Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

Disclaimer:

Smart Particle Collector with Real Time Spectroscopic Analysis

A particle collector breadboard testing system (Racetrack), based on the ACE 1.0 particle collector model, was designed and built to study the mechanisms for particle collection and detection. Several parameters were investigated, such as current and voltage of the filament, magnetic fields and supporting electronics. Advanced optical spectroscopic features with data logging capabilities were designed in this project. The advanced features were tested for future incorporation into a new breed of particle collectors. Several experiments conducted with the Racetrack provided a path for a new prototype particle collector "ESP-EV1". Preliminary results suggest that the new particle collector is an order of magnitude more efficient in collecting material than currently used collector systems. This project also demonstrated the capability to extract nanoparticulates from a sample containing material from 100 nm to 10 micron-sized particulates.

Awards and Recognition

None.

Intellectual Property Review

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publicly published in its current form.

SRNL Legal Signature

Signature **Date**

Smart Particle Collector with Real Time Spectroscopic Analysis

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Thrust Area: NS

Project Start Date: October 1, 2017
Project End Date: September 30, 2018

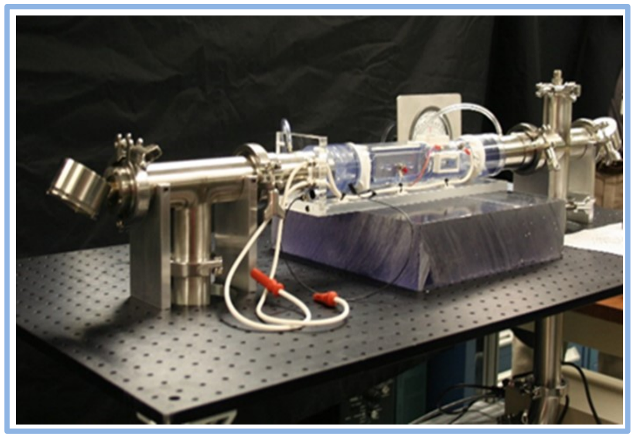
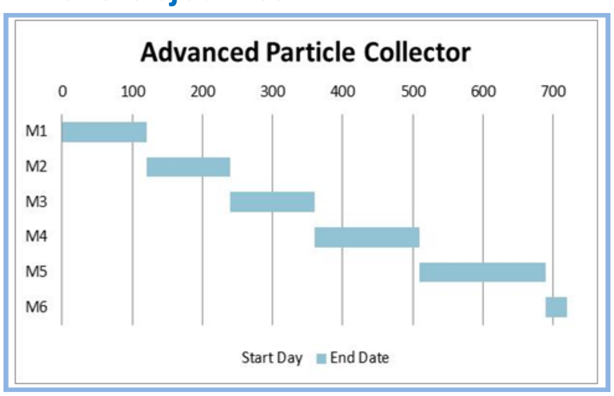


Figure 1. *Racetrack experimental breadboard for collection studies.*

Facilities manufacturing materials for nuclear weapons programs release particulate matter to the environment. Particle collections from suspected facilities can help assess proliferation programs. SRNL designs and manufactures unique particle collectors for a variety of applications. The goal of this project is to develop new technologies to develop and manufacture smart particle collectors. Significant engineering advances to the collector were made using the Racetrack, an experimental breadboard setup based on the ACE 1.0 collector. Preliminary experimental results suggest significant improvement in the particle collection efficiency. The new prototype collector, "ESP-EV1", relies on a two-stage collection region, with higher wire corona currents and voltages. Preliminary results also suggest that it is possible to extract nanoparticulates from a sample containing material from 100 nm to 10 micron-sized particulates. This project also developed new tools for spectroscopic validation of a sample and unique smart features for the collection system.

FY2018 Objectives



	Milestones, Deliverables, or Go/No-Go Decision	Progress Notes	% Complete
FY18	M1 – Design and construction of Racetrack for gas and particle characterization.		100%
	M2 – Measure emission corona for various gaseous effluents and particulates	• Delays in the M1 milestone led to research	65%
	M3 – Characterize particulates under laser illumination.		20%
FY19	M4 –Build an experimental breadboard with photosensors for particulate collection.	Preliminary results suggest that the new ESP-EV1 collector can perform significantly better (~ one order of magnitude) to current technologies.	60%
	M5 – Improve and modify existing collectors with smart attributes.		60%
	M6 – Write report on work conducted in this project.		100%

- Original project consisted of 6 objectives (M1 – M6) spread over a two-year period (FY18 and FY19).
- Some objectives in the FY18 and FY19 were exchanged due to delays in the construction of the Racetrack (M1).
- FY18 Objectives completed: Construction of the Racetrack (M1) and testing gas and particle emissions in a plasma (M2).

- FY19 Objectives completed: Designed and constructed a new collector; completed smart current monitoring, data loggers and collector triggering mechanisms using light, sound, and motion (M4 and M5 were partly completed).

Introduction

The nonproliferation technology section at SRNL develops particle collectors for use in the characterization of facilities dedicated to the production of nuclear material. The particle collectors are based on electrostatic precipitation technology. Although the particle collectors have been shown to work through the years, our preliminary analysis suggest that there is significant room for improvement. In addition to the particle collector performance, very little information is available on the operational conditions, the type of particulate collected, etc.

In order to characterize the performance of the particle collectors, a benchtop electrostatic precipitator system similar to the ACE 1.0 was designed and built to test different parameters affecting the collection. The recirculating particle collector system (Racetrack) enabled us to change ionizer wire length, current, voltage, and test changes to the flow tube design. These parameters were changed systematically to identify particle collection improvements to the system. The preliminary data measured in the first year indicates that the performance of the collector can be improved by at least one order to magnitude. Similarly, preliminary data suggest that under the new particle collector configuration and working parameters, it is possible to extract nanoparticles from a sample.

This project has advanced the state of science by enhancing the collection efficiency of particulates with the new prototype collector (ESP-EV1). This is important since the particle distribution of released material from some industrial processes is heavy on the nanoparticulate size. Preliminary results suggest that the ESP-EV1 can extract the nanoparticulate fraction from a sample loaded with environmental particulate matter and aerosols. Further work will be required to quantify the fraction and efficiency of the particulates and to incorporate the smart attributes tested and developed in this program.

Approach

The original project was funded as a two-year project. The overarching approach consisted of the development of a platform that could enable particle collection efficiency studies and the incorporation of advanced optical characterization and data logging features using a transformable collection system. The work concentrated on a parallel approach of tests where systems were designed and built to test plasma generation and optical characterization and other systems to test particle collection efficiency, particle separation and performance drives, such as air flow, current, voltage, etc. The development of the Racetrack breadboard system, based on the ACE 1.0 particle collector with pulsed particle injection, provided a testing platform for optical laser characterization and imaging capabilities.

Engineering delays in the construction and delivery of the Racetrack, resulted in the shuffling of tasks from the 2nd year to the 1st year and vice-versa. The premature first year technical assessment of the project resulted in the cancellation of the 2nd year of the project and affected the final deliveries. Even then, significant advances were made in the 1st year to understand the variables affecting the performance of the particle collectors. The 1st year experimental approach resulted in the design and construction of a two-stage particle collector (ESP-EV1) with significant enhancement in the collection efficiency and particle size separation.

Results/Discussion

The development of the Racetrack using additive manufacturing and new materials enabled us to visualize the injection of particulates into the system. The Racetrack helped us develop new methods to measure ionization current and its effect on the particle collection. With this information on hand, several modifications were made to control air flow and tube design to enhance collection efficiency. Physical modifications to the Racetrack helped us improve particulate collection using a two-stage collection system. Analysis of particulate matter collected on silicon plates with a scanning electron microscope (SEM) suggests that operational conditions can be selected to separate particulates based on mass/charge ratio. The collection efficiency was also increased significantly. Preliminary results suggest at least an order of magnitude improvement in particle collection after modifications have been made. At the end of the year, two variants of the new ESP-EV1 collector were built incorporating most advanced features for future deployment next to the current particle collector.

New optical concepts were also developed and tested in the 1st year program. Preliminary plasma generation with optical characterization provided successful results. Although further testing will be needed to incorporate the advanced features in the collectors, this approach will help provide timely information during a collection by providing information on the material collected. Similarly, new circuitry was designed to incorporate activation of the collectors based on light, sound and motion.

FY2018 Accomplishments

- Racetrack design: Experimental breadboard for particle collection and analysis testing was designed and built. A clear-through, 3D printed particle collector tube was designed, built and tested specifically for the Racetrack with special electrical properties. The Racetrack system enabled us to monitor: a) particle collection process within the electrostatic precipitator, b) current and voltage measurement of corona wire, c) particle collection dependence on variable air flow, d) gas and particle optical emission, e) answer questions regarding air flow particle size collection, etc.
- Corona wire current/voltage monitoring: A circuitry board design was completed to measure current and voltage of corona discharge directly from the power supply. This information was useful to identify operational parameters of the collector.
- Collector event triggering: Sound, motion or light burst triggers were procured and integrated in the circuitry of the particle collector to detect unusual events. Tests were conducted and modifications to the system will be required prior to deployment.
- Plasma generation: A new design for the collector tube with electrodes for plasma generation to produce emission from different gases and particles was completed. Preliminary studies indicate a positive outcome in the identification of particle material composition using optical spectroscopy.
- Advanced Collection System: First prototype design of collector “ESP-EV1” incorporating smart advanced concepts operating at one order of magnitude better collection than previous systems.
    - New flow tube material to eliminate electrical arcing at high voltages.
    - New electronics board to monitor and control the ionizer wire current and voltage.
    - Stream line flow tube for simplified airflow.
    - High current collector.
    - Two stage collection system for nanoparticle separation.
    - Large collection surface.
    - Air flow control capabilities.

Future Directions

Future funding will be required to:

- Complete collection efficiency studies for particulates of different sizes.
- Design a particle sorting collector to separate particulates based on the mass/charge ratio across the collection substrate.
- Incorporate a miniaturized picoammeter in the particle collector to study relationship between particles collected and charge measured.
- Incorporate smart features, such as data loggers and optical analysis of particle elemental composition during a collection.
- Continue optical signatures development for system characterization.
- Write patents on new concepts.

FY 2018 Publications/Presentations

1. None

References

1. List any references used in the report.

Acronyms

1. ACE (Airborne Contaminant Extractor)
2. ESP (Electrostatic Precipitator)

Intellectual Property

None

Total Number of Post-Doctoral Researchers

None