INTERNATIONAL MARITIME ORGANIZATION

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SUB-COMMITTEE ON POLLUTION PREVENTION AND RESPONSE
1st session
Agenda item 8

PPR 1/8/3
10 December 2013
Original: ENGLISH

# CONSIDERATION OF THE IMPACT ON THE ARCTIC OF EMISSIONS OF BLACK CARBON FROM INTERNATIONAL SHIPPING

## Proposed measurement method for Black Carbon

**Submitted by the European Association of Internal Combustion Engine Manufacturers (EUROMOT)**

**SUMMARY**

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| *Executive summary:* | This document comments on the report of the correspondence group (CG) on consideration of the impact on the Arctic of emissions of Black Carbon (BC) from international shipping and provides information on the filter smoke number (FSN) method for the determination of equivalent Black Carbon (eBC) as well as determination of elemental carbon (EC) by a multi-step thermal method |
| *Strategic direction:* | 7.3 |
| *High-level action:* | 7.3.2 |
| *Planned output:* | 7.3.2.2 |
| *Action to be taken:* | Paragraph 14 |
| *Related documents:* | PPR 1/8 and PPR 1/8/4 |


## Introduction

1 This document is submitted in accordance with the provisions of paragraph 6.12.5 of the Committees' Guidelines (MSC-MEPC.1/Circ.4/Rev.2) and comments on document PPR 1/8.

2 Document PPR 1/8 on the report of the correspondence group, under terms of reference 2 – consideration of measurement methods for Black Carbon (BC), recommends a shift in focus from theoretical instrument capability to the real-life performance and output required from methods used for measuring BC from ships and to discuss sample treatment and testing protocol, in particular, any areas where those procedures might be similar across instruments. Further, the report recommends that the working group consider any testing protocol adjustments that would be needed for use with different fuels or under different test

conditions and that the working group assess the practicability of various test methods. To facilitate the discussion, additional information on the subjects of measurement methods and method comparison are provided by EUROMOT.

3 In this document, the nomenclature according to Petzold is strictly used.

4 EUROMOT would like to exclude any methods regarding refractory Black Carbon (rBC), e.g. Laser Incandescence, owing to lack of available measurement data and missing experience outside of laboratory test engines, as well as lack of standardization and calibration of this method for diesel engine applications. Besides, safety issues by the incorporation of a strong laser source on board ships might call for additional concerns.

5 Furthermore, EUROMOT aligns with the outcome of the correspondence group to exclude Opacimeter methods. According to Petzold, opacity does not fit into any of his EC, rBC or eBC categories as opacity in general is not specific to the detection of carbonaceous material as its wavelength has neither been adjusted specifically to carbon nor to ultra-fine nm particles.

6 In addition, EUROMOT would like to exclude Photo Acoustic Soot Spectrometer (PASS) methods again owing to lack of experience and lack of available measurement data for marine diesel engines especially operating on residual fuels. Besides, standardization and calibration is still missing for this method. For marine diesel engines, an additional dilution stage is necessary, which adds further complexity to this method.

7 EUROMOT would like to focus on measurement options for EC and eBC. In the following diagrams, EC and eBC measurements are compared for different fuels and different particulate matter (PM) measurement procedures. PM has been determined according to ISO-9096 (2003) (PM hot-in-stack filtration method) equivalent to US-EPA method 17 as prescribed for stationary applications. The hot-in-stack filtration method compared to ISO-8178-1 (2006) (PM dilution method), as prescribed for mobile applications, has the advantage of lower bias introduction from collected organic material (OM) and, therefore, suffers less from pyrolytic conversion. The PM filter samples have been further examined for its EC content by a multi-step thermal method with a thermal carbon analyser according to VDI-2465 Part 2 (1999) with an additional step from VDI-2465 Part 1 (1996) to minimize the effect of pyrolytic conversion of OM into EC during the thermal treatment in the inert gas phase. Further details of the method can be found in document PPR 1/8/4.

8 Furthermore, eBC has been determined with heated FSN method according to ISO-10054 (1998). This method has been used as standard in the automotive industry until elaborate exhaust gas after treatment for EURO-5/6 made it necessary to look for alternative methods with higher sensitivity. AVL-415S heated and its corresponding conversion formula has been used to calculate eBC. AVL-415S uses a wide band light source with green filter which results in an overall narrow band sensitivity peaking at 570 nm. As the FSN method has been especially developed for the detection of carbonaceous material, it fulfils the definition of eBC, confirmed by direct conversation with Petzold.

9 Multi-Angle Absorption Photometer (MAAP) is a more sophisticated and complex version of the FSN method. In the case of Thermo Scientific Model 5012, an additional dilution stage is required, which owing to its complex system and required control of the dilution ratio does not offer significant advantages over FSN method.

10 A comparison of measurements for DM-A grade fuel can be found in diagram 1. Both, an unconstraint fit and a fit constraint, to go through the origin have been performed. Linear coefficients and $r^2$ values were also calculated for each comparison. This comparison provides sufficient evidence that simple and robust FSN based eBC measurements can be used instead of laborious and expensive EC measurements.

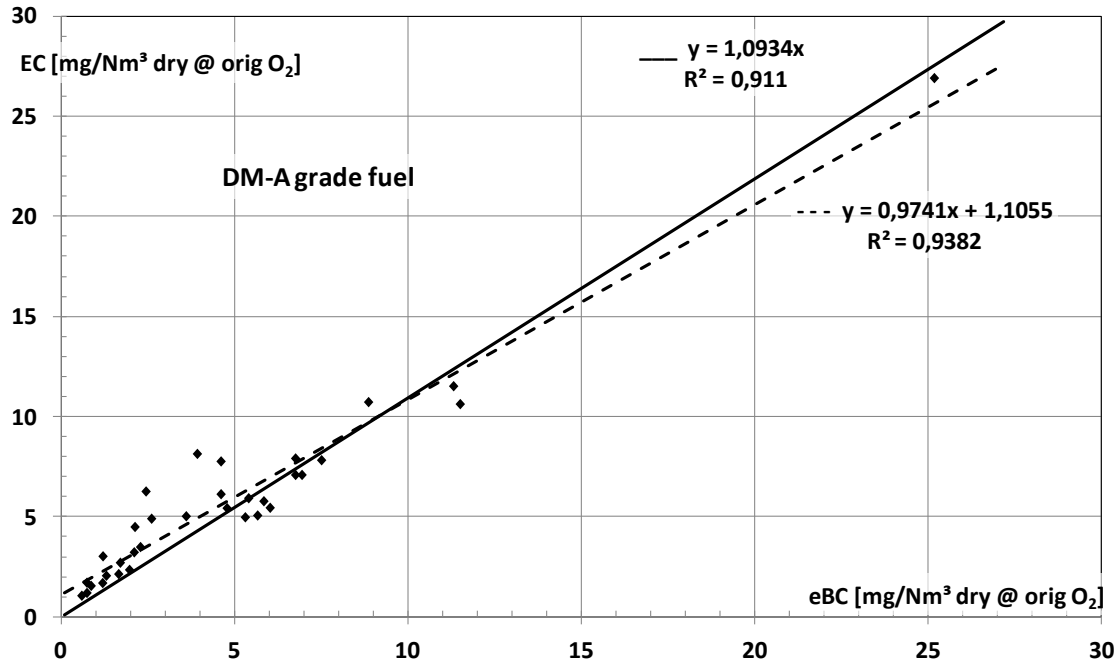


**Diagram 1: EC vs. eBC measured with DM-A fuel on 4-stroke medium speed engines**

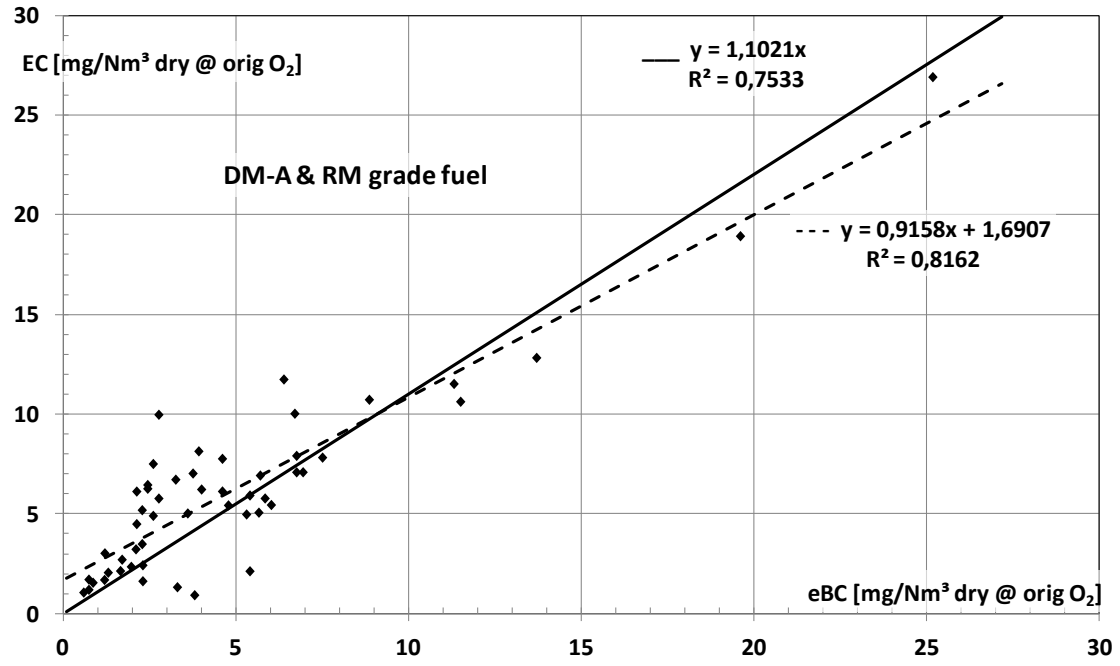


**Diagram 2: EC vs. eBC for DM-A & RM fuel grades on 4-stroke medium speed engines**

11 A comparison of measurements for DM-A and RM fuel grades according to ISO-8217 (2010/2011) can be found in diagram 2. Again, constraint and unconstraint fits with linear coefficients and $r^2$ values are given. The diagram is based on 52 measurement pairs, representing a wide range of 4-stroke medium speed engines.

12 The deviations in diagram 2 from diagram 1 are still within the findings made by Watson with respect to inter-laboratory comparisons for the determination of EC or eBC, showing typical differences of a factor of 2 between methods, but sometimes even discrepancies of a factor of 7. EC measurement methods can actually vary by a factor of 10. It is doubtful that future carbon comparisons will add much information to those already completed. While it is possible to observe differences, they are not possible to explain with current scientific understanding.

13 EUROMOT is of the opinion that, at the current state of art, the determination of eBC by the simple, robust and widespread FSN method is adequate to fit the purpose of accessing the impact on the Arctic of emissions of Black Carbon from international shipping. Any other method will add complexity and effort by granting questionable additional benefit. EUROMOT would also refrain from EC determination by any thermal, thermo-optical or thermo-chemical methods, owing to its complexity, introduction of additional biases and uncertainties.

**Action requested of the Sub-Committee**

14 The Sub-Committee is invited to consider the above information and take action as appropriate.

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**References:**

Petzold, A.; et. al.: Recommendations for reporting "black carbon" measurements, Atmos. Chem. Phys., 13, 8365-8379, doi:10.5194/acp-13-8365-2013, 2013.

MAN and Wärtsilä: Measurement data provided via direct conversation to EUROMOT.
AVL Deutschland GmbH: AVL-415S Information provided by direct conversation to EUROMOT.

Germanischer Lloyd accredited laboratory "Analysetechnik": Determination of Elemental Carbon from PM Filter Samples.

Watson, J.G.; et. al.: Summary of organic and elemental carbon/black carbon analysis methods and intercomparisons. AAQR, 5(1):65-102, 2005.

ISO-8178-1: Reciprocating internal combustion engines – Exhaust emission measurement – Part 1: Test-bed measurement of gaseous and particulate exhaust emissions, 2006.
ISO-9096: Stationary source emissions – Manual determination of mass concentration of particulate matter, 2003.

US-EPA method 17 – In-Stack PM: Determination of particulate matter from stationary sources.

ISO-10054: Internal combustion compression-ignition engines – Measurement apparatus for smoke from engines operating under steady-state conditions – Filter-type smokemeter, 1998.

ISO-8217: Petroleum products – Fuels (class F) – Specifications of marine fuels, 2010/2011.