Performance Assessment of EAGLE 5000 in Tobacco Smoke Environment.

REPORT

Reference 943/78357

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October 2006

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1. INTRODUCTION

Object of Report

The aim of this report is to present the results obtained from environmental analysis and monitoring carried out in a test chamber, in order to assess performance of the EAGLE 5000 device when dealing with tobacco smoke. This study took place on September 26, 2006 at *Ladeal Laboratories* located in Valencia (Spain).

Fig 1. Extraction Capabilities Disabled

A test chamber, equipped with a TELSTAR 2ª, model BIO-II-A extraction hood, with a capacity of 0,48 m^3 (sterile air class 10 , Rule EN 12469) was used for the assessment. The hood's extraction ability was not used during the tests. It was only used after each test was run, in order to extract stuffy air from the chamber.

Inside the chamber, the radio wave ion generator EAGLE 5000 was placed. The EAGLE 5000 features a maximum air displacement capacity of 48 m^3 per hour. It features a fan to create air flow to distribute ionized air. The device was lifted on a platform so it was placed at the central zone of the chamber.

Once the chamber was set up, four tests were executed. In each one of them, the nicotine and breathable particle rates were measured as indicators of the device's effectiveness when dealing with tobacco smoke.

Fig 2. EAGLE 5000 device

1.1. Background

Tobacco smoke is a mix of substances generated in a main current coming from cigar ignition, and in a secondary current exhaled by the smoker. Both air currents have different characteristics, since they are produced at different temperatures and follow distinct paths, but both are formed by mixes of aerosols, gases and vapours, being emitted into the environment.

Contribution from each of both currents to indoor air pollution is about 50%, except for particles, of which the exhaled current emits about 43% due to smoker's retention.

In the dilution and cooling process the smoke generated is formed by a mix of particles and VOCs. With respect to particles, sizes range from 0,02 to 2 µm with an average of 0,2 µm (Klepeis and Nazarov 2002, Chung and Dunn-Rankin, 1996; Ingebrethsen and Sears, 1989).

Particles with an aerodynamic size under 0,3 µm (MPPS-Most Penetrating Particle Size) are the most difficult to retain. This size is the best indicator to assess retaining performance..

Regarding gases and vapours, there is a huge amount of substances, which some researchers (Leaderer and Hammond, 1991) have estimated in more than 4.000 chemicals. Some of the most common ones are:

Nicotine, carbon monoxide, nitrogen dioxide, pyridine, Aldehides, nitrous acid, acroleine, benzene, toluene, nitrosamine, phenol, ammoniac, etc. Nicotine can be classified as a semi volatile compound in this mix.

In this study, we are taking the first three pollutants amongst all the others as reference indicators.

2. DESCRIPTION AND METHODOLOGY

The report is about performance assessment of EAGLE 5000 in Tobacco Smoke environments. Two lighted cigarettes were introduced into the test chamber with sampling equipment. There was no ventilation or extraction into the chamber.

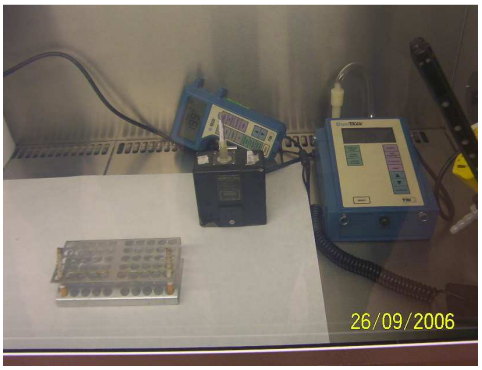


Fig 3. Monitoring equipment and suction pump.

During tests, concentration of particles up to 0,3 µm, CO_2 and CO were monitored, and temperature and humidity variations into the test chamber were recorded.
In addition, nicotine samples were taken for further analysis in the laboratory.

Smoke emanated from cigarettes releases most gas amount and about half of all particles released. From all the chemicals found in tobacco, nicotine is one of the easiest to identify, so it is used as a quality indicator.

Study scheme

Four different tests were made, using different purifying ability levels. The device's purifying ability can be set up according to the rate of electrons generated, by using the built-in tuner in the ionizer needles.
No tests were made with the device working at full capacity (100%), due to the high air renovation rate it would have generated inside the test chamber.

The test process includes the following proceedings:

TEST 1: Measurement of nicotine concentration in the chamber environment after two cigarettes have been consumed during 12 minutes with the equipment working during combustion to different capacities.

P1N1 Equipment to 25% of purifying ability.
P1N2 Equipment to 50% of purifying ability.
P1N3 Equipment to 75% of purifying ability.

TEST 2: Measurement of nicotine concentration in the chamber environment after two cigarettes have been consumed with the equipment off. After combustion, the device is turned on to a 25% of its purifying capacity and measurements are made every 5 minutes.

P2N1 After 12 minutes with equipment off.
P2N2 After 17 minutes with equipment working.
P2N3 After 22 minutes with equipment working.
P2N4 After 27 minutes with equipment working.

TEST 3: Measurement of nicotine concentration in the chamber environment after two cigarettes have been consumed with the equipment off. After combustion, the equipment is placed working to 50% of its purifying capacity and measurements are made every 5 minutes.

P3N1 After 13 minutes with equipment off.
P3N2 After 18 minutes with equipment working.
P3N3 After 23 minutes with equipment working.
P3N4 After 28 minutes with equipment working.

TEST 4: Measurement of nicotine concentration in the chamber environment after two cigarettes have been consumed with the equipment off. After combustion, the device is turned on to a 75% of its purifying capacity and measurements are made every 5 minutes.

P4N1 After 14 minutes with equipment off.
P4N2 After 19 minutes with equipment working.
P4N3 After 24 minutes with equipment working.
P4N4 After 25 minutes with equipment working.

Rates of CO_2, CO, particles under 0.3 µm, temperature and relative humidity concentrations, were monitored throughout all tests.

Test Methodology

Air suspended particles (under 0,3 µm)

The effect of particles on health depends directly upon its size, since the human body is designed to filter bigger particles and prevent them to block lungs, which are ultimately the filters preventing the smallest particles to pass into the blood flow. The tobacco smoke exhaled contains particles with an aerodynamic range smaller than 4 µm, so they can get into lungs. These smaller particles, known as respirable suspended particles (RSP), are the most important from the health point of view, so particle measurement during the tests were focused in the RSP range.

The RSP pollution rate assessment was made by monitoring weighing by laser reflection, using a TSI Dust-Trak 8520 device, put into the test chamber to record concentrations (mg/m^3) each minute.

Environmental tobacco smoke monitoring

From all substances present in tobacco, nicotine is one of the easiest to identify, therefore it is used as an indicator. Nicotine is an alkaloid ((*S*)-3-(1-Methyl-2-pyrrolidinyl)pyridine). The two possible nicotine isomers are L-nicotine, which is the active form found in tobacco, and pyridine.

Today, most cigarettes in the worldwide market contain 0,8 milligrams (mg) or more of nicotine. It is absorbed by skin, and mouth and nose mucosa or it is inhaled through lungs. Depending on how tobacco is used, nicotine can rapidly reach high rates in the brain and blood stream. As an example, cigarette smoking results in a fast nicotine distribution all over the body, reaching the brain ten seconds after having been inhaled.

Fig 4. XAD-4 adsorbents, 80/40 mg

Sampling of components from environmental tobacco smoke was made following the **NIOSH 2551** method, using XAD-4 adsorbents.

1 litre air samples were taken through the XAD-4 adsorbent tubes, using an ESCORT MSA suction pump at 1 litre/minute flow rate. The analysis technique used is gas chromatography.

CO_2 measurements

Carbon dioxide is not a deep pollutant. It is a simple asphyxiant by displacing oxygen, but it needs very high rates to have effects. When carbon dioxide levels exceed 800 to 1.000 ppm in indoor areas, most people start to feel uncomfortable, suffer headaches, tiredness and general apathy.

Carbon dioxide levels were measured using a TSI Q-Trak Plus 8554 no dispersion, infrared absorption monitor. It was put into the test chamber, and recorded CO_2 concentrations (ppm) each minute.

CO measurements

CO is a powerful chemical asphyxiant, causing reversible phenomena at low rates, but that can cause death at high rates.

Carbon monoxide levels were measured using a TSI Q-Trak Plus 8554 no dispersion, infrared absorption monitor. It was put into the test chamber, and recorded CO concentrations (ppm) each minute.

Other aspects

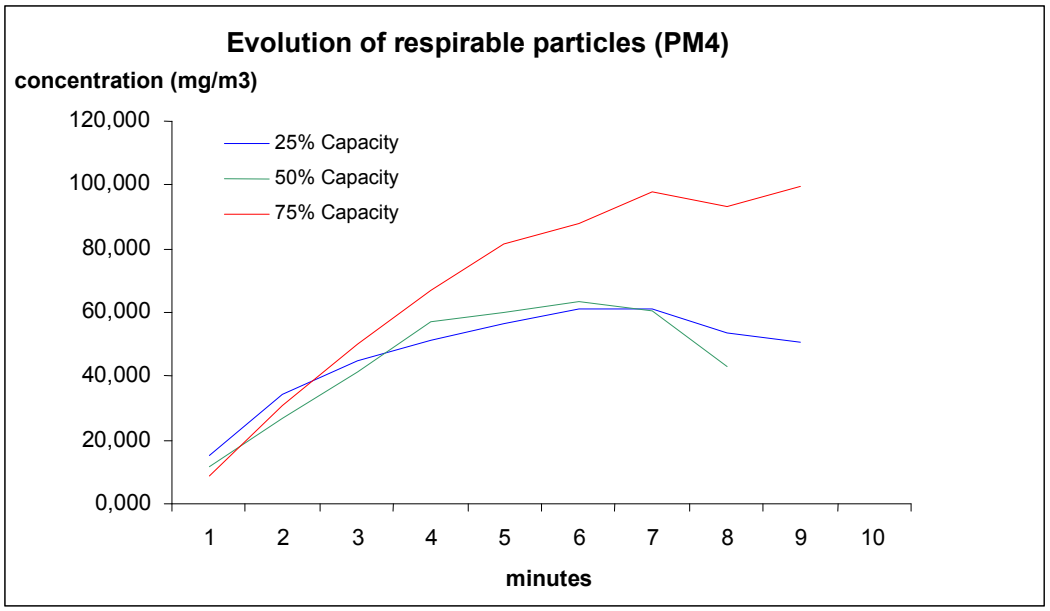
Furthermore, temperature in Celsius degrees and relative humidity percentage into the test chamber were monitored using a thermo hygrometer.

3. RESULTS

Air suspended particles (under 0,3 µm)

In **TEST 1**, the environment respirable suspended particle rate (sized to 0,3 µm) was monitored while combusting two cigarettes during 12 minutes with the equipment working during combustion to different capacities, obtaining a maximum PM_4 rate of:

TEST 1 (25% capacity) 61,113 mg/m^3 after 7´.
TEST 1 (50% capacity) 63,354 mg/m^3 after 6´.
TEST 1 (75% capacity) 99,589 mg/m^3 after 9´.



Pic. 1. Evolution of RSP with equipment working during combustion

From these maximum values, the particle concentration rate starts to lower.

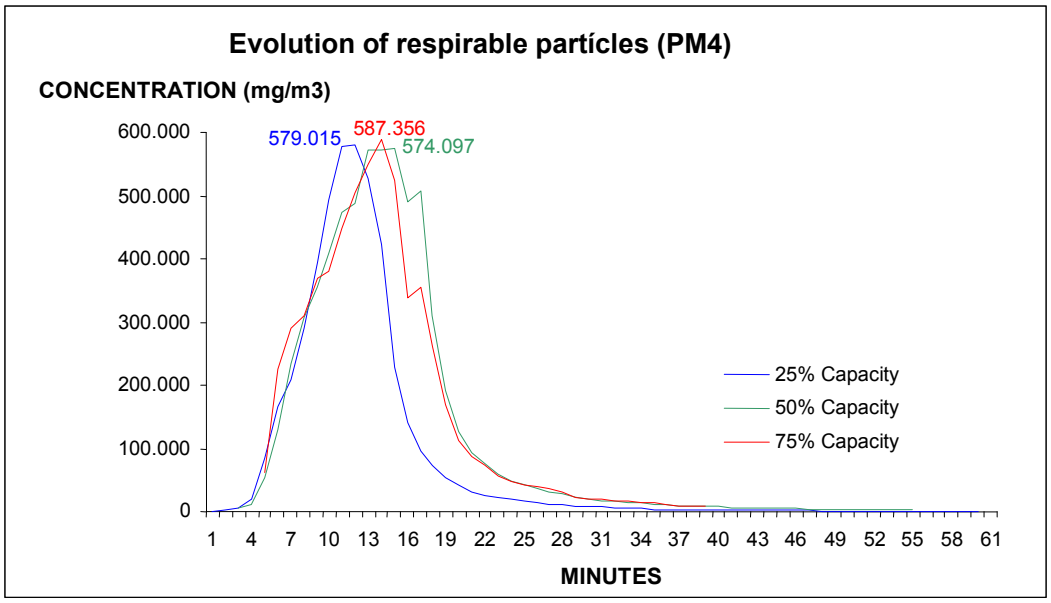
During **TESTS 2, 3 and 4**, two cigarettes were combusted with the equipment off and the test chamber extraction ability disabled. The particle rate (sized to 3 µm) was smaller than 1 mg/m^3 before cigarette combustion.

After combustion, the following maximum particle rates were reached (sized to 3 µm):

TEST 2 579,015 mg/m^3 after 12´.

TEST 3 574,097 mg/m^3 after 16´.

TEST 4 587,356 mg/m^3 after 13´.



Pic. 2. Evolution of RSP with equipment off during combustion

In that moment, the air purifier is connected, using different purifying ability levels in order to monitor the PM_4 particle concentration drop.

Results obtained after the purifier has been working for five minutes were:

TEST 2 (25% performance) 95,015 mg/m^3 after 17´.

TEST 3 (50% performance) 125,857 mg/m^3 after 21´.

TEST 4 (75% performance) 168,640 mg/m^3 after 18´.

After ten minutes:

TEST 2 (25% performance) 26,123 mg/m^3 after 22´.

TEST 3 (50% performance) 31,415 mg/m^3 after 26´.

TEST 4 (75% performance) 47,302 mg/m^3 after 23´.

After fifteen minutes:

TEST 2 (25% performance) 12,092 mg/m^3 after 27´.

TEST 3 (50% performance) 19,485 mg/m^3 after 31´.

TEST 4 (75% performance) 23,705 mg/m^3 after 28´.

Environmental tobacco smoke monitoring (Nicotine)

In **TEST 1**, the environment nicotine rate was monitored while combusting two cigarettes during 10 minutes with the equipment working during combustion to different capacities:

BIL-8051-P1N1 (25% performance) 1,0 mg/m^3 equipment on.

BIL-8051-P1N2 (50% performance) 1,3 mg/m^3 equipment on.

BIL-8051-P1N3 (75% performance) 1,2 mg/m^3 equipment on.

During **TESTS 2, 3 and 4**, two cigarettes were combusted with the equipment off and the test chamber extraction ability disabled.

Once combustion finished, the environment nicotine rate was measured, obtaining these results:

TEST 2 7,2 mg/m^3 equipment off after 12´

TEST 3 6,2 mg/m^3 equipment off after 13´

TEST 4 4,8 mg/m^3 equipment off after 14´

The air purifier was turned on, and the environment nicotine rate reduction results after 5 minutes of operation were:

TEST 2 (25% performance) <0,1 mg/m^3 equipment on after 17´

TEST 3 (50% performance) 0,1 mg/m^3 equipment on after 18´

TEST 4 (75% performance) <0,1 mg/m^3 equipment on after 19´

The environment nicotine rate reduction results after 10 minutes of operation were:

TEST 2 (25% performance) <0,1 mg/m^3 equipment on after 22´

TEST 3 (50% performance) <0,1 mg/m^3 equipment on after 23´

TEST 4 (75% performance) <0,1 mg/m^3 equipment on after 24´

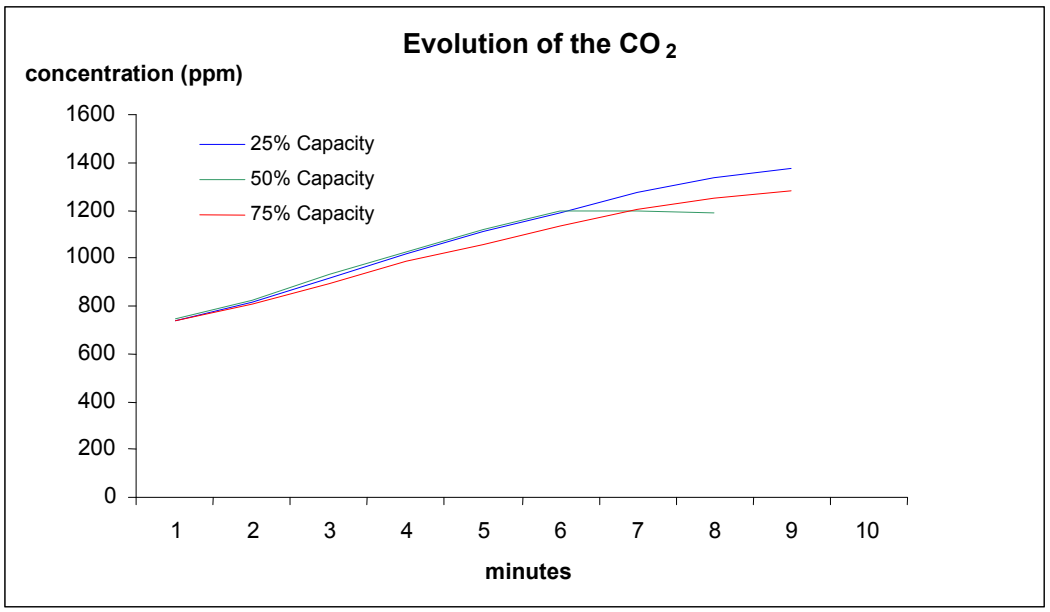
The environment nicotine rate reduction results after 15 minutes of operation were:

TEST 2 (25% performance) <0,1 mg/m^3 equipment on after 27´
TEST 3 (50% performance) <0,1 mg/m^3 equipment on after 28´
TEST 4 (75% performance) <0,1 mg/m^3 equipment on after 29´

CO^2 measurements

In **TEST 1**, the environment carbon dioxide rate was monitored while combusting two cigarettes during 10 minutes with the equipment working during combustion to different capacities, obtaining a maximum CO_2 concentration rate of:

TEST 1 (25% performance) 1.376 ppm after 9´.
TEST 1 (50% performance) 1.189 ppm after 8´.
TEST 1 (75% performance) 1.283 ppm after 9´.



Pic. 3. CO_2 rate evolution with equipment turned on during combustion.

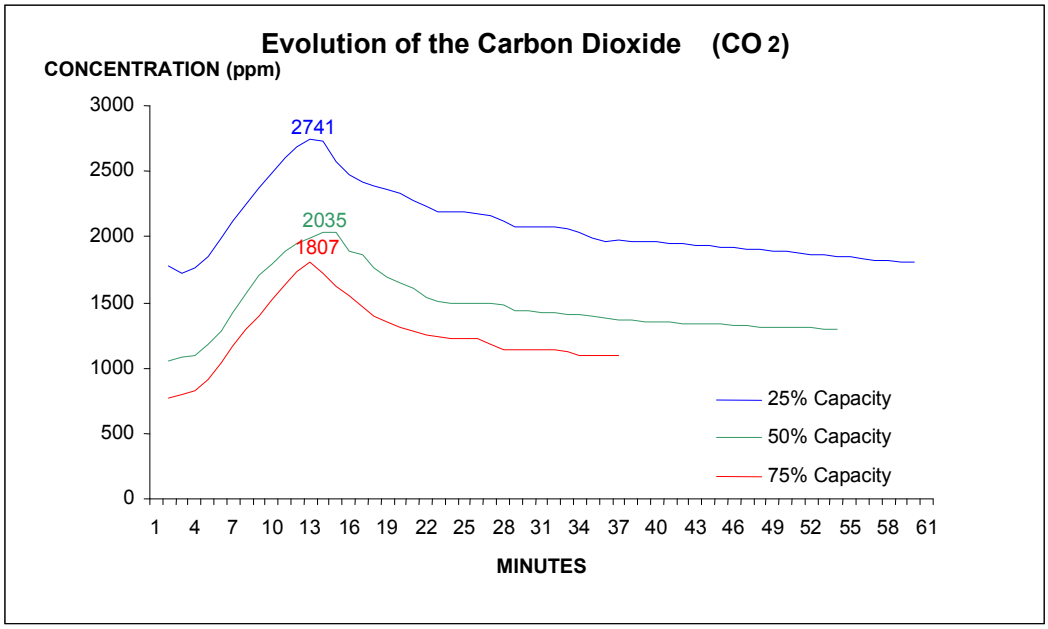
During **TESTS 2, 3 and 4**, two cigarettes were combusted with the equipment off and the test chamber extraction ability disabled. The initial CO_2 was lesser than 1.000 ppm before cigarette combustion.

Once combustion finished, the maximum CO_2 rate was measured, obtaining these results:

TEST 2 2.741 ppm after 12´.

TEST 3 2.035 ppm after 14´.

TEST 4 1.807 ppm after 12´.



Pic. 4. CO_2 rate evolution with equipment turned off during combustion

The air purifier was then turned on, and the environment CO_2 rate reduction results after 5 minutes of operation were:

TEST 2 (25% performance) 2 386 ppm after 17´.

TEST 3 (50% performance) 1 644 ppm after 19´.

TEST 4 (75% performance) 1.390 ppm after 17´.

The environment CO_2 rate reduction results after 10 minutes of operation were:

TEST 2 (25% performance) 2.188 ppm after 22´.

TEST 3 (50% performance) 1.492 ppm after 26´.

TEST 4 (75% performance) 1.233 ppm after 22´.

The environment CO_2 rate reduction results after 15 minutes of operation were:

TEST 2 (25% performance) 2.116 ppm after 27´.

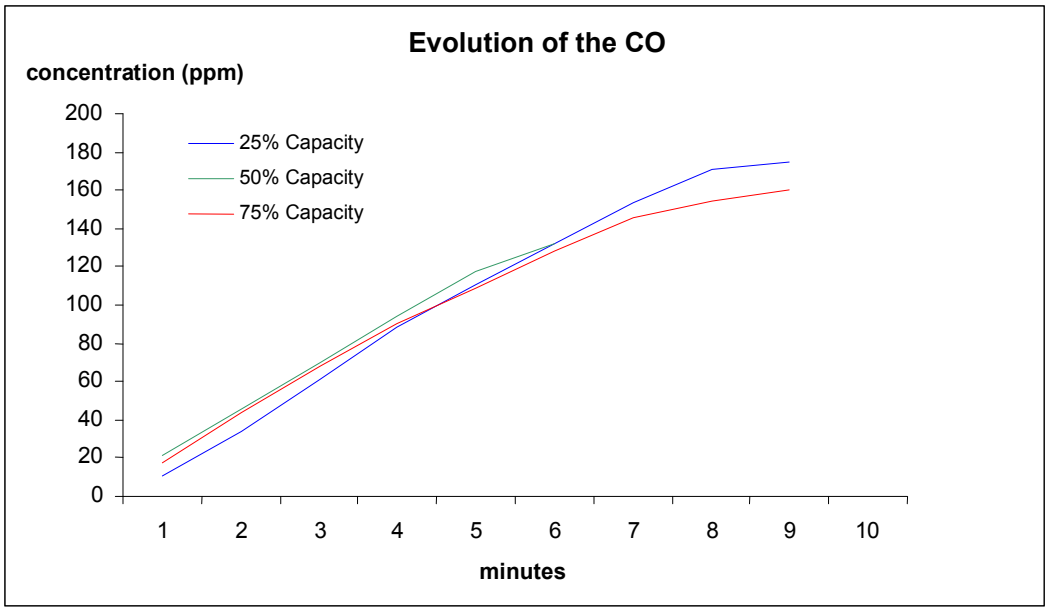
TEST 3 (50% performance) 1.431 ppm after 31´.

TEST 4 (75% performance) 1.141 ppm after 27´.

CO measurements

In **TEST 1**, the environment carbon dioxide rate was monitored while combusting two cigarettes during 10 minutes with the equipment working during combustion to different capacities, obtaining a maximum CO concentration rate of:

TEST 1 (25% performance) 175 ppm after 12´.
TEST 1 (50% performance) 121 ppm after 9´.
TEST 1 (75% performance) 160 ppm after 12´.



Gráf. 5 CO rate evolution with equipment turned on during combustion

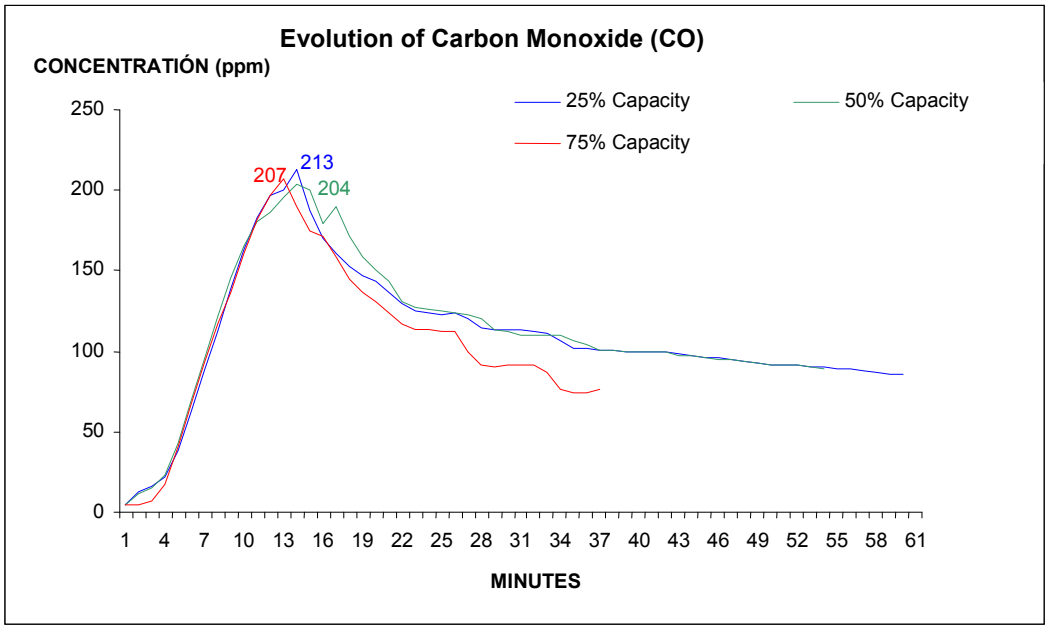
During **TESTS 2, 3 and 4**, two cigarettes were combusted with the equipment off and the test chamber extraction ability disabled. The initial CO was less than 1.000 ppm before cigarette combustion.

Once combustion finished, the maximum CO rate was measured, obtaining these results:

TEST 2 (25% performance) 213 ppm after 13´.

TEST 3 (50% performance) 204 ppm after 13´.

TEST 4 (75% performance) 207 ppm after 12´.



Gráf. 6. CO rate evolution with equipment turned off during combustion

The air purifier was then turned on, and the environment CO rate reduction results after 5 minutes of operation were:

TEST 2 (25% performance) 147 ppm after 18´.

TEST 3 (50% performance) 158 ppm after 18´.

TEST 4 (75% performance) 145 ppm after 17´.

The environment CO rate reduction results after 10 minutes of operation were:

TEST 2 (25% performance) 124 ppm after 23´.

TEST 3 (50% performance) 126 ppm after 23´.

TEST 4 (75% performance) 113 ppm after 22´.

The environment CO rate reduction results after 15 minutes of operation were:

TEST 2 (25% performance) 113 ppm a los 28´.

TEST 3 (50% performance) 114 ppm a los 28´.

TEST 4 (75% performance) 91 ppm a los 27´.

Temperature and relative humidity monitoring

In **TEST 1**, temperature and relative humidity were monitored while combusting two cigarettes during 10 minutes with the equipment working during combustion to different capacities, obtaining the following temperature results:

TEST 1 (25% performance) 26,7 ºC +1 ºC after 3´ and +2 ºC en 8´.
TEST 1 (50% performance) 27,6 ºC +1 ºC after 4´ and +2 ºC after 10´.
TEST 1 (75% performance) 27,6 ºC +1 ºC after 3´ and +2 ºC after 9´.

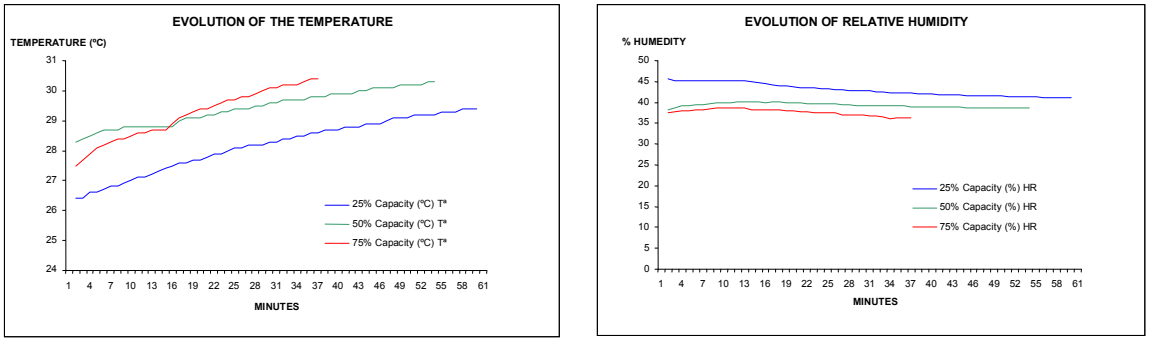
The relative humidity values obtained were:

TEST 1 (25% performance) 37,7% +10% after 4´ and -10% after 10´.
TEST 1 (50% performance) 37,1% +10% after 3´ and -10% after 12´.
TEST 1 (75% performance) 37,9% +10% after 4´ and -10% after 9´.

During **TESTS 2, 3 and 4**, two cigarettes were combusted with the equipment off and the test chamber extraction ability disabled.

Once combustion finished, temperature and relative humidity were measured, obtaining these results:

TEST 2 (25% performance) 27,2 ºC and 45% after 12´.
TEST 3 (50% performance) 29,0 ºC and 40% after 16´.
TEST 4 (75% performance) 28,7 ºC and 38% after 13´.



Pic 7. Evolution of temperature and relative humidity with equipment working during combustion

The results after 5 minutes of operation were:

TEST 2 (25% performance) 27,6 ºC and 44% after 17´.

TEST 3 (50% performance) 29,2 ºC and 40% after 21´.

TEST 4 (75% performance) 29,3 ºC and 38% after 18´.

The results after 10 minutes of operation were:

TEST 2 (25% performance) 27,9 ºC and 43% after 22´.

TEST 3 (50% performance) 29,4 ºC and 39% after 26´.

TEST 4 (75% performance) 29,7 ºC and 37% after 23´.

The results after 15 minutes of operation were:

TEST 2 (25% performance) 28,2 ºC and 43% after 27´.

TEST 3 (50% performance) 29,7 ºC and 39% after 31´.

TEST 4 (75% performance) 28,7 ºC and 37% after 28´.

4. CONCLUSIONS

Once the obtained results were analyzed, we are able to assess the efficiency of the EAGLE 5000 in tobacco smoke environments.

Pollutants generation rate

Looking at **TEST 1** results we can compare the different pollutants concentrations with the equipment working to different purifying capacities during the combustion of 2 cigarettes, with the results from **TESTS 2, 3 and 4** during the combustion of 2 cigarettes with the equipment turned off and the air extraction from the test chamber off. The obtained data are displayed in the following sheet:

	PURIFYING CAPACITY	RSP_4	NIC.	CO_2	CO	Tª	R.H.
		mg/m^3	mg/m^3	ppm	ppm	ºC	%
INITIAL STATE	0%	< 0,150	< 0,1	< 1.000	< 5	< 24,0	> 37
TEST 1	25%	61,113	1,0	1.376	175	26,7	37,7
	50%	63,354	1,3	1.189	132	27,6	37,1
	75%	99,589	1,2	1.283	160	27,6	37,9
TESTS 2, 3 and 4	0%	579,015	7,2	2.741	213	27,2	45
	0%	574,097	6,2	2.035	204	29,0	40
	0%	587,356	4,8	1.807	207	28,7	38

Sheet 1. Results from different tests with the device off, and with the device working at different purifying capacities.

The sheet is also showing the environment conditions before the tests (Initial state). Below those values, it is agreed that indoor air quality is acceptable in health terms.

- Working at a 25% of the equipment purifying capacity, RSP_4 concentration decreased a 89,5%, Nicotine concentration decreased a 98,6%, CO_2 concentration decreased a 49,8%, and CO concentration decreased a 17,9% in previously explained test conditions.

- Working at a 50% of the equipment purifying capacity, RSP_4 concentration decreased a 89%, Nicotine concentration decreased a 98,4%, CO_2 concentration decreased a 41,6%, and CO concentration decreased a 40,7%.

- Working at a 75% of the equipment purifying capacity, RSP_4 concentration decreased a 83,1%, Nicotine concentration decreased a 98%, CO_2 concentration decreased a 29%, and CO concentration decreased a 22,7%.

- There were no significant variations in temperature and relative humidity values, in tests with no purifying process.

In test conditions the device was effective in RSP rate reduction, as well as in nicotine rate reduction.

With respect to Carbon dioxide and Carbon monoxide, there was no reduction of both pollutants generation rate in two tests. This could be greatly improved by adding ventilation (natural or forced) in the tests, allowing for higher environment oxygen rates. This would also correct the slight variations in relative humidity.

The raise of temperature would be issued by using a thermal control system.

Pollutants elimination rate

With **TESTS 2, 3 and 4** results, we can compare the different pollutants´ elimination rates when the equipment is turned on with different purifying capacities, after combustion of two cigarettes.

The resulting data are displayed here:

	PURIFYING CAPACITY	RSP_4 mg/m^3	NIC. mg/m^3	CO_2 ppm	CO ppm	Tª ºC	R.H. %
TESTS 2, 3 and 4	25%	579,015	7,2	2.741	213	27,2	45
	50%	574,097	6,2	2.035	204	29,0	40
	75%	587,356	4,8	1.807	207	28,7	38
AFTER 5´	25%	-83,5%	>-98,6%	-13,0%	-31,0%	1,5%	-2,2%
	50%	-78,0%	-98,4%	-19,2%	-22,6%	0,7%	-1,5%
	75%	-71,3%	>-98,0%	-23,1%	-30,0%	2,1%	-0,5%
AFTER 10´	25%	-95,5%	>-98,6%	-20,2%	-41,0%	2,6%	-3,8%
	50%	-94,5%	>-98,4%	-26,7%	-38,2%	1,4%	-1,8%
	75%	-91,9%	>-98,0%	-31,8%	-45,4%	3,5%	-3,3%
AFTER 15´	25%	-97,9%	>-98,6%	-22,8%	-47,0%	3,7%	-4,9%
	50%	-96,6%	>-98,4%	-29,7%	-41,1%	2,4%	-2,2%
	75%	-96,0%	>-98,0%	-36,9%	-56,0%	4,5%	-3,7%

Sheet 2. Results obtained with equipment working to different purifying capacities over time.

- Working at a 25% of the equipment purifying capacity, RSP_4 concentration decreased more than 83% after 5 minutes, more than 95% after 10 minutes, and more than 98% after 15 minutes. Nicotine concentration shows even faster decreases, with an environmental nicotine rate reduction of 98% in just five minutes. CO_2 concentration decreased between 13% and 22%, and CO concentration decreased between 30% and 47% in previously explained test conditions.

- Working at a 50% of the equipment purifying capacity, RSP_4 concentration decreased more than 78% after 5 minutes, more than 94% after 10 minutes, and more than 96% after 15 minutes. Nicotine concentration shows even faster decreases, with an environmental nicotine rate reduction of 98,4% in just five minutes. CO_2 concentration had much inferior reduction rates, decreasing between 19% after five minutes, and 22% after 15 minutes. CO concentration decreased 31% after five minutes, and 47% after 15 minutes in previously explained test conditions.

- Working at a 75% of the equipment purifying capacity, RSP_4 concentration decreased more than 71,3% after 5 minutes, more than 92% after 10 minutes, and more than 96% after 15 minutes. Nicotine concentration shows even faster decreases, with an environmental nicotine rate reduction of 98% in just five minutes. CO_2 concentration decreased between 23% and 37%, and CO concentration decreased between 30% and 56% in previously explained test conditions.

As with the pollutants generation rate, the EAGLE 5000 reaches high levels of efficiency against nicotine and Respirable Suspended Particles with aerodynamic diameter up to 0,3 µm. The reductions in CO2 and CO concentrations showed minor decreases.

It must be noted than tests were made up to a 75% of the equipment´s maximum performance. Results would ideally be improved with the equipment at full performance.

General conclusion

Globally considering all tests, we reach the following conclusions:

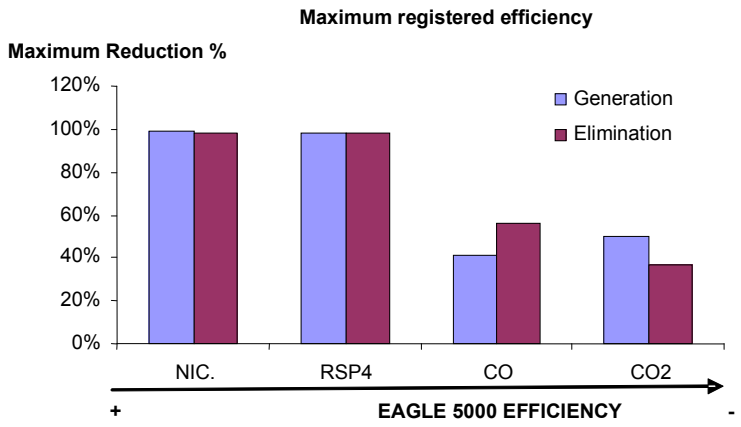
The pollutants **generation rate** decreased during combustion with the EAGLE 5000 equipment turned on. The pollutants generation rate varied upon the EAGLE 5000 operation time and the equipment's purifying capacity applied. The maximum reduction rates recorded during pollutant generation were:

- Nicotine up to 99% of the concentration.
- Respirable Suspended Particles up to 98% of the concentration.
- CO_2 up to 50% of the concentration.
- CO up to 41% of the concentration.

The pollutants **reduction rate** varied upon the EAGLE 5000 operation time and the equipment's purifying capacity applied. The maximum reduction rates recorded during pollutant elimination were:

- Nicotine up to 98% of the concentration.
- Respirable Suspended Particles up to 98% of the concentration.
- CO_2 up to 37% of the concentration.
- CO up to 56% of the concentration.

The following picture shows the compared maximum reductions in all evaluated pollutant rates during their generation and elimination processes.



Pic 8. EAGLE 5000 maximum performance recorded during tests

The EAGLE 5000 air purifier, working to a 75% of its full capacity, was able to obtain a reduction of about 99% on the environmental nicotine rate, and a reduction of about a 98% on the Respirable Suspended Particles rate, showing high effectiveness in suppression of both tobacco pollutants.

The CO_2 and CO concentration rate reductions were smaller. However, combining these measures with a supply of natural or mechanic ventilation, reduction rates close to the former could be reached in periods similar to those used in tests.

5. ANNEXES

Annex 1: Laboratory Report MA06-01340

Annex 2: AIQ ENAC Accreditation

Annex 3: Equipment Calibration Certifications