ANNEX 18

RESOLUTION MEPC.416(84)
(adopted on 1 May 2026)

GUIDELINES FOR CONTINUOUS EMISSION MONITORING SYSTEMS (CEMS) USED TO QUANTIFY METHANE (CH_4) AND/OR NITROUS OXIDE (N_2O) EMISSIONS FROM MARINE DIESEL ENGINES

THE MARINE ENVIRONMENT PROTECTION COMMITTEE

RECALLING Article 38(a) of the Convention on the International Maritime Organization concerning the functions of the Marine Environment Protection Committee conferred upon it by international conventions for the prevention and control of marine pollution from ships,

RECALLING ALSO that, at its eightieth session, it adopted, by resolution MEPC.377(80), the *2023 IMO Strategy on reduction of GHG emissions from ships* (2023 IMO GHG Strategy) setting out the levels of ambition for the international shipping sector in reducing GHG emissions,

NOTING that the 2023 IMO GHG Strategy provides that in order to support the global availability and uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources, the Organization may consider and analyse measures to address emissions of methane (CH_4) and nitrous oxide (N_2O),

HAVING CONSIDERED, at its eighty-fourth session, draft guidelines for continuous emission monitoring systems (CEMS) used to quantify methane (CH_4) and/or nitrous oxide (N_2O) emissions from marine diesel engines,

1 ADOPTS the *Guidelines for continuous emission monitoring systems (CEMS) used to quantify methane (CH_4) and/or nitrous oxide (N_2O) emissions from marine diesel engines*, as set out in the annex to the present resolution;

2 INVITES Member States to encourage shipowners, ship operators, shipbuilders, marine diesel engine manufacturers and any other interested groups to voluntarily apply these Guidelines when undertaking measurements, calculation and reporting of CH_4 and/or N_2O emission values from marine diesel engines;

3 ALSO INVITES Member States to share data gathered in applying these Guidelines to future sessions of the Committee;

4 AGREES to keep these Guidelines under review in light of the experience gained with their implementation.

ANNEX

GUIDELINES FOR CONTINUOUS EMISSION MONITORING SYSTEMS (CEMS) USED TO QUANTIFY METHANE (CH_4) AND / OR NITROUS OXIDE (N_2O) EMISSIONS FROM MARINE DIESEL ENGINES

TABLE OF CONTENTS

1 Introduction

1.1 The purpose of these Guidelines is to provide a uniform framework for the onboard measurement and mass basis quantification of the emissions of methane (CH_4) and/or nitrous oxide (N_2O) emitted from marine diesel engines by means of a continuous emission monitoring system (CEMS). As such, these are the CH_4 or N_2O emissions to the atmosphere resulting from the particular fuel oil or, in the case of dual-fuel operation, the fuel oils and mix ratio in use at the time of measurement. Additionally, these Guidelines provide a framework for the certification of a CEMS by the Administration.

1.2 These Guidelines are divided into sections as shown in table 1.

Table 1: Section Topics

Section	Topic
2	Exhaust gas measurement and associated requirements. In addition to CH_4 and/or N_2O, this section also covers the measurement of other exhaust gas components as may be required to be measured.
3	Determination of exhaust gas flow as required in order to quantify by mass the emission rate of CH_4 and / or N_2O. Two options are provided: .1 carbon balance method. This is as given in appendix VI of the NO_x Technical Code 2008 (NTC 2008). The output from the given calculation procedures is the mass flow rate (wet) of the exhaust gas. .2 direct measurement method. This involves the measurement of the velocity of the exhaust gas. From that the volumetric exhaust gas flow rate (wet) at reference conditions is determined.
4	Intermediate and final calculations which are used to give the mass basis emission rate of CH_4 and / or N_2O over a time period referred to in these Guidelines as the reporting interval.
5	Data recording and storage requirements associated with the operation of the CEMS. It also covers the scope of the reports that the data recording device should be capable of generating.
6	Documentation requirements: For each CEMS there should be an Administration approved CEMS file detailing the system and the operating procedures to be followed together with related requirements covering the functionality of the CEMS and verification that the data generated is reliable. Additionally, a CEMS record book should be maintained on board, detailing all maintenance and servicing actions undertaken in respect of the CEMS together with details of the actions taken to resolve recorded fault conditions.
7	Certification. This covers the initial and annual surveys which should be undertaken together with the form of the CEMS Certificate to be issued.

1.3 Terms, abbreviations and definitions

1.3.1 Unless otherwise specified, the terms and definitions used in this Guideline have the same meaning as those set forth in MARPOL Annex VI, as amended, and in the NTC 2008.

1.3.2 References to the NTC 2008 mean the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines, adopted by resolution MEPC.177(58), as amended.

1.3.3 Abbreviations, as given in table 2, and definitions as given in table 3, are applied in these Guidelines.

Table 2: Abbreviations

General	
CEMS	Continuous emission monitoring system
NTC 2008	NO_x Technical Code 2008, as amended
UTC	Universal Time Coordinated
Chemical compounds and related terms	
CH_4	Methane
$C_{slip\text{-}CH4}$	Methane slip as mass % of methane based gas fuel used
C_2H_6	Ethane
CO_2	Carbon dioxide
CO	Carbon monoxide
H_2O	Water vapour
HC	Hydrocarbons
N_2O	Nitrous oxide
NMHC	Non-methane hydrocarbons
Abbreviations for analysers which may be used for the measurement of emissions	
ECS	Electrochemical sensor
FTIR	Fourier transform infrared
HFID	Heated flame ionization detector
LIA	Laser infrared analyser including TDLAS
MS	Mass spectrometry
NDIR	Non-dispersive infrared
NDUV	Non-dispersive ultraviolet
NMC	Non-methane cutter
PMD	Paramagnetic detector
TDLAS	Tunable diode laser absorption spectroscopy
ZRDO	Zirconium dioxide sensor

Table 3: Definitions

Applicant	The entity which presents a CEMS for certification in accordance with these Guidelines.
Continuous emission monitoring system (CEMS)	A system for the ongoing measurement, quantification and reporting of CH_4 and / or N_2O emissions from one or more installed marine diesel engines in service. A CEMS includes the other measurement and supporting devices necessary to achieve those objectives. A CEMS may be in operation only under certain engine conditions as given by 6.1.1.3.
Extractive sampling system	System which extracts a representative sample flow from the exhaust gas stream of the monitored marine diesel engine and transfers that sample to the exhaust gas analysers which form part of a CEMS.
In situ	Exhaust gas analyser arrangements installed on the exhaust duct which directly measure one or more of the emission components of the exhaust gas stream from the monitored marine diesel engine.
Maintenance	Activities scheduled, or condition indicated, undertaken on board by ship's staff in order that the CEMS and its component parts continues to function as intended and to meet the requirements of these Guidelines. Maintenance does not include repair periods when the required CEMS output would not be available owing to malfunction or failure of a system component.
Methane based gas fuel	Fuel oils such as natural gas, biomethane or e-methane, of which the principal component is methane. Typically supplied and stored onboard in a cooled and/or pressurized condition. It does not include such as ″gas-to-liquid″ (GTL) liquid fuel oils.
Reporting interval (RI)	The time interval, as given by 5.14, in hours, over which the emission of CH_4 and / or N_2O, in kg, is reported by the CEMS. The overall emission of CH_4 and / or N_2O over a required period of CEMS operation being the sum of all the reporting interval values over that period.
Servicing	Specialist services periodically undertaken in order that the CEMS and its component parts continues to function as intended and to meet the requirements of these Guidelines.

2 Exhaust gas measurement

2.1 In situ analysers, or the sample probe of an extractive sampling system, should be located on the exhaust duct at a position such that the exhaust gas being analysed or sampled is representative of the exhaust gas as emitted to the atmosphere from the marine diesel engine being monitored. That location should be at least 0.5 m or 3 pipe diameters, whichever is the greater, upstream of the exit to atmosphere. Where HFID + NMC is used to measure CH_4, the requirements of 5.9.3.2 of the NTC 2008 should be met.

2.2 Exhaust gas streams from different engines should not be combined upstream of the in situ analysers or the extractive sampling position.

2.3 The exhaust gas should be analysed, as required, with instruments operating on the respective listed principles as given in table 4.

Table 4: Exhaust gas reference measurement methods

CH_4	HFID + NMC, FTIR, LIA
N_2O	FTIR, LIA, NDIR, NDUV
CO_2	NDIR
HC	HFID
H_2O	FTIR, MS, LIA
O_2	PMD, ECS, ZRDO[1]

2.4 Exhaust gas analysers operating on principles other than those given by 2.3 may be accepted, subject to the approval of the Administration, provided they yield equivalent results to those of analysers operating on the listed reference operating principles when used with exhaust gas of the compositions to be measured.

2.5 The analyser specifications and performance should meet the requirements of 1.6, 1.7, 1.8, 1.9 and 1.10 of appendix III of the NTC 2008.

2.6 The selected analyser range should be such that the measured emission value is within 15% - 100% of that range. Analysers should have the capability to automatically switch ranges as necessary in order to remain within 15% - 100% of the range applied according to the concentrations measured in which case the output signal to the data recording device should be duly scaled or so indicated.

2.7 As an alternative to the requirements of 2.6, the provisions of 1.4 of appendix III of the NTC 2008 may be applied as agreed to by the Administration.

[1] Where O_2 is to be measured in order to determine the dry / wet correction factor the analyser type should be ZRDO but should not be used for engines using a low-flashpoint fuel.

2.8 Analysers should be arranged, installed, operated, maintained and serviced in accordance with the respective manufacturers' recommendations in order to meet the requirements of 1.7, 1.8, 1.9 and 1.10 of appendix III of the NTC 2008, and section 5 and, if applicable, section 8 or 9 of appendix IV of the NTC 2008 together with, if relevant, appendix 3 of these Guidelines.

2.9 Where used, the HFID should be calibrated and spanned using a methane in air gas mixture of the appropriate concentration.

2.10 If used, an NMC should be arranged, installed, operated, maintained and serviced in accordance with the manufacturer's recommendations in order to meet the requirements of appendix 4 of these guidelines.

2.11 Pure, calibration and span gases, as required, should comply with section 2 of appendix IV of the NTC 2008. Declared concentrations should be traceable to national and/or international standards. Calibration and span gases should be in accordance with the analyser manufacturer's recommendations.

2.12.1 C_2H_6, where required for NMC efficiency verification, should be as a C_2H_6 and purified synthetic air mixture.

2.12.2 N_2O calibration and span gases should be as a N_2O and purified nitrogen mixture.

2.12.3 H_2O calibration and span gas should be as a H_2O and purified synthetic air or nitrogen mixture or an alternative approach as agreed to by the Administration.

2.13 Analysers should have an ongoing zero and span check capability in order to periodically verify that the zero or span drift has not exceeded 2% of full scale of the selected range. In order to avoid the zero or span drift exceeding 2% full scale of the range used, the zero and/or span values should be capable of being reset as required. Analyser span gases should be between 80% to 100% of the analyser scale being spanned.

2.14 Alternative arrangements to those required by 2.13 may be accepted, subject to the approval of the Administration, provided that the resulting zero or span drift is verified as being no more than 2% full scale of the range selected.

2.15 Extractive sampling systems

2.15.1 For each engine to be monitored the exhaust gas sample probe, of either a centreline or multi-hole – closed-end design, should extract from a zone covering 10% to 90% of the exhaust duct internal diameter.

2.15.2 The sample transfer line should be constructed of suitable material and maintained at a temperature sufficient to prevent the deposition or condensation of exhaust gas components.

2.15.3 The gas sampling system should have an ongoing procedure to periodically verify that the sampling system meets the requirements of section 4 of appendix IV of the NTC 2008 in respect of ingress leakage.

2.15.4 The exhaust gas sample as analysed may be in a wet or dry condition according to the design and operating arrangements of the analysers which are to be used. A gas-drying device, if used, should have minimal effect on the composition of the gases to be measured and should meet the requirements of 1.2.13 of appendix III of the NTC 2008. Chemical dryers should not be used.

2.15.5 Where an analyser is used to process exhaust gas samples from more than one engine's exhaust duct, a flushing arrangement should be provided of sufficient duration to ensure that the gas stream as analysed and reported to the data recording device as required by 5.5 is representative of the exhaust gas emitted from the engine to which the analyser's output signal will be assigned.

3 Determination of exhaust gas flow rate

3.1 Where required, the exhaust gas flow rate should be determined by either:

.1 carbon balance method; or

.2 direct measurement method.

3.2 Carbon balance method

3.2.1 The measured values required for the carbon balance method, as given by appendix VI of the NTC 2008, should be obtained in accordance with the requirements of this paragraph.

3.2.2 The exhaust gas CO_2 concentration should be measured in accordance with the requirements of section 2 as applicable. The background, ambient CO_2ad value should be set to 0.03%.

3.2.3 It is not required to measure the exhaust gas CO concentration and in the calculation procedure CO should be set to zero.

3.2.4 Where the engine operates on a methane based gas fuel, the CH_4 concentration should be measured and used in place of HC in the calculation procedure if HC is not separately measured in accordance with 1.2.9 and 3.3 of appendix III of the NTC 2008. Where the CEMS is to report only N_2O emissions to the atmosphere it is not required to measure HC and in the calculation procedure HC should be set to zero.

3.2.5 Liquid fuel mass basis composition, in terms of carbon, hydrogen and nitrogen, may be obtained by:

.1 analysis of a representative sample of the liquid fuel used;

.2 use of default values as given in table 5 for petroleum-derived fuel oils; or

.3 in the case of liquid fuels not covered by table 5, use of default values as agreed to by the Administration.

Table 5: Petroleum-derived fuel oils: default composition values

Sulphur content:	Carbon %	Hydrogen %	Nitrogen %
≤ 0.10 %	87.5 %	12.44 %	0.0 %
> 0.10 - ≤ 0.50 %	87.0 %	12.35 %	0.2 %
> 0.50 %	85.0 %	11.90 %	0.4 %

3.2.6 Methane based gas fuel mass basis composition, in terms of carbon, hydrogen and nitrogen, may be obtained by:

.1 analysis of a representative sample of the gas fuel used; or

.2 calculation from the cargo certificate of quality, in the case of boil-off gas, or the bunker delivery note, in the case of a supplied gas fuel on the basis of:

Carbon % = $(100 – N_2\ \%) \cdot 0.75$
Hydrogen % = $(100 – N_2\ \%) \cdot 0.25$

3.2.7 The absolute humidity value, H_a or H_{sc} as appropriate, should be determined in accordance with section 5.12.3.2.1 of the NTC 2008 for H_a or 5.12.4.6 of the NTC 2008 for H_{sc}.

3.2.8 The liquid fuel mass net flow consumption rate of the monitored engine should be determined by direct measurement on either a mass flow or volume flow – temperature compensated basis.

3.2.9 As an alternative to the requirements of paragraph 3.2.8, where for a dual-fuel engine, the liquid fuel mass flow rate does not exceed 10% of the gas fuel flow rate, the engine builder's declared liquid fuel rates as given in the CEMS file, as agreed to by the Administration, may instead be used.

3.2.10 The gas fuel mass net flow consumption rate of the monitored engine should be determined by direct measurement on either a mass flow or volume flow – temperature and pressure compensated basis.

3.2.11 The engine performance and ambient condition monitoring equipment used to provide data for the carbon balance method should be installed and maintained in accordance with the respective manufacturers' recommendations such that the requirements of section 1.3 and table 3 or table 4 of appendix IV of the NTC 2008 are met in respect of the possible deviations.

3.3 Direct measurement method

3.3.1 In order to apply the direct measurement method, the following parameters should be measured:

.1 exhaust gas mean velocity (m/s)[2];

.2 exhaust duct relative pressure (kPa) at the position where .1 is measured;

.3 exhaust gas temperature (K) at the position where .1 is measured; and

.4 barometric pressure p_b (kPa).

3.3.2 The exhaust gas and ambient condition measurement devices used to provide data for the application of the direct measurement method should be installed and maintained in accordance with the respective manufacturers' recommendations such that the requirements of section 1.3 and table 3 or table 4 of appendix IV of the NTC 2008 are met in respect of the possible deviations.

[2] Guidance on the installation requirements for devices to measure exhaust gas velocity is provided in appendix 5 of these Guidelines.

3.3.3 Where there is an arrangement by which the exhaust gas stream from a monitored engine could bypass the exhaust velocity measurement point:

.1 whenever the CEMS is in operation, there should be a continuously operating monitoring system fitted to all such bypass arrangements. The monitoring system should be capable of detecting whether the bypass is not shut or is subject to leakage. The bypass monitoring system should be approved by the Administration; and

.2 where the bypass monitoring system as required by paragraph 3.3.3.1 detects that a bypass is not shut or is subject to leakage, a signal indicating that should be transmitted to the data recording device as a fault condition to be recorded under 5.12.

3.3.4 In order to assess whether the means used to measure the exhaust gas flow are within the permitted deviation as given by table 3 of appendix IV of the NTC 2008 at the time of installation and at intervals not exceeding 12 months thereafter or whenever the data screening as required by 4.4 or 4.12 indicates an validity issue, the values determined at four equally spaced loads across the used load range of the engine should be cross-checked by comparison with the application carbon balance method, as given by 3.2, at each of those load points. The CO_2 analyser and the other measurement equipment required to perform that carbon balance method check need not be permanently installed but are required to meet the requirements of section 2 as applicable.

3.3.5 An alternative procedure to the requirements of 3.3.4 in respect of exhaust gas flow rate verification may be used, subject to approval by the Administration, provided it can be so shown by that procedure that the exhaust gas flow rates across the used load range of the monitored engine are within the permitted deviation as given by table 3 of appendix IV of the NTC 2008.

4 Calculation procedures

4.1 The end point of the calculation procedures of this Guideline is to quantify, by weight (kg), the emission to the atmosphere of CH_4 and / or N_2O over a reporting interval (RI), as given by 5.14, at the time of measurement.

4.2 The calculation steps which are to be followed, as given by the CEMS file, may be undertaken offline or, to the extent required, may be automated and undertaken in real-time. In either case the same requirements apply to the processing of the measured, input and default - fixed data through to the required end value of CH_4 and / or N_2O emitted over the particular reporting interval as applied at the time of measurement.

4.3 The calculation procedure should include the following steps:

.1 screening of all measured and input data;

.2 alignment of device output signals, as applicable;

.3 intermediate calculations, as applicable;

.4 determination of CH_4 and / or N_2O, as required, emission quantity over the reporting interval; and

.5 review of outcomes of intermediate and CH_4 and / or N_2O emission quantity calculations.

4.4 Measured or input data screening

4.4.1 All measured and input data, as recorded in accordance with section 5, should be screened for validity prior to use in the calculation procedures.

4.4.2 The screening of each data item should be against an ongoingly developed expected value range for the fuel type and mix and engine load which should also take into account such aspects as ambient conditions and other potentially influencing factors in accordance with the procedure as given in the CEMS file. Guidance as to this screening procedure is provided in appendix 6. Where a measured or input value is found to be outside the expected range, it should be evaluated as to whether it is a valid, representative, value. If it is a valid value, even if outside the expected range, then it should be used in the calculation procedure as applied and comment covering that finding entered into the CEMS record book. If it is found not to be a valid value, then that finding and the determined reasons for the error together with the resolving action taken should be recorded under section 5.12 and in the CEMS record book.

4.4.3 The screening of measured data should also be used to filter out signal spikes which do not reflect the actual parameter being measured. Where such spikes are removed from the data prior to use in the calculation procedures, a comment covering that action should be entered into the CEMS record book.

4.5 Signal alignment

4.5.1 Owing to time lags through the engine, and any emission abatement device if fitted, together with potentially differing response times between the various measurement devices used, it may be necessary to align all data to a common time reference. This need for signal alignment should also be taken into account where an analyser is to monitor the exhaust gas emissions from more than one engine.

4.5.2 Where signal alignment is required, the procedure by which that is to be undertaken should be detailed in the CEMS file.

4.6 Intermediate calculation – dry / wet correction

4.6.1 Where an emission species is not measured on a wet basis it should be converted, as required, to a wet basis using one of the following methods:

4.6.2 Calculation of dry / wet correction factor

4.6.2.1 The dry / wet correction factor should be calculated in accordance with section 5.12.3 of the NTC 2008.

4.6.2.2 Measurement of CO_2 should be in accordance with the relevant requirements as given by section 2. CO is not required to be measured and should be taken as zero.

4.6.2.3 The carbon and hydrogen content values of the fuel or fuels as used should be obtained in accordance with paragraph 3.2.5 or 3.2.6, as appropriate.

4.6.2.4 Where $H_a \geq H_{sc}$, with H_{sc} as calculated in accordance with paragraph 5.12.4.6 of the NTC 2008, then H_{sc} should be used instead of H_a in the calculation.

4.6.2.5 If water or steam is added or injected into the fuel oil as is to be used, charge air, engine combustion chamber or exhaust gas stream prior to the measurement or sampling position, then the metered quantity so added or injected should also be taken into account when determining the applicable dry / wet correction factor using a procedure approved by the Administration. That procedure should be detailed in the CEMS file.

4.6.2.6 If the water content of the exhaust gas stream, as a product of the inlet air humidity and water formed by combustion, is reduced by exhaust gas duct arrangements or devices prior to the measurement or sampling position, then either sections 4.6.3 or 4.6.4 should instead be used.

4.6.3 Direct measurement of water content

4.6.3.1 Where the water vapour content of the exhaust gas stream is directly measured the analyser used should meet the relevant requirements of section 2.

4.6.3.2 The dry / wet correction factor from direct measurement:

$$k_{wr3} = (1 - c_{H2Ow}/100) \cdot 1.008$$

where:

c_{H2Ow} = measured water vapour concentration (%)

4.6.4 Indirect measurement of water content

4.6.4.1 Where the water vapour content of the exhaust gas stream is to be determined by the measurement of both the wet and dry concentrations of oxygen before and after the dryer unit that should be undertaken using a zirconium dioxide sensor meeting the requirements of section 2.

4.6.4.2 The dry / wet correction factor from indirect measurement:

$$k_{wr4} = O_2w/O_2d$$

where

O_2w = Measured O_2 concentration – wet basis (%)

O_2d = Measured O_2 concentration – dry basis (%)

4.7 Intermediate calculation – NMC CH_4 correction

4.7.1 Where the NMC methane efficiency is not 0 % and/or the NMC ethane efficiency is not 100 %, the corrected CH_4 concentration to be used in paragraphs 4.10.1 and 4.11.1 should be calculated as follows:

$$c_{CH4corr} = \frac{c_{HC}(wCutter) \cdot (1 - E_m) - c_{HC}(w/oCutter) \cdot (1 - E_e)}{E_e - E_m}$$

where:

c_{HC} (wCutter) = HC concentration with sample gas through NMC (ppmC1)

c_{HC} (w/oCutter) = HC concentration with NMC bypassed – i.e. usual HC reading (c_{HC}) (ppmC1)

E_m = NMC methane efficiency (see appendix 4)

E_e = NMC ethane efficiency (see appendix 4)

4.8 Intermediate calculation – exhaust gas mass flow rate by carbon balance

4.8.1 The calculation of the exhaust gas mass flow rate by the carbon balance method should be undertaken in accordance with the procedures as given by appendix VI of the NTC 2008.

4.9 Intermediate calculation – exhaust gas volume flow rate by direct measurement

4.9.1 The exhaust gas volume flow rate under reference conditions (101.3 kPa, 273 K) should be calculated as follows:

$$q_{vew} = \frac{v_n \cdot D^2 \cdot \pi \cdot 3600 \cdot P_{da} \cdot T_{ref}}{4 \cdot T_d \cdot P_{ref}}$$

where:

q_{vew} = exhaust gas volume flow rate at reference conditions (Nm^3/h)

v_n = mean velocity of exhaust gas (m/s)

D = internal diameter of exhaust duct at point of velocity measurement (m)

P_{da} = absolute pressure of exhaust gas in the duct = $P_{dr} + P_b$

P_{dr} = relative pressure of exhaust gas in duct (kPa)

P_b = barometric pressure (kPa)

T_{ref} = reference temperature: 273 (K)

T_d = temperature of exhaust gas at point of velocity measurement (K)

P_{ref} = reference pressure: 101.3 (kPa)

4.10 Intermediate calculation (CH_4 only) - direct calculation of the methane slip method

4.10.1 For the application of this method, methane slip % should be calculated as follows:

$$c_{slip\text{-}CH4} = \frac{CH_4\text{m}}{\frac{CO_2\text{m}}{GF\text{-}C_f + LF_{mf} \cdot LF\text{-}C_f} + CH_4\text{m}} \cdot 100$$

where:

$C_{slip\text{-}CH4}$ = methane slip (%)

CH_4m = CH_4 (mg/m^3)

= CH_4 (ppm) · 0.716

CO_2m = CO_2 (mg/m^3)

= CO_2 (%) · 10,000 · 1.964

Note: CH_4 (ppm) and CO_2 (%), as used above, are to be either both dry basis readings or both to the same wetness fraction. Where it is necessary to convert a dry basis reading to a wet basis then one of the Dry / Wet Correction options as given by section 4.6 should be used.

$GF\text{-}C_f$ = gas fuel carbon factor

= carbon % (from 3.2.6) · 0.03664

$LF\text{-}C_f$ = liquid fuel carbon factor

= carbon % (from 3.2.5) · 0.03664

LF_{mf} = liquid fuel mass fraction (to a precision of not less than three decimal places)

$$= \frac{\text{liquid fuel mass flow rate (kg/h)}}{\text{gas fuel mass flow rate (kg/h)}}$$

Note: For the purposes of these Guidelines a fuel which is not a methane based gas fuel should be regarded as a liquid fuel

4.10.2 The exhaust gas CH_4 and CO_2 concentrations should be measured in accordance with the requirements of section 2 as applicable.

4.10.3 The liquid fuel mass net flow consumption rate of the monitored engine should be determined by direct measurement on either a mass flow or volume flow – temperature compensated basis.

4.10.4 As an alternative to the requirements of paragraph 4.10.3, where, for a dual-fuel engine, the liquid fuel mass flow rate does not exceed 10% of the gas fuel flow rate, the engine builder's declared liquid fuel rates as given in the CEMS file, as agreed to by the Administration, may instead be used.

4.10.5 The gas fuel mass net flow consumption rate of the monitored engine should be determined by direct measurement on either a mass flow or volume flow – temperature and pressure compensated basis.

4.10.6 The fuel flow meters and other measurement devices to be used in the application of the direct calculation of methane slip method should be installed and maintained in accordance with the respective manufacturers' recommendations such that the requirements of section 1.3 and table 3 or table 4 of appendix IV of the NTC 2008 are met in respect of the possible deviations.

4.11 Determination of CH_4 and / or N_2O emission quantity over the reporting interval

4.11.1 The CH_4 and / or N_2O emission quantity (kg), to a precision of at least one decimal place, over a reporting interval, as given by 5.14, should be calculated, as applicable, from the data as recorded in accordance with section 5, as follows:

$q_{mgas} = u_{gas} \cdot c_{gas} \cdot q_{mew} \cdot RI / 1000$

$= w_{gas} \cdot c_{gas} \cdot q_{vew} \cdot RI / 1000$

$= C_{slip\text{-}CH4} \cdot m_{fg} \cdot RI / 100$

where:

q_{mgas} = mass of CH_4 or N_2O emitted to atmosphere over the reporting interval (kg)

u_{gas} = as given by appendix 2 of these guidelines

w_{gas} = as given by appendix 2 of these guidelines

c_{gas} = wet basis concentration of CH_4 corrected or N_2O (ppm)

Note: where a NMC is used the c_{gas} CH_4 value is the value as corrected by 4.7.1.

q_{mew} = exhaust gas mass flow rate (g/h) – 4.8.1

q_{vew} = exhaust gas volume flow rate at reference conditions (Nm^3/h) – 4.9.1

RI = reporting interval used at time of measurement (h) – 5.14

$C_{slip\text{-}CH4}$ = % CH_4 Slip – 4.10.1

m_{fg} = gas fuel mass flow rate (kg/h) – 4.10.5

4.11.2 In the case of CH_4 reporting, where the crankcase emissions from trunk piston engines are not led to the exhaust duct upstream of the CH_4 measurement or sampling point, the outcome of the quantification under 6.1.2.1.7.2 should be added to the outcome of paragraph 4.11.1.

4.12 Review of outcomes of intermediate and CH_4 or N_2O emitted quantity calculations

4.12.1 The outcomes of the intermediate and CH_4 or N_2O emitted quantity calculations should be screened for possible calculation errors.

4.12.2 The review of each calculated value should be against an ongoingly developed expected value range for the fuel type and mix and engine load which should also take into account such aspects as ambient conditions and other potentially influencing factors in accordance with the procedure as given in the CEMS file. Guidance as to this screening procedure is provided in appendix 6 of these guidelines. Where a calculated value is found to be outside the expected range it should be evaluated as to whether it is a valid calculated value. If it is a valid calculated value, then it should be retained. If it is found not to be a valid calculated value, then that finding and the determined reasons for that error, together with the resolving action taken, should be recorded under paragraph 5.13 and in the CEMS record book.

5 Data recording device

5.1 The data recording device should be of a robust, tamper-proof design meeting the requirements of section 4 of the *Guidelines for the use of Electronic Record Books under MARPOL Annex VI*[3].

[3] Resolution MEPC.312(74) on *Guidelines for the use of electronic record books under MARPOL.*

5.2 Where the calculations in accordance with section 4 are to be undertaken on board in an automated manner as part of the CEMS, those processing functions should be considered to be an inherent part of the data recording device and all requirements related to that device should be considered to be equally applicable, as appropriate, to its data processing functions.

5.3 Where a CEMS covers more than one engine, appropriate arrangements, as agreed to by the Administration, should be in place to ensure that the data recorded for each engine is clearly distinguished so that the data in respect of each engine can be readily identified, duly recorded and reported as required.

5.4 The data recording device should record whenever an engine, identified under paragraph 6.1.1.2, is in operation and whether or not the engine operating conditions identified under paragraph 6.1.1.3 apply.

5.5 Whenever the CEMS is in operation the data recording device should, as a minimum, record the following:

.1 the averaged output, over the reporting interval applied, of each of the exhaust gas analysers as listed in the CEMS file. The output from analysers for CO_2, H_2O and O_2 should be recorded in terms of % to a precision of not less than two decimal places. The output from analysers for CH_4 and /or N_2O should be recorded in terms of ppm to at least the nearest whole number;

.2 the outcomes of the zero and span checks of the exhaust gas analysers as listed in CEMS file including the evaluation and acceptability of any zero or span drift together with subsequent resets of the respective zero / span values;

.3 where an Administration has, under paragraph 2.14, approved an alternative approach to the zero / span check procedure, data showing the functionality of that approach so that drift does not exceed 2% of the full scale of the range used;

.4 where exhaust gas analysers are used in an extractive sampling arrangement, the measured values of the sample transfer line leak test procedure used and the evaluation together with the pass / fail assessment of that finding;

.5 where the carbon balance method is used to calculate exhaust gas mass flow rate, the averaged measured values, over the reporting interval applied, are used in that calculation;

.6 where the direct measurement method is used to calculate exhaust gas volume flow rate at reference conditions, the averaged measured values, over the reporting interval applied, are used in that calculation;

.7 where the direct calculation of the methane slip method is used, the averaged measured net fuel flow rates and other measured values, over the reporting interval applied, are used in that calculation;

.8 where the dry/wet correction factor is to be calculated or determined, the measured values, averaged over the reporting interval applied, are used in that calculation or determination;

.9 for extractive sampling systems incorporating a sample gas dryer, the sample gas outlet temperature from the dryer, averaged over the reporting interval applied;

.10 other measured data as used in the calculation processes or which are used indicate the operating condition of the CEMS or component parts thereof;

.11 other measured data used in the application of alternative or additional procedures, as agreed to or approved by the Administration, to those given by these Guidelines; and

.12 periods when the required data is not being transmitted to the data recorder owing to the agreed maintenance periods as given by paragraph 6.1.8.2.

5.6 The data recording device should record the following input data together with the time-date range over which they apply:

.1 zero and span gas composition data together with respective validity dates of those zero or span gases;

.2 if applicable, determined liquid fuel composition data;

.3 if applicable, determined gas fuel composition data;

.4 where an NMC is used, E_m and E_e;

.5 where the provisions of either paragraph 3.2.9 or 4.10.4 are followed, the derived liquid fuel mass flow rates are used;

.6 other input data as used in the calculation procedures applied; and

.7 other input data used in the application of alternative or additional procedures, as agreed to or approved by the Administration, to those given by these Guidelines.

5.7 The data recording device should have the capability to upload and store copies of the test certificates or other documentation from which the input data under paragraph 5.6 was obtained.

5.8 The data recording device should record the default values used and, if applicable, the time-date range, or other criteria, over which they apply together with any fixed values used in the calculation procedures:

.1 if applicable, default liquid fuel composition data;

.2 if applicable, exhaust duct internal diameter at the point of velocity measurement;

.3 other default or fixed values used in the calculation procedures applied; and

.4 other default or fixed values used in the application of alternative or additional procedures, as agreed to by the Administration, to those given by these Guidelines.

5.9 The data recording device should record the following intermediate calculation values determined for each reporting interval:

.1 if NMC is used, the E_m and E_e corrected CH_4 concentration;

.2 if used, absolute humidity values and whether that is as H_a or H_{sc};

.3 if used, dry / wet correction factor;

.4 if the carbon balance method is used, the exhaust gas mass flow rate (kg/h);

.5 if the direct measurement method is used, the exhaust gas volume flow rate at reference conditions (Nm^3/h);

.6 if the direct calculation of the methane slip method is used, the $C_{slip\text{-}CH4}$ value; and

.7 calculated values related to the application of alternative or additional procedures, as agreed to or approved by the Administration, to those given by these Guidelines.

5.10 The data recording device should record:

.1 the determined weight, expressed in kg, of CH_4 and / or N_2O emission to the atmosphere, as determined under section 4.11 and screened by section 4.12 as valid, for each reporting interval; or

.2 for each reporting interval during a zero/span check procedure as recorded under paragraph 5.5.2 or 5.5.3, a leak check procedure as recorded under paragraph 5.5.4 or an agreed CEMS maintenance period as recorded under paragraph 5.5.12, the CH_4 and / or N_2O emission (kg) to atmosphere as the average of that of the last reporting interval before reporting ceased and that of the first reporting interval following stabilization on restart.

5.11 Where the calculations in accordance section 4 of these Guidelines are undertaken remotely from the CEMS, the data recording device should be capable of being uploaded with the data required by paragraphs 5.6, 5.7, 5.8, 5.9 and 5.10.

5.12 The data recording device should record those periods when the CEMS was not able to generate the CH_4 and / or N_2O emission value required by paragraph 5.10.1 owing to:

.1 non-availability of data due to malfunction or failure of an identified exhaust gas analyser, other measurement device or necessary item of support equipment which forms part of the CEMS. Such periods are outside those provided for by paragraph 5.10.2;

.2 a measurement or input data fault condition, as identified by the screening required by section 4.4, and should additionally record details of the fault which resulted in that inability to provide valid data. The related inputs for this function may be manual, automated or a mix of both;

.3 a fault detected by the zero or span check facility required by paragraph 2.13 or 2.14 by which the zero or span drift exceeded 2% of the full scale of the range used. That fault condition should be applied to all data recorded since the last data point where the zero or span drift was within the required range. This function should be automated;

.4 in the case of an extractive sampling system, where the sample line leak detection procedure, required by paragraph 2.15.3, detects that there is an ingress leakage. That fault condition should be applied to all data recorded since the last data point where the sampling system was verified as free of ingress leakage. This function should be automated; and

.5 the monitoring system required by paragraph 3.3.3 detecting that a bypass arrangement was either not shut or subject to leakage. This function should be automated.

5.13 The data recording device should also record periods when the CEMS was not able to generate the CH_4 and / or N_2O emission value required by paragraph 5.10.1 owing to calculation fault conditions, as identified by the review required by section 4.12, and should additionally record details of the fault which resulted in that error. The related inputs for this function may be manual, automated or a mix of both.

5.14 The recording undertaken in accordance with paragraphs 5.4, 5.5, 5.9, 5.10, 5.12 and 5.13 should be against UTC with a reporting interval (RI) not greater than 0.20 hours. Where required, shorter reporting intervals may be used in order to cover periods of different engine operating conditions.

5.15 The data recording device should be capable of preparing and downloading reports in a readily usable format over user selected time-date ranges covering, but not limited to, the following either individually or as a user selected combined report:

.1 periods of engine operation and engine operating condition under section 5.4;

.2 measured data values under paragraph 5.5;

.3 input values under paragraph 5.6 and the associated supporting data under paragraph 5.7;

.4 default or fixed values under paragraph 5.8;

.5 intermediate calculated values under paragraph 5.9;

.6 CH_4 and / or N_2O emitted to the atmosphere for each reporting interval under paragraph 5.10;

.7 CH_4 and / or N_2O emitted to atmosphere;

.8 occurrence and duration of zero/span check periods, leak check periods and maintenance periods, as allowed by paragraph 6.1.8.2, which interrupted the CEMS from generating the required output under paragraph 5.10.1; and

.9 occurrence, duration and summary details of fault conditions which prevented the CEMS from operating as required as recorded under paragraphs 5.12 or 5.13.

5.16 The data recorded should be retained on board for a period of not less than 18 months from the date of recording. If the data recording device is changed over that period, it should be ensured that the required data is retained on board and available as required for surveys or inspections.

6 CEMS documentation

6.1 CEMS file

6.1.1 For each CEMS there should be a CEMS file, prepared by the applicant and approved by the Administration. The CEMS file should be retained on board the ship on which the CEMS is installed and be available for surveys and inspections as required. The CEMS file should, as a minimum, contain:

.1 whether CH_4, N_2O or both are to be monitored and reported;

.2 identify the engine, or engines, whose exhaust gas streams the CEMS is to monitor;

.3 under what engine operating conditions the CEMS is intended to operate[4]; and

.4 the information required by paragraphs 6.1.2 to 6.1.10.

6.1.2 Marine diesel engine

6.1.2.1 Details of the marine diesel engine, or engines, the exhaust emissions of which the CEMS is to monitor. Those details should include, but are not limited to:

.1 engine onboard reference and duty;

.2 manufacturer, model number and serial number;

.3 rated power and rated speed;

.4 NO_x certification 'engine approval number';

.5 where fuel oil consumption is to be measured as part of these procedures, details should be given of the fuel flow meters to be used and other associated measurement devices together with the calculation procedures, if required, to present the data on a net mass flow basis. The relevant fuel oil service system piping diagrams should be included showing the location of the fuel flow measurement devices;

.6 diagram giving the layout of the engine's exhaust gas system including all incorporated devices and any bypass arrangements; and

.7 where CH_4 is to be monitored and reported, in the case of trunk piston engines using a methane based gas fuel, the means by which the crankcase emissions of CH_4, in terms of kg of CH_4 over each reporting interval, are to be determined:

.1 where the crankcase vent, or vents, discharge only into either the engine's intake air or the exhaust duct at a position upstream of the exhaust gas sampling position, that arrangement should be detailed on the exhaust gas piping diagram as required by paragraph 6.1.2.1.6; or

[4] It may, for example, be given that the CEMS is only intended to operate when the engine is in a dual fuel mode, or not under 'standby' conditions, or not under a certain minimum % of rated power or speed.

.2 where the crankcase vent does not discharge into the engine's inlet air or exhaust duct at a position upstream of the measurement or sampling position:

.1 The procedures by which the total CH_4 crankcase emissions are to be quantified in terms of kg CH_4 over each reporting interval, as agreed to by the Administration. In the case where the crankcase has more than one outlet, the means by which the CH_4 emissions from each outlet are to be determined, in terms of kg CH_4 over each reporting interval, should be given. The influence of crankcase ventilation systems on that quantification should also be described, including any mitigation or correction procedures applied so that the reported CEMS data accurately reflects the total crankcase CH_4 emissions for each reporting interval; or

.2 The crankcase emissions of CH_4, in terms of kg of CH_4 over each reporting interval, should be derived from the engine builder's advised values, taking into account relevant influencing factors including, but not limited to, design specifics, torque, speed and time between top-end overhauls.

6.1.3 CH_4 and / or N_2O emission reduction device

6.1.3.1 Where a CH_4 and / or N_2O emission reduction device is fitted, details of the device should be given. Those details should include, but are not limited to:

.1 the exhaust emission component(s) intended to be reduced;

.2 the manner of operation of the reduction device, including details and criteria governing usage of any required energy inputs and/or consumables;

.3 the engine operating conditions under which the reduction device is intended to function; and

.4 the arrangement of the reduction device relative to the layout of the exhaust system as required by paragraph 6.1.2.1.6.

6.1.4 Exhaust gas analysers

6.1.4.1 Details of each exhaust gas analyser device which are to form part of the CEMS should be given. Those details for each such device should include, but are not limited to:

.1 measured exhaust emission component;

.2 analyser manufacturer and model;

.3 measurement principle. Where that measurement principle differs from that given by paragraph 2.3 the approval certification of that equivalent means as issued by the Administration;

.4 details of any necessary ancillary components or system requirements necessary for the analyser to function;

.5 whether that analyser measures on a wet or dry basis;

.6 if required, the means by which a dry basis reading will be corrected to wet basis, or wet to dry, together with:

.1 details of the measurement equipment necessary to apply that dry/wet correction; and

.2 the means by which other required data to perform that dry / wet correction will be obtained;

.7 analyser ranges to be used and the criteria for any range change;

.8 zero and span gas compositions, as applicable;

.9 if applicable, details of the zero and span check procedures, the frequency of that operation and the means by which the analyser would be reset such that the drift, in either case, does not exceed 2% full scale of the range used. Additionally, it should be given that such zero and span checks should only be undertaken under steady CH_4 and / or N_2O emission rate conditions, as indicated by paragraph 5.5 or as recorded by paragraph 5.10.1 prior to undertaking that check;

.10 the minimum reporting interval required in order to obtain a stable reading from the analyser;

.11 where a NMC is used, details of that device including CH_4 / NMHC ranges and design E_m and E_e efficiencies; and

.12 where an analyser is to be used to monitor the exhaust gas emissions from more than one exhaust duct, the means by which it will be ensured that the analysed gas sample will be representative of the engine to which the findings will be assigned. This is to also cover sample switching, flushing, how the gas sample in the disengaged sample feed lines will remain updated, the T_{90} response factors (that is the time required for the analyser's output signal to register 90% of the input change) of the analysers involved and other relevant factors particular to the proposed system. This arrangement is to be agreed to by the Administration.

6.1.4.2 In the case of extractive sampling systems, details of the individual components of that system should be given which should include, but are not limited to:

.1 sample probe - design, fittings, and materials;

.2 sample transfer lines - operating temperatures and materials;

.3 if fitted, sample filter arrangements;

.4 if fitted, sample dryer - operating principle and exhaust gas sample outlet temperature range; and

.5 details of the leak check procedure to be applied and the frequency of that operation. Additionally, it should be given that such leak checks should only be undertaken under steady CH_4 and / or N_2O emission rate conditions, as indicated by paragraph 5.5 or as recorded by paragraph 5.10.1 prior to undertaking that check.

6.1.4.3 A diagram should be included showing the arrangement of the exhaust gas analysers and any associated devices or systems relative to the layout of the exhaust system as required by paragraph 6.1.2.1.6.

6.1.5 Exhaust gas flow

6.1.5.1 Where the exhaust gas flow rate is to be determined, it should be given whether that is to be by means of the carbon balance method or the direct measurement method:

6.1.5.2 Where the carbon balance method is to be used:

.1 details of the measurement devices necessary to apply the carbon balance method;

.2 a diagram showing the arrangement of those measurement devices relative to the layout of the exhaust system as required by paragraph 6.1.2.1.6;

.3 the means by which fuel composition data required for the carbon balance method will be obtained;

.4 where the provisions of paragraph 3.2.9 are to be followed, the derived liquid fuel mass flow rate to be used across the load engine range. If there is more than one such rate, the basis by which the particular liquid fuel rate would be selected should be given; and

.5 the means by which the exhaust gas water vapour content is to be determined.

6.1.5.3 Where the direct measurement method is to be used:

.1 details of the exhaust gas velocity measurement device to be used including its declared maximum deviation across the required operating range when used with exhaust gas;

.2 details of the installation requirements of the velocity measurement device;

.3 exhaust duct internal diameter at the point of velocity measurement;

.4 details of the other measurement equipment necessary to apply the direct measurement method;

.5 the means by which the exhaust gas water vapour content, if required, is to be determined;

.6 a diagram should be included showing the arrangement of the required measurement devices relative to the layout of the exhaust system as required by paragraph 6.1.2.1.6;

.7 where there is an arrangement by which the exhaust gas stream from a monitored engine could bypass the exhaust gas velocity measurement point, details should be provided of the Administration agreed monitoring system as required by paragraph 3.3.3; and

.8 details of the procedures to be applied to verify that the exhaust gas flow rates across the used load range of the monitored engine are within the permitted deviation limit as given by table 3 of appendix IV of the NTC 2008.

6.1.6 Calculation procedures

6.1.6.1 It should be given as to whether the required calculations, are to be undertaken offline or, to the extent required, automated and undertaken in real-time.

6.1.6.2 Details of the measured and input data screening procedure as required by paragraph 4.4 should be given. For each measured or input parameter to be used in the calculation procedures to be applied, the initially expected value range should be given for the engine loads and fuel types and mixes to be covered. These procedures should also cover how this aspect of the data screening procedure is to be informed from subsequent in service measured or input data and how it may be affected by such as ambient conditions and other relevant potentially influencing factors. The procedure should also cover the evaluation of measured or input values falling outside the expected range as to whether or not they represent valid values together with, where they are not valid, the resolving action to be taken. Guidance on the development of this screening procedure is provided in appendix 6.

6.1.6.3 Details should be given of the signal alignment procedure, if required, in accordance with 4.5. That procedure should give which baseline parameter the other signals are to be aligned to together with the rationale of that selection.

6.1.6.4 Where the provisions of paragraph 4.10.4 are to be followed, the derived liquid fuel mass flow rate to be used across the load engine range. If there is more than one such rate, the basis by which the particular liquid fuel rate would be selected should be given.

6.1.6.5 All intermediate calculations which are to be undertaken should be given. Where default values are to be used those should be given relative to the criteria for their application.

6.1.6.6 The means by which the CH_4 and / or N_2O emission quantity is to be calculated over each reporting interval in accordance with section 4.11 should be given.

6.1.6.7 Details of the procedures for the review of the outcomes of the intermediate and CH_4 and / or N_2O emitted quantity calculations as required by section 4.12 should be given. For each calculated item, the initially expected value range should be given for the engine loads and fuel types and mixes to be covered. These procedures should include how this aspect of the data screening procedure is to be informed from subsequent in service calculated data. The procedure should also cover the evaluation of calculated values falling outside the expected range as to whether or not they represent valid values together with, where they are not valid, the resolving action to be taken. Guidance as to the development of this review procedure is provided in appendix 6 of these guidelines.

6.1.7 Data recording device

6.1.7.1 Details should be given of the data recording device. Those details should include information showing that the design of that device meets the requirements of section 4 of the *Guidelines for the use of Electronic Record Books under MARPOL*[5].

6.1.7.2 The reporting interval to be used should be given. Where the reporting interval may be altered, the criteria for the selection of the particular reporting interval, together with the range of reporting intervals to be used, should be given.

6.1.7.3 The real-time measurement, input and calculated value data streams to the data recording device as required by paragraphs 5.5, 5.6 and 5.9, respectively should be given.

6.1.7.4 The means by which the uploading of data as required by paragraph 5.7 is to be undertaken should be given.

6.1.7.5 The default values to be used under 5.8 and, if applicable, whether there would be a time-date range, or other criteria, over which they would apply together with any fixed values used in the calculation procedures, should be given.

6.1.7.6 Where calculation procedures are to be undertaken offline, details of the procedure and frequency for uploading the processed data into the data recording device, as required by paragraph 5.11, should be given. That frequency should not be more than 30 days from the date on which the measurements were undertaken.

6.1.7.7 Details should be given of the means by which reports, as required, may be obtained in accordance with paragraph 5.15.

6.1.7.8 The period over which, in accordance with paragraph 5.16, data will be retained on board should be given. Procedures covering the possible change of the data recording device should also be given.

6.1.8 CEMS maintenance

6.1.8.1 Details should be given of the routine maintenance requirements of the CEMS and its component parts so that it continues to function as intended and to meet the requirements of these Guidelines. In this reference may be made to the respective manufacturer's specified documentation, which would not be required to be reproduced in the CEMS file itself. However, any such documentation should be retained on board and be available as required.

6.1.8.2 It should be given that maintenance of exhaust gas analysers, other measurement devices or necessary support equipment which form part of the CEMS should, whenever possible, be undertaken when the CEMS itself is not required to be in operation. Where that is not possible, the frequency and duration of the respective required maintenance periods should be given, as agreed to by the Administration.

6.1.8.3 It should be given that maintenance of CEMS components which interrupts the determination of the CH_4 and / or N_2O emission value under section 4.11 should be coordinated so as to minimize the overall duration when paragraph 5.10.2 applies. Additionally, it should also be given that such maintenance should only be undertaken under steady CH_4 and / or N_2O emission rate conditions, as indicated by paragraph 5.5 or recorded by paragraph 5.10.1 prior to undertaking that maintenance.

5 Resolution MEPC.312(74) as may be amended.

6.1.9 CEMS servicing

6.1.9.1 Details should be given of the servicing requirements of the CEMS and its component parts so that it continues to function as intended and to meet the requirements of these Guidelines. This should include the exhaust gas analyser calibration and interference checks as required by these Guidelines, together with the calibration checks on other measurement devices.

6.1.9.2 It should be given that servicing of exhaust gas analysers, other measurement devices or necessary support equipment which form part of the CEMS should not be undertaken when the CEMS itself is intended, by paragraph 6.1.1.3, to be in operation.

6.1.10 Additional information

6.1.10.1 The CEMS file may include any additional information the applicant considers necessary to describe the CEMS and/or its manner of operation.

6.1.10.2 The CEMS file should include any additional information the Administration considers to be necessary to describe the CEMS and/or its manner of operation.

6.1.11 Amendments to CEMS file

6.1.11.1 Any amendment to the CEMS file should be approved by the Administration, taking into account the effect of the proposed change on the performance of the CEMS, prior to the implementation of the change requiring that amendment. Where an addition, deletion or amendment to the CEMS file is separate from the CEMS file as initially approved, it should be retained with the CEMS file and should be considered as part of it.

6.2 CEMS record book

6.2.1 A CEMS record book should be maintained up to date on board and should be available for surveys and inspections as required. The format and extent of the CEMS record book should be approved by the Administration. Where the CEMS record book is to be maintained in an electronic form it should meet the relevant requirements of section 4 of the *Guidelines for the use of Electronic Record Books under MARPOL* (resolution MEPC.312(74)), as may be amended. Where the CEMS record book is to be maintained in a written form, it should cover the points as given by section 4 of the *Guidelines for the use of Electronic Record Books under MARPOL*.

6.2.2 The CEMS record book should be used to record:

.1 all maintenance actions, both as provided for under paragraph 6.1.8.1 and otherwise, undertaken on the CEMS, including like-for-like replacements;

.2 servicing actions undertaken on the CEMS including all servicing reports covering calibration, interference checks and other repair / replacement activities;

.3 open / shut status of a bypass connection as covered by paragraph 3.3.3.

.4 the corrective actions taken to resolve any fault conditions as recorded by paragraphs 5.12 or 5.13; and

.5 actions undertaken under paragraph 4.4.3 to remove signal spikes from the recorded data prior to use in the calculation procedures.

6.2.3 The CEMS record book should be retained onboard for a period of not less than two years from the date of last entry or for longer as required by the Administration.

7 CEMS certification

7.1 Prior to the use of a CEMS for the purpose of providing CH_4 and / or N_2O emission data in accordance with relevant requirements, that CEMS should be subject to an initial survey. On satisfactory completion of that survey, a CEMS Certificate, the form of which is given in appendix 1 of these guidelines, should be issued by the Administration.

7.2 Thereafter, and for as long as that CEMS continues to be used in relation to the provision of CH_4 and / or N_2O data, it should remain subject to annual surveys which should be undertaken not less than 12 months following the date of the previous survey.

7.3 The initial and annual surveys of the CEMS should confirm that the CEMS is as detailed in the CEMS file, that the CEMS functions in accordance with the relevant requirements of these Guidelines and that the procedures as given in the CEMS file are being duly applied.

7.4 Where a CEMS covers more than one engine, the initial and annual survey should verify that the arrangements to separately measure, calculate and report the emissions from each engine are operating as required.

7.5 Initial and annual surveys should include a period when the CEMS is in operation in accordance with paragraph 6.1.1.3.

7.6 At the initial survey, the screening of the CEMS measured, input and output data in accordance with the procedures detailed in the CEMS file should be demonstrated.

7.7 At annual surveys, it should be verified that the CEMS measured, input and reported data streams have been subject to the review procedures as detailed in the CEMS file.

7.8 If the CEMS is not in service at the time that an annual survey is due, an initial survey should be undertaken and, at that time a new CEMS Certificate duly issued before further CH_4 and / or N_2O emission data is provided.

7.9 At annual surveys, it should be confirmed that the CEMS record book has been maintained as required.

APPENDIX 1

FORM OF CEMS CERTIFICATE

Issued in accordance with the *Guidelines for continuous emission monitoring systems (CEMS) used to quantify methane (CH_4) and/or nitrous oxide (N_2O) emissions from marine diesel engines* (resolution MEPC.416(84)) under the authority of the Government of:

……
(full designation of the country)

by.....
(full designation of the competent person or organization authorized)

Particulars of ship

Name of ship .....
IMO Number.....

CEMS

CEMS file approval reference.....
Engines covered by CEMS

Engine	1	2	3	4
Manufacturer:				
Model:				
Serial number:				
NO_x approval number:				

CH_4 reported – yes / no*
N_2O reported – yes / no*

THIS IS TO CERTIFY that the CEMS as installed is as detailed in the CEMS file, that the CEMS functions in accordance with the relevant provisions of the CEMS Guidelines and that the screening of the CEMS output data in accordance with the procedures detailed in the CEMS file has been satisfactorily demonstrated.

Issued at……...
(place of issue of the Statement)

(dd/mm/yyyy): ....
(date of issue) *(signature of duly authorized official issuing the Statement)*

(seal or stamp of the authority, as appropriate)

* Delete as appropriate

ENDORSEMENT FOR ANNUAL SURVEYS

THIS IS TO CERTIFY that the CEMS as installed remains as detailed in the CEMS file, that the CEMS functions and is operated in accordance with the CEMS file and that the CEMS reported data streams have been subject to the screening procedures as detailed in the CEMS file:

Annual Survey 1

Signed ……..
(signature of duly authorized official)

Place .....

Date (dd/mm/yyyy) .....

(seal or stamp of the authority, as appropriate)

Annual Survey 2

Signed ……..
(signature of duly authorized official)

Place .....

Date (dd/mm/yyyy) .....

(seal or stamp of the authority, as appropriate)

Annual Survey 3

Signed ……..
(signature of duly authorized official)

Place .....

Date (dd/mm/yyyy) .....

(seal or stamp of the authority, as appropriate)

Annual Survey 4

Signed ……..
(signature of duly authorized official)

Place .....

Date (dd/mm/yyyy) .....

(seal or stamp of the authority, as appropriate)

Annual Survey n*

* Add as appropriate

APPENDIX 2

CH_4 AND N_2O U_{GAS} AND W_{GAS} VALUES

1 For the calculation of the exhaust gas mass flow rates in paragraph 4.11.1, u_{gas} values for CH_4 and / or N_2O, as required, should be calculated using table 5 of the NTC 2008 as extended by the following:

Gas		HC	CH_4	N_2O
ρ_{gas} kg/m^3		*	0.716	1.9631
	ρ_e†	Coefficient u_{gas}‡		
Liquid fuel**	1.2943	0.000479	0.000553	0.001517
Rapeseed Methyl Ester	1.2950	0.000536	0.000553	0.001516
Methanol	1.2610	0.001133	0.000568	0.001557
Ethanol	1.2757	0.000805	0.000561	0.001539
Natural gas	1.2661	0.000558*	0.000565	0.001551
Propane	1.2805	0.000512	0.000559	0.001533
Butane	1.2832	0.000505	0.000558	0.001530

In the case of dual-fuel operation, the u_{gas} value to be used should be determined from the values given above proportioned according to the respective fuel mass ratio.

* in the case of HC emissions when using natural gas as the fuel, the given u_{gas} value of 0.000558 should be used for NMHC on the basis of CH2.93. For total HC, the u_{gas} of CH_4 should be used.

2 For the calculation of the exhaust gas volume flow rate at reference conditions (Nm^3/h) in 4.11.1, w_{gas} values for CH_4 and / or N_2O, as required, should be calculated using table 5 of the NTC 2008 as extended by the following:

Gas		**HC**	**CH_4**	**N_2O**
ρ_{gas} kg/m^3		*	0.716	1.9631
	ρ_e†	Coefficient w_{gas}‡		
Liquid fuel**	1.2943	0.000620	0.000716	0.001964
Rapeseed Methyl Ester	1.2950	0.000694	0.000716	0.001964
Methanol	1.2610	0.001429	0.000716	0.001964
Ethanol	1.2757	0.001027	0.000716	0.001964

Gas		**HC**	**CH_4**	**N_2O**
ρ_{gas} kg/m^3		*	0.716	1.9631
Natural gas	1.2661	0.000706*	0.000716	0.001964
Propane	1.2805	0.000656	0.000716	0.001964
Butane	1.2832	0.000648	0.000716	0.001964

In the case of dual-fuel operation, the w_{gas} value to be used should be determined from the values given above proportioned according to the respective fuel mass ratio.

* in the case of HC emissions when using natural gas as the fuel, the given w_{gas} value of 0.000706 should be used for NMHC on the basis of CH2.93. For total HC, the w_{gas} of CH_4 should be used.

APPENDIX 3

CH_4 ANALYSER AND N_2O ANALYSER INTERFERENCE CHECKS

1 The interference should be checked prior to the first use of an analyser and after major servicing or updating of software.

2 In those cases where the analyser applies compensation algorithms which use as inputs the concentrations of other measured gases those measurements should be undertaken concurrently with this verification check.

3 For NDIR or NDUV - The potential for cross interferences effects of CO, CO_2, H_2O, CH_4 and SO_2 as applicable should be checked.

3.1 Apart from H_2O the interference species are dependent on the selected N_2O absorption band used by the device which should be known. From that knowledge good engineering judgement should be used to determine the interference gases to be used based on those which may be expected to be present in the exhaust gases to be measured.

4 For FTIR or LIA – The interference gases depend on the selected CH_4 or N_2O absorption band used by the device which should be known. Based on that knowledge, good engineering judgement should be used to determine the interference gases to be used.

5 The combined effect of the interference gases should not be more than 2% of the measured range or 2 ppm, whichever is the greater.

6 Verification procedure:

.1 the concentrations of the interference span gases as identified from paragraphs 3 or 4 of this appendix should be at least as high as the maximum values to be encountered in service. Those interference gases may be presented in the form of a multi-component span gas;

.2 the CH_4 or N_2O analyser is started, operated, zeroed and spanned as in service;

.3 humified interference test gas should be fed into the analyser. That test gas should be generated by bubbling the multi-component span gas through distilled H_2O in a sealed container. If the sample is not treated by a dryer the container temperature should be controlled to generate a H_2O concentration at least as high as the expected maximum when in service. If the sample is treated by a dryer the container temperature should be controlled to generate a H_2O concentration at least as high as the expected maximum based on the dryer outlet temperature when in service;

.4 the water mole fraction of the test gas should be determined from measurements taken as close as possible to the analyser inlet. Those measurements may be dew point and absolute pressure;

.5 condensation in the piping leading from the container generating the humidified test gas to the analyser should be minimized by maintaining an adequate minimum temperature; and

.6 following stabilization, the analyser output should be recorded for 30 seconds. The arithmetic mean response over that period should be compared with the limit in paragraph 5 of this appendix.

7 As an alternative to the multi-component span gas in paragraph 6 of this appendix, individual span gases may be run separately. In either case, where an interference gas concentration is higher than that to be measured in service the determined interference value should be scaled down by the ratio of in-service maximum / span concentration. Where the H_2O concentration is below that to be measured in service, but not below 0.025 % H_2O content, the determined interference may be scaled up by the ratio of maximum in-service value / the value used. The sum of the individual interferences should be compared with the limit in paragraph 5 of this appendix.

8 An interference verification check report documenting the procedure as followed, including the rational for the interference gases used and their concentrations, and the outcomes of that procedure is to be prepared and should be included in the CEMS record book.

9 Alternative approaches to the verification of CH_4 or N_2O analyser interference may be accepted if agreed to by the Administration. Where so used the justification for the approach taken should be included in the report as required by paragraph 8 of this appendix. Irrespective of the procedure followed, the limit given by paragraph 5 of this appendix remains applicable.

APPENDIX 4

EFFICIENCY OF THE NON-METHANE CUTTER (NMC)

1 The NMC is used for the removal of the non-methane hydrocarbons from the sample gas by oxidizing all hydrocarbons except CH_4. Ideally, the conversion rate for CH_4 is 0% and for the other hydrocarbons, as represented by ethane, C_2H_6, is 100%. Since a NMC may fail or performance deteriorate rapidly and without warning if operated outside certain ranges of gas concentrations and temperature ranges, the efficiency of the NMC should be checked as frequently as necessary to confirm that the requirements of paragraph 2 of this appendix are met. With the agreement of the Administration, alternative approaches to the assessment of NMC efficiency may be accepted.

2 Methane efficiency should not be more than 15%. Ethane efficiency should be at least 98%.

NMC methane efficiency

3 Methane calibration gas at a concentration typical of that to be measured is flowed through the FID analyser with and without the NMC bypassed. The methane efficiency, E_m, is determined as:

$$E_m = 1 - \frac{c_M\ (wCutter)}{c_M\ (w/oCutter)}$$

where:

$c_M\ (wCutter)$ HC concentration with CH_4 flowing through the NMC (ppmC1)

$c_M\ (w/oCutter)$ HC concentration with CH_4 bypassing NMC (ppmC1)

NMC ethane efficiency

4 Ethane calibration gas at a concentration typical of the expected non-methane hydrocarbon concentration to be measured is flowed through the FID analyser with and without the NMC bypassed. The ethane efficiency, E_e, is determined as:

$$E_e = 1 - \frac{c_E\ (wCutter)}{c_E\ (w/oCutter)}$$

where:

$c_E\ (wCutter)$ HC concentration with C_2H_6 flowing through the NMC (ppmC1)

$c_E\ (w/oCutter)$ HC concentration with C_2H_6 bypassing NMC (ppmC1)

APPENDIX 5

GUIDANCE ON THE INSTALLATION REQUIREMENTS FOR DEVICES TO MEASURE EXHAUST GAS VELOCITY

1 The determination of exhaust gas flow via direct measurement of mean exhaust gas velocity for an installed marine diesel engine is complex, owing to the fluid dynamic behaviour of that exhaust gas and the arrangement of the typical exhaust duct and associated devices such as exhaust gas boilers and silencers. Consequently, particular care should be taken to avoid errors in the measurement of that velocity across the load range – see paragraph 5.5.2.1 of the NTC 2008.

Objective definition

2 Prior to selecting a monitoring methodology, the objective of the direct measurement should be clearly communicated to the potential providers of the velocity measurement device in order to ensure methodological alignment.

3 A particular point to note is that for gases the viscosity increases as temperature increases, the converse to that experienced with liquids, hence the resulting flow profile in the engine's exhaust duct will alter over the engine's load range as the uptake exhaust gas temperature changes. A further point on this is where there are exhaust duct connections, such as wastegates / bypasses feeding in, or equipment such as exhaust gas boilers, extracting heat from the exhaust gas stream, a significant range of different exhaust gas temperatures can be encountered at the point of measurement for the same nominal engine load, noting additionally that where if engine can operate with a highly variable torque / speed profile, that in itself will be a another complicating factor.

4 Furthermore, if the device is to measure velocity when operating in both liquid only and dual-fuel modes there will be different exhaust gas compositions and hence densities.

Measurement requirements

5 Direct measurement of the mean velocity of the exhaust gas stream necessitates the following core components:

.1 preliminary investigation of the exhaust gas flow profiles across the engine's operating load range should be conducted either through validated in situ measurements or computational fluid dynamics (CFD) simulations, taking into account expected ranges of operating conditions and exhaust gas temperatures to be encountered; and

.2 mean velocity measurement at the designated sampling location.

6 Mean velocity may be derived from a series of point velocity measurements across the measurement plane or through alternative validated techniques. Measurement points should be distributed to represent regions of equal cross-sectional area. The selected measurement plane needs to be representative of the duct's volumetric flow rate and located in a region exhibiting uniform and stable flow characteristics.

APPENDIX 6

GUIDANCE ON THE DEVELOPMENT OF THE SCREENING AND REVIEW PROCEDURES AS REQUIRED BY SECTIONS 4.4 AND 4.12

1 The user of a CEMS as covered by these Guidelines should ensure, in accordance with section 4.12, that the intermediate calculated values and output data, as retained on the data recording device and as submitted to the Administration are, to the extent possible, correct. To that end, these Guidelines also require, in section 4.4, that the measured and input data is screened prior to use in the relevant calculation procedures as included in the CEMS file.

2 As given by these Guidelines, there are performance requirements in respect of the various measurement devices which should be met, in part that is demonstrated by the periodic checking or calibration of those devices. However, such devices may be subject to malfunction in service either as a result of problems with the measurement device itself or other factors such as its mounting or the transmission of the output signal. Similarly, input data may not have been correctly determined or could be subject to transcription errors through the reporting and entry processes.

3 Consequently, the CEMS file includes procedures which cover the screening (6.1.6.2) and review (6.1.6.6) activities. The particular nature and performance of these activities will depend on individual company processes and quality management procedures and hence it is not the intent of these Guidelines to detail such. Instead, the guidance as provided by this appendix is intended to assist users of CEMS in developing their particular procedures.

4 In this, there would be seen to be the:

.1 **initial data**, i.e. the data that is available and has been collected during commissioning of both the engine and the CEMS together with its supporting systems; and

.2 **ongoing data**, i.e. the data that is collected with the CEMS running.

5 In either case the same core point applies – if nothing changes the inputs, the outputs equally do not change. If there is a change in the outputs, is that level of change commensurate with the recorded changes to the inputs.

Initial data

6 From the factory acceptance test (FAT) of an engine and basic engineering experience, there should be a set of data available, augmented by in-service engine-room data logging, in terms of such parameters as fuel rates, both liquid and gas, operating pressures and temperatures across the load range.

7 In terms of the emission values and exhaust gas flow rates across the load range, there will be the Parent Engine test report as included the engine's approved technical file. Where the engine in question was either the Parent Engine or is an identical Member Engine to that Parent Engine, then the emission values and exhaust flow rates as given in that report provide a starting point for the emission values to be encountered in service. In some instances, CH_4 will have been measured (ppm) and quantified, for example in terms of methane slip – being the % of the methane based gas fuel which was present in the exhaust gas stream. Where CH_4 was not previously measured there will nevertheless be the

hydrocarbons (HC) reading – which for an engine using a methane based gas fuel will not be higher than the CH_4 value. Of course, where the test report is in respect of the NO_x certification requirements, then the engine's rating and NO_x critical components, settings / operating values will have been that combination which resulted in the highest NO_x values – one aspect of which is that the engine would have been tested with the highest liquid/gas fuel ratio, whereas the lower the liquid/gas fuel ratio the likelihood is that HC and CH_4 emission would have been higher. Of course, where the engine in question is not identical in some way to the Parent Engine, such as rating, number of cylinders, then due allowance would need to be applied as to how the Parent Engine test values related to that engine.

8 However, it would be seen that at the commissioning of a CEMS, which of necessity should be with the engine in operation, would be the time at which the initial benchmark of all to be measured values would be established across the load range.

9 In terms of the input values, for example those from a fuel testing service, engineering knowledge and experience should be applied to the values as received – and as entered into the CEMS system – most notably as to whether the units of a reported value are those as used by the CEMS system or is conversion first necessary. Similarly for the default values – are they correct, and in the units as used by the CEMS?

10 From these initial measured and input / default values then benchmark intermediate and final values would be determined and verified, as part of the CEMS commissioning process, as being as expected.

Ongoing data

11 There will be changes in the measured values at or around any particular load point over time due to differing influencing conditions, and this information should be used to build on the initial data. However, for the measured values, these should alter gradually as those influencing factors such as differing fuel qualities, wear, ambient conditions change over time. Hence, if there are any major differences in measured values due to, for example, a different engine management package being used – in contrast if there is a major change in just one measured value, then that may be indicative of a sensor malfunction – not ignoring that more than one sensor could fail / malfunction at the same time (as a result of a voltage spike?).

12 Similarly for the intermediate calculated values and final output data, there will be evolving changes – hence if there are major changes, jumps, in those values why? As before, are these due, for example, to a change in the engine management package or have the units of a particular input value have been incorrectly entered.

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