Determination of the filtration performance of air filter VILPE Wiwe 100 suodatinpussi according to EN ISO 16890:2016

Requested by

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Assignment

Determination of the filtration performance of air filter VILPE Wiwe 100 suodatinpussi according to EN ISO 16890:2016

Sample details

The customer delivered ten air filters, from which eight was randomly selected for tests and are detailed in Appendix 1. Picture from filter adapting panel is presented in Appendix 9.

The sample were received 12.7.2022.
The measurements were made 2. - 9.11.2022.

Methods

The tests were made according to EN ISO 16890:2016 standard series /1, 2, 3 and 4/

Deviating from standard, test air flow rate was lower than 0.25 m³/s.

The filter discharging treatment were made by exposing it to isopropanol vapor. The purity of the isopropanol used in the test was ≥99.5 %.

The air flow rates were measured with a calibrated orifice plate with corner pressure tappings.

The instruments used in the measurements are presented in Appendix 8.

FINAS Finnish Accreditation Service has accredited our laboratory (T001, Appendix 1.08, Eurofins Expert Services Oy) to perform measurements according to EN ISO 16890:2016 standard series.

Results

A summary of the test results, fractional efficiency values and calculation of the particulate matter efficiencies (ePM) are presented in Appendix 1.

Initial and conditioned fractional efficiency measurement results are presented in accordance with EN ISO 16890-2:2016 and EN ISO 16890-4:2016 in Appendix 2.

Air flow rate and pressure drop measurement results are presented in accordance with EN ISO 16890-2:2016 in Appendix 3.

Test aerosol particle numbers measured in determination of initial fractional efficiency is presented in Appendix 4 and for conditioned fractional efficiency in Appendix 5.

Normalized downstream particle size distributions and measured efficiencies in standardized environments are presented in Appendix 6.

The EN ISO 16890-1:2016 guideline for interpretation of test reports is presented in Appendix 7.

The measurements have been made so that the accuracy demands set in the standard ISO 16890-2 are fulfilled, i.e. pressure difference accuracy ±2 Pa in the range 0 - 70 Pa, above 70 Pa 3 % of the measured value, uncertainty of air flow rate ≤ 5 % at a 95 % confidence level.

The results are only valid for the tested filter sample.

References

/1/ EN ISO 16890-1:2016. Air filters for general ventilation - Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)

/2/ EN ISO 16890-2:2022. Air filters for general ventilation - Part 2: Measurement of fractional efficiency and air flow resistance

/3/ EN ISO 16890-3:2016. Air filters for general ventilation - Part 3: Determination of the gravimetric efficiency and the air flow resistance versus the mass of test dust captured

/4/ EN ISO 16890-4:2022. Air filters for general ventilation - Part 4: Conditioning method to determine the minimum fractional test efficiency

Espoo, 9.11.2022

Antti Korhonen
Expert

Appendices 9

Distribution Customer, electronically approved

EN ISO 16890-1:2016 Air Filter Test Results

GENERAL

Test no.: 224700		Device receiving date: 12.7.2022	
Test requested by: VILPE Oy		Date of test: 2. - 9.11.2022	
Device delivered by: VILPE Oy		Operator: RB	Supervisor: AK

DEVICE TESTED

Model VILPE Wiwe 100 suodatinpussi		Manufacturer VILPE Oy	Construction 8 units tested in parallel
Type of medium Synthetic	Net effective filtering area -	Filter dimensions (inner/outer x depth) Ø 92/54 mm x 180 mm	

TEST DATA

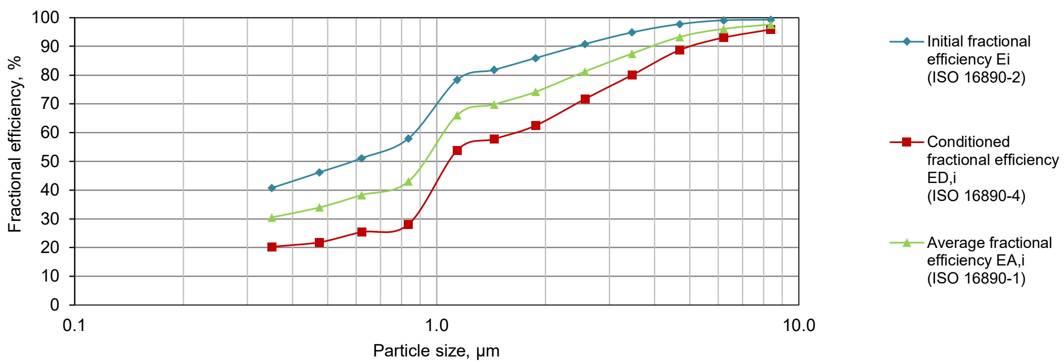
Test air flow rate	Test air temperature	Test air relative humidity	Test aerosol	Loading dust
40 dm³/s	22 - 23 °C	44 - 46 %	DEHS and KCl	-

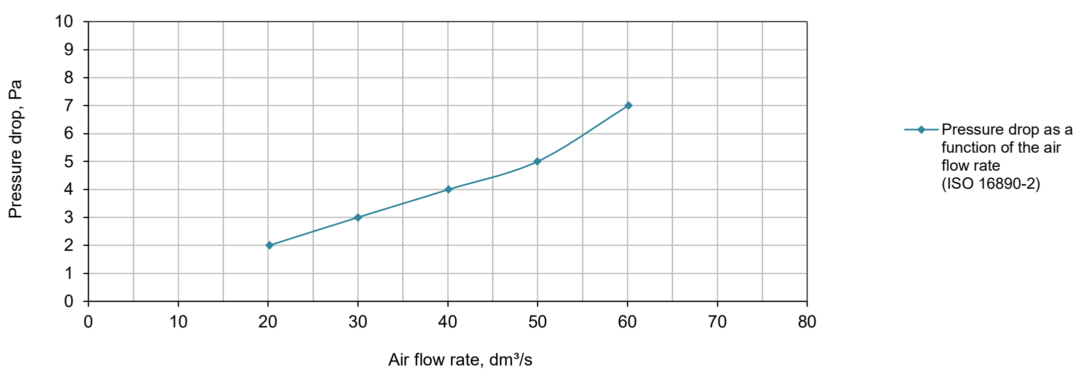
CONDITIONING ENVIRONMENT

Time of conditioning	Room temperature	Room relative humidity	Barometric pressure	Evaporated IPA amount
24 h	18 - 18 °C	55 - 60 %	100.1 - 100.7 kPa	163 g

RESULTS

Initial pressure drop 4 Pa	Initial gravimetric arrestance -	$ePM_{1,\,min}$ 23 %		$ePM_{2.5,\,min}$ 36 %	ISO rating **ISO ePM_{10} 75 %**
Final test pressure drop -	Test dust capacity -	ePM_1 35 %	$ePM_{2.5}$ 47 %	ePM_{10} 77 %	
Remarks: Eight filters were tested in parallel. Air flow rate through one filter is 5 l/s					





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

ilac-MRA FINAS Finnish Accreditation Service T001 (EN ISO/IEC 17025)

The results are only valid for the tested sample(s).
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Fractional efficiency values
EN ISO 16890-1,2,4:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 40 dm³/s

Particle size				Fractional efficiency		
OPC Bin, *i*	Δd_i µm	$\bar{d}_i$ µm	$\Delta \ln d_i$ µm	E_i %	$E_{D,i}$ %	$E_{A,i}$ %
1	0.30 - 0.41	0.35	0.31237	41	20	30
2	0.41 - 0.55	0.47	0.29376	46	22	34
3	0.55 - 0.70	0.62	0.24116	51	25	38
4	0.70 - 1.00	0.84	0.35667	58	28	43
5	1.00 - 1.30	1.14	0.26236	78	54	66
6	1.30 - 1.60	1.44	0.20764	82	58	70
7	1.60 - 2.20	1.88	0.31845	86	62	74
8	2.20 - 3.00	2.57	0.31015	91	72	81
9	3.00 - 4.00	3.46	0.28768	95	80	87
10	4.00 - 5.50	4.69	0.31845	98	89	93
11	5.50 - 7.00	6.20	0.24116	99	93	96
12	7.00 - 10.00	8.37	0.35667	99	96	98

Symbols and units

Δd_i	Particle size range i, µm
$\bar{d}_i$	Geometric mean diameter of a size range i, µm
$\Delta \ln d_i$	Logarithmic width of particle diameter size range *i*
E_i	Initial fractional efficiency of particle 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 artificial conditioning step, %
$E_{A,i}$	Average fractional efficiency of particle size range *i* , %

Calculation of the particulate matter efficiencies (*e*PM)
EN ISO 16890-1:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 40 dm³/s

Particle size				Urban size distribution					
OPC Bin, *i*	Δd_i µm	$\bar{d}_i$ µm	$\Delta \ln d_i$ µm	$q_{3u}(\bar{d}_i)$	$q_{3u}(\bar{d}_i) * \Delta \ln d_i$	$E_{D,i} * q_{3u}(\bar{d}_i) * \Delta \ln d_i$	$E_{A,i} * q_{3u}(\bar{d}_i) * \Delta \ln d_i$	$e\text{PM}_{x,\,min}$ %	$e\text{PM}_x$ %
1	0.30 - 0.41	0.35	0.31237	0.225685	0.070498	0.014262	0.021490		
2	0.41 - 0.55	0.47	0.29376	0.197321	0.057965	0.012664	0.019715		
3	0.55 - 0.70	0.62	0.24116	0.158372	0.038193	0.009699	0.014610		
4	0.70 - 1.00	0.84	0.35667	0.115223	0.041097	0.011555	0.017691	**$e\text{PM}_{1,\,min}$**	**$e\text{PM}_1$**
				Σ line 1-4	**0.207754**	**0.048180**	**0.073506**	**23**	**35**
5	1.00 - 1.30	1.14	0.26236	0.085032	0.022309	0.012019	0.014752		
6	1.30 - 1.60	1.44	0.20764	0.076177	0.015817	0.009143	0.011047		
7	1.60 - 2.20	1.88	0.31845	0.080218	0.025546	0.015952	0.018948		
8	2.20 - 3.00	2.57	0.31015	0.099839	0.030966	0.022210	0.025164	**$e\text{PM}_{2,5,\,min}$**	**$e\text{PM}_{2,5}$**
				Σ line 1-8	**0.302392**	**0.107505**	**0.143417**	**36**	**47**

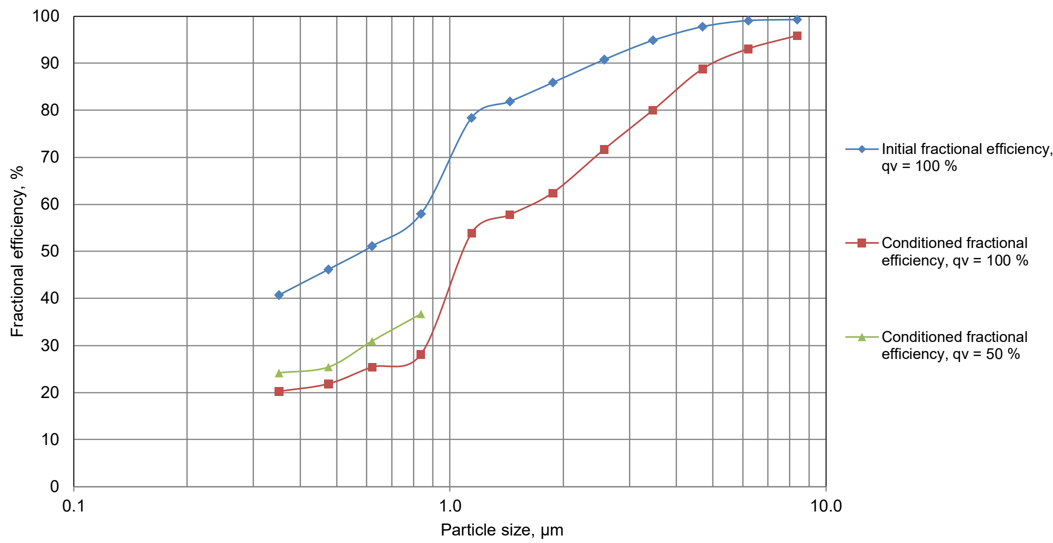
Particle size				Rural size distribution					
OPC Bin, *i*	Δd_i µm	$\bar{d}_i$ µm	$\Delta \ln d_i$ µm	$q_{3r}(\bar{d}_i)$	$q_{3r}(\bar{d}_i) * \Delta \ln d_i$		$E_{A,i} * q_{3r}(\bar{d}_i) * \Delta \ln d_i$		$e\text{PM}_x$ %
1	0.30 - 0.41	0.35	0.31237	0.093806	0.029303		0.008932		
2	0.41 - 0.55	0.47	0.29376	0.083478	0.024522		0.008340		
3	0.55 - 0.70	0.62	0.24116	0.074324	0.017924		0.006856		
4	0.70 - 1.00	0.84	0.35667	0.070137	0.025016		0.010769		
5	1.00 - 1.30	1.14	0.26236	0.076281	0.020013		0.013234		
6	1.30 - 1.60	1.44	0.20764	0.088326	0.018340		0.012808		
7	1.60 - 2.20	1.88	0.31845	0.108042	0.034406		0.025521		
8	2.20 - 3.00	2.57	0.31015	0.137262	0.042573		0.034597		
9	3.00 - 4.00	3.46	0.28768	0.167084	0.048067		0.042041		
10	4.00 - 5.50	4.69	0.31845	0.195424	0.062233		0.058038		
11	5.50 - 7.00	6.20	0.24116	0.216707	0.052261		0.050203		
12	7.00 - 10.00	8.37	0.35667	0.231428	0.082545		0.080531		**$e\text{PM}_{10}$**
				Σ line 1-12	**0.457204**		**0.351871**		**77**

Symbols and units

Δd_i	Particle size range i, µm
$\bar{d}_i$	Geometric mean diameter of a size range *i*, µm
$\Delta \ln d_i$	Logarithmic width of particle diameter size range *i*
$q_{3u}(\bar{d}_i)$	Discrete urban particle volume distribution, dimensionless
$q_{3r}(\bar{d}_i)$	Discrete rural particle volume distribution, dimensionless
$E_{D,i}$	Fractional efficiency of particle size range *i* of the filter element after an artificial conditioning step, %
$E_{A,i}$	Average fractional efficiency of particle size range *i*, %
$e\text{PM}_{x,\,min}$	Minimum particulate matter efficiency value of the conditioned filter, %
$e\text{PM}_x$	Particulate matter efficiency, %

Initial and conditioned fractional efficiency
EN ISO 16890-2,4:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 40 dm³/s



Particle size		Fractional efficiency and upstream concentration					
Δd_i	$\bar{d}_i$	Initial, q_V = 100 %		Conditioned, q_V = 100 %		Conditioned, q_V = 50 %	
µm	µm	%	#/dm³	%	#/dm³	%	#/dm³
0.30 - 0.41	0.35	40.7	36 588	20.2	24 221	24.2	27 858
0.41 - 0.55	0.47	46.2	23 802	21.8	15 939	25.4	18 279
0.55 - 0.70	0.62	51.1	15 947	25.4	10 868	30.9	12 444
0.70 - 1.00	0.84	58.0	18 143	28.1	12 545	36.7	14 518
1.00 - 1.30	1.14	78.4	5 482	53.9	8 824		
1.30 - 1.60	1.44	81.9	5 240	57.8	8 382		
1.60 - 2.20	1.88	85.9	7 207	62.4	11 337		
2.20 - 3.00	2.57	90.8	5 310	71.7	8 314		
3.00 - 4.00	3.46	94.9	4 390	80.0	6 904		
4.00 - 5.50	4.69	97.8	2 486	88.8	3 901		
5.50 - 7.00	6.20	99.1	759	93.1	1 105		
7.00 - 10.00	8.37	99.3	768	95.9	1 095		
DEHS concentration		122 303		83 493			
KCl concentration		107 568		168 584			
Pressure drop		4 Pa		5 Pa			

Particle counter coincidence value is 250 000 #/dm³

Symbols and units

Δd_i Particle size range, µm
$\bar{d}_i$ Geometric mean diameter of a size range i, µm
q_V Air flow rate at filter

Air flow rate and pressure drop
EN ISO 16890-2:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Air flow rate: 40 dm³/s

Date	Loaded dust	Calibrated orifice plate [1]				Filter								% of rated air flow
	m_{tot} g	t_f °C	p_{sf} kPa	Δp_f Pa	q_m kg/s	t °C	φ %	p_a kPa	ρ kg/m³	q_V dm³/s	$q_{Vsingle}$ dm³/s	Δp Pa	$\Delta p_{1.20}$ Pa	
Clean Filter														
2.11.2022	-	21.6	-0.020	141	0.072	22.8	45.0	101.9	1.194	60	7.5	7	7	150 %
"	-	21.3	-0.020	97	0.060	22.6	44.5	101.9	1.194	50	6.2	5	5	125 %
"	-	21.4	-0.020	62	0.048	22.6	45.2	101.9	1.195	40	5.0	4	4	100 %
"	-	21.6	-0.015	35	0.036	22.6	45.3	101.9	1.194	30	3.7	3	3	75 %
"	-	21.7	-0.015	15	0.024	22.6	45.1	101.9	1.194	20	2.5	2	2	50 %
Clean filter pressure drop is proportional to $(q_V)^n$, where n = 1.106														
Conditioned filter														
9.11.2022	-	22.4	-0.020	63	0.048	22.4	45.8	100.7	1.181	40	5.0	5	5	100 %
"	-	22.5	-0.015	15	0.024	22.5	45.8	100.7	1.180	20	2.5	2	2	50 %

Symbols and units

m_{tot}	Cumulative mass of dust fed to filter, g
p_a	Absolute air pressure upstream of filter, kPa
p_{sf}	Air flow meter static pressure, kPa
q_m	Mass flow rate, kg/s
q_V	Air flow rate at filter, dm³/s
$q_{Vsingle}$	Air flow rate through one filter, dm³/s
t	Temperature upstream of filter, °C
t_f	Temperature at air flow meter, °C
ρ	Air density upstream of filter, kg/m³
φ	Relative humidity upstream of filter, %
Δp	Measured filter pressure drop, Pa
Δp_f	Air flow meter differential pressure, Pa
$\Delta p_{1.20}$	Filter pressure drop at air density 1.20 kg/m³, Pa

[1] Orifice plate dimensions

Duct dimensions: 610 mm x 610 mm
Orifice diameter: 90 mm

Correlation data for initial efficiency
EN ISO 16890-2:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 40 dm³/s

OPC Bin, i	$\bar{d}_i$ µm	Initial and final background					
		$U_{B,c,b}$	$U_{B,c,f}$	**$U_{B,c}$**	$D_{B,c,b}$	$D_{B,c,f}$	**$D_{B,c}$**
1	0.35	3	4	**3.5**	2	5	**3.5**
2	0.47	1	0	**0.5**	1	0	**0.5**
3	0.62	0	0	**0**	0	0	**0**
4	0.84	0	1	**0.5**	0	0	**0**
5	1.14	0	0	**0**	0	0	**0**
6	1.44	0	0	**0**	0	0	**0**
7	1.88	0	0	**0**	1	0	**0.5**
8	2.57	0	0	**0**	0	0	**0**
9	3.46	0	0	**0**	0	0	**0**
10	4.69	0	0	**0**	0	0	**0**
11	6.20	0	0	**0**	0	0	**0**
12	8.37	0	0	**0**	0	0	**0**

All data shown is the number of particle counts for 60 seconds

OPC Bin, i	$\bar{d}_i$ µm	Upstream correlation (five measurements)						Downstream correlation (five measurements)					
		1	2	3	4	5	**$U_{c,tot}$**	1	2	3	4	5	**$D_{c,tot}$**
1	0.35	33666	34695	35558	36585	37461	**177965**	31110	32174	33007	33964	34365	**164620**
2	0.47	21515	22427	23216	23496	24239	**114893**	22784	23406	24419	24760	25352	**120721**
3	0.62	14835	15231	15674	15844	16359	**77943**	15102	15313	15718	16199	16415	**78747**
4	0.84	16684	17495	17666	17920	18541	**88306**	16410	16936	17573	17757	17992	**86668**
5	1.14	5357	5734	5804	5856	6055	**28806**	5108	5547	5690	5916	5908	**28169**
6	1.44	5129	5387	5551	5744	5822	**27633**	4259	4642	4950	5021	5084	**23956**
7	1.88	6988	7343	7779	7702	7982	**37794**	6528	6937	7351	7650	7784	**36250**
8	2.57	5122	5376	5514	5675	5769	**27456**	4811	5309	5604	5791	5803	**27318**
9	3.46	4213	4431	4513	4651	4679	**22487**	3872	4324	4471	4620	4705	**21992**
10	4.69	2466	2566	2612	2729	2678	**13051**	2388	2508	2674	2721	2785	**13076**
11	6.20	775	783	790	841	789	**3978**	743	847	816	937	854	**4197**
12	8.37	736	777	853	821	840	**4027**	792	786	854	817	858	**4107**

All data shown is the number of particle counts for 60 seconds

OPC Bin, i	$\bar{d}_i$ µm	Correlation ratios (five measurements)							Uncertainty limits		
		R_1	R_2	R_3	R_4	R_5	**R_{avg}**	Pass/Fail	δ_c	e_c	Pass/Fail
1	0.35	0.924	0.927	0.928	0.928	0.917	**0.925**	Pass	0.0047	0.0058	Pass
2	0.47	1.059	1.044	1.052	1.054	1.046	**1.051**	Pass	0.0062	0.0076	Pass
3	0.62	1.018	1.005	1.003	1.022	1.003	**1.010**	Pass	0.0091	0.0113	Pass
4	0.84	0.984	0.968	0.995	0.991	0.970	**0.982**	Pass	0.0120	0.0148	Pass
5	1.14	0.954	0.967	0.980	1.010	0.976	**0.977**	Pass	0.0210	0.0260	Pass
6	1.44	0.830	0.862	0.892	0.874	0.873	**0.866**	Pass	0.0227	0.0282	Pass
7	1.88	0.934	0.945	0.945	0.993	0.975	**0.958**	Pass	0.0248	0.0307	Pass
8	2.57	0.939	0.988	1.016	1.020	1.006	**0.994**	Pass	0.0331	0.0411	Pass
9	3.46	0.919	0.976	0.991	0.993	1.006	**0.977**	Pass	0.0340	0.0422	Pass
10	4.69	0.968	0.977	1.024	0.997	1.040	**1.001**	Pass	0.0303	0.0376	Pass
11	6.20	0.959	1.082	1.033	1.114	1.082	**1.054**	Pass	0.0607	0.0753	Pass
12	8.37	1.076	1.012	1.001	0.995	1.021	**1.021**	Pass	0.0323	0.0402	Pass

Symbols and units

$\bar{d}_i$	Geometric mean diameter of a size range i, µm	$D_{B,c}$	Downstream background count average for correlation
$U_{B,c,b}$	Upstream begining background count for correlation	$U_{c,tot}$	Total upstream particle counts
$U_{B,c,f}$	Upstream final background count	$D_{c,tot}$	Total downstream particle counts
$U_{B,c}$	Upstream background count average for correlation	R_{avg}	Average correlation ratio
$D_{B,c,b}$	Downstream begining background count for correlation	δ_c	Standard deviation of the correlation values
$D_{B,c,f}$	Downstream final background count	e_c	Uncertainty at 95 % confidence interval for correlation values

Initial efficiency data
EN ISO 16890-2:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 40 dm³/s

OPC Bin, i	$\bar{d}_i$ µm	Initial and final background					
		$U_{B,e,b}$	$U_{B,e,f}$	**$U_{B,e}$**	$D_{B,e,b}$	$D_{B,e,f}$	**$D_{B,e}$**
1	0.35	2	2	**2**	5	6	**5.5**
2	0.47	2	0	**1**	1	0	**0.5**
3	0.62	0	0	**0**	0	0	**0**
4	0.84	0	1	**0.5**	0	0	**0**
5	1.14	0	0	**0**	0	0	**0**
6	1.44	1	1	**1**	0	0	**0**
7	1.88	0	0	**0**	0	0	**0**
8	2.57	0	0	**0**	0	0	**0**
9	3.46	0	0	**0**	0	0	**0**
10	4.69	0	0	**0**	0	0	**0**
11	6.20	0	0	**0**	0	0	**0**
12	8.37	0	0	**0**	0	0	**0**

All data shown is the number of particle counts for 60 seconds

OPC Bin, i	$\bar{d}_i$ µm	Upstream efficiency (five measurements)						Downstream efficiency (five measurements)					
		1	2	3	4	5	**$U_{e,tot}$**	1	2	3	4	5	**$D_{e,tot}$**
1	0.35	36276	36581	36561	36772	36751	**182941**	19993	20103	20363	19709	20123	**100291**
2	0.47	23471	23720	23687	24155	23976	**119009**	13368	13465	13507	13345	13621	**67306**
3	0.62	15838	15701	15903	16152	16140	**79734**	7967	7797	7845	7825	7950	**39384**
4	0.84	17895	18024	18230	18394	18173	**90716**	7347	7445	7433	7557	7636	**37418**
5	1.14	4893	5409	5585	5794	5727	**27408**	1028	1088	1197	1243	1241	**5797**
6	1.44	4539	5145	5496	5534	5487	**26201**	728	784	843	909	849	**4113**
7	1.88	6462	6980	7405	7511	7675	**36033**	881	876	1017	1037	1061	**4872**
8	2.57	4698	5204	5514	5471	5662	**26549**	411	493	500	519	505	**2428**
9	3.46	3875	4307	4487	4615	4666	**21950**	194	205	254	234	209	**1096**
10	4.69	2224	2541	2539	2583	2543	**12430**	45	55	55	74	51	**280**
11	6.20	691	799	761	739	806	**3796**	10	9	4	8	6	**37**
12	8.37	672	805	785	785	793	**3840**	5	4	9	5	6	**29**

All data shown is the number of particle counts for 60 seconds

OPC Bin, i	$\bar{d}_i$ µm	Observed penetration (five measurements)						
		P_{o1}	P_{o2}	P_{o3}	P_{o4}	P_{o5}	**P_o**	δ_o
1	0.35	0.551	0.550	0.557	0.536	0.548	**0.548**	0.008
2	0.47	0.570	0.568	0.570	0.552	0.568	**0.566**	0.007
3	0.62	0.503	0.497	0.493	0.484	0.493	**0.494**	0.007
4	0.84	0.411	0.413	0.408	0.411	0.420	**0.412**	0.005
5	1.14	0.210	0.201	0.214	0.215	0.217	**0.211**	0.006
6	1.44	0.160	0.152	0.153	0.164	0.155	**0.157**	0.005
7	1.88	0.136	0.126	0.137	0.138	0.138	**0.135**	0.005
8	2.57	0.087	0.095	0.091	0.095	0.089	**0.091**	0.003
9	3.46	0.050	0.048	0.057	0.051	0.045	**0.050**	0.004
10	4.69	0.020	0.022	0.022	0.029	0.020	**0.022**	0.004
11	6.20	0.014	0.011	0.005	0.011	0.007	**0.010**	0.004
12	8.37	0.007	0.005	0.011	0.006	0.008	**0.008**	0.002

OPC Bin, i	$\bar{d}_i$ µm	Penetration data reduction			Uncertainty limits			Efficiency
		P	δ	e	Static	Dynamic	Pass/Fail	%
1	0.35	0.593	0.009	0.011	0.05	0.041	Pass	**40.7**
2	0.47	0.538	0.008	0.010	0.05	0.038	Pass	**46.2**
3	0.62	0.489	0.008	0.010	0.05	0.034	Pass	**51.1**
4	0.84	0.420	0.007	0.009	0.05	0.029	Pass	**58.0**
5	1.14	0.216	0.008	0.010	0.05	0.015	Pass	**78.4**
6	1.44	0.181	0.008	0.009	0.05	0.013	Pass	**81.9**
7	1.88	0.141	0.007	0.008	0.05	0.010	Pass	**85.9**
8	2.57	0.092	0.005	0.006	0.05	0.006	Pass	**90.8**
9	3.46	0.051	0.005	0.006	0.05	0.008	Pass	**94.9**
10	4.69	0.022	0.004	0.004	0.05	0.003	Pass	**97.8**
11	6.20	0.009	0.003	0.004	0.05	0.002	Pass	**99.1**
12	8.37	0.007	0.002	0.003	0.05	0.001	Pass	**99.3**

Symbols and units

$\bar{d}_i$	Geometric mean diameter of a size range i, µm	$U_{e,tot}$	Total upstream particle counts
$U_{B,e,b}$	Upstream begining background count for penetration	$D_{e,tot}$	Total downstream particle counts
$U_{B,e,f}$	Upstream final background count	P_o	Observed penetration, -
$U_{B,e}$	Upstream background count average for penetration	P	Penetration, -
$D_{B,e,b}$	Downstream begining background count for penetration	δ_o	Standard deviation of the observed penetration
$D_{B,e,f}$	Downstream final background count	δ	Standard deviation of the penetration
$D_{B,e}$	Downstream background count average for penetration	e	Uncertainty at 95 % confidence interval for penetration values

Correlation data for conditioned efficiency
EN ISO 16890-2:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 40 dm³/s

OPC Bin, i	$\bar{d}_i$ µm	Initial and final background					
		$U_{B,c,b}$	$U_{B,c,f}$	**$U_{B,c}$**	$D_{B,c,b}$	$D_{B,c,f}$	**$D_{B,c}$**
1	0.35	0	0	**0**	0	0	**0**
2	0.47	0	0	**0**	0	0	**0**
3	0.62	0	0	**0**	0	0	**0**
4	0.84	0	0	**0**	0	0	**0**
5	1.14	29	15	**22**	43	23	**33**
6	1.44	60	27	**43.5**	32	27	**29.5**
7	1.88	42	23	**32.5**	52	32	**42**
8	2.57	9	8	**8.5**	18	5	**11.5**
9	3.46	0	3	**1.5**	5	5	**5**
10	4.69	1	2	**1.5**	2	0	**1**
11	6.20	0	0	**0**	0	0	**0**
12	8.37	0	0	**0**	0	0	**0**

All data shown is the number of particle counts for 60 seconds

OPC Bin, i	$\bar{d}_i$ µm	Upstream correlation (five measurements)						Downstream correlation (five measurements)					
		1	2	3	4	5	**$U_{c,tot}$**	1	2	3	4	5	**$D_{c,tot}$**
1	0.35	18743	20000	21216	21706	21816	**103481**	17397	18511	19457	19868	19845	**95078**
2	0.47	12192	12954	13971	14089	14357	**67563**	12688	13375	13977	14402	14558	**69000**
3	0.62	8596	8893	9291	9510	9855	**46145**	8452	9023	9418	9607	9896	**46396**
4	0.84	9769	10480	11130	11383	11463	**54225**	9463	10067	10624	10784	11263	**52201**
5	1.14	9504	9433	9443	9479	9533	**47392**	9737	9432	9458	9272	9283	**47182**
6	1.44	9098	9208	9164	8952	9115	**45537**	8622	8375	8379	8274	8284	**41934**
7	1.88	12337	12336	12611	12224	12703	**62211**	12523	12269	12126	12078	12014	**61010**
8	2.57	8809	8928	8886	8765	9120	**44508**	9399	9211	9233	9193	9182	**46218**
9	3.46	7307	7561	7393	7284	7756	**37301**	7566	7334	7459	7417	7440	**37216**
10	4.69	4035	4239	4077	4130	4188	**20669**	4376	4219	4330	4378	4343	**21646**
11	6.20	1169	1197	1251	1214	1261	**6092**	1391	1304	1303	1303	1237	**6538**
12	8.37	1183	1276	1237	1183	1298	**6177**	1318	1257	1291	1323	1286	**6475**

All data shown is the number of particle counts for 60 seconds

OPC Bin, i	$\bar{d}_i$ µm	Correlation ratios (five measurements)							Uncertainty limits		
		R_1	R_2	R_3	R_4	R_5	**R_{avg}**	Pass/Fail	δ_c	e_c	Pass/Fail
1	0.35	0.928	0.926	0.917	0.915	0.910	**0.919**	Pass	0.0076	0.0094	Pass
2	0.47	1.041	1.032	1.000	1.022	1.014	**1.022**	Pass	0.0157	0.0195	Pass
3	0.62	0.983	1.015	1.014	1.010	1.004	**1.005**	Pass	0.0129	0.0160	Pass
4	0.84	0.969	0.961	0.955	0.947	0.983	**0.963**	Pass	0.0136	0.0168	Pass
5	1.14	1.025	1.000	1.002	0.978	0.974	**0.996**	Pass	0.0204	0.0254	Pass
6	1.44	0.948	0.910	0.914	0.924	0.909	**0.921**	Pass	0.0162	0.0201	Pass
7	1.88	1.015	0.995	0.962	0.988	0.946	**0.981**	Pass	0.0275	0.0341	Pass
8	2.57	1.067	1.032	1.039	1.049	1.007	**1.039**	Pass	0.0222	0.0275	Pass
9	3.46	1.035	0.970	1.009	1.018	0.959	**0.998**	Pass	0.0325	0.0403	Pass
10	4.69	1.085	0.995	1.062	1.060	1.037	**1.048**	Pass	0.0338	0.0420	Pass
11	6.20	1.190	1.089	1.042	1.073	0.981	**1.075**	Pass	0.0764	0.0949	Pass
12	8.37	1.114	0.985	1.044	1.118	0.991	**1.050**	Pass	0.0643	0.0798	Pass

Symbols and units

$\bar{d}_i$	Geometric mean diameter of a size range i, µm	$D_{B,c}$	Downstream background count average for correlation
$U_{B,c,b}$	Upstream begining background count for correlation	$U_{c,tot}$	Total upstream particle counts
$U_{B,c,f}$	Upstream final background count	$D_{c,tot}$	Total of the downstream particle counts
$U_{B,c}$	Upstream background count average for correlation	R_{avg}	Average correlation ratio
$D_{B,c,b}$	Downstream begining background count for correlation	δ_c	Standard deviation of the correlation values
$D_{B,c,f}$	Downstream final background count	e_c	Uncertainty at 95 % confidence interval for correlation values

Conditioned efficiency data
EN ISO 16890-2:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 40 dm³/s

OPC	$\bar{d}_i$	Initial and final background					
Bin, i	µm	$U_{B,e,b}$	$U_{B,e,f}$	**$U_{B,e}$**	$D_{B,e,b}$	$D_{B,e,f}$	**$D_{B,e}$**
1	0.35	0	0	**0**	0	0	**0**
2	0.47	0	0	**0**	0	0	**0**
3	0.62	0	0	**0**	0	0	**0**
4	0.84	0	0	**0**	0	0	**0**
5	1.14	0	0	**0**	0	0	**0**
6	1.44	0	0	**0**	0	0	**0**
7	1.88	0	0	**0**	0	0	**0**
8	2.57	0	0	**0**	0	0	**0**
9	3.46	0	0	**0**	0	0	**0**
10	4.69	0	0	**0**	0	0	**0**
11	6.20	0	0	**0**	0	0	**0**
12	8.37	0	0	**0**	0	0	**0**

All data shown is the number of particle counts for 60 seconds

OPC	$\bar{d}_i$	Upstream efficiency (five measurements)						Downstream efficiency (five measurements)					
Bin, i	µm	1	2	3	4	5	**$U_{e,tot}$**	1	2	3	4	5	**$D_{e,tot}$**
1	0.35	25084	24421	24042	23912	23644	**121103**	19398	18335	17559	16966	16600	**88858**
2	0.47	16639	16222	15679	15522	15633	**79695**	13933	13010	12339	12246	12165	**63693**
3	0.62	11241	11064	10774	10682	10580	**54341**	8902	8174	8004	7867	7824	**40771**
4	0.84	13000	12783	12494	12276	12170	**62723**	9385	8956	8596	8351	8147	**43435**
5	1.14	7979	8582	9073	9219	9266	**44119**	3636	3903	4088	4367	4274	**20268**
6	1.44	7623	8332	8766	8469	8721	**41911**	2852	3105	3369	3452	3525	**16303**
7	1.88	10249	11108	11799	11669	11860	**56685**	3797	4026	4304	4354	4404	**20885**
8	2.57	7606	8097	8590	8521	8758	**41572**	2203	2389	2470	2604	2545	**12211**
9	3.46	6300	6902	7073	7083	7161	**34519**	1174	1350	1433	1442	1491	**6890**
10	4.69	3601	3806	3997	4049	4050	**19503**	428	428	485	457	500	**2298**
11	6.20	1003	1095	1223	1088	1118	**5527**	85	83	80	91	71	**410**
12	8.37	1010	1082	1080	1118	1184	**5474**	38	42	58	54	46	**238**

All data shown is the number of particle counts for 60 seconds

OPC	$\bar{d}_i$	Observed penetration (five measurements)						
Bin, i	µm	P_{o1}	P_{o2}	P_{o3}	P_{o4}	P_{o5}	**P_o**	δ_o
1	0.35	0.773	0.751	0.730	0.710	0.702	**0.733**	0.029
2	0.47	0.837	0.802	0.787	0.789	0.778	**0.799**	0.023
3	0.62	0.792	0.739	0.743	0.736	0.740	**0.750**	0.024
4	0.84	0.722	0.701	0.688	0.680	0.669	**0.692**	0.020
5	1.14	0.456	0.455	0.451	0.474	0.461	**0.459**	0.009
6	1.44	0.374	0.373	0.384	0.408	0.404	**0.389**	0.016
7	1.88	0.370	0.362	0.365	0.373	0.371	**0.368**	0.005
8	2.57	0.290	0.295	0.288	0.306	0.291	**0.294**	0.007
9	3.46	0.186	0.196	0.203	0.204	0.208	**0.199**	0.009
10	4.69	0.119	0.112	0.121	0.113	0.123	**0.118**	0.005
11	6.20	0.085	0.076	0.065	0.084	0.064	**0.075**	0.010
12	8.37	0.038	0.039	0.054	0.048	0.039	**0.043**	0.007

OPC	$\bar{d}_i$	Penetration data reduction			Uncertainty limits			Efficiency
Bin, i	µm	P	δ	e	Static	Dynamic	Pass/Fail	%
1	0.35	0.798	0.033	0.041	0.05	0.056	Pass	**20.2**
2	0.47	0.782	0.026	0.032	0.05	0.055	Pass	**21.8**
3	0.62	0.746	0.025	0.031	0.05	0.052	Pass	**25.4**
4	0.84	0.719	0.023	0.029	0.05	0.050	Pass	**28.1**
5	1.14	0.461	0.013	0.016	0.05	0.032	Pass	**53.9**
6	1.44	0.422	0.019	0.024	0.05	0.030	Pass	**57.8**
7	1.88	0.376	0.012	0.014	0.05	0.026	Pass	**62.4**
8	2.57	0.283	0.009	0.011	0.05	0.020	Pass	**71.7**
9	3.46	0.200	0.011	0.013	0.05	0.030	Pass	**80.0**
10	4.69	0.112	0.006	0.007	0.05	0.017	Pass	**88.8**
11	6.20	0.069	0.010	0.013	0.05	0.014	Pass	**93.1**
12	8.37	0.041	0.007	0.009	0.05	0.008	Pass	**95.9**

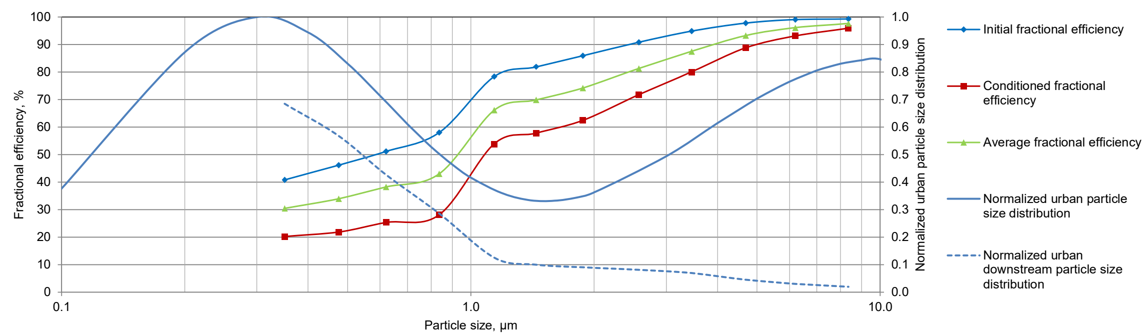
Symbols and units

$\bar{d}_i$	Geometric mean diameter of a size range i, µm	$U_{e,tot}$	Total upstream particle counts
$U_{B,e,b}$	Upstream begining background count for penetration	$D_{e,tot}$	Total downstream particle counts
$U_{B,e,f}$	Upstream final background count	P_o	Observed penetration, -
$U_{B,e}$	Upstream background count average for penetration	P	Penetration, -
$D_{B,e,b}$	Downstream begining background count for penetration	δ_o	Standard deviation of the observed penetration
$D_{B,e,f}$	Downstream final background count	δ	Standard deviation of the penetration
$D_{B,e}$	Downstream background count average for penetration	e	Uncertainty at 95 % confidence interval for penetration values

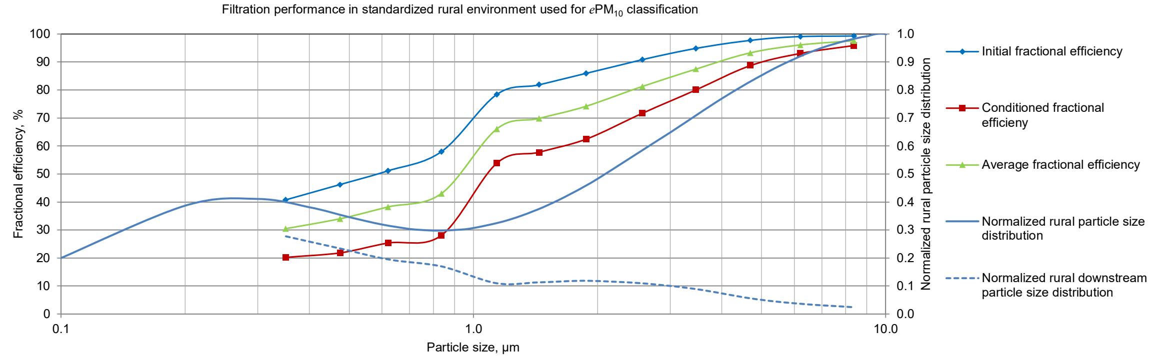
Normalized downstream particle size distribution and measured efficiencies
EN ISO 16890-1,2,4:2016

Air filter: VILPE Wiwe 100 suodatinpussi
Test no.: 224700
Test aerosols: DEHS (0.3 - 1 μm) and KCl (1 - 10 μm)
Air flow rate: 40 dm³/s

Filtration performance in standardized urban environment used for ePM$_1$ and ePM$_{2.5}$ classification



Filtration performance in standardized rural environment used for ePM$_{10}$ classification



Particle size			Urban size distribution					Rural size distribution			Fractional efficiency		
Δd_i μm	$\bar{d}_i$ μm	$\Delta \ln d_i$ μm	$q_{3u}(\bar{d}_i)$	$q_{3u}(\bar{d}_i)^*\Delta \ln d_i$	$E_i^* q_{3u}(\bar{d}_i)^*\Delta \ln d_i$	$E_{D,i}^* q_{3u}(\bar{d}_i)^*\Delta \ln d_i$	$E_{A,i}^* q_{3u}(\bar{d}_i)^*\Delta \ln d_i$	$q_{3r}(\bar{d}_i)$	$q_{3r}(\bar{d}_i)^*\Delta \ln d_i$	$E_{A,i}^* q_{3r}(\bar{d}_i)^*\Delta \ln d_i$	Initial, E_i %	Conditioned $E_{D,i}$ %	Average $E_{A,i}$ %
0.30 - 0.41	0.35	0.31237	0.22568	0.070498	0.028718	0.014262	0.021490	0.093806	0.029303	0.008932	41	20	30
0.41 - 0.55	0.47	0.29376	0.19732	0.057965	0.026766	0.012664	0.019715	0.083478	0.024522	0.008340	46	22	34
0.55 - 0.70	0.62	0.24116	0.15837	0.038193	0.019520	0.009699	0.014610	0.074324	0.017924	0.006856	51	25	38
0.70 - 1.00	0.84	0.35667	0.11522	0.041097	0.023827	0.011555	0.017691	0.070137	0.025016	0.010769	58	28	43
1.00 - 1.30	1.14	0.26236	0.08503	0.022309	0.017485	0.012019	0.014752	0.076281	0.020013	0.013234	78	54	66
1.30 - 1.60	1.44	0.20764	0.07618	0.015817	0.012950	0.009143	0.011047	0.088326	0.018340	0.012808	82	58	70
1.60 - 2.20	1.88	0.31845	0.08022	0.025546	0.021945	0.015952	0.018948	0.108042	0.034406	0.025521	86	62	74
2.20 - 3.00	2.57	0.31015	0.09984	0.030966	0.028118	0.022210	0.025164	0.137262	0.042573	0.034597	91	72	81
3.00 - 4.00	3.46	0.28768	0.12688	0.036500	0.034633	0.029215	0.031924	0.167084	0.048067	0.042041	95	80	87
4.00 - 5.50	4.69	0.31845	0.15556	0.049537	0.048427	0.043968	0.046197	0.195424	0.062233	0.058038	98	89	93
5.50 - 7.00	6.20	0.24116	0.17757	0.042823	0.042422	0.039850	0.041136	0.216707	0.052261	0.050203	99	93	96
7.00 - 10.00	8.37	0.35667	0.19157	0.068329	0.067823	0.065502	0.066662	0.231428	0.082545	0.080531	99	96	98

Particulate matter efficiencies		
ePM$_{1,\,ini}$	ePM$_{1,\,min}$	ePM$_1$
48 %	23 %	35 %
		-
ePM$_{2.5,\,ini}$	ePM$_{2.5,\,min}$	ePM$_{2.5}$
59 %	36 %	47 %
		-
ePM$_{10,\,ini}$	ePM$_{10,\,min}$	ePM$_{10}$
84 %	69 %	77 %
		ISO ePM$_{10}$ 75 %

Symbols and units

Δd_i	Particle size range, μm
$\bar{d}_i$	Geometric mean diameter of a size range i, μm
$\Delta \ln d_i$	Logarithmic width of particle diameter size range i
$q_{3u}(\bar{d}_i)$	Discrete urban particle volume distribution, dimensionless
$q_{3r}(\bar{d}_i)$	Discrete rural particle volume distribution, dimensionless
E_i	Initial fractional efficiency of particle 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 artificial conditioning step, %
$E_{A,i}$	Average fractional efficiency of particle size range i, %
ePM$_{x,\,ini}$	Initial particulate matter efficiency value of the clean filter, %
ePM$_{x,\,min}$	Minimum particulate matter efficiency value of the conditioned filter, %
ePM$_x$	Particulate matter efficiency, %

The interpretation of test reports
ISO 16890-1:2016

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.

Instruments used in the test				
Instrument	Type code	Serial number	Calibration date	Used
Micromanometer	Furness C012	209103	15.7.2022	X
	Furness C012	1211165	15.7.2022	X
	Micatrone MF-PD	32760-068	15.7.2022	X
Barometer	Vaisala PTB330	F4340001	18.7.2022	X
Hygrometer	Vaisala HMT333	D3940024	13.12.2021	X
Temperature meter	Agilent 34970A	MY44034623	3.9.2021	X
Balance	Precisa XB10200D-IP65	5300037	11.1.2022	-
	DFWATEX2GD-1	93411584	11.1.2022	X
Particle counter	TSI 3330	3330152501	11.1.2022	X
	TSI 3330	3330160801	12.1.2022	X
DEHS aerosol generator	ISO 16890-2:2016	-	-	X
KCl aerosol generator	TSI 8108	8108153201	-	X
Dust feeder	TOPAS SAG 440	440 13 03 406	3.10.2022	-
Orifice plate	Ø 216 mm / (610 x 610) mm	-	7.12.2020	-
	Ø 272 mm / (610 x 610) mm	-	7.12.2020	-
	Ø 90 mm / (610 x 610) mm	-	7.12.2020	X

Picture 1. Filter installation in adapting panel allowing eight filter units parallel testing. Any possible leakages around the filter were duct taped.