# Real-time particle size measurements of user triggered 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.

DMS500 application note 12 http://www.cambustion.com/sites/default/files/dms12v01.pdf covered measurements of e-cigarette smoke from cigarettes using an integral flow sensor, which allows the heater to switch on automatically when the user provides flow through the device.

Another variety of electronic cigarette also available commercially uses the same principle to produce an aerosol, but relies on manual activation of the heating element by the user.

## Background

This application note provides some preliminary particle size/concentration/mass data from an e-cigarette, in which the heating element is normally manually triggered by the user.

## 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 10 Hz data with a $T_{10\text{-}90\%}$ of 200 ms, 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 filling the reservoir with e-liquid.

The Smoking Cycle Simulator was used to reproduce a pseudo-square wave smoking profile (4 second puff, 30 cc/s flow rate), while providing dilution close to the cigarette outlet to reduce coalescence effects due to the high concentrations.

The heating element was triggered automatically using an accessory to the SCS, which pushes the button on the cigarette at a programmed time. The button push can be programmed separately to the flow rate described in the puff profile, allowing both good repeatability and investigation of the effects of varying pre-heat times to be achieved. In this study, the device was automatically activated 1 second before the puff starts and heating stopped at the end of the puff.

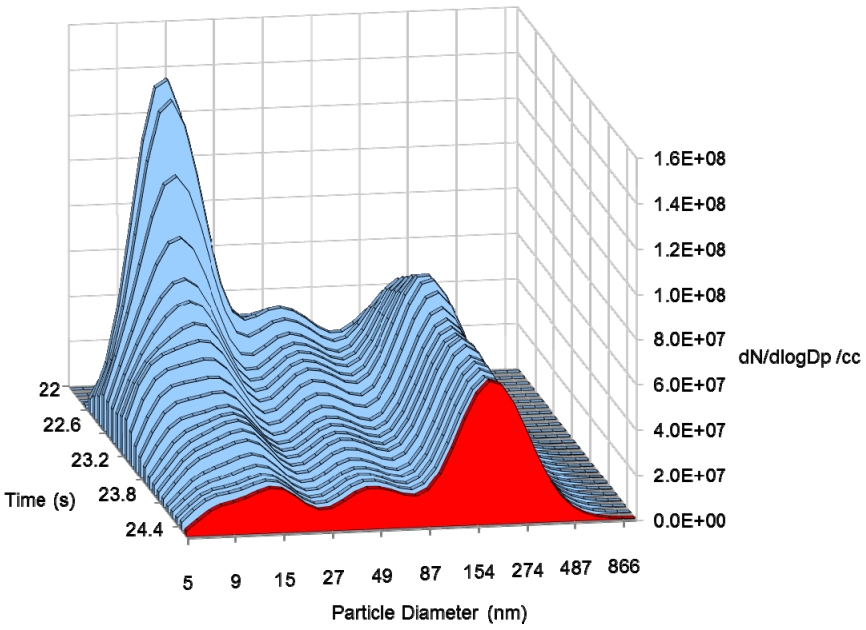
The resultant smoke was fed into a DMS500 system, and particle size / mass data recorded at 10 Hz.

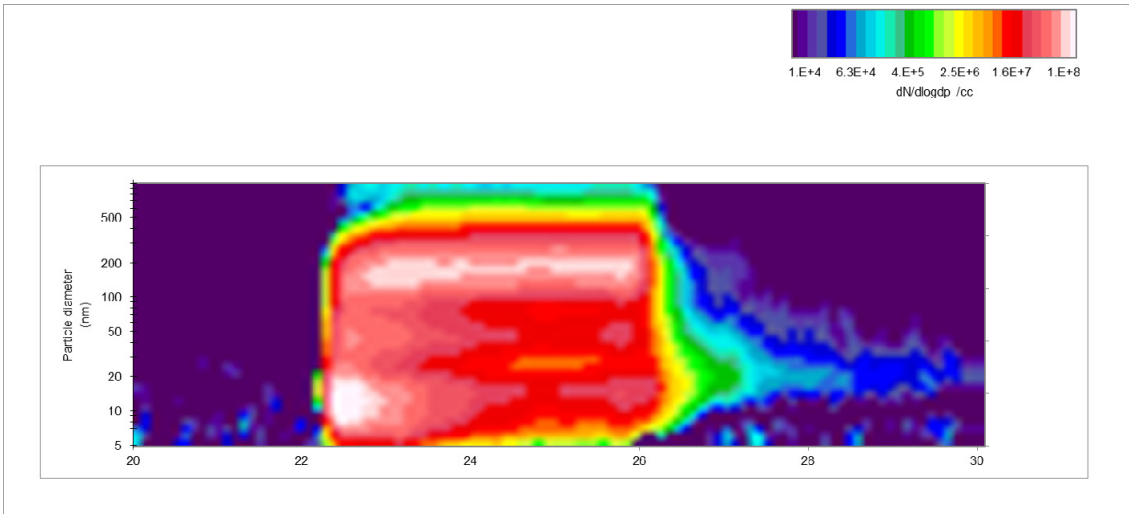
The work was performed in an indoor environment with an ambient temperature of ~23ºC.

## Results

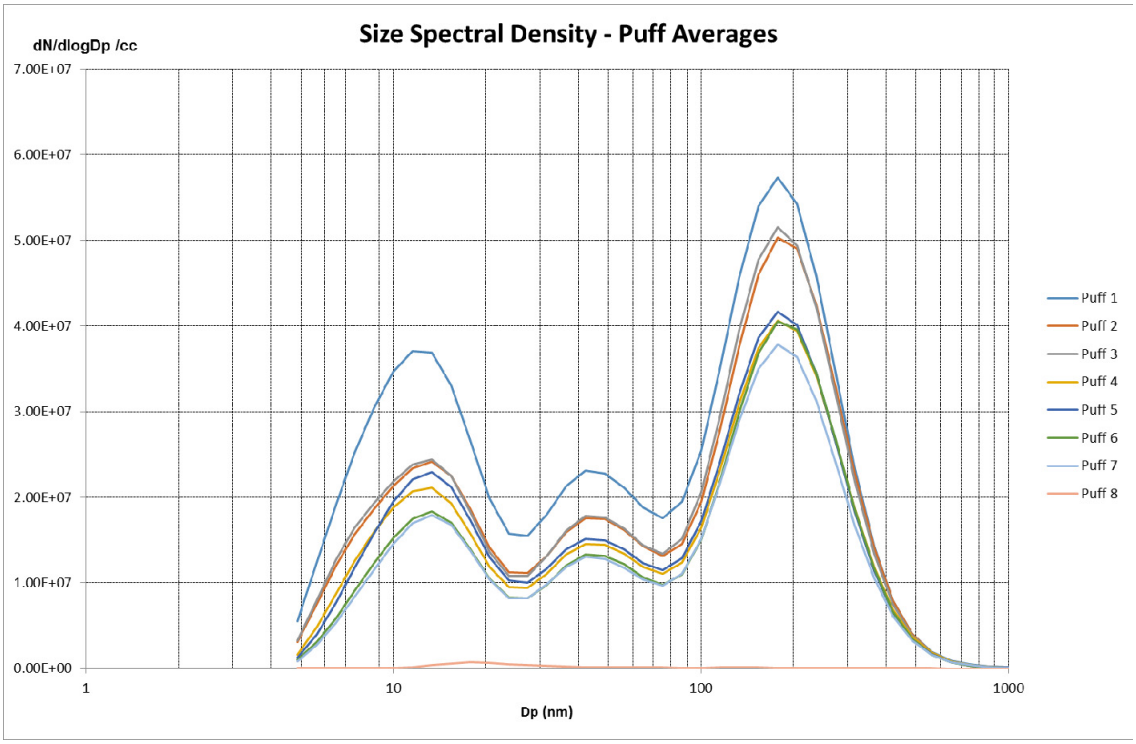
The 10 Hz data available from the DMS500 allows measurement of the development of the aerosol during each puff.

The following waterfall plots show the first 2 seconds of a single puff only, while the contour plot shows a complete 4 second puff.

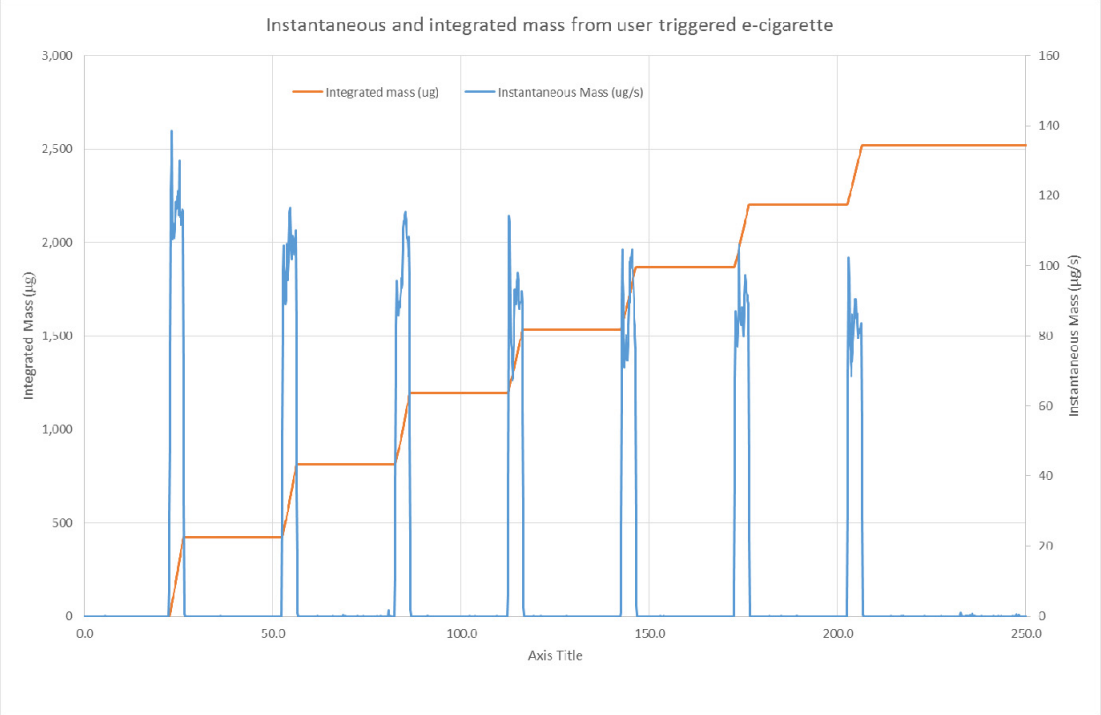





The size spectra were automatically volume weighted and assumed unit density to provide instantaneous and integrated mass.




There is greater variability observed in this test, compared with the automatically triggered e-cigarette previously tested in application note 12. The short interval between puffs means that the device will not have cooled to equilibrium conditions between puffs, and indeed there is a systematic trend observed in the mass concentration.




## Conclusions

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

## Further Reading

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| SCS: | www.cambustion.com/products/scs |
| DMS500 | www.cambustion.com/products/dms500/aerosol |
| Publications | www.cambustion.com/publications/Tobacco%20Aerosol |
| Application note 12: | http://www.cambustion.com/sites/default/files/dms12v02.pdf |