

Process Emissions Monitoring and Control

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Some manufacturing, research, and development conducted within AT&T involves processes that emit air contaminants. These emissions are confined, scrubbed to recover the constituents, and vented outside through stacks. Continuous emission monitoring (CEM) systems analyze the emissions in near-real time and provide feedback to control them. The information collected from CEM systems in some industries is used to prove compliance with applicable environmental regulations. This paper describes CEM technology and an Environmental Monitoring and Reporting System (EMARS) for near-real-time emissions monitoring. It also presents selected applications in AT&T Bell Laboratories and AT&T manufacturing facilities at Montgomery and Richmond.

Introduction

A rapidly increasing awareness of the sometimes damaging effect of industrial operations on the environment has generated an urgent need for more accurate, timely information about the waste these operations create. This waste often takes the form of air emissions generated by industrial processes within factories. It is usually treated by pollution abatement equipment before it is discharged into the atmosphere.

There is a growing need to monitor and quantify these emissions continuously, both in the workplace and where they are discharged into the atmosphere. This assures both safety in the workplace and compliance with dramatically increased federal and state regulatory requirements.

CEM systems use a variety of analytical techniques to obtain automatic quantitative estimates of the emission rates of selected chemical substances in near-real time. Other commonly used methods may limit the analysis to one chemical, take potentially nonrepresentative "snap-shot" readings, and/or require the skill and time of a trained operator.

This paper presents an overview of CEM technology and describes the current regulatory environment and monitoring instruments used for AT&T industrial

processes. It also examines several CEM systems being used in AT&T.

Continuous Emission Monitoring

A complete monitoring system encompasses many individual processes, such as sampling, analysis, calibration, data acquisition, data reduction, and reporting. To analyze ambient air (i.e., "fugitive" emissions from a process) or monitor stationary sources (i.e., the effluents from stacks that emit exhaust to the atmosphere), the first step is to collect representative samples. In samples of gases, as well as liquids, a uniform, homogeneous condition usually exists. Sampling or monitoring may be performed periodically or continuously.

Typically, periodic sampling is a manual operation in which an industrial hygienist selects a time and collects the sample. These samples, which are most useful for generating health data, are collected in specially prepared containers or on adsorbent or absorbent media (activated charcoal, polymeric materials). Each sample is then put into the collection medium by a hand- or battery-operated pump or by immersing the container in the material.

Instantaneous, or "grab," samples are brief periodic samples obtained in a period of less than five minutes (and usually less than one minute). Average, or "integrated," sam-

Panel 1. Abbreviations, Acronyms, and Terms

APCD	air pollution control device
CEM	continuous emission monitoring
cfm	cubic feet/minute
CVD	chemical vapor deposition
EMARS	Environmental Monitoring and Reporting System
EPA	United States Environmental Protection Agency
ERC	Engineering Research Center
ICAMS	Industrial Central Atmosphere Monitoring System

ples are taken over a longer period of time, usually for an eight-hour period. Grab sampling is most suitable for monitoring the different phases of a cyclical process or for determining peak concentration levels. Such sampling implies prior knowledge of the character of the process to ensure that samples are taken at appropriate times.

The term CEM implies the acquisition of emissions data with an uninterrupted measurement of the concentration of the constituent being analyzed. There are three elements that limit the sample acquisition interval: the type of detection technique, the transport of the sample to the detector, and the analysis.

The time requirements of a process guide the choice of an appropriate sampling procedure. For example, if a particular process only operates for twenty minutes each hour, it may not be cost-effective to monitor it continuously with a dedicated detector. It would be logical to monitor a process while it is in use, and perhaps for some small fraction of the time it is not in use, to obtain an idling emission level. Even when the process is active, it may not be cost-effective to take a measurement every microsecond if the process is stable over a one-minute period. Alternatively, if a battlefield exposed to nerve gas were being monitored, a sampling time of one microsecond would seem too long.

Analytical techniques that are sensitive but not particularly selective, such as flame ionization or photoionization, are useful when data must be acquired continuously and no mixtures are involved. Techniques that require more time, but can distinguish the various components emitted by a process, are more expensive and technically complex (mass spectroscopy, infrared spectroscopy). Classical analytical methods, such as gas

chromatography, are being miniaturized at a rate that should allow them to monitor processes at a sampling rate of one minute or less.

Regulatory and Monitoring Requirements

The use of continuous monitoring techniques to measure pollutants emitted from stationary sources was initially mandated by the United States Environmental Protection Agency (EPA) when nationwide ambient air quality standards were established for six criteria pollutants: carbon monoxide, nitrogen oxides, lead, sulfur dioxide, ozone, and particulate matter. To ensure optimum operating performance of affected facilities (those that emitted these pollutants), the EPA promulgated regulations that required the installation and use of CEM systems.

Originally, the EPA did not intend to use CEM data as an enforcement tool, taking the position that CEMs were to be used solely to assist affected facilities to maintain proper operation of their processes and air pollution control apparatus. Recently, however, the EPA declared its intention to use CEM data to determine if facilities are complying with allowable emission standards.

With the recent approval of the Clean Air Act Amendments of 1990, affected facilities must verify that they have reduced hazardous air pollutant emissions to a permissible level, as well as confirmed continuous compliance with permit operating conditions. In addition, facilities that produce, process, handle, or store extremely hazardous chemicals are required to install systems that can quantify emissions resulting during an accidental release episode. These monitoring requirements must be satisfied using CEM systems that comply with EPA performance specifications.

Analytical Techniques. Selecting a CEM system for a particular application depends on the:

- Materials to be monitored
- Sensitivity required
- Specificity to a particular material
- Interfering compounds
- Number of monitoring locations
- Environment in which equipment will operate
- System to be used for quantitative and/or qualitative monitoring
- Level of maintenance and expendables
- Value added given the system cost.

The list of analytical methods that can be used for CEM of air emissions is extensive. Selecting the right CEM system is a critical step requiring careful consideration.

Environmental Monitoring and Reporting System

In response to regulatory requirements, AT&T is actively measuring air emissions from a variety of manufacturing processes. A project at the Engineering Research Center (ERC), initially targeted for the Montgomery (Illinois) Works, has the potential for wide use throughout the company.

The EMARS is an integrated CEM system. It uses commercially available and/or state-of-the-art analytical and other monitoring instruments, as well as data acquisition equipment that samples the process streams. The EMARS can generate alarms and has a real-time process display and a user interface that provides real-time process information, retrieves archived process history, and generates relevant reports. The EMARS' ability to "learn" the dynamics of a process and its corresponding levels of emission during process operation enable it to predict abnormal or unusual emissions before they occur. The EMARS learns process behavior using examples of abnormal process history. Figure 1 shows how the EMARS can monitor the process and predict its levels of emission simultaneously.

General Characteristics. Process emissions result from evaporation, forced air drying of piece parts, process leaks, etc. These emissions are mainly confined to the vicinity of the process. However, low levels of some of these materials escape into the surrounding area and eventually are forced outside through the vents and stacks in exhaust systems. If the emissions are excessive, the constituents are scrubbed or adsorbed in a medium and recovered for reuse. Recovery is the preferable method because it minimizes waste and reduces environmental pollution. The EMARS identifies and quantifies the constituents of emissions in the process environment and the outlet streams from the factory. A real-time measurement can detect abnormal levels of emissions and, in turn, trigger alarms. Corrective action can then be taken to minimize or eliminate the emissions.

Hardware and Software. At the heart of the EMARS are sensors that measure emissions and process variables in real time. Analytical instruments measure the desired species concentration in the stack and/or the process environment, while other sensors monitor

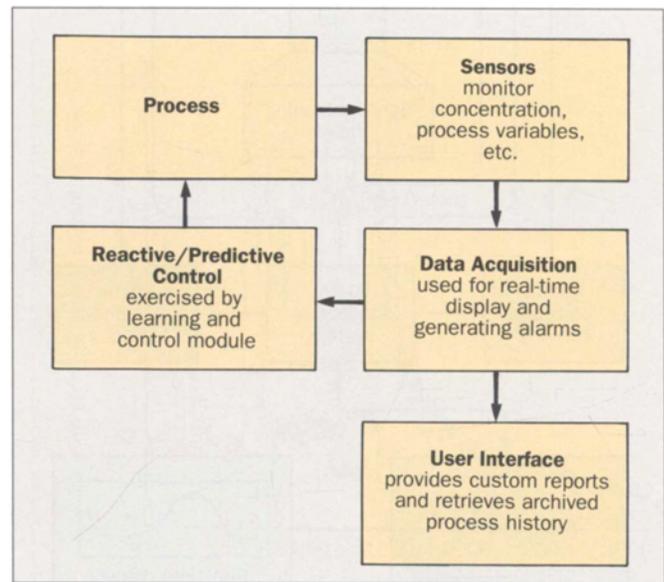


Figure 1. The EMARS evaluates a process using sensors to monitor the concentration of emissions and the process variables. The data gathered can appear as a real-time process display, or it can be used to produce customized reports. The data will also generate alarms, if necessary. The objective of the EMARS is to predict and control abnormal emissions before they occur.

process conditions such as the pH, temperature, humidity, and flow velocity. These analytical instruments most often dictate the data acquisition rate and, hence, the ability to approach a true real-time system. The time constants associated with the processes under study are usually large enough, compared to the instruments' capability, that pseudo-real-time measurements suffice. Data acquisition equipment connected to the instruments collects data at intervals dictated by the sensors. Software controls data acquisition from the sensors at different processes, provides a real-time graphical display of important process variables, generates alarms, transfers the data to a host computer for reports, and trains a control module to predict abnormal process emissions.

User Interface, Graphical Display and Reports. One primary purpose of the EMARS is to give the user daily, weekly, and annual summary reports on cumulative emissions and process history for a given time period. A user-friendly interface provides access to generate either graphical or tabular reports.

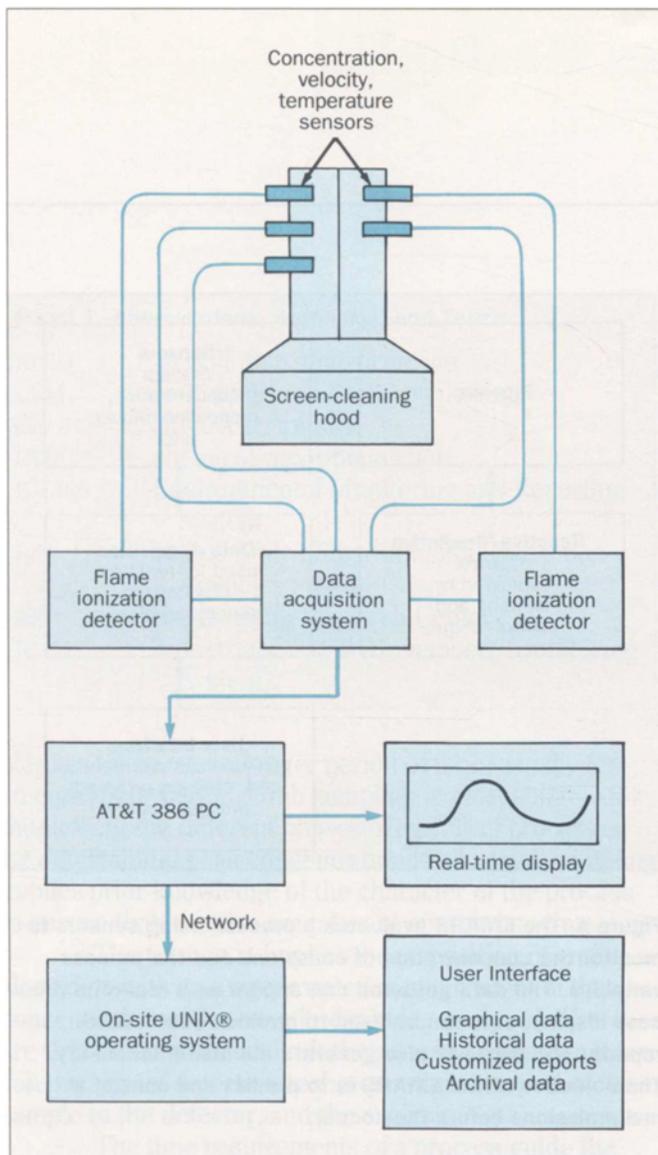


Figure 2. During the screen cleaning process, solvent under pressure is sprayed over a screen, which is then dried by forced air in a fume exhaust hood. The solvents emitted are forced through exhaust stacks that contain instruments to monitor the solvent concentration and stack flow conditions in near-real time. Data transferred to a local UNIX system host computer is used to generate reports and review process history, as well as to provide a real-time display.

Reactive and Predictive Control. Traditional monitoring systems observe process variables and emissions and generate alarms whenever the levels reach preset threshold values. Alarms trigger corrective actions that bring the process, as well as the associated emissions, under control. To eliminate or minimize emissions, the monitoring system should be able to forecast changes in process conditions and emissions that might lead to unacceptable levels. This predictive capability would lead to anticipatory control measures (corrective actions

taken in anticipation of a problem) that will keep the process operating within acceptable emission limits. Predictive control is preferable to reactive control, which relies on near-real-time emissions measurement to generate alarms signaling the need for control actions. True predictive control results from a first principles process model (derived from the basic physical and chemical laws involved in the actual process) and/or a module that learns the process dynamics and the associated emissions from the real-time measurements.

CEM Applications in AT&T

CEM systems are being used at both the Montgomery Works and the AT&T Printed-Circuit Board Headquarters in Richmond, Virginia. The EMARS at Montgomery monitors stack emissions in near-real time and controls processes to reduce solvent emissions. The Industrial Central Atmosphere Monitoring System (ICAMS) at Richmond monitors the fugitive air emissions in printed-circuit board manufacture and assures the health and safety of the work environment.

The EMARS at the Montgomery Works. In the first implementation of the EMARS, solvent emissions from a screen-cleaning process used in printed-circuit board manufacture are monitored at the Montgomery Works. The EMARS quantitatively estimates the solvent emissions rate during the cleaning cycle and provides feedback so process engineers can take corrective measures when necessary.

During screen cleaning, solvent under pressure is sprayed over a screen in an enclosed chamber for a given duration. A forced air stream dries the wet screen in a fume exhaust hood. The solvent emitted during this cycle is forced through exhaust stacks that contain instruments that monitor temperature, humidity, flow velocity, and solvent concentration in near-real time. A data acquisition system provides a real-time display of the operation and transfers the data periodically to a local host UNIX® computer system. (UNIX is a registered trademark of UNIX System Laboratories.) The environmental engineer interacts with the host computer to generate reports and review the history of the process. Figure 2 illustrates how the EMARS monitors the screen cleaning process.

Figure 3 shows that the EMARS detected emissions at a significantly higher level than a comparable screen cleaner. A close examination revealed that

defective gaskets and leaks in the equipment contributed to excessive emission levels. The emission rates were reduced threefold by replacing a defective gasket and fixing leaks in the equipment that would have gone undetected without the EMARS.

Environmental Monitoring at Richmond. The AT&T Printed-Circuit Board Headquarters at Richmond installed an ICAMS manufactured by Perkin-Elmer to supplement routine workplace monitoring and take emission measurements used as data in environmental reports and permits. The ICAMS is a centrally located, on-line mass spectrometer with a high-quality, double-focusing magnetic sector analyzer. The sample collection system is an 80-cubic-feet/min (cfm) vacuum pump that can draw samples from locations up to 2000 feet away.

As many as 50 sample lines are designated for workplace monitoring and 50 for environmental monitoring. The latter lines contain valves that allow both the inlets and outlets of wet scrubbers and incinerators to be monitored to determine their efficiencies. Each sample can be analyzed for up to 25 chemical species.

The monitoring system, which operates 24 hours a day, has over 54,000 feet of Teflon[®]-coated tubing installed in cable trays and conduit throughout the plant. (Teflon is a registered trademark of E. I. Du Pont de Nemours and Company.) The computer-controlled analyzer can be run in a fully automatic mode, manual mode, diagnostic mode, or mass-spectrum scan mode at the various ports.

The ICAMS collects data on concentrations, alarms, investigative scans, diagnostic messages, and system information and transfers it to a remote analysis station for further analysis and archiving. The mass spectrometer can detect "strangers," chemical compounds other than those it is asked to monitor. The library search software uses an investigative scan to help identify chemical strangers.

The trend report software generates various reports from the data collected when the analyzer is in the normal mode. Trend reports are generated by defining the time period of interest and the port and chemical compounds to be included in the report. Concentration for a specific compound in a given area can be determined automatically by specifying the times for trending, the hourly average, 8-hour time-weighted average, or daily average. Figure 4 shows a sample trend plot.

Most of the time, the ICAMS is used to monitor

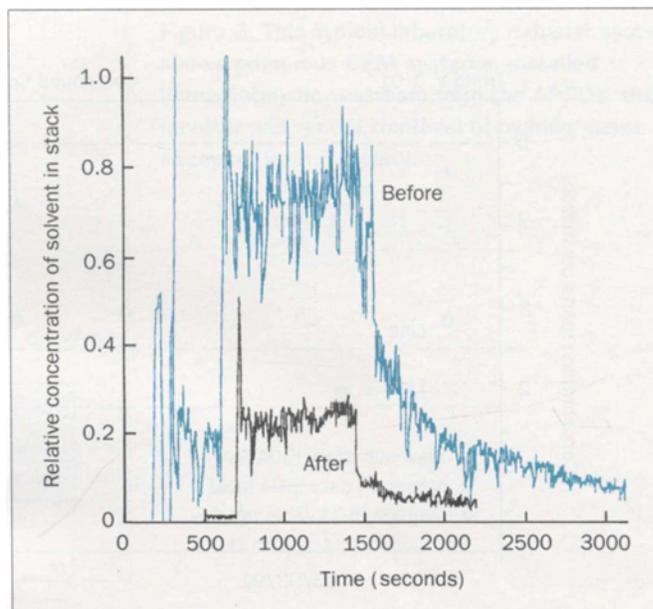


Figure 3. The EMARS detected emissions that were significantly higher than normal. The emission levels were reduced threefold by replacing a defective gasket and repairing leaks in the equipment.

the workplace and develop an extensive database of conditions throughout the manufacturing area. The ICAMS is not meant to replace personnel monitoring, but rather to supplement it. It periodically monitors each area to determine when it should be reevaluated because of changing conditions, and it compares conditions among shifts. (At times, the ICAMS has detected that a process was out of control because an exhaust damper was inadvertently shut.) The ICAMS has also proven useful in addressing employee concerns about an odor or the concentration of a chemical in the air. The system's trending and library search features can detect fugitive emissions that result from machine aging and identify decomposition products.

Using CEM Systems Within Bell Laboratories

AT&T Bell Laboratories has established an environmental management program designed to reduce emissions of toxic substances from its facilities, as well as to prevent the occurrence of accidental release episodes. In accordance with this program, laboratory operations are evaluated to ensure that appropriate engineering controls are used which satisfy the

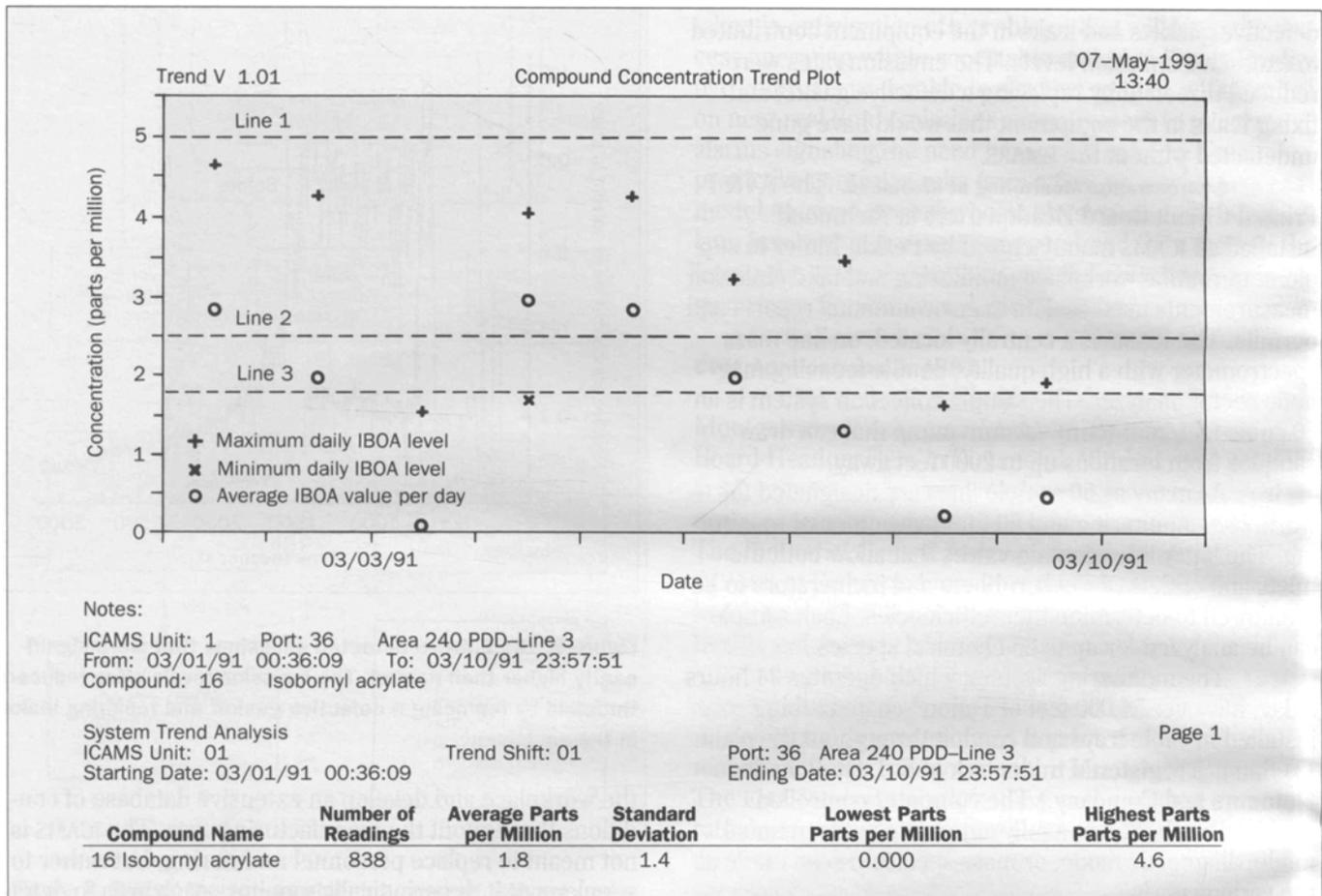


Figure 4. An ICAMS trend plot shows the range and average for isobornyl acrylate (IBOA) levels at a specific port from March 1 through March 10, 1991. Lines 1 and 2 are reference values, with Line 1 representing the 8-hour time-averaged exposure limit of IBOA and Line 2 indicating the action level at which engineering controls should be investigated. Line 3 shows the average concentration of IBOA for the given time period.

environmental management policy for both normal and accidental release scenarios.

Currently, various air pollution control technologies are used to reduce emissions from chemical vapor deposition (CVD) laboratory operations that use hydride gases. One of these gases, arsine, is considered the most dangerous form of arsenic because it is an extremely powerful hemolytic poison. Controlling CVD reactor

exhaust before it is diluted by any additional air stream is the most efficient and cost-effective method for reducing emissions of these toxic gases. To ensure proper operation of installed air pollution control devices (APCDs), CEM systems are installed immediately downstream of each APCD, so they can continuously monitor and record the concentration of hydride gases emitted by the facility.

Although gas cabinet, gas manifold, and reactor enclosure exhausts usually do not contain measurable levels of hydride emissions, an accidental release episode will contaminate them. Therefore, these exhausts are also directed into an APCD, with CEM systems installed both upstream and downstream of the control device to monitor emissions in real time if an accidental release occurs.

Because they are inexpensive, easy to use, and analytically sensitive, colorimetric tape detection devices have become the primary CEM for hydride gases used

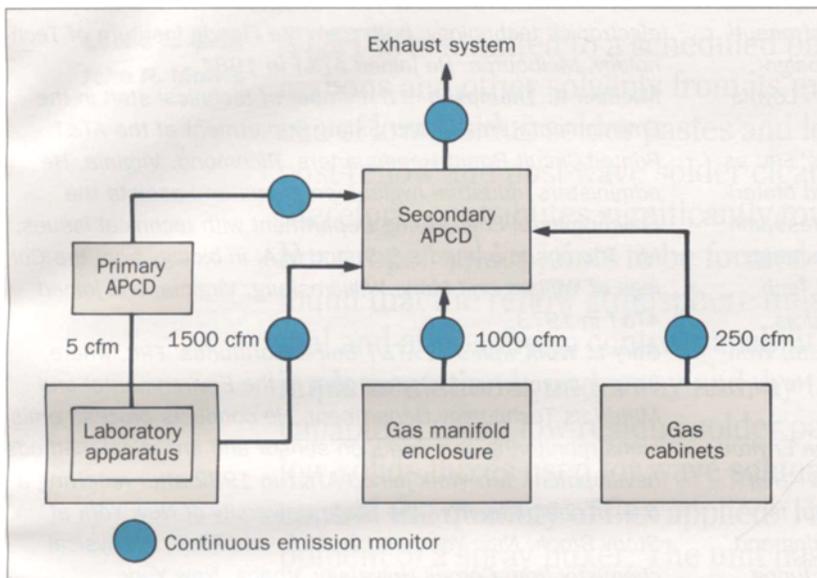


Figure 5. This typical laboratory exhaust system shows numerous CEM systems, installed immediately downstream from the APCDs, that monitor and record the level of hydride gases escaping from a facility.

within AT&T Bell Laboratories. These devices contain a cassette tape treated with proprietary chemicals. When exposed to a hydride substance, the chemicals on the tape react with the hydride compound, causing a color change that is in proportion to the amount of contaminant present. Thus, the higher the concentration of hydride gas present within the sampled gas stream, the more pronounced the tape discoloration.

Figure 5 shows a typical laboratory exhaust system used to contain and direct emissions away from laboratory CVD operations. CEM systems are an integral component of Bell Laboratories' environmental management program.

Summary

In this paper, we discussed applications of CEM system technology to monitor real-time stack emissions and fugitive air emissions within the manufacturing environment, and to monitor exhaust systems in the laboratory. The advantages of CEM have been compared with other, less adequate, approaches that do not meet the requirements of an increasingly difficult regulatory environment. Using CEM in conjunction with appropriate process control systems offers vast opportunities to minimize the environmental impact and improve the efficiency of AT&T manufacturing operations.

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