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Characterisation of E-cigarette Aerosol Generation Behaviour

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CORESTA Congress, Québec City, 2014
ST 42

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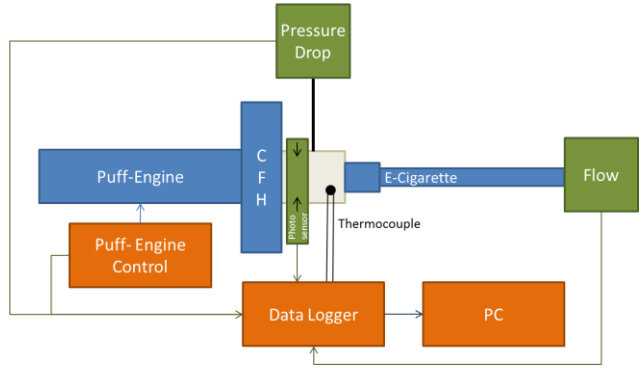
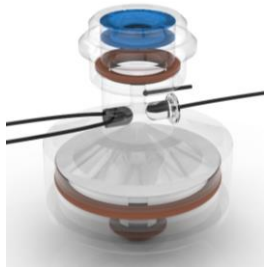
Introduction and Objectives

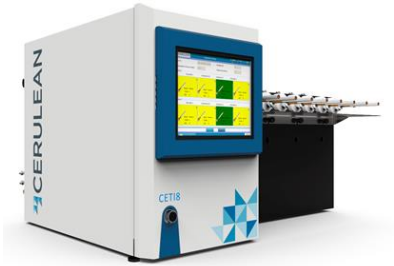
- E-Cigarettes generate aerosol by vaporising ‘e-juice’ carried by a wick to a heating element
- Aerosol production is initiated in many products by a flow sensor in the body of the device
  - Varying trigger flows have been observed
- This work aimed to characterise aerosol production using simple devices to monitor the function of the heater and the resulting production of aerosol in two flow-triggered product types (disposable and rechargeable)

Experimental Set-Up

- Simultaneous logging of:
  - Puff valve state
  - Puff temperature
  - Aerosol opacity (photo cell)
  - Pressure drop
  - Inlet flow (on occasion)
- Logging rate up to 100 samples / s
- Square puffs 55 ml / 3 s / 30 s

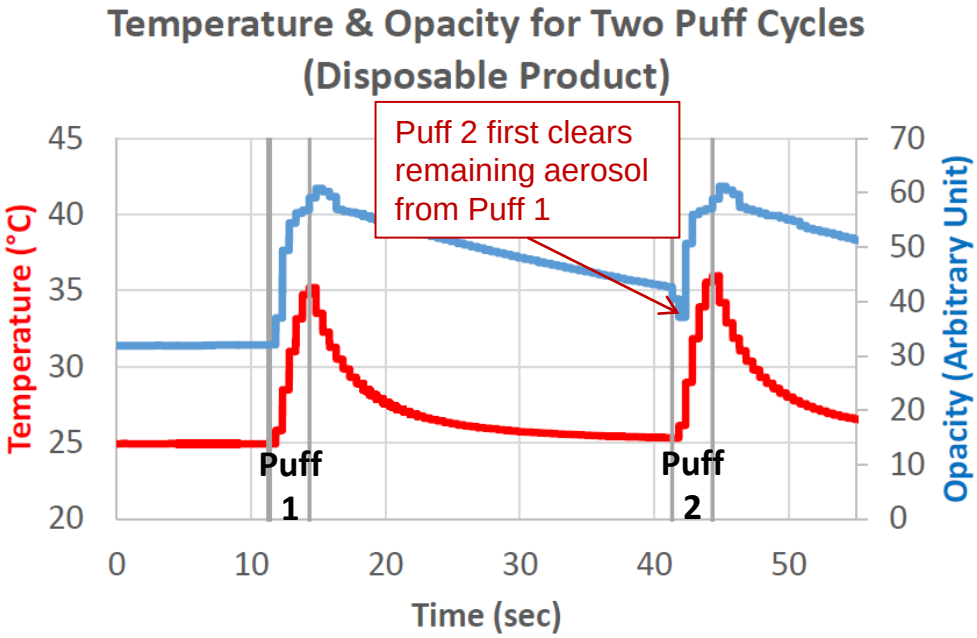






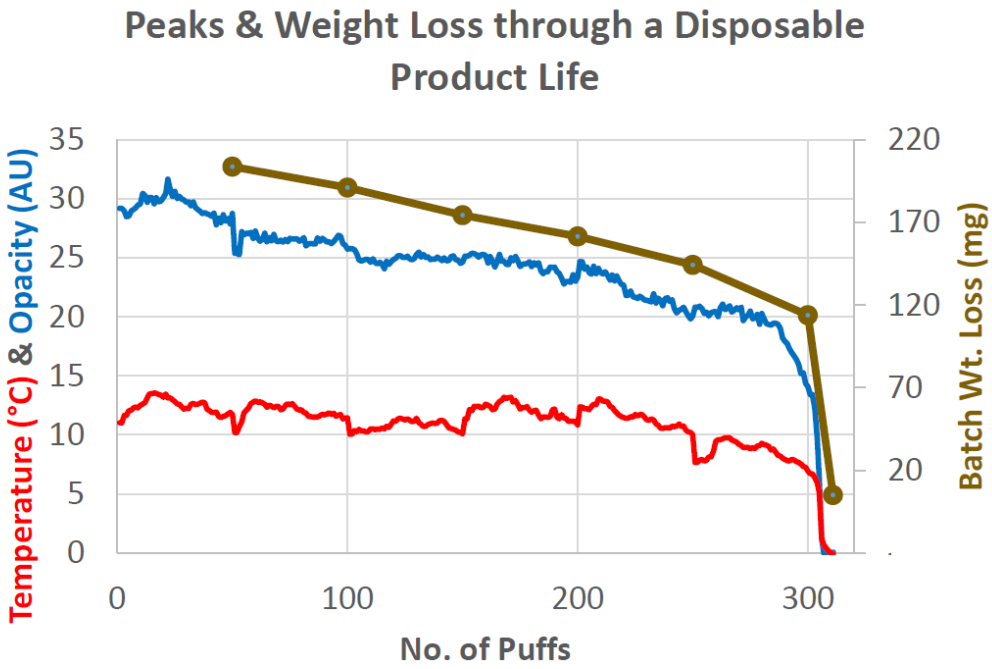
Opacity and Temperature Output Log

- The output of the photo-cell was trimmed to give a convenient range for logging
  - Denser aerosol = +ve
- Measures are
  - Peak value
  - Area under curve
  - Cumulative area



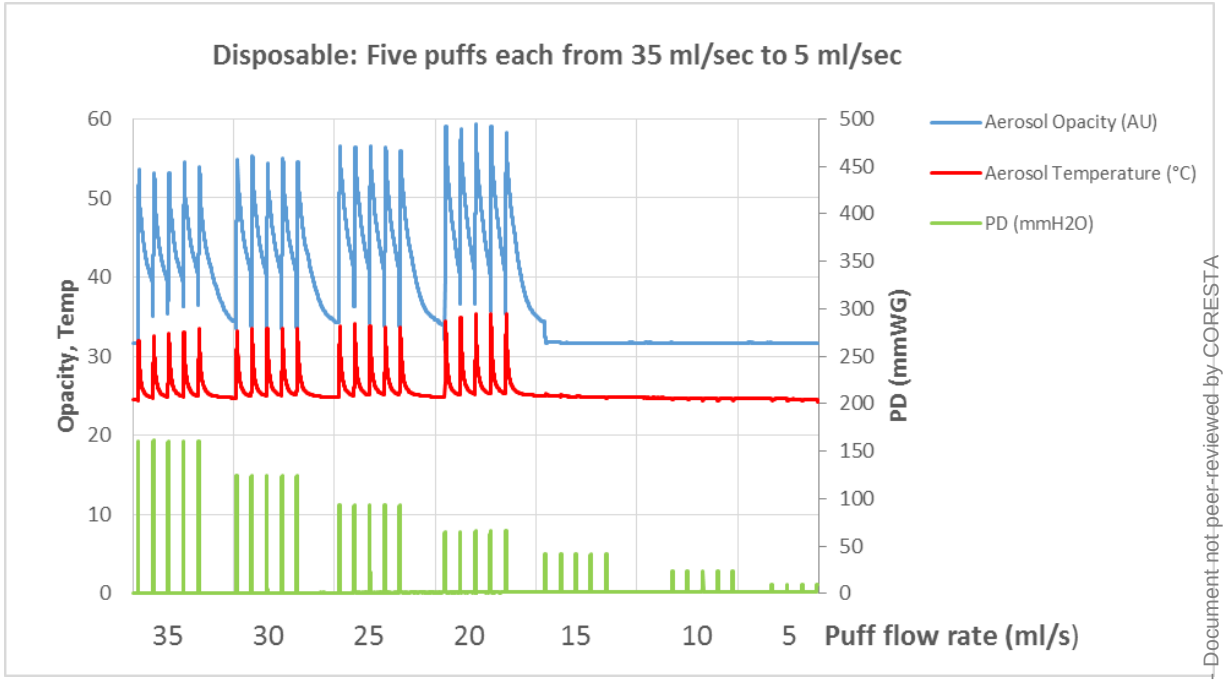
Through-Life Characteristic

- Disposable product
- Plotting opacity & temperature peak values for each puff & weight loss every 50 puffs
- Gradual decline in yield and opacity until the battery is exhausted



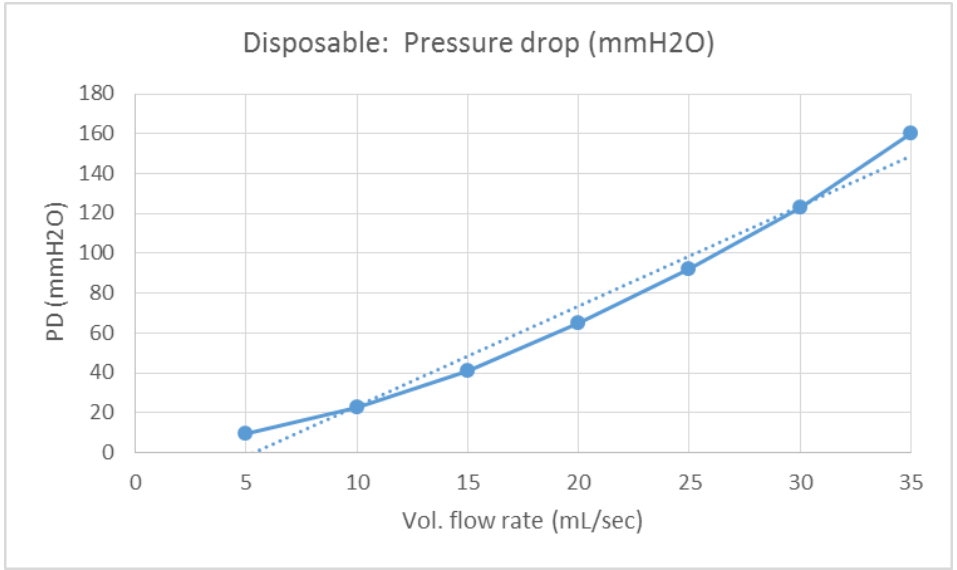
Disposable Product: Effect of Flow Rate

- 5 puffs at each of 35 – 5 ml/s
  - 2 s, square
- Plots of opacity, temp and PD
- Aerosol generation starts between 15 & 20 ml/s
  - 55 ml / 3 s puff = 18.3 ml/s



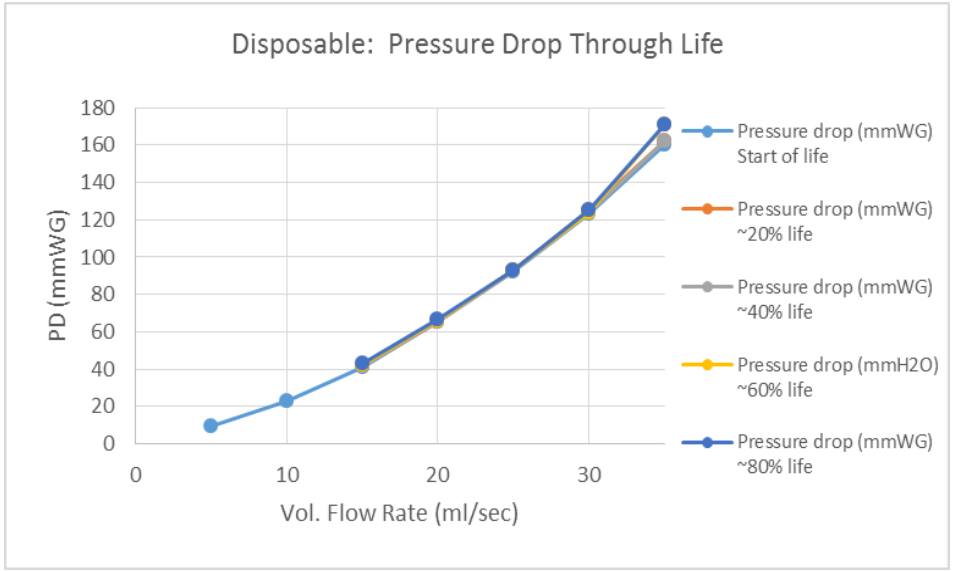
Disposable Product: PD vs flow

- Pressure drop is non-linear with flow rate
- Around 60 mmWG for ‘normal’ puff rates



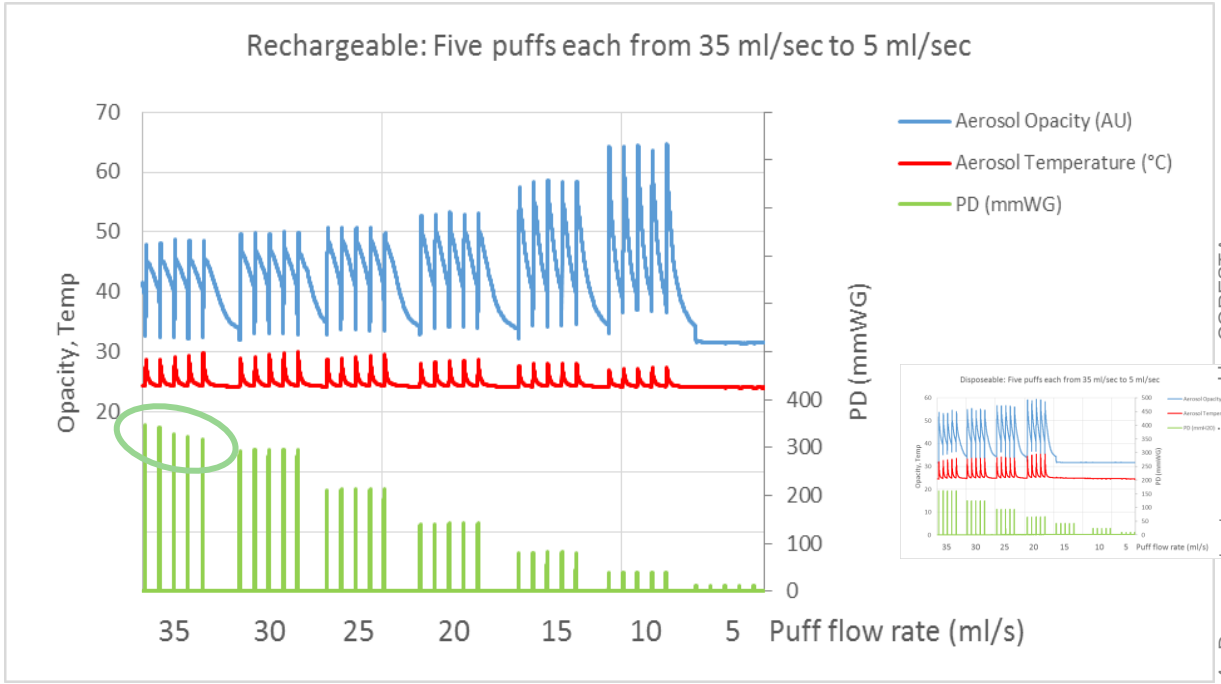
Disposable Product: PD vs flow

- Pressure drop is non-linear with flow rate
- Around 60 mmWG for ‘normal’ puff rates
- No significant change in PD over life



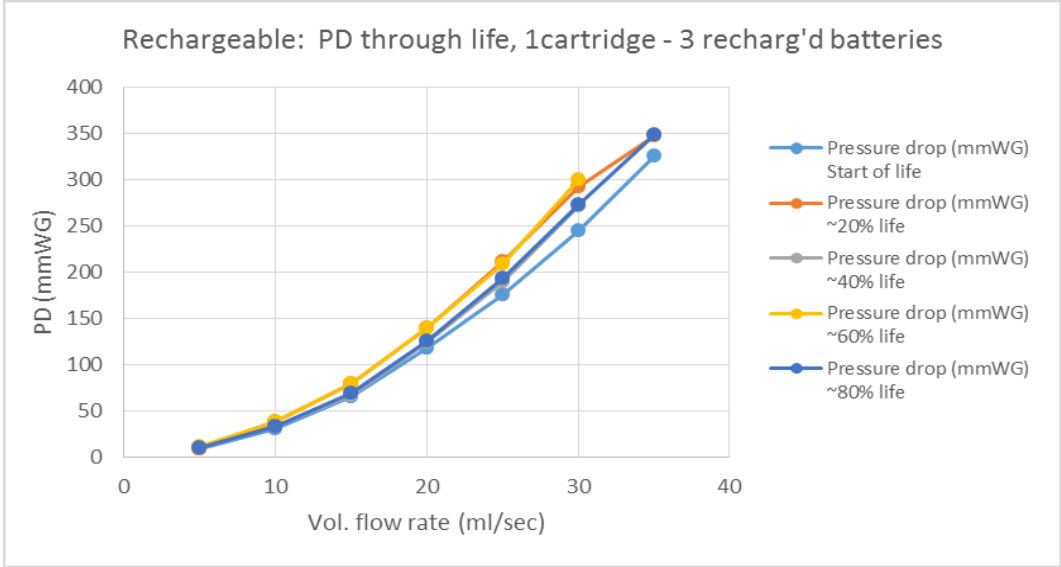
Rechargeable Product

- Aerosol generated down to 10 ml/s
- Unstable PD at high flow
  - Whistling at 35 ml/s



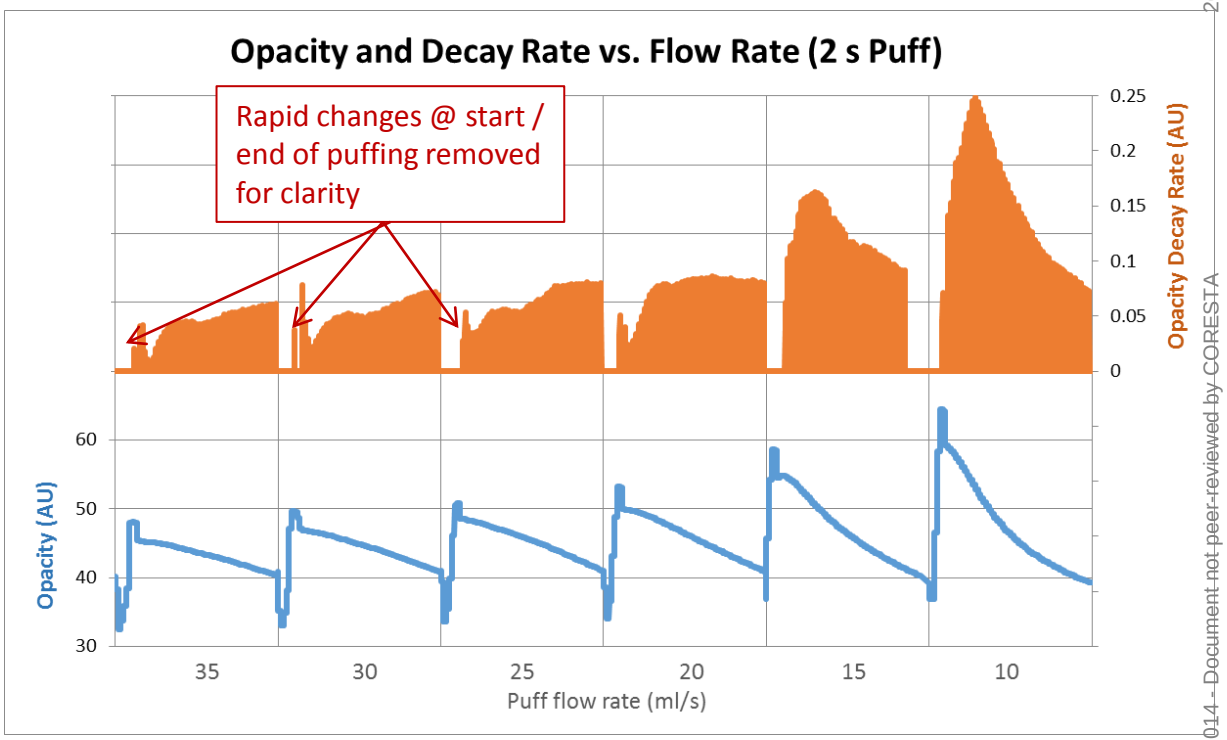
Rechargeable Product

- Higher PD than the disposable
  - ‘Cigarette’ range
- Some variation in PD as the battery unit is exchanged to empty the e-juice reservoir



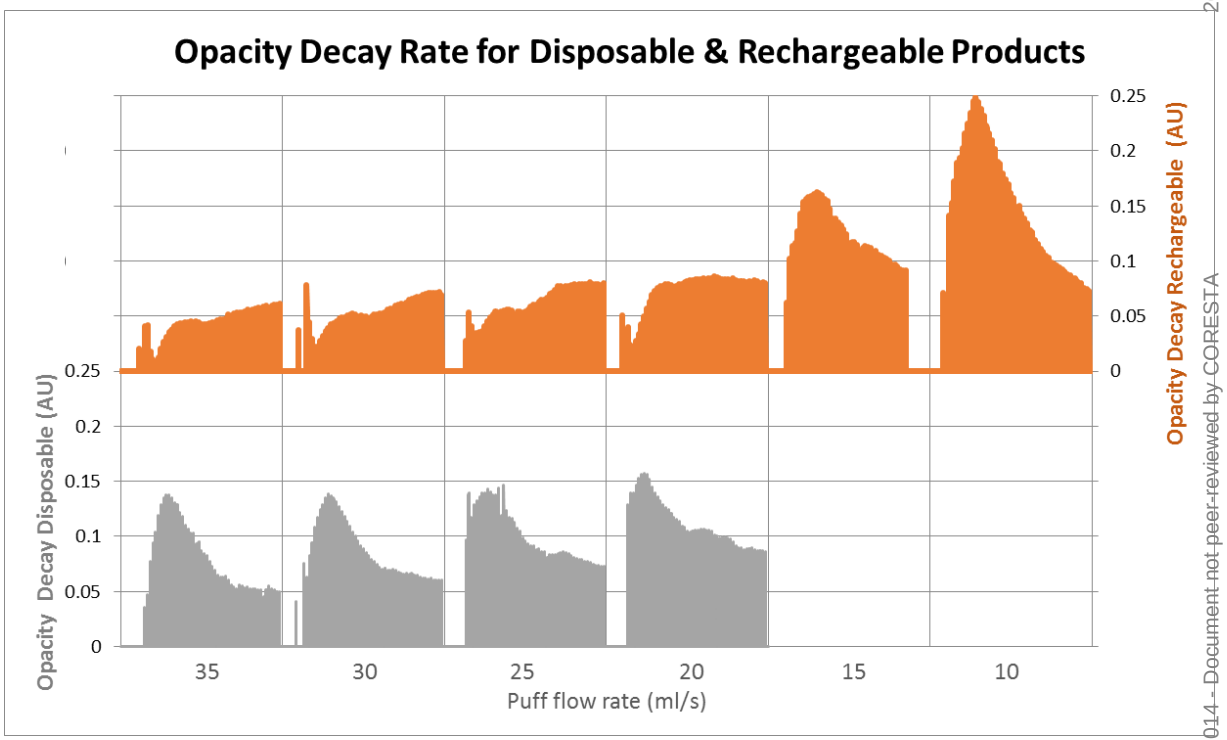
Rechargeable: Aerosol Opacity Between Puffs

- Profile of decay curves for different puff flows (volume)
- Decay profile evolves left to right
- Qualitative idea of the visibility and longevity of the aerosol



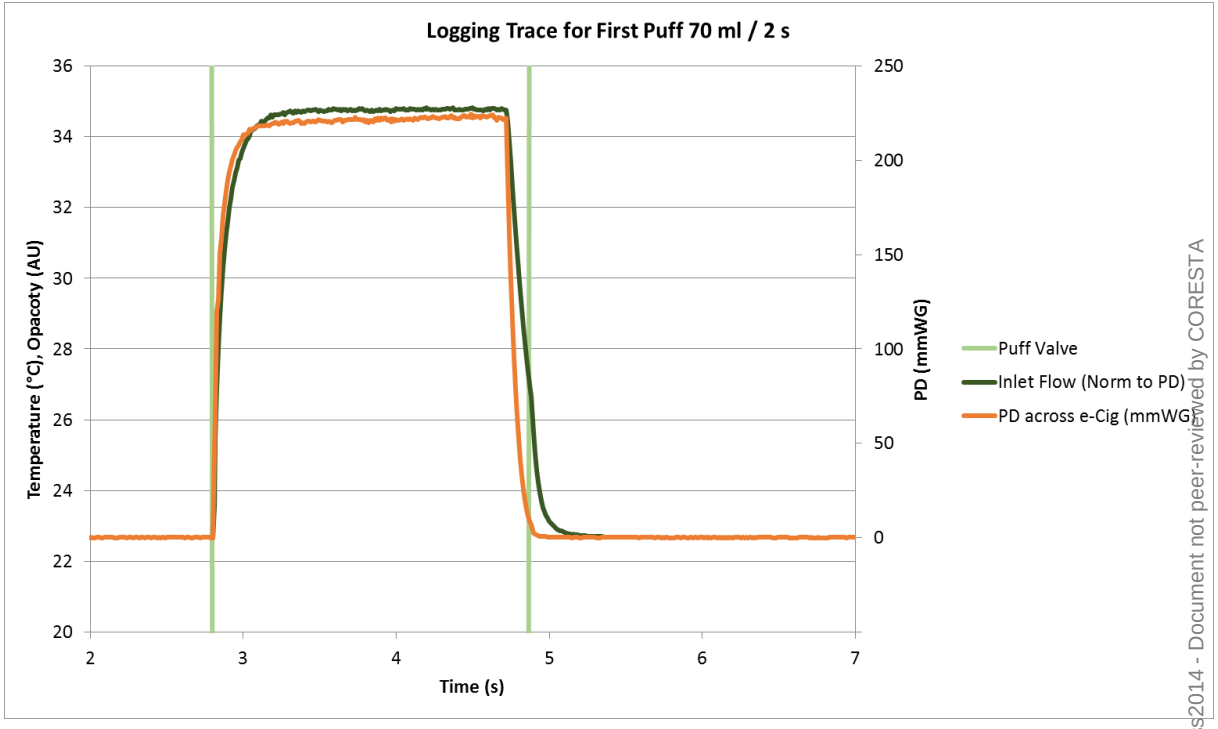
Opacity Decay: Comparing Disposable & Rechargeable

- Plots on same scales
- Clearly different
  - and different evolution
  - Grey profiles similar to 'low flow' orange profiles



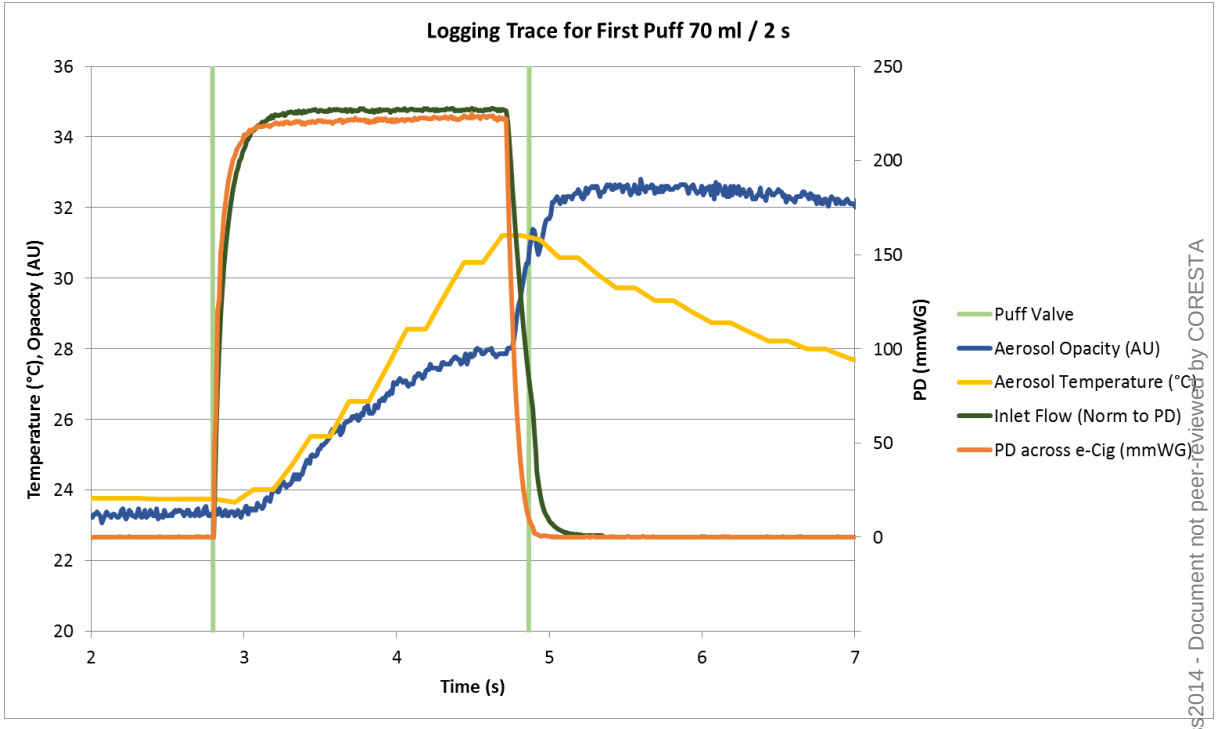
In-Puff Analysis: Disposable Product

- Note that the puff flow is inset within the valve-open time



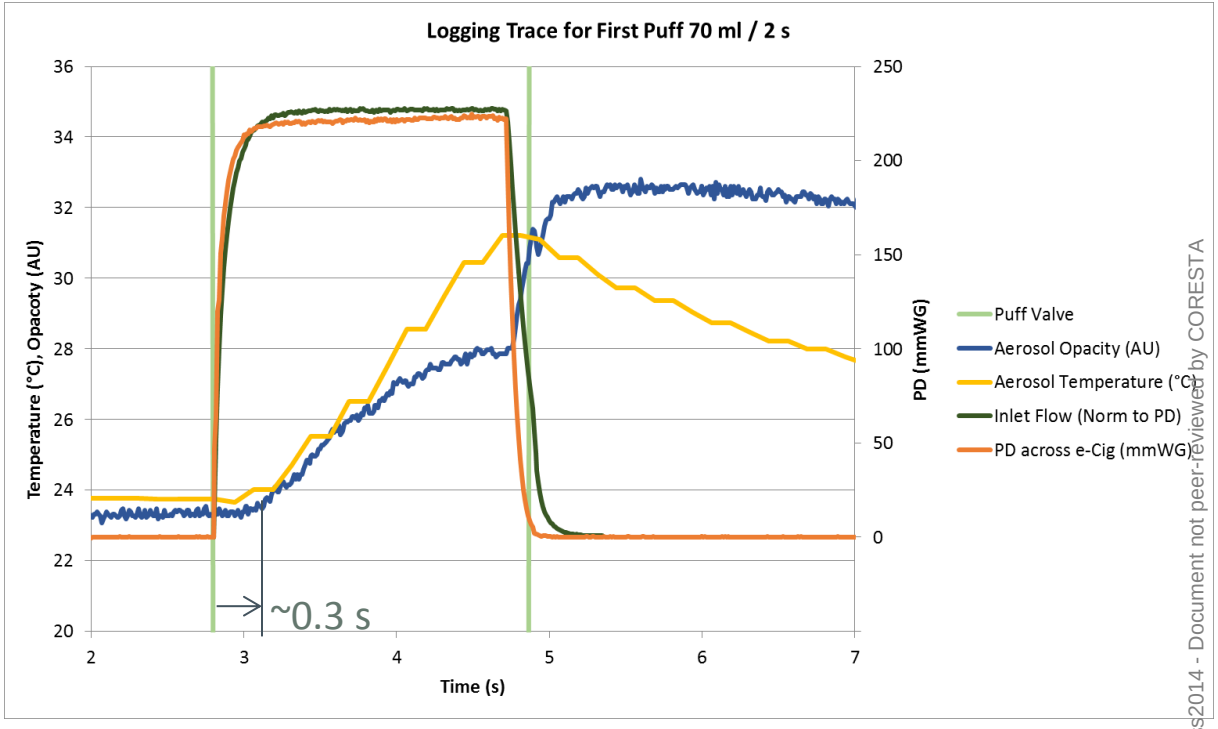
In-Puff Analysis: Disposable Product

- Note that the puff flow is inset within the valve-open time
- First puff



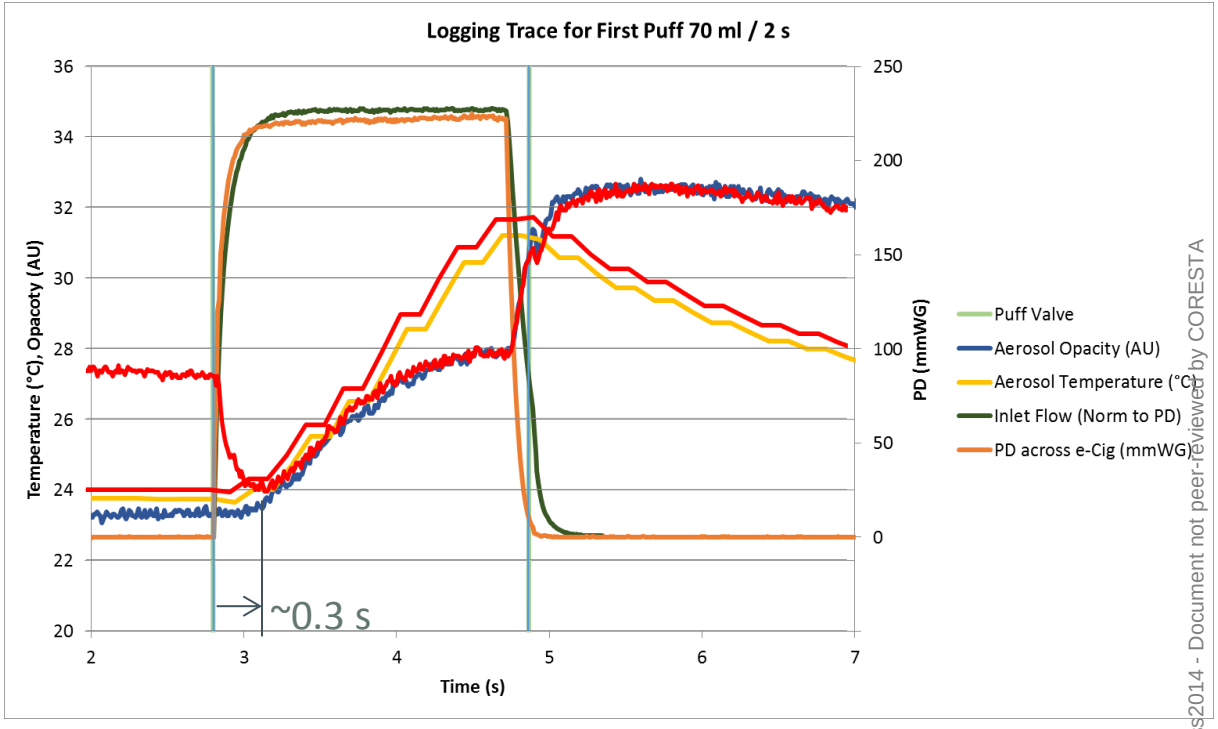
In-Puff Analysis: Disposable Product

- Note that the puff flow is inset within the valve-open time
- First puff
  - ~0.3 s time lag until aerosol starts



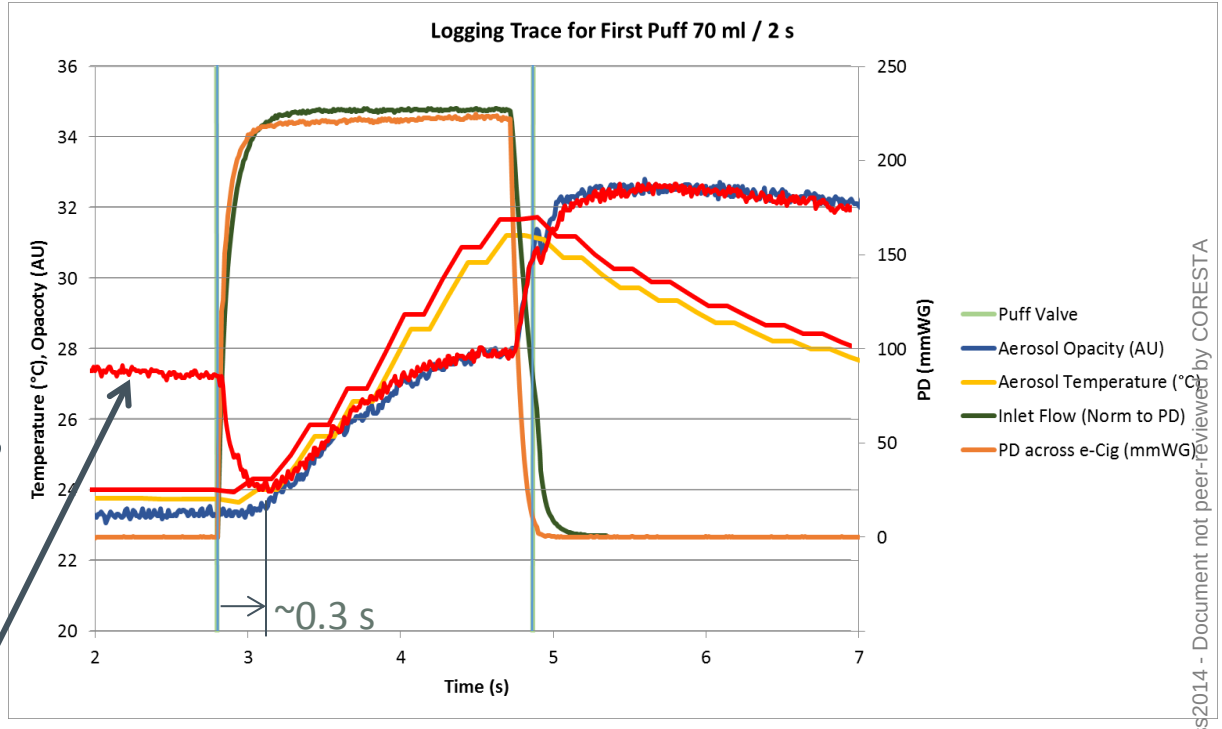
In-Puff Analysis: Disposable Product

- Note that the puff flow is inset within the valve-open time
- First puff
  - ~0.3 s time lag until aerosol starts
- Second puff overlaid



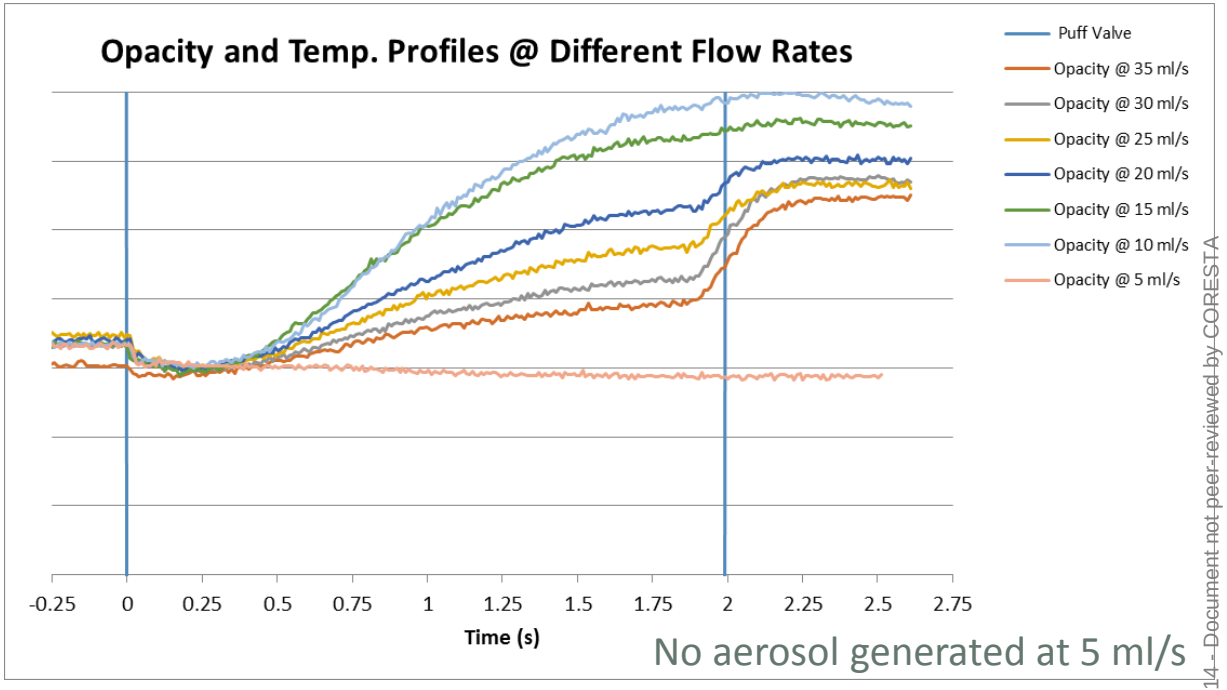
In-Puff Analysis: Disposable Product

- Note that the puff flow is inset within the valve-open time
- First puff
  - ~0.3 s time lag until aerosol starts
- Second puff overlaid
- Aerosol not fully cleared from 1st puff



In-Puff Analysis by Flow Rate (Disposable)

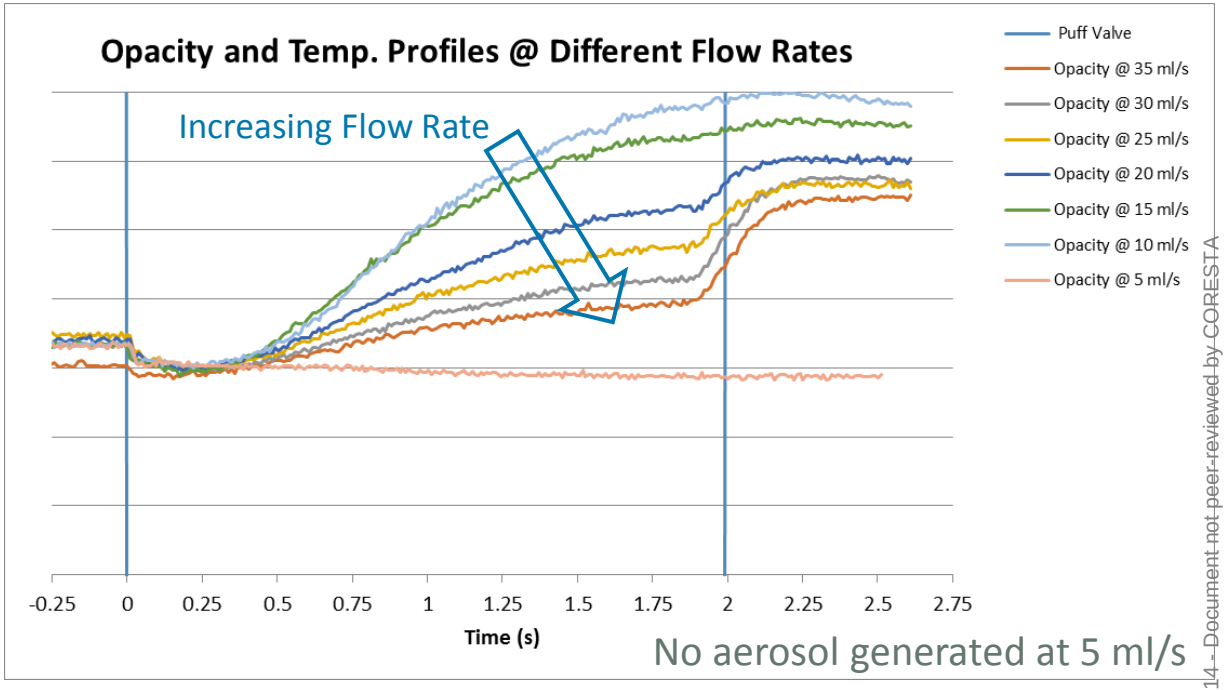
- Opacity profiles @ 5 – 35 ml/s develop with flow-rate



No aerosol generated at 5 ml/s

In-Puff Analysis by Flow Rate (Disposable)

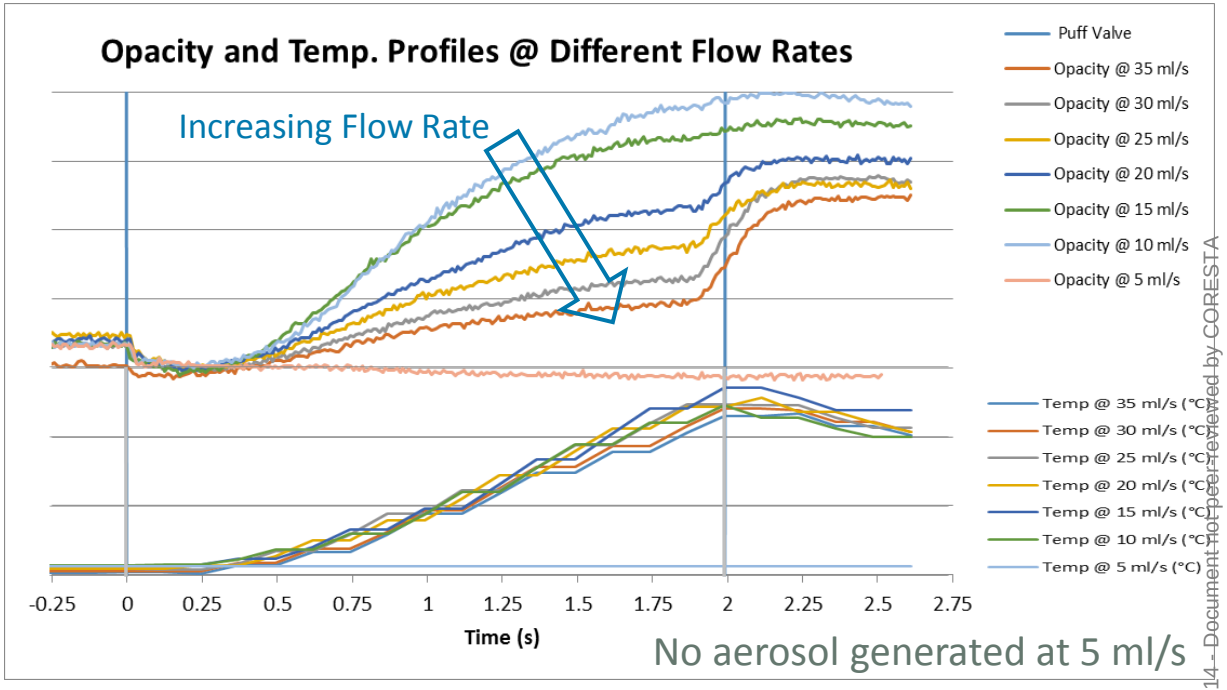
- Opacity profiles @ 5 – 35 ml/s develop with flow-rate
  - Notably the step at the end of the puff @ high flow



No aerosol generated at 5 ml/s

In-Puff Analysis by Flow Rate (Disposable)

- Opacity profiles @ 5 – 35 ml/s develop with flow-rate
  - Notably the step at the end of the puff @ high flow
- Temperature profiles remarkably consistent



Conclusions

- Real-time measurements of aerosol opacity and temperature can be captured using simple hardware
- Details of the aerosol generation process can be determined
  - In principle, test routines can be automated
- The information captured is qualitatively rich and has the potential to prove useful during product development and testing

Acknowledgements

- Daniel Ugbo
- Shabir Moghal
- Tony Baskett

- MOLINS plc for financial support and permission to present

And Finally…

- Thank you for your attention and

Any Questions?

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