

Lab Technologies Migrate To Field

By Richard A. Hovan and G. Vinson Hellwig

When the Clean Air Act was passed in 1970, it was possible to measure gas emissions in the parts per million range. Two decades later, with advances in analytical chemistry, physics, monitoring hardware and software, many substances can be measured in the parts per billion range. Even more impressive, monitoring data can be processed, on a real-time basis, on small computers, where once a mainframe would have been required.

Environmental regulators have taken advantage of these new capabilities. For example, until the 1990 Clean Air Act Amendments, requirements for continuous emissions monitoring (CEM) for new combustion sources basically focused on the SO_x - NO_x - CO_x trilogy. New regulations for municipal waste combustors add lead, mercury, cadmium, hydrogen chloride, dioxins and furans to the pollutants to be continuously monitored. These requirements are possible by advances in analyzer technologies.

The symbiosis between technological measurement capabilities and regulatory requirements promises to continue. One of the less discussed aspects of this relationship is the "migration" of laboratory analytical technologies into the world of emissions monitoring. Technologies that originally were developed for laboratory or research and development use are increasingly being applied in the field for ambient and emission source monitoring, because of their inherent capability to detect compounds at levels far lower than traditional emissions analyzers can. This has meant, of course, that the laboratory technologies have had to be "hardened" or made more rugged to withstand the harsh process, smoke-stack and ambient environments in which they must operate. Three recent developments in the application of laboratory technologies to the continuous emissions monitoring field illustrate this trend.

Laser Opacity Monitors

First is the appearance on the market of laser opacity monitors for use in demonstrating compliance with EPA regulations. Twenty-five years ago, it was typical for opacity to be measured by the human eye. Technicians were trained to become certified "smoke observers," comparing plumes from smokestacks with shades on a chart representing varying percentages of particle content. Over the ensuing years, a number of technology based opacity monitors came onto the market; the most recent of these applies laser technology to opacity measurement.

The basic principle is straightforward. A low-power helium-neon laser beam is directed through the gas stream to be measured from a transmitter to a receiver. Through a light attenuation – light absorbed by or scattered from particles in a beam bath – the concentration of particles can be determined through a mathematical calculation that can be automatically performed by a data handling and acquisition system (DAHS). The basic equation that expresses the opacity percentage is:

$$\text{Op}\% = (1 - I_x/I_0) \times 100$$

where I_0 is the light source intensity and I_x is the received light intensity across the stack.

Laser opacity monitors offer several advantages over more traditional

technologies. They are low-weight, easy to install and operate and provide reliable measurements of low and high concentrations. Perhaps best of all, they are very low maintenance – a valuable long term benefit where the cost of parts, materials, monitor downtime and labor are considered.

There are several variations of the basic laser model. For the opacity monitoring required by EPA to satisfy Performance Specification 1, a model operating at a wavelength of 543 nm, in the middle of the green spectrum, is used. For dust monitoring, a red gas laser is generally preferable in relatively high dust environments. ($>$ than 100 mg/m^3). This has made it the choice for such applications as pulp mills, recovery boilers and lime kilns. The semiconductor laser is used in relatively low dust environments or where space restrictions apply. And monitors using a superled light source are often the choice where the length of the measuring beam is short ($<$ 2 m) or where price is of primary importance.

Fourier Transform Infrared Spectrometry

A second development is the potential for using Fourier Transform Infrared (FTIR) technology in compliance monitoring demonstrations in place of the single pollutant analyzers that have traditionally been used. FTIR is a multi-component system capable of monitoring traditional and more exotic pollutants; it holds the promise of replacing most existing CEM technology.

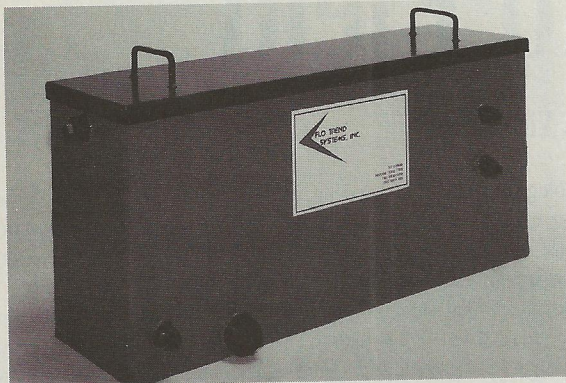
FTIR monitors use infrared light absorption patterns to identify specific organic and inorganic compounds in liquids, solids and gases. The heart of the FTIR is an optical device called an interferometer that uses a beam splitter and mirrors to measure the infrared spectrum of a gas sample. The infrared source is split into a pair of beams that recombine in the device to form a pattern. A computer algorithm converts the pattern into quantitative data.

Unlike more traditional continuous emissions monitors, FTIR has the potential to measure thousands of components at a time. Currently, FTIR can measure up to 80 constituents at one time; 135 of the 189 hazardous air pollutants listed under Title III of the 1990 Clean Air Act Amendments can be measured by this technology.

Another FTIR advance lies in its intrinsic response time of less than one minute for typical gas sampling flows. Compared to the complex organic component mixtures in process stream and vent stack measurements, the SO_x - NO_x - CO_x calibrations required for general power plant application are quite straightforward. Even the additional calibrations for other substances (such as methane, phosgene, hydrogen fluoride, hydrogen chloride and hydrogen bromide) for municipal solid waste combustors and industrial waste incinerators are relatively simple. FTIR easily measures most volatiles in the low parts-per-million-by volume range, although it does have the limitation of being unable to measure heavy metals or parts-per-trillion toxics such as dioxins and furans.

Because FTIR analyzers are widely used in the harsh environments of industrial processing, they are very rugged, with maintenance requirements typically limited to a once-a-year light source changeout.

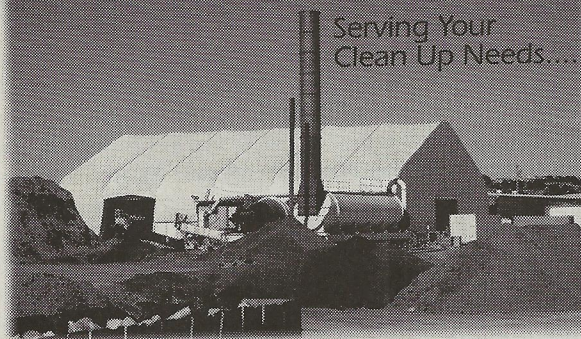
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Ion Mobility Spectrometry

A third example is the development of Ion Mobility Spectrometry (IMS) technology. The IMS is a single component analyzer designed to measure exotic gases and work in series with existing technology for conventional pollutants.

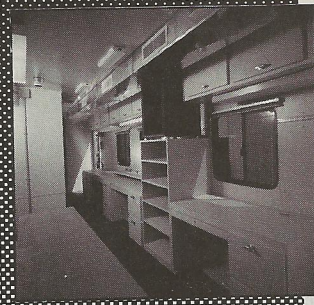
The heart of an IMS analyzer is a cell with a semipermeable membrane on its outside, over which a gas sample is forced. Selected compounds enter the detection cell, where purified dry instrument air sweeps the membrane on the inside and delivers the sample to the reaction region. There the sample is ionized by a weak plasma formed by a small radioactive nickel source. Dopant materials can be added to enhance the ionization process and increase component specificity. The ionized sample molecules drift through the cell under the influence of an electric field. An electronic shutter grid allows periodic introduction of the ions into a drift tube, where they separate based on charge, mass and shape. Small ions move through the tube faster than larger ones and arrive at the detector, where a current created at that location is amplified and measured as a function of time. A unique spectrum is generated and evaluated by a microprocessor to identify the target component and determine its concentration.

Specificity is achieved through several mechanisms. The membrane is selected based on its ability to allow penetration of the target component at a greater rate than is possible for interferents. Most compounds form ions of only one polarity. By biasing the polarity of the electric field, either positive or negative ions are detected. Ions of the opposite polarity are not detected and thus do not interfere. Use of appropriate dopant materials increases specificity by altering the ionization process so that compounds

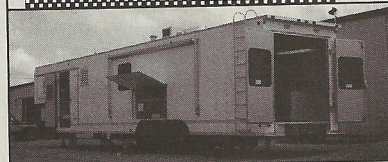
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that may interfere simply are not ionized.

IMS only recently has been applied to CEM systems. It can accurately detect many compounds that cannot be measured easily by other methods. With part-per-billion detection capabilities, IMS allows direct monitoring of low-level gas concentrations virtually unachievable otherwise. Its superior sensitivity permits the use of dilution-type probes which greatly reduce sample transport problems. Other features, such as long-term reliability, ruggedness in harsh environments, low maintenance requirements with no need for consumables and minimal drifts, make it attractive to industry, which uses it to detect compounds such as ammonia, hydrogen chloride, hydrogen fluoride, chlorine and chlorine dioxide.

Applications

Regulators are not the only advocates of adopting increased monitoring technologies. As noted, industrial sources also have taken advantage of technological advances in monitoring to realize economic benefits. Two examples of these applications follow:

- **Municipal solid waste combustion.** With the costs of municipal solid waste incineration rising and the restrictions on emissions tightening, the need for sound process control has become more critical than ever. One major recurring operational cost for incineration is the lime needed for spray drying. Traditionally, operators have "over-limed" the flue gas in the spray dryer to assure adequate sulfur dioxide removal. New regulations shortly to be promulgated by EPA will tighten sulfur dioxide removal requirements and add, for the first time on a national basis, stringent restrictions on hydrogen chloride emissions. CEMS requirements also will be tightened – a potential burden that operators can

convert into a management plus. Using the CEMS and its associated DAHS, spray dryer controls can be operated on both a feed-forward and feed-back control loop. This can result in a significant reduction in lime usage. A lime savings for as much as 50 percent has been noted at some plants, with typical reductions of 25-30 percent in sulfur dioxide emissions. With the cost of lime approximately \$65 a ton and expected to rise, an advanced CEMS/DAHS can yield a payback in only a few years.

- **Black liquor boilers at pulp and paper mills.** These boilers commonly experience HCL breakthrough at the stack outlet, usually indicated by rusty streaks down the stack exit ring. By the time such streaking appears, the HCL content in the flue gas is typically high (20 ppm or greater) indicating both existing and ongoing damage to the boiler. As ash builds in the boiler tubes, boiler temperatures increase. This causes chlorides to leach and combine with moisture to form HCL and O_2 , further damaging stack and boiler. Incorporating an HCL monitoring system in the CEMS would allow early detection of HCL; boiler shutdown and cleaning could immediately begin, reducing damage and replacement or repair costs.

As owners and operators find ways to turn the regulatory burden of monitoring into an economic benefit, manufacturers and suppliers of monitoring technologies will find themselves welcome in boardrooms as well as in regulatory agencies. And the migration of laboratory technologies into environmental compliance applications will continue. **EP**

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