High-flow Personal Respirable Dust Sampler for Increased Sensitivity

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Objective

Results of new medical studies frequently lead to a revision of occupational exposure limits. For example, the ACGIH® recently lowered the TLV® for respirable crystalline silica to 0.025 mg/m³. Methods need to be developed and validated that are more sensitive to meet new lower TLVs. One way to increase sensitivity of a method is to increase the sampling rate to collect more material. The objective of this study was to develop and test a new personal respirable sampler that operates at a two to three times higher flow rate than currently available samplers.

Sampler Design

The design of the new high-flow respirable sampler is based on the commercially available Parallel Particle Impactor (PPI) that operates at 2.0 L/min (U.S. Patent No. 7,073,402). The sampler includes four impactors arranged in parallel; each impactor contains an inlet nozzle, collection plate, and outlet orifice (Figure 1). Each inlet nozzle is sized to achieve the desired particle cut, with a complementary sized outlet orifice to ensure the flow rate through each impactor is equal to and one-fourth of the entire flow through the sampler.

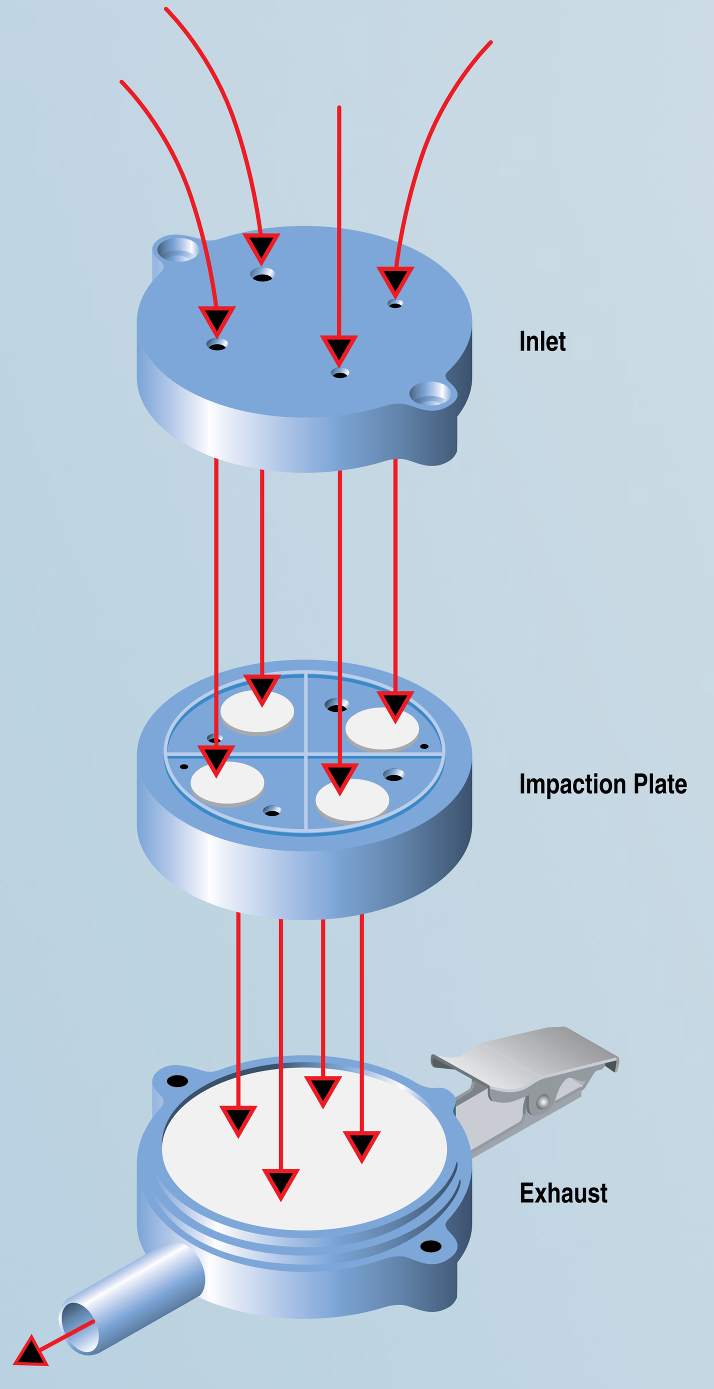

Figure 1. Parallel Particle Impactor, exploded

The cut-off size for each impactor is selected so each impactor simulates a different segment of the respirable curve resulting in an overall performance of the sampler that follows closely the respirable convention (Figure 2).

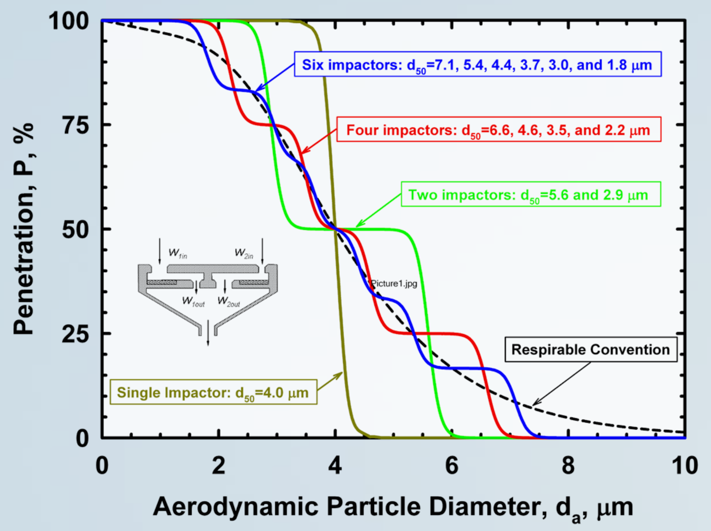

Figure 2. Theoretically predicted performance of samplers containing a different number of inertial impactors arranged in parallel

The parallel impactor concept has been shown to work well in low-flow respirable and thoracic samplers (Figure 3).

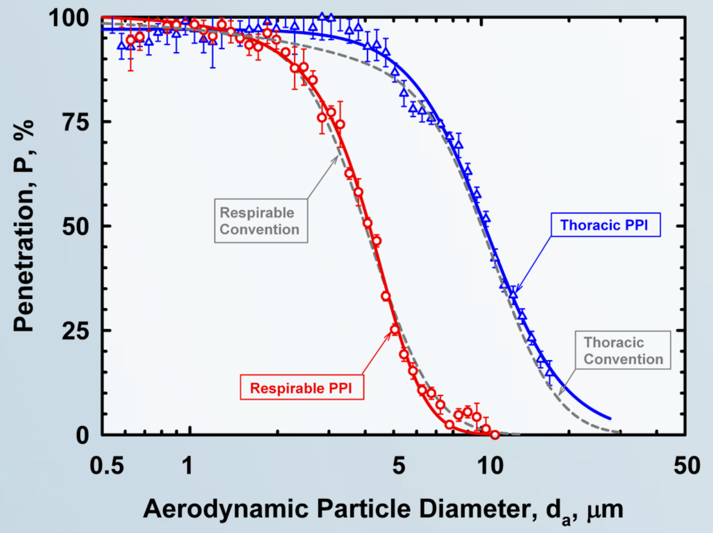

Figure 3. Performance of commercially available low-flow (2.0 L/min) respirable and thoracic PPI samplers

Therefore, a similar approach was used to design a high-flow Parallel Particle Impactor prototype that operated at an 8.0 L/min flow rate. The inlet nozzle sizes were calculated using impaction theory so that the PPI sampler would meet the respirable convention at a sampling flow rate of 8.0 L/min. A PPI prototype containing four impactors with inlet nozzles sized at 4.4, 3.5, 2.9, and 2.15 mm and corresponding outlet orifices of 2.15, 2.2, 2.31, and 4.4 mm was manufactured and tested during this study.

Test Methods

The performance of the high-flow respirable sampler prototype was evaluated by measuring aerosol concentration upstream and downstream of the sampler using an Aerodynamic Particle Sizer (APS 3320). Potassium Sodium Tartrate (PST) was used as a test aerosol. Figure 4 shows a schematic of the experimental setup used in the study. The aerosol chamber was made of a clear Plexiglas® cylinder approximately four feet high and one foot in diameter. Test particles and HEPA-filtered dry air were introduced and mixed at the top of the chamber. Aerosol passed through a honeycomb flow straightener before reaching the test area where two identical sampling lines were installed. The overall airflow through the chamber, combining clean air and test aerosol, ranged from 40 to 80 L/min. This resulted in a vertical air velocity of 10 to 20 mm/s in the chamber. Thus, calm air conditions were simulated in the test chamber.

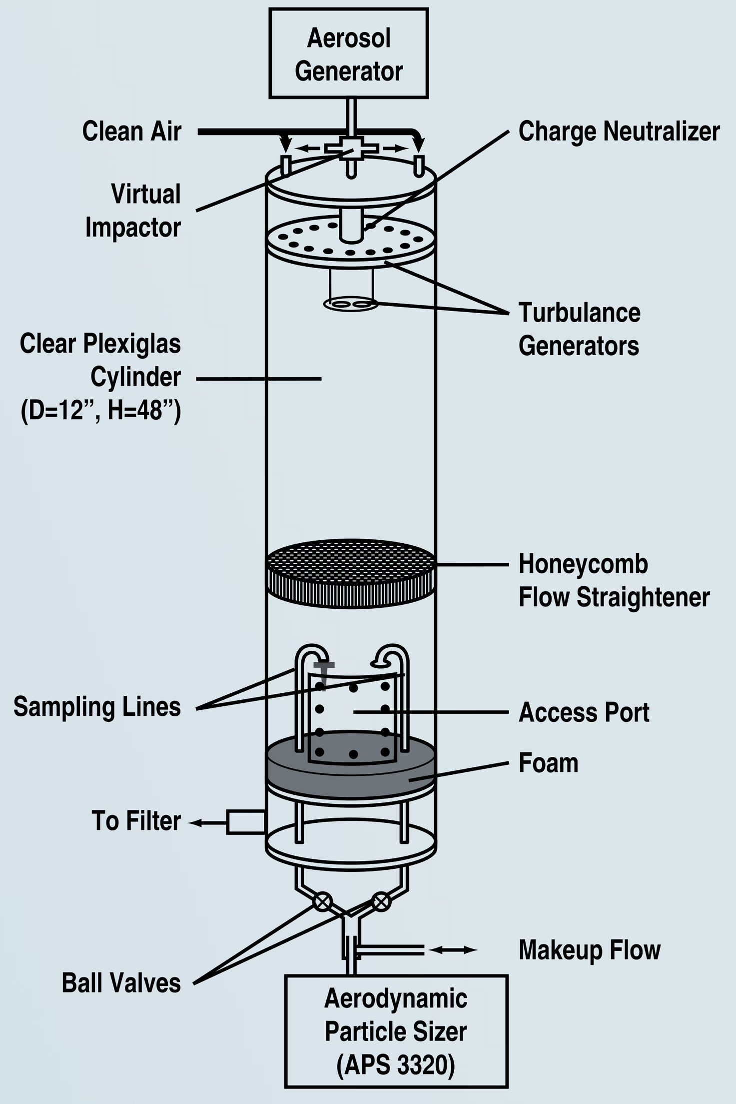

Figure 4. Schematic of experimental setup

Results

Impactors in the high-flow PPI prototype were tested individually to confirm the theoretically predicted cut-off sizes. This was accomplished by closing three out of the four inlets so that air was pulled only through the inlet of the impactor to be tested. Single impactors were tested at 2.0 L/min — the flow rate equal to one-fourth of the overall flow through the sampler.

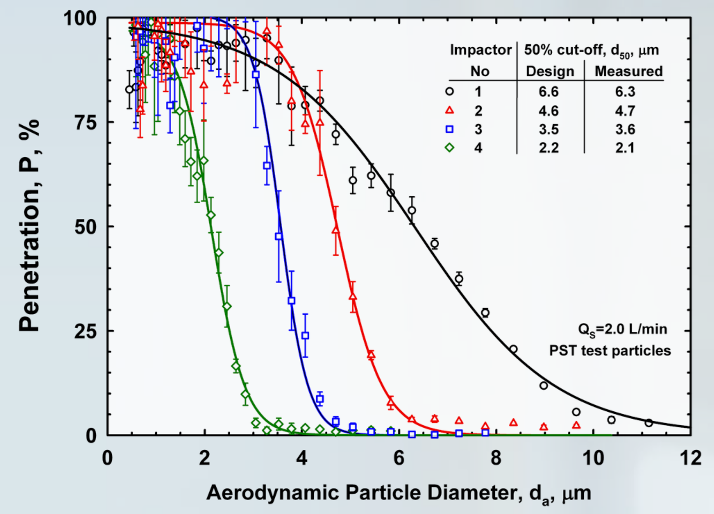

Figure 5. Particle penetration through individual impactors composing the high-flow PPI prototype

Data presented in Figure 5 show penetration as a function of particle aerodynamic size measured for each impactor composing the prototype PPI. The data shows that the measured 50% cut-off sizes (d_{50}) are in very good agreement with the theoretically predicted values.

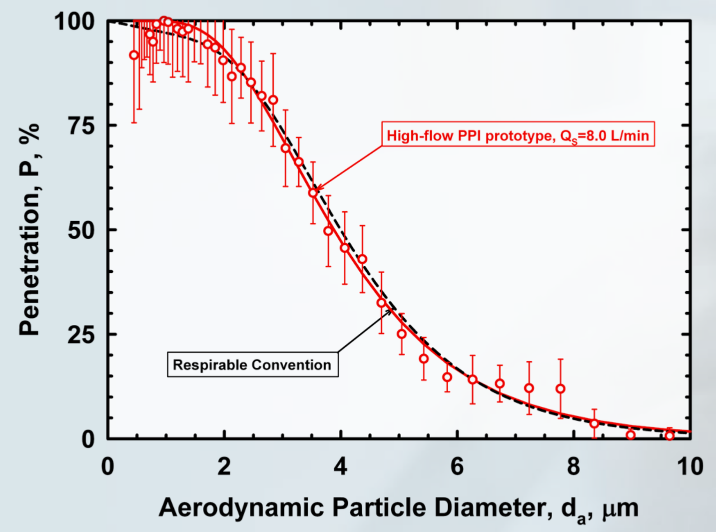

Figure 6. Performance of high-flow personal respirable sampler prototype

The data plotted in Figure 6 shows that performance of the high-flow PPI prototype is in good agreement with the entire respirable convention.

Conclusions

The parallel impactor design was applied to manufacture a personal respirable sampler operating at an 8.0 L/min flow rate. The newly designed sampler performed as predicted and showed good agreement with the entire respirable convention. The new sampler in conjunction with a high-flow personal sample pump can be used to accurately measure occupational exposure when new lower exposure limits need to be met.

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