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**Development of a Tamper Resistant/Indicating Aerosol Collection System for Environmental Sampling at Bulk Handling Facilities**

Lindsay Sexton[1], Paula Cable-Dunlap[2], Daniel Radford[1], Timothy Riley[1], Matthew Wellons[1], Jeff Degange[1], Lee Trowbridge[2], Brian Anderson[2], Rick Poland[1].
[1]Savannah River National Laboratory, Aiken, SC, USA,
[2]Oak Ridge National Laboratory, Oak Ridge, TN, USA

## Abstract

Environmental sampling has become a key component of International Atomic Energy Agency (IAEA) safeguards approaches since its approval for use in 1996. Environmental sampling supports the IAEA's mission of drawing conclusions concerning the absence of undeclared nuclear material or nuclear activities in a Nation State. Swipe sampling is the most commonly used method for the collection of environmental samples from bulk handling facilities. However, augmenting swipe samples with an air monitoring system, which could continuously draw samples from the environment of bulk handling facilities, could improve the possibility of the detection of undeclared activities. Continuous sampling offers the opportunity to collect airborne materials before they settle onto surfaces which can be decontaminated, taken into existing duct work, filtered by plant ventilation, or escape via alternate pathways (i.e. drains, doors).

Researchers at the Savannah River National Laboratory and Oak Ridge National Laboratory have been working to further develop an aerosol collection technology that could be installed at IAEA safeguarded bulk handling facilities. The addition of this technology may reduce the number of IAEA inspector visits required to effectively collect samples. The principal sample collection device is a patented Aerosol Contaminant Extractor (ACE) which utilizes electrostatic precipitation principles to deposit particulates onto selected substrates. Recent work has focused on comparing traditional swipe sampling to samples collected via an ACE system, and incorporating tamper resistant and tamper indicating (TRI) technologies into the ACE system. Development of a TRI-ACE system would allow collection of samples at uranium/plutonium bulk handling facilities in a manner that ensures sample integrity and could be an important addition to the international nuclear safeguards inspector's toolkit. This work was supported by the Next Generation Safeguards Initiative (NGSI), Office of Nonproliferation and International Security (NIS), National Nuclear Security Administration (NNSA).

## Introduction

Since the implementation of safeguards strengthening measures, approved by the International Atomic Energy Agency (IAEA) Board of Governors (1992-1997), international nuclear safeguards inspectors have been able to utilize environmental sampling (e.g. deposited particulates, air, water, vegetation, sediments, soil and biota) in their safeguarding approaches at bulk uranium/plutonium handling facilities.

Environmental sampling supports the IAEA's mission of drawing conclusions concerning the absence of undeclared nuclear material or nuclear activities in a State. Swipe sampling is the most commonly used method for the collection of environmental samples from bulk handling facilities. However, augmenting swipe samples with an aerosol collection system, which could continuously draw samples from the environment, could improve the possibility of the detection of undeclared activities. Continuous sampling offers the advantage of collecting airborne materials before they settle onto surfaces which can be decontaminated, taken into existing duct work, filtered by plant ventilation, or escape via alternate pathways (i.e. drains, doors).

Savannah River National Laboratory (SRNL) and Oak Ridge National Laboratory (ORNL) researchers have been working on the extended development of an air monitoring approach that may allow for continuous sample collection at IAEA safeguarded bulk handling facilities. The principal sample collection device referred to herein is a patented Aerosol Contaminant Extractor (ACE) which utilizes electrostatic precipitation principles to deposit particulates onto selected substrates (Figure 1). This device has proven effective in the collection of fuel cycle signatures including an operational demonstration conducted at the Uranium Gas Centrifuge Enrichment Plant (GCEP) in Capenhurst, England.

This technique is applicable for quick turnaround analysis of samples collected inside operational facilities and may serve as a complimentary method to the gold standard environmental sampling protocol used by the IAEA. Incorporation of tamper resistant and tamper indicating technologies into the ACE system will allow continuous collection of samples at uranium/plutonium bulk handling facilities in a manner that enhances the probability that sample integrity has not been compromised during collection in the absence of a safeguards inspector. Tamper resistant/indicating components will deter attempts to alter the samples by the operator and indicate if any such tampering has taken place. A TRI-ACE has the potential to be an important addition to the international nuclear safeguards inspector's toolkit when developing advanced safeguards approaches for the IAEA.


Figure 1. ACE sampler.

**ACE Background**

In terms of collection devices, electrostatic precipitation collectors developed for the DOE at SRNL have proven effective in multiple field trials conducted on behalf of various entities. Rigorous laboratory testing and development of a high precision, rapid collection efficiency assessment scheme based on particle depletion dynamics have allowed SRNL to develop a variety of high and low volume electrostatic precipitation collectors. The mainstay particle collection device used in deployment scenarios is the

ACE, a two stage electrostatic precipitation system which captures aerosol particulates onto two substrates.

The ACE operates by pulling air (aerosol) and particles suspended (contaminants) in the air through a non-metallic flow tube via a muffin fan at the rate of approximately 300 LPM. The flow tube has two sections. The first section creates a negatively charged particle, which is accomplished by applying a *negative* 8.5 KV voltage to a corona wire mounted axially in the middle of the air flow. The corona wire passes through a grounded metallic tube mounted on the inside perimeter of the section, which creates the negative electrostatic field. The second section collects the negatively charged particles on two positively charged substrates. This second section consists of two charged substrates (*positive* 8.5 KV) mounted in the air stream with two adjacent ground plates affixed to the inside edge of the flow tube. This creates the second electrostatic field. The negatively charged particles repel from the ground plates and are deposited onto the positively charged substrates (Figure 2). The collection plates may then be analyzed directly for morphological/elemental and/or isotopic composition without chemical processing of the sample via SEM/EDS analysis or secondary ion mass spectrometry (SIMS) analysis, respectively. Conversely, collection plates may be chemically processed with conventional actinide extraction techniques and analyzed for isotopic concentrations by inductively coupled or thermal ionization mass spectrometry.

Figure 2. Example of a typical ACE collection plate.

ACE systems have been successfully deployed in field campaigns at the Savannah River Site, Nevada Test Site, Hanford, and Oak Ridge. Additionally, ACE units have been deployed at commercial facilities in New Mexico, Illinois, and Capenhurst, England. Aerosol particles were collected during a field trial of the ACE conducted at Urenco's Capenhurst GCEP. The airborne particulates were collected onto silicon substrates and analyzed directly using scanning electron microscopy/energy dispersive x-ray spectroscopy and Nano-Secondary Ion Mass Spectrometry (NanoSIMS) to obtain elemental and gross isotopic composition without matrix modification. The sample substrates were then processed using total digestion protocols for determination of the isotopic U composition of the bulk material. These deployments demonstrated the feasibility of a concerted effort to evaluate further development and determine applicability of air monitoring in safeguarding uranium/plutonium bulk handling facilities.

The active ACE collector will be made more viable as a deployable safeguards tool through inclusion of tamper resistant tamper indicating features incorporated into the collection scheme. The specific engineering design requirements and features that have been selected for a prototype TRI-ACE system are discussed below.

**Evaluation of Active and Passive Collection**

The collection performance of the base TRI-ACE system was tested in a controlled uranium dispersal system at ORNL to assess the collection efficiency relative to that of passive deposition sampling (swipe method). An ACE sample collector was placed in-line with the dispersal system (Figure 3) for active collection, while layout samples of various materials were placed inside the dispersal system to evaluate swipe sampling. Two distinct uranium exposure scenarios were run to assess collection efficiency. The capture efficiency of the ACE was tested under low humidity (10%) and high humidity (70%) conditions inside the dispersal unit.

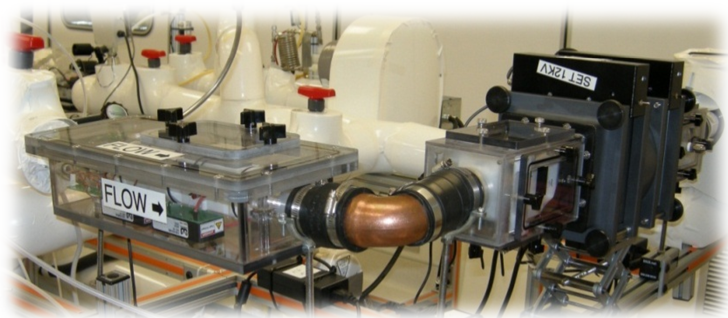

Figure 3. ACE collection system in-line with dispersal system.

The loadings on the TRI-ACE plates were more than 1000 times greater than the passive deposition samples. This finding illustrates the advantage of active collection. The capture efficiencies appear to be slightly greater at higher relative humidity for both TRI-ACE and standard ACE collectors.

**Incorporation of Tamper Resistant/Indicating Components**

The active ACE collector will be made more viable for safeguards-applicable air monitoring through inclusion of tamper resistant/tamper indicating features incorporated into the collection scheme (Figure 4). Specific engineering design requirements and features have been selected for a prototype TRI-ACE system. These components include:

***Housing***
The TRI-ACE sampling system housing will be enclosed, keyed and sealed. Currently, a stainless steel 20” X 20” X 8” Hoffman enclosure has been selected. For safety, the unit will de-energize when the access door is opened. The sampler inlet and outlet will have barriers installed on the exterior of the enclosure to prevent water infusion. Other than the inlet and outlet, any penetrations will be sealed.

***Power***
The TRI-ACE will normally be powered from the facility it serves. An internal battery backup system will allow the unit to run without facility power for a period of at least 72

hours. Intermittent system operation will be an option. A power interference filter will be installed so the unit will not be damaged in case of power deviations or spikes.

***ACE Collection System***

A single fan will be used to provide an air flow of 300 L/min for two ACE flow tube assemblies with their enclosed sample substrates inside the TRI-ACE housing. One tube is normally in service and the other will serve as a backup if abnormal particle size and number are detected in the sample tube. Abnormalities will activate a diversion damper which will change the sample flow from one ACE tube to another. The entire tube assembly can be easily removed for shipping. A replacement tube assembly can then be re-installed.

***Data Logging***

The TRI-ACE will have a fully programmable embedded controller that queries/ monitors and time stamps data received from each of the featured devices. Normal parameters will be established and any abnormalities will be flagged. Storage will be on a thumb drive embedded within the flow tube assembly which can be easily removed for analysis.

***Tamper Resistant/Indicating Features***

<u>Particle Counter</u> – A particle counter will be installed within the housing at the inlet upstream from the ACE flow tubes. The particle counter will pull a stream of air from the inlet sample flow and will be utilized to divert sample flow to the alternate ACE flow tube during abnormal particle counts or size.

<u>Temperature/Humidity Sensor</u> – A temperature/humidity sensor will be installed within the housing at the inlet upstream from the ACE flow tubes and one internal to the unit. This device will be utilized to detect and record temperature and humidity differences between the interior and exterior of the TRI-ACE housing.

<u>External Proximity Locator</u> – Several ultrasonic sensors will be installed to detect and record when someone approaches the TRI-ACE.

<u>Vibration/Tilt Detector</u> – Vibration and tilt detectors will be installed within the housing to detect and record sampler movement and shock.

<u>Voltage/Current Data Logger</u> – A voltage and current data logger will be used to record fan power data in order to detect if the fan inlet or outlet is obstructed.

<u>Air Flow Sensor</u> – An air flow sensor will be installed at the inlet upstream from the ACE flow tubes to record variations in air flow, which could be caused from inlet and/or outlet obstructions

<u>Ambient Light Detector</u> – An internal light detector will be installed to record changes when the enclosure is opened or closed.

<u>Magnetic Field/Flux Detector</u> – This device detects and records the magnetic field in close proximity to housing. A magnetic field could be used to sabotage electronically stored data.

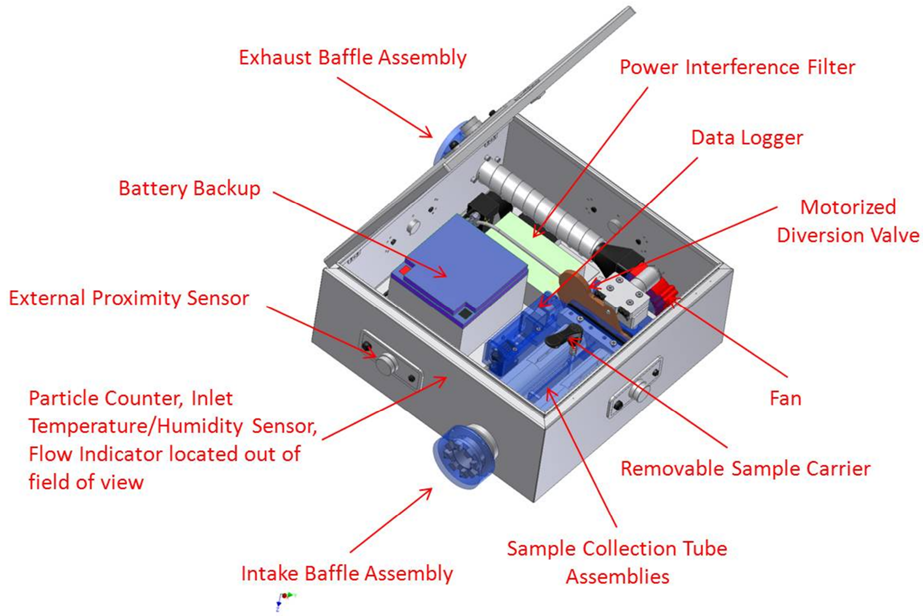


Figure 4. TRI-ACE design.

**Recent Progress**

The TRI-ACE prototype unit, described above, is being constructed at SRNL. Figure 5 shows the progress towards construction of the TRI-ACE prototype. The major mechanical components have been assembled and the electrical components are currently being installed and tested. Once fully assembled, laboratory testing of the electrical components and robustness testing will be conducted at SRNL.

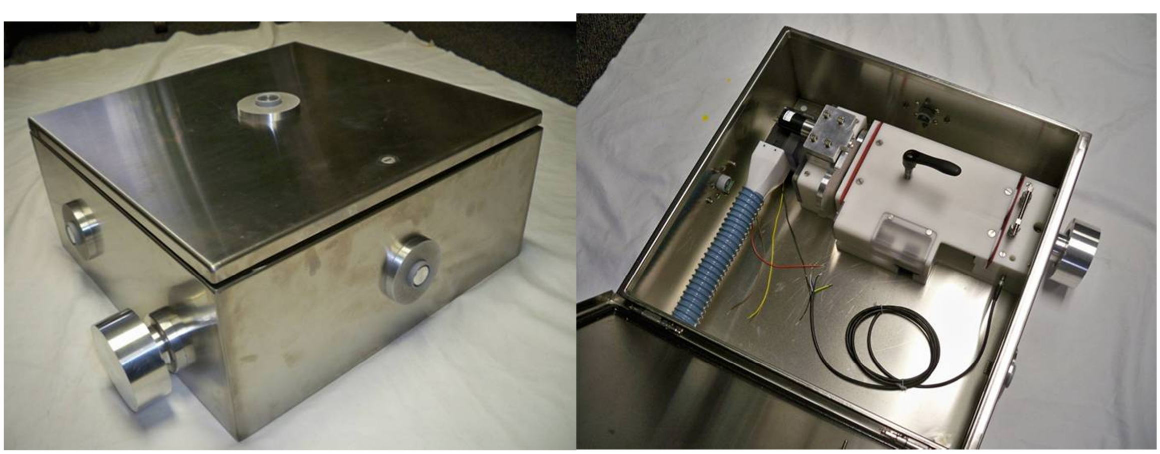

Figure 5. Tamper resistant/indicating housing (left) and the mechanical ACE components inside the housing (right). Not shown are the battery backup and additional electrical components.

## Future Work

Following completion of the TRI-ACE prototype, the unit will be tested for collection efficiency in the uranium dispersal system at ORNL. The unit will then be field tested along with conventional ACE systems at an operational bulk handling facility. Field testing will focus on demonstration of the TRI-ACE tamper resistant/indicating features.

## Acknowledgements

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