

Progress on Developing a Federal Reference PM Fine Source Test Method

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ABSTRACT

As a result of a new ambient air quality standard for particulate that is based upon particulate smaller than $2.5 \mu\text{m}$ in diameter, increased emphasis will be required in accurately measuring directly emitted emissions of this pollutant from source. This paper provides summary information on operating parameters and potential impacts of the mass of pollutant measured for several commonly used EPA reference test methods for particulate. In addition, operational parameters for several dilution based test methods are presented. Lastly, design criteria and progress toward the development of a fine particulate test method that incorporates the advantages of several of these test methods will be presented.

INTRODUCTION

On July 18, 1997, the U.S. Environmental Protection Agency promulgated an ambient air quality standard for fine particulate matter. Although challenged in the courts, the constitutionality of the standard was upheld by the Supreme Court. To assess the air quality throughout the US, a network of over 1,000 ambient air monitoring samplers has been established to measure fine particulate mass concentrations. Additionally, a network of approximately 200 samplers has been established to characterize not only the total mass of particulate but also the speciation of the collected particulate. Air quality management depends upon emission inventories that accurately estimate source emissions directly emitted to the atmosphere and source emissions that are chemically transformed in the atmosphere. Emission inventories are directly or indirectly based on the results of emission tests conducted for these pollutants. To more fully understand the sources of this particulate, a significant amount of additional emissions information will be required to characterize and allocate the particulate measured by the ambient air monitoring network. The Emission Measurement Center of EPA's Office of Air Quality Planning and Standards has identified a need to develop a Federal Reference Method to better characterize the source emissions of both the filterable and condensable particulate matter. To the extent practicable, the measurement method will attempt to also allow for the characterization of significant ambient air particulate precursor emissions. The paper includes information on the characteristics of existing particulate source test methods, the requirements needed in an improved test method and the progress in developing and evaluating the hardware to satisfy these requirements.

BODY

Background

Unlike other criteria air pollutants and most hazardous air pollutants, the amount of particulate mass that exists in ambient air or flue gas released from an emission source is determined by the conditions under which it exists and the method used to collect the material. The physical conditions that may have the greatest effect on mass concentration of particulate include temperature, humidity and pressure. For ambient particulate sampling, the differences between the ambient conditions and sample collection conditions are minimal. However, for particulate source sampling, the flue gas conditions soon after release to the ambient air and the sampling conditions may be significantly different. As

stated in 40CFR51.100, “Particulate matter emissions means all finely divided solid or liquid material, other than uncombined water, emitted to the ambient air as measured by applicable reference methods, or an equivalent or alternative method, specified in this chapter, or by a test method specified in an approved State implementation plan.” A similar statement is made concerning PM₁₀ emissions. While there is only one ambient reference method for PM₁₀ and PM_{2.5}, there are several reference methods for particulate emissions from sources. Source sampling and analytical methodologies used to quantify particulate mass concentrations control the sampling temperature, control the temperature and humidity levels for analytical analyses, and make adjustments to analytical results to achieve consistency. This consistency is achieved at the detriment of accurately characterizing the mass of material in the flue gas following release to the environment. Most of the EPA reference source test methods for particulate were developed as part of a process to establish a national new source performance standard for a source with a unique flue gas condition. To achieve consistent results on the controllable portion of particulate emissions, different filtration temperatures were employed, different components of the sample train were included and different analytical finishes were employed. While most EPA reference test methods were not designed to measure total particulate emissions to the environment, one combination of test methods was designed to obtain this information. However, because of differences between the flue gas release conditions and the sample collection method, concern has been raised that this measurements made with this method are not an accurate representation of that mass of particulate contained in the flue gas immediately following release to the environment. Although several research test methods are available that more closely replicates the release of source emissions to the environment, these methods are not well established outside the research community and are not amenable for routine application at the variety of potential source sampling location that exist. For the last three years, OAQPS has been developing a source sampling method that incorporates aspects of many of the dilution based research test methods, is more suitable for use by the more typical individuals engaged in source sampling and can be used at test locations which are difficult to access and where there is limited space at the sampling location.

Existing Federal Reference Methods for PM Source Sampling

There are several common methods for collecting and analyzing particulate emissions from stationary sources. The more commonly used methods are codified in the Title 40 of the Code of Federal Regulations (CFR) Subchapter C, in either Part 60 or Part 51. Some State and local agencies require the use of additional source test methods. Although most of the State test methods are similar to the federal reference methods, minor variations may create substantial differences in the material collected or what is considered to be particulate. Each federal reference source test method was developed to provide information for a specific limited purpose. Most of the particulate methods are contained in the Appendix A of 40CFR60, Standards of Performance for New Stationary Sources (NSPS). A few particulate test methods are contained in Appendix M of 40CFR51, Requirements for Preparation, Adoption, and Submittal of Implementation Plans. Appendix M contains Recommended Test Methods for State Implementation Plans.

While a few of the particulate test methods developed for evaluating compliance with the NSPS include analyses of particulate that pass through the filter, generally only the filterable particulate is required to be weighed. The filterable particulate is that material collected on or before the sample filter. One of the reasons that the methods weigh only the filterable particulate is that the methods were designed to evaluate the capability of sources to control the portion of the particulate emissions that is amenable to collection through the use of add on control devices. To prevent condensation and corrosion problems, many particulate add on control devices operate at temperatures over 121 °C. As a result, vapor state particulate is not controlled. In addition, measured emissions of the particulate that passed through the filter was highly variable. Therefore, to provide a measurement method that

provided a fair representation of the performance of add on control devices, only the filterable portion of the particulate is required to be measured in most test methods presented in 40CFR60.

The particulate source test methods that are most familiar to most air pollution specialists are EPA Method 5 and EPA Method 17. In Method 5, the sampled gas is maintained at temperatures between 106° C and 134° C to preclude the condensation and collection of water. Some applications of Method 5 allow the sampled gas temperature to be between 146 °C and 174 °C to minimize the collection of sulfuric acid. In addition to precluding condensation and collection of water and sulfuric acid, the high temperatures preclude the condensation and collection of several organic and inorganic (sulfates, nitrates, chlorides, fluorides, metal) compounds. Differences in the sample gas temperature will result in differences in the amounts of these organic and inorganic compounds collected and may result in significant differences in the total mass collected. EPA Method 17 uses an in-stack filter, therefore the sampled gas temperature varies with the process. Variations in stack temperature would have the same effect on the mass collected as variations of the Method 5 sampled gas temperature. Some EPA Method 5 variants require further laboratory adjustments of the collected sample. EPA Method 5B requires the probe and filter catch to be heated to 160 °C for six hours to volatilize any condensed sulfuric acid that may have been collected. EPA Method 5F requires the probe and filter catch to be extracted with water, analyzed for sulfate and the weight of ammonium sulfate subtracted from the particulate weight. Because of the variations in the filtration temperatures and analytical finish used by these test methods, there will be differences in particulate emissions measured by these methods and each of these methods will measure less particulate than is actually emitted to the air.

There are three particulate test methods in Appendix M of 40CFR51. Two of the methods measure that portion of the particulate matter that is filterable at stack temperatures and has an aerodynamic diameter of 10 μM or less. The third method is designed to measure condensible particulate matter. Condensible particulate is that material that is in a vapor state at the filtration temperatures of other particulate test methods but would become solid/liquid at ambient temperatures.

EPA Method 201A is similar to EPA Method 17 in that an in-stack filter is used to collect the particulate. However, in Method 201A, a cyclone separates the particulate that is larger than 10μM aerodynamic diameter from the sample gas. As a result, only that particulate that is 10 μM in aerodynamic diameter or less (PM₁₀) is measured. As with the EPA Method 17, the measured PM₁₀ emissions may vary with the gas temperature and the measured PM₁₀ will be less than the PM₁₀ emitted to the air since condensible particulate is not collected.

EPA Method 202 is designed to determine the condensible particulate that passes through the filter of other test methods. Following filtration, the sampled gas is quenched in cold water to condense some of the inorganic and organic vapors. At the completion of sampling, the organic and inorganic material in the water is separated with methylene chloride. The impinger water is evaporated at 105 °C leaving the inorganic material for weighing. The methylene chloride is evaporated at room temperature leaving the organic material for weighing. Some potential biases were recognized in the development of Method 202. To minimize these biases, optional provisions are incorporated into the method. For example, SO₂ in the sampled gas is absorbed in the water and slowly converts to sulfate. To minimize the bias that would be created, Method 202 allows for the purging of the absorbed SO₂ from the impinger water. Also, Ammonia gas and hydrogen chloride gas may quickly convert to ammonium chloride particulate in the water. There may be other similar situations that would result in a bias between what is measured by Method 202 and what would exist in the near field stack plume. However, these situations have not been documented in well controlled studies.

The potential biases due to differences in chemical reactions in water verses air has been the basis for much of the criticism of Method 202. Additional criticism of Method 202 stems from the

demonstration of an apparent lack of precision in the method. Because EPA Method 202 is more complicated and requires scrupulous cleanliness and attention to detail, variations in reported results are greater than with the filterable particulate test methods. In addition, process conditions that may result in variations in the condensible emissions may not be well understood and controlled by many sources.

Existing Dilution Source Sampling Methods

There are several existing dilution sampling systems that have been used for characterizing source emissions. Variations in four common components in the design and orientation of the hardware can be used to differentiate these sampling systems. The four components are: (1) the probe/dilution air interface; (2) the mixing chamber; (3) the time-delay chamber; and (4) the sampling module. Although the following descriptions provide basic design considerations of the most common dilution sampling systems, each sampler is modified by the researcher to meet their specific design requirements.

University Research Glassware (URG) Dilution System

The University Research Glassware (URG) Dilution System is designed to simulate far-field plume aerosol chemistry involving condensation and coagulation of reactants. The semi-portable inverse U-shaped modular system is divided into four major components: (1) probe/dilution air interface, (2) mixing chamber; (3) time-delay module; and (4) sampling manifold module:

Probe/dilution air interface: Stack gas is extracted from the source isokinetically through an in-stack cyclone. Particles and gases are moved through the heated probe to the interface of the dilution air. Purified dilution air is introduced concurrent with the flow of hot stack gas through holes drilled in concentric circles at the back of the probe to facilitate thorough mixing. Typically, depending upon isokinetic flow rate, a side stream of the stack gas is extracted at a gas flow rate of 1-5 liters per minute (L/min) with the dilution flow rate of 40 L/min, to yield dilution ratios ranging from 8:1 - 40:1.

Mixing chamber: The mixing chamber is approximately three feet long, made of glass which is Teflon(l) coated inside to minimize the loss of reactants. The chamber is heated to ensure that water remains in the vapor state.

Time-delay module: The time-delay module allows the diluted stack gas to react and simulate plume chemistry reactions. The time-delay module is made of both interior coated Teflon[®] glass and interior coated Teflon[®] aluminum. The module is comprised of various sections which can extend the residence time of the reactive stack gas to up to several minutes. The U-shape module extends vertically approximately three feet in the air and then returns horizontally to form the sampling manifold. The time-delay module is designed to provide the diluted stack gas at ambient air conditions involving temperature, pressure and humidity to the sampling module representing a 5-40 second residence time.

Sampling module: The sampling module is attached to the end of the time-delay module and allows up to 10 sampling ports. Depending upon the analytes of interest, the sampling ports allow the user to attach different systems to quantify simulated plume constituents. Each sampler would be equipped with its own pump, flow controllers etc.

The basic URG system has been used extensively by various researchers for source profile studies both in Canada and the US.

CalTech System

Similar to the URG system, the CalTech system is also a dilution system. Because of the unique application of rinsing the complete system between sample runs (to quantify organic aerosols which adhere to the interior walls of the dilution system), the inverse U-shaped semi-portable system is constructed of stainless steel and Teflon[®], rather than aluminum.

Stack gas is extracted from the source isokinetically through a 10-micrometer (μm) cyclone. Following the cyclone, the stack gas flows down a heated probe, through a heated venturi to the entrance of the dilution chamber. Purified dilution gas is then introduced at a 90° angle to the stack gas, where initial mixing occurs. The dilution gas is purified by passing ambient air through a dehumidifier, a high-efficiency particulate filter, an activated carbon bed, and a final filter. Dilution ratios of up to 55:1 have been documented. Upon exiting the mixing chamber, the diluted gas stream flows through the inverse U-shaped tube downstream to the entrance of the residence time chamber.

At this point, approximately 20 % of the diluted gas stream is extracted for additional "aging," allowing for plume chemistry reactions to go to completion. The residence time chamber allows simulated plume travel of 40-60 seconds from point of origin. As with other dilution systems, a multi-port arrangement is provided at the end of the residence time chamber for parallel sample collection for organic aerosols and other reactive gases and condensibles.

Desert Research Institute (DRI) Dilution System

The Desert Research Institute (DRI) Dilution System is very similar in construction and operation as the CalTech Dilution System, with some minor changes. Like the CalTech dilution system, the DRI dilution system uses a U-shaped configuration. In operation, the stack gas is extracted at a rate of 20-30 Lpm through a heated probe (without pre-separation of particles in a cyclone) and heated venturi to the entrance of a 15 centimeter (cm) diameter mixing chamber. Purified dilution air is introduced at a 90° angle to the stack gas in the mixing chamber at a dilution ratio of between 25:1 to 50:1. From the mixing chamber, the gas flows down the U-shaped dilution tunnel at a rate of 1200 Lpm for approximately 2.4 seconds. At this point, a portion of the gas stream is extracted into a 18 in. by 6 ft. residence chamber where an additional 80 second of residence time is provided for the development of the simulated plume. Parallel sampling ports are provided at the end of the residence chamber where diluted stack gas is extracted by different sampling systems, depending upon the analytes of interest.

As with the CalTech dilution system, the DRI dilution system is constructed entirely of stainless steel and Teflon[®] to facilitate cleaning of the system between runs in preventing cross-contamination. External sensors are used to monitor and record stack and dilution flow rates, ambient and dilution tunnel temperatures, relative humidity, and other system variables.

Nuclear Environmental Analysis Inc. (NEA) Dilution System

This sampling system is linear in design rather than a U-shaped construction like the previous dilution systems. In operation, this system extracts a sample isokinetically through a traditional EPA Method 5 buttonhook nozzle down a heated stainless probe to the entrance of the mixing chamber. The unfiltered stack gas stream enters the mixing chamber at a 90° angle to the dilution gas. The dilution gas has been cryogenically dried, filtered (i.e., HEPA filter), and purified of organics by passage through

activated carbon. The mixing of the dilution gas with the unfiltered stack gas stream provides a diluted sample of the sample gas at near ambient temperature and low (i.e., less than 30%) relative humidity within a residence time of two seconds. The fully diluted stack gas sample is immediately filtered by an 8 in. by 10in. quartz filter for mass determination. If particulate sizing is needed, a parallel port attached to the mixing chamber is used for cascade impactor sampling. Following the removal of particles, gas phase samples can be collected through a downstream six-port manifold.

Southern Research Institute (SRI) Dilution System

Similar to the NEA Dilution System, the SRI Dilution System is linear in construction. All active components of the dilution system are made of glass or Teflon[®] coated aluminum to maintain the integrity of the extracted sample. The system employs an 8- μm in-stack cyclone, heated probe and an external EPA Method 5 filter to remove primary particles. Similar with other systems, the dilution gas used in the system is cooled, dried, scrubbed through activated carbon, and finally filtered before delivery to the mixing chamber. The dry dilution gas enters the mixing chamber through a cone assembly containing 82 perforations which create a well mixed, stable velocity profile at the exit of the mixing chamber. The filtered extracted gas stream enters at the apex of the cone assembly.

The SRI Dilution System can reach dilution ratios of up to 20:1 and achieve a residence time of approximately two seconds. The dilution ratio is set to provide a diluted stack gas stream at near ambient temperature, with moisture remaining in the vapor state. To quantify condensables, the complete diluted stack gas stream is then filtered through a quartz filter maintained at 20°C at the exit of the mixing chamber. Dilution ratios can be varied through adjustments of the mixing chamber pump and dilution air flow rate to simulate plume chemistry.

Brigham Young University (BYU) Dilution System

The design and construction of the Brigham Young University (BYU) Dilution System is similar to the URG Dilution System. The main body of the BYU dilution system is the inversed U-shaped dilution chamber (i.e., 0.75 meter diameter, 7.5 meters long, water jacketed, Teflon[®] coated aluminum). The stack gas is extracted isokinetically from the source through a nozzle attached to a 3-5 meters long, 1 cm diameter stainless steel probe. At the exit of the probe is an elutriator-impactor assembly to remove particles larger than 2.5 μm at a flow rate of 18 Lpm. Immediately upon exiting the probe, the stack gas is mixed with dry, filtered and purified dilution air, at a ratio of 1:6 to 1:45, in the first section (mixing chamber) of the inversed U-shaped dilution system. After the mixing chamber, the diluted stack gas is further cooled and equilibrated. The equilibrium time of the diluted stack gas in the dilution system is about four minutes with a total flow of 0.75 cubic meters per minute (m^3/min) or 30 minutes with a total flow of 0.11 m^3/min . Parallel sampling ports are positioned at the exit of the dilution system, similar to the other described dilution systems.

Design Goals for OAQPS Fine PM Sampling System

Several aspects that would preclude widespread use of the existing dilution sampling systems have been identified by industries and source test contractors that perform the majority of particulate source tests. The more significant aspect is the size and weight of the existing systems. For many sources, physical restrictions limit access to the stack sampling location. These restrictions include narrow stairways, partially blocked pathways, small two to three person elevators and numerous other

restrictions. Space limitations at many sampling locations also restrict the use of existing dilution sampling systems. The geometry of existing stack sampling ports limits the potential widespread use of the existing dilution sampling equipment. While the existing dilution systems can be adapted to sample in vertical or horizontal ducts, adaption to inclined ducts becomes difficult due to the size and weight of the equipment. The second aspect of the existing dilution sampling systems restricting their widespread use is the complexity of their operation. Heretofore, these sampling systems have been operated by highly trained and experienced source testers or research assistants.

When OAQPS began conceptual development of the fine particulate sampling method, several goals were identified. While the existing dilution sampling systems were used primarily to develop source profiles or “fingerprints” for use in source receptor modeling, OAQPS wanted a method that would additionally quantify the total fine particulate emissions. OAQPS also wanted a method which was not as limited in accessing the available sampling locations. Lastly, OAQPS wanted a method that could be performed by the more typical experienced source testers. As a result, the following goals were established:

- Eliminate chemical reactions in water by the use of dilution sampling to condense vapors to particulate.
- Reduce the size and weight of the individual modules of the sampling system.
- Reduce the footprint and height of the assembled sampling system.
- Reduce the complexity and/or automate the operation of the sampling system.
- Construct the internal components between the PM_{2.5} sizer and the filter to minimize deposition of fine particulate.
- Construct the internal components between the PM_{2.5} sizer and the filter to allow recovery of the deposited material for later analysis.
- Incorporate sampling of a slipstream of diluted sample gas to allow for collection and analysis of particulate by existing ambient air speciation methods.

To achieve these goals, design concepts used in several existing dilution sampling systems were adopted. However, some design concepts used by most of the existing dilution sampling systems were not compatible with achieving these goals. In-stack particle sizing to exclude all particulate larger than 2.5 μm in aerodynamic diameter allowed for the recovery of material deposited on the internal surfaces between the final particle sizer and the filter. Use of glass/quartz probe and the use of Teflon[®] coated metal between the particle sizer and filter minimized electrostatic forces which would collect fine particulate. Maintaining the temperature of the parts of the sampling system prior to the dilution chamber above the stack temperature minimized deposition of fine particulate on these components. Reducing the diameter and length of the dilution tunnel resulted in a smaller footprint and less weight. Eliminating the residence time chamber also resulted in a smaller footprint and less weight. The reduction in size of these components made it possible for field recovery of the material deposited on the internal surfaces and preparation of the sampling system for subsequent testing. In addition, the smaller size minimized the quantity of solvents used to recover the deposited. Including a port in the dilution tunnel allowed for the optional connection of an ambient air speciation sampling system for developing source profiles for use in receptor modeling.

To allow the test method to determine both coarse particulate (PM₁₀) and PM-2.5, these fractions would require segregation and separate analysis. To accommodate measurement of PM₁₀, the

sampling train would need to be easily moved during testing to allow traversing of the entire stack. To maximize the amount of material collected on the filters, the sampling train would need to minimize the deposition of fine particulate on the internal surfaces of the train prior to the filters.

In summary, the primary goal in developing the fine PM sampling system was to make it comparable to existing source test methods with respect to size, complexity and complete recovery of PM. Additional primary goals were to mimic ambient particulate formation mechanisms, minimize potential for artifact formation and accommodate the collection of samples for speciation analysis. Each of the major components of the sampling system were selected or designed to achieve these goals

Components of OAQPS Fine PM Sampling System

Figures 1 through 6 are pictures of the major components of OAQPS's fine particulate sampling system. Figure 7 is a picture of all but one of components of the sampling system. This picture was taken during the second hardware shakedown test which was performed at a pulverized coal fired electric generating unit. Figure 8 is a picture of the stack platform and sampling system during the first hardware shakedown test. As can be seen in the photographs, both sampling locations were on typical stack sampling platforms. The elevation of the platform shown in Figure 7 was about 250 feet above the ground and the platform in Figure 8 was about 100 feet above the ground. Access to the platform in Figure 7 was by a three person elevator while access to the platform in Figure 8 was by way of a vertical ladder on the side of the stack. The following paragraphs provide more detail on the components of the sampling system.

Figure 1 shows the particulate sizing devices as they would be assembled (but prior to alignment) for use during a source test. The PM₁₀ cyclone and nozzle are identical to the hardware required by EPA Method 201A. A smaller cyclone is inserted after the PM₁₀ cyclone. The smaller cyclone is sized to separate particulate larger than 2.5 μM from the sample gas stream when operated at the required sampling rate. As a result, particulate between 2.5 μM and 10 μM is collected in the smaller cyclone. As with Method 201A, a constant sampling rate is required to maintain the size of the particulate separated by the cyclones. The required sampling rate to maintain particle sizing at 10 μM and 2.5 μM is about 0.14 cubic meters per minute. To maintain isokinetic sampling at the required sampling rate, a nozzle with a diameter that results in a sample velocity that most closely matches the average velocity in the duct being sampled. Particulate smaller than 2.5 μM and material that will condense to particulate exits the PM_{2.5} cyclone to a heated glass or quartz probe that maintains the sample gas 5.6° C hotter than the stack gas.

Figure 2 shows the heated sample venturi box which is kept outside the stack and connected to the 16 mm internal diameter sample probe inserted in the stack. This box is heated to maintain the temperature of the sample gas at the probe temperature. The Teflon[®] coated venturi has pressure taps at the venturi throat and downstream. The venturi is calibrated to provide accurate gas flows from the measured pressure differentials between the two taps. Immediately after exiting the venturi, the sample gas enters the T-connector dilution chamber (shown in Figure 3), where it is mixed with cool filtered air. The volume of air that is mixed with the sample gas is 10 to 50 times the volume of the sample gas. The temperature of the resulting combined gas is less than 6° C hotter than the dilution air prior to mixing. Organic and inorganic vapors contained in the sample gas are condensed at these lower temperatures.

Although the mixing in the dilution chamber is turbulent, laboratory evaluations indicated that additional mixing was required to uniformly distribute the sample and dilution gas and therefore the particulate. While it was expected that uniform mixing would not be required for total fine PM mass testing, obtaining samples suitable for speciation analysis from a slipstream of the diluted gas was also desired. Initial designs used turbulent flow in an extended mixing area to achieve uniform mixing of the gases. However, the required mixing length was over 1.5 meters. Even when looped around the sample venturi box, the resulting system was cumbersome and recovering the deposited material was difficult. Therefore, a static mixer was added to provide further mixing in a significantly shorter distance. A picture of the static mixer partially removed from the mixing tube is shown in Figure 4.

Figure 5 is a picture of the major components of the fine PM sample train assembled in their straight line orientation. For sampling locations with limited distance between the stack and an obstruction a 90° orientation of the mixing area can be used. This orientation can be seen in Figure 2. In addition to the components already described, Figure 5 shows the dilution air venturi attached to the dilution air inlet of the dilution chamber. As with the sample venturi, the pressure differential between the throat and the downstream pressure taps provides an accurate measurement of dilution air flow. The extraction port for the speciation samples is visible between the mixing area and the 142 mm final filter holder. The speciation sample module is visible on the left side of Figure 6. Three of the four legs of the speciation sampler are visible in the module. Two of the visible legs include annular denuders which were used to collect SO₂ gas prior to filtration on 47 mm filters. With alternative coatings, these denuders can be used to collect for quantification other acidic, basic and organic gases such as ammonia, NO_x HF and HCl. Depending on the critical orifice used for each leg, speciation sampling rates up to 8 liters per minute can be achieved with a standard EPA Method 5 sample pump. In addition to the Teflon[®] hose between the speciation module and the extraction port at the end of the mixing area of the sampler, the hose connecting the exit end of the final filter to the high volume air mover is visible.

Figure 7 shows a more complete view of the hoses connected to the fine PM sampler. These hoses are connected to the flow control module which contains two gate valves. These valves control the dilution air flow and the air flow through the final filter. While the control module in the picture contains manual gate valves, these will be replaced by valves that are controlled automatically by the computer data acquisition system (DAS). The DAS is also used to monitor and record temperatures, pressures, velocities, humidities, gas flow rates and isokinetic variations. The DAS computer is highest component located behind and above final filter in Figure 7. Also visible in the figure and connected to the flow control module is the high volume air mover which is located in the lower right corner of the picture. The other hose leads to the dehumidifier and high efficiency particulate filter module which is not visible in the picture. The speciation module is also not visible in the picture but is located behind the stack off the left side of the picture.

Current Activities

Two hardware evaluation tests have been conducted over the last six months. The majority of the evaluations focused on the physical aspects of preparing the hardware for sampling, assembling it at the sampling location, successful operation of the equipment during the testing periods, documentation of the sampling parameters during the test periods and clean up of the hardware components and sample recovery subsequent to the test periods. A secondary objective during the hardware evaluations was to assess the relative quantities of fine PM collected on various components of the sampling system. The first test evaluated the hardware against 14 quality criteria while the second test excluded one of the

criteria. Hardware operational performance included maintaining isokinetic sampling, maintaining particle cut size by the cyclones (only 2.5 μM cyclone for the second test), maintaining constant dilution ratio, maintaining dilution air humidity, maintaining sample temperature prior to dilution and maintaining exhaust air temperature. Sample collection performance criteria included the quantities of particulate collected on the 142 mm filter, the 47 mm filters and the internal surfaces between the exit of the 2.5 μM cyclone and the filters. Additional sample collection performance criteria included denuder SO_2 removal efficiency, denuder breakthrough and the removal efficiency precision of the denuders.

Both hardware evaluation tests showed that the operational performance was as expected and met or exceeded the goals that we had established. In addition, at the first test, the performance of the denuders in removing and providing a semi-quantitative measurement of SO_2 emissions was met. However, insufficient fine particulate was collected on the first test to evaluate the performance of the sampling system to measure fine particulate. It is believed that insufficient material was collected because of low emissions (PM, SO_2 and NO_x) at the relatively new facility. The second test was conducted in March. The second test site is a more typical utility boiler with higher concentrations of PM, SO_2 , and NO_x . In addition, the second test site has recent information on their emissions of filterable particulate, condensable particulate and sulfuric acid. Laboratory results are not available at this time to assess the performance of the sampling system to measure fine particulate nor the performance of the denuders to remove and quantify SO_2 .

Next Steps

When laboratory result from the second test are available, the performance of the sampling system in measuring fine particulate and SO_2 will be compared to the criteria that were established. It is expected that the denuder samples will have performed favorably as they have in the past. It is unclear whether the hardware performance will meet our criteria for measuring fine particulate. However, previous testing by other methods indicate that sufficient emissions exist to be able to perform this evaluation. In addition to evaluating the test methods performance against our established criteria, the results obtained will be compared to the emissions information previously collected emissions data collected by other test methods.

Following the successful hardware evaluation of the test method, several comparison tests will be performed. Several researchers have indicated an interest in collaborating on a test to compare their dilution sampling system with our sampling system. Potential sources where these comparisons would be made include coal and oil fired boilers. As a minimum, the comparisons would include the mass of fine PM measured and those constituents included in the ambient air speciation analyses. In addition, there is interest in comparing the results of detailed species of a broad range of volatile and semi-volatile organic compounds. During these comparison tests, we would also include testing by the existing reference test methods. While there is information to indicate that the existing methods do not produce a significant bias for total particulate when used at a coal or oil fired boiler, information is not available to determine the level of bias for fine PM.

At the conclusion of the comparison tests between research level dilution systems and the OAQPS sampling system, we would begin a process to establish a standardized methodology for routine source testing for fine PM and for collecting source specific speciation profiles. Several alternative are available as a result of the National Technology Transfer and Advancement Act (NTTAA). The Act requires that federal agencies adopt private sector standards, particularly those developed by standards

developing organizations, wherever possible in lieu of creating proprietary, non-consensus standards. Participation by EPA in the development of consensus standard for fine particulate sampling system by a standard developing organization (such as ASTM, ASME or ISO) has some several advantages. Alternatively, EPA could use establish a reference method by the proposal and comment process through publication in the Federal Register.

CONCLUSIONS

The promulgation of an ambient air quality standard for fine particulate matter has created the need for the development of a source test method which can be used for quantifying the primary fine particulate emissions at many stationary sources. In addition to quantifying the fine PM emissions from sources a need exists to determine facility specific speciation source profiles for use in receptor models. Because of the limitations of existing test methods EPA initiated a project to develop and evaluate a source test method that would meet the future needs of the Agency, States and industry. At this time, EPA has developed hardware that meets the physical requirements for universally applicable test method. It is unclear at this time whether this test method will meet the measurement goals that have been established.

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KEYWORD

Fine Particulate Matter

PM

Speciation

Source Test Method

Emission Inventory

Figure 1. In Stack PM_{10} and $PM_{2.5}$ Cyclones.

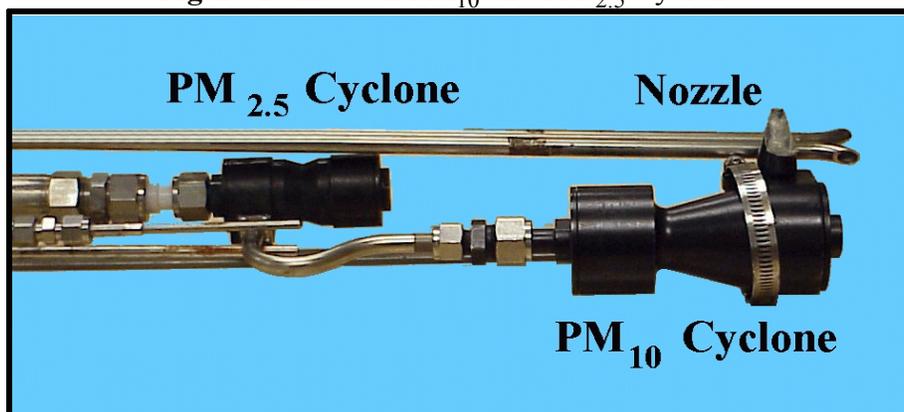


Figure 2. Heated Sample Venturi Box.

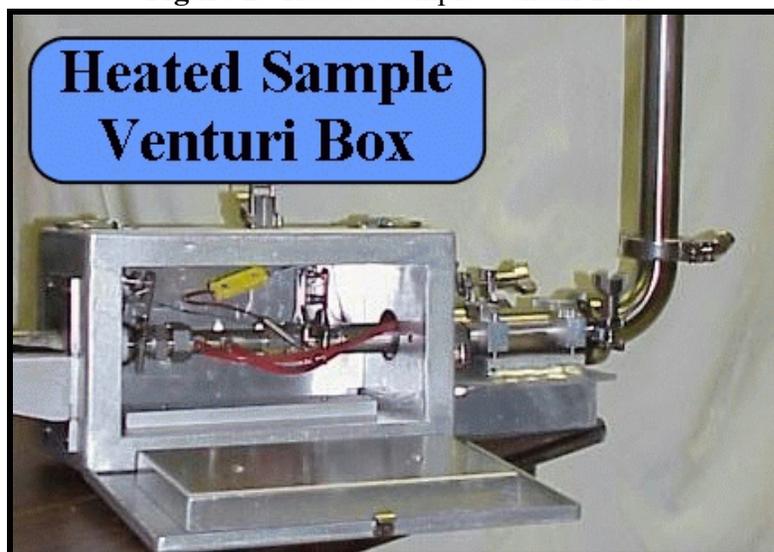


Figure 3. Mixing Chamber

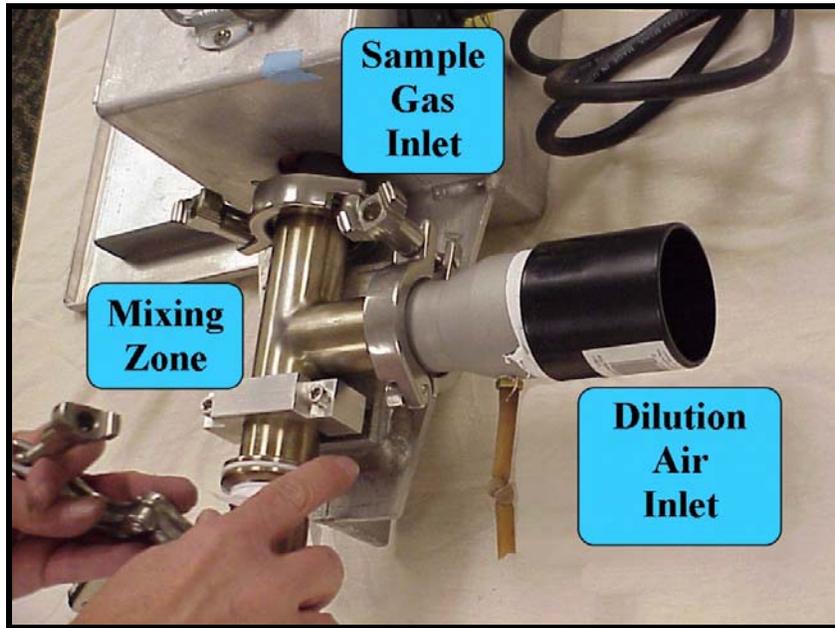


Figure 4. Static Mixer.

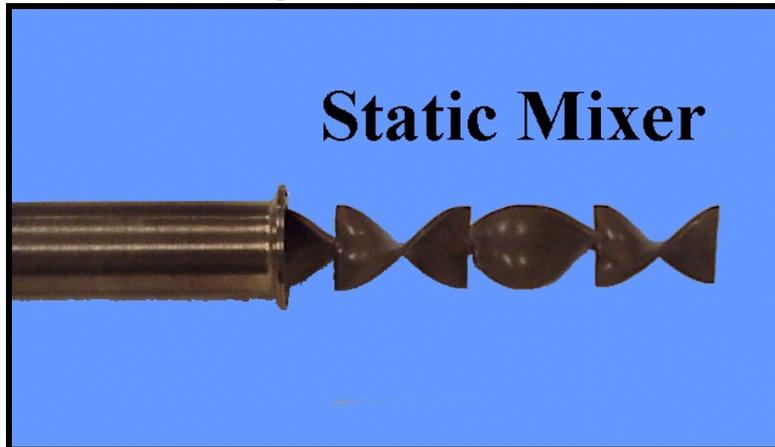


Figure 5 Assembled fine PM Sampling System.

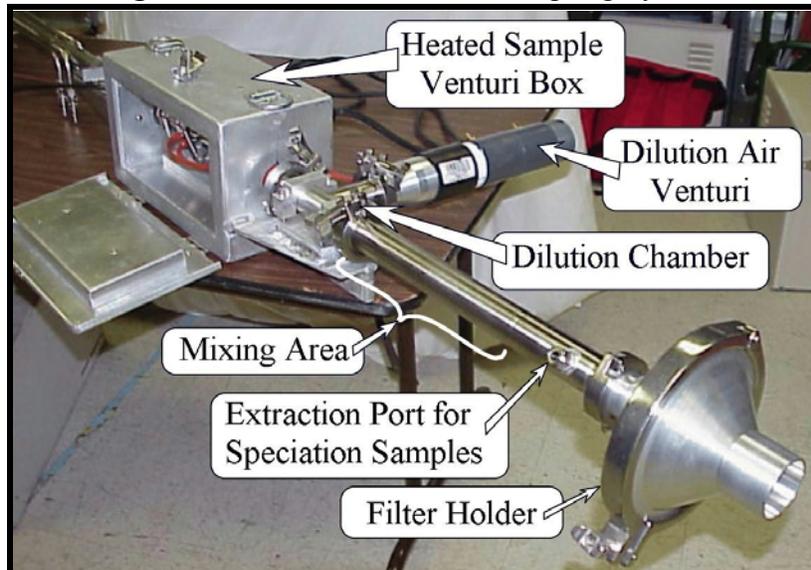


Figure 6 Speciation Sample Module.



Figure 7 Fine PM Sampling System in Use.



Figure 8 Elevated Sampling Platform.

