Note: Additional data has demonstrated that the current version of OTM – 36 has a significant negative bias. As a result, we have removed it from our website. Work is being done to try and correct this negative bias. If you have any questions about the status of this method, please contact Kim Garnett at 919-541-1158 or garnett.kim@epa.gov.

Other Test Method – 36: Method for the Determination of Filterable $PM_{2.5}$ Emissions from Moisture Saturated and/or Droplet-laden Stationary Source Gas Streams (Constant Sampling Rate Procedure)

Note: Please submit a copy, either electronic or paper, of any test report from application of this OTM to EPA's Measurement Technology Group.

Electronic copies should be submitted via email with the subject line "OTM-036" to: EMC@epa.gov

Paper copies should be mailed to:
Measurement Technology Group
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency (Mail Code E143-02)
Research Triangle Park, NC 27711

This test method is designed to measure filterable particulate matter emissions equal to or less than a nominal aerodynamic diameter of 2.5 micrometers ($PM_{2.5}$) in moisture saturated (wet) and/or droplet-laden gas streams from stationary sources. This method addresses the equipment, preparation, and analysis necessary to measure filterable $PM_{2.5}$ emissions in droplet-laden and/or moisture-saturated gas streams. **You must use this method in combination with Method 202 of 40 CFR Part 51, Appendix M (Method 202) for measuring condensable particulate matter regardless of the temperature of the gas stream.**

A heated probe and filter box for the sampling train is used to vaporize water droplets in the sample gas stream, which may also vaporize volatile particulate matter in the gas stream. This method measures filterable $PM_{2.5}$ particulate matter based on the material passing through a $PM_{2.5}$ cyclone and depositing in the cyclone exit tubing, filter, and front half of the filter holder. This method can also be used to measure total filterable particulate matter based on the material captured in all parts of the sampling train. When used to measure total filterable particulate matter, the results obtained with this method are similar to those measured by Methods 5 and 5B.

This method was submitted by the American Petroleum Industry (API) and the National Council for Air and Stream Improvement (NCASI) to EPA's Office of Air Quality, Planning and Standards – Air Quality Assessment Division – Measurement Technology Group (MTG) for inclusion into the Other Test Method (OTM) category on EPA's Emission Monitoring Center (EMC) website at: http://www.epa.gov/ttn/emc/tmethods.html#CatC/.

The posting of a test method on the OTM portion of the EMC website is neither an endorsement by EPA regarding the validity of the test method nor a regulatory approval of the test method. The purpose of the OTM portion of the EMC website is to promote discussion of developing emission measurement methodologies and to provide regulatory agencies, the regulated community, and the public at large with potentially helpful tools.

Other Test Methods are test methods which have not yet been subject to the Federal rulemaking process. Each of these methods, as well as the available technical documentation supporting them, have been reviewed by the EMC staff and have been found to be potentially useful to the emission measurement community. The types of technical information reviewed include field and laboratory validation studies; results of collaborative testing; articles from peer-reviewed journals; peer- review comments; and quality assurance (QA) and quality control (QC) procedures in the method itself. A table summarizing the available technical information for each method can be found at the link below. The EPA strongly encourages the submission of additional supporting field and laboratory data as well as comments in regard to these methods.

These methods may be considered for use in federally enforceable State and local programs (e.g., Title V permits, State Implementation Plans (SIP)) provided they are subject to an EPA Regional SIP approval process or permit veto opportunity and public notice with the opportunity for comment. The methods may also be considered to be candidates to be alternative methods to meet Federal requirements under 40 CFR Parts 60, 61, and 63. However, they must be approved as alternatives under 60.8, 61.13, or 63.7(f) before a source may use them for this purpose. Consideration of a method's applicability for a particular purpose should be based on the stated applicability as well as the supporting technical information outlined in the table. The methods are available for application without EPA oversight for other non-EPA program uses including state permitting programs and scientific and engineering applications.

As many of these methods are submitted by parties outside the Agency, the EPA staff may not necessarily be the technical experts on these methods. Therefore, technical support from EPA for these methods is limited, but the table contains contact information for the developers so that you may contact them directly. Also, be aware that these methods are subject to change based on the review of additional validation studies or on public comment as a part of adoption as a Federal test method, the Title V permitting process, or inclusion in a SIP.

Method History

Final – 04/07/2016

EPA advises all potential users to review the method and all appendices carefully before application of this method.

Wet Stack Measurement and OTM-036 Caveats and Cautions

Principles of "Wet Stack" Measurement

EPA recognizes the need to measure particulate matter (PM) less than 2.5 micrometers (µm) aerodynamic diameter ($PM_{2.5}$) emissions from industrial sources. Currently, there are no promulgated methods available for the measurement of filterable $PM_{2.5}$ from sources with entrained water droplets (See Method 201A Section 1.5). One common example of a source with entrained moisture droplets is an exit of wet scrubbers, routinely used for emissions control boilers. Entrained water droplets confound the ability of current particulate matter sampling using manual methods and continuous monitoring systems (CEMS) to obtain representative results due to size of the droplet compared to the size of the final dried particle and other practical issues dealing with water droplets themselves.

Note: Entrained water droplets (or a "wet stack") occur when a gas stream is saturated with water and is then cooled. This condition can occur at any moisture range or temperatures between 0 deg F and approximately 220 deg F. Verification of entrained droplets can be done when comparing gravimetric moisture results with calculations based on temperature and pressure (See Section 4.1 of Method 4).

The droplets entrained in the effluent gas streams of saturated sources make representative sampling extremely difficult by presenting a set of challenges not found with traditional testing for filterable $PM_{2.5}$ using Method 201A. The water droplets contain both soluble and insoluble materials that become solid particles as the droplets are emitted to the atmosphere and the water evaporates. As a result, the ultimate dried particle size will be dependent on the concentration and makeup of the materials within the droplet. These water droplets, which will become filterable $PM_{2.5}$ particles, must be extracted from the stack, transported, and dried in a manner representative of emissions to the atmosphere, which presents difficultly due to the size of the water droplets needed. These dried particles must then be size classified as $PM_{2.5}$. The specific mix of soluble and insoluble materials and concentration in water droplets depend on the source (industrial sector, controls, raw materials, etc) and cannot be generalized. Therefore, it is difficult to determine the size range of the water droplets that must be sampled in order to capture the ones that will dry and become $PM_{2.5}$.

Another confounding factor is that particles are measured and regulated based on their aerodynamic diameter, not their physical diameter, and the $PM_{2.5}$ moniker represents a 50% transmission point at nominally 2.5 µm aerodynamic diameter along a penetration curve for a size classification device. Along this curve, the larger particles are not excluded altogether, but are collected with substantially decreasing efficiency and smaller particles are collected with increasing (up to 100%) efficiency. For a more in-depth discussion of these topics, please see the paper titled "Development of Plans for Monitoring Emissions of PM_1, $PM_{2.5}$ and PM_{10} from Stationary Sources with Wet Stacks" by David Leith and Maryanne G. Boundy, located in Appendix H and "2009 Final Report: Integrated Science Assessment for Particulate Matter" (http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=216546).

In addition to entrained water droplets, the exhaust gas may contain solid particles that are not associated with water droplets. Finally, the exhaust may also contain gaseous organic and inorganic compounds that condense or react to form particles when the gas cools. It is necessary in the measurement of $PM_{2.5}$ from sources with entrained water droplets that both filterable and condensible material are characterized.

A Word of Caution

As discussed above, OTMs are test methods which have not yet been subject to the Federal rulemaking process. For this particular OTM, we have the particular concerns explained in the next section. Additionally, the EPA strongly encourages the submission of additional supporting field and laboratory data as well as comments in regard to these methods.

More Information Needed

The appropriateness of the following aspects of OTM-036 have not yet been assessed. Additional data is needed is these areas before this method can be fully evaluated regarding the issues discussed below. Any data developed during the application of this OTM that may assist in the further evaluation of these unknowns should be submitted to EPA's Measurement Technology Group.

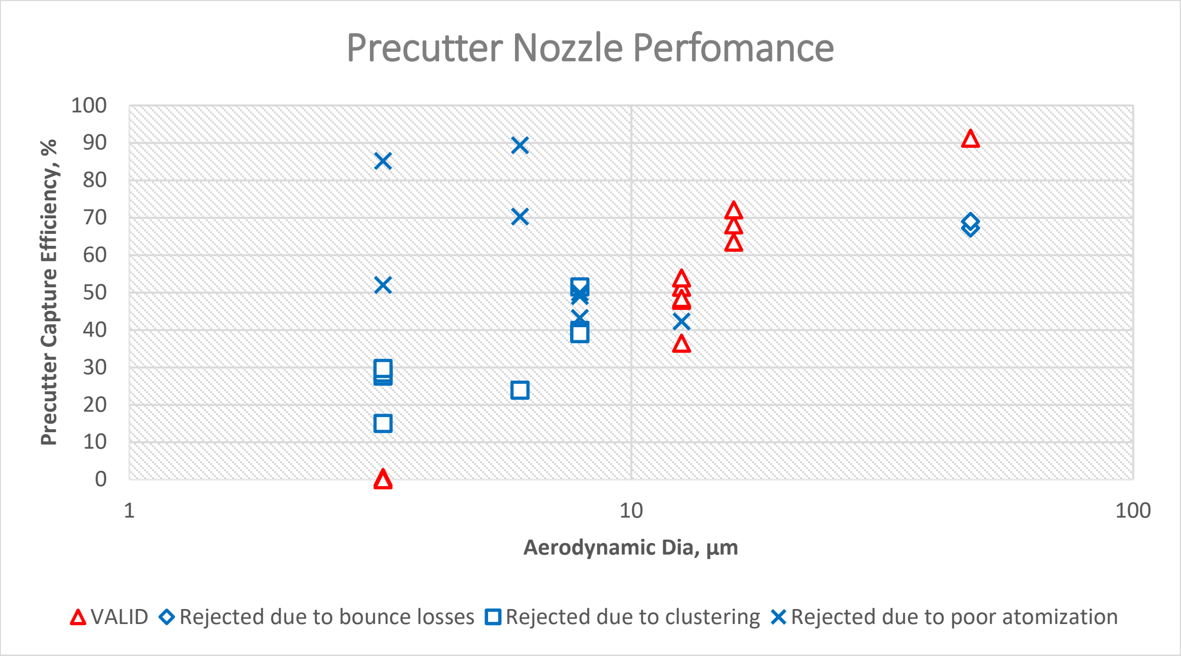
Electronic copies should be submitted via email with the subject line "OTM-036" to: EMC@epa.gov

Paper copies should be mailed to:

Measurement Technology Group
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency (Mail Code E143-02)
Research Triangle Park, NC 27711

- **Probe transfer efficiency** - If water droplets, which become $PM_{2.5}$, and particles are not being efficiently transferred through the probe, the corresponding $PM_{2.5}$ results would be biased low.
- **Droplet shattering during drying** - More information is needed to determine whether or not water droplets are shattering during the drying process. If this shattering is occurring, it would cause the $PM_{2.5}$ results to be biased high.
- **Probe water droplet residence time** - More information is also needed about the probe water droplet residence time. This aspect of the method is difficult to assess as it is a function of flow rate, probe temperature, probe inside diameter, specific heat of the gas stream and water droplet concentration and size distribution. Improperly low residence time would bias the $PM_{2.5}$ results low.
- **Nozzle -** While nozzle efficiency testing was conducted (See Appendix E, F and G of this document), EPA believes the results were inconclusive due to imprecision of the experimental design and measurements. It should be noted that 27 % of runs were rejected based on test observations of poor PSL atomization or microsphere dispersion, 30 % of the runs were rejected during data analysis for microsphere clustering, and 7 % of the runs were rejected during data analysis for microsphere bounce. After all the various data points were rejected as invalid, the nozzle efficiency curve was determined with only 37% of the

runs. In addition, there was only one run deemed valid in the critical <10um range.



EPA recommends further evaluation of the nozzle efficiency using a vibrating orifice aerosol generator (VOAG) and monodisperse droplets or other experimental design with appropriate data quality indicators for precision.

- **Method 301 Testing –** The Method 301 testing conducted to validate the method using analyte spiking approach did not meet the required number of test runs due to issues with either train setup or train recovery which resulted in damage to the filter. The end user should be aware that during the Method 301 testing the trains were not validated using dynamic spiking, due to the nature of measurement. Instead, a static spike of salt particles were introduced into the nozzle of the sampling trains following sampling of a wet stack as additive to the field runs. This issue was discussed prior to testing with EPA and EPA recognized the extreme difficulty in dynamically spiking water droplets during test runs and agreed to static spiking. The salt particles were nominally less than $PM_{2.5}$, which is substantially smaller than the water droplets that would form $PM_{2.5}$ particles when dried.
- **QA/ QC Procedures -** This version of OTM-036 contains new QA/QC procedures that have not been demonstrated in the field. These new QA/QC procedures may require further study to determine their suitability (i.e., posttest leak check.)

Caveats

- **EPA advises all potential users to review the method and all appendices carefully before application of this method.**
- **End users should be aware that due to the lack of verification and validation for this test method, any data gathered using this test method may be invalidated in the future.**
- **You must use this method in combination with Method 202 of 40 CFR Part 51, Appendix M for measuring particulate matter regardless of the temperature of the gas stream. This method should not be used directly for filterable $PM_{2.5}$ emission limits due to the elevated filtration temperature required.**
- This method may be considered for use in Federally enforceable State and local programs (e.g., Title V permits, State Implementation Plans (SIP)) provided it is subject to an EPA Regional SIP approval process or permit veto opportunity and public notice with the opportunity for comment.
- This method may also be considered to be a candidate for use as an alternative method to meet Federal requirements under 40 CFR Parts 60, 61, and 63. However, any alternative method must be approved under 60.8, 61.13, or 63.7(f) before use for this purpose. Consideration of a method's applicability for a particular purpose should be based on the stated applicability as well as the supporting technical information outlined in the table.
- This method is available for application without EPA oversight for other non-EPA program uses including state permitting programs and scientific and engineering applications.
- This method was submitted by parties outside the Agency, the EPA staff may not necessarily be the technical experts on these methods. Therefore, technical support from EPA for these methods is limited, but the table contains contact information for the developers so that you may contact them directly.
- This method is subject to change based on the review of additional validation studies or on public comment as a part of adoption as a Federal test method, the Title V permitting process, or inclusion in a SIP.