Real-time particle size measurements of electronic cigarette smoke

Introduction

Electronic cigarettes (e-cigarettes) are on sale to the general public in a variety of countries. These devices use a range of techniques to deliver an aerosol, which may contain nicotine and flavourings, without the combustion processes associated with a tobacco based cigarette.

A common e-cigarette design uses an electrically heated element to vaporize a solution of water, glycol and (optionally) nicotine. (Other flavorings may be added to the mixture.) This produces a condensation aerosol, comprising liquid droplets of the working fluid. A battery provides the electrical supply, and an integral flow sensor allows the heater to switch on automatically when the user provides flow through the device.

Background

This application note provides some preliminary particle size/concentration/mass data from an e-cigarette.

Smoking Cycle Simulator

The Cambustion Smoking Cycle Simulator allows the reproduction of smoking flow profiles such as ISO or Heath Canada, or recorded real world profiles. The use of the Constant Volume Sampling principle allows straightforward calculation of total particle mass / number emissions from the cigarette, based on downstream concentration measurements.

www.cambustion.com/products/scs

DMS500 Fast Particulate Spectrometer

The DMS500 Fast Particulate Spectrometer uses unipolar corona charging and parallel detection of particles of varying electrical mobility (using electrometers) to offer real-time measurement of the particle size spectrum between 5 and 1,000 nm (optionally between 5 and 2,500 nm). Various design features allow the instrument to offer 10Hz data with a $T_{10-90\%}$ of 200ms, which is well suited to the short duration of puffs on a standard smoking profile.

This is sufficiently fast to allow resolution not only of puff-puff variation, but also intra-puff variation in particle size and concentration. The DMS500 is the only instrument to provide this speed of size-spectrum measurement in the nanoparticle range.

www.cambustion.com/products/dms500/aerosol

Experimental Setup

An electronic cigarette operating on the electrical heating principle was purchased at a retail outlet, and fully charged using the supplied USB charger before fitting a new cartridge.

The Smoking Cycle Simulator was used to reproduce a standard ISO smoking profile, while providing a high level of dilution (minimum 10:1) close to the cigarette outlet to reduce coalescence effects due to the high concentrations.

The resultant diluted smoke was fed into a DMS500 system, and particle size / mass data recorded at 10Hz.
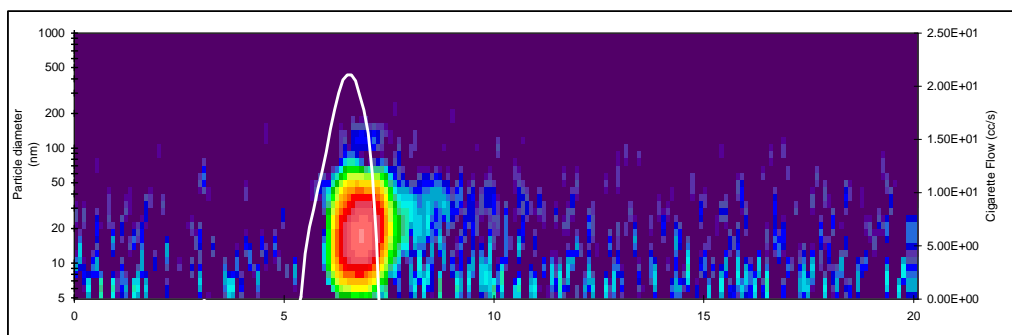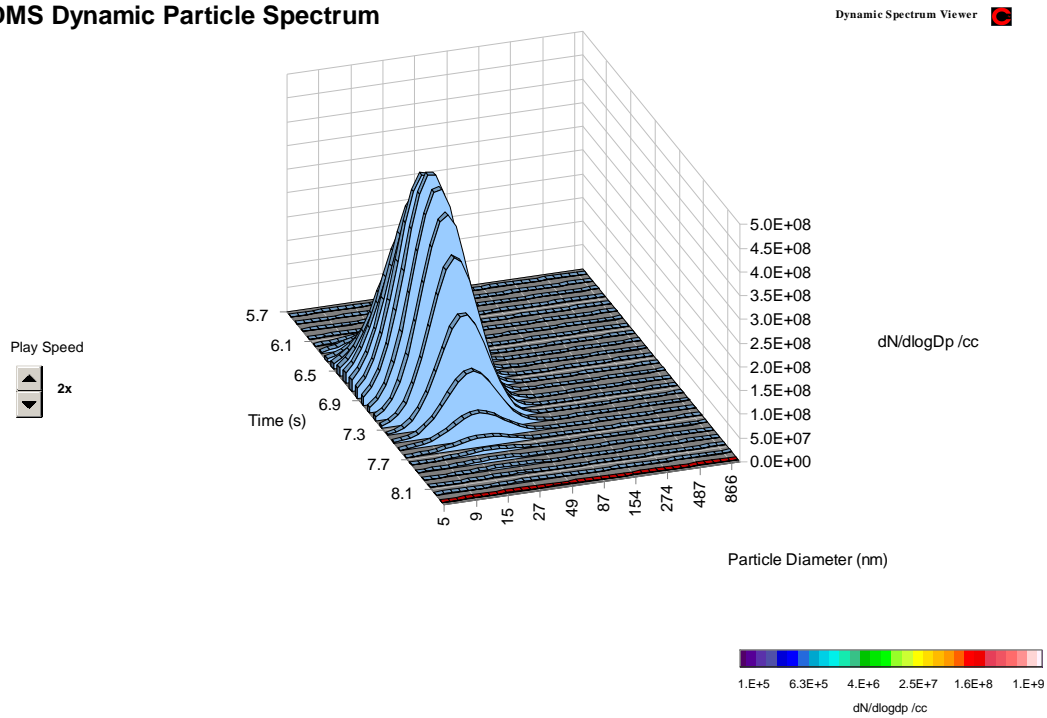
The work was performed in an indoor environment with an ambient temperature of ~20ºC.

Results

The 10Hz data available from the DMS500 allows measurement of the development of the aerosol during each puff.
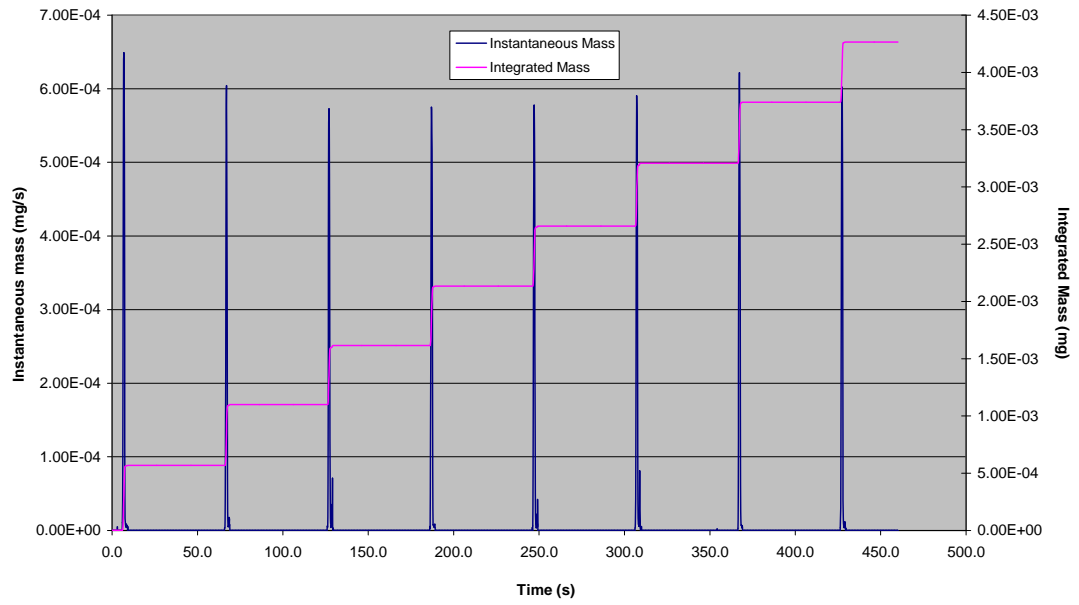
The following waterfall and false colour contour plots are shown the first puff only:
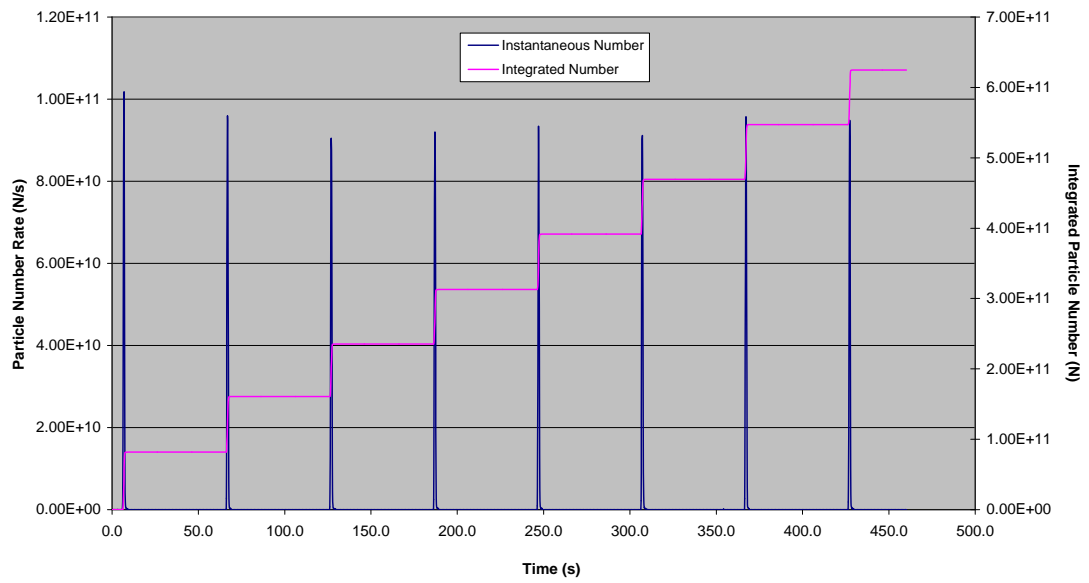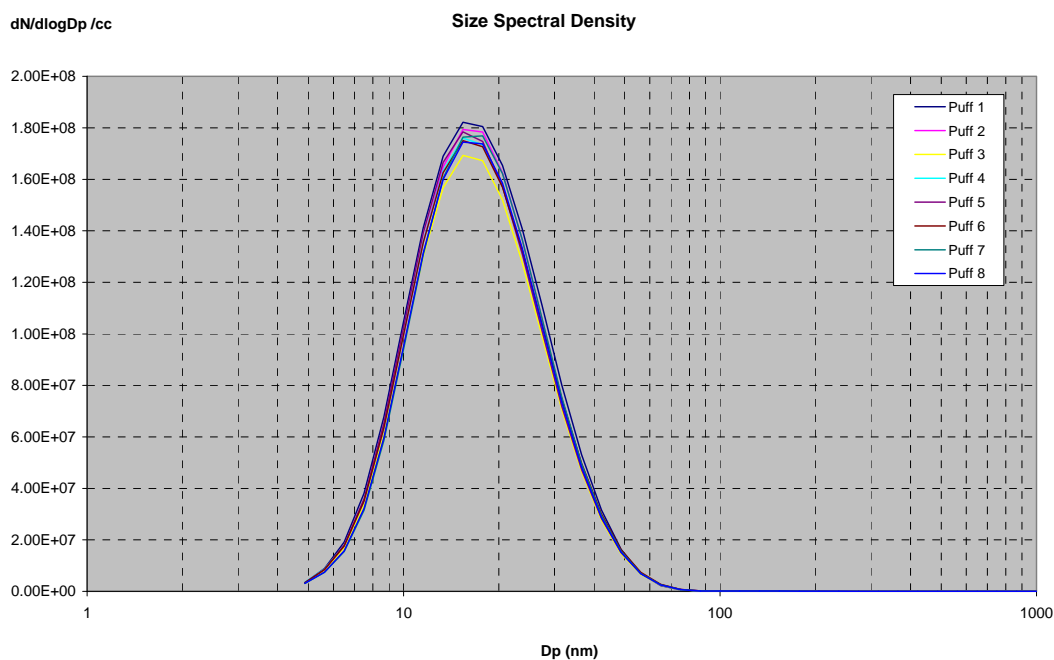

The size spectra were automatically volume weighted and assumed unit density to provide instantaneous and integrated mass.

Instantaneous and integrated mass rate from an E-cigarette

Instantaneous and Integrated Number from an E-cigarette

dN/dlogDp /cc

Size Spectral Density

Conclusions

The combination of DMS500 and SCS allow reproduction of standard smoking profiles, and measurement of instantaneous and integrated particle mass and number, combined with puff-by-puff size/number spectra.

Further Reading

SCS: www.cambustion.com/products/scs
DMS500   www.cambustion.com/products/dms500/aerosol
Publications   www.cambustion.com/publications/Tobacco%20Aerosol