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Project Summary

Long-Term Continuous Monitor Demonstration Program: Columbus and Southern Ohio Electric Company, Conesville Unit 6

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A continuous emission monitoring (CEM) demonstration program was conducted at the Columbus and Southern Ohio Electric Co.'s Conesville Generating Station. The primary purpose of this program was to demonstrate the feasibility of the monitoring requirements specified in 40 CFR, Part 60, Subpart Da. A secondary objective was to adhere to the draft quality assurance requirements scheduled for promulgation as Appendix F.

An assessment of system availability as a percentage of hourly unit uptime indicated an average of 78 and 75 percent availabilities for the SO_2 outlet emissions and control system removal efficiency reporting parameters, respectively. Availability for the NO_x system averaged 65 percent. Subpart Da availabilities (number of valid 30-day rolling averages) were 67, 59, and 62 percent for the SO_2 emissions, efficiency and NO_x emissions reporting parameters, respectively.

Evaluation of labor requirements indicates that the total average weekly level of effort was 27 hours. Of the total, 64 percent are attributable to daily operations, 23 percent to nonroutine maintenance, and the remaining 13 percent to preventive maintenance.

The system consistently complied with the performance specifications criteria. Relative accuracy results were well within the 20 percent limit except on one occasion when the NO_x result slightly exceeded this level.

This Project Summary was developed by EPA's Industrial Environmental Research 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

On June 11, 1979, the U.S. EPA promulgated new source performance standards (NSPS) for new utility steam generators for which construction commenced after September 18, 1978. To demonstrate compliance, EPA also promulgated a reference method (Method 19) that supplies a protocol for determining the control device, sulfur input rate by either fuel sampling and analysis or continuous monitors, and the final sulfur emissions to the atmosphere by continuous flue gas analysis. In addition, the sulfur removal efficiency for the control device is calculated using these measurements. This method was used to collect data for developing the current set of performance standards.

EPA's Office of Air Quality Planning and Standards, assisted by the Technical Support Office of EPA's Industrial Environmental Research Laboratory at Research Triangle Park (IERL-RTP), initiated a program to demonstrate the feasibility of the requirements for monitoring and control of SO_2 emissions. This program focused on sources subject to the NSPS specified in 40 CFR 60, Subpart Da.

GCA/Technology Division was contracted to conduct the portion of the program associated with measuring gaseous emissions. The primary objective of the program was to demonstrate the feasibility of the monitoring requirements specified in Subpart Da. Of secondary importance was the development of background and support data for quality assurance regulations. The study involved a planning and procurement stage, a 1-year field demonstration phase, and final evaluation of the data. Approximately 12 months of data were collected during the field portion of the program.

General Program Approach

The approach simulated activities involved in preparing for and complying with the Subpart Da requirements. To fulfill these requirements: the utility must prepare a monitoring system specification; procure, install, and certify the system; and (finally) operate the system. Subsequently, the data are reported according to the Subpart Da specifications. In this program, a number of prospective utility sites were surveyed as possible test locations. Since no sources subject to Subpart Da were operational, newer operational facilities subject to Subpart D specifications were considered. The test site selection criteria were:

- Coal-fired steam generator, 100 MWE minimum, less than 10 years old.
- Coal sulfur content, 2-5 percent; and medium to high ash content.
- Flue gas desulfurization (FGD) system designed for a minimum of 80 percent SO_2 removal on 100 percent of the flue gas.
- FGD system which employs multiple scrubber modules which are parallel.

Installation of the monitoring system was followed by a start-up and trouble-shooting phase, during which the system was operated and debugged. Shortly thereafter, the system was certified according to proposed Appendix B "Performance Specifications Tests 2 and 3," specified in the October 10, 1979, *Federal Register*. After certification, the 1-year field demonstration involved:

- Routine operation according to Method 19 and Proposed Quality Assurance Requirements.
- Reporting consistent with Subpart Da.
- Data Collection and Quality Assurance activities for assessing monitoring economics and system performance.

Routine activities were conducted daily by an onsite technician. Additional data were collected during quarterly quality assurance and stratification tests.

After the test phase, all data were evaluated, including an assessment of continuous emission monitor (CEM) availability and data capture, the costs of procurement and operation, and monitoring system performance. System performance is discussed in reference to 40 CFR 60, Appendix B, and proposed quality assurance protocols.

Test Facility Description

The Conesville Generating Station's Unit 6 was selected as the site for the CEM demonstration program. In Unit 6, the flue gas exiting the boiler passes through two, parallel, air preheaters and into two, parallel, electrostatic precipitator modules. The gas from the precipitators passes into two, double-inlet/single-outlet, ID fans, which move the gas through the two scrubber modules. The modules are spray types designed to operate with free floating balls; however, the balls were removed to reduce module pressure drop and increase flow capacity. Each module can handle 50 percent of the flue gas at full load conditions. Gas exiting the scrubber modules and the bypass duct are combined into a single common duct before entering the 244 m (800 ft) tall stack.

At full generating capacity, total flue gas flow rate through the system is about 1.3×10^6 acfm (36.8×10^3 m^3/min) at 300°F (149°C). About 30 percent of the total flue gas flow is bypassed for reheat purposes around the scrubber modules during full load conditions.

During the initial period of the Field Demonstration Phase, Unit 6 was operated year-round as a baseload unit. Unit 6 normally operated at full-load capacity during daytime peak power demand periods; at night, the unit operated at half-load with only one scrubber module in service. During the later stages of the demonstration period, Unit 6 operated intermittently as a baseload unit and was frequently taken offline for varying lengths of time as a result of the low power demands during spring and early summer of 1982. The unit was never operated in a swing load configuration.

Continuous Emission Monitoring System (CEMS) Description

The overall design objectives for the CEMS were to meet Subpart Da monitoring and reporting requirements while minimizing manpower requirements. To meet these requirements, the following CEM capabilities were required:

- Dual inlet FGD emissions monitoring for SO_2.
- Outlet FGD emissions monitoring for SO_2 and NO_x.
- Daily emissions and removal efficiency average calculations.
- 30-Day rolling averaged emissions and removal efficiency calculations.

These requirements were met with a system approach entailing automatic CEMS operation.

Monitoring points were at each scrubber module inlet and at the combined outlet breaching prior to entering the stack. At the inlet to each scrubber module, a single sample probe was downstream of the ID fans and just upstream of a guillotine bypass damper door. A single outlet sampling point was in the common breaching, downstream from both the scrubber module and bypass duct outlets.

The multilocation extractive system was specified by GCA and designed and constructed by KVB, Inc., of Irvine, CA. The system consisted of two sets of gas sensors and the conditioning hardware and data acquisition equipment listed in Table 1. One set of instruments measured inlet SO_2 and O_2 on a time-shared cycling basis, and a second set measured outlet concentrations of SO_2, O_2, and NO_x. Samples were conditioned by filtering particles using an in-stack filter and a high-surface area, glass fiber filter, both at the extraction point. A dual-pass condensation unit in the instrumentation shelter removed moisture. The KVB system operated automatically, including multipoint calibration, zero/span checks, automatic data acquisition, and onsite data reporting.

Routine Operation

During the field demonstration period, a CEMS operator was onsite most of the time Unit 6 was online. The operator performed dialy diagnostic checks, maintenance, and logistical support services for the CEMS. In keeping with the approach of minimal operator attention, the CEMS operator left the site and checked the CEMS status remotely using the modem link during Unit 6 outages. The modem link was also used when an operator was not onsite when Unit 6 was operating.

Daily, weekly, and monthly operator routines involved CEMS diagnostic checks, checking analyzer calibrations, generating daily reports, performing

Table 1. Major KVB System Components

INLET MEASUREMENTS
● *SO_2 — DuPont Model 400; 0-5000 ppm*
O_2 — Thermox WDG III, 0-25 percent
OUTLET MEASUREMENTS
● *SO_2 — DuPont Model 400; 0-1000 ppm (Normal Range 1000-5000 ppm (Auto range)*
NO_x — Thermo Electron Model 10A; 0-1000 ppm
O_2 — Thermox WDG III; 0-25 percent
COMPUTER SYSTEM
● *Cromemco System Three*
● *Dual 8 in. floppy disc drive*
● *CRT Terminal*
● *Report Format Printer*
EXTRACTION SYSTEM
● *Particulate Removal—Filtration*
● *Moisture Removal—Dual Pass Condensation*

routine and nonroutine maintenance, computer operations, and general administrative duties, including project documentation and logistical support.

The CEMS diagnostic checks were performed twice daily, including visual checks of various CEMS operating parameters such as sample flow rates, vacuum and pressure levels, and temperatures, to ensure that all were within specified operating limits.

Calibration checks were controlled automatically by the computer at midnight, and the results were evaluated by the operator each morning. If calibration results indicated excessive drift, the operator terminated CEMS operations and manually recalibrated the affected analyzer.

The CEMS operator reviewed the process and emissions data, and noted any process upsets (e.g., scrubber malfunctions) and any emissions data invalidations (e.g., periods when an analyzer was offline for repair or an analyzer was malfunctioning). The time and nature of process upsets or data invalidations were recorded in the CEMS uptime log.

Discussion of Results

The KVB system was operated and performance tested over a period of 16 months in which Unit 6 was operational for approximately 12 months. During this period, various external quality assurance tests were conducted in addition to the routine monitoring activities. In total, program activities provided the necessary data for assessing system performance, system availability, and monitoring economics. The following subsections summarize each area.

Assessment of Monitoring System Performance

The continuous monitoring system was operated and maintained according to 40 CFR 60, proposed Appendix B. In addition, other tests were conducted to further evaluate system performance, including initial and final performance specifications tests, stratification testing, relative accuracy audits, and calculation of precision estimates.

Stratification Tests

Before initiating the Operational Test Period and the routine monitoring phase, stratification tests were conducted at the monitoring locations, to ensure that the probes were placed to provide representative flue gas samples. The procedure consisted of measuring the SO_2 and O_2 concentrations at each designated traverse point. Between each pair of ports (three traverse points per port), the monitoring system was switched from the traverse point to a reference point. Data from the reference point were used to correct for temporal process variations during the test. Temporally corrected traverse data were used to define the spatial variability of the flue gas stream.

One stratification test was conducted at one of the two inlets. Additional tests were not conducted because the probability of stratification is low at scrubber inlets.

During the program, eight stratification tests were conducted at the outlet: four at full load with both modules online, and the remaining four with the boiler operating at half load and one module online. Two such tests were conducted for each module.

Performance Specifications Tests

Monitoring system performance was assessed using the Performance Specifications Tests outlined in the October 10, 1979, *Federal Register*. These tests provide a basis for determining adherence to minimum compliance monitoring system performance levels. Tests were conducted to quantify both short- and long-term drift, calibration error (precision), response time, and system accuracy relative to the reference methods.

These tests were conducted during the latter part of May and the first week of June 1981. An abbreviated version of these tests was conducted during the last month of the program (August 1982). During this last test session, the relative accuracy and calibration error tests were repeated.

The entire monitor system conformed to all performance criteria, except that the outlet SO_2 monitor exceeded the 24-hour drift and mid-scale calibration error criteria. As a result of the drift exceedance, the monitor was equipped with an automatic zero function which rezeroed the analyzer every 15 minutes. The mid-scale calibration error result exceeded the specification during the first tests, but was within limits during the final tests.

The relative accuracy tests conducted at the beginning and the conclusion of the demonstration phase indicate performance consistent with regulatory requirements. During the initial tests, the inlet and outlet SO_2 system relative accuracies (emission rate) were 6.5 and 15.6 percent, respectively. Results for the concluding test were comparable with inlet and outlet relative accuracies of 9.8 and 4.8 percent, respectively. Emission rate relative accuracies for the NO_x monitoring system were not appreciably different when comparing the two tests. Initially, the relative accuracy was 15.2 percent; the concluding result was 14.8 percent.

Accuracy and Precision

As an extension of current monitoring methodologies, EPA's Quality Assurance Division is formulating and evaluating quality assurance measures applicable to power plant monitoring. These procedures include protocols for demonstrating the accuracy of data relative to a reference method, as well as a simple daily routine to determine the necessary data for assessing the precision of the measurement equipment on a monthly basis.

To demonstrate the utility of these methods, GCA conducted the accuracy and precision estimating methods. Various draft versions of Appendix F were prepared during the 1980-1982 time frame. The precision and accuracy checks were conducted according to the November 19, 1981, version.

Accuracy

Proposed Appendix F provides two options for assessing system accuracy: one involves standard gases in which the standard gas is analyzed and processed as a flue gas sample; and the other involves side-by-side comparisons of CEMS outputs using applicable reference methods. For this program, the reference method was chosen.

Results of the relative accuracy audits are shown in Table 2, which includes results of the initial and final relative accuracy tests. Each relative accuracy audit consisted of at least six valid test replicates; whereas, the initial and final relative accuracy tests consisted of nine replicates.

The inlet and outlet SO_2/O_2 monitoring system exhibited relative accuracies in the range of 4.8 to 16.9 percent on an emission rate basis. When reviewing these results, note that the monitoring system and reference methods each contributed an imprecision and bias component to the relative accuracy result.

NO_x results were in the range of 9.7 to 23.2 percent on an emission rate basis. During the July 1982 audit, the relative accuracy exceeded the allowable 20.0 percent criterion. This result indicates a comparable bias to other test periods; however, the confidence interval (precision component) was much larger than before.

Table 2. *Summary of Relative Accuracy Audits*

	Inlet[a]			Outlet[a]			Outlet[a]	
Date	SO_2	O_2	System	SO_2	O_2	System	NO_x	System
June 1981	4.3	0.46	6.5	10.9	0.28	15.6	12.8	15.2
July 1981	11.6	0.55	15.0	16.0	0.40	16.9	6.7	9.7
June 1982	6.5	0.68	7.8	13.3	0.19	12.8	17.2	17.7
July 1982	7.4	1.53	9.4	12.9	0.24	14.2	23.7[b]	23.2[b]
August 1982	9.8	0.53	9.8	3.9	0.43	4.8	12.7	14.8

[a] SO_2, NO_x, and system are in terms of % relative accuracy; O_2 is in terms of % O_2 concentration.
[b] Exceeded the allowable criterion of ≤20%.

Precision

Data from the daily calibration checks were used to estimate the upper and lower probability limits for each analyzer. These estimates were determined using the protocol in the proposed Draft Appendix F Quality Assurance procedures, dated November 19, 1981.

Daily, the zero and high span gases were input through the entire system (including all extraction equipment) and analyzed as a sample gas. The resulting voltages were substituted in the appropriate calibration equation to determine the corresponding concentration in units of ppm SO_2, ppm NO_x, or percent O_2. Using these data as inputs, the upper and lower probability estimates for the zero and high span levels were calculated by determining the relative percent differences between the measured span (zero) gas concentration and the accepted concentration.

CEMS Availability

For this discussion, two definitions of availability are presented. Total availabilities refer to a simple proportion of CEMS uptime to boiler uptime on an hourly basis. This proportion is also modified to conform to Subpart Da requirements, which involve definitions of valid periods of data that are required for reporting purposes. A valid data hour must consist of at least two quarters of data; and a valid daily average must contain at least 18 hours of data for a 24-hour, midnight to midnight, boiler operating day. A valid 30-day rolling average must contain at least 22 valid days of data.

Figure 1 shows valid monitoring data availability based on the number of boiler operating hours in each calendar month. The primary Subpart Da reporting parameters are outlet SO_2 and NO_x emission rates (ng/J) and the control unit SO_2 removal efficiency. Emission rates are calculated using the data generated by the pollutant and diluent monitor combination. Similarly, the SO_2 removal efficiency is calculated using concurrent data generated by the inlet SO_2/O_2 and outlet SO_2/O_2 monitor pairs.

The hourly availability rates shown in Figure 1 range from 38 to 90 percent for the outlet SO_2 emission rate, 18 to 90 percent for the NO_x emission rate, and 35 to 88 percent for removal efficiency. Overall, the outlet SO_2 emission rate availability averaged 78 percent; the NO_x emission rate, 65 percent; and removal efficiency, 75 percent.

Table 3 summarizes the overall availability, indicates the adherence to the Subpart Da data capture requirement on a daily basis, and shows the data availability for reporting the 30-day rolling averaged data. In total, there were 277 "boiler operating days (as defined in Subpart Da)" during the demonstration phase. For these boiler operating days, the daily data capture rate for outlet SO_2 emission rate was met 72 percent of the time; the removal efficiency availability requirement was slightly less (69 percent). The daily NO_x reporting requirement was met 59 percent of the time. About half of

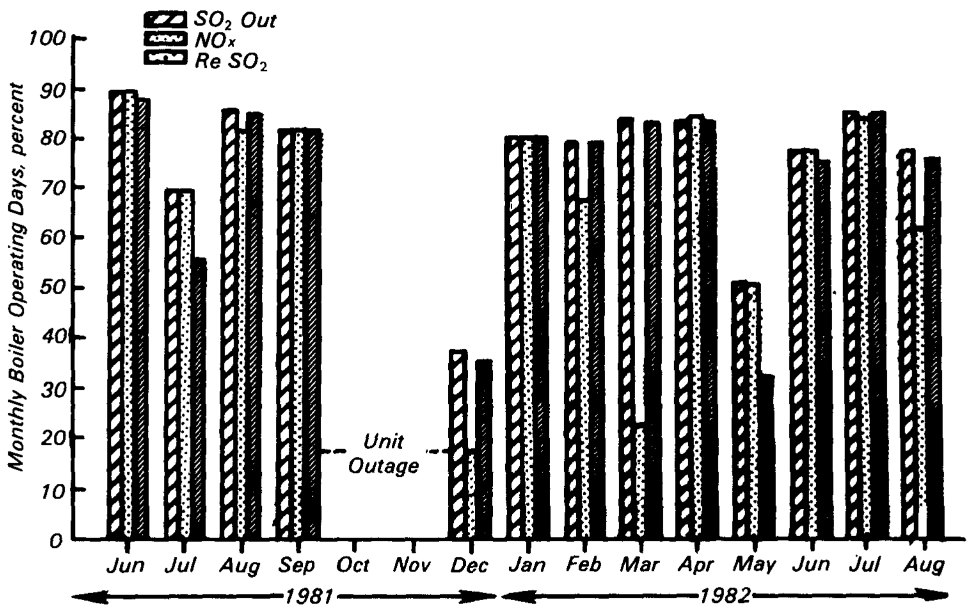

Figure 1. *Monitoring data availability by calendar month for outlet SO_2 and NO_x emission rates and SO_2 removal efficiency (percentage of CEMS uptime relative to total boiler uptime).*

Table 3. Availability Summary for Required Subpart Da Reporting Requirements

Parameter units	*Outlet SO_2 Emissions*	*Outlet NO_x Emissions*	*SO_2 Removal Efficiency*
Total availability			
% total Unit 6 uptime	*78*	*65*	*75*
24 hour availability[a]	*72*	*59*	*69*
% valid 18-24 hour days			
Subpart Da availability			
% of valid 30-day rolling averages	*67*	*62*	*59*

[a]Based on 277 total boiler operating days.

the NO_x data unavailability was due to NO_x vacuum pump failure.

Subpart Da 30-day rolling average availabilities were 67 and 59 percent for the SO_2 outlet emissions and removal efficiency, respectively. The availability for the NO_x reporting requirement was 62 percent. For rolling averages that do not fulfill the minimum data capture requirements, the upper and lower confidence intervals for each parameter are calculated. The upper limit is used for reporting outlet emission rates, and the ratio of the upper outlet emission limit and the lower inlet interval limit are used to report the efficiency parameter.

Assessment of Economic Requirements

The economic impact of continuous monitoring regulations is also an area of concern. The cost data presented are based solely on actual costs associated with the Conesville program. The applicability of these costs to other utilities installations provides a basis for projections. Proper use of the experience gained in this program should significantly reduce certain costs; however, site-specific variables must be considered if meaningful projections are to be obtained.

The utility operator experiences two cost categories in fulfilling the Subpart Da reporting requirements. Initially, major capital expenditures are made in purchasing, installing, and certifying a monitoring system. Subsequently, ongoing costs result from routine operation and data reporting.

The total $269,030 "premonitoring" costs for the Conesville CEMS include: (1) the system purchase price, $181,000; (2) the cost to build a temperature controlled monitor room and to route electrical wiring and sample line, $31,030; (3) final installation, start-up, and checkout, nearly $36,000; and (4) the certification tests, $21,000.

Operating costs at Conesville are shown in Table 4. The 1,438 labor hours include 915 (68 hr/mo) for daily operations, 327 (24 hr/mo) for nonroutine maintenance, and 196 (16 hr/mo) for preventive maintenance. Nonroutine material costs were $2,769, routine expendable material costs were $2,869, and calibration gas costs were $8,607. (Note that the nonroutine material costs are biased low because many of the replacement parts were supplied under warranty, free of charge.)

A comparison of the CEMS operating costs with the total quality assurance activities is given in the full report. The quality assurance costs were $90,000 and covered an initial and final performance specifications test series, three abbreviated relative accuracy audits, four stratification test series, and the calculation of monthly precision estimates. The utility operator is required to conduct the initial performance specifications test series and a location representativeness (stratification) test. Future regulations may include the reporting of precision estimates and the conduct of a periodic relative accuracy audit and/or a cylinder gas audit.

Conclusions

While program results do not fully answer all questions concerning continuous monitoring, several conclusions and/or judgements can be made. Statements concerning this program should be prefaced by several qualifiers. First and foremost is that the experience and results may be specific to the Conesville monitoring situation. Second, several economic constraints precluded implementation of system modifications which would have most likely improved system uptime.

Design and Software Deficiencies

Several design deficiencies noted with the CEMS severely hampered availability and the subsequent fulfillment of monitoring requirements. The primary problems were not hardware related, but more "action and reaction" related; specifically, system reactions to alarm conditions. KVB configured this system to be totally automated: all operation and control functions are "slaved" to the computer. As a result, normal data acquisition ceased whenever computer operations terminated. Provisions should be made for the system to be operated manually during computer outage.

Other problems were related to the conditioning and switching system. Responsible for most of the hardware-related downtime was the valve switching system, which primarily used solenoid valves which are prone to sticking. These could be replaced with multiport ball valves.

The NO_x converter and vacuum system were responsible for most of the NO_x downtime. When exposed to high-sulfur and -chloride laden gases, the stainless steel converters show a high corrosion rate. Bypassing the converter would eliminate this problem. The NO_x vacuum pump was failure prone for unknown reasons: it appears that the best approach for maintaining uptime is to keep a spare pump on hand.

The computer disc system was very failure prone. Repeated read/write errors resulted in significant data loss. Much of the problem can be attributed to dust.

Aside from the read/write problems, the durability of the floppy disc system for field applications is questioned. During the 16 month demonstration phase, the disc system was replaced once and underwent significant component replacement on another occasion. For future applications, a sealed Winchester or electronic disc storage device is recommended.

Availability

Overall availability for future systems of this sort can be improved significantly by implementing several generic design changes. Based on the results of this study, future systems should be configured in two basic subsystems: the conditioning/monitoring subsystem and the data storage/reduction system. In addition, these two systems should be separable; i.e., if the data system is removed, the monitoring subsystem should continue to collect and store data on a secondary system such as a secondary buffer or strip chart recorder. Data availability should be significantly higher since the monitoring process is not terminated upon the termination of computer control.

Other considerations should be given to the servicing of alarm conditions. Often, the computer system terminates system operation for what may be a very minor problem. The power plant environ-

Table 4. *CEMS Operation Manhour Requirement Summary*

	CEMS Maintenance Summary									
	Conditioning System		*Analyzers*		*Computer*		*Total*			
	NR[a]	*R*[b]	*NR*	*R*	*NR*	*R*	*NR*	*R*	*Daily Operations*	*Total Manhour Requirements*
Total Hours	242	62	60	118	25	16	327	196	915	1438
% Total	17%	4%	4%	8%	2%	1%	23%	14%	63%	—
Weekly Average Hours	4.5	1	1	2.2	0.5	0.3	6	4	17	27

[a]*NR = Nonroutine Maintenance.*
[b]*R = Routine Maintenance.*

ment is well geared to the use of enunciator panels to report alarm conditions. After acknowledging these types of alarms, the appropriate action is taken by operators or technicians.

Automatic routines such as calibrations should be scheduled during time periods when more personnel are on duty. Considerable downtime was encountered during the Conesville program when an automatic function occurred at midnight, activating an alarm. The alarm would not be discovered until morning because personnel were unavailable to correct the problem.

Projected Utility Costs

The operational experience gained during the program can be used to determine projected costs to the utility industry. Yearly operations comprise the largest cost element associated with the monitoring. An estimated 900 manhours per year will be expended to operate the system, verify the data being stored, and acquire the proper process and monitor documentation for preparing the quarterly Subpart Da and Appendix F reports.

Quarterly relative accuracy audits constitute the next major labor requirement. Approximately 140 manhours per audit will be expended if conducted by inhouse personnel. An outside contractor would charge approximately $10,000 per audit including travel.

Routine maintenance labor constitutes about 8 percent of the yearly level of effort, or 210 manhours. This level may be elevated slightly as the maintenance schedules are refined. The nonroutine maintenance level should be reduced with a slight increase in preventive maintenance.

Nonroutine maintenance has been estimated at slightly over 310 manhours per year. This is higher than expected, but should decrease with time as the preventive maintenance program is refined.

Quarterly Subpart Da and Appendix F (Draft) reports are projected at a combined yearly total of 220 manhours, based on using an automated data reduction system.

Calibration gas cost is the single largest quarterly expendable material expense and most predictable utilizing automatic analyzer calibration systems in which the gas is injected at the probes. The estimated yearly cost (based on the Conesville system) is $13,940 using Protocol I certified span gases. Other types of systems which use gas diluters for blending the various span gas concentrations will require about 30 percent of the gases required for Conesville.

The spare parts inventory cost is a somewhat significant addition to the original purchase cost of a CEMS. Usage rate and quarterly replacement cost are difficult to predict. A good warranty maintenance agreement with the CEMS vendor can drastically reduce this cost for the first years of CEMS operation. An adequate spare parts inventory for the Conesville system would approach $11,600, or 6.4 percent of the system cost.

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The complete report, entitled "Long-Term Continuous Monitor Demonstration Program: Columbus and Southern Ohio Electric Company, Conesville Unit 6," (Order No. PB 84-178 649; Cost: $13.00, subject to change) will be available only from:
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