

GUIDANCE ON FUEL MONITORING

1 PURPOSE

This paper provides guidance on onboard monitoring of fuel oil and recording of data for the purpose of monitoring of fuel consumption required by Regulation (EU) 2015/757.

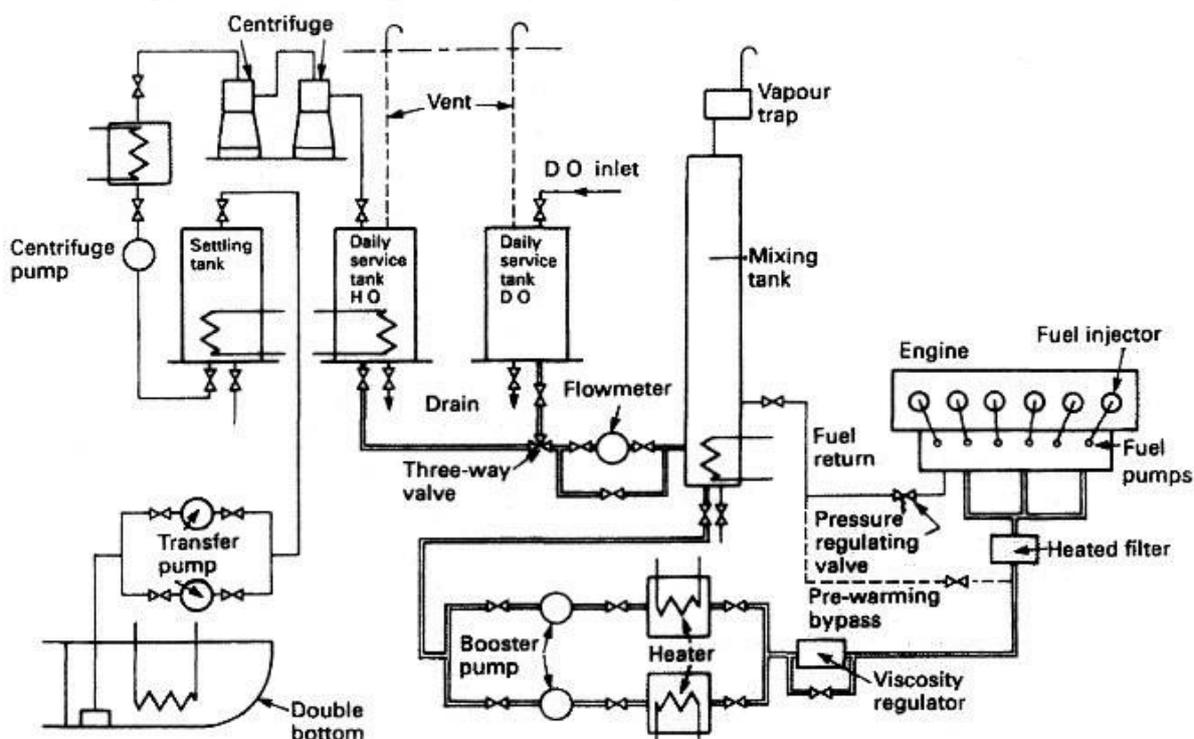
2 RESPONSIBILITIES

The Master has ultimate responsibility for the monitoring of ship's bunker consumption and for reporting the data to the office as set by the company's procedures.

The Chief Engineer is responsible for the overall bunker operations, including the verification of bunker received, the sounding of the bunker tanks and calculation of the exact quantity of bunkers onboard.

3 A GENERIC FUEL OIL SYSTEM ONBOARD

The following picture shows a generic ships fuel oil system.



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The diagram indicates that fuel oil onboard undergoes several process steps before being used. Own process steps are e.g.: bunkering, storage, heating, settling, cleaning (centrifuging) and in-between several transfers take place.

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4 TANKS SOUNDING FUEL OIL MEASUREMENT AND MONITORING

This is a generic guidance for fuel oil measurement through manual sounding / ullage measurements. Depending on the situation onboard, it should be taken into account that not all ships may need to follow each step and the frequency of measurements provided below.

4.1 Fuel consumption “in port” and “at sea”

For clarification, the fuel consumption “in port” is the total amount of fuel from the time the ship arrives at first berth of a port and up to the time the ship leaves the last berth of the port where commercial cargo operations or embarkation/disembarkation of passenger took place.

For example: a chemical tanker’s “in port” fuel consumption should include the total of the fuel consumed after the ship is securely moored at the first berth of a port including: fuel used for cargo operations to that berth and any other berth of the same port, fuel consumption used by the ship to move from one berth to another berth and fuel consumption used by the ship for moving out to sea for cargo tank cleaning and return to a berth of the same port.

The total fuel consumed “in port” can be:

- the difference between the fuel measured on board when the ship arrives at the first berth of a port and the fuel measured on board when the ship leaves the last berth of the port (eventual fuel bunkered during the stay in the port is not accounted for in this measurement) ; and
- when applicable, the fuel consumed while the ship was waiting at anchor or is carrying out ship-to-ship transfers within the port area

All other fuel consumption except the above, should be considered as “at sea”.

4.2 Frequency

The frequency of fuel tanks’ stock takings through soundings/ ullages should occur:

(1) For fuel monitoring method A)¹:

- a) Upon bunkering and de-bunkering
- b) Upon arrival to the first berth of a port² and before leaving the last berth of the port where commercial cargo operations or embarkation/ disembarkation of passengers took place³ prior to engaging on a voyage for a port outside the scope of the Regulation.
- c) For ships in short and regular trades and for ships using shore power while at berth the measurements may take place either upon arrival at the first berth or before leaving the last berth.²
- d) Allocation of all fuel consumption (for each fuel type) not under the scope of the regulation is needed as the sum is to be subtracted from the amount provided in the Bunker Delivery Note (BDN)

(2) For fuel monitoring method B)⁴:

- a) Upon bunkering and de-bunkering

¹ Annex I, Although Method A is based on fuel data from BDN, ships need to measure fuel in tanks to make the balance at the end of the voyage or the end of the monitoring period...

² under the scope of the Regulation

³ this may be applicable for fuel monitoring method B) as well

⁴ Annex I, B Methods for DETERMINING CO₂ EMISSIONS, (b) Bunker fuel tank monitoring on board;

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- b) Fuel tank readings for all bunker tanks onboard should occur daily when the ship is at sea⁵. These could be on a daily basis at 12:00 noon time, the start/end of a canal crossing, a voyage interruption, etc.
- c) While at sea passage prior entry and exit of an Sulphur Emission Control Area (SECA), if there is a fuel switch.

4.3 Calculating the volume of bunker in each tank

The ship specific sounding / calibration tables produced by shipyard for each individual bunker tank should be used to determine the volume of bunker in each tank taking into account the trim and list of the vessel.

ASTM D 1250-80 Standard Guide for Petroleum Measurement, table 54B, or equivalent tables or a substantiated software for temperature and atmospheric pressure corrections of density and mass calculations should be used.

The software could additionally be supported by dedicated ship specific software for trim, list and temperature corrections is available on board.

4.4 Density

Density values to be used could be one of the following:

- (a) on-board measurement systems;
- (b) the density measured by the fuel supplier at fuel bunkering and recorded on BDN;
- (c) the density measured in a test analysis conducted in an accredited fuel test laboratory, where available.

The source of density values should be stated at all times. However, the fuel oil volumes recorded onboard after each monitoring may always be related to the standard temperature of 15°C⁶.

To cater for most practical handling onboard with the density issue -as an alternative to above- volume to mass conversion - may be done using standard conversion factors. The company may use bespoke conversion factors for the entire reporting period subject to criteria for establishing these have met the agreement of the verifier. The company may also use the following standard conversion factors:

- 0.96 when using RME180, RMG 180/380/500/700 or RMK 380/500/700
- 0.88 when using MGO/MDO

These standard conversion factors derive from ISO 8217 Fuel Standard figures after having been corrected with ASTM D1250 density temperature variation tables (using 60°C - 80°C for IFO/HFO and 40°C for MDO/MGO) and apply regardless of whether the volume measurements are made in the bunker tanks or at a volume flowmeter placed between the service tank and the engine inlet.

4.5 Density for Commingled bunkers

⁵ fuel tank readings from tanks that have no transfer nor consumption can be omitted

⁶ reference is made to: ISO 8217; Specifications of Marine Fuels

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When there are 2 types of fuels (or more) are mixed and stored in one fuel tank then the density volume to mass conversion factor of the fuel tank of the mixed oil should be calculated as per the below mentioned formula:

$$\frac{\text{'A' fuel volume} \times \text{Density (A)} + \text{'B' fuel volume} \times \text{Density (B)}}{\text{'A' fuel volume} + \text{'B' fuel volume}} = \text{mixed fuel Density}$$

4.6 Density for blended fuels

In the rare event that fuel types with different densities are blended in a tank, the weighted average density should be determined, unless a density analysis of the mixed fuel sample is available.

$$\rho_w = \rho_{add} \times \frac{m_{add}}{m_{total}} + \rho_{exist} \times \frac{m_{exist}}{m_{total}}$$

Where:

- ρ_w : is the weighted average density of fuel in the tank after additions [t/m^3]
- ρ_{add} : is the density of the fuel added to the tank [t/m^3]
- m_{add} : is the amount of fuel added to the tank [t]
- m_{total} : is the total amount of fuel in the tank after addition [t]
- ρ_{exist} : is the density of the existing fuel in the tank before addition [t/m^3]
- m_{exist} : is the existing amount of fuel in the tank before addition [t]

4.7 Gauging Equipment

In general, there are several methods of gauging fuel tanks, e.g., manual soundings, gauges with audible noise when an oil interface is reached, pressure transducers, radar and so forth; each ship will adapt this part for description according to the equipment they use.

As back-up for fixed installed tank sounding / gauging equipment, the method of determination of a tank's sounding or ullage is suggested to be manual soundings. The tape or measuring device is to be graduated in feet, inches and fractions of an inch; or meters, centimetres, and millimetres.

Tapes which have been kinked or spliced or which contain illegible markings should not be used.

4.8 Gauging criteria

Vessel's equipment used for gauging should always be substantiated for accuracies. This should be done by:

- Checking the condition and calibration (if applicable) of the instrumentation used for gauging the quantity of bunkers on board
- Recording the calibration certification (if applicable).
- Visual inspection of ullage tape to ensure there has been no damage to the tape and/or whether any repairs have been made that may alter readings.

Repeated measurements are taken for each tank to obtain at least two consistent readings. If two measurements are not similar then an average reading based on at least three measurements is recommended to do.

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5 CONTINUOUS FUEL OIL MONITORING

This procedure is for ships using flowmeters on consumers (e.g. main engines, auxiliary diesels, inert gas generators, boilers, etc.).

The data from all flow meters linked to fuel consumers minus the data from all flow meters at the return lines from the same consumers (if applicable) should be combined to determine fuel consumption over a period⁷.

Regardless if the fuel measurements are automatically recorded and transmitted, it is a good practice for ships engaged in long voyages when at sea, to record daily measurements in the Engine Logbook. Depending on type of ship operation the master, chief engineer or the operator may follow other practice as per company SMS.

The validity of fuel flowmeters should be compared on a periodic basis through comparison with the fuel figures that derive from flowmeters and tank soundings. The ship operator's PMS should provide guidance on comparison frequency.

To ensure proper readings, fuel flowmeters onboard should be calibrated as per makers recommendations or based on the ship's operational experience if flow meter is maintaining operational accuracy within manufactures suggested tolerances. Any records of manufacturer calibration should be maintained onboard and captured within the PMS onboard.

In the event that a fuel measurement cannot be made due to failure of a flow metering device the daily fuel consumption should be determined by utilising the tank soundings method⁸.

5.1 Volume flowmeter.

The amount of fuel consumed is determined in units of volume, expressed in litres, and it is converted to mass by using the density values corrected for the applicable temperature by the use of the formula below:

$$M = \rho \times V$$

Where:

M: mass of fuel (kg)

V: volume of fuel (l)

ρ : density at applicable temperature (kg/l).

Density values to be used should originate from BDN or provided through a fuel test analysis conducted in an accredited fuel test laboratory. Source of density values should be stated at all times.

ASTM D 1250-80 table 54B or equivalent tables or a substantiated software for temperature corrections of density should be used.

Temperature to be used for density corrections should be the fuel temperature at the flowmeters.

⁷ The need for a fuel meter in the return line may not be necessary depending on the arrangements, e.g. on where in the system the supply meter is fitted

⁸ means inherently that this is a fall-back solutions for filling (avoiding) data gaps for Methods A), B) and/or C)

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5.2 Mass flowmeters

The mass flow meters measures directly the mass flow rate of the fuel and eliminates the need for further mathematical calculations to derive the mass of fuel consumed.

6 FUEL OIL MONITORING AND RECORDING

This section describes the different sequences of fuel oil handling onboard. This includes that fuel oil measurements on board ships are (or can be) done for different situations and purposes. The sequence and procedures in this chapter are generic and not each of them may apply to all the different ship types and ship trades we are faced with.

Ships may develop (or have) assessment procedures for dealing with possible mistakes or omissions that could occur and lay down control measures that are to be taken by the company to minimize this risk for data gaps.

Data flow charts for every fuel oil measurement method in use would be helpful to indicate the sequence of actions step by step along with the control activities.

6.1 BUNKERING

Bunkering should be covered by routine operational procedures. Therefore, in this guidance paper a description of bunkering is not included as an own part / chapter. However, to just provide an info on what could / might be included in such descriptions, an own annex is attached for informational reasons.

6.2 "NOON REPORT"

As a matter of routine but on a voluntary basis only, ships engaged on long voyages do report the total amount of fuel on board on a daily basis⁹. The report is done at noon local time where the ship is located. This measurement provides also a daily monitor of the fuel consumption. The Officer in charge makes relevant entries in the Engine Log Book. However, ships engaged in shorter voyages may not do this reporting.

6.3 WEEKLY MEASUREMENT

As a matter of best practice for good housekeeping but also to check and confirm proper function of Mass Flow Meters, Volumetric Flow Meters, ships may measure by manual tank sounding and make the balance of the fuel oil onboard on a weekly basis.

The procedure to follow was presented under section 3.

The Chief Engineer makes entries into the Engine Room log of the fuel oil remaining on board (ROB) and, comparing with the previous measurement results, could make the balance of the total fuel consumed during that week.

⁹ If you opt for monitoring Method B) it is required, for Method A) and C) it is a suggestion.

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6.4 END OF VOYAGE MEASUREMENT

As a matter of best practice for easy monitoring and recording of the fuel consumption for each voyage, ships do measure the fuel oil ROBs at the end of each voyage or as determined by company SMS.

The procedure is similar to the one done as presented in section 4.

6.5 FUEL OIL MONITORING IN PORTS

A separated fuel oil monitoring / consumption analysis is required for ships in ports. Although ships may have various ways to monitor fuel consumption while in port, some ships may separately assess / calculate it using a method that with a reasonable accuracy establishes the mass of the individual fuel types consumed during the port stay(s).

6.6 EMISSION FACTORS FOR “NON-STANDARD”-FUELS

Since 1 January 2015, ships have been supplied with an increased number of Ultra Low Sulphur Fuel Oils (ULSFO) which are new products not yet categorised under the ISO 8217. In regard of the CO₂-conversion factor of these fuels, it is that test results from accredited laboratories indicate that the large majority of these new products are within the RMA-RMD grades (i.e. residuals - light fuel oils) and only one or two are categorised as DMB grades (i.e. distillates).

For simplicity and consistency reasons, it is suggested that such new fuels (so-called “hybrid-fuels”) should use the standard CO₂ - conversion factors applied for light fuel oil (i.e. 3.151 when its viscosity is within RMA to RMD grades) and for distillates (i.e. 3,206 when similar to DMA or DMZ grades) as per this regulation.

| Type of fuel | Reference | Emission factor (t-CO ₂ /t-fuel) |
|-----------------------|---------------------------------|---|
| Distillates (MGO/MDO) | ISO 8217 Grades DMA through DMZ | 3,206 |
| Light fuel oil (LFO) | ISO 8217 Grades RMA through RMD | 3,151 |

The above assignment should not be seen as an exhaustive list as new products might be provided in the future.

6.7 UNCERTAINTY ASSOCIATED WITH FUEL MONITORING

The quantity determination is inherently subject to uncertainty. The Regulation requires to specify the uncertainty level within the Monitoring Plan (Art. 6.3.(f).(iv)) as well as in the Emission Report (Art. 11.3.(c)). Supplementary, uncertainty is further dealt with in COMMISSION IMPLEMENTING REGULATION (EU) 2016/1927 and COMMISSION DELEGATED REGULATION (EU) 2016/2072.

To deal comprehensively with the overall uncertainty figure with fuel monitoring on board a ship, it is to be noted that the measurement accuracy (uncertainty) of single equipment (e.g. flowmeters for receiving bunkers, density determination, storage in bunker tank,...) provide not the full picture of uncertainty levels for all processes of fuel oil handling on board.

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By way of illustration, all process steps as mentioned in chapter 3 contributes to the overall “uncertainty level” to be stated according to the regulation. To serve as best practice within this guidance document it is proposed (for the time being) to state an overall uncertainty level as follows:

| Monitoring Method acc. Reg. EU 2015/757 | overall max. uncertainty level |
|--|-----------------------------------|
| method A) | ± 10% |
| method B) | ± 10% |
| method C) | ± 10% |

In case the uncertainty will be determined in more detail, the combined uncertainty is calculated to the following formula:

$$u_c(V) = \sqrt{u(V, bunkering)^2 + u(V, density)^2 + u(\dots)^2 + \dots}$$

Appendix I

Abbreviations

| | |
|--------|---|
| BDN | Bunker Delivery Note |
| ESSF | European Sustainable Shipping Forum |
| HFO | Heavy Fuel Oil (RME, RMG and RMK grades as per ISO 8217) |
| IMO | International Maritime Organisation |
| LFO | Light Fuel Oil (RMA, RMB, RMD grades as per ISO 8217) |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| MDO | Marine Diesel Oil (DMA, DMB, DMZ grades as per ISO 8217) |
| MEPC | Maritime Environmental Protection Committee |
| MGO | Marine Gas Oil (DMX, DMA grades as per ISO 8217) |
| PMS | Plant Management System Planned Maintenance System |
| RO | Recognised Organisation |
| ROB | Fuel Oil Remaining |
| SECA | Sulphur Emission Control Area |
| SEEMP | Ship Energy Efficiency Management Plan |
| SMS | Safety Management System |

Appendix II

An example for a general description of bunkering procedures

Chief Engineer or other appointed crew members ¹⁰ check ALL bunker tanks and complete the respective part of the “Bunkers Calculation” Form.

All quantities of bunkers (e.g. HFO, ULSHFO, MGO or other types of LSFOs) are recorded separately.

Common practice is to plan to receive new bunker in EMPTY bunker tanks. If not possible, comingling of different fuel batches may happen. In general, comingling is not favourable.

The appointed Engineer Officer has to implement the bunkering plan, supervise bunkering process and ensure that bunkering procedure is followed throughout the bunkering operations.

Relevant actions to secure correct assessment of the bunker received:

- carry out a pre-bunkering survey of the bunker barge, as per shipping company / bunker suppliers agreement, in order to determine exact quantity onboard together with the appointed Deck Officer of the watch.
- check ALL bunker tanks.
- witness the completion of the ullage report
(for this purpose, the co-operation of bunker barge personnel should be secured)
- sign and obtain a copy of the completed ullage report;
the copy should be attached to the Bunker Receipt Form.
- inform Master and request approval to start receiving bunkers when both quantity i.e. own vessel and bunker barge have been completed.
- upon completion of the bunkering, the Master and the Chief Engineer should arrange for a post bunkering survey (own vessel and bunker barge) similarly as with the “pre-bunkering survey procedures’ above.
- the Chief Engineer reviews the BDN and declaration of compliance with MARPOL Annex VI, presented by the bunker barge.
- during the review, Chief Engineer compares received quality and quantity against the Company’s bunkering information i.e. ordered regarding quality and quantity.
- both the Chief Engineer and the Master should sign for acceptance the Bunker Delivery Note issued by the bunker barge only if they agree with the figures received.

¹⁰ or otherwise stated by company procedures

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Note : The ship (i.e. the chief engineer on behalf of owner) issues a Letter of Protest in the following situations, but not limited to:

- shortage of bunker delivered,
- quality issues (e.g. failure of fulfilling ISO specifications)
- slow pumping rate,
- ship's fuel samples not signed by the supplier
- lack of co-operation from bunker barge personnel to conduct mutual ullage inspections.

Upon completion of each bunkering, the following documentation are to be submitted to ships' operational Head Office:

1. Bunkering Report Form.
2. Bunkers Quantity Calculation Form
3. Bunkering samples registration and consumption log Form
4. Bunkering pre-loading plan Form
5. Letter of Protest, if applicable
6. Ship-Barge Safety Checklist Form or Ship-Shore Safety Checklist Form, if bunkering by barge or terminal respectively.

The Chief Engineer should also maintain copies onboard. All relevant forms and checklists are kept on board for minimum 3 years.

Officer in charge makes relevant entries in the Engine Log Book and in the Oil Record Book.