Appendices

Appendix A
Acronyms

A&WMA	Air & Waste Management Association
BACT	Best Available Control Technology
BBS	Bulletin Board System
BIF	Boiler and Industrial Furnace
BTU	British Thermal Unit
BTX	Benzene, Toluene, Xylenes
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAM	Compliance Assurance Monitoring
CC	Confidence Coefficient
CEM	Continuous Emission Monitoring
CFR	Code of Federal Regulations
CTS	Calibration Transfer Standard
DAHS	Data Acquisition and Handling System
DAR	Data Assessment Report
DCPL	Demonstrated Compliance Parameter Limit
DCS	Distributive Control System
DEQ	Department of Environmental Quality
DER	Discrete Emission Reductions
DNPH	Dinitro phenol hydrazine
DOAS	Differential Optical Absorption Spectroscopy
DOS	Disk Operating System
DRE	Destruction and Removal Efficiencies
ECD	Electron Capture Detector
EMC	Emission Measurement Center
EMTIC	Emission Measured Technology Information Center
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERC	Emission Reduction Credit
FID	Flame Ionization Detector
FR	Federal Register
FTIR	Fourier Transform Infrared Spectroscopy
GC	Gas Chromatography
GCMS	Gas Chromatography Mass Spectrometry
HAP	Hazardous Air Pollutant
HON	Hazardous Organic NESHAP
I/O	Input/Output
IR	Infrared
ISO	International Standards Organization
LAN	Local Area Network

LTD	Long Tons Per Day
MACT	Maximum Achievable Control Technology
MARAMA	Mid-Atlantic Regional Air Management Association
NDIR	Nondispersive infrared
NDUV	Nondispersive ultraviolet
NESCAUM	North East States Consortium for Air Use Management
NESHAP	National Emission Standards for Hazardous Air Pollutants
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NSPS	New Source Performance Standards
OAQPS	Office of Air Quality Planning and Standards
O&M	Operation and Maintenance
OMT	Open Market Trading
OMTG	Open Market Trading Guidance
OMTR	Open Market Trading Rule
PEEK	Polyether ether ketone
PEM	Predictive Emission Monitoring
PID	Photoionization Detector
PLC	Programmable Logic Controller
PS	Performance Specification
PST	Performance Specification Test
QA	Quality Assurance
QC	Quality Control
RA	Relative Accuracy
RATA	Relative Accuracy Test Audit
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RECLAIM	Regional Clean Air Incentives Market
RTD	Resistance Temperature Device
RTU	Remote Terminal Unit
SCAQMD	South Coast Air Quality Management District
S/N	Signal to Noise
TC	Technical Committee
TCD	Thermal Conductivity Detector
THC	Total Hydrocarbon
TÜV	Technische Uberwachung Verein
TRS	Total Reduced Sulfur
TTN	Technology Transfer Network
USEPA	United States Environmental Protection Agency
UV	Ultra-violet
VDI	Verein Deutscher Ingenieur
VOC	Volatile Organic Compound
WAN	Wide Area Network
WG	Working Group
WTE	Waste To Energy

Appendix B
Glossary

Accuracy - The closeness of the measurement made by a continuous emission monitoring system, a pollutant concentration monitor or a flow monitor, to the true value of the emissions or volumetric flow. It is expressed as the difference between the measurement and a reference method value, which is assumed to be equivalent to the true value. Variation among these differences represents the variation in accuracy that could be caused by random and/or systematic error.

Analyte - A compound or set of compounds that are to be measured by an analytical method.

Analyze - To conduct a measurement and arrive at a specific result or set of results.

Analyzer - An instrument that is capable of performing the measurement of the compounds of interest and generating an output proportioned to the concentration of the analyte.

Acid Gas - A gas comprised of compounds such as SO_2, HCl, or H_2SO_4 that is corrosive in nature and that can be difficult to sample.

Bias - Systematic error. The result of bias is that measurements will be either consistently low or high, relative to the true value.

Blowback - A procedure conducted periodically by some extractive sampling systems during which compressed air is blown out of the sample probe to remove accumulated particulate matter from the probe tip.

Calibration - The procedure for adjusting the output of a device to bring it to a desired value (within a specified tolerance) for a particular value of input (typically the value of the reference standard).

Calibration check - The procedure of testing a device against a known reference standard.

Calibration Drift - The difference between 1) the response of a gaseous monitor to a calibration gas or standard and the known concentration of the gas or standard, or 2) the response of a flow monitor to a reference signal and the expected value of the reference signal, or 3) the response of a continuous opacity monitoring system to an attenuation filter and the previously determined value of the filter after a stated period of operation during which no unscheduled maintenance, repair, or adjustment took place.

Calibration Gas - A gas of known concentration that is traceable to either a standard reference material gas or a National Institute of Standards and Technology or whose concentration is established by an analytical method, on a manufacturer's certification.

Calibration Gas Cell or a Filter - a device that, when inserted between the transmitter and detector of the analyzer, produces a desired output level on the data recorder.

Chemiluminescence - Loss of energy by a chemically excited molecule that results in emission of electromagnetic radiation at a particular wavelength. The energy of the radiation is indicative of the amount and type of species that luminesce.

Chillers - See condenser systems.

Close-coupled - An extractive CEM system that is installed at the sampling location.

Condensate - The resultant water and water soluble compounds that are removed from a flue gas sample by condenser systems.

Condenser Systems - A system designed to physically remove the moisture from the flue gas sample stream by cooling before introduction into an analyzer.

Condensible Gas - A gas that has chemical and physical properties that allow it to change from a gas to a liquid in sampling systems before analysis.

Continuous Emission Monitoring System - The equipment used to analyze, measure, and provide, on a continuous basis, a record of flue gas emissions.

Corrective Action Codes - Entered by the data acquisitions system operator to describe actions taken to correct CEM fault conditions or emission exceedances.

Data Acquisition and Handling System (DAHS) - A system of hardware and software that is used to collect and store emissions data from gas analzyers and to produce summary reports. For regulatory purposes, the DAHS is considered to be an integral part of the CEM system.

Data Acquisition System - One or more devices used to receive, compute, store, and report CEM system measurement data from single or multiple measurement devices.

Data Assessment Report (DAR) - For a CEM system subject to 40 CFR 60, Appendix F, quality assurance requirements, the DAR is a quarterly report which includes all accuracy audit results, reasons for downtime, and corrective actions.

Data Availability - A statistic used to indicate the percentage of plant operating time for which valid CEM system data are available. Some monitoring regulations or permit conditions have minimum data availability requirements for each quarter of the year.

Data Flags - A code that the data acquisition system associates with each data point to identify whether the data point is valid, invalid, or questionable. Data flags are used to determine which data points are included in emission averages.

Data Logger - A simple digital data recorder that can be used to convert gas analyzer output signals to concentrations and emission rates and to calculate averages. Emission results may be printed real-time or stored in memory for later retrieval by computer.

Data Recorder - A device capable of providing a permanent record of data.

Desulfurization - Removal of sulfurous compounds in stack emissions. Often accomplished at utility boilers by use of lime/limestone scrubbers.

DeNox - Removal of oxides of nitrogen from flue gas using selective catalytic reduction (SCR) or non-selection catalytic reduction (non-SCR).

Detector - The device used to sense an analyte in a monitoring system.

Detection Limit - The lower level of quantification achievable by a particular measurement.

Diffusion - The transport of a liquid or gaseous substance through a solid material.

Diluent Gas - A major gaseous constituent in a gaseous pollutant mixture. For combustion sources, carbon dioxide, nitrogen, and oxygen are the major diluent gases.

Direct Calibration - Introduction of the calibration gas directly to an analyzer without passing it through the sampling system.

Distributed Control System (DCS) - A type of computer system used in plant environments for process control. It relies on a system of independent processors that are linked to a central computer.

Drift - Change in analyzer output, over a period of time, that is unrelated to input or equipment adjustments.

Dual Range System - A pollutant concentration monitor that has two distinct ranges of values over which measurements are made.

Emission Standard - The maximum emission level, in specified units, and averaging period allowed by an environmental regulation.

Extractive System - A monitoring system that withdraws a gas sample from the stack and transports the sample to the analyzer.

Flow Monitor - A stand alone monitor, or a component of the continuous emission monitoring system that generates an output proportional to the volumetric flow of exhaust gas.

Hazardous Air Pollutants (HAPs) - Specific pollutants and groups of pollutants listed in Title III of the 1990 Clean Air Act Amendments. (See Appendix D of this handbook.)

Hydrocarbons - Compounds composed of carbon and hydrogen.

In-situ Monitor - A monitor that senses the gas concentration, particulate concentration, opacity, or velocity in the flue gas and does not extract a sample for analysis.

Interference Rejection - The ability of a CEM system to measure a gaseous species, within specified limits, without responding to other gases or substances present in the flue gas.

Invalid Data - Data that were generated while the measurement device(s) was out-of-control.

Linearity - The degree to which a CEM system exhibits a straight line (first order) response to changes in concentration (or other monitored value), over the range of the system.

Lower Detection Limit - The minimum value that a device can measure.

Mass Flow Meter/Controller - A device that is used to measure precisely known volumes for flow rates of gas.

Measurement Cell - The chamber where a gas sample is subject to analysis.

Opacity - The degree to which a flue gas stream reduces the transmission of visible light or obscures the visibility of an object in the background.

Path Continuous Emission Monitoring System - A continuous emission monitoring system that measures the pollutant concentration along a path greater than 10% of the equivalent diameter of the stack or duct cross section.

Point Continuous Emission Monitoring System - A continuous emission monitoring system that measures the pollutant concentration either at a single point or along a path equal to or less than 10% of the equivalent diameter of the stack or duct cross section.

Parts Per Million (ppm) - One part in one million total parts ($1x10^{-6}$).

Parts Per Billion (ppb) - One part in one billion total parts ($1x10^{-9}$).

Path Length - The distance a light beam travels through the a sample gas before reaching the detector.

PEEK™ - A tubing (poly ether ether ketone) substance manufactured to be inert relative to chemical adsorption.

Permeation - Diffusion of a gaseous substance through a solid material.

Precision - The closeness of a measurement to the actual measured value expressed as the uncertainty associated with repeated measurements of the same sample or of different samples from the same process (e.g., the random error associated with simultaneous measurements of a process made by more than one instrument). A measurement technique is determined to have increasing precision as the variation among the repeated measurements decreases.

Programmable Logic Controller (PLC) - An electronic device that can be used to automatically control sampling and calibration cycles and alarm condition responses in a CEM system.

Reason Codes - Entered by the data acquisition system operator at the time of a CEM malfunction or process upset, they are used to describe the reasons for invalid data or emission limit exceedances.

Reference Spectra - Spectra that have been acquired under specific conditions and stored for later use.

Reference value - The known concentration of a verification standard or calibration gas or the known value of a reference thermometer or output value of a temperature, pressure, current or voltage calibrator.

Relative Accuracy - The absolute mean difference between the gas concentration or emission rate determined by a CEM system and the value determined by an appropriate reference method plus the 2.5 percent error confidence coefficient of a series of tests, divided by the mean of the reference method tests. The relative accuracy provides a measure of the systematic and random errors associated with data from a continuous emission monitoring systems.

Remote Terminal Unit (RTU) - An electronic device that is used to periodically report emissions data to the control agency by telephone modem.

Response Time - The amount of time required for the continuous emission monitoring system to display on the data recorder, 95% of a step change in pollutant concentration. This period includes the time from when the sample is first extracted from the stack (if any extractive system is used) to when the concentration is recorded.

Span Gas - A high range calibration gas.

Span - The algebraic difference between the upper and lower range values of the monitoring system or analyzer.

Standard Reference Material - A reference material distributed and certified by the National Institute of Standards and Technology (NIST).

System Calibration - A calibration procedure that directs gas through the entire sampling system.

Stripchart Recorder - A device for recording data in graphical form on a continuous chart.

Test Method - Any method of sampling and analyzing for a substance or determining the flow rate as specified in the applicable regulations.

VEO (Visible Emission Observation) - A measurement of the opacity of a plume by a trained human observer in accordance with EPA Method 9.

Volatility - The degree to which any compound is a gas at specific temperature and pressure conditions.

Appendix C
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Appendix D
Hazardous Air Pollutants 1990 CAAA Title III Listing

CAS NUMBER	CHEMICAL NAME
75070	Acetaldehyde
60355	Acetamide
75058	Acetonitrile
98862	Acetophenone
53963	2-Acetylaminofluorene
107028	Acrolein
79061	Acrylamide
79107	Acrylic Acid
107131	Acrylonitrile
107051	Alyl Chloride
92671	4-Aminobiphenyl
62533	Aniline
90040	o-Anisidine
1332214	Asbestos
71432	Benzene (including benzene from gasoline)
92875	Benzidine
98077	Benzotrichloride
100447	Benzyl chloride
92524	Biphenyl
117817	Bis(2-ethylhexyl)phthalate(DEHP)
542881	Bis(chloromethyl)ether
75252	Bromoform
106990	1,3-Butadiene
156627	Calcium cyanamide
105602	Caprolactam
133062	Captan

CAS NUMBER	CHEMICAL NAME
63252	Carbaryl
75150	Carbon disulfide
56235	Carbon tetrachloride
463581	Carbonyl sulfide
120809	Catechol
133904	Chloramben
57749	Chlordane
7782505	Chlorine
79118	Chloroacetic acid
532274	2-Chloroacetophenone
108907	Chlorobenzene
510156	Chlorobenzilate
67663	Chloroform
107302	Chloromethyl methyl ether
126998	Chloroprene
1319773	Cresols/Cresylic acid (isomers and mixture)
95487	o-Cresol
108394	m-Cresol
106445	p-Cresol
98828	Cumene
94757	2,4-D, salts and esters
3547044	DDE
334883	Diazomethane
132649	Dibenzofurans
96128	1,2-Dibromo-3-chloropropane
84742	Dibutylphthalate
106467	1,4-Dichlorobenzene(p)
91941	3,3-Dichlorobenzidene
111444	Dichloroethyl ether (Bis(2-chloroethyl)ether
542756	1,3-Dichloropropene

CAS NUMBER	CHEMICAL NAME
62737	Dichlorvos
111422	Diethanolamine
121697	N,N-Diethyl aniline (N,N-Dimethylaniline)
64675	Diethyl sulfate
119904	3,3-Dimethoxybenzidine
60117	Dimethyl aminoazobenzene
119937	3,3'-Dimethoxybenzidine
79447	Dimethyl carbamoyl chloride
68122	Dimethyl formamide
57147	1,1-Dimethyl hydrazine
131113	Dimethyl phthalate
77781	Dimethyl sulfate
534521	4,6-Dinitro-o-cresol, and salts
51285	2,4-Dinitrophenol
121142	2,4-Dinitrotoluene
123911	1,4-Dioxane (1,4-Diethyleneoxide)
122667	1,2-Diphenylhydrazine
106898	Epichlorohydrin (1-Chloro-2,3-epoxypropane)
106887	1,2-Epoxybutane
140885	Ethyl acrylate
100414	Ethyl benzene
51796	Ethyl carbamate (Urethane)
75003	Ethyl chloride (Chloroethane)
106934	Ethylene dibromide (Dibromoethane)
107062	Ethylene dichloride (1,2-Dichloroethane)
107211	Ethylene glycol
151564	Ethylene imine (Aziridine)
75218	Ethylene oxide
96457	Ethylene thiourea
75343	Ethylidene dichloride (1,1-Dichloroethane)

CAS NUMBER	CHEMICAL NAME
50000	Formaldehyde
76448	Heptachlor
118741	Hexachlorobenzene
87683	Hexachlorobutadiene
77474	Hexachlorocyclopentadiene
67721	Hexachloroethane
822060	Hexamethylene-1,6-diisocyanate
680319	Hexamethylphosphoramide
110543	Hexane
302012	Hydrazine
7647010	Hydrochloric acid
7664393	Hydrogen fluoride (Hydrofluoric acid)
123319	Hydroquinone
78591	Isophorone
58899	Lindane (all iosmers)
108316	Maleic anhydride
67561	Methanol
72435	Methoxychlor
74839	Methyl bromide (Bromomethane)
74873	Methyl chloride (Chloromethane)
71556	Methyl chloroform (1,1,1-Trichloroethane)
78933	Methyl ethyl ketone (2-Butanone)
60344	Methyl hydrazine
74884	Methyl iodide (Iodomethane)
108101	Methyl isobutyl ketone (Hexone)
624839	Methyl isocyanate
80626	Methyl methacrylate
1634044	Methyl tert butyl ether
101144	4,4-Methylene bis (2-chloroaniline)
75092	Methylene chloride (Dichloromethane)

CAS NUMBER	CHEMICAL NAME
101688	Methylene diphenyl diisocyanate (MDI)
101779	4,4-Methylenedianiline
91203	Naphthalene
98953	Nitrobenzene
92933	4-Nitrobiphenyl
100027	4-Nitrophenol
79469	2-Nitropropane
684935	N-Nitroso-N-methylurea
62759	N-Nitrosodimethylamine
59892	N-Nitrosomorphloline
56382	Parathion
82688	Pentachloronitrobenzene (Quintobenzene)
87865	Pentachlorophenol
108952	Phenol
106503	p-Phenylenediamine
75445	Phosgene
7803512	Phosphine
7723140	Phosphorus
85449	Phthalic anhydride
1336363	Polychlorinated biphenyls (Aroclors)
1120714	1,3-Propane sultone
57578	beta-Propiolactone
123386	Propionaldehyde
114261	Propoxur (Baygon)
78875	Propylene dichloride (1,2-Dichloropropane)
75569	Propylene oxide
75558	1,2-Propylenimine (2-Methyl aziridine)
91225	Quinoline
106514	Quinone
100425	Styrene

CAS NUMBER	CHEMICAL NAME
96093	Styrene oxide
1746016	2,3,7,8-Tetrachlorodibenzo-p-dioxin
79345	1,1,2,2-Tetrachloroethane
127184	Tetrachloroethylene (Perchloroethylene)
7550450	Titanium tetrachloride
108883	Toluene
95807	2,4-Toluene diamine
584849	2,4-Toluene diisocyanate
95534	o-Toluidine
8001352	Toxaphene (chlorinated camphene)
120821	1,2,4-Trichlorobenzene
79005	1,1,2-Trichloroethane
79016	Trichloroethylene
95954	2,4,5-Trichlorophenol
88062	2,4,6-Trichlorophenol
121448	Triethylamine
1582098	Trifluralin
540841	2,2,4-Trimethylpentane
108054	Vinyl acetate
593602	Vinyl bromide
75014	Vinyl chloride
75354	Vinylidene chloride (1,1-Dichloroethylene)
1330207	Xylenes (isomers and mixture)
95476	o-Xylenes
108383	m-Xylenes
106423	p-Xylenes
0	Antimony Compounds
0	Arsenic Compounds (inorganic including arsine)
0	Beryllium Compounds
0	Cadmium Compounds

CAS NUMBER	CHEMICAL NAME
0	Chromium Compounds
0	Cobalt Compounds
0	Coke Oven Emissions
0	Cyanide Compounds[1]
0	Glycol ethers[2]
0	Lead Compounds
0	Manganese Compounds
0	Mercury Compounds
0	Fine mineral fibers[3]
0	Nickel Compounds
0	Polycylic Organic Matter[4]
0	Radionuclides (including radon)[5]
0	Selenium Compounds

NOTE: For all listings above which contain the word "compounds" and for glycol ethers, the following applies: Unless otherwise specified, these listings are defined as including any unique chemical substance that contains the named chemical (i.e., antimony, arsenic, etc.) as part of that chemical's infrastructure.

[1] X'CN where X = H' or any other group where a formal disocciation may occur. For example KCN or $CA(CN)_2$

[2] includes mono- and di-ethers of ethylene glycol, diethylene glycol, and triethylene glycol $R\text{-}(OCH_2CH_2)_n\text{-}OR$. Polymers are excluded from the glycol category.

[3] includes mineral fiber emissions from facilities manufacturing or processing glass, rock, or slag fibers (or other mineral derived fibers) of average diameter 1 micrometer or less.

[4] includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100°C.

[5] a type of atom which spontaneously undergoes radioactive decay.

Appendix E
Units of the Standard

Regulations can impose design constraints on a CEM system through the form in which an emissions standard is expressed. Different types of standards have been used by environmental control agencies for a variety of purposes. In these regulations, emissions have been required to be expressed in the following forms:

A. Concentration when expressed in mg/m^3, corrected to standard conditions (20°C, 101.325 kpa)

B. Wet-basis concentration (ppm, mg/m^3) corrected to dry conditions

C. Concentration (ppm, mg/m^3) corrected to 12% (or other percentage) CO_2

D. Concentration (ppm, mg/m^3) corrected to 6% (or other percentage) O_2

E. Mass emission rate (kg/hr, tons/yr)

F. Mass emission rate (thermal) (ng/Joule)

G. Process weight rate (kg/ton of product produced)

H. Control device efficiency (%)

Calculating emissions in any of these forms implies that specific types of instruments or parameters are to be monitored. A control device efficiency requirement implies that measurements must be made both upstream and downstream from the control device. The basic calculations and their implications follow:

A. Concentration when expressed in mg/m^3 corrected to standard conditions (20°C, 101.325 kpa)

$$\overline{C}_{s_{corr}} = C_s \frac{P_{std} T_s}{P_s T_{std}}$$

This calculation is necessary when reporting particulate, metal, or other concentrations in units of mg/m^3 corrected to standard conditions. It implies that both temperature and pressure measurements be made. Note that by applying this correction only, emissions will be expressed on a wet basis. A wet basis calculation can be used to calculate a pollutant mass rate.

B. Concentration (ppm, mg/m^3) corrected to dry conditions

$$\bar{c}_{sd} = \bar{c}_{sw} (1 - B_{ws})$$

When a concentration standard is to be used alone, without subsequently calculating a pollutant mass rate, results typically are required to be expressed on a dry basis. In this case, the flue gas temperature, pressure, and moisture content must be known. For wet-basis monitoring systems such as in-situ systems, in-stack dilution systems, out-of-stack/non-dry dilution systems, and hot-wet source level extractive systems, the moisture content then must be measured, or in the case of stable processes, often is assumed to have a constant value, based on stack test data. For dry-basis source level extractive systems, pollutant gases are measured on a dry basis and a moisture determination is not necessary.

C. Concentration (ppm, mg/m^3) corrected to 6% (or other percentage) O_2

$$\bar{c}_{s_{6\% O_2}} = \frac{\bar{c}_s (20.9 - 6.0)}{20.9 - \% O_2}$$

The expressions given in A and B do not correct for the effects of dilution air. Dilution air corrections are almost always required so that emission's requirements can be normalized between sources. Since dilution air is usually ambient air, the percent oxygen concentration or percent CO_2 concentration is measured to perform the correction.

D. Concentration (ppm, mg/m^3) corrected to 12% (or other percentage) CO_2

$$\bar{c}_{s12} = \bar{c}_s \frac{12}{\% CO_2}$$

This expression gives the dilution air correction in terms of percent CO_2 and requires the use of a CO_2 monitor.

E. Mass emission rate (kg/hr, tons/yr)

$$pmr = c_{sw} Q_{sw}$$

Mass emission rate standards in units of kg/hr or tons/yr are useful because they give directly the pollutant burden to the atmosphere. Calculating a mass emission rate requires either that a flow monitor be installed or that the volumetric flow rate be calculated in some manner from operational parameters. Since flow is always monitored on a wet basis, concentration also must be be determined on a wet basis. Therefore, in-situ dilution or hot-wet source level extractive systems are appropriate for this type of standard. A cool-dry system can be used if moisture is monitored to correct the data back to wet conditions.

F. Mass emission rate (thermal) (ng/Joule)

$$E = \overline{c}_s F_d \frac{20.9}{20.9 - \%O_2} \qquad E = \overline{c}_s F_c \frac{100}{\%CO_2}$$

$$E = c_{sw} F_w \frac{20.9}{20.9(1 - B_{wa}) - \%O_{2w}}$$

$$E = c_{ws} F_d \frac{20.9}{20.9(1 - B_{ws}) - \%O_{2w}}$$

Electric utilities and industrial boilers combusting carbonaceous fuels usually are required to express emissions in terms of mass per unit heat input. These calculations are performed by using the procedures of EPA Method 19, the F-factor methods, which require the measurement of either oxygen or CO_2 to correct for dilution. A number of monitoring options are available using the F factors. If the F_c factor is used, either a wet or dry system can be used provided that both the pollutant and CO_2 are measured on the same basis. If the F_d factor is used, the pollutant and oxygen concentration measurements must be made on a dry basis. If the pollutant and oxygen are measured on a wet basis, the "wet" F factor can be used if the control system does not employ a wet scrubber. After wet scrubbers, the moisture content must be measured.

G. Process weight rate (kg/ton of product produced)

$$PWR = \frac{pmr}{p}$$

Process weight rate standards are based upon the amount of product produced from the process industries. The first of these types of standards were established in the NSPS nitric acid and sulfuric acid plant and petroleum refinery requirements. The method requires accounting for the mass of the pollutant emitted and accounting for the amount of product produced that is associated with the emissions. This, in general, requires the measurement of the mass emission rate as in E, above, and a determination of the production rate, p. For some industries, such as certain types of sulfuric acid plants, alternative calculation methods based on process parameter measurements have been developed.

H. Control device efficiency (%)

$$\%\ Efficiency = \frac{\overline{C}_{s(in)_{corr}} - \overline{C}_{s(out)_{corr}}}{\overline{C}_{s(in)_{corr}}} 100$$

Removal efficiency is required to be reported in some standards. This requires the use of two CEM systems or one time-shared system measuring or extracting sample gas both upstream and downstream from the control device. If a time-shared system is used, with one bank of analyzers, multi-ranging analyzers may be required because of the difference in concentration between the uncontrolled and controlled flue gas stream. Concentration measurements are corrected for variations in diluent gas concentrations (or expressed as thermal mass emission rates) prior to calculating the control device efficiency.

The monitoring requirements of A-H above are summarized in Table E-1.

TABLE E-1. Monitoring Requirements Based upon Conditions of the Units of the Emissions Standard

Eq.	Gases Monitored		Parameters Monitored
A	Pollutant		P, T
B	Pollutant	H_2O or none	
C	Pollutant	O_2	
D	Pollutant	CO_2	
E	Pollutant	None or H_2O	Flow
F	Pollutant	O_2 or CO_2, possibly H_2O	
G	Pollutant		Flow, Production Rate, Parameters
H	Pollutant (Inlet & Outlet)	O_2 or CO_2 (Inlet & Outlet)	

Symbols:

$\bar{c}_{scorr}$	=	average stack concentration in mg/m^3 corrected to standard conditions
c_s	=	uncorrected concentration
P_{std}	=	standard pressure (101.325 kpa)
T_{std}	=	standard temperature (20°C, 493°K)
T_s	=	stack temperature (°K, °R)
P_s	=	stack pressure (kpa)
$\bar{c}_{sd}$	=	average, dry concentration
$\bar{c}_{sw}$	=	average, wet concentration
B_{ws}	=	moisture fraction
$\bar{c}_{s6\%02}$	=	average stack concentration corrected to 6% O_2
20.9	=	percentage of O_2 in ambient air
$\bar{c}_{s12}$	=	average stack concentration corrected to 12% CO_2
pmr	=	pollutant mass rate
Q_{sw}	=	wet, flue gas volumetric flow rate
F_d	=	dry F factor
F_c	=	F factor for CO_2
F_w	=	wet F factor
B_{wa}	=	moisture fraction in ambient air
PWR	=	process weight rate (Kg, lbs/tonne, ton product produced, for example)
p	=	production rate (units/ton, tonnes/hr, for example)
$\bar{C}_{s(in)corr}$	=	average concentration, corrected for dilution, in gas entering control device
$\bar{C}_{s(out)corr}$	=	average concentration, corrected for dilution, in gas leaving control device
E	=	thermal mass emission rate (ng/J, lbs/MMBtu)

APPENDIX F Guide for Evaluating CEM System Costs

Table F-1. CEM System Cost Elements Checklist

1. Design/planning of the CEM system program - This element includes the identification of all applicable regulations (e.g., standards, monitoring requirements, location requirements, testing and QA requirements, reporting and recordkeeping requirements) and source-specific constraints (i.e., tentative sampling locations, physical installation constraints, effluent conditions, environmental conditions, personnel constraints, etc.). It may also include some amount of training, formal or otherwise, for the person(s) responsible for the design of the system.

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
A. Familiarization with regulations (read, research...)					
B. Resolution of regulatory questions (calls, letters, meetings, etc.)					
C. Source-specific constraints					
1. Review drawings/plans					
2. Inspect source (inspect similar facility if source not yet built)					
3. Identify physical installation constraints, evaluate existing utilities (electricity, air)					
4. Estimate effluent conditions and parameters (based on stack test report reviews, measurements, and/or engineering judgment, etc.)					
5. Estimate environmental conditions					
6. Evaluate personnel constraints (interview process operators, instrument tech., supervisory personnel, and corporate representatives to determine availability, expertise, previous experience, and opinions/bias)					
7. Summarize results of 1.-6. in written form					
D. Training for person(s) responsible for design/planning of the CEM system					

Table F-1. Continued

2. Selection of CEM system equipment - This element includes deciding between component purchases versus system purchases and deciding about support alternatives (i.e., vendor maintenance agreements, emergency repair services, need for instrument training, availability of spare parts, etc.) It also includes the effort and cost associated with a) investigating monitoring technologies and available equipment options, b) developing equipment specifications, c) identifying and selecting potential vendors, d) developing an RFP and performance guarantees, e) evaluating proposals, and f) negotiating and executing a contract with the successful bidder(s).

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
A. Decide on basic approach (general approach, type of monitoring system, components vs. system purchase, level of vendor support, etc.)					
B. Develop written equipment specifications					
C. Identify potential bidders (call other sources, go to trade shows, read journal articles and trade magazines, call consultants, rely on previous experience)					
D. Develop RFP and performance guarantees (Define the monitoring program in terms of the applicable regulations, source specific constraints, as well as the performance specifications and guarantees that are needed. This must be done in accordance with the purchasing practices of the buyer and may also include legal, insurance, performance bonds, and other terms and conditions)					
E. Compile and send out RFP					
F. Conduct bidders meeting and response to questions raised by the bidders					
G. Bidder presentations (some companies allow or require that all or selected bidders make an on-site presentation of their proposal)					

Table F-1. Continued

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
H. Evaluate proposals and select a winner					
I. Negotiate details of the contract, draft and execute the agreement					
J. Administrative costs associated with implementing the contract					

3. Purchase of Capital Equipment - This element should reflect the actual cost associated with the CEM system and would include all components, calibration materials, and support utilities. Technical and administrative time associated with the purchase activity should also be included.

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
A. Pollutant and diluent analyzers					
B. Monitor remote control units and junction boxes					
C. Sample acquisition, sample conditioning, and sample transport equipment for extractive CEM systems					
D. Sample interface equipment (i.e., air purge blowers, filters, etc.) for in situ CEM systems					
E. Signal cables, communications, alarms, etc.					
F. DAHS computers, software, chart recorders, remote readouts, etc.					
G. Support utilities, electrical power conditioners, isolation transformers, lightening protection, compressed air supply, instrument air, air clean-up systems, etc.					
H. Evaluate proposals and select a winner					

Table F-1. Continued

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
I. Negotiate details of the contract, draft and execute the agreement					
J. Administrative costs associated with implementing the contract					

4. CEM System Installation - This element should include costs for a) stratification tests, if necessary (see text), b) agency approval of the monitoring location, if required, c) installation of sample acquisition/conditioning equipment, sample transport lines, analyzers, monitor control units, calibration gases and related equipment, and data handling/recording equipment, d) installation of sampling ports and utilities as well as ladders, platforms and other access to both the monitoring location and the manual testing location, and e) construction of protective shelters and safety equipment.

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
A. Submit proposed monitor locations to the control agency					
B. Discuss agency response					
C. Conduct stratification test if necessary					
1. Assemble equipment or hire testing firm					
2. Travel to source and return					
3. Perform test and reduce data					
4. Write report and letter to the agency					
5. Determine agency's response					
D. Determine alternate monitoring location, if necessary					
E. Install monitor and manual testing ports					

Table F-1. Continued

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
F. Install necessary support utilities (electricity, compressed air, communications, etc.)					
G. Design and erect protective shelters for monitor components and/or manual sampling					
H. Design and install necessary scaffolding and access (i.e., ladders, elevators etc.) for both monitor and manual sampling locations					
I . Receive and check out monitoring equipment from vendor(s)					
J. Supervise and inspect vendor, or install sample probes, sample acquisition equipment, sample lines, analyzers, monitor control units, calibration gases/manifolds, and DAHS					

5. Start-up and Performance Testing - This element should include the costs for start-up and debugging of the system, on-site training, preliminary testing, arrangements for the performance specification test (PST) (e.g., selecting a contractor, pretest meeting, development and submission of a protocol to the agency, safety requirements, etc.) and the actual PST cost including preparation of a test report.

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
A. Observe start-up					
B. On-site training					
C. Debugging and problem resolution during first few weeks					
D. Select contractor for RA test or entire performance specification test					

Table F-1. Continued

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
E. Travel and attend pretest meeting with testing contractor and agency, if necessary					
F. Develop and submit test protocol to agency, if necessary					
G. Notify agency of test dates					
H. Travel and contractor travel for PST					
I. Preliminary testing as necessary					
J. Conduct RA test (source and contractor expenses)					
K. Source personnel conduct drift test and forward data to contractor (assumption)					
L. Contractor prepares report, source reviews report, and submits to agency (assumption)					
M. Allowance to represent likelihood of test postponement					
N. Allowance to represent likelihood of PST failure and subsequent repeat tests					

6. Operation and Maintenance - At a minimum, this element should include the costs associated with performing the manufacturer's recommended maintenance activities. It should also include the costs associated with expected use of spare parts, maintenance of a parts inventory, emergency repair service, etc. Furthermore, this element would include the cost of performing daily zero and upscale calibration checks of the CEM system (including the costs of calibration gases or materials).

Table F-1. Continued

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
A. Spare parts inventory (capital cost plus interest)					
B. Administrative effort to maintain parts and supply inventory					
C. Effort to perform manufacturer's recommended maintenance activities					
D. Daily calibration checks (time to review calibration data and adjust the CEM system if necessary; calibration gas costs)					
E. Corrective action and emergency repair service, if not included in QA costs					

7. Quality Assurance - The costs for this element depend on the applicable requirements. For this example, we assume that requirements similar to 40 CFR 60, Appendix F, Procedure 1 would apply. To estimate these costs accurately, some frequency of failure to meet QA criteria must be assumed. It may be appropriate to estimate costs for participation in, or observation of, agency inspections or audits of the monitoring program.

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
A. Development of QA/QC Plan					
B. Annual and/or quarterly accuracy audits					
C. Daily precision checks					
D. Corrective action for malfunctioning monitors					
E. Agency Inspections or Audits					

Table F-1. Continued

8. Recordkeeping and Reporting Costs - This element should include the costs associated with the preparation of the required periodic reports describing both emissions problems and monitoring problems/events and data quality reports. It should also include the costs associated with maintenance of the records necessary to generate these reports and other records which are required to be maintained on-site for agency inspection. Most companies will have to maintain additional records in accordance with their own internal procedures to substantiate labor and capital expenditures as well as contracts with other involved parties.

ACTIVITY	LABOR HOURS (PM, TECH. MGT, ADM)	LABOR COST	SUB-CONTRACTS	OTHER DIRECT COSTS	TOTAL COSTS
A. Compilation of CEM system QA Data - (daily and periodic checks, work requests, corrective action records, preventive maintenance records, monitor logs, audit/test reports, etc.)					
B. Back-up procedure for computer files and magnetic media					
C. Implementation of emissions and monitor record keeping and retrieval system					
D. Preparation of draft periodic reports					
1. Confirm unit and CEM system on-line/off-line periods					
2. Review DAHS alarms for effect on data quality					
3. Confirm or resolve issues or reason/corrective action codes					
4. Review emissions data for consistency with known performance					
5. Prepared edited emission summaries					
6. Prepared Data Assessment Report					
E. Internal review of draft report					
F. Revision and submission of report to agency					

Table F-1. Continued

9. Response Plan and Other Action - Sources will need to develop a plan for responding to emissions problems and CEM malfunctions. The costs for developing such a plan and responding to problems obviously will depend on the specific requirements and how the regulations are written and enforced. Costs may also be incurred in responding to agency questions or other follow-up actions. Guidance for estimating these costs is not provided here.

Table F-2. Summary of CEM System Cost Elements

ACTIVITY	ESTIMATED COST
1. Design/planning of the CEM System Program	
2. Selection of CEM System Equipment	
3. Purchase of Capital Equipment	
4. CEM System Installation	
5. Start-up and Performance Testing	
Subtotal Initial Costs	
6. Operation and Maintenance	
7. Quality Assurance	
8. Recordkeeping and Reporting Costs	
9. Response Plan and Other Action	
Subtotal Recurring Costs	
TOTAL Lifetime Costs	

Appendix G
Effects of Sample Matrix on Analyte Spike

Spiking the target analytes/surrogates into a flue gas matrix and calculating the recoveries can be challenging and can be influenced by experimental noise. To calculate the recovery of the analyte spikes, one must know the concentration of the target or surrogate compounds in the flue gas and whether these concentrations fluctuate with time. Calculating the recovery of the spiked analytes requires accurate knowledge of: 1) the flow rate of the spike gas, 2) the total sample flow rate (spike plus flue gas sample), 3) the concentration of the target/surrogate in the flue gas, and 4) the extent to which the concentrations vary with time. When flue gas concentrations vary significantly with time, an accurate calculation of the spike recovery may not be possible. A graphical representation of the effects of concentration variations on an analyte spiking experiment is given in Figure G-1.

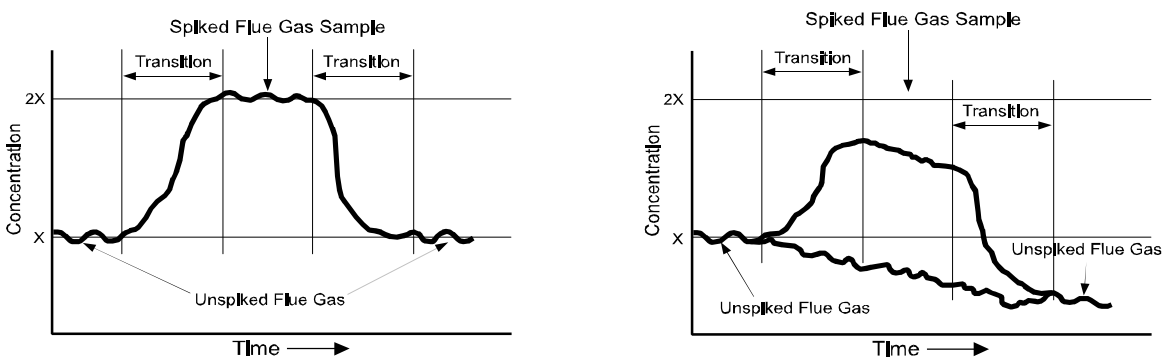

Figure G-1. Effects of concentration variations on analyte spiking experiments.

An ideal analyte spike concentration is one that approximates twice the flue gas concentration so that the spike most closely approximates the flue gas concentration. This may be difficult to accomplish without prior knowledge of the actual flue gas analyte concentrations. In practice, the spike concentration is constrained both by the available range of calibration standards and by the desire to limit the spike flow rate to less than 10 percent of the total sample flow rate so that sample matrix effects are not obscured by excessive dilution of the sample gas. In some cases, high level calibration standards may be diluted quantitatively with nitrogen to obtain spike gases that approximate the ideal analyte spike concentration.

Analyte Spike Calculations

The percent recovery (%R) of the spiked analytes are calculated as:

$$\%R = (S_m/C_e) \times 100 \qquad \text{Equation G-1}$$

Where:

S_m = Mean concentration of the analyte spiked flue gas samples (observed)

C_e = Expected concentration of the spiked samples (theoretical)

The expected concentration (C_e) of the spiked samples are calculated as:

$$C_e = D_f C_s + S_u (1 - D_f) \qquad \text{Equation G-2}$$

Where:

D_f = Dilution Factor (Spike flow/Total flow)
total flow = spike flow plus flue gas sample flow
C_s = Cylinder concentration of spike gas
S_u = Native concentration of analytes in unspiked samples

The spike dilution factor may be confirmed by measuring the total flow and the spike flow directly. Alternately, the spike dilution can be verified by comparing the concentration of the tracer compound in the spiked samples (diluted) to the tracer concentration in the direct (undiluted) measurement of the spike gas. If SF_6 is the tracer gas, then:

$$D_f = [SF_6]_{spike} / [SF_6]_{direct} \qquad \text{Equation G-3}$$

Where:

$[SF_6]_{spike}$ = The diluted SF_6 concentration measured in a spiked sample
$[SF_6]_{direct}$ = The SF_6 concentration measured directly

The bias is determined by calculating the difference between the observed spike value and the expected response (i.e., the equivalent concentration of the spiked material plus the analyte concentration adjusted for spike dilution). Bias is defined by EPA Method 301 (Section 6.3.1) as:

$$B = S_m - C_e \qquad \text{Equation G-4}$$

Where:

B = Bias at spike level
S_m = Mean concentration of the analyte spiked samples
C_e = Expected concentration of the analyte in spiked samples

The bias (accuracy) is defined in terms of concentration where the recovery is expressed as a percentage of the expected concentration. For example, if a measurement technique gives a 2 ppm positive bias when attempting to measure 10 ppm, then the percent recovery would correspond to 120%.