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FRACTIONAL AEROSOL FILTRATION EFFICIENCY OF AIR CLEANERS

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ABSTRACT

Under contract to the U. S. Environmental Protection Agency, the Research Triangle Institute (RTI) is evaluating the fractional filtration efficiency of air cleaners. The test duct accepts air cleaners up to 610 mm x 610 mm (24 x 24 inches) in size and provides test flow rates up to 470 L/s (1,000 cfm). Filtration efficiency is computed from upstream and downstream aerosol concentration measurements performed with a differential mobility analyzer, a laser aerosol spectrometer, and a white-light optical particle counter. The measurements cover the particle diameter size range from 0.01 to 3 μm in 16 sizing channels. Air cleaners tested include furnace filters, pleated filters and statically charged panel filters.

The efficiency of the air cleaners was often found to be highly dependent on particle size and dust load. A minimum in efficiency was frequently observed in the 0.1 to 0.5 μm range. The presence of a dust load on the air cleaner frequently increased its efficiency. However, for some air cleaners, little change or a decrease in efficiency accompanied the dust loading. The common furnace filter was seen to have a fractional efficiency of less than 10% over much of the 0.01 to 1 μm size range.

INTRODUCTION

Air cleaner filtration efficiency ratings based on current standardized test methods do not provide information sufficient to address indoor air quality concerns. In the United States, for example, the filtration efficiency rating of in-duct air cleaners is most often based on the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.) Standard 52-76 (1). This test provides an overall value of filter performance for atmospheric aerosol and a coarser test dust. While such tests are useful for relative ranking of filter performance, they do not quantify filtration efficiency as a function of particle size.

The objective of this program has been to measure the fractional aerosol filtration efficiency of in-duct air cleaners typically used in residential and office ventilation systems. The measurements have been made over the particle diameter range from 0.01 to 3 μm. Particles of this size are important because they are respirable, have relative low settling velocities (thereby remaining airborne for long time periods), and this range

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16. ABSTRACT The paper gives results of an evaluation of the fractional filtration efficiency of air cleaners. The test duct accepts air cleaners up to 610 x 610 mm in size and provides test flow rates up to 470 L/s. Filtration efficiency is computed from upstream and downstream aerosol concentration measurements performed with a differential mobility analyzer, a laser aerosol spectrometer, and a white-light optical particle counter. The measurements cover the particle diameter size range from 0.01 to 3 micrometer in 16 sizing channels. Air cleaners tested include furnace filters, pleated filters, and statically charged panel filters. The efficiency of the air cleaners was often found to be highly dependent on particle size and dust load. A minimum in efficiency was frequently observed in the 0.1 to 0.5 micrometer range. The presence of a dust load on the air cleaners frequently increased their efficiency. However, for some air cleaners, little change or a decrease in efficiency accompanied the dust loading. The common furnace filter was seen to have a fractional efficiency of less than 10% over much of the 0.01 to 1 micrometer size range.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Measurement	Pollution Control	13B
Air Cleaners		Stationary Sources	13A, 13I
Filtration		Particulate	07D
Efficiency			14G
Aerosols			
Particles			

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includes the size of many indoor aerosol pollutants such as cigarette smoke, cooking fumes, resuspended dusts, and radon progeny (2). Residential furnace filters, a residential electrostatic precipitator (ESP), pleated paper-media filters, pocket filters, panel electronic air cleaners, and statically charged panel filters have been tested.

METHODS

The air cleaners were tested in RTI's filter test facility (Figure 1). The duct accommodates air cleaners with face dimensions up to 610 x 610 mm and operates at flow rates up to 470 L/s (1,000 cfm). The system is equipped with a high efficiency particulate air (HEPA) filter bank on the blower inlet allowing the instrument-zeros and background counts (e.g., particle shedding) to be quantified prior to each test. A second HEPA bank is located on the exhaust to allow indoor discharge. The system operates at positive pressure (i.e., the blower is upstream of the test filter) to minimize infiltration of room aerosol. Because the downstream ducting runs back under the test section, the challenge and penetrating aerosol test ports are located physically near each other, thereby facilitating aerosol sampling. This duct configuration reduces overall particle loss by using extra duct length (in which particle loss is low) to allow short sample line lengths (in which particle losses can be high).

Three instruments were used to perform the fractional efficiency measurements: a TSI Differential Mobility Particle Sizer (DMPS) for particle sizes from 0.01 to 0.09 μm, a PMS Laser Aerosol Spectrometer (LAS-X) for sizes from 0.09 to 0.3 μm, and a Climet 226/8040 Optical Particle Counter (OPC) for sizes from 0.3 to 3 μm. The DMPS measures particle size based on the electrical mobility of the aerosol particles. The LAS-X and OPC are wide-angle light scattering particle counters using a laser and white light source, respectively.

The test aerosol used in the fractional efficiency tests was solid potassium chloride (KCl) generated by drying a nebulized aqueous solution. KCl was selected as the test aerosol because of its relatively high water solubility, high deliquescence humidity, known cubic shape, and low toxicity. Laskin and Collison nozzles were used to generate the challenge aerosol. Upon generation, the aerosol was passed through a charge neutralizer (TSI Model 3054) to neutralize any electrostatic charge on the aerosol (electrostatic charging is an unavoidable consequence of most aerosol generation methods).

The loading dust was composed of 93.5% by weight of Standardized Air Cleaner Test Dust Fine and 6.5% by weight #7 ground cotton linters. This dust is similar to the loading dust specified in the ASHRAE 52-76 Standard except that the ASHRAE dust also includes a carbon black component. We omitted the carbon black because its presence makes the dust highly conductive and incompatible with the operation of electronic air cleaners. While dusts having high conductivities may be encountered in industrial applications, it appeared unlikely for the residential and office building applications of interest to this study. The loading dust was disseminated by use of an aspirator nozzle. Preweighed amounts of dust were fed until the desired pressure drop across the air cleaner was achieved. Typically, the filters were loaded to levels of 125 and 250 Pa (0.5 and 1 in. water) pressure drop.

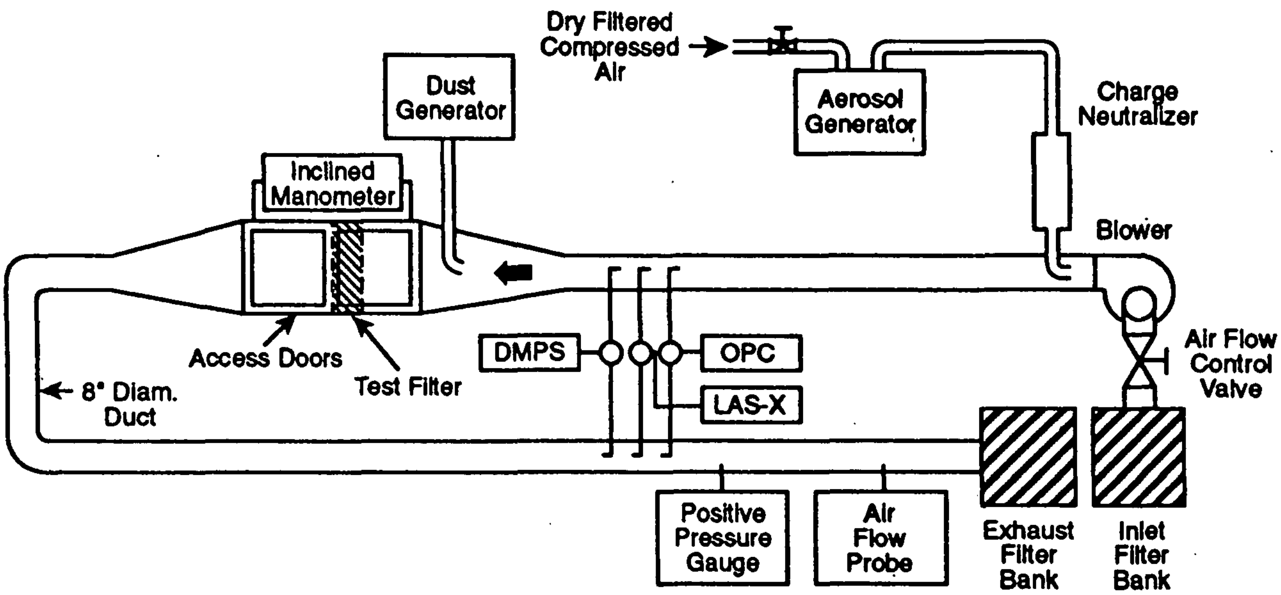

Figure 1. Schematic diagram of RTI's air cleaner test facility.

RESULTS

Figure 2 presents the fractional filtration curves for four clean (i.e., no dust load) filters having ASHRAE Efficiencies ranging from 40 to 95%. The shape of the curves is a consequence of filtration by diffusional collection being effective for particles smaller than 0.1 μm diameter and interception and inertial collection being effective for particles larger than 1 μm. In the region from 0.1 to 0.5 μm these processes are less effective, giving a minimum in filtration efficiency in this size range for most filters.

Figures 3, 4, and 5 show the clean and dust-loaded efficiency curves for a common furnace panel filter, a pleated-paper filter (65% ASHRAE efficiency), and a charged-fiber panel filter, respectively. The furnace filter had a clean efficiency of less than approximately 10% for particle diameters between 0.02 and 1 μm. The efficiency improves somewhat with dust loading, though it remained below 20 % over the 0.03 to 0.3 μm range.

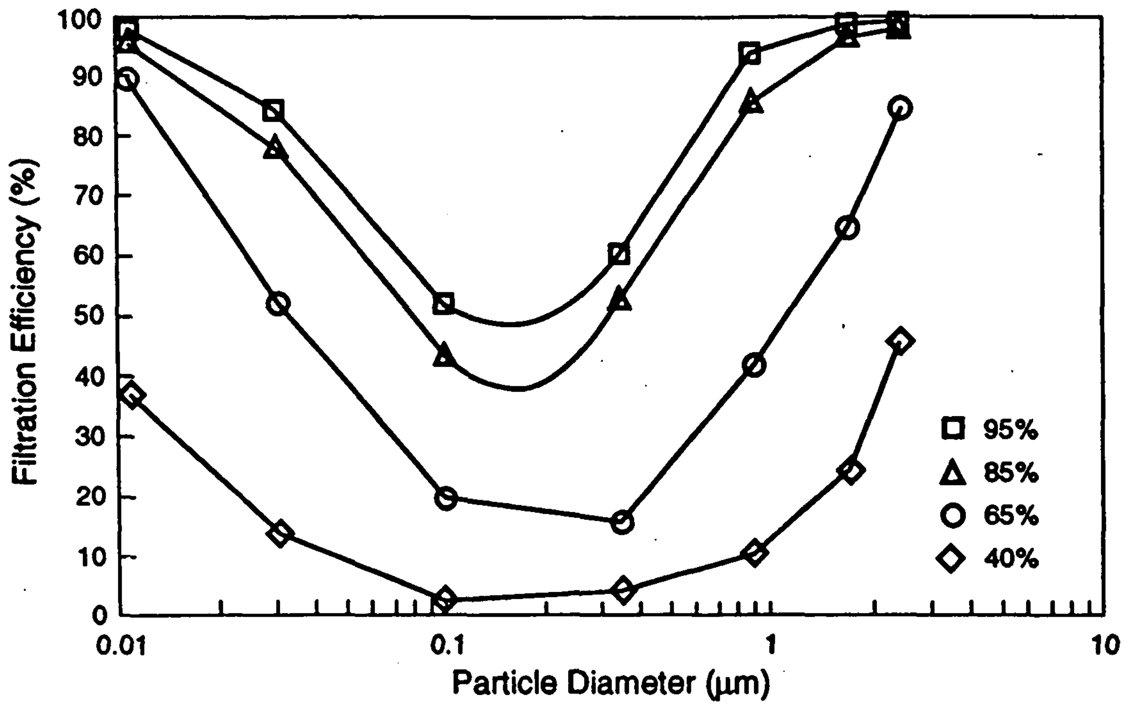

Figure 2. Fractional filtration efficiency of four pleated filters having ASHRAE efficiencies ranging from 40 to 95%.

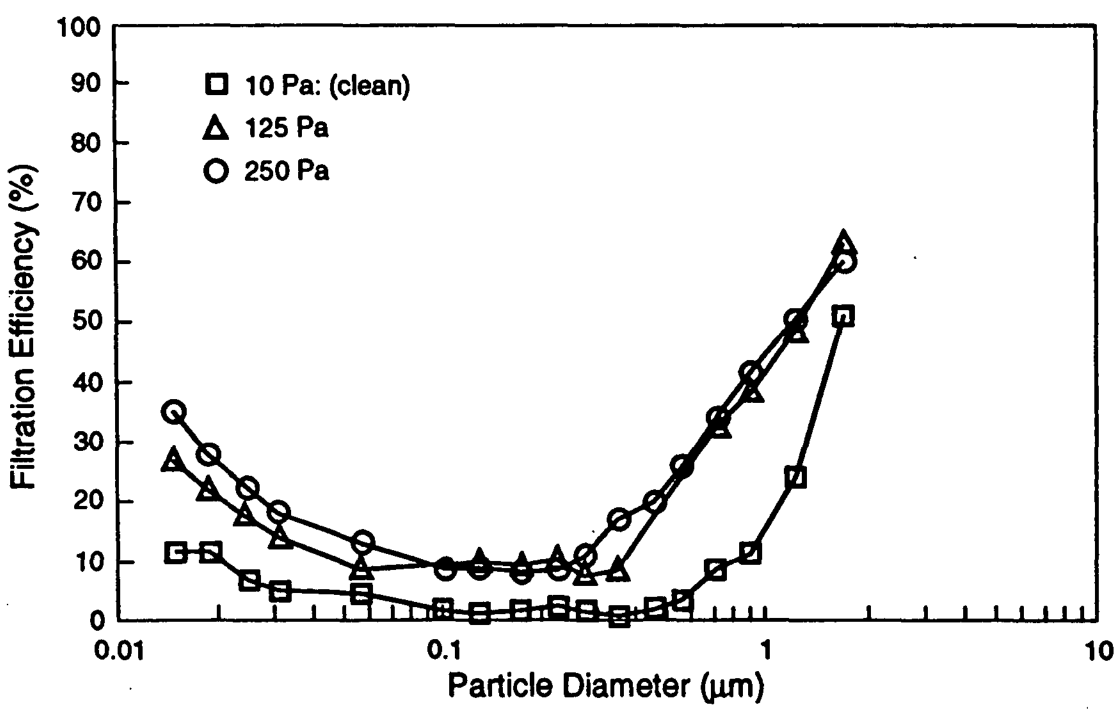

Figure 3. The fractional filtration efficiency of a furnace filter for clean and dust-loaded conditions.

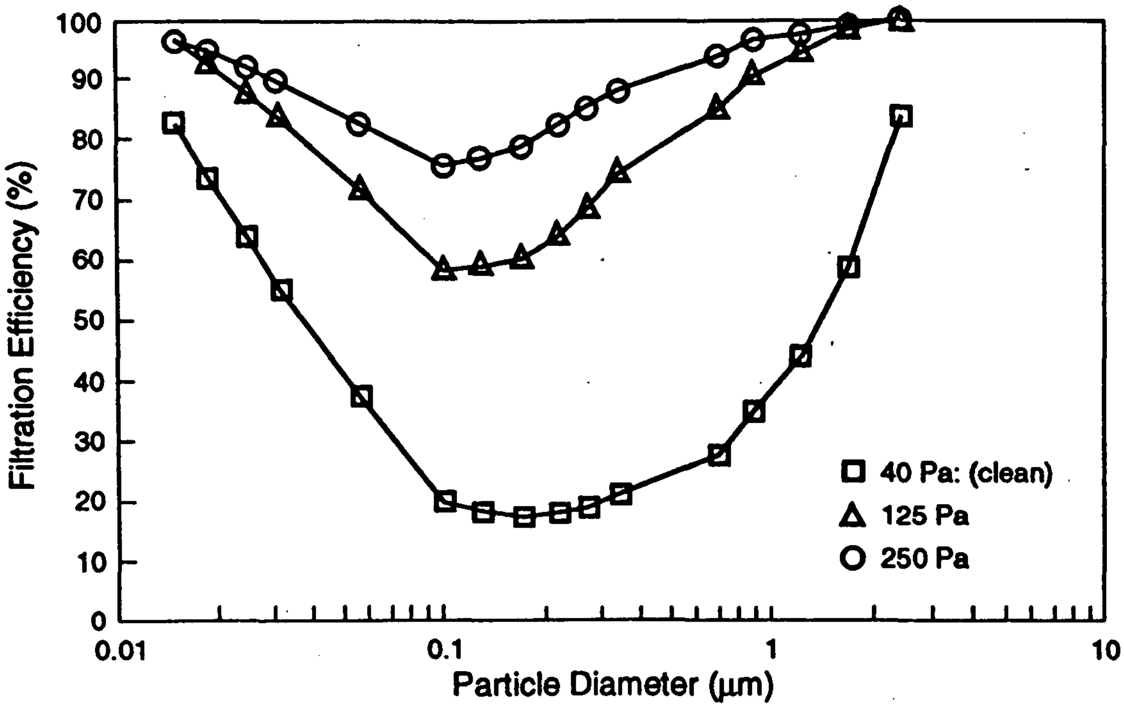

Figure 4. The fractional filtration efficiency of a pleated-paper filter (65% ASHRAE efficiency) for clean and dust-loaded conditions.

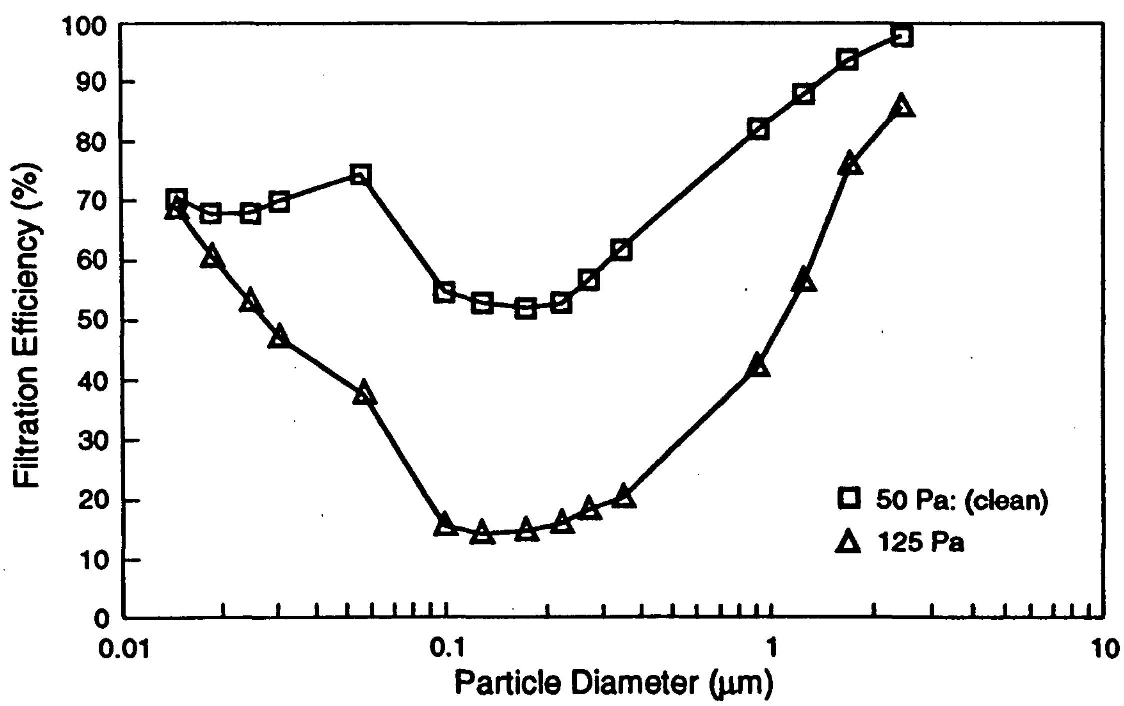

Figure 5. The fractional filtration efficiency of a charged-fiber panel filter for clean and dust-loaded conditions.

The efficiency of the pleated paper filter increased markedly with dust loading. The charged-fiber filter showed a high initial efficiency but a marked decrease with dust loading.

DISCUSSION

The test results illustrate the strong dependence of filtration efficiency on particle size over the 0.01 to 3 μm diameter size range. All of the filters exhibited a minimum in filtration efficiency in the 0.1 to 0.5 μm diameter size range. This is consistent with filtration theory for particle collection by diffusion, interception, and inertial impaction mechanisms.

The common residential furnace filter provided very little (averaging less than about 10%) collection of particles throughout the 0.01 to 3 μm size range. Upon dust-loading, the air cleaners showed a variety of responses with a decrease in efficiency for the charged-fiber filter, a modest increase for the furnace filter, and a substantial increase for the pleated media filter.

The strong dependence of filtration efficiency on particle size, combined with the respirable and abundant nature of aerosol particles, requires that fractional filtration efficiency tests be performed to fully assess the potential impact of an air cleaner on indoor air quality.

RTI is currently completing construction of a new test rig to allow testing at particle diameters up to 10 μm and flow rates up to 1400 L/s (3,000 cfm). A wide range of air cleaners are scheduled for testing including single- and two-stage ESPs, self-charging (i.e. "passive") electrostatic panel filters, bag filters, charged-fiber filters, pleated-paper filters, and spun-fiber furnace filters.

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