# Experimental Investigation of ultrafine particle loss through flow splitters, flow fittings, and coiled tubes typically used in aerosol sampling systems

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## Background

- All aerosol measurement systems are subject to particle losses that can be described by discrete physical particle loss mechanisms, mainly including: diffusion, impaction, thermophoretic, etc..
- For ultrafine particles (<100 nm), diffusional particle loss mechanisms typically cause the majority of the losses – see Figure.1.
- For ultrafine particles the loss can be as large as 90% in terms of number[2].
- There are multiple particle loss models used (UTRC[3], PLC[4], aerocalc, etc..), which use semi-empirical relations.
- However, not all the relations have be rigorously validated against experimental results.
- In addition, not all aerosol sampling equipment has been fully validated.

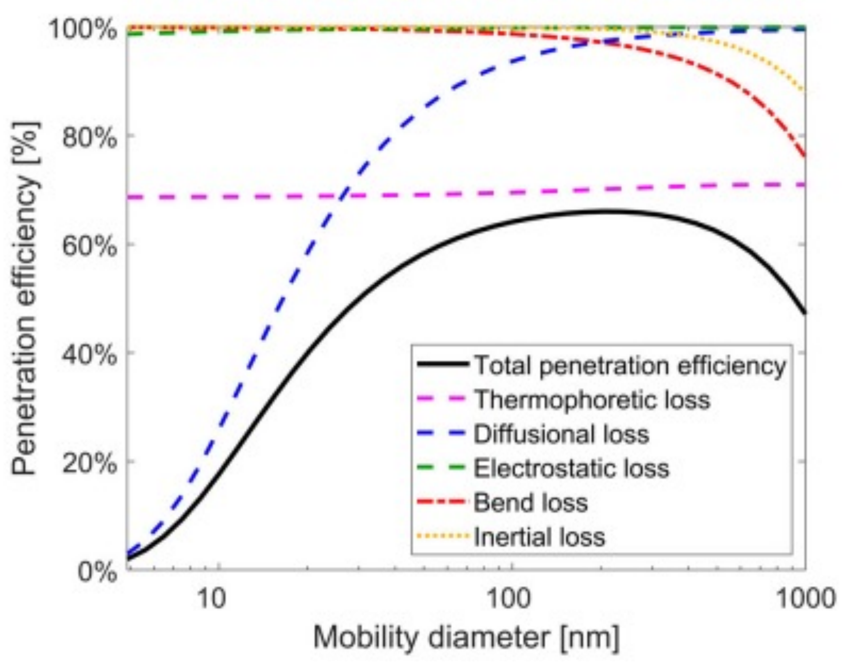


**Figure.1:** Typical particle loss curve using UTRC model[1]

## Aims

- Develop a test rig to repeatedly measure ultrafine particle losses.
- Use test rig to quantify ultrafine particle losses through aerosol measurement system elements.

## Methods

- Particle penetration measurements using a tandem SMPS system (Figure.2) for silver (~5-20 nm) and salt (20-60 nm).

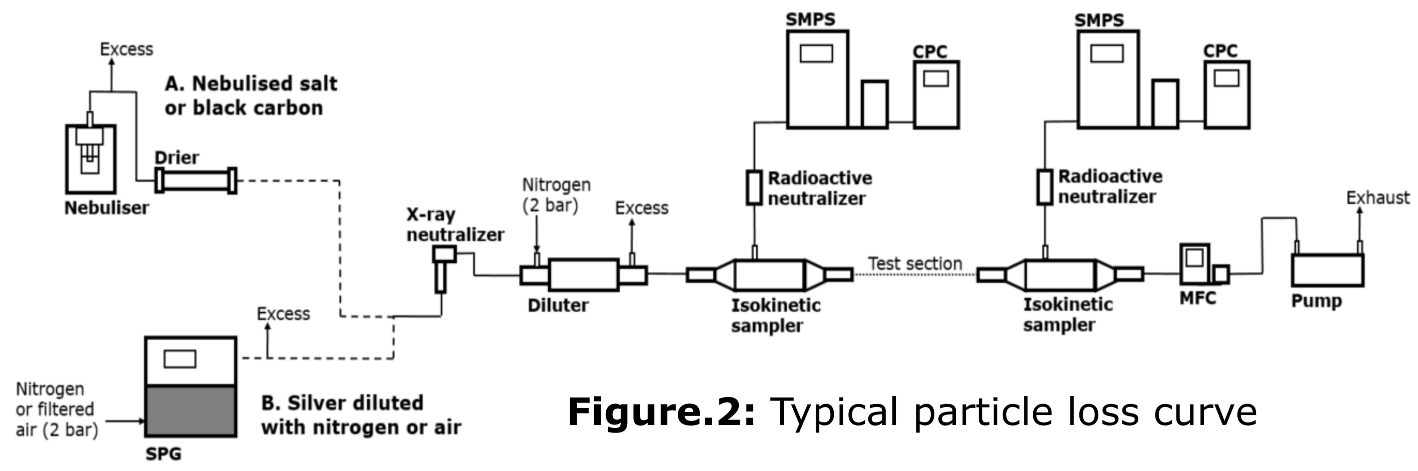


**Figure.2:** Typical particle loss curve

- Splitters: ¼" tee-piece, ¼" y-splitter, ¼" to ¼" and 1/8" y-splitter.
- Flow fittings: ¼" union, 3x ¼" unions in series, ¼" valve, ¼" x 5 cm long silicone all connecting two 3 m long ¼" stainless steel (extruded) tubes.
- Coiled and straight ¼" stainless steel tubes with bend radii of 10 cm – above the recommended 10 x internal tube diameters to mitigate additional particle losses[5].
- Experimental results compared against turbulent diffusion only model[6].

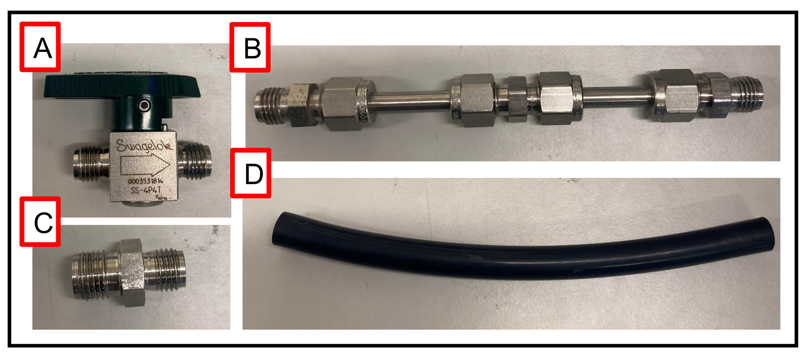

**Figure.3:** Flow fittings

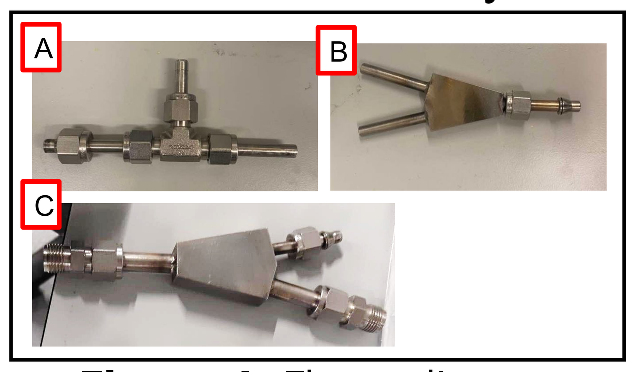

**Figure.4:** Flow splitters

## Results

### Flow splitters

- No significant additional particle losses observed using different flow splitters.
- Some potential evidence of particle losses with uneven flow split.

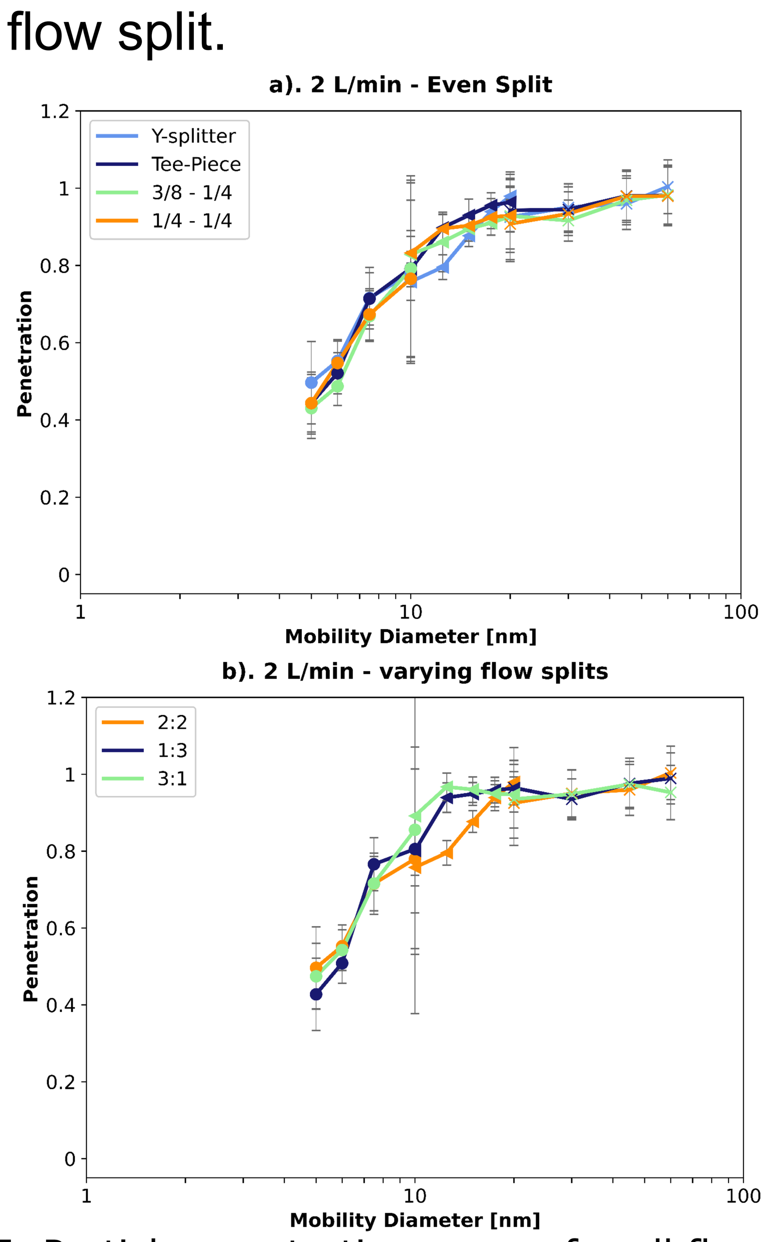


**Figure.5:** Particle penetration curves for all flow splitters with a). 2 L/min through each leg and b). varying flowrates

### Flow fittings

- For small particles (sub-20 nm), no perceivable difference between particle penetration curves.
- For large particles (above-20 nm), flow fittings start to have a small effect (red box) – below 10% difference from extruded tube.
- Flow fittings cause additional particle losses, most likely due to inertial or enhanced turbulence.

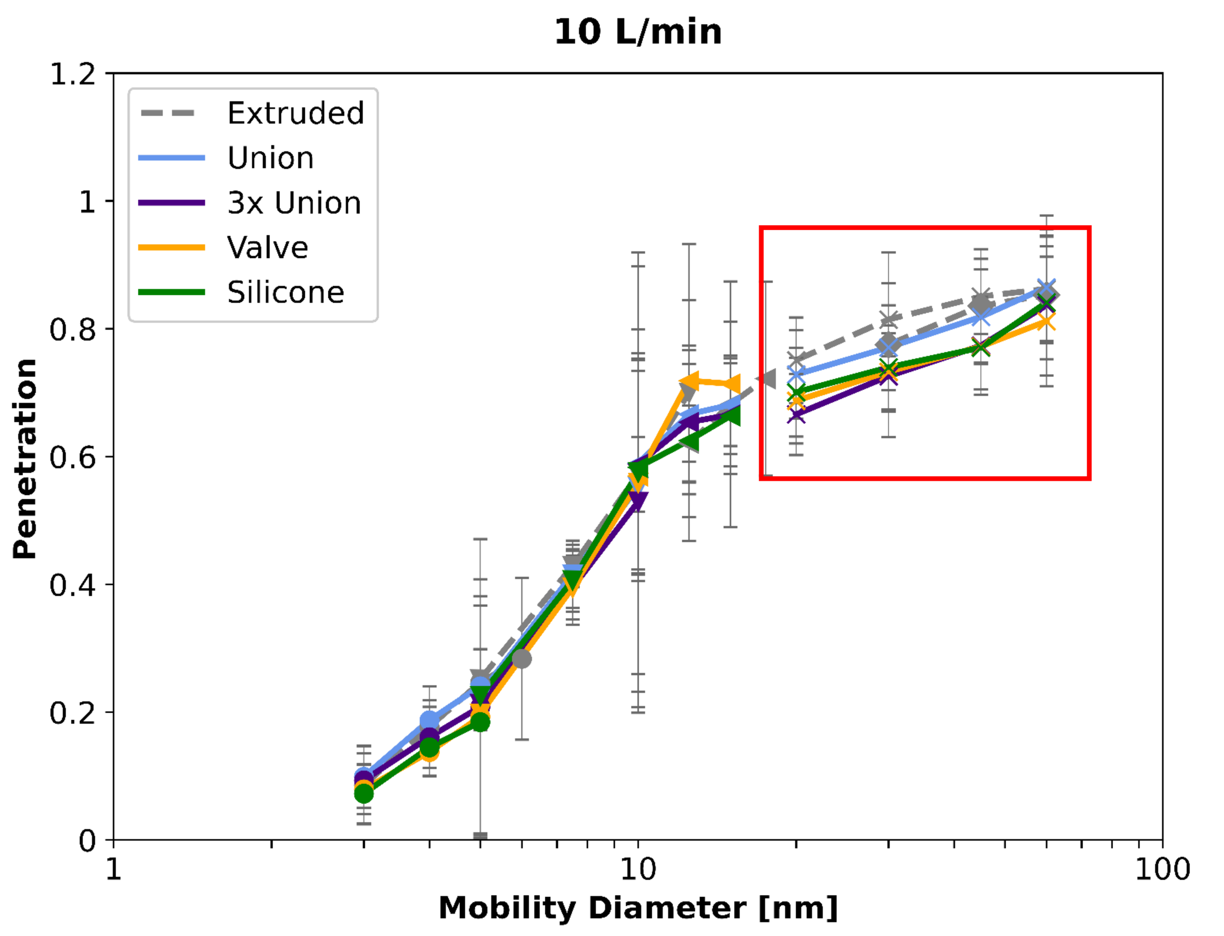


**Figure.6:** Particle penetration curves for all flow fittings for a flowrate of 10 L/min

### Coiled tubes

- Additional particle losses observed in coiled tubes for laminar, around 20% across all particle sizes, which was not observed for turbulent.
- More particle losses occurred for smaller particles compared to larger particles.
- The additional particle losses were caused by secondary flows set up from the tube coiling

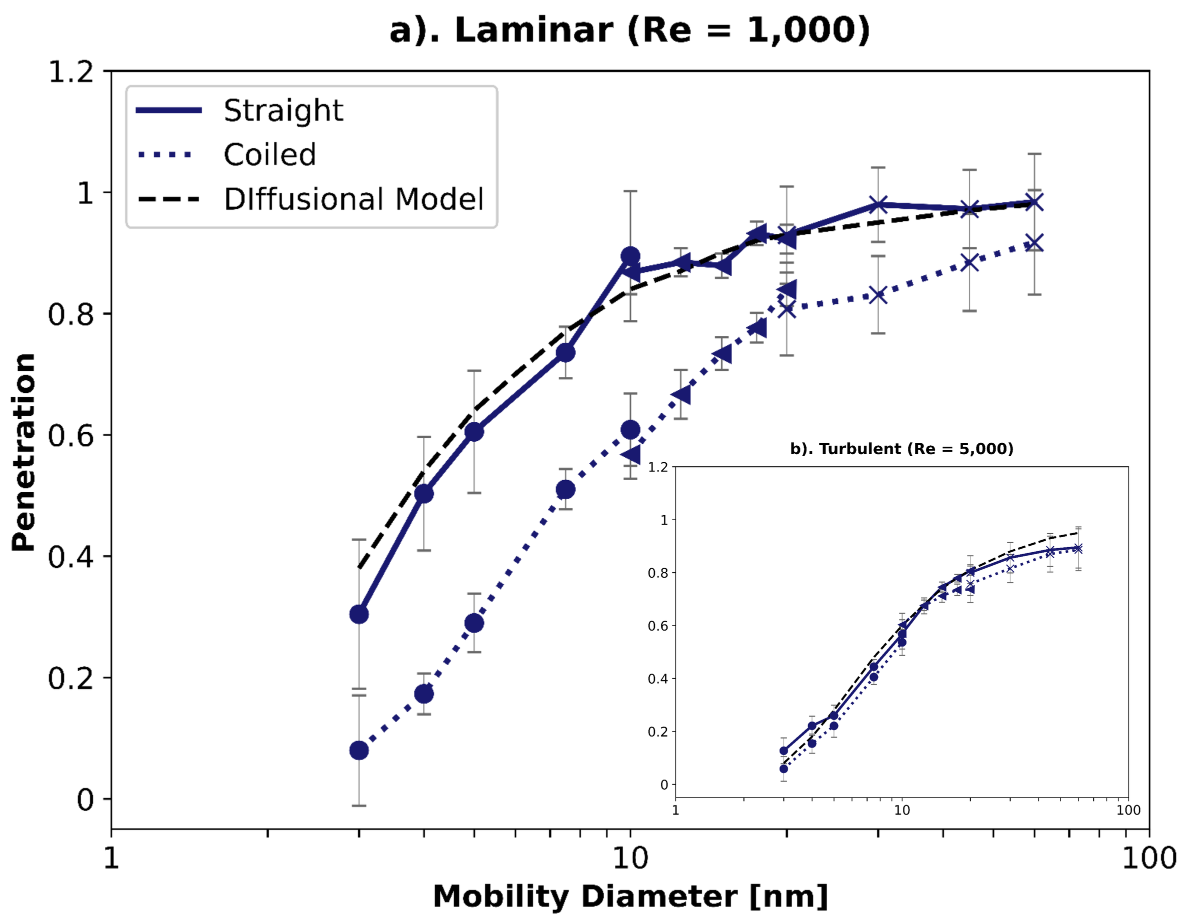


**Figure.7:** Particle penetration curves for straight and coiled tubes for laminar and turbulent flows

## Summary and Future Work

- A novel particle penetration test rig was developed using a tandem SMPS methodology to measure silver and salt particle from ~5-60 nm.
- No additional particle losses observed for different flow splitters, but some evidence of additional particle losses occurring for uneven flow splitting.
- No additional sub-20 nm particle losses across the different flow fittings, but additional particle loss above 60 nm were observed.
- Additional particle losses observed for coiled tubes in laminar flow due to secondary flows, but not additional particle losses for turbulent flow.

- Determine particle losses for higher flowrates for the flow splitters and flow fittings and for different uneven flowrates through the flow splitters.

## References

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