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Project Summary

Application Guide for the Source PM_{10} Exhaust Gas Recycle Sampling System

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This document describes assembly, operation, and maintenance of the Exhaust Gas Recycle (EGR) sampling system. The design of the sampling train allows the operator to maintain a constant flow rate through an inertial sampler while the gas flow rate into the sampling nozzle is adjusted to remain isokinetic with the local duct velocity. This manual specifically addresses the operation of the EGR system for determination of stationary source PM_{10} emissions. Material in the text includes: construction details, calibration procedures, presampling calculations, sample retrieval, data reduction, and equipment maintenance.

This Project Summary was developed by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

To ensure that a representative sample of particulate matter is obtained from a flowing gas stream, the sample must be withdrawn isokinetically; that is, the gas flow rate of the sample must be adjusted so that the velocity in the sampling nozzle equals that in the surrounding gas stream. If a velocity mismatch occurs at the nozzle, the particulate matter in the sample gas may be selectively enriched or depleted; the concentration increase or decrease will depend in part on the particle size. This bias is avoided in EPA Reference Methods 5 and 17 by specifying isokinetic sampling. To obtain a spatially representative sample, the duct is divided into a number of equal area zones. The centroid of each zone is then sampled for a fixed time interval, and the sample flow rate is adjusted at each centroid to be isokinetic with respect to the local gas stream velocity.

The procedure outlined above is satisfactory for total particulate mass measurements. However, when sampling is conducted with inertial particle-sizing devices such as cascade impactors or sampling cyclones, an additional constraint is introduced. These samplers must be operated at a constant flow rate to maintain constant size cuts for each particle size fraction. For a fixed nozzle size, it is impossible to satisfy both the requirements of constant sampler flow rate and isokinetic nozzle velocity with conventional sampling trains.

This manual describes assembly, operation, and maintenance of a sampling train that allows isokinetic sampling while maintaining a constant flow rate through an inertial particle-sizing device. The sampling train uses the principle of exhaust gas recycle (EGR). Its design allows a preselected constant flow rate through the inertial sampler while the gas flow rate into the sampling nozzle is adjusted to remain isokinetic with the local duct velocity.

Although the potential uses of this system are numerous, this manual specifically addresses the operation of the EGR system for the determination of stationary source emissions of particulate matter with diameter ≤10 μm (PM_{10}). However, most components of the EGR system are independent of the type of inertial sampler used, and the material provided in this manual pertaining to these components is applicable to most sampling situations.

Details Of The EGR Sampling Train

The design of the EGR system allows the operator to maintain a preselected constant flow rate through an inertial sampler while the gas flow rate into the sampling nozzle is adjusted at each traverse point to remain isokinetic with the local gas velocity. The isokinetic sample flow rate, Q_s, enters the sample nozzle where it is mixed with a metered flow rate of recycled exhaust gas, Q_r. The combination of these two flow rates brings the total flow rate to the predetermined constant level, Q_t. After passing through the inertial sampler, which collects the larger particle size fraction (>10 μm), through an in-stack filter that collects the smaller PM_{10} size fraction, and through a heated probe, the water vapor is removed from the gas stream by condensation in an ice-cooled condenser or impinger train. The gas stream then enters the control console where the total flow rate is eventually split into the component flow rates, Q_s and Q_r. The total and recycle flow rates are measured by calibrated laminar flow elements (LFEs). The sample flow rate is monitored in the usual manner by using a dry gas meter and calibrated orifice.

For the purposes of this method, an in-stack cyclone is the recommended PM_{10} sampler based upon the research to date. The candidate classifier must be shown, in laboratory calibrations, to satisfy specific collection efficiency criteria. The PM_{10} sampler specifically described in this manual and known to meet these criteria is the commercially available version of Cyclone I, the first stage of the Southern Research Institute (SRI)/EPA five-stage series cyclone. The cyclone is available in a variety of outer dimensions and styles from different commercial sources. The critical inner dimensions, however, are standardized to the original design parameters. Laboratory calibrations have shown Cyclone I produces a 10-μm fractionation at a flow rate of approximately 0.5 dscfm; the precise flow rate depends on local stack conditions.

A range of nozzle sizes suitable for isokinetic sampling at varying recycle rates should be available. Because inertia tends to cause deposition of particles in the PM_{10} size range in bends, only straight sampling nozzles should be used. "Gooseneck" or other nozzle extensions designed to turn the sample gas flow 90°, as in Methods 5 and 17, should not be used. The EGR sampling nozzle designed for use with Cyclone I is attached to the stainless steel cyclone body with a flange plate or straight pipe threads. The recycled exhaust gas enters the nozzle through a 1/4-in. side entry tube and fills an annular region around the sample inlet tube. The temperature of the recycle gas is monitored near the EGR nozzle to ensure isothermal mixing of the recycle and sample gases.

Procedures

Initial calibration of the components of the EGR system is essentially the same as a Method 5 or 17 sampling train with the exception of the flow metering system. In the EGR train, the total and recycle LFEs must be calibrated in addition to the dry gas meter and sample orifice. The total flow rate LFE may be calibrated simultaneously with the dry gas meter and the sample orifice. Calibration of the recycle flow rate LFE requires an additional, separate step. Pretest and posttest calibration checks of the flow metering system are recommended.

Pretest calculation of sampling parameters for operation of the system involves determining target pressure differentials (ΔH, ΔP_t, ΔP_r) for a range of possible velocity pressures, ΔP_{vel}, and stack temperatures. An approximate solution of the governing equations provides acceptable agreement with the exact solution and allows calculation of these parameters in a few simple steps.

Operation of the sampling train is the same as Method 5 except that valve settings must be adjusted for two flow rates (Q_t and Q_s). Recovery of the collected sample after a run is dependent on the type of sampling device used. For Cyclone I, a combination of brushing and rinsing with a suitable solvent is required to quantitatively recover the larger size fraction. The PM_{10} size fraction is recovered by simply removing the filter from the filter holder.

Test data reduction and analysis requires the same calculations outlined in Method 5 (gas meter volume, water fraction, percent isokinetic) with the addition of average flow rate calculations (Q_t, Q_s, Q_r) and cyclone cut diameter, D_{50}. Acceptance criteria for test data is percent isokinetic in the range 100 ± 10% and cyclone D_{50} in the range 10 ± 1 μm.

Conclusions

The EGR sampling system allows the operator to maintain a preselected constant flow rate through an inertial sampling while adjusting the gas flow rate into the sampling nozzle at each traverse point to remain isokinetic with the local gas velocity. This allows determination of stationary source PM_{10} emissions within the constraints placed on total emissions by Method 5.

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The complete report, entitled "Application Guide for the Source PM_{10} Exhaust Gas Recycle Sampling System," (Order No. PB 89-189 856/AS; Cost: $21.95, subject to change) will be available only from:

National Technical Information Service
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