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Data-Acquisition and Control Systems—Recording and Reporting CEM System Data

A CEM system is not complete without incorporating a subsystem that records the data produced by the analyzers. The data acquisition system (DAS) provides this record of emissions measurements, both for documenting plant operations and for reporting to the environmental control agency. On a daily basis, the CEM system operator or plant environmental engineer works more with the DAS than with any other CEM subsystem. Activities such as reviewing data, checking calibration values, responding to excess emissions problems, and generating reports are all performed within the DAS. This system's importance cannot be overemphasized.

The actual CEM DAS functions depend heavily on regulatory requirements and the complexity of the monitoring system. The DAS can be as simple as a strip chart recorder, or it can incorporate personal computers (PCs) or plant mainframe computers. The principal function of a CEM DAS computer is to collect and record data. Analyzer analogue signals must be converted to digital signals at some point in order to be processed by a computer; however, many newer analyzers are incorporating their own microprocessors to produce digital outputs that can be processed directly. After the data are recorded, they can be manipulated, converted into different units, averaged, and reported by the computer.

The computer also can provide controlling functions for the analyzers, such as performing automatic daily calibrations and adjustments. Alternatively, these controlling functions can be performed by programmable logic controllers (PLCs), or other devices, so that the computer can be dedicated to recording and reporting data.

CONTROL SYSTEMS

A control system provides for the automatic operations of the CEM system hardware. Functions such as zero and span checks, extractive probe blowback, and alarms for excess emissions and system malfunctions all may be performed automatically. Either programmable logic controllers or the CEM system computer will provide the signals to activate relays or valves for these operations.

Programmable logic controllers have been applied widely in industry to handle the logic, timing, counting, and data transfer in manufacturing operations. PLCs are modular and can be chosen to perform a number of functions, such as triggering automatic functions, providing analog to digital (A/D) signal conversion, registering alarms, and data logging. They can be programmed to perform mathematical calculations, to perform calibration corrections to data, and to average the data.

Data-logger–controllers perform similar functions, but are usually single units designed to receive a fixed number of analogue inputs and to provide a fixed number of outputs. These can be tailored to meet the general monitoring requirements.

An advantage of PLCs and similar control systems is that, using them, the choice of actual data recording and reporting system becomes more flexible. The plant computer or a PC using a standard CEM program can then simply accept inputs without having to be programmed for the control functions of the system.

RECORDING AND REPORTING DEVICES

There are four devices that can be used to record and report CEM system data, including

1. the strip chart recorder
2. the data logger
3. the PC or dedicated CEM computer
4. the plant mainframe computer

Various combinations of these subsystems are often incorporated into the CEM DAS. Given that data are increasingly recorded, corrected, converted, and stored using computerized systems, a failure in the computer can be catastrophic—worse than an analyzer failure. For this reason, data backup and computer quality assurance are important.

Strip Chart Recorders

The strip chart recorder is the most basic CEM system recording device and can be an invaluable tool to an instrument operator. Even if a computer system is used to acquire CEM data, a strip chart recorder is useful in providing a backup record. Advantages of the strip chart recorder include the following:

- The continuous, high-speed response of a strip chart recorder is invaluable for system troubleshooting.
- The strip chart recorder provides the most accessible record for the auditor or inspector.
- The strip chart record readily indicates if an instrument is properly "zeroed" and "calibrated."
- Trends in source performance and instrument performance are easily detected.
- The appearance of the strip chart and the annotation of dates, times, strip chart speeds, and so on can indicate how well the instrument is being operated and maintained.

A strip chart recorder should be easy to read and be flexible enough to be used for multiple purposes. A chart width of 6 in. or greater is recommended. The recorder should have a range switch for different inputs, and it should be possible to change the chart speed. Accordion-fold paper that allows for easy folding is convenient for data storage; however, chart rolls can be manually folded for the same effect.

A strip chart recorder should be chosen so that data can be interpolated at a level suitable to the measurement range specified for the CEM system. Changes in the chart trace should be distinguishable at a level better than the drift limit. In a 1000-ppm range, for example, it should be possible to distinguish changes better than 2.5% of the range, which is 25 ppm. Although the strip chart recorders offer many advantages, there are several disadvantages associated with their use:

- Strip chart recorders are high-maintenance devices. Paper and pens must be replaced periodically.
- Recorder failures can result in the total loss of data.
- Multiple recorders can occupy valuable panel space, particularly in the control room.
- Strip chart data can be difficult to store and access.
- In computerized systems, automatic calibration corrections or calculations are sometimes made only on the computer record. Such corrections are performed mathematically by the computer and do not constitute physical adjustments to the calibration potentiometers of the analyzers. As a result, these changes do not register on the strip chart record, so the strip chart data are difficult to interpret or are virtually useless.

Despite these problems, the strip chart record can be invaluable for "at-a-glance" evaluations of emissions, system troubleshooting, or as backups to the computer data. In many plants, strip chart recorders are installed in the control room to monitor opacity, but gaseous emissions data are provided by computer.

Data Loggers

Data loggers are devices that print data in digital form. They are convenient to use when the amount of effort required to reduce strip chart data to actual numbers becomes excessive and when data manipulation needs are minimal. A data logger is not a sophisticated microprocessor, but it can be designed to perform rudimentary calculations and alarm functions. Data loggers are often used with microprocessors to convert analyzer analogue signals into digital forms that are acceptable to the computer. The data logger can also store the data for backup purposes. For example, battery-backed solid-state, nonvolatile storage cartridges can be used for backup in the case of power failure.

Although data loggers have limited capabilities, they may perform all of the functions necessary for limited applications. However, for full data-reporting capabilities, a computer system may be used in conjunction with a data logger.

Personal Computers and Dedicated CEM System Computers

A computerized system can process, display, and transmit CEM analyzer data and can support other functions necessary for CEM system operations, such as analyzer control. Various types of systems are available in today's market, supplied either by the CEM system vendor or by companies that develop data acquisition systems. In general, these systems are IBM-compatible, use a 386 or 486 chip, are equipped with hard drives of up to 120 megabytes. Depending on the system, an internal A/D conversion capability may be included. Continuous emissions monitoring data acquisition systems should be designed to minimize the loss of data during power interruption or system failure.

The data acquisition system design offered by a CEM systems vendor often remains fixed. A potential user may ask for special features such as touch screens, laser printers, color displays, and multitasking capabilities, but many of these features come at increased cost and CEM system vendors are not always willing to spend the time and effort to deviate from their existing software.

The Plant Mainframe Computer

Using the plant mainframe computer for CEM system data acquisition may appear to be an attractive option. If sufficient memory is available, the mainframe generally offers more programming flexibility than a dedicated CEM computer. The ability to incorporate spreadsheet and graphics programs into the CEM software can provide the state-of-the-art displays to which process engineers have become accustomed. The CEM system data will also be directly part of the plant information system and may be more easily transmitted through that system. The main advantage is that if plant personnel are responsible for the system programming, the plant will have control of the software and will be able to modify it as needed, without having to rely on an outside vendor.

However, there are disadvantages with this approach. A plant programmer is generally not dedicated to the CEM system software and other departments make demands on his or her time. Also, the programmer usually does not have experience in the many obscure points associated with CEM regulation and will only learn these over a period of time. It normally takes from six months to a year to develop operating and debugged CEM software; with this in mind, the costs associated with its development may be equivalent to those of a system provided by an outside vendor.

Telemetry

As an option, the system may be designed to transmit data to the regulatory agency or to corporate offices. The protocol used to transmit data via a dial-up telecommunications system should follow a data telemetry access protocol specified by the requesting organization. Care should be exercised by agencies in requiring real-time CEM system data. Real-time data may not be quality-assured, and knowledge of real-time data may make the agency a party to plant emission problems. Because the agency would have current knowledge of plant emissions, if a plant upset or catastrophic release should occur and no agency action is taken, the public may respond negatively.

UNITS OF THE STANDARD

Practically every emissions regulation requires that analyzer data be converted into specified units. These units, or "units of the standard," depend upon the regulatory policies of the national or local environmental control agency and the type of source regulated. Mass rate standards are common in Europe, whereas process rate standards are more frequently specified in the United States. Table 8-1 gives several examples of units that are commonly used.

Gaseous emission values may require reporting in one of these forms (transmissometer data is normally reported in percentage of opacity). For example, in the United States, emissions from fossil-fuel-fired steam generator facilities are expressed in pounds per million British thermal units (nanograms per joule); for a discussion of F-factor methods used to perform these calculations see Appendix A and, for example, U.S. EPA (1991b) or Jahnke and Aldina (1979). In the U.S. acid rain program, allowance trades for SO_2 emissions are expressed in tons of SO_2 per year and in the large furnace orders in the Federal Republic of Germany (FRG 1988), gaseous emission limits are expressed in kilograms per hour. In the United States, for total reduced sulfur (TRS) emissions from Kraft pulp mill lime kilns, emissions are monitored in parts per million by volume, corrected to 10% O_2 on a dry basis. How emissions standards are determined affects the design of the CEM system. For this reason, a facility that is purchasing a CEM system should include regulatory requirements in the CEM system request for proposals.

RECORDING AND REPORTING DATA

Continuous emission monitoring systems can give a wealth of data; however, not all of the data are required to be recorded. These requirements may differ between federal and state governments and certainly between different countries (Bühne 1981). As an example, Table 8-2 gives U.S. federal recording requirements for opacity and gaseous emissions (U.S. EPA 1991a).

These requirements specify the minimum number of data points required to be recorded. Systems are commonly designed to poll the continuous analyzer data for a period of typically every 10 s and then average the numbers obtained over the required period of 6 or 15 min. The 15-min recording period for gas analyzers allows for the installation of analyzer time-sharing systems. In time-sharing systems, one analyzer can be used to measure emissions from two to three stacks (e.g., 5-min sequential measurements for each 15-min period) to meet the specification. The intent of

TABLE 8-1 Common "Units of the Standard"

Units of the Standard	Form of Calculation	Analyzers Required	Nomenclature
E mass per heat input (ng/J; lb/10^6 Btu)	$E = c_w F_c \dfrac{100}{\%CO_{2w}}$ or	Pollutant analyzer CO_2 analyzer	E = emission rate c_w = wet pollutant concentration (g/dscm; lb/dscf)[a] $\%CO_{2w}$ = wet CO_2 percentage F_c = ratio of volume of CO_2 produced to gross calorific value of combusted fuel
	$E = \dfrac{20.9 c_d F_d}{(20.9 - \%O_{2d})}$	Pollutant analyzer O_2 analyzer Dry system or H_2O determination	F_d = dry F-factor ratio of dry combustion products to gross calorific value of fuel
pmr mass/time (kg/h); lb/h); tonnes/yr; tons/yr)	$\text{pmr} = c_w Q_w$	Pollutant analyzer Flow monitor	pmr = pollutant mass rate Q_w = flue-gas volumetric flow rate = $v_w A_s$, where v_w = flue-gas velocity A_s = stack cross-sectional area
E' mass/(mass product) (lb/ton; kg/t)	$E' = \dfrac{c_s Q_s}{R_p}$	Pollutant analyzer	E' = process weight rate R_p = production rate (t/h)
$c_{d(12\%\,CO_2)}$ concentration (ppm)	$c_{d(12\%\,CO_2)} = c_w \dfrac{12}{\%CO_{2w}}$	Pollutant analyzer CO_2 analyzer	$c_{d(12\%\,CO_2)}$ = dry basis pollutant concentration corrected to 12% CO_2
$c_{d(6\%\,O_2)}$ concentration dry (ppm)	$c_{d(6\%\,O_2)} = c_s \dfrac{15}{(21 - \%O_{2d})}$	Pollutant analyzer O_2 analyzer Dry system or H_2O determination	$c_{d(6\%\,O_2)}$ = dry basis pollutant concentration corrected to 6% O_2 $\%O_{2d}$ = dry basis O_2 concentration
$c_{d(50\%\,EA)}$ concentration dry (ppm)	$c_{d(50\%\,EA)} = c_d \dfrac{100 + \%EA}{150}$	Pollutant analyzer O_2 analyzer Dry system or H_2O determination	$c_{d(50\%\,EA)}$ = dry basis pollutant concentration corrected to 50% Excess air (EA)

[a] dscm = dry standard cubic meter; dscf = dry standard cubic foot.

TABLE 8-2 New Source Performance Standards Recording Requirements

Opacity	A cycle of sampling and analyzing for each successive 10-s period, and one cycle of data recording for each successive 6-min period
Gaseous emissions	One cycle of sampling, analyzing, and data recording for each successive 15-min period

this approach is to reduce the number of analyzers in a CEM system; however, this increases the complexity and decreases the flexibility of the system.

Data Averaging

Emissions data reporting is further complicated by data-averaging requirements. In most cases, the requirements will necessitate that they be determined by a computerized data-acquisition system for CEM system data.

Block averages and rolling averages are two averages commonly used in regulatory reporting. A block average is an average of sequential data points or an integrated average obtained over a specified time period. Examples of these methods are given next.

The Block Average

Block averages are used in U.S. federal regulations for the averaging of opacity and gas emissions data. Their application depends upon the source category and the pollutant being regulated; for example, for Subpart D electric utilities in the United States, opacity 6-min block averages are to be calculated from 36 or more data points equally spaced over each 6-min period. For gaseous emissions, 1-h block averages are to be calculated from four or more data points equally spaced over each 1-h period.

Opacity monitoring data are generally recorded and reported in 6-min block averages. Gaseous emissions monitoring data, however, can be recorded and reported as an hourly average, or the 1-h block average can be further averaged over 3 or 24 h before reporting.

The Rolling Average

Block-averaged data can be further treated by using a "rolling average," which is an arithmetic average of a specified number of contiguous periods. For example, in a 3-h rolling average, three contiguous 1-h averages are averaged (this is shown in Figure 8-1). The 3-h rolling average is used in the U.S. federal reporting requirements for NSPS Subpart D fossil-fuel-fired steam generator facilities.

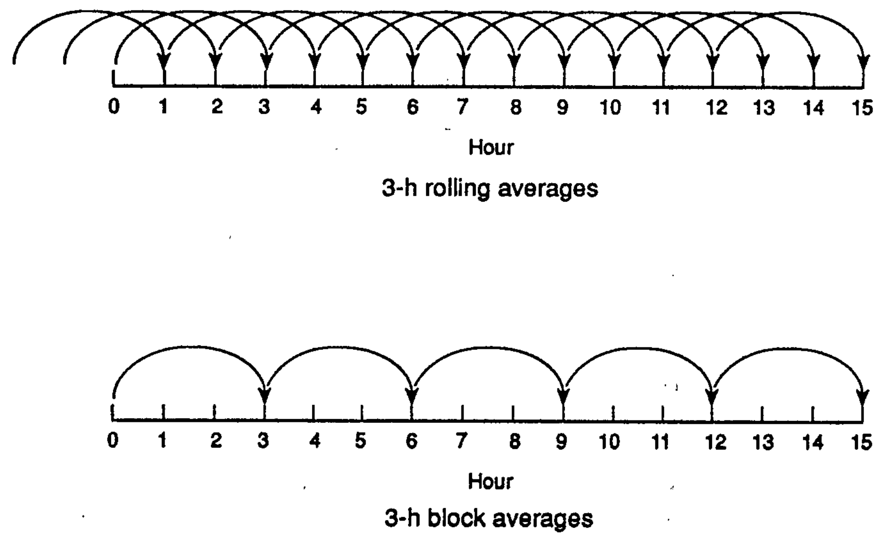

FIGURE 8-1. A 2-h rolling average and how it differs from a 3-h block average.

Note from the figure that at the end of 4 h, the 1-h value of the previous 3-h average is dropped, and the 4-h value is averaged with the remaining 2 h. Similarly, the average "rolls" along from hour to hour. This differs from a block average, given that in a 24-h period, there will actually be 24 contiguous 3-h periods. If one were to average blocks of 3-h periods, only $\frac{24}{3} = 8$ averaged values would be obtained.

A 30-day rolling average is specified in the reporting requirements for U.S. NSPS Subpart Da (electric utility steam generating units). This is an average of 30 contiguous 24-h averages, as shown in Figure 8-2. This average is similar to the 3-h rolling average, except that 30 days of daily data are averaged. In a 30-day period, 30 averages (not one average) would be obtained, after the initial 30-day lapse. To allow for CEM system shutdown time, the rolling average may not actually be the average of 30 days of data, and the daily data may not be composed of an average of 24 h of data. [*Note:* The specification allows a minimum of 18 h of hourly data (block averaged) to be included in each 24-h block average. It also allows a minimum of 22 daily averages to be used in calculating a 30-day rolling average. This works out to a CEM system availability of approximately 75%; that is, the CEM system is available to give data 75% of the time. Because CEM system availability for gas monitoring systems is currently between 90 and 97% (McCoy 1990), the specification is particularly generous.]

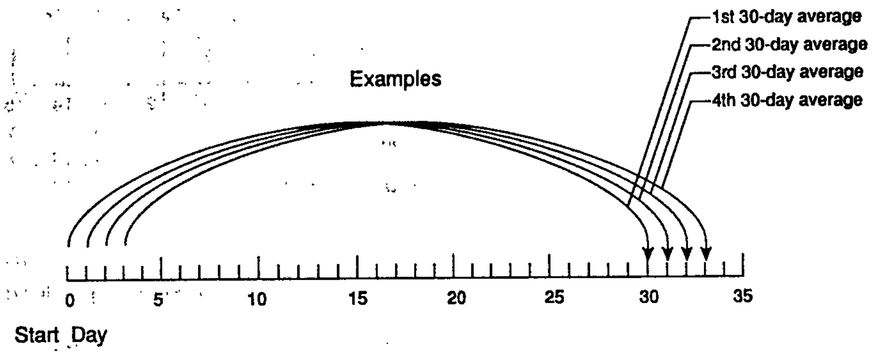

FIGURE 8-2. A 30-day rolling average.

Rolling averages are useful to the regulated source because the averaging period allows for the correction of control system problems. For example, if the removal efficiency of an SO_2 scrubber was found to be decreasing and the 24-h average was beginning to exceed the compliance value, steps could be taken to improve the scrubber performance (such as increasing lime feed) and balance the previous high-data averages with subsequent lower averages. The source could then remain in compliance with emission regulations, although it may have exceeded the emission standard for a short time. The net effect of the rolling average is to smooth out highs and lows in emissions data.

Generally, the longer the rolling average period, the easier it is for a facility to meet the emissions standard. For a short averaging period, the facility may often have to "overcontrol" to ensure that emissions standards are met. For a longer averaging period, flexibility is provided to make up for excess emissions by overcontrolling at a later time, instead of all the time. This has been demonstrated from the data of McRanie (1990) shown in Table 8-3.

TABLE 8-3 Effect of Averaging Period on Actual Emissions—Averaging Time Versus Long-Term Means to Comply with a 1.2-lb SO_2 / 10^6 Btu Emissions Limit (McRanie 1990)

Rolling-Average Time	Long-Term Mean (lb $SO_2/10^6$ Btu)
90 days	1.04
30 days	0.95
24 h	0.76
3 h	0.63

McRanie obtained the data in Table 8-3 from a large data base provided by the electric utilities. Although the emissions standard here is 1.2 lb/10^6 Btu, the actual long-term means are well below this value, and the mean is lower for shorter averaging periods.

Reporting Requirements

CEM system reports are submitted to provide emissions compliance data for agency enforcement personnel. Reporting requirements and formats vary, depending upon the source category and the agency that is regulating the source. Data-acquisition systems can be designed to provide reporting functions, as well as recording and averaging functions. Computerized systems can average and summarize data and can print out reports in formats specified by state and national agencies.

Data editing, which can be performed with some of today's increasingly flexible CEM system software programs, may be required. Because CEM formats are not standardized, vendors offering CEM data-acquisition systems often have to customize programs, which results in added costs to the CEM system user.

The most common reporting format in the United States is the excess emissions report (EER) (Paley 1984). Depending on the NSPS source category, data summaries must be submitted to the agency either quarterly or semiannually (U.S. EPA 1990). The EER contains reports on the following:

1. the magnitude of any excess emissions (emission values in units of the standard that exceed the standard
2. the dates and times of the excess emissions
3. the reason for the excess emissions
4. the corrective action taken

Data requirements for an EER can be very extensive. For example, when opacity data frequently exceed the standard, reports can be very large.

The source operator must also maintain a file of the continuous monitoring data, including records of adjustments, repairs, calibration checks, and audits. The file must be retained for two years and is required to be maintained in such a condition that it can be easily audited by an agency inspector.

All of these requirements directly impact on the design of the CEM data-acquisition system. In some cases where there are relatively few monitors and few excess emissions, a strip chart recorder or data logger may be sufficient to meet regulatory requirements. In most cases, where emission data are used for control operations and environmental reporting, a computerized system is usually necessary. Facilities often increase the sophistication of the DAS and reporting system when it becomes apparent that too much time is spent by senior personnel in reducing the emission report data.

SUGGESTED FUNCTIONS FOR CEM SYSTEM SOFTWARE

In the preceding discussion, general requirements were given for recording and reporting emissions data. It is the responsibility of the CEM system programmer to incorporate these requirements into a consistent set of programs. Programming can be either rudimentary or sophisticated; however, users are becoming more demanding because of their experience with the flexibility and graphics capabilities of commercial software. User concern should not be directed so much at the CEM system hardware because hardware is continuously developing and basically is a set of tools with which the programmer works. Instead, the primary concern of the user should be with what comes out of the system and how easy it is to work with. Some initial suggestions for the user in this regard are given here.

Software should be written in a standard computer language (e.g., BASIC, PASCAL, or FORTRAN) and should consist of an optimum combination of a real-time operating system and program to provide (1) the data-base structure, (2) an easy-to-use operator interface, (3) user-selectable parameters, (4) report formats, (5) editing commands, and (6) archiving features. Specifically, the computer system should do the following:

1. *General Features*

- The system should acquire data from the emission monitors as it is generated, while simultaneously allowing for operator input and report generation.
- The data base should incorporate the entire past quarter's data and the data generated during the current quarter.
- The user should be able to edit and demand reports for any period in the previous quarter, as well as for the current quarter.
- Status and editing codes should be incorporated into the reporting system for conditions such as out-of-service instruments, abnormal calibrations, insufficient samples, data substitutions, and edited data invalidations. The user also should be able to enter additional codes after system installation.
- The user should be able to configure the system on-site to change parameters such as emission limits, data correction constants, alarm set points, calibration tolerances, and range scales. Also, textual information fault codes should be able to be defined.
- Printed reports should be generated from the data base on demand. The capability to insert comments from the keyboard into the report also should be available.
- Editing provisions should be made for conditions such as reason code entry or modification, comment entry, data invalidation (due to CEM malfunction), plant malfunction and emergency conditions, and nonoperating conditions.
- Provision should be made for the entry of manual test or alternate monitor data in case of CEM system malfunction.
- Menu-driven programs, help screens, or other user aids should be incorporated into the software, to minimize user training time with the system.

2. *Calculations*. The system should correct pollutant data to the units of the standard. Parameters such as combustion efficiency, SO_2 removal efficiency, or emissions in units other than the standard (e.g., kilograms per hour, pounds per hour, nanograms per joule, or parts per million corrected to 6% O_2) may also be calculated.

3. *Screen displays*. The system should provide a continually updated display of parameters measured and corrected by the monitoring system. The displays should provide easily readable formats in one screen or several screens.

4. *Recording*. Data should be recorded on 3.25- or 5.25-in. disks so that they are readable by IBM PC–compatible disk drives.

5. *Reports*. Reports should be able to be generated by the DAS on command. The system should be capable of producing hard copy of reports such as the following:

- *CEM system daily report*. A daily CEM system status report that includes monitor calibration data, hourly averages, excess emission data, and monitor availability
- *Quarterly emissions reports*. A report prepared for each compliance parameter for each unit of the facility (i.e., opacity, SO_2 concentration)

6. *Inputs.* The CEM data-acquisition–control system should provide inputs to the plant mainframe computer to display desired CEM data for the control room operator.

Although commercial data-acquisition systems may not offer all of the features listed here, the capabilities are available in today's technology to meet such requirements. It is expected that the systems will evolve as users begin to require increased programming sophistication.

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