

ANNEX 11**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:	<u>2015</u>		
	Location:	<input checked="" type="checkbox"/> Testbed <input type="checkbox"/> Ship		
1.2 Engine freshly manufactured	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No			
	If no: Documentation of relevant maintenance provided	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
1.3 Engine total running hours		<u>100</u> [h]		
1.4 Regular maintenance interval		<u>-</u> [h]		
1.5 Hours since last regular maintenance		<u>-</u> [h]		
1.6 Engine category	<input type="checkbox"/> 4-stroke <input checked="" type="checkbox"/> 2-stroke			
1.7 Engine fuel type	<input checked="" type="checkbox"/> Diesel <input type="checkbox"/> Gas <input type="checkbox"/> Dual fuel			
1.8 Engine max. rated power		<u>28310</u> [kW]		
1.9 Mean effective pressure at rated power		<u>16.52</u> [bar]		
1.10 Engine speed	<input checked="" type="checkbox"/> Less than 130 rpm <input type="checkbox"/> 130 or more but less than 2,000 rpm <input type="checkbox"/> 2,000 rpm or more			
1.11 Method of air aspiration	<input type="checkbox"/> Naturally aspirated <input checked="" type="checkbox"/> Pressure-charged single stage <input type="checkbox"/> Pressure-charged multi stage			
1.12 Injection system	<input type="checkbox"/> Conventional <input checked="" type="checkbox"/> Common rail			
1.13 Applicable emission limit	<input type="checkbox"/> IMO Tier I <input checked="" type="checkbox"/> IMO Tier II <input type="checkbox"/> IMO Tier III <input type="checkbox"/> Others: _____			
1.14 Applicable test cycle	<input type="checkbox"/> C1 <input type="checkbox"/> D2 <input type="checkbox"/> E2 <input checked="" type="checkbox"/> E3 <input type="checkbox"/> Others: _____			

1.15.1 Specific lubrication oil consumption	SLOC:	<u>-</u>	[g/kWh]
	Breaking-in period:	<input type="checkbox"/> Finished <input type="checkbox"/> Not finished <input type="checkbox"/> Not applicable	
1.15.2 Cylinder liner lubrication	<input type="checkbox"/> None <input checked="" type="checkbox"/> Yes, active at	<input checked="" type="checkbox"/> 100% <input checked="" type="checkbox"/> 75% <input checked="" type="checkbox"/> 50% <input checked="" type="checkbox"/> 25% <input checked="" type="checkbox"/> 10%	Feed rate: <u>39634.0</u> [g/h] Feed rate: <u>30518.2</u> [g/h] Feed rate: <u>21362.7</u> [g/h] Feed rate: <u>12390.4</u> [g/h] Feed rate: <u>6443.0</u> [g/h]
	Breaking-in period:	<input checked="" type="checkbox"/> Finished <input type="checkbox"/> Not finished <input type="checkbox"/> 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		
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	72	JIS K2265
Viscosity @ 40/50°C **)	[mm ² /s] / ISO 3104	3.04/2.49	JIS K2283
Density @ 15°C *)	[kg/m ³] / ISO 3675 or 12185	871.2	JIS K2249
Net calorific value (Hu) *)	[J/g] / DIN 51900	41920	JIS K2279
Sulphur content*)	ppm [mg/kg] / ISO 8754 or 14596	5800	JIS K2541
Ash content*)	ppm [mg/kg] / ISO 6245	< 100	JIS K2272
Water content*)	ppm [mg/kg] / ISO 3733	<100	JIS K275
Carbon content*)	wt.-% [kg/kg] / ASTM D5291	-	
Hydrogen content*)	wt.-% [kg/kg] / ASTM D5291	12.6	JIS M8819
Nitrogen content*)	wt.-% [kg/kg] / DIN 51444	-	

	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	-	
Grade	Multi / Mono		
BN	mg KOH/g / ISO 3771	3.8	JIS K2501
Ash content	wt.-% [kg/kg] / ISO 6245	0.56	JIS K2272
Viscosity/40°C	[mm ² /s] / ASTM D7042	99.7	JIS K2283
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: <u>AVL</u>	Model: <u>415S (SE)</u>								
4.2 Measurement principle	<input type="checkbox"/> LII <input checked="" type="checkbox"/> FSN <input type="checkbox"/> PAS <input type="checkbox"/> MAAP <input type="checkbox"/> Others: _____									
4.3 Values reported as	<input type="checkbox"/> EC (thermal) Protocol acc.: _____ <input type="checkbox"/> rBC <input type="checkbox"/> eBC <input checked="" type="checkbox"/> FSN <input type="checkbox"/> Others: _____									
4.4 Values reported in unit	<input type="checkbox"/> mg/m_n^3 (wet basis; act. O_2 -concentration) H_2O -conc.: _____ [Vol.-%] (wet) <input type="checkbox"/> mg/m_n^3 (dry basis; act. O_2 -concentration) <input type="checkbox"/> mg/m_n^3 (dry basis; Ref. O_2 -concentration) O_2 -conc.: _____ [Vol.-%] (dry) <input type="checkbox"/> mg/kWh refer to 5. <input checked="" type="checkbox"/> FSN <input type="checkbox"/> mg/kg fuel refer to 5. <input type="checkbox"/> Others: _____									
4.5 Reference conditions	Norm temperature: _____ [°C] <small>(only if 4.4 is referred to Norm-cubic meters [m_n^3])</small> Norm pressure: _____ [mbar]									
4.6 Sampling time / -number	Sampling time of each measurement: <u>18</u> [s] If mean values are reported: Number of consecutive measurements at each mode point: <u>3</u> [-] Acc. manufacturer specification: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No									
4.7 BC instrument parameter	Temperature inside measuring cell: <u>70</u> [°C] Pressure inside measuring cell: <u>Ambient</u> [mbar] Wavelength(s) used: <u>550</u> [nm] Mass absorption cross section(s) used: <u>2</u> [m^2/g] Conversion equation(s) used: <u>-</u> Repeatability of the instrument used: <u>$\leq 0.005 \text{ FSN} + 3\%$</u> of measured value Reproducibility of the instrument used: <u>$\leq 0.005 \text{ FSN} + 6\%$</u> of measured value Acc. manufacturer specification: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No Other parameters which could influence the measured values: <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Parameter / Correction</th> <th style="text-align: center;">Unit</th> </tr> </thead> <tbody> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> </tbody> </table>		Parameter / Correction	Unit						
Parameter / Correction	Unit									

4.8 BC Instrument Calibration	Date of last calibration: <u>-</u> (dd.mm.yyyy) Calibration procedure according manufacturer specification: <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Others: _____ Calibration including zero point: <input type="checkbox"/> Yes <input type="checkbox"/> No Used medium for zero point calibration: _____ Used calibration standard: <input type="checkbox"/> Synthetic flame soot <input type="checkbox"/> Printex-U <input type="checkbox"/> Graphite spark aerosol generator GfG soot <input type="checkbox"/> Soot with inorganic coatings <input type="checkbox"/> Soot without inorganic coatings <input type="checkbox"/> Reflectance standards <input type="checkbox"/> Others: _____ Remark: _____ Leakage test performed before or after calibration: <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not applicable
4.9 Sample gas pre-treatment Please fill in if applicable	Exhaust gas dilution: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> 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 [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: - _____ [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, 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

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 ₂ and CO ₂ determination	Horiba PG250/PG350
5.6.2 Estimated accuracy of O ₂ and CO ₂ determination	+/- < 2 _____ [%] of reading

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

Date of measurement (dd.mm.yyyy)

24.03.2015	24.03.2016	24.03.2016	24.03.2016	24.03.2016
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Engine parameters

Measurement at mode points:	<table><tr><td>100</td><td>85</td><td>75</td><td>50</td><td>25</td></tr></table> [%]	100	85	75	50	25
100	85	75	50	25		
	<table><tr><td>↓</td><td>↓</td><td>↓</td><td>↓</td><td>↓</td></tr></table>	↓	↓	↓	↓	↓
↓	↓	↓	↓	↓		
6.1 Stabilized mode point						
Actual Speed	<table><tr><td>64.1</td><td>60.7</td><td>58.2</td><td>50.9</td><td>40.4</td></tr></table> [rpm]	64.1	60.7	58.2	50.9	40.4
64.1	60.7	58.2	50.9	40.4		
Speed variation during measuring	<table><tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr></table> +/- [%]	1	1	1	1	1
1	1	1	1	1		
Actual Load	<table><tr><td>28310</td><td>24064</td><td>21233</td><td>14155</td><td>7078</td></tr></table> [kW]	28310	24064	21233	14155	7078
28310	24064	21233	14155	7078		
Load variation during measuring	<table><tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr></table> +/- [%]	1	1	1	1	1
1	1	1	1	1		
6.2 Charge air temperature	<table><tr><td>37.7</td><td>34.8</td><td>32.8</td><td>29.4</td><td>28.5</td></tr></table> [°C]	37.7	34.8	32.8	29.4	28.5
37.7	34.8	32.8	29.4	28.5		
6.3 Charge air pressure	<table><tr><td>3470.000</td><td>3020.000</td><td>2680.000</td><td>1520.000</td><td>640.000</td></tr></table> [mbar]	3470.000	3020.000	2680.000	1520.000	640.000
3470.000	3020.000	2680.000	1520.000	640.000		
6.4 Exhaust gas temp. at engine outlet	<table><tr><td>409</td><td>359</td><td>341</td><td>298</td><td>247</td></tr></table> [°C]	409	359	341	298	247
409	359	341	298	247		
6.5 Exh. gas temp. at sampling point	<table><tr><td>222</td><td>192</td><td>184</td><td>193</td><td>197</td></tr></table> [°C]	222	192	184	193	197
222	192	184	193	197		
(only if there is a significant difference to the exhaust gas temperature at the engine outlet)						
6.6 Exhaust gas back pressure	<table><tr><td>47.3</td><td>39.7</td><td>33.5</td><td>15.5</td><td>4.8</td></tr></table> [mbar]	47.3	39.7	33.5	15.5	4.8
47.3	39.7	33.5	15.5	4.8		

6.7 Exhaust gas mass flow

100080.000	93600.000	87480.000	60840.000	37080.000
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[kg/h]

Ambient conditions

6.8 Ambient temp. at engine inlet

15	14.3	14	13.2	12.5
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[°C]

6.9 Ambient pressure at engine inlet

1036	1037	1037	1038	1038
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[mbar]

6.10 Absolute humidity of ambient air

2.1	2.5	2.7	2.7	2.5
-----	-----	-----	-----	-----

[g/kg]

7. Black Carbon

Reported as (see 4.3): FSN Unit (see 4.4): FSN

7.1 Estimated accuracy of measured value

-	-	-	-	-
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+/- [%]

7.2 Black Carbon emission

0.018	0.011	0.013	0.013	0.017
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Remark: _____

8. Measurement repeatability Indicators

8.1 95% confidence interval
(+/- unit measured)

-	-	-	-	-
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8.2 Variance

-	-	-	-	-
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8.3 Sample size
(number of measurements taken)

3	3	3	3	3
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