

Continuous Emission Monitoring

Introduction	2
How is a Source Subject to CEM Regulations?	3
MDEQ AQD Monitoring Plan	4
Testing	5
Reporting Requirements	6
Excess Emission Reporting (EER)	7
Summary Report	7
Enforcement	9
Quality Assurance and Maintenance Program	9
Other Options: Fuel Sampling Analysis (FSA)	10
References	12
Appendix A. Acronyms Used in Continuous Monitoring Systems.....	13
Appendix B. Source Monitoring Systems	14
Opacity Continuous Monitoring Systems in Stationary Sources	14
Gas continuous Monitoring Systems in Stationary Sources	14
Appendix C. Extractive Gas Monitoring Systems	15
In-situ Gas Monitoring Systems.....	16
Path In-situ Analyzers	16
Flow Rate Continuous Monitoring Systems in Stationary Sources.....	17
Selection Procedures	17

Continuous Emission Monitoring

Introduction

Continuous emissions monitoring (CEM) systems involve the installation of monitoring equipment which accumulates data on a pre-determined time schedule in a stack or duct. Many of the principles of stack testing also apply to continuous monitoring systems. The difference is that the stack test is for a relatively short time period (hours), while the CEM is for a longer time period (months or years). Continuous Emissions Monitoring test and reporting procedures are specified in Part 11 of the *Michigan Administrative Rules for Air Pollution Control*. Performance specifications for nine classes of continuous emission monitors have been established by the U.S. Environmental Protection Agency (USEPA) and can be found in 40 CFR Part 60, Appendix B. Quality Assurance programs have established standards, and are found in 40 CFR Part 60, Appendix F.

The application of continuous monitoring techniques to the measurement of pollutants emitted from stationary sources has become an area of considerable importance to regulatory agencies and industry environmental engineers. Regulatory agencies rely on continuous monitoring techniques that require emission sources to be self-reporting when permit limits are exceeded. The application of CEM systems serves many purposes, including:

- Indicators of control equipment performance.
- Compliance monitors.
- Accounting or emission trading applications.
- Michigan Air Emissions Reporting System (MAERS).
- As a public relations tool in assuaging public concerns over stack emissions.

Continuous measurements provide data under all source operating conditions. These data can be used both by the source and by regulatory agencies, and can be accessed by the public. The regulatory uses of CEM data provide so many advantages to environmental control agencies that federal and state CEM requirements have been steadily increasing since the 1970s. Public awareness of environmental pollution, especially the release of toxic pollutants, is increasing. CEM systems (CEMS) are used to provide assurance that a source is not emitting pollutants in excess of its standards.

Two other uses of CEM data include emissions trading and ambient air modeling. The use of CEMS has been incorporated into the proposed 1990 Clean Air Act Amendments in a policy designed to control acidic deposition. CEM data are used in ambient air quality programs to provide data for dispersion and source receptor models.

Use of CEM requires attention to detail and strict adherence to the published state and federal guidelines. Approved sampling ports and equipment must be installed, and samples drawn, analyzed, and reported strictly according to the guidance procedures pre-approved by the Michigan Department of Environmental Quality (MDEQ), Air Quality Division (AQD). Due to the precision and accuracy required for acceptable test results, it is recommended that experienced professionals establish a CEM program. Employee training and education is an essential element to ensure proper CEM results.

How is a Source Subject to CEM Regulations?

Both federal and state air quality regulations may require continuous emissions monitoring systems. For example, a facility may be required to monitor according to provisions found in:

- Part 11 of the *Michigan Administrative Rules for Air Pollution Control*.
- A specific permit condition.
- The State Implementation Plan (SIP) for Michigan in 40 CFR, Part 51.
- New Source Performance Standards (NSPS) in 40 CFR, Part 60.
- Existing National Emission Standards for Hazardous Air Pollutants (NESHAPs) in 40 CFR, Part 61.
- New NESHAPs in 40 CFR, Part 63, MACT Standards.
- Clean Air Market Program regulations in 40 CFR, Parts 75, 96, and 97.
- Title V, Compliance Assurance Monitoring.

Some other regulations that require CEMS are the boiler industrial furnace (BIF) regulations of the Resource Conservation and Recovery Act that regulate facilities that burn hazardous waste and the Part 503 regulations of the Clean Water Act for sewage sludge incinerators.

A source may be required to perform CEM as specified by rule in Part 11 of the *Michigan Administrative Rules for Air Pollution Control*, as well as by other administrative rules. Included in these specified sources are:

- Rule 1101 Fossil fuel-fire steam generators
- Rule 1102 Sulfuric acid-producing facilities
- Rule 1103 Fluid bed catalytic cracking unit catalyst regenerators at petroleum refineries

Under Rule 1199, some sources are exempt from continuous emission monitoring requirements. These include:

1. A source subject to a new source performance standard promulgated under the standards of performance for new stationary sources, 40 CFR part 50, pursuant to section 111 of the Clean Air Act, 42 USC 7411.
2. A source not subject to an applicable emission standard.

CEM may also be required by permit conditions for a source which is not explicitly included in the above mentioned rules.

Pre-installation and operating requirements are the same regardless of the reason for a source requiring a CEM system. The USEPA has established performance specifications which specify design criteria for the CEM system. The continuous monitoring system is first checked to verify that the design specifications are met. The system is then installed, calibrated, and operated for a specific length of time. During this specified time period, the systems are evaluated to determine conformance with the established performance specifications.

As of March 2004, there were about 107 companies in Michigan with over 850 single monitors that were being tracked in a database by the AQD. Items that are logged into the database include the facility name, plant contacts, source specific information, permit numbers and limits, monitor type, and monitor location. Also, specific information on monitors such as whether performance specification testing has been submitted, if monitors have been formally certified, if and when periodic audits are performed, and whether monthly or quarterly excess emission reports have been submitted. The database serves as the basis for the AQD's CEMS program and it also has the capability of tracking the excess emission reporting program. Each quarter the database is copied and sent to US EPA Region V.

MDEQ, AQD Monitoring Plan

Facilities requiring CEMS are asked by the AQD to submit a monitoring plan or pre-installation information. This is an opportunity to clarify or uncover problems that can occur with CEMS involving locations of probes or monitors, types of monitors, what the data acquisition system (DAS or DAHS) should be capable of producing, the monitor's span and instrument range, and when the CEMS will be installed and tested.

The AQD has developed a list of monitoring plan (pre-installation) requirements for gaseous, opacity, and process parameter monitors. The list includes the following:

1. Provide a general description of the process(es) and pollution control equipment
2. Explain and show that the location of the monitor(s) will be representative of emissions and also be accessible. Provide a flow diagram showing the sample acquisition point(s) or path(s) in relation to:
 - a. Flow disturbances (fans, elbows, inlets, outlets, etc.).
 - b. Pollution control equipment.
 - c. Emission point of monitored gases to the atmosphere.
 - d. Flue walls at the sample acquisition location.

If necessary, include any test data and explanations as the basis for the choice of the location. Explain any deviations from locations criteria in Performance Specification 1, section 4 and/or Performance Specification 2, section 3 of Appendix B in 40 CFR Part 60.

3. Provide the following system information:
 - a. Pollutant(s) and/or parameter(s) to be monitored.
 - b. Operating principles of the analyzers.
 - c. Number of analyzers, including number of sample acquisition point(s) or path(s) per analyzers, and locations monitored by each.
 - d. Equipment manufacturer, model number(s), and serial number(s).
 - e. Type of probe (with the system be able to accept an external audit?)
 - f. Equipment specification of monitor(s) which will be verified by the applicable Performance Specification of Appendix B in 40 CFR Part 60.
 - g. Formulas, including any factors used to calculate emission in the units of the applicable standard.
 - h. Span values of all pollutant monitors.
 - i. Instrument ranges of all pollutant monitors.
 - j. Proposed daily calibration gas, calibration error, linearity and/or cylinder gas audit values.
 - k. Data acquisition system/data recorder resolution.

4. Expected date of monitor installation and performance specification testing.

See Tab 18 for a copy of the “Continuous Opacity and Continuous Emission Monitoring Systems” fact sheet, Monitoring Plan for COMS and CEMS, and Checklists for Compliance with CEMS and COMS. These three related documents were developed by the Clean Air Assistance Program of the Environmental Science and Services Division (formerly, the Environmental Assistance Division) and the Air Quality Division.

Facilities are not required to submit the Monitoring Plan form; however, their plan must contain the information that the form encompasses.

Testing

The AQD witnesses the initial performance specification testing and/or annual relative accuracy test audits (RATAs). Testers or contractors should provide the facility and the AQD with a test protocol before testing occurs. On site, the AQD will review the probe locations, specific monitor information such as model/make, serial numbers, DAS/DAHS, how the data are being downloaded for testing, and the operating load on the unit during testing. A written quality assurance manual should be available for review. The manual must be site specific - not just installation and maintenance manuals that come with analyzers.

The Reference Method (RM) testing will be observed to assure that the correct RMs is being used as referenced in the test plan procedures. The AQD will also verify that the Performance Specification stated in the protocol is being followed. The certification procedures that should be followed are found in 40 CFR 60, Appendix B, unless instructed otherwise.

For the AQD to complete a review, CEMS testers should provide, at a minimum, all of the following information:

1. CEMS description, which should include the following:
 - a. Manufacture, model and serial number of each monitor.
 - b. Sample acquisition system (extractive, point in-situ or path in-situ) and analytical principle.
 - c. Span values and instrument ranges of each monitor.
 - d. Dimensioned sketch showing location of each monitor’s sampling point(s).
 - e. If monitors are shared, indicate the time strategies.
2. Reference Method (RM) testing description which should include the following:
 - a. Dimensioned sketch showing location of sampling points in relation to breeching and to upstream and downstream disturbances or obstruction of gas flow.
 - b. Sketch of cross-sectional view indicating traverse point locations and exact stack or duct dimensions.
 - c. Sampling and analysis procedures.

3. 7-Day Calibration Drift (CD) Test

- a. **ALL** CEMS responses from the **source's** CEMS data acquisition system (DAS) are to be submitted. All final responses are to be delineated.
- b. 7-Day CD Test data is to be summarized for all measured pollutants using Figure 2-1 of Performance Specification 2, Appendix B, 40 CFR 60. Span values are to be specified.
- c. All cylinder gas concentration certifications are to be submitted.

4. Relative Accuracy (RA) Test

- a. **ALL** CEMS responses from the **source's** CEMS data documenting the 9-12 minute runs are to be submitted. Each run is to be delineated from start to end.
- b. **ALL** supporting reference method (RM) data are to be submitted. This includes all data logger printouts and/or chart recordings with each of the 9 to 12 twenty-one minute runs being clearly delineated from start to end. All bias, zero, calibration drift, and interference checks are to be submitted. If applicable, all supporting field data for the velocity profile measurement and moisture determinations are to be submitted.
- c. All cylinder gas concentration certifications used for the calibration of the RM testing are to be submitted.
- d. RA data is to be summarized for all measured pollutants using Figure 2-2 of Performance Specification 2, Appendix B, 40 CFR 60 in the units consistent with the applicable standard.

5. Calculations

Example calculations of CEMS and RM test results in the units of the applicable standard are to be submitted. Include F-factor if applicable.

6. Source operating data

Process data verifying the source was operating greater than 50 percent of normal load, or as specified in an applicable subpart are to be submitted.

Submission of a complete report is important. Monitors are not certified until an administrator such as a state, local, or federal agency provides a written letter.

Reporting Requirements

Within 30 days of the end of each calendar quarter, a written report for each calendar quarter must be submitted to the AQD when CEMS are required by permit or regulation.

The regulations allow for an alternative data reporting or reduction procedure. The AQD may approve alternative procedures that do not comply with the requirements of this part if the owner or operator demonstrates to the satisfaction of the AQD that such procedures are at least as accurate as the quarterly reporting procedures.

Two reporting elements are expected: an excess emission report (EER) and a summary report. There is no set format for the EER, but guidance on content is given in the following sections.

Excess Emission Reporting (EER)

There are uses for CEM data beyond permit provisions. Excess Emission Reports (EERs) track the events when monitored emissions exceed the emission standards. EERs can be used for several purposes. EERs can indicate if the source is using good operating and maintenance practices on its process and its control equipment to minimize emissions. They can provide the AQD with data on upset conditions or trend data indicating degradation of control equipment performance, and a continuous record of the source's ability to comply with standards. This information can be used as a screening tool in inspections to target programs.

According to the format specified by the USEPA-Region 5 and federal regulations, Excess Emission Reporting requirements involve reporting:

1. Total operating time of each source during the reporting period.
2. Documentation of excess emissions, including:
 - a. Date of each exceedance of the applicable standard.
 - b. Start and end time of each exceedance of the applicable standard.
 - c. Magnitude of each exceedance of the applicable limit. Opacity exceedances shall be reported in 6-minute block averages. For continuous emission monitoring systems (CEMS) other than opacity monitors, exceedances shall be reported in the units of the standard and averaging period.
 - d. Nature or cause of each exceedance of the applicable standard and averaging period.
 - e. Corrective action or preventive measures of each exceedance of the applicable standard.
3. Any mathematical factors used to convert emission to units of the applicable standard.
4. Documentation of monitoring system performance, including:
 - a. Date when monitoring system was inoperative (daily zero and span checks are exempt).
 - b. Start and end time when the monitoring system was inoperative.
 - c. Nature of system repairs or adjustments.
5. Documentation of any time the monitor exceeded the instrument range. Include date, date, duration, nature or cause, and corrective action.
6. Incidences when no exceedances or monitor system outage occurred.
7. Summary of EER.

Note: The Owner/Operator shall maintain a log of all measurements, including all CEMS downtimes, repairs, adjustments, maintenance, calibrations, audits, and testing in a permanent form suitable for inspection.

Summary Report

The summary report conveys information on CEM system downtime and excess emissions. An easy way to report is in a table format. Table 1 is an example of how to present data for EER and the CEM system summary. The important numbers are the excess emissions (% EE) and monitor downtime (% MDT). A copy of the summary will be sent to the USEPA-Region 5.

Table 1.
MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION

Summary Report for Gaseous and Opacity Excess Emission and Monitoring System Performance

Pollutant: SO₂/NO_x/TRS/H₂S/CO/THC/HCL/Opacity Reporting period: _____

Diluent: O₂/CO₂ Volumetric Flow: Yes / No

Company: _____ Unit Description: _____

Emission Limit: _____ Total Source Operation Time: _____ min./hours*

Monitor Manufacturer, Model No., & Serial No.: _____

Emission Data Summary

1. Duration of Excess Emissions (EE) in reporting period due to:
 - a. Startup/Shutdown _____
 - b. Soot Blowing _____
 - c. Control Equipment Problems _____
 - d. Process Problems _____
 - e. Other Known Causes _____
 - f. Unknown Causes _____
2. Total Duration of EE's _____
3. Total Duration of EE's/Total Source Operation Time X 100 _____ %

CEM System Summary

1. CEM system downtime in reporting period due to:
 - a. Monitor Equipment Malfunctions _____
 - b. Non-Monitor Equipment Malfunctions _____
 - c. Quality Assurance Calibrations (Excess) _____
 - d. Other Known Causes _____
 - e. Unknown Causes _____
2. Total CEM System Downtime _____
3. Total CEM System Downtime/Total Source Operation Time X 100 _____ %

Comments:

I certify that the information contained in this report is true, accurate and complete.

Signature: _____ Date: _____

*Opacity operation time is to be recorded in minutes, Gaseous is recorded in hours.

Enforcement

The AQD Technical Programs Unit and the district staff will send letters of violation (LOVs) on noncompliance issues relating to CEMS. Examples of violations include failed relative accuracy test audits (RATAs), failure to test, failure to install required monitors, failure to submit CEMS test results, and an excess or high percentage of EEs and/or MDT.

From a regulatory standpoint, EEs and MDT may provide the AQD with sufficient data to issue a Letter of Violation if the source is not in compliance with regulations or standards. The continuous monitor can be used to establish whether the source is in violation of the standards. CEM systems can provide an enforcement agency with the data necessary to issue fines or other penalties if the source is not in compliance with regulations or emission standards.

Quality Assurance and Maintenance Program

After monitors are certified, it is expected that a facility will perform continuing quality assurance (QA) on the CEMS. This includes daily calibrations and periodic preventative maintenance as well as an annual RATA, quarterly cylinder gas audits (CGAs) and relative accuracy audit (RAA) for gaseous monitors, and an annual calibration error test (CE) for opacity monitors. Specific guidelines for continuing QA procedures can be found in Appendix F of 40 CFR Part 60. If the source is subject to the federal acid rain or nitrogen oxide reduction CEMS rules, the guidelines in Appendices A & B of 40 CFR Part 75, which are more stringent, will apply.

A maintenance program for a continuous emission monitor should be part of a plant quality assurance program for instrument systems. A quality assurance program is essentially a management system organized to ensure that quality control activities are performed for these instruments. Quality control activities are those activities performed to ensure that data generated from the monitoring system is both accurate and precise. Preventive and corrective maintenance activities are actually just two of the many quality control procedures that can be used for this purpose.

Important quality assurance principles include, but are not limited to, the following:

1. **Responsibility** - Plant management should make a clear and direct assignment as to who is responsible for the upkeep of the CEM. There are five common methods of providing maintenance service for CEM systems:
 - A dedicated full-time trained person
 - Formation of a centralized department responsible for all of the CEMS for the source
 - Purchase of a full maintenance agreement with the vendor
 - Purchase maintenance from an independent contractor
 - Purchase of an emergency service agreement

2. Training - Most vendors of CEM systems offer training programs for their specific systems. There are two types - start-up training at the monitor site and classroom instruction at the vendor's facility.
3. Communication - When the calibration, operational checks, data handling and corrective action procedures are not handled by one individual it is important that these functions be clearly defined. Management should provide clear lines of communication for a well functioning quality assurance program.

A facility-specific quality assurance manual should be developed, keeping in mind that this is a "living document." Table 2 provides suggestions for the content of a CEM system quality assurance manual.

Other Options: Fuel Sampling Analysis (FSA)

Fuel sampling analysis is an option available to coal-burning utilities in lieu of continuous emission monitoring of SO₂. The sulfur content of the coal is analyzed daily and recorded. These reports are submitted to the AQD on a quarterly basis. The USEPA has no established standards or policies regarding FSA - it has been left to the individual states to format their own individual plans. Michigan does not have an established plan.

Table 2.

Outline for a CEM System QA Manual

Section 1 - The Quality Assurance Plan

1. Quality policy and objectives
2. Document control system
3. CEM regulatory mandates and CEM system description
4. Organization and responsibilities
5. Facilities, equipment, and spare parts inventory
6. Methods and procedures-analysis and data acquisition
7. Calibration and quality control checks
8. Maintenance-preventive
9. Systems audits
10. Performance audits
11. Corrective action program
12. Reports
13. References

Section 2 - Standard Operating Procedures

1. Start-up and operation
2. Daily CEM system inspection and preventive maintenance
3. Calibration procedures
4. Preventive maintenance procedures
5. Corrective maintenance procedures
6. Audit procedure 1-cylinder gas audits
7. Audit procedure 2-relative accuracy test audit
8. Systems audit procedures
9. Data backup procedures
10. Training procedures
11. CEM system security
12. Data reporting procedures

Appendices:

- A. Facility operating permit
- B. CEM specifications and rules
- C. Reference test methods
- D. Blank forms

Excerpt from Continuous Emission Monitoring; James A. Jahnke, Ph.D.; Copyright 2000

References

Michigan Department of Environmental Quality, *Administrative Rules for Air Pollution Control*, Part 11 - Continuous Emission Monitoring.

Continuous Source Monitoring Manual, Commonwealth of Pennsylvania, Department of Environmental Resources, Bureau of Air Quality Division of Technical Services and Monitoring, January 1996, Revision 6 (available at <http://www.dep.state.pa.us/dep/deputate/airwaste/aq/cemspage/cemshome.htm>).

Jahnke, James A., *Continuous Emissions Monitoring Systems Handbook*, Source Technology Associates, February 1991.

An Operator's Guide to Eliminating Bias in CEM Systems, EPA 430-R-94-016, November, 1994.

Continuous Emission Monitoring Systems for Non-criteria Pollutants, USEPA Handbook, EPA/625/R-97/001, August 1997.

Jahnke, James A., *Continuous Emission Monitoring*, 2000, John Wiley & Sons, Inc., Second Edition, ISBN 0-471-29227-3 - 2nd ed.

Useful Websites

US EPA-OAQPS-Emission Measurement Center
<http://www.epa.gov/ttn/emc/>

US EPA-Clean Air Market Program
<http://www.epa.gov/airmarkets>

MDEQ-AQD
<http://www.michigan.gov/deq>
Select "Air" and then "Air Emissions" from the left menu. Choose "Emissions Monitoring" from the central menu selection for the Michigan Air Emissions Monitoring Program (site contains documents and forms for reporting.)

Code of Federal Regulations
<http://www.access.gpo.gov/nara/cfr/index.html>

Appendix A.

Acronyms used in Continuous Monitoring Systems

CEM	continuous emission monitoring
CEMS	continuous emission monitoring systems
COMS	continuous opacity monitoring systems
CERMS	continuous emission rate monitoring system

Pollutant monitor types

NO _x	nitrogen oxides
SO ₂	sulfur dioxides
O ₂	oxygen
CO ₂	carbon dioxide
CO	carbon monoxide
H ₂ S	hydrogen sulfide
TRS	total reduced sulfur
VOC	volatile organic compound
THC	total hydrocarbons
HCl	hydrogen chloride
NH ₃	ammonia

Testing terminology

RA/RAA/or	
RATA	relative accuracy test audit
CGA	cylinder gas audit
CD Test	7-day calibration drift test
CE Test	calibration error test
RM Test	reference method test

Miscellaneous

DAS	data acquisition system
DAHS	data acquisition handling system
EE	excess emission
EER	excess emission report
MDT	monitor down time
CFR	<i>Code of Federal Regulations</i>

Appendix B.

Source Monitoring Systems

Federal and state regulations require continuous monitoring in three categories: opacity, gas concentration, and flow rate. Techniques used for laboratory analysis, as well as techniques developed specifically for emissions monitoring, have been incorporated into commercially marketed systems.

Opacity continuous monitoring systems in stationary sources

The opacity particulate matter in stack emissions is continuously monitored by two instrumental methods. The first is measurement based upon the principle of transmissometry, and is relatively straightforward. Light having specific spectral characteristics is projected from a lamp through the effluent in the duct stack. The intensity of the projected light is then measured by a sensor. The projected light is attenuated, or lessened, due to absorption and scatter by the particulate matter in the effluent. The percentage of visible light attenuated is defined as the opacity of the emission. Transparent stack emissions that do not attenuate light will have a transmittance of 100 percent or an opacity of zero percent. Opaque stack emissions that attenuate all of the visible light will have a transmittance of zero percent or an opacity of 100 percent.

The second method is designated as an alternate Reference Method 9A called the LIDAR (Light Detection and Ranging) Technique. This latest development in source emission monitors has been developed from the technology of the United States space program. These monitors are remote sensors that can detect emission concentrations merely by beaming light up to the stack, or by sensing the light radiating from the "hot" molecules emitted from the stack. Neither reference methods nor performance specifications for the remote sensing of pollutant gases have been established.

Gas continuous monitoring systems in stationary sources

The selection of gas monitoring systems is more difficult since the USEPA has not established design specifications for gas analyzers. A CEM system for measuring gases is approved only if it performs according to USEPA specifications after installation. Any chemical or physical monitoring method can be used, providing the system accurately measures the emissions. Accuracy is relative to the Reference Methods for determining pollutant gas concentration as defined in 40 CFR 60, Appendix A.

Gas monitoring systems are classified into two basic groups - extractive systems and in-situ systems. In an extractive system, the sample is withdrawn from the stack and analyzed; in "in-situ" systems, the analysis takes place inside the stack. Features of both are presented in Table 1. The analytical techniques used in extractive and in-situ CEM systems encompass a wide range of chemical and physical methods. These vary from chemical methods using simple electrochemical cells to advanced electro-optical techniques such as gas filter correlation spectroscopy. A summary of current commercially marketed techniques used in source monitoring are presented in Appendix C.

Extractive Gas Monitoring Systems

With extractive gas monitoring systems, gas is extracted from a duct or stack and transported to analyzers for the measurement of pollutant concentrations. Extractive analyzers are designed to monitor source-level gas concentrations, or at ambient pollutant concentrations when used in conjunction with a dilution system. The choice of gas analyzers for an extractive CEM system is important since some analytical techniques will work better than others in a source application or system design. One of three analytical methods is generally used to determine these concentrations: absorption spectroscopic, luminescence, and electroanalytical.

Absorption spectroscopic methods involve the use of infrared analyzers to individually monitor heteroatomic molecules including SO₂, NO, CO, HCl, CO₂ and hydrocarbons. Nondispersive techniques utilizing optical filters or gas filters are well established. With Fourier transform infrared spectroscopy, a number of gases can be monitored at the same time by a single instrument. This is applicable when monitoring toxic waste incinerators and complex industrial processes. Ultraviolet photometers are useful for detecting subtle changes in absorption, and therefore, in concentration.

Luminescence methods are based on the emission of light from a molecule that has been excited in some manner. Photoluminescence is the release of light after a molecule has been excited by ultraviolet, visible or infrared radiation. Chemiluminescence is the emission of light from an excited molecule as a result of a chemical reaction. Chemiluminescence analyzers are used to measure NO and NO_x, with ozone used to excite NO through a series of reactions. Fluorescence analyzers are used for SO₂ ambient and source level measurements. Flame photometric analyzers are available for measuring sulfur compounds; however the restrictions for use of hydrogen gas to create the flame renders this method inappropriate for many industrial applications.

Electroanalytical methods of analysis can be classified into four types: polarography, electrocatalysis, amperometric analysis, and conductivity. Polarographic analyzers are used to monitor gases such as SO₂, NO_x, CO and O₂. Electrocatalytic analyzers are used for measuring O₂. Amperometric analysis is a technique used for both ambient and source monitoring by measuring the number of coulombs required to produce a chemical reaction. Conductive analyzers sense the change in the electrical conductivity of a liquid reagent after reaction with the sample gas.

One of the problems associated with extractive systems is that they are indeed "systems". In order for an instrument to measure gas concentrations, the gas sample must be free of particulate matter. Water vapor must be removed and the sample cooled to instrument temperature. This requires the use of valves, pumps, chillers, sample tubing, and other components necessary for gas transport and conditioning - components which require periodic maintenance. Failure to perform this maintenance and problems associated with poor system designs lead to frequent probe plugging, corrosion, and leaks.

In-situ gas monitoring systems

Difficulties with extractive systems led to the development of methods which measure the flue gases as they exist in the stack or duct, without conditioning. In-situ analyzers became a second generation of source monitoring systems. These systems consist primarily of an analyzer that does not extract the gas, but uses some type of sensor to measure the gas directly in the stack, or beams a light through the stack to make the measurements.

There are two types of in-situ analyzers: point and path. The distinction is the path length of measurement. A path equal to or less than 10 percent of the equivalent diameter of the stack or duct cross-section is considered point, where any amount greater than 10 percent is considered path. The point, in-stack measurement is usually made by the sensor over a distance of only a few centimeters.

Point analyzers consist of an electrochemical or electro-optical sensor mounted on the end of a probe, and inserted into the stack. Point analyzers are used to measure the concentrations of pollutant and combustion gases, and can be either single-pass or double pass systems. In the case of single-pass instruments light is transmitted to a detector on the other side of the stack, making only one pass through the stack. In a double-pass system, the light is reflected from a mirror on the other side, doubles back on itself, and is detected back at the transceiver. In practice, double-pass systems offer more flexibility in calibration than the single-pass design, and are preferred with respect to meeting regulatory requirements.

Point in-situ analyzers can also measure the particulate mass emissions in flue gases. However, since these emissions are not currently required to be monitored on a continuous basis, this is not common CEM system.

Path in-situ analyzers

Path analyzers measure along a path which runs across the duct or stack. In these "cross-stack" analyzers, light is transmitted through the gas and the interaction of the light with the flue gas is used to make the emission measurements. Acoustical techniques are also used with path systems.

Two principle techniques use commercially available path analyzers: differential absorption spectroscopy and gas filter correlation spectroscopy. Single-pass and double-pass designs of differential absorption are used to measure criteria pollutant gases. Gas filter correlation techniques can be used to monitor single or multiple gases.

One advantage of path in-situ analyzers is that a single instrument can monitor a number of gases economically. However, an in-situ system can only monitor one flue or stack at a time. Extractive systems can be used between several stacks. In-situ systems may also be sensitive to environmental factors such as vibration and elevated temperatures, both of which cause operational problems.

Flow rate continuous monitoring systems in stationary sources

Some regulations require continuous measurement of stack gas velocity. Pollutant mass emission rates are estimated from the measured velocity from a stack or duct. A number of techniques are currently available to monitor flue gas volumetric flow rate. The methods vary in complexity from the use of pitot tubes to transmitting ultrasonic signals across the stack.

Selection procedures

There are many systems for continuous monitoring commercially available. Many factors must be considered in order to determine the best equipment for a specific source. These include, but are not limited to, type of system required, design characteristics, environmental requirements, maintenance and operational considerations, and USEPA requirements.