BRITISH AMERICAN TOBACCO

REAL-TIME MEASUREMENT OF INHALED AND EXHALED TOBACCO SMOKE

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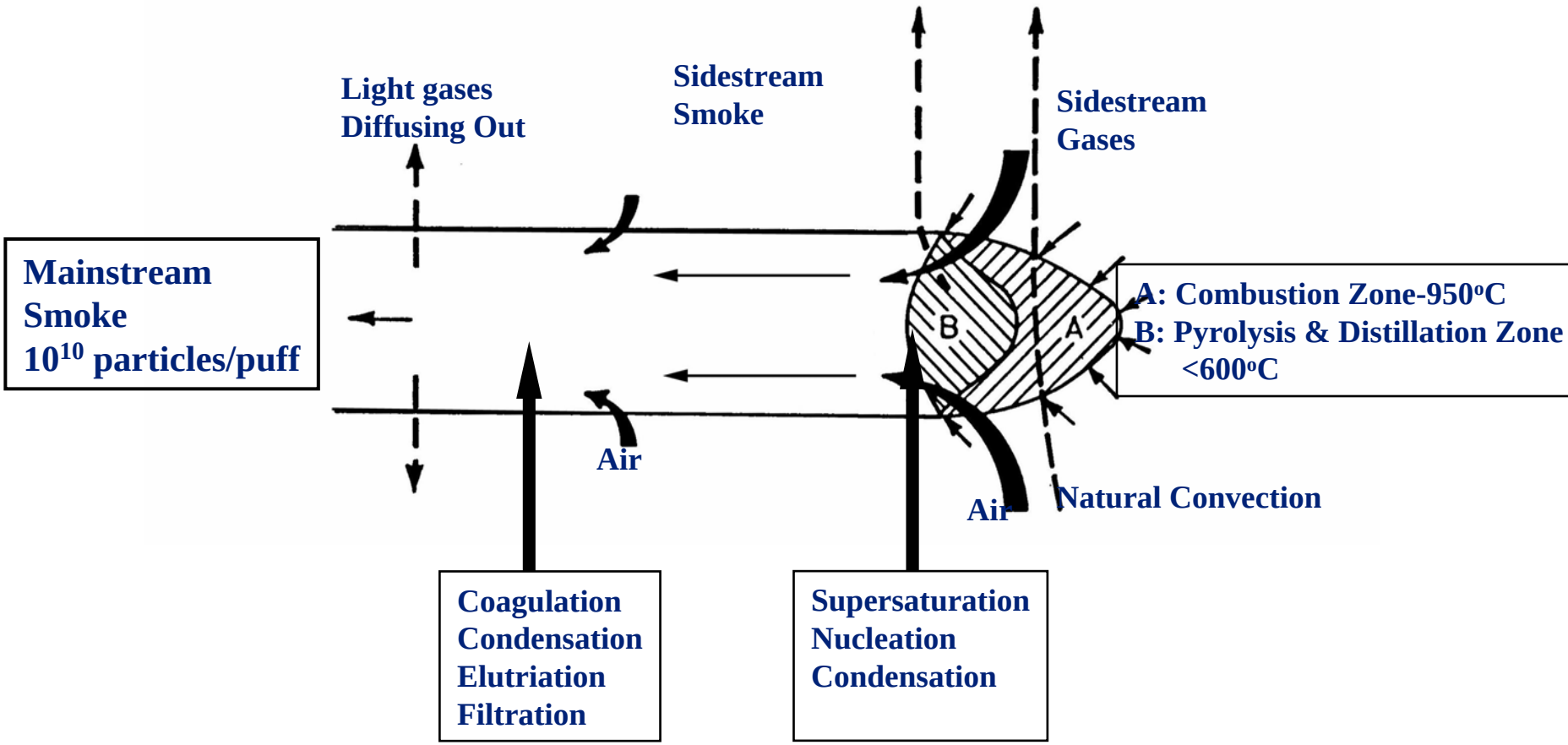
Background

- Wide range of particle diameters for tobacco smoke reported in scientific literature from 180 – 860 nm
  - Ingebrethsen Rec. Adv. Tob. Sci. 12: 54-142. (1986)
  - McRae Rec. Adv. Tob. Sci. 16: 233-323. (1990)
  - Bernstein, Inhalation Toxicology, 16: 675-689 (2004)
- Deposition efficiency of tobacco smoke = 60-80%
- Numerous mechanisms to explain enhanced deposition efficiency but no modelled fit
  - Coagulative growth
  - Hygroscopic growth
  - Cloud behaviour
- Direct measurement issues
  - Dynamics
    - Condensation / evaporation, concentration & coagulation effects
  - Size & concentration
    - Scattering intensity a d^{-6}
- Exhale capture studies
  - Solanesol markers
  - Particle diameter data e.g. Ingebrethsen via Las-X at high dilution (as MMD)
    - Machine 284 $\pm$ 4 nm
    - Mouth 378 $\pm$ 23 nm
    - Exhaled 331 $\pm$ 16 nm

Study design

- Direct measurement of mainstream smoke
  - Minimum dead time (300 ms)
  - Minimum dilution (50:1)
  - Fast resolution electrical mobility spectrometry (10 Hz)
- Particle growth *in vitro* by coagulation and hygroscopicity
  - Adapted water-based CPC as saturator
  - Reduced flow rate to match lung residence time (~7.5s)
- Particle growth *in vivo* by inhalation and exhalation
  - Data from three volunteers smoking four cigarette brands
  - Smoking pattern measured and re-smoked as above
  - Spectra from smoke sampled directly to mobility spectrometer on exhalation
- Supporting data from a parallel solanesol exhale capture study

Thermal and physical processes inside a burning cigarette



Human Smoking -Puffing Cycle

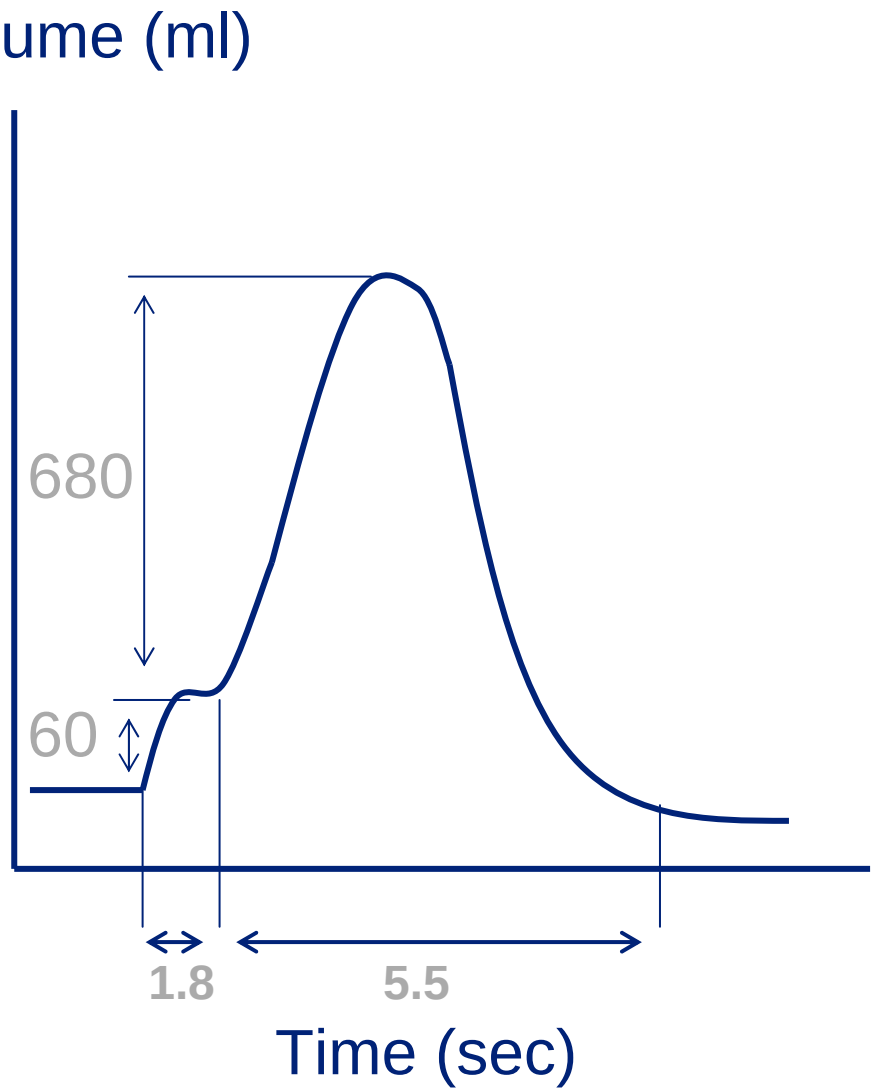
1.Puff

2. Mouth-hold

3. Inhalation

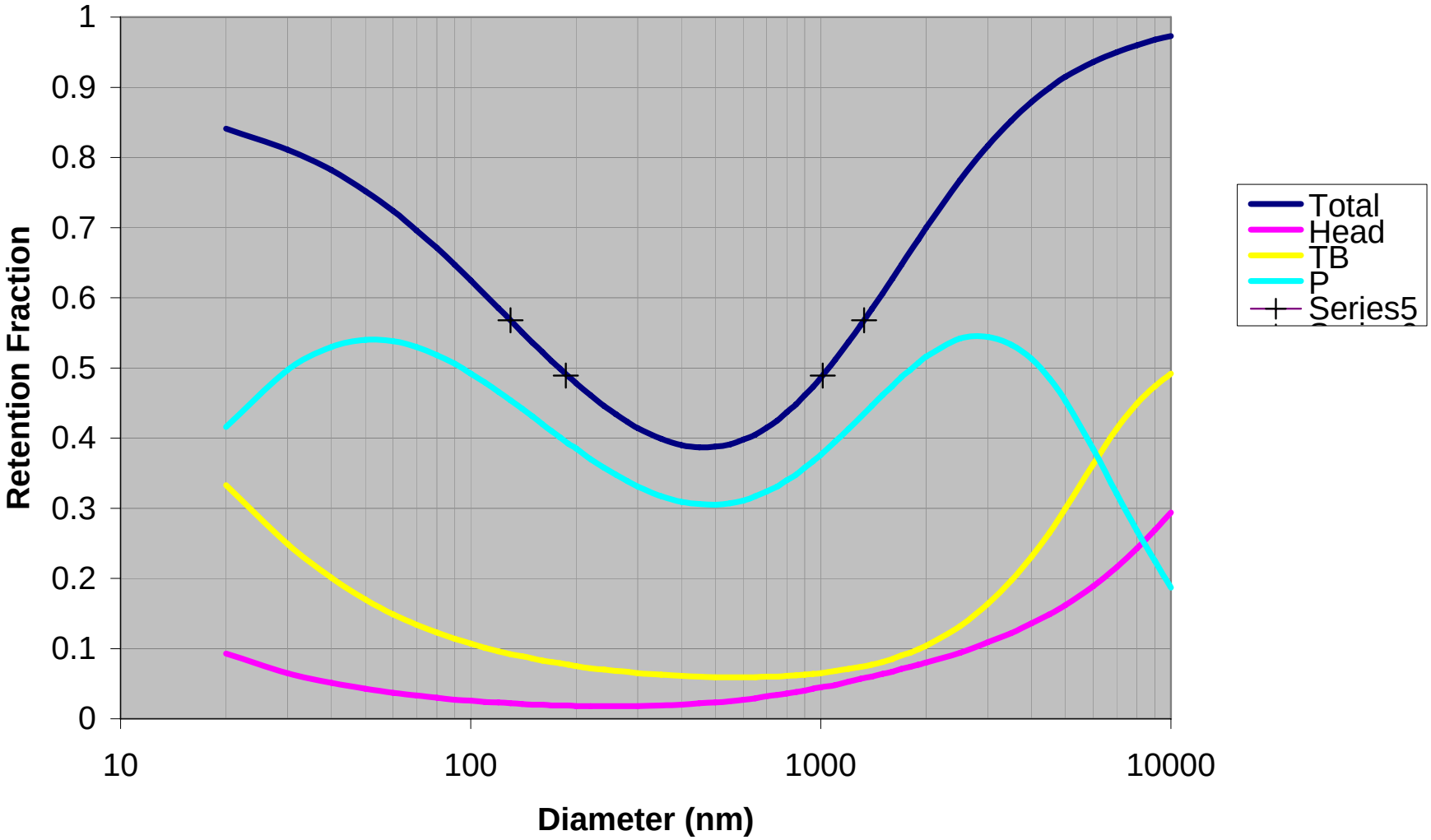
4. Breath-hold

5. Exhalation



Retention curve, MPPD Model

Modelled data for solanesol exhale capture study with controlled inhalation to VC_{15}



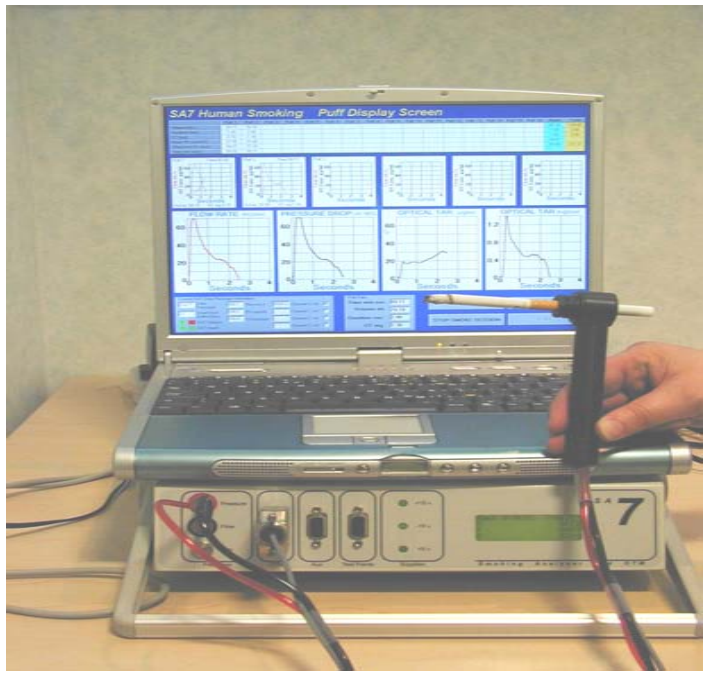
Human Smoking

Puffing behaviour measurements

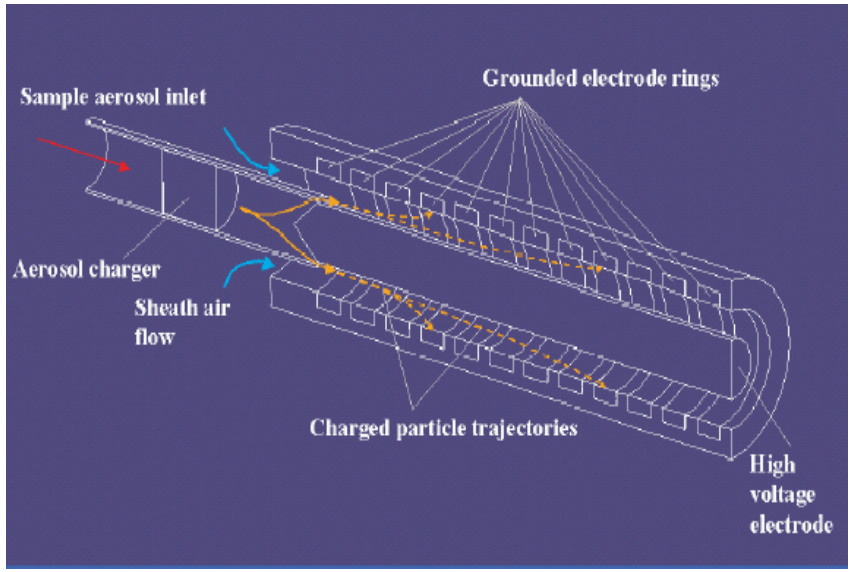
Cigarettes smoked through orifice type holder/ flow meter

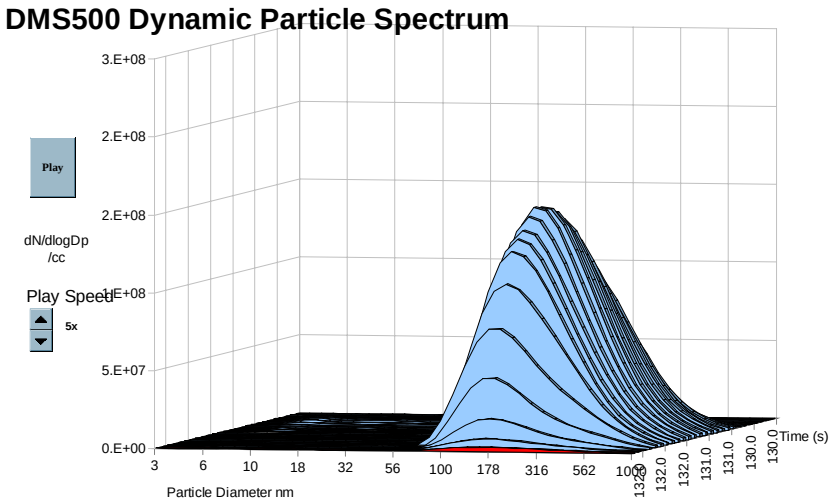
Smoking behaviour parameters measured:

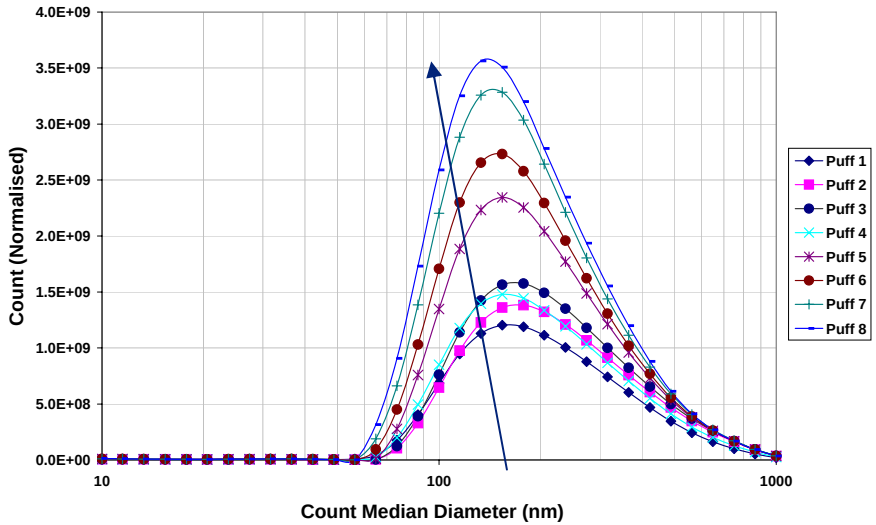
- Puff number
- Mean puff volume
- Mean puff duration
- Mean flow rate
- Intra puff interval



Measurement Sequence

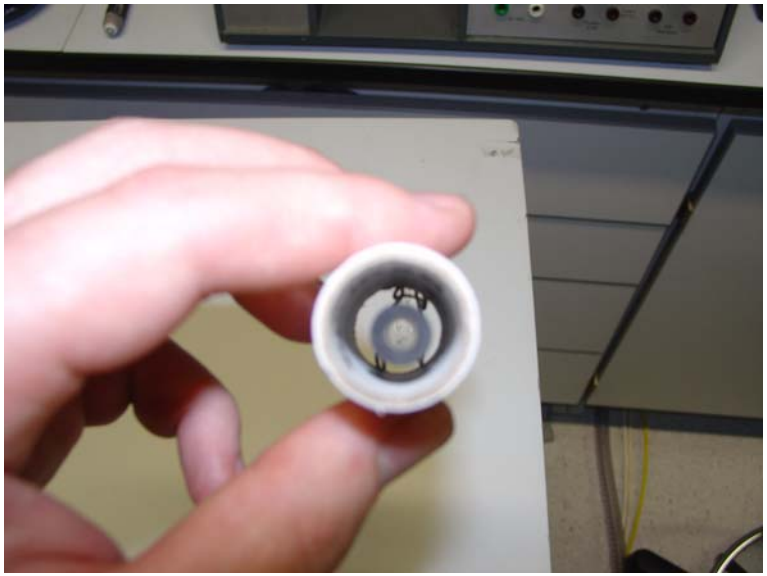




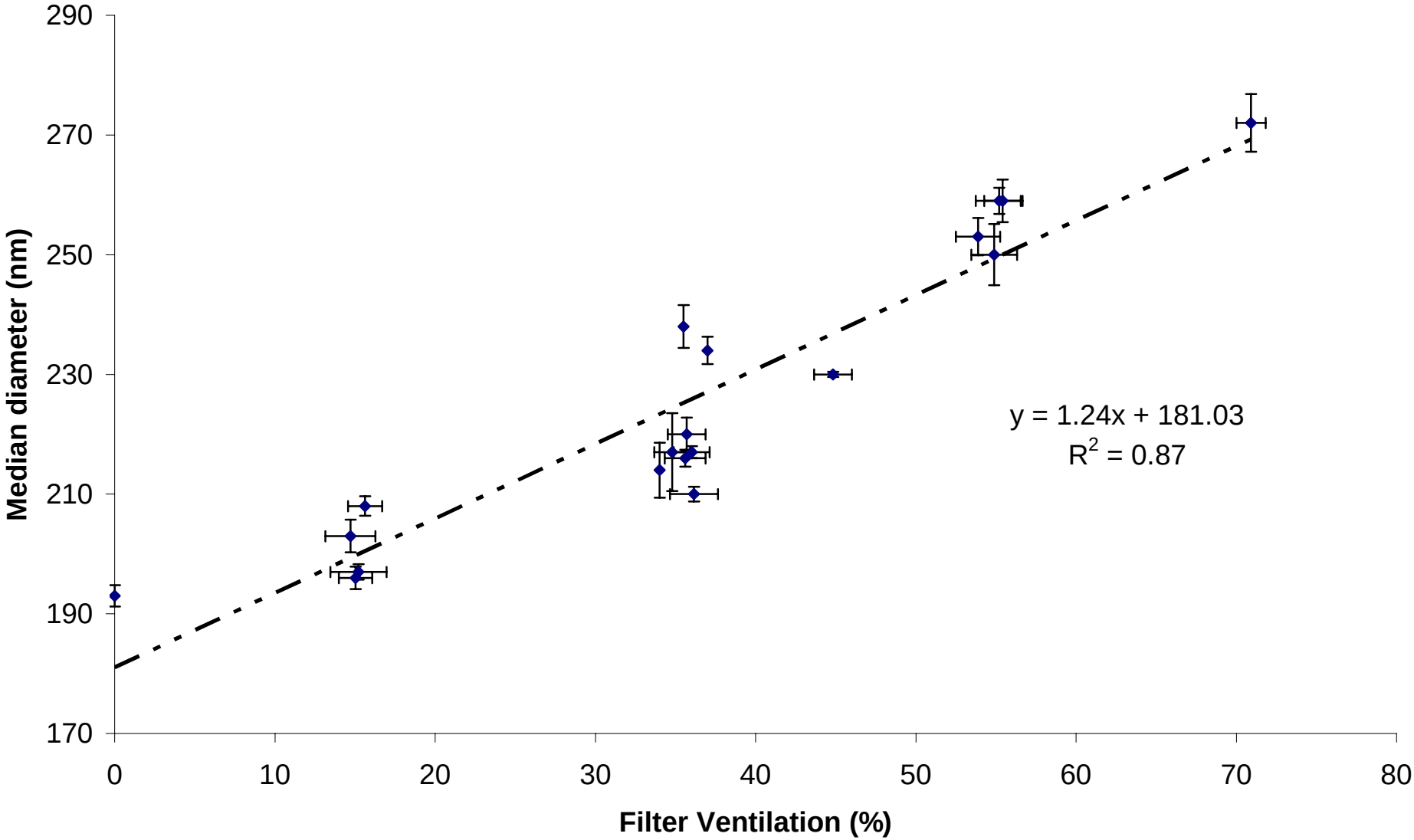


Discrimination of size puff by puff possible

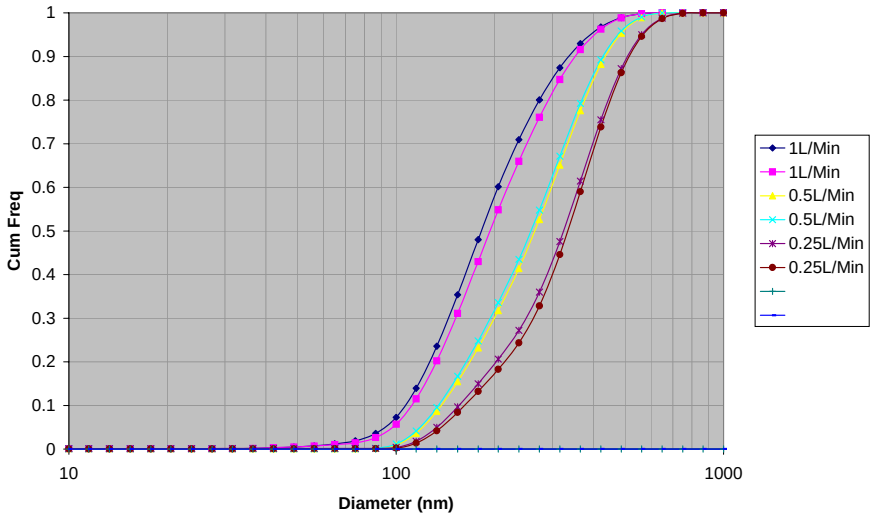
Sampling – Exhaled smoke

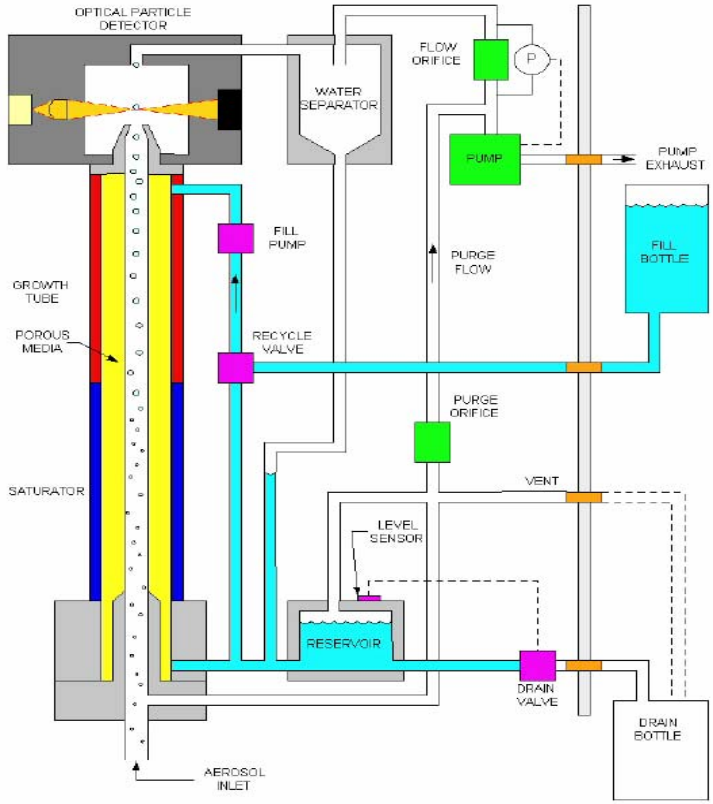


Diameter versus Ventilation



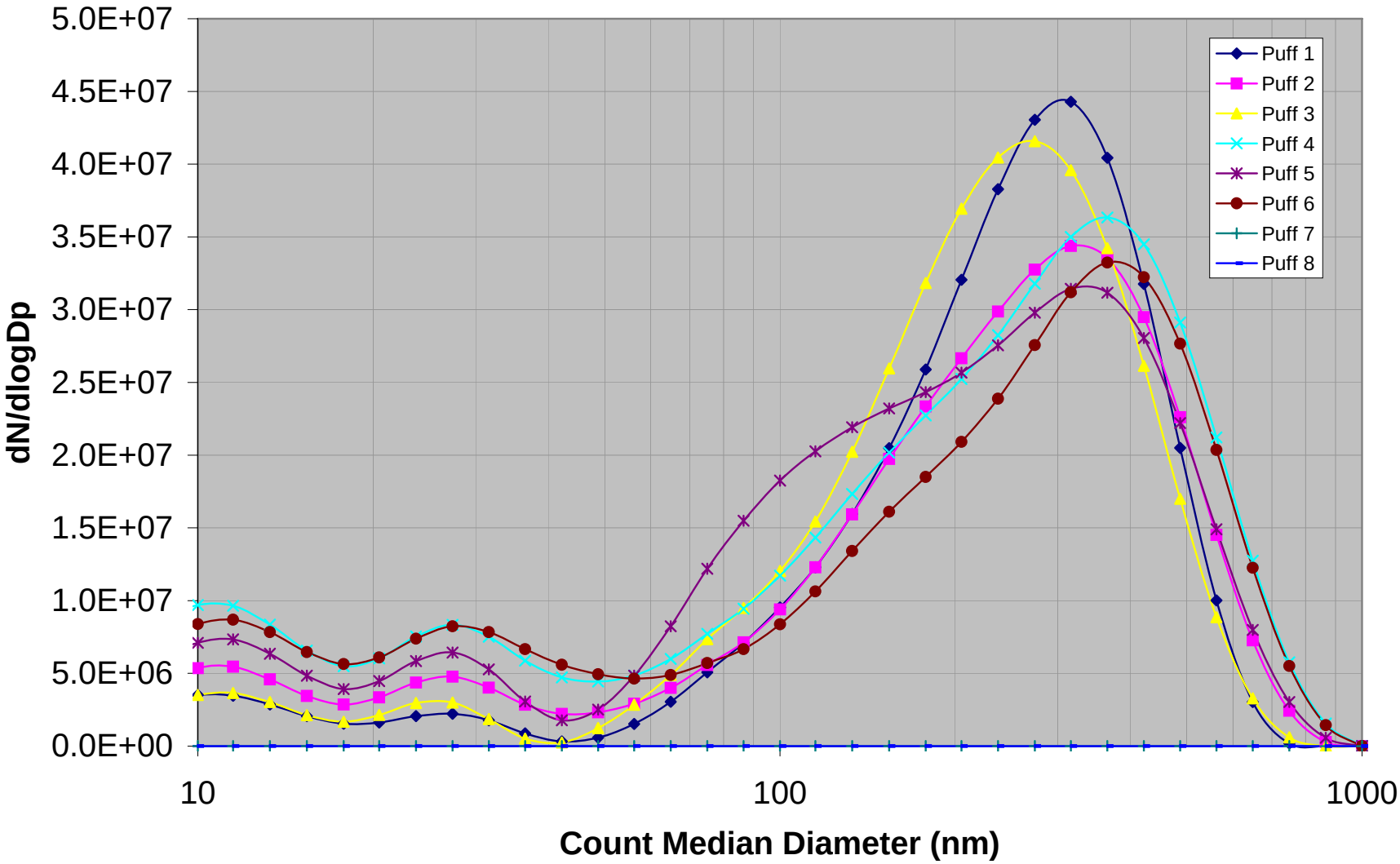
In vivo coagulative & hygroscopic growth



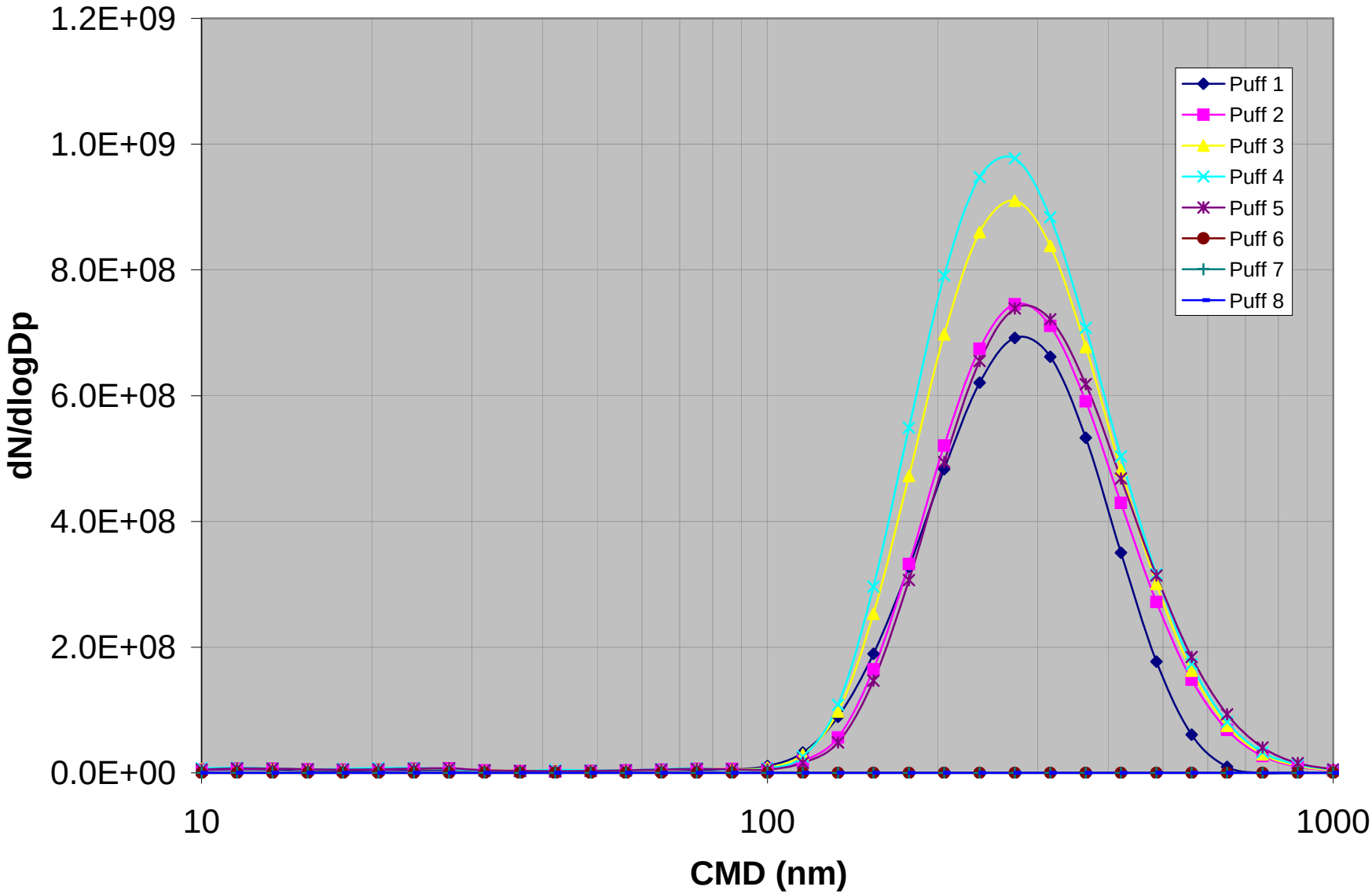


- Water based CPC used as saturator (TSI 3085)
- Undiluted smoke passed through
- Growth factors of 1.8 – 2.7 measured at 8 s ageing for various cigarettes

Smoke – Aged in mouth



Exhaled mainstream smoke



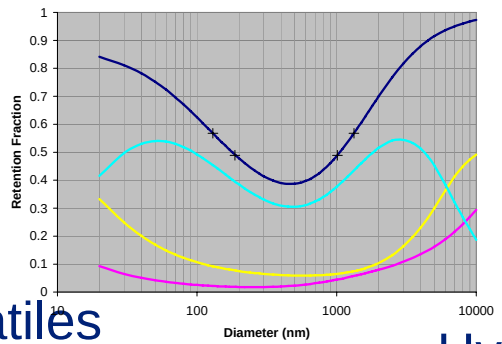
Smoking behaviour

Subject	B	H	J
	M	F	M
Mean solanesol retention (%)	37 ± 4	40 ± 4	45 ± 3
Mean puff volume (ml)	94	55	62
Mean puff flow (ml/s)	33	30	36
CMD (nm) : Inhaled	182 ± 8	186 ± 12	184 ± 8
CMD (nm) : Exhaled	250 ± 15	223 ± 18	187 ± 1
Growth Factor	1.38 ± 0.08	1.20 ± 0.02	1.03 ± 0.04

Particle deposition hypothesis

Enhanced Brownian Motion deposition
e.g. smaller particles in still air

Coagulative Growth



Evaporation of volatiles
e.g. nicotine with soluble sink

Hygroscopic Growth

Flow-mediated deposition
e.g. impaction

Further work

- Puff by puff analysis
- Within puff analysis (lung depth)
- Quantify retention by sampling efficiency correction from pneumotach data
- Repeat using controlled breathing profiles
- Investigate chemical-specific behaviour