Implementation of Shipping MRV Regulation

Third Working Paper on monitoring (possible amendments to Annex I and II)

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Content

1. Introduction

1.1. Background

The EU Regulation on the monitoring, reporting and verification of emissions of CO_2 from maritime transport (EU 2015/757) (hereafter: EU MRV Regulation) lays down rules for the accurate monitoring, reporting and verification of CO2 emissions and other relevant information from ships above 5,000GT calling at EU ports.

Article 4 of the EU MRV contains the principles and Article 5 together with Annex I contain the methods for monitoring and reporting emissions of CO_2 emissions and other relevant information on maritime transport. Annex I contains a list of methods which can be applied to measure fuel consumption and CO2 emissions:

(a) Bunker Fuel Delivery Note (BDN) and periodic stock-takes of fuel tanks;

(b) Bunker fuel tank monitoring on board;

(c) Flow meters for applicable combustion processes;

(d) Direct emissions measurements.

For the calculation of CO2 emissions, the fuel consumption must be multiplied with the emission factor of the fuel used (Methods A, B, C) or CO2 emissions can be measured directly in the exhaust gas (Method D).

Furthermore, Annex II contains rules on the monitoring of other relevant information including distance travelled, time spent at sea and cargo carried (for passenger, ro-ro and container ships).

These provisions could be amended (by means of delegated acts) in order to take into account relevant international rules as well as international and European standards. Furthermore, the rules could be refined in the light of technological and scientific developments.

This document has been prepared to analyze the related existing rules and standards, as well as the scientific and technological developments, which might have an impact on the current MRV regulation.

1.2. Purpose of this paper

This paper is based on written comments from Member States and stakeholder organisations on the working paper published in **January 2016 (the 'second** Working Paper') and discussion of that paper in the ESSF subgroup on MRV on 27 October 2015. The **second** Working Paper contained a list of options for measuring fuel consumption, density, temperature and pressure, as well as the international rules and standards and the technological and scientific developments, to see if amendments to Annex I of the MRV Regulation are required.

The aim of this **third** working paper is to **summarize the conclusions reached during the** discussions of the Shipping MRV subgroup of experts on shipping MRV monitoring established under the European Sustainable Shipping Forum (ESSF) in view of the discussion on the need for amendments to Annex I and II to the MRV Regulation and if required the preparation of the above mentioned delegated act.

As several valuable comments received do not directly address possible amendments to Annex I or II (as the scope for such amendments is limited by the MRV Regulation), those issues are flagged in dedicated sections as relevant for possible best practice documents. These could be developed by the ESSF sub-group at a later stage to facilitate the harmonized implementation of the provisions of the MRV Regulation. **A summary of the issues to be covered in best-practice and guidance documents can be found in chapter 2.11.1.**

All substantial changes from the concept paper are in bold.

Disclaimer

The information and views set out in this paper are those of the author(s) and do not necessarily reflect the official opinion of the Commission.

2. Key elements with regard to fuel monitoring

2.1. Bunker delivery notes (BDN) and regular stock-takes of fuel tanks (Method A)

2.1.1. International and European rules and standards

MARPOL 73/78 Annex VI Appendix V: Information to be included in the bunker delivery note (Regulation 18 (3). The BDN's are to be kept on board for a period of three years after the fuel oil has been delivered and readily available for inspection at all times.

The BDN requires reporting of the sulphur content and density according to ISO standards:

- BDN Sulfur content has to be measured according to ISO 8754.
- BDN density: ISO 3675 is used to determine the density at 15°C, which is important to convert the volume of fuel supplied to mass, unless mass flow meters (Coriolis type) are used during bunkering (see chapter 2.3). Further methods for the determination of density are listed in chapter 2.4.

For ships using LNG as fuel:
The IMO - IGF Code has been finalized at MSC 95 in June 2015 (resolution MSC.391 (95)) and will enter into force as SOLAS-amendment by 01. Jan 2017 with rules for the ship using LNG as fuel. The IGF code also contains information to be included as a minimum in the BDN for LNG bunkering (annex C1). The LNG BDN was developed for safety reasons. However, it contains the amount of fuel delivered to the ship in tonnes.

Regarding regular stocktakes of fuel tanks please refer to method B (2.2).

2.1.2. Technological and scientific developments

LNG CTMS
Due to the fact that the density of LNG in the tanks changes through the use of more volatile boil-off gas, LNG fuel consumption should be measured as volume like reported in the LNG custody transfer management system (CTMS) records (readings before and after completion of cargo transfer). The volume will then be converted to mass by multiplication with the density.

ISO is working on a new standard (ISO 19970) for "Metering of gas fuel on LNG carriers during cargo transfer operations".

2.1.3. Impact on the regulation

None

2.1.4. Issues possibly covered by best Practices and Guidance

Best practice and guidance documents will be developed at a later stage. SIGTTO already works on Best Practice and Guidance for LNG carriers using boil-off gas as fuel. For those ships the existing Custody Transfer Management System (CTMS) can serve as a very advanced method to determine the fuel consumed on its voyages. LNG consumed at berth can be derived by the flow meters installed on the piping supplying gas to the consumers (engines, boilers, etc.) **or by level gauges and calibration tables.**

The consumption of pilot fuels and other fuels on LNG carriers can be monitored with methods A, B and C.

2.1.5. Conclusions

- No amendments are triggered by the identified international and European rules and standards or technological and scientific developments.

2.2. Fuel tank readings (Methods A/B)

2.2.1. International and European rules and standards

International Organization of Legal Metrology OIML R 95: Ships' tank – General requirements.

There are also a number of ISO standards dealing with the measurement of liquid levels for petroleum products (see Annex 1).

The density at 15°C can also be derived from the BDN. Conversion to actual temperatures is required (see paragraph 2.4 for density and 2.5 for temperature corrections.

LNG: ISO 10976 "Measurement of cargoes on board LNG carriers".

2.2.2. Technological and scientific developments

Fuel tank readings can be carried out manually (sounding tapes or ullage), mechanically e.g. floats or gauge glasses) or by automatic tank gauges. There are a number of automatic (or electronic) tank gauges based on different technologies, which are already widely accepted for fuel tank level readings:

- Bubbler gauge (famous for remote reading gauges)
- Ultrasonic Level gauges
- Radar Level gauges
- Pressure Based Level Measurement
- Ultra-Sonic/Microwave Level Sensor
- Capacitive Level Sensor
- LNG: Laser System (LIDAR)
- Raman Spectrum (also for LNG composition analysis).

2.2.3. Issues possibly covered by best Practices and Guidance

- In cases of equipment failure, where electronic equipment is used, fuel tank readings can be carried out with manual tank reading methods.

2.2.4. Conclusions

- List of standards complete. Relevant standards are listed in Annex 1 of this document.
- No amendments are triggered by the identified international and European rules and standards or triggered by technological and scientific developments.
- Keep requirements for calibration of instruments as lean as possible.

2.3. Fuel flow meters

2.3.1. International and European rules and standards

Directive 2004/22/EC on measuring instruments (MID) defines the requirements that the devices have to satisfy including maximum permissible error based on accuracy classes and associated measuring systems (temperature, density and pressure).

Meter and liquid measuring systems newly designed after 30 October 2006 will have to be submitted for type evaluation under the new MID. The evaluation required on these new meters and systems will result in an EC type examination certificate with reference to the MID. Compliance with this directive is assumed when using the OIML recommendations OIML R117-1 (measuring systems for liquids other than water). The MID applies to devices and systems with a measuring function defined in the instrument-specific annexes:

Annex MI-002: Gas meters and volume conversion devices.

Annex MI-005 Measuring systems for the continuous and dynamic measurement of quantities of liquids other than water. This annex includes measuring systems on pipelines and systems for (un-)loading ships.

This MID is only relevant for the manufacturers of measuring instruments.

International Recommendation (contained in above directive): International Organization of Legal Metrology (OILM) 2007: Dynamic measuring systems for liquids other than water Part 1: Metrological and technical requirements.

International Recommendation: OIML R117-2 (2007): Dynamic Measuring Systems for Liquids other than Water Part 2: Metrological controls and performance tests.

Further several ISO standards for measuring liquid hydrocarbons have been reviewed, also for the evaluation of uncertainties [Annex 1].

ISO is working on a new standard – ISO 19970 **Refrigerated hydrocarbon and non-petroleum based liquefied gaseous fuels.** Metering of gas as fuel on LNG carriers during cargo transfer operations.

2.3.2. Technological and scientific developments

There are basically four types of flow meters:

1. Volumetric flow meters (also called positive displacement meters) measure the volume of a liquid
2. Differential Pressure flow meters
3. Velocity flow meters
4. Mass flow meters measure the mass of a liquid passing.

These can be subdivided into many different technologies with varying accuracies. The latest development is the mass flow meter (Coriolis meter) which does not require temperature/density correction.
New developments: Multiphase flow meters, which can detect e.g. entrapped air in the fuel pipe. Forecast expects continued multiphase flowmeter growth, especially in the oil and gas industry.

LNG: While some LNG carriers re-liquefy boil-off gas in a closed system, most LNG carriers in service today consume the boil-off as fuel in the ship's machinery plant. Traditionally the quantity consumed is measured volumetrically by flow meters and some recent designs have utilized mass flow meters. If volumetric meters are used, the system converts the quantity consumed to mass using a pre-set conversion factor.

2.3.3. Issues possibly covered by best Practices and Guidance

To be developed at a later stage.

2.3.4. Conclusions

- No amendments are triggered by the identified international and European rules and standards or triggered by technological and scientific developments.

2.4. Density values (Methods A/B/C)

2.4.1. International and European rules and standards

Actual density recorded in the BDN: MARPOL Annex VI Appendix V requires fuel suppliers to report fuel density (tested using ISO 3675:1998 or ISO 12185:1996).

Actual On-board density measurements are carried out according to ISO 650:1977: Relative density 60/60 degrees F (15°C) hydrometers for general purposes or ISO 12185:1996: Crude petroleum and petroleum products -- Determination of density -- Oscillating U-tube method.

Laboratory density is measured according to ISO 3675:1998: Crude petroleum and liquid petroleum products -- Laboratory determination of density -- Hydrometer method.

Another lab method is carried out with pycnometers (ISO 3838:1984).

Standard density values are given in Petroleum measurement tables (ISO 91-1 and 91-2:1991)

Density of LNG will be included in the BDN of LNG (IGF code).

LNG: here are two methods available

1. In-situ measurement with the help of a densitometer, however technological progress has not reached the stage where it is possible for a reliable apparatus to be available on board a LNG carrier under normal operating conditions.

2. Density is calculated based on the gas composition and temperature (ISO 6578 Klosek McKinley method or ISO 20765 – Part 2 Gerg 2004 equation). The gas composition is determined by a gas chromatographic analysis **in the lab** according to ISO 6974-6:2002: Natural gas -- Determination of composition with defined uncertainty by gas chromatography -- Part 6: Determination of hydrogen, helium, oxygen, nitrogen, carbon dioxide and C1 to C8 hydrocarbons using three capillary columns.

2.4.2. Technological and scientific developments

Density is not required when mass flow meters are used.

When fuel oil quality changes (e.g. to more residual fuel), the standard density tables require revision.

Scientific developments show that density could be measured in fuel test laboratories for all **four** monitoring methods.

2.4.3. Issues possibly covered by best Practices and Guidance

- **The relationship between fuel oil density, temperature and pressure is not linear. This has to be taken into account when converting measured volumes into mass at varying temperatures.**
- Guidance is needed in case of varying densities due to different measurement methods.
- **Test laboratories used by ships have solid procedures to provide evidence their value determination is in accordance with the international recognised standards (e.g. ISO 3675:1998).**
- The mixture of fuels made on board, bunkering on top, transferring from various tanks to the settling and then to service tanks, made necessary to check the density on board, and records of it to be kept on board as usually it is done.
- Density can also be affected by the return flow during fuel change over procedure. This operation is very common nowadays in SECAs, as in order to avoid cross contamination and not compliant risks, MGO

returning from Main Engine should be returned to HFO tanks, thus reducing its density, but density can be measured by the various options stated in Annex I.

2.4.4. Conclusions

Triggered by ISO 3675:1998 it is recommended that the option to measure fuel density in an accredited fuel test laboratory should also be included into Methods A, C and D.

2.5. Temperature correction (Methods A/B/C)

2.5.1. International and European rules and standards

There are standard petroleum measurement tables for reference temperatures of 15 °C and 20°C:

ISO 91-1:1992: Petroleum measurement tables - Part 1: Tables based on reference temperatures of 15 degrees C and 60 degrees F.

ISO 91-2:1991: Petroleum measurement tables - Part 2: Tables based on a reference temperature of 20 degrees C.

ISO 4268:2000: Petroleum and liquid petroleum products -- Temperature measurements -- Manual methods.

API, Manual of Petroleum Measurement Standards Chapter 7: Temperature determination. This includes static glass mercury thermometers, dynamic thermometers, portable thermometers and fixed automatic tank thermometers.

LNG: ISO 15970:2008 Natural gas -- Measurement of properties -- Volumetric properties: density, pressure, temperature and compression factor.

Info: The LNG temperature is measured by probes placed at different heights in the tanks. These probes are generally three- or four-wire platinum resistance temperature sensors, of which there are typically five per cargo tank. Temperature is determined in the liquid and the gas phase.

2.5.2. Technological and scientific developments

Mass flow meters do not require temperature correction.

2.5.3. Issues possibly covered by best Practices and Guidance

To be developed at a later stage.

2.5.4. Conclusions

No amendments are triggered by the identified international and European rules and standards or triggered by technological and scientific developments.

2.6. Pressure measurement (Methods A/B/C/D)

2.6.1. International and European rules and standards

Pressure is relevant for all methods A/B/C using LNG or other (liquefied) gaseous fuels and for method D for the CO_2 direct emission monitoring.

ISO 10976:2012: Refrigerated light hydrocarbon fluids - Measurement of cargoes on board LNG carriers.

LNG: ISO 15970:2008 Natural gas -- Measurement of properties -- Volumetric properties: density, pressure, temperature and compression factor.

2.6.2. Technological and scientific developments

2.6.3. Issues possibly covered by best Practices and Guidance

To be developed at a later stage.

2.6.4. Conclusions

Closed, no amendments triggered. Some comments are for Best Practices and Guidance.

2.7. Emission factors (Methods A/B/C/D)

For fossil fuels standard emission factors exist (see below). In the case of biofuels and alternative non-fossil fuels the monitoring plan should contain the methodologies for determining the emission factors, including the methodology for sampling, methods of analysis and a description of the laboratories used, with the ISO 17025 accreditation of those laboratories, if any.

2.7.1. International and European rules and standards

Default values:

- RESOLUTION MEPC.245 (66) - "2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships" contains a definition of the emission or conversion factor CF. CF is a non-dimensional conversion factor between fuel consumption measured in g and CO2 emission also measured in g based on carbon content (and IPCC on the net calorific values). Emissions factors are adjusted for fuel type (HFO, MDO, MGO, and LNG) and the sulphur content of the fuel being burned (Third IMO GHG Study 2014).
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2, Chapter 3 Mobile combustion, Table 3.5.2. Default, upper and lower (uncertainty) emission factors in kg CO2/TJ and Volume 2, Chapter 1, Table 1.4.
- Commission Regulation (EU) No°601/2012 Annex VI on the monitoring and reporting of greenhouse gas emissions refers to IPCC 2006. This also includes biofuels.
- EN 16258:2012: Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers).
- American Petroleum Institute (API) 2009 Table 4-3 page 150.

2.7.2. Technological and scientific developments

2.7.3. Impact on the regulation

The exclusive use of IMO emission factors instead of IPCC emission factors should be noted in Annex I of the MRV regulation.

2.7.4. Issues possibly covered by best Practices and Guidance

Use of Non-Standard emission factors:

In case of biofuels and alternative non-fossil fuels are used, the monitoring plan should contain the methodologies for determining the emission factors, including the methodology for sampling, methods of analysis and a description of the laboratories used, with the ISO 17025 accreditation of those laboratories, if any (Chapter 2.4.2 of the Monitoring Plan).

To be developed further.

2.7.5. Conclusions

The exclusive use of the latest IMO emission factors was concluded. These can be found in Resolution MEPC 245 (66) 2014: Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships.

2.8. Direct emission measurements/CO_2 analyzers (Method D)

2.8.1. International and European rules and standards

MARPOL Annex VI NOx Technical Code: Specification for analysers to be used in the determination of gaseous components of diesel engine emissions. CO_2 analysis shall be done with Non-Dispersive InfraRed (NDIR) absorption type analysers. Other analysers may, subject to approval by the Administration, be accepted if they yield equivalent results to that of NDIR absorption.

Calibration methods: MARPOL Annex VI Resolution 2 Appendix 4: Calibration and permissible deviation (uncertainty) of the analytical instruments.

Directive 2004/22/EC on measuring instruments (MID), ANNEX MI-010: Exhaust Gas Analysers (further details of the MID can be found in chapter 2.3.1).

2.8.2. Technological and scientific developments

So far CO_2 Analyzers could measure CO_2 on a dry basis, only. A new technological development enables to measure CO_2 also on a wet basis. This lead to amendments of the 2009 Guidelines for Exhaust Gas Cleaning Systems to reflect the new technology. (RESOLUTION MEPC.259 (68), Annex 1: Allowance of CO2 Analyzers measuring on a wet basis.) If CO_2 is measured on a wet basis the water content in the exhaust gas stream should also be determined in order to correct the readings to dry basis values.

Note: CO2 is measured as gas volume concentration in the exhaust gas volume: ppm (V/V). Conversion to mass is required (Chapter 2.9).

2.8.3. Issues possibly covered by best Practices and Guidance

To be developed at a later stage.

2.8.4. Conclusions

No need for amendments to Annex I.

2.9. Mass Flow calculation (Method D)

2.9.1. International and European rules and standards

MARPOL Annex VI, NOx Technical Code, Chapter 5
5.5.1: Direct measurement method
Direct measurement of exhaust gas flow by flow nozzles or equivalent metering system in accordance with a recognized international standard. There is a note that direct flow measurement is a difficult task.
5.5.2: Air and fuel measurement method.
5.5.3: Calculation of the exhaust gas mass flow (carbon-balance method).

The latter two methods include fuel consumption data.
Mass flow is calculated in kg/h, CO2 analyzers measure Volume in Volume. This requires conversion to mass.

In case the exhaust flow is measured directly by e.g. nozzles in the exhaust gas system (5.5.1), the NOx Technical Code requires the instrument to be approved according to a recognized international standard. In a Note it says that "Precautions shall be taken to avoid measurement errors which will result in emission value errors."

Directive 2004/22/EC (Annex MI-010) on measuring instruments: Defines the requirements that the devices have to satisfy including maximum permissible error based on accuracy classes and associated lambda calculation (air/fuel ratio).

2.9.2. Technological and scientific developments

Normally the air/fuel ratio serves as basis for the mass flow calculation. However, this method is not suitable for diesel engines, as they use excess air.

As two of the three mass flow calculation methods require fuel consumption data, there will be a link to the other methods on measurement of fuel consumption. This way method D will fall back in most cases to methods A/B/C.

2.9.3. Issues possibly covered by best Practices and Guidance

To be developed at a later stage.

2.9.4. Conclusions

No need for amendments to Annex I.

2.10. Uncertainty of determination of fuel consumption and CO_2 emissions

According to Article 3 (k) of the EU MRV Regulation, 'uncertainty' means a parameter, associated with the result of the determination of a quantity, that characterises the dispersion of the values that could reasonably be attributed to the particular quantity, including the effects of systematic as well as of random factors, expressed as a percentage, and describes a confidence interval around the mean value comprising 95 % of inferred values taking into account any asymmetry of the distribution of values".

The level of uncertainty is determined by two different concepts which are accuracy and precision. Accuracy is defined as the proximity of measured values in relation to the actual value. Precision describes the proximity of the measurements with the same quantity and under the same conditions, in other words, the standard deviation of the average.

The MRV Regulation requires that the monitoring plan as well as the annual emission reports needs to contain information on the level of uncertainty of the monitoring method used (Annex I; Article 11 (3) (c)). Furthermore, according to Article 6 (3) (f) (iv), the monitoring plan needs to establish a procedure to ensure that the total uncertainty of fuel measurements is consistent with requirements of the Regulation.

The Regulation does not set quantitative requirements for the acceptable level of uncertainty. In principle, such requirements could be introduced if reference could be made to relevant international and European rules and standards or technological and scientific developments.

Verifiers are required to check if the level of uncertainty of the monitoring method used is specified and consistent.

2.10.1. International and European rules and standards

ISO 5725-1: 1994/Cor. 1: 1998, Accuracy (trueness and precision) of measurement methods and results – Part 1: General principles and definitions, Technical Corrigendum 1.

ISO 5725-2: 1994, Accuracy (trueness and precision) of measurement methods and results – Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method.

Under development, finalization expected in summer 2016:
ISO 19030: Ships and marine technology -- Measurement of changes in hull and propeller performance -- Part 1: General principles, Part 2: Default method and Part 3: Alternative Methods.

2.10.2. Technological and scientific developments

The state of the art of uncertainty of determination of fuel consumption and CO_2 emissions is described in relevant studies (see section 2.10.4). However, no relevant technological and scientific developments have been identified.

2.10.3. Impact on the regulation

As no relevant international and European rules and standards or technological and scientific developments could trigger amendments to Annex I, it is suggested to provide guidance on expected levels of uncertainty for the different monitoring methods including default values which could be applied in the monitoring plans.

2.10.4. Issues possibly covered by best practices and guidance

- Indications for the level of uncertainty regarding Bunker delivery notes (BDNs) and regular stock-takes of fuel tanks. The BDN is out of the ships boundary and can therefore not be influenced by the ship operator. The uncertainty of BDNs together with regular stock-takes of fuel tanks has been reported to be up to ±5% (CE-Delft, 2013).

- Indications for the level of uncertainty regarding fuel tank readings (e.g. uncertainty of on-board measurement systems provided by ship manufacturers' specifications or by the manufacturer of the measurement system, calibration certificates of measurement systems). Uncertainties of electronic fuel tank readings have been reported to be ±5% and 2 – 5%. (CE-Delft, 2013 and ECOFYS, 2014, respectively). In the ECOFYS study manual tank gauging was regarded as limited up to very inaccurate.

- Indications for the level of uncertainty regarding fuel flow measurements (e.g. uncertainty of on-board measurement systems provided by ship manufacturers specifications or by the manufacturer of the measurement system, certificates of routine checks of the certification and operation of on-board measurement systems as checked by the competent port authority as part of Port State Control, calibration certificates of measurement systems, national laws requiring satisfaction of uncertainty thresholds in fuel measurements). Uncertainty is estimated to be from 0.1 – 3.0%, depending on the flow meter technology (ECOFYS, 2014).

- Indications for the level of uncertainty regarding emission measurements (e.g. uncertainty of on-board measurement systems provided by ship manufacturers' specifications or by the manufacturer of the measurement system, calibration certificates of measurement systems). CE Delft (2013) reported an uncertainty range of ±2%.

Sources for the development of documents on best practices and guidance:

- MEPC 68/INF.3 "Goal-based approach to fuel and CO2 emissions monitoring – uncertainty considerations"

- Ecofys report (2014) on Maritime transport greenhouse gas data collection and management

- CE Delft 2013, Monitoring of bunker fuel oil consumption

2.10.5. Conclusions

No need for amendments to Annex I.

2.11. Summary for Monitoring of CO_2 Emissions

2.11.1. Identified issues for best practice and guidance

Based on the discussions at the ESSF sub-group MRV meetings and written comments on the working papers, a number of issues and areas of concern have been identified, which did not trigger amendments to Annex I, but are relevant for possible best practice and guidance documents. These best practice and guidance documents could be developed at a later stage to facilitate implementation and unified interpretation of the MRV regulation.

Regarding Method A (BDN and regular stock-takes of fuel tanks), guidance will be needed especially for LNG carriers, using boil-off gas as fuel. Ships using fuel oil will need guidance of how to take the sludge content in the fuel into account. For the regular stock-takes of fuel tanks in method A and fuel tank readings (Method B) guidance is needed for cases of electronic tank reading equipment failure and how to deal with inaccuracies caused by curved tanks, internal structures of tanks and the ships trim and heel.

For Method C (fuel flow meters) areas for best practice and guidance are related to equipment failure, return of fuel from the engines to the tanks and leakage of fuel pumps.

Density is regarded as most relevant for all methods and requires a lot of guidance related to mixing of fuels on board, return flow densities, and the non-linear relationship between density and temperature. Temperature and pressure do not require much guidance, however, these parameters are most relevant for the determination of the density and some issues will be identified in future.

Direct emission measurements/CO_2 analyzers and the related mass flow calculation or measurement (Method D) are regarded as not reliable and expensive. As a consequence, this method will probably only be applied on those ships using exhaust gas cleaning systems, which require Type Approval anyway. Possibly some issues for best practice and guidance will be identified at a later stage.

The determination of uncertainty of fuel consumption and CO_2 emission measurements will require a lot of guidance for all monitoring methods. Especially, when monitoring methods are combined, the impact on uncertainty has to be regarded in detail. However, input from stakeholders regarding fuel consumption measurements onboard of ships is required to gain experience with the different monitoring methods, to verify the uncertainties claimed by manufacturers of measurement equipment and to quantify the impact of the human error.

2.11.2. Summary of conclusions and recommendations for amendments to Annex I and II

The room for amendments to Annex I and II is very limited by the MRV Regulation and can only be triggered by new scientific or technological developments or European and international standards. Most methods do not require amendments to the annexes of the MRV regulation. Only the associated measurement of density and the emission factor initiated amendments.

Regarding the density measurement, it is recommended that the option to measure fuel density in an accredited fuel test laboratory should also be included into Methods A, C and D, as currently the lab measurement is only included in method B.

Further, it was concluded to exclusively use the latest IMO emission factors, instead of the IPCC emission factors.

3. *Key elements with regard to monitoring other relevant information*

3.1. *Distance travelled*

The Regulation specifies when monitoring on a per voyage basis, the following parameters amongst others shall be monitored for each ship and for each voyage to or from an EU port: port of departure and port of arrival including the date and hour of departure and arrival, amount of fuel consumed, distance travelled and time spent at sea. The Regulation goes similarly when indicating the monitoring parameters relevant on an annual basis.

'Voyage' is defined in the regulation as '*any movement of a ship that originates from or terminates in a port of call and that serves the purpose of transporting passengers or cargo for commercial purposes'*. A 'port of call' is defined as *'the port where a ship stops to load or unload cargo or to embark or disembark passengers'*. The regulation distinguishes between ships on a voyage and 'ships at berth' and requires ships to monitor fuel separately for both situations. A 'ship at berth' is defined as '*a ship which is securely moored or anchored in a port falling under the jurisdiction of a Member State while it is loading, unloading or hotelling, including the time spent when not engaged in cargo operations'*.

During the first meeting of the ESSF subgroup on MRV, as well as in many written stakeholder comments, it became apparent that there is a need to further refine or determine the way to calculate port of departure and port of arrival information as these are the moments where voyage begins and ends. This will influence the calculations of fuel consumption and related emissions, time at sea, and distance travelled.

3.1.1. *International and European rules and standards*

IMO Assembly Resolution A.916(22) – 'guidelines for the recording of events related to navigation' requires that for each voyage, records must be kept so that 'a complete record of the voyage' can be restored. This is included in Annex 22 of Solas chapter V. Solas does not prescribe *how* distance should be measured but it is clear that when a complete record of a voyage can be restored, the distance over ground can be calculated.

The EEOI guidelines define 'distance sailed' as 'the actual distance sailed in nautical miles (deck log-book data) for the voyage or period in question.' ('voyage' being defined as 'the period between a departure from a port to the departure from the next port' while acknowledging that 'alternative definitions of a voyage could also be acceptable.').

The Convention on the International Regulations for Preventing Collisions at Sea, (COLREG) has a definition for when a ship is 'underway'. Rule 3 *(i)* states: 'The word "underway" means that a vessel is not at anchor, or made fast to the shore, or aground.'

It is common practice in shipping to record in the ship log when a ship is 'Full Away on Passage (FAOP)' and the time and location of the 'End of Passage (EOP)'. Passage (or "sea passage") is the phase of a voyage between the seaward limits of pilotage waters at the ports or places of departure and destination.

The VTMIS directive (2002/59/EC) requires ships to inform ports about the estimated time of arrival at the port of destination or pilot station.

3.1.2. Technological and scientific developments

The Intersessional meeting of the MEPC Working Group on Further Technical and Operational Measures for Enhancing Energy Efficiency, held in London from 9 – 11 September 2015, discussed a global data collection system. One of the data elements to be collected is 'distance travelled', and the Intersessional meeting agreed to recommend a berth to berth definition for this.

3.1.3. Impact on the regulation

In line with the relevant definitions provided by the MRV Regulation, distance could be calculated from berth in one port to berth in another for the following reasons:

- The ultimate objective of the MRV is to have a comprehensive view of EU-related emissions and other relevant information (as a first step with a view to include maritime emissions in the EU commitment). The Regulation requires ships to monitor and report emissions during voyages and also separately when at berth. Therefore, voyages coverage should be comprehensive both of information when at sea and when in EU ports.

- A pilot station or the point where the sea passage starts or ends is not the place where the voyages ends as this is determined by the purpose of transporting cargo or passengers not loaded or unloaded yet and hence does not fit the definition of 'voyage' in Article 3 of the regulation.

- Ships are required to monitor 'time spent at sea' which, as specified in Annex II, A.1 (a) 'shall be calculated based on port departure and arrival information and shall exclude anchoring' (Annex II A 1 a) Ships are also required to monitor distance which may be either the most direct route or on the real distance travelled. Moreover, the efficiency indicators in the Regulation are 'the annual average fuel consumption and CO_2 emissions per distance travelled of voyages' and 'the annual average fuel consumption and CO_2 emissions per distance travelled and cargo carried on voyages' (Article 21.2(e) and (f)).

- This means that the time and distance parameters shall relate to voyages as different from activities 'at berth' when the ship 'securely moored or anchored in a port falling under the jurisdiction of a Member State while it is loading, unloading or hotelling, including the time spent when not engaged in cargo operations ', defined by Art 3. (n)

- It is logical that the definitions for the beginning and end of a voyage determine the way both 'distance travelled' and 'time spent at sea' are to be calculated. In this perspective, when a ship drops anchor at the pilot station, the time at anchor is not part of the voyage.

- This means that the EEOI definition is not suitable for the purpose of this regulation, as it includes for example anchoring at a pilot station.

- The COLREG definition of 'underway' is suitable but impracticable as it is, for example, not clear whether a movement from the pilot station to a berth, or from one berth to another in the same port, would constitute a new voyage, or an extension of the voyage at sea, or yet something else.

- Defining a voyage as the movement from berths of port of departure to berth of port of arrival allows ships to use log book information to calculate time and distance. It can also be easily verified.

The 'berth-to-berth' concept could be specified in Annex II, section A, point 1. (a).

3.1.4. Need for further guidance and best practices

A need for guidance has been identified for the following situations.

- A laden ship makes a detour with the sole purpose to bunker. Should the distance of the detour be included, taking into account Article 3 of the regulation?[1]

- A ship is at anchor outside a port, and goes into the port with the sole purpose to refuel. Should the distance between the place of anchorage and the port be counted as distance sailed, taking into account Article 3 of the regulation?

- Should distance spent drifting be counted as distance sailed?

- Should moves out of port for cargo tank cleaning with return to the port for cargo operations be counted as distance sailed?

- Should distance be measured either through the water or over ground?

[1] Article 3 (b) 'port of call' means the port where a ship stops to load or unload cargo or to embark or disembark passengers; consequently, stops for the sole purposes of refuelling, obtaining supplies, relieving the crew, going into dry-dock or making repairs to the ship and/or its equipment, stops in port because the ship is in need of assistance or in distress, ship-to-ship transfers carried out outside ports, and stops for the sole purpose of taking shelter from adverse weather or rendered necessary by search and rescue activities are excluded; (c) 'voyage' means any movement of a ship that originates from or terminates in a port of call and that serves the purpose of transporting passengers or cargo for commercial purposes;

3.2. Total time spent at sea

3.2.1. International and European rules and standards

IMO Assembly Resolution A.916(22) – 'guidelines for the recording of events related to navigation' requires that for each voyage, records must be kept so that 'a complete record of the voyage' can be restored. This is included in Annex 22 of Solas chapter V. Solas does not prescribe *how* time should be measured but it is clear that when a compete record of a voyage can be restored, the time of departure from a port and the time of arrival in another port are logged and hence the total time spent at sea can be calculated.

The EEOI guidelines define 'voyage' as 'the period between a departure from a port to the departure from the next port' while acknowledging that 'alternative definitions of a voyage could also be acceptable'. This means that the 'total time spent at sea' is different than the voyage-time, since the time in port is not included. It is important to note that the term 'voyage' is defined in Article 3 (c) of the MRV Regulation which is outside the scope of this concept paper.

The Convention on the International Regulations for Preventing Collisions at Sea, (COLREG) has a definition for when a ship is 'underway'. Rule 3 *(i)* states: 'The word "underway" means that a vessel is not at anchor, or made fast to the shore, or aground.'

It is common practice in shipping to record in the ship log when a ship is 'Full Away on Passage (FAOP)' and the time and location of the 'End of Passage (EOP)'. Passage (or "sea passage") is the phase of a voyage between the seaward limits of pilotage waters at the ports or places of departure and destination.

The VTMIS directive (2002/59/EC) requires ships to inform ports about the estimated time of arrival at the port of destination or pilot station.

The Intersessional meeting of the MEPC Working Group on Further Technical and Operational Measures for Enhancing Energy Efficiency, held in London from 9 – 11 September 2015, discussed a global data collection system. One of the data elements to be collected is 'service hours', and the Intersessional meeting agreed to recommend a definition of 'hours not at berth'.

3.2.2. Technological and scientific developments

Not applicable

3.2.3. Impact on the regulation

Time spent at sea should be calculated on the same basis as distance travelled. **Error! Reference source not found.**.

3.2.4. Need for further guidance and best practices

A need for guidance has been identified for many of the same situations as mentioned in 3.1.4.

3.3. Amount of cargo – passenger ships

The MRV regulation does not clearly define ‘passenger ships’. During the first meeting of the ESSF subgroup on MRV, as well as in many written stakeholder comments, it became apparent that there is a need for a clear definition of a passenger ship to distinguish it from a Ro-Ro ship, which need to monitor different cargo parameters.

3.3.1. International and European rules and standards

SOLAS defines a passenger ship as ‘a ship which carries more than twelve passengers’.

StatCode 5 v1082 contains different definitions for ‘passenger (cruise) ships’, ‘passenger/ro-ro cargo ships’, as well as a number of other ships with the ability to take passengers on board (e.g. general cargo/passenger ships).

3.3.2. Technological and scientific developments

Not applicable

3.3.3. Stakeholder comments

From the stakeholder comments, there appear to be four main ship types that carry passengers:

i. Cruise ships

ii. Pure passenger ships, carrying passengers on relatively short trips, which means that these ships do not have extensive passenger facilities, i.e. no cabins as example

iii. RoRo Cruise ships with passenger cabins and associated large areas for relaxation and pleasure including restaurants and cafeterias (Cruise Ferry)

iv. Passenger ships carrying cargo, i.e. Ro-Ro passenger ships (RoPax)

The first two categories do not carry cargo.

3.3.4. Impact on the regulation

Triggered by the SOLAS definition, ‘passenger ships’ could be defined as ‘ships that carry more than twelve passengers but not cargo’.

The other ships carrying passengers and cargo could be covered by the category 'Ro-Ro passenger ships' which is considered for the Implementing Act on cargo parameters.

3.4. Amount of cargo – ro-ro ships

3.4.1. International and European rules and standards

The EEOI guidelines prescribe the use of mass of the cargo for ro-ro ships.

The CEN standard EN 16258 (2012) is mentioned in REGULATION (EU) 2015/757.

3.4.2. Technological and scientific developments

Not applicable

3.4.3. Impact on the regulation

Triggered by the EEOI guidelines and the CEN standard EN 16258 (2012), cargo – ro-ro ships should have the option to monitor and report the actual cargo mass, in addition to 'the number of cargo units (trucks, cars, etc.) or lane-metres multiplied by default values for their weight'.

3.5. Amount of cargo – container ships

3.5.1. International and European rules and standards

The 39th session of the Maritime Safety Committee (MSC) of the IMO (14 to 23 May 2014) approved the *Guidelines regarding the verified gross mass of a container carrying cargo*, and issued MSC.1/Circ.1475, which contains these guidelines.

The main principle of the guidelines is that the shipper shall inform the master of a ship about the verified gross mass of a packed container in writing and prior to loading a container. Hence, for ships to which SOLAS Chapter VI applies, masters know the weight of the packed containers on board.

3.5.2. Technological and scientific developments

Not applicable

3.5.3. Impact on the regulation

The current text in Annex II reads 'for container ships, cargo carried shall be defined as the total weight in metric tonnes of the cargo or, failing that, the amount of 20-foot equivalent units (TEU) multiplied by default values for their weight. Where cargo carried by a container ship is defined in accordance with applicable IMO Guidelines or instruments pursuant to the Convention for the Safety of Life at Sea (SOLAS Convention), that definition shall be deemed to comply with this Regulation'. In view of the above, a specific reference to MSC.1/Circ.1475 could be inserted.

Annex 1: List of ISO standards

1. **ISO standard methods for determination of water content in petroleum products**

- ISO 3734:1997: Petroleum products -- Determination of water and sediment in residual fuel oils -- Centrifuge method.
- ISO 3735:1999: Crude petroleum and fuel oils -- Determination of sediment -- Extraction method.
- ISO 12937:2000: Petroleum products -- Determination of water -- Coulometric Karl Fischer titration method.
- ISO 9029:1990: Crude petroleum -- Determination of water -- Distillation method.
- ISO 9030:1990: Crude petroleum -- Determination of water and sediment -- Centrifuge method.
- ISO 9114:1997: Crude petroleum -- Determination of water content by hydride reaction -- Field method.
- ISO 6296:2000: Petroleum products -- Determination of water -- Potentiometric Karl Fischer titration method.

2. **Bunker delivery**

- ISO 13739:2010: Petroleum products -- Procedures for transfer of bunkers to vessels.

3. **Fuel tank readings**

- ISO 4512:2000: Petroleum and liquid petroleum products -- Equipment for measurement of liquid levels in storage tanks -- Manual methods.
- ISO 4512:2000: Petroleum and liquid petroleum products -- Equipment for measurement of liquid levels in storage tanks -- Manual methods.
- ISO 4266-2:2002: Petroleum and liquid petroleum products -- Measurement of level and temperature in storage tanks by automatic methods -- Part 2: Measurement of level in marine vessels.
- ISO 4266-5:2002: Petroleum and liquid petroleum products -- Measurement of level and temperature in storage tanks by automatic methods -- Part 5: Measurement of temperature in marine vessels.
- ISO 4269:2001: Petroleum and liquid petroleum products -- Tank calibration by liquid measurement -- Incremental method using volumetric meters.

4. **Density**

4.1 Actual density values determined by on-board measurement system

- ISO 650:1977: Relative density 60/60 degrees F (15°C) hydrometers for general purposes.
- ISO 12185:1996: Crude petroleum and petroleum products -- Determination of density -- Oscillating U-tube method.

4.2 Actual density values determined by Laboratory methods

- ISO 3675:1998: Crude petroleum and liquid petroleum products -- Laboratory determination of density -- Hydrometer method.
- ISO 3838:2004: Crude petroleum and liquid or solid petroleum products -- Determination of density or relative density -- Capillary-stoppered pycnometer and graduated bicapillary pycnometer methods.
- ISO 3993:1984: Liquefied petroleum gas and light hydrocarbons -- Determination of density or relative density – Pressure.

4.3 Standard density values

- ISO 91-1:1991: Petroleum measurement tables — Part 1: Tables based on a reference temperature of 15 degrees C.
- ISO 91-2:1991: Petroleum measurement tables — Part 2: Tables based on a reference temperature of 20 degrees C.

4.4 Temperature correction for density

- ISO 91-1:1992: Petroleum measurement tables -- Part 1: Tables based on reference temperatures of 15 degrees C and 60 degrees F.

- ISO 91-2:1991: Petroleum measurement tables -- Part 2: Tables based on a reference temperature of 20 degrees C.
- ISO 4268:2000: Petroleum and liquid petroleum products -- Temperature measurements -- Manual methods.

5. Fuel flow meters

- BS ISO 11631:1998: Measurement of fluid flow. Methods of specifying flowmeter performance.
- ISO 9200:1993: Crude petroleum and liquid petroleum products -- Volumetric metering of viscous hydrocarbons.
- ISO 4124:1994 Liquid hydrocarbons -- Dynamic measurement -- Statistical control of volumetric metering systems.
- ISO 2714:1980: Liquid hydrocarbons -- Volumetric measurement by displacement meter systems other than dispensing pumps.
- ISO 2715:1981: Liquid hydrocarbons -- Volumetric measurement by turbine meter systems.

5.1 Accuracy of fuel flow meters

- ISO-5168:2005 "Measurement of fluid flow – Procedures for the evaluation of uncertainties.

5.2 Calibration (proving) methods for flow meters

- ISO 7278-1:1987: Liquid hydrocarbons -- Dynamic measurement -- Proving systems for volumetric meters -- Part 1: General principles.
- ISO 7278-2:1988: Liquid hydrocarbons -- Dynamic measurement -- Proving systems for volumetric meters -- Part 2: Pipe provers.
- ISO 7278-3:1998: Liquid hydrocarbons -- Dynamic measurement -- Proving systems for volumetric meters -- Part 3: Pulse interpolation techniques.
- ISO 7278-4:1999: Liquid hydrocarbons -- Dynamic measurement -- Proving systems for volumetric meters -- Part 4: Guide for operators of pipe provers.
- ISO 8222:2002: Petroleum measurement systems -- Calibration -- Temperature corrections for use when calibrating volumetric proving tanks.