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Lindbergs Ventilation AB
Västkustvägen 400
254 77 FLENINGE

Testing of Air Filter according to ISO 16890:2016
(7 appendices)

A test according to ISO 16890:2016 was carried out by request from Lindbergs Ventilation AB.

Tested item

Lindbergs Ventilation AB, 700163M10, ePM1-70% (F7) 592x592x635-10/25, a 592 mm x 592 mm x 635 mm, 10 pocket air filter.

Pictures can be found in appendix 5.

The item was sent to RISE by Lindbergs Ventilation AB and was received by RISE on November 6, 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*

- *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.

Additional to the test:

An energy calculation was performed according to Eurovent 4/21-2018 “Energy efficiency evaluation of air filters for general ventilation purposes”, Third edition”.

Date and Place

The test was carried out at RISE’s laboratory of Energy and circular economy in Borås, Sweden on November 19 – December 6, 2018.

Tests according to ISO 16890-2 were carried out on November 19, 2018.
Tests according to ISO 16890-3 were carried out on December 5-6, 2018.
Tests according to ISO 16890-4 were carried out on November 23, 2018. Conditioning procedure according to ISO 16890-4 was carried out on November 19-20, 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.

In appendix 7 the energy calculation according to Eurovent 4/21 -2018 is reported.

Measurement equipment

- Pressure gauge Furness model 318, RISE's inventory no. 901 568
- Pressure gauge Furness model 318, RISE's inventory no. 901 569
- Pressure gauge Furness FC012, RISE's inventory no. 201 691
- Pressure gauge Furness FC012, RISE's inventory no. BX70943
- 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, Mettler, PBK 785-15 LA, RISE's inventory no. BX81958
- 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 ºC
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

Signed by: Christian Mossberg
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Examined by

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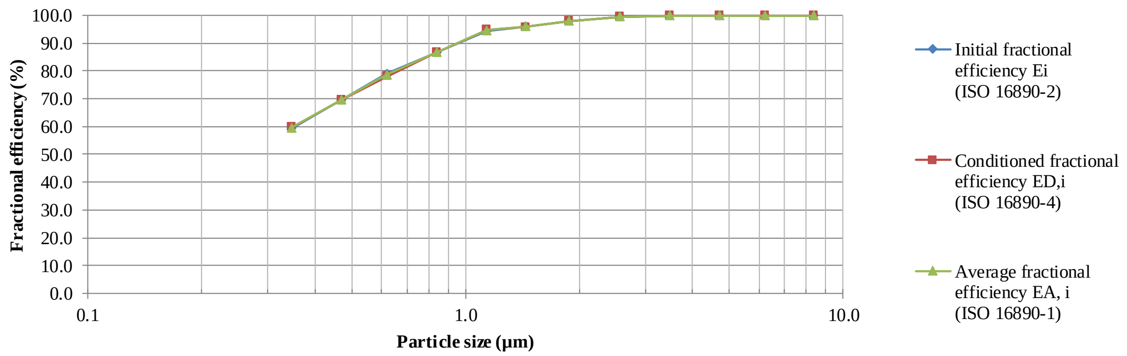
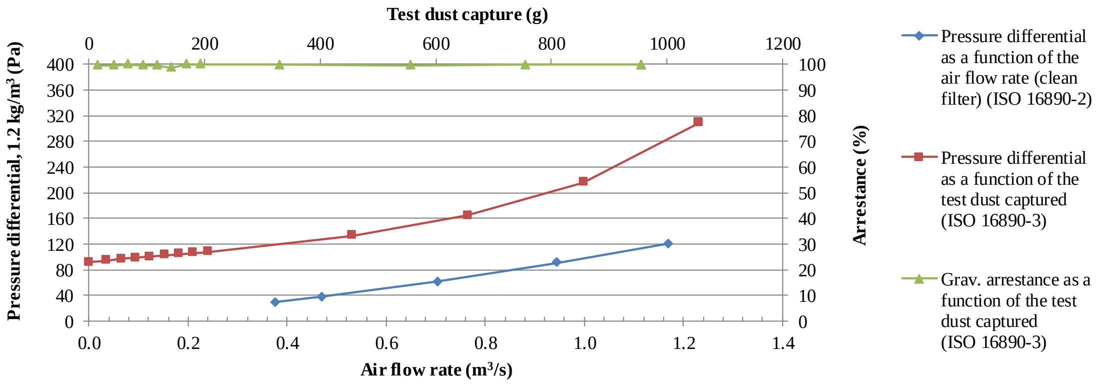
Tobias Eriksson

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
7. Energy calculation according to Eurovent 4/21-2018

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.: 8P02546-03H	Date of tests: 2018-11-19 - 2018-12-06					Date of report: 2018-12-11	
Supervisor: CM				Device obtained (when and how obtained):			
Test(s) requested by: Lindbergs Ventilation AB				The device was sent and obtained on 2018-11-06			
DEVICE TESTED							
Model: 700163M10, ePM1-70% (F7) 592x592x635-10/25		Manufacturer: Lindbergs Ventilation AB				Construction: Pocket filter, 10 Pockets	
Article number: -	Type of medium: Glass	Net effective filtering area: 7.3 m^2				Filter dimensions (width x height x depth) 592x592x635 mm	
TEST DATA AND ATTACHED TEST REPORTS							
Test air flow rate: 0.944 m^3/s	Test aersole: KCl (1-10 µm)	Test report to ISO 16890-2				Report no. 8P02546-03H Appendix 2	
		Test report to ISO 16890-3				Report no. 8P02546-03H Appendix 3	
	Test aersole: DEHS (0.3-1 µm)	Test report to ISO 16890-4				Report no. 8P02546-03H Appendix 4	
RESULTS							
Initial pressure differential: 90 Pa	Initial grav. arrestance: >99 %		$ePM_{1, min}$ 71 %	$ePM_{2.5, min}$ 80 %		$ePM_{10, min}$ 94 %	ISO rating
Final test pressure differential: 300 Pa	Test dust capacity: 1033 g		ePM_1 72 %	$ePM_{2.5}$ 80 %		ePM_{10} 94 %	**ISO ePM 1 70 %**
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: 8P02546-03H		
Model: 700163M10, ePM1-70% (F7) 592x592x635-10/25					Manufacturer: Lindbergs Ventilation AB		
Test air flow rate: 0.944 m^3/s					Date of report: 2018-12-11		
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	59.4	59.9	59.7
2	0.40	0.55	0.47	0.32	69.6	69.5	69.5
3	0.55	0.70	0.62	0.24	79.1	78.2	78.6
4	0.70	1.00	0.84	0.36	86.7	86.7	86.7
5	1.00	1.30	1.14	0.26	94.5	94.9	94.7
6	1.30	1.60	1.44	0.21	96.1	95.9	96.0
7	1.60	2.20	1.88	0.32	97.9	97.9	97.9
8	2.20	3.00	2.57	0.31	99.5	99.5	99.5
9	3.00	4.00	3.46	0.29	99.8	99.8	99.8
10	4.00	5.50	4.69	0.32	99.9	99.8	99.9
11	5.50	7.00	6.20	0.24	100.0	100.0	100.0
12	7.00	10.00	8.37	0.36	99.9	100.0	99.9

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.:	8P02546-03H
Model:	700163M10, ePM1-70% (F7) 592x592x635-10/25	Manufacturer:	Lindbergs Ventilation AB
Test air flow rate:	0.944 m^3/s	Date of report:	2018-12-11

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	3.898	3.88		
2	0.47	0.32	0.199	0.063	4.404	4.41		
3	0.62	0.24	0.158	0.038	2.985	3.00		
4	0.84	0.36	0.115	0.041	3.562	3.56	**$ePM_{1,\ min}$**	**ePM_1**
			∑ line 1-4	0.208	14.849	14.853	71	72
5	1.14	0.26	0.085	0.022	2.117	2.113		
6	1.44	0.21	0.076	0.016	1.517	1.518		
7	1.88	0.32	0.080	0.026	2.500	2.500		
8	2.57	0.31	0.100	0.031	3.082	3.081	**$ePM_{2.5,\ min}$**	**$ePM_{2.5}$**
			∑ line 1-8	0.302	24.065	24.066	80	80

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	1.621	1.615		
2	0.47	0.32	0.084	0.027	1.859	1.859		
3	0.62	0.24	0.074	0.018	1.401	1.409		
4	0.84	0.36	0.070	0.025	2.168	2.168		
5	1.14	0.26	0.076	0.020	1.899	1.895		
6	1.44	0.21	0.088	0.018	1.759	1.761		
7	1.88	0.32	0.108	0.034	3.367	3.368		
8	2.57	0.31	0.137	0.043	4.237	4.236		
9	3.46	0.29	0.167	0.048	4.799	4.799		
10	4.69	0.32	0.195	0.062	6.213	6.216		
11	6.20	0.24	0.217	0.052	5.224	5.225		
12	8.37	0.36	0.231	0.083	8.254	8.250	**$ePM_{10,\ min}$**	**ePM_{10}**
			∑ line 1-12	0.457	42.804	42.801	94	94

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: SP201811191	Date of test: 2018-11-19	Operator: IS

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 2018-11-06

DEVICE TESTED

Model: 700163M10, ePM1-70% (F7) 592x592x635-10/25	Manufacturer: Lindbergs Ventilation AB	Construction: Pocket filter, 10 Pockets
Article number: - | Type of media: Glass	Net effective media area (m^2) 7.3 m^2	Filter dimensions (width x height x depth) 592x592x635 mm
Filter/media electrostatic charge: No	Media colour: pink	Media adhesive: N/A

Device Condition: Clean / Initial

Other descriptive information:

TEST DATA SUMMARY

Test air flow rate:	Test air temperature:	Test air RH:	Test aersol:
0.944 m^3/s	21 - 21.5 ° C	37.5 - 42.8 %	DEHS (0.3-1 µm) KCl (1-10 µm)

RESULTS

Resistance to airflow (Pa)

Measured:		Rated initial:	Rated Final:
90	Pa	-	-

Fractional Efficiency (%)

Range (µm)	Measured Efficiency	Rated Efficiency	Upstream concentration (particles / dm^3)
0.30 - 0.40	59		16868
0.40 - 0.55	70		14482
0.55 - 0.70	79		8663
0.70 - 1.00	87		8785
1.00 - 1.30	95		9087
1.30 - 1.60	96		4890
1.60 - 2.20	98		19304
2.20 - 3.00	99		11142
3.00 - 4.00	100		5155
4.00 - 5.50	100		2779
5.50 - 7.00	100		725
7.00 - 10.00	100		497

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 2

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

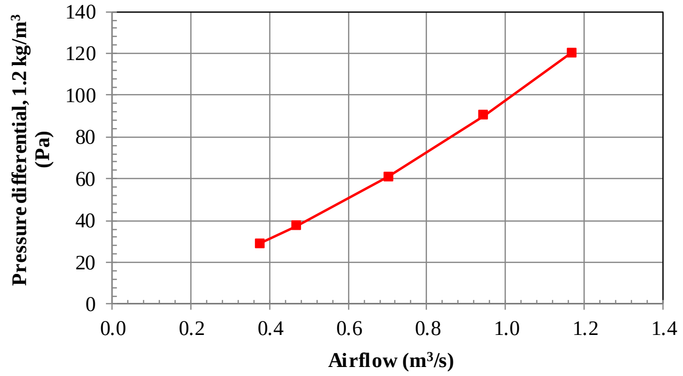
Testing Organization:
RISE
Research Institutes of Sweden AB
Brinellgatan 4, 501 15 Borås, Swedan
+460105165000

Test ID: SP201811191 | Date of test: 2018-11-19 | Operator: IS

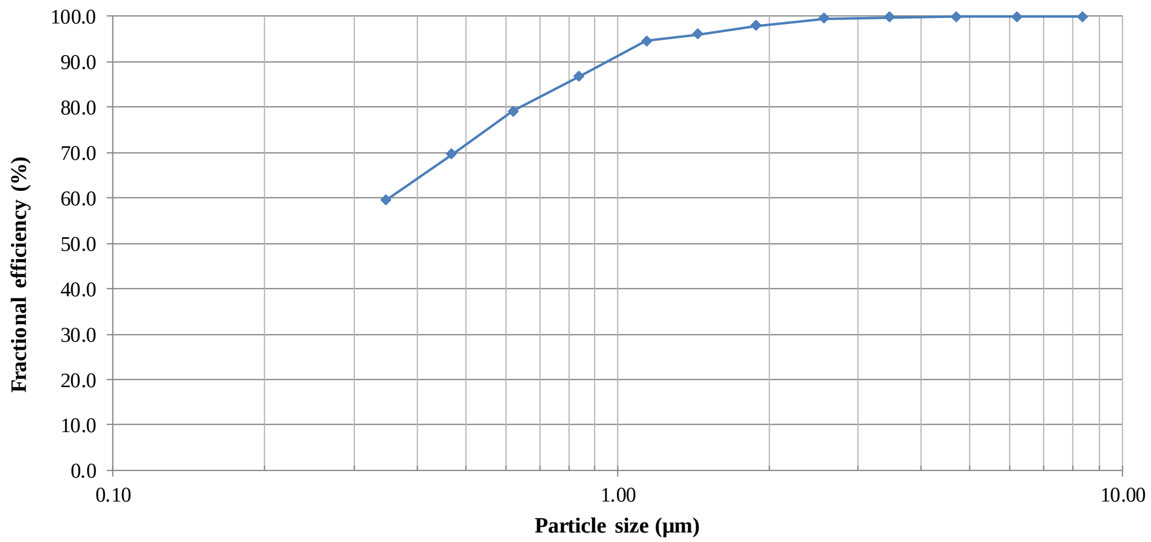
TEST DATA DETAILS

Resistance to Airflow 1.2 kg/m³

% of rated airflow	Airflow (m^3/s)	Resistance to Airflow (Pa)
40%	0.374	29
50%	0.468	37
75%	0.702	61
100%	0.944	90
125%	1.169	120



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	$\mathbf{U_{e,tot}}$
1	0.35	16750	17110	17064	17200	16215	**84339**
2	0.47	14375	14572	14794	14778	13889	**72408**
3	0.62	8757	8734	8687	8863	8273	**43314**
4	0.84	8720	8829	8833	9083	8462	**43927**
5	1.14	9299	9236	9391	9131	8378	**45435**
6	1.44	4952	5032	4933	4856	4677	**24450**
7	1.88	19479	19704	19642	19490	18207	**96522**
8	2.57	11395	11452	11309	11081	10472	**55709**
9	3.46	5377	5212	5160	5107	4920	**25776**
10	4.69	2816	2894	2806	2718	2659	**13893**
11	6.20	671	712	796	763	681	**3623**
12	8.37	462	535	532	543	411	**2483**
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	$\mathbf{D_{e,tot}}$
1	0.35	6689	6716	6793	6749	6508	**33455**
2	0.47	4449	4466	4483	4504	4167	**22069**
3	0.62	1764	1835	1848	1877	1725	**9049**
4	0.84	1199	1223	1153	1260	1141	**5976**
5	1.14	526	530	499	473	433	**2461**
6	1.44	224	235	218	220	193	**1090**
7	1.88	409	384	403	415	364	**1975**
8	2.57	55	51	65	65	55	**291**
9	3.46	4	10	6	11	10	**41**
10	4.69	2	1	2	2	2	**9**
11	6.20	0	1	0	0	0	**1**
12	8.37	1	1	1	0	0	**3**
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	0.406	0.008	0.010	≤ 0.05	0.028	Pass	**59.4**
2	0.47	0.304	0.005	0.006	≤ 0.05	0.021	Pass	**69.6**
3	0.62	0.209	0.005	0.006	≤ 0.05	0.015	Pass	**79.1**
4	0.84	0.133	0.004	0.004	≤ 0.05	0.009	Pass	**86.7**
5	1.14	0.055	0.003	0.003	≤ 0.05	0.004	Pass	**94.5**
6	1.44	0.039	0.002	0.002	≤ 0.05	0.003	Pass	**96.1**
7	1.88	0.021	0.001	0.001	≤ 0.05	0.001	Pass	**97.9**
8	2.57	0.005	0.001	0.001	≤ 0.05	0.000	Pass	**99.5**
9	3.46	0.002	0.001	0.001	≤ 0.05	0.000	Pass	**99.8**
10	4.69	0.001	0.000	0.000	≤ 0.05	0.000	Pass	**99.9**
11	6.20	0.000	0.001	0.001	≤ 0.05	0.000	Pass	**100.0**
12	8.37	0.001	0.001	0.001	≤ 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: SP201811191	Date of test: 2018-12-05 - 2018-12-06	Operator: HC
	Air flow measurement: Annubar, Micatrone Air flow sensor MFS-SS	Test sample obtained: The device was sent and obtained on 2018-11-06

DEVICE TESTED

Model: 700163M10, ePM1-70% (F7) 592x592x635-10/25	Manufacturer: Lindbergs Ventilation AB	Construction: Pocket filter, 10 Pockets
Article number: - / Type of media: Glass	Net effective media area (m^2): 7.3 m^2	Filter dimension (width x height x depth) 592x592x635 mm
Filter/media electrostatic charge: No	Media colour: pink	Media adhesive: 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:	Loading dust:
0.944 m^3/s	20.8 - 21.3 °C	41.8 - 45.8 %	Particle Technology, ISO 121031 A2-fine

RESULTS

Resistance to airflow		Dust loading results		
Measured: 90 Pa	Rated initial: - Pa	Initial arrestance (%)	Average arrestance(%)	Test dust capacity (g)
Final test pressure: 300 Pa	Rated Final: - Pa	>99 %	>99 %	1033 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

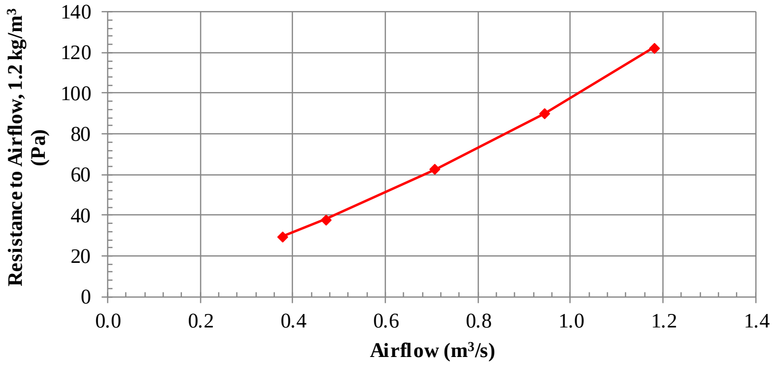
Testing Organization:
RISE
Research Institutes of Sweden AB
Brinellgatan 4, 501 15 Borås, Swedan
+460105165000

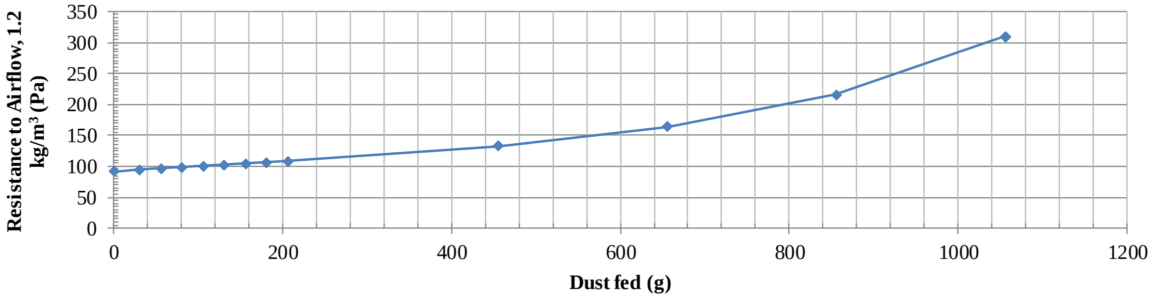
Test ID: SP201811191 | Date of test: 2018-12-05 - 2018-12-06 | Operator: HC

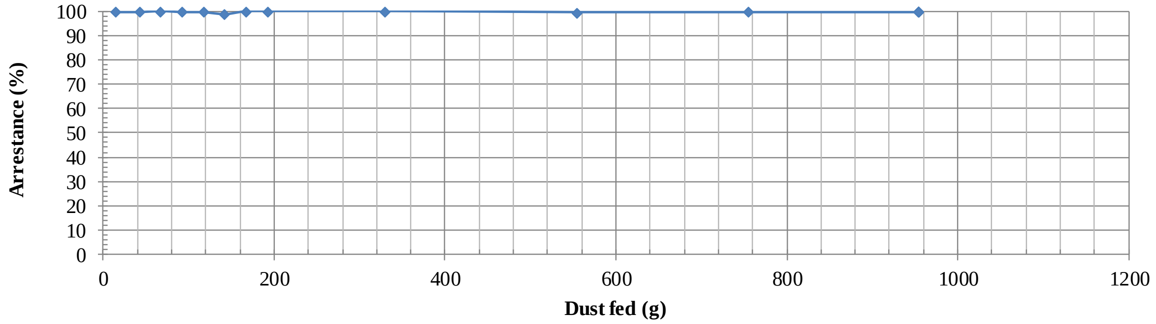
TEST DATA DETAILS

Resistance to Airflow 1.2 kg/m^3

% of rated airflow	Airflow (m^3/s)	Resistance to Airflow (Pa)
40%	0.379	30
50%	0.472	38
75%	0.708	63
100%	0.944	90
125%	1.181	123







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:	700163M10, ePM1-70% (F7) 592x592x635-10/25
Test no.:	SP201811191
Test dust:	Particle Technology, ISO 121031 A2-fine, Batch nr: 9552
Air flow rate:	0.944 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											
2018-11-23	-	20.8	26	85	0.45	20.8	41.9	100.4	1.185	0.379	30	30
2018-11-23	-	20.9	39	131	0.56	20.9	42.5	100.4	1.184	0.472	38	38
2018-11-23	-	21.0	74	290	0.84	21.0	41.2	100.4	1.184	0.708	63	63
2018-11-23	-	21.2	110	509	1.12	21.2	41.6	100.4	1.184	0.944	90	90
2018-11-23	-	21.4	137	790	1.40	21.4	41.7	100.4	1.183	1.181	123	123
	Clean filter pressure drop is proportional to $(q_v)^n$, where n = 1.25											
	Dust loading phase											
2018-12-05	0	21.3	39	507	1.112	21.3	43.0	99.9	1.177	0.944	91	91
2018-12-05	30	20.9	38	507	1.113	20.9	45.8	99.9	1.179	0.944	94	94
2018-12-05	55	20.9	38	507	1.113	20.9	43.3	99.9	1.179	0.944	96	96
2018-12-05	80	20.8	39	507	1.113	20.8	42.5	99.9	1.179	0.944	98	98
2018-12-05	105	20.8	40	507	1.113	20.8	41.8	99.9	1.179	0.944	100	100
2018-12-05	130	20.8	44	507	1.113	20.8	42.7	99.9	1.179	0.944	102	102
2018-12-05	155	20.8	42	507	1.113	20.8	42.7	99.9	1.179	0.944	104	104
2018-12-06	180	21.0	50	505	1.107	21.0	45.0	99.4	1.172	0.945	106	106
2018-12-06	205	21.0	55	505	1.108	21.0	43.3	99.4	1.173	0.944	108	108
2018-12-06	455	21.0	73	504	1.106	21.0	43.3	99.4	1.172	0.944	133	133
2018-12-06	655	20.9	75	504	1.106	20.9	43.2	99.4	1.173	0.943	164	164
2018-12-06	855	20.8	112	504	1.107	20.8	44.0	99.4	1.173	0.943	215	216
2018-12-06	1055	21.0	164	504	1.106	21.0	42.6	99.4	1.173	0.943	308	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:	700163M10, ePM1-70% (F7) 592x592x635-10/25
Test no.:	SP201811191
Test dust:	Particle Technology, ISO 121031 A2-fine, Batch nr: 9552
Air flow rate:	0.944 m^3/s

Date	Δp_1	Δm	m_{tot}	Δp_2	m_1	m_2	Δm_{ff}	m_d	A_j	A_m
	Pa	g	g	Pa	g	g	g	g	%	%
2018-12-05	91	30	30	94	2733.7	2733.8	0.1	0.0	99.7	99.7
2018-12-05	94	25	55	96	2733.8	2733.9	0.1	0.0	99.6	99.6
2018-12-05	96	25	80	98	2733.9	2733.9	0.0	0.0	100.0	99.7
2018-12-05	98	25	105	100	2733.9	2734.0	0.1	0.0	99.6	99.7
2018-12-05	100	25	130	102	2734.0	2734.1	0.1	0.0	99.6	99.7
2018-12-05	102	25	155	104	2734.1	2734.4	0.3	0.0	98.8	99.5
2018-12-06	104	25	180	106	2734.4	2734.4	0.0	0.0	100.0	99.6
2018-12-06	106	25	205	108	2734.4	2734.4	0.0	0.0	100.0	99.7
2018-12-06	108	250	455	133	2734.4	2734.7	0.3	0.0	99.9	99.8
2018-12-06	133	200	655	164	2734.7	2735.6	0.9	0.0	99.6	99.7
2018-12-06	164	200	855	216	2735.6	2736.0	0.4	0.0	99.8	99.7
2018-12-06	216	200	1055	309	2736.0	2736.4	0.4	0.0	99.8	99.7

Mass of tested device

Initial mass of tested device: 2451.6 g

Final mass of tested device: 3475.8 g

Test dust: Particle Technology, ISO 121031 A2-fine, Batch nr: 9552

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_{ff}	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: SP201811191	Date of test: 2018-11-23	Operator: CM

Particle counter information			Air flow measurement:	Device obtained (when and how obtained):
Manufacturer: TSI Gmbh	Model: OPS 3330	Coincidence value (p/cm^3): 300	Annubar, Micatrone Air flow sensor MFS-SS	The device was sent and obtained on 2018-11-06

DEVICE TESTED

Model: 700163M10, ePM1-70% (F7) 592x592x635-10/25	Manufacturer: Lindbergs Ventilation AB	Construction: Pocket filter, 10 Pockets
Article number: - / Type of media: Glass	Net effective media area (m^2): 7.3 m^2	Filter dimensions (width x height x depth): 592x592x635 mm
Filter/media electrostatic charge: No	Media colour: pink	Media adhesive: 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:
0.944 m^3/s	20.5 - 21.4 ° C	38.9 - 44.3 %	DEHS (0.3-1 µm) KCl (1-10 µm)

RESULTS

Resistance to airflow (Pa)

Measured:	Rated initial:	Rated Final:
90 Pa	-	-

Test item photo

Fractional Efficiency (%)

Range (µm)	Measured Efficiency	Rated Efficiency	Upstream concentration (particles / dm^3)
0.30 - 0.40	60		18265
0.40 - 0.55	70		15594
0.55 - 0.70	78		9122
0.70 - 1.00	87		9347
1.00 - 1.30	95		5659
1.30 - 1.60	96		3091
1.60 - 2.20	98		12683
2.20 - 3.00	100		7804
3.00 - 4.00	100		3692
4.00 - 5.50	100		2068
5.50 - 7.00	100		613
7.00 - 10.00	100		577

Remarks:

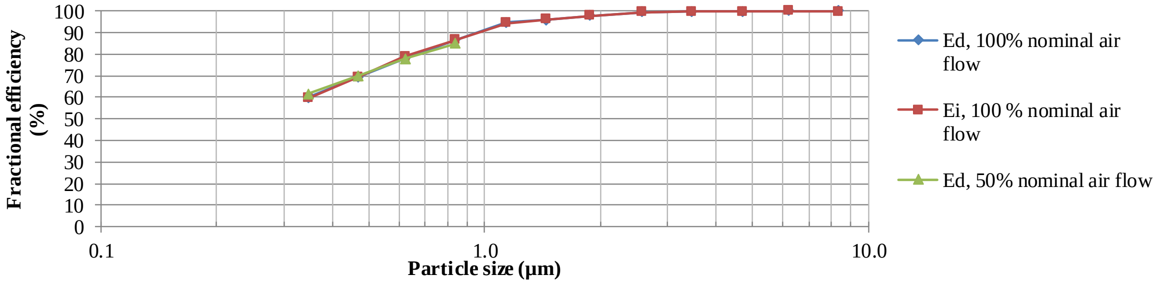
NOTE: The results of this test relate only to the test device in the condition stated herein. The performance results cannot by themselves be quantitatively applied to predict filtration performance in all "real life" environments.

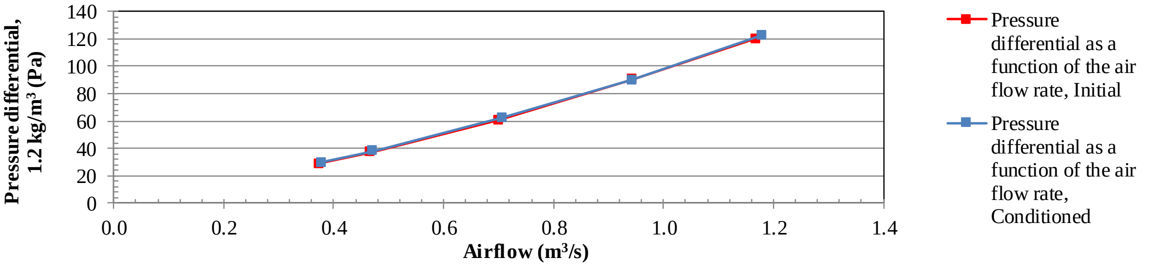
Appendix 4

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: SP201811191	Date of test: 2018-11-23	Operator: CM

TEST DATA DETAILS

Resistance to Airflow, 1.2 kg/m³		**Fractional efficiency**			
Initial		Range (µm)	E_i, 100 % nominal air flow	E_d, 100% nominal air flow	E_d, 50% nominal air flow
Airflow (m^3/s)	Resistance to Airflow (Pa)				
0.374	29	0.30 - 0.40	59.4	59.9	61.5
0.468	37	0.40 - 0.55	69.6	69.5	69.9
0.702	61	0.55 - 0.70	79.1	78.2	77.8
0.944	90	0.70 - 1.00	86.7	86.7	84.9
1.169	120	1.00 - 1.30	94.5	94.9	
Conditioned		1.30 - 1.60	96.1	95.9	
Airflow (m^3/s)	Resistance to Airflow (Pa)	1.60 - 2.20	97.9	97.9	
0.379	30	2.20 - 3.00	99.5	99.5	
0.472	38	3.00 - 4.00	99.8	99.8	
0.708	63	4.00 - 5.50	99.9	99.8	
0.944	90	5.50 - 7.00	100.0	100.0	
1.181	123	7.00 - 10.00	99.9	100.0	





CONDITIONING PROCEDURE

Date:	Temperature in the chamber:	Relative humidity in the chamber:	Atmospheric pressure:
2018-11-19 - 2018-11-20	20.2 - 21.3 ° C	25.2 - 27.4 %	1007.2 - 1014 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	$\mathbf{U_{e,tot}}$
1	0.35	18362	18303	18233	18278	18149	**91325**
2	0.47	15425	15715	15619	15671	15542	**77972**
3	0.62	9091	9234	8945	9230	9111	**45611**
4	0.84	9403	9539	9316	9196	9282	**46736**
5	1.14	5727	5835	5797	5320	5616	**28295**
6	1.44	3086	3225	3139	2851	3154	**15455**
7	1.88	12629	13286	12717	11967	12817	**63416**
8	2.57	7870	7988	7986	7387	7791	**39022**
9	3.46	3667	3785	3705	3576	3729	**18462**
10	4.69	2080	2155	2080	1937	2088	**10340**
11	6.20	614	606	665	576	604	**3065**
12	8.37	574	566	585	557	601	**2883**
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	$\mathbf{D_{e,tot}}$
1	0.35	7320	7103	7366	7313	7118	**36220**
2	0.47	4807	4900	4831	4785	4805	**24128**
3	0.62	1964	2050	1999	2034	2019	**10066**
4	0.84	1352	1324	1347	1265	1281	**6569**
5	1.14	268	301	312	290	250	**1421**
6	1.44	141	131	150	130	150	**702**
7	1.88	248	282	281	246	249	**1306**
8	2.57	32	49	36	33	35	**185**
9	3.46	6	5	7	7	3	**28**
10	4.69	5	3	1	4	4	**17**
11	6.20	0	0	0	1	0	**1**
12	8.37	0	0	0	0	0	**0**
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	0.401	0.010	0.012	≤ 0.05	0.028	Pass	**59.9**
2	0.47	0.305	0.005	0.006	≤ 0.05	0.021	Pass	**69.5**
3	0.62	0.218	0.005	0.006	≤ 0.05	0.015	Pass	**78.2**
4	0.84	0.133	0.004	0.005	≤ 0.05	0.009	Pass	**86.7**
5	1.14	0.051	0.005	0.006	≤ 0.05	0.004	Pass	**94.9**
6	1.44	0.041	0.003	0.004	≤ 0.05	0.003	Pass	**95.9**
7	1.88	0.021	0.001	0.001	≤ 0.05	0.001	Pass	**97.9**
8	2.57	0.005	0.001	0.001	≤ 0.05	0.000	Pass	**99.5**
9	3.46	0.002	0.000	0.001	≤ 0.05	0.000	Pass	**99.8**
10	4.69	0.002	0.001	0.001	≤ 0.05	0.000	Pass	**99.8**
11	6.20	0.000	0.001	0.001	≤ 0.05	0.000	Pass	**100.0**
12	8.37	0.000	0.000	0.000	≤ 0.05	0.000	Pass	**100.0**

$d_{a,i}$: 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	$d_{a,i}$ µm	Upstream efficiency count data 1	2	3	4	5	$U_{e,tot}$
1	0.35	21306	21355	21285	21198	21575	**106719**
2	0.47	18707	18515	18578	18197	18683	**92680**
3	0.62	10957	11124	11418	10976	11228	**55703**
4	0.84	11539	11472	11632	11316	11451	**57410**

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 µm	Downstream efficiency count data 1	2	3	4	5	$D_{e,tot}$
1	0.35	8116	8184	8166	8083	8086	**40635**
2	0.47	5632	5661	5642	5622	5769	**28326**
3	0.62	2534	2531	2496	2506	2445	**12512**
4	0.84	1864	1826	1778	1781	1891	**9140**

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	0.385	0.008	0.010	≤ 0.05	0.027	Pass	**61.5**
2	0.47	0.301	0.005	0.006	≤ 0.05	0.021	Pass	**69.9**
3	0.62	0.222	0.007	0.009	≤ 0.05	0.016	Pass	**77.8**
4	0.84	0.151	0.005	0.006	≤ 0.05	0.011	Pass	**84.9**

$d_{a,i}$: 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 5

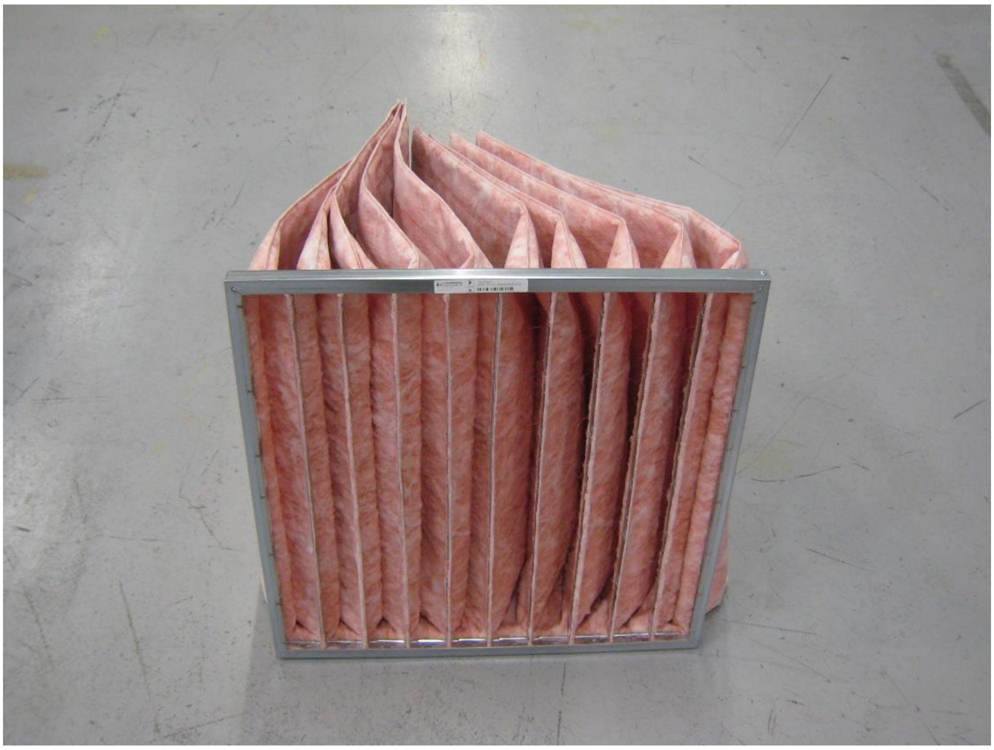


Fig1. Overview of the test item

Fig2. Label on the test item

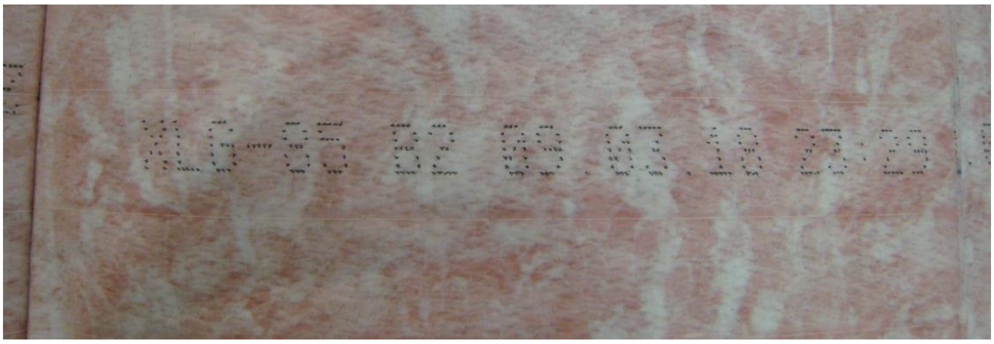


Fig3. Media in the test item

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.

Appendix 7

Eurovent 4/21 - 2018
Energy efficiency evaluation of air filters for general ventilation purposes

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

Test ID: SP201811191 | Date of test: 2018-12-05 | Operator: HC

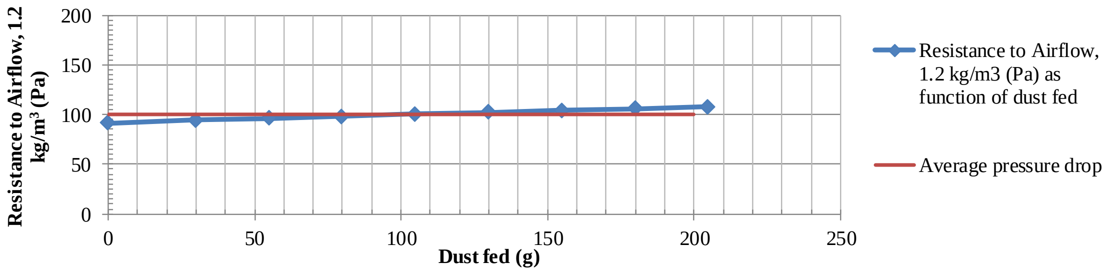
DEVICE TESTED

Model: 700163M10, ePM1-70% (F7) 592x592x635-10/25		Manufacturer: Lindbergs Ventilation AB	Construction: Pocket filter, 10 Pockets
Article number: -	Type of medium: Glass	Net effective filtering area: 7.3 m^2	Filter dimensions (width x height x depth) 592x592x635 mm

TEST DATA DETAILS

i	$m_{i,}$	Δp_i	$\Delta p_{i,a}$	Δm_i
	g	**Pa**	**Pa**	**g**
0	0	91.2		
1	30	94.2	92.7	30
2	55	96.2	95.2	25
3	80	98.2	97.2	25
4	105	100.2	99.2	25
5	130	102.2	101.2	25
6	155	104.3	103.2	25
7	180	105.9	105.1	25
8	205	107.9	106.9	25
	M_x	Δp_x	$\Delta p_{n,a}$	Δm_n
	g	**Pa**	**Pa**	**g**
	200	107.5	106.7	20

i number of the dust loading step
$m_{i,}$ total amount of dust fed to the air filter after the dust loading step *i*
Δp_i pressure drop of the air filter after dust loading step *i*
$\Delta p_{i,a}$ average of the pressure drops of the air filter measured before and after the dust loading step *i*
Δm_i dust increment fed to the air filter during loading step *i*
n total number of dust loading steps to feed the amount of test dust M_x to the air filter ($n \geq 8$)



RESULTS

ISO group	PM1	Δp_a, Average pressure drop	**99.7 Pa**
Amount of dust fed, M_x	200	Yearly energy konsumption, W	**1130 kWh**

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.