Testing of Air Filter according to ISO 16890:2016

(6 appendices)

A test according to ISO 16890:2016 was carried out by request from

Tested item

YD/7, a 592 mm x 592 mm x 48 mm, Panel filter.

Pictures can be found in appendix 5.

The item was sent to RISE b, z o.o. and was received by RISE on June 21, 2018.

The item was without visible defects.

Test method

The test was carried out according to standard ISO 16890:2016 "Air filters for general ventilation". The standard consists of four parts:

- ISO 16890-1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)

- ISO 16890-2: Measurement of fractional efficiency and air flow resistance

Measurements were performed with dual particle counters according to section 9.3.4 - Testing sequence for dual OPC testing.

- ISO 16890-3: Determination of the gravimetric efficiency and the airflow resistance versus the mass of test dust captured

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Accred. No. 1002
Testing
ISO/IEC 17025

- ISO 16890-4: Conditioning method to determine the minimum fractional test efficiency

Eight cabinets with a total surface area of 1.82 m^2 were placed in the chamber according to ISO 16890-4 section 7. The purity of the 2-propanol was 99.5 %. The test item was conditioned for 24.5 +/- 0.5 hours.

Efficiency at 50% nominal air flow was measured with DEHS in the range 0.3 – 1 µm.

Deviation from the standard:

Section 9.2.2 and 9.2.8, the evaporated amount of 2-propanol was not determined. The temperature and humidity was not recorded during the discharge procedure.

Date and Place

The test was carried out at RISE's laboratory of Energy and circular economy in Borås, Sweden on July 6 – August 6, 2018.

Tests according to ISO 16890-2 were carried out on July 6, 2018.
Tests according to ISO 16890-3 were carried out on August 6, 2018.
Tests according to ISO 16890-4 were carried out on July 20, 2018. Conditioning procedure according to ISO 16890-4 was carried out on July 09-10, 2018.

Results

The results are presented in appendix 1-4 and are valid only for the item tested.

In appendix 1 a summary of the results are reported according ISO 16890-1. It also includes the fractional efficiencies and the calculation of PM-efficiencies.

In appendix 2 fractional efficiency and air flow resistance are reported according to ISO 16890-2.

In appendix 3 determination of the gravimetric efficiency (arrestance) and the air flow resistance versus the mass of test dust capture (test dust capacity) are reported according to ISO 16890-3.

In appendix 4 the minimum fractional efficiency is reported according to ISO 16890-4.

The measured particle concentrations are reported in appendix 2 and appendix 4. Table A6 (upstream count data), A7 (downstream count data) and A9 Uncertainty in ISO 16890-2 Annex A are reported.

Measurement equipment

- Pressure gauge Furness model 318, RISE's inventory no. 901 568 (static P Filter)
- Pressure gauge Furness model 318, RISE's inventory no. 901 569 (static P Flow)
- Pressure gauge Furness FC012, RISE's inventory no. 201 691 (ΔP Filter)
- Pressure gauge Furness FC012, RISE's inventory no. 201 690 (ΔP Flow)
- Particle counter TSI, OPS 3330, RISE's inventory no. 902240
- Particle counter TSI, OPS 3330, RISE's inventory no. 902241
- Barometer, Testo 511, RISE's inventory no. 900 078
- Temperature and RH, Testo 635, RISE's inventory no. 900 065
- Weighing scale, Kern EMS6K0.1, RISE's inventory no. BX81724
- Flow meter, MFS-C-250, RISE's inventory no. 202 742
- Temperature and RH, Tinytag, DIV 94 S
- Barometer, Druck PACE 1001, RISE's inventory no. 902243

Uncertainty of measurement

The uncertainty of the Air flow is better than ± 5 %
The uncertainty of the Pressure Drop is better than ± 3 %
The uncertainty of the Temperature is better than ± 0.5 °C
The uncertainty of the Relative Humidity is better than ± 2 % RH
The uncertainty of the Atmospheric Pressure is better than ± 1 mbar
The uncertainty of the Measured mass is better than ± 0.5 g

The uncertainty has been calculated according to EA-4/16 with a coverage factor k=2.

The uncertainty of the filtration efficiency according to ISO 16890:2016 is presented in appendices 2 and 4.

RISE Research Institutes of Sweden AB
Energy and circular economy - Sustainable energysystems

Performed by

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Appendices
1. Summary test report according to ISO 16890-1:2016
2. Test report according to ISO 16890-2:2016
3. Test report according to ISO 16890-3:2016
4. Test report according to ISO 16890-4:2016
5. Additional pictures of the test item.
6. The interpretation of test reports

Appendix 1

ISO 16890-1:2016 - Air Filter Test Results

Testing Organization:
RISE Research Institutes of Sweden AB
Brinellgatan 4, 501 15 Borås, Swedan
+460105165000

GENERAL

Report no.: 8P04418-01E	Date of tests: 2018-07-06 - 2018-08-06	Date of report: 2018-08-15
Supervisor: CM		Device obtained (when and how obtained):
Test(s) requested by:		The device was sent and obtained on 2018-06-21

DEVICE TESTED

Model: LYD/7		Manufacturer:	Construction: Panel filter
Article number: -	Type of medium: Glass	Net effective filtering area: 5.6 m^2	Filter dimensions (width x height x depth) 592x592x48 mm

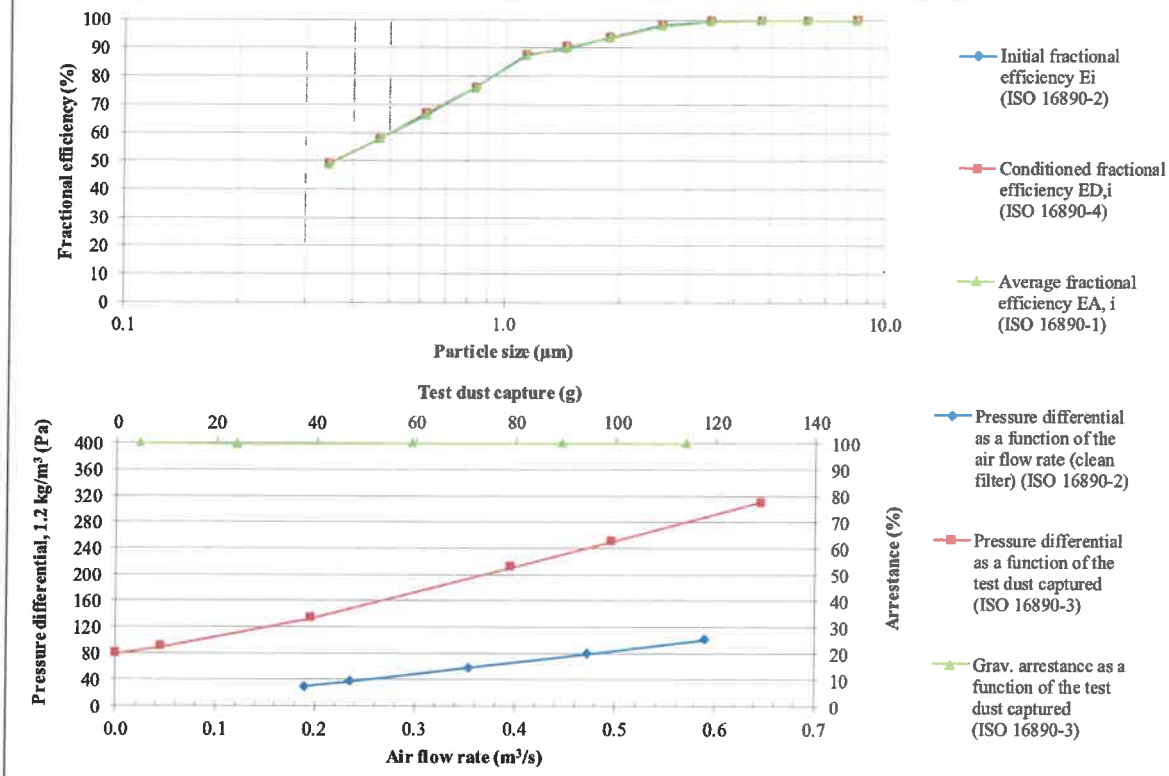
TEST DATA AND ATTACHED TEST REPORTS

Test air flow rate: 0.472 m^3/s	Test aersole: KCl (1-10 µm)	Test report to ISO 16890-2	Report no.	8P04418-01E Appendix 2
		Test report to ISO 16890-3	Report no.	8P04418-01E Appendix 3
	DEHS (0.3-1 µm)	Test report to ISO 16890-4	Report no.	8P04418-01E Appendix 4

RESULTS

Initial pressure differential: 79 Pa	Initial grav. arrestance: >99 %	$ePM_{1,min}$ 60 %	$ePM_{2.5,min}$ 70 %		ISO rating (1700 m^3/h)
Final test pressure differential: 300 Pa	Test dust capacity: 124 g	ePM_1 60 %	$ePM_{2.5}$ 70 %	ePM_{10} 90 %	**ISO ePM_1 60 %**

Remarks:



NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.

Appendix 1

ISO 16890-1:2016 - Fractional efficiency values

Testing organisation:	RISE Research Institutes of Sweden AB	Report no:	8P04418-01E
Model: LYD/7		Manufacturer:	[illegible]
Test air flow rate:	0.472 m^3/s	Date of report:	2018-08-15

i	d_i µm	d_{i+1} µm	$d_{a,i}$ µm	$\Delta ln\ d_i$ µm	E_i %	$E_{D,i}$ %	$E_{A,i}$ %
1	0.30	0.40	0.35	0.29	48.6	48.9	48.8
2	0.40	0.55	0.47	0.32	57.8	57.6	57.7
3	0.55	0.70	0.62	0.24	66.3	66.8	66.6
4	0.70	1.00	0.84	0.36	76.0	75.9	76.0
5	1.00	1.30	1.14	0.26	87.5	87.4	87.4
6	1.30	1.60	1.44	0.21	89.8	90.4	90.1
7	1.60	2.20	1.88	0.32	93.9	93.6	93.8
8	2.20	3.00	2.57	0.31	98.0	97.9	97.9
9	3.00	4.00	3.46	0.29	99.4	99.4	99.4
10	4.00	5.50	4.69	0.32	99.7	99.7	99.7
11	5.50	7.00	6.20	0.24	99.8	99.7	99.7
12	7.00	10.00	8.37	0.36	99.9	99.8	99.8

d_i: Lower limit particle diameter in a size range i, µm

d_{i+1}: Upper limit particle diameter in a size range i, µm

$d_{a,i}$: Geometric mean diamter of a size range i, µm

$\Delta ln\ d_i$: Logarithmic width of a particle diameter size in range i; ln is the natural logaritm to the base of e, where e is an irrational and transcendetal constant approximately equal to 2.718281828, dimensionless $\Delta ln\ d_i = ln\ (d_{i+1}/d_i)$

E_i: Initial fractional efficiency of partcile size range i of the untreated and unloaded filter element, %

$E_{D,i}$: Fractional efficiency of particle size range i of the filter element after an artifical conditioning step, %

$E_{A,i}$: Average fractional efficeincy $(E_i + E_{D,i})/2$ of particle size range i, %

Appendix 1

ISO 16890-1:2016 - Calculation of PM-efficiencies

Testing organisation:	RISE Research Institutes of Sweden AB	Report no.:	8P04418-01E
Model:	LYD/7	Manufacturer:	
Test air flow rate:	0.472 m^3/s	Date of report:	2018-08-15

i	$d_{a,i}$ µm	$\Delta ln\, d_i$ µm	urban distribution $q_{3u}(d_{a,i})$	$q_{3u}(d_{a,i}) \cdot \Delta ln\, d_i$	$E_{D,i} \cdot q_{3u}(d_{a,i}) \cdot \Delta ln\, d_i$	$E_{A,i} \cdot q_{3u}(d_{a,i}) \cdot \Delta ln\, d_i$	$ePM_{x,\,min}$ %	ePM_x %
1	0.35	0.29	0.226	0.065	3.186	3.18		
2	0.47	0.32	0.199	0.063	3.646	3.65		
3	0.62	0.24	0.158	0.038	2.553	2.54		
4	0.84	0.36	0.115	0.041	3.119	3.12	$ePM_{1,\,min}$	ePM_1
			∑ line 1-4	0.208	12.504	12.494	60	60
5	1.14	0.26	0.085	0.022	1.950	1.951		
6	1.44	0.21	0.076	0.016	1.430	1.425		
7	1.88	0.32	0.080	0.026	2.392	2.396		
8	2.57	0.31	0.100	0.031	3.032	3.033	$ePM_{2.5,\,min}$	$ePM_{2.5}$
			∑ line 1-8	0.302	21.308	21.298	70	70

i	$d_{a,i}$ µm	$\Delta ln\, d_i$ µm	rural distribution $q_{3u}(d_{a,i})$	$q_{3u}(d_{a,i}) \cdot \Delta ln\, d_i$		$E_{A,i} \cdot q_{3u}(d_{a,i}) \cdot \Delta ln\, d_i$		ePM_x %
1	0.35	0.29	0.094	0.027		1.321		
2	0.47	0.32	0.084	0.027		1.542		
3	0.62	0.24	0.074	0.018		1.193		
4	0.84	0.36	0.070	0.025		1.900		
5	1.14	0.26	0.076	0.020		1.750		
6	1.44	0.21	0.088	0.018		1.652		
7	1.88	0.32	0.108	0.034		3.226		
8	2.57	0.31	0.137	0.043		4.170		
9	3.46	0.29	0.167	0.048		4.778		
10	4.69	0.32	0.195	0.062		6.206		
11	6.20	0.24	0.217	0.052		5.213		
12	8.37	0.36	0.231	0.083		8.242		ePM_{10}
			∑ line 1-12	0.457		41.193		90

Appendix 2

ISO 16890-2:2016 - AIR FILTER TEST RESULTS SUMMARY

Testing Organization:
RISE
Research Institutes of Sweden AB
Brinellgatan 4, 501 15 Borås, Swedan
+460105165000

GENERAL

Test ID: SP201807061	Date of test: 2018-07-06	Operator: CM

Particle counter information

Manufacturer:	Model:	Coincidence value (p/cm^3):	Air flow measurement:	Device obtained (when and how obtained):
TSI Gmbh	OPS 3330	300	Annubar, Micatrone Air flow sensor MFS-SS	The device was sent and obtained on 2018-06-21

DEVICE TESTED

Model:	Manufacturer:	Construction:
LYD/7		Panel filter

Article number:	Type of media:	Net effective media area (m^2)	Filter dimensions (width x height x depth)
-	Glass	5.6 m^2	592x592x48 mm

Filter/media electrostatic charge:	Media colour:	Media adhesive:
No	white	N/A

Device Condition: Clean / Initial

Other descriptive information:

TEST DATA SUMMARY

Test air flow rate:	Test air temperature:	Test air RH:	Test aersol:
0.472 m^3/s	22.3 - 22.7 ° C	45.9 - 49.7 %	DEHS (0.3-1 µm) KCl (1-10 µm)

RESULTS

Resistance to airflow (Pa)

Measured: 79 Pa | Rated initial: - | Rated Final: -

Test Device Photo

Fractional Efficiency (%)

Range (µm)	Measured Efficiency	Rated Efficiency	Upstream concentration (particles / dm^3)
0.30 - 0.40	49		18705
0.40 - 0.55	58		16065
0.55 - 0.70	66		9640
0.70 - 1.00	76		10623
1.00 - 1.30	87		9517
1.30 - 1.60	90		5133
1.60 - 2.20	94		20887
2.20 - 3.00	98		12795
3.00 - 4.00	99		6180
4.00 - 5.50	100		3489
5.50 - 7.00	100		991
7.00 - 10.00	100		754

Remarks:

NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.

Appendix 2

ISO 16890-2:2016 - AIR FILTER TEST RESULTS DETAILS

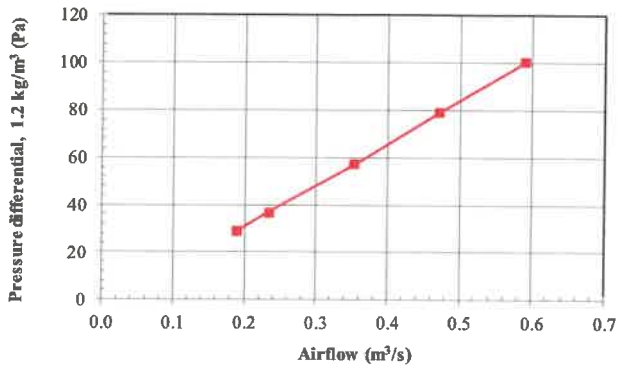
Testing Organization:
RISE
Research Institutes of Sweden AB
Brinellgatan 4, 501 15 Borås, Swedan
+460105165000

Test ID: SP201807061 | Date of test: 2018-07-06 | Operator: CM

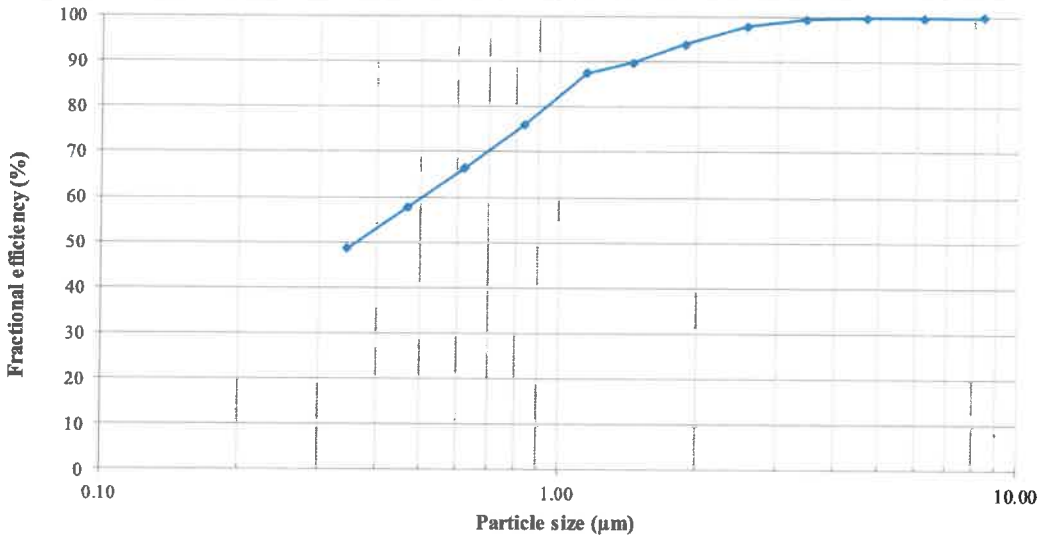
TEST DATA DETAILS

Resistance to Airflow 1.2 kg/m³

% of rated airflow	Airflow (m^3/s)	Resistance to Airflow (Pa)
40%	0.189	29
50%	0.234	37
75%	0.353	57
100%	0.472	79
125%	0.590	101



Fractional Efficiency by Particle Size



NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.

Appendix 2

Efficiency measurement

Upstream count data

OPC bin	$d_{a,i}$	Upstream efficiency count data					
	µm	1	2	3	4	5	$U_{e,tot}$
1	0.35	18875	18351	18826	18875	18600	**93527**
2	0.47	16158	15927	16043	16319	15880	**80327**
3	0.62	9734	9424	9561	9781	9698	**48198**
4	0.84	10821	10348	10716	10633	10596	**53114**
5	1.14	8823	9518	9571	9358	10314	**47584**
6	1.44	4788	5140	5056	4946	5735	**25665**
7	1.88	19636	21275	21050	19859	22614	**104434**
8	2.57	12122	13001	12997	12193	13663	**63976**
9	3.46	5763	6389	6282	5867	6601	**30902**
10	4.69	3265	3561	3553	3364	3703	**17446**
11	6.20	930	1016	1018	960	1032	**4956**
12	8.37	793	777	770	689	739	**3768**

Note: All data shown is the number of particle counts for 60 s

Efficiency measurement

Downstream count data

OPC bin	$d_{a,i}$	Downstream efficiency count data					
	µm	1	2	3	4	5	$D_{e,tot}$
1	0.35	9327	9330	9605	9669	9443	**47374**
2	0.47	6809	6966	6950	6901	6822	**34448**
3	0.62	3285	3260	3155	3186	3241	**16127**
4	0.84	2571	2462	2492	2558	2501	**12584**
5	1.14	1142	1309	1269	1199	1354	**6273**
6	1.44	571	631	607	586	634	**3029**
7	1.88	1240	1274	1316	1218	1415	**6463**
8	2.57	259	266	279	263	301	**1368**
9	3.46	35	46	33	42	40	**196**
10	4.69	8	9	11	12	13	**53**
11	6.20	3	1	3	6	0	**13**
12	8.37	1	1	0	2	4	**8**

Note: All data shown is the number of particle counts for 60 s

Efficiency measurement

Final results and uncertainty

OPC bin	$d_{a,i}$	Penetration data reduction			Uncertainty limits		Uncertainty	Efficiency
	µm	P_a	δ	e	Static	Dynamic	Pass/Fail	%
1	0.35	0.514	0.010	0.012	≤ 0.05	0.036	Pass	**48.6**
2	0.47	0.422	0.008	0.010	≤ 0.05	0.030	Pass	**57.8**
3	0.62	0.337	0.009	0.011	≤ 0.05	0.024	Pass	**66.3**
4	0.84	0.240	0.005	0.006	≤ 0.05	0.017	Pass	**76.0**
5	1.14	0.125	0.004	0.004	≤ 0.05	0.009	Pass	**87.5**
6	1.44	0.102	0.004	0.005	≤ 0.05	0.007	Pass	**89.8**
7	1.88	0.061	0.001	0.002	≤ 0.05	0.004	Pass	**93.9**
8	2.57	0.020	0.001	0.001	≤ 0.05	0.001	Pass	**98.0**
9	3.46	0.006	0.001	0.001	≤ 0.05	0.001	Pass	**99.4**
10	4.69	0.003	0.000	0.001	≤ 0.05	0.000	Pass	**99.7**
11	6.20	0.002	0.002	0.002	≤ 0.05	0.000	Pass	**99.8**
12	8.37	0.001	0.001	0.002	≤ 0.05	0.000	Pass	**99.9**

$d_{a,i}$: Geometric mean diameter of a size range i, µm

P_a the final penetration for a given particle size

δ the standard deviation of the penetration for a given particle size

e the uncertainty of the penetration for a given particle size

Appendix 3

ISO 16890-3:2016 - AIR FILTER TEST RESULTS SUMMARY					Testing Organization RISE Research Institutes of Sweden AB Brinellgatan 4, 501 15 Borås, Swedan +460105165000
GENERAL					
Test ID: SP201807061		Date of test: 2018-08-06			Operator: CM
			Air flow measurement: Annubar, Micatrone Air flow sensor MFS-SS		Test sample obtained: The device was sent and obtained on 2018-06-21
DEVICE TESTED					
Model: LYD/7		Manufacturer:			Construction: Panel filter
Article number: -	Type of media: Glass	Net effective media area (m^2) 5.6 m^2			Filter dimension (width x height x depth) 592x592x48 mm
Filter/media electrostatic charge: No		Media colour: white			Media adhesive: N/A
Device Condition: Conditioned per ISO 16890-4					
Other descriptive information:					
TEST DATA SUMMARY					
Test air flow rate: 0.472 m^3/s	Test air temperature: 24.2 - 24.6 °C	Test air RH: 36.2 - 37 %			Loading dust: Particle Technology, ISO 121031 A2-fine
RESULTS					
Resistance to airflow			**Dust loading results**		
Measured: 78 Pa	Rated initial:	- Pa	Initial arrestance (%)	Average arrestance(%)	Test dust capacity (g)
Final test pressure: 300 Pa	Rated Final:	- Pa	>99 %	>99 %	124 g
Test Device Photo					
					
Remarks:					
NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.					

Appendix 3

ISO 16890-3:2016 - AIR FILTER TEST RESULTS DETAILS

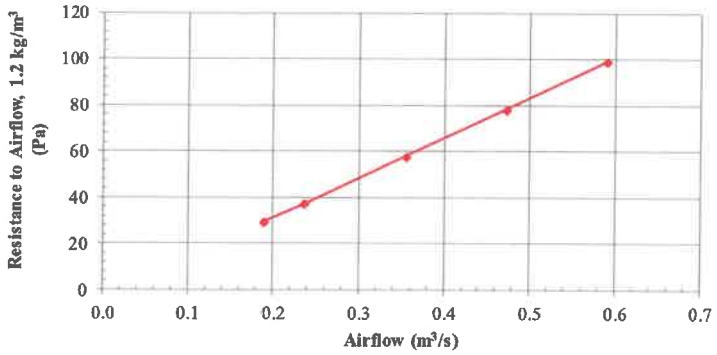
Testing Organization:
RISE
Research Institutes of Sweden AB
Brinellgatan 4, 501 15 Borås, Swedan
+460105165000

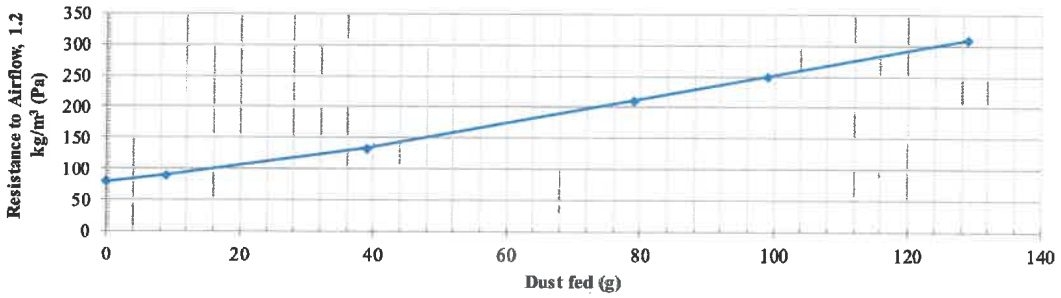
Test ID:	SP201807061	Date of test:	2018-08-06	Operator:	CM

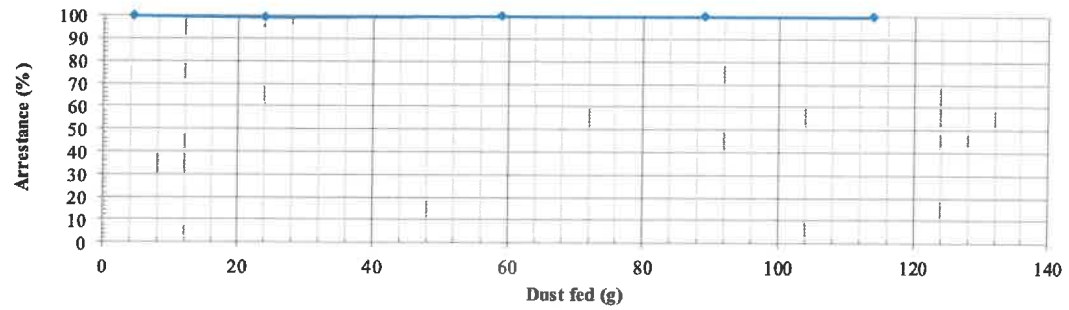
TEST DATA DETAILS

Resistance to Airflow 1.2 kg/m³

% of rated airflow	Airflow (m^3/s)	Resistance to Airflow (Pa)
40%	0.189	29
50%	0.235	37
75%	0.355	58
100%	0.472	78
125%	0.591	99







NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.

Appendix 3

ISO 16890-3:2016 -
Air flow rate and resistance to air flow after different dust loading phases

Test device:	LYD/7
Test no.:	SP201807061
Test dust:	Particle Technology, ISO 121031 A2-fine, Batch nr: 9284
Air flow rate:	0.472 m^3/s

Date	Loaded dust	Air flow meter				Filter						
	m_{tot}	t_f	p_{sf}	Δp_f	q_m	t	ϕ	p_a	ρ	q_v	Δp	$\Delta p_{1.20}$
	g	°C	Pa	Pa	kg/s	°C	%	kPa	kg/m^3	m^3/s	Pa	Pa
	Clean filter											
2018-07-20	-	22.0	33	21	0.22	22.0	50.3	99.2	1.164	0.189	30	29
2018-07-20	-	22.0	44	33	0.27	22.0	50.3	99.2	1.165	0.235	38	37
2018-07-20	-	22.1	71	73	0.41	22.1	50.2	99.2	1.164	0.355	58	58
2018-07-20	-	22.1	98	128	0.55	22.1	50.4	99.2	1.165	0.472	79	78
2018-07-20	-	22.1	130	199	0.69	22.1	50.4	99.2	1.165	0.591	100	99
	Clean filter pressure drop is proportional to $(q_v)^n$, where n = 1.06											
	Dust loading phase											
2018-08-06	0	24.4	100	128	0.548	24.4	36.7	99.5	1.159	0.472	80	79
2018-08-06	9	24.2	108	128	0.548	24.2	37.0	99.5	1.161	0.472	90	89
2018-08-06	39	24.6	147	128	0.548	24.6	36.2	99.6	1.160	0.472	134	133
2018-08-06	79	24.6	208	128	0.548	24.6	36.7	99.6	1.161	0.472	213	211
2018-08-06	99	24.6	242	128	0.548	24.6	36.7	99.7	1.161	0.472	252	250
2018-08-06	129	24.6	288	128	0.548	24.6	36.7	99.7	1.162	0.472	312	309

Symbols and units

Δp_f	air flow meter differential pressure, Pa	q_m	mass flow rate, kg/s
m_{tot}	cumulative mass of dust fed to filter, g	q_v	air flow rate filter, m^3/s
Δp	measured filter pressure drop, Pa	t_f	temperature at air flow meter, °C
$\Delta p_{1.20}$	resistance to air flow at air density 1.20 kg/m^3, Pa	t	temperature upstream of filter, °C
p_a	absolute air pressure upstream of filter, kPa	ϕ	relative humidity upstream of the filter, %
p_{sf}	air flow meter static pressure, kPa	ρ	air density upstream of filter, kg/m^3

Appendix 3

ISO 16890-3:2016 -
Resistance to air flow and arrestance after different dust loading phases

Test device:	LYD/7
Test no.:	SP201807061
Test dust:	Particle Technology, ISO 121031 A2-fine, Batch nr: 9284
Air flow rate:	0.472 m^3/s

Date	Δp_1 Pa	Δm g	m_{tot} g	Δp_2 Pa	m_1 g	m_2 g	Δm_f g	m_d g	A_j %	A_m %
2018-08-06	79	9	9	89	2586.6	2586.6	0.0	0.0	100.0	100.0
2018-08-06	89	30	39	133	2586.6	2586.7	0.1	0.0	99.7	99.7
2018-08-06	133	40	79	211	2586.7	2586.7	0.0	0.0	100.0	99.9
2018-08-06	211	20	99	250	2586.7	2586.7	0.0	0.0	100.0	99.9
2018-08-06	250	30	129	309	2586.7	2586.7	0.0	0.0	100.0	99.9

Mass of tested device

Initial mass of tested device: 1791.6 g

Final mass of tested device: 1904.1 g

Test dust: Particle Technology, ISO 121031 A2-fine, Batch nr: 9284

Symbols and units

A_j	arrestance, %
A_m	average arrestance, %
Δm	dust increment, g
Δp_1	resistance to air flow before dust increment (air density 1.20 kg/m³), Pa
Δp_2	resistance to air flow after dust increment (air density 1.20 kg/m³), Pa
m_d	dust in duct after device, g
m_1	mass of final filter before dust increment, g
m_2	mass of final filter after dust increment, g
m_{tot}	cumulative mass of dust fed to filter, g
Δm_f	mass gain of final filter, g

Appendix 4

ISO 16890-4:2016 - AIR FILTER TEST RESULTS SUMMARY

Testing Organization:
RISE
Research Institutes of Sweden AB
Brinellgatan 4, 50115 Borås, Swedan
+460105165000

GENERAL

Test ID: SP201807061	Date of test: 2018-07-20	Operator: CM

Particle counter information

Manufacturer:	Model:	Coincidence value (p/cm^3):	Air flow measurement:	Device obtained (when and how obtained):
TSI Gmbh	OPS 3330	300	Annubar, Micatrone Air flow sensor MFS-SS	The device was sent and obtained on 2018-06-21

DEVICE TESTED

Model:	Manufacturer:	Construction:
LYD/7		Panel filter

Article number:	Type of media:	Net effective media area (m^2)	Filter dimensions (width x height x depth)
-	Glass	5.6 m^2	592x592x48 mm

Filter/media electrostatic charge:	Media colour:	Media adhesive:
No	white	N/A

Device Condition: Conditioned per ISO 16890-4

Other descriptive information:

TEST DATA SUMMARY

Test air flow rate:	Test air temperature:	Test air RH:	Test aersole:
0.472 m^3/s	22 - 23.8 ° C	41.8 - 50.4 %	DEHS (0.3-1 µm) KCl (1-10 µm)

RESULTS

Resistance to airflow (Pa)

Measured: 78 Pa
Rated initial: -
Rated Final: -

Test item photo

Fractional Efficiency (%)

Range (µm)	Measured Efficiency	Rated Efficiency	Upstream concentration (particles / dm^3)
0.30 - 0.40	49		13631
0.40 - 0.55	58		11805
0.55 - 0.70	67		7257
0.70 - 1.00	76		7973
1.00 - 1.30	87		4717
1.30 - 1.60	90		2566
1.60 - 2.20	94		10521
2.20 - 3.00	98		6619
3.00 - 4.00	99		3319
4.00 - 5.50	100		2020
5.50 - 7.00	100		643
7.00 - 10.00	100		569

Remarks:

NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.

Appendix 4

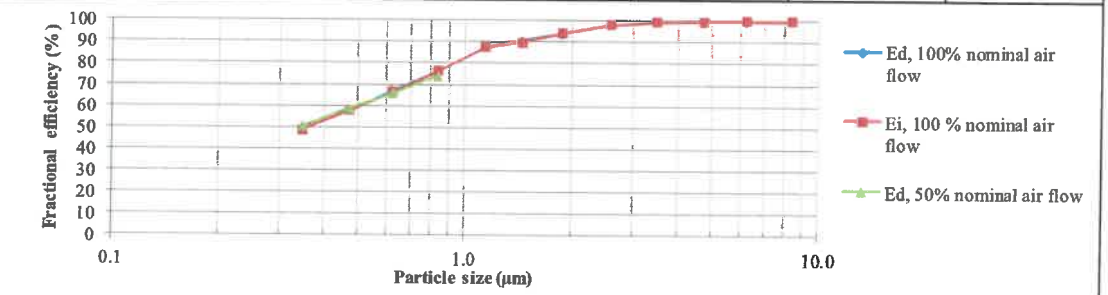
ISO 16890-4:2016 - AIR FILTER TEST RESULTS DETAILS

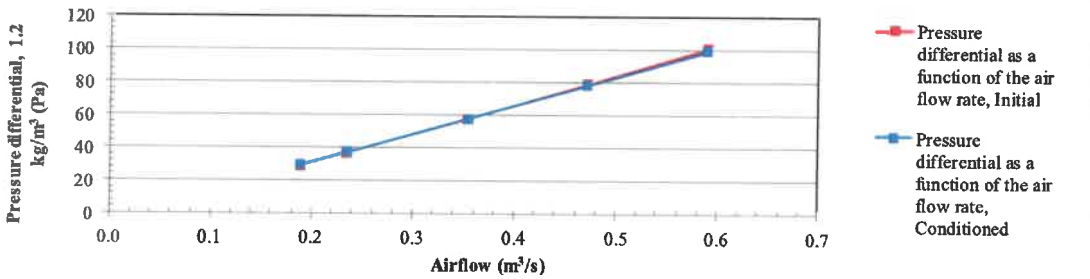
Testing Organization:
RISE
Research Institutes of Sweden AB
Brinellgatan 4, 501 15 Borås, Swedan
+460105165000

Test ID: SP201807061 | Date of test: 2018-07-20 | Operator: CM

TEST DATA DETAILS

Resistance to Airflow, 1.2 kg/m³		Fractional efficiency			
Initial					
Airflow (m³/s)	Resistance to Airflow (Pa)	Range (µm)	E_i, 100 % nominal air flow	E_d, 100% nominal air flow	E_d, 50% nominal air flow
0.189	29	0.30 - 0.40	48.6	48.9	50.3
0.234	37	0.40 - 0.55	57.8	57.6	58.6
0.353	57	0.55 - 0.70	66.3	66.8	65.5
0.472	79	0.70 - 1.00	76.0	75.9	73.8
0.590	101	1.00 - 1.30	87.5	87.4	
Conditioned		1.30 - 1.60	89.8	90.4	
Airflow (m³/s)	Resistance to Airflow (Pa)	1.60 - 2.20	93.9	93.6	
0.189	29	2.20 - 3.00	98.0	97.9	
0.235	37	3.00 - 4.00	99.4	99.4	
0.355	58	4.00 - 5.50	99.7	99.7	
0.472	78	5.50 - 7.00	99.8	99.7	
0.591	99	7.00 - 10.00	99.9	99.8	





CONDITIONING PROCEDURE

Date:	Temperature in the chamber:	Relative humidity in the chamber:	Atmospheric pressure:
2018-07-09 - 2018-07-10	n.a.	n.a.	991.3 - 998.9 mbar

NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.

Appendix 4

Efficiency measurement

Upstream count data

OPC bin	$d_{a,i}$	Upstream efficiency count data					
	µm	1	2	3	4	5	$U_{e,tot}$
1	0.35	13464	13751	13655	13579	13705	**68154**
2	0.47	11747	11812	11700	11830	11936	**59025**
3	0.62	7186	7434	7178	7155	7332	**36285**
4	0.84	8056	8100	7956	7905	7848	**39865**
5	1.14	4404	4958	4961	4583	4677	**23583**
6	1.44	2330	2807	2691	2548	2456	**12832**
7	1.88	9827	10844	11230	10135	10567	**52603**
8	2.57	6124	6991	7128	6403	6449	**33095**
9	3.46	3126	3489	3549	3127	3302	**16593**
10	4.69	1926	2032	2175	1955	2013	**10101**
11	6.20	621	692	672	622	606	**3213**
12	8.37	523	578	613	549	582	**2845**
Note: All data shown is the number of particle counts for 60 s							

Efficiency measurement

Downstream count data

OPC bin	$d_{a,i}$	Downstream efficiency count data					
	µm	1	2	3	4	5	$D_{e,tot}$
1	0.35	6768	7094	7025	6966	7006	**34859**
2	0.47	4989	5342	5054	5163	5149	**25697**
3	0.62	2338	2461	2402	2495	2279	**11975**
4	0.84	1941	1878	1842	1891	1948	**9500**
5	1.14	621	626	703	589	628	**3167**
6	1.44	261	271	339	245	316	**1432**
7	1.88	663	650	746	663	657	**3379**
8	2.57	136	141	158	137	146	**718**
9	3.46	21	23	25	20	18	**107**
10	4.69	5	7	9	6	5	**32**
11	6.20	4	1	0	2	3	**10**
12	8.37	1	2	2	0	0	**5**
Note: All data shown is the number of particle counts for 60 s							

Efficiency measurement

Final results and uncertainty

OPC bin	$d_{a,i}$	Penetration data reduction			Uncertainty limits		Uncertainty	Efficiency
	µm	P	δ	e	Static	Dynamic	Pass/Fail	%
1	0.35	0.511	0.007	0.009	≤ 0.05	0.036	Pass	**48.9**
2	0.47	0.424	0.011	0.014	≤ 0.05	0.030	Pass	**57.6**
3	0.62	0.332	0.014	0.017	≤ 0.05	0.023	Pass	**66.8**
4	0.84	0.241	0.008	0.010	≤ 0.05	0.017	Pass	**75.9**
5	1.14	0.126	0.008	0.010	≤ 0.05	0.009	Pass	**87.4**
6	1.44	0.096	0.014	0.017	≤ 0.05	0.007	Pass	**90.4**
7	1.88	0.064	0.004	0.005	≤ 0.05	0.004	Pass	**93.6**
8	2.57	0.021	0.001	0.001	≤ 0.05	0.001	Pass	**97.9**
9	3.46	0.006	0.001	0.001	≤ 0.05	0.001	Pass	**99.4**
10	4.69	0.003	0.001	0.001	≤ 0.05	0.000	Pass	**99.7**
11	6.20	0.003	0.002	0.003	≤ 0.05	0.001	Pass	**99.7**
12	8.37	0.002	0.002	0.002	≤ 0.05	0.000	Pass	**99.8**

$d_{a,i}$: Geometric mean diameter of a size range i, µm

P_a the final penetration for a given particle size

δ the standard deviation of the penetration for a given particle size

e the uncertainty of the penetration for a given particle size

Appendix 4

Efficiency measurement, 50% nominal air flow

Upstream count data

OPC bin	$d_{a,i}$	Upstream efficiency count data					
	µm	1	2	3	4	5	$U_{e,tot}$
1	0.35	18189	18252	18369	18880	18507	**92197**
2	0.47	16232	16196	16482	16591	16331	**81832**
3	0.62	10120	9931	10031	9918	9992	**49992**
4	0.84	11114	11083	11044	11326	11110	**55677**

Note: All data shown is the number of particle counts for 60 s

Efficiency measurement, 50% nominal air flow

Downstream count data

OPC bin	d_i	Downstream efficiency count data					
	µm	1	2	3	4	5	$D_{e,tot}$
1	0.35	9166	9172	9071	9241	9239	**45889**
2	0.47	7018	6720	7013	6928	7070	**34749**
3	0.62	3390	3421	3445	3432	3463	**17151**
4	0.84	2825	2787	2899	2892	3030	**14433**

Note: All data shown is the number of particle counts for 60 s

Efficiency measurement, 50% nominal air flow

Final results and uncertainty

OPC bin	$d_{a,i}$	Penetration data reduction			Uncertainty limits		Uncertainty	Efficiency
	µm	P	δ	e	Static	Dynamic	Pass/Fail	%
1	0.35	0.497	0.008	0.010	≤ 0.05	0.035	Pass	**50.3**
2	0.47	0.414	0.009	0.012	≤ 0.05	0.029	Pass	**58.6**
3	0.62	0.345	0.005	0.006	≤ 0.05	0.024	Pass	**65.5**
4	0.84	0.262	0.009	0.012	≤ 0.05	0.018	Pass	**73.8**

$d_{a,i}$:	Geometric mean diameter of a size range i, µm
P_a	the final penetration for a given particle size
δ	the standard deviation of the penetration for a given particle size
e	the uncertainty of the penetration for a given particle size

Appendix 5

Fig1. Overview of the test item

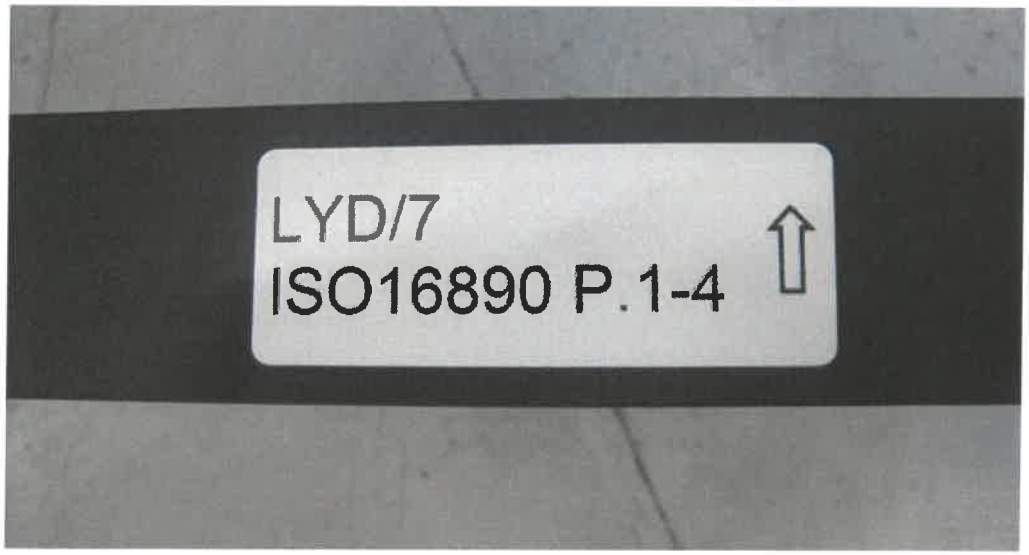


Fig 2. Label on the test item

Appendix 6

The interpretation of test reports according to ISO 16890:2016

This brief review of the test procedures, including those for addressing the testing of electrostatic charged filters, is provided for those unfamiliar with the procedures of this series of ISO standards. It is intended to assist in understanding and interpreting the results in the test report/summary. (For further details of procedures the full ISO 16890 document series shall be consulted).

Air filters may rely on the effects of passive static electric charges on the fibres to achieve high efficiencies, particularly in the initial stages of their working life. Environmental factors encountered in service may affect the action of these electric charges so that the initial efficiency may drop substantially after an initial period of service. This could be offset or countered by an increase in efficiency ("mechanical efficiency") as dust deposits build up. The reported, untreated and conditioned (discharged) efficiency shows the extent of the electrical charge effect on initial performance and indicates the potential loss of particle removal efficiency when the charge effect is completely removed and when at the same time there is no compensating increase of the mechanical efficiency. These test results should not be assumed to represent the filter performance in all possible environmental conditions or to represent all possible "real life" behaviour.