Chapter 1
Introduction

1.1 Background and Objectives of the Handbook

This Handbook provides a description of the methods used to continuously monitor non-criteria pollutants emitted from stationary sources. The Handbook contains a review of current regulatory programs, the state-of-the-art sampling system design, analytical techniques, and the use of computer systems for data acquisition and predictive monitoring. The Handbook is intended for those in industry or in government who are charged with implementing a continuous emission monitoring (CEM) program for this wider range of air pollutants.

In 1979, a Technology Transfer handbook was prepared on the topic of CEM systems to provide the detailed information necessary for developing continuous monitoring programs at stationary sources (EPA, 1979). This information was updated in subsequent publications (EPA, 1991 and Jahnke, 1993); however, the original Handbook and these later materials focused on the monitoring of the criteria pollutants such as sulfur dioxide (SO_2) and the oxides of nitrogen (NO_x). Due to the successes of earlier CEM programs, requirements for CEM have been and are being extended to cover a wider range of pollutant categories such as volatile organic compounds (VOCs) and hazardous air pollutants (HAPs).

Although the installation of monitoring systems is most frequently initiated through regulation, the use of these systems for optimizing and improving process operations has proven to be an important benefit for many companies. When accurate emissions data are available, plant operators are provided with the baseline information necessary to control operations or to change operational practices. The net benefit for both industry and the public is to improve operational efficiencies with a consequent reduction of emissions to the atmosphere.

1.2 Evolution of Continuous Emission Monitoring - Regulatory Programs

Federal CEM requirements were originally established in the U.S. for tracking the performance of air pollution control equipment under the mandates of the EPA New Source Performance Standards (NSPS). Data obtained under this program are reported when emission standards are exceeded. These "excess emission reports" are then used to determine if control equipment performance warrants conducting an inspection or a reference method test (40 CFR 60 Appendix A, USEPA, 1996a) to determine whether the source is in compliance with its emission standards. This program began in the middle 1970's and after a number of years of experience, enough confidence was achieved in CEM systems to use the resultant data directly for the enforcement of emission standards (McCoy, 1986).

To withstand the rigors of litigation, CEM quality assurance programs became necessary to establish the continuing validity of the data. Subsequently, quality assurance requirements for CEM systems (40 CFR 60 Appendix F, USEPA, 1996b) were promulgated in 1986 for sources where the systems are used for monitoring compliance with emissions standards. By the late 1980's, federal experience with electric utilities constructed after 1978 (the Subpart Da sources) and the stringent CEM-based enforcement program of Pennsylvania, indicated that CEM systems could achieve both high levels of accuracy and availability. For SO_2 and NO_x monitoring systems, accuracies of 10%, relative to the EPA Reference Test Methods of 40 CFR 60 Appendix A, were common. System availabilities of 95% were attained for gas measurements and availabilities of 98% for opacity monitors had become achievable in practice.

The encouraging experience of these earlier (and continuing) programs helped to establish CEM as the foundation for the acid rain program of the 1990 Clean Air Act Amendments. In this emissions trading program, emission allowances (one allowance granting the right to emit 1 ton of SO_2 per year) were originally allocated and reserved so that a net reduction of 10,000,000 tons of SO_2 would be realized by the year 2010. Allowances can be viewed as financial instruments that can be bought, sold, traded, etc. CEM systems enter this picture by providing the means of determining who has how many allowances --- how many are used up, and how many are unused and available for trading. The CEM systems are

essentially, the "gold standard" on which the allowance trading program is based (EPA 1991b).

Stringent performance requirements were established (40 CFR 75) for CEM systems used in the acid rain program. As a result of these requirements and the importance of CEM systems for tracking allowances, the systems received greater attention from upper management than in previous programs. Resources were allocated for both purchase and maintenance and responsibility for the systems was given to higher levels of management. After a year of operation of the first phase of the program, relative accuracies of 5 - 6% were common, with corresponding availabilities of 95% or better.

The success of CEM systems at the electric utilities has encouraged their application for monitoring a wider range of pollutants at other types of emissions sources. Monitoring programs are well established at pulp and paper mills, petroleum refineries, municipal waste combustors, hazardous waste incinerators, and cement kilns. At hazardous waste incinerators, stringent operating permits go so far as to require that waste feed be shut off when the monitors indicate that carbon monoxide emission levels are too high or oxygen percentages are too low. Particularly in the case of hazardous waste incineration, continuous monitoring data provide assurances to the public that plant emissions are being controlled continually within safe levels.

The Clean Air Act Amendments of 1990 address two other issues. One is the public concern for the emission of hazardous air pollutants, the so-called "air toxics" (CAAA 1990 - Title III). Title III contains a list of 189 pollutants, principally organic compounds and metals (see Appendix D). Depending upon rules specifying "Maximum Achievable Control Technology" (the so-called "MACT" standards), certain operations likely will be required to monitor the emission of these materials on a continuous basis.

Title VII of the Clean Air Act Amendments refers to the term "enhanced monitoring" (§702(b)(3)), where sources are required to certify that they are in compliance with their emissions limitations. "Enhanced Monitoring" has evolved into the "Compliance Assurance Monitoring" (CAM) rule, where CEM systems or other techniques may be used by the source to track its compliance status.

The air toxics and CAM rules affect a wide variety of emissions sources. Many of these sources are small, relative to the larger industrial sources that have been required to install CEM systems through the NSPS Part 60 or acid rain Part 75 rules. For these smaller sources, arguments often arise that CEM systems are too costly, that the technology is too new, or that extensive evaluation programs need to be conducted before CEM systems can be used for regulatory purposes. However, much is known about CEM systems. With over 25 years of experience both in the United States and Europe, continuous emission monitoring for many pollutants is a mature technology. With the one time upsurge of Acid Rain CEM system sales in the early 1990's, subsequent market pressures have forced CEM system vendors and integrators to reduce costs to remain competitive. In addition to the present knowledge base and market pressures, new technologies are being introduced into this field at a rapid pace. This combination of factors has created an array of options for meeting monitoring requirements for hazardous air pollutants.

1.3 Current Status of Continuous Emission Monitoring - Monitoring Technology

Monitoring pollutant emissions from stationary sources involves two principle functions: 1) extracting or locating a representative sample and 2) analyzing that sample. Monitoring methods in use today are illustrated in Figure 1-1.

Extractive and in-situ methods are used to monitor gas concentrations directly. In the case of extractive systems, gas is withdrawn from the stack, conditioned, and then analyzed. In in-situ systems, gas is not extracted, but is monitored directly in the stack by the analyzer. In the indirect parameter monitoring methods, plant operational or control equipment parameters are correlated to emissions determined by manual or instrument reference methods. To the extent that the parameter method's validity depends on correlated data, representative sampling and analysis are equally as important as in the direct extractive and in-situ measurement methods.

The choice and design of a CEM system depends on both the regulatory requirements and the types of pollutants and/or parameters that are to be monitored. For example, when emissions are reported in kg/hr or tons/year, a pollutant monitor plus a volumetric flow determination are usually necessary. If concentration corrected values are required (such as ppm corrected to 3% O_2 or 12% O_2), then a pollutant monitor plus a diluent monitor (O_2 or CO_2) are required.

Different gases have different properties and some are more amenable to analysis than others. Many well-proven techniques are available for monitoring sulfur

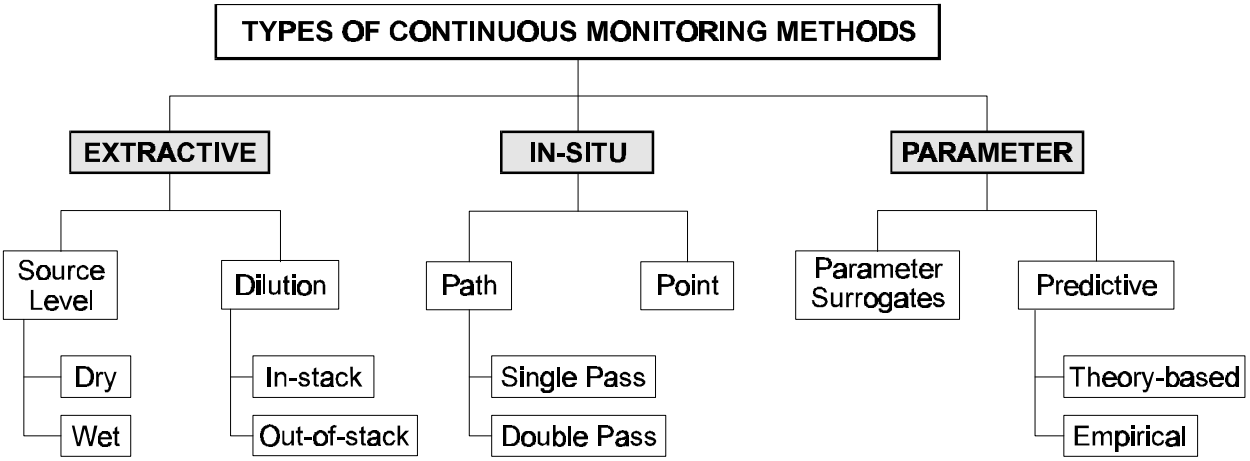

Figure 1-1. Continuous monitoring methods.

dioxide and oxygen. However, concentration measurements of metal vapors and complex organic compounds can be very difficult to perform in field installations. With the advent of modern microprocessor systems, sophisticated laboratory analytical techniques have become available for field use at relatively low cost. Fourier transform infrared spectroscopy (FTIR) and gas chromatographic mass spectroscopy (GCMS) are two such methods that can be used for measurement of a wide range of compounds. Other techniques, such as ion mobility spectroscopy, the use of diode lasers in optical differential absorption systems, and the advent of low-cost catalytic or semi-conductor sensors provide options for monitoring acid and organic gases that were previously very difficult and expensive to monitor on a continuous basis.

Technologies for the measurement of flue gas metal concentrations are developing. The partition of metals between the gas phase and particles provides a challenge in obtaining a representative sample and in making the actual measurement. Some metals, such as mercury, are relatively easy to monitor in the vapor state. When metals are bound in the particulate matter, the continuous measurement of particulate mass concentration can monitor an upper bound of metal emissions. Continuous particulate mass measurement techniques are well established, having evolved in Europe over the past 20 years (Peeler, 1996).

In some cases, sensors used to monitor plant or control equipment performance parameters also can provide continuous data for emissions tracking. Here, data obtained from the sensors are used in place of actually determining emission concentrations. A sensor-determined value is assumed to stand in place of, or correlate to, emissions levels expressed in ppm or mg/m^3. This approach has been used in NSPS requirements since 1975 and may see greater application for process units regulated under the proposed CAM rule. Rather than just serving as emissions surrogates, operational parameter data can also be incorporated into computer models to predict emissions. These models generally are developed by correlating parameter data to actual source test data obtained over a range of operating conditions. However, to develop a robust model, one that remains valid under a wide range of operating conditions, the costs associated with source testing may become comparable with the actual cost of CEM instrumentation.

One of the central problems associated with monitoring hazardous air pollutants is the lack of established or validated reference methods. Traditionally, CEM systems have been certified for use at a facility by performing a series of wet chemical or instrumental reference method tests. The tests are used to determine the "relative accuracy," the accuracy of the CEM system relative to the reference method values. In the past, the effect of other gases on the reference test method results was generally well understood for specific industrial processes. Collaborative tests and years of field data have given confidence that the reference methods indeed give true emission reference values under most conditions.

To similarly validate reference methods for the hazardous, non-criteria pollutants has been difficult.

The reactive nature of many of these gases, their presence in gaseous and solid forms, and their low concentration in flue gases, provide challenges for wet chemical reference methods and instrumental monitoring techniques alike. Because of these problems, few reference methods for the hazardous, non-criteria pollutants have been established. Instead, several new approaches using reference spectra, internal standards, and dynamic spiking offer alternative approval mechanisms.

The engineer choosing between the various monitoring options is of course, looking for the "best" system. However, no generic "best system" exists. CEM systems are application dependent; depending upon regulatory requirements, pollutants to be monitored, location restrictions, flue gas conditions, ambient conditions, and manpower and management considerations. Cost is a factor in choosing a system, but low cost should never be the single deciding factor. In the end, the best system will be one that can analyze a sample representative of flue gas conditions, one that meets all regulatory requirements for accuracy and precision, and one that has low capital costs and low maintenance requirements.

When choosing between parameter surrogates, predictive systems, or CEM systems, cost can be viewed from a different perspective. When applied to market trading programs, the value of an emissions "credit" or "allowance" may be related to how the credit is determined. Credits determined with some uncertainty may be worth less than those obtained with more certainty. In the end, the cost associated with the monitoring method may be counterbalanced by the consequent value of the data.

The decision-making process for choosing a CEM system can become very complex (White, 1995). All of the decision factors for the "best" system are, of course, relative. For example, a 10% relative accuracy may be important for a trading program; however, a 20% relative accuracy may be adequate if normal emissions are at a 50 ppm level when the emissions standard has been set at 200 ppm. Monitoring costs may not be a significant factor when facing $25,000/day penalties for noncompliance, but a small manufacturing facility may not have the capital or manpower necessary to maintain a complex electro-optical monitoring system. This Handbook has been prepared to provide information that can assist the decision-maker in choosing between the variety of available monitoring options.

1.4 Organization of the Handbook

The Handbook is organized in a manner that allows the reader to proceed from a logical progression from implementing rules, technical evaluation, system purchase, and certification. The objective of the Handbook is to provide the reader with the conceptual tools and detailed information necessary to make informed decisions with regard to the monitoring options available.

- The implementing rules through which CEM systems are required to be installed are addressed in Chapter 2. This chapter contains a discussion of various regulations and monitoring programs to assist in evaluating non-criteria pollutant monitoring programs in the context of established regulatory concepts. The chapter provides a review of existing requirements, emphasizing those where non-criteria pollutant monitoring is required.

- Current monitoring instrumentation is discussed in Chapter 3. The authors focus on the dependence of the sampling system and instrumentation on the pollutants to be measured. Reactive and condensable gases, particulate matter, and metals present specific challenges. Due to the special sampling requirements for non-criteria pollutants, sampling systems are addressed separately for gases and particulate matter. The analytical techniques used in analyzers designed for monitoring HAPs and particulate matter are presented.

- Non-traditional methods of monitoring source emissions, focusing on the parameter (surrogate) monitoring and predictive monitoring (modeling) methods, are addressed in Chapter 4. Advantages and disadvantages of the methods and the concept that the combination of CEM instrumentation with modeling methods makes for a powerful tool for both monitoring and process control are advanced in this chapter.

- An important subsystem associated with any monitoring program, the data acquisition and handling system, is discussed in Chapter 5. The state-of-the art of CEM system data acquisition, control, and reporting systems is reviewed in this chapter. It provides a review of the various options available and how they fit into the total system package.

- Common sense approaches to choosing a monitoring system, emphasizing the relationship of the type of CEM system or monitoring technique to the application, are discussed in Chapter 6. This chapter describes what information is needed prior to writing the technical specifications, how to write a technical specification, and how to evaluate bids received.

- Certification and approval mechanisms that can be used for validating non-criteria pollutant monitoring systems are addressed in Chapter 7. Mechanisms are necessary to provide assurances that the installed system will provide data that provide a degree of representativeness, accuracy, and precision consistent with regulatory specifications. Approval procedures specific to advanced monitoring techniques are presented. Issues involved with multi-component systems (such as FTIR and GCMS), where many compounds may be measured concurrently or sequentially, are discussed with respect to procedures that may be required for demonstrating system and analytical performance both on an initial and continuing basis.

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