A Magnetic Passive Aerosol Sampler for Measuring Particle Penetration through Protective Clothing Materials

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OBJECTIVES

- To develop a penetration cell (P-Cell) for use with a previously designed magnetic passive aerosol sampler (MPAS) to measure particle penetration through protective clothing materials
- To minimize upstream flow restrictions and potential particle reentrance from its downstream side that can cause overestimations of particle penetration

BACKGROUND

The MPAS was designed with numerous miniature magnets (Fig. 1a), arranged in an alternating N and S pole pattern, forming an alternating positive and negative magnetic field gradient (Hsiao, *et al*., 2012; Fig. 1b). Fe_3O_4 particles are magnetically susceptible and were collected onto a substrate seated on the magnets, resulting in about 140 particle clusters across the collection area (each of which was collected by a single magnet, see Fig. 1c). Particle deposition had a non-uniform deposition pattern across an individual magnet (Fig. 1d), tending to favor its edges (Fig. 1e). On average, the clusters were uniform in concentration across the entire MPAS, as shown by computer controlled scanning electron microscopy. (Jaques *et al*., 2012).

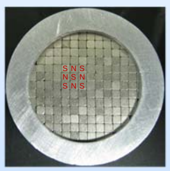

Fig 1a. MPAS (~ 140 exposed magnets: 1.5 mm by 1.5 mm and 0.75 mm thick)

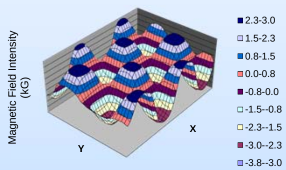

Fig 1b. Magnetic field gradient across 4 magnets

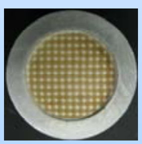

Fig 1c. Particle deposition pattern across the MPAS

Fig 1d. Photo of particle deposition pattern by a single magnet

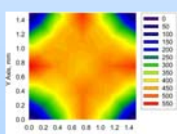

Fig 1e. Contour plot of particle deposition pattern by a single magnet

METHODS & MATERIALS

- **Design and Development of the Shrouded P-Cell**
  - The MPAS is supported within the P-Cell and the fabric is capped at its surface
  - The P-Cell has a threaded tripod design to create space between the fabric and the MPAS
  - The P-Cell and its shroud exhaust unit were designed with smooth transitions to minimize internal and external turbulence
- **Characterization of the Shrouded P-Cell**
  - The shrouded P-Cell was located in the recirculation aerosol wind tunnel (RAWT) to evaluate the effect of the shroud by using smoke visualization
  - The shrouded P-Cell (referred to as "Prototype 2") was compared to an earlier non-shrouded P-Cell design (Prototype 1).

DESIGN OF THE PROTOTYPE 2 P-CELL

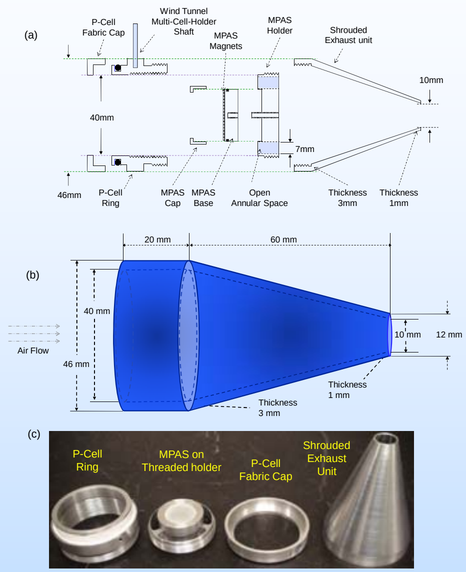

Fig 2. The Prototype 2 with multiple components: a) schematic side view (drawing approximate to scale); b) picture side view ; and c) photograph of the components

- The Prototype 2 ring houses the MPAS holder
- The MPAS uses a threaded backing with an annular space of 450 mm^2 to both adjust its height within the Prototype 2 and minimize resistance to air flow
- A cap is used to attach fabric to Prototype 2 opening
- A shrouded exhaust unit is threaded onto the bottom of the P-Cell ring

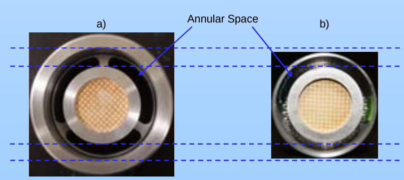

Fig 3. Comparison of inlet of the P-Cells: (a) Prototype 2 with (b) Prototype 1

- To reduce boundary layer effects and airway resistance, the annular air space for Prototype 2 was about 4x that for Prototype 1
- A tripod support allowed for a wider annular opening and enhancement of the MPAS support backing

EXPERIMENTAL EVALUATION OF PENETRATION CELL

1). RAWT and P-Cell Setup

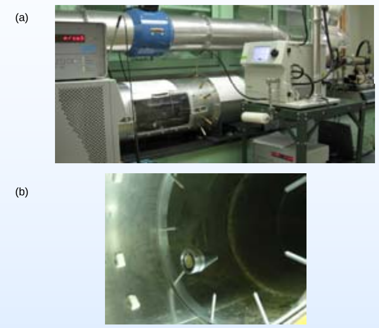

Fig 4. a) RAWT; b) Prototype 2 with MPAS placed in RAWT

- The RAWT was previously designed to have laminar flow (Jaques, *et al*., 2011)
- The multi-P-cell holder with Prototype 2 is located at 235º for flow visualization

2). Smoke Tests in the RAWT across Prototype 2 With and Without a Shrouded Exhaust Unit

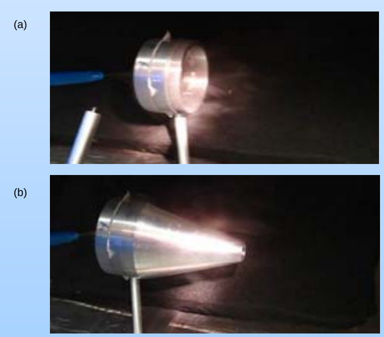

Fig 5. P-Cell located in the RAWT to evaluate the effect of the shrouded exhaust unit on reducing eddies by using smoke visualization: a comparison of Prototype 2 without (a) and with (b) shrouded exhaust unit

- The Prototype 2 with MPAS and fabric was placed in the RAWT, which was set to have a transport velocity of 0.5 m/s
- A portable generator produced a stream of mist
- A flashlight reflected the mist stream pattern, showing visible eddies at the downstream end of the unit without the shroud, but much smoother streams for the unit with the shroud

3). Flow Patterns Outside the Prototype 2 With and Without a Shrouded Exhaust Unit

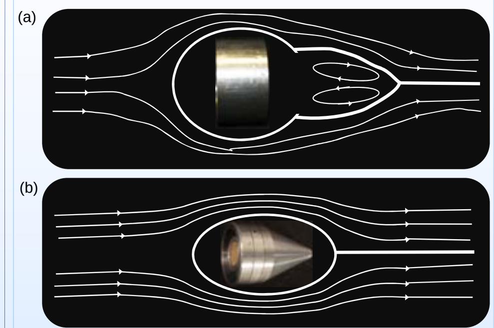

Fig 6. Air streamlines drawn outside the P-Cell to simulate effects of pressure zones on airflow: (a) without, and (b) with the shrouded exhaust unit

- The boundary layer separates forming eddies downstream of the sampler without the shrouded exhaust unit
- With a shrouded exhaust unit, eddies are not formed downstream, because the boundary layer remains attached, although it continues transitionally downstream of the sampler

SUMMARY AND CONCLUSIONS

- The Prototype 2 was designed with a shrouded exhaust unit and increased annular air space to minimize turbulence of and resistance to air flow
- Smoke tests in the wind tunnel show that the Prototype 2 with a shrouded exhaust unit minimizes possible eddy effects downstream of the sampler
- This preliminary study suggests that the shrouded exhaust unit can reduce particle re-entrainment at the back of the MPAS, avoiding overestimations of particle penetration

FUTURE WORK

- Performance of Prototype 2 will be evaluated under conditions of different particle sizes, various fabrics, and different wind velocities

REFERENCES

- Jaques, P.A., Hsiao, T-C. and Gao, P.: A recirculation aerosol wind tunnel for evaluating aerosol samplers and measuring particle penetration through protective clothing materials. *Annals of Occupational Hygiene*. 55(7):784-796 (2011).
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