

ANNEX 26**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

69 [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

8000 [kW]

1.9 Mean effective pressure at rated power

19.1 [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: _____ 0.4 [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: _____ acc. standard: ISO 8217:2010

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

100%	_____	3%
75%	_____	4%
50%	_____	6%
25%	_____	12%
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	~ 84	84,3 - 84,5
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	0.7764	
Methane*)	wt.-% [kg/kg] / ISO 6974 or DIN 51894	84.5749	
Ethane*)	wt.-% [kg/kg] / ISO 6974 or DIN 51894	3.9923	
Propane*)	wt.-% [kg/kg] / DIN 51894	1.9055	
Isobutane*)	wt.-% [kg/kg] / DIN 51894	0.5234	
N-Butane*)	wt.-% [kg/kg] / DIN 51894	0.5169	
Pentane	wt.-% [kg/kg] / DIN 51894		
Hexane	wt.-% [kg/kg] / DIN 51894	0.0894	
Heptane	wt.-% [kg/kg] / DIN 51894		
Nitrogen	wt.-% [kg/kg] / ISO 6974	5.0125	
Sulphur*)	wt.-% [kg/kg] / ISO 6326-5		
Hydrogen sulfide	wt.-% [kg/kg] / ISO 8819		
Carbon dioxide	wt.-% [kg/kg] / ISO 6974	1.999	
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	3.9	at 40°C
Density @ 15°C *)	[kg/m ³] / ISO 3675 or 12185	843	
Net calorific value (Hu) *)	[J/g] / DIN 51900	43022	
Sulphur content*)	ppm [mg/kg] / ISO 8754 or 14596		
Ash content*)	ppm [mg/kg] / ISO 6245		
Water content*)	ppm [mg/kg] / ISO 3733	<200	
Carbon content*)	wt.-% [kg/kg] / ASTM D5291	85.3	
Hydrogen content*)	wt.-% [kg/kg] / ASTM D5291	13.7	
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: 3 [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 ²]
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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: _____ 11 [m]

Diameter of the exhaust gas pipe: _____ 1.2 [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: _____ 0.34 [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: _____ 2 [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)

07/07/2016	07/07/2016	07/07/2016	07/07/2016	
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Engine parameters

Measurement at mode points:

100	75	50	25	
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 [%]

	↓	↓	↓	↓	↓
6.1 Stabilized mode point					
Actual Speed	514	514	514	514	[rpm]
Speed variation during measuring	0	0	0	0	+/- [%]
Actual Load	8020	5996	4006	2005	[kW]
Load variation during measuring	0.3	0.1	0.2	0.3	+/- [%]
6.2 Charge air temperature	43	46	49.8	55.4	[°C]
6.3 Charge air pressure	2800	1920	1100	340	[mbar] rel.
6.4 Exhaust gas temp. at engine outlet	347	372	406	423	[°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	38	23	11	3	[mbar]
6.7 Exhaust gas mass flow	50440	38580	27060	15870	[kg/h]
Ambient conditions					
6.8 Ambient temp. at engine inlet	22	23	22	22	[°C]
6.9 Ambient pressure at engine inlet	967	967	967	967	[mbar]
6.10 Absolute humidity of ambient air	6.88	6.74	6.23	6.41	[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	0.005	0.002	0.002	0.003	
Remark:	§7.1 not applicable due to no determination acc. to §5				
8. Measurement repeatability Indicators					
8.1 95% confidence interval (+/- unit measured)	n.a.	0.00053343	0.000533435	0.001411335	
8.2 Variance	0	2.2222E-07	2.2222E-07	1.55556E-06	
8.3 Sample size (number of measurements taken)	1	1	1	1	