

ANNEX 16**DRAFT MEASUREMENT REPORTING PROTOCOL FOR BLACK CARBON DETERMINATION** PPR 3/WP.4, ANNEX 1**1. Engine design parameters (to be completed before measurement)****1.1 Engine**

Production year: 2016
Location: ☒ Testbed
☐ Ship

1.2 Engine freshly manufactured

☒ Yes ☐ No

If no: Documentation of relevant maintenance provided ☐ Yes ☐ No

1.3 Engine total running hours

237 [h]

1.4 Regular maintenance interval

6000 [h]

1.5 Hours since last regular maintenance

- [h]

1.6 Engine category

☒ 4-stroke
☐ 2-stroke

1.7 Engine fuel type

☒ Diesel ☐ Gas ☐ Dual fuel

1.8 Engine max. rated power

7200 [kW]

1.9 Mean effective pressure at rated power

26.6 [bar]

1.10 Engine speed

☐ Less than 130 rpm
☒ 130 or more but less than 2,000 rpm
☐ 2,000 rpm or more

1.11 Method of air aspiration

☐ Naturally aspirated
☒ Pressure-charged single stage
☐ Pressure-charged multi stage

1.12 Injection system

☒ Conventional
☐ Common rail

1.13 Applicable emission limit

☐ IMO Tier I ☒ IMO Tier II ☐ IMO Tier III
☐ Others: _____

1.14 Applicable test cycle

☐ C1 ☐ D2 ☒ E2 ☐ E3
☐ Others: _____

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 ³] / ISO 6976 | | |
| Density*) | [kg/m ³] / 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 | DMA | |
| Flash point*) | [°C] / ISO 2719 | | |
| Viscosity @ 40/50°C **) | [mm ² /s] / ISO 3104 | 4 | at 40°C |
| Density @ 15°C *) | [kg/m ³] / ISO 3675 or 12185 | 845 | |
| Net calorific value (Hu) *) | [J/g] / DIN 51900 | 42955 | |
| Sulphur content*) | ppm [mg/kg] / ISO 8754 or 14596 | 1100 | |
| Ash content*) | ppm [mg/kg] / ISO 6245 | | |
| Water content*) | ppm [mg/kg] / ISO 3733 | <200 | |
| Carbon content*) | wt.-% [kg/kg] / ASTM D5291 | 85.2 | |
| Hydrogen content*) | wt.-% [kg/kg] / ASTM D5291 | 13.6 | |
| Nitrogen content*) | wt.-% [kg/kg] / DIN 51444 | <0,1 | |
| Oxygen content*) | wt.-% [kg/kg] / DIN 51732 | | |
| Cetane index*) | ISO 4264 | | |
| CCAI*) | | | |
| 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 | Shell Argina T40 | |
| Grade | Multi / Mono | Mono | |
| BN | mg KOH/g / ISO 3771 | 30 | |
| Ash content | wt.-% [kg/kg] / ISO 6245 | 3.7 | |
| Viscosity | [mm ² /s] / ASTM D7042 | 135 | at 40°C |
| Sulphur content | wt.-% [kg/kg] / ISO 20884 | | |

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 ² /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 ² /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: 415S

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 ☐ mg/m_n^3 (wet basis; act. O_2 -concentration) H_2O -conc.: _____ [Vol.-%] (wet)
☐ mg/m_n^3 (dry basis; act. O_2 -concentration)
☐ mg/m_n^3 (dry basis; Ref. O_2 -concentration) O_2 -conc.: _____ [Vol.-%] (dry)
☐ mg/kWh refer to 5.
x FSN
☐ mg/kg fuel refer to 5.
☐ Others: _____

4.5 Reference conditions Norm temperature: _____ [°C]
(only if 4.4 is referred to Norm-cubic meters [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: _____ [m^2/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 CalibrationDate of last calibration: 05/11/2015 (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/volumeAcc. 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 ☐ No Temperature: 70 [°C]

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 ☒ Against flow

☐ Others:

Effective cross section of sample hole opening(s) 17.8 [mm²]

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: 0.8 [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: 0.2 [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: 3 [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, O₂ and CO₂ (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 O₂ and CO₂ determination

5.6.2 Estimated accuracy of O₂ and CO₂ determination +/- _____ [%] of reading

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

Date of measurement (dd.mm.yyyy)

| | | | | |
|------------|------------|------------|------------|------------|
| 13/01/2016 | 13/01/2016 | 13/01/2016 | 13/01/2016 | 13/01/2016 |
|------------|------------|------------|------------|------------|

Engine parameters

Measurement at mode points:

| | | | | |
|-----|-----|----|----|----|
| 110 | 100 | 85 | 75 | 50 |
|-----|-----|----|----|----|

 [%]

| | ↓ | ↓ | ↓ | ↓ | ↓ | |
|---|--|-------|-------|-----------------|-------|------------|
| 6.1 Stabilized mode point | | | | | | |
| Actual Speed | 1032 | 1001 | 948 | 910 | 800 | [rpm] |
| Speed variation during measuring | 0 | 0 | 0 | 0 | 0 | +/- [%] |
| Actual Load | 7932 | 7216 | 6134 | 5411 | 3611 | [kW] |
| Load variation during measuring | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | +/- [%] |
| 6.2 Charge air temperature | 50 | 52 | 45 | 43 | 39 | [°C] |
| 6.3 Charge air pressure | 3555 | 3366 | 2955 | 2591 | 1689 | [mbar] rel |
| 6.4 Exhaust gas temp. at engine outlet | 408 | 377 | 362 | 367 | 338 | [°C] |
| 6.5 Exh. gas temp. at sampling point | | | | | | [°C] |
| (only if there is a significant difference to the exhaust gas temperature at the engine outlet) | | | | | | |
| 6.6 Exhaust gas back pressure | 35 | 29 | 22 | 18 | 12 | [mbar] rel |
| 6.7 Exhaust gas mass flow | 51030 | 48085 | 42360 | 37519 | 31551 | [kg/h] |
| Ambient conditions | | | | | | |
| 6.8 Ambient temp. at engine inlet | 21 | 21 | 21 | 21 | 21 | [°C] |
| 6.9 Ambient pressure at engine inlet | 956 | 954 | 956 | 956 | 956 | [mbar] |
| 6.10 Absolute humidity of ambient air | 4.54 | 4.34 | 4.46 | 4.54 | 4.52 | [g/kg] |
| 7. Black Carbon | Reported as (see 4.3): | | FSN | Unit (see 4.4): | | FSN |
| 7.1 Estimated accuracy of measured value | - | - | - | - | - | +/- [%] |
| 7.2 Black Carbon emission | 0.07 | 0.05 | 0.05 | 0.07 | 0.11 | |
| Remark: | §7.1 not applicable due to no determination acc. to §5 | | | | | |
| 8. Measurement repeatability Indicators | | | | | | |
| 8.1 95% confidence interval (+/- unit measured) | | | | | | |
| 8.2 Variance | | | | | | |
| 8.3 Sample size (number of measurements taken) | 1 | 1 | 1 | 1 | 1 | |