Power Engineering

Design Criteria Manual guides CEM project

Consultant team used surveys to develop a manual for state-of-the-art CEM systems at Alleghany Power System installations.

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In 1991, Allegheny Power System's (APS) operating companies contracted an engineering consultant to install new continuous emission monitoring (CEM) systems on all power plant stacks (see figure below). This planned action was to fulfill the APS goal of meeting present and future demand for electric power while protecting the environment.

Black & Veatch, the engineering consultant chosen, programmed the addition of 63 CEM systems to 25 units in Pennsylvania, West Virginia, and Maryland. Each system was designed to meet gas monitoring requirements of the 1990 Clean Air Act Amendments (CAAA).

In 1993, 36 CEM systems were installed and put into operation. Of these, 26 were certified in 1994. Three more CEM systems were installed and certified on units to be taken out of cold reserve in 1995. All installed systems reflect a plan that included evaluation and testing of CEM technologies

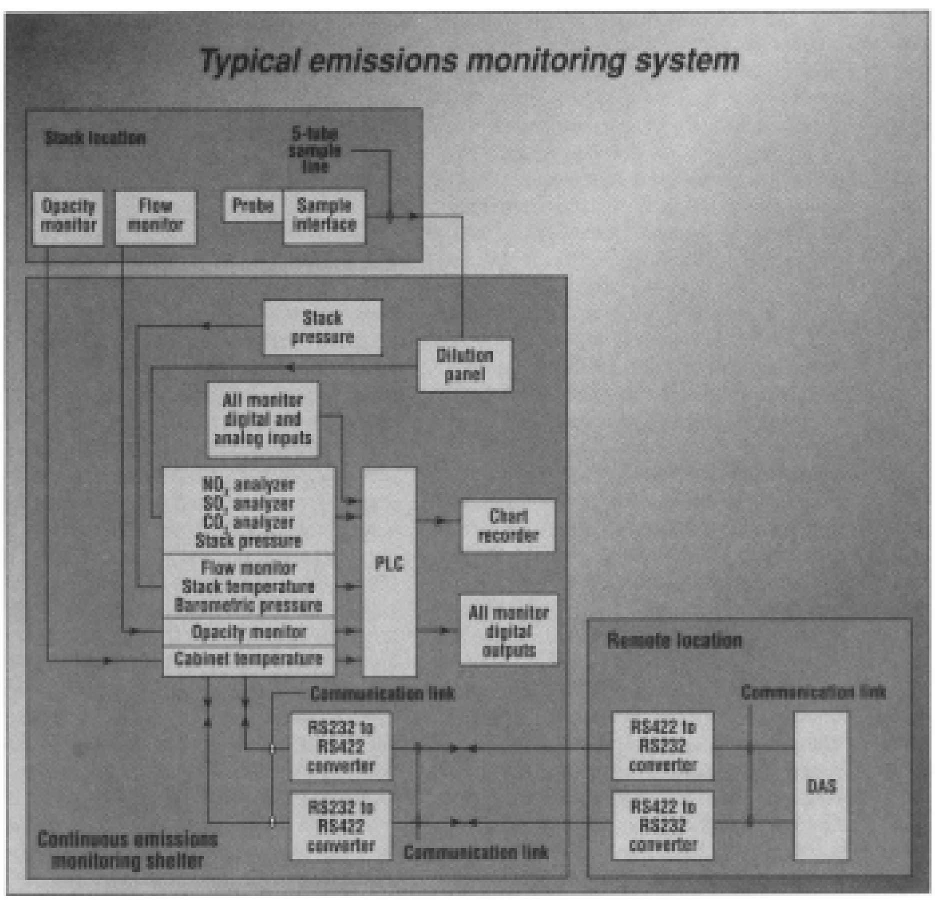
Engineering Evaluations

Little information was available on practical CEM technology and hardware application during the initial phases of this project. To evaluate qualified CEM vendors, Black & Veatch surveyed stack gas technologies in use or available to industry at that time. Questionnaires were sent to 15 CEM vendors. The responses helped to evaluate technology, equipment, installation and maintenance requirements, and their advantages and disadvantages.

A user survey also contacted 75 firms representing 184 installations. Of the 65 firms responding, 81 of the installations burned coal. A follow-up telephone survey confirmed or quantified common problems defined in the questionnaires. Respondents identified the following issues:

- environmentally controlled enclosures for the CEM analyzers should be provided;
- temperature and pressure correction for dilution extractive systems should be provided;
- all metallic surfaces exposed to undiluted flue gas should be Hastelloy C276 or Inconel 625;
- operator and maintenance training should be recommended;
- operation and availability of the data acquisition system (DAS) was a problem at many installations and should be addressed early in the project; and
- sample lines and probes on dilution extractive systems should be heated.

A conceptual design report (CDR) resulted from the surveys, as did discussions with vendors, onsite surveys at each station, and stack gas flow profile tests. The CDR's primary objective was to document the selection of CEM system types. This was



Black & Veatch engineers check out an Alleghany CEM system.

based on defining features to maximize system reliability and accuracy with a minimum of maintenance. The CDR also documented potential CEM system suppliers and listed recommended bidders. The results were compiled into a system design criteria manual incorporating survey results and served as the basis for system design and purchase specifications.

Emissions monitoring technology evaluation

There are two basic system types: *in situ* and extractive, as defined as follows:

Extractive system: One advantage of an in situ CEM system is that real time measurements are made on a wet basis without sample lines or gas conditioning systems. However, this system has disadvantages. For example, the limited path length allowed for gas concentration measurement can reduce accuracy and the sensitive monitoring equipment must be placed in a hostile environment on the stack. Further, available in situ equipment has had operational and service problems, and the user survey revealed poor performance. The stack location makes access and maintenance difficult. In addition, such access is a major consideration for achieving 95 percent equipment availability.

In situ CEM systems were not considered for use on CAAA affected units at APS.

Full extractive dry system: Extractive systems are available in three variations. The full extractive dry CEM system successfully met emission monitoring requirements stipulated by the New Source Performance Standards (NSPS) of the CAAA. This system has a disadvantage. Analysis is made on a dry, particulate-free basis, using complicated and sometimes unreliable gas conditioning equipment. CAAA requirements for SO_2 emission mass flow measurements dictate that moisture corrections be made to dry volumetric concentration measurements to remain consistent with wet basis gas flow measurements. Such corrections increase system complexity, potentially reducing accuracy and reliability. In addition, these systems have had problems monitoring uncontrolled SO_2 emissions at facilities burning high sulfur coal. For these reasons, plus monitoring problems, this system was not chosen for APS.

Full extractive wet systems: The primary advantage of this relatively new CEM technology is that the sample is analyzed on a wet basis and no conditioning is required. System disadvantages include a need for heated analyzers and sample lines to maintain sample temperatures well above the acid dew point. This technology is flexible, allowing monitoring of up to eight gases and easy range changes. It was considered capable of meeting CAAA monitoring requirements. However, surveys showed that full extractive wet systems had problems and minimal experience monitoring wet scrubbed units. One such system was tested on a scrubbed unit for two to three months with inconclusive results, but there were areas of concern. This system was excluded from further evaluation.

Dilution extractive systems: This relatively simple and accurate CEM technology enjoyed wide industry acceptance at the time of the survey. Disadvantages included the needed the need for reliable dilution air cleanup systems and pressure and temperature compensation. One advantage of a dilution extractive system is that is analyzes gas on a wet basis without heated analyzers and sample lines. In addition, the analyzers used for these systems are not designed solely for this service and have proven track records. These relatively uncomplicated systems require low maintenance to meet high equipment availability demands. Based on the wet basis measurements, high accuracy, range change flexibility and their relative simplicity, these systems became the preferred CEM monitoring method.

Stack flow monitor technology testing

Stack flow monitoring technology had not been demonstrated to any great extent at the start of the project. However, reliable stack gas flow measurements. As part of the initial evaluation plan, a test program was developed to demonstrate the performance of various flow monitors under actual unit operating conditions. The program also identified which of these monitors comply best with CAAA requirements. The predominant technologies available included ultrasonic, differential pressure and differential temperature. Application suitability constraints at numerous installations eliminated the differential temperature monitors from the demonstration test program.

Six monitors were tested at three selected sites for approximately four months. One site was a scrubbed unit. A small data acquisition system (DAS) compiled data at each site. The equipment and the technologies tested were ultrasonic, annular differential pressure and Pitot tube differential pressure.

Results from collected data were compared to stack flow testing during initial, baseline, and final demonstration testing periods. Tests indicated that the Pitot tube differential pressure flow monitor and the ultrasonic flow monitors compiles with requirements of 40 CFR Part 75 of the CAAA.

The Pitot tube flow monitor offered advantages in equipment cost, installation, startup, accuracy and reliability. The stack gas flow profile tests performed on all stacks indicated that the gas flow profile was generally uniform, an advantage to a single-point flow measurement offered by Pitot tube monitors.

To minimize the effects of multiple units discharging into a single stack and flow pattern shifts caused by load changes, two Pitot tubes were installed in an averaging arrangement on each stack. Ultrasonic flow monitors were installed as a noncertified backup to minimize the flow measuring risk on stacks identified with possible flow measuring difficulties. This was a valid approach because two stacks had large flow profile shifts during load changes, which required ultrasonic backup flow monitors.

Data acquisition system description

DAS hardware and software were areas of particular concern. According to the survey, they caused major project delays in other CEM projects that were directly attributed to lack of vendor experience or personnel. APS elected to perform this work internally to maintain tighter control and to develop a custom-tailored system.

APS specified that all Phase I and II software regardless of site should be as similar as possible, even though not all sites had all equipment options. A unique ID number was assigned to each CEM programmable logic controller (PLC), which became a part of the PLC code. Upon reading the applicable code, any software program can incorporate the equipment involved and function accordingly.

Spare PLC and DAS equipment was purchased and stimulators were constructed to simulate CEM equipment operation. This equipment was used to develop and debug the PLC and DAS software before installation and reduce field software problems.

The DAS consists of redundant computers with shared hard disks. Each computer uses a real-time, multitasking Unix-based system with several terminals. The DAS compiles instantaneous readings from the PLC and generates CAAA monthly reports. Missing data substitution requirements also are performed. The DAS at each of the 11 stations is capable of transmitting all data via phone modem to the system generation dispatch computer for generation of system-wide emissions reports.

PLC system description

To achieve near 100 percent data availability, two independent CEM systems are installed on each stack and communicate with redundant DAS systems. One system is designated as the primary system and the other as backup. Both systems are continuously in service, certified and pass daily calibrations. If the primary system fails, the backup system supplies required data. This design minimizes downtime for system maintenance, maintenance upgrades or system failure.

CEM operation and control is managed through a PLC that controls overall operation, daily calibrations and system purge. It also performs local compensation and correction of raw data. All data are sent through RS232 links to a local multipoint recorder and through modems to the DAS.

Segregating the DAS and the PLC systems allowed definition and assignment of functions between the PLC (which generally controls operation of the CEM) and the DAS (which is responsible for system reports). This allowed separate system development, fabrication and checkout. Minimal problems were experienced using this approach.

Vendor Supply

Phase I and II CEM equipment was purchased under separate bid specifications.

A different CEM equipment vendor was selected for each phase. The CEM bid specifications prevented major hardware differences and limited software program changes between vendors.

To minimize installation, field startup and check-out requirements, all off-stack CEM equipment was consolidated within one enclosure. This included all the PLC's (but not the DAS) and ancillary equipment, such as flow monitors, opacity analyzers, air compressors and high-voltage alternating current (HVAC) equipment. All off-stack systems were fabricated and tested at the vendor's factory.

Due to the tight project schedule for Phase I and II, Black & Veatch maintained an engineering liaison in each vendor's facility. The liaison served as a quality control engineer to minimize construction problems and errors and to ensure conformance to the production schedule. Because the liaison witnessed all factory startup and testing, almost no field repairs or corrections were needed for vendor-fabricated systems. A liquidated damages clause was included in the vendors' equipment and services contract in view of the tight project schedule. This provision is assessed for delays in equipment or startup in the field, or both, so that APS can recover damages for construction or certification delays.

Construction and startup

Construction was divided into four parts: stack elevators, stack platforms, CEM systems and DAS installation. The work was performed concurrently at 10 stations for Phase I and at two stations for Phase II. Installation specifications were developed and competitive bidding was conducted for each construction package at each station.

Black & Veatch coordinated the startup and certification effort at all stations for both phases, and maintained overall responsibility and acted as liaison among CEM vendors, APS Engineering and startup, construction and station personnel. CEM vendors for Phase I and II were contracted for initial startup, alignment and calibration of all equipment except the DAS.

Certification was completed using an independent contractor selected by APS.

Problems encountered/resolved

Problems encountered and resolved during startup and initial operation include:

- atmospheric barometric pressure changes caused daily calibration failures. These were corrected by adding barometric pressure compensation;
- large changes in stack temperature caused changes in measured gas analysis. This was corrected by adding temperature compensation;
- sensing probe corrosion and plugging was reduced by increasing probe temperature;
- CO_2 monitors required greater purge air flow than originally supplied. Installation of larger capillary tubing corrected the problem;
- close temperature control of the CEM shelters, required because the analyzers were sensitive to major temperature changes, was supplied by redundant HVAC systems;
- poorly-designed sample probe flange seals caused gas sample dilution through air inleakage. The vendor corrected this design problem; and
- stack shell and stack liner structural integrity was a concern due to the large number of penetrations. In many instances, reinforcement for the steel liner was required in the area of the CEM penetrations. The integrity of one concrete stack shell was found to be unacceptable and was reinforced.

Communications, overall coordination and project management were crucial activities from the start of the project. The number of stations involved, the physical distance between the stations, different state regulations and widely varied design and construction requirements demanded excellent communication to achieve project success. To support good communication, a project coordinator was designated for both APS and the contract engineer, and the latter organization kept all parties informed of day-to-day project activities. This task included developing and maintaining communications with regulatory agencies, APS departments and station personnel, and the construction coordinators at each station. Bi-weekly project status meetings were conducted, all telephone calls were documented and distributed, and station activity punch lists and schedules were maintained on a weekly basis. Weekly and monthly progress reports were issued detailing the project status, outstanding issues and all project activities to be completed in the near term. Strong communication lines were developed with all decision-making parties being updated continually on the daily progress of the project.

Conclusions

All Phase I and II CEM systems have been certified and meet all local, state, and federal regulations. This highly successful project enhances Allegheny Power System's position to meet the concerns and standards of today's environmental issues. The systems have proved to be reliable and accurate with only routine maintenance required.

This comprehensive CEM project's success resulted from implementing a definitive conceptual design, maintaining a constant presence, and implementing a paintstaking factory test of all systems in the vendor's facility. The combination of cooperation, communication, and teamwork between Allegheny Power System and Black & Veatch led to the successful accomplishment of a demanding project that was completed within budget and on schedule. **END**

AUTHORS

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COMMENTARY ON THE ATTACHED ARTICLE IN POWER ENGINEERING MAGAZINE

The CEM Gas Flow Monitor Evaluations in the attached article included comparative performance testing for the following systems:

- Dietrich Standard - Annubar
- Air Monitors
- EMRC
- USI
- Panametrics

As noted in the article three different gas streams (stacks) were utilizeed for the evaluation. Parameters to be considered were:

1. Relative Accuracy
2. Calibration Accuracy and Precision
3. Installation Costs
4. Maintenance Costs
5. Operation Costs
6. Reliability

Black and Veatch recommended the EMRC Gas Flow Monitor to Allegheny Power Systems, and Allegheny Power Systems established, as noted in the article, the EMRC Gas Flow Monitor as thir primary gas flow monitoring system. Other comparative testing of gas flow monitors were conducted at Virginia Power and Basin Electric. They also bought EMRC. In fact every tinme a comparative series has been conducted with EMRC as a participant, the EMRC System has taken the order.

SELECTED PARTIAL INSTALLATION LIST

CUSTOMER	PROCESS
Allegheny Power Systems	PP
Arizona Public Service	PP
ASARCO / Helena, MT & Hayden AZ	P
Basin Electric / Wyoming, ND	PP
Northern States Power	PP
Big Cajun	PP
Board of Public Utilities	PP
California Portland Cement	P
Central Hudson, New York	PP
Chateaugay, New York	PP
Coastal Refinery	R
Commonwealth Electric Massachusetts	PP
Dairyland Power	PP
Dakota Gasification	R
Dayton Power & Light	PP
Detroit, Michigan	PP
Edwardsport, Indiana	PP
Elk Hills / Tupman, California	GT
Grand Island, Nebraska	PP
Grand River Dam Authority	PP
Hoosier Electric	PP
Illinois Power	PP
Intermountain Power	PP
Louisville Gas & Electric	PP
Madison Gas & Electric	PP
Nebraska Public Power District	PP
Nipsco	PP
Omaha, Nebraska	PP
Orlando Utilities	PP
San Juan / Farmington	PP
SMEPA	PP
UCLA	GT
Unocal / Carson, California	R
Virginia Power	PP
Wyandotte, Michigan	PP
Yuma Cogeneration	GT
Koch Hyrdrocarbon	R

Legend:

PP - Power Plant
P - Chemical Process sources
R - Refinery
GT - Gas Turbines