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Title:	Design and Integrate Improved Systems for Nuclear Facility Ventilation and Exhaust Operations
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NSR&D Program Fiscal Year (FY) 2014 Call for Proposals

Project Name: Design and Integrate Improved Systems for Nuclear Facility Ventilation and Exhaust Operations

Site: Los Alamos National Laboratory
Program Office:

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Design and Integrate Improved Systems for Nuclear Facility Ventilation and Exhaust Operations

Abstract

Objective:

The objective of this R&D project would complete the development of three new systems and integrate them into a single experimental effort. However, each of the three systems has stand-alone applicability across the DOE complex.

At US DOE nuclear facilities, indoor air is filtered and ventilated for human occupancy, and exhaust air to the outdoor environment must be regulated and monitored. At least three technical standards address these functions, and the Los Alamos National Laboratory would complete an experimental facility to answer at least three questions: (1) Can the drag coefficient of a new Los Alamos air mixer be reduced for better operation in nuclear facility exhaust stacks? (2) Is it possible to verify the accuracy of a new dilution method for HEPA filter test facilities? (3) Is there a performance-based air flow metric (volumetric flow or mass flow) for operating HEPA filters? In summary, the three new systems are: a mixer, a diluter and a performance-based metric, respectively.

The results of this project would be applicable to at least four technical standards:
ANSI N13.1 Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities;
ASTM F1471 Standard Test Method for Air Cleaning Performance of a High-Efficiency Particulate Air Filter System,
ASME N511 In-Service Testing of Nuclear Air Treatment, Heating, Ventilating, and Air-Conditioning Systems, and
ASME AG-1 Code On Nuclear Air And Gas Treatment.

All of the three proposed new systems must be combined into a single experimental device (i.e. to develop a new function of the Los Alamos aerosol wind tunnel).

Technical Approach:

The Radiation Protection RP-SVS group at Los Alamos has an aerosol wind tunnel that was originally (2006) designed to evaluate small air samplers (cf. US EPA 40 CFR 53.42). In 2009, the tunnel was modified for exhaust stack verifications per the ANSI N13.1 standard. In 2010, modifications were started on the wind tunnel for testing HEPA filters (cf. ASTM F1471 and ASME N511). This project involves three systems that were developed for testing the 24*24*11 (inch) HEPA filters (i.e. the already mentioned mixer, diluter and metric). Prototypes of the mixer and the diluter have been built and individually tested on a preliminary basis. However, the third system (the HEPA metric method) has not been tested, since that requires complete operability of the aerosol wind tunnel device. (The experimental wind tunnel has test aerosol injection, control and measurement capabilities, and can be heated for temperature dependent measurements.)

Benefits:

US DOE facilities that use HEPA filters and/or require exhaust stacks from their nuclear facility buildings will benefit from access to the new hardware (mixer and diluter) and performance-based metric (for HEPA filter air flow).

I. INTRODUCTION

Purpose

The US DOE complex must be able to: (1) monitor the exhaust air from nuclear facilities, (2) accurately measure concentrations of test aerosols in air ducts, and (3) specify and understand the measurement unit for air flow through HEPA filters.

To address all of these issues, this R&D project would complete the development of three new systems and integrate them into a single experimental (aerosol wind tunnel) device. The results of this project would be applicable to the following technical standards, respectively:

(A.) ANSI N13.1 Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities;

(B.) ASTM F1471 Standard Test Method for Air Cleaning Performance of a High-Efficiency Particulate Air Filter System, and ASME N511 In-Service Testing of Nuclear Air Treatment, Heating, Ventilating, and Air-Conditioning Systems and

(C.) ASME AG-1 Code on Nuclear Air and Gas Treatment.

All of the three new systems must be combined into the aerosol wind tunnel, since they are all necessary parts of the same effort.

Scope

The Los Alamos National Laboratory would develop a unified experimental facility to answer at least three questions: (1) Can the performance of a new air mixer be designed to meet various requirements for nuclear facility exhaust stacks? (2) Is it possible to evaluate the operational accuracy of a new diluter (and method) for HEPA filter test facilities? (3) Is there a performance-based air flow metric (volumetric flow or mass flow) for operating HEPA filters?

The three new systems are in final stages of development: a mixer, a diluter and a performance-based metric, respectively. The research and development would require:

(I.) The drag coefficient in the new air mixer (compliant to ANSI N13.1 requirements) needs to be reduced (by about 20%) for the wind tunnel. The new mixer ‘works’, but its high drag coefficient prevents the fan from moving enough air for the required tests. This is a typical real-world problem, but we expect to solve it readily.

(II.) The diluter system has been developed, but it hasn't been operated yet with the mixer and the performance-based metric. Additonally, the accuracy of the diluter has not yet been compared in round-robin testing.

(III.) Developing the performance-based air flow metric would solve the current error in the ASME AG-1 Code on Nuclear Air and Gas Treatment. In this standard, the measurement and specification of air flow has been confused and jumbled between volumetric flow (*ACFM*, '*actual cubic feet per minute*') and mass flow (*SCFM, 'standard cubic feet per minute'*).

A typical example of using SCFM as the flow measurement unit requires an unnecessary increase of the fan capacity of 18% on a hot summer day (e.g. 105 ^{o}F) compared to a cold winter day (e.g. 20 ^{o}F). For a HEPA filter that is rated at a volumetric flow of 1000 ACFM, if a flowmeter is used that indicates the SCFM unit, to maintain a value of 1000 SCFM, the fan flow rate would have to be unnecessarily increased to 1180 ACFM. This would require increased power consumption for the ventilation system, and it might not even be possible at attain that increased flow rate, for a particular fan.

Testing in the Los Alamos wind tunnel is necessary to resolve this error. Experimental results from Los Alamos (at an ambient pressure 76% of sea level) would be compared to a set of HEPA filter measurements from the ATI company (DOE contractor, Baltimore, MD) at sea level. Paired measurements from the two different altitudes are necessary to establish the comparative volumetric flow and mass flow quantities.

However, a complete solution of the flow problem would require paired measurements with a nanoparticle spectrometer. (See table below for a comparison of the available aerosol instrumentation.) We propose an experimental plan that would compare results using single channel spectrometers at both locations. This is a necessary first step to ensure the facilities are in basic agreement, especially regarding air flow measurement methods. The Los Alamos wind tunnel would demonstrate measurements using the available 0.3 μm spectrometers. As a part of this project, we would investigate using the Los Alamos 0.3 μm spectrometer at both locations. Based on the results of that work, a second proposal would be developed to perform the complete set of tests with a nanoparticle (0.1 µm) spectrometer. Procuring one or two of these instruments would be a major consideration that would be evaluated pending completion of the currently proposed project.

Aerosol Measurement Instruments in Inventory	Single Channel Photometer (ATI model 2HN)	0.3 micron spectrometer (TSI model 3330 and 3321)	0.1 micron (nanoparticle) spectrometer (TSI model 3910, $29K)
Los Alamos	yes	yes	no
ATI Inc.	yes	no	no

Business Case

(1) Across the DOE complex there are about 156 exhaust stacks in nuclear facilities that are continuously monitored, 'tens' of them are compliant to ANSI N13.1. (*Source: e-mail from Sandra Snyder, PNNL.*) The new mixer developed at LANL could substantially reduce (or effectively eliminate) the customized design and testing required for new or retrofitted exhaust stacks.

(2) The 2013 DOE Filter Test Facility workshop drew representatives from 21 DOE facilities and 6 vendors. (*Source: e-mail conference summary from George Hrbek, LANL attendee.*) The Los Alamos diluter is a new concept that is substantially different from current designs in ASTM F1471, and could be used in future filter testing programs.

(3) The ATI Inc company, under DOE contract, has tested an average of 2,500 HEPA filters per year for the past 16 years. These filters are immediately put into service across the DOE complex, and are built and operated according to ASME AG-1. The filters are used for either 5 years or 10 years, depending if their operating conditions include the possibility of liquid wetting of the filter material. (*Source: e-mail information from Scott Salisbury, LANL.*)

Linkage

(1) The new Los Alamos mixer applicable to DOE exhaust stacks.
40 CFR 61, Subpart H, ‘National Emission Standards for Emissions of Radionuclides Other Than Radon From DOE Facilities.’ “DOE facilities which have a potential to emit radioactive particulates into the environment may require sampling in accordance with 40 CFR 61, Subpart H,” (*Source: LANL ENV-ES-QP-104.7 Measuring The Degree Of Mixing In A Stack Or Duct Using Aerosols And Tracer Gas*).

(2) The new Los Alamos diluter suitable for HEPA filter testing.
DOE-HDBK-1169-2003 DOE Nuclear Air Cleaning Handbook.

(3) The performance-based metric for air flow measurement in HEPA filters.
DOE-HDBK-1169-2003 DOE Nuclear Air Cleaning Handbook.

II. TECHNICAL DESCRIPTION

Technical Approach

In Figure 1, a photograph of the Los Alamos aerosol wind tunnel indicates various components of the device. (The overhead duct is visually distorted in the panorama view.) This tunnel would be utilized for completing the development of the three different systems for nuclear air cleaning and monitoring purposes.

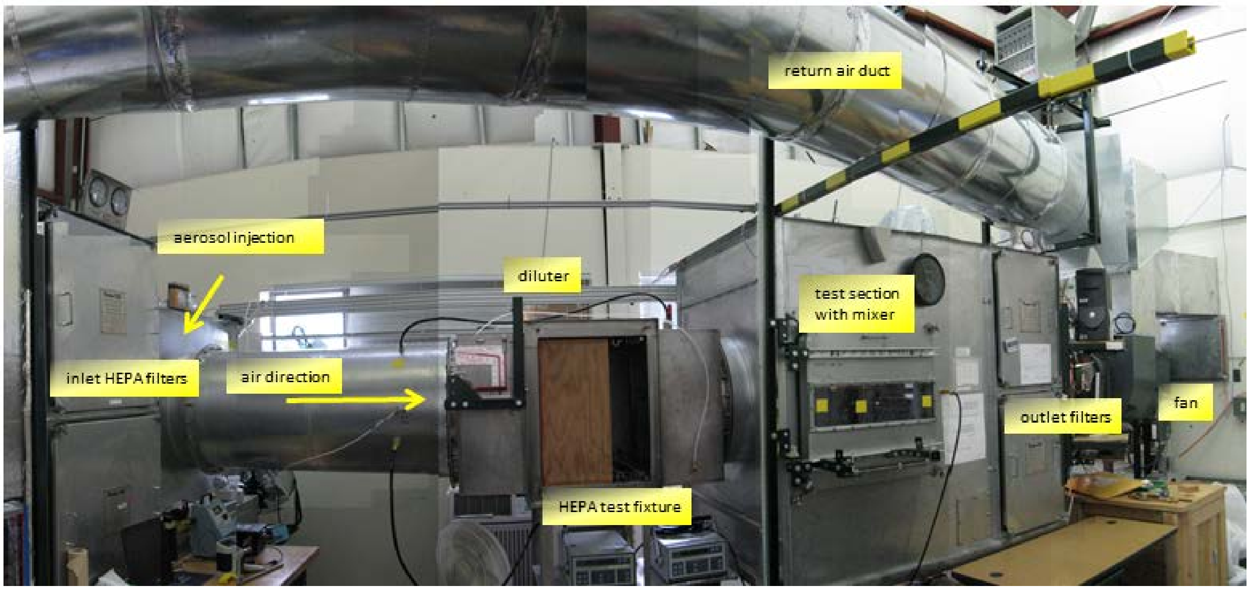


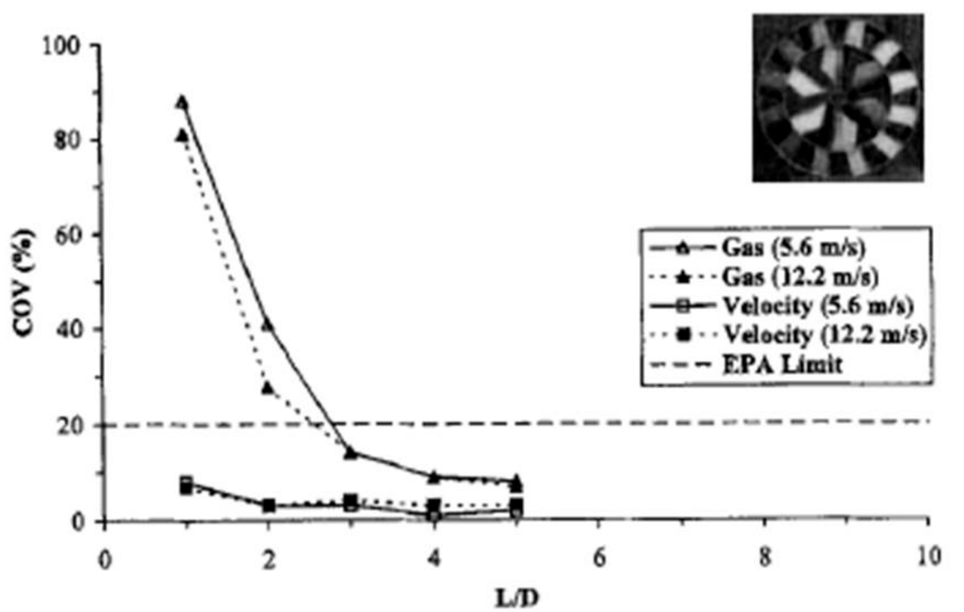
Figure 1. The Los Alamos aerosol wind tunnel requires completion and integration of three systems (i.e. mixer, diluter and performance-based air flow measurement).

System 1. The Los Alamos Mixer

In order to produce an accurate measurement condition, concentrations of aerosol particles in ventilation ducts and exhaust stacks must be spatially uniform over the cross section of the duct (ASME N511, ASTM F1471 and ANSI N13.1-1999/2011). An example of a mixer is the Gas Blender®, a static mixer with fixed vanes that force the air into counter-flow directions, producing an enhanced uniformity of aerosol concentrations in a duct.

Figure 2. A Gas Blender® from www.airblender.com is used to mix air and aerosol particles in a ventilation duct.

However, as seen in Figure 3 (below), the air mixing in ducts often requires not only a mixer but a certain length of duct past the mixing device. This distance is expressed in Figure 3 by the "L/D ratio". For the case of the Los Alamos wind tunnel, this would have required a duct length (past the mixer) of about six feet. This is space simply not available in the tunnel.



Coefficients of variation for velocity and tracer gas concentration profiles measured downstream of Mixer A.

Figure 3. From McFarland etal (1999). The uniformity of air velocities and tracer gas was measured versus the distance in the duct past the mixer.

Referencing the photograph in Figure 1, there is only four feet of open horizontal space in the tunnel test section that is available for achieving the mixing necessary for single point sampling of the aerosol concentration (cf. the label "test section with mixer"). This lack of space motivated the new mixer design at Los Alamos. It requires only two feet of the horizontal space inside of the test section, and its mixing performance meets ANSI N13.1 requirements.

Project Goal for System 1 (the mixer): The new LANL mixer can be scaled to reduce its drag coefficient, and the proposed project would require the fabrication of a new mixer (from standard galvanized sheet metal). (Los Alamos is not releasing photos or drawings of the new mixer at this time.)

<u>System 2. The LANL Diluter</u>

The ASTM F1471 technical standard contains a sketch of a suggested diluter for HEPA filter testing (see Figure 4 below).

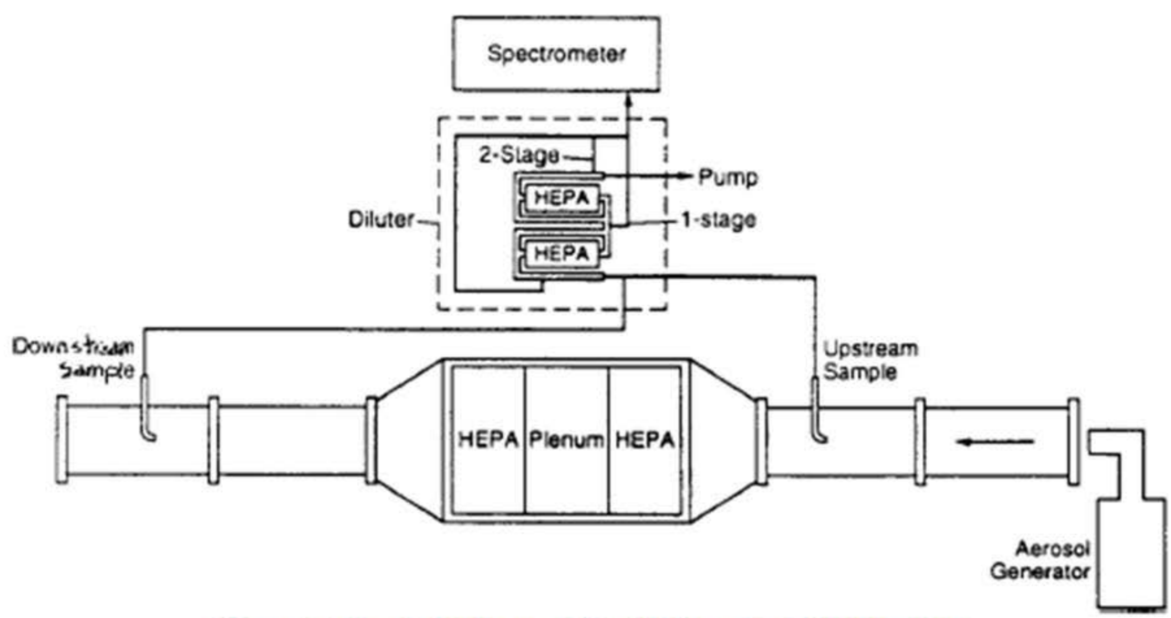


FIG. 1 Schematic Diagram of the In-Place Test Arrangement

Figure 4. The diluter design from technical standard ASTM F1471.

However, this particular approach did not produce reproducible or accurate aerosol concentrations measurements in the Los Alamos wind tunnel, so a new diluter concept was developed (see figure 5 below). This diluter has a radically simple approach, where test aerosol is able to bypass (or not) the tested HEPA filter by toggling open or closed the valve on the bypass line. By performing sets of measurements with the valve open and closed, and with two different magnitudes of challenge test aerosol, the filter collection efficiency, E, is determined where

$$E = 1 - C_D \;/\; ([C_{UN}/(C_{PN} - C_{DN})] * (C_P - C_D)) \qquad (1)$$

The "N" subscript signifies aerosol concentrations that are measured at the lower of two concentrations of generated test aerosol (i.e. oil droplets).

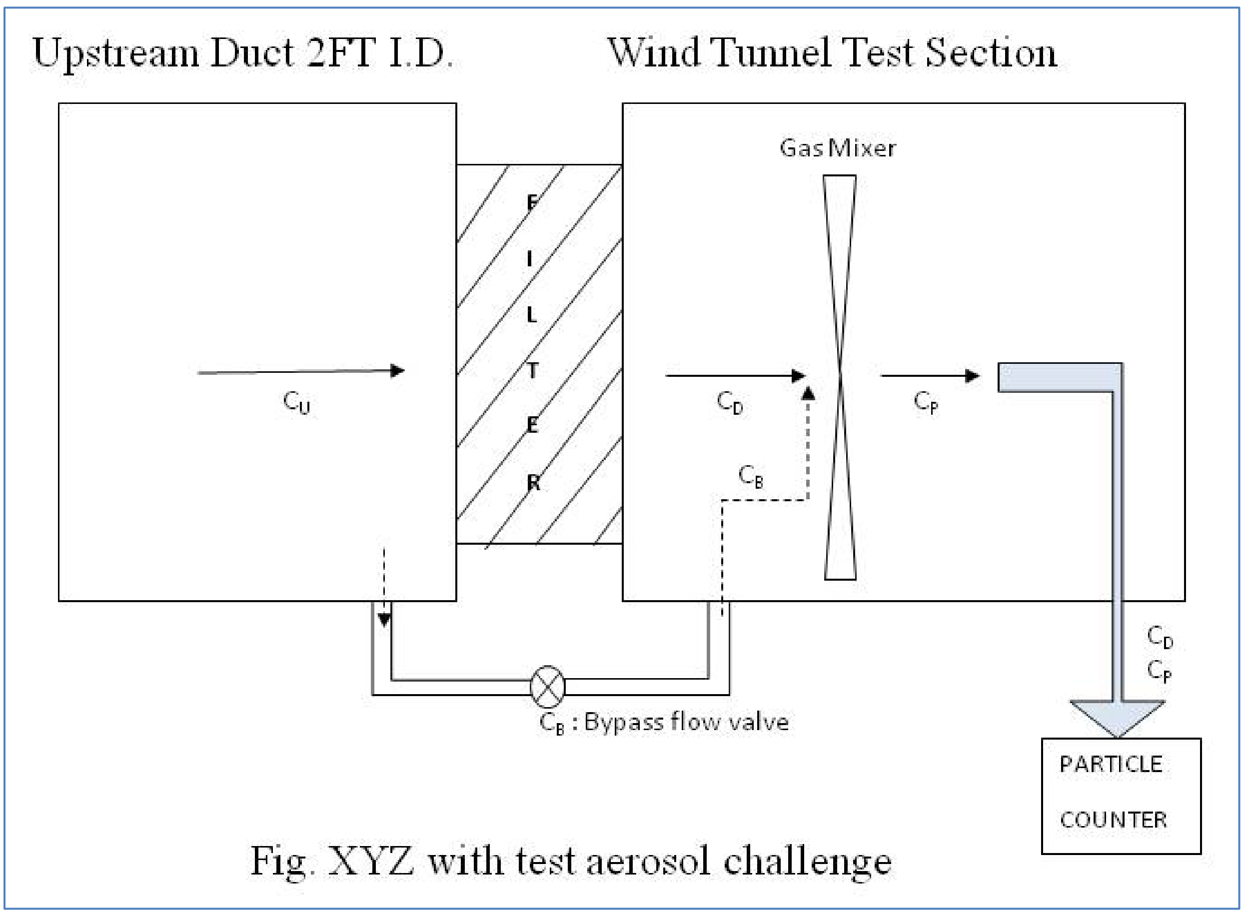


Figure 5. The Los Alamos diluter for HEPA filter measurements. Note this design bleeds test aerosol through a valved bypass line from a location upstream of the tested HEPA filter.

Project Goal for System 2 (the diluter): Preliminary tests have been performed with the new Los Alamos diluter. The goal for the diluter system would include round-robin tests on a representative set of filters would compare efficiency measurements between Los Alamos and the ATI company.

System 3. The performance-based metric for air flow measurement.

Because the ASME AG-1 code does not distinguish or specify the flow measurement unit that should be used, an end user of a HEPA filter cannot be confident that the filter is being used at the optimum flow.

A set of paired tests on the same set of filters will be performed at Los Alamos (7300 ft altitude) and at the ATI company (sea level). Filter efficiencies will be measured for the following conditions:

Test air flows on 1000 ACFM rated filters			
Q_A		deg ^OF	Q_S
SCFM	P_A/P_S	T_{ACTUAL}	ACFM
1000	0.76	70	1316
1000	0.76	120	1440

Test air flows on 1500 ACFM rated filters			
Q_A		deg ^OF	Q_S
ACFM	P_A/P_S	T_{ACTUAL}	SCFM
1500	0.76	70	1140
1500	0.76	120	1042

Project Goal for System 3 (the new metric): The goal of this portion of the project is to establish an agreement in experimental measurements between the Los Alamos facility and the ATI company. This will include equivalency between: (1) air flow measurements using an ASME compliant orifice plate flow calibrator, and (2) measurement of aerosol capture in the set of tested HEPA filters.

The end goal of the performance-based metric is to create a correction factor for filter efficiencies associated with the actual cubic feet per minute (ACFM), or standard cubic feet per minute (SCFM) flow measurement conventions. However, the final form of the correction factor is not in the scope of the proposed project. The flowrate correction factor requires measuring the HEPA filter penetration with an aerosol spectrometer of 0.1 μm (particle diameter) resolution. (For example, the TSI Inc. Model 3910 SMPS Nanoparticle Sizer has a list price of $29,900.) The Los Alamos team is evaluating the purchase of this instrument on a separate project. It is possible that the Los Alamos experiments could include measurements using this nanoparticle spectrometer, but this would not be an explicit goal for this project.

Coordination with the ATI company would be necessary for completing the final goal of the performance-based metric portion of this effort. We would evaluate the options available when the goals of this project are finished.

Technical Description (Milestones)

(1. a.) Design new mixer for lower drag coefficient.

(1. b.) Send the mixer design out for shop quote and fabrication.

(1. c.) Install new mixer in the wind tunnel device.

(2. a.) The new LANL diluter is ready to be tested in the complete wind tunnel device.

(3. a.) A set of HEPA filters will be collected for testing. Several filters were purchased three years ago for this project, and we expect to use these same unused filters.

(4. a.) Paired tests will be performed at Los Alamos and the ATI company. These tests will be limited to the use of an aerosol photometer (a single channel system, with respect to measuring the size of aerosol particles), and the 0.3 μm spectrometer. Air flow measurements will be compared between the two sites with an ASME compliant orifice plate flow calibrator. Filter performance measurements will be compared between the two sites.

(5. a.) Monthly status reports will be written.

(5. b.) A final report of the work will be prepared at the completion of the project. It is expected that three publishable articles could be produced from this effort.

Technical Description (Transition Plan)

(1.) The design of the new Los Alamos mixer would be submitted to the ANSI N13.1 committee for review. That committee is maintaining a database of different designs of exhaust stacks, both in the DOE complex, and also of designs that have been developed for the nuclear power industry. (Murray Moore is on the ANSI N13.1 committee.)

(2.) The design of the new Los Alamos diluter would be sent to the ASTM F1471 and the ASME N511 committees for consideration in their HEPA filter measurement methods.

(3.) Completion of the performance-based metric for the air flow measurements would not be part of the first year goals for this project. However, substantial progress would be made in this phase. We would consult with the ASME AG-1 committee members (Los Alamos staff member Scott Salisbury, for example, is a member) about the next phase of the overall effort.

III. <u>COST AND SCHEDULE</u>

This project is expected to require five months, from October 1, 2014 through February 28, 2015.

Personnel: Murray E. Moore, Kirk Reeves, Austin D. Brown and Ethan W. Clayton

Name	Education	Months on project	Fraction of effort	Costs, $K
Murray E. Moore	PhD, ME	5	0.05	$11
Kirk Reeves	BSME	5	0.13	$13
Ethan W. Clayton	UGS, 3rd year	3	1.00	$23
Austin D. Brown	BSME, May 2014	5	0.75	$29
M&S Costs				$10
TOTAL Project				$86

IV. RESEARCH TEAM

Murray E. Moore, Ph.D.
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Los Alamos personnel:

- Kirk Reeves has two years (staff experience) and three years (student experience) with exhaust stack testing and nuclear filter projects.
- Austin Brown has three years (student experience) with HEPA filters and nuclear filter projects.
- Ethan Clayton will be a new engineering student for this project.

Dr. Werner Bergman
ASME AG-1 Committee
Chief Scientist
(http://www.aerosolscience.com/)
Tel: 360.629.6840

Mr. Chris Hart
Air Techniques International Inc.
(http://atitest.com/index.html)
Tel: 410- 277-8981

REFERENCE

McFarland, AR, Gupta, R and Anand, NK, Suitability Of Air Sampling Locations Downstream Of Bends And Static Mixing Elements, Health Physics, 77(6):703-712, 1999