



Electrostatic Precipitation System for Radionuclide Particle Collection

Updated Briefing

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Radionuclide Aerosol Collection

- **International Monitoring System Radionuclide Stations**
 - Each station includes Radionuclide Particulate Monitoring
 - Existing system is the Radionuclide Aerosol Sampler/Analyzer (RASA)
 - Samples captured in a filter-paper collector over 24-hour sample period (batch process)
 - Decay of fission isotopes are measured with gamma-ray spectrometry: provides positive proof of nuclear detonation
 - Samples are archived for physical analysis if desired

- **Challenges for Current Systems**
 - **Power Consumption**
 - During Fukushima incident, power stability was an issue for aerosol detection near the site
 - Filter-paper based approach requires high blower power due to large ΔP across filter
 - **Sensitivity**
 - Blower power limits air flow rate and total sample quantity
 - Collecting more particles per sample period will increase instrument sensitivity
 - Environments with high background radiation can limit instrument sensitivity (higher noise levels require more signal to overcome)



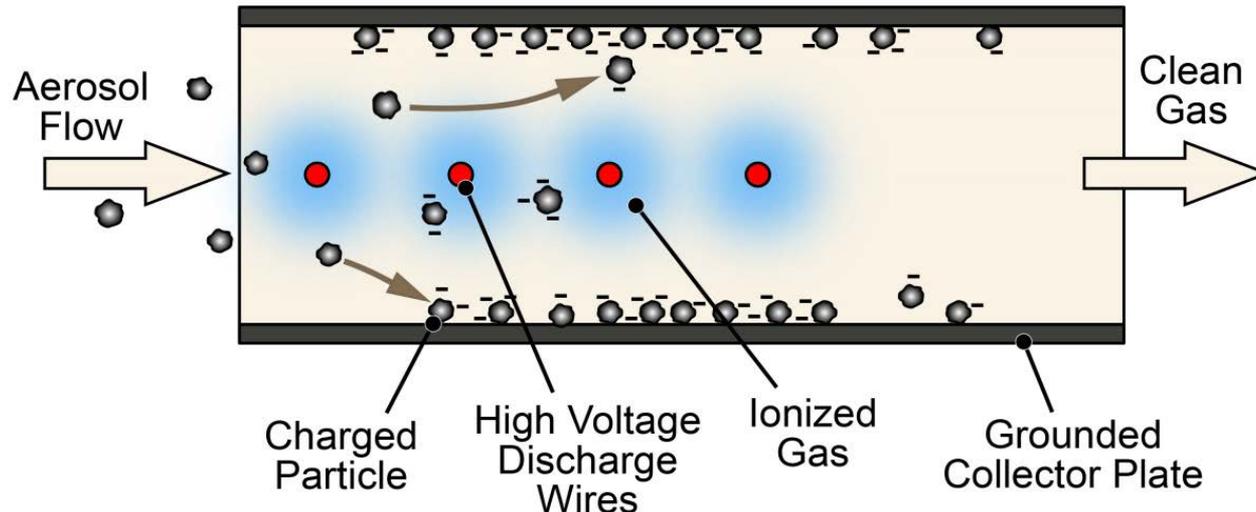
Radionuclide Monitoring Station Locations- 63/80 certified.
<https://www.ctbto.org/map/>

Radionuclide Aerosol Collection

- **A new collection system is desired that consumes less power**
 - Enable operation in power-limited locations/operating periods (existing system employs a 3 hp blower)
 - A system with a lower pressure drop may enable higher sampling rates
- **Electrostatic precipitation offers low power alternative to filter-based approaches**
 - Cross contamination of collected samples must be avoided
 - Commercial ESPs are not focused on sample preservation
 - Samples must be packaged for detector integration
- **System requirements**
 - Full-scale system flow rates: 500 m³/hr to 2,000 m³/hr of higher (current system samples at ~1000 m³/hr)
 - Particle collection efficiency
 - $\eta > 90\%$ for particle diameters 0.1 μm – 1.0 μm
 - $\eta > 50\%$ for particle diameters $> 10 \mu\text{m}$
 - Minimize system power \ll 3 hp (2.2 kW) blower requirement for current RASA
 - Minimize sample cross-contamination
 - Compact system size

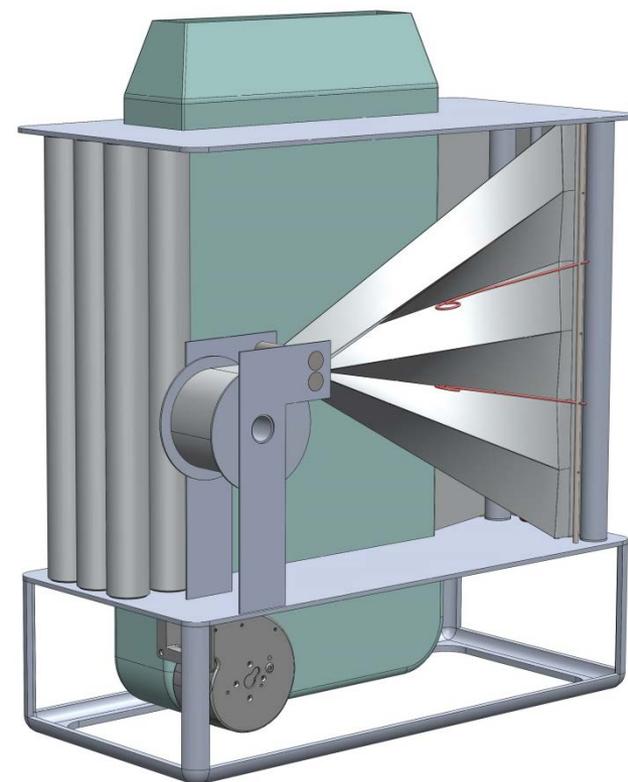
Electrostatic Precipitation

- **Electrostatic precipitation operation:**
 - A high voltage is applied between two electrodes (such as a thin wire and a flat plate) and the aerosol flow is passed between them
 - A corona is generated at the discharge electrode
 - The ionized gas molecules collide with the particles entrained in the flow, and charge builds up on the particles
 - The charged particles are drawn to the collector electrode by the electric field force where they stick, held by static and van der Waals forces
- **ESP systems can achieve very high collection efficiencies (>99.5%) across a wide range of particle sizes: 30 nm to >100 μm**



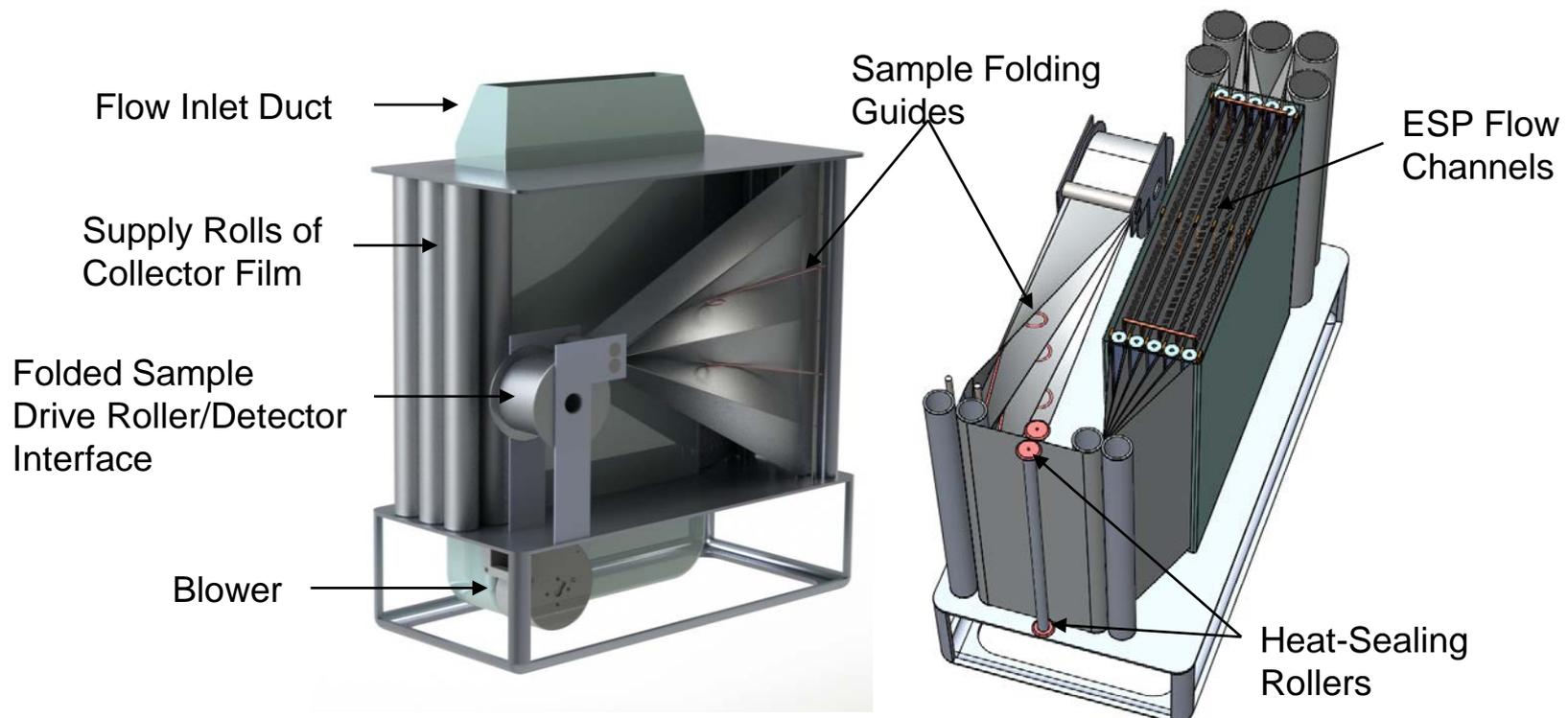
Phase I Design Concept

- **Full-scale system requirements:**
 - Fit within general RASA dimensions if possible ~ (40 cm x 60 cm x 13 cm)
 - Maintain particle collection efficiency >90%
 - Minimize power
 - Reduce sample to at least 10 cm x 40 cm strip to interface with detector
- **ESP collector design:**
 - ESP form factor challenge—long and narrow
 - Longer flow-dimension increases collection efficiency
 - Goal to minimize system volume (length) while maintaining performance
 - Minimize system complexity for sample handling to support long-term, autonomous operation
 - Minimize cross-contamination between successive samples
 - Mode of Operation: Sample 24 hrs, Decay 24 hrs, Detect 24 hrs



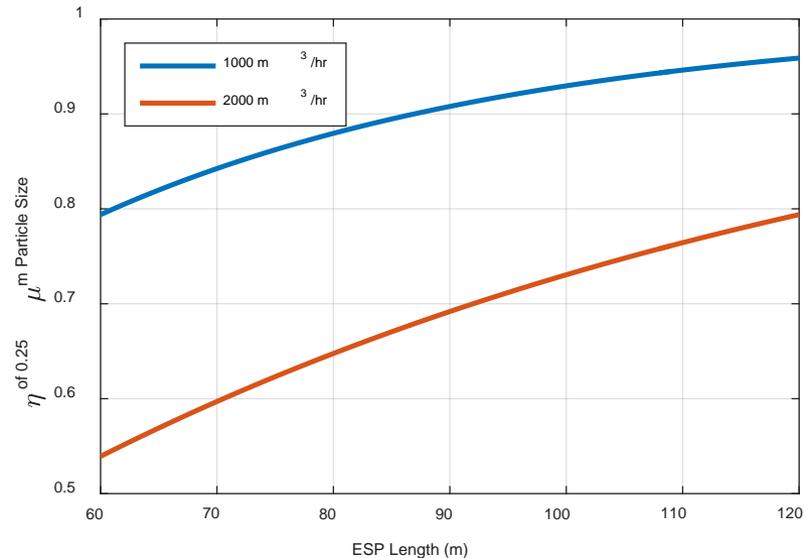
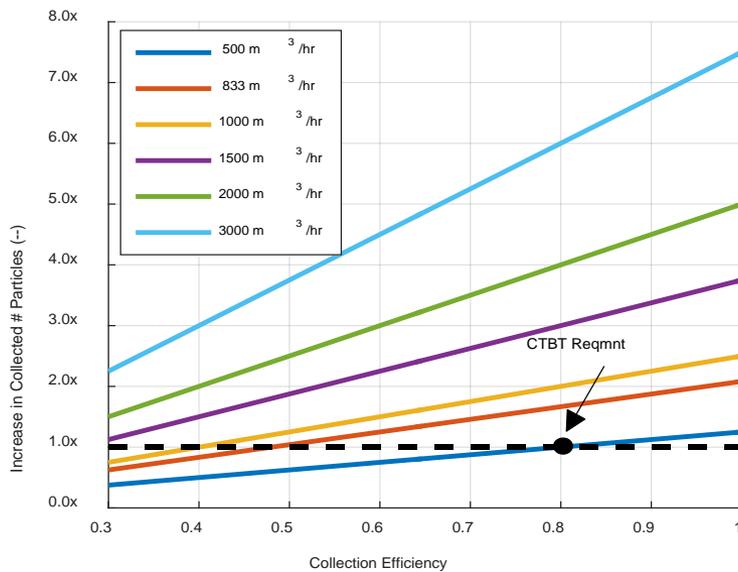
Phase I Design Concept

- **Wire-plate ESP design with multiple rectangular flow channels**
- **Layers of flexible, conductive collector sheets drawn through ESP crosswise to flow direction**
- **Layers are heat sealed at top and bottom edges**
- **Sample is folded in accordion-like fashion to reduce dimensions to detector interface (10 cm Height)**



ESP Modeling

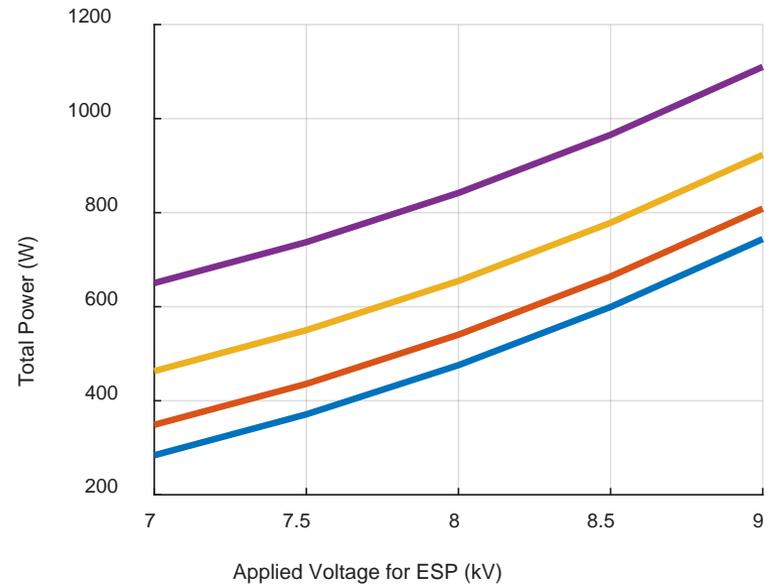
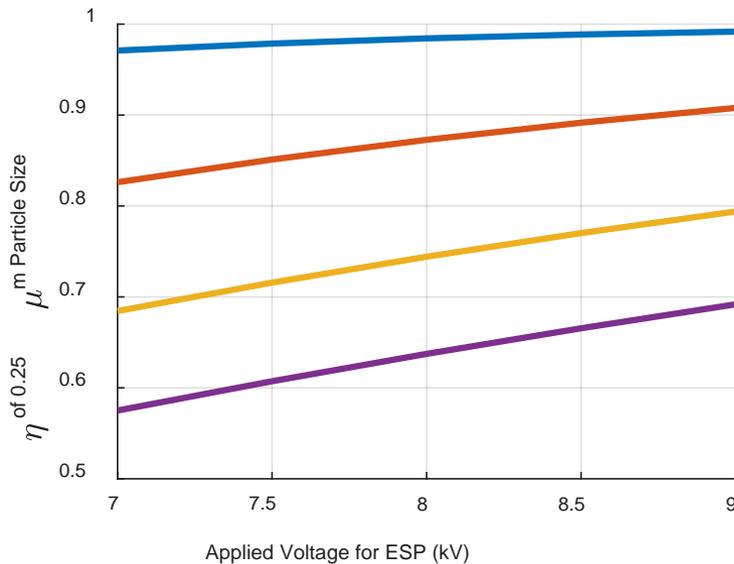
- Instrument sensitivity is a function of collection efficiency AND flow rate (sample volume)
- Optimization of sensitivity vs. power/ size may be better if flow-through collection efficiency target is reduced (90% is goal, IMS requirement is 80%)



Using 12,000 m³ as nominal sample volume

ESP Modeling

Collection Efficiency and Total Power vs ESP Voltage for varying flow rates in an ESP design concept



Sample Handling

Trade-offs in Sample Presentation: Smaller Sample Package Results in Increase Instrument Sensitivity

Sample Format	Folding System Size / Complexity	Instrument Sensitivity Gains
~10 cm Wide Strip; Wrap Around Detector	Least Complex, Allows for Larger Sheets (up to at least 1 m) or More ESP Ducts	Same as RASA (1X)
~5 cm Wide Strip; Wrap Around Detector	More Complex, Limits Sheet Size to < ~1 m	~2X RASA
<10 cm x <10 cm Packet; On Top of Detector	Most Complex, Limits Sheet Size to < ~1 m (Dependent on System Specifics)	> 2X RASA (?) Dependent on Specific Geomtries