presentation to the Marine Club (West England), November 2012, http://www.westpandi.com/globalassets/loss-prevention/loss-prevention-seminars/121108-technical-aspects-of-identifying-and-managing-bunker-problems.pdf Viewed Nov 2016.
4. Gard 2014 "Bunkers and Bunkering", A selection of articles previously published by Gard AS, http://www.gard.no/ikbViewer/Content/72669/Bunkers%20and%20bunkering%20January%202014.pdf published, January 2014, Viewed Nov 2016.