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Effect of the test aerosol charge on the penetration through electret filter

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ABSTRACT

This study deals with the performance of an electret filter towards submicronic aerosol and particularly the dependence of its penetration with the charge distribution of the aerosol and a neutralization effect. An experimental set-up was developed to determine simultaneously the charge density of the aerosol and the filter penetration. It appears that the penetration of electret filters is all the more low that the charge per unit surface of a particle is important. The effect of a neutralization of the filter damages dramatically the performance of the filter.

1. Introduction

In the large domain of the respiratory protection the use of filters composed of charged fibers is very attractive. They are called electret filters. As a matter of fact the presence of these charges leads to an increase of the filtration efficiency without increasing the pressure drop of the filter [1]. Better protection with a low resistance to air flow: the optimum in filtration technology seems to be reached. However the behavior of these filters is not clearly understood and the expected performance of the electret filters may vary as a function of different parameters: the amount of particles collected [2,3], some storage conditions which could induce a neutralization of the fibers [4], and obviously the properties of the collected particles. Among these properties the charge of the particle must play a major role.

The classical filtration theory describes the different mechanisms involved in the capture of an aerosol by charged fibrous filter. As a function of the level of charge brought by the fibers the electrostatic mechanisms can be predominant in comparison with inertia, impaction and Brownian diffusion. These mechanisms called coulombic force between charged particles and charged fibers and polarization force between neutral particles and charged fibers coexist when an aerosol presenting a given charge distribution is filtered by an electret filter.

Today there is no difference between all the filters used in the respiratory protective devices as far as the standards are concerned. The European Standard EN 143: Respiratory protective devices – particle filters – requirements, testing, marking [5] classifies the filters in three categories called P1, P2 and P3 as a function of their penetration value at a filtration velocity of 5.2 cm/s towards two types of test aerosols. The first test aerosol is NaCl with a mass median diameter of 0.6 μm and the second one is composed of paraffin oil droplets presenting a mass median diameter of 0.4 μm. The limit values of this classification are given in Table 1.

Regarding this table there is no difference between the penetration values required as a function of the aerosol nature. But experience feedbacks from filter manufacturers show that an electret filter could be classified P3 considering the NaCl test and P2 towards Oil particles. An explanation could be a different effect of particles charge on the filter penetration as a function of the test aerosol. Forsyth and al. [6] determined experimentally the charge distribution of aerosol generated by the commonly generation methods used in laboratory. The atomization method recommended by the standard for the generation of salt and oil aerosol belongs to them. The authors obtained the charge law for these both aerosols (Table 2).

It appears that the charge brought by a NaCl particle of a given size is larger than in the case of an oil droplet.

All these elements led us to develop a test bench which combines a determination of the charge distribution of the generated aerosol and a measurement of the filter penetration. Combining these both parameters will bring to a better understanding of the mechanisms involved in the filtration by electret filters.

In parallel with these experiments on new electret filters, a neutralization protocol is developed to put into the light the risk of a bad storage on the non-permanent charges brought by the fibers.

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Table 1
Limit values of penetration for the definition of the classes of filters used in RPD (extract from EN 143 [5]).

Filter class	Maximal penetration (%)	
	Salt aerosol	Oil aerosol
P1	20	20
P2	6	6
P3	0.05	0.05

Table 2
Charge law of both aerosols generated by atomization (Forsyth [6]).

Aerosol	NaCl (1% w/w)	Oil (DOS, 100%)
Size range (μm)	0.15 – 0.75	0.15 – 2.0
Charge law Number of charge $N(d_p)$ brought by a particle of size d_p (μm)	$N(d_p) = 13.35 * d_p^{0.8}$	$N(d_p) = 3.15 * d_p^{1.55}$

Table 3
Global current measured after the particle generation in both charge states.

Level of particle charge	Natural charge state	With a positive current from the air ionizer
Global current measured by the electrometer	−240 fA	+930 fA

2. Experimental test bench

2.1. General description

The experimental set-up can be divided into three parts as represented on Fig. 1.

In the first one the aerosol is generated with an atomizer (de Vilbis) from a NaCl solution of 1% w/w. All the air flows supplying the test bench are dried. Then the mean relative humidity of the filtered air flow is under 20%.

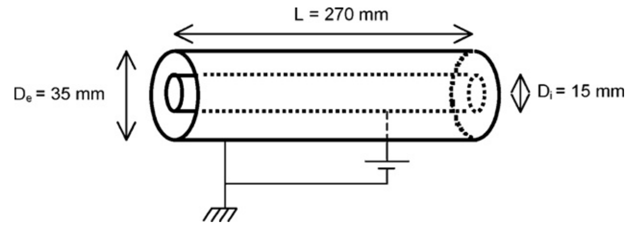

Fig. 2. Dimensions of the cylindrical electrostatic precipitator.

An air ionizer (TOPAS) can be added in order to induce a larger positive or negative charge brought by the particles. Two levels of particle charge are tested in this study: one without using the air ionizer and the second with a strong positive current from the air ionizer. These levels are characterized by the general current measured by an electrometer (TSI) at 5 L/min in the beginning of the second part of the test bench (Table 3).

In the second part of the experimental set up an electrostatic precipitator is used to determine the charge distribution of the particles, that is to say the charge law of the aerosol. This way of charge determination is similar to those presented by Forsyth [6] and Brown [7]. The geometry of the cylindrical precipitator is described on Fig. 2.

This electrostatic precipitator is supplied by high voltage between 0 and 7 kV. The air flow through the precipitator is regulated at 10 NL/min. An optical particle counter (PMT Lasair 1001, based on single particle light scattering system) placed downstream from the precipitator allows the counting of the particles which are not collected by the electrostatic precipitator at each voltage. The theory of the filtration efficiency of this separation process is then used to establish the charge distribution of a given aerosol as it is demonstrated in Section 3.1.

In the third part of the bench tests are carried out to determine the penetration of a given electret filter media. The ratio between the downstream and upstream concentrations is obtained after a dilution step by an optical particle counter (PMT Lasair 1001)

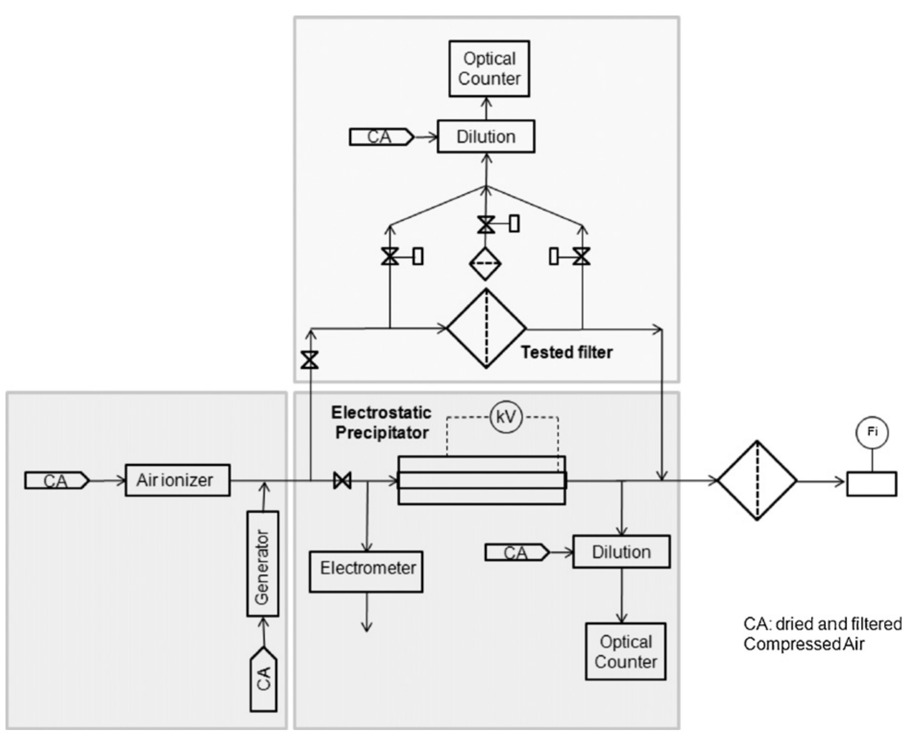

Fig. 1. Description of the test bench.