

Table D.1 — Test report: data and description of test object

Manufacturer of filter system	LiqTech A/S
Type / serial number	
Designation of particle filter family	
Filter medium (particle filter element)	
Manufacturer of filter medium	LiqTech A/S
Type	Wall Flow Filter
External dimensions / weight	Diameter 286mm, Length 355mm
Material	100% Re SiC
Porosity	43%
Pore size distribution	12-15 microns
No. of cells per square inch [CPSI]	150
Wall thickness	0.5mm
Maximum flow-through rate [m ³ /s]	1600 @ 1013.25mbar and 20°C
Maximum space velocity [s ⁻¹]	16.8 in VFT1
Maximum operating temperature [°C]	Exhaust gas at 700°C
Storage capacity for soot/ash	0.276kg soot and 0.322kg ash

Regeneration	
Regeneration procedure	for the purpose of the VFT1: FBC manually dosed
With additive (FBC = fuel borne catalyst) Manufacturer	INNOSPEC
Specification of additive	Satacen 3
Catalytically active substances	Fe
Treat rate	50 ppm metal (for VFT1) (1ml/l)
Additizing procedure	acc. to INNOSPEC
Specification of dosage device	-
With catalytic coating	-
Catalytically active elements / concentration of catalytically active substances	-
OBC (electronic on board control unit)	
Type / serial number	-

Table D.2 — Test report: visual inspection and control of functions

Visual inspection (5.2)	
Presence of Identification plate with serial number, test number and indication of particle family	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Measurement access upstream of filter element	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Flow-through direction indicated by arrow	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Reversal of filter element prevented through structural measures	<input type="checkbox"/> yes <input checked="" type="checkbox"/> no <input type="checkbox"/> not inspected
Control of functions (5.6)	
Recording of pressure loss at intervals of 1 second	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Electronic storage of peak pressure loss levels at 1-minute intervals, with storage capacity for at least 1 month of operation	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Issue of warning if pressure loss exceeds 150 mbar for more than 5 seconds. Warning saved in alarm memory that cannot be overwritten and cannot be deleted.	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Issue of an alarm if pressure exceeds 200 mbar for more than 5 seconds. Alarm saved in alarm memory that cannot be overwritten and cannot be deleted.	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Issue of an alarm if (too low) counter-pressure is recorded that indicates damage to filter (e.g. leak to exterior or fissure/crack in filter element). Alarm saved in alarm memory that cannot be overwritten and cannot be deleted.	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Issue of alarm and switch-off of additive dosage in the event of filter damage	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected
Issue of alarm when minimum level in additive tank is reached	<input checked="" type="checkbox"/> yes <input type="checkbox"/> no <input type="checkbox"/> not inspected

Table D.3 — Test report: test engine data

Manufacturer / type	Liebherr Machines Bulle S.A./ D 934 S
Maximum emission level (legal exhaust level)	97/68/E9 step 3A; EPA/CARB Tier 3
Cylinder number and configuration	4 cylinders in-line
Bore / stroke	136 x 122 [mm]
overall displacement	6.36 [dm ³]
Compression ratio	17 [-]
Serial number / year of manufacture / operating hours	2005 03 1341 / 2005 / -
Cooling medium (air, water, etc.)	water
Combustion process (direct injection, prechamber, etc.)	direct injection
Fuel system type	unit pump Bosch
Speed governor	EDC
Method of air aspiration	turbocharging
Charge air cooling system	intercooler
Measures to reduce emissions	internal EGR
Rated power / Rated speed (presend EDC setting)	111[kW] @ 2000 [min ⁻¹]
Low idle speed / high idle speed	840 [min ⁻¹]; 2170 [min ⁻¹]

Test points of motor in accordance with ISO 8178-4, test cycle C1					
		Rated speed		Intermediate speed	
Test phase		1	3	5	7
Speed	[min ⁻¹]	2000	2000	1400	1400
Torque	[Nm]	500	250	680	340
Power	[kW]	104.7	52.3	99.6	49.8

Table D.4 — Test report: fuel and lubricating oil data

Base fuel (without additive)			
Type	Diesel fuel Swiss market quality		
Manufacturer	Shell Formula		
Property	Method	Unit	
Density (at 15°C)	ISO 3675	kg/l	0.820 – 0.845
Viscosity (at 40°C)	ISO 3104	mm ² /s	2.2 – 2.8
Cetane number	ISO 5165	-	52 - 54
Cetane index	ISO 4264	-	49 - 51
Sulphur content	ISO 4260 / 8754	mg / kg	max. 10
Cloud point	ISO 3015	°C	max. -10
Pour point (CFPP)	ISO 3016	°C	max. -20
Flash point	ISO 2719	°C	min 62
Heating value		MJ/kg	min 42.5
Aromatic hydrocarbons	ISO 3837	% vol	max. 2
Conradson at 10% test residue			max. 0.02 g/100g
Boiling analysis (at 1013 mbar, 340°C)			min. 98 vol%

Lubricating oil

Lubrizol research oil OS No. 165108, blue, 15W/40

Lubrizol research oil OS No. 165108, blue, 15W/40		
Property		
Viscosity kin 40°C	-	mm ² /s
Viscosity kin 100°C	13.98	mm ² /s
Viscosity index	-	(--)
Density 20°C	-	kg/m ³
Pourpoint	- 25	°C
Flamepoint	-	°C
Total Base Number TBN	8.4	mg KOH/g
Sulfur ashes	10 770	mg/kg
Sulfur	3 360	mg/kg
Mg	< 10	mg/kg
Zn	1 200	mg/kg
Ca	2 630	mg/kg
P	1 110	mg/kg

Table D.5 — Test report: results of filtration test (5.3)

Filtration efficiency in stationary operation

Filter status	Particle size range [nm]	Test-cycle	Particle count concentration before filter	Particle count concentration after filter	Penetration [-]	Filtration efficiency [%]	Pressure loss of filter [mbar]
before regeneration	Integrated	op 5					
	20 - 30		5.216E+06	3.670E+03	0.0007036	99.93	
	30 - 40		2.415E+06	3.581E+03	0.001483	99.85	
	40 - 50		2.221E+06	3.943E+03	0.0017749	99.82	
	50 - 60		2.090E+06	4.977E+03	0.0023811	99.76	
	60 - 80		3.442E+06	1.145E+04	0.0033257	99.67	
	80 - 190		7.402E+06	6.036E+04	0.008154	99.18	
	190 - 300		1.378E+06	1.907E+04	0.0138439	98.62	40
	Integrated	op 7					
	20 - 30		7.264E+06	2.661E+03	0.0003663	99.96	
	30 - 40		2.329E+06	1.868E+03	0.0008023	99.92	
	40 - 50		2.043E+06	2.131E+03	0.0010429	99.90	
	50 - 60		1.853E+06	2.044E+03	0.0011032	99.89	
	60 - 80		2.926E+06	3.028E+03	0.0010349	99.90	
	80 - 190		5.621E+06	9.573E+03	0.001703	99.83	
	190 - 300		6.251E+05	1.751E+03	0.0028005	99.72	20
	Integrated	op 3					
	20 - 30		6.654E+06	4.883E+03	0.0007338	99.93	
	30 - 40		4.465E+06	3.873E+03	0.0008673	99.91	
	40 - 50		3.819E+06	3.446E+03	0.0009023	99.91	
	50 - 60		3.270E+06	2.750E+03	0.000841	99.92	
	60 - 80		4.845E+06	3.737E+03	0.0007712	99.92	
	80 - 190		6.975E+06	6.513E+03	0.0009338	99.91	
	190 - 300		3.704E+05	3.124E+02	0.0008436	99.92	30
	Integrated	op 1					
	20 - 30		7.324E+06	4.036E+03	0.000551	99.94	
	30 - 40		3.704E+06	3.721E+03	0.0010046	99.90	
	40 - 50		3.004E+06	2.881E+03	0.000959	99.90	
50 - 60	2.545E+06		2.549E+03	0.0010018	99.90		
60 - 80	3.679E+06		3.116E+03	0.0008471	99.92		
80 - 190	5.593E+06		5.391E+03	0.0009639	99.90		
190 - 300	4.768E+05		6.092E+02	0.0012779	99.87	70	
Integrated	op 5 (r)						
20 - 30		5.805E+06	2.680E+03	0.0004618	99.95		
30 - 40		2.449E+06	2.870E+03	0.001172	99.88		
40 - 50		2.195E+06	3.736E+03	0.001702	99.83		
50 - 60		2.073E+06	3.537E+03	0.0017066	99.83		
60 - 80		3.546E+06	9.216E+03	0.002599	99.74		
80 - 190		7.621E+06	4.873E+04	0.006395	99.36		
190 - 300		1.389E+06	1.558E+04	0.0112182	98.88	30	

Filter status	Particle size range [nm]	Test-cycle	Particle count concentration before filter	Particle count concentration after filter	Penetration [-]	Filtration efficiency [%]	Pressure loss of filter [mbar]
after regeneration	Integrated	op 5					
	20 - 30		5.216E+06	2.414E+03	0.0004629	99.95	
	30 - 40		2.415E+06	2.489E+03	0.0010307	99.90	
	40 - 50		2.221E+06	2.339E+03	0.0010529	99.89	
	50 - 60		2.090E+06	2.671E+03	0.0012777	99.87	
	60 - 80		3.442E+06	5.347E+03	0.0015533	99.84	
	80 - 190		7.402E+06	1.820E+04	0.0024584	99.75	
	190 - 300		1.378E+06	3.275E+03	0.0023772	99.76	40
	Integrated	op 7					
	20 - 30		7.264E+06	6.885E+03	0.0009479	99.91	
	30 - 40		2.329E+06	5.091E+03	0.0021863	99.78	
	40 - 50		2.043E+06	4.661E+03	0.0022811	99.77	
	50 - 60		1.853E+06	4.783E+03	0.0025814	99.74	
	60 - 80		2.926E+06	7.918E+03	0.0027059	99.73	
	80 - 190		5.621E+06	1.491E+04	0.0026522	99.73	
	190 - 300		6.251E+05	1.397E+03	0.0022343	99.78	20
	Integrated	op 3					
	20 - 30		6.654E+06	4.210E+03	0.0006327	99.94	
	30 - 40		4.465E+06	3.548E+03	0.0007946	99.92	
	40 - 50		3.819E+06	3.178E+03	0.0008322	99.92	
	50 - 60		3.270E+06	2.846E+03	0.0008704	99.91	
	60 - 80		4.845E+06	3.701E+03	0.0007639	99.92	
	80 - 190		6.975E+06	4.916E+03	0.0007048	99.93	
	190 - 300		3.704E+05	2.456E+02	0.0006631	99.93	30
	Integrated	op 1					
	20 - 30		7.324E+06	3.058E+03	0.0004175	99.96	
	30 - 40		3.704E+06	2.659E+03	0.0007181	99.93	
	40 - 50		3.004E+06	2.084E+03	0.0006938	99.93	
	50 - 60		2.545E+06	1.970E+03	0.0007741	99.92	
	60 - 80		3.679E+06	2.485E+03	0.0006756	99.93	
	80 - 190		5.593E+06	3.947E+03	0.0007057	99.93	
	190 - 300		4.768E+05	2.392E+02	0.0005016	99.95	80
	Integrated	op 5 (r)					
	20 - 30		5.805E+06	2.709E+03	0.0004667	99.95	
	30 - 40		2.449E+06	2.270E+03	0.0009268	99.91	
40 - 50	2.195E+06		2.485E+03	0.0011321	99.89		
50 - 60	2.073E+06		2.557E+03	0.0012336	99.88		
60 - 80	3.546E+06		5.755E+03	0.0016231	99.84		
80 - 190	7.621E+06		1.985E+04	0.0026045	99.74		
190 - 300	1.389E+06		4.062E+03	0.0029256	99.71	40	

Table D.6 — Test report: results of filtration test (5.3)

Exhaust opacity after filter with free acceleration

	Filter before regeneration	Filter after regeneration
Cooling medium temperature [°C]	82	82
Lubricatingoil temperature [°C]	90	93

Test no.	Max. exhaust opacity [m ⁻¹]	
1	0.02	
2	0.02	
3	0.04	
4	0.00	
5	0.01	
6	0.03	
7		
8		
9		
10		
Average of last four consecutive readings within scatter band of 0.25 m ⁻¹	0.02	

Table D.7 — Test report: results of regeneration test (5.4)

Maximum pressure loss of filter during regeneration cycle		[kPa]
Exhaust temperature at balance point		- [°C]
Maximum gradient of pressure loss reduction over time $\Delta p/\Delta t$		- [kPa]/[s]
Exhaust temperature at which this is reached		- [°C]
Gaseous emissions during regeneration (peak levels)		
	Without Filter	With Filter
	[ppm]	[ppm]
CO	180	188
HC	25	25
NO _x	351	346
Average of Particle number concentration after filter per load phase of regeneration cycle		
Torque [Nm]	Time [s]	Average summary Particle surface (LQ1-DC) after filter, per load phase [$\mu\text{m}^2/\text{cm}^3$]
200	600	80.8
250	600	115.2
300	600	135.6
350	600	143.3
400	600	138.6
450	600	129.3
500	600	127.0
Particle concentration after filter between two regeneration cycles (loading phase)		
Duration of loading phase		Average overall Particle concentration after filter during the whole operation time between 2 regenerations (overall emission)
charged delivered		
Average overall Emission during regeneration / overall emission between two regeneration cycles		
CO		
HC		

Table D.8.1 — Test report: results of secondary emissions test

Nitrogen dioxide (5.5.1)

Load level		Measurement without DPF				Measurement with DPF					
at rated speed 2000 rpm level M		t _{exhaust}	NO ₂	NO _x	NO ₂ /NO _x	t _{exhaust}	NO ₂	NO _x	NO ₂ /NO _x	Δ NO ₂	Δ NO ₂ /NO _x
[%]	[Nm]	[°C]	[ppm]	[ppm]	[%]	[°C]	[ppm]	[ppm]	[%]	[ppm]	[-]
40	200	298	31	247	12.5	317	3	254	1.3	-28	-0.11
50	250	328	25	263	9.3	346	1	267	0.3	-24	-0.09
60	300	351	20	278	7.3	375	1	280	0.4	-19	-0.07
70	350	370	18	296	6.1	394	0	298	0.0	-18	-0.06
80	400	388	17	313	5.3	411	1	312	0.3	-16	-0.05
90	450	406	13	329	4.1	431	0	322	0.0	-13	-0.04
100	500	422	12	334	3.7	443	1	322	0.3	-11	-0.03

$$\Delta \text{NO}_2 = \text{NO}_2 \text{ with DPF} - \text{NO}_2 \text{ without DPF} ;$$

$$\Delta \text{NO}_2/\text{NO}_2 \text{ without DPF}$$