Emissions Measurement Center
Guideline Document

(This is a draft revision to the guideline document GD-008. The alternative testing procedures and acceptance criteria in the guideline are based on general gas flow theories and practices and are supported by little real field experience. The EMC requests your review and comment on the procedures those involving sampling directly in areas of nonaxial flow. Of particular interest would be results of tests for which these or similar procedures were applied and that we could use to verify or modify the guideline. Please, e-mail your comments to westlin.peter@epa.gov.)

Particulate Emissions Sampling in Cyclonic Flow

Summary

Particulate emissions sampling in stacks or ducts with cyclonic or other nonaxial flow patterns presents significant problems in obtaining representative measurements of concentrations and flow rates. Sections 2.4 and 2.5 of Method 1 (40 CFR part 60, appendix A) describe procedures and criteria for verifying the absence of cyclonic or other nonaxial flow patterns (i.e., not parallel to the stack or duct axis). The purpose of this guideline is to provide options to consider when the angular or cyclonic flow conditions exceed acceptable limits as defined in Method 1. Following are three options and detailed recommendations for addressing the measurement of particulate emissions when cyclonic or nonparallel flow patterns exist. We intend that you prioritize these options in the order that they are presented; that is, attempting to sample directly in conditions of cyclonic or nonaxial flow should be the last resort.

Recommendations

1. Find another sampling location.

In many situations, you may find a sampling location downstream or upstream of the original location that exhibits less cyclonic or nonaxial flow tendencies. For example, moving from a duct immediately downstream of the exit of a venturi scrubber with a cyclonic demister to a location multiple equivalent diameters downstream of the duct-stack intersection can often solve a cyclonic flow situation. You may incur extra cost in such a move (e.g., new ports and sampling platforms); however, this option is often less costly or disruptive to the process operation and produces more reliable emissions measurement data than the other options described below.

2. Install flow straightening vanes upstream of the sampling location.

You may use flow straightening vanes, such as are described in Figure 5D-1 of Method 5D (40 CFR part 60, appendix A). Note that the criteria for locating the measurement site downstream of the straightening vanes are based on the average equivalent diameter of the straightening vane openings rather than the stack diameter (section 4.1.1, Method 5D).

Also note that straightening vanes may disrupt the process and may affect control efficiency by creating a back pressure that might change flow characteristics upstream of the vanes. You may need to explore other means sufficient to straighten gas flow, such as addition of stack extensions tangential to the stack axis, that have less effect on the process or control device operations. In any case, you must coordinate use of any flow disturbance alternative with the plant engineer.

3. Apply a modified sampling procedure.

We recommend the following procedures for sampling only when other options as described in 1 and 2 above are not available. We previously published guidance (GD-008) for applying alternative procedures for collecting representative particulate matter samples from areas with nonaxial flow. Among the methods recommended were the alignment method and the time-weighted alignment method. With the publication of new EPA Methods 2F and 2G (40 CFR part 60, appendix A) and further review of the principles involved in such testing, we recommend a revision to those procedures for testing in locations with cyclonic flow. The revised procedures involve aligning the sampling nozzle with the stack or duct axis for nonaxial flow angles up to 50°. For flow angles greater than 50°, you should apply a flow alignment method in which you align the sampling nozzle in the direction of the flow (yaw) angle and you adjust the sampling rate or sampling time per point appropriately. Note that a test run may involve different procedures for sampling points with flow angles both greater than and less than 50°.

Note that applying such sampling procedures as an alternative to those specified in a regulation or an operating permit requires approval by the Administrator prior to conducting the test (see sections 60.8(b), 61.13(h), or 63.7(f) of 40 CFR parts 60, 61, or 63, respectively). Note also that the complexities and special techniques associated with these alternative procedures are such that only experienced and well-equipped field staff should attempt this approach.

The modified sampling procedures are as follows:

a. Prior to each test run, conduct a velocity traverse of the stack to establish the angle(s) of flow at each sampling point using procedures as described in Method 2F, section 8, or Method 2G, section 8. Using the yaw and pitch angles, if available, as measured with either Method 2F or 2G, calculate the resultant angle at each sampling point using equation 1-2 of Method 1. Calculate the axial velocity at each sampling point using equation 2F-8 or 2G-6. Use pitot equipment for these measurements that satisfies the QA/QC requirements of sections 6 and 10 of Method 2F or sections 6 and 10 of Method 2G, as appropriate.

For sampling points with nonaxial resultant angles up to 50°:

b. For each test run following the velocity traverse, conduct the particulate sampling at each sample point with the nozzle axis aligned parallel to the stack or duct axis. Either remove the pitot from the sampling probe or ensure that the impact pressure opening plane of the pitot is at least two nozzle diameters downstream of the sampling nozzle opening. Collect the sample at each point isokinetically relative to the axial velocity, v_a, calculated for that sample point during the pre-run velocity traverse (i.e., do not use the velocity values indicated by the pitot, if attached during the test run). One approach for calculating isokinetic sampling rates is to substitute an adjusted nozzle area for each traverse point in determining the sampling rate using the nomograph referenced in Method 5 (e.g., APTD-0576), or other isokinetic equation procedure (e.g., computer program). Calculate an adjusted nozzle area, A_{na}, for each sample point as follows:

$$A_{na} = A_n\left(\cos R_i\right)$$

where:
A_n is the measured area of the nozzle
R_i is the resultant angle of flow at each sampling point.

For sampling points with nonaxial resultant angles 50° and higher:

c. For each test run following the velocity traverse, conduct the sampling isokinetically at each sampling point rotating the sampling nozzle to point into the gas flow (i.e., parallel to the measured yaw angle) and using the velocity pressure values in the direction of flow (i.e., yaw angle values) determined during the pre-run velocity traverse.

For all test runs:

d. For each test run, conduct a post-run velocity traverse in the same manner as the pre-run velocity traverse as described in step 3.a. above to verify that the average axial stack or duct velocity remains within 10 percent of the pre-test run value. If the post-test and pre-test values do not agree within 10 percent for any of the three or more required test runs, conduct an additional test run to replace that test run. You may use a post-test run velocity traverse as the pre-test run velocity traverse for the next test run.

e. Calculate the isokinetic variation at each sampling point using equation 5-8 of Method 5 based on the average of the results of the pre-test run and post-test run velocity traverses. Isokinetic variations should be within the specification found in section 6.12 of Method 5. Follow the guidelines in section 6.12 of Method 5 for repeating test runs for which you do not meet the isokinetic acceptability criteria.

f. Submit the results for all of the test runs to the responsible regulatory official including the pre-test run and post-test run velocities for each sampling point, the average axial the emissions data for all of test runs, and the results of the isokinetic variations calculations. Identify any results outside of the specified acceptable ranges and any other conditions that might affect conclusions regarding the test results (e.g., process conditions, margin of compliance).

References

1. Peeler, James, Isokinetic Particulate Sampling in Non-Parallel Flow Systems-Cyclonic Flow, Entropy Environmentalists, Inc, RTP, NC, 1977.

2. Stack Sampling Cyclonic Flow, Appendix H, Texas Air Control Board, Sampling Procedures Manual, Texas Air Control Board, 6330 Hwy 290 East, Austin, TX 78723, Revised July 1985.

3. Westlin, P. R., and K. Alexander, Evaluation of Particulate Sampling Methods for Cyclonic Flow, EPA memorandum, EPA mail code D243-02, RTP, NC, 27711, August 1979.

4. Methods 2F and 2G, 40 CFR part 60, Appendix A.

5. Rom, J. J., Maintenance, Calibration, and Operation of Isokinetic Source-Sampling Equipment, EPA Publication Number APTD-0576, March 1972.