



Measurements of Air Cleaner Pro

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Summary <p>The purpose of the commission was to determine the clean air delivery rate (CADR) in particle and gas filtration, air flow rate and ozone generation of the air cleaner Pro. The clean air delivery rate (CADR) was measured with so-called decay method, and air flow rate and ozone generation with a flow through method.</p> <p>The clean air delivery rate (CADR) of the air cleaner in particle and gas filtration, air flow rate and ozone generation are presented in Table 1.</p> <p><i>Table 1. Summary of the results.</i></p> <table border="1"> <thead> <tr> <th>Air Cleaner</th> <th>Fan speed</th> <th>Ozone generation</th> <th>Air flow rate</th> <th>Clean air delivery rate in particle filtration (particle size 0.4 µm)</th> <th>Clean air delivery rate in gas filtration</th> </tr> <tr> <th></th> <th></th> <th>[ppb]</th> <th>[m³/h]</th> <th>[m³/h]</th> <th>[m³/h]</th> </tr> </thead> <tbody> <tr> <td rowspan="6">Pro</td> <td>1</td> <td>0</td> <td>85</td> <td>> 84</td> <td>> 84</td> </tr> <tr> <td>2</td> <td>-</td> <td>105</td> <td>> 104</td> <td>> 104</td> </tr> <tr> <td>3</td> <td>-</td> <td>155</td> <td>> 154</td> <td>> 154</td> </tr> <tr> <td>4</td> <td>-</td> <td>205</td> <td>> 204</td> <td>> 204</td> </tr> <tr> <td>5</td> <td>-</td> <td>255</td> <td>> 254</td> <td>> 254</td> </tr> <tr> <td>6</td> <td>-</td> <td>332</td> <td>> 331</td> <td>> 331</td> </tr> </tbody> </table>						Air Cleaner	Fan speed	Ozone generation	Air flow rate	Clean air delivery rate in particle filtration (particle size 0.4 µm)	Clean air delivery rate in gas filtration			[ppb]	[m³/h]	[m³/h]	[m³/h]	Pro	1	0	85	> 84	> 84	2	-	105	> 104	> 104	3	-	155	> 154	> 154	4	-	205	> 204	> 204	5	-	255	> 254	> 254	6	-	332	> 331	> 331
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1. Description and objectives

The purpose of the assignment was to determine the clean air delivery rate (CADR) in particle and gas filtration, the air flow rates and ozone generation of the air cleaner Pro (Picture 1). The commission was performed to the air cleaner delivered to VTT Technical Research Centre of Finland by the customer on 27.1.2020.



Picture 1. Air cleaner Pro.

2. Methods / realisation

The measurements were made in VTT's air filtration laboratory between 27th and 31st of January 2020.

2.1 Air flow rate

The air flow rate of the air cleaner was measured with the flow through method. The test system followed 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 with a Venturi tube (103 mm) fulfilling the requirements of ISO 5167:2003. Pressure loss was measured with a Mikor TT470S ser 7962 micromanometer.

2.2 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.

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. The measurement setup was located in VTT's air filtration laboratory in which the concentration of ozone in air was approximately 5,5 ppb. Ozone concentration was measured with a Teledyne T400 ozone analyser. Measurement was made with the lowest fan speed.

2.3 Clean air delivery rate (CADR) in particle filtration

Clean air delivery of the air cleaner in particle filtration was measured in the test room (30 m³) with the so-called decay method. The principles of the air cleaner test standard ANSI/AHAM AC-1-2015 was utilized in a test system.

The decay of the particles was determined using liquid DEHS (di-ethyl-hexyl-sebacate) particles generated with a pneumatic aerosol nebulizer. The test aerosol was mixed into gas and HEPA filtered supply air. When the test room reached the desired concentration 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 particle size distributions were determined with an optical particle size analyzer PMS LAS-X2 and in the size range of 0.1 - 2.5 µm.

The clean air delivery rate (CADR) in gas filtration was calculated using formula (1).

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

where **V** is the volume of the test room (m³)

t is the measurement time (h)

C₀ is the concentration of the test agent (kpl/cm³) in the beginning of the test

C is the concentration of the test agent (kpl/cm³) in the test room in the moment **t**.

Natural rate of decay in the test room was reduced from the clean air delivery rate (0.87 m³/h).

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

2.4 Clean air delivery rate (CADR) in gas filtration

The clean air delivery rate of the air cleaner in gas filtration was measured in the test room (30 m³) with the so-called decay method. The principles of the standard ANSI/AHAM AC-1-2015 was utilized in a test system. The decay of the gas was determined using toluene as a test gas. 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 decay of the gas concentration in the test room was measured on a ppbRAE 3000 VOC gas analyser (a photoionization detector PID).

The clean air delivery rate (CADR) was calculated using the formula (2).

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

where **V** is the volume of the test room (m³)

t is the measurement time (h)

C₀ is the concentration of the test agent (ppb) in the beginning of the test

C is the concentration of the test agent (ppb) in the test room in the moment **t**.

Natural rate of decay in the test room (0.45 m³/h) was reduced from the clean air delivery rate.

3. Results

The results apply to the tested air cleaner only.

3.1 Air flow rate

Air flow rates with different fan speeds are presented in the Table 2.

Table 2. Air flow rates, the air cleaner Pro.

Fan speed	Adjustment value	Air flow rate	
		[m ³ /h]	[l/s]
1	2.55	85	24
2	3.44	105	29
3	5.09	155	43
4	6.50	205	57
5	7.88	255	71
6	10.41	332	92

3.2 Ozone generation

Ozone generation was measured with the smallest fan speed (Table 3).

Table 3. Ozone generation, the air cleaner Pro.

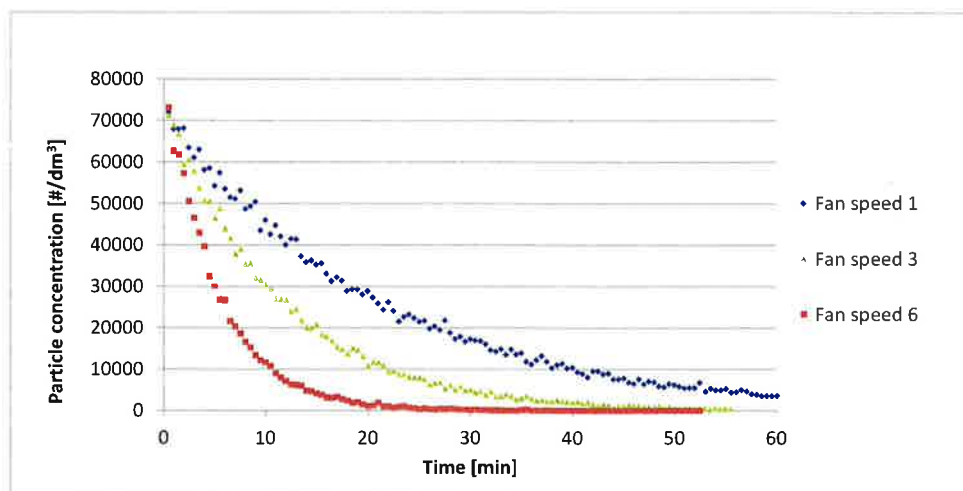
Air cleaner	OZONE GENERATION	
	[ppb]	[ppm]
Pro	0	0

3.3 Clean air delivery rate (CADR) in particle filtration

The clean air delivery rate (CADR) and filtration efficiency of the air cleaner in particle filtration is shown in Table 4. The change of the particle concentration with time with different fan speeds is shown in Picture 2.

Table 4. Clean air delivery rate and filtration efficiency in particle filtration with different particle sizes, the air cleaner Pro.

Particle size	Fan speed	Air flow rate of the air cleaner [m ³ /h]	Clean air delivery rate [m ³ /h]	Filtration efficiency [%]
0.1 µm	1	85	> 84	> 99
	2	105	> 104	> 99
	3	155	> 154	> 99
	4	205	> 204	> 99
	5	255	> 254	> 99
	6	332	> 331	> 99
0.4 µm	1	85	> 84	> 99
	2	105	> 104	> 99
	3	155	> 154	> 99
	4	205	> 204	> 99
	5	255	> 254	> 99
	6	332	> 331	> 99
1.0 µm	1	85	> 84	> 99
	2	105	> 104	> 99
	3	155	> 154	> 99
	4	205	> 204	> 99
	5	255	> 254	> 99
	6	332	> 331	> 99
2.5 µm	1	85	> 84	> 99
	2	105	> 104	> 99
	3	155	> 154	> 99
	4	205	> 204	> 99
	5	255	> 254	> 99
	6	332	> 331	> 99



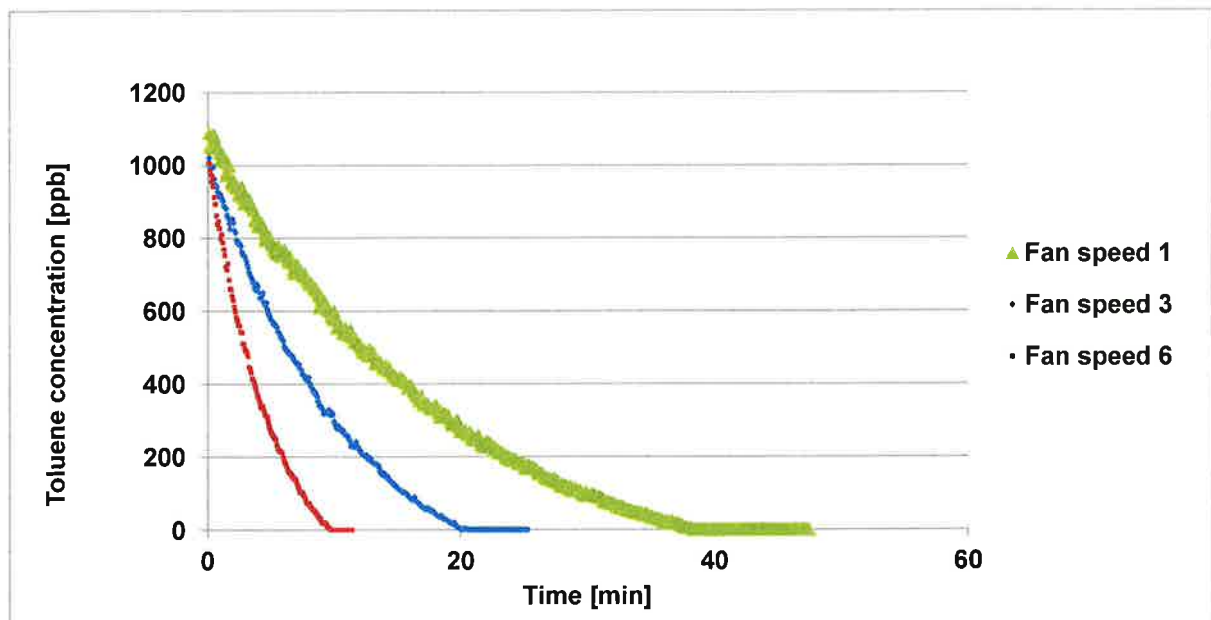
Picture 2. Example of the change of the particle concentration (particle size 0,4 µm) with time with different fan speeds (1, 3 and 6), the air cleaner Pro.

3.4 Clean air delivery rate (CADR) in gas filtration

The clean air delivery rate (CADR) of the air cleaner in gas filtration is shown in Table 5. The change of the toluene concentration in the test room with time with different fan speeds is shown in Picture 3.

Table 5. Clean air delivery rate in gas filtration, the air cleaner Pro.

Air Cleaner	Fan speed	Air flow rate of the air cleaner [m ³ /h]	GAS FILTRATION	
			Clean air delivery rate [m ³ /h]	Filtration efficiency [%]
Pro	1	85	> 84	> 99
	2	105	> 104	> 99
	3	155	> 154	> 99
	4	205	> 204	> 99
	5	255	> 254	> 99
	6	332	> 331	> 99



Picture 3. The change of the toluene concentration with time with different fan speeds (1, 3 and 6), the air cleaner Pro.

4. Summary of the results

The purpose of the commission was to determine the clean air delivery rate (CADR) in particle and gas filtration, air flow rate and ozone generation of the air cleaner Pro. The clean air delivery rate (CADR) was measured with so-called decay method, and air flow rate and ozone generation with a flow through method.

Summary of the results is presented in Table 6.

Table 6. Summary of the results.

Air Cleaner	Fan speed	Ozone generation	Air flow rate	Clean air delivery rate in particle filtration (particle size 0.4 µm)	Clean air delivery rate in gas filtration
		[ppb]	[m ³ /h]	[m ³ /h]	[m ³ /h]
Pro	1	0	85	> 84	> 84
	2	-	105	> 104	> 104
	3	-	155	> 154	> 154
	4	-	205	> 204	> 204
	5	-	255	> 254	> 254
	6	-	332	> 331	> 331

