PARTICULATE SAMPLING GUIDELINES AND REPORTING FORMAT

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Alabama Department of Environmental Management
Air Division
Planning Branch
Emission Measurement Section

1) Introduction

The purpose of this document is to provide guidance for conducting and reporting stack tests under the jurisdiction of the Alabama Department of Environmental Management (ADEM). This document does not supersede established regulations, but provides guidance where the regulations may not be clear or do not address issues that commonly occur. "EPA Methods" in this document refers to test methods found in Appendix A of 40 CFR Part 60.

2) Pretest Protocol Submission

(2.1) All stack tests conducted to demonstrate compliance with EPA or ADEM regulations, must have a written protocol submitted to Air Division's Engineering Services Branch (ESB) at least 15 business days before the start of the test, unless specified otherwise in the applicable regulation. Protocols for test methods that require audit samples from an EPA certified provider should be submitted at least 30 calendar days before the scheduled test date. The ESB will review the protocol to ensure its applicability to the regulations. The Air Division's Emissions Measurement Section (EMS) will review the protocol to ensure the viability of the testing methodology. All deviations from EPA Methods and/or regulations must be approved by the EMS and ESB; and when necessary, the EPA. Allowed deviations are not automatically approved for future tests. For sources regulated under 40 CFR Part 63 regulations, major method modifications must be approved by the EPA. When a protocol has been approved, it must be followed in the field. Deviations from EPA Methods and/or regulations that occur during testing that were not described in the protocol and approved prior to the test will be reviewed in the field by the EMS or ESB personnel that are present and again in the office when results are submitted to determine if the results will be accepted as valid. A pretest meeting may be held at the request of the facility or this office. The necessity for such a meeting and required attendance will be determined on a case-by-case basis. The test protocol must contain the following:

(a) The name, location, and facility number of the facility.

(b) A description of the source(s) to be tested, the permit number(s) associated with each source, and a description of the processes to be tested including the feed rate, operating parameters used to control or influence the operations, and the rated capacity.

(c) The date(s) of the test(s).

(d) The pollutant(s) being tested, the EPA test method(s) to be used, and a complete description of the sampling train to be used including the type of probe lining, type of media filter, probe cleaning method, and solvent used for cleanup.

(e) **A detailed description of any proposed modifications to the EPA test method(s).**

(f) The name and telephone number of the testing firm.

(2.2) For State Implementation Plan (SIP) sources subject to ADEM regulations but not EPA regulations, if the permit provisos or ADEM Admin. Code R. 335-3 regulations do not specify stack test details, testing will adhere to the most applicable EPA regulations and test methods as closely as possible.

3) General

(3.1) All data gathered by the test team that is relevant to the stack test (with the exception of data recorded directly by analyzers) will be recorded in non-erasable ink and signed and dated by the person(s) gathering the data. Changes to data sheets can be made by marking out the erroneous information with a single line and initialing the change. The use of "white-out" is not acceptable to make corrections. If computers are utilized to store and record test data without the benefit of a separate chart recorder, a printed or electronic copy of the data for the run observed will be given to the ADEM observer.

(3.2) If there is a valid reason that all test runs cannot be performed in a single day, the remaining test runs must be performed within seven calendar days of the initiation of the test.

(3.3) When a test run is determined to be invalid after the test or when a third run cannot be completed due to circumstances beyond the test team's control, the average of two runs may be accepted upon approval by the Chief of Air Division or Engineering Services Branch, except for sources that fall under 40 CFR Part 63 regulations which must include 3 runs. The pollutant run average must include 3 consecutive valid test runs. If a run is deemed invalid, the data must be included in the test report along with an explanation for why the run was deemed invalid.

4) Pre-Test Determinations

(4.1) If sampling ports cannot be located as required by EPA Method 1, then the stack should be modified to meet those requirements. If a stack modification is not practical, the possibility of using an alternative procedure will be determined on a case-by-case basis.

(4.2) Type S pitot tubes meeting the geometrical requirements of EPA Method 2 and assuming a calibration factor of 0.84 are preferred; however, calibrated pitot tubes are allowed.

(4.3) If cyclonic flow is present, the test ports should be moved to a location where the stack gas flow is more laminar. If this is not possible, then straightening vanes should be installed to correct the flow profile provided the vanes are greater than 2 stack diameters upstream from the sampling ports. If conditions prevent the correction of cyclonic flow, follow EPA's Method 1, section 11.5.2. If the results are acceptable, sampling must be conducted using the same number of points. If the results are not acceptable, the modified sampling procedure in EPA's guidance document GD-008r must be followed.

(4.4) EPA's Method 2, section 6.2, will be used to determine if a micro manometer is required. It will be determined on a case-by-case basis if alternative flow rate monitoring devices such as electronic devices can be used. To prevent a series of tests from being cancelled and/or voided, a micro manometer should always be available to the stack test team. If an electronic flow measurement device is used, the pre-test protocol must state the accuracy claimed by the manufacturer. The device must be calibrated against an oil manometer. The calibration data as well as data sheets from the manufacturer describing the accuracy must be available for inspection in the field and in the test report.

(4.5) O_2 and CO_2 concentrations do not need to be measured on sources that contain only ambient air. An Orsat or O_2 / CO_2 analyzer calibrated according to EPA Method 3A must be used in all tests that require results to be reported in units based on O_2 or CO_2 measurements. This includes results corrected to 50% excess air or reported in lb/mmBTU. A Fyrite may be used only where the O_2/CO_2 data is for the determination of stack gas molecular weight. Current Fyrite and Orsat standardization documentation must be available in the field at all testing events for review. Failure to provide this documentation in the field may result in a voided test.

(4.6) The use of historical data, wet bulb/dry bulb, the approximation method, or the stoichiometric equation in EPA Method 3B, eq. 3B-2 may be used to determine preliminary moisture.

(4.7) Calibration data for dry gas meters, pitot tubes, thermocouples, electronic flow devices and magnehelic gauges must be brought into the field during testing for verification.

5) Sampling

(5.1) A minimum volume of 30 dry standard cubic feet must be sampled during each run and the minimum sampling time must be 60 minutes, unless another minimum volume or sample time is specified in the applicable subpart of 40 CFR parts 60 or 63.

(5.2) During a run (and more frequently when required by probe position changes) or when Δp changes by more than 20%, Δp and the other parameters on the field sheet must be recorded and ΔH must be set. The minimum sampling time at each point will be 2 minutes, with a maximum of 5 minutes between recordings. Sampling times should be in whole or ½ minute increments. The Δp manometer must be zeroed between runs and port changes, especially on low-flow and water-saturated sources.

(5.3) Anytime the glassware [i.e., probe, filter holder, cyclone (if used), or impingers] is disturbed or replaced, a leak check must be performed at the highest vacuum encountered prior to the disturbance. A leak rate of less than 0.02 CFM or 4% of the average sample rate (whichever is less) is allowed. The dry gas meter readings should be recorded before and after the leak check is performed and this volume excluded from the final volume metered.

(5.4) The sample gas exiting the filter holder must be maintained at 248°F $\pm$ 25°F (except for EPA Method 17), unless otherwise specified in a rule or regulation. This must be determined by a temperature sensor inside the filter holder in direct contact with the sample gas. In the event that the Method 5 train is combined with another Method that requires glass or Teflon® components (i.e. Method 26A, Method 29, etc), the temperature sensor must be coated in glass or Teflon®. If, at the conclusion of the sampling run it is determined that water has contacted the filter (visible water in filter holder or filter staining), or if filter plugging is determined to be the result of a wet filter, the run may be declared invalid due to the potential loss of particulate matter through the filter.

(5.5) Field and analytical balances should be calibrated according to EPA Method 5, section 10.7 and 10.8. Method 5 section 10.7 states that the field balance weight must be an ASTM E617-13 Class 6 (or better) and weigh at least 500g, or within 50g of a loaded impinger. This "calibration" must be completed on-site during testing.

(5.6) If the sample train includes a "jumper" between the heated filter holder and the impingers it must not exceed 25 feet in length. Prior to the first test run of each testing event, the jumper must be pre-wetted and after every run, this line should be "walked" from the exit of the filter holder to the impingers to ensure all moisture has been collected.

6) Theoretical Moisture

(6.1) In saturated gas streams EPA Method 4 will collect moisture droplets entrained in the stack gas and erroneously count them as water vapor. Section 12.1.7, Method 4, states in part:

> "In saturated or moisture droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one using a value based upon the saturated conditions (see section 4.1), and another based upon the results of the impinger analysis."

(6.2) Section 4.1 of Method 4 suggests using a thermocouple to measure stack temperature, then using a psychrometric chart or saturation vapor table to determine the theoretical moisture content. Equation 8 in the attached stack test equations may be used to determine the theoretical moisture content. If the results of this comparison show that the theoretical moisture content is less than the measured concentration, then the theoretical values should be used in all moisture dependent calculations (Ms,

vs, Qa, Qs, I). Equations 9 and 10 in the attached stack test equations may be useful as intermediate values in the calculations.

7) Post-Test

(7.1) EPA Method 5, section 8.4.4 states that if the sampling train leak rate is found to be no greater than 0.020 cfm or 4% of the average sampling rate (whichever is less), the results are acceptable. If the post-test leak rate is greater than 0.02 cfm, an adjustment to the metered volume can be made in accordance with EPA Method 5, section 12.3. The facility should be notified that this will increase the emission results and given the option to use the corrected run data or void the run. If the facility decides to use the corrected run data, the agency may use the data to determine the compliance status of the source. Leak rates in excess of 0.04 cfm shall not be corrected and the run must be voided.

(7.2) When the isokinetic rate is outside the 90% to 110% range, repeat the test run or calculate the corrected Cs and PMR (see equation 24 in the attached stack test equations). The corrected results may be accepted if they do not change the compliance status (subject to Administrator approval).

(7.3) A pitot tube leak check and a check for plugging (the manometer fluid level should return to zero) of the Type S pitot tube lines must be performed after each test run.

(7.4) A post-test dry gas meter calibration must be performed at the average ΔH setting used during the test. If the post-test calibration exceeds ± 5% of the initial calibration, the DGM must be re-calibrated at 5 ΔH settings. The DGM calibration that results in the smallest sample volume must be used in all pertinent calculations. If the ΔH settings during the test runs exceeds the highest ΔH used during the initial calibration, the DGM must be re-calibrated to cover the range of ΔH settings used during the test. A Y_{Qa} calculation may be used in place of a 3 point post-test calibration.

8) Test Report

(8.1) The test report is due at the office of the Air Division within 30 calendar days of completion of the source test, unless otherwise specified in the applicable regulation or permit. The test report shall be in hardcopy form and must include all data outlined in the attachment "Test Report Format." Areas to be given special attention are:

(a) The emission rate is to be presented in terms of the standard applicable to the source being tested.
(b) Complete documentation of process input must be included with validation of correctness by responsible plant personnel.
(c) A drawing of the source to be tested, to include the diameter of the stack and the upstream and downstream distances to disturbances.
(d) **The summary for the report must include a statement of the compliance status of the source.**
(e) Any deviations to the testing methodology, either in sampling or analysis, along with the reason for the change.

(8.2) A complete set of sample calculations for one run shall be included in the test report. Calculations should be performed using the List of Equations included in this document. All calculations should be performed retaining one decimal figure more than the acquired data. **Calculated results should not be rounded until after all calculations are final.**

9) Raw Data / Field Data

(9.1) Copies of the original raw field data and laboratory data sheets must be included in the test report. Data must be certified by the person responsible for its generation. A chain of custody form shall be included in the report documenting the handling of samples. The report must indicate if the samples were collected and analyzed by a single individual.

(9.2) Include all relevant calibration documentation for the dry gas meter, pitot tube coefficient, thermocouples, magnehelic gauges, electronic flow measurement devices, and the diameter of the nozzle. If an Orsat or Fyrite are used, documentation showing the standardization checks of the reagents and operator (as described in sections 11.4 and 7.1 of EPA Method 3) must be available on-site during testing. The reagents must be standardized at least once every three stack tests in which they were used. Gas cylinders used in EPA Method 3A must be certified using EPA Protocol and have copies of their certification sheets included in the report. EPA Method 3A calibration, drift, and bias data must also be included.

(9.3) Any correspondence between the Air Division and the testing firm concerning procedures, or between the Air Division and the source pertaining to specified operating conditions during the test period, should be included. Any test performed for compliance purposes should be reported to the Air Division regardless of compliance status indicated by the report.

10) In addition to the above requirements, the reporting requirements in all applicable subparts in 40 CFR Parts 51, 60, 61, 63 or 75 must be met.

TEST REPORT FORMAT

I. Introduction
   1. Report Certification by Responsible Party
   2. Statement of purpose of test and compliance status
   3. Personnel involved (consultants, plant personnel & observers, if present)
   4. Location and date
   5. Type of process tested and control method (including complete description of control devices)
   6. Type of pollutants to be tested
   7. Other background and pertinent information

II. Summary of Flow Parameters and Emission Rates
   1. Tabular & narrative presentation of test results
      Tabular to include the following:
      a. Sampling period (time of day)
      b. Stack gas temperature (°F)
      c. Moisture content (% volume)
      d. Stack gas velocity (fps)
      e. Volumetric flow rate (SDCFM) 68 °F, 29.92 in Hg
      f. Particulate mass rate (#/hr)
      g. Particulate concentration (grains/SDCF)
      h. Particulate concentration adjusted to 50% excess air or 12% CO_2 (if applicable)
      i. Average process weight rate (tons/hr)
      j. Allowable emissions (#/hr or grains/SDCF)
      k. % isokinetic
   2. Statement of the significance of results

III. Description of Installation and Process Operation
   1. Flow diagram
   2. Type and quantity of fuel and/or process raw materials used during test (validated by responsible plant personnel)
   3. Detailed description of method used to determine heat input or process weight
   4. Description of operating conditions during test with discussion of any changes in operation for the purpose of testing
   5. Relationship between results and any unusual operating conditions

IV. Sampling and Analytical Procedures
   1. Description of sampling train (with diagram)
   2. Description of any modification to specified equipment and /or methods
   3. Dimensional sketch showing sampling ports in relation to breaching and to upstream and downstream disturbances with a block diagram showing sampling points

V. Results
   1. Parameter sheets
   2. Complete calculations from at least one run of test that is being reported
   3. Raw field data (validated by team leader)
   4. Laboratory report (validated by analyst)
   5. Calibration, bias, and drift data.
   6. Any related reports
   7. Nomenclature and equations used
   8. Equipment Calibration Data
   9. Chain of custody sheets
   10. Copies of EPA method 3A gas cylinder certification sheets.

Stack Test Equations

1. $Ps = Pb + \frac{Pg}{13.6}$
2. $Pm = Pb + \frac{\overline{\Delta H}}{13.6}$
3. $Vs = 85.49\ Cp\ \overline{\sqrt{\Delta p}}\ \sqrt{\frac{\overline{Ts}}{Ms\ Ps}}$
4. $Vmstd = 17.64\ Vm\ Y\ \frac{Pm}{\overline{\overline{Tm}}}$
5. $*\ \text{corrected}\ Vm = Vm - \theta\ (Lp - La)$
6. $Vwstd = 0.04716\ Vlc + 0.04716\ SG$
7. $Bws = \frac{Vwstd}{Vmstd + Vwstd}$
8. $TBws = \frac{10^{6.37 - \frac{2827}{ts+365}}}{Ps}$
9. $TVwstd = Vmstd\ \frac{TBws}{1 - TBws}$
10. $TVlc = \frac{TVwstd}{0.04716}$
11. $Md = 0.44\ (\%\ CO_2) + 0.32\ (\%\ O_2) + 0.28\ (100 - (\%\ CO_2 + \%\ O_2))$
12. $Ms = Md\ (1 - Bws) + 18\ Bws$
13. $\%\ E.A. = 100\% \times \frac{\%\ O_2 - 0.5\ (\%\ CO)}{0.264\ (\%\ N_2) - (\%\ O_2) + 0.5\ (\%\ CO)}$
14. $Qa = Vs\ As\ 60$
15. $Qstd = Qa\ (1 - Bws)\ \frac{528}{Ts}\ \frac{Ps}{29.92}$
16. $Wa = \frac{ma\ Vaw}{Va}$
17. $Cs = 0.01543\ \frac{Mn}{Vmstd} = 0.000873\ \frac{Mn\ \overline{Tm}}{Vm\ Y\ (Pb + \Delta H/13.6)}$
18. $Cs\ @\ 50\%\ E.A. = \frac{Cs}{1 - \frac{1.5\ (\%\ O_2) - 0.133\ (\%\ N_2) - 0.75\ (\%\ CO)}{20.9}}$

19. $\text{Cs @ x\% } CO_2 = \frac{\text{X\% Cs}}{\text{\% } CO_2 \text{ in stack}}$

20. $\text{Cs @ x\% } O_2 = \frac{(20.9 - \text{x\%})\ \text{Cs}}{20.9 - \text{\% } O_2 \text{ in stack}}$

21. $\text{PMR} = \text{Cs Qs } \frac{60}{7000}$

22. $\text{Vn} = \frac{\overline{\text{Ts}}}{\text{Ps}} \left[0.002669\ \text{Vlc} + \frac{\text{Vm Y}}{\overline{\text{Tm}}} \left(\text{Pb} + \frac{\overline{\Delta \text{H}}}{13.6}\right)\right]$

23. $\text{\% I} = \frac{\text{Vn}}{60\ \theta\ \text{Vs An}}\ 100\%$

24. ** corrected Cs when % I > 110% or < 90% = $\text{Cs } \frac{\text{\% I}}{100}$

25. $\text{lb} = 2.593 \text{ x } 10^{-9}$ (ppm dry) (molecular weight) (dscf)

26. $\frac{\text{lb}}{\text{hr}} = \frac{\text{(ppm dry) (molecular weight) Qs 60}}{10^6\ 385.3}$

27. $\frac{\text{lb}}{\text{MMBtu}} = \frac{\text{pounds per hour}}{\text{MMBtu per hr}}$ or $\frac{\text{Cs}}{7000}\ \frac{\text{Fd } 20.9}{(20.9 - \text{\% } O_2)}$

28. $\text{Minimum Dn} = \sqrt{0.0358\ \frac{\text{(minimum desired ft}^3\text{) Pm}}{\text{Tm Cp } (1 - \text{Bws})\ \theta} \sqrt{\frac{\overline{\text{Ts}}\ \text{Ms}}{\text{Ps}\ \overline{\Delta \text{P}}}}}$

29. "K factor" $= \frac{\Delta \text{H}}{\Delta \text{P}} = 847\ \text{Dn}^4\ \Delta \text{H@}\ \text{Cp}^2\ (1 - \text{Bws})^2\ \frac{\text{Ps Md Tm}}{\text{Pm Ms Ts}}$

30. $\text{ppm dry} = \frac{\text{(ppm wet)}}{1 - \text{Bws}}$

31. volume dry = (volume wet) $(1 - \text{Bws})$

32. $C_{gas} = \left(\overline{\text{C}} - \text{C}_\text{o}\right) \text{ x } \frac{\text{C}_\text{ma}}{\text{C}_\text{m} - \text{C}_\text{o}}$

33. $C_{diluent} = \frac{\text{C}_\text{ma} - \text{C}_\text{oa}}{\text{C}_\text{m} - \text{C}_\text{o}} \text{ x } \left(\overline{\text{C}} - \text{C}_\text{m}\right) + \text{C}_\text{ma}$

34. $\text{Sd} = \left[\frac{\sum_{\text{i}-1}^{\text{n}} \text{d}_\text{i}^{\,2} - \frac{\left(\sum_{\text{i}-1}^{\text{n}} \text{d}_\text{d}\right)^2}{\text{n}}}{\text{n}-1}\right]^{\frac{1}{2}}$

35. $\text{CC} = \text{t}_{0.975}\ \frac{\text{S}_\text{d}}{\sqrt{\text{n}}}$

36. $\text{RA} = \frac{|\text{d}| + |\text{CC}|}{\overline{\text{RM}}} \text{ x } 100$

- $\overline{\mathrm{Tm}}, \overline{\mathrm{Ts}}, \overline{\Delta \mathrm{H}}$, and $\overline{\sqrt{\Delta \mathrm{P}}}$ are averaged values.

- Fd Factors in dscf/MMBtu :

  - Bituminous Coal = 9,780
  - Oil = 9,190
  - Natural Gas, Methane, Propane, and Butane = 8,710
  - Wood = 9,240
  - Wood Bark = 9,600

- Molecular Weights :

  - CO = 28.01
  - NO2 = 46.00
  - SO2 = 64.06
  - CO2 = 44.01

** If isokinetics are not met and the corrected Cs changes compliance status from uncorrected Cs, then the run has to be repeated within 7 days of Run #1.

Nomenclature for Stack Test Equations

acf = Actual cubic feet, as measured, without corrections for water vapor, temperature, or pressure.
An = Area of nozzle in ft^2.
As = Area of stack in ft^2.
Bws = The volume of the portion of stack gas that is water vapor divided by the total volume of stack gas. There are no units.
Cp = Type S pitot tube coefficient. There are no units.
Cs = Concentration of particulates in grains per dry standard ft^3 of air.
Dn = Diameter of the nozzle in inches.
dscf = Dry standard cubic feet. Standard volumes are corrected to 29.92 inches of Hg and 68 ^oF.
%EA = Excess Air. The amount of air supplied to a combustion source divided by the theoretical minimum amount of air that is necessary to achieve complete combustion, multiplied by 100%.
Fd = F factor as described by Method 19 or Subpart D in dscf/mmBTU.
gr = Grains (1/7000ths of a pound).
%I = Percent isokinetic. The ratio of the average velocity of the sampled gas through the nozzle to the average velocity of the stack gas in the stack during sampling, multiplied by 100%.
Kp = Pitot tube constant, equal to 85.49.
La = Maximum acceptable leakage rate for either a post-test check or a check following a component change (0.02 ft^3/min or 4% of the sampling rate, whichever is less).
Lp = Leakage rate observed during the post-test check in ft^3/min.
Md = Dry molecular weight of the stack gas in lb-moles.
Ms = Molecular weight of the stack gas in lb-moles.
m_a = Mass of acetone blank residue in milligrams.
m_n = Mass of the particulate matter collected in milligrams.
Pb = Barometric pressure at the site in inches of Hg.
Pg = Static pressure in the stack in inches of H_2O.
Pm = Absolute pressure of air inside of dry gas meter in inches of Hg.
Ps = Absolute pressure in the stack in inches of Hg.
Pstd = 29.92 inches of Hg, standard absolute pressure.
PMR = Particulate mass rate exiting the stack in lbs/hour.
Qa = Actual flow rate as measured in ft^3/min without corrections for water, temperature, or pressure.
Qs = Standard dry flow rate, corrected to 29.92 inches of Hg and 68^oF in ft^3/min.
scf = Standard wet cubic feet corrected to 29.92 inches of Hg and 68^oF.
TBws, TVw_{std}, TVlc = Theoretical values used in place of Bws, Vw_{std}, and Vlc when TBws is less than Bws.
Tm = Temperature of stack gas inside dry gas meter in ^{o}Rankine (460+^oF).
t_m = Temperature of stack gas inside dry gas meter in ^oF.
Ts = Temperature of stack gas in stack in ^{o}Rankine (460+^oF).
t_s = Temperature of stack gas in stack in ^oF.
Va,Vaw = Volume of acetone blank and wash in milliliters.
Vlc = Volume of liquid collected from the stack gas in milliliters.
Vm = Volume measured by dry gas meter ft^3, dry, without corrections for temperature or pressure.
Vmstd = Volume measured by dry gas meter ft^3, dry, corrected to 29.92 inches of Hg and 68 ^oF.
Vwstd = Volume of stack gas in ft^3 sampled that is water vapor, corrected to 29.92 inches of Hg and 68^oF.
Vn = Volume collected through nozzle at stack conditions, uncorrected and in actual ft^3.
Vs = Velocity of stack gas at stack conditions, uncorrected and in ft/sec.
Wa = Weight of acetone residue calculated in wash in milligrams.
Y = Correction factor for dry gas meter as determined by calibration. There are no units.
ΔP = Pressure across Type S pitot tube in inches of water.
ΔH = Pressure across orifice inside of dry gas meter in inches of water.
$\Delta H@$ = Orifice pressure differential as determined by calibration that results in 0.75 ft^3/min at 29.92 inches of Hg and 68 ^oF.
θ = Theta, the number of minutes of sampling.