Cigarette Smoke: Size Distribution and Effects on Filters

Cigarette smoke is an important aerosol in the air filtration industry and research. It is an unwanted aerosol and therefore there are many applications for air filtration (ex. cigarette filters, residential and commercial ventilation filters, home air cleaners).

Cigarette smoke is especially important to air filter performance for several reasons. First, the size of cigarette smoke particles (see table below) are near the most penetrating size of air filters (100-300 nm). As a result, they are relatively difficult to capture. Secondly, the efficiency of electret filter is severely degraded by the semi-volatile cigarette particles. It is believed that they form a film on the fiber surface and effectively shield or remove the charges. If this occurs, the electrostatic efficiency of the filter suffers. The remaining mechanical efficiency is usually poor because electret is a depth filter and the fiber size is relatively large. Furthermore, a cigarette can produce a large amount of aerosol quickly. Imagine a room with several cigarette smokers! Whereas large particle (>5 micrometer diameter) tends to settle down by gravity quickly, cigarette smokes are relatively stable and their lifetimes can be on the order of days or weeks. Therefore, cigarette smoke can be viewed as a stringent test for air filters.

Table 1 lists the results of particle size measurements done by previous researchers. As seen below, the count median particle size is between 0.1 to 0.3 μm, near the most penetration particle size of high efficiency particulate arrestor (HEPA) filters. For depth filtration media like microfiberglass, the loading of smoke particles would not be detrimental because the oil droplets can wet the fibers and spread out. For microporous membrane, the loading of smoke particles can have a detrimental effect on the pressure drop. Due to surface filtration, the oil droplets are collected near the surface. As the oil accumulates on the surface, it chokes off the airflow. It is therefore not recommended to use microporous membrane in environments with cigarette smokes.

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Reference

I. Ching and D. Dunn-Rankin (1996) Light Scattering Measurements of Cigarette Smoke. Aerosol Sci. Tech. 24:85-101

Table 1. Survey of cigarette smoke particle size measurements done by researchers.

Reference	Method	Smoke Source	Arithmetic Mean Dia. (μm)	Count Median Dia. (μm)	Geo. St. Dev.	Mass Median Dia. (μm)
Sinclair (1950)	Light scattering			0.3		
Okada & Matsunuma (1974)	Light scattering	mainstream sidestream		0.163-0.179 0.095-0.118		
Ingebrethsen (1986)	Light scattering					0.25-0.35
Dalla Valle et al. (1954)	Electrostatic separation			0.1-0.25		
Anderson et al. (1989)	Electrical aerosol analyzer					0.38
Wells and Gerke (1919)	Oscillation in electric field		0.27			
Keith and Derrick (1960)	Conifuge		0.2 to 0.25 (size range from 0.1-1.0)			
Porstenorfer and Schraub (1972)	Radon attachment and centrifugal deposition	mainstream	0.22			
Carter and Hasegawa (1975)	Electron microscopy		0.45			
Holmberg (1979)	SEM		0.29-0.40			
Keith (1982)	SEM		0.20			
Phalen et al. (1976)	Cascade impactor Centrifugal spiral aerosol separator Electron microscopy		 0.57			0.71-0.73 0.72-0.79
Hinds (1978)	Aerosol centrifuge & cascade impactor					0.52 (tp 0.38 as dilution increased)
Chang et al. (1985)	Cascade impactor	mainstream		bimodal: 0.25 and 5		
Chung & Dunn-Rankin (1996) " " "	Light scattering	mainstream w/o filter (1R3) mainstream w/ filter (1R3f) fresh sidestream smoke captured sidestream smoke	0.15 0.18 0.27 0.26	0.14 0.17 0.27 0.25	2.1 2.0 1.6 1.7	0.71 0.66 0.50 0.52

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