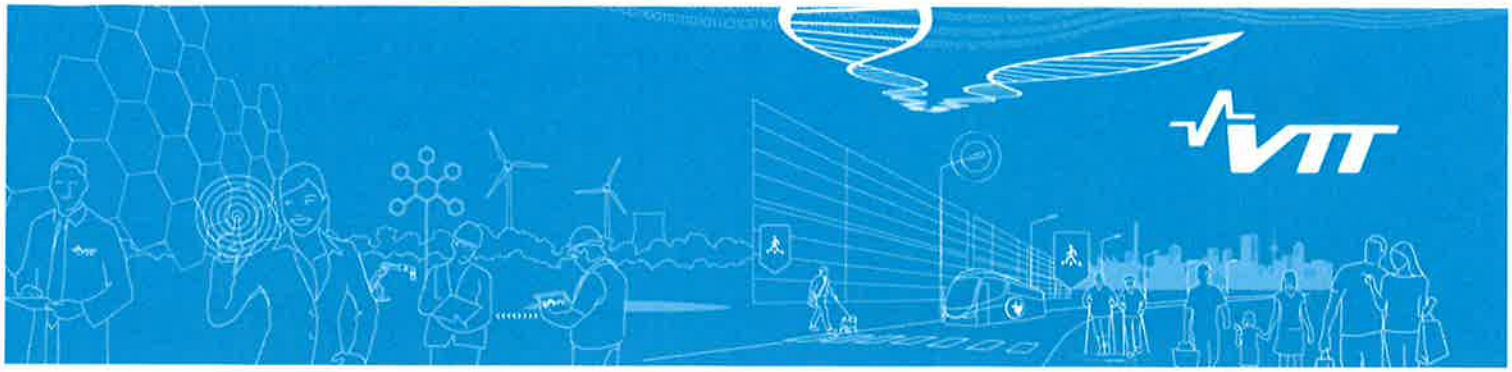

CUSTOMER REPORT

VTT-CR-02254-18 | 8.5.2018

Measurements of Air Cleaners

Authors: Inga Mattila

Confidentiality: Confidential

Report's title

Measurements of Air Cleaners

Asiakkaan nimi, yhteyshenkilö ja yhteystiedot	**Order reference**
Euromate BV Ard van Bergeijk Minervum 7324 4817 ZD BREDA THE NEDERLAND	VTT-CRM-157524-18
Project name	**Project number/Short name**
Measurements of Air Cleaners	119006

Summary

The purpose of the commission was to determine the air flow rate, fractional filtration efficiency and clean air delivery rate (CADR) in particle filtration, clean air delivery rate (CADR) in gas filtration and ozone generation of the air cleaners:

1. VisionAir single, H13, carbon filter 1
2. VisionAir double, H13, carbon filter 1.

The air flow rate was measured with venturi tube and nozzle with a flow through method. The fractional filtration efficiency was measured with a flow through method with DEHS (di-ethyl-hexyl-sebacate) test aerosol. The measurement system followed the principles of air filter test standard EN ISO 16890-2:2016. The fractional filtration efficiency was determined by measuring particle concentrations alternately from upstream and downstream of the air cleaner. The clean air delivery rate was calculated as the multiply of the air flow and the filtration efficiency of the air cleaner. The clean air delivery rate (CADR) in gas filtration was measured with so-called decay method using toluene as a test gas. The concentration of the test gas in a test room was approximately 1 ppm. The ozone generation was measured with flow-through method.

Tampere 8.5.2018

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Distribution (customer and VTT)

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1. Description and objectives

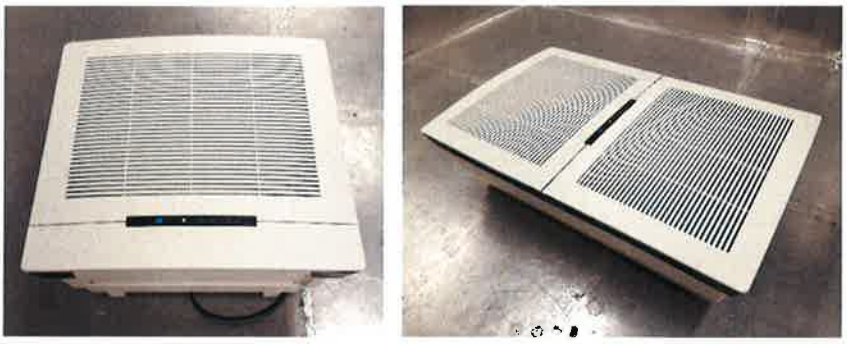
Purpose of the assignment was to determine the air flow rate, fractional filtration efficiency, clean air delivery rate (CADR) in particle filtration and ozone generation with flow-through method and clean air delivery rate (CADR) in gas filtration with so-called decay method. Measurements were made for the air cleaners (Picture 1) supplied by the customer on March 2018:

1. VisionAir single, H13, carbon filter 1
2. VisionAir double, H13, carbon filter 1.

More details of the air cleaners is in the Table 1.

Table 1. Description of filters.

Report	Description Euromate	P/N Euromate
Carbon filter 1	Final Filter OF1, 411x317x24mm	3020315200
H13	Filter HM Visionair Blue Line VA-MK2	3020313200



Picture 1. Air cleaners VisionAir Single and VisionAir Double.

2. Methods / realisation

The measurements were made in VTT's air filtration laboratory from 13 to 24 March 2018.

2.1 Air flow rate, filtration efficiency and clean air delivery rate (CADR) in particle filtration

The air flow rate and fractional filtration efficiency of the air cleaner was measured with a method the principle of which is illustrated in Figure 2. The test system follows the principles of air filter test standard EN ISO 16890-2:2016. The air cleaner was installed between two sealed chambers in such a way that inlet and outlet of the device were connected in different chambers. The pressure drop over the air cleaner was adjusted to zero by using extra fans. In this way the conditions were similar compared to operating in open room space.

Air flow rates were measured of with a Venturi tube (103 mm) or ISA168 nozzle fulfilling the requirements of ISO 5167:2003. Pressure loss was measured with a mikor TT470S ser 7961 micromanometer.

Fractional filtration efficiency was determined using liquid DEHS (di-ethyl-hexyl-sebacate) particles generated with a pneumatic aerosol nebulizer. The test aerosol was mixed into HEPA filtered supply air. The fractional filtration efficiency was determined by measuring

particle concentrations alternately from upstream and downstream of the air cleaner. The particle size distributions were determined with an optical particle size analyzer PMS LAS-X2 and in the size range of 0.1 - 2 µm.

Fractional filtration efficiency was calculated using formula (1).

$$E(d_p) = 100 \cdot \left(1 - \frac{C_2(d_p)}{C_1(d_p)}\right), \quad (1)$$

where $C_1(d_p)$ is the particle concentration of a size class upstream of the air cleaner
$C_2(d_p)$ is the same concentration downstream of the air cleaner.

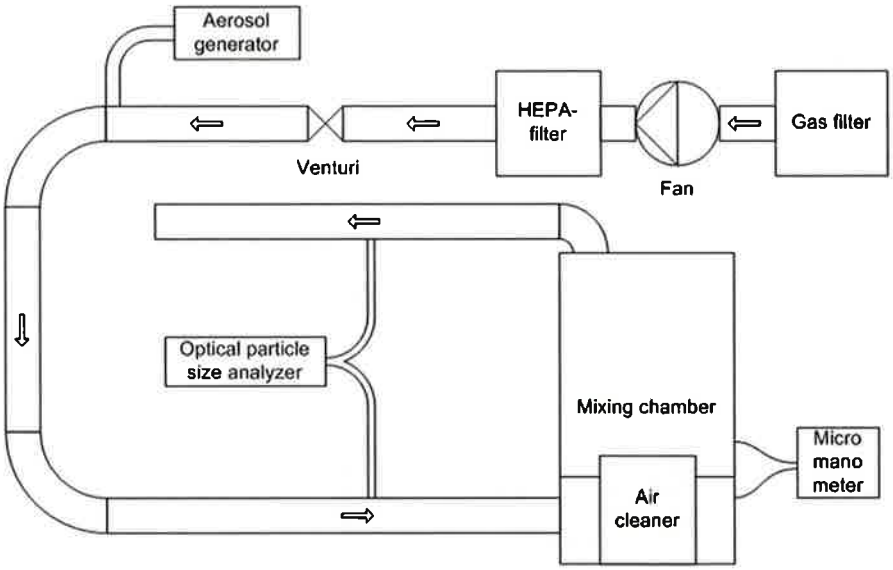


Figure 1. Principle of measurement of fractional filtration efficiency.

The clean air delivery rate (CADR) was calculated by multiplying the fractional filtration efficiency with the air flow rate for each fan speed.

2.2 Clean air delivery rate (CADR) in gas filtration with decay method

The clean air delivery rate of the air cleaner in gas filtration was measured in the test room (33.4 m^3) with the so-called decay method using toluene as a test gas. The principles of the standard ANSI/AHAM AC-1-2015 was utilized in a test system. The concentration of the test room was raised by mixing the test gas (toluene) into HEPA and gas filtered supply air. Test gas was generated with constant power by bubbling compressed air through the bottle filled with toluene. When the test room reached the balance concentration, approximately 1 ppm, the ventilation of the room was stopped and the room was isolated tightly. Mixing fan were used in a test room during the measurement. The air cleaner was started in a test room and the gas concentration in the test room was measured on a ppbRAE 3000 VOC gas analyser (a photoionization detector PID), until the concentration had fallen near zero.

The clean air delivery rate (CADR) in gas filtration was calculated from the test gas concentrations and the volume of the test room using formula (2).

$$\boldsymbol{CADR = V \cdot \frac{1}{t} \cdot ln \frac{C_0}{C}} \quad (2)$$

where **V** is the volume of the test room [m^3]

t is the measurement time [s]

$\mathbf{C_0}$ is the concentration of the test gas in the beginning of the test [ppb]

C is the concentration of the test gas in the test room in the moment t [s].

Natural rate of decay in the test room was reduced from the clean air delivery rate.

The effective air flow rate of the air cleaner in gas filtration was calculated by comparing the clean air delivery rate to the air flow of the air cleaner.

2.3 Ozone generation

For measurement of ozone generation, the air cleaner was installed between two sealed chambers in such a way that inlet and outlet of the device were connected in different chambers. The pressure drop over the air cleaner was adjusted to zero by using extra fans. In this way the conditions were similar compared to operating in open room space. The supply air was purified with HEPA filters.

Ozone concentration was measured upstream and downstream of the air cleaner. The ozone concentration in upstream air was subtracted from the concentration of downstream air. Measurement was made with fan speed set to 1 (lowest setting). Ozone concentration was measured with a Teledyne T400 ozone analyser. The measurement setup was located in VTT's air filtration laboratory in which the concentration of ozone in air was maximum 14 ppb.

3. Results

The results apply to the tested air cleaners only.

3.1 Air flow rate

Air flow rates are presented in the Table 2.

Table 2. Air flow rates of VisionAir single and double.

Air cleaner	Air flow [m^3/h] Speed					
	1	2	3	4	6	8
VisionAir single, H13, carbon filter 1	62	91	162	267	383	465
VisionAir double, H13, carbon filter 1	117	170	309	528	802	982

3.2 Ozone generation

Ozone generation was measured with the smallest fan speed 1 (Table 5).

Table 3. Ozone generation of the air cleaners.

Air cleaner	OZONE GENERATION [ppb]	[ppm]
VisionAir single	0	0
VisionAir double	0	0

3.3 Fractional filtration efficiency and clean air delivery rate (CADR) in particle filtration - VisionAir single

The fractional filtration efficiency and the clean air delivery rate (CADR) in particle filtration by particle size classes to air cleaner VisionAir single are presented in Tables 6 to 9.

Table 4. Fractional filtration efficiency of VisionAir single, H13, carbon filter 1.

VisionAir single, H13, carbon filter 1	**Fractional filtration efficiency [%]**					
	Fan speed					
dp [µm]	**1**	**2**	**3**	**4**	**6**	**8**
0.09	99.96	99.87	99.80	99.50	99.07	98.32
0.10	99.93	99.98	99.87	99.48	99.24	98.79
0.11	99.97	99.91	99.84	99.54	99.41	98.93
0.12	99.96	100.00	99.88	99.58	99.42	99.42
0.14	99.94	99.91	99.88	99.63	99.43	99.17
0.15	100.00	99.96	99.92	99.72	99.57	99.38
0.16	99.98	100.00	99.91	99.87	99.46	99.43
0.18	99.95	99.92	99.92	99.80	99.72	99.68
0.20	99.99	99.96	99.96	99.92	99.80	99.73
0.22	99.97	99.97	99.92	99.92	99.85	99.68
0.24	99.99	99.95	99.95	99.93	99.90	99.82
0.26	99.99	100.00	99.97	99.90	99.94	99.84
0.29	99.98	99.95	99.97	99.97	99.98	99.96
0.31	99.98	99.97	99.96	99.97	99.94	99.93
0.34	99.97	100.00	99.97	99.97	99.99	99.93
0.38	99.98	100.00	99.98	99.96	99.94	99.95
0.41	99.99	99.97	99.99	100.00	100.00	100.00
0.45	100.00	99.97	100.00	99.94	100.00	99.92
0.50	100.00	99.97	99.97	100.00	100.00	100.00
0.54	99.97	100.00	100.00	99.96	100.00	100.00
0.60	100.00	100.00	100.00	100.00	100.00	100.00
0.65	100.00	99.92	100.00	100.00	100.00	100.00
0.72	100.00	100.00	100.00	99.93	99.91	100.00
0.79	100.00	100.00	100.00	100.00	99.91	100.00
0.86	100.00	100.00	100.00	100.00	99.90	99.85
0.95	100.00	99.95	100.00	100.00	100.00	100.00
1.04	100.00	100.00	99.87	100.00	100.00	100.00
1.14	99.89	100.00	100.00	100.00	100.00	100.00
1.25	100.00	100.00	100.00	99.63	100.00	100.00
1.37	100.00	100.00	100.00	100.00	100.00	100.00
1.50	100.00	100.00	100.00	100.00	100.00	100.00
1.65	100.00	100.00	100.00	100.00	100.00	100.00
1.81	100.00	100.00	100.00	100.00	100.00	100.00
1.98	100.00	100.00	100.00	100.00	100.00	100.00
2.17	100.00	100.00	100.00	100.00	100.00	100.00

Table 5. Clean air delivery rate in particle filtration, VisionAir single, H13, carbon filter 1.

VisionAir single, H13, carbon filter 1	Clean air delivery rate [m^3/h]					
	Fan speed					
dp [µm]	1	2	3	4	6	8
0.09	62	91	162	266	379	457
0.10	62	91	162	266	380	459
0.11	62	91	162	266	380	460
0.12	62	91	162	266	380	462
0.14	62	91	162	266	381	461
0.15	62	91	162	267	381	462
0.16	62	91	162	267	381	462
0.18	62	91	162	267	382	463
0.20	62	91	162	267	382	464
0.22	62	91	162	267	382	463
0.24	62	91	162	267	382	464
0.26	62	91	162	267	382	464
0.29	62	91	162	267	383	465
0.31	62	91	162	267	382	464
0.34	62	91	162	267	383	464
0.38	62	91	162	267	382	465
0.41	62	91	162	267	383	465
0.45	62	91	162	267	383	464
0.50	62	91	162	267	383	465
0.54	62	91	162	267	383	465
0.60	62	91	162	267	383	465
0.65	62	91	162	267	383	465
0.72	62	91	162	267	382	465
0.79	62	91	162	267	382	465
0.86	62	91	162	267	382	464
0.95	62	91	162	267	383	465
1.04	62	91	162	267	383	465
1.14	62	91	162	267	383	465
1.25	62	91	162	266	383	465
1.37	62	91	162	267	383	465
1.50	62	91	162	267	383	465
1.65	62	91	162	267	383	465
1.81	62	91	162	267	383	465
1.98	62	91	162	267	383	465
2.17	62	91	162	267	383	465

3.4 Fractional filtration efficiency and clean air delivery rate (CADR) in particle filtration - VisionAir double

The fractional filtration efficiency and the clean air delivery rate (CADR) in particle filtration by particle size classes to air cleaner VisionAir double are presented in Tables 10 to 12.

Table 6. Fractional filtration efficiency of VisionAir double, H13, carbon filter 1.

VisionAir double, H13, carbon filter 1	**Fractional filtration efficiency [%]**					
	Fan speed					
dp [µm]	**1**	**2**	**3**	**4**	**6**	**8**
0.09	99.95	99.86	99.88	99.24	98.35	98.07
0.10	99.92	99.88	99.86	99.43	98.69	97.59
0.11	99.91	99.94	99.91	99.25	99.08	98.60
0.12	99.94	99.94	99.90	99.47	99.14	98.70
0.14	99.96	99.96	99.95	99.70	99.50	98.80
0.15	99.98	99.96	99.95	99.67	99.58	99.39
0.16	99.95	99.98	99.94	99.72	99.56	99.19
0.18	99.95	99.95	99.97	99.84	99.76	99.35
0.20	99.99	99.97	99.97	99.83	99.65	99.53
0.22	99.96	99.96	99.96	99.89	99.79	99.64
0.24	99.97	99.98	99.97	99.89	99.81	99.82
0.26	99.98	99.97	99.96	99.94	99.85	99.81
0.29	99.99	99.99	99.98	99.95	99.94	99.93
0.31	99.99	99.98	99.97	99.94	100.00	99.82
0.34	99.98	99.99	99.99	99.96	99.98	99.98
0.38	99.99	99.99	99.99	99.97	99.93	99.88
0.41	99.99	100.00	99.99	99.96	99.97	99.83
0.45	100.00	100.00	100.00	100.00	100.00	100.00
0.50	100.00	99.99	99.98	99.97	99.96	100.00
0.54	99.97	100.00	100.00	100.00	100.00	100.00
0.60	100.00	99.98	100.00	100.00	100.00	100.00
0.65	100.00	100.00	99.98	100.00	100.00	100.00
0.72	100.00	100.00	100.00	100.00	100.00	100.00
0.79	99.97	100.00	100.00	100.00	100.00	100.00
0.86	100.00	100.00	100.00	100.00	100.00	100.00
0.95	99.98	100.00	100.00	100.00	100.00	100.00
1.04	100.00	100.00	100.00	100.00	100.00	100.00
1.14	99.93	99.90	100.00	100.00	100.00	100.00
1.25	100.00	100.00	100.00	100.00	100.00	100.00
1.37	100.00	100.00	100.00	100.00	100.00	100.00
1.50	99.91	100.00	100.00	100.00	100.00	100.00
1.65	100.00	100.00	100.00	100.00	100.00	100.00
1.81	100.00	100.00	100.00	100.00	100.00	100.00
1.98	100.00	100.00	100.00	100.00	100.00	100.00
2.17	100.00	100.00	100.00	100.00	100.00	100.00

Table 7. Clean air delivery rate in particle filtration, VisionAir double, H13, carbon filter 1.

VisionAir double, H13, carbon filter 1	Clean air delivery rate [m³/h]					
	Fan speed					
dp [µm]	1	2	3	4	6	8
0.09	117	170	308	524	789	963
0.10	117	170	308	525	791	958
0.11	117	170	308	524	794	968
0.12	117	170	308	525	795	969
0.14	117	170	308	526	798	970
0.15	117	170	308	526	798	976
0.16	117	170	308	526	798	974
0.18	117	170	308	527	800	975
0.20	117	170	308	527	799	977
0.22	117	170	308	527	800	978
0.24	117	170	308	527	800	980
0.26	117	170	308	527	801	980
0.29	117	170	309	527	801	981
0.31	117	170	308	527	802	980
0.34	117	170	309	527	802	982
0.38	117	170	309	527	801	981
0.41	117	170	309	527	801	980
0.45	117	170	309	528	802	982
0.50	117	170	308	527	801	982
0.54	117	170	309	528	802	982
0.60	117	170	309	528	802	982
0.65	117	170	308	528	802	982
0.72	117	170	309	528	802	982
0.79	117	170	309	528	802	982
0.86	117	170	309	528	802	982
0.95	117	170	309	528	802	982
1.04	117	170	309	528	802	982
1.14	117	170	309	528	802	982
1.25	117	170	309	528	802	982
1.37	117	170	309	528	802	982
1.50	117	170	309	528	802	982
1.65	117	170	309	528	802	982
1.81	117	170	309	528	802	982
1.98	117	170	309	528	802	982
2.17	117	170	309	528	802	982

3.5 Clean air delivery rate (CADR) in gas filtration

Clean air delivery rate (CADR) of the air cleaners in gas filtration are shown in Tables 14 to 16.

Table 8. Clean air delivery rate in gas filtration.

Air cleaner	Fan speed	Air flow rate of the air cleaner [m³/h]	GAS FILTRATION	
			Clean air delivery rate [m³/h]	Filtration efficiency [%]
VisionAir single, H13, carbon filter 1	2	91	80	87
	8	465	414	89
VisionAir double, H13, carbon filter 1	2	170	157	92
	8	982	835	85

4. Summary

Two air cleaners were measured. The fractional filtration efficiency and the clean air delivery rate (CADR) in particle filtration are shown in Tables 17 and 18 for 0.3 µm particle size.

Table 9. Fractional filtration efficiency in particle filtration.

Air cleaner	Fractional filtration efficiency [%], 0.3 µm						
	Fan speed						
	1	2	3	4	6	8	TURBO
VisionAir single, H13, carbon filter 1	99.98	99.95	99.97	99.97	99.98	99.96	-
VisionAir double, H13, carbon filter 1	99.99	99.99	99.98	99.95	99.94	99.93	-

Table 10. Clean air delivery rate in particle filtration.

Air cleaner	Clean air delivery rate [m^3/h], 0.3 µm					
	Fan speed					
	1	2	3	4	6	8
VisionAir single, H13, carbon filter 1	62	91	162	267	383	465
VisionAir double, H13, carbon filter 1	117	170	309	527	801	981

According to the measurements the air cleaners did not generate ozone.

The clean air delivery rate (CADR) in gas filtration is shown in Table 18.

Table 11. Clean air delivery rate in gas filtration.

Air cleaner	Clean air delivery rate [m^3/h], gas	
	Fan speed	
	2	8
VisionAir single, H13, carbon filter 1	80	414
VisionAir double, H13, carbon filter 1	157	835