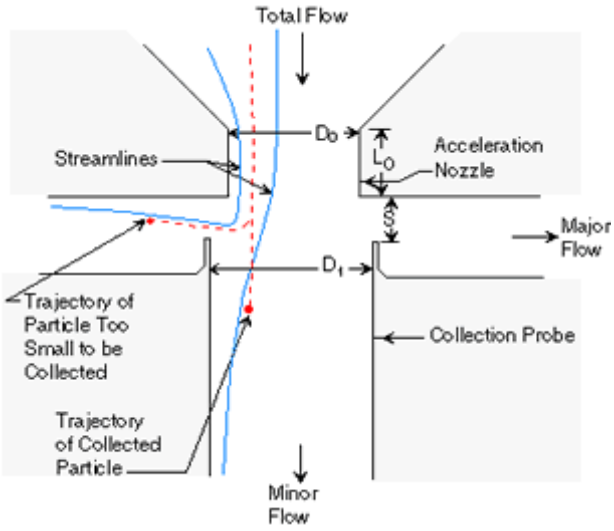
HOW A VIRTUAL IMPACTOR WORKS

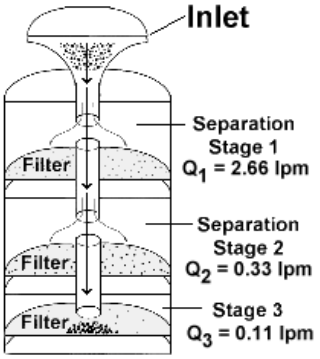
APPLICATION NOTE ITI-051

A virtual impactor is a device used to separate particles by size into two airstreams. It is similar to a conventional impactor, but the impaction surface is replaced with a virtual space of stagnant or slow moving air. Large particles are captured in a collection probe rather than impacted onto a surface.



The figure at right shows a schematic diagram of a virtual impactor. The aerosol passes through an accelerating nozzle and is directed toward a collection probe. At this point a major portion of the flow is diverted 90° away from the collection probe. This is where the particle-size separation takes place. Small particles with low inertia follow the flow streamlines and are carried away radially with the major flow. Large particles with greater inertia deviate from the flowlines and continue moving axially in their forward path down the collection probe with the minor flow. The separation efficiency curve is determined by the ratio of the major and minor flows and the physical dimensions of the nozzle and collection probe.

One characteristic of a virtual impactor is that particles smaller than the cut-size of the impactor remain in both the major and minor flows. Therefore, if the minor flow is 10% of the total flow, then 10% of the small particles will remain with the minor flow. Another characteristic is that particles larger than the cut size become concentrated in the minor flow. The concentration factor is the ratio of the total flow to the minor flow. If the minor flow is 25% of the total flow, then the concentration factor is 4.



RESPICON™ Model 8552 Two-Stage Virtual Impactor

TSI's patented RESPICON Particle Sampler is a two-stage virtual impactor as shown in the figure at right. Three collection filters and two virtual impactors are assembled in a compact concentric unit with cylindrical symmetry. The total flow is controlled with a personal air sampling pump and the split at each stage is controlled by a flow orifice.

The inlet of the sampler is designed to sample inhalable particles according to the ACGIH/ISO/CEN definition for inhalability. In the first virtual impactor stage, the total flow of 3.11 L/min is passed through a center accelerating nozzle and directed toward the collection probe. The major flow of 2.66 L/min is diverted away and the particles smaller than the cut size are collected on the stage one filter. Particles larger than the cut size are carried in the minor flow of 0.44 L/min to the next stage. The second virtual imapctor stage separates the flow into 0.33 L/min for the major flow and 0.11 L/min for the minor flow. Particles in the major flow are collected on the stage-two filter and particles suspended in the minor flow are deposited on the final stage-three filter. The filters at stage one and two have a central hole to allow for the collection probes. The final filter has no center hole.

The 50% particle cut-size for the first stage of the RESPICON is 4 µm aerodynamic diameter. The separation efficiency curve matches the respirable curve as defined by ACGIH/ISO/CEN. Particles collected on the first filter stage represent the respirable fraction of inhalable particles.

The 50% cut-size for the second stage is 10 µm aerodynamic diameter and the efficiency curve matches the thoracic curve. Particles collected on both the first and second filter stages represent the thoracic fraction of inhalable particles.

The final filter stage collects all remaining particles. Particles collected on all three filters represent the inhalable fraction of total suspended particles.

Even though a small percentage of particles smaller than the cut size will be transported with the minor flow and collected on later filter stages, it does not compromise the accuracy of the calculated mass concentration in each size fraction. The particle mass concentration C (mg/m³) in each size fraction can be accurately determined using the following equations.

$$C_{respirable} = m_1 \times 10^3 / V_1$$
$$C_{thoracic} = (m_1 + m_2) \times 10^3 / V_2$$
$$C_{inhalable\text{-}uncorrected} = (m_1 + m_2 + m_3) \times 10^3 / V_3$$
$$C_{extrathoracic} = (C_{inhalable\ -\ uncorrected} - C_{thoracic})$$
$$C_{inhalable} = C_{thoracic} + C_{extrathoracic}$$
$$C_{tracheobronchial} = C_{thoracic} - C_{respirable}$$

where:

m_1, m_2, m_3 = particle mass deposited on each filter stage
V_1 = sampled volume at stage one = $Q_1 \times ts$
V_2 = sampled volume at stages one and two = $(Q_1 + Q_2) \times ts$
V_3 = sampled volume at stages one, two and three = $(Q_1 + Q_2 + Q_3) \times ts$
Q_1, Q_2, Q_3 = major flow at each stage (L/min)
ts = sample time (min)

Bibliography

"Virtual Impactors: A Theoretical Study," Virgil A. Marple and Chung. M. Chein, *Environmental Science and Technology*, Vol. **14**, Issue 7, August 1980, page 976-985.

"Health-Based Particle-Size Selective Sampling," *TSI Application Note #ITI-050*, TSI Incorporated, Health and Safety Instruments Division, St. Paul, Minnesota, 1997.

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