Monitoring puff-by-puff aerosol generation and delivery when vaping viscous liquids by using in-line Pressure Drop Measurement

TAYLOR, Helen Jane; TINDALL, Ian Francis; Cerulean, Milton Keynes, United Kingdom

INTRODUCTION

In the USA we have seen the emergence of new product styles that are exceptionally viscous. Vaping these products has proved challenging due to the high viscosity of the liquid and the tendency for localised heating not to be sufficiently strong to deliver consistent aerosol over the lifetime of the vape experiment. In order to evaluate these deliveries we developed a methodology whereby the user could visualise potentially changing aerosol delivery rates on a puff-by-puff basis. This involved using a Bluetooth in-line Baratron Pressure Drop (PD) transducer recording both the PD and visually showing the puff profile in 'real' time.

EXPERIMENTAL

3 viscous products were selected labelled 17LV (Low Viscosity), 16MV (Medium Viscosity), and 18HV (High Viscosity); all were tested under the same conditions.

These products were tested on the CETI1 vaping machine, fitted with a 70ml puff engine. Deliveries were measured by capturing the total Aerosol Collected Mass (ACM) onto a 44mm Whatman Cambridge Filter Pad (CFP) in a CFH. The CFH-CFP was weighed before and after each experiment to determine the weight of aerosol captured.

Each experiment was conducted in "puff blocks" of 40 puffs, with a 55ml volume, 3 second duration, every 30 seconds, with a square shaped profile (55/3/30/square).

The transducer was placed after the CFH to allow measurement of the Pressure Drop (PD) / flow in the puffing circuit. This had a two-fold purpose; to observe puff shape distortion through increased PD, and to ensure that the PD was not rising and so restricting flow. Prior to analysis the data logging software for the PD / flow device was started.

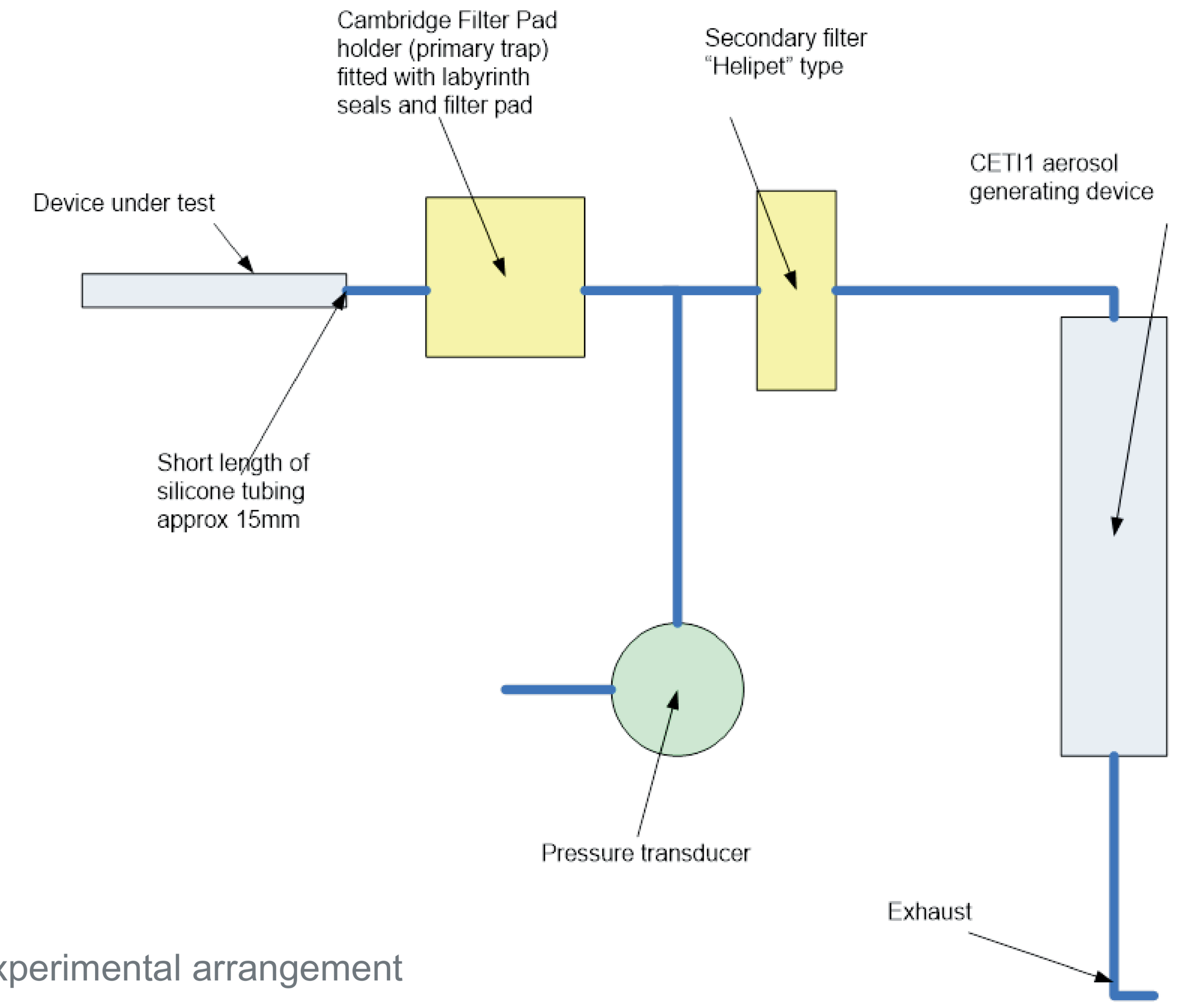

Figure 1: Experimental arrangement

RESULTS

During the tests, we were able to observe aerosol delivery problems in 'real time' using the transducer, these were denoted by a significant change in monitored PD. These PD traces are shown in figures 2 and 3.

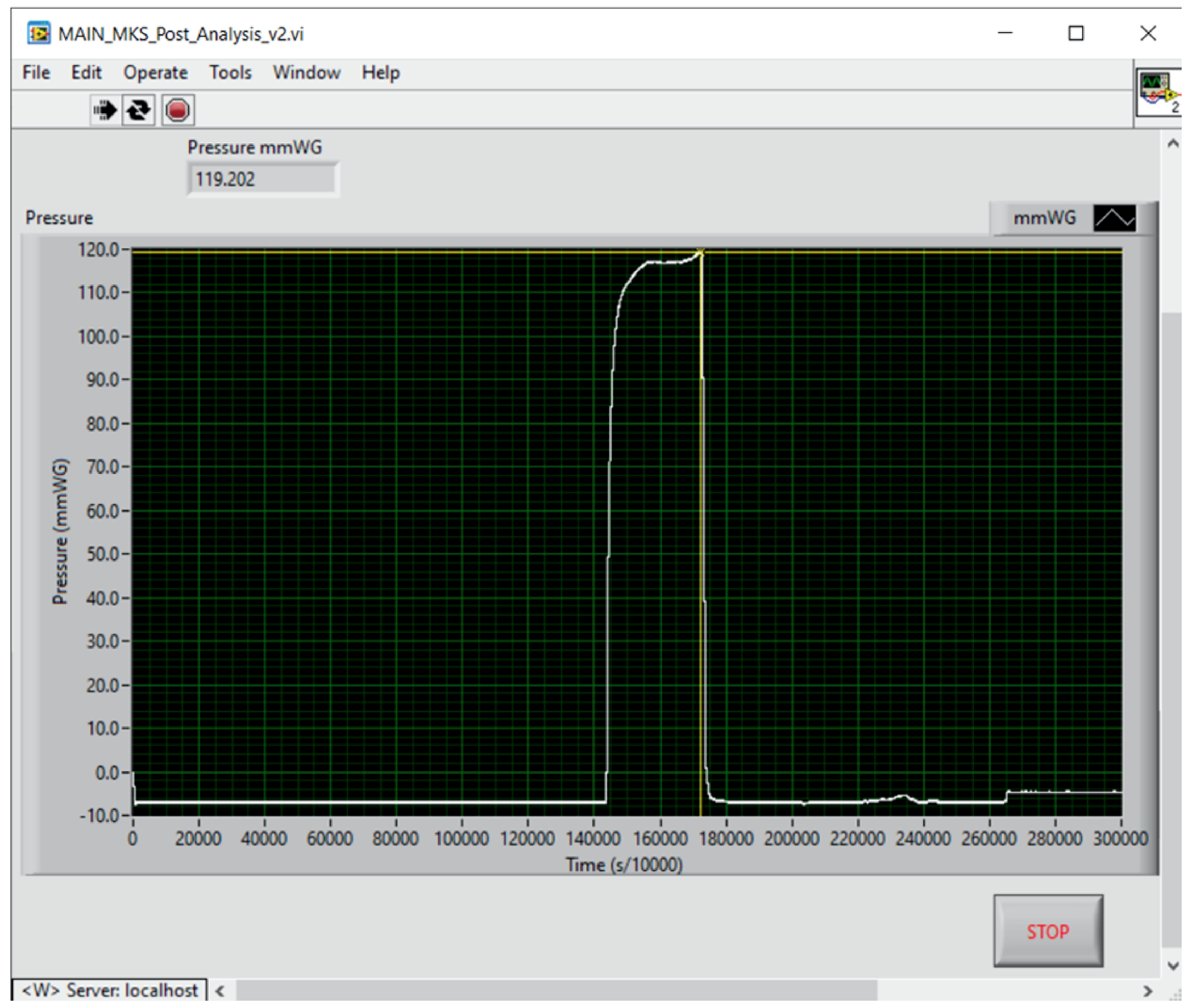

Figure 2: Pressure drop trace captured by the Baratron transducer and logging system - normal (PD - 110mmWG, cartridge delivering consistent aerosol). Note slight distortion/rounding of leading edge of the nominally square wave form as a slight vacuum is produced in the system before aerosol is generated.

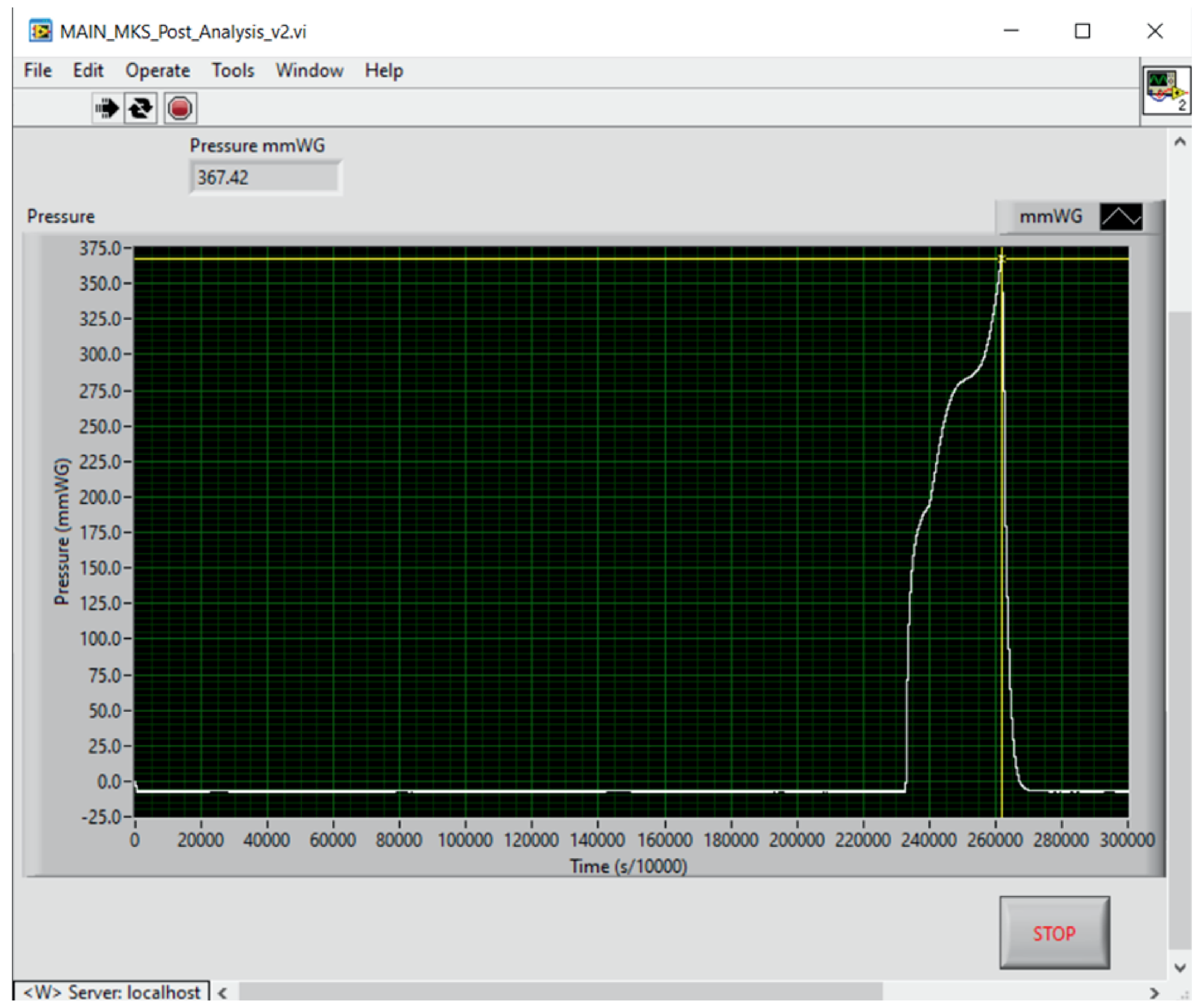

Figure 3: Pressure drop profile distorted (PD 375mmWG, indicating a blockage or solidifying liquid in cartridge, aerosol delivery impeded).

This highly distorted PD profile is caused by the liquid under test cooling impeding aerosol delivery.

17LV and 16MV were able to maintain fluidity throughout as the puffing regime self-heated the cartridge and produced a constant PD and aerosol with ACMs of 1.16mg/puff (17LV) and 1.33mg/puff (16MV) respectively.

The highly viscous product (18HV) which at room temperature resembled a 'solid' occasionally 'froze' in situ. When this occurred it was moderately heated to 50°C in an oven which increased aerosol delivery, although ACM was still lower than 17LV and 16MV with an ACM of 0.76mg/puff.

CONCLUSIONS

Our experiments highlighted the challenges of producing a consistent aerosol delivery on a puff-by-puff basis with these very viscous liquids, but showed it was possible to distinguish between the products, whereby the mass of ACM delivered varied between 0.76mg and 1.33mg per puff dependent upon the liquid viscosity. The use of the in-line transducer alerted us in 'real time' to increased PD, which indicated volatilisation was dropping during puffing due to liquid fluidity (viscosity) restricting transport to the heater.

ACKNOWLEDGEMENTS

We would like to thank Kaycha Laboratories, Denver, Colorado, USA, for sourcing the test products, and for the use of their laboratory to conduct the analyses.

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