RESEARCH & DEVELOPMENT

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# Electrostatic Precipitation System for Radionuclide Particle Collection

## Updated Briefing

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## Acknowledgment

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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)**

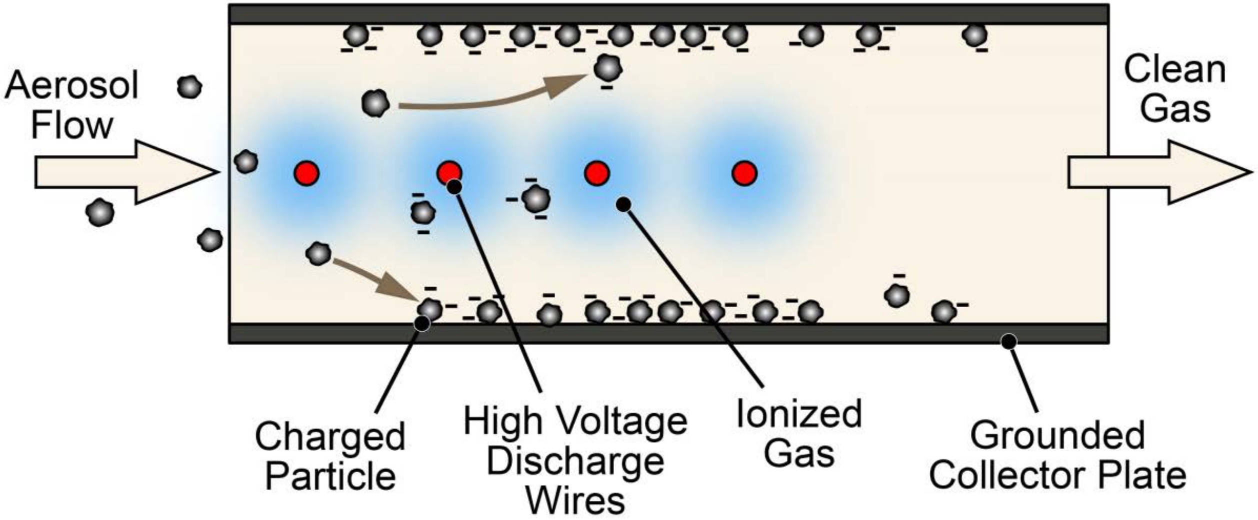
Radionuclide Monitoring Station Locations- 63/80 certified.
https://www.ctbto.org/map/

# 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 $m^3$/hr to 2,000 $m^3$/hr of higher (current system samples at ~1000 $m^3$/hr)
  - Particle collection efficiency
    - $\eta > 90\%$ for particle diameters 0.1 μm – 1.0 μm
    - $\eta > 50\%$ for particle diameters > 10 μm
  - Minimize system power << 3 hp (2.2 kW) blower requirement for current RASA
  - Minimize sample cross-contamination
  - Compact system size

# Electrostatic Precipitation

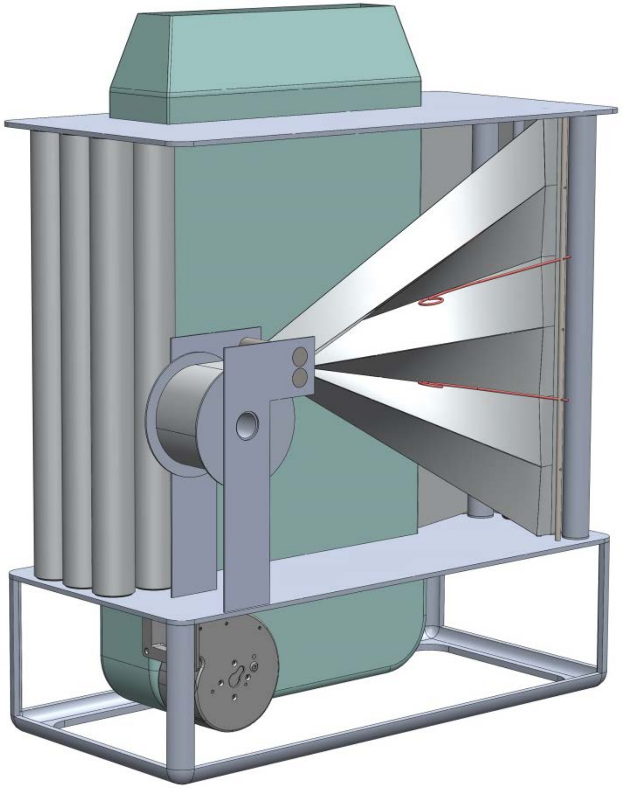
- **Electrostatic precipitation operation:**
  - **A high voltage is applied between two electrodes (such as a thin wire and a flat plate) and the aerosol flow is passed between them**
  - **A corona is generated at the discharge electrode**
  - **The ionized gas molecules collide with the particles 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 Walls 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

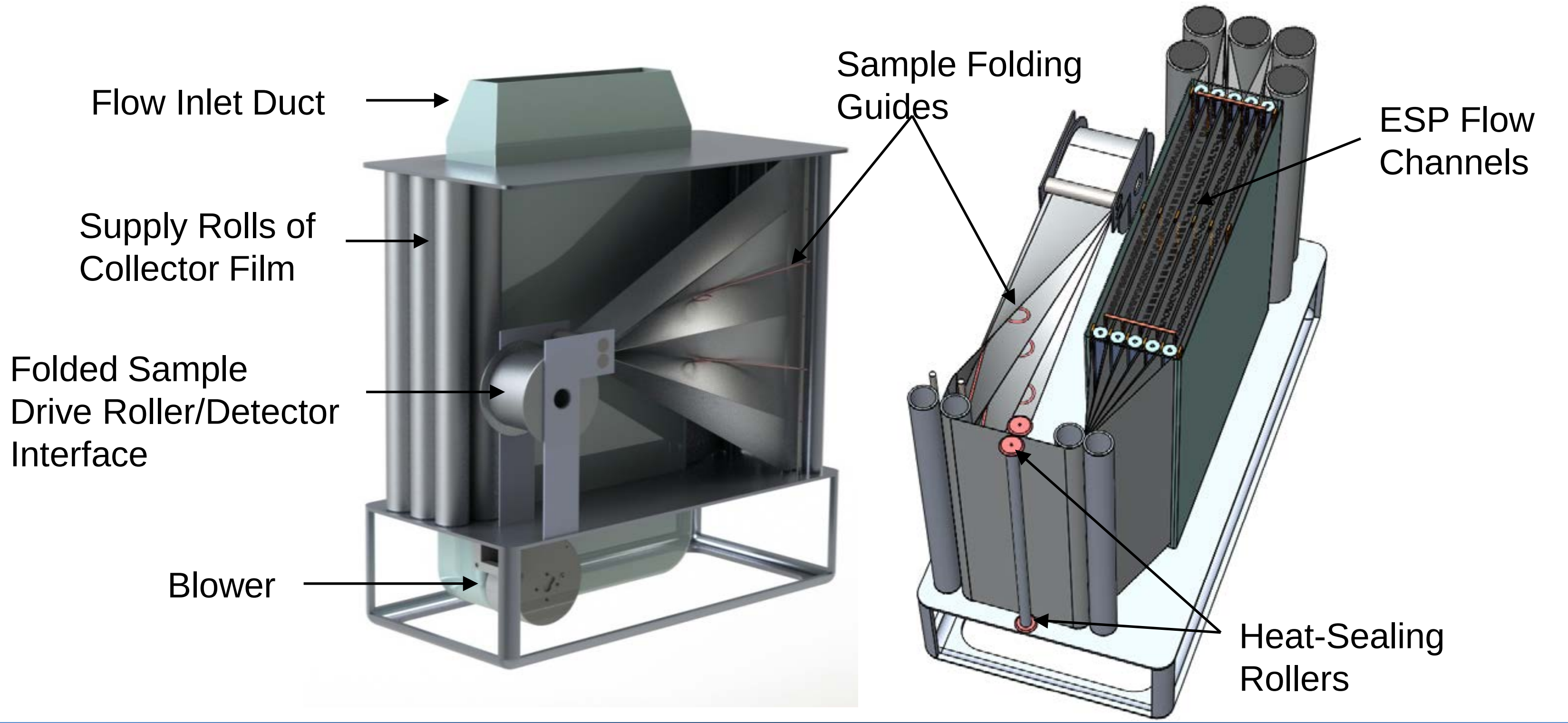
- **Full-scale system requirements:**
  - **Fit within general RASA dimensions if possible ~(40 cm x 60 cm x 13 cm)**
  - **Maintain particle collection efficiency >90%**
  - **Minimize power**
  - **Reduce sample to at least 10 cm x 40 cm strip to interface with detector**

- **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**



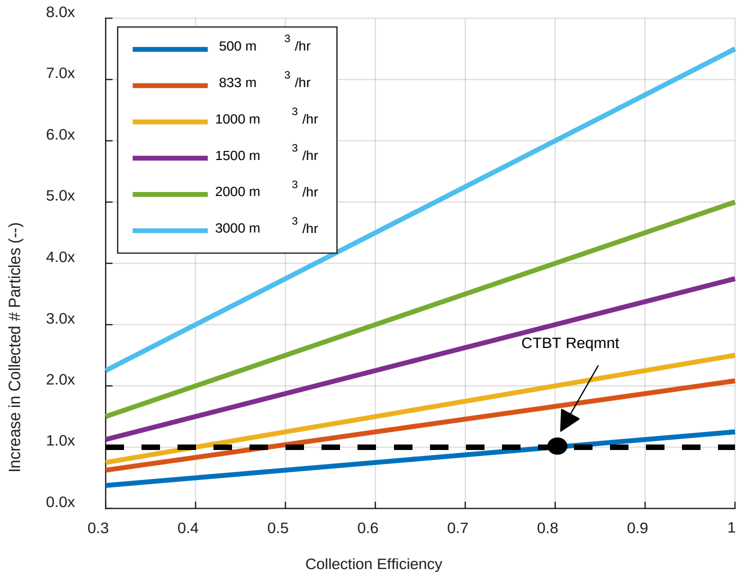
# Phase I Design Concept

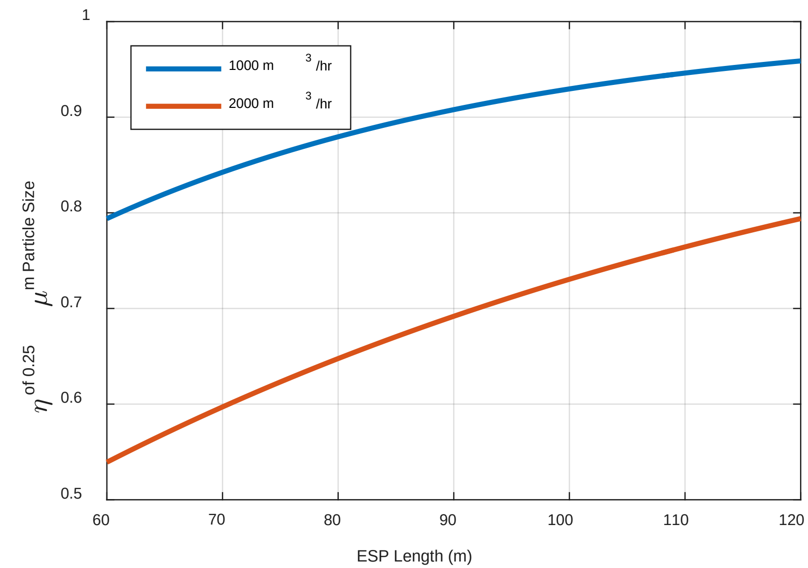
- Wire-plate ESP design with multiple rectangular flow channels
- Layers of flexible, conductive collector sheets drawn through ESP crosswise to flow direction
- Layers are heat sealed at top and bottom edges
- Sample is folded in accordion-like fashion to reduce dimensions to detector interface (10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

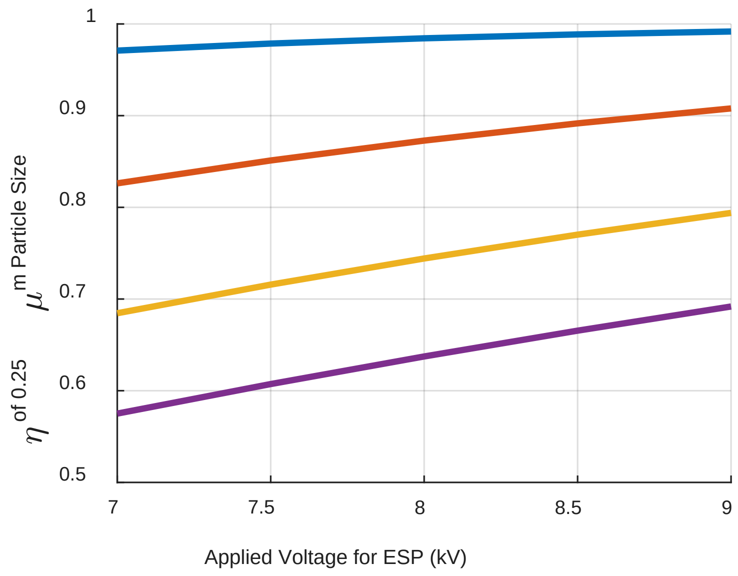


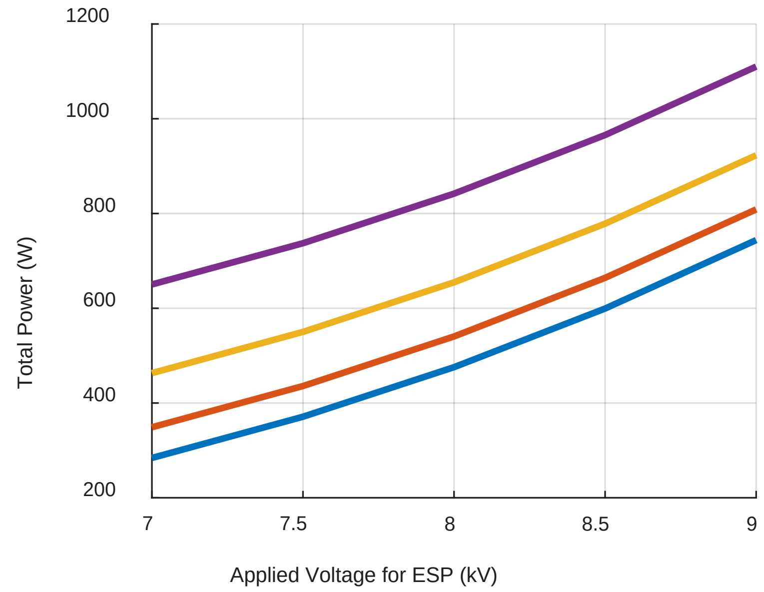




Using 12,000 m³ as nominal sample volume

# 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

| Table 1: Sampling Handling System Trade-Offs | | |
|---|---|---|
| **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 |