

# ANNEX 7

## 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: 2015  
 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 100 [h]

1.4 Regular maintenance interval - [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 5450 [kW]

1.9 Mean effective pressure at rated power 14.77 [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: \_\_\_\_\_

1.15.1 Specific lubrication oil consumption SLOC: - [g/kWh]

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

1.15.2 Cylinder liner lubrication ☐ None  
☒ Yes, active at

<input checked="" type="checkbox"/> 100%	Feed rate: <u>7630</u> [g/h]
<input checked="" type="checkbox"/> 75%	Feed rate: <u>5875</u> [g/h]
<input checked="" type="checkbox"/> 50%	Feed rate: <u>4113</u> [g/h]
<input checked="" type="checkbox"/> 25%	Feed rate: <u>2385</u> [g/h]
<input checked="" type="checkbox"/> 10%	Feed rate: <u>1240</u> [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: \_\_\_\_\_ acc. standard: \_\_\_\_\_  
☒ 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	64.6	
Lower calorific value*)	[MJ/kg] / ISO 6976	49.09	JIS K2301
Higher calorific value	[MJ/kg] / ISO 6976	-	
Wobbe Indices Ws / Wi	[MJ/m <sup>3</sup> ] / ISO 6976	57.12	JIS K2301
Density*)	[kg/m <sup>3</sup> ] / ISO 6976	0.8553	
Methane*)	wt.-% [kg/kg] / ISO 6974 or DIN 51894	86.32	JIS K2301 - 2011
Ethane*)	wt.-% [kg/kg] / ISO 6974 or DIN 51894	7.87	JIS K2301
Propane*)	wt.-% [kg/kg] / DIN 51894	4	JIS K2301 - 2011
Isobutane*)	wt.-% [kg/kg] / DIN 51894	0.85	JIS K2301 - 2011
N-Butane*)	wt.-% [kg/kg] / DIN 51894	0.96	JIS K2301 - 2011
Pentane	wt.-% [kg/kg] / DIN 51894	0	JIS K2301 - 2011
Hexane	wt.-% [kg/kg] / DIN 51894	-	
Heptane	wt.-% [kg/kg] / DIN 51894	-	
Nitrogen	wt.-% [kg/kg] / ISO 6974	0	JIS K2301 - 2011
Sulphur*)	wt.-% [kg/kg] / ISO 6326-5	0	JIS K2301 - 2011
Hydrogen sulfide	wt.-% [kg/kg] / ISO 8819	23.42	JIS K2301 - 2011
Carbon dioxide	wt.-% [kg/kg] / ISO 6974	76.6	JIS K2301 - 2011
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	66	JIS K2265
Viscosity @ 40/50°C **)	[mm <sup>2</sup> /s] / ISO 3104	2.46/2.05	JIS K2283
Density @ 15°C *)	[kg/m <sup>3</sup> ] / ISO 3675 or 12185	865.3	JIS K2249
Net calorific value (Hu) *)	[J/g] / DIN 51900	41990	JIS K2279

Sulphur content*)	ppm [mg/kg] / ISO 8754 or 14596	5000	JIS K2541
Ash content*)	ppm [mg/kg] / ISO 6245	100	JIS K2272
Water content*)	ppm [mg/kg] / ISO 3733	100	JIS K2275
Carbon content*)	wt.-% [kg/kg] / ASTM D5291	86.27	JIS M8819
Hydrogen content*)	wt.-% [kg/kg] / ASTM D5291	12.7	JIS M8819
Nitrogen content*)	wt.-% [kg/kg] / DIN 51444	0.02	JIS K2276
Oxygen content*)	wt.-% [kg/kg] / DIN 51732	0.51	Calc.
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	0.02	JIS K2270
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	-	
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	-	

#### 3.2 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: 415S (SE)

###### 4.2 Measurement principle

☐ LII ☒ FSN ☐ PAS ☐ MAAP  
☐ Others: \_\_\_\_\_

###### 4.3 Values reported as

☐ EC (thermal) Protocol acc.: \_\_\_\_\_  
☐ rBC  
☐ eBC  
☒ 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.  
☒ FSN  
☐  $\text{mg}/\text{kg}$  fuel refer to 5.  
☐ Others: \_\_\_\_\_

###### 4.5 Reference conditions

(only if 4.4 is referred to Norm-cubic meters [ $\text{m}_n^3$ ])

Norm temperature: \_\_\_\_\_ [°C]  
Norm pressure: \_\_\_\_\_ [mbar]

###### 4.6 Sampling time / -number

Sampling time of each measurement: 18 [s]  
If mean values are reported: Number of consecutive measurements at each mode point: 3 [-]  
Acc. manufacturer specification: ☒ Yes ☐ No

###### 4.7 BC instrument parameter

Temperature inside measuring cell: 70 [°C]  
Pressure inside measuring cell: Ambient [mbar]  
Wavelength(s) used: 550 [nm]  
Mass absorption cross section(s) used: 2 [ $\text{m}^2/\text{g}$ ]  
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: ☒ Yes ☐ No

Other parameters which could influence the measured values:

Parameter / Correction	Unit

###### 4.8 BC Instrument Calibration

Date of last calibration: - (dd.mm.yyyy)  
Calibration procedure according manufacturer specification:  
☐ Yes ☐ No ☐ Others: \_\_\_\_\_  
Calibration including zero point: ☐ Yes ☐ No  
Used medium for zero point calibration: \_\_\_\_\_  
Used calibration standard: ☐ Synthetic flame soot  
☐ Printex-U  
☐ Graphite spark aerosol generator GfG soot  
☐ Soot with inorganic coatings  
☐ Soot without inorganic coatings

☐ Reflectance standards

☐ Others: \_\_\_\_\_

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

Leakage test performed before or after calibration: ☐ Yes ☐ No ☐ Not applicable

#### 4.9 Sample gas pre-treatment

Please fill in if applicable

Exhaust gas dilution: ☐ Yes ☒ 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 ☒ No

Temperature \_\_\_\_\_ [°C] acc. manufacturer spec. ☐ Yes ☐ No

Catalytic stripper ☐ Yes ☒ No

Temperature \_\_\_\_\_ [°C] acc. manufacturer spec. ☐ Yes ☐ No

Thermo-denuder ☐ Yes ☒ No

Temperature \_\_\_\_\_ [°C] acc. manufacturer spec. ☐ Yes ☐ No

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

#### 4.10 Sample flow rate/volume

Acc. manufacturer specification: ☒ Yes ☐ No

Sample 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 ☐ 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: \_\_\_\_\_ [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 [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:    - \_\_\_\_\_ [m]

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

Downstream sample probe:    \_\_\_\_\_ [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

Waterbreak 4-20mA

5.2.2 Estimated accuracy of engine load determination

+/- 1 [%] of reading

5.3.1 Method of exhaust gas flow determination

Calculation

5.3.2 Estimated accuracy of exhaust gas flow determination

+/- 1 [%] of reading

5.4.1 Method of exhaust water content determination

Calculation

5.4.2 Estimated accuracy of exhaust water content determination

+/- 1 [%] of reading

5.5.1 Method of fuel mass flow determination

Flowmeter ProMass F

5.5.2 Estimated accuracy of fuel mass flow determination

+/- 1 [%] of reading

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

Horiba PG250/PG350

5.6.2 Estimated accuracy of O<sub>2</sub> and CO<sub>2</sub> determination

+/- 2 [%] of reading

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

Date of measurement (dd.mm.yyyy)

02.11.2015	02.11.2015	02.11.2015	02.11.2015	
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Engine parameters

Measurement at mode points:	100	75	50	20		[%]
	↓	↓	↓	↓	↓	
6.1 Stabilized mode point						
Actual Speed	110.4	110.2	110.1	110.2		[rpm]
Speed variation during measuring	1	1	1	1		+/- [%]
Actual Load	5473	4109	2729	1370		[kW]
Load variation during measuring	1	1	1	1		+/- [%]
6.2 Charge air temperature	30	29	28	22		[°C]
6.3 Charge air pressure	2720.000	1690.000	730.000	280.000		[mbar]
6.4 Exhaust gas temp. at engine outlet	356	347	354	311		[°C]
6.5 Exh. gas temp. at sampling point	198	223	277	272.3		[°C]
(only if there is a significant difference to the exhaust gas temperature at the engine outlet)						
6.6 Exhaust gas back pressure	27.01	16.31	6.12	2.04		[mbar]
6.7 Exhaust gas mass flow	50423.000	39200.000	24714.000	16034.000		[kg/h]
<b>Ambient conditions</b>						
6.8 Ambient temp. at engine inlet	16.1	17	17.9	17.4		[°C]
6.9 Ambient pressure at engine inlet	1023.7	1023	1022.1	1021.81		[mbar]
6.10 Absolute humidity of ambient air	9.9	10.1	10	10.3		[g/kg]
<b>7. Black Carbon</b>						
	Reported as (see 4.3):		FSN		Unit (see 4.4): FSN	
7.1 Estimated accuracy of measured value	-	-	-	-	-	+/- [%]
7.2 Black Carbon emission	0.003	0.002	0.003	0.186		
	Remark: _____					
<b>8. Measurement repeatability Indicators</b>						
8.1 95% confidence interval ( +/- unit measured)	-	-	-	-		
8.2 Variance	-	-	-	-		
8.3 Sample size (number of measurements taken)	3	3	3	3		