S3.4.4 Modeling of Aerosol Penetration through Electret Filter Media

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Electret filters are filters whose fibers are semi-permanently charged. This charge results in electrostatic interactions between particles and fibers which can increase filtration efficiency without increasing the pressure drop across the filter, making electret media well-suited for HVAC and respirator filters. Two of the major approaches to modeling the collection efficiency of an electret filter are Brownian dynamics, where the particle equation of motion is stochastic, and limiting trajectories, where the particle equation of motion is deterministic. For models which employ limiting trajectories there has been little advancement since the early 1990s, with most previous studies only considering one electrostatic force at a time and ignoring both interceptional effects and the random orientation of the dipole on the fiber. It has been demonstrated that for the higher charge densities of modern electret filters the additivity of polarization and Coulombic collection efficiencies for charge particles no longer holds due to a negative interaction between the two electrostatic forces. Semi-empirical expressions developed from models which do account for the interaction of these forces were unable to give functional relationships for charge density dependent constants. While more recent studies have used Brownian dynamics models, easily implementable regression equations from their results were limited to cases where there was no angular dependency on electrostatic forces. In this presentation the development of a new model for electret filtration using the method of limiting trajectories will be presented.

Single fiber efficiencies for randomly orientated electret filter fibers with circular cross-section and bipolar surface charge distribution were calculated for combined mechanical and electrostatic collection mechanisms. The electrostatic interactions considered were Coulombic, polarization, and image forces. Single fiber efficiency was assumed to be the sum of deterministic mechanisms (e.g., interception, Coulombic, polarization, and image forces) and stochastic mechanisms (i.e., diffusion). Deterministic efficiencies were calculated from the particle flux between limiting trajectories of inertialess particles which were solved numerically using an explicit Runge-Kutta formula. Diffusional efficiency was determined using an empirical power law relation. For a fitted surface charge density the model was able to adequately simulate experimental results obtained which isolated collection mechanisms through control of the particle charge state and/or discharging of the electret media.