

**ANNEX 23****DRAFT MEASUREMENT REPORTING PROTOCOL FOR BLACK CARBON DETERMINATION** PPR 3/WP.4, ANNEX 1**1. Engine design parameters (to be completed before measurement)**

|   |   |   |                                       |                             |
|---|---|---|---------------------------------------|-----------------------------|
| <b>1.1 Engine</b>                                 | Production year:  | <u>2012</u>                                     |                                       |                             |
|   | Location:   | <input checked="" type="checkbox"/> Testbed     |                                       |                             |
|   |   | <input type="checkbox"/> Ship                   |                                       |                             |
| <b>1.2 Engine freshly manufactured</b>            | <input type="checkbox"/> Yes  | <input checked="" type="checkbox"/> No          |                                       |                             |
|   | <b>If no:</b> Documentation of relevant maintenance provided            | <input type="checkbox"/> Yes                    | <input type="checkbox"/> No           |                             |
| <b>1.3 Engine total running hours</b>             |   | <u>1370</u> [h]                                 |                                       |                             |
| <b>1.4 Regular maintenance interval</b>           |   | <u>6000</u> [h]                                 |                                       |                             |
| <b>1.5 Hours since last regular maintenance</b>   |   | <u>-</u> [h]                                    |                                       |                             |
| <b>1.6 Engine category</b>                        | <input checked="" type="checkbox"/> 4-stroke                            |   |                                       |                             |
|   | <input type="checkbox"/> 2-stroke                                       |   |                                       |                             |
| <b>1.7 Engine fuel type</b>                       | <input checked="" type="checkbox"/> Diesel                              | <input type="checkbox"/> Gas                    | <input type="checkbox"/> Dual fuel    |                             |
| <b>1.8 Engine max. rated power</b>                |   | <u>3498</u> [kW]                                |                                       |                             |
| <b>1.9 Mean effective pressure at rated power</b> |   | <u>26.4</u> [bar]                               |                                       |                             |
| <b>1.10 Engine speed</b>                          | <input type="checkbox"/> Less than 130 rpm                              |   |                                       |                             |
|   | <input checked="" type="checkbox"/> 130 or more but less than 2,000 rpm |   |                                       |                             |
|   | <input type="checkbox"/> 2,000 rpm or more                              |   |                                       |                             |
| <b>1.11 Method of air aspiration</b>              | <input type="checkbox"/> Naturally aspirated                            |   |                                       |                             |
|   | <input checked="" type="checkbox"/> Pressure-charged single stage       |   |                                       |                             |
|   | <input type="checkbox"/> Pressure-charged multi stage                   |   |                                       |                             |
| <b>1.12 Injection system</b>                      | <input checked="" type="checkbox"/> Conventional                        |   |                                       |                             |
|   | <input type="checkbox"/> Common rail                                    |   |                                       |                             |
| <b>1.13 Applicable emission limit</b>             | <input type="checkbox"/> IMO Tier I                                     | <input checked="" type="checkbox"/> IMO Tier II | <input type="checkbox"/> IMO Tier III |                             |
|   | <input type="checkbox"/> Others:  | <u></u>   |                                       |                             |
| <b>1.14 Applicable test cycle</b>                 | <input type="checkbox"/> C1   | <input checked="" type="checkbox"/> D2          | <input type="checkbox"/> E2           | <input type="checkbox"/> E3 |
|   | <input type="checkbox"/> Others:  | <u></u>   |                                       |                             |

**1.15.1 Specific lubrication oil consumption**

SLOC: \_\_\_\_\_ 0.5 [g/kWh]

Breaking-in period: ☒ Finished  
☐ Not finished  
☐ Not applicable

**1.15.2 Cylinder liner lubrication**☒ None☐ Yes, active at

☐ 100% Feed rate: \_\_\_\_\_ [g/h]  
☐ 75% Feed rate: \_\_\_\_\_ [g/h]  
☐ 50% Feed rate: \_\_\_\_\_ [g/h]  
☐ 25% Feed rate: \_\_\_\_\_ [g/h]  
☐ 10% Feed rate: \_\_\_\_\_ [g/h]

Breaking-in period: ☐ Finished  
☐ Not finished  
☒ Not applicable

**1.15.3 Inlet valve seat lubrication**☐ None☒ Yes, active at

☒ 100% Feed rate: - \_\_\_\_\_ [g/h]  
☒ 75% Feed rate: - \_\_\_\_\_ [g/h]  
☒ 50% Feed rate: - \_\_\_\_\_ [g/h]  
☒ 25% Feed rate: - \_\_\_\_\_ [g/h]  
☒ 10% Feed rate: - \_\_\_\_\_ [g/h]

**1.16 Exhaust gas treatment device**☒ None☐ Yes

☐ SCR  
☐ Scrubber  
☐ EGR  
☐ Water injection  
☐ Others: \_\_\_\_\_

**2. Fuel****2.1 Fuel in use**

☐ ULSD ☐ DMX ☐ DMA ☐ DMZ ☐ DMB  
☐ RMA ☐ RMB ☐ RMD ☐ RME ☐ RMG ☐ RMK  
☒ Other: HFO acc. standard: ISO 8217:2010

☐ Natural Gas☐ Other gases acc. IGF: \_\_\_\_\_☐ Liquid to gas fuel ratio as certified at mode point:

100% \_\_\_\_\_  
75% \_\_\_\_\_  
50% \_\_\_\_\_  
25% \_\_\_\_\_  
10% \_\_\_\_\_

**Fuel properties and composition (in use during testing)****2.2 Gas**

Please fill in as far as possible  
most important marked with \*)

| Property                | Unit / Standard                       | Actual value | Remark |
|-------------------------|---------------------------------------|--------------|--------|
| Methane number*)        | [-] / DIN EN 16726                    |              |        |
| Lower calorific value*) | [MJ/kg] / ISO 6976                    |              |        |
| Higher calorific value  | [MJ/kg] / ISO 6976                    |              |        |
| Wobbe Indices Ws / Wi   | [MJ/m <sup>3</sup> ] / ISO 6976       |              |        |
| Density*)               | [kg/m <sup>3</sup> ] / ISO 6976       |              |        |
| Methane*)               | wt.-% [kg/kg] / ISO 6974 or DIN 51894 |              |        |
| Ethane*)                | wt.-% [kg/kg] / ISO 6974 or DIN 51894 |              |        |
| Propane*)               | wt.-% [kg/kg] / DIN 51894             |              |        |
| Isobutane*)             | wt.-% [kg/kg] / DIN 51894             |              |        |
| N-Butane*)              | wt.-% [kg/kg] / DIN 51894             |              |        |
| Pentane                 | wt.-% [kg/kg] / DIN 51894             |              |        |
| Hexane                  | wt.-% [kg/kg] / DIN 51894             |              |        |
| Heptane                 | wt.-% [kg/kg] / DIN 51894             |              |        |
| Nitrogen                | wt.-% [kg/kg] / ISO 6974              |              |        |
| Sulphur*)               | wt.-% [kg/kg] / ISO 6326-5            |              |        |
| Hydrogen sulfide        | wt.-% [kg/kg] / ISO 8819              |              |        |
| Carbon dioxide          | wt.-% [kg/kg] / ISO 6974              |              |        |
| Hydrogen                | wt.-% [kg/kg] / DIN 51894             |              |        |
| Others                  |                                       |              |        |

**2.3 Liquid fuel**

Please fill in as far as possible  
most important marked with \*)  
essential \*\*)

| Property                    | Unit / Standard                          | Actual value | Remark    |
|-----------------------------|--|--------------|-----------|
| Type of fuel                | Grade / ISO 8217                         | HFO          |           |
| Flash point*)               | [°C] / ISO 2719                          |              |           |
| Viscosity @ 40/50°C **)     | [mm <sup>2</sup> /s] / ISO 3104          | 472          | ASTMD7042 |
| Density @ 15°C *)           | [kg/m <sup>3</sup> ] / ISO 3675 or 12185 | 990          | DIN51757  |
| Net calorific value (Hu) *) | [J/g] / DIN 51900                        | 40117        |           |
| Sulphur content*)           | ppm [mg/kg] / ISO 8754 or 14596          | 2.86         | wt.-%     |
| Ash content*)               | ppm [mg/kg] / ISO 6245                   | 0.05         | wt.-%     |
| Water content*)             | ppm [mg/kg] / ISO 3733                   | 0.04         | wt.-%     |
| Carbon content*)            | wt.-% [kg/kg] / ASTM D5291               | 85.8         |           |
| Hydrogen content*)          | wt.-% [kg/kg] / ASTM D5291               | 10.7         |           |
| Nitrogen content*)          | wt.-% [kg/kg] / DIN 51444                | 0.39         |           |
| Oxygen content*)            | wt.-% [kg/kg] / DIN 51732                |              |           |
| Cetane index*)              | ISO 4264                                 |              |           |
| CCAI*)                      |  | 849          |           |
| FAME content*)              | wt.-% [kg/kg] / EN 14078                 |              |           |
| Mono aromatic compounds*)   | wt.-% [kg/kg] / EN 12916                 |              |           |
| Poly aromatic compounds*)   | wt.-% [kg/kg] / EN 12916                 |              |           |
| Di aromatic compounds       | wt.-% [kg/kg] / EN 12916                 |              |           |
| Tri aromatic compounds      | wt.-% [kg/kg] / EN 12916                 |              |           |
| Inorganic constituents (V)  | ppm [mg/kg] / ISO 14597 or 8691          |              |           |
| Inorganic constituents (Ni) | ICP                                      |              |           |
| Carbon residues*)           | wt.-% [kg/kg] / ASTM D4530               |              |           |
| Others                      |  |              |           |

### 3. Lube oil properties and composition (in use during testing; Producers specification can be used)

#### 3.1 Circulation lubrication oil

Please fill in as far as possible

| Property        | Unit / Standard                   | Actual value | Remark       |
|-----------------|-----------------------------------|--------------|--------------|
| Lube oil        | Brand / Type                      | T40          | Shell Argina |
| Grade           | Multi / Mono                      | Mono         |              |
| BN              | mg KOH/g / ISO 3771               | 30           |              |
| Ash content     | wt.-% [kg/kg] / ISO 6245          | 2.98         |              |
| Viscosity       | [mm <sup>2</sup> /s] / ASTM D7042 | 140          |              |
| Sulphur content | wt.-% [kg/kg] / ISO 20884         | 0.69         |              |

#### 3.2 Cylinder oil

Please fill in as far as possible

Please fill in if applicable

| Property        | Unit / Standard                   | Actual value | Remark |
|-----------------|-----------------------------------|--------------|--------|
| Lube oil        | Brand / Type                      |              |        |
| Grade           | Multi / Mono                      |              |        |
| BN              | mg KOH/g / ISO 3771               |              |        |
| Ash content     | wt.-% [kg/kg] / ISO 6245          |              |        |
| Viscosity       | [mm <sup>2</sup> /s] / ASTM D7042 |              |        |
| Sulphur content | wt.-% [kg/kg] / ISO 20884         |              |        |

#### 3.3 Valve seat lubrication oil

Please fill in as far as possible

Please fill in if applicable

| Property        | Unit / Standard                   | Actual value | Remark |
|-----------------|-----------------------------------|--------------|--------|
| Lube oil        | Brand / Type                      |              |        |
| Grade           | multi / mono                      |              |        |
| BN              | mg KOH/g / ISO 3771               |              |        |
| Ash content     | wt.-% [kg/kg] / ISO 6245          |              |        |
| Viscosity       | [mm <sup>2</sup> /s] / ASTM D7042 |              |        |
| Sulphur content | wt.-% [kg/kg] / ISO 20884         |              |        |

#### 4. Measurement equipment information (to be completed before measurement) and parameters

##### Measurement instrument

4.1 BC measurement instrument information      Make: AVL      Model: 415 S

4.2 Measurement principle      ☐ LII      x FSN      ☐ PAS      ☐ MAAP  
☐ Others: \_\_\_\_\_

4.3 Values reported as      ☐ EC (thermal)      Protocol acc.: \_\_\_\_\_  
☐ rBC  
☐ eBC  
x FSN  
☐ Others: \_\_\_\_\_

4.4 Values reported in unit      ☐  $\text{mg}/\text{m}_n^3$  (wet basis; act.  $\text{O}_2$ -concentration)       $\text{H}_2\text{O}$ -conc.: \_\_\_\_\_ [Vol.-%] (wet)  
☐  $\text{mg}/\text{m}_n^3$  (dry basis; act.  $\text{O}_2$ -concentration)  
☐  $\text{mg}/\text{m}_n^3$  (dry basis; Ref.  $\text{O}_2$ -concentration)       $\text{O}_2$ -conc.: \_\_\_\_\_ [Vol.-%] (dry)  
☐  $\text{mg}/\text{kWh}$  refer to 5.  
x FSN  
☐  $\text{mg}/\text{kg}$  fuel refer to 5.  
☐ Others: \_\_\_\_\_

4.5 Reference conditions      Norm temperature: \_\_\_\_\_ [°C]  
(only if 4.4 is referred to Norm-cubic meters [ $\text{m}_n^3$ ])      Norm pressure: \_\_\_\_\_ [mbar]

4.6 Sampling time / -number      Sampling time of each measurement: automatic mode [s]  
If mean values are reported: Number of consecutive  
measurements at each mode point: 3 [-]  
Acc. manufacturer specification:      x Yes      ☐ No

4.7 BC instrument parameter      Temperature inside measuring cell: 70 [°C]  
Pressure inside measuring cell: ambient [mbar]  
Wavelength(s) used: \_\_\_\_\_ [nm]  
Mass absorption cross section(s) used: \_\_\_\_\_ [ $\text{m}^2/\text{g}$ ]  
Conversion equation(s) used: \_\_\_\_\_  
Repeatability of the instrument used:  $\leq 0.005 \text{ FSN} + 3$  % of measured value  
Reproducibility of the instrument used:  $\leq 0.005 \text{ FSN} + 6$  % of measured value  
Acc. manufacturer specification:      x Yes      ☐ No

Other parameters which could influence the measured values:

| Parameter / Correction | Unit |
|------------------------|------|
|                        |      |
|                        |      |

**4.8 BC Instrument Calibration**Date of last calibration: 06/11/2015 (dd.mm.yyyy)

Calibration procedure according manufacturer specification:

x Yes ☐ No ☐ Others: \_\_\_\_\_Calibration including zero point: x Yes ☐ NoUsed medium for zero point calibration: Reflectance standard and clean filterUsed calibration standard: ☐ Synthetic flame soot☐ Printex-U☐ Graphite spark aerosol generator GfG soot☐ Soot with inorganic coatings☐ Soot without inorganic coatings

x Reflectance standards

☐ Others: \_\_\_\_\_

Remark: \_\_\_\_\_

Leakage test performed before or after calibration: x Yes ☐ No ☐ Not applicable**4.9 Sample gas pre-treatment**

Please fill in if applicable

Exhaust gas dilution: ☐ Yes x No

If yes, dilution ratio (1:x) \_\_\_\_\_ at mode point: \_\_\_\_\_ [%]

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Dilution medium: ☐ Ambient air ☐ Exhaust gas☐ Others: \_\_\_\_\_Filtration of the dilution medium before dilution: ☐ Yes ☐ No

Temperature of the dilution medium: \_\_\_\_\_ [°C]

Temperature of the diluted exhaust gas: \_\_\_\_\_ [°C]

Evaporation tube ☐ Yes x NoTemperature \_\_\_\_\_ [°C] acc. manufacturer spec. ☐ Yes ☐ NoCatalytic stripper ☐ Yes x NoTemperature \_\_\_\_\_ [°C] acc. manufacturer spec. ☐ Yes ☐ NoThermo-denuder ☐ Yes x NoTemperature \_\_\_\_\_ [°C] acc. manufacturer spec. ☐ Yes ☐ No

Others: \_\_\_\_\_

**4.10 Sample flow rate/volume**Acc. manufacturer specification: x Yes ☐ NoSample flow rate of the raw exhaust gas: 10 [l/min]

Sample flow rate of the diluted exhaust gas: \_\_\_\_\_ [l/min]

Sample volume of the raw exhaust gas: \_\_\_\_\_ [l]

Sample volume of the diluted exhaust gas: \_\_\_\_\_ [l]

☐ Subkinetic ☐ Isokinetic ☐ Superkinetic x Not applicable

## Sample line and probe

#### 4.11 Sample/transfer line

Please fill in if applicable

Use of a sample line:      ☒ Yes      ☐ No (in situ,...)

Acc. manufacturer specification: ☒ Yes ☐ No

Length of the sample line: 2 [m]

Heated sample line: ☒ Yes      Temperature: 70 [°C]  
☐ No

Sample line material: Viton

Inner diameter of the sample line: 4 [mm]

Isolated or heated connections between sample line, measurement instrument and probe:    ☒ Yes            ☐ No

Electrical conductive (sample line material): ☐ Yes ☒ No

Grounded: ☐ Yes ☒ No

Grounding method: -

Backflushing sample line between measurements:      ☒ Yes      ☐ No

#### 4.12 Sample probe

**Please fill in if applicable**

Use of sample probe:      ☒ Yes                      ☐ No (in situ,...)

Acc. manufacturer specification: ☒ Yes ☐ No

Material:    ☒ Stainless steel                      ☐ Others:

Type/design:

- ☐ Probe with single hole at the end (pipe)
- ☒ Probe with single hole at the end (45° beveled)
- ☐ Multi-hole
- ☐ L-shaped pipe with single hole, opening shielded with preclassifier (e.g. hat)
- ☐ Others:

Direction of the probe opening relative to the exhaust gas flow:

- ☐ With flow   x   Against flow
- ☐ Others:

|   |      |                    |
|---|------|--------------------|
| Effective cross section of sample hole opening(s) | 17.8 | [mm <sup>2</sup> ] |
|---|------|--------------------|

Backflushing sample probe between measurements:      ☒ Yes      ☐ No

## Sampling point and probe location

### 4.13 Sample point and probe location ☒ Engine Outlet

☐ Downstream heat exchanger

☐ Downstream exhaust gas treatment device

Treatment device active during measurement ☐ Yes ☐ No

☐ Others: \_\_\_\_\_

Distance between engine outlet and sampling point: \_\_\_\_\_ 8 [m]

Diameter of the exhaust gas pipe: \_\_\_\_\_ 1 [m]

Type of exhaust gas pipe where the sample probe is located:

☐ Straight part of the exhaust gas pipe

☒ Bent part of the exhaust gas pipe

Immersion depth of the sample probe: \_\_\_\_\_ 0.3 [m]

Orientation of the exhaust gas pipe where the sample probe is located:

☒ Horizontal ☐ Vertical ☐ Others: \_\_\_\_\_

Length of straight part of the exhaust gas pipe,

if sample probe is located at straight part of the exhaust gas pipe:

Upstream sample probe: \_\_\_\_\_ 0 [m]

Downstream sample probe: \_\_\_\_\_ 2 [m]

Exhaust gas pulsation at the sampling point during measurement:

☒ No ☐ Yes \_\_\_\_\_ [mbar]

## 5. Determination of engine load, exhaust gas flow, exhaust water content, fuel mass flow, O<sub>2</sub> and CO<sub>2</sub> (if applicable)

5.1 Determination of values, instrument performance and calibration shall be in accordance with the requirements of NOx Technical Code 2008 (NTC 2008) and its applicable appendices

5.2.1 Method of load determination

5.2.2 Estimated accuracy of engine load determination +/- \_\_\_\_\_ [%] of reading

5.3.1 Method of exhaust gas flow determination

5.3.2 Estimated accuracy of exhaust gas flow determination +/- \_\_\_\_\_ [%] of reading

5.4.1 Method of exhaust water content determination

5.4.2 Estimated accuracy of exhaust water content determination +/- \_\_\_\_\_ [%] of reading

5.5.1 Method of fuel mass flow determination

5.5.2 Estimated accuracy of fuel mass flow determination +/- \_\_\_\_\_ [%] of reading

5.6.1 Method of O<sub>2</sub> and CO<sub>2</sub> determination

5.6.2 Estimated accuracy of O<sub>2</sub> and CO<sub>2</sub> determination +/- \_\_\_\_\_ [%] of reading

## 6. Measured values for BC determination (to be completed during measurement; measured values)

Date of measurement (dd.mm.yyyy) 

|            |            |            |            |            |
|------------|------------|------------|------------|------------|
| 01/03/2016 | 01/03/2016 | 01/03/2016 | 01/03/2016 | 01/03/2016 |
|------------|------------|------------|------------|------------|

Engine parameters

Measurement at mode points: 

|     |    |    |    |    |
|-----|----|----|----|----|
| 100 | 75 | 50 | 25 | 10 |
|-----|----|----|----|----|

 [%]

|   | ↓  | ↓         | ↓           | ↓           | ↓                   |             |
|---|--|-----------|-------------|-------------|---------------------|-------------|
| <b>6.1 Stabilized mode point</b>  |  |           |             |             |                     |             |
| Actual Speed  | 750  | 750       | 750         | 750         | 750                 | [rpm]       |
| Speed variation during measuring  | 0  | 0         | 0           | 0           | 0                   | +/- [%]     |
| Actual Load   | 3502   | 2632      | 1746        | 879         | 350                 | [kW]        |
| Load variation during measuring   | 0.1  | 0.3       | 0.2         | 0.5         | 0.1                 | +/- [%]     |
| <b>6.2 Charge air temperature</b>   | 42   | 39        | 37          | 35          | 35                  | [°C]        |
| <b>6.3 Charge air pressure</b>  | 4860   | 3910      | 2730        | 1590        | 1160                | [mbar] abs. |
| <b>6.4 Exhaust gas temp. at engine outlet</b>   | 334  | 326       | 359         | 367         | 295                 | [°C]        |
| <b>6.5 Exh. gas temp. at sampling point</b>   | -  | -         | -           | -           | -                   | [°C]        |
| (only if there is a significant difference to the exhaust gas temperature at the engine outlet) |  |           |             |             |                     |             |
| <b>6.6 Exhaust gas back pressure</b>  | 52   | 35        | 16          | 5           | 2                   | [mbar]      |
| <b>6.7 Exhaust gas mass flow</b>  | 23080  | 18730     | 13040       | 7580        | 5300                | [kg/h]      |
| <b>Ambient conditions</b>   |  |           |             |             |                     |             |
| <b>6.8 Ambient temp. at engine inlet</b>  | 30   | 29        | 30          | 31          | 31                  | [°C]        |
| <b>6.9 Ambient pressure at engine inlet</b>   | 963  | 962       | 962         | 961         | 961                 | [mbar]      |
| <b>6.10 Absolute humidity of ambient air</b>  | 3.95   | 3.9       | 3.86        | 3.87        | 3.91                | [g/kg]      |
| <b>7. Black Carbon</b>  | Reported as (see 4.3):                                 |           | FSN         |             | Unit (see 4.4): FSN |             |
| <b>7.1 Estimated accuracy of measured value</b>   | -  | -         | -           | -           | -                   | +/- [%]     |
| <b>7.2 Black Carbon emission</b>  | 0.146  | 0.163     | 0.254       | 0.320       | 0.499               |             |
| Remark:   | §7.1 not applicable due to no determination acc. to §5 |           |             |             |                     |             |
| <b>8. Measurement repeatability Indicators</b>  |  |           |             |             |                     |             |
| <b>8.1 95% confidence interval</b><br>( +/- unit measured)                                      | 0.00053343   | 0.0016003 | 0.006810437 | 0.001923326 | 0.00615187          |             |
| <b>8.2 Variance</b>   | 2.22E-07   | 2.00E-06  | 3.62E-05    | 2.89E-06    | 2.96E-05            |             |
| <b>8.3 Sample size</b><br>(number of measurements taken)  | 1  | 1         | 1           | 1           | 1                   |             |