Determination of the filtration performance of air filter CA-Q according to EN ISO 16890:2016

Requested by

Filtech BV
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Order ref.

Q3JAPT200065-01, dated 23.7.2020

Contact person

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Assignment

Determination of the filtration performance of air filter CA-Q according to EN ISO 16890:2016

Sample details

The customer delivered two air filters which is detailed in Appendix 1. One was randomly selected for the test.

The sample were received 24.7.2020.
The measurements were made 17. - 19.8.2020.

Methods

Deviating from the standard the test air flow rate is lower than 0.25 m3/s.

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

The filter discharging treatment were made by exposing the filter to isopropanol (IPA) 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.

Airflow rate and pressure drop measurement results are presented in accordance with EN ISO 16890-3:2016 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.

The net effective filtering area 0.6 m² was calculated using the following measured approximate dimensions: pleat depth 18 mm, pleat tip width 1 mm pleat width 155 mm, number of pleats per filter pack 94, number of packs in the filter 1.

Normalized downstream particle size distribution and measured efficiencies 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% 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 16890-2:2016. 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 16890-4:2016. Air filters for general ventilation - Part 4: Conditioning method to determine the minimum fractional test efficiency

Espoo, 20.8.2020

Antti Korhonen
Consulting Expert

Appendices 8

Distribution Customer, electronically approved

EN ISO 16890-1:2016 Air Filter Test Results

GENERAL

Test no.:	204224	Device receiving date:	24.7.2020	
Test requested by:	Filtech BV	Date of test:	17. - 19.8.2020	
Device delivered by:	Filtech BV	Operator: JR	Supervisor: AK	

DEVICE TESTED

Model	Manufacturer	Construction
CA-Q	Filtech BV	Panel

Type of medium	Net effective filtering area	Filter dimensions (width × height × depth)
Synthetic fibre	0.6 m²	160 mm x 500 mm x 22 mm

TEST DATA

Test air flow rate	Test air temperature	Test air relative humidity	Test aerosol	Loading dust
0.097 m³/s	23 - 23 °C	47 - 53 %	DEHS and KCl	-

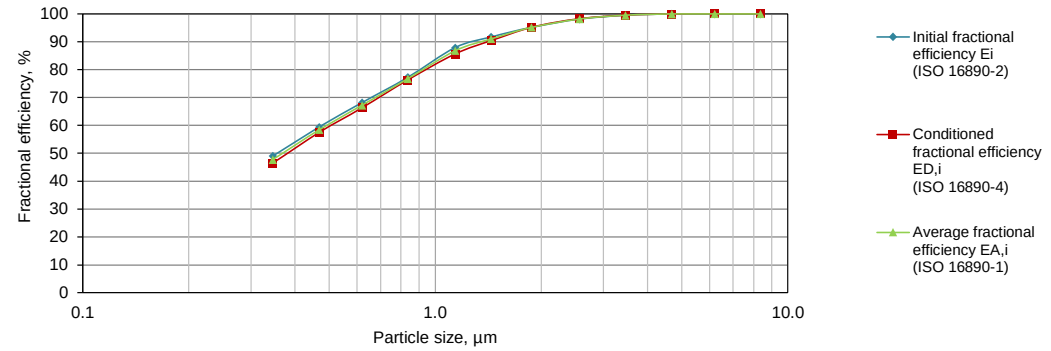
CONDITIONING ENVIRONMENT

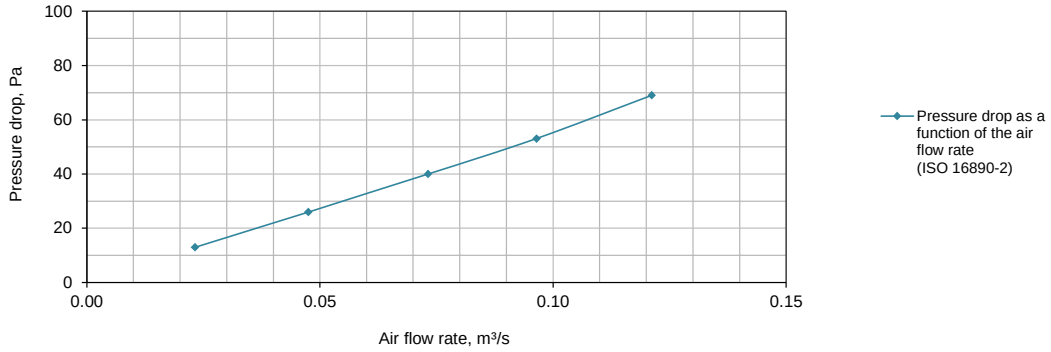
Time of conditioning	Room temperature	Room relative humidity	Barometric pressure	Evaporated IPA amount
24 h	19 - 20 °C	42 - 45 %	101.1 - 101.5 kPa	Not measured

RESULTS

Initial pressure drop	Initial gravimetric arrestance	$ePM_{1,\,min}$	$ePM_{2.5,\,min}$	$ePM_{10,\,min}$	ISO rating
53 Pa	-	59 %	70 %	90 %	**ISO ePM_1 60 %**
Final test pressure drop	**Test dust capacity**	ePM_1	$ePM_{2.5}$	ePM_{10}	
-	-	60 %	71 %	90 %	

Remarks: -





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.

Fractional efficiency values
EN ISO 16890-1,2,4:2016

Air filter: CA-Q
Test no.: 204224
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 0.097 m³/s

Particle size				Fractional efficiency		
OPC Bin, *i*	Δd_i µm	$\overline{d}_i$ µm	$\Delta \ln d_i$ µm	E_i %	$E_{D,i}$ %	$E_{A,i}$ %
1	0.30 - 0.40	0.35	0.28768	49	46	48
2	0.40 - 0.55	0.47	0.31845	59	57	58
3	0.55 - 0.70	0.62	0.24116	68	66	67
4	0.70 - 1.00	0.84	0.35667	77	76	77
5	1.00 - 1.30	1.14	0.26236	88	86	87
6	1.30 - 1.60	1.44	0.20764	92	90	91
7	1.60 - 2.20	1.88	0.31845	95	95	95
8	2.20 - 3.00	2.57	0.31015	98	98	98
9	3.00 - 4.00	3.46	0.28768	99	100	99
10	4.00 - 5.50	4.69	0.31845	100	100	100
11	5.50 - 7.00	6.20	0.24116	100	100	100
12	7.00 - 10.0	8.37	0.35667	100	100	100

Symbols and units

Δd_i	Particle size range i, µm
$\overline{d}_i$	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: CA-Q
Test no.: 204224
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 0.097 m³/s

Particle size				Urban size distribution					
OPC Bin, *i*	Δd_i µm	$\bar{d}_i$ µm	$\Delta \ln d_i$ µm	$q_{3u}(\bar{d}_i)$	$q_{3u}(\bar{d}_i)$ * $\Delta \ln d_i$	$E_{D,i}$*$q_{3u}(\bar{d}_i)$ *$\Delta \ln d_i$	$E_{A,i}$*$q_{3u}(\bar{d}_i)$ *$\Delta \ln d_i$	$e\mathrm{PM}_{x,\,min}$ %	$e\mathrm{PM}_x$ %
1	0.30 - 0.40	0.35	0.28768	0.226274	0.065095	0.030267	0.031082		
2	0.40 - 0.55	0.47	0.31845	0.198908	0.063343	0.036415	0.037027		
3	0.55 - 0.70	0.62	0.24116	0.158372	0.038193	0.025319	0.025679		
4	0.70 - 1.00	0.84	0.35667	0.115223	0.041097	0.031349	0.031540	**$e\mathrm{PM}_{1,\,min}$**	**$e\mathrm{PM}_1$**
				Σ line 1-4	**0.207728**	**0.123350**	**0.125329**	**59**	**60**
5	1.00 - 1.30	1.14	0.26236	0.085032	0.022309	0.019098	0.019350		
6	1.30 - 1.60	1.44	0.20764	0.076177	0.015817	0.014291	0.014397		
7	1.60 - 2.20	1.88	0.31845	0.080218	0.025546	0.024299	0.024299		
8	2.20 - 3.00	2.57	0.31015	0.099839	0.030966	0.030409	0.030394	**$e\mathrm{PM}_{2.5,\,min}$**	**$e\mathrm{PM}_{2.5}$**
				Σ line 1-8	**0.302366**	**0.211447**	**0.213768**	**70**	**71**

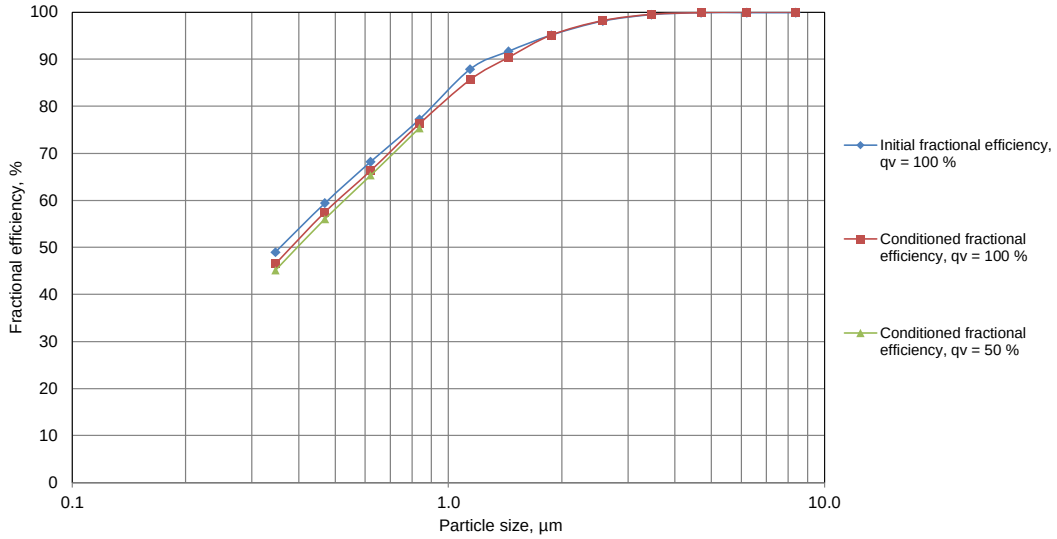
Particle size				Rural size distribution					
OPC Bin, *i*	Δd_i µm	$\bar{d}_i$ µm	$\Delta \ln d_i$ µm	$q_{3r}(\bar{d}_i)$	$q_{3r}(\bar{d}_i)$ * $\Delta \ln d_i$		$E_{A,i}$*$q_{3r}(\bar{d}_i)$ *$\Delta \ln d_i$		$e\mathrm{PM}_x$ %
1	0.30 - 0.40	0.35	0.28768	0.094121	0.027077		0.012929		
2	0.40 - 0.55	0.47	0.31845	0.083946	0.026733		0.015627		
3	0.55 - 0.70	0.62	0.24116	0.074324	0.017924		0.012051		
4	0.70 - 1.00	0.84	0.35667	0.070137	0.025016		0.019199		
5	1.00 - 1.30	1.14	0.26236	0.076281	0.020013		0.017359		
6	1.30 - 1.60	1.44	0.20764	0.088326	0.018340		0.016693		
7	1.60 - 2.20	1.88	0.31845	0.108042	0.034406		0.032727		
8	2.20 - 3.00	2.57	0.31015	0.137262	0.042573		0.041786		
9	3.00 - 4.00	3.46	0.28768	0.167084	0.048067		0.047817		
10	4.00 - 5.50	4.69	0.31845	0.195424	0.062233		0.062162		
11	5.50 - 7.00	6.20	0.24116	0.216707	0.052261		0.052234		
12	7.00 - 10.0	8.37	0.35667	0.231428	0.082545		0.082505		**$e\mathrm{PM}_{10}$**
				Σ line 1-12	**0.457189**		**0.413089**		**90**

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* , %
$e\mathrm{PM}_{x,\,min}$	Minimum particulate matter efficiency value of the conditioned filter, %
$e\mathrm{PM}_x$	Particulate matter efficiency, %

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

Air filter: CA-Q
Test no.: 204224
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 0.097 m³/s



Particle size		Fractional efficiency and upstream concentration					
Δd_i	d_i	Initial, q_V = 100 %		Conditioned, q_V = 100 %		Conditioned, q_V = 50 %	
µm	µm	%	#/dm³	%	#/dm³	%	#/dm³
0.30 - 0.40	0.35	49.0	27 340	46.5	28 157	45.1	18 306
0.40 - 0.55	0.47	59.4	23 594	57.5	24 188	56.0	15 865
0.55 - 0.70	0.62	68.2	14 237	66.3	14 665	65.3	9 902
0.70 - 1.00	0.84	77.2	15 753	76.3	16 265	75.4	11 620
1.00 - 1.30	1.14	87.9	3 820	85.6	3 983		
1.30 - 1.60	1.44	91.7	3 641	90.4	3 956		
1.60 - 2.20	1.88	95.1	5 637	95.1	6 045		
2.20 - 3.00	2.57	98.1	4 215	98.2	4 415		
3.00 - 4.00	3.46	99.5	3 337	99.5	3 448		
4.00 - 5.50	4.69	99.9	2 058	99.9	2 128		
5.50 - 7.00	6.20	99.9	643	100.0	654		
7.00 - 10.0	8.37	99.9	835	100.0	781		
DEHS concentration		103 819		106 027			
KCl concentration		84 941		87 028			
Pressure drop		53 Pa		55 Pa			
Device mass		97 g		99 g			

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: CA-Q
Test no.: 204224
Air flow rate: 0.097 m³/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/m³	t °C	φ %	p_a kPa	ρ kg/m³	q_V m³/s	Δp Pa	$\Delta p_{1.20}$ Pa	
Clean Filter													
17.8.2020	-	23.2	-0.099	627	0.144	23.4	46.7	101.7	1.189	0.121	70	69	125 %
"	-	23.2	-0.083	401	0.115	23.4	46.6	101.7	1.189	0.096	54	53	100 %
"	-	23.3	-0.070	233	0.087	23.4	46.7	101.7	1.189	0.073	40	40	75 %
"	-	23.3	-0.055	100	0.056	23.4	46.9	101.7	1.189	0.047	26	26	50 %
"	-	23.3	-0.040	24	0.028	23.4	47.3	101.7	1.188	0.023	13	13	25 %
Clean filter pressure drop is proportional to $(q_V)^n$, where n = 1.011													
Conditioned filter													
19.8.2020	-	22.8	-0.084	407	0.115	23.1	52.5	101.5	1.186	0.097	56	55	100 %
"	-	22.9	-0.055	102	0.057	23.1	50.0	101.5	1.187	0.048	26	26	50 %

Symbols and units

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

[1] Orifice plate dimensions

Duct dimensions: 610 mm x 610 mm
Orifice diameter: 216 mm

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

Air filter: CA-Q
Test no.: 204224
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 0.097 m³/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	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 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	24132	25877	26586	27533	27163	**131291**	22335	24284	25582	25670	25778	**123649**
2	0.47	20754	22071	22941	23618	23292	**112676**	19652	20893	22039	22377	22467	**107428**
3	0.62	12418	13566	14017	14219	14096	**68316**	12209	13316	14005	14165	14147	**67842**
4	0.84	13650	14962	15353	15754	15726	**75445**	12672	13821	14385	14884	14821	**70583**
5	1.14	3681	3752	3846	3941	3742	**18962**	4094	4175	4276	4415	4315	**21275**
6	1.44	3475	3581	3728	3710	3648	**18142**	3435	3465	3568	3573	3540	**17581**
7	1.88	5466	5550	5618	5451	5519	**27604**	5039	4989	4994	5329	5182	**25533**
8	2.57	4083	3887	4042	4107	4033	**20152**	3829	3717	3687	3875	3745	**18853**
9	3.46	3216	3223	3376	3417	3226	**16458**	3083	3113	3140	3140	3046	**15522**
10	4.69	2006	1981	2096	2010	1943	**10036**	1907	1926	2014	1972	1903	**9722**
11	6.20	575	671	642	641	645	**3174**	586	589	634	659	559	**3027**
12	8.37	746	751	826	814	803	**3940**	636	703	658	684	669	**3350**

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	0.926	0.938	0.962	0.932	0.949	**0.942**	Pass	0.0144	0.0179	Pass
2	0.47	0.947	0.947	0.961	0.947	0.965	**0.953**	Pass	0.0087	0.0108	Pass
3	0.62	0.983	0.982	0.999	0.996	1.004	**0.993**	Pass	0.0098	0.0122	Pass
4	0.84	0.928	0.924	0.937	0.945	0.942	**0.935**	Pass	0.0090	0.0112	Pass
5	1.14	1.112	1.113	1.112	1.120	1.153	**1.122**	Pass	0.0177	0.0220	Pass
6	1.44	0.988	0.968	0.957	0.963	0.970	**0.969**	Pass	0.0118	0.0147	Pass
7	1.88	0.922	0.899	0.889	0.978	0.939	**0.925**	Pass	0.0352	0.0437	Pass
8	2.57	0.938	0.956	0.912	0.944	0.929	**0.936**	Pass	0.0165	0.0205	Pass
9	3.46	0.959	0.966	0.930	0.919	0.944	**0.944**	Pass	0.0195	0.0241	Pass
10	4.69	0.951	0.972	0.961	0.981	0.979	**0.969**	Pass	0.0129	0.0160	Pass
11	6.20	1.019	0.878	0.988	1.028	0.867	**0.956**	Pass	0.0779	0.0967	Pass
12	8.37	0.853	0.936	0.797	0.840	0.833	**0.852**	Pass	0.0516	0.0640	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: CA-Q
Test no.: 204224
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 0.097 m³/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	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 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	27468	27165	27444	27264	27361	**136702**	12606	12942	13153	13520	13413	**65634**
2	0.47	23317	23709	23655	23668	23622	**117971**	8743	8910	9183	9433	9369	**45638**
3	0.62	14034	14277	14451	14198	14227	**71187**	4390	4313	4418	4702	4662	**22485**
4	0.84	15832	15870	15580	15824	15660	**78766**	3330	3209	3345	3454	3447	**16785**
5	1.14	3402	3789	3923	4055	3931	**19100**	435	544	554	537	534	**2604**
6	1.44	3225	3719	3762	3794	3706	**18206**	247	303	310	299	310	**1469**
7	1.88	5111	5710	5806	5798	5758	**28183**	230	238	261	283	261	**1273**
8	2.57	3687	4255	4314	4442	4379	**21077**	62	90	92	61	69	**374**
9	3.46	3003	3329	3470	3451	3432	**16685**	11	16	14	22	24	**87**
10	4.69	1790	2099	2055	2156	2191	**10291**	2	4	2	1	4	**13**
11	6.20	593	635	692	629	665	**3214**	2	0	0	1	0	**3**
12	8.37	674	885	859	860	899	**4177**	2	0	0	1	0	**3**

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	0.459	0.476	0.479	0.496	0.490	**0.480**	0.014
2	0.47	0.375	0.376	0.388	0.399	0.397	**0.387**	0.011
3	0.62	0.313	0.302	0.306	0.331	0.328	**0.316**	0.013
4	0.84	0.210	0.202	0.215	0.218	0.220	**0.213**	0.007
5	1.14	0.128	0.144	0.141	0.132	0.136	**0.136**	0.006
6	1.44	0.077	0.081	0.082	0.079	0.084	**0.081**	0.003
7	1.88	0.045	0.042	0.045	0.049	0.045	**0.045**	0.003
8	2.57	0.017	0.021	0.021	0.014	0.016	**0.018**	0.003
9	3.46	0.004	0.005	0.004	0.006	0.007	**0.005**	0.001
10	4.69	0.001	0.002	0.001	0.000	0.002	**0.001**	0.001
11	6.20	0.003	0.000	0.000	0.002	0.000	**0.001**	0.001
12	8.37	0.003	0.000	0.000	0.001	0.000	**0.001**	0.001

OPC Bin, i	$\bar{d}_i$ µm	Penetration data reduction			Uncertainty limits			Efficiency
		P	δ	e	Static	Dynamic	Pass/Fail	**%**
1	0.35	0.510	0.017	0.021	0.05	0.036	Pass	**49.0**
2	0.47	0.406	0.012	0.015	0.05	0.028	Pass	**59.4**
3	0.62	0.318	0.013	0.017	0.05	0.022	Pass	**68.2**
4	0.84	0.228	0.008	0.010	0.05	0.016	Pass	**77.2**
5	1.14	0.121	0.006	0.007	0.05	0.008	Pass	**87.9**
6	1.44	0.083	0.003	0.004	0.05	0.006	Pass	**91.7**
7	1.88	0.049	0.003	0.004	0.05	0.003	Pass	**95.1**
8	2.57	0.019	0.004	0.004	0.05	0.001	Pass	**98.1**
9	3.46	0.005	0.002	0.002	0.05	0.001	Pass	**99.5**
10	4.69	0.001	0.001	0.001	0.05	0.000	Pass	**99.9**
11	6.20	0.001	0.002	0.002	0.05	0.000	Pass	**99.9**
12	8.37	0.001	0.002	0.002	0.05	0.000	Pass	**99.9**

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

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

Air filter: CA-Q
Test no.: 204224
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 0.097 m³/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	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 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	27584	28128	28157	28550	28468	**140887**	26864	27184	26654	27015	26790	**134507**
2	0.47	23933	24000	24238	24086	24242	**120499**	23081	23485	23610	23445	23344	**116965**
3	0.62	14618	14629	14876	14852	14989	**73964**	14726	14975	14919	14766	14620	**74006**
4	0.84	15935	16373	16283	16489	16486	**81566**	15177	15008	14911	15017	15180	**75293**
5	1.14	3664	3755	3954	4051	4035	**19459**	4006	4001	4263	4129	4220	**20619**
6	1.44	3612	3647	3877	3869	4169	**19174**	3209	3344	3592	3560	3552	**17257**
7	1.88	5333	5533	5824	5777	6025	**28492**	4977	5148	5268	5460	5643	**26496**
8	2.57	4027	4211	4203	4342	4406	**21189**	3710	3738	3970	3931	4052	**19401**
9	3.46	3275	3274	3504	3456	3449	**16958**	3102	2991	3269	3230	3275	**15867**
10	4.69	2052	2045	2096	2048	2154	**10395**	1963	1906	1989	1948	2072	**9878**
11	6.20	550	616	685	641	719	**3211**	626	604	604	636	681	**3151**
12	8.37	775	790	856	854	952	**4227**	674	739	666	736	793	**3608**

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	0.974	0.966	0.947	0.946	0.941	**0.955**	Pass	0.0144	0.0179	Pass
2	0.47	0.964	0.979	0.974	0.973	0.963	**0.971**	Pass	0.0067	0.0083	Pass
3	0.62	1.007	1.024	1.003	0.994	0.975	**1.001**	Pass	0.0177	0.0220	Pass
4	0.84	0.952	0.917	0.916	0.911	0.921	**0.923**	Pass	0.0167	0.0207	Pass
5	1.14	1.093	1.066	1.078	1.019	1.046	**1.060**	Pass	0.0289	0.0358	Pass
6	1.44	0.888	0.917	0.926	0.920	0.852	**0.901**	Pass	0.0309	0.0384	Pass
7	1.88	0.933	0.930	0.905	0.945	0.937	**0.930**	Pass	0.0153	0.0189	Pass
8	2.57	0.921	0.888	0.945	0.905	0.920	**0.916**	Pass	0.0211	0.0261	Pass
9	3.46	0.947	0.914	0.933	0.935	0.950	**0.936**	Pass	0.0143	0.0178	Pass
10	4.69	0.957	0.932	0.949	0.951	0.962	**0.950**	Pass	0.0113	0.0140	Pass
11	6.20	1.138	0.981	0.882	0.992	0.947	**0.988**	Pass	0.0943	0.1171	Pass
12	8.37	0.870	0.935	0.778	0.862	0.833	**0.856**	Pass	0.0573	0.0712	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: CA-Q
Test no.: 204224
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 0.097 m³/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	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 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	25994	27675	28775	29229	29113	**140786**	12578	14254	14764	15223	15184	**72003**
2	0.47	22486	23845	24682	24813	25116	**120942**	8806	9859	10306	10441	10544	**49956**
3	0.62	13478	14444	15090	15147	15165	**73324**	4421	4798	5084	5299	5151	**24753**
4	0.84	14942	16162	16510	16795	16917	**81326**	3162	3558	3657	3702	3744	**17823**
5	1.14	4276	4203	3927	3773	3736	**19915**	665	586	641	573	572	**3037**
6	1.44	4500	4192	3792	3652	3644	**19780**	391	366	353	306	304	**1720**
7	1.88	6583	6362	5900	5698	5683	**30226**	350	268	239	269	250	**1376**
8	2.57	4801	4625	4375	4181	4092	**22074**	75	79	71	74	64	**363**
9	3.46	3627	3591	3477	3281	3264	**17240**	12	21	15	13	18	**79**
10	4.69	2107	2181	2217	2070	2066	**10641**	5	3	1	0	1	**10**
11	6.20	602	667	691	659	649	**3268**	0	0	0	0	0	**0**
12	8.37	725	791	771	834	783	**3904**	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	Observed penetration (five measurements)						
		P_{o1}	P_{o2}	P_{o3}	P_{o4}	P_{o5}	**P_o**	δ_o
1	0.35	0.484	0.515	0.513	0.521	0.522	**0.511**	0.016
2	0.47	0.392	0.413	0.418	0.421	0.420	**0.413**	0.012
3	0.62	0.328	0.332	0.337	0.350	0.340	**0.337**	0.008
4	0.84	0.212	0.220	0.222	0.220	0.221	**0.219**	0.004
5	1.14	0.156	0.139	0.163	0.152	0.153	**0.153**	0.009
6	1.44	0.087	0.087	0.093	0.084	0.083	**0.087**	0.004
7	1.88	0.053	0.042	0.041	0.047	0.044	**0.045**	0.005
8	2.57	0.016	0.017	0.016	0.018	0.016	**0.016**	0.001
9	3.46	0.003	0.006	0.004	0.004	0.006	**0.005**	0.001
10	4.69	0.002	0.001	0.000	0.000	0.000	**0.001**	0.001
11	6.20	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000
12	8.37	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000

OPC Bin, i	$\bar{d}_i$ µm	Penetration data reduction			Uncertainty limits			Efficiency
		P	δ	e	Static	Dynamic	Pass/Fail	**%**
1	0.35	0.535	0.018	0.023	0.05	0.037	Pass	**46.5**
2	0.47	0.425	0.013	0.016	0.05	0.030	Pass	**57.5**
3	0.62	0.337	0.010	0.013	0.05	0.024	Pass	**66.3**
4	0.84	0.237	0.006	0.008	0.05	0.017	Pass	**76.3**
5	1.14	0.144	0.009	0.011	0.05	0.010	Pass	**85.6**
6	1.44	0.096	0.005	0.007	0.05	0.007	Pass	**90.4**
7	1.88	0.049	0.005	0.007	0.05	0.003	Pass	**95.1**
8	2.57	0.018	0.001	0.001	0.05	0.001	Pass	**98.2**
9	3.46	0.005	0.001	0.001	0.05	0.001	Pass	**99.5**
10	4.69	0.001	0.001	0.001	0.05	0.000	Pass	**99.9**
11	6.20	0.000	0.000	0.000	0.05	0.000	Pass	**100.0**
12	8.37	0.000	0.000	0.000	0.05	0.000	Pass	**100.0**

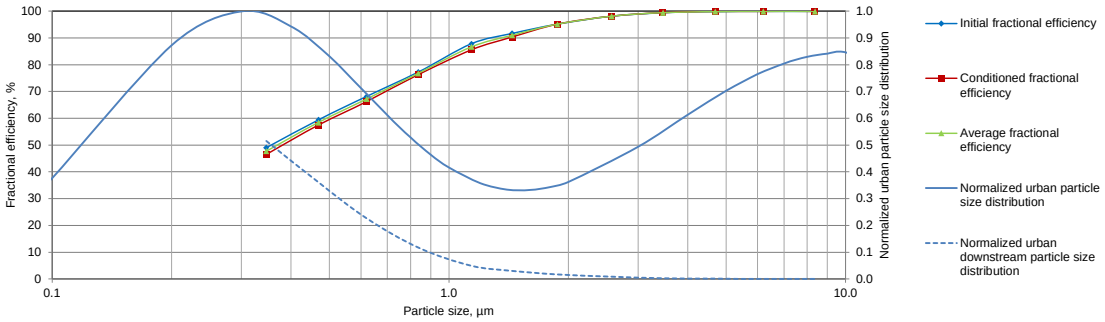
Symbols and units

$\bar{d}_i$	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

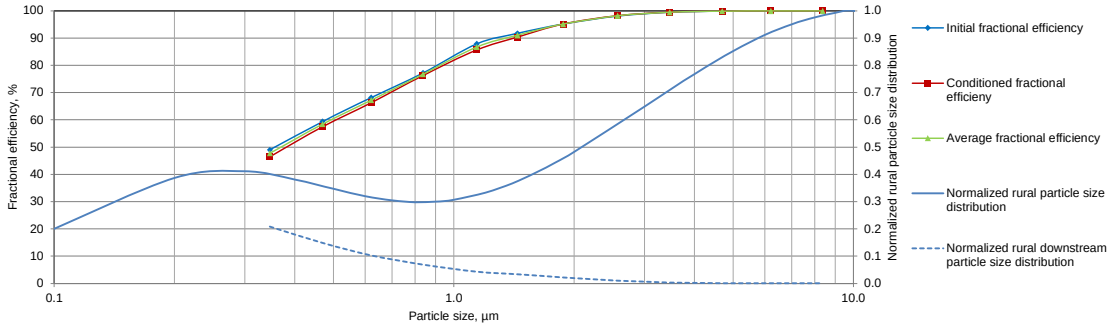
Normalized downstream particle size distribution and measured efficiencies
EN ISO 16890-1,2,4:2016

Air filter: CA-Q
Test no.: 204224
Test aerosols: DEHS (0.3 - 1 µm) and KCl (1 - 10 µm)
Air flow rate: 0.097 m³/s

ePM_1 and $ePM_{2.5}$



ePM_{10}



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 - 0.40	0.35	0.28768	0.22627	0.065095	0.031898	0.030267	0.031082	0.094121	0.027077	0.012929	49	46	48
0.40 - 0.55	0.47	0.31845	0.19891	0.063343	0.037638	0.036415	0.037027	0.083946	0.026733	0.015627	59	57	58
0.55 - 0.70	0.62	0.24116	0.15837	0.038193	0.026040	0.025319	0.025679	0.074324	0.017924	0.012051	68	66	67
0.70 - 1.00	0.84	0.35667	0.11522	0.041097	0.031732	0.031349	0.031540	0.070137	0.025016	0.019199	77	76	77
1.00 - 1.30	1.14	0.26236	0.08503	0.022309	0.019602	0.019098	0.019350	0.076281	0.020013	0.017359	88	86	87
1.30 - 1.60	1.44	0.20764	0.07618	0.015817	0.014502	0.014291	0.014397	0.088326	0.018340	0.016693	92	90	91
1.60 - 2.20	1.88	0.31845	0.08022	0.025546	0.024299	0.024299	0.024299	0.108042	0.034406	0.032727	95	95	95
2.20 - 3.00	2.57	0.31015	0.09984	0.030966	0.030378	0.030409	0.030394	0.137262	0.042573	0.041786	98	98	98
3.00 - 4.00	3.46	0.28768	0.12688	0.036500	0.036300	0.036321	0.036310	0.167084	0.048067	0.047817	99	100	99
4.00 - 5.50	4.69	0.31845	0.15556	0.049537	0.049473	0.049488	0.049481	0.195424	0.062233	0.062162	100	100	100
5.50 - 7.00	6.20	0.24116	0.17757	0.042823	0.042778	0.042823	0.042800	0.216707	0.052261	0.052234	100	100	100
7.00 - 10.0	8.37	0.35667	0.19157	0.068329	0.068262	0.068329	0.068296	0.231428	0.082545	0.082505	100	100	100

Particulate matter efficiencies		
$ePM_{1,\ ini}$	$ePM_{1,\ min}$	ePM_1
61 %	59 %	60 % **ISO ePM_1 60 %**
$ePM_{2.5,\ ini}$	$ePM_{2.5,\ min}$	$ePM_{2.5}$
71 %	70 %	71 % **ISO $ePM_{2.5}$ 70 %**
$ePM_{10,\ ini}$	$ePM_{10,\ min}$	ePM_{10}
91 %	90 %	90 % **ISO ePM_{10} 90 %**

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	23.7.2020	X
	Furness C012	1211165	23.7.2020	X
	MicaFlex-PD	32760-068	23.7.2020	X
Barometer	Vaisala PTB330	F4340001	23.7.2020	X
Hygrometer	Vaisala HMT333	D3940024	2.12.2019	X
Temperature meter	Agilent 34970A	MY44034623	21.7.2020	X
Balance	Precisa XB10200D-IP65	5300037	31.1.2020	X
	DFWATEX2GD-1	93411584	4.11.2019	X
Particle counter	TSI 3330	3330152501	20.5.2020	X
	TSI 3330	3330160801	20.5.2020	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	31.10.2019	-
Orifice plate	ϕ 216 mm / (610 x 610) mm	-	8.9.1999	X
	ϕ 272 mm / (610 x 610) mm	-	25.5.1999	-
	ϕ 90 mm / (610 x 610) mm	-	17.3.2005	-