AIR EMISSIONS MONITORING FOR SAFE AND EFFICIENT MEDICAL WASTE INCINERATOR OPERATION

INSTITUTE OF CLEAN AIR COMPANIES
EMISSIONS MEASURING DIVISION

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The Institute of Clean Air Companies (ICAC) is the national association of companies that supply stationary source air pollution monitoring and control systems, equipment, and services. It was formed in 1960 as a nonprofit corporation to promote the industry and encourage improvement of engineering and technical standards.

The Institute's mission is to assure a strong and workable air quality policy that promotes public health, environmental quality, and industrial progress.

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RECOMMENDATIONS

In their implementation of the federal emissions guidelines for medical waste incinerators (MWI), the States should consider adding the following continuous monitoring requirements to ensure public health in the communities surrounding these incinerators:

- ALL medical waste incinerators should monitor carbon monoxide emissions and excess oxygen levels

- LARGE (more than 500 lb/hr capacity) medical waste incinerators should also monitor opacity

- VERY LARGE (more than 1000 lb/hr capacity) medical waste incinerators should also monitor hydrochloric acid (HCl) emissions

Except at large and very large incinerators, this continuous monitoring need not meet Appendix F requirements, i.e., the states need not require the use of continuous emissions monitoring systems (CEMS) for direct enforcement of emission limits other than at large and very large units.

ICAC is not suggesting that the States require monitoring of CO and O_2 using a specific instrument, or even a specific methodology. What we are suggesting is that minimal monitoring of medical waste incinerators is an absolute requirement to assure low emissions of toxic species, and so to protect public health and the environment.

Carbon Monoxide/Oxygen Monitoring Minimizes Emissions

Good combustion is central to EPA's strategy for reducing MWI air toxics and particulate emissions. Continuous monitoring of CO and O_2 is a minimum requirement for ensuring that good combustion is occurring.

In fact, as discussed below, CO/O_2 monitoring allows both minimization of incinerator emissions and optimization of incinerator thermal efficiency.

CO/O_2 Monitoring for Minimizing Emissions. The measurement of oxygen concentration in flue gas is essential for the control of the air flow to the combustion chamber. Insufficient oxygen feed to the combustion chamber results in an excess of fuel and consequent incomplete combustion, so that uncombusted medical waste and products of incomplete combustion (PIC) are emitted from the chamber. Lower temperatures which also result from incomplete combustion will exacerbate these PIC emissions.

Measuring flue gas oxygen concentration alone will not assure complete combustion, however. Particularly in the face of the varying loads and fuels which typify medical waste incinerators, continuous monitoring of flue gas carbon monoxide concentration also is necessary. CO is an indicator of the onset of incomplete combustion, as shown in the following equations:

$$C + O_2 \rightarrow CO \qquad \text{(incomplete combustion)}$$

$$CO + O_2 \rightarrow CO_2 \qquad \text{(complete combustion)}$$

(Given that fuel carbon content varies, CO_2 concentration is not a reliable indicator of complete combustion.) Thus, only combined continuous monitoring of flue gas oxygen and carbon monoxide levels will give the incinerator operator the reliable indication of complete combustion needed to ensure complete destruction of waste fuels.

Alternatives to CO/O_2 monitoring, e.g., parameter monitoring, will give measures of emissions which are indirect at best. For example, monitoring primary and secondary chamber temperatures and charge weights will provide often misleading indications of good combustion, given typically nonhomogeneous temperatures and flows in incinerators. At worst, operating parameters may become completely decoupled from emissions as equipment ages.

CO/O_2 Monitoring for Minimizing Supplemental Fuel Consumption. While the above discussion applies to all incinerator types, MWIs differ from larger, more familiar municipal waste combustors in that they require a continuous supply of supplemental fuel for complete destruction of medical waste. In a typical MWI, natural gas or fuel oil is fed to a secondary combustion chamber in which waste and pollutant destruction is completed. Without the use of a heated secondary chamber to provide a long residence time at high temperature, significant emissions of dioxins/furans, organic particulate, and other products of incomplete combustion would occur. The use of supplemental fuel results in an operating cost that can be minimized by optimizing incinerator energy efficiency.

Incinerator energy efficiency correlates directly with carbon monoxide (CO) and oxygen (O_2) stack concentrations. Figures 1 and 2 illustrate this correlation. As seen in these figures, maximum energy efficiency occurs when the stack CO level is in the range of 50-300 ppm, with O_2 in a range determined by incinerator load. When oxygen levels are too low, heat is lost from the incinerator as CO and other partially combusted species. When oxygen levels are too high, heat is carried from the incinerator by large volumes of excess air. If the operating unit can minimize the excess O_2 and maintain the CO between 50 and 300 ppm, the efficiency of the incinerator will be optimized. Optimizing efficiency reduces operating costs through fuel savings.

Assuring good combustion through continuous CO/O_2 monitoring will reduce energy requirements, thus preventing pollution through reduced fuel consumption, and lowering emissions of CO_2, a greenhouse gas. Maintaining good combustion on a continuous basis will also reduce maintenance requirements, e.g., the need to remove soot build-ups.

Monitoring Costs Should Not Exceed Monitoring Benefits

We emphasize that, other than on units with capacities of greater than 500 lb/hour, we are not arguing for the use of CEMS for compliance monitoring. Because most medical waste incinerators are small, the added expense of compliance with Appendix F requirements would not lead to a significant contribution to public welfare. Non-Appendix F monitoring, while of lower accuracy, will give a reasonable picture of emissions for use in developing better inventories, and will help sources to determine the need for improved process control to lower emissions on units with 500 lb/hr and lower capacities.

In fact, CO/O_2 process monitors should be sufficient on small incinerators. These devices are less expensive than traditional CEMS, and will provide the information necessary for ensuring good combustion and compliance with the CO emission limit.

On medium and large units, which can support a somewhat greater expense, continuous monitoring of opacity will provide further confirmation of good combustion as well as compliance with the applicable opacity limit. Very large (greater than 1000 lb/hr) units begin to approach the size of small municipal waste combustors. Equity and the comparable emission quantities from both types of incinerators suggest comparable monitoring requirements. While SO_2 monitors required on municipal waste combustors would not be appropriate for medical waste incinerators, HCl monitors would be useful given much higher feed chlorine concentrations.

Benefits of Emissions Monitoring Relative to Parameter Monitoring

Beyond providing assurance of good combustion, CEMS also provide the only direct measurement of emissions on a continuous basis. Because it is a direct measure of emissions, CEMS output is easy to interpret, both for owners/operators of units, and for regulatory agencies. Other methods, e.g., parameter monitoring, will give measures of emissions which are indirect at best. At worst, operating parameters may become completely decoupled from emissions as equipment ages.

Continuous emissions monitoring also is simple relative to parameter monitoring. Use of CEMS frees regulators from devising parameter monitoring schemes for each type of control device, and frees owners/operators from the need to submit detailed parameter monitoring plans for each system configuration, and from the need to monitor control device parameters unrelated to emissions.

Where States allow parameter monitoring instead of continuous CO/O_2 monitoring for ensuring good combustion and compliance with the applicable CO emission limit, then the States should build safety margins into the allowed operating parameter ranges to account for the indirectness of this technique. For example, while a stack test may show CO emissions below the applicable limit at some secondary chamber temperature, the operating permit for that unit should require a minimum secondary chamber temperature consistent with CO emissions of no more than 75% of the limit.

Figures 1 and 2 (next page). Incinerator carbon monoxide concentration and heat loss vary with the excess air level (flue gas oxygen concentration). If the incinerator load and fuel are constant, maintaining the flue gas carbon monoxide concentration in a predetermined range will be sufficient to minimize incinerator heat loss (Figure 1). However, given the varying loads and fuels characteristic of medical waste incinerators, minimizing heat loss requires knowledge of both the flue gas oxygen and carbon monoxide concentrations (Figure 2).

Figure 1

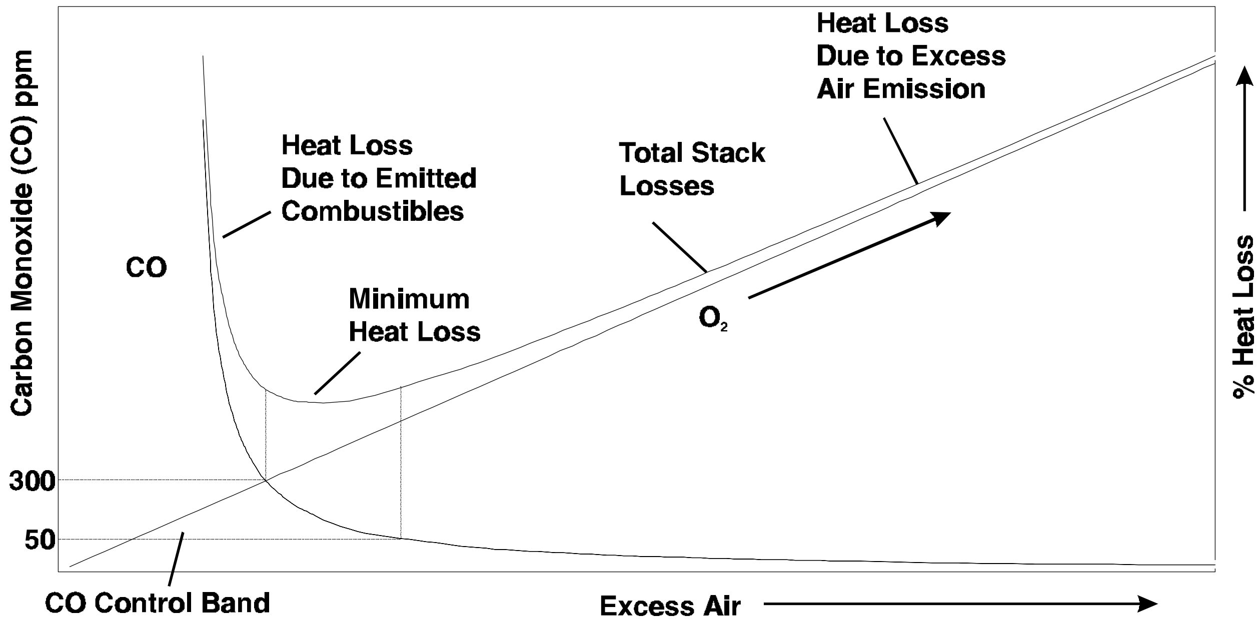
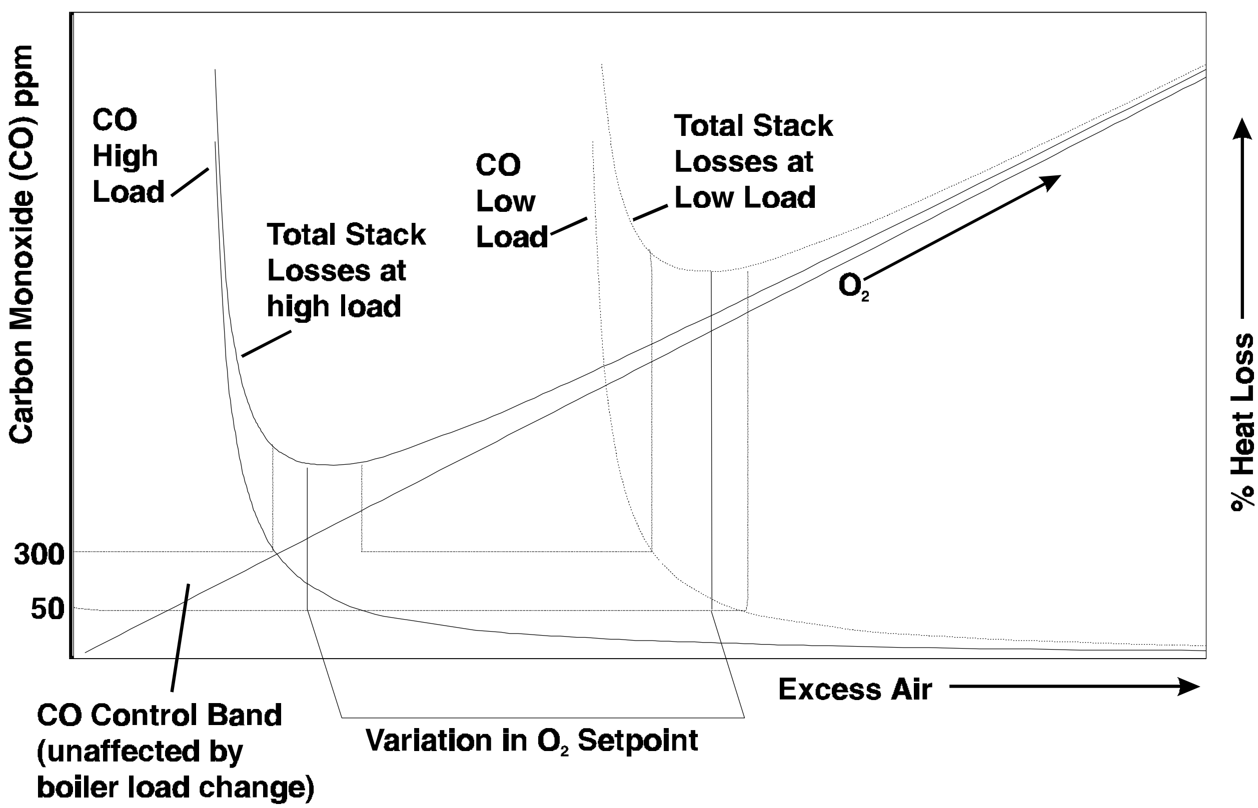


Figure 2



Continuous Emissions Monitoring Costs are Reasonable

Cost is a crucial issue in promulgating rules for smaller sources such as MWI. Based on aggregate quotes from several vendors on continuous emissions monitoring systems (CEMS) for MWI, on actual capital and maintenance costs for CEMS installed on MWI, and on information on trends in CEMS costs, the recommendations above would be affordable. Further, regulators may take simple steps to ease the monitoring costs.

Aggregate CEMS Vendor Quotes

Table 1 lists capital and annual costs for continuous opacity and emissions monitoring systems. In the table, we use an EPA framework (laid out in a memorandum from Thomas Holloway of MRI to Rick Copland dated May 20, 1996 ("Testing and Monitoring Options and Costs for MWI's -- Methodology and Assumptions"). However, in contrast to EPA's use of a cost model, ICAC's costs are based on actual, current vendor quotes, except as noted in the table.

As noted in Table 1, the total capital investment for installing a 40 CFR 60 Appendix F system for continuous monitoring of opacity, CO, and O_2 should be $82,000-$140,500. This total capital investment covers planning, equipment selection, support facilities, purchased equipment, including a PC-based data acquisition system, installation, certification, and preparation of a QA/QC plan for a system meeting Appendix F requirements (i.e., a system for compliance monitoring of CO). The total annual cost of an opacity/CO/O_2 monitoring system is $30,900-40,100.

As indicated in Table 1, the costs of continuous opacity monitoring systems, or of continuous emissions monitoring systems which do not meet Appendix F requirements (but meeting 40 CFR 60 Appendix B requirements) are comparably low. In particular, capital and annual costs for non-Appendix F CO/O_2/opacity monitoring systems are $72,000-119,500 and $19,400-26,900, respectively.

A typical total capital investment for an in situ CO/O_2 process monitoring system for ensuring complete combustion is even lower, at $26,500 (Table 2). The total annual cost of owning an operating such a system is about $6,350. These low costs should not represent an undue burden to owners/operators of even small medical waste incinerators, particularly as the process monitoring system should lower fuel and incinerator maintenance costs.

Based on quotations from two vendors, the total capital investment for adding a continuous HCl emission monitoring system to an opacity/CO/O_2 system meeting Appendix F requirements is $68,000-147,000 (Table 3). (Actual costs for a combined HCl/opacity/CO/O_2 system are likely to be lower than the sum of the costs of separate HCl and opacity/CO/O_2 systems given the possibility of using analyzers with the capability to monitor more than one gas, as well as duplication of planning and installation costs for separate systems.) The incremental total annual costs associated with this type of system are $22,000-35,000. We recognize that the Agency may be hesitant to impose these costs on any but the largest medical waste incinerators.

Simple, non-compliance CO/O_2 continuous monitoring systems are available with total installed capital costs below $27,000, and total annual operating costs, including capital recovery, below $6,500. CO/O_2 monitoring will help to minimize MWI supplemental fuel costs, thus at least partly defraying these already very reasonable monitoring costs.

Costs of Actual CEMS Installations on Medical Waste Incinerators

Actual costs should give the best indication of expected costs of CEMS for MWI. Unfortunately, limited federal and state requirements have meant that very few CEMS installed have been installed at MWI. The costs for those systems which have been installed generally do not give an accurate picture of expected costs for two reasons. First, costs have dropped significantly since many of the existing units were installed. Second, many, if not most, CEMS have been installed on MWI in Pennsylvania, and Pennsylvania monitoring requirements go beyond those contemplated by EPA, with consequent higher costs. Below, we present costs for three actual MWI CEMS, along with explanations of why these costs may not be relevant to expected future costs.

(Because of confidentiality agreements, we must keep the names of suppliers and purchasers confidential. As needed, we may be able to provide additional information to interested States.)

System A, a CO/O_2/opacity monitoring system for a medical waste incinerator in Pennsylvania, was purchased in late 1994. This system was designed to meet the requirements of the Pennsylvania Department of Environmental Resources (DER). Neglecting planning and equipment selection by the facility owner, the total capital requirement for the monitoring system was approximately $141,000 (see Table 4). Given technical advances (e.g., the use of a combined CO/O_2 analyzer rather than two separate analyzers), this system would cost at most about $131,000 today. A system which would not need to meet Pennsylvania DER requirements could use a simpler programmable logic controller-based data acquisition system (DAS) selling for perhaps $12,000, leading to a total capital requirement of less than $111,000. In fact, actual costs should be lower: while we use 1994 installation and start-up, certification, etc., costs to estimate current costs, recent actual bids for these elements have been lower.

Table 1. Capital and Annual Costs for Continuous Emissions Monitoring Systems ($1996)

Parameters	CEMS Costs: Opacity (w/o Appendix F) Low	Opacity (w/o Appendix F) High	CO, O_2 (Appendix F); Opacity (w/o Appendix F) Low	CO, O_2 (Appendix F); Opacity (w/o Appendix F) High	CO, O_2, Opacity (w/o Appendix F) Low	CO, O_2, Opacity (w/o Appendix F) High
Capital costs						
Planning[a]	500	500	2,500	2,500	2,500	2,500
Select type of equipment[a]			1,000	1,000	1,000	1,000
Provide support facilities[b]	500	500	5,000	5,000	5,000	5,000
Purchased equipment: CEM[c]	17,000	22,000	45,000	83,000	45,000	83,000
Purchased equipment: DAS[c]			11,500	27,000	7,000	11,500
Install and check CEMS[d]	2,500	2,500	7,000	10,700	7,000	10,700
Performance spec. tests (certification)[e]	1,000	2,000	4,500	5,800	4,500	5,800
Prepare QA/QC plan[d]			5,500	5,500		
Total Capital Investment	21,500	27,500	82,000	140,500	72,000	119,500
Annual costs						
Operation and maintenance[f]	1,000	1,000	6,000	6,000	6,000	6,000
Annual RATA[d]			5,200	5,200		
Quarterly CGA[d]			3,200	3,200		
Recordkeeping and reporting[g]	1,040	1,040	2,080	2,080	2,080	2,080
Annual review and update[d]			1,500	1,500		
Property taxes, insurance, admin.[h]	860	1,100	3,280	5,620	2,880	4,780
Capital recovery	2,525	3,230	9,632	16,503	8,457	14,036
Total annual cost	5,425	6,370	30,892	40,103	19,417	26,896

[a] Figures based on market rates for hiring independent consultants to perform the indicated tasks.

[b] Support facilities include ports for opacity monitors, and ports, access, and motor control centers for CO/O_2/opacity monitoring systems.

[c] High and low figures represent extremes of ranges of quotes supplied by five vendors.

[d] Cost estimates obtained from a third-party firm performing the indicated services.

[e] High and low figures represent extremes of range of quotes supplied by two vendors and a third-party firm.

[f] Costs include consumables ($500/yr for opacity, $1000/yr for CO/O_2), calibration gas ($2000/yr for CO/O_2), labor (16 hr/yr @ $20/hr for opacity, 96 hr/yr for CO/O_2).

[g] Estimated at 1 hr/wk for opacity and 2 hr/wk for CO, O_2, and opacity, given the installation of a PC-based data acquisition system designed to meet part 60 reporting requirements.

[h] We question the appropriateness of charging taxes, insurance, and administrative costs on certification and QA/QC plan preparation, but include these charges here anyway.

Table 2. Capital and Annual Costs for an In Situ CO/O_2 Continuous Emissions Monitoring System for Determining Combustion Efficiency ($1996)

Parameters	CEMS Costs
Capital costs	
Planning[a]	500
Select type of equipment[a]	1,000
Provide support facilities[b]	500
Purchased equipment: CEM[c]	22,000
Purchased equipment: DAS[d]	
Install and check CEMS[e]	2,500
Performance spec. tests (certification)[e]	
Prepare QA/QC plan[e]	
Total Capital Investment	26,500
Annual costs	
Operation and maintenance[f]	1,040
Annual RATA[e]	
Supplemental RATA[g]	
Quarterly CGA[e]	
Recordkeeping and reporting[h]	1,040
Annual review and update[e]	
Property taxes, insurance, admin.	1,060
Capital recovery	3,212
Total annual cost	6,352

[a] Figures based on market rates for hiring independent consultants to perform the indicated tasks.
[b] Support facilities include ports and access.
[c] Figures represent quotes supplied by two vendors.
[d] Because CO/O_2 CEM output typically would be plotted on an existing strip-chart recorder, no DAS would be required.
[e] Cost estimates obtained from a third-party firm performing the indicated services.
[f] Costs include labor (52 hr/yr @ $20/hr).
[g] Supplemental RATA is only a required component of part 75 monitoring, and so is inappropriate here.
[h] Estimated at 1 hr/wk.

Table 3. Capital and Annual Costs for an HCl Continuous Emissions Monitoring System Added to a Compliance (Appendix F) CO/O_2/Opacity Monitoring System ($1996)

	CEMS Costs	
Parameters	Low	High
Capital costs		
Planning[a]	2,500	2,500
Select type of equipment[a]	1,000	1,000
Provide support facilities[b]	2,000	2,000
Purchased equipment: HCl CEM[c]	45,854	114,000
Purchased equipment: DAS[d]		
Install and check CEMS[e]	7,000	7,000
Performance spec. tests (certification)[e]	7,000	7,000
Prepare QA/QC plan[e]	2,500	2,500
Total Capital Investment	67,854	136,000
Annual costs		
Operation and maintenance[f]	5,000	5,000
Annual RATA[e]	5,200	5,200
Supplemental RATA[g]		
Quarterly CGA[e]	1,200	1,200
Recordkeeping and reporting[h]		
Annual review and update[h]		
Property taxes, insurance, admin.[i]	2,714	5,440
Capital recovery	7,970	15,975
Total annual cost	22,084	32,815

[a] Figures based on market rates for hiring independent consultants to perform the indicated tasks.
[b] Support facilities are ports for HCl monitoring systems.
[c] High and low figures represent extremes of ranges of quotes supplied by two vendors.
[d] The HCl CEM would be connected to the existing DAS.
[e] Cost estimates obtained from a third-party firm performing the indicated services.
[f] Costs include consumables ($1000/yr), calibration gas ($2000/yr), and labor (96 hr/yr @ $20/hr).
[g] Supplemental RATA is only a required component of part 75 monitoring, and so is inappropriate here.
[h] Addition of an HCl CEM to an existing CO/O_2/opacity monitoring system should result in negligible incremental recordkeeping and reporting and review and update costs.
[i] We question the appropriateness of charging taxes, insurance, and administrative costs on certification and QA/QC plan preparation, but include these charges here anyway.

To investigate costs beyond purchased equipment, we obtained a copy of a third-party quote of $9,800 for CO/O_2 CEMS installation/startup/training at a boiler in the mid-Atlantic. (Costs for these services should be quite similar at medical waste incinerators.) This figure includes installation, installation hardware (heated sample line, temperature controller, calibration gases for one year, regulators, and fittings), and training. While the indicated CEMS does not include an opacity monitor, the installation/startup/training costs clearly would still be lower than EPA estimates for a continuous CO/O_2/opacity monitoring system.

Further, a third-party contractor has provided us with actual charges for annual maintenance of a CO/O_2 CEMS at a medical waste incinerator. In calendar year 1995, this charge was $4,812, and included supplies ($503.60), emergency service ($458.52), and quarterly inspections, preventive maintenance, and cylinder gas audits ($3,850).

Note that these actual costs are in the range of our quotes (see below), after allowing for planning and equipment selection. Of course, we believe that these items can be minimized through the promulgation of a detailed specification (see below).

Table 4. Actual cost of system A, a CEMS installed on a medical waste incinerator in Pennsylvania, and estimated costs of a current CEMS installation which would meet Pennsylvania or expected MACT monitoring requirements.

Item	Cost ($)		
	1994 PA DER System[a]	1996 PA DER System[b]	1996 MACT System[c]
Monitoring System (probe, 50' sample line, sample conditioning system, CO and O_2 analyzers, opacity monitor)	68,971	62,411	62,411
DAS	35,624	32,543	12,000
Installation	10,200	10,200	10,200
Certification, Training, Start Up, Documentation	15,965	15,965	15,965
Subtotal	130,760	121,119	100,576
Demolition, Spares, Piping and Wiring, Bonds, QA/QC Manual	10,238	10,238	10,238
Total Capital Investment	140,998	131,357	110,814

[a] Actual (1994) cost of a continuous CO/O_2/opacity monitoring system meeting Pennsylvania DER requirements at a medical waste incinerator.

[b] Estimated current cost of a continuous CO/O_2/opacity monitoring system meeting Pennsylvania DER requirements at a medical waste incinerator.

[c] Estimated current cost of a non-Appendix F continuous CO/O_2/opacity monitoring system at a medical waste incinerator. Assumes use of a simple programmable logic controller-based DAS.

System B, a CO/O_2/opacity monitoring system at a MWI in Ohio, was sold in 1991. This system was designed to meet Ohio EPA and Appendix F requirements, and cost $153,245. This cost included purchased equipment, field service to oversee installation and startup, training and checkout services, and certification testing by an independent testing company to meet 40 CFR 60 Appendix B requirements. Not included were planning and equipment selection, hiring of a local contractor to ensure conformity with local codes (three days at $300/day), and calibration gases and regulators.

Table 5. Actual costs of systems B and C, continuous CO and opacity monitoring systems installed on medical waste incinerators in Ohio and North Carolina, and estimated cost of an Appendix F CO/O_2/opacity monitoring system.

Item	Cost ($)[a]		
	1991 OH System[b]	1996 NC, Two Systems[c]	1996 NC, Single System[d]
Monitoring System (probe, sample conditioning system, CO analyzer, opacity monitor, strip chart recorder, cabinet, manuals)	121,745	95,000	47,500
Sample Line and Cabinet Air Conditioner	included	not included	8,360
O_2 Analyzer	included	not included	5,270
Appendix F DAS	included	not included	28,600
Field Service for Installation and Start Up	13,500	included	included
Training/Checkout Services	4,500	included	included
Subtotal	139,745	95,000	89,730

[a] Costs do not include the services of a local contractor for installation, or certification testing.

[b] Actual (1991) cost of a continuous CO/O_2/opacity monitoring system meeting Appendix F and Ohio EPA requirements at a waste incinerator.

[c] Actual (1996) cost of a continuous CO/opacity monitoring system for two collocated MWI in North Carolina.

[d] Estimated current cost of an Appendix F continuous CO/O_2/opacity monitoring system at a MWI, based on the actual cost of a CO/opacity system for two MWI in North Carolina, along with estimated costs for additional hardware.

System C included CO/opacity monitoring systems for two collocated MWI in North Carolina. When sold in September 1996, the cost of these systems was $95,000, including hardware, field service to oversee installation and startup, and training. Not included were planning and equipment selection, a local contractor for installation, certification testing, and miscellaneous equipment and supplies, such as a cabinet air conditioner, sample line, and calibration gases and regulators. Also not included were an O_2 analyzer, which was not required under the plant's operating permit. The DAS for this system was a simple strip chart recorder.

Note that the addition of dual oxygen analyzers, cabinet air conditioners, and 150 feet of sample line per MWI would bring the cost of the two systems to $122, 260, i.e., $61,130 per system. Inclusion of an Appendix F DAS would bring the cost of each system to $89,730.

Trends in CEMS and Component Costs

CEMS capital costs have fallen over the past 5-10 years because of technical innovation and increased competition. While comparing the costs of different systems is difficult because of site-specific factors and differences in scope, the trend toward lower CEMS costs is particularly clear. For example, comparing systems B and C shows a 36% decrease in the capital cost of comparable systems over five years, from $139,745 in 1991 to $89,730 in 1996. This trend is not abating: we estimate that the current cost of system A would be at least 7% less than the actual 1994 cost of $140,998.

In fact, the trend toward lower costs will accelerate somewhat as commercial single multi-gas analyzers replace the traditional multiple single-gas analyzers used in systems A, B, and C.

Current CEMS are easier to install and maintain than their forbears, and tend to be highly automated, so that operating and maintenance costs for these systems are much lower than they were during the last decade.

Minimizing CEMS Costs

Our examination of CEMS costs has convinced us that regulators can write the monitoring requirements for MWI in a way which reduces the cost of direct monitoring. First, regulators should consider whether CEMS for MWI need to meet Appendix F requirements. As is obvious from Tables 1, 2, and 3, Appendix F requirements significantly add to both capital and annual costs of CEMS ownership. The Agency should determine whether the benefit to the environment and society is greater than these incremental costs.

Second, regulators should make it easier and thus cheaper for MWI owners/ operators to purchase CEMS by spelling out monitoring requirements clearly. To the extent that monitoring requirements are unclear, owners/operators will need to spend additional time understanding these requirements, and likely will need to hire consultants or engineering firms to develop detailed specifications. Expenditures for these consultants or engineering firms will be unproductive in that they will not contribute to environmental protection.