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Use of Multicomponent Infrared Gas Analyzers at Waste-to-Energy Facilities

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ABSTRACT
Multicomponent Infrared Gas analyzers have been a workhorse as Continuous Emissions Monitoring Systems (CEMS) in the waste-to-energy (WTE) application for the past two decades. It is the technique of choice for many facilities. With obsolescence for electronics, instrumentation and data acquisition systems (DAS) averaging less than 10 years, the earlier multicomponent CEMS are being upgraded to what is now a third generation of that technology.

This paper describes the evolution of the three generations of multicomponent CEMS. The evaluation of this technology in the WTE application encompasses the operating histories of nearly two dozen facilities demonstrating compliance with this type of CEMS. Specific details explaining the sampling systems, analyzer optics & controls, interface and communication with plant distributed control systems, and DAS systems are presented. Relative accuracy test audit (RATA) results, CEMS availability histories and annual maintenance costs are reviewed presenting a unique insight into both initial capital costs and operating costs. Actual annual man-hour totals for preventive maintenance (PM), unscheduled maintenance, and annual consumable parts costs are provided.

Advances in computer capabilities have provided an opportunity for CEMS functions to not only become more comprehensive but also more robust. Key among these advances is the ability for factory-support services to be provided not only for the software platform but now even down to the basic auditing parameters of the analyzers themselves. Third generation CEMS now feature remote access of the analyzers from the instrumentation repair shop, the vendor's factory or from the company's technical service center.

TECHNOLOGY BACKGROUND
In 1989, the first multi-component infrared analyzer was introduced for both CEMS and process control monitoring. The underlying advantages were as obvious then as they are today. If just a single instrument could measure all of the gases, using just one source lamp, sample cell and detector, then it could replace a room full of analyzers and attendant complexity. Indeed, if one has four gas analyzers, each must have its own sample cell, sources, detectors, electronics, and ancillary equipment. Then, if it could be an infrared photometer, it could greatly reduce the components in contact with flue gas, perhaps to less complexity than any one of the four it replaced. Figures 1 and 2 illustrate the comparative differences in complexity of the traditional discrete analyzer approach versus the hot-wet multicomponent Infrared (IR) analyzer approach.

Prior to its introduction in 1989 many were skeptical about the ability of any IR based photometer to accurately measure NO_x and SO_2 in the infrared region. Interference with other common gases such as CO_2 and H_2O abound in the infrared region and it was thought to be an insurmountable problem. The first generation of these analyzers brought several innovations that could be deemed breakthroughs. First, it was able to use Gas Filter Correlation [1], that is a technique that allows much greater selectivity and interference rejection, and at the same time Single Beam Dual Wavelength that has advantages in some gas measurements. This is all done simultaneously to measure up to 8 different gases, including the interfering gases. It thus opened the door for continuous real time corrections to internal analyzer signals.

The ultimate result of this multicomponent infrared approach was an amazingly sensitive and accurate device with some significant advantages.

The fact is that all gas analyzers suffer interference from other common stack gas constituents. This is as true for Chemiluminescence NO_x and Pulsed Fluorescence SO_2 analyzers as it is for Infrared devices. In most cases the effect is manageable but still, it detracts from the overall accuracy and none of those discrete devices are capable of performing dynamic corrections for interferences. Given that a multicomponent analyzer can easily measure those interfering compounds, it is just as easy to continuously correct the measured variable in real time. And with recent advances in computing power and advanced iterative techniques, it is possible to be extremely accurate. The continuing availability of higher-powered processors has allowed these corrections to become even faster and more accurate.

SYSTEM DESIGN

Application engineering of CEMS may be one of the most important part and it is in sampling systems where that is most critical. But it is not easy, there literally are hundreds of important variables that must be taken into account for every installation, any one of which ignored…can result in serious problems. This means that each system should be custom engineered for the job it is intended for, and a "generalized template" approach cannot be applied to all applications—and those doing the engineering must have sufficient experience. Indeed, even the best technology is almost guaranteed to fail in the wrong application…the CEMS industry has seen far too much of that, especially in the WTE industry.

The sampling system may be the least understood part of a CEMS. The fact is that it is very difficult to extract a sample of gas from the exhaust stream of a combustion source and transport it for analysis without degrading or affecting the gases to be measured. There is the problem of particulate buildup, moisture, corrosive acid condensates--and the gases to be measured may themselves be highly reactive, perhaps even with the sample system itself. However, through proper consideration of the source conditions, required measurements and site geography it is possible to produce very reliable, low maintenance CEMS sampling systems. More than 400 multicomponent IR installations have shown that to be true.

The primary key for a successful sampling system is to keep the system as simple as possible while addressing four primary concerns related to particulate, corrosion, condensates and reactive gases (see Fig. 1). This is most difficult when measuring at the boiler outlet location prior to the plant fabric filter and acid gas control equipment

In the hot-wet system only four parts (probe, sample line, pump and analyzer cell) are in contact with the flue gas and materials selection and operating temperatures for each must be managed. For the measurement of reactive gases such as HCl, or in the case of a sample gas with a very high acid dew point temperature it may be necessary to maintain elevated temperatures all the way through the gas analyzer. The hot-wet sampling system can maintain such conditions at temperatures up to 240 ºC. The hot-wet system also includes the unique capability to directly measure stack water vapor content.

The HW3 Probe Assembly consists of a coarse (20 micron) sintered metal filter mounted on the probe tip, a probe tube, and a fine filter body, which is mounted on a 3"or 4" 150PSI flange. The heat traced sample umbilical will maintain the gases at an appropriate temperature all the way from the probe to the analyzer enclosure. Lengths up to 150m are possible. The heated sample pump has been specially designed for this service and has proven to be very reliable.

INSTALLATIONS

Novelty technologies with little or no track record often have a rigorous learning curve in the waste incineration and waste-to-energy (WTE) industries. However the hot-wet multicomponent analyzer technology is not a novel immature one. For the past two decades hot-wet multicomponent Infrared analyzers have been widely utilized as CEMS in the waste processing industry (waste incineration and (WTE) applications). Simplicity in design of the sampling system along with a reliable multicomponent analyzer has provided high availability CEMS for this extremely harsh and demanding application. As a result, this technique has been the technology of choice for many waste-processing facilities.

The installation base of this multicomponent analyzer spans the gamut of WTE facility configurations over the past 14 years. Table 1 provides an overview of WTE plants that have installed hot-wet multicomponent CEMS. Table 2 provides a more detailed overview of this technologies installation base and better illustrates the comprehensive demonstrated success within the WTE industry.

CERTIFICATION AND RATA RESULTS

Being actively involved the Relative Accuracy test audits (RATA) for dozens of hot-wet multicomponent systems first-hand as a feature of multiyear maintenance contracts, a significant database of RATA histories has been established. Large data sets of RATA, and maintenance records are not readily available on this large a scale. This particular data set on this population of CEMS provides ongoing feedback on systems' current and past accuracy performance. This data feedback is critical for a systems provider to confirm and address system design and analyzer performance.

Recently (September 2003) the Relative Accuracy Test Audit (RATA) was performed for four third generation hot-wet multicomponent CEMS at a WTE facility in Pennsylvania. The four CEMS at this facility are located at the inlet and outlet of the pollution control devices (Spray Dryer Absorber and Fabric Filter) for two units. The demonstrated relative accuracies during the certification of the CEMS at this installation are all within requirements and are typically less than one-half of the allowable regulatory requirements [2]. Table 3 provides the RATA results for one unit. In addition, the operational testing, calibration error (linearity) tests, response time tests, and drift tests all demonstrated results respectfully within regulatory requirements.

COST INFORMATION

Several techniques and approaches have been proposed to formally estimate the costs associated with purchase and operating of CEMS [3]. However in this paper we wish to enumerate the historical costs associated with operating a typical CEMS from our installed based of WTE CEMS (Table 4). Following are some notes regarding individual cost items:

Capital Costs

The capital cost of the hot-wet multicomponent IR analyzer based CEMS has decreased in price even as the capabilities of the equipment have been enhanced. Installation costs have been positively impacted with the use of serial interfacing and the use of pre-existing local area networks. In the past ten years, an average price decrease of approximately 25% is not uncommon. DAS pricing has decreased even with increasing complexity of compliance reporting.

Personnel, Training and Third Party Maintenance Support Costs

A significant cost factor is on-site personnel required to meet and maintain CEMS availability requirements. There are several approaches to addressing this issue. In-house on-site staff can be assigned. Initial and routine training and/or allocating technicians with the proper degree of previous experience is costly especially with the typical turnover in these positions. Another option is a team approach utilizing plant staff and third party on-site factory support. Over the years this approach has proven to be the most cost effective and with the advent of dial-in diagnostics, it is particularly successful in keeping costs manageable. Readily available spare parts, a documented Preventive Maintenance (PM) program and good communication are key. A cell phone in the field with competent support on the other end can save many service trips.

Maintenance & Parts Costs

Scheduled preventative maintenance is typically 2-4 hours per month per CEMS. This has been achieved by learning through experience. We have developed an approach that allows flexibility in frequency of visits, degree of testing support required by the plant commiserate with their staff and built-in emergency visits to address unscheduled maintenance (lightening strike, component failure, etc).

Consumable Parts Costs

As with other costs, this category will vary markedly from design to design, however, the running 4-year average for 42 of the hot-wet CEMS is fairly well documented at $650 annually. The reason for this low cost is due to the very limited number of consumable parts: pump diaphragm and filters. This is unique to the hot-wet multicomponent analyzer technology.

CONCLUSIONS

Computerized hot-wet multicomponent analyzer based CEMS have been widely used for the WTE application for the past two decades. These analyzers have an inherent advantage over discrete analyzer systems due to reduced parts count, less maintenance and lower purchase costs. The multicomponent analyzers have evolved over time and have incorporated better interference resolution algorithms, reduced size, increased accuracy and lower purchase costs. For the harsh and demanding conditions associated with WTE applications the multicomponent gas analyzer based CEMS have a proven track record, providing high data availability and accurate measurements in a cost-effective manner.

ACKNOWLEDGEMENT

Dr. Wolfgang Berkhahn and David Dillehay pioneered the field of computerized hot-wet multicomponent CEMS over two decades ago. The authors appreciate the lively discussions with these pioneers and acknowledge their contribution, advice and guidance.

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[2] Continuous Source Monitoring Manual, 2003, Rev. 7, Dept. of Environmental Protection, ttp://www.dep.state.pa.us/dep/deputate /airwaste/aq/cemspage/cemshome.htm.

[3] User Manual: U.S. Environmental Protection Agency's Continuous Emission Monitoring System Cost Model Version 3.0, 1998, http://www.epa.gov/ttn/emc/userman.pdf.

Characteristic	Data
Design Capacity	200 tons/day to 3,150 tons per day
Technology:	Mass burn, Refuse-derived fuel (RDF),
Acid Gas Controls	Spray drier absorbers, Dry sorbent injection (DSI), urea injection, carbon injection
Dust Collection:	Electrostatic precipitator (ESP), fabric filters (FF)
Location:	USA Domestic (over a dozen states) and international
Regulatory Entities:	US EPA, PADEP (Pennsylvania Department of Environmental Protection), TUV (German certification organization)

Table 1: Overview of WTE plants which have installed Hot-Wet Multicomponent CEMS

Technology	Time Frame	Waste Processing Facility
First Generation (MCS 100)	1989-1997	~ 119 installations
Second Generation (MCS 100e)	1998-2001	~ 32 installations including Westchester RESCO (Peeskill, NY), Baltimore RESCO (Baltimore, MD), Onyx Environmental (Port Arthur, TX), Wheelabrator McKay Bay (Tampa, FL), Wheelabrator North Broward (Pompano Beach, FL), Wheelabrator South Broward (Ft. Lauderdale, FL), Wheelabrator Spokane (Spokane, WA)
Third Generation (MC3)	Late 2001 - 2003	~ 21 installations including Onyx Environmental (Sauget, IL), Eli Lilly (Shadeland, IN), Sartec (Sardinia, Italy), Atlas Equipment (Taipei, Taiwan), SE Analytics (Mozambique), SE Analytics (Kazakhstan), Wheelabrator Falls Township (Morrisville, PA), Onyx Environmental (Sauget, IL)

Table 2: Hot-Wet Multicomponent Analyzer Installations at Waste Processing Facilities

Location	Gas	Reference Monitor Mean	CEMS Mean	Mean Difference (MD)	Relative Accuracy	Relative Accuracy Criteria
INLET #2						
Spray Dryer Absorber Inlet	SO_2 (ppm)	191.2	196.8	5.6	5.50%	20%
Spray Dryer Absorber Inlet	O_2 (%)	9.85	9.87	0.02	1.40%	20%
Spray Dryer Absorber Inlet	CO_2 (%)	10.14	10.10	0.04	2.50%	20%
Spray Dryer Absorber Inlet	CO (ppm)	47.2	43.7	3.5	NA	5 ppm MD
OUTLET #2						
Fabric Filter Outlet	O_2 (%)	10.56	10.50	0.06	0.9%	20%
Fabric Filter Outlet	NO_x (ppm)	166.7	167.6	0.9	1.9%	20%
Fabric Filter Outlet	CO (ppm)	42.8	45.2	2.4	NA	5 ppm MD
Fabric Filter Outlet	SO_2 (ppm)	5.9	4.0	1.9	NA	10% Standard or 5.8 ppm MD
Fabric Filter Outlet	HCl (ppm)	16.3	14.4	1.9	NA	5 ppm MD
	SO_2 Removal Efficiency (%)	97.2	98.5	1.3	NA	2% MD

Table 3: Relative Accuracy Test Audit (RATA) for two third-generation hot-wet multicomponent IR analyzer-based CEMS (O_2 concentrations are % Dry; NO_x, SO_2, HCl and CO are ppm @ 7% O_2; MD – Mean Difference)

Item	Data
Plants included in cost estimation	Westchester RESCO (Peeskill, NY), Wheelabrator Falls Township (Morrisville, PA), Wheelabrator Frackville (Frackville, PA), Baltimore RESCO (Baltimore, MD), Wheelabrator McKay Bay (Tampa, FL), Wheelabrator North Broward (Pompano Beach, FL), Wheelabrator South Broward (Ft. Lauderdale, FL), Wheelabrator Pinellas (St. Petersburg, FL), Wheelabrator Ridge (Auburndale, FL), Wheelabrator Spokane (Spokane, WA)
Number of CEMS	42
Initial Capital Cost	$190,000 per CEM (1992) -- $140,000 per CEM (2003)
Consummable Parts	$650 per CEM per year
Average cost	$5,100 per CEM per year (includes comprehensive maintenance and consumable parts)
Preventive Maintenance	Approximately 2 – 4 hours per CEM per month

Table 4: Summary of Capital Costs and Maintenance Requirements for Multicomponent Gas Analyzer based CEMS

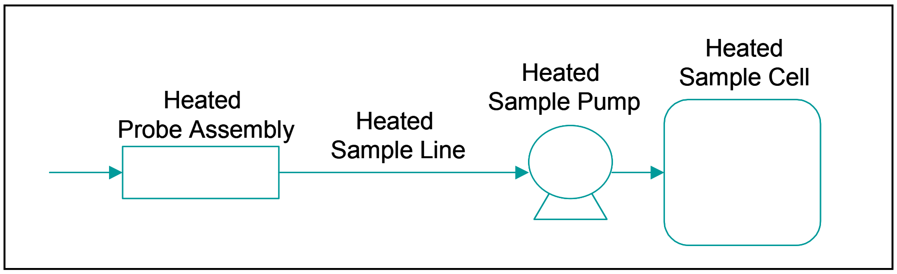

Figure 1: Hot and Wet Sampling System Flow Diagram

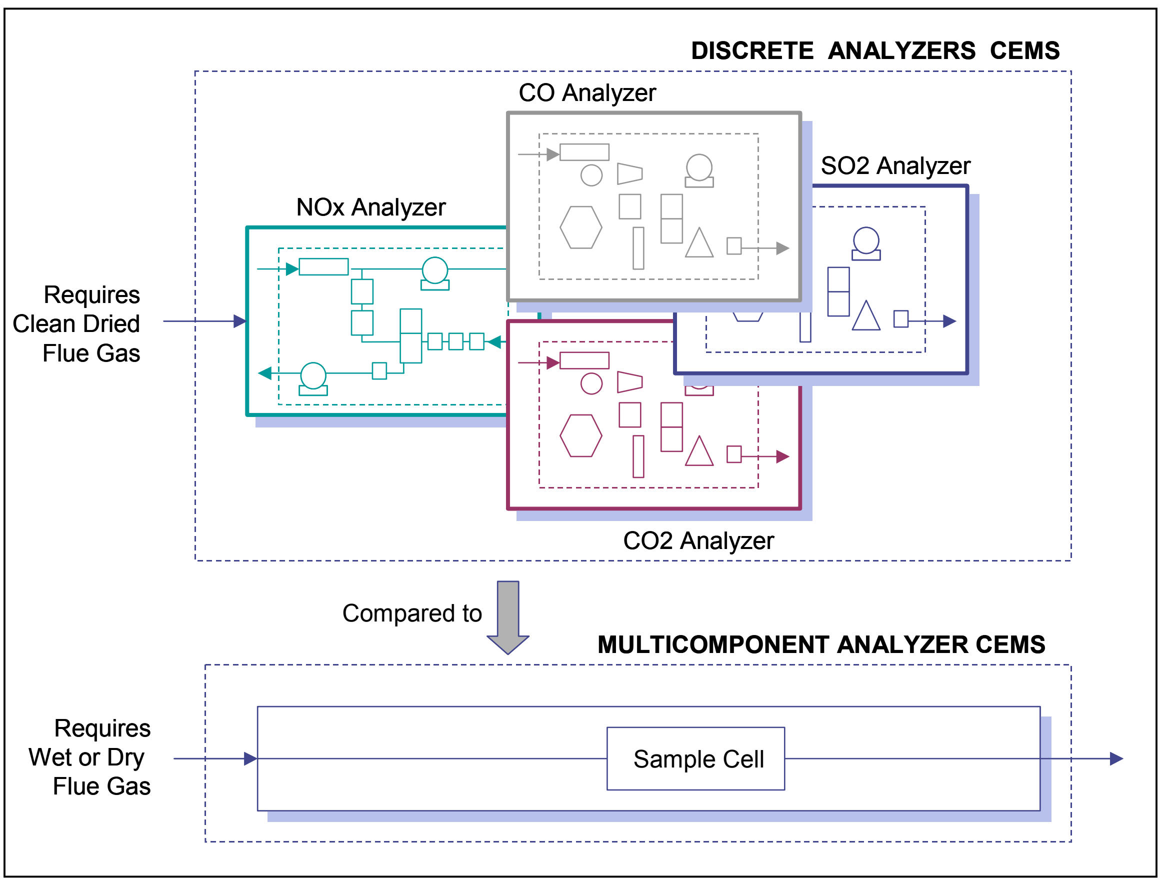

Figure 2: Comparison in Complexity between CEMS using Discrete Analyzers and a Multicomponent Analyzer