

Puff Profile Simulator for Tobacco Smoke Particle Diameter and Mass Measurement



BRITISH AMERICAN TOBACCO



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INTRODUCTION

This paper describes a system for cigarette testing, measuring fresh TPM (total particulate matter) mass, median particle diameter, and particle number concentration, with any desired flow profile. This allows measurements at conditions representative of human smoking or for regulatory pre-defined machine smoking profiles. The size data are collected at 10 Hz time resolution with cumulative number and TPM mass measurement in real time on a puff by puff basis.

The system is designed to be used with real-time aerosol instruments such as DMS-type fast electrical mobility spectrometers (Reavell *et al.*, 2002) to provide continuous measurement of the aerosol inhaled from the cigarette during smoking. The flow through the cigarette is metered with an orifice pressure-drop type flow sensor and controlled to follow a specified profile at 12.5 Hz (Figure 1). To follow highly dynamic puff profiles a feed-forward type controller is used. The complete smoking of a cigarette with a different profile for each puff can be reproduced.

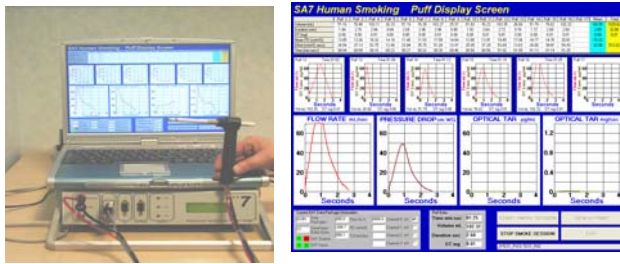


Figure 1 : BAT Smoking analyser (SA7) and measured parameters

EXPERIMENTAL

The sampling head (Figure 2) contains the orifice for metering the cigarette flow, an annular slot mixer for the dilution air and a pinch valve to shut off the cigarette between puffs. The sampling head is typically mounted near the analyser input to maximise the frequency response of concentration measurements. The control unit contains the dilution flow control and metering system, the ΔP sensor for the cigarette flow orifice meter, the blower to provide dilution air and the power supplies and electronics for the system. The interface software allows cigarette flow profiles to be loaded, tests to be started and stopped, the instrument to be calibrated and configured, and it displays the flow profile desired and achieved. The flow drawn through the cigarette is diluted with filtered air close to the filter holder to halt agglomeration processes. The system operates with a constant total diluted flow to minimise errors in the measurement of total mass emissions from the cigarette. A dilution ratio signal is provided to allow calculation of the undiluted concentrations if desired. The system has been tested with standard machine profiles and those measured from human smokers. Control of cigarette flows down to approximately 1 ml/s is possible, with a dynamic range of at least 30:1. The typical error in the integrated volume of a puff is around 1%.

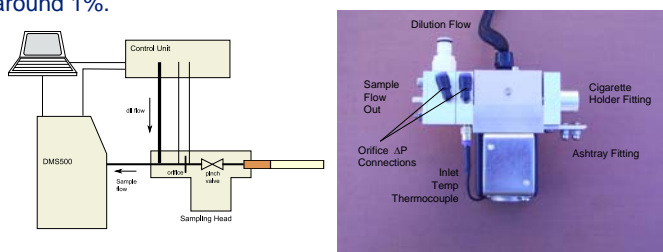


Figure 2 : Schematic and sampling head

RESULTS

Size and concentration data from a human smoked profile of a commercial 9 mg yield cigarette are shown in Figures 3 (spectrometer data) and 4 (summary of data generated from analogue outputs).

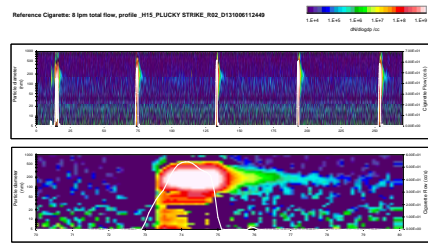


Figure 3 : DMS-500 output data

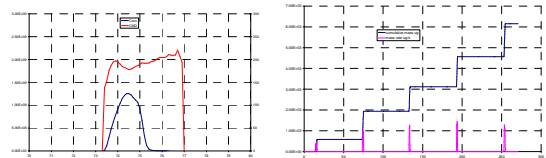


Figure 4 : DMS-500 summary size and mass data

Flow profiles were checked by re-recording by the SA7 smoking analyser using calibration sinusoidal, triangular, early triangular and square wave puffs each at 25, 50, 75 and 100 ml. Compliance ($n = 408$) was 25.4 ± 0.7 , 48.8 ± 1.1 , 72.6 ± 1.3 and 98.6 ± 1.9 ml respectively. As an example, Figure 5 shows a complex double puff on lighting the cigarette and the compliance with the recorded trace.

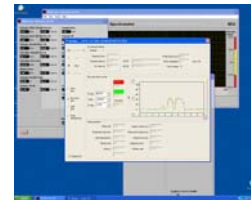


Figure 5 : Lighting puff

Puff by puff measurements were carried out on a series of 1- and 4-mg yielding products using a 35 ml puff of 2 s duration every 60 s, using an ISO puff profile, and normalised to 7 puffs. These data were compared with gravimetric measurements. Count median diameters (CMD) were also measured puff by puff and ranged from 163 - 247 nm, depending on the puff number and yield of each puff. Individual puffs were measured from 0.18 to 1.05 mg TPM and correlated well with the equivalent gravimetric data ($r^2 = 0.88$) (Figure 6). Further smoking of cigarettes to ISO and other regulatory regimes show good correlation of calculated with gravimetric mass, with coefficients of variation for diameter, number and mass of the order of 1, 8 and 10% respectively

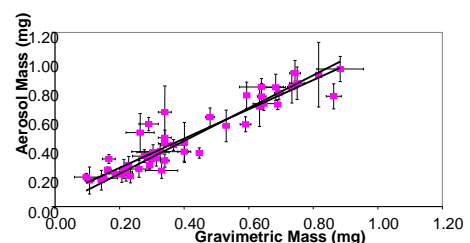


Figure 6 : Puff by puff gravimetric and calculated mass

REFERENCES

Reavell, K. *et al.* (2002). *A fast response particulate spectrometer for combustion aerosols*. SAE Technical Paper, 2002-01-2714.