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FIELD CHEMICAL EMISSIONS MONITORING PROJECT: SITE 21 EMISSIONS MONITORING

EPRI Project RP3177-9

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EPRI
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May 14, 1993

Mr. William H. Maxwell, P.E. (MD13)
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Dear Mr. Maxwell:

In response to the Clean Air Act Amendments of 1990, the Electric Power Research Institute (EPRI) initiated the PISCES (Power Plant Integrated Systems: Chemical Emissions Studies) program to better characterize the source, distribution, and fate of trace elements from utility fossil-fuel-fired power plants. As part of the PISCES program, the Field Chemical Emissions Monitoring (FCEM) program has sampled extensively at a number of utility sites, encompassing a range of fuels, boiler configurations, and particulate, SO_2, and NO_x control technologies. EPRI continues to actively pursue additional FCEM sampling programs and add to the more than 20 sites already completed or currently planned.

This site report presents a preliminary summary of data gathered during a sampling program conducted at one of the FCEM sampling programs - Site 21. Site 21 consists of a pilot-scale electrostatic precipitator (ESP) and wet flue gas desulfurization (FGD) system. The flue gas for the pilot unit is provided by an adjacent power plant boiler which burns a bituminous coal. The primary objective in the Site 21 sampling and analytical program was to quantify the various components of variance in the measurement of trace chemical species. In addition to the replicate sample trains typically conducted at previous PISCES FCEM programs, duplicate analyses and duplicate (simultaneous) sample trains were also conducted at Site 21. This enabled the variance due to sampling, analytical, and process conditions to be estimated. The target analytes was a select group of the trace metals, anions, and the polyaromatic hydrocarbons at the FGD outlet. The complete PISCES FCEM sampling protocol was not conducted. The volatile organic compounds, the aldehydes, and some of the trace metals were not measured. A complete material balance was not an objective, thus some solid samples were not taken.

It should be noted that the results presented in this report are considered PRELIMINARY. The results are believed to be essentially correct except as noted. As additional data from other sites are collected and evaluated, however, EPRI may decide to conduct additional verification tests at this site. If

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this is done, the new data will be made available to the Environmental Protection Agency (EPA).

The primary objective of this report is to transmit the preliminary results from Site 21 to the EPA for use in evaluating select trace chemical emissions from fossil-fuel-fired steam generating plants. In addition to the raw data in the Appendix, the report discusses the data quality, identifies suspect data, and offers possible explanations for the questionable data. Because some of the discussion focuses upon the suspect data, please keep in mind that most of the data meet the standards of quality established for this study. This report does not compare the results from Site 21 with the results from previous utility sites. Generic conclusions and recommendations were not drawn concerning the effectiveness of an electrostatic precipitator or wet FGD system as potential control technologies for trace elements; however, removal efficiencies were calculated where possible. Nor does this site report attempt to address the environmental and health risk impacts associated with the trace chemical emissions.

EPRI hopes that this site report is of assistance to the EPA in evaluating utility trace chemical emissions as well as the associated health risk impacts.

Sincerely,

Paul Chu
Manager, Toxic Substances Control
Environment Division

LIST OF ILLUSTRATIONS

LIST OF TABLES

CONTENTS

Section 1

INTRODUCTION

This report summarizes data gathered during a sampling program sponsored by the Electric Power Research Institute (EPRI). The report is one in a series being produced under the Field Chemical Emissions Monitoring (FCEM) project (RP 3177-1) sponsored by EPRI. The primary objective of this project is to measure selected inorganic and organic substances in the process and discharge streams of power plants, although at this site additional objectives were defined. The data have been prepared in a manner suitable for use by the Environmental Protection Agency to study emissions from fossil-fuel-fired power plants, as mandated by the Clean Air Act Amendments of 1990 (CAAA).

This report summarizes information from the operation of Site 21, a pilot-scale ESP/wet FGD system (4-MW equivalent) treating a portion of the flue gas from a balanced draft, natural circulation, pulverized coal-fired boiler firing medium-sulfur bituminous coal. Sampling was conducted during August of 1992.

Test Objectives

There were five major objectives for the testing at this site:

- Measure emissions from an ESP/wet FGD system;
- Measure emission control efficiency of an ESP/wet FGD system;
- Investigate options for obtaining lower detection limits in the stack gas stream;
- Provide benchmark variance and variance components for FCEM substances typically found in stack gas streams; and
- Perform gas stream mercury speciation measurements using a solid sorbent procedure.

The first two objectives address the relative lack of information available describing the use of an ESP/wet FGD system for control of trace substances. Although a pilot plant was evaluated at this site, the mechanisms for controlling emissions should be similar to larger systems. The third objective was intended to determine if extended sampling and alternate analytical methods could quantify the low concentrations found in most emission streams. At previous sites, the procedures used often do not detect measurable values in the stack gas; therefore, the only result that can be presented is "not detected

at concentration X." Finally, the Site 21 test was designed to determine the variability of measurements in a more rigorous experimental design than is possible with the standard FCEM protocol (triplicate samples). At prior sites, the variability seen from triplicate measurements was typically on the order of the mean concentration. Without a nested design, it was not possible to determine if the sampling and analytical activities were responsible for this variability or if day-to-day variations (process conditions) were variable. The use of a fully nested experimental design, with duplicate samples for each train collected on each of four days and each sample analyzed in duplicate, has allowed the components of measurement variability to be defined. In addition, the precision of the results has been more accurately expressed by using a larger sample set at this site. Mercury speciation tests were performed by Brooks Rand Ltd. The method employed was under development. Coincident testing permitted a convenient check on the results.

Table 1-1 lists the substances of interest to the FCEM program. The body of the report presents information on the coal and gas stream concentrations of these substances. Unlike FCEM sites tested previously, only coal and gas stream data were generated at this site, except for mercury analysis. Therefore, material balances are not used to assess the results. Because the scope of the Site 21 activities was focused on specific analytical procedures, the coal was not analyzed for all of the FCEM inorganic substances. Previous work at the station (Sites 12 and 14) has revealed that benzene, toluene, and formaldehyde levels were very low; therefore, these substances were not measured in this study. Phosphorus also was not measured in the gas streams. Because of the multiple analysis (duplicates and methods) employed, the outlet gas filter digestate volume was not large enough to provide aliquots for all desired fractions. Of the eight fractions needed (duplicates for ICP-AES, GFAAS, CVAAS, and ICP-MS), it was decided to eliminate the CVAAS analysis for particulate-phase mercury. Therefore, only vapor-phase mercury values are presented. These agree very well with the mercury speciation results. Data on additional substances detected by the analytical methods employed in any of the sampled streams, are presented in the appendices.

Data Quality

The quality of the results reported in this document is generally good and meets the objectives of the FCEM program. The samples on which the reported results are based were collected carefully using accepted and appropriate sampling and analytical methods from a pilot system with extensive instrumentation. All process monitoring information indicates that the system was operating in a normal, stable fashion. The sampling and analytical results were subjected to an extensive quality assurance/quality control (QA/QC) evaluation. The detailed information presented in Section 4 supports the following:

- A significant quantity of phenanthrene was detected in the XAD trip blanks. This increases the uncertainty associated with these results. (Phenanthrene was detected in all process samples.)

Table 1-1

FCEM Substances

Elements	Organic Compounds
Arsenic	Benzene[a]
Barium[d]	Toluene[a]
Beryllium	Formaldehyde[a]
Cadmium	Polycyclic Organic Matter (POM)[b,c]
Chlorine (as chloride)	
Chromium	
Cobalt[d]	
Copper[d]	
Fluorine (as fluoride)[d]	
Lead	
Manganese[d]	
Mercury	
Molybdenum[d]	
Nickel	
Phosphorus[a]	
Selenium	
Vanadium[d]	

[a]Not measured at Site 21.

[b]Also referred to as semivolatile organic compounds.

[c]Includes polynuclear aromatic hydrocarbons (PAHs).

[d]Not measured in coal at Site 21.

- Laboratory check samples (LCS) indicate a bias in the inductively coupled argon plasma-mass spectroscopy (ICP-MS) (an alternate, more sensitive analytical technique) data for most of the seven elements analyzed.

- Laboratory control sample data suggest a possible high bias in the coal mercury results by cold vapor atomic absorption spectroscopy (CVAAS) while spike recovery data indicate a possible low bias in the flue gas selenium results by graphite furnace atomic absorption spectroscopy (GFAAS).

- Concentrating impinger solutions may bias results. Results from analysis without concentration are presented in Section 3. A comparison of methods is presented in Section 4.

Variability Components and Alternate Analytical Methods

In addition to the fuel and gas-phase concentrations typically presented in this series of reports, the additional project objectives have produced the following observations:

- After the removal of particulate matter and SO_2 (by the ESP/wet FGD system), the coefficient of variation (CV) for semivolatile organic compounds is about 100%, regardless of whether a specific substance is consistently detected. With the understanding that none of the error terms that occur ahead of the introduction of spikes are quantified, the analysis of variance (ANOVA) indicates that the combination of day-to-day variability and sampling/recovery errors are the principal components of the CV when a substance is consistently detected. Analytical variance is most important when the substance is not consistently detected.

- For the stack gas particulate phase, a majority of inorganic substances have CVs below 20 percent. The ANOVA indicates roughly equal dependence on daily and sampling/preparation variability. Analytical variability is a minor contributor. The CVs for chloride and fluoride are about 40%, with a predominant dependence on the combination of day-to-day and sampling/recovery variability.

- For the stack gas vapor phase, the CV for most inorganic substances is about 100%, usually dependent on sampling and preparation variability. The mercury CV was low at 15%, all attributable to sampling and preparation variability. The vapor-phase anions had CVs of 50 and 20% for HCl and HF. For HCl, daily variability is dominant, while it represents 40% of the HF CV.

- The stack gas particulate analyses CV using ICP-MS varied from 35 to 160% for seven substances. CVs for the same substances analyzed by ICP-AES or GFAAS varied from 12 to 55 percent.

- The CVs for the stack gas vapor-phase analyses using ICP-MS varied from 50 to 150% for seven substances. Concentrating the impinger solutions before ICP-AES or

GFAAS analysis generated CVs of 60 to 180 percent. Straight analysis using ICP-AES or GFAAS resulted in CVs of 45 to 130% (excluding a probable outlier).

These results show that the best precision that can be obtained with these procedures, when only three samples are obtained, is about ±70% at the ESP inlet and ±50% in the stack for those substances primarily present in the particulate phase. As expected, these CVs are somewhat lower than seen at full-scale sites previously tested. Vapor-phase substances and semivolatile organic compounds could have much higher CVs.

Report Organization

Section 2 of this report gives a brief description of the plant and sample locations. Section 3 discusses the results of the chemical analyses of the coal and the two gas streams sampled at the site. Section 4 discusses the QA/QC results. Section 5 presents a discussion of process, sampling, and analytical variability based on the nested experimental design. Section 6 presents mercury speciation results and a comparison to the multi-metals results. Section 7 shows example calculations, and a glossary of terms appears in Section 8. The appendices contain information on the sampling and analytical methods used, stream concentrations from each measurement, particulate measurement results, QA/QC information, blank correction data, and other supporting material. In particular, Appendix B contains the detailed analytical results for the substances listed in Table 1-1. Appendix C includes the results for other substances.

Section 2

SITE DESCRIPTION

The test site (Site 21) and the sampling locations are described in this section.

Facility Information

A pilot-scale (4-MW equivalent) wet limestone flue gas desulfurization (FGD) system was tested at Site 21. The pilot unit consists of an electrostatic precipitator (ESP) followed by a spray tower absorber. The pilot system has demonstrated the capability of mimicking full-scale FGD systems.

Figure 2-1 is a process flow diagram of the pilot ESP and FGD system. Flue gas for the pilot unit is isokinetically extracted from the duct of the adjacent power plant. The extraction point is located before the power plant ESP. The flue gas is routed to the pilot system through 450 feet of 36-inch duct followed by 200 feet of 24-inch duct. The normal sulfur content (1.6%) of the coal fired at the adjacent power plant produces a flue gas SO_2 concentration of approximately 1,000 ppmv. The inlet SO_2 concentration to the FGD system is normally controlled by a dilution/SO_2 spiking system to allow testing at concentrations ranging from 1,500 to 4,000 ppmv. However, during FCEM testing, the inlet SO_2 concentration was not controlled and varied from 900 to 1,000 ppm. The inlet flue gas temperature is kept constant by an electrical resistance heater. The pilot ESP was detuned to give performance similar to that normally seen at the adjacent power plant (~98% particulate removal). On leaving the ESP, a portion of the flue gas passes through an induced draft fan. A variable-speed drive on the induced draft fan controls the flue gas flow rate through the pilot system.

In the spray tower absorber, acid gases, specifically SO_2, HCl, and HF, are removed from the flue gas stream by counter-current contact with the alkaline absorber slurry. The absorbed acidic species are neutralized by the addition of solid calcium carbonate (finely ground limestone) to the absorber reaction tank. The FGD system was operated in inhibited oxidation mode for these tests by the addition of sodium thiosulfate. On leaving the absorber, the treated flue gas from the FGD system combines with gas streams from other pilot systems and returns to the adjacent power plant. Table 2-1 gives a summary of the pilot system operating parameters. Tables 2-2 and 2-3 summarize the absorber slurry chemical composition. These data were produced by the routine testing of the pilot system and are provided here only for reference.

The pilot equivalent coal feed rate in Table 2-1 was calculated from the measured coal rate at the adjacent power plant and the measured flue gas flow rate used by the pilot system. The flue gas flow rate for the power plant is first calculated from the measured

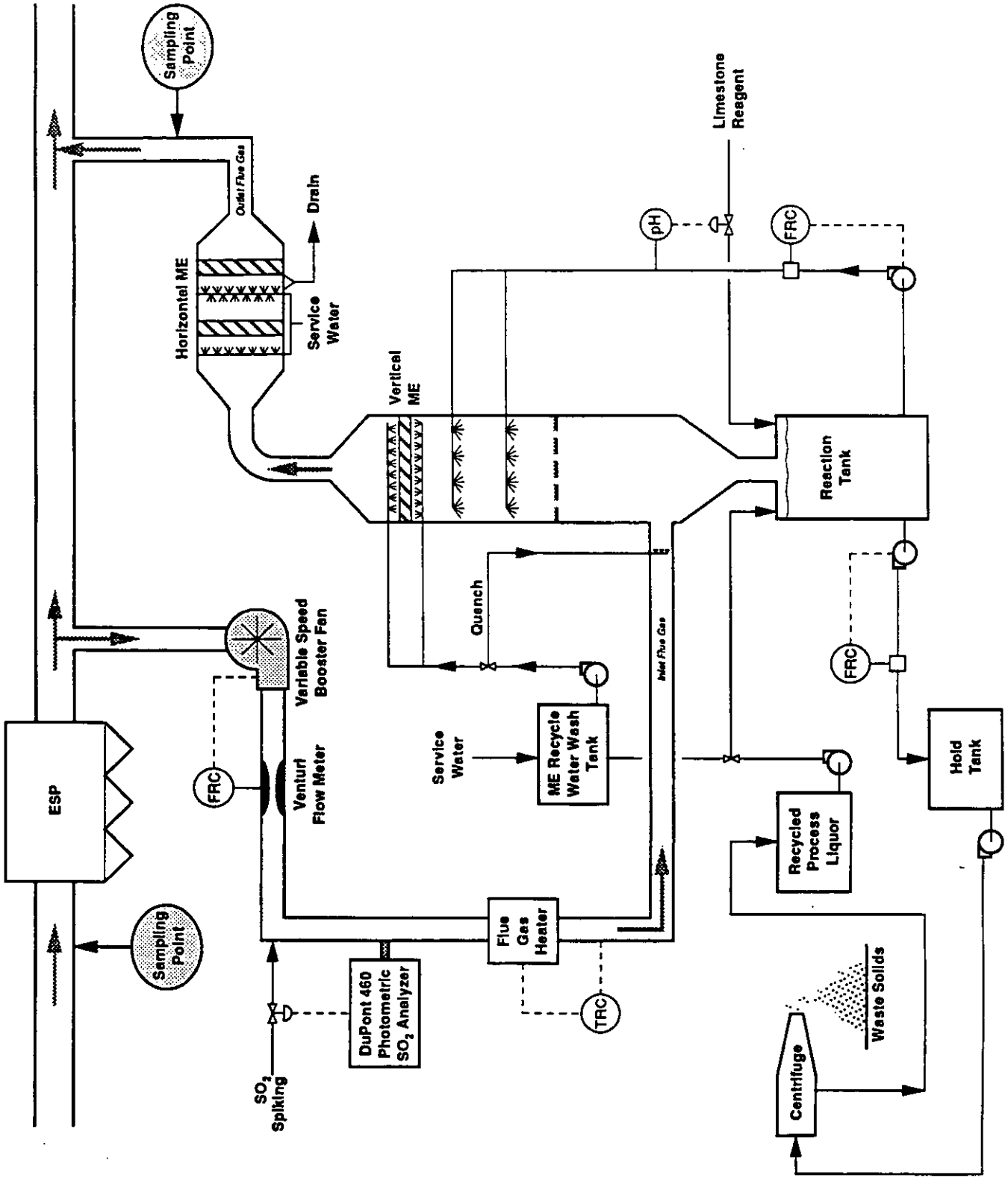


Figure 2-1. FCEM Site 21 Pilot ESP and Wet FGD Process Flow Diagram

Table 2-1

Process Summary

Parameter	Average	Std. Dev.
Station Gross Load, MWe	667	9
Station Coal Feed Rate, klb/hr	452	12
Calculated Station Flue Gas, dscfm @ 6.0% O_2 wet	1,339,000	
Equivalent Pilot system Coal Feed Rate, klb/hr as-fired	2.73	
ESP Inlet O_2, % by Orsat	4.0	0.3
ESP Outlet Opacity, %	0.76	0.11
SO_2 Removal, %	82.5	1.0
L/G, gal/1000 acf	88	0
Recirculation pH	5.5	0
Absorber pH	4.8	0.1
Flue Gas Flow Rate, dscfm @ 5.7% O_2	8,109	42
Total Absorber Slurry Flow Rate, gpm	850	0
Absorber Inlet SO_2, ppm wet	936	55
Absorber Outlet SO_2, ppm wet	154	14
Absorber Outlet O_2, % wet CEM	6.0	0.5
Absorber Outlet O_2, % dry Orsat	5.7	0.1
Absorber Inlet Temperature, °F	323	1
Absorber Outlet Temperature, °F	129	1
Absorber ΔP, H_2O"	1.90	0.02
Spray zone ΔP, H_2O"	0.96	0.01

Table 2-2

Absorber Slurry Chemical Composition

Substance	Concentration[a]
Liquor Calcium, mMole/l	208 ± 6
Liquor Magnesium, mMole/l	139 ± 5
Liquor Sodium, mMole/l	24.7 ± 0.8
Liquor Chloride, mMole/l	640 ± 23
Liquor Carbonate, mMole/l	3.2 ± 0.8
Liquor Sulfite, mMole/l	3.2 ± 0.1
Liquor Sulfate, mMole/l	0.10 ± 0.03
Liquor Thiosulfate, ppmw	339 ± 20
$CaSO_3 \cdot ½H_2O$ Relative Saturation	6.6
$CaSO_4 \cdot 2H_2O$ Relative Saturation	0.01
Solid Calcium, mMol/g	7.69 ± 0.50
Solid Magnesium, mMol/g	0.05 ± 0.01
Solid Sulfite, mMol/g	6.77 ± 0.20
Solid Sulfate, mMol/g	0.27 ± 0.02
Solid Carbonate, mMol/g	0.56 ± 0.21
Inerts, %	1.7 ± 0.1
Sulfite Oxidation, %	1.6 ± 0.3
Reagent Utilization, %	92.6 ± 2.7
Reaction Tank wt % Solids	6.1 ± 0.3

[a]Confidence intervals are 95% confidence intervals around the mean.

Table 2-3

Absorber Liquor Trace Species[a]

Substance	Concentration, ppm
Aluminum	0.27
Barium	0.66
Boron	262
Chromium	1.0
Copper	0.04
Iron	3.2
Lead	0.05
Manganese	3.6
Nickel	0.53
Potassium	44
Silicon	7.5
Zinc	0.1

[a]The results of one routine sample collected and analyzed by on-site personnel, provided as background information.

coal flow rate at a reference O_2 concentration. The ratio of the measured pilot system flue gas flow rate and the calculated power plant flue gas flow rate is then applied to the measured power plant coal flow rate to obtain a pilot equivalent coal feed rate. Details of these calculations appear in Section 7. As can be seen in Table 2-1, the station load and coal consumption were relatively constant during the test periods.

The pilot system ran without incident throughout the test periods. The power plant reduced load the mornings of August 20, 21, and 22; however, the station boiler was at full load during the sampling period except between 08:00 and 09:00, August 21. Full load was established on August 21 by 10:00. Full load was established before sampling began on August 20 and 22. The operation of the power plant while samples were being collected was representative of standard operation. A set of operating plots is provided in Appendix I.

Sampling Locations

Samples were collected at six locations at the pilot plant:

- ESP inlet flue gas;
- Absorber outlet flue gas;
- Coal feed to the adjacent power station;
- Collected ESP ash;
- FGD systems liquor; and
- FGD system solids.

The ESP inlet, absorber outlet, and coal samples were submitted for analysis. Samples from the other three streams were archived for possible future analysis for trace substances.

A description of the sampling activities appears in Appendix A.

Section 3

RESULTS

This section discusses the analytical results derived from the sampling of Site 21. The results for FCEM substances and for selected major elements analyzed by standard methods are presented here. Data for additional substances are included in the appendices.

Sampling Schedule

Site 21 was sampled in late August of 1992. The host utility supplying flue gas to the pilot plant operated at full load during the sampling. Three types of sampling trains were used at the ESP inlet and absorber outlet (stack) to obtain samples for the analytes listed in Table 1-1. The multi-metals (metals), Modified Method 5 semivolatile organic (MM5), and anions trains were used to fully traverse the ducts.

Six metals runs were made at the ESP inlet and four sets of duplicate samples were collected at the absorber outlet. An additional set of duplicate metals impinger samples from the absorber outlet were analyzed for mercury. Four MM5 and anions runs were made at the ESP inlet and four sets of duplicates from each train were collected at the absorber outlet. Coal samples were collected each day. Figure 3-1 shows an outline of the sampling activities, which are described in more detail in Appendix A. The initial outlet runs were voided when it was determined that the filters were wet. The first inlet run was voided when the filters became dislodged.

Data Treatment

Several conventions were developed during the FCEM project for treating the test data and developing average concentrations of substances in the various streams. To determine the total gas concentration for each run, both the solid and vapor phase contributions were considered; however, the absence of some detectable (above the MDL) concentrations in either (or both) phase(s) required that conventions be developed for dealing with these data and formulating emission factors. The MDL is that value determined for a specific instrument by the protocol of 40 CFR 136 Appendix B. These conventions are summarized below.

For each substance, there are three possible combinations of vapor- and solid-phase concentrations in the emitted gas stream. These are:

Case 1: The concentrations in both the solid and vapor phases are above the method detection limits.

Train	Run 1 8/19	Run 2 8/19	Run 3 8/20	Run 4 8/21	Run 5 8/22	Run 6 8/23	Run 7 8/24
Inlet:							
Metals	Void	Completed	Completed	Completed	Completed	Completed	Completed
Anions	Void	Completed	Completed	Completed	Completed		
MM5	Void	Completed	Completed	Completed	Completed		
Outlet:							
Metals A	Void	Void	Hg Only	Completed	Completed	Completed	Completed
Metals B	Void	Void	Hg Only	Completed	Completed	Completed	Completed
Anions A		Completed	Completed	Completed	Completed		
Anions B		Completed	Completed	Completed	Completed		
MM5 A	Aborted	Completed	Completed	Completed	Completed		
MM5 B	Aborted	Completed	Completed	Completed	Completed		

Figure 3-1. Sample Schedule

Case 2: The concentrations in both the solid and vapor phases are below the method detection limits.

Case 3: The concentration in one phase is above the method detection limit, and the concentration in the other phase is below the method detection limit.

For those constituents of interest other than mercury, HCl, and HF, the stack gas stream data from coal-fired power plants have indicated that most of the material is present in the solid phase and that only a minor fraction is generally found in the vapor phase. Thus, the following conventions were selected for defining total gas stream concentrations:

Case 1: The total concentration is the sum of the concentrations in the vapor and solid phases.

For example, the total cadmium (Cd) concentration in the absorber outlet gas is calculated as follows for Run 4a:

Cd in solid phase = 0.17 $\mu g/Nm^3$

Cd in vapor phase = 0.26 $\mu g/Nm^3$

Total Cd in absorber outlet gas = 0.43 $\mu g/Nm^3$

Case 2: The total concentration is considered to be the method detection limit in the solid phase. This case does not apply to Site 21.

Case 3: The total concentration is considered to be the level measured above the reporting limit, regardless of which phase this represents.

For example, the total arsenic (As) level in the absorber outlet gas is calculated as follows for Run 4a:

As in solid phase = 7.42 $\mu g/Nm^3$

As in vapor phase = ND(0.2 $\mu g/Nm^3$)

where ND(0.2) indicates that the analytical result was below the method detection limit of 0.2 $\mu g/Nm^3$

Total As in the absorber outlet gas = 7.42 $\mu g/Nm^3$

The above conventions also agree with guidance provided by EPA (*Technical Implementation Document for EPA's Boiler and Furnace Regulations*, U.S. Environmental Protection Agency, Office of Solid Waste, Washington, D.C., March 1992).

Testing at several previous sites indicated that mercury, HCl, and HF are present primarily in the vapor phase. For Case 2, then, the total concentration in the gas stream is considered to be the reporting limit in the vapor phase. For Cases 1 and 3, the methodologies are unchanged from those described above.

The following criteria were used when averaging the results from different runs:

- When all values for a given variable were above the method detection limit, the mean concentration was calculated as the true arithmetic mean.

- For results that include values both above and below the detection limit, one-half of the detection limit was used to calculate the mean. For example:

Analytical Values	Calculation	Mean Value
10, 12, ND(8)	(10+12+[8/2])/3	8.7

  By convention, the calculated mean was not allowed to be smaller than the largest detection limit value. In the following example, using one-half the detection limit value would yield a calculated value of 2.8. This is less than the highest detection level obtained, so the reported mean is ND(4).

Analytical Values	Calculation	Mean Value
5, ND(4), ND(3)	(5+[4/2]+[3/2])/3 = 2.8	ND(4)

- When all analytical results for a given variable are less than the detection limit, the reported mean is ND (the largest detection limit). The bias estimate is one-half of the reporting level, and no confidence interval is reported.

- Questionable analytical data are normally excluded from all summary calculations. These include results that indicate a sampling bias, analytical interference, or the presence of organic compounds known to be laboratory contaminants. None of the results from Site 21 were excluded. Although some outlier results were identified, no systemic problems were discovered. The outlier data are discussed in Section 4.

Concentrations of solid phase metals and anions were corrected for the background concentration of the blank filter media. Four blank filters were digested and analyzed to determine the blank level. Appendix G contains a comparison of the solid phase results with the blank filter results.

Coal

Table 3-1 presents the analytical results for the coal samples. Appendix A discusses the analytical method reported for each combination of substance and stream. For each substance, a mean concentration has been calculated along with a 95% confidence interval about the mean. The mean, plus and minus the confidence interval, represents the range where the probability is 95% that the true mean lies. For example, we are

Table 3-1

Coal Composition (mg/dry kg unless noted)

Substance	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Mean	95% CI
Coal Flow Rate (dry klb/hr)							2.54	--
Ash, dry %	6.48	6.53	6.66	7.04	6.61	6.61	6.66	0.23
HHV, Btu/dry lb	14,072	14,054	14,011	13,938	14,037	14,028	14,032	30
Sulfur, dry %	1.65	1.55	1.66	1.69	1.50	1.72	1.63	0.09
Arsenic	1.82	4.00	5.00	5.00	5.00	5.00	4.30	1.3
Beryllium	0.80	0.70	0.80	0.77	0.90	0.80	0.79	0.07
Cadmium	ND(0.1)	0.20	ND(0.1)	ND(0.1)	0.10	0.10	ND(0.1)	--
Chloride	800	900	900	1,000	800	900	860	110
Chromium	11.00	11.00	12.00	11.00	12.00	11.00	11.3	0.60
Lead	2.50	3.00	3.10	2.70	2.50	3.30	2.85	0.35
Mercury	0.15	0.14	0.13	0.15	0.14	0.20	0.15	0.03
Nickel	8.00	8.00	10.00	8.00	8.00	8.00	8.33	0.86
Selenium	1.00	1.00	1.00	1.00	1.00	2.00	1.17	0.43

ND = Not detected. Method detection limit shown in parentheses.

CI = Confidence interval.

95% confident that the mean coal arsenic concentration was between 3.0 mg/kg and 5.6 mg/kg. The calculation of this confidence interval is presented in Appendix E.

Bituminous coal burned at the plant is obtained from three sources. Approximately 25% is obtained from the Bailey mine in Pennsylvania. The balance is equally split between the Blacksville 1 and 2 mines in West Virginia.

Electrostatic Precipitator Inlet Gas

Tables 3-2, 3-3, and 3-4 summarize the results of the metals and anions measurements made on the gas entering the electrostatic precipitator at Site 21. The solid phase results are presented in Table 3-2, the vapor phase results are presented in Table 3-3, and the combined results are presented in Table 3-4. In addition to the species shown in these tables, other substances were also analyzed; however, only the results for FCEM target substances are presented. Appendices B and C present these additional results, as well as the FCEM target results. The results of the analyses for semivolatile organic compounds are not presented because of an analytical interference problem. The ESP inlet MM5 analysis problems are described in detail in Appendix A. In addition, details about the gas sampling runs are also presented in Appendix A (gas compositions, sample times, moisture levels, etc). Run 1 was void because the filter was dislodged during sampling.

For the multi-metals train, the particulate filter and probe and nozzle rinse fractions were combined and analyzed. The laboratory reported the elemental result on a total weight basis, i.e., total milligrams of arsenic. If appropriate, this result was corrected for the blank result (i.e., if the substance was reported in the filter blank). This total weight was divided by the sample gas volume to obtain the solid phase concentration. The multi-metals train impingers were analyzed directly for total elemental mass, which was divided by the sampled gas volume to obtain the vapor phase concentration.

At previously tested FCEM sites, most of the target elements were found primarily in the solid phase. HCl and HF were found primarily in the vapor phase. Similar amounts of cadmium were found in each phase. Previous analyses at this site have indicated that mercury is not present above the method detection limit in the suspended particulate matter; therefore, only the vapor phase was analyzed. As discussed in the introduction, the duplicate and multiple analytical methods examined required eliminating the particulate-phase mercury analysis.

Stack Gas

Tables 3-5, 3-6, and 3-7 present the stack (absorber outlet) gas metal and anion concentrations for the solid phase, vapor phase, and the combined solid and vapor phases, respectively. As was the case at the ESP inlet, additional species were analyzed but only FCEM target substance results are summarized here. Also, the analysis for mercury was only performed on the vapor phase. A comparison of the vapor-phase mercury results with the mercury speciation procedure in Section 6 indicates good agreement between the vapor-phase only results and those obtained by the speciation procedure which also

Table 3-2

ESP Inlet Solid-Phase Composition ($\mu g/dNm^3$)

Substance	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Mean	95% CI
Flow Rate (Nm^3/hr)	11,700	11,400	12,200	11,700	11,500	11,700	11,700	300
Temperature (°C)	143	147	145	147	146	147	146	2
Particulate (g/Nm^3)	3.14	2.41	2.34	1.90	2.06	2.90	2.46	0.50
Arsenic	446	747	514	412	390	545	509	137
Barium	1,560	1,439	1,380	1,106	1,198	1,806	1,415	265
Beryllium	39.3	40.3	40.6	27.2	28.0	38.2	35.6	6.6
Cadmium	@4.45	4.18	3.37	2.37	3.02	4.10	3.58	0.84
Chloride	0.98	@1.01	1.35	1.23			1.14	0.23
Chromium	624	690	704	369	468	665	587	144
Cobalt	128	125	132	87	112	142	121	20
Copper	239	284	247	180	208	269	238	40
Fluoride	0.22	0.42	0.29	@0.30			0.30	0.11
Lead	171	245	193	146	154	209	186	39
Manganese	482	448	397	331	342	523	421	81
Molybdenum	35	69	55	39	69	54	53	15
Nickel	450	478	446	305	352	498	421	80
Selenium	50.9	67.0	49.5	45.9	44.8	39.4	49.6	9.9
Vanadium	826	1,100	921	692	797	956	882	149

@ = Concentration shown is less than five times the method detection limit.
CI = Confidence interval.

Table 3-3

ESP Inlet Vapor-Phase Composition ($\mu g/dNm^3$)

Substance	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Mean	95% CI
Arsenic	@1.56	@0.63	ND(0.22)	ND(0.23)	ND(0.23)	ND(0.31)	0.45	0.56
Barium	8.06	@0.93	@1.50	@0.61	@1.44	@0.65	2.20	2.79
Beryllium	ND(0.06)	ND(0.04)	ND(0.08)	@0.09	ND(0.08)	@0.04	ND(0.08)	--
Cadmium	@2.1	3.7	@1.5	@1.6	3.8	0.8	2.2	1.2
Chloride	155,000	165,000	154,000	98,000			143,000	36,000
Chromium	@3.0	@1.4	@1.3	3.5	6.5	3.5	3.2	1.8
Cobalt	ND(2)	ND(2)	ND(1)	ND(2)	ND(2)	ND(2)	ND(2)	--
Copper	ND(1)	ND(1)	ND(1)	@1	ND(1)	ND(1)	ND(1)	--
Fluoride	8,200	9,300	8,100	9,000			8,700	700
Lead	33	3	30	10	34	11	20	13
Manganese	216	@6	62	@8	@12	20	54	79
Mercury	9.9	10.1	9.1	11.8	9.7	11.7	10.4	1.1
Molybdenum	ND(1)	ND(2)	ND(1)	ND(0.5)	ND(2)	ND(3)	ND(3)	--
Nickel	6.7	2.3	2.3	4.8	5.9	@1.9	4.0	2.0
Selenium	@3.1	2.8	8.3	3.6	4.2	@1.1	3.8	2.3
Vanadium	@3	ND(2)	ND(0.08)	ND(2)	@3	ND(3)	ND(3)	--

ND = Not detected. Method detection limit shown in parentheses.

@ = Concentration shown is less than five times the method detection limit.

CI = Confidence interval.

Table 3-4

ESP Inlet Combined Composition ($\mu g/dNm^3$)

Substance	Mean	95% CI
Flow Rate (Nm^3/hr)	11,700	600
Particulate (g/Nm^3)	2.46	0.5
Arsenic	510	130
Barium	1,420	240
Beryllium	35.6	6.0
Cadmium	5.8	1.4
Chloride	143,000	36,000
Chromium	590	130
Cobalt	121	19
Copper	238	37
Fluoride	8,700	700
Lead	206	30
Manganese	470	130
Mercury	10.4	1.1
Molybdenum	53	14
Nickel	425	72
Selenium	53	10
Vanadium	880	140

CI = Confidence interval.

Table 3-5

Stack Gas Solid-Phase Composition ($\mu g/dNm^3$)

Method	Substance	Run 4a	Run 4b	Run 5a	Run 5b	Run 6a	Run 6b	Run 7a	Run 7b	Mean	95% CI
	Flow Rate (Nm^3/hr)	13,100[a]		13,000		13,100		13,100		13,100	60
	Temperature (°C)	52[a]		52		49		51		51	2
	Particulate (g/Nm^3)	0.0066	0.0095	0.0075	0.021	0.017	0.015	0.011	0.018	0.013	0.0043
GFAAS	Arsenic	7.42	6.73	6.97	6.00	7.38	8.89	7.42	8.48	7.41	0.77
ICP-AES	Barium	3.71	3.50	3.12	2.38	4.15	4.14	4.15	4.28	3.68	0.55
ICP-AES	Beryllium	0.16	0.15	0.14	0.11	0.16	0.16	0.15	0.15	0.14	0.01
GFAAS	Cadmium	0.17	0.15	0.18	0.09	0.16	@0.12	0.12	0.15	0.14	0.02
ICP-AES	Chromium	3.73	3.25	2.70	2.80	3.61	3.43	3.11	3.58	3.28	0.32
ICP-AES	Cobalt	0.33	0.31	@0.24	@0.19	@0.28	@0.28	@0.27	2.45	0.54	0.64
ICP-AES	Copper	1.38	1.36	1.17	1.00	1.28	1.22	1.18	1.27	1.23	0.10
GFAAS	Lead	1.51	1.24	1.29	0.89	1.50	1.42	1.43	1.35	1.33	0.17
ICP-AES	Manganese	1.27	1.15	1.00	0.82	1.20	1.13	1.11	2.28	1.24	0.37
ICP-AES	Molybdenum	0.87	0.80	0.58	0.53	0.80	0.83	0.76	0.81	0.75	0.10
GFAAS	Nickel	1.95	1.69	1.42	1.58	1.95	1.54	1.55	1.94	1.70	0.18
GFAAS	Selenium	2.3	8.0	10.9	20.0	11.5	10.2	3.1	10.4	9.6	4.6
ICP-AES	Vanadium	7.49	7.06	6.05	4.47	6.85	6.97	6.66	6.76	6.54	0.77
		Run 2a	Run 2b	Run 3a	Run 3b	Run 4a	Run 4b	Run 5a	Run 5b	Avg	95% CI
	Flow Rate (Nm^3/hr)	13,100[a]		12,900		13,100		13,000		13,000	150
	Temperature	49[a]		51		52		52		51	2
IC	Chloride	235	267	611	451	374	261	222	282	338	112
ISE	Fluoride	3.5	6.0	5.6	7.5	2.2	2.5	3.1	3.6	4.2	1.6

CI = Confidence interval.
@ = Concentration shown is less than five times the method detection limit.

[a]Value is average of morning and afternoon measurements.

Table 3-6

Stack Gas Vapor-Phase Composition ($\mu g/dNm^3$)

Method	Substance	Run 3a	Run 3b	Run 4a	Run 4b	Run 5a	Run 5b	Run 6a	Run 6b	Run 7a	Run 7b	Mean	95% CI
GFAAS	Arsenic			ND(0.2)	ND(0.2)	@1.21	ND(0.1)	ND(0.2)	ND(0.3)	ND(0.3)	ND(0.2)	ND(0.30)	--
ICP-AES	Barium			@0.16	@0.39	1.02	ND(0.1)	@0.29	@0.18	ND(0.2)	ND(0.1)	0.28	0.26
ICP-AES	Beryllium			ND(0.01)	ND(0.01)	0.09	ND(0.0)	@0.02	@0.01	ND(0.01)	ND(0.01)	0.02	0.03
GFAAS	Cadmium			0.26	0.44	0.22	0.65	0.34	1.52	0.44	0.63	0.56	0.35
ICP-AES	Chromium			ND(0.5)	ND(0.4)	ND(0.5)	ND(0.2)	ND(0.5)	@0.68	ND(0.5)	ND(0.5)	ND(0.5)	--
ICP-AES	Cobalt			10.0	9.4	5.6	ND(0.8)	5.5	5.6	ND(0.9)	ND(0.8)	4.7	3.3
ICP-AES	Copper			@0.48	@0.75	@0.87	@0.81	@0.85	@0.87	@0.89	ND(0.3)	0.71	0.22
GFAAS	Lead			@0.4	7.2	2.6	2.5	2.3	26.1	1.6	8.7	6.4	7.1
ICP-AES	Manganese			64	33	@2	@1	@3	4	30	@1	17	19
CVAAS	Mercury	0.79	0.97	1.07	1.00	1.21	0.82	1.12	1.03	1.09	1.14	1.02	0.10
ICP-AES	Molybdenum			ND(0.8)	ND(0.8)	ND(0.9)	ND(0.8)	ND(0.9)	ND(0.9)	ND(0.9)	ND(0.9)	ND(0.9)	--
GFAAS	Nickel			ND(0.3)	ND(0.3)	@0.60	ND(0.1)	ND(0.40)	@1.60	@0.70	ND(0.3)	0.46	0.43
GFAAS	Selenium			@0.67	3.89	3.33	2.31	2.36	2.31	2.97	2.86	2.59	0.79
ICP-AES	Vanadium			ND(0.8)	ND(0.7)	@1.57	ND(0.8)	ND(0.8)	ND(0.8)	ND(0.8)	ND(0.8)	ND(0.8)	--

		Run 2a	Run 2b	Run 3a	Run 3b	Run 4a	Run 4b	Run 5a	Run 5b	Avg	95% CI
IC	Chloride	573	543	3,206	3,432	2,883	3,749	2,646	2,368	2,425	1,027
ISE	Fluoride	45.7	50.7	28.9	34.5	33.4	45.3	32.3	41.6	39.0	6.5

ND = Not detected. Method detection limit shown in parentheses.

CI = Confidence interval.

@ = Concentration shown is less than five times the method detection limit.

Table 3-7

Stack Gas Combined Composition ($\mu g/dNm^3$)

Method	Substance	Mean	95% CI
	Flow Rate (Nm^3/hr)	13,000	650
	Particulate (g/Nm^3)	0.013	0.0043
GFAAS	Arsenic	7.56	0.78
ICP-AES	Barium	3.93	0.55
ICP-AES	Beryllium	0.16	0.03
GFAAS	Cadmium	0.70	0.34
IC	Chloride	2,800	1,100
ICP-AES	Chromium	3.36	0.40
ICP-AES	Cobalt	5.1	3.2
ICP-AES	Copper	1.92	0.24
ISE	Fluoride	43	7
GFAAS	Lead	7.7	7.1
ICP-AES	Manganese	19	19
CVAAS	Mercury	1.02	0.10
ICP-AES	Molybdenum	0.75	0.10
GFAAS	Nickel	2.06	0.40
GFAAS	Selenium	12.2	4.8
ICP-AES	Vanadium	6.74	0.81

CI = Confidence interval.

samples the particulate phase. The results of the additional analyses appear in the appendices. Also shown in these tables is the analytical method for each result (the results obtained by alternate methods are discussed in later sections). Section 4 contains a comparison of the methods and the rationale for those selected. Table 3-8 presents the results for the semivolatile organic species. No interference problem occurred during the analysis of the absorber outlet MM5 samples. High-resolution GCMS was used for this analysis. Table 3-9 presents emission factors for each of the substances on a mass-per-unit-energy basis.

Each absorber outlet result is the average of duplicate analyses; "a" and "b" denote the sampling train. For example, the absorber outlet solid phase-arsenic concentration for Run 4a is the average result of two analyses of the same digested sample. When averaging duplicate analytical results, the conventions for averaging run results presented earlier were used. The Run 4a semivolatile organic data are not presented in Table 3-8 because this sample was spiked and the results were used for QA/QC purposes. Runs 1, 2, and 3 encountered sampling problems such as wet and dislodged filters. Appendix A discuses these issues in detail.

System Control Efficiency Performance

Table 3-10 presents the removal efficiencies calculated for the ESP/wet FGD system for selected substances. The average particulate removal was 99.5 percent. Since all substances were present in the solid phase at the ESP inlet, most of the trace substances were also removed quite effectively. Titanium removal is shown as a tracer, acting as a surrogate for coal ash to illustrate that the measured particulate removal efficiency (99.5) was lower than the removal efficiency of boiler ash (99.8 titanium). This is due to scrubber-generated solids entrained in the gas downstream of the absorber.

When calculating the system removal efficiency, the actual measured ESP inlet flow was not used. Since the gas treated by the ESP is used by more than one pilot system, it was necessary to calculate the ESP inlet flow rate that would be used by the tested pilot. This was done by using the measured flow rate at the absorber outlet adjusted to the O_2 concentration at the ESP inlet.

Also shown in Table 3-10 is an estimated removal efficiency for those substances analyzed in the coal. This calculation was performed using the coal feed rate and composition, assuming an 80/20 fly ash-to-bottom ash ratio (except for volatile substances which were assumed to be 100% in the ESP inlet gas) and calculating the removal efficiency using the measured outlet gas values. The calculated removals are slightly higher for most substances. This is because the inlet particulate loading is believed to be biased low. This topic is addressed in the next section.

Table 3-8

Stack Semivolatile Organic Compounds (ng/dNm^3)

Substance	Run 2a	Run 2b	Run 3a	Run 3b	Run 4a	Run 5a	Run 5b	Mean	95% CI
Flow Rate (Nm^3/hr)	13,100[a]		12,900		13,100	13,000		13,000	150
Temperature (°C)	49[a]		51		52	52		51	2
5-Methyl chrysene	1.6	7.8	ND(1.0)	ND(0.3)	1.1	1.5	0.6	1.9	2.5
7H-Dibenzo[c,g]carbazole	ND(3.4)	ND(4.1)	ND(0.8)	ND(2.2)	ND(2.3)	ND(3.0)	ND(1.8)	ND(4.1)	--
Acenapthene	50	71	17	5	3	6	2	22	25
Acenapthylene	16.2	22.9	4.0	4.2	3.9	9.0	4.4	9.2	7.1
Anthracene	29	32	7	3	5	6	3	12	12
Benz[a]anthracene	3.1	4.6	1.0	0.5	0.7	0.7	0.6	1.6	1.5
Benzo[a]pyrene	3.1	6.6	1.2	ND(0.8)	ND(0.8)	2.8	0.5	2.1	2.4
Benzo[b,j&k]fluoranthenes	14.6	29.4	4.8	1.2	1.8	3.0	1.6	8.1	9.9
Benzo[g,h,i]perylene	1.9	4.8	1.3	0.4	0.7	ND(0.9)	1.0	1.5	1.5
Chrysene	11	32	6	2	2	5	2	8	10
Dibenz[a,h]acridine	0.7	ND(1.8)	0.2	0.5	ND(0.8)	ND(1.9)	ND(0.4)	ND(1.9)	--
Dibenz[a,h]anthracene	ND(1.1)	ND(3.2)	ND(0.8)	ND(0.8)	ND(1.6)	ND(1.3)	0.6	ND(3.2)	--
Dibenz[a,i]acridine	ND(0.8)	ND(2.0)	0.1	ND(1.1)	ND(0.3)	ND(1.3)	ND(0.4)	ND(2.0)	--
Dibenzo[a,e]pyrene	ND(1.0)	ND(1.8)	ND(0.7)	ND(0.6)	ND(1.2)	ND(0.8)	ND(0.7)	ND(1.8)	--
Dibenzo[a,h]pyrene	ND(1.3)	ND(1.7)	ND(0.4)	ND(0.3)	ND(1.1)	ND(1.5)	ND(0.6)	ND(1.7)	--
Dibenzo[a,i]pyrene	ND(1.4)	ND(3.1)	ND(0.6)	ND(0.8)	ND(1.3)	ND(1.9)	ND(1.1)	ND(3.1)	--
Fluoranthene	149	215	40	14	9	22	7	65	77
Fluorene	162	254	43	24	21	26	23	79	87
Indeno[1,2,3-cd]pyrene	3.6	5.5	1.5	ND(0.6)	ND(1.0)	ND(0.7)	0.8	1.8	1.9
Phenanthrene	678	727	179	56	40	62	46	256	288
Pyrene	68	85	22	11	6	11	5	30	30

[a]Value is average of morning and afternoon measurements.

ND= Not detected. Method detection limit shown in parentheses.

CI= Confidence interval.

Table 3-9

Stack Emission Factors

Method	Substance	Emission Factor ($lb/10^{12}$ Btu)	95% CI
HRGCMS	Acenapthene	0.018	0.021
HRGCMS	Acenapthylene	0.0075	0.0057
HRGCMS	Anthracene	0.0099	0.0096
GFAAS	Arsenic	6.17	0.79
ICP-AES	Barium	3.21	0.51
HRGCMS	Benz[a]anthracene	0.0013	0.0012
HRGCMS	Benzo[a]pyrene	0.0018	0.002
HRGCMS	Benzo[b,j,k]fluoranthenes	0.0066	0.0079
HRGCMS	Benzo[g,h,i]perylene	0.0012	0.0012
ICP-AES	Beryllium	0.13	0.03
GFAAS	Cadmium	0.57	0.29
IC	Chloride	1,980	880
ICP-AES	Chromium	2.74	0.39
HRGCMS	Chrysene	0.0069	0.0083
ICP-AES	Cobalt	4.1	2.7
ICP-AES	Copper	1.57	0.23
HRGCMS	Dibenz[a,h]acridine	ND(0.001)	--
HRGCMS	Dibenz[a,h]anthracene	ND(0.003)	--
HRGCMS	Dibenz[a,i]acridine	ND(0.002)	--
HRGCMS	Dibenzo[a,e]pyrene	ND(0.002)	--
HRGCMS	Dibenzo[a,h]pyrene	ND(0.001)	--
HRGCMS	Dibenzo[a,i]pyrene	ND(0.002)	--
HRGCMS	Fluoranthene	0.053	0.063
HRGCMS	Fluorene	0.064	0.070
ISE	Fluoride	31.9	5.9

Table 3-9 (Continued)

Method	Substance	Emission Factor (lb/10^{12} Btu)	95% CI
HRGCMS	Indeno[1,2,3-cd]pyrene	0.0015	0.0015
GFAAS	Lead	6.32	6.00
ICP-AES	Manganese	15	16
CVAAS	Mercury	0.84	0.10
ICP-AES	Molybdenum	0.61	0.10
GFAAS	Nickel	1.68	0.36
HRGCMS	Phenanthrene	0.21	0.23
HRGCMS	Pyrene	0.024	0.025
GFAAS	Selenium	9.9	4.1
ICP-AES	Vanadium	5.50	0.79
HRGCMS	5-Methyl chrysene	0.0015	0.0020
HRGCMS	7H-Dibenzo[c,g]carbazole	ND(0.003)	--

ND = Not detected. Emission factor based on method detection limit shown in parentheses.

CI = Confidence interval.

Table 3-10

Removal Efficiencies for the ESP/FGD System

Method	Substance	Measured Removal Efficiency	95% CI	Estimated Removal Efficiency[a]
	Particulate	99.46	0.19	99.72
GFAAS	Arsenic	98.34	0.21	98.02
ICP-AES	Barium	99.69	0.05	
ICP-AES	Beryllium	99.50	0.10	99.71
GFAAS	Cadmium	86.6	6.7	
IC[b]	Chloride	98.11	0.88	96.33
ICP-AES	Chromium	99.36	0.09	99.58
ICP-AES	Cobalt	95.3	3.1	
ICP-AES	Copper	99.10	0.13	
ISE[b]	Fluoride	99.50	0.10	
GFAAS	Lead	95.8	1.0	96.19
ICP-AES	Manganese	95.6	4.7	
CVAAS	Mercury	89.0	1.2	92.33
ICP-AES	Molybdenum	98.44	0.25	
GFAAS	Nickel	99.46	0.11	99.65
GFAAS	Selenium	75	11	88.24
ICP-AES	Titanium	99.75	0.04	
ICP-AES	Vanadium	99.15	0.12	
ICP-AES	Zinc	97.2	1.1	

[a]As discussed in Section 4, the ESP inlet particulate loading is believed to be biased low. The values in this column were calculated using the coal composition data and flow rate and an estimated 80/20 fly ash-to-bottom ash ratio for all substances except arsenic, chloride, mercury, and selenium (assumed 100% volatilized) as an inlet mass. The mean outlet mass rates were used to calculate the estimated removal efficiency.

[b]Removal of vapor phase anions only.

CI = Confidence interval.

Section 4

DATA EVALUATION

Several procedures can be used to evaluate the information developed during a field sampling program. In the case of Site 21, two methods were used to evaluate data quality. First, and most important, was evaluation of the traditional QA/QC protocol for the sampling and analytical procedures used at Site 21, i.e., equipment calibration and leak checks, duplicates, blanks, spikes, etc. Site 21 QA/QC data are compared with FCEM project objectives. The second data assessment tool involves a comparison of the precision of the analytical methods used. The implications of the analytical methods used and of process and sampling variability are discussed in Section 5.

Evaluation of Measurement Data Quality

This section presents a discussion of the data obtained during the characterization of Site 21. Topics addressed fall into three major categories: process conditions, sampling, and analytical issues. At other FCEM sites, material balances have often been used to provide an overall quality assessment (if a material balance accounts for the distribution of most mass, it can be presumed that the process, sampling, and analytical components are reasonable). At Site 21, although all major streams were sampled, only the coal and gas streams were analyzed for all substances.

Process Operations

The pilot system at Site 21 was designed with extensive instrumentation and control capabilities that permit extremely stable operation. The pilot system draws about 4% of the flue gas from the host power plant. During all test periods, operation at the host plant was consistent, with a nominal load variation of ± 5 percent (the host plant generates a nominal 700 MW). Gas temperatures, oxygen, and CO_2 concentrations were all consistent on a day-to-day basis, as demonstrated by the process plots in Appendix I.

Sampling

Appendix A presents details about the sampling procedures used at Site 21. Significant observations are as follows:

- A decrease in a number of sampling points per traverse used to collect samples at the absorber outlet from six to two was made to prevent the filters from getting wet by entrained water on the duct wall. Although not meeting the requirements of Method 1, the gas after scrubbing should be well mixed so that vapor phase values should not

be biased. In addition, without a significant amount of larger particles ($< 10\ \mu$), particulate values should also not be biased.

- Due to the relatively large gas volume samples (300 scf), larger moisture impingers were used which required the use of Teflon connecting lines rather than fitted glass joints.

- Several gas sampling runs were voided due to wet or dislodged filters. All reported runs were satisfactorily obtained.

- The outlet duct gas velocity profile was performed twice a day (prior and post sampling with six traverse points) since during sampling only two points were monitored on the traverse. In all cases, the daily flow variation was less than three percent.

Particulate Loading

The 2.5 g/Nm^3 grain loading measured at the ESP inlet (see Table 3-2) is about one-half of what would be expected, based on the coal ash fraction and an assumed 80/20 fly ash/bottom ash split. Since the measured grain loadings are internally consistent and six-point traverses were made (both horizontally and vertically) to collect each sample, it appears that the problem is systemic and unrelated to sampling. Either the grain loading of the gas extracted from the parent power plant is not representative or there is stratification of the ash in the ESP inlet duct.

One cause for the biased grain loading is stratification in the ESP inlet duct. Since a horizontal run of duct was sampled, the use of both vertical and horizontal traversing, as mandated by the method, may not be appropriate. If there is any vertical stratification (which would be expected in a horizontal duct with a 48 ft/sec gas velocity), the measured particulate loading would be biased low. It would be expected that the particulate loading would be higher in the lower portion of the duct; therefore, three-fourths of the traverse points would have lower than average particulate loadings. Other measurements made at this site using only vertical traverses have agreed well with the coal ash balance. Although no data are available, this anecdotal information is believed the most plausible explanation for the ash balance discrepancy.

The biased particulate loadings would affect the measured ESP/FGD system removals. Assuming that the particulate loading is twice what was measured and that the collected ash composition is representative, a calculated removal of 98% would actually be 99%, 99% would be 99.5%, and 99.8% would be 99.9%, etc. for a substance found in the solid phase only. The biased particulate loadings at the inlet do not affect the variance analysis at the FGD system outlet. Table 3-10 presents both measured and calculated removals. As shown, the relative differential is greatest for particulates.

Analytical Quality Control Results

Evaluation of the quality of the measurement data is based on quality control data obtained experimentally during sampling and analyses. Generally, the type of quality assessment information obtained pertains to measurement precision, accuracy (which includes bias and precision), and blank effects, determined using various types of replicate, spiked, and blank samples. The specific characteristics evaluated depend on the type of quality control checks performed. For example, blanks may be prepared at different stages in the sampling and analysis process to isolate the source of a blank effect. Similarly, replicate samples may be generated at different stages to isolate and measure the sources of variability. The QA/QC measures commonly used as part of the FCEM data assessment protocol, and the characteristic information obtained, are summarized in Table 4-1. The absence of any of these types of quality control checks does not necessarily reflect poorly on the quality of the data, but does limit the ability to measure the various components of measurement error.

As shown in the table, different QC checks provide different types of information, particularly pertaining to the sources of inaccuracy, imprecision, and blank effects. As part of FCEM, measurement precision and accuracy are typically estimated from QC indicators that include as much of the total sampling and analytical process as feasible. Precision and accuracy measurements are based primarily on the actual sample matrix. For purposes of comparability, the actual precision and accuracy estimates obtained experimentally during the test programs are compared with the data quality objectives (DQOs) established for the FCEM project.

These objectives are not intended to be used as validation criteria but rather as empirical estimates of the precision and accuracy that would be expected from existing reference measurement methods and that would be considered acceptable. Although analytical precision and accuracy are relatively easy to control and quantify, sampling precision and accuracy are unique to each site and each sample matrix. Data that do not meet these objectives are by no means unacceptable. Rather, the intent is to document the precision and accuracy actually obtained, and the objectives serve as a benchmark for comparison. The effects of not meeting the objectives should be considered in light of the intended use of the data.

Table 4-2 presents the types of quality control data reported for this site. The results for these analyses are in Appendix F. Table 4-3 presents a summary of the precision and accuracy estimates.

Analytical QA/QC

The QA/QC results from Site 21 indicate that the data are valid and meet the project data quality objectives; however, the following problems were identified in the QA/QC analyses:

Table 4-1

Types of Quality Control Samples

QC Activity	Characteristic Measured
Precision	
Replicate Samples collected over time under the same conditions	Total variability, including process or temporal, sampling, and analytical (but not bias)
Duplicate Field Samples collected simultaneously	Sampling plus analytical variability at the actual sample concentrations
Duplicate Analyses of a single sample	Analytical variability at the actual sample concentrations
Matrix- or media-spiked duplicates	Sampling plus analytical variability at an established concentration
Laboratory control sample duplicates	Analytical variability in the absence of sample matrix effects
Surrogate-spiked sample sets	Analytical variability in the sample matrix but at established concentrations
Bias (Mean Measured Minus True)	
Matrix-Spiked Samples	Average recovery of the spiked analyte in the sample matrix, indicating possible matrix interferences and other effects. In a single sample, includes both random error (imprecision) and systematic error (bias).
Media-Spiked Samples	Same as matrix-spiked samples. Used where a matrix spiked sample is not feasible, such as certain stack sampling methods.
Surrogate-Spiked Samples	Analyte recovery in the sample matrix, to the extent that the surrogate compounds are chemically similar to the compounds of interest. Primarily used as indicator of analytical efficacy.
Laboratory control samples (LCS)	Analyte recovery in the absence of actual sample matrix effects. Used as an indicator of analytical control.
Blank Effects	
Field Blank	Total sampling plus analytical blank effect, including sampling equipment and reagents, sample transport and storage, and analytical reagents and equipment.
Trip Blank	Blank effects arising from sample transport and storage. Typically used only for volatile organic compounds analyses.
Method Blank	Blank effects inherent in the analytical method, including reagents and equipment.
Reagent Blank	Blank effects from reagents used.

Table 4-2

Types of Quality Control Data Reported

Analysis	Precision					Accuracy			Blank			
	Replicate Runs	Duplicate Field Samples	Duplicate Lab Analysis	Matrix or Media Spiked Duplicate	Lab Control Sample Duplicate	Matrix or Media Spike	Surrogate Spike	Lab Control Sample	Field Blank	Trip Blank	Method Blank	Reagent Blank
METALS												
Coal												
CVAAS	X				X			X				
GFAAS	X				X			X				
ICP-AES	X				X			X				
ESP Inlet Gas, Solid Phase												
CVAAS	X				X			X				X
GFAAS	X		X		X			X				X
ICP-AES	X		X		X			X				X
ESP Inlet Gas, Vapor Phase												
GFAAS	X		X	X	X	X		X				X
ICP-AES	X		X	X	X	X		X				X
Absorber Outlet Gas, Solid Phase												
GFAAS	X	X	X		X			X				X
ICP-AES	X	X	X		X			X				X
ICP-MS	X	X	X		X			X				X
Absorber Outlet Gas, Vapor Phase												
CVAAS	X	X	X	X	X	X		X				X
GFAAS	X	X	X	X	X	X		X				X
ICP-AES	X	X	X	X	X	X		X				X
ICP-MS	X	X	X		X	X		X				X

Table 4-2 (Continued)

Analysis	Precision					Accuracy			Blank			
	Replicate Runs	Duplicate Field Samples	Duplicate Lab Analysis	Matrix or Media Spiked Duplicate	Lab Control Sample Duplicate	Matrix or Media Spike	Surrogate Spike	Lab Control Sample	Field Blank	Trip Blank	Method Blank	Reagent Blank
ANIONS												
Coal	X											
ESP Inlet Gas, Solid Phase												
IC	X											X
SIE	X											X
ESP Inlet Gas, Vapor Phase												
IC	X			X	X	X		X				
SIE	X			X	X	X		X				
Absorber Outlet Gas, Solid Phase												
IC	X	X	X									X
SIE	X	X	X					X				X
Absorber Outlet Gas, Vapor Phase												
IC	X	X	X	X	X	X		X				
SIE	X	X	X	X	X	X		X				
PAHs												
Absorber Outlet Gas												
HRGCMS	X	X	X	X		X	X			X		X

Table 4-3

Summary of Precision and Accuracy Estimates

Measurement Parameter	How Measured	Objectives		Measured	
		Precision (% RPD)	Accuracy (% Recovery)	Precision (% RPD) [a]	Accuracy (% Recovery)
Metals by CVAAS + GFAAS	Precision and Accuracy - Matrix Spike Duplicates				
ESP Inlet					
Arsenic		20	75-125	1.8	90
Cadmium		20	75-125	7.9	87
Lead		20	75-125	17	75
Mercury		20	75-125	0.9	108
Nickel		20	75-125	5.1	92
Selenium		20	75-125	12	71
Absorber Outlet					
Arsenic		20	75-125	11	81
Cadmium		20	75-125	7.0	112
Lead		20	75-125	16	98
Mercury		20	75-125	4.6	90
Nickel		20	75-125	9.0	90
Selenium		20	75-125	15	67
Metals by ICP-AES	Precision and Accuracy - Matrix Spike Duplicates				
ESP Inlet					
Arsenic		20	75-125	2.7	98
Barium		20	75-125	2.7	84
Beryllium		20	75-125	1.1	90
Cadmium		20	75-125	7.0	93
Chromium		20	75-125	1.0	93
Cobalt		20	75-125	1.9	96

Table 4-3 (Continued)

Measurement Parameter	How Measured	Objectives		Measured	
		Precision (% RPD)	Accuracy (% Recovery)	Precision (% RPD) [a]	Accuracy (% Recovery)
Copper		20	75-125	1.3	96
Lead		20	75-125	0.4	93
Manganese		20	75-125	0.9	95
Molybdenum		20	75-125	2.8	104
Nickel		20	75-125	3.9	95
Vanadium		20	75-125	1.7	95
Metals by ICP-AES	Precision and Accuracy - Matrix Spike Duplicates				
Scrubber Outlet					
Arsenic		20	75-125	4.3	105
Barium		20	75-125	1.7	86
Beryllium		20	75-125	0.3	93
Cadmium		20	75-125	0.7	94
Chromium		20	75-125	9.4	105
Cobalt		20	75-125	0.7	94
Copper		20	75-125	0.9	95
Lead		20	75-125	5.7	90
Manganese		20	75-125	0.8	93
Molybdenum		20	75-125	0.7	97
Nickel		20	75-125	3.0	97
Vanadium		20	75-125	0.9	95
Metals by ICP-MS - Microwave Digestion	Precision and Accuracy - Laboratory Control Samples				
Liquids					
Arsenic		20	75-125	21	55
Beryllium		20	75-125	22	60
Cadmium		20	75-125	2.2	54
Chromium		20	75-125	23	55

Table 4-3 (Continued)

Measurement Parameter	How Measured	Objectives		Measured	
		Precision (% RPD)	Accuracy (% Recovery)	Precision (% RPD) [a]	Accuracy (% Recovery)
Nickel		20	75-125	16	400
Lead		20	75-125	18	91
Selenium		20	75-125	6.5	128
Metals by ICP-MS - Method 3020 Digestion	Precision and Accuracy - Matrix-Spike Duplicate				
Liquids					
Arsenic		20	75-125	12	76
Beryllium		20	75-125	NA [b]	NA
Cadmium		20	75-125	7	96
Chromium		20	75-125	13	69
Mercury		20	75-125	NA	NA
Nickel		20	75-125	11	80
Lead		20	75-125	74	205
Selenium		20	75-125	15	294
Metals by ICP-AES	Precision and Accuracy - Laboratory Control Samples				
Filters					
Barium		20	75-125	4.1	77
Beryllium		20	75-125	2.0	92
Cobalt		20	75-125	6.8	87
Chromium		20	75-125	1.1	84
Copper		20	75-125	3.3	82
Manganese		20	75-125	1.5	87
Nickel		20	75-125	5.2	91
Lead		20	75-125	NA	122
Vanadium		20	75-125	2.4	88

Table 4-3 (Continued)

Measurement Parameter	How Measured	Objectives		Measured	
		Precision (% RPD)	Accuracy (% Recovery)	Precision (% RPD) [a]	Accuracy (% Recovery)
Metals by ICP-MS - Microwave Digestion	Precision and Accuracy - Laboratory Control Samples				
Filters					
Arsenic		20	75-125	2.7	54
Beryllium		20	75-125	15	65
Cadmium		20	75-125	0.4	68
Chromium		20	75-125	10	20
Mercury		20	75-125	20	1500
Nickel		20	75-125	11	470
Lead		20	75-125	6.2	97
Selenium		20	75-125	23	111
Metals in Coal	Precision and Accuracy - Laboratory Control Samples				
CVAAS & GFAAS					
Arsenic		20	85-115	3.4	119
Cadmium		20	85-115	5.3	106
Lead		20	85-115	1.4	92
Mercury		20	85-115	2.8	109
Nickel		20	85-115	6.2	111
Selenium		20	85-115	21.4	91
ICP-AES					
Beryllium		20	90-110	4.1	95
Chromium		20	90-110	9.5	103
Lead		20	90-110	22.2	88
Nickel		20	90-110	10.1	102

Table 4-3 (Continued)

Measurement Parameter	How Measured	Objectives		Measured	
		Precision (% RPD)	Accuracy (% Recovery)	Precision (% RPD) [a]	Accuracy (% Recovery)
Metals by CVAAS & GFAAS	Precision and Accuracy - Laboratory Control Samples				
Solids					
Arsenic		20	85-115	3.4	119
Cadmium		20	85-115	5.3	106
Mercury		20	85-115	2.8	109
Nickel		20	85-115	6.2	111
Lead		20	85-115	1.4	92
Selenium		20	85-115	21.4	91
Liquids					
Arsenic		20	85-115	6.1	92
Cadmium		20	85-115	12	98
Mercury		20	85-115	3.2	100
Nickel		20	85-115	6.5	93
Lead		20	85-115	7.0	97
Selenium		20	85-115	6.5	96
Metals by ICP-AES	Precision and Accuracy - Laboratory Control Samples				
Solids					
Barium		20	90-110	4.2	87
Beryllium		20	90-110	4.1	95
Cobalt		20	90-110	11	91
Chromium		20	90-110	10	103
Copper		20	90-110	3.8	93
Manganese		20	90-110	1.6	91
Nickel		20	90-110	10	102
Lead		20	90-110	22	88
Vanadium		20	90-110	2.9	93

Table 4-3 (Continued)

Measurement Parameter	How Measured	Objectives		Measured	
		Precision (% RPD)	Accuracy (% Recovery)	Precision (% RPD) [a]	Accuracy (% Recovery)
Metals by ICP-AES	Precision and Accuracy - Laboratory Control Samples				
Liquids					
Arsenic		20	90-110	0.3	98
Barium		20	90-110	0.5	102
Beryllium		20	90-110	0.7	100
Cadmium		20	90-110	1.8	101
Cobalt		20	90-110	1.6	100
Chromium		20	90-110	0.7	99
Copper		20	90-110	0.3	100
Manganese		20	90-110	1.2	99
Nickel		20	90-110	2.4	101
Lead		20	90-110	0.4	101
Vanadium		20	90-110	1.6	102
PAHs in Outlet Gas (Condensate)	Precision - Data Not Available Accuracy - Matrix Spike				
Acenaphthalene		40	50-150	NA	84
Acenaphthene		40	50-150	NA	82
Fluorene		40	50-150	NA	118
Phenanthrene		40	50-150	NA	84
Anthracene		40	50-150	NA	86
Fluoranthene		40	50-150	NA	79
Pyrene		40	50-150	NA	81
Benzo(a)anthracene		40	50-150	NA	64
Chrysene		40	50-150	NA	75
5-methyl chrysene		40	50-150	NA	78
Benzo(b,j&k)fluoranthenes		40	50-150	NA	71
Benzo(a)pyrene		40	50-150	NA	66

Table 4-3 (Continued)

Measurement Parameter	How Measured	Objectives		Measured	
		Precision (% RPD)	Accuracy (% Recovery)	Precision (% RPD) [a]	Accuracy (% Recovery)
Dibenz(a,h)acridine		40	50-150	NA	92
Benz(a,i)acridine		40	50-150	NA	57
Indeno(1,2,3-cd)pyrene		40	50-150	NA	48
Dibenz(a,h)anthracene		40	50-150	NA	88
7H-dibenzo(c,g)carbazole		40	50-150	NA	74
Benzo(g,h,i)perylene		40	50-150	NA	75
Dibenzo(a,e)pyrene		40	50-150	NA	50
Dibenzo(a,i)pyrene		40	50-150	NA	35
Dibenzo(a,h)pyrene		40	50-150	NA	18
PAHs in Outlet Gas (XAD Resin)	Precision and Accuracy - Matrix Spike Duplicates				
Acenaphthalene		40	50-150	16	90
Acenaphthene		40	50-150	18	89
Fluorene		40	50-150	19	91
Phenanthrene		40	50-150	14	101
Anthracene		40	50-150	12	94
Fluoranthene		40	50-150	8.1	87
Pyrene		40	50-150	11	93
Benzo(a)anthracene		40	50-150	9.3	81
Chrysene		40	50-150	15	90
5-methyl chrysene		40	50-150	28	88
Benzo(b,j&k)fluoranthenes		40	50-150	14	83
Benzo(a)pyrene		40	50-150	14	78
Dibenz(a,h)acridine		40	50-150	14	86
Dibenz(a,i)acridine		40	50-150	18	76
Indeno(1,2,3-cd)pyrene		40	50-150	8.4	75
Dibenz(a,h)anthracene		40	50-150	8.1	95
7H-dibenzo(c,g)carbazole		40	50-150	15	91

Table 4-3 (Continued)

Measurement Parameter	How Measured	Objectives		Measured	
		Precision (% RPD)	Accuracy (% Recovery)	Precision (% RPD) [a]	Accuracy (% Recovery)
Benzo(g,h,i)perylene		40	50-150	8.0	85
Dibenzo(a,e)pyrene		40	50-150	26	93
Dibenzo(a,i)pyrene		40	50-150	12	88
Dibenzo(a,h)pyrene		40	50-150	19	63
Anions in ESP Inlet and Scrubber Outlet	Precision and Accuracy - Matrix Spike Duplicates				
Chloride		20	80-120	5.0	101
Fluoride		20	80-120	3.1	93
Sulfate		20	80-120	5.2	98

[a]RPD = Relative percent difference.

[b]NA = Not available.

- A significant quantity of phenanthrene was detected in the XAD trip blanks (see Appendix G for a relative comparison of measured and blank phenanthrene results);

- Laboratory check samples (LCS) and matrix-spike samples (MS) indicate a high and significant bias in the ICP-MS data; and

- Lab control sample data suggest a possible high bias in the coal mercury results (CVAAS) (see Table F-2, page F-16), while spike recovery data indicate a possible low bias in the flue gas selenium results by GFAAS.

Precision estimates shown in Table 4-3 are based on replicate spiked sample analyses. Duplicate analyses were also performed on a number of samples; these are summarized in Appendix F.

Accuracy estimates in this study are based on the recovery of an analyte spiked into a sample or sample medium. These results are summarized in Table 4-3. Surrogate spike recoveries for PAH analyses are summarized in Appendix F.

A discussion of precision and accuracy appears below for each measurement type.

Precision is a measure of the reproducibility of measurements under a given set of conditions. It is expressed in terms of the distribution, or scatter, of the data, calculated as the standard deviation and coefficient of variation (standard deviation divided by the mean). For duplicates, precision is expressed as the relative percent difference (RPD).

Accuracy is a measure of the deviation from a measurement result and the "true" or expected value. In a single measurement, accuracy includes components of both random error, or imprecision, and systematic error, or bias. The average of several recovery values tends toward a limiting mean, which is an estimate of the bias, or persistent positive or negative deviation from the "true" value of the collected sample only, not of the stream sampled, and then only of a single laboratory. No estimate is made of the bias between laboratories in this study. Bias estimates from spike recoveries only include the error in the measurement process from the point where the spike was introduced through the succeeding steps in the analytical procedure. Bias introduced by sampling and by autocorrelation effects of the sampled population cannot be found since the "true" mean value of the sampled population (the flue gas) is not known.

The efficiency of the analytical procedure in the sample matrix is quantified by the analysis of spiked samples containing target or indicator analytes or other quality assurance measures, as necessary. Spiked samples usually provide a measure of accuracy or bias at medium concentration levels, expressed as percent recovery; blank samples also provide a measure of bias, although at low or near-detection levels.

Metals

Precision. Table 4-3 lists the objectives for the reported precision of the metals analytical data. When the analyte levels were sufficiently above the detection limit, duplicate precision was within acceptance criteria. Higher relative variability is typically a consequence of values at or below the detection limit.

Accuracy. Table 4-3 lists the objectives for and the reported accuracy of the metals analytical data. In flue gas samples that were spiked, recoveries of metals by absorption (GFAAS and CVAAS) techniques were generally within the objectives, except for selenium, for which recoveries were slightly low, averaging about 70% recovery. The average recoveries for metals in flue gas samples that were spiked then analyzed by ICP-AES were all within the recovery objective.

Laboratory control sample results show acceptable recoveries for metals in solids representing coal by both absorption and emission (ICP-AES) spectroscopy. Laboratory control sample results were also within the objectives for solids and liquids associated with gas sample analyses by CVAAS, GFAAS, and ICP-AES. Results for metals analyses by ICP-MS, although more sensitive than ICP-AES, showed significantly lower average recoveries for several of the metals, except nickel in the solid phase and both nickel and selenium in the impinger solution samples, which were exceedingly high and effectively not useable.

Appendix F (Table F-2) contains accuracy estimates for mercury in coal, based on analysis of coal standards (SARM 18, 19, and 20) at three different concentrations. The results showed 130% recovery at the lowest concentration (0.04 ppm), 96% at 0.2 ppm, and 87% at 0.25 ppm. These data show acceptable measurements for mercury in coal. The mean sample value was 0.15 ppm.

Blank Effects. Blank results are summarized in Appendix F. Appendix G shows the relationship of blank to sample results and the blank corrections applied.

PAHs

Precision. The precision estimates for PAH analyses summarized in Table 4-3 are based on matrix spike duplicate analyses of XAD resin. The repeatability for all 21 analytes reported was within the precision objective.

Accuracy. Table 4-3 lists the objective for and the reported accuracy of the semi-VOST analyses. The accuracy estimates are based on the recovery of matrix spikes in condensate and XAD resin. All recoveries were within the objective for the XAD resin spikes. Three out of the 21 results in the spiked condensate were below the objective.

Blank Effects. Appendix F summarizes the blank results for PAH analyses. Many below-detection-limit measurement values were reported. The concentrations in the blanks were extremely low, typically not exceeding five times the method detection limit

and, more often, well below. The phenanthrene concentration was relatively high in the blanks, reported at approximately 3-9 ng/sample in the laboratory XAD blank, and from 25-40 ng/sample in XAD trip blanks. Acenaphthene, fluorene, anthracene, fluoranthene, and pyrene were also detected in the XAD trip blanks in the 10 ng/sample range.

Anions

Precision. Table 4-3 lists the objective for and the reported precision of the acid gas (anion) analyses. Precision estimates are based on matrix-spiked duplicate sample analysis. The precision measured was well within the objective.

Accuracy. Table 4-3 lists the objective for and the reported accuracy of the acid gas analyses. The accuracy estimates are based on the recovery from samples spiked with the analyte of interest. The accuracy measured was well within the recovery objectives.

Blank Effects. Blank sample results for anions are summarized in Appendix F. The concentrations detected were on the order of 0.01 mg/L and reveal no contamination concerns.

Comparison of Analytical Methods

Two alternative methods for metals analyses were evaluated at Site 21: ICP-MS and impinger concentration followed by GFAAS or ICP-AES.

Historically, three analytical techniques have been used to analyze for the FCEM target metals. Because of its greater sensitivity, GFAAS is used to analyze for arsenic, cadmium, lead, nickel, and selenium; CVAAS is used for mercury; and ICP-AES is used for the others. ICP-MS, which is sensitive enough for all of the target elements (except mercury), was investigated as an alternative analytical method at Site 21. ICP-MS analyses were done on both the front half (solid phase) and back half (impinger catch) of all eight of the multi-metals trains at the absorber outlet.

The multi-metals method specifies that the impinger solutions be concentrated before analysis to lower the detection limits. In past FCEM efforts, the detection limits were adequate to meet the desired gas phase detection level of 20 $\mu g/Nm^3$ without concentration. At Site 21, a portion of the impinger solutions from the eight absorber outlet metals trains was concentrated and then analyzed by the standard GFAAS or ICP-AES methods to compare concentrated and unconcentrated results.

Table 4-4 presents a comparison of GFAAS and ICP-AES to ICP-MS analytical results for the solid phase fraction. These data show that the ICP-MS results are consistently higher than the standard GFAAS or ICP-AES results. This could be caused by an analytical inference in the sample matrix. In addition, QA spike recoveries for a laboratory control sample (LCS) were generally below the data quality objectives, which indicates a method (sample preparation/analysis) bias may exist. The LCS is a blank filter that is prepared in a standardized aqueous solution. Since the entire sample filters

Table 4-4

Comparison of ICP-MS to Standard Methods for Stack Gas Solid Phase ($\mu g/Nm^3$)

Method	Substance	Mean	95% CI
GFAAS	Arsenic	7.41	0.77
ICP-MS	Arsenic	9.83	3.17
ICP-AES	Beryllium	0.14	0.01
ICP-MS	Beryllium	0.41	0.38
GFAAS	Cadmium	0.14	0.02
ICP-MS	Cadmium	0.21	0.08
ICP-AES	Chromium	3.28	0.32
ICP-MS	Chromium	5.17	1.54
GFAAS	Lead	1.33	0.17
ICP-MS	Lead	3.49	0.93
GFAAS	Nickel	1.70	0.18
ICP-MS	Nickel	6.36	1.93
GFAAS	Selenium	9.6	4.6
ICP-MS	Selenium	13.50	12.03

CI = Confidence interval.

were digested, it was not possible to prepare matrix spike/duplicate QA samples for analysis. The matrix spike and matrix spike duplicate (MS/MSD) sample may have been able to indicate if interferences or method biases were responsible for these poor results. Also, the precision of the ICP-MS results is lower, as shown by the larger confidence intervals. For these reasons, the ICP-MS results were not presented in Section 3.

The impingers (vapor phase fraction) were analyzed by:

- ICP-MS (not concentrated);
- GFAAS or ICP-AES (not concentrated); and
- GFAAS or ICP-AES (concentrated).

The results for the vapor-phase fractions appear in Table 4-5. (Barium, cobalt, copper, manganese, molybdenum, and vanadium were not analyzed by ICP-MS. Only concentrated and unconcentrated ICP-AES measurements were made.) These results show that, except for selenium, for analyte concentrations above the detection limit, ICP-MS and the unconcentrated standard methods are within a factor of two and have similar confidence interval-to-mean value ratios. Also, the analytes not detected by standard methods (arsenic and chromium) were detected by ICP-MS at or below the standard method detection limits. Selenium concentrations measured by ICP-MS were higher than those measured by GFAAS. Because of interference from argon in the plasma, the selenium values by ICP-MS are probably biased high.

Of the nine analytes in Table 4-5 detected by unconcentrated standard methods, four (beryllium, cadmium, cobalt, and lead) were measured at significantly lower levels (<20% of the mean value) when the impinger solutions were concentrated before analysis, one was measured at a higher level (selenium was 10 times higher), and four (barium, copper, manganese and nickel) were not significantly different. The significant decrease in the measured concentrations of the four analytes after concentration of the impinger solutions suggests: 1) volatilization and loss of these specific compounds; 2) the formation of an insoluble form of the compounds; or 3) precipitation of the compounds on glassware during the concentration process. The reason for the higher selenium values seen after concentration is not known. An explanation may be that an interfering substance becomes more of a problem as its level increases by concentration, although likely substances have not been identified. The four analytes not detected by the standard methods (arsenic, chromium, molybdenum, and vanadium) were detected when the impingers were concentrated before analysis.

Further study is needed to address the apparent bias problem associated with analysis of the solid-phase fraction of the metals trains by ICP-MS before this method can be used as the primary means of analysis. Since ICP-MS and the standard GFAAS and ICP-AES methods agree relatively well for the analysis of impinger solutions, an interference from one or more of the major substances (aluminum, iron, etc.) digested in the solid-phase fraction may be responsible for the solid-phase bias. Because of an apparent loss of a

Table 4-5

Comparison of ICP-MS and Impinger Solution Concentration[a] to Standard Methods for Stack Gas Vapor Phase ($\mu g/Nm^3$)

Method	Analyte	Mean	95% CI
GFAAS	Arsenic	ND(0.3)	--
ICP-MS	Arsenic	0.27	0.35
Conc/GFAAS	Arsenic	0.27	0.41
ICP-AES	Barium	0.28	0.26
Conc/ICP-AES	Barium	0.16	0.16
ICP-AES	Beryllium	0.02	0.03
ICP-MS	Beryllium	0.01	0.01
Conc/ICP-AES	Beryllium	0.004	0.01
GFAAS	Cadmium	0.56	0.35
ICP-MS	Cadmium	0.43	0.29
Conc/GFAAS	Cadmium	0.06	0.04
ICP-AES	Chromium	ND(0.5)	--
ICP-MS	Chromium	0.36	0.16
Conc/ICP-AES	Chromium	0.35	0.17
ICP-AES	Cobalt	4.67	3.27
Conc/ICP-AES	Cobalt	0.16	0.07
ICP-AES	Copper	0.71	0.22
Conc/ICP-AES	Copper	0.24	0.11
GFAAS	Lead	6.42	7.06
ICP-MS	Lead	6.62	6.16
Conc/GFAAS	Lead	0.08	0.05

Table 4-5 (Continued)

Method	Analyte	Mean	95% CI
ICP-AES	Manganese	17.41	19.32
Conc/ICP-AES	Manganese	8.60	12.28
ICP-AES	Molybdenum	ND(0.9)	--
Conc/ICP-AES	Molybdenum	0.04	0.04
GFAAS	Nickel	0.46	0.43
ICP-MS	Nickel	0.81	0.36
Conc/GFAAS	Nickel	0.55	0.34
GFAAS	Selenium	2.59	0.79
ICP-MS	Selenium	35.60	15.04
Conc/GFAAS	Selenium	24.99	9.04
ICP-AES	Vanadium	ND(0.8)	--
Conc/ICP-AES	Vanadium	0.20	0.33

[a]Impinger solutions concentrated by a factor of 25.

ND = Not detected. Method detection limit shown in parentheses.

Conc = Concentration of impinger solutions followed by analysis by GFAAS or ICP-AES.

CI = Confidence interval.

large portion of some analytes during concentration of the impinger solutions, this procedure is not recommended as a way to improve detection limits for vapor-phase metals. Therefore, the unconcentrated standard method results were selected for presentation in Section 3 for the vapor-phase results.

Section 5

DATA PRECISION AND ANALYSIS OF VARIANCE

One of the primary objectives of the Site 21 sampling effort was to characterize the precision of the analytical results. At the ESP inlet, only replicate samples were taken; therefore, the overall precision (day-to-day sampling/preparation, and analytical variability) is expressed using the coefficient of variation (CV). The CV is the ratio of the sample population standard deviation divided by the mean. Using the appropriate "t" value for the number of samples allows the calculation of confidence intervals. At the absorber outlet, data were collected to allow a nested experimental analysis of variance (ANOVA) to be conducted for each analyte. This analysis is used in conjunction with the coefficient of variation (CV) to evaluate the precision of the data for each substance. The ANOVA allows the magnitude of the components of variance to be determined. Refer to Appendix H for a discussion of the ANOVA technique.

ESP Inlet Data

Coefficients of variation for the six combined (solid- and vapor-phase) ESP inlet metals and anions runs are shown in Table 5-1. The CVs for substances found mainly in the solid phase are between 15 and 30 percent. For the substances found predominately in the vapor phase (mercury, HCl, and HF), the CVs range from 7 to 21 percent.

With six samples, a 15% CV is equivalent to a 95% confidence interval (CI) of $\pm$ 15% of the mean value. Assuming the same population variance, the measurement uncertainty can be predicted for fewer numbers of samples. For example, with the three samples normally collected at FCEM sites, the 95% CI will increase from 15% to 36% of the mean. It would be useful if the data from Site 21 could be used to predict variance at other sites as a function of the number of samples collected. If this were possible, by defining a precision objective, the required number of measurements could be made. However, it is also necessary that the interlaboratory precision and bias be established for all of the sampling and analysis steps (probe collection, recovery, preparation and analysis for each sample train). Only in this way can a determination at each site of the representativeness of the sample collected by the probe and its possible time dependency and the variability and bias of the entire sampling/measurement process be separated from the day-to-day variability.

The evaluation of high-dust gas solid phase data from other FCEM sites (11, 12, 14, and 15) indicates that the 15-30% CV range seen at Site 21 is on the low end of what has typically been found. Also, because of the relatively small sample set normally obtained at other sites, the range of CVs is much wider; therefore, it cannot be shown that the variances at the FCEM sites are similar (the CVs cannot be pooled). Although the

Table 5-1

ESP Inlet Combined Coefficient of Variation

Substance	CV %
Arsenic	26
Barium	18
Beryllium	18
Cadmium	25
Chloride	21
Chromium	23
Cobalt	16
Copper	16
Fluoride	7
Lead	15
Manganese	28
Mercury	11
Molybdenum	27
Nickel	18
Selenium	19
Titanium	17
Vanadium	16

15-30% CV is representative of the population at the ESP inlet sampled at Site 21, there is no statistical basis to confirm that these data can be used to predict the variability of high-dust gas results obtained at future sites. As discussed in Section 4, the accuracy of the results measured at the ESP inlet are possibly biased by 50% due to stratification in the duct. These phenomena make the relatively small CVs measured all the more remarkable. It also indicates that using statistical evaluation of only a portion of the error terms included in the overall measurement of the true concentration in the stream sampled can produce "acceptable" results that may not be physically correct and thus are an artifact of the abbreviated measurement process itself.

Absorber Outlet Gas

The evaluation of the absorber outlet gas results is divided into three sections: semi-volatile organic compounds, solid-phase metals and anions, and vapor-phase metals and anions. A CV analysis and an ANOVA was completed for each substance.

Figure 5-1 shows the nested experimental design used to collect data for the ANOVA of the absorber outlet results. The ANOVA provides a breakdown of variance into a day-to-day or process component, a sampling and sample preparation component, and an analytical component. The analytical component represents only instrument variability; variance resulting from sample location, equipment, sample recovery, digestion, extractions, and handling are included in the sampling and preparation component. All other variance is attributed to day-to-day differences (varying fuel and process conditions). A description of the ANOVA analysis and a summary of the calculated variance components for each substance is included in Appendix H. In the following discussion, the results are discussed generally rather than element by element.

In this analysis, a random number between zero and the method detection limit (MDL), with an equal probability for any number in this range, was used for runs in which an analyte was not detected. A constant value such as zero, the MDL, or one-half the MDL was not used, since this would artificially bias the population variance in most cases. A probability distribution for the random number based on detected values or on some other maximum likelihood estimator (MLE) method was not used, since reliable distributions could not be predicted with the available data. This methodology may overestimate the analytical variability component when some of the values are not detected, i.e., if a substance is detected in some of the samples, the probability is high that it is present in all samples. Allowing "zero" or close to zero values using the random equal probability approach may overestimate the variability. Conversely, if a substance is never detected, the random approach will overestimate the variability by having values near the detection limit.

Semivolatile Organic Compounds

CVs for the semivolatile organic compounds are shown in Figure 5-2. The CVs are generally about 100 percent. The results of the ANOVA are presented in Figure 5-3, which shows that for 5-methyl chrysene (as an example), 6.5% of the variance is due to

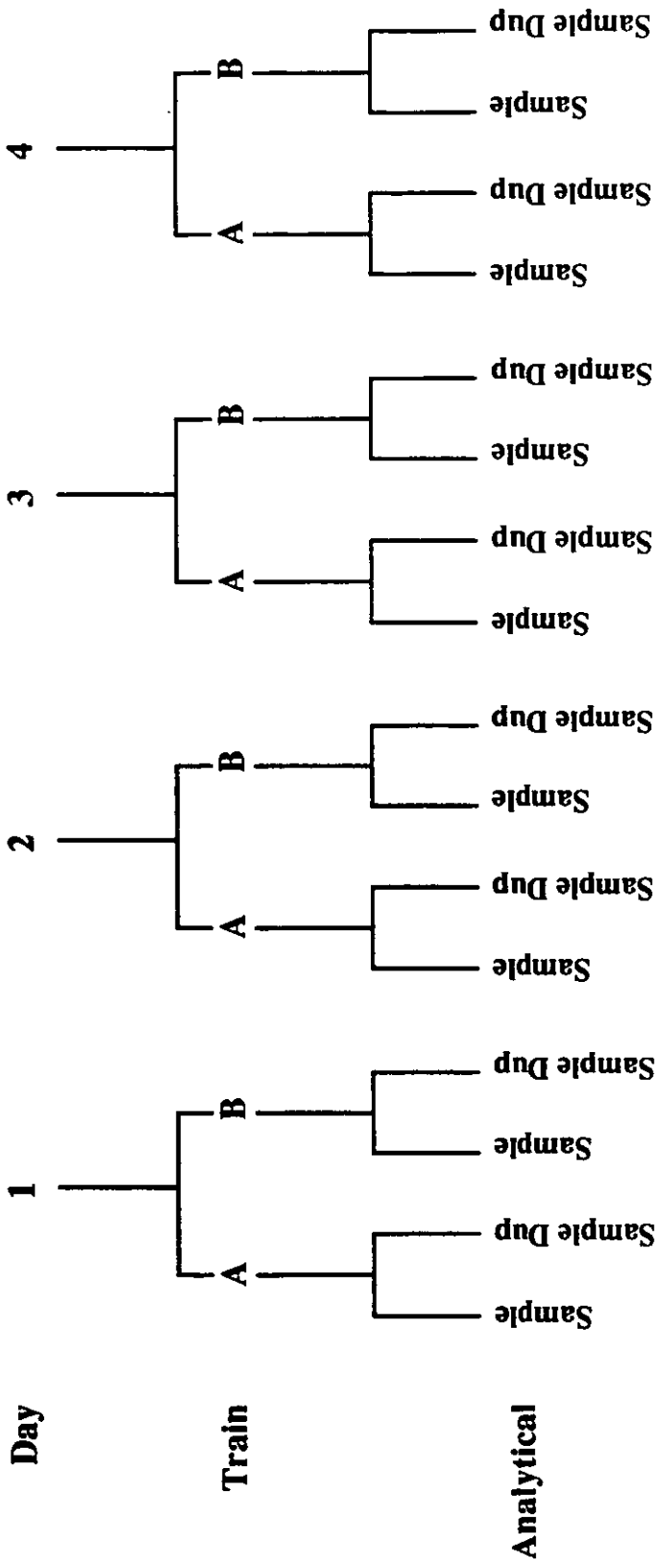
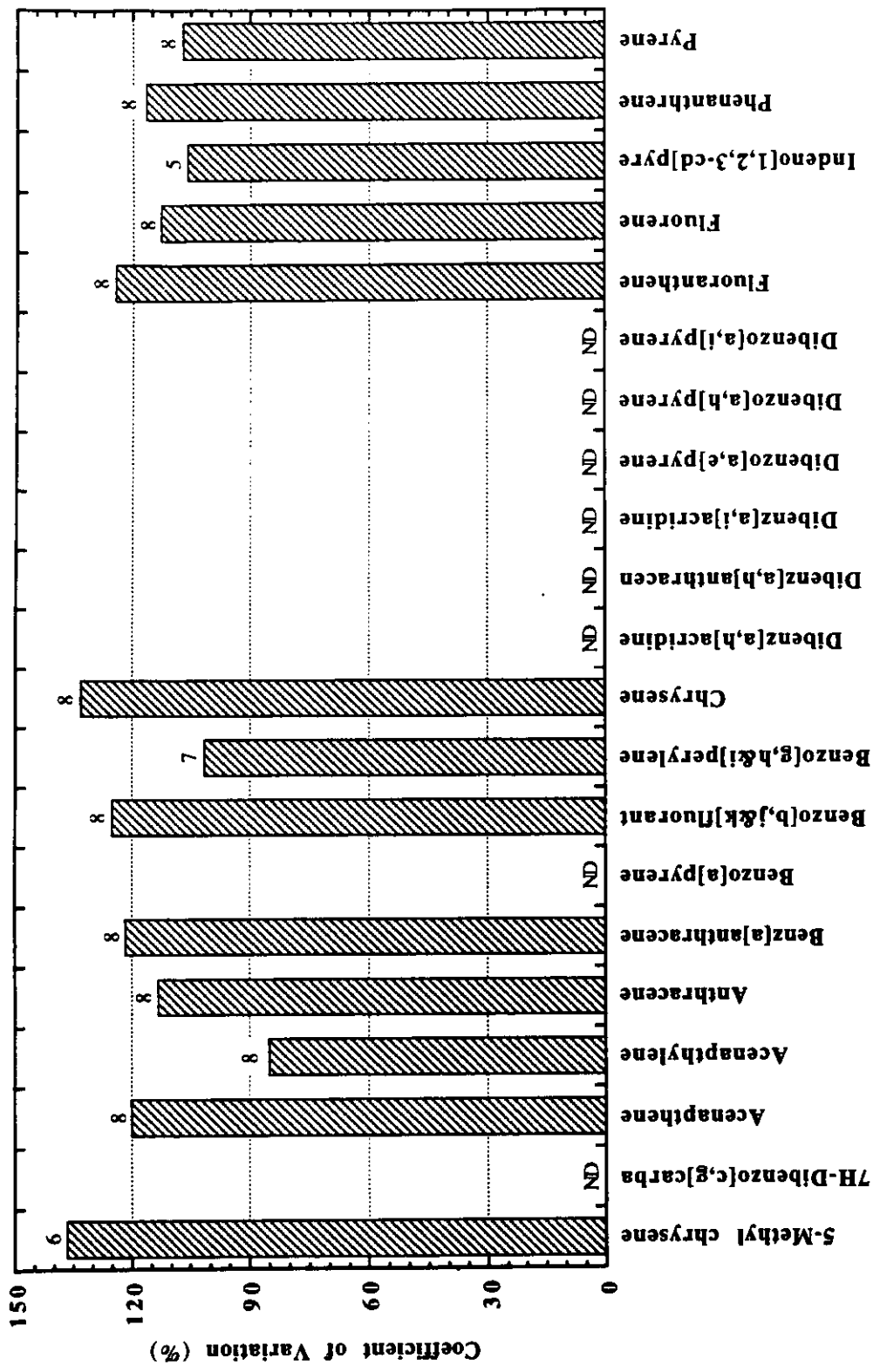
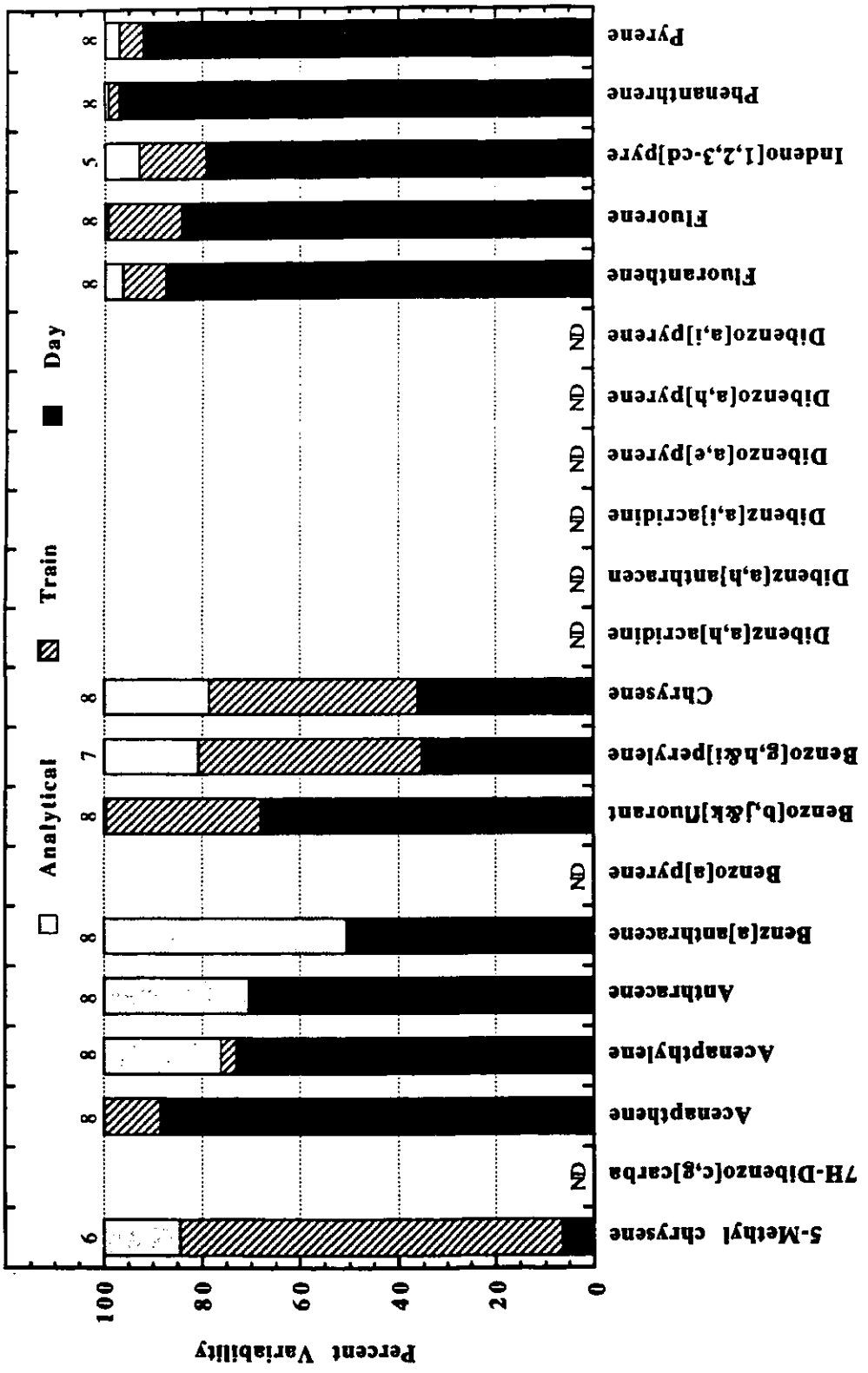


Figure 5-1. FCEM Site 21 Analysis of Variance Experimental Design, Absorber Outlet Gas



ND = Substance was not detected (mean less than detection limit). Number indicates how many of the eight samples had results greater than the detection limit.

Figure 5-2. FCEM Site 21 - Semivolatile Organic Compounds Coefficient of Variation



ND = Substance was not detected (mean less than detection limit). Number indicates how many of the eight samples had results greater than the detection limit.

Figure 5-3. FCEM Site 21 - Semivolatile Organic Compounds Percentages of Variability

day-to-day fluctuations, 78% is due to sampling (including sample preparation), and 15.5% is due to analytical variation. For the analytes detected in all eight samples, such as acenaphthene, fluorene, and phenanthrene, the major source of variance was the sample date.

In other words, there was more variability between sampling days than between duplicate trains or duplicate analyses. This might be expected, since the emissions of organic compounds from a coal-fired boiler are not related to any type of mass balance constraint, as are the emitted metals and anions. Organic emissions are related to boiler operation or fuel quality. Discrete events of low excess air, or flow distribution problems associated with small load or fuel changes could result in higher organic emissions for that period. Although there is no indication that the power plant boiler was operating atypically while the Run 2 samples were being collected, Table 3-8 clearly shows that the emissions for that day (August 19, 1992) were much higher than for the other three.

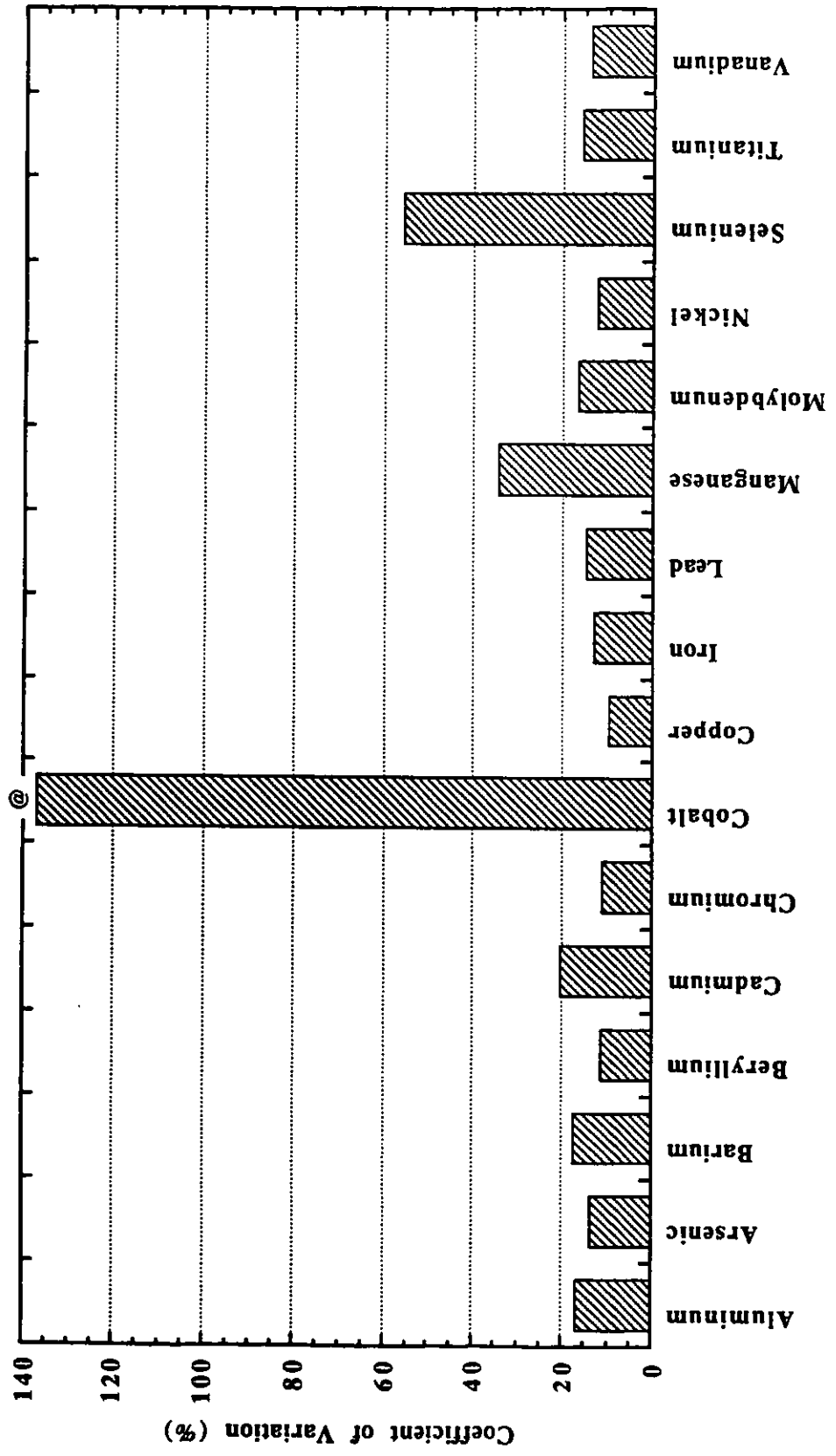
For the MM5 analytes with values near the method detection limit or the method blank value (the average run values are compared with the blank values in Appendix G), analytical variance contributes more to the overall variability. This is expected, since near the detection limit, or sampling media background (blank), instrument noise is significant. Random errors in sample recovery and background ambient contamination contribute a portion of this instrument noise. Also, with significant values in the "not detected" range, the variability contribution from the random equal probability numbers is significant.

Solid-Phase Metals

Standard Analytical Procedures

Figure 5-4 shows the CVs for solid phase metals. As shown in the figure, most of the CVs are less than 20 percent. Selenium, cobalt, and manganese have CVs greater than 20 percent. Aluminum, iron, and titanium are included to represent the major constituents of the boiler ash fraction of the collected solids. The higher CV for cobalt is related to the low measured values and one apparent outlier (Run 7b). Cobalt was less than five times the MDL in five of the eight runs and a factor of 10 higher than the average in Run 7b. A Dixon's[1] ratio test for outliers indicates, that with a confidence of more than 99%, this point is an outlier. Eliminating this point decreases the cobalt CV to 17%, and most of the variance is attributed to the day of testing. The higher manganese CV can also be explained since the Run 7b value is considered to be an outlier, with a confidence greater than 99 percent. Without this point, the manganese CV is 13 percent. The reason for the higher CV for selenium is not apparent. However, since the analytical duplicates agreed well, and sampling variance for the other metals is low, a

[1]Crow, E.L., F.A. Davis, and M.W. Maxfield. "Statistics Manual," Research Department, U.S. Naval Ordnance Test Station, Dover Publications, New York, 1960.



@ = Mean value less than five times detection limit. All substances were detected in all eight samples.

Figure 5-4. FCEM Site 21 - Solid-Phase Metals Coefficient of Variation (GFAAS & ICP-AES)

random contamination during sample preparation is probably responsible for the higherselenium variability. Considering the four sampling pairs, the relative difference between same-day samples for three of the pairs is about 100 percent.

The ANOVA results presented in Figure 5-5 indicate that a major source of variability for 10 of the 16 substances in the solid-phase analysis is from the day-to-day variance in the process. The sampling and preparation component dominates for 6 of the 16 substances. This indicates that a 10-20% CV is the lowest that could be achieved at this site for solid-phase metals.

An additional observation from the ANOVA analysis of the solid-phase metals data is that, although the metals analyzed by GFAAS (arsenic, cadmium, lead, and nickel) had CVs similar to those analyzed by ICP-AES, the contribution of sampling and sample preparation to the overall variance was larger.

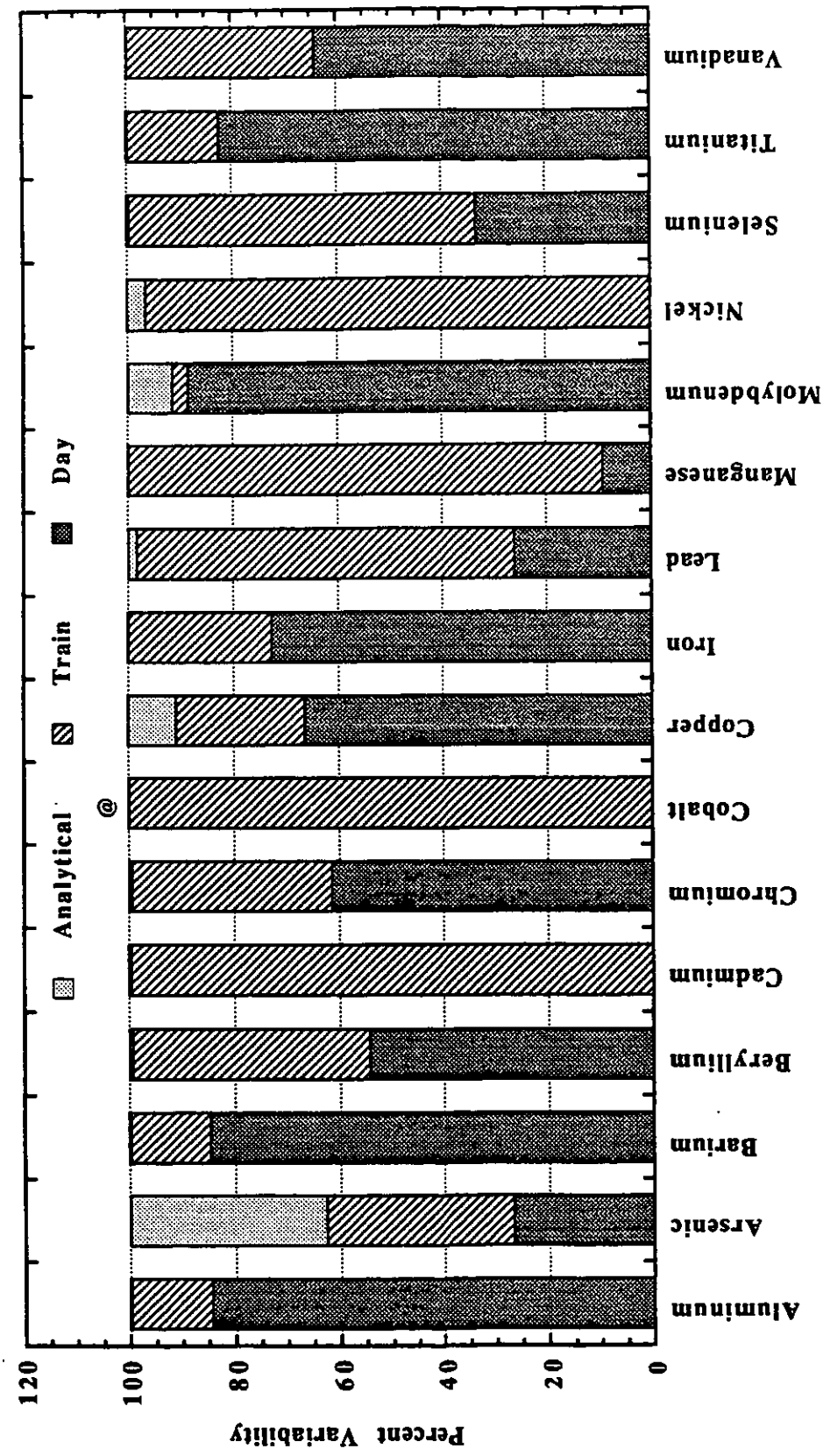
ICP-MS Results

The CVs and ANOVA results for the solid-phase ICP-MS results are presented in Figures 5-6 and 5-7, respectively. As discussed in the section on the comparison of analytical methods, the ICP-MS results are less precise than those obtained by GFAAS or ICP-AES. Except for beryllium and selenium, the ICP-MS CVs ranged from 30 to 60 percent. The beryllium measurements are near the MDL and there is a strong interference from boron. Also, the Run 5b value can be eliminated as an outlier (>99% confidence), reducing the CV from 165 to 35 percent. The selenium values are also strongly influenced by the Run 5b value, which can be considered an outlier (>99% certainty). Without this value, the CV is 48 percent.

Interestingly, although the ICP-MS CVs are larger than those for ICP-AES or GFAAS, the ANOVA indicates that the variance is primarily due to day-to-day variation in the sampled gas (as was seen with GFAAS and ICP-AES above). This suggests that there is some substance that: 1) positively interferes with all of the analytes (recall that all of the ICP-MS data results were higher for the stack gas solid phase than those obtained by GFAAS or ICP-AES), and 2) the concentration of this substance varied from day to day. This substance could have been in the sampled gas stream or encountered in the site lab where the trains were recovered each day. Hydrofluoric, hydrochloric, nitric, and boric acid used in microwave digestion could possibly cause interferences due to ion pairs whose mass cannot be resolved by the quadrapole mass spectrometer.

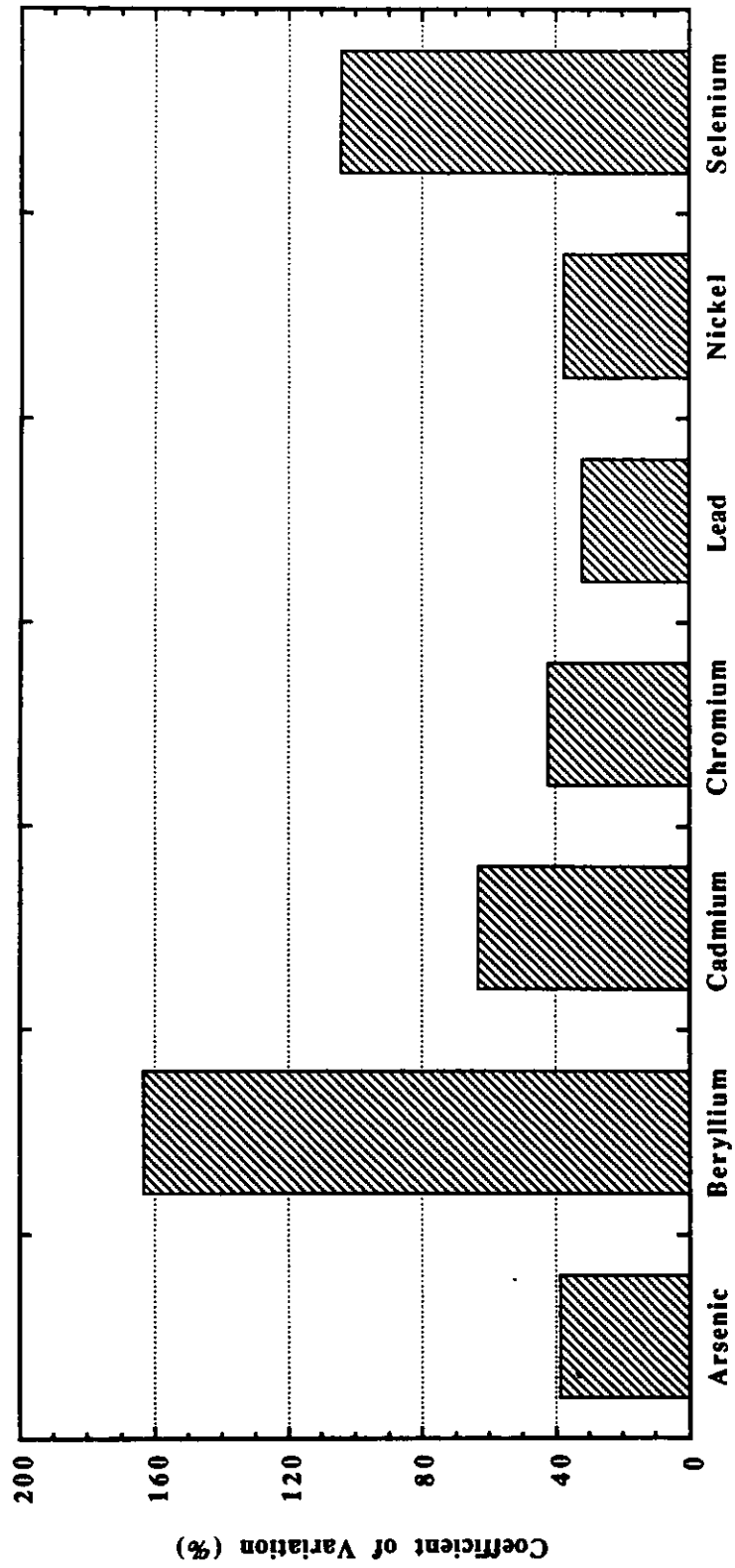
Cross-Site Comparison

As was done with the ESP inlet results, the absorber outlet GFAAS and ICP-AES results from Site 21 were compared with those for other FCEM sites. With eight samples, a 20% CV equates to a 95% CI of 17 percent. With the standard three FCEM samples, the 95% CI would be 50% of the mean. The Site 21 CVs are generally lower than at any other site. Also, the CVs at the other sites vary over a wide range (more than 100% for some analytes at some sites). Therefore, the Site 21 results cannot be used to predict



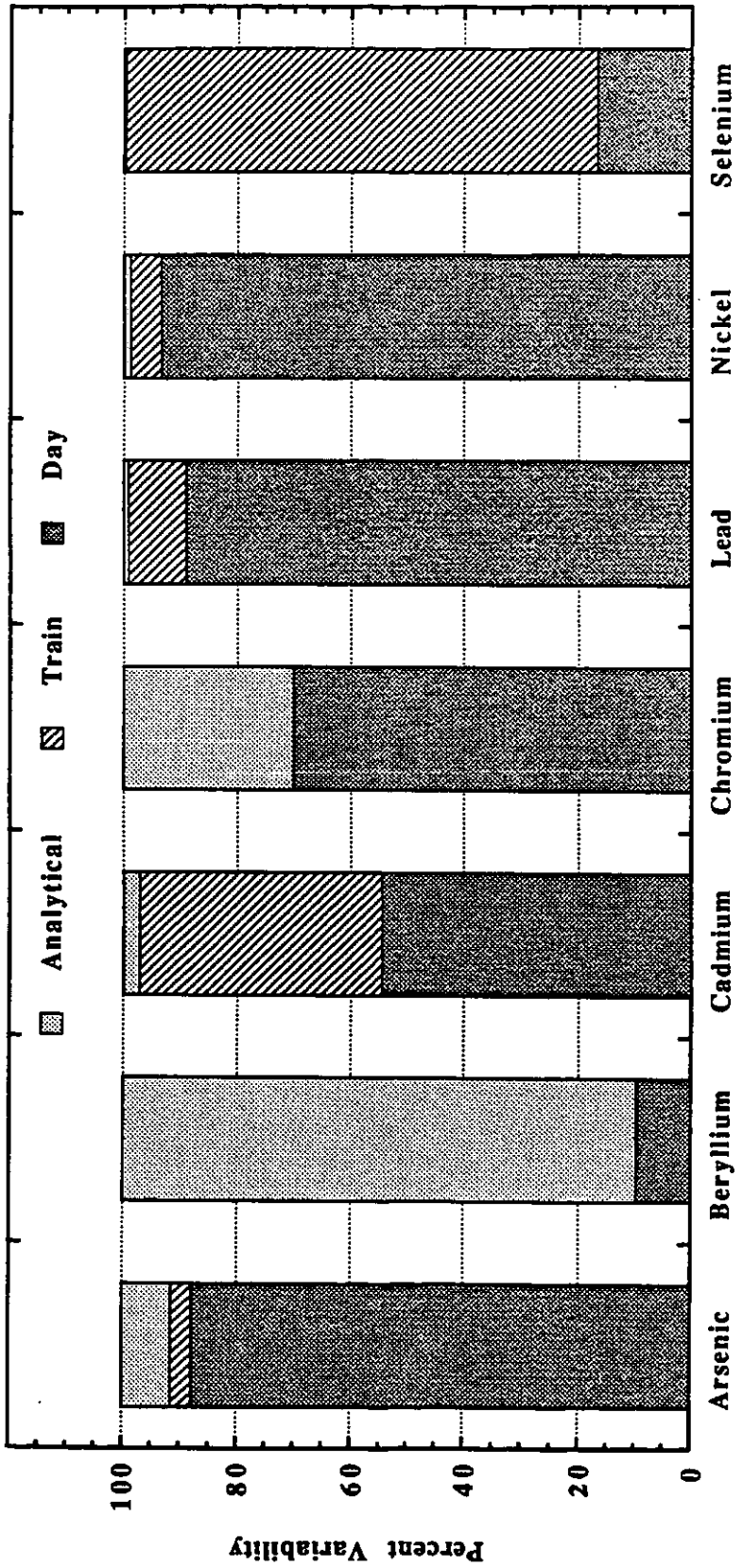
@ = Mean value less than five times detection limit. All substances were detected in all eight samples.

Figure 5-5. FCEM Site 21 - Solid-Phase Metals Percentages of Variability (GFAAS & ICP-AES)



All substances were detected in all eight samples.

Figure 5-6. FCEM Site 21 - Solid-Phase Metals Coefficient of Variation (ICP-MS)



All substances were detected in all eight samples.

Figure 5-7. FCEM Site 21 - Solid-Phase Metals Percentages of Variability (ICP-MS)

the precision of solid-phase metals and anions results at other sites. However, since operation of the pilot-scale ESP and absorber was probably much more steady than would be observed at a full-scale facility, the CVs measured at Site 21 could be considered minimum variations.

Solid-Phase Anions

The solid-phase chloride and fluoride CVs and ANOVA analysis results are shown in Figures 5-8 and 5-9, respectively. The variance in the results for these substances was primarily daily fluctuations. Since the source of solid-phase chloride and fluoride is carry-over from the FGD system, this result is expected. As seen in Table 3-5, both substances were detected in all eight samples.

Vapor-Phase Metals

Standard Analytical Procedures

The CVs and ANOVA results for the vapor-phase metals are presented in Figures 5-10 and 5-11. The CVs vary considerably--from 13% for mercury to 200% for beryllium. The ANOVA indicates that the primary variance component is either analytical or sampling and sample preparation. Since the solid-phase analysis indicated that the samples collected by the duplicate trains were similar, the preparation portion of the sampling and sample preparation variance component is probably responsible for the higher variance in the gas phase results. The relative precision of the results decreases as the method detection limit is approached. At these very low levels, small contaminations and instrument noise can have a large effect on the precision of results. It is also at these low levels that day-to-day sample collection error within laboratory as well as random bias between laboratories (sample teams) adds greatly to the already higher analytical error. Four of the 15 target metals were not detected and four were detected at concentrations less than five times the method detection limit.

ICP-MS Results

An analysis of variance was also made on the vapor-phase results obtained by ICP-MS. CV and ANOVA results are presented in Figure 5-12 and 5-13. As discussed earlier, the CVs for measurement by ICP-MS are comparable to those for measurement by ICP-AES and GFAAS. The ANOVA indicates that nearly all of the variance results from sampling and sample preparation. Again, since the solid-phase results show that the duplicate trains agreed well, most of the variability in the vapor-phase results is probably the result of sampling handling and preparation.

Concentrated Impinger Results

Duplicate analyses were not conducted for the samples concentrated before analysis; therefore, the variance has only two components: 1) process and 2) sampling/analytical. Figures 5-14 and 5-15 present the CVs and ANOVA results. The CVs are of the same

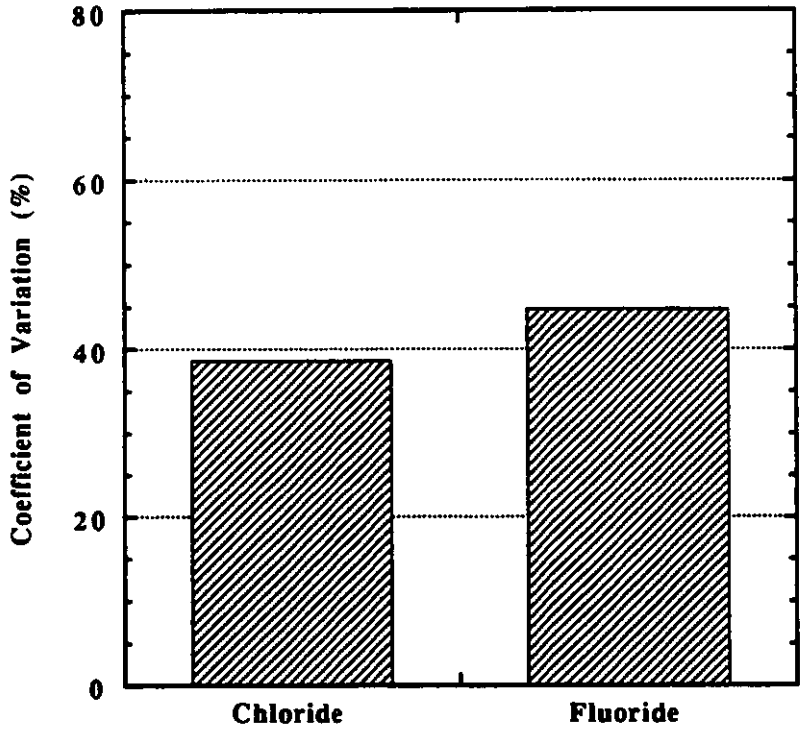


Figure 5-8. FCEM Site 21 - Solid-Phase Anions Coefficient of Variation (IC)

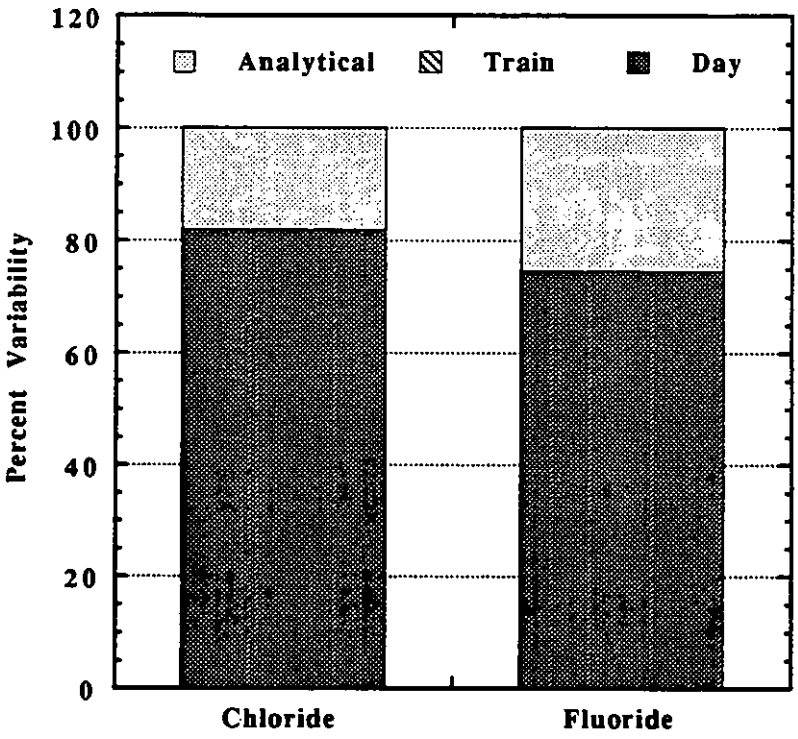
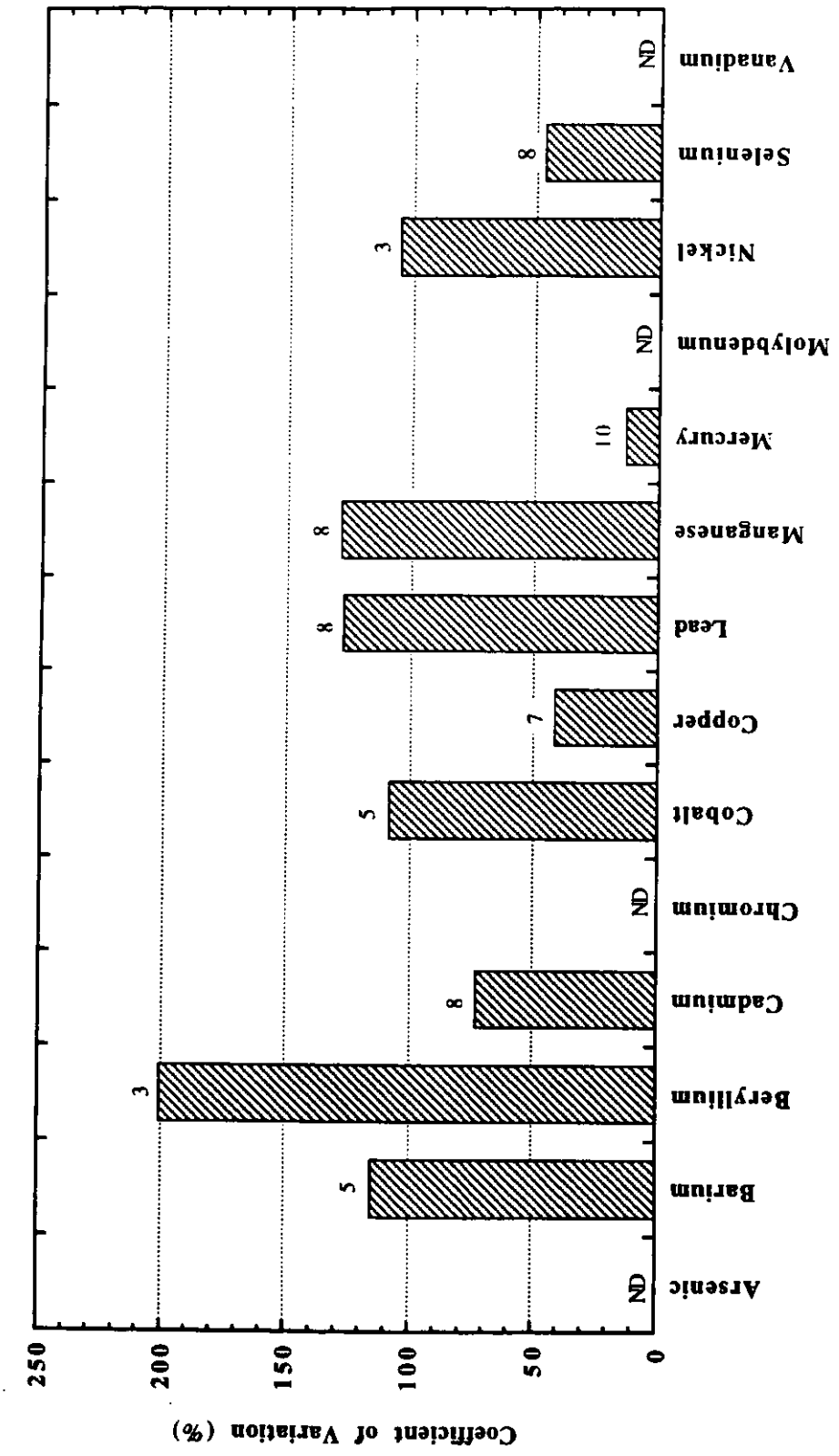
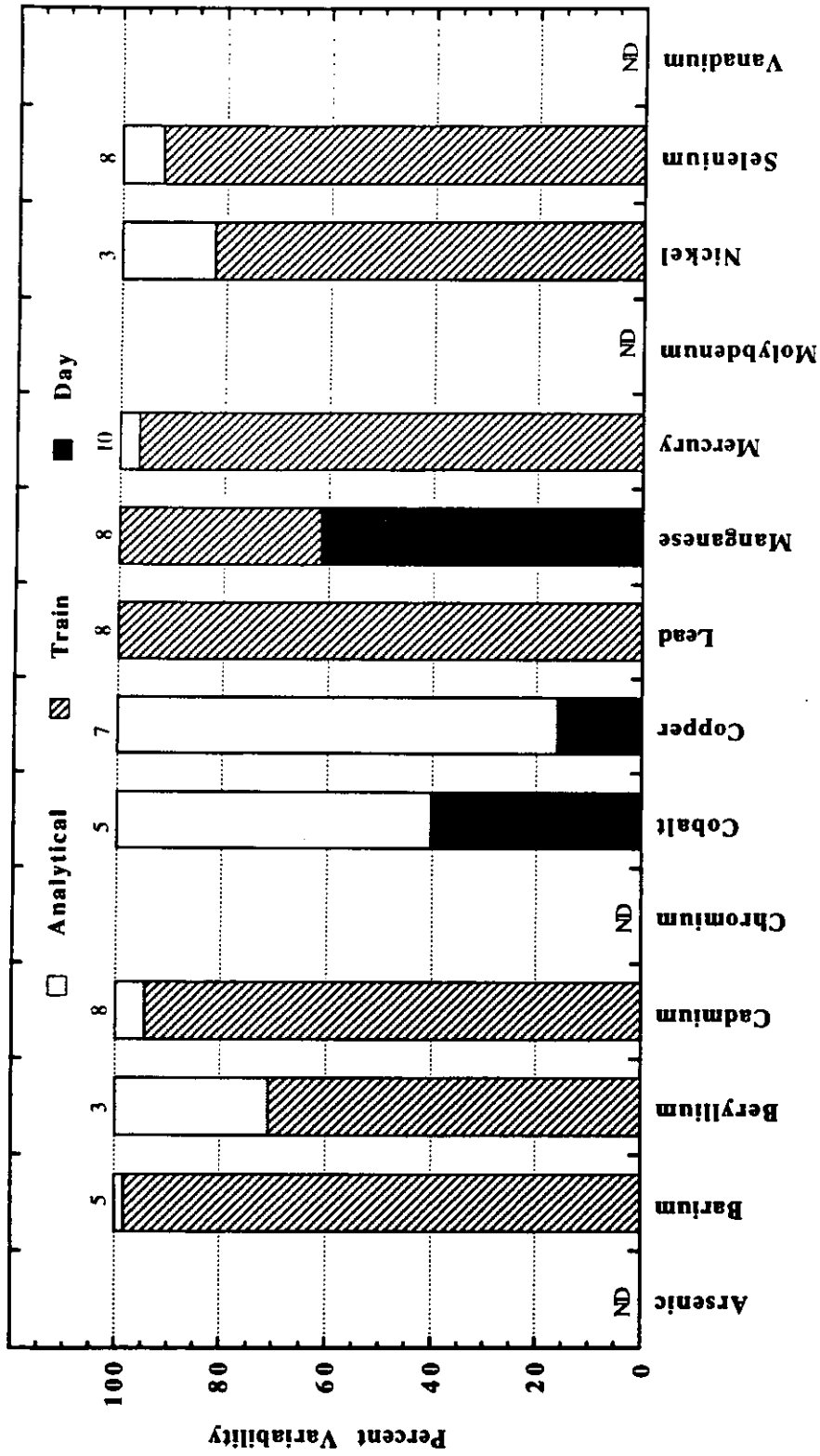


Figure 5-9. FCEM Site 21 - Solid-Phase Anions Percentages of Variability (IC)



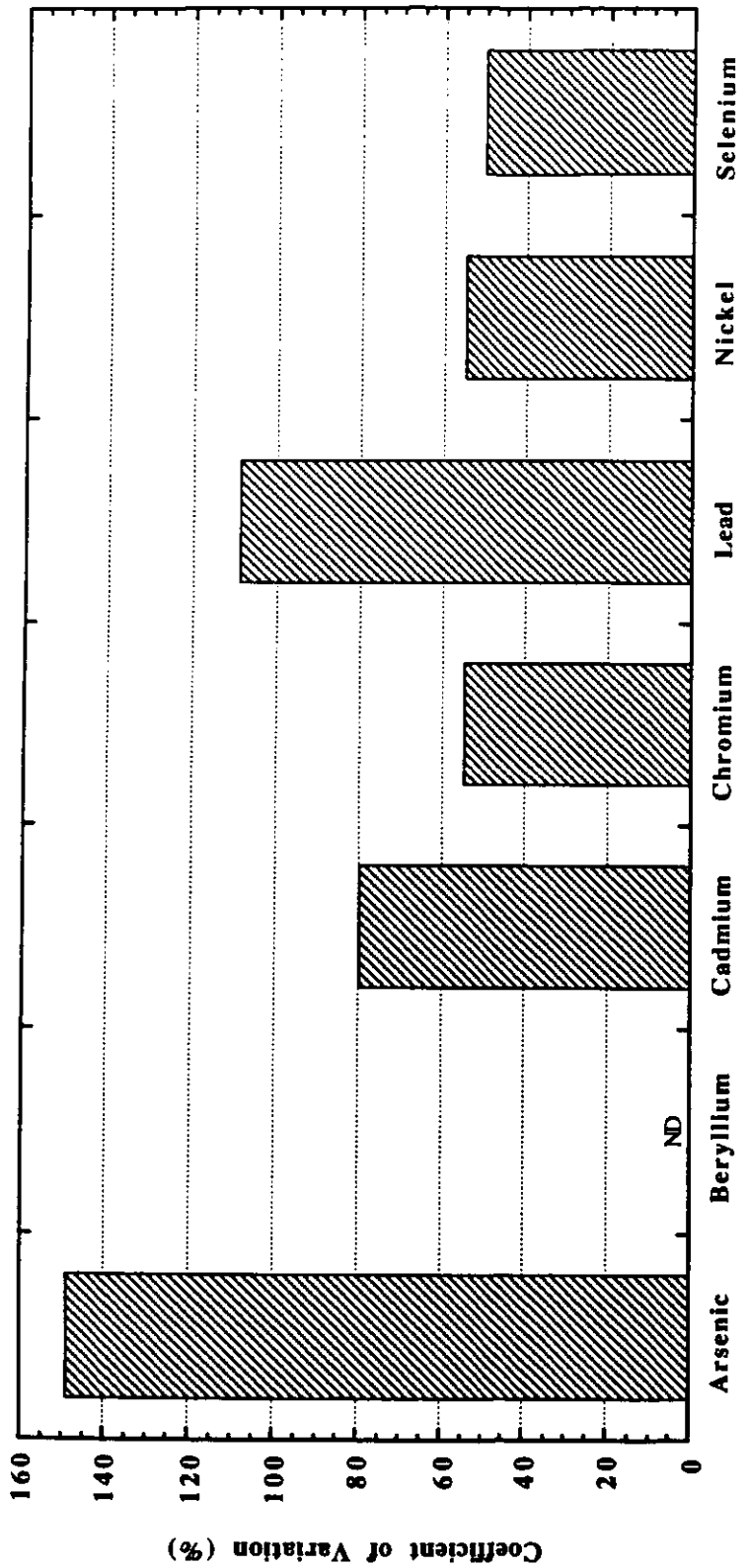
ND = Substance was not detected (mean less than detection limit). Number indicates how many of the eight samples (ten for mercury) had results greater than the detection limit.

Figure 5-10. FCEM Site 21 - Vapor-Phase Metals Coefficient of Variation (GFAAS & ICP-AES)



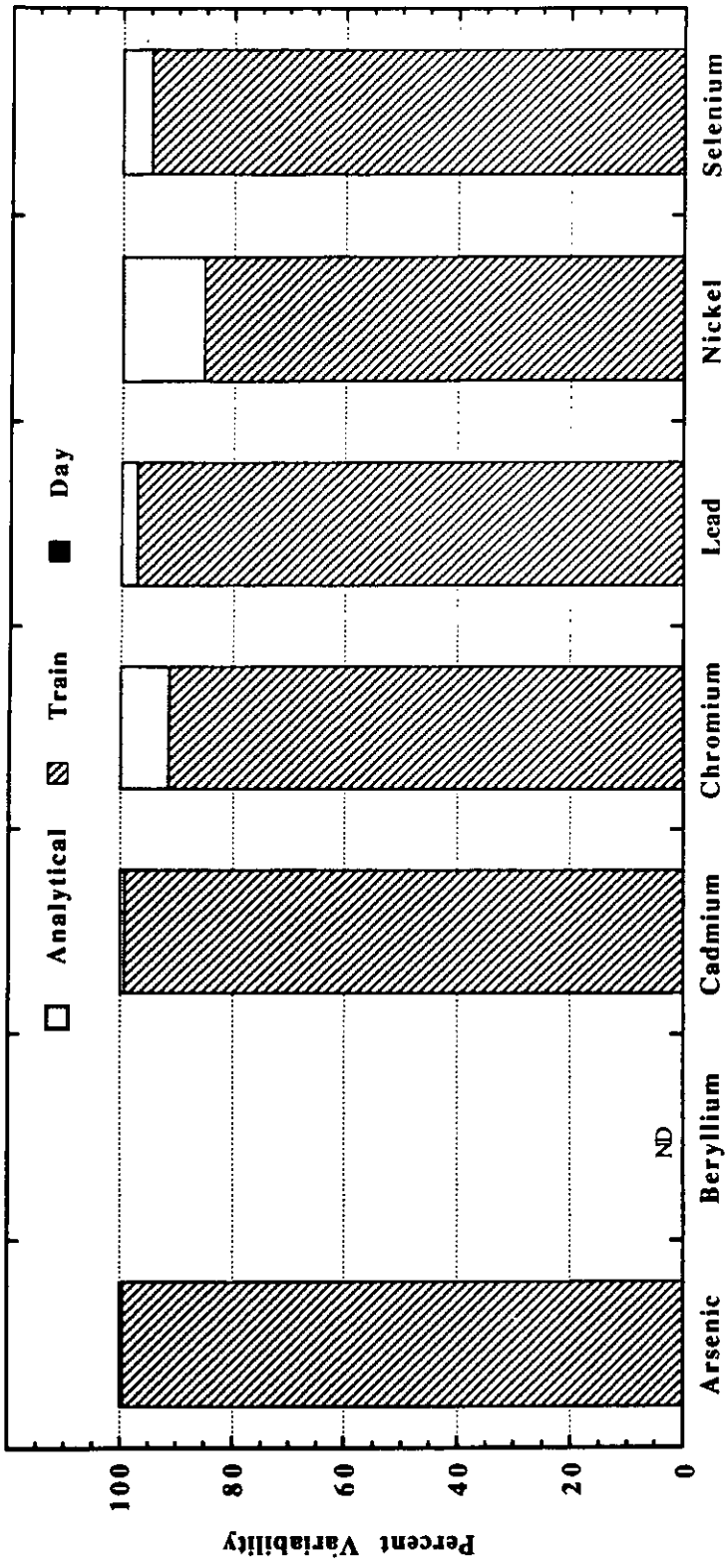
ND = Substance not detected in any sample. Number indicates how many of the eight samples (ten for mercury) had results greater than the detection limit.

Figure 5-11. FCEM Site 21 - Vapor-Phase Metals Percentages of Variability (GFAAS & ICP-AES)



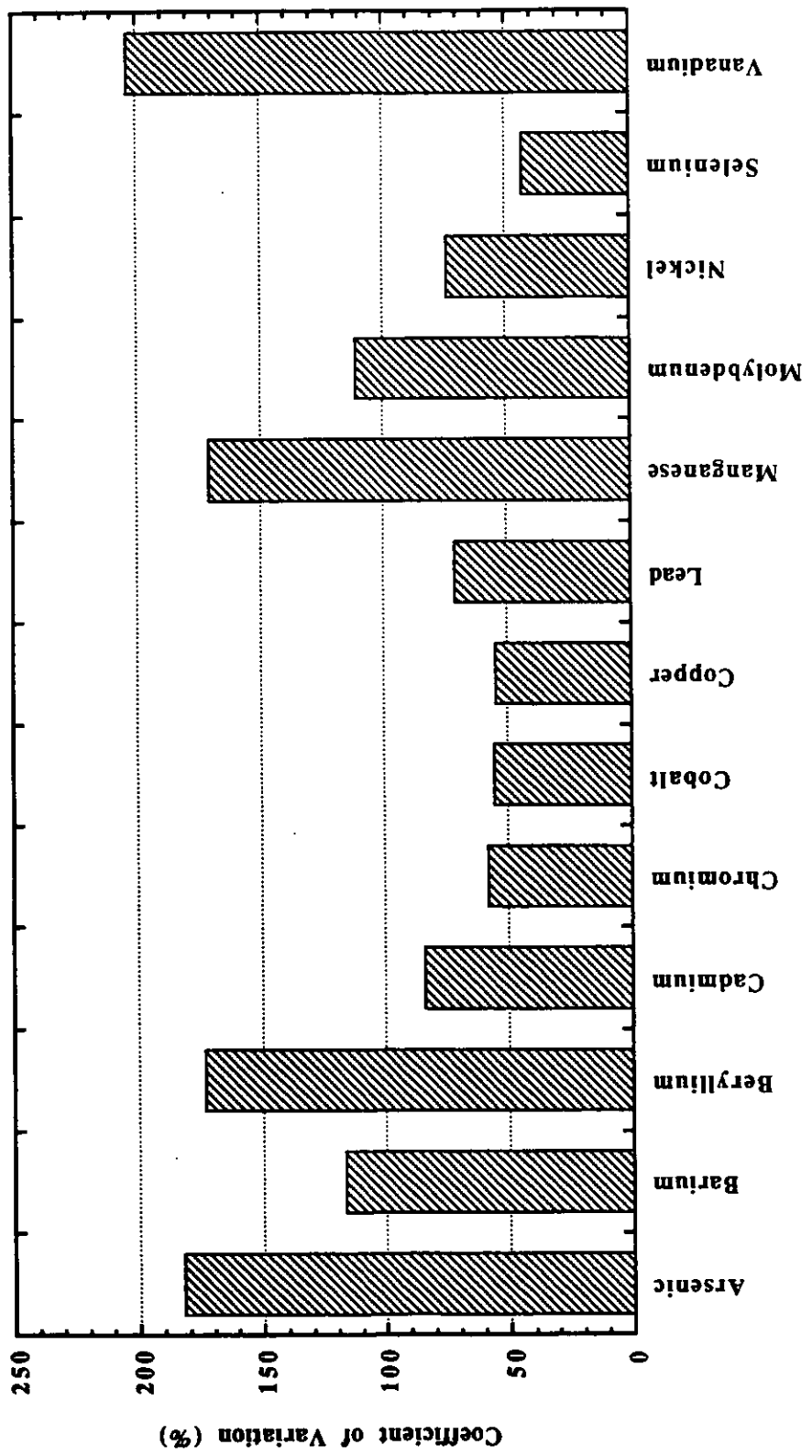
ND = Substance was not detected (mean less than the detection limit). Other substances detected in all eight samples.

Figure 5-12. FCEM Site 21 - Vapor-Phase Metals Coefficient of Variation (ICP-MS)



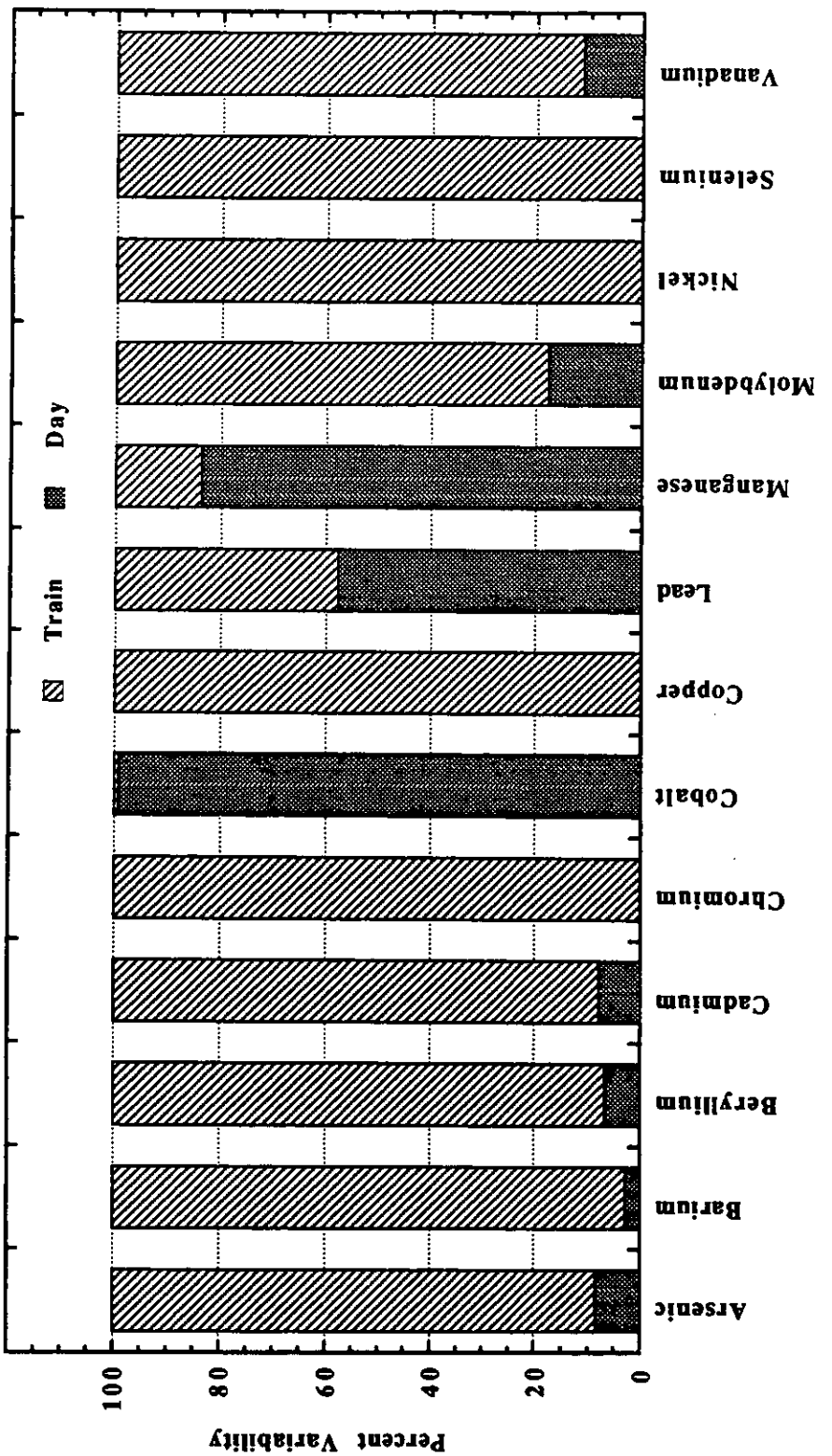
ND = Substance was not detected (mean less than the detection limit). Other substances detected in all eight samples.

Figure 5-13. FCEM Site 21 - Vapor-Phase Metals Percentages of Variability (ICP-MS)



Substances detected in all eight samples.

Figure 5-14. FCEM Site 21 - Vapor Phase-Metals Coefficient of Variation (Concentrated GFAAS & ICP-AES)



Substances detected in all eight samples.

Figure 5-15. FCEM Site 21 - Vapor-Phase Metals Percentages of Variability (Concentrated GFAAS & ICP-AES)

magnitude as the results for the samples not concentrated. As expected, the ANOVA indicates that much of the variance for most of the analytes is from sampling and analysis. The high process contribution for cobalt and manganese was caused by low cobalt and high manganese values during Run 4 (a and b trains). It is not known why the concentrations of these analytes are different in the Run 4 samples.

Vapor-Phase Anions

Figures 5-16 and 5-17 present the CV and ANOVA results for the vapor-phase anions. The 50% CV for chloride is caused primarily by day-to-day variation in the process. The 20% CV for fluoride is lower and the ANOVA shows significant contributions from both daily or sampling and preparation components. The absorber outlet anions concentration will depend on the inlet concentration and on removal in the absorber. Since the ESP inlet chloride CV was 20%, the increase in CV to 50% must be caused by variability in the operation of the pilot absorber. As the pilot absorber operation is better controlled than a full-scale absorber, the level of variability observed at Site 21 may be typical of the minimum that would be seen at a well-controlled, full-scale FGD system. However, the high removal efficiency (98+%) allows minor fluctuations in the outlet concentration to have a significant effect on the CV. At most commercial systems, the removal is not so high, so daily variations would have less of an impact on the CV.

Overall Assessment of Precision

One of the objectives of this project was to determine the variance components at a well-controlled pilot system. The variability at this site is presumably lower than would be expected for a full-scale system. It must be noted that variability noted at Site 21 itself is a random variable. The single CV obtained for eight sample runs would itself be different for the next eight sample runs and the eight after that, etc. The range of expected CVs for the same true population mean is described by the Chi distribution. For repeated eight samples, the 95% confidence interval within which the true CV lies is between 19% and 58 percent.

To evaluate the confidence interval (which can be considered the precision of a data set) several parameters must be specified. For any set of data, there are a given number of results. In addition, a mean and sample standard deviation (N-1) can be calculated for the data set. For any desired confidence interval (i.e., 80%, 90%, 95%, etc.), the "t" statistic may be found from a table in a statistics reference book. The sample standard deviation divided by the mean is the coefficient of variation. The CV, when multiplied by the "t" statistic and divided by the square root of the number of samples, produces the confidence interval for the mean expressed as a percentage of the mean. Figure 5-18 shows the relationship between the number of samples and the confidence interval as a percent of the mean value for four CVs (20, 30, 50, and 100% of the mean). This relationship is used below to discuss intersite comparisons.

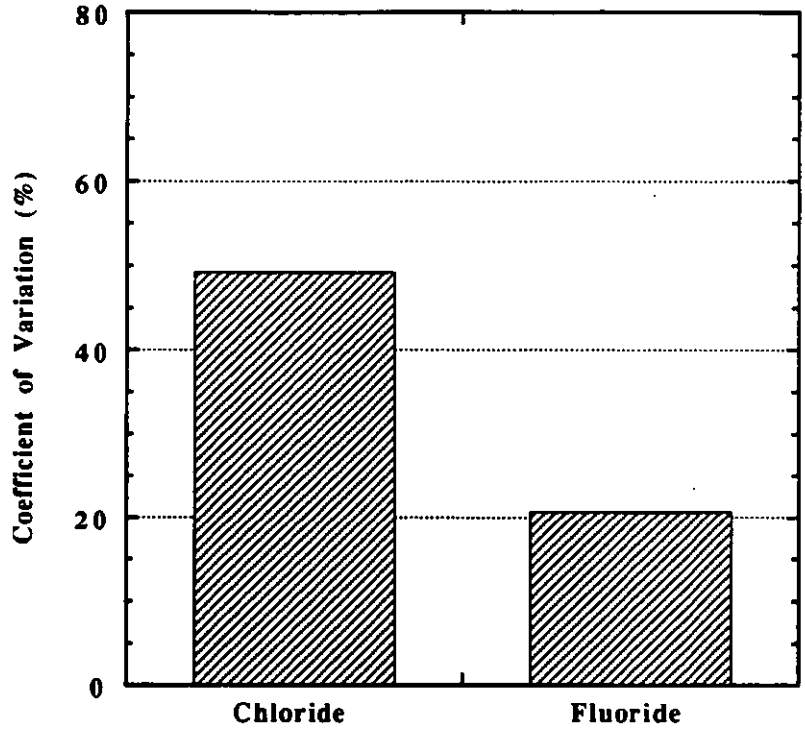


Figure 5-16. FCEM Site 21 - Vapor-Phase Anions Coefficient of Variation (IC) Substances detected in all eight samples.

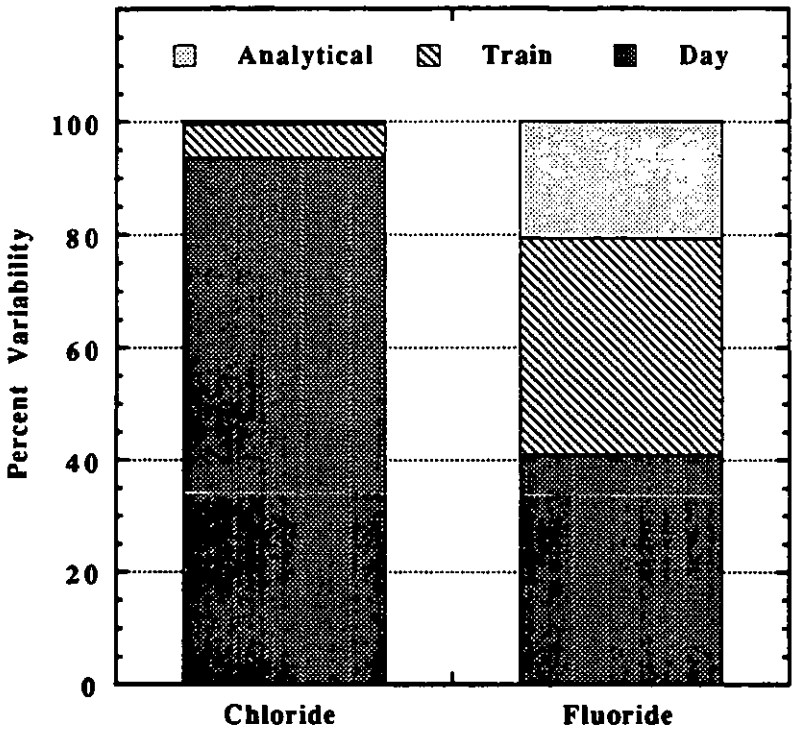


Figure 5-17. FCEM Site 21 - Vapor-Phase Anions Percentages of Variability (IC) Substances detected in all eight samples.

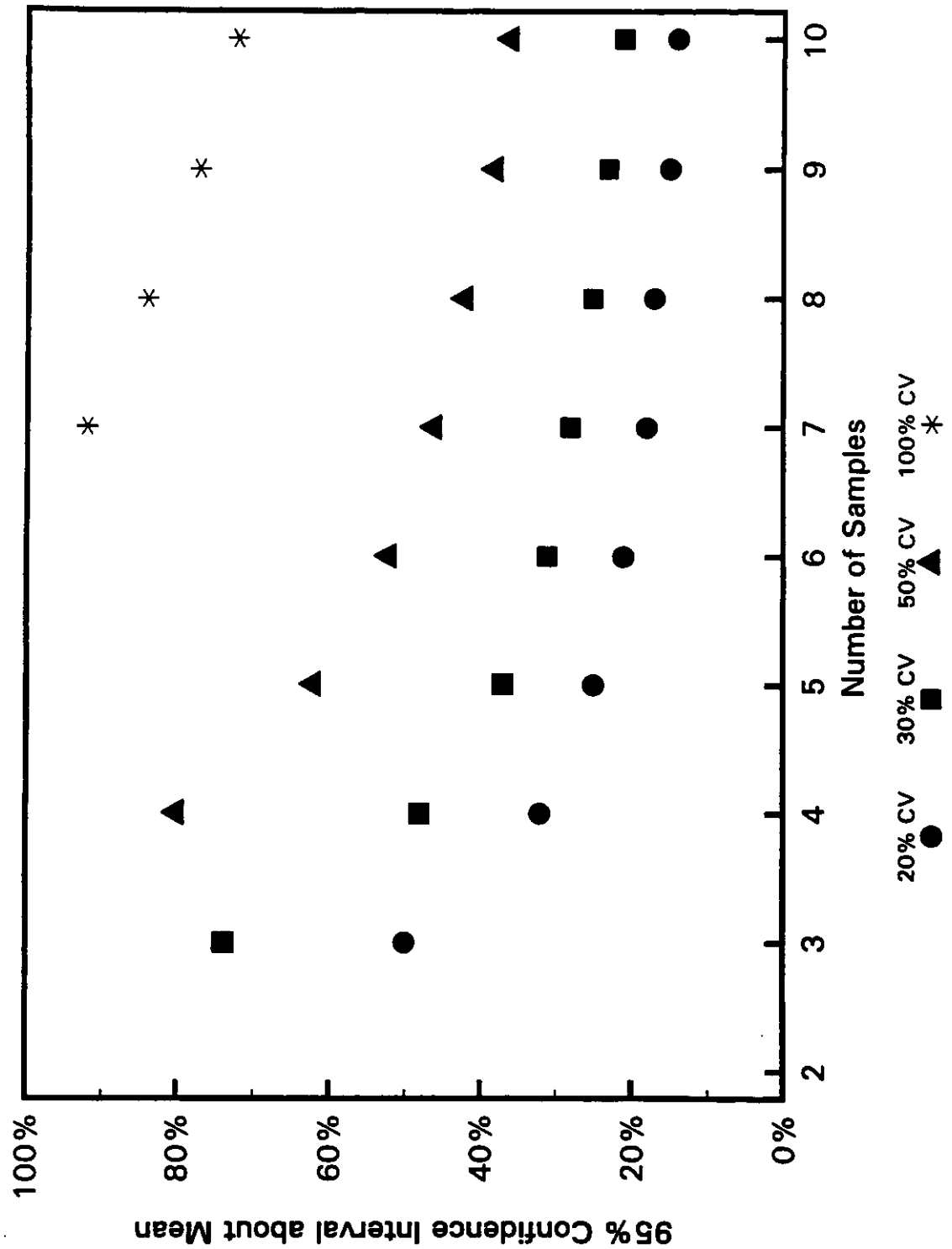


Figure 5-18. Relationship Between 95% CI and Number of Samples

ESP Inlet

The Site 21 ESP inlet results indicate that CVs of <30% can be achieved for the metals and anions target substances. For three samples, this corresponds to a 95% CI of <70 percent. At the ESP inlet, the solid phase accounts for most of the substance distribution except for mercury, chloride, and fluoride. Since it was shown at the absorber outlet that, in general, solid phase duplicate sampling and preparation and analysis agreed well, and, therefore, that day-to-day variability is the cause of most of the <20% CV seen there, most of the <30% CV observed at the ESP inlet is probably also caused by process variation. The ESP inlet variability is caused by variability in the boiler flue gas from the adjacent power plant. The pilot-scale ESP and absorber, which are controlled very well, would be expected to damp out some of the variability in the inlet gas. A reduction in the solid-phase CVs across the ESP/FGD system from <30% to <20% is, therefore, reasonable. If the variability in the flue gas from the adjacent power plant is considered typical of boilers of that design, a 95% CI of 70% of the mean is the best that could be expected with the collection of three samples, when sampling high-dust gas at future sites. However, analysis of CVs from other FCEM sites indicates that there may be no "typical" daily variability associated with coal-fired boilers and that variance measured at Site 21 can not be applied to other sites with any high degree of confidence.

Absorber Outlet

Absorber outlet CVs for the solid-phase metals fraction were generally <20%, and vapor-phase metals CVs were much higher--up to 200 percent. As discussed above, the operation of the pilot-scale ESP is expected to be more consistent than would be seen in a full-scale unit. Therefore, for metals emitted mainly in the solid phase, the 20% CV at Site 21 could be used as an estimate of the lowest achievable variability. As seen in Table 5-2, most of the substances are emitted primarily in the solid phase. With the standard three samples collected by FCEM, this corresponds to a 95% CI of 50% of the mean for these elements. CVs for the elements emitted in the vapor phase could be much larger (although not necessarily larger as shown by the 13% CV for vapor-phase mercury). The minimum attainable CV at other sites will, of course, depend on the contribution of the solid-phase fraction to total emissions. For example, if the ESP performance had been improved at Site 21, the vapor-phase emissions would dominate for more substances and the CVs for the emission factors of these substances would increase as the absolute value of the total emissions decreased.

All of the foregoing reaffirms that comparability of data between sites requires more than knowledge of the variability and the measured mean at each site; it requires knowledge of the expected precision and bias of the entire sampling and analysis protocol in order that the true concentrations in each of the streams being sampled can be better estimated and meaningful comparisons made.

Table 5-2

Stack Gas Combined Metals Phase Distribution

Methods	Substance	% Solid Phase	% Vapor Phase
GFAAS	Arsenic	98	2
ICP-AES	Barium	94	6
ICP-AES	Beryllium	90	10
GFAAS	Cadmium	20	80
ICP-AES	Chromium	97	3
ICP-AES	Cobalt	11	89
ICP-AES	Copper	64	36
GFAAS	Lead	17	83
ICP-AES	Manganese	7	93
ICP-AES	Molybdenum	100	0
GFAAS	Nickel	82	18
GFAAS	Selenium	79	21
ICP-AES	Vanadium	97	3

Section 6

MERCURY SPECIATION AND MATERIAL BALANCE

During the testing at Site 21, Brooks Rand Ltd. conducted mercury speciation measurements using a solid sorbent method. This section presents a brief discussion of the sampling and analytical procedures used in the speciation method, presents the results of the measurements, compares the results to the data in Section 3 by the multi-metals train, and presents a mercury material balance for the pilot system. Additional details of this testing are presented in Appendix J.

Sampling and Analytical Procedures

The sampling procedure for the speciation method involves extracting gas using a heated probe (212 $\pm$ 9°F) and passing it through two solid sorbents. The first sorbent consists of two soda-lime traps. Two iodated carbon traps, located immediately after the soda-lime traps, are used to capture elemental mercury. Mercury was collected on both soda-lime traps and on the first of the two iodated carbon traps.

An integrating mass flowmeter was used to measure the gas volume sampled. Sampling flow rates started at 0.5 liter/minute (lpm). Flow rates slowed to 0.2 lpm over several hours as the traps began swelling due to fly ash and moisture.

For methyl and ionic mercury analysis, the soda-lime traps were dissolved in acetic acid. Methylmercury analysis was performed by aqueous phase ethylation, GC separation, and cold vapor atomic fluorescence spectroscopy (CVAFS). Five percent HCl was then added to the acetic acid/soda-lime trap solution to solubilize Hg(II). $SnCl_2$ was used to reduce Hg(II). A gold amalgamation step was employed to concentrate mercury which was then analyzed by CVAFS.

Gas-phase elemental mercury (Hg^0) was determined by analysis of the iodated carbon traps. The carbon was digested with hot acid (7:3 mixture of HNO_3 and H_2SO_4) followed by reduction, gold amalgamation, and CVAFS.

Probe rinses were treated with BrCl in HCl and analyzed for total mercury by CVAFS. It was assumed that the mercury in the probe was present in the ash in an ionic state. (No methylmercury was detected, and low levels of vaporous elemental mercury should not condense in a heated probe.)

Two methods were used to verify the various speciation measurements. Total mercury measurements were occasionally performed on samples obtained with the iodated carbon traps. Second, some of the soda-lime traps were dissolved in BrCl and analyzed for total

oxidized mercury (this should equal the ionic and methylmercury values). These QC results are presented in Appendix J.

Ash samples and scrubber solids were analyzed for total mercury after digestion in aqua regia and sulfuric acid. Coal samples were digested using a mixture of perchloric, nitric, and sulfuric acids in Teflon microwave bombs. Scrubber liquids were oxidized with BrCl and analyzed for total mercury. All total mercury analyses were by gold amalgamation and CVAFS.

Results of Speciation Measurements

Table 6-1 presents the results of the gas phase speciation measurements at the ESP inlet and the absorber outlet. Each daily value is typically the average of four runs at the inlet (two sets of simultaneous runs) and two or three sequential runs at the outlet. Also shown in this table are the results presented in Section 3 (these are based on the multi-metals train method for collection of vapor phase mercury samples and coal mercury values from CVAAS). As can be seen, even though the sampling dates do not coincide, the two mean results for the methods agree closely.

At the ESP inlet, the majority of the mercury is present in the ionic state, presumably as $HgCl_2$. After particulate and SO_2 removal, the total mercury concentration is reduced and the predominant phase is elemental mercury, according to the speciation results. Also presented in Table 6-1 are the concentrations obtained from the nitric acid/ peroxide and the potassium peroxide impingers from the multi-metals trains. It has been hypothesized that the nitric impingers remove oxidized mercury while the permanganate captures elemental mercury. The two impinger fractions indicate that the distribution of mercury in the multi-metals train differs from the sorbent speciation distribution.

Material Balance Results

Partial mercury material balances were a secondary objective of both the Brooks Rand and Radian testing at Site 21. Table 6-2 presents the results of two material balances, using mean flow rates and concentrations measured during this test program and at earlier programs at this plant. As stated earlier, Radian did not analyze particulate catch fractions for mercury because of the insufficient filter digestate sample volume. In Table 6-2, for the Radian material balance, the collected fly ash mercury value presented is from the Site 12 report. (The host plant where the pilot system is located.) The mean coal mercury values during the Site 12 and Site 21 testing were identical (0.15 mg/kg). Similarly, a bottom ash analysis was not performed at Site 21, the Site 12 value is used here for both balances. Brooks Rand did analyze fly ash obtained during Site 21 testing using CVAFS and detected a small quantity of mercury.

The results show good closure (ratio of outlet to inlet stream mass flow) across all systems measured. The pilot system outlet streams include collected fly ash, FGD solids, and outlet gas. This is compared to the ESP inlet gas in the first balance, with a closure of about 110 percent. The overall balance which uses the coal analysis and bottom ash

Table 6-1

Mercury Speciation Results

Stream/Species	Date 8/18	8/19	8/20	8/21	8/22	8/23	8/24	Mean	95% CI
Coal (mg/kg)									
Hg by CVAFS (Brooks Rand)		0.09	0.13	0.11	0.17			0.13	0.05
Hg by CVAAS (Radian) [a]		0.15	0.14	0.13	0.15	0.14	0.20	0.15	0.03
ESP Inlet ($\mu g/Nm^3$)									
Sorbent Speciation									
Methylmercury	1.1	0.9	1.3	2.1	1.5			1.4	0.6
Ionic Mercury	6.6	6.8	4.8	4.8	5.6			5.7	1.1
Elemental Mercury	3.2	1.7	3.5	2.8	3.9			3.0	1.0
Sum of Species	10.9	9.3	9.6	9.7	10.9			10.1	0.9
Multi-Metals Trains									
Nitric Acid Impingers		8.9	9.2	8.3	11.0	9.0	10.6	9.5	1.1
Permangate Impingers		1.0	0.9	0.8	0.8	0.7	1.1	0.9	0.1
Total Vapor-Phase Mercury [b]		9.9	10.1	9.1	11.8	9.7	11.7	10.4	1.2

Table 6-1 (Continued)

Stream/Species	Date 8/18	8/19	8/20	8/21	8/22	8/23	8/24	Mean	95% CI
Absorber Outlet ($\mu g/Nm^3$)									
Sorbent Speciation									
Methylmercury	0.017	0.011	0.011	0.02	0.01			0.01	0.01
Ionic Mercury	0.09	0.04	0.07	0.13	0.11			0.09	0.04
Elemental Mercury	0.74	0.60	0.70	0.71	0.87			0.72	0.12
Sum of Species	0.85	0.65	0.78	0.86	0.99			0.83	0.15
Multi-Metals Trains									
Nitric Acid Impingers - Run A			0.63	0.61	0.88	0.80	0.86	Runs A & B	
Nitric Acid Impingers - Run B			0.55	0.68	0.62	0.80	0.81	0.73	0.09
Permangate Impingers - Run A			0.16	0.46	0.33	0.32	0.23		
Permangate Impingers - Run B			0.42	0.32	0.20	0.23	0.33	0.30	0.07
Total Vapor-Phase Mercury- Run A [c]			0.79	1.07	1.21	1.12	1.09		
Total Vapor-Phase Mercury- Run B [c]			0.97	1.00	0.82	1.03	1.14	1.02	0.10

[a]From Table 3-1.

[b]From Table 3-3.

[c]From Table 3-6.

Table 6-2

Mercury Material Balances

Stream	Pilot System Flow Rates	Radian Measurements		Brooks Rand Measurements	
		Concentration	Mass (mg/hr)	Concentration	Mass (mg/hr)
Coal	1138 kg/hr	0.15 mg/kg	171	0.13 mg/kg	148
Bottom Ash	15 kg/hr	<0.045 mg/kg[a]	<1	<0.045mg/kg[a]	<1
ESP Inlet Gas	11,700 Nm^3/hr	10.4 $\mu g/Nm^3$	122	10.1 ug/Nm^3	118
Collected Ash	61 kg/hr	<0.045 mg/kg[a]	<3	0.065 mg/kg	4
FGD Solids	68 kg/hr	1.76 mg/kg	120	1.67 mg/kg	114
Absorber Outlet Gas	13,000 Nm^3/hr	1.02 $\mu g/Nm^3$	13	0.83 $\mu g/Nm^3$	11
Pilot System Mass Closure (ESP Inlet - Ash, Solids, Outlet Gas)			110%		109%
Overall Closure (Coal - Ashes, Solids, Outlet Gas)			79%		87%
Gas Phase Reduction			89%		91%

[a]Value obtained from Site 12 Report.

streams also, had closures of 79 and 87 percent. These values are not statistically different, based on the variabilities of the inputs to the calculations (i.e., the relative confidence interval for the coal mercury values are $\pm 38\%$ and $\pm 20\%$ for the Brooks Rand and Radian values, respectively).

The overall vapor phase removal across the ESP/wet limestone FGD system is about 90 percent, with the mercury almost exclusively accumulating in the FGD solid phase.

Section 7

EXAMPLE CALCULATIONS

This section presents selected sample calculations used to develop the results discussed in Sections 3 and 4. Specifically, the calculation of stream flow rates and unit-energy basis results are discussed.

Stream Flow Rates

The pilot system at Site 21 is extensively instrumented. Much of the information presented in Table 2-1 was collected by the data acquisition system. The absorber outlet flue gas flow rate shown in Table 2-1 was measured during sampling; Appendix A includes the details of these measurements. The two values in Table 2-1 that were calculated are the power plant flue gas flow rate, and the pilot equivalent coal flow rate.

The power plant flue gas flow rate was estimated using a simplified combustion calculation. This calculation involves calculating the air required to oxidize the carbon, hydrogen, and sulfur in the coal and adding enough excess air to match the measured flue gas O_2 concentration. The CEM O_2 value of 6.0% wet was used rather than the Orsat values obtained during sampling since there is more precision in the CEM values. However, use of the Orsat O_2 values would result in less than a 5% change in the calculated flue gas flow. Figure 7-1 shows the values in the spreadsheet used to do this calculation.

The pilot equivalent coal flow rate was calculated by simply taking the ratio of the measured absorber outlet flue gas flow rate to the calculated power plant flue gas flow rate, and multiplying by the measured power plant coal flow rate.

Pilot Coal Flow Rate = 8109/1,339,000 * 452,000

= 2.73 klb/hr as-fired

Unit Energy Calculation

A unit-energy basis emission factor was developed for each substance. These values were determined by using the mass flow rate of a substance and dividing by the pilot equivalent fuel energy input to the boiler during testing. The heat input was obtained from the coal flow rate and the higher heating valve (HHV) of the fuel for the sampling period. The calculations are illustrated below, using barium concentrations in the stack gas as an example.

Coal Composition						
C	0.73	Carbon in oxidized/mole	27202			
O	0.07	O needed	54404			
H	0.05	Sulfur in oxidized/moles	215			
S	0.02	O needed	431			
N	0.01	Hydrogen in oxidized/mo	22233			
Moisture	0.07	O needed	11116			
Ash	0.06					
		Total O needed	65951			
Coal Flow Rate	452000	O in with coal/moles	1904			
Coal Flow Dry	419546	O in with air	64047			
FG O2	6.0%	Flue gas CO2	27202			
FG CO	0.00	Flue gas N2	120645			
		Flue gas SO2	215			
Combustion Efficiency	99	Flue gas H2O	12919			
		Moles Combustion gas	160982			
FG O2 Dry	6.3%					
		Moles Excess air	63943	28.43%		
						% wet
		Total Flue gas moles	224925	CO2	27201.91	12.09%
				O2	13428	5.97%
				N2	171160	76.10%
				SO2	215.3559	0.0957%
				H2O	12919.45	5.74%
				MW	29.63388	
		SCFM	1420676			
		Nm3/hr	2285343			
		dscfm	1339074			
		dNm3/hr	2154075			

Figure 7-1. Combustion Calculations Spreadsheet

$$E = \frac{g * c}{HHV * coal} * 2202.6 \qquad (7\text{-}1)$$

where:

E = Mean stack emission factor, $lb/10^{12}$ Btu

g = Mean flue gas flow rate, Nm^3/hr

c = Mean total flue gas concentration, $\mu g/Nm^3$

HHV = Mean coal higher heating value, Btu/lb

coal = Mean coal feed rate, lb/hr

2202.6 = Unit conversion factor, $lb/10^{12}$ μg

Barium will be used for this example. The following mean values were taken from Tables 3-1, 3-5, and 3-7.

g = 13,000 Nm^3/hr

c = 3.9 $\mu g/Nm^3$

HHV = 14,032 Btu/lb

coal = 2,540 lb/hr

The emission factor for barium is calculated from Equation 7-1:

$$E = \frac{13{,}000 * 3.9 * 2202.6}{14{,}032 * 2{,}540} = 3.2 \text{ lb}/10^{12} \text{ Btu}$$

Section 8

GLOSSARY

ANOVA	Analysis of Variance
Btu	British Thermal Unit
CAAA	Clean Air Act Amendments
CI	Confidence Interval
CV	Coefficient of Variance
CVAAS	Cold Vapor Atomic Absorption Spectrophotometry
DGA	Double Gold Amalgamation
dNm^3	Dry Normal Cubic Meter (1 atm, 0° C)
DQO	Data Quality Objectives
dscfh	Dry Standard Cubic Feet per Hour (1 atm, 68° F)
ESP	Electrostatic Precipitator
FCEM	Field Chemical Emissions Monitoring
FGD	Flue Gas Desulfurization
GFAAS	Graphite Furnace Atomic Adsorption Spectroscopy
HGAAS	Hydride Generation Atomic Absorption Spectroscopy
HRGCMS	High Resolution Gas Chromatography/Mass Spectroscopy
HHV	Higher Heating Value
IC	Ion Chromatography
ICP (ICAP, ICAPES, ICP-AES)	Inductively Coupled Argon Plasma Emissions Spectroscopy
ICP-MS	Inductively Coupled Argon Plasma Mass Spectroscopy
ID	Induced Draft
MDL	Method Detection Limit
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MW	Megawatt
INAA	Neutron Activation Analysis
NBS	National Bureau of Standards
NC	Not Calculated
ND	Not Detected
NR	Not Reported
PAH	Polynuclear Aromatic Hydrocarbons
POM	Polycyclic Organic Matter
PSD	Particle Size Distribution
QA/QC	Quality Assurance/Quality Control
RPD	Relative Percent Difference
SIE	Selective Ion Electrode
VOC	Volatile Organic Compound
VOST	Volatile Organic Sampling Train

Appendix A

Sampling and Analytical Summary

Details of the sampling activities at Site 21, and descriptions of the analytical method used are presented in this section.

Sampling Summary

Sampling was performed from August 18 to August 24, 1992. Samples from several process streams were collected during each day of sampling. These streams included:

- ESP inlet flue gas;
- Absorber outlet flue gas;
- Coal fed to the power plant boiler;
- ESP collected fly ash;
- Absorber liquor; and
- Absorber solids.

The ESP inlet, absorber outlet flue gas samples, and power plant coal samples were submitted for analysis. Samples from the other three process streams were archived for possible future analysis.

Flue Gas Sampling

Flue gas samples were collected at the ESP Inlet and the absorber outlet to determine the concentration of the following groups of substances:

- Trace metals;
- Semivolatile organics; and
- Anions.

Table A-1 provides a summary of the specific dates and times during which the flue gas samples were collected. Comments pertaining to problems encountered during testing are also included in Table A-1. Table A-2 provides a summary of the sampling methods that were used to collect each type of sample. Information pertaining to the number of samples collected and the number of samples submitted for analysis is also included in Table A-2. The flue gas sampling data sheets and the sample log book entries are included in Appendix D.

Sampling was performed based upon the technical approach in the project specific sampling and analytical test plan with the exception of two deviations. These include:

- A decrease in the number of sampling points per traverse used to collect flue gas samples at the absorber outlet from six to two; and
- A decrease in the volume of gas sampled during the collection of metals samples at the absorber outlet from 500 to 300 standard cubic feet (scf).

The sampling trains traversed both horizontally and vertically, one train being at the inner point while the other sampled the outer point. At port charge, the probe filter box was rotated 90 degrees. The number of sampling points used per traverse to collect flue gas samples at the absorber outlet was reduced from six to two after the first day of testing to minimize problems encountered with the filters becoming wet while sampling close to the duct walls. The two sampling points were located at 14.6% and 85.4% across the diagonal. The use of two sampling points per traverse does not meet the requirements specified in the Code of Federal Regulations (CFR Part 40). However, the flue gas exiting the wet absorber should be well mixed and therefore sampling only two points per diagonal should not significantly affect the vapor phase results. There should also be minimal effect on the mass of particulate collected if the outlet particles are relatively small (<10 microns). Large particles could potentially be stratified along the bottom of the duct and not picked up by the sampling train depending upon the degree of particulate stratification. Velocity profiles were performed using six points per diagonal at the absorber outlet as specified in the test plan. The absorber outlet velocity

Table A-1

FCEM Site 21 - Variability Tests Flue Gas Samples Collection Time Periods

		ESP	Scrubber Outlet				
		Inlet	Train "A"		Train "B"		
	Parameter	Start-Stop	Start - Stop		Start - Stop		Comments
RUN 1 8/18/92	Velocity	0945-1005	0841	--	1000	1)	Inlet anions and semivolatiles filters became dislodged allowing solids to bypass filter. Samples discarded.
	Metals	1400-1730	1201 - 2241		1147 - 2239	2)	Outlet metals filters become wet. Run aborted.
	Anions	1823-1911	N/A		N/A	3)	Outlet anions train not started because of time factor. One train used for field blank.
	Semivolatiles	1423-1815	1748 - 1836		1720 - 1832	4)	Outlet semivolatiles sampling aborted due to problems in collecting metals samples.
RUN 2 8/19/92	Velocity	0845-0900	0815	--	0856	1)	Outlet samples collected using 4 sampling points instead of 12 to minimize chances of filters becoming wet.
		1500-1520					
	Metals	1123-1408	0951 - 0138		0956 - 0150	2)	Outlet metals filters become dislodged sometime during testing - solids noted in the first impingers. Samples discarded.
	Anions	1715-1846	1935 - 2238		1855 - 2229		
	Semivolatiles	1132-1531	1340 - 1633		1317 - 1640		
RUN 3 8/20/92	Velocity	0945-1010	0752	--	0827	1)	Inlet nozzle lost during port change on semivolatiles train, nozzle replaced, and run completed.
		1600-1630	0245	--	0300		
	Metals	1040-1419	0908 - 2250		0901 - 2258	2)	Outlet metals "A" encounters high vaccum. Unable to pull rate for about 30 minutes. Impingers analyzed for mercury only.
	Anions	1534-1706	1533 - 1839		1540 - 1832		
	Semivolatiles	1115-1514	1125 - 1415		1111 - 1430		

Table A-1 (Continued)

	Parameter	ESP Inlet Start-Stop	Scrubber Outlet Train "A" Start - Stop	Scrubber Outlet Train "B" Start - Stop		Comments
RUN 4 8/21/92	Velocity	0900-0915	0750 -- 0825		1)	Outlet anions nozzle cracked during port change. Nozzle was replaced and the run was completed.
		1630-1655	2150 -- 2210			
	Metals	1009-1306	0850 - 1749	0845 - 1814	2)	Outlet metals sample volume reduced from 500 to 300 scf.
	Anions	1412-1610	1605 - 1937	1620 - 1942		
	Semivolatiles	1022-1425	1130 - 1442	1124 - 1459		
RUN 5 8/22/92	Velocity	0830-0840	0730 -- 0800		1)	Inlet anions nozzle chipped during port change. Nozzle was replaced and the run completed.
		1625-1640	1750 -- 1815			
	Metals	1005-1244	0843 - 1702	0829 - 1714		
	Anions	1409-1556	1428 - 1833	1435 - 1828		
	Semivolatiles	0952-1350	1018 - 1319	1026 - 1316		
RUN 6 8/23/92	Velocity	0900-0915	0800 -- 0815			
		1230-1240	1745 -- 1758			
	Metals	1038-1209	0912 - 1734	0908 - 1729		
RUN 7 8/24/92	Velocity	0815-0835	0735 -- 0755			
		1028-1045	1645 -- 1705			
	Metals	0847-1015	0810 - 1626	0812 - 1622		

Table A-2

FCEM Site 21 – Variability Tests Sampling Methods Summary

Process Stream	Parameters of Interest	Sampling Method	Samples Collected	Samples Analyzed
ESP Inlet Flue Gas	Trace Metals	Specified in Section 3.1 of 40 CFR Part 266, Appendix IX	7	6
	Semivolatile Organics	Method 0010 of SW 846	5	4
	Anions	Modified EPA Method 5	5	4
Scrubber Outlet Flue Gas	Trace Metals	Specified in Section 3.1 of 40 CFR Part 266, Appendix IX	7 Pair	4 Pair
	Semivolatile Organics	Method 0010 of SW 846	5 Pair	4 Pair
	Anions	Modified EPA Method 5	4 Pair	4 Pair
Coal	Ultimate/proximate, chlorine, high heating value, trace metals	Auto Sampler - 24-hour composite	7	6
ESP Collected Fly Ash	Not Applicable	Sample Thief - 24-hour composite	7	0
Scrubber Solids	Not Applicable	Grab Sample	7	0
Scrubber Liquor	Not Applicable	Grab Sample	7	0

profile was reasonably flat across each traverse during the on-site test effort. The relative standard deviation was less than 10% for the six velocity sampling points across each diagonal. The flat velocity profile does not indicate a bias in the distribution of the outlet flue gas. The targeted trace metals sample gas volume was reduced from 500 to 300 scf at the absorber outlet to eliminate the need for using more than one filter per train. Using multiple filters at the absorber outlet would have defeated the benefits of sampling longer because of the background concentrations of trace metals present in the quartz filters.

Multi-Metals Collection

A modification of the sampling methodology specified in Section 3.1 of the 40 CFR Part 266, Appendix IX was used to determine the particulate mass loading and simultaneously collect solid and vapor phase samples of the ESP Inlet and absorber outlet flue gas for trace metals analysis. Modifications to the specified procedure included the use of a Teflon® sample line to transfer flue gas from the filter holder to the impinger train. After sample collection, the Teflon® sample line was allowed to soak for 15 minutes with nitric acid solution to recover any trace metals that might have been adsorbed. The resulting Teflon® sample line rinse was added to the first nitric acid impinger sample. A second modification included the use of two empty impingers to help collect the large volume of moisture present at the absorber outlet. A third modification included not monitoring the flue gas flow rate during actual sampling. A velocity profile was performed just prior to testing and the flow rate data from the velocity profile was used to determine the sampling rate needed to collect the sample at isokinetic conditions. This approach of using velocity profile data to calculate isokinetic sampling rates was also used during the collection of semivolatile organics and anions samples at the absorber outlet.

A summary of the ESP inlet and absorber outlet trace metals source sampling data is presented in Table A-3. A total of seven sets of ESP inlet and absorber outlet trace

Table A-3

FCEM Site 21 - Variability Test
Trace Metals Source Sampling Data

ESP INLET

Run No.	Sample Gas Volume (dscf)	Flue Gas Composition: Moisture (%)	O_2* (%)	CO_2* (%)	% Isokinetic
2	29.62	9.4	4.1	12.8	98
3	42.42	9.1	3.8	12.5	94
4	43.41	9.4	4.6	12.2	95
5	42.22	9.2	3.9	12.5	96
6	36.53	8.9	3.8	12.7	94
7	34.98	9.6	3.8	12.7	93

SCRUBBER OUTLET

Run No.	Sample Gas Volume (dscf)	Flue Gas Composition: Moisture (%)	O_2* (%)	CO_2* (%)	% Isokinetic
3A	458.676	12.2	5.8	12.4	97
3B	458.539	12.2			93
4A	313.087	12.3	5.7	12.2	98
4B	311.823	12.2			97
5A	306.666	12.9	5.7	12.1	98
5B	312.678	12.8			97
6A	302.029	12.3	5.9	12.6	93
6B	302.214	11			92
7A	326.368	13.2	5.6	12.6	96
7B	324.73	13.3			96

*The ESP Inlet O_2 and CO_2 data was obtained during collection of the anions sample on August 19 through August 22 and during the collection of the metals sample on August 23 and 24.

metal samples were collected over the period of August 18 to August 24. All of the metals samples collected on August 18 were discarded because of problems encountered during sampling at both locations. The remaining six sets of ESP inlet metals samples were submitted for analysis. The absorber outlet trace metals samples collected on August 19 were discarded because the filters became dislodged from the filter holder during testing, allowing solids to enter the impingers. The impingers from the metals samples collected at the absorber outlet on August 20 were analyzed for mercury only. A complete metals analysis was not performed on this sample set because two filters were used in the collection of each of the two outlet trains. The four pair of trace metals samples collected at the absorber outlet from August 21 to August 24 were submitted for analysis.

Semivolatile Organics Collection

A modification of the sampling methodology specified in Method 0010 of SW-846 was used to collect samples of the ESP inlet and absorber outlet flue gas for semivolatile organic analysis. The modification included the use of a Teflon® sample line to transfer the flue gas from the XAD resin cartridge to the impinger train. The sample line was allowed to soak with methylene chloride for 15 minutes after sample collection to recover any organics of interest that may have adsorbed onto the tubing. The methylene chloride rinse was added to the condensate sample that was collected in the first impinger.

A summary of the ESP inlet and absorber outlet semivolatile organics source sampling data is presented in Table A-4. A total of five sets of semivolatile organics samples were collected at both the ESP inlet and absorber outlet from the period of August 18 to August 22. The set of semivolatile samples collected on August 18 were discarded because of problems encountered in collecting these samples. The four sets of semivolatile organic samples collected from August 19 to August 22 were submitted to the labs for analysis. The August 22 ESP inlet semivolatile organic sample was collected at 87%

Table A-4

FCEM Site 21 - Variability Test

Semivolatiles Source Sampling Data

ESP INLET

Run No.	Sample Gas Volume (dscf)	Flue Gas Composition: Moisture[a] (%)	O_2[b] (%)	CO_2[b] (%)	% Isokinetic
2	91.728	9.2	4.1	12.8	91
3	86.428	8.9	3.8	12.5	87
4	89.915	9.3	4.6	12.2	92
5	92.419	9.4	3.9	12.5	92

SCRUBBER OUTLET

Run No.	Sample Gas Volume (dscf)	Flue Gas Composition: Moisture[c] (%)	O_2[d] (%)	CO_2[d] (%)	% Isokinetic
2A	101.43	12.4	5.9	12.6	98
2B	103.37				103
3A	103.49	12.2	5.8	12.4	100
3B	102.02				101
4A	108.53	12.3	5.7	12.2	105
4B	100.81				101
5A	102.36	12.9	5.7	12.1	99
5B	100.58				100

[a]The ESP inlet moisture data represent the average of the anions and trace metals moisture for the day.

[b]The ESP inlet O_2 and CO_2 data represent the analysis of a bag sample collected during anions sampling that day.

[c]The scrubber outlet moisture data for Runs 2 and 3 represent the average of the two anions trains collected that day. The scrubber outlet moisture data for Runs 4 and 5 represent the average of the two trace metals sampls collected that day.

[d]The scrubber outlet O_2 and CO_2 data represent the analysis of a bag sample collected during trace metals sampling that day.

of the isokinetic rate. The sub-isokinetic rate is not expected to have a significant effect on the semivolatile organics results.

Anions Collection

An adaptation of the procedures specified in EPA Method 5 were used to collect solid and vapor phase samples of the ESP inlet and absorber outlet flue gas for anions analysis. This sampling train was used to collect anions samples only and not to determine the particulate mass loading. A Teflon® sample line was used to transfer the flue gas from the filter holder to the impingers. After sample collection the Teflon® sample line was soaked for 15 minutes with a carbonate/bicarbonate solution to recover any anions that may have adsorbed onto the walls of the tubing during testing. The resulting rinse solution was added to the first impinger sample for analysis. Two impingers containing 6% hydrogen peroxide were used to collect the vapor phase anions. The two impinger samples were recovered into separate sample containers. Upon completion of sampling the probe and sampling nozzle (P&N) were rinsed with a carbonate/bicarbonate solution. The P&N rinse was combined with the filter to generate the solid phase anions sample.

A summary of the ESP inlet and absorber outlet source sampling data is presented in Table A-5. A total of five sets of ESP inlet anions samples were collected over the period of August 18 to August 22 while four sets were collected at the absorber outlet. The anions sample collected at the ESP inlet on August 18 was discarded because the filter became dislodged from the support plate during sampling allowing solids to enter the first impinger. The remaining anion sample sets were submitted to the lab for analysis.

Flue Gas Flow Rate

The flow rate of flue gas entering the ESP and exiting the wet absorber was determined using the procedures specified in EPA Methods 1, 2, 3, and 4. EPA Method 1 was used

Table A-5

FCEM Site 21 - Variability Test
Anions Source Sampling Data

ESP INLET

Run No.	Sample Gas Volume (dscf)	Flue Gas Composition: Moisture (%)	O_2 (%)	CO_2 (%)	% Isokinetic
2	37.685	9.0	4.1	12.8	96
3	37.715	8.7	3.8	12.5	95
4	43.259	9.2	4.6	12.2	94
5	42.009	9.5	3.9	12.5	94

SCRUBBER OUTLET

Run No.	Sample Gas Volume (dscf)	Flue Gas Composition: Moisture (%)	O_2* (%)	CO_2* (%)	% Isokinetic
2A	106.482	12.5	5.9	12.6	100
2B	108.675	12.2	5.9	12.6	101
3A	106.654	12.3	5.8	12.4	99
3B	106.827	12.1	5.8	12.4	99
4A	129.521	12.5	5.7	12.2	101
4B	106.571	12.5	5.7	12.2	99
5A	131.873	12.8	5.7	12.1	102
5B	120.779	13.6	5.7	12.1	94

*The scrubber outlet O_2 and CO_2 sample was collected during multi-metals sampling.

to determine the number of sampling points required to perform a velocity profile. EPA Method 2 was used to determine the velocity and volumetric flow rate of the flue gas. EPA Methods 3 and 4 were used to determine the molecular weight and moisture content of the flue gas, respectively.

A velocity probe was used to measure the average velocity head pressure and temperature at the ESP inlet and absorber outlet. An integrated bag sample was collected each day at the inlet and outlet sampling locations during one of the sampling episodes for use in determining the flue gas molecular weight. An Orsat apparatus was used to analyze the bag samples for oxygen and carbon dioxide. The moisture content of the flue gas was determined simultaneously during the collection of metals and anions samples. This was accomplished by weighing the impingers before and after sampling to determine the mass of water condensed during sampling. The mass of condensed water was then related to the volume of flue gas sampled to determine the fraction of water vapor present in the original flue gas.

A summary of the flue gas flow rate data obtained at the ESP inlet and absorber outlet during the period of August 18 to August 24 is presented in Table A-6. Two velocity profiles were performed each day at the ESP inlet and absorber outlet, except on August 18 and 19. One velocity profile was performed in the morning prior to collecting any flue gas samples and a second velocity profile was performed after sampling was completed. On each day, the morning velocity profile agreed with the evening one within $\pm$ 3% at both the ESP inlet and absorber outlet. This indicates a constant flow rate of flue gas during the course of a day and supports the validity of using the morning velocity data to set the isokinetic sampling rate.

Particulate Mass Loading Data

The particulate mass loading was determined simultaneously during the collection of multi-metals samples at the ESP inlet and absorber outlet. A summary of the ESP inlet and absorber outlet particulate mass loading data is presented in Table A-7. The

Table A-6

FCEM Site 21 – Variability Tests
Flue Gas Flow Rate Data

ESP Inlet

		Flue Gas Composition			Average Flue Gas				
Run No.	Time	Moisture (%) [a]	O_2 (%) [b]	CO_2 (%)	ΔP (inches H_2O)	Temperature (°F)	Velocity (ft/sec)	Flow Rate (dscfm)	Average of Morning & Evening
2	Morning	9.2	4.1	12.8	1.35	291	79.14	8,960	9,010
	Evening				1.38	286	79.49	9,060	
3	Morning	8.9	3.8	12.5	1.36	297	80.16	9,020	
	Evening				1.40	296	80.87	9,112	9,066
4	Morning	9.3	4.6	12.2	1.39	292	80.71	9,109	
	Evening				1.36	294	79.72	9,003	9,056
5	Morning	9.4	3.9	12.5	1.31	296	78.36	8,834	
	Evening				1.29	298	78.05	8,776	8,805
6	Morning	8.4	3.8	12.7	1.31	293	78.14	8,897	
	Evening				1.35	296	79.26	8,988	8,943
7	Morning	7.6	3.8	12.7	1.20	297	76.88	8,609	
	Evening				1.34	297	79.09	8,856	8,733

Table A-6 (Continued)

Scrubber Outlet

Run No.	Time	Flue Gas Composition: Moisture (%) [a]	Flue Gas Composition: O_2 (%) [b]	Flue Gas Composition: CO_2 (%)	Average Flue Gas: ΔP (inches H_2O)	Average Flue Gas: Temperature (°F)	Average Flue Gas: Velocity (ft/sec)	Average Flue Gas: Flow Rate (dscfm)	Average of Morning & Evening
2	Morning	12.4	5.9	12.6	0.82	120	47.70	8,135	8,135
3	Morning	12.2	5.8	12.4	0.80	126	51.97	8,042	
	Evening				0.80	122	51.49	8,026	8,034
4	Morning	12.3	5.7	12.2	0.80	126	51.92	8,052	
	Evening				0.82	123	52.4	8,178	8,115
5	Morning	12.9	5.7	12.1	0.80	123	51.72	8,017	
	Evening				0.83	122	52.65	8,180	8,099
6	Morning	11.7	5.9	12.6	0.81	119	51.52	8,151	
	Evening				0.81	123	51.81	8,141	8,146
7	Morning	13.3	5.6	12.6	0.85	123	53.27	8,219	
	Evening				0.82	125	52.54	8,064	8,142

[a]The ESP inlet moisture data for Runs 2 to 5 represents the average of anions and trace metals moisture data for those days. The moisture for Runs 6 and 7 were obtained from the meatals runs performed that day.

[b]The ESP inlet O_2 and CO_2 data for Runs 2 to 5 represents the analysis of a bag sample collected during anions sampling that day. The O_2 and CO_2 data for Runs 6 and 7 were obtained during the collection of the trace metals sample that day.

[c]The scrubber outlet moisture data represents the average of trace metals trains "A" and "B" collected that day.

[d]The scrubber outlet O_2 and CO_2 data represents the analysis of a bag sample collected during trace metals sampling that day.

Table A-7

FCEM Site 21 – Variability Tests
Particulate Mass Loading Results

Run No.	Mass Gain (grams) Filter	P&N Rinse	Total	Sample Gas Volume (dscf)	Mass Loading (gr/dscf) Filter	P&N Rinse	Total
			ESP INLET				
2	2.4626	0.1680	2.6306	31.4	1.208	0.082	1.291
3	2.7854	0.2343	3.0197	47.2	0.910	0.077	0.986
4	2.8056	0.0797	2.8853	46.6	0.929	0.026	0.955
5	1.9036	0.3674	2.2710	44.8	0.656	0.127	0.782
6	1.9560	0.1949	2.1509	39.2	0.770	0.077	0.847
7	2.7660	0.1392	2.9052	37.6	1.135	0.057	1.192
Average							1.0
			SCRUBBER OUTLET				
4A	0.04648	0.0058	0.05228	302.9	0.0024	0.0003	0.0027
4B	0.05931	0.0180	0.07731	305.5	0.0030	0.0009	0.0039
5A	0.05236	0.0074	0.05976	296.8	0.0027	0.0004	0.0031
5B	0.15752	0.0188	0.17632	307.8	0.0079	0.0009	0.0088
6A	0.10895	0.0199	0.12885	282.6	0.0059	0.0011	0.0070
6B	0.1068	0.0101	0.1169	286.8	0.0057	0.0005	0.0063
7A	0.08489	0.0110	0.09589	315.4	0.0042	0.0005	0.0047
7B	0.10009	0.0526	0.15269	318.0	0.0049	0.0026	0.0074
Average							0.0055

individual filter and P&N mass gains and related mass loadings are included in Table A-7 for comparative purposes.

Process Stream Sampling

One sample each of the coal, collected ESP fly ash, wet absorber solids, and absorber liquor were collected during each day of flue gas sampling. The coal sample was collected using an auto-sampler on the power plant coal preparation circuit just up stream of the final pulverizers. The auto-sampler collected a coal sample each 24-hour period (1200 to 1200). A riffler was then used to obtain a subset of the power plant 24-hour coal sample for use by Radian.

A composite sample of the ESP fly ash was collected from each of the five hoppers servicing the ESP. The fly ash is transferred out of the hoppers once per shift. During the ash transfer step, a fraction of the solids that were present in each hopper was diverted to a 55-gallon drum. The fly ash was allowed to accumulate in the 55-gallon drum over a 24-hour period. A tube thief sampler was then used to retrieve a sample of the fly ash from the 55-gallon drum.

A portion of the absorber solids and absorber liquor that is normally collected each day by personnel from the Site 21 laboratory was provided to Radian for use on this project. The coal samples were submitted for analysis, but the ESP fly ash, absorber solids, and absorber liquor samples were archived.

Analytical Methods

Semivolatile Organic Compounds

Sample Collection. Polycyclic aromatic hydrocarbons (PAH) were collected using a Modified Method 0010 train containing a pre-cleaned filter, XAD resin cartridge and two water condensate impingers separated from the cartridge by a moisture knockout

impinger. The cleaning, preparation and analysis were performed by Twin City Testing Corporation, St. Paul, MN. The XAD resin and filters were cleaned by methylene chloride Soxhlet extraction and dried by a purified nitrogen gas stream. The resin was packed in a cleaned glass cartridge and labeled with surrogate spikes.

Sample Preparation and Analysis. The recovered cartridges were combined with the filter and the filtered PNR, then Soxhlet extracted with methylene chloride for eighteen hours. The extract was concentrated to 10 mL split into 5 mL aliquots, one of which was archived. The remaining split was further concentrated to 1 mL, spiked with internal standards and analyzed. The analysis was performed by modified SW-846 Method 8290, capillary gas chromatography coupled with high resolution mass spectrometer (GC/HRMS). The method modifications were as follows: target analytes were PAHs (instead of dioxin and furans) and isotopic spikes contained deuterium, not carbon 13. Two types of analytical spikes were performed. Surrogate spikes were added to the resin before sampling and extraction. Internal or recovery spikes were performed after extraction and before analysis. Additional SW-846 Method 8270 analysis was performed on the inlet XAD cartridges for semivolatile compounds. The 8270 was performed to investigate the poor spike recoveries caused by high unknown organic concentrations in the GC/HRMS analysis for these samples (see the 8270 Semivolatile results).

Anions

Sample Collection. Anions were collected by a Modified Method 5 train with filter, two impingers containing 6% hydrogen peroxide (separated by a knockout impinger) and a silica gel impinger. The filters were combined with the PNR and shaken for 20 minutes. The impingers were collected and analyzed separately with no sample preparation.

Sample Preparation and Analysis. The fluoride was analyzed by ion selective electrode using EPRI FGD Handbook Method P1 (CS 3612). Analysis of chloride and sulfate was performed by ion chromatography using EPRI FGD Handbook Method 13. This method uses a modified eluent to separate chloride and sulfate with conductivity detection.

Chromatograms from the second impinger of the outlet trains presented a peak tentatively identified as sulfite. The addition of 2 mL 30% hydrogen peroxide eliminated this peak and increased the sulfate peak. Review of the first outlet impinger and both inlet impingers did not show the same sulfite peak. The loss of peroxide in the second impinger is not easily explained. Calculations based on CEM sulfur dioxide concentrations at both the inlet and outlet indicated the 5% peroxide to be sufficient for complete sulfur dioxide oxidation. The peroxide loss due to sulfur dioxide reaction is the best explanation but the loss does not occur in the first impinger where the concentration of sulfur dioxide is greater nor in either inlet impinger where the sulfur dioxide concentration was greater than 1000 ppm. Subsequent anion analysis for other FCEM locations need be closely monitored for this phenomenon. An increase in hydrogen peroxide concentration to 10% would easily provide the excess necessary to react with the available sulfur dioxide.

Gas Phase Metals

Sample Collection. The vapor and particulate phase metals were collected and analyzed by BIF multiple metals method. The train consisted of two 5% nitric acid/10% hydrogen peroxide impingers, two 4% potassium permanganate/10% sulfuric acid impingers, two moisture knockout impingers before and after the second nitric impingers and one silica gel impinger. Upon recovery, the nitric impingers and their three rinses were combined in the same sample bottle. The permanganate impingers were all combined in the same sample bottle with the nitric and hydrochloric acid rinses. Particulate loading was calculated from the metals trains; this required the use of an acetone PNR in addition to the nitric acid PNR.

Sample Preparation and Analysis. Filters and PNRs were returned to Radian for desiccation and weighing to determine particulate loading. The residual PNR and filters from the outlet were combined and microwave digested using CEM methods (40 CFR 136.5). The inlet filters, which contained between 1.9 and 2.5 grams of solid material, were not completely digested. Instead, approximately 0.15 g of the filtered ash was

digested and analyzed separate from the PNR. Vapor phase metals were determined from the digested nitric impingers.

Table A-8 lists the methods used for the eight target elements (As, Be, Cd, Cr, Hg, Ni, Pb and Se). Additional elements were analyzed by inductively coupled plasma emission spectroscopy (ICP-AES) SW-846 Method 6010. For the nitric impingers a 100 mL aliquot was digested by SW-846 Method 3020 in nitric acid, reduced in volume and diluted to a final volume of 100 mL. This "3020" fraction which contained no hydrochloric acid was used for analysis by graphite furnace atomic spectroscopy (GFAAS) and inductively coupled plasma mass spectrometry (ICP-MS). Another 100 mL aliquot was digested, volume reduced and diluted to a final volume of 100 mL with hydrochloric acid. This fraction "6010" was used for analysis by ICP-AES. Both these fraction were digested per the BIF method but were not concentrated. The remaining nitric impinger samples (~1.5 liters) from the outlet location were concentrated by low temperature heating with the addition of extra nitric acid and diluted to a final volume of 50 mL. This was approximately a 25 fold concentration for each impinger.

Mercury analysis was performed by a modified EPA Method 245.1A using cold vapor atomic spectroscopy (CVAAS). A 10 mL aliquot was taken from both the nitric and permanganate impingers, prior to any other metals analysis. The samples were diluted to 50 mL, acidified, digested and analyzed by CVAAS. Additional potassium permanganate (2.3 g) was added to the nitric aliquots to consume the residual peroxide present indicated by a persistent pink or brown color. The one modification was the use of an oven instead of a hot bath during the sample digestion. This modification allowed more samples to be digested and analyzed together than could be digested using the hot bath. Though no comparison study between the water bath and oven was performed QC data met laboratory and project requirements. No mercury analysis was performed on the particulate phase. Previous particulate mercury analysis performed at the same site indicated mercury at or below the method detection limit.

Table A-8

Methods for the Target Metals for Site 21

Element	Method	Instrument	MDL µg/L
Arsenic	SW-846, 7060	GFAAS	1.5
Beryllium	SW-846, 6010	ICP-AES	0.054
Cadmium	SW-846, 7131	GFAAS	0.24
Chromium	SW-846, 6010	ICP-AES	2.96
Lead	SW-846, 7421	GFAAS	1.4
Mercury	EPA 245.1	CVAAS	0.1
Nickel	EPA 249.2	GFAAS	2.2
Selenium	SW-846, 7740	GFAAS	2.5

Mercury in FGD Solids

Mercury analysis of the FGD solids used the same Modified Method EPA 245.1 used for the vapor phase mercury. The solids were collected by filtering the FGD slurry and rinsing twice with 50% acetone and drying. The solids were acidified, digested and analyzed by CVAAS.

Coal Composition

Coal samples were obtained from the daily composite sample used by the power plant. The daily composite was mixed and three splits made. One split was archived, one sent for bulk analysis and a third provided to Brooks-Rand Ltd. for additional mercury analysis. Bulk coal analysis was performed by CT&E for ultimate and short proximate, total chlorine, higher heating value, and the target metals listed in Table A-8. The methods are listed in Table A-9. Analytical methods used to determine the target metals followed ASTM D3683 (Trace metals in Coal). ICP-AES was used for Be, Cr, Pb and Ni; GFAAS for As, Cd and Se. Mercury was analyzed using Double Gold Amalgamation CVAAS.

ESP Inlet Semivolatile Organic Analysis

During analysis of the ESP inlet MM5 extracts by HRGCMS, large amounts of an interfering compound or compounds were encountered. Table A-10 presents the results from the two runs where partial data was obtained. This data is not believed to be reliable because of the interference problem with the other two runs.

Semivolatile Organic Compounds by Method 8270

The four inlet, front half composites were analyzed following SW-846 Method 8270 (GC/Low Resolution Mass Spectrometry) for semivolatile compounds. This attempt was made to investigate the recovery and analysis difficulties encountered during the

GC/High Resolution Mass Spectrometry analysis of the same samples. Although a number of high concentration organics were detected none were expected to cause problems with the initial HRMS analysis. However, the sample from Run 2 (HG220-223) did contain material which caused chromatographic difficulties and is not reported

Table A-9

Coal Methods for Site 21

Parameter	Method
Percent Moisture	ASTM D3172-89
Percent Ash	ASTM D3172-89
Percent Carbon	ASTM D3176-89
Percent Hydrogen	ASTM D3176-89
Percent Nitrogen	ASTM D3176-89
Percent Sulfur	ASTM D3176-89
Percent Oxygen	ASTM D3176-89
Heating Value	ASTM D3286-85
Percent Chlorine	ASTM D4208-88

Table A-10

Invalid ESP Inlet Semivolatiles by HRGCMS (ng/dNm^3)

Substance	Run 3	Run 5
5-Methyl chrysene	NRS	NRS
7H-Dibenzo[c,g]carbazole	NRS	NRS
Acenapthene	6.54	16.41
Acenapthylene	12.32	37.58
Anthracene	15.03	53.56
Benz[a]anthracene	NRS	NRS
Benzo[a]pyrene	NRS	NRS
Benzo[b,j&k]fluoranthenes	NRS	NRS
Benzo[g,h,i]perylene	NRS	NRS
Chrysene	NRS	NRS
Dibenz[a,h]acridine	NRS	NRS
Dibenz[a,h]anthracene	NRS	NRS
Dibenz[a,i]acridine	NRS	NRS
Dibenzo[a,e]pyrene	NRS	NRS
Dibenzo[a,h]pyrene	NRS	NRS
Dibenzo[a,i]pyrene	NRS	NRS
Fluoranthene	45.12	286.36
Fluorene	2.26	54.85
Indeno[1,2,3-cd]pyrene	NRS	NRS
Phenanthrene	84.14	359.35
Pyrene	39.38	235.39

NRS = No resolvable signal.

here. The high concentration organics were not members of the 8270 list and many were not identifiable using the NIST/Mass Spectral Database.

Table A-11 lists the 8270 target compounds identified and Tables A-12a and A-12b, the ancillary compounds detected. All mass values are semiquantitative, either below the cutout limit for the 8270 compounds or no calibration was performed.

Raw Analytical Data

The 408 pages of raw analytical data are on file at Radian Corporation as an extension of Appendix A.

Table A-11

ESP Inlet Method 8270 Target Compounds (ng)

Sample Code	Compound	Result	POL[a]
Method Blank	Benzyl Alcohol	21,000	10,000
	Naphthalene	1,200	10,000
Run 3	Benzoic Acid	21,000	10,000
	Di-n-butylphthalate	1,600	10,000
	bis(2-Ethylhexyl) phthalate	5,100	10,000
Run 4	Benzoic Acid	27,000	10,000
	Di-n-butylphthalate	1,500	10,000
	bis(2-Ethylhexyl) phthalate	4,900	10,000
Run 5	Phenol	7,700	10,000
	2-Nitrophenol	3,900	10,000
	Benzoic Acid	30,000	10,000
	Di-n-butylphthalate	3,200	10,000
	Butylbenzylphthalate	1,300	10,000
	bis(2-Ethylhexyl) phthalate	6,800	10,000

[a]Practical quantitation limit.

Table A-12a

ESP Inlet Semivolatile Organics Detected (not part of 8270 list) (ng)

Sample Code	Compound	Result
Method Blank	Toluene	6,600,000
	Unknown	22,000
	Cyclopentane, ethyl, methyl isomer	8,500
	Cyclopentane, propyl-	13,000
	Unknown, mw = 112	16,000
	Unknown C_8H_{10} aromatic	18,000
	Unknown C_8H_{10} aromatic	10,000
	Unknown $C_{10}H_{18}$	11000
	Unknown	11,0000
	Unknown	43,000
Run 3	Toluene	1,000,000
	Unknown	80,000
	Unknown $C_6H_{10}O$	100,000
	Unknown $C_6H_{10}O$	360,000
	2-Pentanone, 4-hydroxyl-4-methyl	650,000
	Unknown mw = 118	60,000
	Unknown	20,000
	Unknown	24,000
	Unknown $C_{24}H_{50}$	25,000
	Unknown $C_{25}H_{52}$	24,000

Table A-12b

ESP Inlet Semivolatile Organics Detected (not part of 8270 list) (ng)

Sample Code	Compound	Result
Run 4	Unknown	55,000
	Toluene	1,400,000
	3-Penten-2-one, 4-methyl	22,0000
	Unknown	48,000
	2-Pentanone, 4-hydroxy-4-methyl	1,100,000
	Unknown	25,000
	Unknown $C_{23}H_{48}$	14,000
	Unknown $C_{24}H_{50}$	26,000
	Unknown $C_{25}H_{52}$	27,000
	Unknown $C_{27}H_{56}$	15,000
Run 5	3-Pente-2-one isomer	46,000
	Unknown	160,000
	Toluene	1,000,000
	3-Pente-2-one, 4-methyl	1,100,000
	Unknown	110,000
	2-Pentanone, 4-hydroxy-4-methyl	1,000,000
	Unknown	33,000
	Unknown, mw = 112	28,000
	Unknown	15,000
	Unknown $C_{25}H_{52}$	15,000

Appendix B

Analytical Data - FCEM Substances

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>>	FGD solids	<<<<<<<<<<<<<						
Mercury	CVAA	mg/kg			1.82000	1.72000	1.95000	1.63000
>>>>>>>>>>>>	coal	<<<<<<<<<<<<<						
Arsenic	GFAA	mg/kg	1.82000	4.00000	5.00000	5.00000	5.00000	5.00000
Beryllium	ICPES	mg/kg	.80000	.70000	.80000	.80000	.90000	.80000
Cadmium	GFAA	mg/kg <	.10000	.20000 <	.10000 <	.10000	.10000	.10000
Chromium	ICPES	mg/kg	11.00000	11.00000	12.00000	11.00000	12.00000	11.00000
Lead	GFAA	mg/kg	2.50000	3.00000	3.10000	2.70000	2.50000	3.30000
Mercury	DGAA	mg/kg	.15000	.14000	.13000	.15000	.14000	.20001
Nickel	GFAA	mg/kg	8.00000	8.00000	10.00000	8.00000	8.00000	8.00000
Selenium	GFAA	mg/kg	1.00000	1.00000	1.00000	1.00000	1.00000	2.00000
>>>>>>>>>>>>	high dust gas, solid phase	<<<<<<<<<<<<<						
Arsenic	GFAA	ug/Nm3	446.19680	746.75233	514.43286	411.74539	389.80490	544.60422
Barium	ICPES	ug/Nm3	1559.83036	1.03978	1380.34597	1106.06483	1197.87689	1805.65141
Beryllium	ICPES	ug/Nm3	39.32936	0.32691	40.62308	27.20674	27.95614	38.19324
Cadmium	GFAA	ug/Nm3	4.44835 @	4.18317	3.37424	2.36797	3.02258	4.10010
Chloride	IC	ug/Nm3	.97685	1.00676 @	1.35307	1.22628		
Chromium	ICPES	ug/Nm3	624.20643	690.47561	704.07807	368.60668	468.49593	665.02809
Cobalt	ICPES	ug/Nm3	128.23517	124.83614	132.07656	86.67781	112.28034	141.64694
Copper	ICPES	ug/Nm3	238.77104	283.55898	247.29897	180.45050	207.93382	269.36958
Fluoride	ISE	ug/Nm3	.21598	.41577	.28649	.30124 @		
Lead	GFAA	ug/Nm3	171.30419	244.69388	192.90097	146.47233	153.66150	208.73407
Manganese	ICPES	ug/Nm3	481.55473	448.29191	397.43266	331.31128	341.71798	522.87559
Molybdenum	ICPES	ug/Nm3	34.76100	68.82922	55.26019	38.89973	69.22448	53.83841
Nickel	GFAA	ug/Nm3	450.43471	477.60993	445.67904	305.27530	351.85940	497.76738
Selenium	GFAA	ug/Nm3	50.94017	66.97091	49.46665	45.94868	44.81273	39.35477
Vanadium	ICPES	ug/Nm3	825.62905	1100.26937	921.26431	691.70752	796.71246	956.19279
>>>>>>>>>>>>	high dust gas, vapor phase	<<<<<<<<<<<<<						
Arsenic	GFAA	ug/Nm3	1.56136 @	.63078 @ <	.22255 <	.22706 <	.23310 <	.31141
Barium	ICPES	ug/Nm3	8.06418	.93466 @	1.49502 @	.60952 @	1.43831	.64740
Beryllium	ICPES	ug/Nm3 <	.06291 <	.04400 <	.07998	.08781 @ <	.08380	.03840
Cadmium	GFAA	ug/Nm3	2.11613 @	3.68340	1.49502 @	1.60128 @	3.83102	.76810

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> high dust gas, vapor phase	<<<<<<<<<<<<							
Chloride	IC	ug/Nm3	154690.94897	164916.62799	154174.36224	97843.45045		
Chromium	ICPES	ug/Nm3	3.03694 @	1.39969 @	1.27077 @	3.51765	6.50602	3.53874
Cobalt	ICPES	ug/Nm3	< 1.82445	< 1.78184	< .80731	< 1.79756	< 2.33894	< 2.02449
Copper	ICPES	ug/Nm3	< 1.10831	< .89225	< .96572	1.00106 @	< 1.30252	< 1.06324
Fluoride	ISE	ug/Nm3	8193.25060	9344.95221	8143.46179	8995.35232		
Lead	GFAA	ug/Nm3	33.28619	2.76255	29.80070	9.71097	34.41199	10.58880
Manganese	ICPES	ug/Nm3	215.61671	5.57114 @	61.79409	8.36797 @	12.23239	19.75113
Mercury	CVAA	ug/Nm3	9.92483	10.08579	9.05782	11.83396	9.69521	11.68203
Molybdenum	ICPES	ug/Nm3	< 1.19533	< 2.45349	< 1.38040	< .48038	< 2.39943	< 2.92303
Nickel	GFAA	ug/Nm3	6.69155	2.34817	2.34220	4.75218	5.91456	1.86538
Selenium	GFAA	ug/Nm3	3.13988 @	2.78557	8.27244	3.55897	4.23429	1.06457
Vanadium	ICPES	ug/Nm3	3.21423 @	< 2.21695	< .08472	< 2.48715	3.23621	< 2.64162
>>>>>>>>>>>> stack gas, A	<<<<<<<<<<<<							
5-Methyl chrysene	HRGCMS	ng/Nm3	2.17208	< 1.02433		2.55188		
7H-Dibenzo[c,g]carbazole	HRGCMS	ng/Nm3	< 3.42379	< .72136		< 3.02580		
Acenapthene	HRGCMS	ng/Nm3	49.22153	17.44606		6.05159		
Acenapthylene	HRGCMS	ng/Nm3	21.02131	3.61401		14.18114		
Anthracene	HRGCMS	ng/Nm3	26.46992	8.16217		7.61918		
Benz[a]anthracene	HRGCMS	ng/Nm3	1.73030	1.02072		.61974		
Benzo[e]pyrene	HRGCMS	ng/Nm3	3.49742	1.38501		< 19.28125		
Benzo[b,j&k]fluoranthenes	HRGCMS	ng/Nm3	13.73196	4.44718		2.73415		
Benzo[ghi]perylene	HRGCMS	ng/Nm3	.69948	1.14335		< .94784		
Chrysene	HRGCMS	ng/Nm3	14.35781	5.83940		4.77566		
Dibenz[a,h]acridine	HRGCMS	ng/Nm3	< .40496	.24887		< 1.89568		
Dibenz[a,h]anthracene	HRGCMS	ng/Nm3	< 1.06763	< .45806		< 1.31239		
Dibenz[a,i]acridine	HRGCMS	ng/Nm3	< .77311	.11181		< .98430		
Dibenzo[a,e]pyrene	HRGCMS	ng/Nm3	< .47859	< .69611		< .83847		
Dibenzo[a,h]pyrene	HRGCMS	ng/Nm3	< 1.32534	< .36789		< 1.49467		
Dibenzo[a,i]pyrene	HRGCMS	ng/Nm3	< 1.32534	< .53741		< 1.85922		
Fluoranthene	HRGCMS	ng/Nm3	141.44286	40.87940		25.15421		
Fluorene	HRGCMS	ng/Nm3	170.74752	46.30401		28.83621		
Indeno[1,2,3-cd]pyrene	HRGCMS	ng/Nm3	3.09245	1.30205		< .65620		
Phenanthrene	HRGCMS	ng/Nm3	658.61863	170.12884		55.12054		
Pyrene	HRGCMS	ng/Nm3	64.79423	20.90137		12.32192		

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, A		<<<<<<<<<<<<						
>>>>>>>>>>>> stack gas, A, DUP		<<<<<<<<<<<<						
5-Methyl chrysene	HRGCMS	ng/Nm3	1.10445	< .97383	.55034	.43746		
7H-Dibenzo[c,g]carbazole	HRGCMS	ng/Nm3	< 3.05564	< .75743	< 2.27016	< 1.84829		
Acenapthene	HRGCMS	ng/Nm3	51.20953	16.12597	3.50842	5.97868		
Acenapthylene	HRGCMS	ng/Nm3	11.44944	4.41472	3.02688	3.90073		
Anthracene	HRGCMS	ng/Nm3	30.74044	5.12886	4.26514	4.48401		
Benz[a]anthracene	HRGCMS	ng/Nm3	4.38097	1.01351	1.03189	.69265		
Benzo[a]pyrene	HRGCMS	ng/Nm3	2.79793	1.10368	.34396	2.84352		
Benzo[b,j&k]fluoranthenes	HRGCMS	ng/Nm3	15.53589	5.08558	1.68542	3.35390		
Benzo[ghi]perylene	HRGCMS	ng/Nm3	3.16608	1.36697	.85991	.36455		
Chrysene	HRGCMS	ng/Nm3	8.46743	6.58240	.82551	4.59338		
Dibenz[a,h]acridine	HRGCMS	ng/Nm3	1.25171	.14427	.24077	< .45569		
Dibenz[a,h]anthracene	HRGCMS	ng/Nm3	1.14126	< .75743	.37836	.32810		
Dibenz[a,i]acridine	HRGCMS	ng/Nm3	.69948	< .06492	.20638	< 1.31239		
Dibenzo[a,e]pyrene	HRGCMS	ng/Nm3	< 1.03082	< .28854	< .89430	< .47757		
Dibenzo[a,h]pyrene	HRGCMS	ng/Nm3	< .51541	< .38953	< .41276	< 1.14470		
Dibenzo[a,i]pyrene	HRGCMS	ng/Nm3	< 1.36215	< .57709	< 1.13508	< .71453		
Fluoranthene	HRGCMS	ng/Nm3	157.34690	38.62154	5.67539	17.89959		
Fluorene	HRGCMS	ng/Nm3	152.48733	39.53406	18.71159	23.14917		
Indeno[1,2,3-cd]pyrene	HRGCMS	ng/Nm3	4.19690	1.61584	.65353	.72911		
Phenanthrene	HRGCMS	ng/Nm3	698.26828	187.88148	37.52637	69.77560		
Pyrene	HRGCMS	ng/Nm3	70.75824	23.15922	5.77858	10.24396		
>>>>>>>>>>>> stack gas, B		<<<<<<<<<<<<						
5-Methyl chrysene	HRGCMS	ng/Nm3	9.35063	.26351		.47498		
7H-Dibenzo[c,g]carbazole	HRGCMS	ng/Nm3	< 4.07962	< 2.22518	< 1.30706	< 1.81828		
Acenapthene	HRGCMS	ng/Nm3	69.02859	5.35434	3.19886	1.94815		
Acenapthylene	HRGCMS	ng/Nm3	25.66910	4.57479	4.74669	2.63836		
Anthracene	HRGCMS	ng/Nm3	48.26947	3.46586	5.91616	2.56414		
Benz[a]anthracene	HRGCMS	ng/Nm3	2.02176	.51970	.34396	.75700		
Benzo[a]pyrene	HRGCMS	ng/Nm3	2.85212	< .72465	< .79112	.81266		
Benzo[b,j&k]fluoranthenes	HRGCMS	ng/Nm3	29.96534	1.14919	1.96059	2.17451		
Benzo[ghi]perylene	HRGCMS	ng/Nm3	4.51285	.64047	.55034	1.31732		
Chrysene	HRGCMS	ng/Nm3	42.02368	1.72744	2.64852	1.71066		

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, B		<<<<<<<<<<<<						
Dibenz[a,h]acridine	HRGCMS	ng/Nm3	< 1.22750	.83444	< .79112	.19667		
Dibenz[a,h]anthracene	HRGCMS	ng/Nm3	< 1.84124	< .60387	< 1.58223	.91656		
Dibenz[a,i]acridine	HRGCMS	ng/Nm3	< 1.98565	< 1.06501	< .30957	< .38963		
Dibenzo[a,e]pyrene	HRGCMS	ng/Nm3	< 1.69683	< .29645	< 1.16947	< .74215		
Dibenzo[a,h]pyrene	*HRGCMS*	*ng/Nm3*	*< 1.19139*	*< .31475*	< 1.06629	< .55661		
Dibenzo[a,i]pyrene	HRGCMS	ng/Nm3	< 2.77992	< .82346	< 1.27266	< 1.14663		
Fluoranthene	HRGCMS	ng/Nm3	245.60746	11.61631	11.35078	8.59785		
Fluorene	HRGCMS	ng/Nm3	264.38093	24.95275	22.73596	21.92692		
Indeno[1,2,3-cd]pyrene	HRGCMS	ng/Nm3	4.72947	< .61119	< .96310	1.11323		
Phenanthrene	HRGCMS	ng/Nm3	777.32974	56.99460	43.33935	50.43303		
Pyrene	HRGCMS	ng/Nm3	98.06959	11.86518	7.18883	5.08004		
>>>>>>>>>>>> stack gas, B, DUP		<<<<<<<<<<<<						
5-Methyl chrysene	HRGCMS	ng/Nm3	6.24579	< .26351		.82008		
7H-Dibenzo[c,g]carbazole	HRGCMS	ng/Nm3	< 2.27448	< .79784		< 1.14663		
Acenapthene	HRGCMS	ng/Nm3	73.46923	4.60773		1.75519		
Acenapthylene	HRGCMS	ng/Nm3	20.14537	3.82087		6.18214		
Anthracene	HRGCMS	ng/Nm3	16.42678	3.04864		*3.06880*		
Benz[a]anthracene	HRGCMS	ng/Nm3	7.14836	.41722		.36737		
Benzo[a]pyrene	HRGCMS	ng/Nm3	10.26930	< .77223		.16327		
Benzo[b,j&k]fluoranthenes	HRGCMS	ng/Nm3	28.73784	1.22970		1.02788		
Benzo[ghi]perylene	HRGCMS	ng/Nm3	5.05439	.24887		.66423		
Chrysene	HRGCMS	ng/Nm3	22.16713	1.29924		1.91847		
Dibenz[a,h]acridine	HRGCMS	ng/Nm3	< 1.80514	< .38794		< .43787		
Dibenz[a,h]anthracene	HRGCMS	ng/Nm3	< 3.21315	< .79784		.29686		
Dibenz[a,i]acridine	HRGCMS	ng/Nm3	< 1.29970	< .52336		.22636		
Dibenzo[a,e]pyrene	*HRGCMS*	*ng/Nm3*	*< 1.84124*	*< .59289*		< .74215		
Dibenzo[a,h]pyrene	HRGCMS	ng/Nm3	< 1.69683	< .30743		< .36366		
Dibenzo[a,i]pyrene	HRGCMS	ng/Nm3	< 3.10484	< .62217		< .37108		
Fluoranthene	HRGCMS	ng/Nm3	183.43841	15.62017		4.50487		
Fluorene	HRGCMS	ng/Nm3	243.83842	22.97278		23.15889		
Indeno[1,2,3-cd]pyrene	HRGCMS	ng/Nm3	6.28189	< .50506		.43045		
Phenanthrene	HRGCMS	ng/Nm3	676.31406	55.94057		41.20806		
Pyrene	HRGCMS	ng/Nm3	73.75805	9.34722		4.09669		

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>>	stack gas, solid phase A	<<<<<<<<<<<<						
Arsenic	GFAA	ug/Nm3			8.18382	6.89400	7.39684	7.23275
Arsenic	ICPMS	ug/Nm3			6.55293	14.50955	6.37026	10.07033
Barium	ICPES	ug/Nm3			3.72558	3.17040	4.12209	4.11131
Beryllium	ICPES	ug/Nm3			.15793	.14053	.15508	.14578
Beryllium	ICPMS	ug/Nm3			.18323 @	.37442 @	.15895	.22930
Cadmium	GFAA	ug/Nm3			.16969	.17688	.15615	.11817
Cadmium	ICPMS	ug/Nm3			.16807	.39780	.12393	.15734
Chromium	ICPES	ug/Nm3			3.69396	2.72429	3.58251	3.13171
Chromium	ICPMS	ug/Nm3			3.67719	6.30283	3.18851	4.30156
Cobalt	ICPES	ug/Nm3			.29783	.22371 @	.29642	.28117
Copper	ICPES	ug/Nm3			1.35280	1.19602	1.27891	1.18330
Lead	GFAA	ug/Nm3			1.49333	1.28106	1.48641	1.44394
Lead	ICPMS	ug/Nm3			2.78142	5.10825	2.47708	3.49904
Manganese	ICPES	ug/Nm3			1.26763	1.01170	1.18691	1.10161
Mercury	ICPMS	ug/Nm3			.02528 @	.04188 @	.02096	.01918
Molybdenum	ICPES	ug/Nm3			.83877	.55198	.77071	.79315
Nickel	GFAA	ug/Nm3			2.00989	1.38239	1.93543	1.52769
Nickel	ICPMS	ug/Nm3			5.12692	9.63419	4.43032	6.10461
Selenium	GFAA	ug/Nm3			2.25317	11.20980	11.54496	3.12207
Selenium	ICPMS	ug/Nm3			2.25233	11.17073	9.09637	8.15090
Vanadium	ICPES	ug/Nm3			7.45720	6.07919	6.81658	6.65011
>>>>>>>>>>>>	stack gas, solid phase A DUP	<<<<<<<<<<<<						
Arsenic	GFAA	ug/Nm3			6.65770	7.04006	7.37212	7.59873
Arsenic	ICPMS	ug/Nm3			8.38032	17.04052	5.24161	12.05841
Barium	ICPES	ug/Nm3			3.68981	3.06085	4.17154	4.17993
Beryllium	ICPES	ug/Nm3			.15793	.13566	.15632	.14692
Beryllium	ICPMS	ug/Nm3			.24231 @	.38081 @	.19554	.26755
Cadmium	GFAA	ug/Nm3			.16254	.17688	.15491	.12046
Cadmium	ICPMS	ug/Nm3			.19147	.42974	.14745	.18888
Chromium	ICPES	ug/Nm3			3.76550	2.67560	3.64432	3.09740
Chromium	ICPMS	ug/Nm3			5.17918	8.26893	4.29407	5.97111
Cobalt	ICPES	ug/Nm3			.37056	.24806 @	.25933	.25253
Copper	ICPES	ug/Nm3			1.41241	1.14368	1.27891	1.17187
Lead	GFAA	ug/Nm3			1.52910	1.30540	1.52350	1.40961

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, solid phase A DUP <<<<<<<<<<<<								
Lead	ICPMS	ug/Nm3			2.93715	5.27430	2.58947	3.65920
Manganese	ICPES	ug/Nm3			1.26763	.98127	1.20668	1.10847
Mercury	ICPMS	ug/Nm3			.01914 @	.03389 @	.02162	.02194
Molybdenum	ICPES	ug/Nm3			.89838	.60067	.83252	.72453
Nickel	GFAA	ug/Nm3			1.89066	1.45542	1.96015	1.57344
Nickel	ICPMS	ug/Nm3			5.23752	9.16409	4.25064	6.12360
Selenium	GFAA	ug/Nm3			2.37240	10.62557	11.47079	3.15638
Selenium	ICPMS	ug/Nm3			2.44043	11.31075	9.46642	8.50558
Vanadium	ICPES	ug/Nm3			7.51682	6.03051	6.89074	6.67299
>>>>>>>>>>>> stack gas, solid phase B <<<<<<<<<<<<								
Arsenic	GFAA	ug/Nm3			7.52353	5.81861	8.35547	8.74224
Arsenic	ICPMS	ug/Nm3			6.34891	12.01489	5.44563	11.86777
Barium	ICPES	ug/Nm3			3.51363	2.39328	4.13172	4.27080
Beryllium	ICPES	ug/Nm3			.15021	.10644	.15621	.15111
Beryllium	ICPMS	ug/Nm3			.17697 @	< .32542	.14145	.30709
Cadmium	GFAA	ug/Nm3			.14406	.08634	.12146	.15373
Cadmium	ICPMS	ug/Nm3			.14128	.22798	.09853	.25534
Chromium	ICPES	ug/Nm3			3.26638	2.79140	3.43191	3.58499
Chromium	ICPMS	ug/Nm3			3.19702	7.17174	2.65235	4.30323
Cobalt	ICPES	ug/Nm3			.31584	.18838 @	.28387	2.46240
Copper	ICPES	ug/Nm3			1.43027	.99400	1.21136	1.26998
Lead	GFAA	ug/Nm3			1.24814	.90073	1.42367	1.39399
Lead	ICPMS	ug/Nm3			2.59192	4.49409	2.11056	4.27110
Manganese	ICPES	ug/Nm3			1.15678	.82277	1.12806	2.28006
Mercury	ICPMS	ug/Nm3			.01268 @	.04369 @	.01001	.01747
Molybdenum	ICPES	ug/Nm3			.79438	.52945	.83196	.76282
Nickel	GFAA	ug/Nm3			1.67106	1.55881	1.55121	1.91509
Nickel	ICPMS	ug/Nm3			4.86910	9.85897	3.97805	7.96785
Selenium	GFAA	ug/Nm3			7.55442	20.03183	10.63556	10.19749
Selenium	ICPMS	ug/Nm3			6.30850	46.29827	6.66042	15.26341
Vanadium	ICPES	ug/Nm3			7.10517	4.47029	6.97265	6.71942
>>>>>>>>>>>> stack gas, solid phase B DUP <<<<<<<<<<<<								
Arsenic	GFAA	ug/Nm3			5.94316	6.18869	9.41781	8.21336

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, solid phase B DUP	<<<<<<<<<<<<							
Arsenic	ICPMS	ug/Nm3			7.41661	14.01804	6.44309	13.55437
Barium	ICPES	ug/Nm3			3.48969	2.36941	4.14407	4.28229
Beryllium	ICPES	ug/Nm3			.14781	.10429	.15621	.15114
Beryllium	ICPMS	ug/Nm3			.22451 @	2.87218	.18740	.38900
Cadmium	GFAA	ug/Nm3			.14765	.08646	.12393	.15098
Cadmium	ICPMS	ug/Nm3			.16400	.26173	.10798	.26936
Chromium	ICPES	ug/Nm3			3.24244	2.81527	3.41956	3.57349
Chromium	ICPMS	ug/Nm3			4.26147	9.41715	3.32041	7.16319
Cobalt	ICPES	ug/Nm3			.30745	.19196 @	.27893	2.42791
Copper	ICPES	ug/Nm3			1.29858	1.01549	1.22865	1.26998
Lead	GFAA	ug/Nm3			1.22419	.88640	1.42367	1.31352
Lead	ICPMS	ug/Nm3			2.69303	4.67247	2.19790	4.49804
Manganese	ICPES	ug/Nm3			1.13763	.80964	1.13053	2.28006
Mercury	ICPMS	ug/Nm3			.01198 @	.04550 @	.01037	.02236
Molybdenum	ICPES	ug/Nm3			.80635	.52945	.83196	.86629
Nickel	GFAA	ug/Nm3			1.70698	1.60656	1.52650	1.96108
Nickel	ICPMS	ug/Nm3			4.66455	9.63901	3.44019	7.30283
Selenium	GFAA	ug/Nm3			8.42841	20.03183	9.80792	10.65736
Selenium	ICPMS	ug/Nm3			6.60905	49.50669	7.12473	15.77927
Vanadium	ICPES	ug/Nm3			7.02137	4.47029	6.97265	6.79990
>>>>>>>>>>>> stack gas, vapor phase A	<<<<<<<<<<<<							
Arsenic	GFAA	ug/Nm3			< .23829	1.21271 @	< .25007	< .26227
Arsenic	ICPMS	ug/Nm3			.04289	1.22125	.09336	.08561
Barium	ICPES	ug/Nm3			.17002 @	.98825	.30342	< .16135
Beryllium	ICPES	ug/Nm3			< .00858	.13152	.03001	< .00944
Beryllium	ICPMS	ug/Nm3			< .00381	.01366 @	< .00400	< .00420
Cadmium	GFAA	ug/Nm3			.47658	.25621	.33343	.43704
Cadmium	ICPMS	ug/Nm3			.03654	.18447	.27508	.43878
Chloride	IC	ug/Nm3	571.34656	3108.29129	2866.79502	2564.15943		
Chromium	ICPES	ug/Nm3			< .47022	< .50558	< .49347	.66604
Chromium	ICPMS	ug/Nm3			.21605	.44238	.13004	.55241
Cobalt	ICPES	ug/Nm3			10.01707	10.76016	< .84574	< .88683
Copper	ICPES	ug/Nm3			.80607 @	.86587 @	.84574	.88683
Fluoride	ISE	ug/Nm3	43.81492	30.46658	34.88006	33.11332		

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, vapor phase A		<<<<<<<<<<<<						
Lead	GFAA	ug/Nm3			30183 @	2.49374	2.30064	1.62577
Lead	ICPMS	ug/Nm3			.56713	3.21795	2.52737	2.20790
Manganese	ICPES	ug/Nm3			64.35258	2.15060 @	2.83412	30.06806
Mercury	CVAA	ug/Nm3		.78046	1.06257	1.21709	1.09381	1.11465
Mercury	ICPMS	ug/Nm3			.50994	.80961	.71353	78317
Molybdenum	ICPES	ug/Nm3			< .84675	< .90957	< .88841	< .93159
Nickel	GFAA	ug/Nm3			< .34949	.66614 @	< .36677	1.20622
Nickel	ICPMS	ug/Nm3			.48770	1.26053	.62184	1.61179
Selenium	GFAA	ug/Nm3			.50200 @	3.29652	2.11726	2.76207
Selenium	ICPMS	ug/Nm3			12.45935	58.74637	22.08783	36.01874
Vanadium	ICPES	ug/Nm3			< .76508	1.27329 @	< .80272	< .84173
>>>>>>>>>>>> stack gas, vapor phase A DUP		<<<<<<<<<<<<						
Arsenic	GFAA	ug/Nm3			< .23829	1.21271 @	.27571	< .26222
Arsenic	ICPMS	ug/Nm3			.05401	1.33056	.10003	.08566
Barium	ICPES	ug/Nm3			.15254 @	1.04458	.26841	< .16135
Beryllium	ICPES	ug/Nm3			< .00858	.05637	.01334	< .00944
Beryllium	ICPMS	ug/Nm3			.00477 @	.02733	< .00400	< .00420
Cadmium	GFAA	ug/Nm3			.04766 @	.18788 @	.35010	.43704
Cadmium	ICPMS	ug/Nm3			.04289	.22375	.29008	.50871
Chloride	IC	ug/Nm3	574.85178	3304.39800	2899.65723	2728.31092		
Chromium	ICPES	ug/Nm3			< .47022	.57561 @	< .49347	< .51745
Chromium	ICPMS	ug/Nm3			.25100	.51070	.19672	.66954
Cobalt	ICPES	ug/Nm3			10.01707	< .86587	10.50994	< .88683
Copper	ICPES	ug/Nm3			< .30794	.86587 @	.84562	.88683
Fluoride	ISE	ug/Nm3	47.67063	27.31486	31.99741	31.41520		
Lead	GFAA	ug/Nm3			.44481 @	2.63038	2.30064	1.50340
Lead	ICPMS	ug/Nm3			.91185	3.41950	2.70409	2.36699
Manganese	ICPES	ug/Nm3			64.19369	2.09939 @	2.75077	30.41769
Mercury	CVAA	ug/Nm3		.79157	1.07682	1.19994	1.15556	1.07261
Mercury	ICPMS	ug/Nm3			.45275	.79936	.65852	.78492
Molybdenum	ICPES	ug/Nm3			< .84675	< .90957	< .88841	< .93159
Nickel	GFAA	ug/Nm3			< .34949	.52949 @	< .36677	< .38459
Nickel	ICPMS	ug/Nm3			.36538	.73617	.50181	1.16251
Selenium	GFAA	ug/Nm3			.84513 @	3.36484	2.60073	3.18162

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, vapor phase A DUP	<<<<<<<<<<<<<							
Selenium	ICPMS	ug/Nm3			15.66672	70.51819	27.23761	44.65631
Vanadium	ICPES	ug/Nm3			< .76508	1.86044 @	< .80272	< .84173
>>>>>>>>>>>> stack gas, vapor phase A, conc	<<<<<<<<<<<<<							
Arsenic	conc/GFAA	ug/Nm3			.02385 @	1.48494	.07664	.05890
Barium	conc/ICPES	ug/Nm3			.06462	.61467	.10025	.07800
Beryllium	conc/ICPES	ug/Nm3			.00391	.02313	.00082	.00076
Cadmium	conc/GFAA	ug/Nm3			.01931	.06780	.01582	.16126
Chromium	conc/ICPES	ug/Nm3			.21223	.44061	.11965	.55241
Cobalt	conc/ICPES	ug/Nm3			< .03024	.22396	.20396	.18528
Copper	conc/ICPES	ug/Nm3			.08239	.36150	.17923	.43918
Lead	conc/GFAA	ug/Nm3			.04459	.21787	.08195	.04884
Manganese	conc/ICPES	ug/Nm3			40.06064	1.26585	1.81707	1.30382
Molybdenum	conc/ICPES	ug/Nm3			< .03177	.14728 @	< .03362	< .03047
Nickel	conc/GFAA	ug/Nm3			.16930	.43331	.34116	1.16657
Selenium	conc/GFAA	ug/Nm3			10.66168	27.50783	22.99152	32.02355
Vanadium	conc/ICPES	ug/Nm3			< .02870	1.16604	< .02976	< .02753
>>>>>>>>>>>> stack gas, vapor phase B	<<<<<<<<<<<<<							
Arsenic	GFAA	ug/Nm3			< .22296	< .09516	< .25763	< .24068
Arsenic	ICPMS	ug/Nm3			.32701	.07676	.10305	.09306
Barium	ICPES	ug/Nm3			.33444 @	< .14798	.18378	< .14810
Beryllium	ICPES	ug/Nm3			< .00803	< .00343	.00927	< .00866
Beryllium	ICPMS	ug/Nm3			.01189 @	.00190 @	.00515	.00802
Cadmium	GFAA	ug/Nm3			.44592	.64107	1.51144	.62576
Cadmium	ICPMS	ug/Nm3			.45781	.21569	1.15247	.53590
Chloride	IC	ug/Nm3	556.34872	3383.49647	3668.59617	2492.29278		
Chromium	ICPES	ug/Nm3			< .43997	< .18778	.61488	< .47493
Chromium	ICPMS	ug/Nm3			.31363	.09452	.53072	.25832
Cobalt	ICPES	ug/Nm3			9.37048	< .81334	< .87131	< .81396
Copper	ICPES	ug/Nm3			.75404 @	.81334 @	.87088	< .31095
Fluoride	ISE	ug/Nm3	53.57432	34.95348	38.87115	41.10043		
Lead	GFAA	ug/Nm3			7.22385	2.48550	26.45012	8.76058
Lead	ICPMS	ug/Nm3			10.26648	1.10891	24.97132	10.04579
Manganese	ICPES	ug/Nm3			33.14646	1.06618 @	4.43125	1.13920

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, vapor phase B	<<<<<<<<<<<<							
Mercury	CVAA	ug/Nm3		.98458	.98454	.82206	1.03896	1.10013
Mercury	ICPMS	ug/Nm3			.52172	.20681	.61316	.64020
Molybdenum	ICPES	ug/Nm3			< .79210	< .85439	< .91528	< .85504
Nickel	GFAA	ug/Nm3			< .32701	< .13957	1.52861	< .35299
Nickel	ICPMS	ug/Nm3			.72238	.28167	1.50972	.80386
Selenium	GFAA	ug/Nm3			3.29978	2.37329	1.95800	3.11273
Selenium	ICPMS	ug/Nm3			52.02210	14.83708	27.85507	33.11853
Vanadium	ICPES	ug/Nm3			< .71570	< .77198	< .82700	< .77257
>>>>>>>>>>>> stack gas, vapor phase B DUP	<<<<<<<<<<<<							
Arsenic	GFAA	ug/Nm3			< .22296	< .09516	< .25763	< .24068
Arsenic	ICPMS	ug/Nm3			.36862	.08881	.13053	.12836
Barium	ICPES	ug/Nm3			.44592 @	.15392 @	.18378	< .14810
Beryllium	ICPES	ug/Nm3			< .00803	< .00343	.00927	< .00866
Beryllium	ICPMS	ug/Nm3			.00743 @	.00381 @	.00515	.00963
Cadmium	GFAA	ug/Nm3			.43105	.65779	1.52861	.64180
Cadmium	ICPMS	ug/Nm3			.45929	.23790	1.23835	.54874
Chloride	IC	ug/Nm3	528.87471	3480.89403	3828.63325	2244.14510		
Chromium	ICPES	ug/Nm3			< .43997	< .18778	.74541	< .47493
Chromium	ICPMS	ug/Nm3			.35673	.13639	.74026	.35941
Cobalt	ICPES	ug/Nm3			9.37041	< .81334	10.82772	< .81396
Copper	ICPES	ug/Nm3			.75405 @	.81334 @	.87131	< .31095
Fluoride	ISE	ug/Nm3	47.73609	33.96848	51.82820	42.02750		
Lead	GFAA	ug/Nm3			7.16439	2.53326	25.76310	8.72849
Lead	ICPMS	ug/Nm3			10.52363	1.17298	19.47004	10.45494
Manganese	ICPES	ug/Nm3			33.14646	1.04053 @	4.49996	1.26274
Mercury	CVAA	ug/Nm3		.95551	1.00835	.81909	1.02904	1.18595
Mercury	ICPMS	ug/Nm3			.48456	.18841	.61831	.63057
Molybdenum	ICPES	ug/Nm3			< .79210	< .85439	< .91528	< .85504
Nickel	GFAA	ug/Nm3			< .32701	< .13957	1.66601	.43322
Nickel	ICPMS	ug/Nm3			.53510	.24678	1.41010	.69154
Selenium	GFAA	ug/Nm3			4.47403	2.24436	2.66219	2.61534
Selenium	ICPMS	ug/Nm3			61.49931	18.48354	34.69947	39.75956
Vanadium	ICPES	ug/Nm3			< .71570	< .77198	< .82700	< .77257

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, vapor phase B, conc		<<<<<<<<<<<<						
Arsenic	conc/GFAA	ug/Nm3			.25142	.15519	.06856	.05461
Barium	conc/ICPES	ug/Nm3			.16163	.10314	.09018	.06415
Beryllium	conc/ICPES	ug/Nm3			.00457	.00195	< .00033	< .00031
Cadmium	conc/GFAA	ug/Nm3			.02706	.10505	.05065	.03357
Chromium	conc/ICPES	ug/Nm3			.26818	.23160	.73129	.27018
Cobalt	conc/ICPES	ug/Nm3			< .03037	.21727	.20753	.17935
Copper	conc/ICPES	ug/Nm3			.17240	.20772	.38170	.11842
Lead	conc/GFAA	ug/Nm3			.06226	.10756	.06794	.03403
Manganese	conc/ICPES	ug/Nm3			22.26888	.24473	1.08458	.78868
Molybdenum	conc/ICPES	ug/Nm3			< .03190	.03259 @	< .03291	< .03063
Nickel	conc/GFAA	ug/Nm3			.49925	.25309	1.23528	.34031
Selenium	conc/GFAA	ug/Nm3			36.15701	34.62037	28.90567	6.84063
Vanadium	conc/ICPES	ug/Nm3			.22628	.11675 @	< .02974	.03782

Appendix C

Analytical Data - Other Substances

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> coal		<<<<<<<<<<<<						
Ash	Proximate	wt. %	6.48000	6.53000	6.66000	7.04000	6.61000	6.61000
Carbon	Ultimate	wt. %	77.92000	77.95000	77.16000	77.56000	77.91000	77.88000
Chlorine	ISE	wt. %	.08000	.09000	.09000	.10000	.08000	.09000
HHV	Calorimetry	Btu/lb	14072.00000	14054.00000	14011.00000	13938.00000	14037.00000	14028.00000
Hydrogen	Ultimate	wt. %	5.21000	5.21000	5.33000	5.19000	5.26000	5.20000
Moisture	Proximate	wt. %	4.96000	7.00000	4.78000	6.51000	5.07000	6.34000
Nitrogen	Ultimate	wt. %	1.55000	1.56000	1.51000	1.56000	1.60000	1.59000
Oxygen	Ultimate	wt. %	7.19000	7.20000	7.68000	6.82000	7.12000	7.00000
Sulfur	Ultimate	wt. %	1.65000	1.55000	1.66000	1.72000	1.50000	1.72000
>>>>>>>>>>>> high dust gas, solid phase		<<<<<<<<<<<<						
Aluminum	ICPES	ug/Nm3	311127.76852	216943.75011	257018.77342	211484.65412	244342.37569	352580.42387
Antimony	ICPES	ug/Nm3	24.82351 @	95.89943	44.98566	32.40024	61.02224 <	.81387
Calcium	ICPES	ug/Nm3	54783.73302	41897.87134	39647.71201	37372.16961	35461.85503	58853.33965
Iron	ICPES	ug/Nm3	303483.80356	204008.77579	213543.37406	158053.72689	187030.07618	277467.60952
Magnesium	ICPES	ug/Nm3	13346.31358	8978.67333	9757.66154	10846.62621	9906.62487	13248.14150
Phosphorus	ICPES	ug/Nm3	6.45792	9.20993	6.32984	5.69418	5.79794	8.72112
Potassium	ICPES	ug/Nm3	36043.79779	33699.53811	34564.42593	26011.01180	30398.91226	43285.57493
Silver	ICPES	ug/Nm3	.79198 @	12.80710	12.20103	45.78659	2.95133	2.86688
Sodium	ICPES	ug/Nm3	11932.19674	11953.04824	11354.49906	8794.65339	10588.89176	13132.25318
Strontium	ICPES	ug/Nm3	2759.36234	2537.04898	2403.66759	1937.92236	2040.21551	2958.60568
Sulfate	IC	ug/Nm3	77.87241	104.59417	95.32001	87.41922		
Sulfur	ICPES	ug/Nm3	17723.93999	31450.76960	19967.16794	21651.16378	20908.98075	19923.40536
Thallium	ICPES	ug/Nm3	464.92648	106.69450	32.59035	64.65192	49.76653	58.58708
Titanium	ICPES	ug/Nm3	17327.49736	17113.73168	16209.18311	11898.29556	13247.81555	19151.96347
Zinc	ICPES	ug/Nm3	416.93764	687.65253	515.19859	395.71387	450.16289	567.62095
>>>>>>>>>>>> high dust gas, vapor phase		<<<<<<<<<<<<						
Aluminum	ICPES	ug/Nm3	1183.89015	82.41604 @	52.32564 @	61.98494 @	53.90315	75.16402
Antimony	ICPES	ug/Nm3	26.57005 @ <	21.38995 <	23.15136	23.99695 @	31.22417 <	25.48770
Boron	ICPES	ug/Nm3	2796.72600	5617.18238	3687.71200	4349.27670	4019.21257	4125.79136
Calcium	ICPES	ug/Nm3	606.24326	320.91608	203.32250	223.66233	174.74837	268.83481
Iron	ICPES	ug/Nm3	789.26010	148.25678	75.24926	65.08419	72.58779	58.70474
Magnesium	ICPES	ug/Nm3	76.63830 @ <	16.29904 <	6.62791 <	11.77714 <	3.75037 <	1.20153

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> high dust gas, vapor phase	<<<<<<<<<<<<							
Phosphorus	ICPES	ug/Nm3	40.03493	23.02124	124.58486	56.81953	26.88437	10.97071
Potassium	ICPES	ug/Nm3	491.28581 @	< 10.35956	< 162.95700	< 1.45148	< 28.36301	330.34424
Silicon	ICPES	ug/Nm3	3740.40655	2371.18764	2073.09215	2339.93152	2076.81720	2386.59474
Silver	ICPES	ug/Nm3	< 18.57063	< 14.94973	< 16.18077	16.77261 @	21.82406	< 17.81497
Sodium	ICPES	ug/Nm3	926.52272	593.94797	667.77488	671.50353	1478.64008	652.88454
Strontium	ICPES	ug/Nm3	15.49924	1.62070	1.97342	1.47731	1.92223	1.14686
Sulfate	IC	ug/Nm3	5339918.87723	5275321.54514	4955302.96861	5048306.70891	-	
Sulfur	ICPES	ug/Nm3	1750098.47607	1906158.60968	1519935.35296	1707232.46691	1471918.98621	1837952.26830
Thallium	ICPES	ug/Nm3	< 10.18031	< 2.36658	< 6.92692	< 11.20894	< 8.46857	< 40.15953
Titanium	ICPES	ug/Nm3	66.91553	2.45406 @	1.33057 @	1.76657 @	< .68555	1.46488
Zinc	ICPES	ug/Nm3	25.96551 @	282.24039	20.28242 @	< 10.53744	24.33035	156.36310
>>>>>>>>>>>> stack gas, solid phase A	<<<<<<<<<<<<							
Aluminum	ICPES	ug/Nm3			422.34461	292.40151	385.95155	353.66868
Calcium	ICPES	ug/Nm3			262.35245	266.60988	271.99521	247.08744
Iron	ICPES	ug/Nm3			360.54274	285.29938	328.05866	296.67248
Magnesium	ICPES	ug/Nm3			62.79236	53.75681	65.84196	49.82607
Phosphorus	ICPES	ug/Nm3			59.25612	55.96991	63.63953	63.57133
Potassium	ICPES	ug/Nm3			77.43864	60.55373	74.22799	70.39463
Silver	ICPES	ug/Nm3			< .04915	< .02629	< .05095	< .04714
Sodium	ICPES	ug/Nm3			74.98254	49.52626	54.25256	48.13826
Strontium	ICPES	ug/Nm3			6.34436	4.95530	6.02131	5.63981
Sulfur	ICPES	ug/Nm3			719.25234	1154.18156	2692.55075	1759.30248
Thallium	ICPES	ug/Nm3			.52123	< .02058	.12258	.47940
Titanium	ICPES	ug/Nm3			39.25427	29.36238	36.61792	33.53744
Zinc	ICPES	ug/Nm3			7.52550	9.16747	17.36953	9.02590
>>>>>>>>>>>> stack gas, solid phase A DUP	<<<<<<<<<<<<							
Aluminum	ICPES	ug/Nm3			421.15233	285.09854	390.89596	358.24348
Calcium	ICPES	ug/Nm3			263.54473	266.60988	274.46741	249.37483
Iron	ICPES	ug/Nm3			360.54274	281.64789	330.53087	298.95987
Magnesium	ICPES	ug/Nm3			63.38850	52.53965	66.58362	49.82607
Phosphorus	ICPES	ug/Nm3			59.11805	55.72648	64.25758	64.02881
Potassium	ICPES	ug/Nm3			85.78460	59.33657	73.98077	69.93715
Silver	ICPES	ug/Nm3			< .04915	< .05017	< .05095	< .04714

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, solid phase A DUP	<<<<<<<<<<<<							
Sodium	ICPES	ug/Nm3			74.38640	47.21366	54.87051	48.13826
Strontium	ICPES	ug/Nm3			6.30860	4.80924	6.10783	5.73130
Sulfur	ICPES	ug/Nm3			719.25234	1118.44959	2729.63384	1770.73946
Thallium	ICPES	ug/Nm3			.63927	.11462	.17326	.75389
Titanium	ICPES	ug/Nm3			39.13504	28.75380	37.11236	33.99492
Zinc	ICPES	ug/Nm3			7.50165	8.87535	17.49315	9.07164
>>>>>>>>>>>> stack gas, solid phase B	<<<<<<<<<<<<							
Aluminum	ICPES	ug/Nm3			378.60994	235.45733	377.04912	364.71784
Calcium	ICPES	ug/Nm3			232.31774	176.73402	228.58022	286.32074
Iron	ICPES	ug/Nm3			336.90367	226.10386	326.60626	307.42323
Magnesium	ICPES	ug/Nm3			51.91972	44.36869	49.86320	58.59462
Phosphorus	ICPES	ug/Nm3			54.33608	40.92844	64.46211	66.08856
Potassium	ICPES	ug/Nm3			75.00783	45.06617	71.46124	72.83262
Silver	ICPES	ug/Nm3			< .04935	< .04921	< .05092	< .01276
Sodium	ICPES	ug/Nm3			60.80842	44.51702	47.79318	61.03684
Strontium	ICPES	ug/Nm3			5.86797	3.91712	5.94320	5.80730
Sulfur	ICPES	ug/Nm3			1434.61599	4128.48840	2443.71179	2584.79072
Thallium	ICPES	ug/Nm3			.48749	.26642	.23738	.81877
Titanium	ICPES	ug/Nm3			37.26288	22.71058	36.71721	34.40284
Zinc	ICPES	ug/Nm3			6.88641	6.95016	16.36981	18.22465
>>>>>>>>>>>> stack gas, solid phase B DUP	<<<<<<<<<<<<							
Aluminum	ICPES	ug/Nm3			376.21544	233.06972	377.04912	364.71784
Calcium	ICPES	ug/Nm3			229.92324	175.54021	229.81551	287.47042
Iron	ICPES	ug/Nm3			334.50917	223.71625	327.84155	308.57291
Magnesium	ICPES	ug/Nm3			50.84220	43.89117	49.61615	58.70959
Phosphorus	ICPES	ug/Nm3			55.41360	41.16720	64.46211	66.68157
Potassium	ICPES	ug/Nm3			71.05690	51.75149	67.75538	75.47690
Silver	ICPES	ug/Nm3			< .04935	< .01242	< .05092	< .04739
Sodium	ICPES	ug/Nm3			60.44925	43.92012	47.66965	60.80691
Strontium	ICPES	ug/Nm3			5.84403	3.85743	5.95556	5.84179
Sulfur	ICPES	ug/Nm3			1422.64347	4104.61228	2431.35894	2584.79072
Thallium	ICPES	ug/Nm3			.30670	.37864	.27321	.32901
Titanium	ICPES	ug/Nm3			36.90370	22.47182	36.71721	34.51781

5/19/93 10:33 am FC21 Data Page 4

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, solid phase B DUP		<<<<<<<<<<<<						
Zinc	ICPES	ug/Nm3			6.81458	6.91435	16.24628	18.22465
>>>>>>>>>>>> stack gas, vapor phase A		<<<<<<<<<<<<						
Aluminum	ICPES	ug/Nm3			9.66083 @	54.78908	8.78579	10.20915
Calcium	ICPES	ug/Nm3			39.24713 @	86.36530	39.67775	38.98359
Iron	ICPES	ug/Nm3			9.00936 @	61.95772	9.38595	7.90161
Magnesium	ICPES	ug/Nm3			< 6.73382	10.10440 @	< 7.06514	< 7.40845
Phosphorus	ICPES	ug/Nm3			30.19010	.90957	13.33706	20.97771
Potassium	ICPES	ug/Nm3			166.84003 @	< 102.76993	< 100.38003	< 105.25778
Silver	ICPES	ug/Nm3			< .65497	< .70355	< .68719	< .72058
Sodium	ICPES	ug/Nm3			262.17719	216.76667	223.39571	206.28086
Strontium	ICPES	ug/Nm3			.19226 @	1.35351	.36677	.15209
Sulfate	IC	ug/Nm3	653094.68939	756394.77147	772467.07137	661145.01899		
Sulfur	ICPES	ug/Nm3			230398.13279	227007.61286	196721.59848	223762.28352
Thallium	ICPES	ug/Nm3			3.82938 @	2.61144 @	< 2.20028	< 2.30720
Titanium	ICPES	ug/Nm3			.42266 @	5.88854	.52681	< .29561
Zinc	ICPES	ug/Nm3			< 5.15949	< 5.54223	< 5.41334	< 5.67639
>>>>>>>>>>>> stack gas, vapor phase A DUP		<<<<<<<<<<<<						
Aluminum	ICPES	ug/Nm3			8.88225 @	55.47179	8.38567	12.02722
Calcium	ICPES	ug/Nm3			38.29376 @	87.04803	39.84446	39.15840
Iron	ICPES	ug/Nm3			8.46912 @	62.29908	8.96917	8.30368
Magnesium	ICPES	ug/Nm3			95.67275	16.57326 @	< 7.06514	< 7.40845
Phosphorus	ICPES	ug/Nm3			4.76686	6.82730	6.66853	10.48886
Potassium	ICPES	ug/Nm3			149.52044 @	< 102.76993	< 100.38003	< 105.25778
Silver	ICPES	ug/Nm3			< .65497	.70355 @	< .68719	< .72058
Sodium	ICPES	ug/Nm3			266.94404	216.76667	230.06424	202.78457
Strontium	ICPES	ug/Nm3			.19226 @	1.35351	.36677	.17307
Sulfate	IC	ug/Nm3	705958.96831	736107.53273	760914.85312	693273.14422		
Sulfur	ICPES	ug/Nm3			228809.18015	225300.78870	196721.59848	223762.28352
Thallium	ICPES	ug/Nm3			< 2.09710	16.64256	< 2.20028	< 2.30720
Titanium	ICPES	ug/Nm3			4.41729	5.93975	.54849	.35487
Zinc	ICPES	ug/Nm3			< 5.15949	< 5.54223	< 5.41334	< 5.67639

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, vapor phase A, conc	<<<<<<<<<<<<<							
Aluminum	conc/ICPES	ug/Nm3			3.71992	36.02795	3.74539	6.37040
Calcium	conc/ICPES	ug/Nm3			12.87663	45.15665	9.69105	15.89741
Iron	conc/ICPES	ug/Nm3			4.04183	38.70570	4.26456	5.44400
Magnesium	conc/ICPES	ug/Nm3			.91090 @	6.93781	.84549	1.26951
Potassium	conc/ICPES	ug/Nm3			116.96275	15.82309 @	3.74539	9.03522
Silver	conc/ICPES	ug/Nm3			< .02457	< .02509	< .02548	< .02357
Sodium	conc/ICPES	ug/Nm3			101.82078	120.37717	113.47426	97.09999
Strontium	conc/ICPES	ug/Nm3			.05639	.80819	.07825	.06039
Sulfur	conc/ICPES	ug/Nm3			174072.99875	178922.59221	158221.19106	182991.72679
Thallium	conc/ICPES	ug/Nm3			< .43638	< .44547	< .45240	< .41858
Titanium	conc/ICPES	ug/Nm3			.21461	3.77320	.24969	.11894
Zinc	conc/ICPES	ug/Nm3			1.38305	2.09352	1.02967	1.41819
>>>>>>>>>>>> stack gas, vapor phase B	<<<<<<<<<<<<<							
Aluminum	ICPES	ug/Nm3			84.87276	12.76212 @	< 7.67191	< 7.16699
Calcium	ICPES	ug/Nm3			37.75426 @	51.62566	43.45377	31.44824
Iron	ICPES	ug/Nm3			58.11778	12.61782 @	12.52087	7.38071
Magnesium	ICPES	ug/Nm3			9.31965 @	96.53545	103.41435	< 6.79972
Phosphorus	ICPES	ug/Nm3			5.94555	8.01641	< .00344	14.44052
Potassium	ICPES	ug/Nm3			< 89.49721	< 96.53550	< 103.41516	< 96.60900
Silver	ICPES	ug/Nm3			< .61269	< .66087	< .70797	< .66138
Sodium	ICPES	ug/Nm3			181.33935	202.01346	194.08205	174.89073
Strontium	ICPES	ug/Nm3			.45781	.31745	.18893	.17650
Sulfate	IC	ug/Nm3	683166.64404	753208.95691	835693.31961	753256.47975		
Sulfur	ICPES	ug/Nm3			228903.77590	214839.70758	195799.58782	221421.29240
Thallium	ICPES	ug/Nm3			4.65239 @	5.18257 @	16.74676	15.64486
Titanium	ICPES	ug/Nm3			5.00913	.81126 @	.30400	.50702
Zinc	ICPES	ug/Nm3			4.99426 @	12.31320 @	10.47700	< 5.20998
>>>>>>>>>>>> stack gas, vapor phase B DUP	<<<<<<<<<<<<<							
Aluminum	ICPES	ug/Nm3			87.10235	11.25504 @	< 7.67191	< 7.16699
Calcium	ICPES	ug/Nm3			37.90290 @	52.42730	44.14078	31.44824
Iron	ICPES	ug/Nm3			57.96914	12.44146 @	11.83385	7.58930
Magnesium	ICPES	ug/Nm3			12.69375 @	< 6.79455	< 7.27876	< 6.79972
Phosphorus	ICPES	ug/Nm3				4.80984	< .00344	8.02251

Substance	Method	Units	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
>>>>>>>>>>>> stack gas, vapor phase B DUP	<<<<<<<<<<<<							
Potassium	ICPES	ug/Nm3			137.34227 @	< 96.53550	< 103.41516	< 96.60900
Silver	ICPES	ug/Nm3			< .61269	< .66087	.70797	< .66138
Sodium	ICPES	ug/Nm3			173.90741	203.61674	200.95221	208.58528
Strontium	ICPES	ug/Nm3			.47416	.33509	.16832	.14120
Sulfate	IC	ug/Nm3	653081.27807	770252.51178	843392.95915	693160.23947		
Sulfur	ICPES	ug/Nm3			227417.38774	214839.70758	194082.04757	221421.29240
Thallium	ICPES	ug/Nm3			2.12554 @	< 2.11601	16.74704	< 2.11762
Titanium	ICPES	ug/Nm3			5.14290	.68941 @	< .29044	.42519
Zinc	ICPES	ug/Nm3			4.89022 @	12.50559 @	10.39112	< 5.20998
>>>>>>>>>>>> stack gas, vapor phase B, conc	<<<<<<<<<<<<							
Aluminum	conc/ICPES	ug/Nm3			12.21197	6.67338	3.81703	3.97791
Calcium	conc/ICPES	ug/Nm3			18.31795	22.44355	19.76456	15.06089
Iron	conc/ICPES	ug/Nm3			10.99077	7.47323	7.76994	4.94365
Magnesium	conc/ICPES	ug/Nm3			2.26281	1.67428	1.43293	1.09220
Potassium	conc/ICPES	ug/Nm3			69.08143	7.71199 @	8.72111	4.59874
Silver	conc/ICPES	ug/Nm3			< .02468	< .02460	< .02546	< .02370
Sodium	conc/ICPES	ug/Nm3			120.92244	122.96201	125.99907	107.72560
Strontium	conc/ICPES	ug/Nm3			.25621	.13490	.09178	.07025
Sulfur	conc/ICPES	ug/Nm3			183179.53100	174295.66968	158116.47616	179351.05369
Thallium	conc/ICPES	ug/Nm3			.49566 @	< .43692	< .45210	< .42077
Titanium	conc/ICPES	ug/Nm3			.95301	.48469	.11698	.21269
Zinc	conc/ICPES	ug/Nm3			2.53817	8.07013	6.89289	2.90871

Appendix D

Source Sampling Summaries

(On file at Radian Corporation)

Appendix E

Error Propagation and Uncertainty Calculations

An error propagation analysis was performed on calculated results to determine the contribution of process, sampling, and analytical variability, and measurement bias, to the overall uncertainty in the result. This uncertainty was determined by propagating the bias and precision error of individual parameters into the calculation of the results. This uncertainty does not represent the total uncertainty in the result since many important bias errors are unknown and have been assigned a value of zero for this analysis. Also, this uncertainty is only the uncertainty in the result for the period of time that the measurements were taken.

The procedure described below is based on ANSI/ASME PTC 19.1-1985, "Measurement Uncertainty."

Nomenclature

r = Calculated result;

S_{pi} = Sample standard deviation of parameter i;

θ_i = Sensitivity of the result to parameter i;

β_{pi} = Bias error estimate for parameter i;

v_i = Degrees of freedom in parameter i;

v_r = Degrees of freedom in result;

S_r = Precision component of result uncertainty;

B_r = Bias component of result uncertainty;

t = Student "t" factor (two-tailed distribution at 95%);

U_r = Uncertainty in r; and

N_i = Number of measurements of parameter i.

For a result, r, the uncertainty in r is calculated as:

$$U_r = \sqrt{\beta_r^2 + (S_r * t)^2} \quad (1)$$

The components are calculated by combining the errors in the parameters used in the result calculation.

$$\beta_r = \sqrt{\sum_{i=1}^{j} \theta_i * \beta_{\overline{pi}}} \quad (2)$$

$$S_r = \sqrt{\sum_{i=1}^{j} \theta_i \, S_{\overline{pi}}} \quad (3)$$

The sensitivity of the result to each parameter is found from a Taylor series estimation method:

$$\theta_i = \frac{\partial r}{\partial pi} \quad (4)$$

Or using a perturbation method (useful in computer applications):

$$\theta_i = \frac{r(P_i + \Delta P_i) - r(P_i)}{\Delta P_i} \quad (5)$$

The standard deviation of the average for each parameter is calculated as:

$$S_{\overline{pi}} = \frac{S_{pi}}{\sqrt{N}} \quad (6)$$

The degrees of freedom for each parameter is found from

$$v_i = N_i - 1 \tag{7}$$

and the degrees of freedom for the result if found by weighing the sensitivity and precision error in each parameter.

$$v_r = \frac{S_r^4}{\sum_{i=1}^{j} \left[\frac{(S_{\bar{p}_i} \times \theta_i)^4}{v_i} \right]} \tag{8}$$

The student "t" in Equation 1 is associated with the degrees of freedom in the result.

The precision error terms are easily generated using collected data. When calculating the $S_{\bar{p}}$, care is taken in assigning degrees of freedom to each parameter. For example, running duplicate analyses does not increase the degrees of freedom in analytical results.

The bias error terms are more difficult to quantify. The following conventions were used for this report:

- 5% bias on coal flow rates;
- 20% bias in limestone and FGD flow rates;
- 5% bias in gas flow rate; and
- No bias in analytical results unless the result is less than reporting limit. Then one-half the reporting limit is used for both the parameter value and its bias in calculations.

The flow rate bias values are assigned using engineering judgment. No bias is assigned to the analytical results (above the reporting limit) or gas flow rate since a good estimate for magnitude of these terms is unknown. These bias terms may be very large (relative

to the mean values of the parameters) and may represent a large amount of unaccounted uncertainty in each result. Analytical bias near the instrument reporting limit may be especially large. Therefore, the uncertainty values calculated for this report should be used with care.

In addition to the assumptions about bias errors referred to above, the calculations also assume that the population distribution of each measurement is normally distributed and that the samples collected reflect the true population.

Also, the uncertainty calculated is only for the average value over the sampling period. The uncertainty does not represent long-term process variations. In other words, the calculated uncertainty does not include a bias term to reflect the fact that the sampled system was probably not operating (and emitting) at conditions equivalent to the average conditions for that system over a longer period (in other words, autocorrelation may be important). An example of the confidence interval calculation is provided below.

Confidence Interval Calculations

Confidence intervals (CIs) were calculated for the mean particulate phase concentrations, the mean vapor phase concentrations, and the total concentrations in all gas streams. In addition, confidence intervals were determined for the stack gas emission factors presented in Table 3-8.

The following example shows an example calculation for the 95% confidence interval around the emission factor. This procedure utilizes the same method outlined earlier in this appendix and used in the computer program. This is a generic example and values used in the calculation are not from Site 21.

$$E = \frac{(g * s) + (g * v)}{HHV * Coal} * 2204.6 \qquad (5\text{-}3)$$

where:

g = Gas flow rate, Nm^3/hr

s = Solid phase conc., mg/Nm^3

v = Vapor phase conc., mg/Nm^3

HHV = Coal higher heating value, Btu/lb

Coal = Coal feed rate, klb/hr

The values used to calculate the emission factor and the confidence interval are as follows:

	Parameter				
	g Nm^3/hr	s mg/Nm^3	v mg/Nm^3	HHV Btu/lb	Coal Klb/hr
Mean	2,607,500	0.00073	0	11,890	573.75
S_p	34,100	0.00039	0	75.6	8.76
$S_{\bar{p}}$	24,116	0.00027	0	43.6	1.26
N	3	2	2	3	48
β_p	0	0	0	0	28.7
θ	$2.4x10^{-7}$	843	--	$-5.2x10^{-5}$	$-1.0x10^{-3}$
v_p	1	1	1	2	47

The calculation for the solid phase values is included for reference.

Solid phase analytical: 0.000452 mg/Nm^3

0.00100 mg/Nm^3

N=2

Mean = 0.00073

S_p = 0.00039

$S_{\bar{p}} = \frac{0.00039}{\sqrt{2}} = 0.00027$

As explained in Appendix E, the β for analytical results is assigned as zero.

$\beta_p = 0$

Next, calculate the sensitivity using perturbation method and a 0.0001 mg/Nm^3 perturbation:

$$\theta_i = \frac{r\,(0.00083) - r\,(0.00073)}{0.0001}$$

$$= \frac{0.7 - 0.61}{0.0001}$$

$$= 843$$

Similar calculations can be done for each parameter.

The precision component is then found by root-sum-squaring the product of the parameter $S_{\bar{p}}$s and their sensitivities.

$$S_r = \sqrt{(\theta_g\ S_{\bar{g}})^2 + (\theta_s\ S_{\bar{s}})^2 + (\theta_v\ S_{\bar{v}})^2 + (\theta_{HHV}\ S_{\bar{HHV}})^2 + (\theta_{coal}\ S_{\bar{coal}})^2}$$

S_r = 0.236

The bias component is found using the same equation substituting β_p for the $S_{\bar{p}}$ term.

$$\beta_r = \sqrt{(\theta_g \beta_g)^2 + (\theta_s \beta_s)^2 + (\theta_v \beta_v)^2 + (\theta_{HHV} \beta_{HHV})^2 + (\theta_{coal} \beta_{coal})^2}$$

$$\beta_r = 0.03$$

The uncertainty in the result is then

$$U_r = \sqrt{\beta_r^2 + (t \times S_r)^2}$$

The degrees of freedom is found to be 1.0 for a "t" of 12.7 (i.e., one degree of freedom for N=2).

$$v_r = \frac{S_r^4}{\sum_{i=1}^{j} \frac{(S_{pi} \theta_i)^4}{v_{pi}}}$$

$$= \frac{6.4 \times 10^4}{6.4 \times 10^4} = 1$$

$$U_r = \sqrt{(0.03)^2 + (12.7 \times 0.236)^2}$$

$$= 3.0$$

The emission rate is calculated as 0.59 lb/10^{12} Btu.

The value is reported as 0.59 $\pm$ 3.0 lb/10^{12} Btu.

Improvements in bias estimates can be made as more data is collected and the QA/QC database is expanded. Spike and standard recoveries can be used to begin to estimate

analytical bias. Also, as the analytical methods improve accuracy will improve, resulting in the true bias of the analytical results being closer to the zero bias now assigned.

Accounting for long-term system variability will require repeated sampling trips to the same location.

Appendix F

Quality Assurance/Quality Control

The objective of quality assurance and quality control (QA/QC) efforts associated with the Site 21 study was to ensure that all data collected are of known and sufficient quality to qualitatively and quantitatively characterize the various process streams. This section summarizes the results of QA/QC activities associated with chemical analyses of samples from the program.

Summary of Data Quality and QA/QC Approach

Quality assurance and quality control procedures used for this program are consistent with those described in the Site 21 sampling and analytical plan and the Laboratory Quality Assurance Program Plan for Radian's Austin Laboratories. The following key types of QA/QC provide the primary basis for quantitatively evaluating data quality:

- Laboratory and field blank samples;
- Laboratory control samples;
- Matrix spiked samples;
- Surrogate spiked samples; and
- Duplicate samples and analyses.

Quality assurance/quality control data associated with the sampling and analytical procedures for this study indicate that data quality was acceptable for the types of samples and analyses encountered. There were QC indicators that were outside nominal laboratory objectives, but these are not intended as validation criteria; rather, they are meant to indicate where potential problems might exist, and thereby prompt further scrutiny by the data users. Reanalyses and alternate approaches were followed as necessary to obtain acceptable data. Ultimately, the data may be considered valid and usable for project needs. Quality control data are summarized in Tables F-1 through F-5. These include results for metals that are not specifically of interest to the program,

but are included because the effect of concentrations of other metals may be considered in evaluating the quality of the primary elements of interest.

Blank sample results are summarized in Table F-1. Table F-2 presents a summary of laboratory control sample results. Matrix spiked sample results are summarized in Table F-3. Surrogate recovery data for PAH analyses are presented in Table F-4. Duplicate analysis results are summarized in Table F-5.

Table F-1

Summary of Blank Sample Results

Analyte	Number of Blank Samples Analyzed	Number of Detects	Range of Concentrations Detected	Detection Limits
Polynuclear Aromatic Hydrocarbons				
Lab Blanks (XAD & Condensate)				
Acenaphthalene	2	2	0.22-0.47 ng	NS
Acenaphthene	2	2	0.11-1.74 ng	NS
Fluorene	2	2	0.90-1.26 ng	NS
Phenanthrene	2	2	3.32-8.71 ng	NS
Anthracene	2	2	0.15-0.63 ng	NS
Fluoranthene	2	2	0.99-1.26 ng	NS
Pyrene	2	2	0.46-0.93 ng	NS
Benzo(a)anthracene	2	1	ND-0.13 ng	0.32 ng
Chrysene	2	2	0.24-0.32 ng	NS
5-methyl chrysene	2	0	ND	0.15-0.18 ng
Benzo(b,j&k)fluoranthenes	2	2	0.91-2.35 ng	NS
Benzo(a)pyrene	2	1	ND-0.32 ng	0.27 ng
Dibenz(a,h)acridine	2	1	ND-0.93 ng	0.29 ng
Dibenz(a,i)acridine	2	2	0.18-0.23 ng	NS
Indeno(1,2,3-cd)pyrene	2	1	ND-0.73 ng	0.25 ng
Dibenz(a,h)anthracene	2	1	ND-0.86 ng	0.14 ng
7H-dibenzo(c,g)carbazole	2	0	ND	1.02-1.34 ng
Benzo(g,h,i)perylene	2	2	0.24-1.08 ng	NS
Dibenzo(a,e)pyrene	2	0	ND	0.28-0.55 ng
Dibenzo(a,i)pyrene	2	0	ND	0.32-1.28 ng
Dibenzo(a,h)pyrene	2	0	ND	0.34-1.18 ng

Table F-1 (Continued)

Analyte	Number of Blank Samples Analyzed	Number of Detects	Range of Concentrations Detected	Detection Limits
Trip Blanks				
Acenaphthalene	4	3	ND-4.23 ng	5.56 ng
Acenaphthene	4	4	4.0-8.0 ng	NS
Fluorene	4	4	8.4-10.7 ng	NS
Phenanthrene	4	4	25.3-41.4 ng	NS
Anthracene	4	4	2.8-8.7 ng	NS
Fluoranthene	4	4	5.0-13.8 ng	NS
Pyrene	4	4	4.4-18.0 ng	NS
Benzo(a)anthracene	4	2	ND-0.96 ng	0.95-1.15 ng
Chrysene	4	4	0.67-1.14 ng	NS
5-methyl chrysene	4	1	ND-0.96 ng	0.45-1.0 ng
Benzo(b,j&k)fluoranthenes	4	3	ND-2.71 ng	3.18 ng
Benzo(a)pyrene	4	1	ND-1.26 ng	1.15-2.33 ng
Dibenz(a,h)acridine	4	0	ND	0.6-2.1 ng
Dibenz(a,i)acridine	4	0	ND	0.7-2.3 ng
Indeno(1,2,3-cd)pyrene	4	2	ND-1.04 ng	1.45-1.62 ng
Dibenz(a,h)anthracene	4	0	ND	1.5-2.8 ng
7H-dibenzo(c,g)carbazole	4	0	ND	4.0-8.5 ng
Benzo(g,h,i)perylene	4	2	ND-1.09 ng	0.97-2.1 ng
Dibenzo(a,e)pyrene	4	0	ND	1.0-2.4 ng
Dibenzo(a,i)pyrene	4	0	ND	0.3-2.7 ng
Dibenzo(a,h)pyrene	4	0	ND	1.2-2.4 ng
Lab Blanks				
Chloride	3	1	ND-0.01 mg/L	0.012 mg/L
Lab Blanks				
Sulfate	3	3	0.01-0.01 mg/L	0.022 mg/L
Lab Blanks				
Fluoride	3	0	ND	0.03 mg/L

Table F-1 (Continued)

Analyte	Number of Blank Samples Analyzed	Number of Detects	Range of Concentrations Detected	Detection Limits
Metals (GFAAS, CVAAS) - Impinger Solutions				
Lab Blanks				
Arsenic	3	1	ND-0.0016 mg/L	0.004 mg/L
Cadmium	3	3	0.0001-0.0002 mg/L	0.001 mg/L
Selenium	4	0	ND	0.005 mg/L
Lead	4	4	ND-0.0016	0.003 mg/L
Mercury	4	3	0.00015-0.0004 mg/L	0.00018 mg/L
Nickel	3	2	0.0022-0.0025 mg/L	0.003 mg/L
Metals (ICP-AES) - Probe & Nozzle Rinse + Filter				
Lab Blanks				
Aluminum	7	7	2.34-18.1 μg	0.5-1 μg
Barium	7	4	ND-0.12 μg	0.5-1 μg
Beryllium	7	1	ND-0.004 μg	0.1-0.2 μg
Calcium	7	7	1.33-4.59 μg	50-100 μg
Chromium	7	4	ND-0.46 μg	0.5-1 μg
Cobalt	7	5	ND-0.39 μg	0.5-1 μg
Iron	7	7	0.15-4.07 μg	2.5-5 μg
Magnesium	7	5	ND-1.79 μg	50-100 μg
Manganese	7	3	ND-0.25 μg	0.5-1 μg
Molybdenum	7	1	ND-0.33 μg	2.5-5 μg
Nickel	7	4	ND-0.72 μg	1-2 μg
Potassium	7	3	ND-19.7 μg	150-300 μg
Sodium	8	7	ND-12.2 μg	50-100 μg
Silicon	8	3	ND-363 μg	50-100 μg
Strontium	7	5	ND-0.095 μg	0.15-0.3 μg
Vanadium	7	3	ND-0.3 μg	1-2 μg
Zinc	7	2	ND-0.43 μg	1-2 μg

Table F-1 (Continued)

Analyte	Number of Blank Samples Analyzed	Number of Detects	Range of Concentrations Detected	Detection Limits
Metals (ICP) Impinger Solutions				
Lab Blanks				
Aluminum	1	1	0.02 mg/L	0.2 mg/L
Barium	1	1	0.0004 mg/L	0.01 mg/L
Beryllium	1	1	0.0006 mg/L	0.002 mg/L
Calcium	1	1	0.04 mg/L	1 mg/L
Chromium	1	0	ND	0.01 mg/L
Cobalt	1	1	0.002 mg/L	0.01 mg/L
Copper	1	0	ND	0.02 mg/L
Iron	1	1	0.01 mg/L	0.05 mg/L
Lead	1	0	ND	0.05 mg/L
Manganese	1	1	0.001 mg/L	0.01 mg/L
Molybdenum	1	1	0.001 mg/L	0.05 mg/L
Nickel	1	1	0.001 mg/L	0.02 mg/L
Sodium	2	2	0.02-0.11 mg/L	1 mg/L
Silicon	2	2	0.007-0.07 mg/L	1 mg/L
Strontium	1	1	0.0007 mg/L	0.003 mg/L
Titanium	1	0	ND	0.05 mg/L
Vanadium	1	1	0.0003	0.2 mg/L
Zinc	1	1	0.003 mg/L	0.02 mg/L
Metals (GFAAS, CVAAS) - Probe & Nozzle Rinse + Filter				
Lab Blanks				
Arsenic	5	3	ND-0.15 μg	0.40 μg
Cadmium	5	4	ND-0.052 μg	0.10 μg
Lead	6	2	ND-0.353 μg	0.30 μg
Nickel	5	0	ND	0.30 μg
Selenium	5	0	ND	0.50 μg

Table F-1 (Continued)

Analyte	Number of Blank Samples Analyzed	Number of Detects	Range of Concentrations Detected	Detection Limits
Metals (GFAAS, CVAAS) - FGD Solids				
Lab Blanks				
Mercury	1	1	0.09 ng/kg	0.045 ng/kg
Metals (ICP-MS) Microwave Digestion - Reagents				
Arsenic	2	2	2.3-3.4 µg/L	0.014 µg/L
Beryllium	2	2	0.5-0.8 µg/L	0.47 µg/L
Cadmium	2	2	0.02-0.02 µg/L	0.011 µg/L
Chromium	2	2	8.8-24.7 µg/L	0.25 µg/L
Lead	2	2	0.25-0.28 µg/L	0.018 µg/L
Mercury	2	2	0.4-0.5 µg/L	0.037 µg/L
Nickel	2	2	1.9-2.4 µg/L	0.054 µg/L
Selenium	2	2	3.0-4.1 µg/L	0.036 µg/L
Metals (ICP-MS) Method 3020 - Digestion - Reagents				
Arsenic	2	2	0.02-0.04 µg/L	0.026 µg/L
Beryllium	2	1	0.01-0.03 µg/L	0.024 µg/L
Cadmium	2	2	0.06-0.06 µg/L	0.041 µg/L
Chromium	2	2	0.17-0.25 µg/L	0.107 µg/L
Lead	2	2	1.2-1.7 µg/L	0.096 µg/L
Mercury	2	2	0.16-0.18 µg/L	0.044 µg/L
Nickel	2	2	1.3-1.3 µg/L	0.081 µg/L
Selenium	2	2	1.2-1.3 µg/L	0.51 µg/L

Table F-1 (Continued)

Analyte	Number of Blank Samples Analyzed	Number of Detects	Range of Concentrations Detected	Detection Limits
Metals (ICP-MS) Microwave Digestion - Filters				
Arsenic	4	4	0.9-1.6 µg/L	0.14 µg/L
Beryllium	4	2	0.02-0.25 µg/L	0.97 µg/L
Cadmium	4	4	0.02-0.06 µg/L	0.011 µg/L
Chromium	4	4	2.6-4.8 µg/L	0.25 µg/L
Lead	4	4	1.3-1.7 µg/L	0.018 µg/L
Mercury	4	4	0.2-0.4 µg/L	0.037 µg/L
Nickel	4	4	2.2-3.2 µg/L	0.054 µg/L
Selenium	4	4	0.9-1.9 µg/L	0.36 µg/L

ND = Not detected.

NS = Not specified.

Table F-2

Summary of Laboratory Control Sample Results

Analyte	No. of LCS/LCSD [a] Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by AAS						
Solids						
As	4	119	3.4	0	3	85-115
Cd	5	106	5.3	0	0	85-115
Hg	1	109	2.8	0	0	80-120
Ni	4	111	6.2	0	0	85-115
Pb	4	92	1.4	0	0	85-115
Se	4	91	21.4	1	0	85-115
Liquids						
As	4	92	6.1	1	0	85-115
Cd	4	98	12.1	0	0	85-115
Hg	6	100	3.2	0	0	80-120
Ni	4	93	6.5	0	0	85-115
Pb	5	97	7.0	0	0	85-115
Se	5	96	6.5	0	0	85-115
Metals by ICP-MS						
Liquids (Microwave Digestion)						
As	1	55	20.8	2	0	85-115
Be	1	60	22.2	2	0	85-115
Cd	1	54	2.2	2	0	85-115
Cr	1	55	23.2	2	0	85-115
Hg	1	2,073	11.7	0	2	80-120
Ni	1	399	16.2	0	2	85-115
Pb	1	91	17.9	1	0	85-115
Se	1	128	6.5	0	2	85-115

Table F-2 (Continued)

Analyte	No. of LCS/LCSD [a] Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by ICP-MS						
Liquids w/Filter (Microwave Digestion)						
As	1	54	2.7	2	0	75-125
Be	1	65	15.4	2	0	75-125
Cd	1	68	0.4	2	0	75-125
Cr	1	20	10.0	2	0	75-125
Hg	1	1,522	20.0	0	2	75-125
Ni	1	468	10.6	0	2	75-125
Pb	1	97	6.2	0	0	75-125
Se	1	111	22.7	0	0	75-125
Liquids (Method 3020 Digestion)						
As	1	63	12.4	2	0	85-115
Be	1	--	--	--	--	85-115
Cd	1	89	0.0	0	0	85-115
Cr	1	53	14.2	2	0	85-115
Hg	1	--	--	--	--	85-115
Ni	1	63	5.0	2	0	85-115
Pb	1	179	36.9	0	2	85-115
Se	1	66	8.2	2	0	85-115

Table F-2 (Continued)

Analyte	No. of LCS/LCSD [a] Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by ICP-AES						
Filters						
Al	2	25	34.1	2	0	75-125
Ba	2	77	4.1	1	0	75-125
Be	1	92	2.0	0	0	75-125
Ca	2	86	1.4	0	0	75-125
Co	2	87	6.8	0	0	75-125
Cr	2	84	1.1	0	0	75-125
Cu	2	82	3.3	0	0	75-125
Fe	2	89	1.2	0	0	75-125
K	2	81	1.1	1	0	75-125
Mg	2	48	9.9	2	0	75-125
Mn	2	87	1.5	0	0	75-125
Na	2	107	2.8	0	0	75-125
Ni	2	91	5.2	0	0	75-125
Pb	1	122	NC	0	0	75-125
Sr	2	82	1.2	0	0	75-125
Ti	2	76	3.7	1	0	75-125
V	2	88	2.4	0	0	75-125
Zn	2	80	0.9	0	0	75-125

Table F-2 (Continued)

Analyte	No. of LCS/LCSD [a] Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by ICP-AES						
Liquids						
Ag	2	96	0.8	0	0	90-110
Al	2	103	1.0	0	0	90-110
As	2	98	0.3	0	0	90-110
B	2	105	3.4	0	0	90-110
Ba	2	102	0.5	0	0	90-110
Be	2	100	0.7	0	0	90-110
Ca	2	100	1.4	0	0	90-110
Cd	2	101	1.8	0	0	90-110
Co	2	100	1.6	0	0	90-110
Cr	2	99	0.7	0	0	90-110
Cu	2	100	0.3	0	0	90-110
Fe	2	102	0.5	0	0	90-110
K	2	107	1.4	0	1	90-110
Mg	2	97	0.6	0	0	90-110
Mn	2	99	1.2	0	0	90-110
Mo	2	98	1.3	0	0	90-110
Na	2	107	3.7	0	0	90-110
Ni	2	101	2.4	0	0	90-110
Pb	2	101	0.4	0	0	90-110
Sb	2	97	3.6	0	0	90-110
Se	2	99	0.6	0	0	90-110
Si	2	101	2.3	0	0	90-110
Sr	2	102	0.5	0	0	90-110
Ti	2	97	0.9	0	0	90-110
Tl	2	102	1.6	0	0	90-110
V	2	98	0.8	0	0	90-110
Zn	2	100	1.5	0	0	90-110

Table F-2 (Continued)

Analyte	No. of LCS/LCSD [a] Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by ICP-AES						
Solids						
Al	4	96	12.6	1	0	90-110
Ba	4	87	4.2	2	0	90-110
Be	4	95	4.1	2	0	90-110
Ca	4	96	6.9	1	0	90-110
Co	4	91	11.3	2	0	90-110
Cr	4	103	9.5	1	1	90-110
Cu	4	93	3.8	1	0	90-110
Fe	4	92	2.5	2	0	90-110
K	4	92	6.8	1	0	90-110
Mg	4	90	11.5	2	0	90-110
Mn	4	91	1.6	2	0	90-110
Na	4	102	3.8	1	1	90-110
Ni	4	102	10.1	2	2	90-110
Pb	2	88	22.2	1	0	90-110
Si	2	40	6.0	2	0	90-110
Sr	4	95	5.8	1	0	90-110
Ti	4	90	2.7	2	0	90-110
V	4	93	2.9	2	0	90-110
Zn	4	88	3.2	3	0	90-110

Table F-2 (Continued)

Analyte	No. of LCS Analyses	Mean % Recovery	Std. Dev. (% Recovery)	No. Below Limits	No. Above Limits	Limits
Mercury in Coal						
Hg (0.04 ppm)	5	130	20.9	--	--	NS
Hg (0.20 ppm)	6	96	17.4	--	--	NS
Hg (0.25 ppm)	6	87	8.2	--	--	NS
Anions						
Chloride	13	99	4.8	0	0	90-110
Sulfate	13	100	2.1	0	0	90-110
Fluoride	7	102	3.2	0	0	90-110

*LCS/LCSD - Laboratory Control Sample/Laboratory Control Sample Duplicate

NS = Not specified.

Table F-3

Summary of Spiked Sample Results

Analyte	No. of Spikes	% Recovery	Std. Dev.	No. Below Limits	No. Above Limits	Limits
Polynuclear Aromatic Hydrocarbons						
Spiked Sample Results (Condensate)						
Acenaphthalene	1	84	NA	0	0	50-150
Acenaphthene	1	82	NA	0	0	50-150
Fluorene	1	118	NA	0	0	50-150
Phenanthrene	1	84	NA	0	0	50-150
Anthracene	1	86	NA	0	0	50-150
Fluoranthene	1	79	NA	0	0	50-150
Pyrene	1	81	NA	0	0	50-150
Benzo(a)anthracene	1	64	NA	0	0	50-150
Chrysene	1	75	NA	0	0	50-150
5-methyl chrysene	1	78	NA	0	0	50-150
Benzo(b,j&k)fluoranthenes	1	71	NA	0	0	50-150
Benzo(a)pyrene	1	66	NA	0	0	50-150
Dibenz(a,h)acridine	1	92	NA	0	0	50-150
Benz(a,i)acridine	1	57	NA	0	0	50-150
Indeno(1,2,3-cd)pyrene	1	48	NA	1	0	50-150
Dibenz(a,h)anthracene	1	88	NA	0	0	50-150
7H-dibenzo(c,g)carbazole	1	74	NA	0	0	50-150
Benzo(g,h,i)perylene	1	75	NA	0	0	50-150
Dibenzo(a,e)pyrene	1	50	NA	0	0	50-150
Dibenzo(a,i)pyrene	1	35	NA	1	0	50-150
Dibenzo(a,h)pyrene	1	18	NA	1	0	50-150
Spiked Sample Results XAD Resin						
Acenaphthalene	3	90	15.5	0	0	50-150
Acenaphthene	3	89	17.6	0	0	50-150
Fluorene	3	91	18.5	0	0	50-150
Phenanthrene	3	101	14.2	0	0	50-150
Anthracene	3	94	12.2	0	0	50-150
Fluoranthene	3	87	8.1	0	0	50-150
Pyrene	3	93	11.4	0	0	50-150
Benzo(a)anthracene	3	81	9.3	0	0	50-150

Table F-3 (Continued)

Analyte	No. of Spikes	% Recovery	Std. Dev.	No. Below Limits	No. Above Limits	Limits
Chrysene	3	90	15.0	0	0	50-150
5-methyl chrysene	3	88	27.5	0	0	50-150
Benzo(b,j&k)fluoranthenes	3	83	13.5	0	0	50-150
Benzo(a)pyrene	3	78	14.2	0	0	50-150
Dibenz(a,h)acridine	3	86	14.1	0	0	50-150
Dibenz(a,i)acridine	3	76	17.9	0	0	50-150
Indeno(1,2,3-cd)pyrene	3	75	8.4	0	0	50-150
Dibenz(a,h)anthracene	3	95	8.1	0	0	50-150
7H-dibenzo(c,g)carbazole	3	91	15.4	0	0	50-150
Benzo(g,h,i)perylene	3	85	8.0	0	0	50-150
Dibenzo(a,e)pyrene	3	93	25.7	0	0	50-150
Dibenzo(a,i)pyrene	3	88	11.5	0	0	50-150
Dibenzo(a,h)pyrene	3	63	19.4	1	0	50-150

Analyte	No. of MSD Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by AAS in ESP Inlet						
Arsenic	5	90	1.8	1	0	75-125
Cadmium	4	87	7.9	1	0	75-125
Lead	5	75	17.0	2	0	75-125
Mercury	2	108	0.9	0	0	75-125
Nickel	5	92	5.1	0	0	75-125
Selenium	5	71	12.1	1	0	75-125
Metals by AAS in Scrubber Outlet						
Arsenic	4	81	10.6	1	0	75-125
Cadmium	4	112	7.0	0	1	75-125
Lead	5	98	15.9	1	1	75-125
Mercury	3	90	4.6	1	0	75-125
Nickel	4	90	9.0	0	0	75-125
Selenium	5	67	14.9	2	0	75-125

Table F-3 (Continued)

Analyte	No. of MSD Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by ICP-AES in Scrubber Outlet						
Aluminum	6	107	2.4	0	0	75-125
Antimony	3	88	10.8	0	0	75-125
Arsenic	6	105	4.3	0	0	75-125
Barium	6	86	1.7	1	0	75-125
Beryllium	6	93	0.3	0	0	75-125
Boron	2	111	3.1	0	0	75-125
Cadmium	4	94	0.7	0	0	75-125
Calcium	6	101	2.4	0	0	75-125
Chromium	6	105	9.4	0	1	75-125
Cobalt	6	94	0.7	0	0	75-125
Copper	6	95	0.9	0	0	75-125
Iron	6	106	4.0	0	0	75-125
Lead	6	90	5.7	0	0	75-125
Magnesium	6	90	0.9	0	0	75-125
Manganese	6	93	0.8	0	0	75-125
Molybdenum	6	97	0.7	0	0	75-125
Nickel	6	97	3.0	0	0	75-125
Potassium	6	109	1.9	0	0	75-125
Selenium	6	118	5.4	0	0	75-125
Silicon	2	124	24.7	0	2	75-125
Silver	6	87	0.5	1	0	75-125
Sodium	6	104	0.8	0	0	75-125
Strontium	6	97	0.7	0	0	75-125
Sulfur	6	93	3.7	0	0	75-125
Thallium	6	99	4.0	0	0	75-125
Titanium	6	102	2.4	0	0	75-125
Vanadium	6	95	0.9	0	0	75-125
Zinc	6	96	0.7	0	0	75-125

Table F-3 (Continued)

Analyte	No. of MSD Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by ICP-AES in ESP Inlet						
Aluminum	5	72	0.9	2	0	75-125
Antimony	6	99	7.1	0	0	75-125
Arsenic	3	98	2.7	0	0	75-125
Barium	5	84	2.7	1	0	75-125
Beryllium	7	90	1.1	0	0	75-125
Boron	1	120	0.8	0	0	75-125
Cadmium	3	93	7.0	0	0	75-125
Calcium	7	95	1.7	0	0	75-125
Chromium	7	93	1.0	0	0	75-125
Cobalt	5	96	1.9	0	0	75-125
Copper	5	96	1.3	0	0	75-125
Iron	5	106	2.1	0	1	75-125
Lead	5	93	0.4	0	0	75-125
Magnesium	5	86	6.7	1	0	75-125
Manganese	5	95	0.9	0	0	75-125
Molybdenum	5	104	2.8	0	0	75-125
Nickel	7	95	3.9	0	0	75-125
Potassium	5	96	2.6	0	0	75-125
Selenium	2	103	4.7	0	0	75-125
Silicon	1	108	11.1	0	0	75-125
Silver	3	35	8.7	2	0	75-125
Sodium	5	105	4.5	0	1	75-125
Strontium	5	97	1.4	0	0	75-125
Sulfur	5	100	0.3	0	0	75-125
Thallium	7	102	8.4	0	0	75-125
Titanium	7	78	10.4	3	0	75-125
Vanadium	5	95	1.7	0	0	75-125
Zinc	5	95	1.2	0	0	75-125
Anions						
Chloride	3	101	5.0	0	0	80-120
Fluoride	3	93	3.1	0	0	80-120
Sulfate	3	98	5.2	0	0	80-120

NA = Not applicable.

Table F-3 (Continued)

Analyte	No. of MSD Pairs	Mean % Recovery	Mean RPD	No. Below Limits	No. Above Limits	Limits
Metals by ICP-MS in Scrubber Outlet Impingers						
Arsenic	2	76	12	1	0	75-125
Cadmium	2	96	7	0	0	75-125
Chromium	2	69	13	1	0	75-125
Lead	2	205	74	0	2	75-125
Nickel	2	80	11	0	0	75-125
Selenium	2	294	15	0	2	75-125

NA = Not applicable.

Table F-4

Summary of Surrogate Recoveries for Semivolatile Organic Analyses

Surrogate Compound	No. of Analyses	Mean % Rec.	Std. Dev. (% Rec.)	No. Below Limits	No. Above Limits	QC Limits %
PAH Analyses by HRGCMS (XAD)						
Biphenyl-d10	23	136[a]	93.5[a]	0	7	50-150
Hexachlorobenzene	23	73	40.0	8	1	50-150
Perylene-d12	23	99	33.0	1	1	50-150

[a]Excludes one outlier reported as 1669% recovery.

Table F-5

Duplicate Analysis Results

	No. of Pairs	Range	Mean RPD
ESP Inlet - PRN & Filter			
Metals by ICP-AES (μg/sample)			
Aluminum	8	2,020 - 3,580	0.6%
Arsenic	8	27.55 - 58.05	27.0%
Barium	8	21.4 - 41.2	0.5%
Beryllium	8	0.888 - 1.385	3.9%
Cadmium	4	0.453 - 0.798	21.0%
Calcium	8	1,505 - 2,845	0.9%
Chromium	8	23.7 - 31.9	2.1%
Cobalt	8	1.125 - 22.5	54.4%
Copper	8	7.305 - 11.55	5.2%
Iron	8	1,890 - 3,085	0.7%
Lead	6	6.695 - 12.85	58.7%
Magnesium	8	375 - 566.5	1.3%
Manganese	8	7.005 - 21.4	2.3%
Molybdenum	8	14.5 - 18.55	6.1%
Nickel	8	10.205 - 261.95	69.4%
Potassium	8	386 - 797	9.8%
Selenium	8	50.1 - 158	11.8%
Silver	1	0.3055 - 0.3055	127.3%
Sodium	8	404.5 - 630	1.1%
Strontium	8	32.85 - 54.3	0.7%
Sulfur	8	11,950 - 36,450	1.4%
Thallium	5	2.415 - 5.34	45.5%
Titanium	8	190 - 342	0.7%
Vanadium	8	41.2 - 66.65	1.5%
Zinc	8	57.7 - 162.5	0.8%

Table F-5 (Continued)

	No. of Pairs	Range	Mean RPD
Metals by AAS (μg/sample)			
Arsenic	4	50.45 - 73.9	13.8%
Cadmium	4	0.7705 - 1.37	1.7%
Lead	4	7.66 - 11.95	3.2%
Nickel	4	12.7 - 17.1	2.3%
Selenium	4	66.95 - 168	7.1%
ESP Inlet Impingers			
Metals by ICP-AES (μg/samples)			
Aluminum	10	74.55 - 4,050	1.8%
Arsenic	9	2.3365 - 60.85	42.0%
Barium	10	1.76 - 42.3	2.2%
Beryllium	8	1.14 - 1.47	2.7%
Cadmium	5	0.07005 - 0.9565	39.6%
Calcium	10	95.1 - 2675	5.4%
Chromium	10	1.0875 - 33.95	44.5%
Cobalt	9	0.2655 - 2.985	84.7%
Copper	9	1.285 - 11.75	5.2%
Iron	10	38.4 - 3270	7.1%
Lead	6	10.93 - 20.4	66.1%
Magnesium	10	9.21 - 632.5	29.0%
Manganese	10	1.23 - 11.3	3.5%
Molybdenum	10	9.73 - 19	5.6%
Nickel	10	1.955 - 16.2	37.2%
Potassium	9	29.4 - 755	19.1%
Selenium	8	19.05 - 84.9	12.0%
Sodium	10	208.5 - 816	4.9%
Strontium	10	0.8335 - 57.4	6.2%
Sulfur	10	49.75 - 23,800	7.0%
Thallium	4	1.545 - 7.035	57.2%
Titanium	10	2.635 - 360	3.9%
Vanadium	9	0.2875 - 68.85	23.5%
Zinc	10	7.84 - 151.5	2.6%

Table F-5 (Continued)

	No. of Pairs	Range	Mean RPD
Metals by AAS (μg/sample)			
Arsenic	5	0.43 - 65	9.5%
Cadmium	5	0.366 - 1.5	2.4%
Lead	5	0.47 - 12.85	4.3%
Nickel	5	2.16 - 16.6	4.0%
Selenium	5	0.36 - 93.3	3.4%
Scrubber Outlet Impinger			
Metals by ICP-AES (mg/L)			
Aluminum	9	0.0344 - 0.5785	11.0%
Barium	9	0.00064 - 0.006	18.7%
Beryllium	3	0.000025 - 0.0006	68.1%
Boron	9	0.01655 - 0.9765	3.9%
Cadmium	3	0.0005 - 0.0045	29.7%
Calcium	9	0.143 - 163.66	66.5%
Chromium	5	0.001295 - 0.004	97.9%
Cobalt	2	0.001835 - 0.0043	66.8%
Iron	9	0.0419 - 0.3905	54.9%
Lead	6	0.01169 - 0.0457	49.5%
Magnesium	3	0.00346 - 0.0782	99.1%
Manganese	9	0.00657 - 0.4045	3.8%
Molybdenum	2	0.0011 - 0.0029	57.1%
Nickel	6	0.001015 - 0.0091	125.4%
Potassium	4	0.028175 - 0.9955	88.1%
Selenium	8	0.1102 - 0.469	17.9%
Silicon	9	0.134 - 2.84	21.2%
Sodium	9	0.6645 - 1.665	3.5%
Strontium	9	0.00077 - 0.0079	13.5%
Sulfur	9	2.275 - 1,535	0.5%
Thallium	5	0.00189 - 0.059	128.2%
Titanium	9	0.001015 - 0.0347	26.4%
Vanadium	2	0.000995 - 0.0092	31.1%
Zinc	9	0.0166 - 0.0774	5.6%

Table F-5 (Continued)

	No. of Pairs	Range	Mean RPD
Metals by AAS (mg/L)			
Arsenic	2	0.0003 - 0.0071	94.3%
Cadmium	9	0.0003 - 0.0089	10.5%
Lead	9	0.00235 - 0.152	14.2%
Mercury	22	0.00059 - 0.0076	3.6%
Nickel	7	0.00055 - 0.0093	53.2%
Selenium	9	0.00424 - 0.0222	22.3%

Appendix G

Selected Blank Results

- **Comparison of Stack MM5 Results to Blanks**

  (Blank corrections were not applied to results)

- **Comparison of Stack Solid Phase Results to Blank Filters**

  (Results are blank corrected)

Table G-1

Semivolatile Organics Stack Comparison of Value and Blank

Substance	Mean Emission Factor ($lb/10^{12}$ Btu) [a]	Emission Factor from Blank ($lb/10^{12}$ Btu)
5-Methyl chrysene	0.001549	0.000558
7H-Dibenzo[c,g]carbazole	ND(0.003328)	ND(0.005346)
Acenaphthene	0.018001	0.002937
Acenaphthylene	0.00754	0.001544
Anthracene	0.009885	0.005052
Benz[a]anthracene	0.001286	0.00052
Benzo[a]pyrene	ND(0.01573)	ND(0.001224)
Benzo[b,j&k]fluoranthenes	0.006574	0.001923
Benzo[g,h,i]perylene	0.001234	0.000894
Chrysene	0.006931	0.001455
Dibenz[a,h]acridine	ND(0.001547)	ND(0.001455)
Dibenz[a,h]anthracene	ND(0.002621)	ND(0.002316)
Dibenz[a,i]acridine	ND(0.00162)	ND(0.001158)
Dibenzo[a,e]pyrene	ND(0.001502)	ND(0.001693)
Dibenzo[a,h]pyrene	ND(0.001384)	ND(0.001515)
Dibenzo[a,i]pyrene	ND(0.002533)	ND(0.001633)
Fluoranthene	0.052897	0.009912
Fluorene	0.064318	0.009754
Indeno[1,2,3-cd]pyrene	0.001456	0.000337
Phenanthrene	0.208551	0.035287
Pyrene	0.024204	0.035287

ND = Emission factor based on method detection limit.

[a] Not blank corrected.

Table G-2

Stack Gas Solid Phase Filter Blank Correction

Run	Cited Name	Method	Substance	Result $\mu g/Nm^3$	Blank $(\mu g/Nm^3)$	Blank % of Value
4	stack gas, solid phase A	GFAA	Arsenic	8.18	0.02	0.2
4P	stack gas, solid phase A DUP	GFAA	Arsenic	6.66	0.02	0.3
4	stack gas, solid phase B	GFAA	Arsenic	7.52	0.02	0.3
4P	stack gas, solid phase B DUP	GFAA	Arsenic	5.94	0.02	0.3
5	stack gas, solid phase A	GFAA	Arsenic	6.89	0.02	0.3
5P	stack gas, solid phase A DUP	GFAA	Arsenic	7.04	0.02	0.3
5	stack gas, solid phase B	GFAA	Arsenic	5.82	0.02	0.3
5P	stack gas, solid phase B DUP	GFAA	Arsenic	6.19	0.02	0.3
6	stack gas, solid phase A	GFAA	Arsenic	7.40	0.02	0.3
6P	stack gas, solid phase A DUP	GFAA	Arsenic	7.37	0.02	0.3
6	stack gas, solid phase B	GFAA	Arsenic	8.36	0.02	0.2
6P	stack gas, solid phase B DUP	GFAA	Arsenic	9.42	0.02	0.2
7	stack gas, solid phase A	GFAA	Arsenic	7.23	0.02	0.3
7P	stack gas, solid phase A DUP	GFAA	Arsenic	7.60	0.02	0.2
7	stack gas, solid phase B	GFAA	Arsenic	8.74	0.02	0.2
7P	stack gas, solid phase B DUP	GFAA	Arsenic	8.21	0.02	0.2
4	stack gas, solid phase A	GFAA	Cadmium	0.17	0.01	3.3
4P	stack gas, solid phase A DUP	GFAA	Cadmium	0.16	0.01	3.4
4	stack gas, solid phase B	GFAA	Cadmium	0.14	0.01	3.9
4P	stack gas, solid phase B DUP	GFAA	Cadmium	0.15	0.01	3.8
5	stack gas, solid phase A	GFAA	Cadmium	0.18	0.01	3.2
5P	stack gas, solid phase A DUP	GFAA	Cadmium	0.18	0.01	3.2
5	stack gas, solid phase B	GFAA	Cadmium	0.09	0.01	6.5
5P	stack gas, solid phase B DUP	GFAA	Cadmium	0.09	0.01	6.5
6	stack gas, solid phase A	GFAA	Cadmium	0.16	0.01	3.7
6P	stack gas, solid phase A DUP	GFAA	Cadmium	0.15	0.01	3.7
6	stack gas, solid phase B	GFAA	Cadmium	0.12	0.01	4.8
6P	stack gas, solid phase B DUP	GFAA	Cadmium	0.12	0.01	4.7
7	stack gas, solid phase A	GFAA	Cadmium	0.12	0.01	4.5
7P	stack gas, solid phase A DUP	GFAA	Cadmium	0.12	0.01	4.4
7	stack gas, solid phase B	GFAA	Cadmium	0.15	0.01	3.5
7P	stack gas, solid phase B DUP	GFAA	Cadmium	0.15	0.01	3.6
4	stack gas, solid phase A	GFAA	Lead	1.49	0.02	1.4

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm^3	Blank (µg/Nm^3)	Blank % of Value
4P	stack gas, solid phase A DUP	GFAA	Lead	1.53	0.02	1.4
4	stack gas, solid phase B	GFAA	Lead	1.25	0.02	1.7
4P	stack gas, solid phase B DUP	GFAA	Lead	1.22	0.02	1.7
5	stack gas, solid phase A	GFAA	Lead	1.28	0.02	1.7
5P	stack gas, solid phase A DUP	GFAA	Lead	1.31	0.02	1.6
5	stack gas, solid phase B	GFAA	Lead	0.90	0.02	2.3
5P	stack gas, solid phase B DUP	GFAA	Lead	0.89	0.02	2.4
6	stack gas, solid phase A	GFAA	Lead	1.49	0.02	1.5
6P	stack gas, solid phase A DUP	GFAA	Lead	1.52	0.02	1.4
6	stack gas, solid phase B	GFAA	Lead	1.42	0.02	1.5
6P	stack gas, solid phase B DUP	GFAA	Lead	1.42	0.02	1.5
7	stack gas, solid phase A	GFAA	Lead	1.44	0.02	1.4
7P	stack gas, solid phase A DUP	GFAA	Lead	1.41	0.02	1.4
7	stack gas, solid phase B	GFAA	Lead	1.39	0.02	1.4
7P	stack gas, solid phase B DUP	GFAA	Lead	1.31	0.02	1.5
4	stack gas, solid phase A	GFAA	Nickel	2.01	0.03	1.4
4P	stack gas, solid phase A DUP	GFAA	Nickel	1.89	0.03	1.5
4	stack gas, solid phase B	GFAA	Nickel	1.67	0.03	1.7
4P	stack gas, solid phase B DUP	GFAA	Nickel	1.71	0.03	1.7
5	stack gas, solid phase A	GFAA	Nickel	1.38	0.03	2.1
5P	stack gas, solid phase A DUP	GFAA	Nickel	1.46	0.03	2.0
5	stack gas, solid phase B	GFAA	Nickel	1.56	0.03	1.9
5P	stack gas, solid phase B DUP	GFAA	Nickel	1.61	0.03	1.8
6	stack gas, solid phase A	GFAA	Nickel	1.94	0.03	1.5
6P	stack gas, solid phase A DUP	GFAA	Nickel	1.96	0.03	1.5
6	stack gas, solid phase B	GFAA	Nickel	1.55	0.03	1.9
6P	stack gas, solid phase B DUP	GFAA	Nickel	1.53	0.03	2.0
7	stack gas, solid phase A	GFAA	Nickel	1.53	0.03	1.8
7P	stack gas, solid phase A DUP	GFAA	Nickel	1.57	0.03	1.8
7	stack gas, solid phase B	GFAA	Nickel	1.92	0.03	1.5
7P	stack gas, solid phase B DUP	GFAA	Nickel	1.96	0.03	1.4
4	stack gas, solid phase A	GFAA	Selenium	2.25	0.02	1.1
4P	stack gas, solid phase A DUP	GFAA	Selenium	2.37	0.02	1.0
4	stack gas, solid phase B	GFAA	Selenium	7.55	0.02	0.3
4P	stack gas, solid phase B DUP	GFAA	Selenium	8.43	0.02	0.3

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result $\mu g/Nm^3$	Blank $(\mu g/Nm^3)$	Blank % of Value
5	stack gas, solid phase A	GFAA	Selenium	11.21	0.02	0.2
5P	stack gas, solid phase A DUP	GFAA	Selenium	10.63	0.02	0.2
5	stack gas, solid phase B	GFAA	Selenium	20.03	0.02	0.1
5P	stack gas, solid phase B DUP	GFAA	Selenium	20.03	0.02	0.1
6	stack gas, solid phase A	GFAA	Selenium	11.54	0.02	0.2
6P	stack gas, solid phase A DUP	GFAA	Selenium	11.47	0.02	0.2
6	stack gas, solid phase B	GFAA	Selenium	10.64	0.02	0.2
6P	stack gas, solid phase B DUP	GFAA	Selenium	9.81	0.02	0.3
7	stack gas, solid phase A	GFAA	Selenium	3.12	0.02	0.7
7P	stack gas, solid phase A DUP	GFAA	Selenium	3.16	0.02	0.7
7	stack gas, solid phase B	GFAA	Selenium	10.20	0.02	0.2
7P	stack gas, solid phase B DUP	GFAA	Selenium	10.66	0.02	0.2
4	stack gas, solid phase A	ICP-AES	Aluminum	422.34	6.88	1.6
4P	stack gas, solid phase A DUP	ICP-AES	Aluminum	421.15	6.88	1.6
4	stack gas, solid phase B	ICP-AES	Aluminum	378.61	6.91	1.8
4P	stack gas, solid phase B DUP	ICP-AES	Aluminum	376.22	6.91	1.8
5	stack gas, solid phase A	ICP-AES	Aluminum	292.40	7.02	2.4
5P	stack gas, solid phase A DUP	ICP-AES	Aluminum	285.10	7.02	2.5
5	stack gas, solid phase B	ICP-AES	Aluminum	235.46	6.89	2.9
5P	stack gas, solid phase B DUP	ICP-AES	Aluminum	233.07	6.89	3.0
6	stack gas, solid phase A	ICP-AES	Aluminum	385.95	7.13	1.8
6P	stack gas, solid phase A DUP	ICP-AES	Aluminum	390.90	7.13	1.8
6	stack gas, solid phase B	ICP-AES	Aluminum	377.05	7.12	1.9
6P	stack gas, solid phase B DUP	ICP-AES	Aluminum	377.05	7.12	1.9
7	stack gas, solid phase A	ICP-AES	Aluminum	353.67	6.60	1.9
7P	stack gas, solid phase A DUP	ICP-AES	Aluminum	358.24	6.60	1.8
7	stack gas, solid phase B	ICP-AES	Aluminum	364.72	6.63	1.8
7P	stack gas, solid phase B DUP	ICP-AES	Aluminum	364.72	6.63	1.8
4	stack gas, solid phase A	ICP-AES	Barium	3.73	0.17	4.6
4P	stack gas, solid phase A DUP	ICP-AES	Barium	3.69	0.17	4.7
4	stack gas, solid phase B	ICP-AES	Barium	3.51	0.17	4.9
4P	stack gas, solid phase B DUP	ICP-AES	Barium	3.49	0.17	5.0
5	stack gas, solid phase A	ICP-AES	Barium	3.17	0.18	5.6
5P	stack gas, solid phase A DUP	ICP-AES	Barium	3.06	0.18	5.8
5	stack gas, solid phase B	ICP-AES	Barium	2.39	0.17	7.2

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result $\mu g/Nm^3$	Blank $(\mu g/Nm^3)$	Blank % of Value
5P	stack gas, solid phase B DUP	ICP-AES	Barium	2.37	0.17	7.3
6	stack gas, solid phase A	ICP-AES	Barium	4.12	0.18	4.4
6P	stack gas, solid phase A DUP	ICP-AES	Barium	4.17	0.18	4.3
6	stack gas, solid phase B	ICP-AES	Barium	4.13	0.18	4.3
6P	stack gas, solid phase B DUP	ICP-AES	Barium	4.14	0.18	4.3
7	stack gas, solid phase A	ICP-AES	Barium	4.11	0.17	4.0
7P	stack gas, solid phase A DUP	ICP-AES	Barium	4.18	0.17	4.0
7	stack gas, solid phase B	ICP-AES	Barium	4.27	0.17	3.9
7P	stack gas, solid phase B DUP	ICP-AES	Barium	4.28	0.17	3.9
4	stack gas, solid phase A	ICP-AES	Beryllium	0.16	0.00	0.4
4P	stack gas, solid phase A DUP	ICP-AES	Beryllium	0.16	0.00	0.4
4	stack gas, solid phase B	ICP-AES	Beryllium	0.15	0.00	0.4
4P	stack gas, solid phase B DUP	ICP-AES	Beryllium	0.15	0.00	0.4
5	stack gas, solid phase A	ICP-AES	Beryllium	0.14	0.00	0.5
5P	stack gas, solid phase A DUP	ICP-AES	Beryllium	0.14	0.00	0.5
5	stack gas, solid phase B	ICP-AES	Beryllium	0.11	0.00	0.6
5P	stack gas, solid phase B DUP	ICP-AES	Beryllium	0.10	0.00	0.6
6	stack gas, solid phase A	ICP-AES	Beryllium	0.16	0.00	0.4
6P	stack gas, solid phase A DUP	ICP-AES	Beryllium	0.16	0.00	0.4
6	stack gas, solid phase B	ICP-AES	Beryllium	0.16	0.00	0.4
6P	stack gas, solid phase B DUP	ICP-AES	Beryllium	0.16	0.00	0.4
7	stack gas, solid phase A	ICP-AES	Beryllium	0.15	0.00	0.4
7P	stack gas, solid phase A DUP	ICP-AES	Beryllium	0.15	0.00	0.4
7	stack gas, solid phase B	ICP-AES	Beryllium	0.15	0.00	0.4
7P	stack gas, solid phase B DUP	ICP-AES	Beryllium	0.15	0.00	0.4
4	stack gas, solid phase A	ICP-AES	Calcium	262.35	3.53	1.3
4P	stack gas, solid phase A DUP	ICP-AES	Calcium	263.54	3.53	1.3
4	stack gas, solid phase B	ICP-AES	Calcium	232.32	3.54	1.5
4P	stack gas, solid phase B DUP	ICP-AES	Calcium	229.92	3.54	1.5
5	stack gas, solid phase A	ICP-AES	Calcium	266.61	3.60	1.4
5P	stack gas, solid phase A DUP	ICP-AES	Calcium	266.61	3.60	1.4
5	stack gas, solid phase B	ICP-AES	Calcium	176.73	3.53	2.0
5P	stack gas, solid phase B DUP	ICP-AES	Calcium	175.54	3.53	2.0
6	stack gas, solid phase A	ICP-AES	Calcium	272.00	3.66	1.3
6P	stack gas, solid phase A DUP	ICP-AES	Calcium	274.47	3.66	1.3

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm^3	Blank (µg/Nm^3)	Blank % of Value
6	stack gas, solid phase B	ICP-AES	Calcium	228.58	3.65	1.6
6P	stack gas, solid phase B DUP	ICP-AES	Calcium	229.82	3.65	1.6
7	stack gas, solid phase A	ICP-AES	Calcium	247.09	3.38	1.4
7P	stack gas, solid phase A DUP	ICP-AES	Calcium	249.37	3.38	1.4
7	stack gas, solid phase B	ICP-AES	Calcium	286.32	3.40	1.2
7P	stack gas, solid phase B DUP	ICP-AES	Calcium	287.47	3.40	1.2
4	stack gas, solid phase A	ICP-AES	Chromium	3.69	0.03	0.7
4P	stack gas, solid phase A DUP	ICP-AES	Chromium	3.77	0.03	0.7
4	stack gas, solid phase B	ICP-AES	Chromium	3.27	0.03	0.8
4P	stack gas, solid phase B DUP	ICP-AES	Chromium	3.24	0.03	0.8
5	stack gas, solid phase A	ICP-AES	Chromium	2.72	0.03	1.0
5P	stack gas, solid phase A DUP	ICP-AES	Chromium	2.68	0.03	1.0
5	stack gas, solid phase B	ICP-AES	Chromium	2.79	0.03	0.9
5P	stack gas, solid phase B DUP	ICP-AES	Chromium	2.82	0.03	0.9
6	stack gas, solid phase A	ICP-AES	Chromium	3.58	0.03	0.8
6P	stack gas, solid phase A DUP	ICP-AES	Chromium	3.64	0.03	0.7
6	stack gas, solid phase B	ICP-AES	Chromium	3.43	0.03	0.8
6P	stack gas, solid phase B DUP	ICP-AES	Chromium	3.42	0.03	0.8
7	stack gas, solid phase A	ICP-AES	Chromium	3.13	0.02	0.8
7P	stack gas, solid phase A DUP	ICP-AES	Chromium	3.10	0.02	0.8
7	stack gas, solid phase B	ICP-AES	Chromium	3.58	0.03	0.7
7P	stack gas, solid phase B DUP	ICP-AES	Chromium	3.57	0.03	0.7
4	stack gas, solid phase A	ICP-AES	Cobalt	0.30	0.02	7.3
4P	stack gas, solid phase A DUP	ICP-AES	Cobalt	0.37	0.02	5.9
4	stack gas, solid phase B	ICP-AES	Cobalt	0.32	0.02	6.9
4P	stack gas, solid phase B DUP	ICP-AES	Cobalt	0.31	0.02	7.1
5	stack gas, solid phase A	ICP-AES	Cobalt	0.22	0.02	9.9
5P	stack gas, solid phase A DUP	ICP-AES	Cobalt	0.25	0.02	8.9
5	stack gas, solid phase B	ICP-AES	Cobalt	0.19	0.02	11.5
5P	stack gas, solid phase B DUP	ICP-AES	Cobalt	0.19	0.02	11.3
6	stack gas, solid phase A	ICP-AES	Cobalt	0.30	0.02	7.6
6P	stack gas, solid phase A DUP	ICP-AES	Cobalt	0.26	0.02	8.7
6	stack gas, solid phase B	ICP-AES	Cobalt	0.28	0.02	7.9
6P	stack gas, solid phase B DUP	ICP-AES	Cobalt	0.28	0.02	8.1
7	stack gas, solid phase A	ICP-AES	Cobalt	0.28	0.02	7.4

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm³	Blank (µg/Nm³)	Blank % of Value
7P	stack gas, solid phase A DUP	ICP-AES	Cobalt	0.25	0.02	8.2
7	stack gas, solid phase B	ICP-AES	Cobalt	2.46	0.02	0.8
7P	stack gas, solid phase B DUP	ICP-AES	Cobalt	2.43	0.02	0.9
4	stack gas, solid phase A	ICP-AES	Copper	1.35	0.02	1.4
4P	stack gas, solid phase A DUP	ICP-AES	Copper	1.41	0.02	1.3
4	stack gas, solid phase B	ICP-AES	Copper	1.43	0.02	1.3
4P	stack gas, solid phase B DUP	ICP-AES	Copper	1.30	0.02	1.4
5	stack gas, solid phase A	ICP-AES	Copper	1.20	0.02	1.6
5P	stack gas, solid phase A DUP	ICP-AES	Copper	1.14	0.02	1.6
5	stack gas, solid phase B	ICP-AES	Copper	0.99	0.02	1.8
5P	stack gas, solid phase B DUP	ICP-AES	Copper	1.02	0.02	1.8
6	stack gas, solid phase A	ICP-AES	Copper	1.28	0.02	1.5
6P	stack gas, solid phase A DUP	ICP-AES	Copper	1.28	0.02	1.5
6	stack gas, solid phase B	ICP-AES	Copper	1.21	0.02	1.6
6P	stack gas, solid phase B DUP	ICP-AES	Copper	1.23	0.02	1.5
7	stack gas, solid phase A	ICP-AES	Copper	1.18	0.02	1.5
7P	stack gas, solid phase A DUP	ICP-AES	Copper	1.17	0.02	1.5
7	stack gas, solid phase B	ICP-AES	Copper	1.27	0.02	1.4
7P	stack gas, solid phase B DUP	ICP-AES	Copper	1.27	0.02	1.4
4	stack gas, solid phase A	ICP-AES	Iron	360.54	0.72	0.2
4P	stack gas, solid phase A DUP	ICP-AES	Iron	360.54	0.72	0.2
4	stack gas, solid phase B	ICP-AES	Iron	336.90	0.72	0.2
4P	stack gas, solid phase B DUP	ICP-AES	Iron	334.51	0.72	0.2
5	stack gas, solid phase A	ICP-AES	Iron	285.30	0.73	0.3
5P	stack gas, solid phase A DUP	ICP-AES	Iron	281.65	0.73	0.3
5	stack gas, solid phase B	ICP-AES	Iron	226.10	0.72	0.3
5P	stack gas, solid phase B DUP	ICP-AES	Iron	223.72	0.72	0.3
6	stack gas, solid phase A	ICP-AES	Iron	328.06	0.74	0.2
6P	stack gas, solid phase A DUP	ICP-AES	Iron	330.53	0.74	0.2
6	stack gas, solid phase B	ICP-AES	Iron	326.61	0.74	0.2
6P	stack gas, solid phase B DUP	ICP-AES	Iron	327.84	0.74	0.2
7	stack gas, solid phase A	ICP-AES	Iron	296.67	0.69	0.2
7P	stack gas, solid phase A DUP	ICP-AES	Iron	298.96	0.69	0.2
7	stack gas, solid phase B	ICP-AES	Iron	307.42	0.69	0.2
7P	stack gas, solid phase B DUP	ICP-AES	Iron	308.57	0.69	0.2

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm³	Blank (µg/Nm³)	Blank % of Value
4	stack gas, solid phase A	ICP-AES	Magnesium	62.79	0.64	1.0
4P	stack gas, solid phase A DUP	ICP-AES	Magnesium	63.39	0.64	1.0
4	stack gas, solid phase B	ICP-AES	Magnesium	51.92	0.64	1.2
4P	stack gas, solid phase B DUP	ICP-AES	Magnesium	50.84	0.64	1.3
5	stack gas, solid phase A	ICP-AES	Magnesium	53.76	0.65	1.2
5P	stack gas, solid phase A DUP	ICP-AES	Magnesium	52.54	0.65	1.2
5	stack gas, solid phase B	ICP-AES	Magnesium	44.37	0.64	1.4
5P	stack gas, solid phase B DUP	ICP-AES	Magnesium	43.89	0.64	1.5
6	stack gas, solid phase A	ICP-AES	Magnesium	65.84	0.66	1.0
6P	stack gas, solid phase A DUP	ICP-AES	Magnesium	66.58	0.66	1.0
6	stack gas, solid phase B	ICP-AES	Magnesium	49.86	0.66	1.3
6P	stack gas, solid phase B DUP	ICP-AES	Magnesium	49.62	0.66	1.3
7	stack gas, solid phase A	ICP-AES	Magnesium	49.83	0.61	1.2
7P	stack gas, solid phase A DUP	ICP-AES	Magnesium	49.83	0.61	1.2
7	stack gas, solid phase B	ICP-AES	Magnesium	58.59	0.61	1.0
7P	stack gas, solid phase B DUP	ICP-AES	Magnesium	58.71	0.61	1.0
4	stack gas, solid phase A	ICP-AES	Manganese	1.27	0.02	1.6
4P	stack gas, solid phase A DUP	ICP-AES	Manganese	1.27	0.02	1.6
4	stack gas, solid phase B	ICP-AES	Manganese	1.16	0.02	1.7
4P	stack gas, solid phase B DUP	ICP-AES	Manganese	1.14	0.02	1.8
5	stack gas, solid phase A	ICP-AES	Manganese	1.01	0.02	2.0
5P	stack gas, solid phase A DUP	ICP-AES	Manganese	0.98	0.02	2.1
5	stack gas, solid phase B	ICP-AES	Manganese	0.82	0.02	2.4
5P	stack gas, solid phase B DUP	ICP-AES	Manganese	0.81	0.02	2.5
6	stack gas, solid phase A	ICP-AES	Manganese	1.19	0.02	1.7
6P	stack gas, solid phase A DUP	ICP-AES	Manganese	1.21	0.02	1.7
6	stack gas, solid phase B	ICP-AES	Manganese	1.13	0.02	1.8
6P	stack gas, solid phase B DUP	ICP-AES	Manganese	1.13	0.02	1.8
7	stack gas, solid phase A	ICP-AES	Manganese	1.10	0.02	1.7
7P	stack gas, solid phase A DUP	ICP-AES	Manganese	1.11	0.02	1.7
7	stack gas, solid phase B	ICP-AES	Manganese	2.28	0.02	0.8
7P	stack gas, solid phase B DUP	ICP-AES	Manganese	2.28	0.02	0.8
4	stack gas, solid phase A	ICP-AES	Molybdenum	0.84	1.20	143.1
4P	stack gas, solid phase A DUP	ICP-AES	Molybdenum	0.90	1.20	133.6

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result $\mu g/Nm^3$	Blank $(\mu g/Nm^3)$	Blank % of Value
4	stack gas, solid phase B	ICP-AES	Molybdenum	0.79	1.21	151.7
4P	stack gas, solid phase B DUP	ICP-AES	Molybdenum	0.81	1.21	149.4
5	stack gas, solid phase A	ICP-AES	Molybdenum	0.55	1.23	221.9
5P	stack gas, solid phase A DUP	ICP-AES	Molybdenum	0.60	1.23	204.0
5	stack gas, solid phase B	ICP-AES	Molybdenum	0.53	1.20	226.9
5P	stack gas, solid phase B DUP	ICP-AES	Molybdenum	0.53	1.20	226.9
6	stack gas, solid phase A	ICP-AES	Molybdenum	0.77	1.24	161.4
6P	stack gas, solid phase A DUP	ICP-AES	Molybdenum	0.83	1.24	149.4
6	stack gas, solid phase B	ICP-AES	Molybdenum	0.83	1.24	149.4
6P	stack gas, solid phase B DUP	ICP-AES	Molybdenum	0.83	1.24	149.4
7	stack gas, solid phase A	ICP-AES	Molybdenum	0.79	1.15	145.1
7P	stack gas, solid phase A DUP	ICP-AES	Molybdenum	0.72	1.15	158.9
7	stack gas, solid phase B	ICP-AES	Molybdenum	0.76	1.16	151.7
7P	stack gas, solid phase B DUP	ICP-AES	Molybdenum	0.87	1.16	133.6
4	stack gas, solid phase A	ICP-AES	Potassium	77.44	3.76	4.8
4P	stack gas, solid phase A DUP	ICP-AES	Potassium	85.78	3.76	4.4
4	stack gas, solid phase B	ICP-AES	Potassium	75.01	3.77	5.0
4P	stack gas, solid phase B DUP	ICP-AES	Potassium	71.06	3.77	5.3
5	stack gas, solid phase A	ICP-AES	Potassium	60.55	3.83	6.3
5P	stack gas, solid phase A DUP	ICP-AES	Potassium	59.34	3.83	6.5
5	stack gas, solid phase B	ICP-AES	Potassium	45.07	3.76	8.3
5P	stack gas, solid phase B DUP	ICP-AES	Potassium	51.75	3.76	7.3
6	stack gas, solid phase A	ICP-AES	Potassium	74.23	3.89	5.2
6P	stack gas, solid phase A DUP	ICP-AES	Potassium	73.98	3.89	5.3
6	stack gas, solid phase B	ICP-AES	Potassium	71.46	3.89	5.4
6P	stack gas, solid phase B DUP	ICP-AES	Potassium	67.76	3.89	5.7
7	stack gas, solid phase A	ICP-AES	Potassium	70.39	3.60	5.1
7P	stack gas, solid phase A DUP	ICP-AES	Potassium	69.94	3.60	5.2
7	stack gas, solid phase B	ICP-AES	Potassium	72.83	3.62	5.0
7P	stack gas, solid phase B DUP	ICP-AES	Potassium	75.48	3.62	4.8
4	stack gas, solid phase A	ICP-AES	Silver	0.05	0.00	0.0
4P	stack gas, solid phase A DUP	ICP-AES	Silver	0.05	0.00	0.0
4	stack gas, solid phase B	ICP-AES	Silver	0.05	0.00	0.0
4P	stack gas, solid phase B DUP	ICP-AES	Silver	0.05	0.00	0.0
5	stack gas, solid phase A	ICP-AES	Silver	0.03	0.00	0.0

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm³	Blank (µg/Nm³)	Blank % of Value
5P	stack gas, solid phase A DUP	ICP-AES	Silver	0.05	0.00	0.0
5	stack gas, solid phase B	ICP-AES	Silver	0.05	0.00	0.0
5P	stack gas, solid phase B DUP	ICP-AES	Silver	0.01	0.00	0.0
6	stack gas, solid phase A	ICP-AES	Silver	0.05	0.00	0.0
6P	stack gas, solid phase A DUP	ICP-AES	Silver	0.05	0.00	0.0
6	stack gas, solid phase B	ICP-AES	Silver	0.05	0.00	0.0
6P	stack gas, solid phase B DUP	ICP-AES	Silver	0.05	0.00	0.0
7	stack gas, solid phase A	ICP-AES	Silver	0.05	0.00	0.0
7P	stack gas, solid phase A DUP	ICP-AES	Silver	0.05	0.00	0.0
7	stack gas, solid phase B	ICP-AES	Silver	0.01	0.00	0.0
7P	stack gas, solid phase B DUP	ICP-AES	Silver	0.05	0.00	0.0
4	stack gas, solid phase A	ICP-AES	Sodium	74.98	4.07	5.4
4P	stack gas, solid phase A DUP	ICP-AES	Sodium	74.39	4.07	5.5
4	stack gas, solid phase B	ICP-AES	Sodium	60.81	4.08	6.7
4P	stack gas, solid phase B DUP	ICP-AES	Sodium	60.45	4.08	6.8
5	stack gas, solid phase A	ICP-AES	Sodium	49.53	4.15	8.4
5P	stack gas, solid phase A DUP	ICP-AES	Sodium	47.21	4.15	8.8
5	stack gas, solid phase B	ICP-AES	Sodium	44.52	4.07	9.1
5P	stack gas, solid phase B DUP	ICP-AES	Sodium	43.92	4.07	9.3
6	stack gas, solid phase A	ICP-AES	Sodium	54.25	4.22	7.8
6P	stack gas, solid phase A DUP	ICP-AES	Sodium	54.87	4.22	7.7
6	stack gas, solid phase B	ICP-AES	Sodium	47.79	4.21	8.8
6P	stack gas, solid phase B DUP	ICP-AES	Sodium	47.67	4.21	8.8
7	stack gas, solid phase A	ICP-AES	Sodium	48.14	3.90	8.1
7P	stack gas, solid phase A DUP	ICP-AES	Sodium	48.14	3.90	8.1
7	stack gas, solid phase B	ICP-AES	Sodium	61.04	3.92	6.4
7P	stack gas, solid phase B DUP	ICP-AES	Sodium	60.81	3.92	6.4
4	stack gas, solid phase A	ICP-AES	Strontium	6.34	0.03	0.5
4P	stack gas, solid phase A DUP	ICP-AES	Strontium	6.31	0.03	0.5
4	stack gas, solid phase B	ICP-AES	Strontium	5.87	0.03	0.6
4P	stack gas, solid phase B DUP	ICP-AES	Strontium	5.84	0.03	0.6
5	stack gas, solid phase A	ICP-AES	Strontium	4.96	0.04	0.7
5P	stack gas, solid phase A DUP	ICP-AES	Strontium	4.81	0.04	0.7
5	stack gas, solid phase B	ICP-AES	Strontium	3.92	0.03	0.9
5P	stack gas, solid phase B DUP	ICP-AES	Strontium	3.86	0.03	0.9

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm³	Blank (µg/Nm³)	Blank % of Value
6	stack gas, solid phase A	ICP-AES	Strontium	6.02	0.04	0.6
6P	stack gas, solid phase A DUP	ICP-AES	Strontium	6.11	0.04	0.6
6	stack gas, solid phase B	ICP-AES	Strontium	5.94	0.04	0.6
6P	stack gas, solid phase B DUP	ICP-AES	Strontium	5.96	0.04	0.6
7	stack gas, solid phase A	ICP-AES	Strontium	5.64	0.03	0.6
7P	stack gas, solid phase A DUP	ICP-AES	Strontium	5.73	0.03	0.6
7	stack gas, solid phase B	ICP-AES	Strontium	5.81	0.03	0.6
7P	stack gas, solid phase B DUP	ICP-AES	Strontium	5.84	0.03	0.6
4	stack gas, solid phase A	ICP-AES	Sulfur	719.25	2.08	0.3
4P	stack gas, solid phase A DUP	ICP-AES	Sulfur	719.25	2.08	0.3
4	stack gas, solid phase B	ICP-AES	Sulfur	1434.62	2.09	0.1
4P	stack gas, solid phase B DUP	ICP-AES	Sulfur	1422.64	2.09	0.1
5	stack gas, solid phase A	ICP-AES	Sulfur	1154.18	2.12	0.2
5P	stack gas, solid phase A DUP	ICP-AES	Sulfur	1116.45	2.12	0.2
5	stack gas, solid phase B	ICP-AES	Sulfur	4128.49	2.08	0.1
5P	stack gas, solid phase B DUP	ICP-AES	Sulfur	4104.61	2.08	0.1
6	stack gas, solid phase A	ICP-AES	Sulfur	2692.55	2.15	0.1
6P	stack gas, solid phase A DUP	ICP-AES	Sulfur	2729.63	2.15	0.1
6	stack gas, solid phase B	ICP-AES	Sulfur	2443.71	2.15	0.1
6P	stack gas, solid phase B DUP	ICP-AES	Sulfur	2431.36	2.15	0.1
7	stack gas, solid phase A	ICP-AES	Sulfur	1759.30	1.99	0.1
7P	stack gas, solid phase A DUP	ICP-AES	Sulfur	1770.74	1.99	0.1
7	stack gas, solid phase B	ICP-AES	Sulfur	2584.79	2.00	0.1
7P	stack gas, solid phase B DUP	ICP-AES	Sulfur	2584.79	2.00	0.1
4	stack gas, solid phase A	ICP-AES	Thallium	0.52	0.04	8.0
4P	stack gas, solid phase A DUP	ICP-AES	Thallium	0.64	0.04	6.5
4	stack gas, solid phase B	ICP-AES	Thallium	0.49	0.04	8.6
4P	stack gas, solid phase B DUP	ICP-AES	Thallium	0.31	0.04	13.6
5	stack gas, solid phase A	ICP-AES	Thallium	0.02	0.00	0.0
5P	stack gas, solid phase A DUP	ICP-AES	Thallium	0.11	0.04	37.0
5	stack gas, solid phase B	ICP-AES	Thallium	0.27	0.04	15.6
5P	stack gas, solid phase B DUP	ICP-AES	Thallium	0.38	0.04	11.0
6	stack gas, solid phase A	ICP-AES	Thallium	0.12	0.04	35.1
6P	stack gas, solid phase A DUP	ICP-AES	Thallium	0.17	0.04	24.8
6	stack gas, solid phase B	ICP-AES	Thallium	0.24	0.04	18.1

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm³	Blank (µg/Nm³)	Blank % of Value
6P	stack gas, solid phase B DUP	ICP-AES	Thallium	0.27	0.04	15.7
7	stack gas, solid phase A	ICP-AES	Thallium	0.48	0.04	8.3
7P	stack gas, solid phase A DUP	ICP-AES	Thallium	0.75	0.04	5.3
7	stack gas, solid phase B	ICP-AES	Thallium	0.82	0.04	4.9
7P	stack gas, solid phase B DUP	ICP-AES	Thallium	0.33	0.04	12.2
4	stack gas, solid phase A	ICP-AES	Titanium	39.25	0.09	0.2
4P	stack gas, solid phase A DUP	ICP-AES	Titanium	39.14	0.09	0.2
4	stack gas, solid phase B	ICP-AES	Titanium	37.26	0.09	0.2
4P	stack gas, solid phase B DUP	ICP-AES	Titanium	36.90	0.09	0.2
5	stack gas, solid phase A	ICP-AES	Titanium	29.36	0.09	0.3
5P	stack gas, solid phase A DUP	ICP-AES	Titanium	28.75	0.09	0.3
5	stack gas, solid phase B	ICP-AES	Titanium	22.71	0.09	0.4
5P	stack gas, solid phase B DUP	ICP-AES	Titanium	22.47	0.09	0.4
6	stack gas, solid phase A	ICP-AES	Titanium	36.62	0.09	0.3
6P	stack gas, solid phase A DUP	ICP-AES	Titanium	37.11	0.09	0.3
6	stack gas, solid phase B	ICP-AES	Titanium	36.72	0.09	0.3
6P	stack gas, solid phase B DUP	ICP-AES	Titanium	36.72	0.09	0.3
7	stack gas, solid phase A	ICP-AES	Titanium	33.54	0.09	0.3
7P	stack gas, solid phase A DUP	ICP-AES	Titanium	33.99	0.09	0.3
7	stack gas, solid phase B	ICP-AES	Titanium	34.40	0.09	0.3
7P	stack gas, solid phase B DUP	ICP-AES	Titanium	34.52	0.09	0.3
4	stack gas, solid phase A	ICP-AES	Vanadium	7.46	0.45	6.0
4P	stack gas, solid phase A DUP	ICP-AES	Vanadium	7.52	0.45	6.0
4	stack gas, solid phase B	ICP-AES	Vanadium	7.11	0.45	6.3
4P	stack gas, solid phase B DUP	ICP-AES	Vanadium	7.02	0.45	6.4
5	stack gas, solid phase A	ICP-AES	Vanadium	6.08	0.46	7.5
5P	stack gas, solid phase A DUP	ICP-AES	Vanadium	6.03	0.46	7.6
5	stack gas, solid phase B	ICP-AES	Vanadium	4.47	0.45	10.0
5P	stack gas, solid phase B DUP	ICP-AES	Vanadium	4.47	0.45	10.0
6	stack gas, solid phase A	ICP-AES	Vanadium	6.82	0.46	6.8
6P	stack gas, solid phase A DUP	ICP-AES	Vanadium	6.89	0.46	6.7
6	stack gas, solid phase B	ICP-AES	Vanadium	6.97	0.46	6.7
6P	stack gas, solid phase B DUP	ICP-AES	Vanadium	6.97	0.46	6.7
7	stack gas, solid phase A	ICP-AES	Vanadium	6.65	0.43	6.5
7P	stack gas, solid phase A DUP	ICP-AES	Vanadium	6.67	0.43	6.4

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result $\mu g/Nm^3$	Blank $(\mu g/Nm^3)$	Blank % of Value
7	stack gas, solid phase B	ICP-AES	Vanadium	6.72	0.43	6.4
7P	stack gas, solid phase B DUP	ICP-AES	Vanadium	6.80	0.43	6.3
4	stack gas, solid phase A	ICP-AES	Zinc	7.53	0.06	0.8
4P	stack gas, solid phase A DUP	ICP-AES	Zinc	7.50	0.06	0.8
4	stack gas, solid phase B	ICP-AES	Zinc	6.89	0.06	0.8
4P	stack gas, solid phase B DUP	ICP-AES	Zinc	6.81	0.06	0.8
5	stack gas, solid phase A	ICP-AES	Zinc	9.17	0.06	0.6
5P	stack gas, solid phase A DUP	ICP-AES	Zinc	8.88	0.06	0.7
5	stack gas, solid phase B	ICP-AES	Zinc	6.95	0.06	0.8
5P	stack gas, solid phase B DUP	ICP-AES	Zinc	6.91	0.06	0.8
6	stack gas, solid phase A	ICP-AES	Zinc	17.37	0.06	0.3
6P	stack gas, solid phase A DUP	ICP-AES	Zinc	17.49	0.06	0.3
6	stack gas, solid phase B	ICP-AES	Zinc	16.37	0.06	0.4
6P	stack gas, solid phase B DUP	ICP-AES	Zinc	16.25	0.06	0.4
7	stack gas, solid phase A	ICP-AES	Zinc	9.03	0.06	0.6
7P	stack gas, solid phase A DUP	ICP-AES	Zinc	9.07	0.06	0.6
7	stack gas, solid phase B	ICP-AES	Zinc	18.22	0.06	0.3
7P	stack gas, solid phase B DUP	ICP-AES	Zinc	18.22	0.06	0.3
4	stack gas, solid phase A	ICP-MS	Arsenic	6.55	0.01	0.2
4P	stack gas, solid phase A DUP	ICP-MS	Arsenic	8.38	0.01	0.2
4	stack gas, solid phase B	ICP-MS	Arsenic	6.35	0.01	0.2
4P	stack gas, solid phase B DUP	ICP-MS	Arsenic	7.42	0.01	0.2
5	stack gas, solid phase A	ICP-MS	Arsenic	14.51	0.01	0.1
5P	stack gas, solid phase A DUP	ICP-MS	Arsenic	17.04	0.01	0.1
5	stack gas, solid phase B	ICP-MS	Arsenic	12.01	0.01	0.1
5P	stack gas, solid phase B DUP	ICP-MS	Arsenic	14.02	0.01	0.1
6	stack gas, solid phase A	ICP-MS	Arsenic	6.37	0.01	0.2
6P	stack gas, solid phase A DUP	ICP-MS	Arsenic	5.24	0.01	0.3
6	stack gas, solid phase B	ICP-MS	Arsenic	5.45	0.01	0.3
6P	stack gas, solid phase B DUP	ICP-MS	Arsenic	6.44	0.01	0.2
7	stack gas, solid phase A	ICP-MS	Arsenic	10.07	0.01	0.1
7P	stack gas, solid phase A DUP	ICP-MS	Arsenic	12.06	0.01	0.1
7	stack gas, solid phase B	ICP-MS	Arsenic	11.87	0.01	0.1
7P	stack gas, solid phase B DUP	ICP-MS	Arsenic	13.55	0.01	0.1

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm^3	Blank (µg/Nm^3)	Blank % of Value
4	stack gas, solid phase A	ICP-MS	Beryllium	0.18	0.00	1.6
4P	stack gas, solid phase A DUP	ICP-MS	Beryllium	0.24	0.00	1.2
4	stack gas, solid phase B	ICP-MS	Beryllium	0.18	0.00	1.7
4P	stack gas, solid phase B DUP	ICP-MS	Beryllium	0.22	0.00	1.3
5	stack gas, solid phase A	ICP-MS	Beryllium	0.37	0.00	0.8
5P	stack gas, solid phase A DUP	ICP-MS	Beryllium	0.38	0.00	0.8
5	stack gas, solid phase B	ICP-MS	Beryllium	0.33	0.00	0.0
5P	stack gas, solid phase B DUP	ICP-MS	Beryllium	2.87	0.00	0.1
6	stack gas, solid phase A	ICP-MS	Beryllium	0.16	0.00	1.9
6P	stack gas, solid phase A DUP	ICP-MS	Beryllium	0.20	0.00	1.6
6	stack gas, solid phase B	ICP-MS	Beryllium	0.14	0.00	2.2
6P	stack gas, solid phase B DUP	ICP-MS	Beryllium	0.19	0.00	1.6
7	stack gas, solid phase A	ICP-MS	Beryllium	0.23	0.00	1.2
7P	stack gas, solid phase A DUP	ICP-MS	Beryllium	0.27	0.00	1.1
7	stack gas, solid phase B	ICP-MS	Beryllium	0.31	0.00	0.9
7P	stack gas, solid phase B DUP	ICP-MS	Beryllium	0.39	0.00	0.7
4	stack gas, solid phase A	ICP-MS	Cadmium	0.17	0.00	0.2
4P	stack gas, solid phase A DUP	ICP-MS	Cadmium	0.19	0.00	0.2
4	stack gas, solid phase B	ICP-MS	Cadmium	0.14	0.00	0.3
4P	stack gas, solid phase B DUP	ICP-MS	Cadmium	0.16	0.00	0.3
5	stack gas, solid phase A	ICP-MS	Cadmium	0.40	0.00	0.1
5P	stack gas, solid phase A DUP	ICP-MS	Cadmium	0.43	0.00	0.1
5	stack gas, solid phase B	ICP-MS	Cadmium	0.23	0.00	0.2
5P	stack gas, solid phase B DUP	ICP-MS	Cadmium	0.26	0.00	0.2
6	stack gas, solid phase A	ICP-MS	Cadmium	0.12	0.00	0.3
6P	stack gas, solid phase A DUP	ICP-MS	Cadmium	0.15	0.00	0.3
6	stack gas, solid phase B	ICP-MS	Cadmium	0.10	0.00	0.4
6P	stack gas, solid phase B DUP	ICP-MS	Cadmium	0.11	0.00	0.4
7	stack gas, solid phase A	ICP-MS	Cadmium	0.16	0.00	0.3
7P	stack gas, solid phase A DUP	ICP-MS	Cadmium	0.19	0.00	0.2
7	stack gas, solid phase B	ICP-MS	Cadmium	0.26	0.00	0.2
7P	stack gas, solid phase B DUP	ICP-MS	Cadmium	0.27	0.00	0.1
4	stack gas, solid phase A	ICP-MS	Chromium	3.68	0.04	1.2
4P	stack gas, solid phase A DUP	ICP-MS	Chromium	5.18	0.04	0.8
4	stack gas, solid phase B	ICP-MS	Chromium	3.20	0.04	1.3

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result $\mu g/Nm^3$	Blank $(\mu g/Nm^3)$	Blank % of Value
4P	stack gas, solid phase B DUP	ICP-MS	Chromium	4.26	0.04	1.0
5	stack gas, solid phase A	ICP-MS	Chromium	6.30	0.04	0.7
5P	stack gas, solid phase A DUP	ICP-MS	Chromium	8.27	0.04	0.5
5	stack gas, solid phase B	ICP-MS	Chromium	7.17	0.04	0.6
5P	stack gas, solid phase B DUP	ICP-MS	Chromium	9.42	0.04	0.5
6	stack gas, solid phase A	ICP-MS	Chromium	3.19	0.04	1.4
6P	stack gas, solid phase A DUP	ICP-MS	Chromium	4.29	0.04	1.0
6	stack gas, solid phase B	ICP-MS	Chromium	2.65	0.04	1.7
6P	stack gas, solid phase B DUP	ICP-MS	Chromium	3.32	0.04	1.3
7	stack gas, solid phase A	ICP-MS	Chromium	4.30	0.04	0.9
7P	stack gas, solid phase A DUP	ICP-MS	Chromium	5.97	0.04	0.7
7	stack gas, solid phase B	ICP-MS	Chromium	4.30	0.04	0.9
7P	stack gas, solid phase B DUP	ICP-MS	Chromium	7.16	0.04	0.6
4	stack gas, solid phase A	ICP-MS	Lead	2.78	0.02	0.6
4P	stack gas, solid phase A DUP	ICP-MS	Lead	2.94	0.02	0.6
4	stack gas, solid phase B	ICP-MS	Lead	2.59	0.02	0.7
4P	stack gas, solid phase B DUP	ICP-MS	Lead	2.69	0.02	0.6
5	stack gas, solid phase A	ICP-MS	Lead	5.11	0.02	0.3
5P	stack gas, solid phase A DUP	ICP-MS	Lead	5.27	0.02	0.3
5	stack gas, solid phase B	ICP-MS	Lead	4.49	0.02	0.4
5P	stack gas, solid phase B DUP	ICP-MS	Lead	4.67	0.02	0.4
6	stack gas, solid phase A	ICP-MS	Lead	2.48	0.02	0.7
6P	stack gas, solid phase A DUP	ICP-MS	Lead	2.59	0.02	0.7
6	stack gas, solid phase B	ICP-MS	Lead	2.11	0.02	0.8
6P	stack gas, solid phase B DUP	ICP-MS	Lead	2.20	0.02	0.8
7	stack gas, solid phase A	ICP-MS	Lead	3.50	0.02	0.5
7P	stack gas, solid phase A DUP	ICP-MS	Lead	3.66	0.02	0.5
7	stack gas, solid phase B	ICP-MS	Lead	4.27	0.02	0.4
7P	stack gas, solid phase B DUP	ICP-MS	Lead	4.50	0.02	0.4
4	stack gas, solid phase A	ICP-MS	Mercury	0.03	0.00	13.1
4P	stack gas, solid phase A DUP	ICP-MS	Mercury	0.02	0.00	17.3
4	stack gas, solid phase B	ICP-MS	Mercury	0.01	0.00	26.2
4P	stack gas, solid phase B DUP	ICP-MS	Mercury	0.01	0.00	27.7
5	stack gas, solid phase A	ICP-MS	Mercury	0.04	0.00	8.1
5P	stack gas, solid phase A DUP	ICP-MS	Mercury	0.03	0.00	10.0

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm³	Blank (µg/Nm³)	Blank % of Value
5	stack gas, solid phase B	ICP-MS	Mercury	0.04	0.00	7.6
5P	stack gas, solid phase B DUP	ICP-MS	Mercury	0.05	0.00	7.3
6	stack gas, solid phase A	ICP-MS	Mercury	0.02	0.00	16.4
6P	stack gas, solid phase A DUP	ICP-MS	Mercury	0.02	0.00	15.9
6	stack gas, solid phase B	ICP-MS	Mercury	0.01	0.00	34.2
6P	stack gas, solid phase B DUP	ICP-MS	Mercury	0.01	0.00	33.0
7	stack gas, solid phase A	ICP-MS	Mercury	0.02	0.00	16.5
7P	stack gas, solid phase A DUP	ICP-MS	Mercury	0.02	0.00	14.5
7	stack gas, solid phase B	ICP-MS	Mercury	0.02	0.00	18.3
7P	stack gas, solid phase B DUP	ICP-MS	Mercury	0.02	0.00	14.3
4	stack gas, solid phase A	ICP-MS	Nickel	5.13	0.03	0.6
4P	stack gas, solid phase A DUP	ICP-MS	Nickel	5.24	0.03	0.6
4	stack gas, solid phase B	ICP-MS	Nickel	4.87	0.03	0.6
4P	stack gas, solid phase B DUP	ICP-MS	Nickel	4.66	0.03	0.6
5	stack gas, solid phase A	ICP-MS	Nickel	9.63	0.03	0.3
5P	stack gas, solid phase A DUP	ICP-MS	Nickel	9.16	0.03	0.3
5	stack gas, solid phase B	ICP-MS	Nickel	9.86	0.03	0.3
5P	stack gas, solid phase B DUP	ICP-MS	Nickel	9.64	0.03	0.3
6	stack gas, solid phase A	ICP-MS	Nickel	4.43	0.03	0.7
6P	stack gas, solid phase A DUP	ICP-MS	Nickel	4.25	0.03	0.7
6	stack gas, solid phase B	ICP-MS	Nickel	3.98	0.03	0.8
6P	stack gas, solid phase B DUP	ICP-MS	Nickel	3.44	0.03	0.9
7	stack gas, solid phase A	ICP-MS	Nickel	6.10	0.03	0.5
7P	stack gas, solid phase A DUP	ICP-MS	Nickel	6.12	0.03	0.5
7	stack gas, solid phase B	ICP-MS	Nickel	7.97	0.03	0.4
7P	stack gas, solid phase B DUP	ICP-MS	Nickel	7.30	0.03	0.4
4	stack gas, solid phase A	ICP-MS	Selenium	2.25	0.02	0.7
4P	stack gas, solid phase A DUP	ICP-MS	Selenium	2.44	0.02	0.7
4	stack gas, solid phase B	ICP-MS	Selenium	6.31	0.02	0.3
4P	stack gas, solid phase B DUP	ICP-MS	Selenium	6.61	0.02	0.3
5	stack gas, solid phase A	ICP-MS	Selenium	11.17	0.02	0.2
5P	stack gas, solid phase A DUP	ICP-MS	Selenium	11.31	0.02	0.1
5	stack gas, solid phase B	ICP-MS	Selenium	46.30	0.02	0.0
5P	stack gas, solid phase B DUP	ICP-MS	Selenium	49.51	0.02	0.0
6	stack gas, solid phase A	ICP-MS	Selenium	9.10	0.02	0.2

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result µg/Nm³	Blank (µg/Nm³)	Blank % of Value
6P	stack gas, solid phase A DUP	ICP-MS	Selenium	9.47	0.02	0.2
6	stack gas, solid phase B	ICP-MS	Selenium	6.66	0.02	0.3
6P	stack gas, solid phase B DUP	ICP-MS	Selenium	7.12	0.02	0.2
7	stack gas, solid phase A	ICP-MS	Selenium	8.15	0.02	0.2
7P	stack gas, solid phase A DUP	ICP-MS	Selenium	8.51	0.02	0.2
7	stack gas, solid phase B	ICP-MS	Selenium	15.26	0.02	0.1
7P	stack gas, solid phase B DUP	ICP-MS	Selenium	15.78	0.02	0.1
2	stack gas, vapor phase A	IC	Chloride	239.76	5.26	2.2
2P	stack gas, vapor phase A DUP	IC	Chloride	230.29	5.26	2.3
2	stack gas, vapor phase B	IC	Chloride	273.02	5.15	1.9
2P	stack gas, vapor phase B DUP	IC	Chloride	260.66	5.15	2.0
3	stack gas, vapor phase A	IC	Chloride	618.09	5.25	0.8
3P	stack gas, vapor phase A DUP	IC	Chloride	604.08	5.25	0.9
3	stack gas, vapor phase B	IC	Chloride	436.57	5.24	1.2
3P	stack gas, vapor phase B DUP	IC	Chloride	465.23	5.24	1.1
4	stack gas, vapor phase A	IC	Chloride	364.66	4.32	1.2
4P	stack gas, vapor phase A DUP	IC	Chloride	383.97	4.32	1.1
4	stack gas, vapor phase B	IC	Chloride	257.04	5.25	2.0
4P	stack gas, vapor phase B DUP	IC	Chloride	264.74	5.25	2.0
5	stack gas, vapor phase A	IC	Chloride	229.53	4.25	1.8
5P	stack gas, vapor phase A DUP	IC	Chloride	214.25	4.25	2.0
5	stack gas, vapor phase B	IC	Chloride	286.78	4.64	1.6
5P	stack gas, vapor phase B DUP	IC	Chloride	278.12	4.64	1.7
2	stack gas, vapor phase A	IC	Fluoride	3.33	0.88	26.3
2P	stack gas, vapor phase A DUP	IC	Fluoride	3.68	0.88	23.8
2	stack gas, vapor phase B	IC	Fluoride	6.01	0.86	14.3
2P	stack gas, vapor phase B DUP	IC	Fluoride	6.01	0.86	14.3
3	stack gas, vapor phase A	IC	Fluoride	4.73	0.88	18.5
3P	stack gas, vapor phase A DUP	IC	Fluoride	6.48	0.88	13.5
3	stack gas, vapor phase B	IC	Fluoride	8.21	0.87	10.6
3P	stack gas, vapor phase B DUP	IC	Fluoride	6.82	0.87	12.8
4	stack gas, vapor phase A	IC	Fluoride	2.16	0.72	33.3
4P	stack gas, vapor phase A DUP	IC	Fluoride	2.16	0.72	33.3
4	stack gas, vapor phase B	IC	Fluoride	2.28	0.88	38.5
4P	stack gas, vapor phase B DUP	IC	Fluoride	2.63	0.88	33.3

Table G-2 (Continued)

Run	Cited Name	Method	Substance	Result $\mu g/Nm^3$	Blank ($\mu g/Nm^3$)	Blank % of Value
5	stack gas, vapor phase A	IC	Fluoride	2.97	0.71	23.8
5P	stack gas, vapor phase A DUP	IC	Fluoride	3.25	0.71	21.7
5	stack gas, vapor phase B	IC	Fluoride	3.55	0.77	21.7
5P	stack gas, vapor phase B DUP	IC	Fluoride	3.55	0.77	21.7
2	stack gas, vapor phase A	IC	Sulfate	14649.78	33.12	0.2
2P	stack gas, vapor phase A DUP	IC	Sulfate	14246.68	33.12	0.2
2	stack gas, vapor phase B	IC	Sulfate	17335.59	32.45	0.2
2P	stack gas, vapor phase B DUP	IC	Sulfate	16192.67	32.45	0.2
3	stack gas, vapor phase A	IC	Sulfate	22168.99	33.09	0.1
3P	stack gas, vapor phase A DUP	IC	Sulfate	22291.55	33.09	0.1
3	stack gas, vapor phase B	IC	Sulfate	23123.65	33.03	0.1
3P	stack gas, vapor phase B DUP	IC	Sulfate	24512.70	33.03	0.1
4	stack gas, vapor phase A	IC	Sulfate	19427.76	27.24	0.1
4P	stack gas, vapor phase A DUP	IC	Sulfate	19551.72	27.24	0.1
4	stack gas, vapor phase B	IC	Sulfate	26794.30	33.09	0.1
4P	stack gas, vapor phase B DUP	IC	Sulfate	27628.81	33.09	0.1
5	stack gas, vapor phase A	IC	Sulfate	23626.63	26.75	0.1
5P	stack gas, vapor phase A DUP	IC	Sulfate	22421.25	26.75	0.1
5	stack gas, vapor phase B	IC	Sulfate	29476.58	29.20	0.1
5P	stack gas, vapor phase B DUP	IC	Sulfate	30478.13	29.20	0.1

Appendix H

ANOVA

An Analysis of Variance (ANOVA) is a statistical method for determining the total variability of a process and the variability that each different component of the process contributes to the total variability. The design of an experiment helps to identify the components of variability in the process. The sampling design at Site 21 consisted of collecting one sample (analyzed in duplicate) from each of two trains once a day over a period of four days. The components of variability for Site 21, therefore, are a "day" component (describing variability in the process from day to day), a "train" component (describing variability between sampling trains within each day), and an analytical component (describing the variability between duplicate analyses of one sample from one train). This type of model is known as a hierarchical, or "nested", model; analytical variability is "nested" within each train, and train variability is "nested" within each day. The statistical software package SAS®, specifically the SAS® procedure NESTED, can be used to perform an analysis of variance on data with a nested structure. This software was used for the FCEM Site 21 analysis of variance.

The model for data from a completely nested design with three factors (two of which are nested) is given as:

$$y_{ijr} = \mu + \alpha_i + \beta_{ij} + \varepsilon_{ijr}$$

where:

y_{ijr} = the value of the dependent variable observed at the r^{th} replication with the first factor at its i^{th} level and the second factor at its j^{th} level;

μ = the overall mean of the sampling population; and

$\alpha_i, \beta_{ij}, \epsilon_{ijr}$ = mutually uncorrelated random effects with means 0 and respective variances σ_1^2, σ_2^2, and σ_3^2 (the variance components day, train, and analytical) (1).

This model is the basis of an analysis of variance for a nested design. Using this model, the NESTED procedure produces an estimate of the variability of each specified

component, and the percentage of the total variability that each component contributes. The variability estimates and percentages of variability for the FCEM Site 21 data are presented in tabular form in Table H-1. Figure H-1 depicts a bar graph of the percentage of total variability for each analyte, sub-sectioned into the percentage of variability from each of the three components. This type of data presentation is very useful for illustrating the how the components of variability relate to one another within an analyte, and how they relate between analytes.

The actual computation of the variance components using the NESTED procedure involves complex mathematical derivations, and will, therefore, not be given here. However, the equations and statistical methods used in NESTED can be found in the SAS/STAT User's Guide[1].

[1]SAS/STAT User's Guide, Version 6, Volume 2, 4th Edition, SAS Institute, Inc., Cary, NC.

Stream=stack gas

Method	Species	Day Variability Component	Train Variability Component	Analytical Variability Component	Day Percentage of Variability	Train Percentage of Variability	Analytical Percentage of Variability
HRGCMS	5-Methyl chrysene	0.49428	5.91066	1.17580	6.50	78.0	15.5
HRGCMS	7H-Dibenzo[c,g]carbazole	0.63210	0.00000	0.77838	44.8	0.00	55.2
HRGCMS	Acenapthene	767.75134	98.91668	1.86499	88.4	11.4	0.20
HRGCMS	Acenapthylene	53.37340	2.26469	17.46749	73.0	3.10	23.9
HRGCMS	Anthracene	180.11258	0.00000	75.31280	70.5	0.00	29.5
HRGCMS	Benz[a]anthracene	2.48817	0.00000	2.42493	50.6	0.00	49.4
HRGCMS	Benzo[a]pyrene	1.37974	2.31260	4.82539	16.2	27.2	56.7
HRGCMS	Benzo[b,j&k]fluoranthenes	83.39550	38.33278	0.49639	68.2	31.4	0.40
HRGCMS	Benzo[ghi]perylene	0.95384	1.22871	0.52265	35.3	45.4	19.3
HRGCMS	Chrysene	51.75905	60.87852	30.93674	36.1	42.4	21.5
HRGCMS	Dibenz[a,h]acridine	0.08889	0.03138	0.16719	30.9	10.9	58.2
HRGCMS	Dibenz[a,h]anthracene	0.02556	0.00282	0.07911	23.8	2.60	73.6
HRGCMS	Dibenz[a,j]acridine	0.11913	0.06710	0.04294	52.0	29.3	18.7
HRGCMS	Dibenzo[a,e]pyrene	0.01231	0.00000	0.13728	8.20	0.00	91.8
HRGCMS	Dibenzo[a,h]pyrene	0.00317	0.00000	0.01101	22.4	0.00	77.6
HRGCMS	Dibenzo[a,l]pyrene	0.04204	0.00000	0.43675	8.80	0.00	91.2
HRGCMS	Fluoranthene	7020.44745	706.68523	302.90393	87.4	8.80	3.80
HRGCMS	Fluorene	8222.47494	1457.13206	61.08839	84.4	15.0	0.60
HRGCMS	Indeno[1,2,3-cd]pyrene	3.63789	0.63400	0.32577	79.1	13.8	7.10
HRGCMS	Phenanthrene	108179.0000	2494.94179	887.58436	97.0	2.20	0.80
HRGCMS	Pyrene	1159.18271	58.45334	39.43471	92.2	4.70	3.10

Table H1. Site 21 Components and Percentages of Variability

2

Stream=stack gas, solid phase

Method	Species	Day Variability Component	Train Variability Component	Analytical Variability Component	Day Percentage of Variability	Train Percentage of Variability	Analytical Percentage of Variability
ICPES	Aluminum	3499.87450	639.08753	6.97291	84.4	15.4	0.20
GFAA	Arsenic	0.29440	0.39414	0.40798	26.8	35.9	37.2
ICPMS	Arsenic	15.26658	0.58510	1.49772	88.0	3.40	8.60
ICPES	Barium	0.41896	0.07417	0.00137	84.7	15.0	0.30
ICPES	Beryllium	0.00018	0.00015	0.00000	54.3	45.0	0.70
ICPMS	Beryllium	0.05086	0.00000	0.47065	9.80	0.00	90.2
GFAA	Cadmium	0.00000	0.00134	0.00001	0.00	99.6	0.40
ICPMS	Cadmium	0.00585	0.00458	0.00032	54.4	42.6	2.90
ICPES	Calcium	0.00000	1578.31876	1.42324	0.00	99.9	0.10
IC	Chloride	16616.00000	0.00000	3683.60130	81.9	0.00	18.1
ICPES	Chromium	0.09818	0.06054	0.00087	61.5	37.9	0.50
ICPMS	Chromium	3.65629	0.00000	1.55824	70.1	0.00	29.9
ICPES	Cobalt	0.00000	0.59317	0.00059	0.00	99.9	0.10
ICPES	Copper	0.01130	0.00418	0.00153	66.4	24.6	9.00
IC	Fluoride	3.13342	0.00000	1.07335	74.5	0.00	25.5
ICPES	Iron	1387.38611	518.09345	2.43495	72.7	27.2	0.10
GFAA	Lead	0.01106	0.03055	0.00073	26.1	72.2	1.70
ICPMS	Lead	1.27914	0.14479	0.01196	89.1	10.1	0.80
ICPES	Magnesium	0.00000	70.84266	0.24064	0.00	99.7	0.30
ICPES	Manganese	0.01818	0.17897	0.00012	9.20	90.7	0.10
ICPMS	Mercury	0.00013	0.00003	0.00001	76.6	18.1	5.30
ICPES	Molybdenum	0.01658	0.00057	0.00158	88.5	3.00	8.40
GFAA	Nickel	0.00000	0.05067	0.00178	0.00	96.6	3.40
ICPMS	Nickel	5.81889	0.34203	0.06798	93.4	5.50	1.10
ICPES	Potassium	87.17896	25.58838	9.52724	71.3	20.9	7.80
GFAA	Selenium	10.64495	21.19761	0.12641	33.3	66.3	0.40
ICPMS	Selenium	35.61659	176.97507	0.69898	16.7	83.0	0.30
ICPES	Silver	0.00011	0.00000	0.00024	30.4	0.00	69.6
ICPES	Sodium	57.11791	52.90090	0.41493	51.7	47.9	0.40
ICPES	Strontium	0.55599	0.15412	0.00275	78.0	21.6	0.40

Stream=stack gas, solid phase (continued)

Method	Species	Day Variability Component	Train Variability Component	Analytical Variability Component	Day Percentage of Variability	Train Percentage of Variability	Analytical Percentage of Variability
IC	Sulfate	18835016.00	0.00000	9929314.000	65.5	0.00	34.5
ICPES	Sulfur	0.00000	1267110.000	237.22940	0.00	100	0.00
ICPES	Thallium	0.03437	0.00208	0.02429	56.6	3.40	40.0
ICPES	Titanium	27.55967	5.81536	0.06485	82.4	17.4	0.20
ICPES	Vanadium	0.61057	0.33848	0.00159	64.2	35.6	0.20
ICPES	Zinc	15.83479	11.27895	0.00781	58.4	41.6	0.00

Table H1. Site 21 Components and Percentages of Variability

4

Stream=stack gas, vapor phase

Method	Species	Day Variability Component	Train Variability Component	Analytical Variability Component	Day Percentage of Variability	Train Percentage of Variability	Analytical Percentage of Variability
ICPES	Aluminum	0.00000	974.53150	2.25172	0.00	99.8	0.20
conc/ICPES	Aluminum	6.00922	117.44190	0.00000	4.90	95.1	0.00
GFAA	Arsenic	0.00000	0.16207	0.00359	0.00	97.8	2.20
ICPMS	Arsenic	0.00000	0.18877	0.00100	0.00	99.5	0.50
conc/GFAA	Arsenic	0.02109	0.22751	0.00000	8.50	91.5	0.00
ICPES	Barium	0.00000	0.11267	0.00193	0.00	98.3	1.70
conc/ICPES	Barium	0.00100	0.03392	0.00000	2.90	97.1	0.00
ICPES	Beryllium	0.00000	0.00089	0.00037	0.00	70.7	29.3
ICPMS	Beryllium	0.00000	0.00004	0.00002	0.00	73.7	26.3
conc/ICPES	Beryllium	0.00000	0.00006	0.00000	6.70	93.3	0.00
GFAA	Cadmium	0.00000	0.19917	0.01187	0.00	94.4	5.60
ICPMS	Cadmium	0.00000	0.12628	0.00092	0.00	99.3	0.70
conc/GFAA	Cadmium	0.00021	0.00237	0.00000	7.90	92.1	0.00
ICPES	Calcium	166.23872	159.66961	0.16063	51.0	49.0	0.00
conc/ICPES	Calcium	45.52794	80.95854	0.00000	36.0	64.0	0.00

Table H1. Site 21 Components and Percentages of Variability

Stream=stack gas, vapor phase
(continued)

Method	Species	Day Variability Component	Train Variability Component	Analytical Variability Component	Day Percentage of Variability	Train Percentage of Variability	Analytical Percentage of Variability
IC	Chloride	1.64060	0.10464	0.01025	93.5	6.00	0.60
ICPES	Chromium	0.00000	0.05220	0.02559	0.00	67.1	32.9
ICPMS	Chromium	0.00000	0.05430	0.00511	0.00	91.4	8.60
conc/ICPES	Chromium	0.00000	0.06257	0.00000	0.00	100	0.00
ICPES	Cobalt	13.83206	0.00000	20.55133	40.2	0.00	59.8
conc/ICPES	Cobalt	0.00872	0.00007	0.00000	99.2	0.80	0.00
ICPES	Copper	0.00000	0.08364	0.01598	0.00	84.0	16.0
conc/ICPES	Copper	0.00000	0.02195	0.00000	0.00	100	0.00
IC	Fluoride	0.00003	0.00003	0.00001	41.0	38.4	20.6
ICPES	Iron	0.00000	612.49941	0.08203	0.00	100	0.00
conc/ICPES	Iron	7.11139	129.53667	0.00000	5.20	94.8	0.00
GFAA	Lead	0.00000	83.08358	0.03331	0.00	100	0.00
ICPMS	Lead	0.00000	67.25692	1.91986	0.00	97.2	2.80
conc/GFAA	Lead	0.00220	0.00161	0.00000	57.7	42.3	0.00
ICPES	Magnesium	0.00000	0.00000	1658.37685	0.00	0.00	100
conc/ICPES	Magnesium	0.70885	3.48045	0.00000	16.9	83.1	0.00
ICPES	Manganese	360.73125	227.02570	0.01111	61.4	38.6	0.00
conc/ICPES	Manganese	206.39309	39.79891	0.00000	83.8	16.2	0.00
CVAA	Mercury	0.00000	0.01967	0.00075	0.00	96.3	3.70
ICPMS	Mercury	0.00000	0.04922	0.00052	0.00	99.0	1.00
ICPES	Molybdenum	0.00361	0.00000	0.08252	4.20	0.00	95.8
conc/ICPES	Molybdenum	0.00036	0.00167	0.00000	17.8	82.2	0.00
GFAA	Nickel	0.00000	0.28333	0.06196	0.00	82.1	17.9
ICPMS	Nickel	0.00000	0.20676	0.03531	0.00	85.4	14.6
conc/GFAA	Nickel	0.00000	0.20294	0.00000	0.00	100	0.00
ICPES	Potassium	846.89249	98.64107	1166.15075	40.1	4.70	55.2
conc/ICPES	Potassium	1651.60460	300.35576	0.00000	84.6	15.4	0.00
GFAA	Selenium	0.00000	1.93975	0.16606	0.00	92.1	7.90
ICPMS	Selenium	0.00000	509.04223	27.75338	0.00	94.8	5.20

Table H1. Site 21 Components and Percentages of Variability

Stream=stack gas, vapor phase (continued)

Method	Species	Day Variability Component	Train Variability Component	Analytical Variability Component	Day Percentage of Variability	Train Percentage of Variability	Analytical Percentage of Variability
conc/GFAA	Selenium	0.00000	169.94980	0.00000	0.00	100	0.00
ICPES	Silver	0.00000	0.03157	0.04515	0.00	41.2	58.8
conc/ICPES	Silver	0.00003	0.00002	0.00000	62.1	37.9	0.00
ICPES	Sodium	0.00000	1054.98545	82.48412	0.00	92.7	7.30
conc/ICPES	Sodium	37.49728	80.16582	0.00000	31.9	68.1	0.00
ICPES	Strontium	0.01782	0.14561	0.00017	10.9	89.0	0.10
conc/ICPES	Strontium	0.00478	0.06169	0.00000	7.20	92.8	0.00
IC	Sulfate	3006.46429	751.54289	527.18261	70.2	17.5	12.3
ICPES	Sulfur	202258037.0	17012813.00	662332.0000	92.0	7.70	0.30
conc/ICPES	Sulfur	102568890.0	14700185.00	0.00000	87.5	12.5	0.00
ICPES	Thallium	0.00000	27.45254	29.40861	0.00	48.3	51.7
conc/ICPES	Thallium	0.00116	0.02607	0.00000	4.20	95.8	0.00
ICPES	Titanium	1.24794	3.72788	1.00489	20.9	62.3	16.8
conc/ICPES	Titanium	0.15188	1.42324	0.00000	9.60	90.4	0.00
ICPES	Vanadium	0.02967	0.15668	0.05978	12.1	63.7	24.3
conc/ICPES	Vanadium	0.01858	0.14376	0.00000	11.4	88.6	0.00
ICPES	Zinc	0.00000	15.35544	2.01101	0.00	88.4	11.6
conc/ICPES	Zinc	0.00000	9.20665	0.00000	0.00	100	0.00

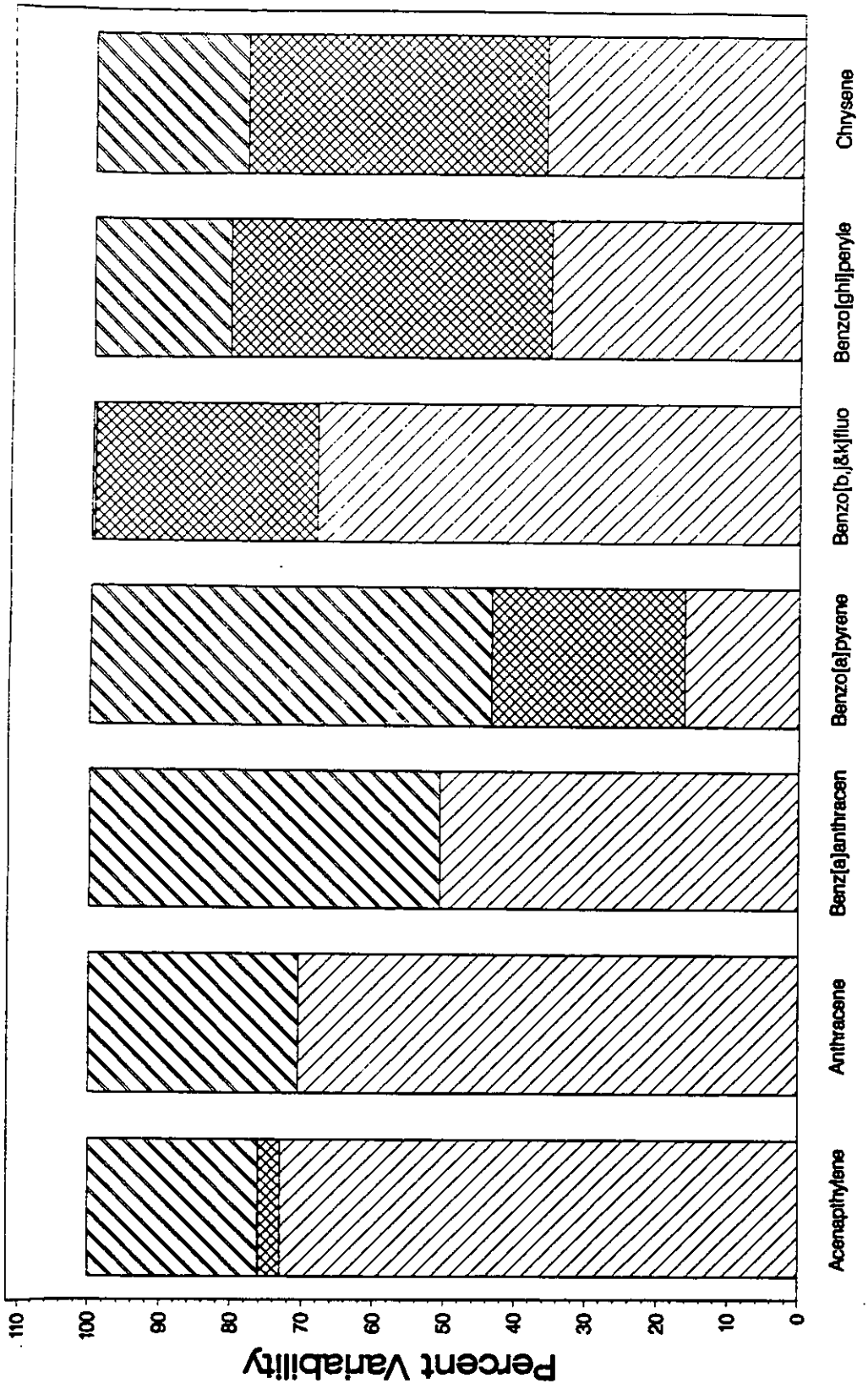
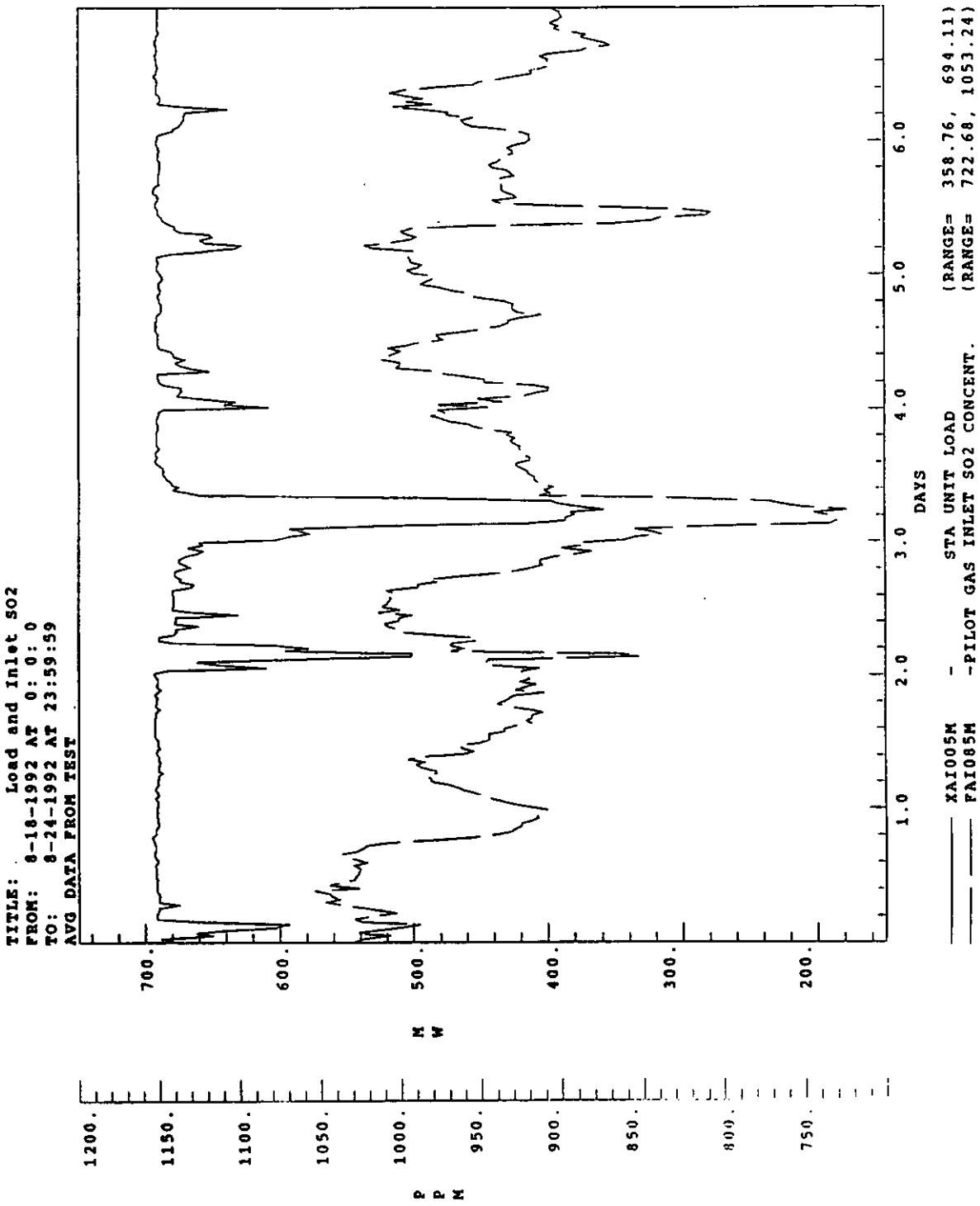
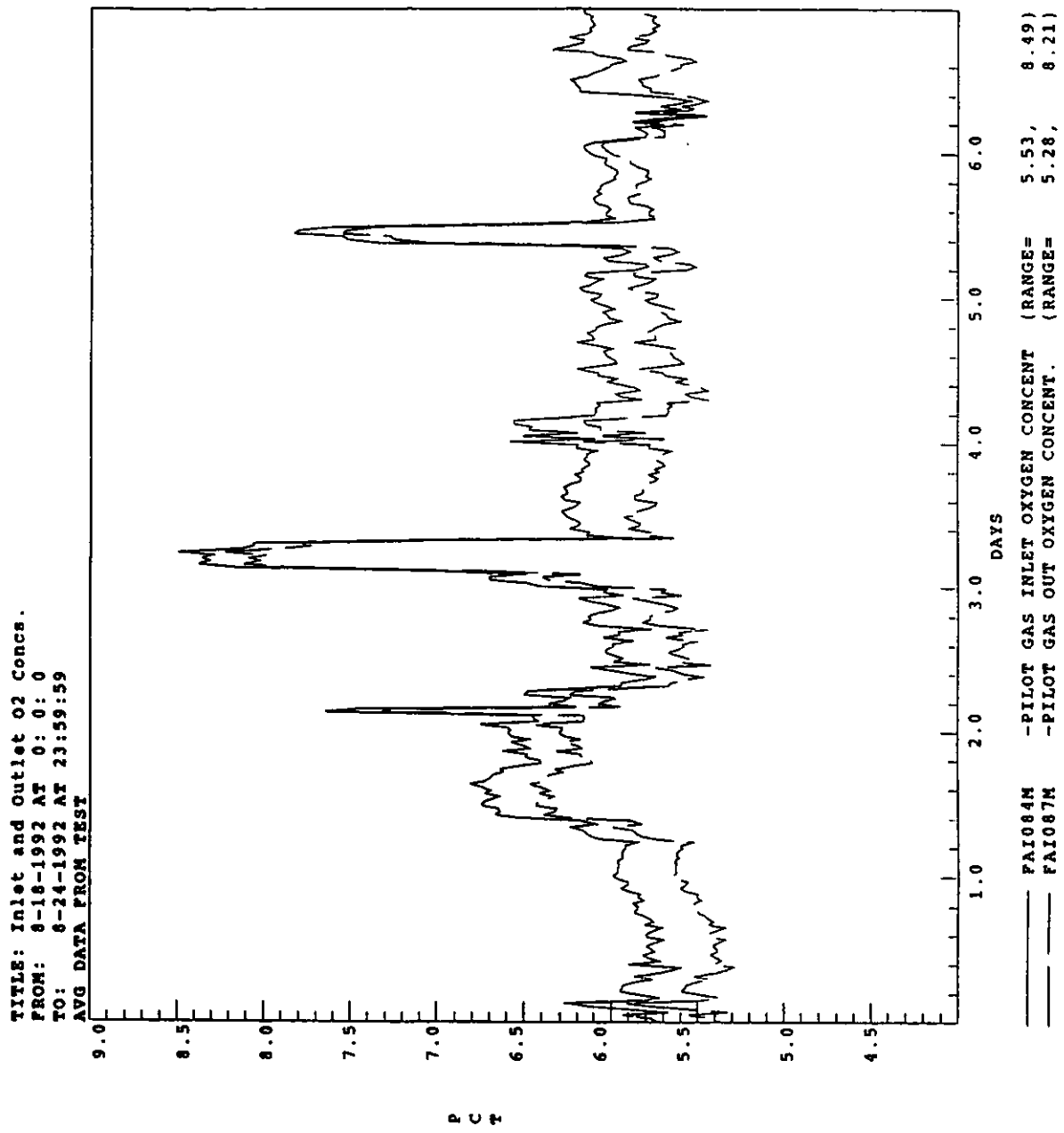


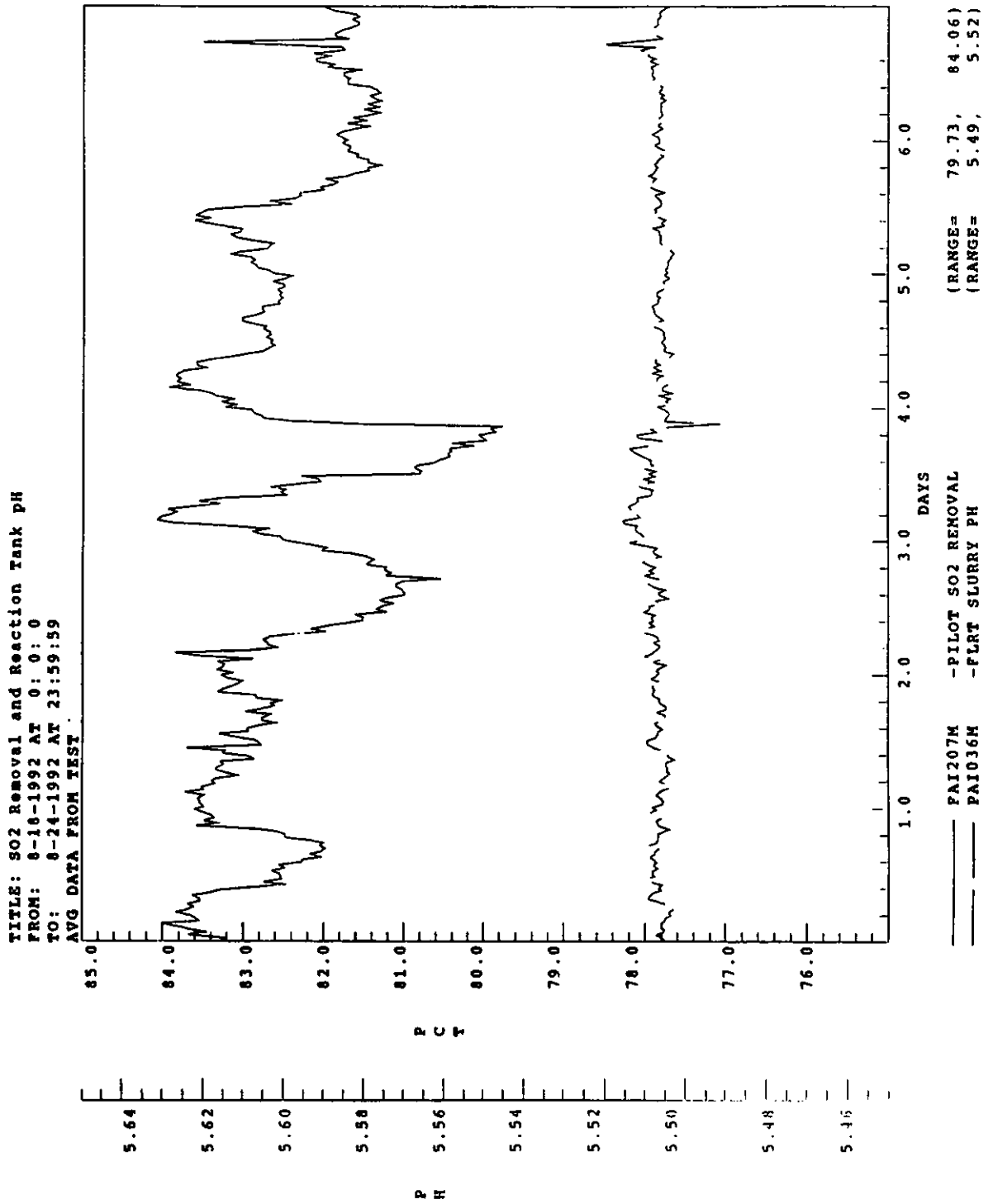
Figure H-1. Percentages of Variability

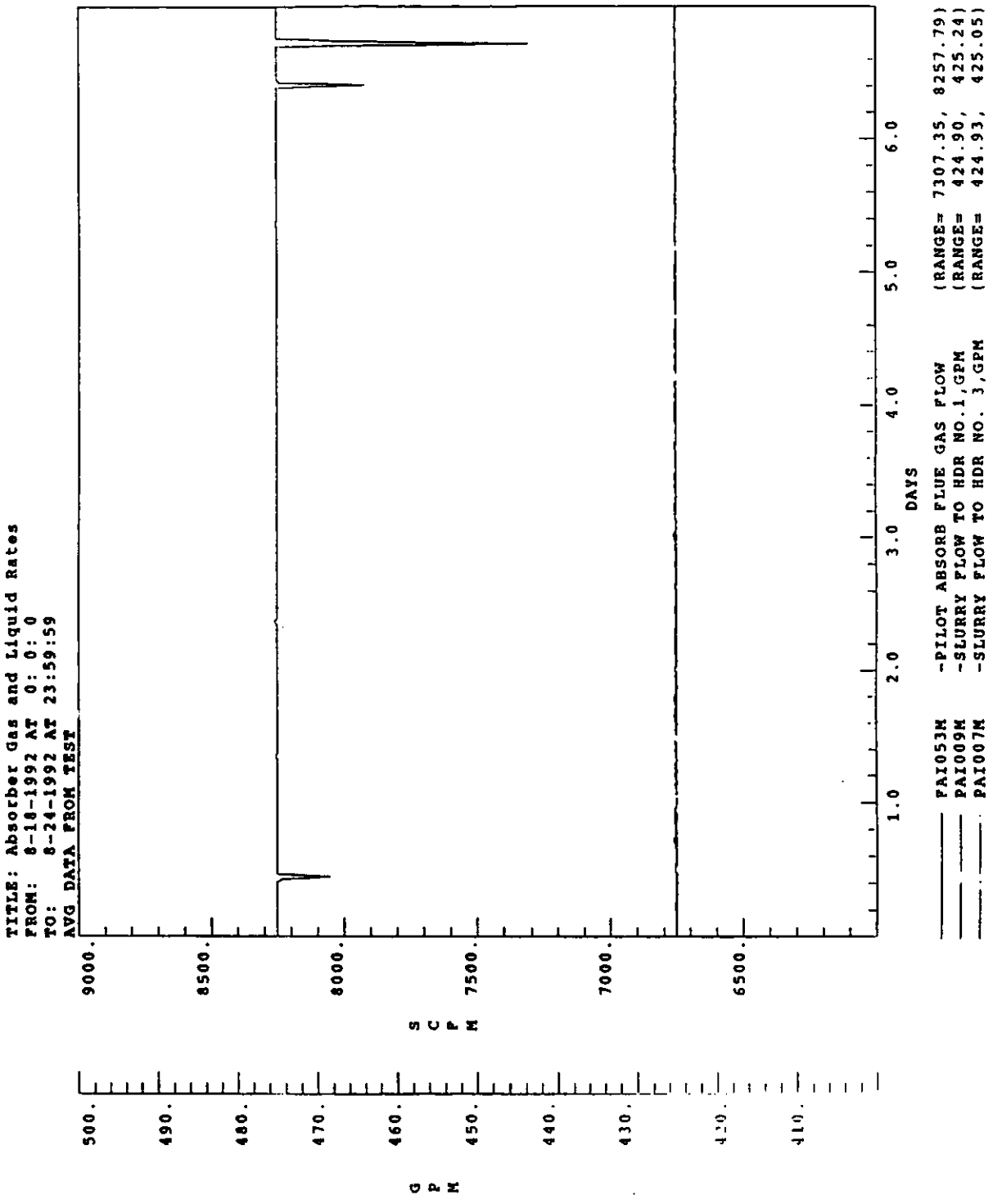
Appendix I

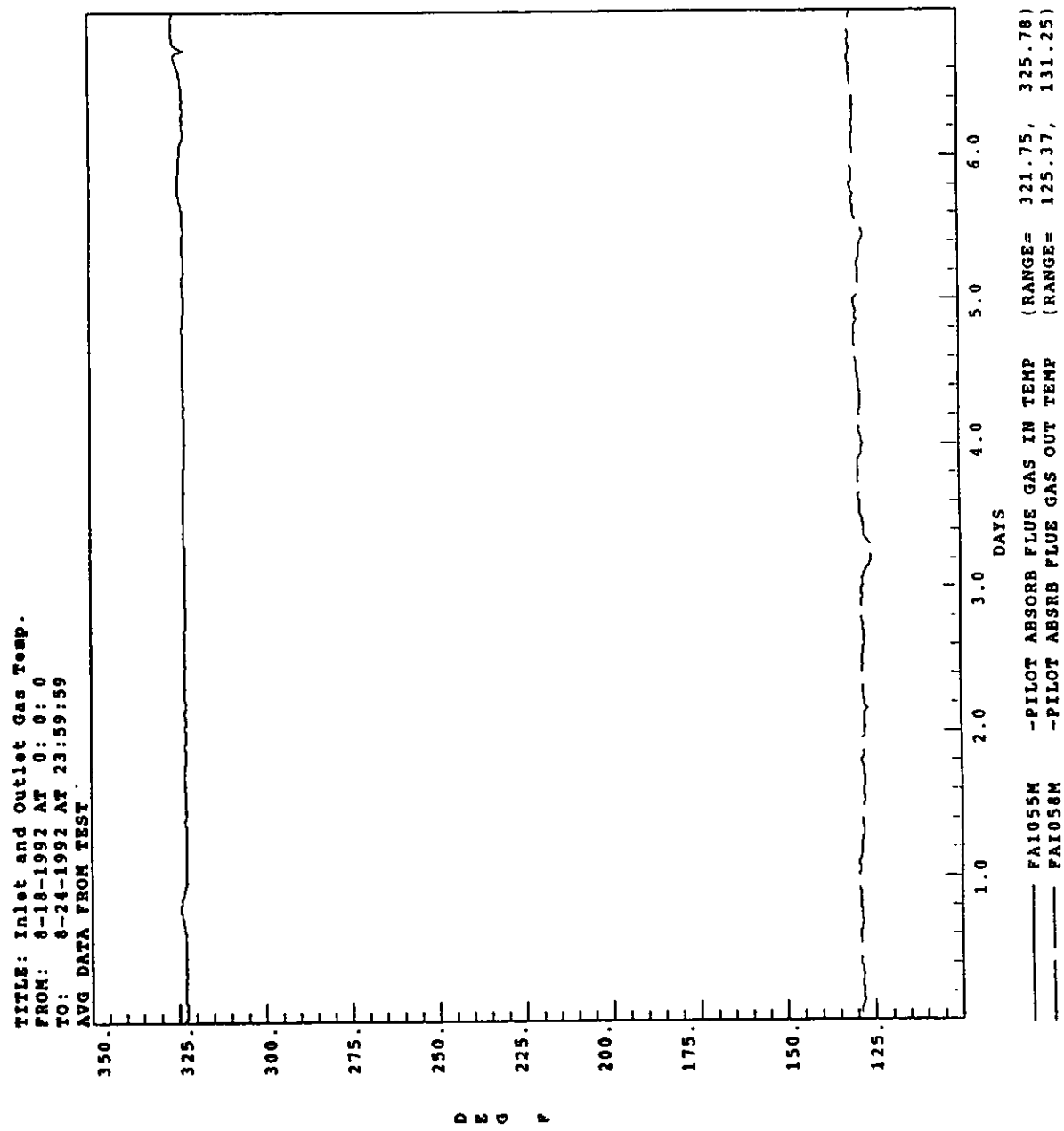
Process Plots











Appendix J

Mercury Speciation Results

Overall Mean Results (μg/Nm^3)						
(corrected from dry STP (21.1°C) to normal (0°C), and Hg found on probe walls added to Hg(II) value)						
date	**location**	**total**	**Hg(0)**	**MMHg**	**Hg(II)**	
8/18	outlet	0.86	0.74	0.017	0.09	
8/19		0.65	0.60	0.011	0.04	
8/20		0.79	0.70	0.011	0.07	
8/21		0.85	0.71	0.02	0.13	
8/22		0.98	0.87	0.01	0.11	
mean		**0.83**	**0.72**	**0.01**	**0.09**	
SD		**0.12**	**0.10**	**0.005**	**0.03**	
8/18	inlet	10.75	3.24	1.11	6.55	
8/19		9.73	1.68	0.88	6.78	
8/20		9.88	3.50	1.31	4.82	
8/21		9.81	2.79	2.05	4.84	
8/22		10.93	3.85	1.51	5.57	
mean		**10.22**	**2.99**	**1.37**	**5.71**	
SD		**0.57**	**0.84**	**0.44**	**0.92**	

Ancillary Mercury Data				
	coal	**flyash**	**scrubber solids**	**scrubber liquid**
result	**μg/g (dry)**	**μg/g (dry)**	**μg/g (dry)**	**μg/L**
Bloom	0.128	0.065	1.67	1.98
SD	0.030	0.017	0.13	0.50
N	4	4	4	6
Radian	0.15	—	1.76	—
SD	0.03	—	0.15	—
N	6	—	8	—
NBS	0.120	0.158	—	—
SD	0.007	0.004	—	—
N	8	3	—	—
certified	0.13	0.16	—	—
SD	0.02	0.01	—	—

Individual Run Results

date	location	concentration, ug/m^3 @ 70°F, 1 atm, dry, amb. O_2				
		total Hg	Hg(0)	MMHg	Hg(II)	probe
8/18	outlet	0.78	0.70	0.010	<0.04	0.007
		0.81	0.67	0.022	0.11	0.008
	mean	**0.80**	**0.69**	**0.016**	**0.07**	**0.008**
8/18	inlet	9.81	2.75	*6.72 (total ox'd Hg)*		0.34
		8.86	*0.78*	0.981	5.49	1.60
		10.14	2.46	1.016	5.80	0.86
		10.00	3.82	1.086	4.09	1.01
	mean	**9.98**	**3.01**	**1.028**	**5.13**	**0.95**
	SD	**0.17**	**0.72**	**0.053**	**0.91**	**0.51**
8/19	outlet	0.64	0.62	0.009	<0.04	0.014
		0.56	0.49	0.010	0.049	0.013
		0.85				
	mean	**0.60**	**0.56**	**0.010**	**0.03**	**0.014**
8/19	inlet	9.60	1.07	0.540	3.51	4.48
		8.23	2.55	5.42 (total ox'd Hg)		0.27
		10.09	1.07	1.093	4.71	3.22
		8.21				0.73
	mean	**9.03**	**1.56**	**0.817**	**4.11**	**2.18**
	SD	**0.96**	**0.85**			**2.01**
8/20	outlet	0.66	0.62	0.020	<0.04	0.013
		0.79	0.67	<0.002	0.10	0.012
	mean	**0.73**	**0.65**	**0.010**	**0.06**	**0.013**
	inlet	9.39				0.068
		9.79	2.89	1.571	4.47	0.862
		8.45	3.28	1.265	3.43	0.473
		9.06	3.59	0.820	3.91	0.732
	mean	**9.17**	**3.25**	**1.22**	**3.94**	**0.534**
	SD	**0.57**	**0.35**	**0.38**	**0.52**	**0.350**

date	location	concentration, ug/m^3 @ 70^{o}F, 1 atm, dry, amb. O_2				
		total Hg	Hg(0)	MMHg	Hg(II)	probe
8/21	outlet	0.80	0.67	0.13 (total ox'd Hg)		0.006
		0.78	0.64	0.13 (total ox'd Hg)		0.006
		0.78				0.012
	mean	**0.79**	**0.66**	**0.02 (est)**	**0.11 (est)**	**0.008**
8/21	inlet	9.49	2.48	2.42	4.59	0.009
		8.58	1.55	6.90 (total ox'd Hg)		0.124
		8.83	2.81	1.58	4.44	<0.002
		9.52	3.50	1.69	4.33	0.007
	mean	**9.11**	**2.59**	**1.90**	**4.45**	**0.04**
	SD	**0.47**	**0.81**	**0.46**	**0.13**	**0.06**
8/22	outlet	0.96	0.85	0.11 (total ox'd Hg)		0.008
		1.01				0.010
		0.84				0.010
		0.83	0.76	0.012	0.06	0.008
	mean	**0.91**	**0.81**	**0.01 (est)**	**0.09 (est)**	**0.009**
	SD	**0.09**				
8/22	inlet	9.89	3.41	1.30	4.85	0.344
		9.35	*2.97*	*2.83*	*3.42*	*0.130*
		10.22	3.94	1.554	4.69	0.040
		10.34	3.37	1.356	5.43	0.182
	mean	**10.15**	**3.57**	**1.403**	**4.99**	**0.174**
		0.23	**0.32**	**0.130**	**0.39**	**0.128**

Field Data Records

date	start time	stop time	elapsed time	Port location	volume L (corr.)	flow (L/min)	traps
RUN: OUTLET 1			note: mist in gas stream results in moisture condensation. Radian scrapped this run.				
8/18	12:20	16:40	260	outlet	103.4	0.398	S261
							C231
8/18	17:00	19:55	170	outlet	85.3	0.502	S275 + S267
							C-NM
RUN: INLET 1A			note: possibly compromised by air inlet from open ports upstream. Estimated dilution:				
8/18	14:00	15:50	110	inlet	51.3	0.466	S291
							C206
8/18	16:30	18:35	125	inlet	30.8	0.246	S262
							C244
RUN: INLET 1B			note: possibly compromised by air inlet from open ports upstream. Estimated dilution:				
8/18	14:00	15:50	110	inlet	31.9	0.290	S287
							C237
8/18	16:30	18:35	125	inlet	49.0	0.392	S252
							C225
RUN: OUTLET 1.5			note: total Hg and field blanks run				
8/19	7:45	9:50	125	outlet	59.0	0.472	S274 (bl)
							C302 (bl)
							C301 (tot)
RUN: OUTLET 2							
8/19	10:15	14:35	260	outlet	100.6	0.387	S285
							C228
	14:40	19:05	265	outlet	103.4	0.390	S278
							C234

date	start time	stop time	elapsed time	Port location	volume L (corr.)	flow (L/min)	traps
RUN: INLET 2A			note: 11:35 sample possibly compromised by air inlet from open ports upstream. Estimated dilution:				
8/19	11:35	13:15	100	inlet	38.5	0.385	S271
							C220
	16:25	19:15	165	inlet	51.9	0.314	S290
							C236
RUN: INLET 2B			note: second sample is total Hg with a soda-lime field blank back-up				
8/19	11:35	13:15	100	inlet	38.7	0.387	S282
							C219
	16:25	19:15	165	inlet	51.2	0.310	S281 (bl)
							C223 (t)
RUN: OUTLET 3							
8/20	8:00	11:55	235	outlet	95.2	0.405	S277
							C203
	12:10	16:10	240	outlet	103.1	0.430	S289
							C235
RUN: INLET 3A			note: total Hg and carbon field blank				
8/20	8:25	10:15	110	inlet	35.4	0.322	C204 (t)
							C202 (b)
	10:40	13:20	160	inlet	68.7	0.423	S250
							C-211
RUN: INLET 3B							
8/20	8:25	10:15	110	inlet	45.7	0.415	S266
							C232
	10:40	13:20	160	inlet	67.8	0.424	S284
							C208

date	start time	stop time	elapsed time	Port location	volume L (corr.)	flow (L/min)	traps
RUN: OUTLET 4							
8/21	10:10	14:08	238	outlet	106.4	0.447	S251
							C227
	14:44	18:13	209	outlet	99.4	0.476	S265
							C349
	16:07	18:13	126	outlet	58.6	0.465	S350 (b)
							C350 (t)
RUN: INLET 4A							
8/21	8:55	10:20	85	inlet	45.9	0.540	S259
							C226
	10:37	13:01	144	inlet	54.8	0.381	S286
							C205
RUN: INLET 4B							
8/21	8:55	10:20	85	inlet	43.5	0.512	S-NM
							C222
	10:37	13:01	144	inlet	74.6	0.518	S268
							C242
RUN: OUTLET 5							
8/22	9:05	12:27	202	outlet	98.0	0.485	S352
							C356
	9:05	12:04	179	outlet	80.2	0.448	S354 (b)
							C358 (t)
	12:25	15:47	202	outlet	77.6	0.384	S264 (b)
							C355 (t)
	12:43	16:03	200	outlet	101.5	0.507	S359
							C354

date	start time	stop time	elapsed time	Port location	volume L (corr.)	flow (L/min)	traps
RUN: INLET 5A							
8/22	8:30	10:10	100	inlet	38.9	0.389	S256
							C229
	10:31	12:51	140	inlet	53.7	0.383	S360
							C352
RUN: INLET 5B							
8/22	8:30	10:10	100	inlet	48.4	0.484	S351
							C359
	10:31	12:51	140	inlet	60.4	0.431	S357
							C351

Laboratory Results

Hg-0 sample	Hg-0 B/U	MMHg sample	MMHg B/U	Hg(II) sample	Hg(II)) B/U	probe + liner	traps
RUN: OUTLET 1 (8/18)			note: mist in gas stream results in moisture condensation. Radian scrapped this run.				
		1.2	<0.2	3.6	1.9	0.7	S261
73.7 76.2	1.5						C231
		1.8	0.3	14.6	2.4	0.7	S275 + S267
59.7	1.8 1.9						C-NM
RUN: INLET 1A (8/18)			note: possibly compromised by air inlet from open ports upstream. Estimated dilution:				
				371 308	12.6	17.4	S291
146.2 143.5	0.8						C206
		24.4 26.6	4.9	159.4 159.6	16.8	49.3	S262
26.3 26.7	2.0 2.4						C244
RUN: INLET 1B (8/18)			note: possibly compromised by air inlet from open ports upstream. Estimated dilution:				
		28.9	3.7	180.6 182.3	10.7	27.5	S287
82.2 78.4	2.1 3.5						C237
		45.0 43.6	9.1	178.3 181.8	20.2	49.3	S252
189.6 189.9	2.0						C225
RUN: OUTLET 1.5 (8/18)			note: total Hg and field blanks run				
		<0.2	0.2	1.2	0.8	0.0	S274 (bl)
4.8 6.2	4.0 5.9						C302 (bl)
52.3 52.6	2.8 2.3						C301 (tot)
RUN: OUTLET 2 (8/19)							
		1.1	<0.2	2.8	2.9	1.4	S285
58.9 59.4	7.9 7.6						C228
		1.2	<0.2	10.5	1.8	1.4	S278
54.9 54.0	1.4						C234

Hg-0 sample	Hg-0 B/U	MMHg sample	MMHg B/U	Hg(II) sample	Hg(II) B/U	probe + liner	traps
RUN: INLET 2A (8/19)			note: 11:35 sample possibly compromised by air inlet from open ports upstream. Estimated dilution:				
		18.8	2.5 1.9	131.3 129.2	12.2	172.3	S271
41.7 43.0	3.1 3.5						C220
				258 252	33.4	13.8	S290
132.4 130.9	5.4 5.4						C236
RUN: INLET 2B (8/19)			note: second sample is total Hg with a soda-lime field blank back-up				
		40.3 38.1 37.6	3.8	171.8 174.9	16.4	124.5	S282
45.0 45.0	1.0						C219
		<0.2	<0.2	2.4	2.0	37.3	S281 (bl)
384.8	2.9						C223 (t)
RUN: OUTLET 3 (8/20)							
		1.7	0.2	1.3	2.7	1.2	S277
60.1 63.5	2.5 1.6						C203
		<0.2	<0.2	7.7	10.1	1.2	S289
73.9 68.1	2.8						C235
RUN: INLET 3A (8/20)			**note: total Hg and carbon field blank**				
333.5	1.1					2.4	C204 (t)
2.6 2.7	1.8						C202 (b)
		100.4 102.0 100.0	7.1 7.4	284.4	29.7	58.7	S250
204.1 198.7	1.5						C211 (271)
RUN: INLET 3B (8/20)							
		50.6 49.8	7.7 7.9	143.7 137.5	22.4	21.6	S266
153.0 152.6	2.0 1.5						C232
		40.9 40.8	14.9	236.5 233.8	37.0 37.9	49.6	S284
248.7 242.2 245.2	2.4						C208

Hg-0 sample	Hg-0 B/U	MMHg sample	MMHg B/U	Hg (II) sample	Hg (II) B/U	probe + liner	traps
RUN: OUTLET 4 (8/21)							
				18.3 17.4	3.1	0.6	S251
73.2 76.4	1.0						C227
				16.4 16.7	3.8	0.6	S265
67.7 66.9	1.2						C349
		<0.2	nd	nd	7.0	0.6	S350 (b)
49.1 50.0	1.6						C350 (t)
RUN: INLET 4A (8/21)							
		107.8	3.4	203.8	14.0	0.4	S259
115.9 115.6	2.6						C226
				347 322	50.8	6.8	S286
88.3 86.7	2.2						C205
RUN: INLET 4B (8/21)							
		66.9	2.0	186	14.2	0.0	S-XXX
120.7 125.5	3.7						C222
		114.1	12.3	263	67.2	0.5	S268
263.9	1.4						C242
RUN: OUTLET 5 (8/22)							
				10.7 15.3	4.9	0.8	S352
87.6 81.9 84.5 85.8	4.0 1.8						C356
		<0.2	<0.2	3.6	1.9	0.8	S354 (b)
83.0 83.6	1.7						C358 (t)
		0.5	0.5	9.9	3.9	0.8	S264 (b)
70.9 65.8	0.8						C355 (t)
		1.4	<0.2	7.4	5.6	0.8	S359
83.2 74.3	2.6						C354

Hg-0 sample	Hg-0 B/U	MMHg sample	MMHg B/U	Hg(II) sample	Hg(II) B/U	probe + liner	traps
RUN: INLET 5A (8/22)							
		44.8	5.8	173.2 180.1	19.0	13.4	S256
134.4 132.4	3.7						C229
		13.2/138		179.9	11.2	7.0	S360
160.9 159.6	3.8						C352
RUN: INLET 5B (8/22)							
		69.1	6.3	208.2	26.1	1.9	S351
191.3 196.1	1.4						C359
		73.4 64.5	13.1	307.1	nd	11.0	S357
201.4 207.0 202.6 210.8 211.0 204.5	2.1 2.8 1.5						C351
							scrubber liquor
		0.37 ug/L					DW3 XXl
1.53 ug/L							DW2XXd
2.64 ug/L							DWXXd
2.61 ug/L							DW4XXd
1.83 ug/L							DW4XXd
1.65 ug/L							DW2XXc
1.64 ug/L							DW1XXa
							coal
0.090 ppm							CO2
0.123 ppm	0.120 ± 0.029 ppm						CO3a
0.109 ppm	wet (≈ 5% H_2O)						CO3b
0.157 ppm							CO4
0.033 ppm	±0.005						blanks
0.114 ppm							NBS
0.010 ppm							FP oil 1400
0.006 ppm							FP oil 0100

Method References

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