

## Annex

### *Guidelines for exhaust gas-SO<sub>x</sub> cleaning systems – MARPOL Annex VI, regulation 14(4)(b)*

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## Introduction

Regulation 14(4) of Annex VI to MARPOL 73/78 requires ships within SO<sub>x</sub> emission control areas to either use fuel oil with a sulphur content not exceeding 1.5% or apply an exhaust gas (SO<sub>x</sub>) cleaning system (EGCS-SO<sub>x</sub>) to reduce the total emission of SO<sub>x</sub> to 6.0 g/kW·h. (6.0 g SO<sub>x</sub>/kW·h or less should be calculated as the total weight of sulphur dioxide emission). The EGCS-SO<sub>x</sub> unit is to be approved by the Administration taking into account guidelines developed by the Organization.

Similar to a NO<sub>x</sub> emission reduction system, a EGCS-SO<sub>x</sub> unit may be type approved subject to periodic parameter and emission checks or the system may be equipped with a continuous emission monitoring system. These guidelines have been developed with the intention of being objective and performance-oriented. Introduction of the SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio method would simplify the monitoring of SO<sub>x</sub> emission and facilitate type approval of the EGCS-SO<sub>x</sub> unit. See appendix for the rationale explaining the use of SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) as the basis for system monitoring.

These guidelines are recommendatory in nature; however, Administrations are invited to base their implementation on these guidelines.

## Safety note

Due attention is to be given to the safety implications related to the handling and proximity of exhaust gases, the measurement equipment and the storage and use of cylindered pure and calibration gases. Sampling positions and access staging should be such that this monitoring may be performed safely. In locating discharge outlet of waste water used in the EGCS-SO<sub>x</sub> unit, due consideration should be given to the location of the ship's seawater inlet and other implications of the acidic nature of such water.

## Scheme A – EGCS-SO<sub>x</sub> unit type approval and certification

*Unit certification of Exhaust Gas-SO<sub>x</sub> Cleaning Systems (EGCS-SO<sub>x</sub>) by the Administration with subsequent in-service verification at survey intervals by indirect means together with unit use monitoring.*

### 1 General

#### 1.1 Purpose

The purpose of these guidelines is to specify the requirements for the design, testing, survey and certification of exhaust gas cleaning-SO<sub>x</sub> systems (EGCS-SO<sub>x</sub>) to ensure that they comply with the requirements of regulation 14(4)(b) of Annex VI of MARPOL 73/78.

## 1.2 Application

1.2.1 These guidelines apply to any EGCS-SO<sub>x</sub> unit as fitted to fuel oil combustion machinery, excluding shipboard incinerators, installed on board a ship which is to operate within a SO<sub>x</sub> Emission Control Area (SECA).

1.2.2 These guidelines cover only the certification, survey, and testing of the EGCS-SO<sub>x</sub> unit for compliance with regulation 14(4)(b) of Annex VI.

## 1.3 Definitions

*ppm* means “parts per million”. It is assumed that ppm is measured by gas analysers on a molar basis, assuming ideal micro-moles of substance per mole of total amount ( $\mu\text{mol/mol}$ ), but ppm is used in order to be consistent with units in the NO<sub>x</sub> Technical Code.

*Fuel oil combustion unit* means any engine, boiler, gas turbine, or other fuel-oil-fired equipment.

## 2 Survey and certification

### 2.1 General

2.1.1 Prior to use within a SECA, each EGCS-SO<sub>x</sub> unit should be issued with a SECA Compliance Certificate (SCC) by the Administration.

2.1.2 The EGCS-SO<sub>x</sub> unit should be subject to survey on installation and at Initial, Annual/Intermediate and Renewals Surveys by the Administration, irrespective of whether or not the ship is in a SECA at the time of survey.

2.1.3 The ship’s SCC should be duly endorsed at each survey as required by 2.1.2.

2.1.4 In accordance with regulation 10 of MARPOL Annex VI, EGCS-SO<sub>x</sub> units may also be subject to inspection by PSC Officers when operating within a SECA.

### 2.2 Procedures for the certification of an EGCS-SO<sub>x</sub> unit

2.2.1 In order to meet the requirements of 2.1.1 either prior to or after installation on board, each EGCS-SO<sub>x</sub> unit should be certified as meeting the emission limit of 6.0 g SO<sub>x</sub>/kW·h under the operating conditions and restrictions as given by the EGCS-SO<sub>x</sub> Technical Manual (ETM) as approved by the Administration.

2.2.2 Determination of the emission value should be in accordance with the provisions of these guidelines.

2.2.3 Each EGCS-SO<sub>x</sub> unit meeting the requirements of 2.2.1 should be issued by the Administration with a SCC.

2.2.4 Application for a SCC should be made by the EGCS-SO<sub>x</sub> manufacturer, shipowner or other party.

2.2.5 Subsequent EGCS-SO<sub>x</sub> units of the same design and rating as that certified under 2.2.1 may be issued with SCC by the Administration without the need for testing in accordance with 2.2.1 subject to section 4.2 of these guidelines.

2.2.6 EGCS-SO<sub>x</sub> units of the same design, but with ratings different from that certified under 2.2.1 may be accepted by the Administration subject to section 4.3 of these guidelines.

2.2.7 EGCS-SO<sub>x</sub> units which treat only part of the exhaust gas flow of the uptake in which they are fitted should be subject to special consideration by the Administration to ensure that, under all defined operating conditions, the overall emission value of the exhaust gas downstream of the system is no more than 6.0 g SO<sub>x</sub>/kW·h.

### 2.3 EGCS-SO<sub>x</sub> unit Technical Manual

2.3.1 Each EGCS-SO<sub>x</sub> unit is to be supplied with a EGCS-SO<sub>x</sub> Technical Manual (ETM) provided by the manufacturer. This ETM should, as a minimum, contain the following information:

- (a) the identification of the unit (manufacturer, model/type, serial number and other details as necessary) including a description of the unit and any required ancillary systems;
- (b) the operating limits, or range of operating values, for which the unit is certified. These should, as a minimum, include:
  - (i) maximum and, if applicable, minimum mass flow rate of exhaust gas;
  - (ii) the power, type and other relevant parameters of the fuel oil combustion unit for which the EGCS-SO<sub>x</sub> unit is to be fitted. In the cases of boilers, the maximum air/fuel ratio at 100% load should also be given. In the cases of diesel engines, whether the engine is of 2- or 4-stroke cycle;
  - (iii) maximum and minimum wash water flow rate, inlet pressures and minimum inlet water alkalinity (pH);
  - (iv) exhaust gas inlet temperature ranges and maximum exhaust gas outlet temperature with the EGCS-SO<sub>x</sub> unit in operation;

- (v) exhaust gas differential pressure range and the maximum exhaust gas inlet pressure with the fuel oil combustion unit operating at MCR or 80% of power rating, whichever is appropriate;
  - (vi) salinity levels or fresh water elements necessary to provide adequate neutralizing agents; and
  - (vii) other factors concerning the design and operation of the EGCS-SO<sub>x</sub> unit relevant to achieving a maximum emission value no higher than 6.0 g SO<sub>x</sub>/kW·h;
- (c) any requirements or restrictions applicable to the EGCS-SO<sub>x</sub> unit or associated equipment necessary to enable the unit to achieve a maximum emission value no higher than 6.0 g SO<sub>x</sub>/kW·h;
  - (d) maintenance, service or adjustment requirements in order that the EGCS-SO<sub>x</sub> unit can continue to achieve a maximum emission value no higher than 6.0 g SO<sub>x</sub>/kW·h;
  - (e) the means by which the EGCS-SO<sub>x</sub> unit is to be surveyed to ensure that its performance is maintained and that the unit is used as required (see section 6);
  - (f) through-range performance variation in wash water characteristics;
  - (g) design requirements of the wash water system; and
  - (h) the SCC.

2.3.2 The ETM should be approved by the Administration.

2.3.3 The ETM should be retained on board the ship onto which the EGCS-SO<sub>x</sub> unit is fitted. The ETM should be available for surveys as required.

2.3.4 Additions, deletions or amendments to the ETM should be approved by the Administration. Where additions, deletions or amendments to the ETM are separate to the ETM as initially approved, they should be retained with the ETM and should be considered as part of the ETM.

2.3.5 As an alternative to the maximum emission rate stipulated in 2.3.1(b)(vii) of 6.0 g SO<sub>x</sub>/kW·h, SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio of 65 or below, measured downstream of EGCS-SO<sub>x</sub> unit, may be used.

### 3 Emission limit

3.1 Each EGCS-SO<sub>x</sub> unit should be capable of reducing emissions to no more than 6.0 g SO<sub>x</sub>/kW·h at any load point when operated in accordance

with the criteria as given within 2.3.1(b), as specified in paragraphs 3.2 through 3.5 of these guidelines, and as excepted in paragraphs 3.7 and 3.8.

3.2 EGCS-SO<sub>x</sub> units fitted to main propulsion diesel engines should meet the requirements of 3.1 at all loads between 25 and 100% of the load range of the engines to which they are fitted.

3.3 EGCS-SO<sub>x</sub> units fitted to auxiliary diesel engines should meet the requirements of 3.1 at all loads between 10 and 100% of the load range of the engines to which they are fitted.

3.4 EGCS-SO<sub>x</sub> units fitted to diesel engines which supply power for both main propulsion and auxiliary purposes should meet the requirements of 3.3.

3.5 EGCS-SO<sub>x</sub> units fitted to boilers should meet the requirements of 3.1 at all loads between 10 and 100% of the load range (steaming rates) of the boilers to which they are fitted.

3.6 In order to demonstrate performance, emission measurements should be undertaken, with the agreement of the Administration, at a minimum of four load points. One load point is to be at 95–100% of the maximum exhaust gas mass flow rate for which the unit is to be certified. One load point is to be within  $\pm 5\%$  of the minimum exhaust gas mass flow rate for which the unit is to be certified. The other two load points are to be equally spaced between the maximum and minimum exhaust gas mass flow rates. Where there are discontinuities in the operation of the system, the number of load points should be increased, with the agreement of the Administration, so that it is demonstrated that the required performance over the stated exhaust gas mass flow rate range is retained. Additional intermediate load points should be tested if there is evidence of an emission peak below the maximum exhaust gas mass flow rate and above, if applicable, the minimum exhaust gas flow rate. These additional tests should be sufficient in number as to establish the emission peak value.

3.7 For loads below those specified in 3.2 to 3.5, the EGCS-SO<sub>x</sub> unit should continue in operation. In those cases where the fuel oil combustion equipment may be required to operate under idling conditions, the SO<sub>2</sub> emission concentration (ppm) at standardized O<sub>2</sub> concentration (15.0% diesel engines, 3.0% boilers) should not exceed 50 ppm.

3.8 Alternatively to the provisions of 3.2–3.5 and 3.7, each EGCS-SO<sub>x</sub> unit should be capable of reducing emissions to 65 or below, in SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio, at any load point when operated in accordance with the criteria as given within 2.3.1(b) and 2.3.4.

## 4 Approval of an EGCS-SO<sub>x</sub> unit

### 4.1 Unit approval

4.1.1 An EGCS-SO<sub>x</sub> unit should be capable of meeting the limit value of 6.0 g SO<sub>x</sub>/kW·h (other than as given in section 3) with fuel oils of up to 4.5% m/m sulphur and for the range of operating parameters, as listed in 2.3.1(b), for which they are to be approved.

4.1.2 Where testing is not to be undertaken with fuel oils of 4.5% m/m sulphur content or above, testing should be undertaken to demonstrate the effect of fuel oil sulphur content on system performance. In such cases a minimum of two tests, in accordance with section 3 as appropriate, should be performed. These need not be sequential and could be undertaken on two different, but identical, EGCS-SO<sub>x</sub> units. The minimum sulphur content of the fuel oil used in one test should not be less than 2.0% m/m sulphur. The other fuel oil should have a sulphur content of at least 1.0% m/m sulphur above that of the lower sulphur content fuel oil. The EGCS-SO<sub>x</sub> unit manufacturer should justify, on the basis of the above considerations and other testing as may be required, that the EGCS-SO<sub>x</sub> unit would meet the required limit of 6.0 g SO<sub>x</sub>/kW·h when used with a fuel oil of 4.5% m/m sulphur.

4.1.3 The maximum and, if applicable, minimum exhaust gas mass flow rate of the unit should be stated. The effect of variation of the other parameters defined in 2.3.1(b) should be justified by the equipment manufacturer. The effect of variations in these factors is to be assessed by testing or otherwise as appropriate. No variation in these factors, or combination of variations in these factors, should be such that the emission value of the EGCS-SO<sub>x</sub> unit would be in excess of 6.0 g SO<sub>x</sub>/kW·h.

4.1.4 Data obtained in accordance with this section should be submitted to the Administration for approval together with the ETM.

### 4.2 Serially manufactured units

In the case of nominally similar EGCS-SO<sub>x</sub> units of the same mass flow ratings as that certified under 4.1, and to avoid the testing in accordance with 2.2.1 of each EGCS-SO<sub>x</sub> unit, the equipment manufacturer may submit, for acceptance by the Administration, a conformity of production arrangement. The certification of each EGCS-SO<sub>x</sub> unit under this arrangement should be subject to such surveys that the Administration may consider necessary as to assure that each EGCS-SO<sub>x</sub> unit has an emission value of not more than 6.0 g SO<sub>x</sub>/kW·h when operated in accordance with the parameters defined in 2.3.1(b).



### 4.3 Product range approval

4.3.1 In the case of an EGCS-SO<sub>x</sub> unit of the same design, but of different maximum exhaust gas mass flow capacities, the Administration may accept, in lieu of tests on an EGCS-SO<sub>x</sub> unit of all capacities in accordance with section 4.1, tests of EGCS-SO<sub>x</sub> systems of three different capacities provided that the three tests are performed at intervals including the highest, lowest and one intermediate capacity rating within the range.

4.3.2 Where there are significant differences in the design of EGCS-SO<sub>x</sub> units of different capacities, this procedure should not be applied unless it can be shown, to the satisfaction of the Administration, that in practice those differences do not materially alter the performance between the various EGCS-SO<sub>x</sub> unit types.

4.3.3 For EGCS-SO<sub>x</sub> units of different capacities, the sensitivity to variations in the type of combustion machinery to which they are fitted should be detailed together with sensitivity to the variations in the parameters listed in 2.3.1(b). This should be on the basis of testing, or other data as appropriate.

4.3.4 The effect of changes of EGCS-SO<sub>x</sub> capacity on wash water characteristics should be detailed.

4.3.5 All supporting data obtained in accordance with this section, together with the ETM for each capacity unit, should be submitted to the Administration in accordance with 4.1.6.

4.3.6 An SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio of 65 may be used for emission limit values specified in 4.1.2, 4.1.3 and 4.2.

## 5 Emission testing

5.1 Emission testing should follow the requirements of the NO<sub>x</sub> Technical Code, chapter 5, and associated appendices, except as provided for in these guidelines.

5.2 CO<sub>2</sub>, O<sub>2</sub> and SO<sub>2</sub> should be measured. CO<sub>2</sub> and O<sub>2</sub> as % to a precision of 2 decimal places. SO<sub>2</sub> to a precision of  $\pm 1\%$  of the true reading for a signal averaging time of 10 s, but not less than a lower detectable limit of 5 ppm.

5.3 SO<sub>2</sub> should be measured on a dry or wet basis, using analysers operating on NDIR or NDUV principles and with additional equipment such as dryers as necessary. Other systems or analysers may be accepted, subject to the approval of the Administration, provided they yield equivalent results to those of the equipment referenced above.

5.4 An exhaust gas sample for SO<sub>2</sub> should be obtained from a representative sampling point downstream of the EGCS-SO<sub>x</sub> unit.

5.5 SO<sub>2</sub> should be monitored on-line, using either cross-duct or extractive sample systems.

5.6 Extractive exhaust gas samples for SO<sub>2</sub> determination should be maintained at a sufficient temperature to avoid condensed water in the sampling system and hence loss of SO<sub>2</sub>.

5.7 If an extractive exhaust gas sample for determination needs to be dried prior to analysis, it should be done in a manner which does not result in loss of SO<sub>2</sub> in the sample as analysed.

5.8 Where SO<sub>2</sub> is measured by a cross-duct system, the water content in the exhaust gas stream at that point is also to be determined in order to correct the reading to a dry-basis value.

5.9 Where the exhaust gas mass flow is to be calculated in accordance with the NO<sub>x</sub> Technical Code, appendix 6, the complete combustion case calculations may be used. The exhaust gas mass flow (GEXHW) should be determined in respect of the mass flow into the EGCS-SO<sub>x</sub> unit.

5.10 In applying the NO<sub>x</sub> Technical Code, equation 15, the dry-basis SO<sub>2</sub> concentration should be converted to a wet-basis value using the dry/wet correction factor applicable to the exhaust gas at entry into the EGCS-SO<sub>x</sub> unit (NO<sub>x</sub> Technical Code, equation 11, CO = 0):

$$w = 0.002855, u = w/\text{exhaust gas density in g/m}^3 \text{ at } 0^\circ\text{C and } 101.3 \text{ kPa}$$

5.11 The fuel oil as used in the test should be a residual blend product. A representative sample of that fuel should be analysed in order to establish its chemical composition (carbon, hydrogen and sulphur) together with the other parameters as necessary to establish its grade in accordance with the ISO 8217 specification.

5.12 For diesel engines the power should be the uncorrected brake power.

5.13 For boilers the “power” should be determined based on the fuel rate and assumed brake specific fuel consumption of 200 g/kW·h.

5.14 The determined emission value at each test point should be equal to, or less than, 6.0 g SO<sub>x</sub>/kW·h.

5.15 In lieu of the testing procedure laid down in 5.9 to 5.10 and 5.12 to 5.14, compliance may be demonstrated by continuous monitoring of SO<sub>2</sub> and CO<sub>2</sub> concentration in the exhaust gas downstream of the EGCS-SO<sub>x</sub> unit and demonstrating that the SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio, at each test point, is 65 or below.

5.16 Should the SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio method be used:

- (a) The conditions stipulated in 5.4 and 5.5 should also apply to the measurement of CO<sub>2</sub> (%) and it is recommended that SO<sub>2</sub> and CO<sub>2</sub> samples should be obtained at the same location.

- (b) Measurement of SO<sub>2</sub> and CO<sub>2</sub> should either be carried out above the respective dewpoints or on a fully dry basis, recognizing that the conditions stipulated in 5.6–5.8 should also apply to the measurement of CO<sub>2</sub> (%).
- (c) The carbon and hydrogen content of the test fuel as stipulated in 5.11 need not be determined.
- (d) Calculation of the SO<sub>2</sub>/CO<sub>2</sub> ratio should comply with the requirements of Scheme B, section 10.

## 6 *Procedures for demonstrating compliance with emission limit on board*

6.1 For each EGCS-SO<sub>x</sub> unit, the ETM should contain a verification procedure for use at surveys as required. This procedure should not require specialized equipment or an in-depth knowledge of the system. Where particular devices are required, they should be provided and maintained as part of the system. The EGCS-SO<sub>x</sub> unit should be designed in such a way as to facilitate inspection as required. The basis of this verification procedure is that if all relevant components and operating values or settings are within those as approved, then the performance of the EGCS-SO<sub>x</sub> system is within that required without the need for actual exhaust emission measurements. It is also necessary to ensure that the EGCS-SO<sub>x</sub> unit is fitted to an item of fuel oil combustion equipment for which it is rated – this forms part of the SCP.

6.2 Included in the verification procedure should be all components and operating values or settings which may affect the operation of the EGCS-SO<sub>x</sub> unit and its ability to meet the required emission limit.

6.3 The verification procedure should be submitted by the EGCS-SO<sub>x</sub> manufacturer and approved by the Administration.

6.4 The verification procedure should cover both a documentation check and a physical check of the EGCS-SO<sub>x</sub> unit.

6.5 The Surveyor should verify that each EGCS-SO<sub>x</sub> unit is installed in accordance with the ETM and has a SCC as required.

6.6 At the discretion of the Administration, the Surveyor should have the option of checking one or all of the identified components, operating values or settings. Where there is more than one EGCS-SO<sub>x</sub> unit, the Administration may, at its discretion, abbreviate or reduce the extent of the survey on board. However, the entire survey should be completed for at least one of each type of EGCS-SO<sub>x</sub> unit on board provided that it is expected that the other EGCS-SO<sub>x</sub> units perform in the same manner.

6.7 The EGCS-SO<sub>x</sub> unit should include means to automatically record when the system is in use. This should automatically record, as a minimum,

wash water pressure and flow rate at the EGCS-SO<sub>x</sub> unit's inlet connection, pH of wash water at the EGCS-SO<sub>x</sub> unit's inlet and outlet connections, exhaust gas pressure before and pressure drop across the EGCS-SO<sub>x</sub> unit, fuel oil combustion equipment load, and exhaust gas temperature before and after the EGCS-SO<sub>x</sub> unit. The data-recording system should comply with the requirements of Scheme B, sections 12 and 13.

6.8 If a continuous exhaust gas monitoring system is not fitted, it is recommended that a daily spot check of the exhaust gas quality, in terms of SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio, is used to verify compliance in conjunction with parameter checks stipulated in 6.7. If a continuous exhaust gas monitoring system is fitted, only daily spot checks of the parameters listed in paragraph 6.7 would be needed to verify proper operation of the EGCS-SO<sub>x</sub> unit.

6.9 If the EGCS-SO<sub>x</sub> manufacturer is unable to provide assurance that the EGCS-SO<sub>x</sub> unit will meet the limit value of 6 g SO<sub>x</sub>/kW·h or SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio of 65 or below between surveys, by means of the verification procedure stipulated in 6.1, or if this requires specialist equipment or in-depth knowledge, it is recommended that continuous exhaust gas monitoring of each EGCS-SO<sub>x</sub> unit be used to assure ship operators of compliance when operating within a SECA and in the event of port State authority inspection.

6.10 An EGCS-SO<sub>x</sub> Record Book should be maintained by the shipowner recording maintenance and service of the unit. The form of this record should be submitted by the EGCS-SO<sub>x</sub> manufacturer and approved by the Administration. This record book should be available at surveys as required and may be read in conjunction with engine-room log-books and other data as necessary to confirm the correct operation of the EGCS-SO<sub>x</sub> unit. Alternatively, this information is to be recorded in the vessel's planned maintenance record system as approved by the Administration.

## 7 Wash water monitoring

7.1 The clean seawater supply to the EGCS-SO<sub>x</sub> unit and the wash water being discharged should also be monitored, at a defined frequency appropriate to the sensors used, for pH and oil content together with other parameters which may have an adverse impact on ecosystems in the area in which the ship operates, taking into account the requirements of section 17. The data provided by this monitoring should be used by the ship in assessing the acceptability of water discharge against criteria which may be developed by individual port State authorities.

7.2 The wash water monitor and data recording system should comply with the requirements of Scheme B, sections 12 and 13.

## **Scheme B – Continuous monitoring of SO<sub>x</sub> emissions**

*Compliance demonstrated in service by continuous exhaust gas monitoring. Monitoring system should be approved by the Administration and the results of that monitoring should be available to the Administration as necessary to demonstrate compliance as required.*

Additionally for all ships which are to use an EGCS-SO<sub>x</sub> unit, in part or in total, in order to comply with the requirements of regulation 14(4) there should be a SECA Compliance Plan (SCP) for the ship, approved by the Administration, detailing how:

- (a) compliance is to be achieved;
- (b) that compliance is to be demonstrated.

### **8 General**

This Scheme should be used to demonstrate that the emissions from an item of fuel oil combustion equipment fitted with an EGCS will, with that system in operation, result in an emission value of SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio of 65 or below at any load point, including during transient operation, and thus compliance with the requirements of regulation 14(4)(b) of MARPOL Annex VI.

### **9 Exhaust gas measurement**

Exhaust gas composition (SO<sub>2</sub> plus CO<sub>2</sub>) measurement should be at an appropriate position after the EGCS-SO<sub>x</sub> unit and comply with the requirements of 5.2 and 5.16, Scheme A.

### **10 Calculation of emission rate**

10.1 SO<sub>2</sub> (ppm) and CO<sub>2</sub> (%) are to be continuously monitored and recorded onto a data recording and processing device at a rate which should not be less than 0.005 Hz.

10.2 If more than one analyser is to be used to determine the SO<sub>2</sub>/CO<sub>2</sub> ratio, these should be tuned to have similar sampling and measurement times and the data outputs aligned so that the SO<sub>2</sub>/CO<sub>2</sub> ratio is fully representative of the exhaust gas composition.

### **11 Wash water monitoring**

The clean seawater to the EGCS-SO<sub>x</sub> unit and the wash water being discharged should also be monitored, at a defined frequency appropriate to the sensors used, for pH and oil content together with other parameters which may have an adverse impact on ecosystems in the area in which the ship operates. The data provided by this monitoring should be used by the

ship in assessing the acceptability of water discharge against criteria which may be developed by individual port State authorities.

## **12** *Data recording and processing device*

12.1 The recording and processing device should be of robust, tamperproof design with read-only capability.

12.2 The recording and processing device should record the data required by section 10.1 against UTC and ship's position by a Global Navigational Satellite System (GNSS).

12.3 The recording and processing device should be capable of preparing reports over specified time periods.

12.4 Data should be retained for a period of not less than 18 months from the date of recording. If the unit is changed over that period, the shipowner should ensure that the required data is retained on board and available as required.

12.5 The device should be capable of downloading a copy of the recorded data and reports in a readily useable format. Such copy of the data and reports should be available to the Administration or port State authority as requested.

## **13** *On-board Monitoring Manual*

13.1 An On-board Monitoring Manual (OMM) should be prepared to cover each item of fuel oil combustion equipment, which should be identified, for which compliance is to be demonstrated by this Scheme.

13.2 The OMM should, as a minimum, include:

- (a) the sensors to be used in evaluating EGCS performance and discharge water, their service, maintenance and calibration requirements;
- (b) the positions from which exhaust emission measurements are to be taken together with details of any necessary ancillary services such as sample transfer lines and sample treatment units and any related service or maintenance requirements;
- (c) the analysers to be used, their service, maintenance, and calibration requirements;
- (d) analyser zero and span-check procedures; and
- (e) other information or data relevant to the correct functioning of the monitoring system or its use in demonstrating compliance.

13.3 The OMM should specify how the monitoring is to be surveyed.

13.4 The OMM should be approved by the Administration.

## 14 SECA Compliance Plan (SCP)

For all ships which are to use an EGCS-SO<sub>x</sub> unit, in part or in total, in order to comply with the requirements of regulation 14(4) there should be a SECA Compliance Plan (SCP) for the ship, approved by the Administration.

## 15 Ship compliance

15.1 The SCP should list each item of fuel oil combustion equipment which is to meet the requirements for operating in a SECA by means of an approved EGCS-SO<sub>x</sub> unit.

15.2 Under Scheme A, the SCP should present continuous monitoring data demonstrating that the parameters in paragraph 6.7 are maintained within the manufacturer's recommended specifications. Under Scheme B, this would be demonstrated using daily recordings.

15.3 Under Scheme B, the SCP should present continuous monitoring demonstrating that the SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio is 65 or below. Under Scheme A, this would be demonstrated using daily recordings.

15.4 There may be some equipment, such as small engines and boilers, to which the fitting of EGCS-SO<sub>x</sub> units would not be practical, particularly where such equipment is located in a position remote from the main machinery spaces. All such fuel oil combustion units should be listed in the SCP. For these fuel oil combustion units which are not to be fitted with EGCS-SO<sub>x</sub> units, compliance may be achieved by means of regulation 14(4)(a) while operating within a SECA. Alternatively, compliance may be achieved based on total ship emissions as described in paragraphs 15.7 and 15.8.

15.5 Ship construction requirements generally require that each fuel oil combustion unit should have its own exhaust gas system venting to the atmosphere. Therefore compliance by the ship may be demonstrated by each item of fuel oil combustion equipment meeting the requirements of either Scheme A or Scheme B. Alternatively, compliance may be demonstrated on the basis of total emissions generated by the ship as noted in paragraphs 15.7 and 15.8.

15.6 If each fuel oil combustion unit meets the requirements of either regulation 14(4)(a) or 14(4)(b) the ship is considered to be in compliance with the requirements.

15.7 Recognizing that the limit given in regulation 14(4)(b) is for the ship, not each individual item of combustion equipment, the shipowner should have the opportunity to balance performance which considerably exceeds

the requirement of 6.0 g SO<sub>x</sub>/kW·h or SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio of 65 or below against that of equipment, potentially not fitted with EGCS-SO<sub>x</sub> units, which does not meet that requirement. These cases should be subject to special consideration by the Administration. In particular the SCP should detail how the actual emissions from each fuel oil combustion unit are to be aggregated together to obtain an overall, real-time, emission value for the ship which does not exceed 6.0 g SO<sub>x</sub>/kW·h or SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio of 65 or below.

15.8 Since the emission value in regulation 14(4)(b) is an alternative to that given in regulation 14(4)(a), not an equivalent, compliance in excess of that required by means of regulation 14(4)(a) in respect of fuel oil burning units, such as given in section 2.3, should only be set against the requirements of regulation 14(4)(b) where it can be clearly documented as to the actual sulphur content of the fuel oil being used at any time together with the requirement that the specific fuel consumption rate (g fuel/kW·h) of that equipment is capable of determination on a real-time basis (calibration requirements of such equipment to comply with those as given in the NO<sub>x</sub> Technical Code).

15.9 At no time during operation in a SECA should the total ship emissions, as described in paragraph 15.5, exceed the requirement of 6.0 g SO<sub>x</sub>/kW·h or exceed the SO<sub>2</sub> (ppm)/CO<sub>2</sub> (%) ratio of 65 or below. Shipowners are advised to consider worst case operating scenarios, such as manoeuvring or high power operation, in their SO<sub>x</sub> control strategies.

## 16 *Demonstration of compliance*

16.1 The SCP should refer to, not reproduce, the ETM and Record Book as specified under that Scheme. Alternatively, this information is to be recorded in the ship's Planned Maintenance Record System, as allowed by the Administration.

16.2 For all fuel oil combustion equipment listed under 15.1, details should be provided demonstrating that the rating and restrictions for the EGCS-SO<sub>x</sub> unit as specified in paragraph 2.3.1(b) are complied with.

16.3 The wash water flow rate and pressure at the EGCS-SO<sub>x</sub> unit inlet connections, pH of the wash water at the EGCS-SO<sub>x</sub> unit's inlet and outlet connections, exhaust gas pressure before and pressure drop across the EGCS-SO<sub>x</sub> unit, fuel oil equipment load, and other parameters, as considered necessary, should be monitored and recorded continuously while within a SECA in order to demonstrate compliance.

16.4 The SCP should refer to the On-board Monitoring Manual as approved by the Administration and the input data and resulting reports.



## 17 *Wash water*

EGCS-SO<sub>x</sub> unit's wash water systems should:

- (a) eliminate, or reduce to a level at which they are not harmful, hydrocarbons, carbon residue, ash, vanadium, other heavy metals, and other substances contained within EGCS-SO<sub>x</sub> unit's wash water that may have an adverse impact on ecosystems if discharged overboard;
- (b) ensure that the approach adopted to control wash water quality and residual waste is not achieved in a way that causes pollution in other areas or environmental media;
- (c) also take into account guidelines to be developed by the Organization.

## 18 *Wash water residues*

18.1 Residues generated by the EGCS-SO<sub>x</sub> unit should be land-disposed. Such residues should not be discharged to the sea or incinerated on board.

18.2 The record-keeping requirements in respect of the disposal of wash water residues are to take into account guidelines to be developed by the Organization.

## Appendix

### SO<sub>2</sub> over CO<sub>2</sub> monitoring method

1 Correspondence between 65 (\*ppm/%) SO<sub>2</sub>/CO<sub>2</sub> and 1.5% sulphur in fuel is demonstrated by first calculating the mass ratio of fuel sulphur to fuel carbon, which is tabulated in table 1 for various fuels and fuel sulphur contents; including 1.5% sulphur for both distillate and residual fuels. These ratios were used to solve for the corresponding SO<sub>2</sub> and CO<sub>2</sub> concentrations in exhaust, which are tabulated in table 2. Molecular weights (MW) were taken into account to convert mass fractions to mole fractions. For the 1.5% sulphur fuels in table 2, the amount of CO<sub>2</sub> is set first at 8% and then changed to 0.5% to show that there is no effect due to changes in excess air. As expected, the absolute SO<sub>2</sub> concentration changes, but the SO<sub>2</sub>/CO<sub>2</sub> ratio does not. This indicates that the SO<sub>2</sub>/CO<sub>2</sub> ratio is independent of fuel-to-air ratios. Therefore, SO<sub>2</sub>/CO<sub>2</sub> ratio can be used robustly at any point of operation, including operation where no brake power is produced.

Note that the SO<sub>2</sub>/CO<sub>2</sub> ratio varies slightly from distillate to residual fuel. This occurs because of the very different atomic hydrogen-to-carbon ratios (H:C) of the two fuels. Figure 1 illustrates the extent of the SO<sub>2</sub>/CO<sub>2</sub> ratio's sensitivity to H:C over a broad range of H:C and fuel sulphur concentrations. From figure 1, it can be concluded that for fuel sulphur levels less than 3.00% S, the difference in S/C ratios for distillate and residual fuel is less than 5.0%.

**Table 1: Fuel properties for marine distillate and residual fuel**

	Carbon	Hydrogen	Sulphur	Other	H:C	Fuel S/C
	g/g	g/g	g/g	g/g	mol/mol	g/g
Distillate <sup>†</sup>	86.20%	13.60%	0.17%	0.03%	1.880	0.00197
Residual <sup>†</sup>	86.10%	10.90%	2.70%	0.30%	1.509	0.03136
Distillate 1.5% S	85.05%	13.42%	1.50%	0.03%	1.880	<u>0.01764</u>
Residual 1.5% S	87.17%	11.03%	1.50%	0.30%	1.509	<u>0.01721</u>

<sup>†</sup> Based on properties in the IMO NO<sub>x</sub> Monitoring Guidelines, MEPC.103(49).

\* *ppm* means “parts per million”. It is assumed that ppm is measured by gas analysers on a molar basis, assuming ideal gas behaviour. The technically correct units are actually micro-moles of substance per mole of total amount (μmol/mol), but ppm is used in order to be consistent with units in the NO<sub>x</sub> Technical Code.

Table 2: Emissions calculations corresponding to 1.5% fuel sulphur

	CO <sub>2</sub>	SO <sub>2</sub>	Exh SO <sub>2</sub> /CO <sub>2</sub>	Exh S/C
	%	ppm	ppm/%	g/g
Distillate 0.17% S	8	59.1	7.4	0.00197
Residual 2.70% S	8	939.7	117.5	0.03136
Distillate 1.5% S	8	528.5	<u>66.1</u>	<u>0.01764</u>
Residual 1.5% S	8	515.7	<u>64.5</u>	<u>0.01721</u>
Distillate 1.5% S	0.5	33.0	<u>66.1</u>	<u>0.01764</u>
Residual 1.5% S	0.5	32.2	<u>64.5</u>	<u>0.01721</u>

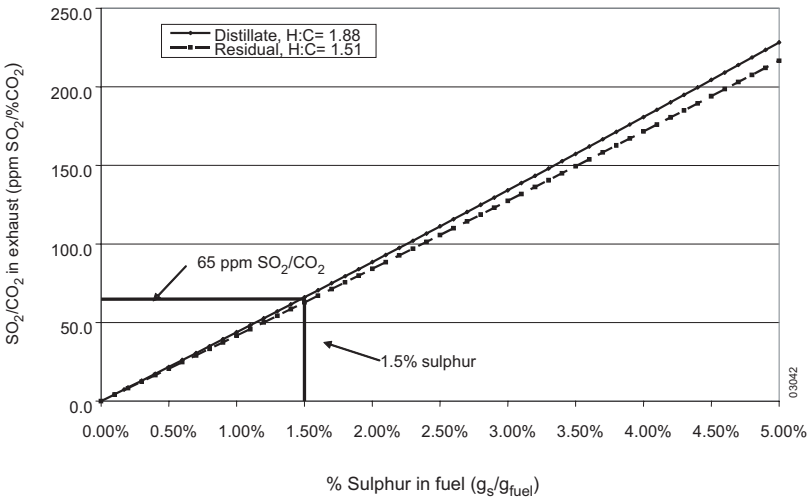


Figure 1 – SO<sub>2</sub>/CO<sub>2</sub> versus % sulphur in fuel

2 Correspondence between 65 (ppm/%) SO<sub>2</sub>/CO<sub>2</sub> and 6.0 g of SO<sub>2</sub>/kW·h is demonstrated by showing that their S/C ratios are similar. This requires the additional assumption of a brake-specific fuel consumption (BSFC) value of 200 g/kW·h. This is an appropriate average for marine diesel engines. The calculation is as follows:

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$$\frac{S}{C_{\text{fuel}}} = \frac{\text{brake-specific SO}_2 \times \left(\frac{MW_S}{MW_{\text{SO}_2}}\right)}{\text{BSFC} \times \left(\frac{\% \text{ carbon in fuel}}{100}\right)}$$

brake-specific SO<sub>2</sub> = 6.0 g/kW·h

MW<sub>S</sub> = 32.065 g/mol

MW<sub>SO<sub>2</sub></sub> = 64.064 g/mol

BSFC = 200 g/kW·h

% carbon in 1.5% S fuel (from table 1) = 85.05% (distillate) & 87.17% (residual)

$$\frac{S}{C_{\text{residual fuel}}} = \frac{6.0 \times \left(\frac{32.065}{64.064}\right)}{200 \times \left(\frac{87.17\%}{100}\right)}$$

$$\frac{S}{C_{\text{residual fuel}}} = 0.01723$$

$$\frac{S}{C_{\text{distillate fuel}}} = \frac{6.0 \times \left(\frac{32.065}{64.064}\right)}{200 \times \left(\frac{85.05\%}{100}\right)}$$

$$\frac{S}{C_{\text{distillate fuel}}} = 0.01765$$

Note that the S/C mass ratios calculated above, based on 6.0 g SO<sub>2</sub>/kW·h and 200 g/kW·h BSFC, are both within 0.10% of the S/C mass ratios in the emissions table (table 2). Therefore, 65 ppm/% SO<sub>2</sub>/CO<sub>2</sub> corresponds well to 6.0 g SO<sub>x</sub>/kW·h in regulation 14(4)(b).

3 Thus, the working formulae are as follows:

$$\text{For complete combustion} = \frac{\text{SO}_2(\text{ppm}^*)}{\text{CO}_2(\%*)} \leq 65$$

$$\text{For incomplete combustion} = \frac{\text{SO}_2(\text{ppm}^*)}{\text{CO}_2(\%*) + \left(\frac{\text{CO}(\text{ppm}^*)}{10000}\right) + \left(\frac{\text{THC}(\text{ppm}^*)}{10000}\right)} \leq 65$$

4 The following is the basis of using the 65 (ppm/%) SO<sub>2</sub>/CO<sub>2</sub> as the limit for determining compliance with regulation 14:

- (a) This limit can be used to determine compliance from fuel oil burners that do not produce mechanical power.
- (b) This limit can be used to determine compliance at any power output, including idle.

\*Note: gas concentrations must be sampled or converted to the same residual water content (e.g., fully wet, fully dry).

- (c) This limit only requires two gas concentration measurements at one sampling location.
- (d) There is no need to measure any engine parameters such as engine speed, engine torque, engine exhaust flow, or engine fuel flow.
- (e) If both gas concentration measurements are made at the same residual water content in the sample (e.g. fully wet, fully dry), no dry-to-wet conversion factors are required in the calculation.
- (f) This limit completely decouples the thermal efficiency of the fuel oil combustion unit from the EGCS-SO<sub>x</sub> unit.
- (g) No fuel properties need to be known.
- (h) Because only two measurements are made at a single location, transient engine or EGCS-SO<sub>x</sub> unit effects can be minimized by aligning signals from just these two analysers. (Note that the most appropriate points to align are the points where each analyser responds to a step change in emissions at the sample probe by 50% of the steady-state value).
- (i) This limit is independent of the amount of exhaust gas dilution. Dilution may occur due to evaporation of water in an EGCS-SO<sub>x</sub> unit, and as part of an exhaust sampler's preconditioning