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Preliminary Draft

FIELD CHEMICAL EMISSIONS MONITORING PROJECT:

SITE 15 EMISSIONS MONITORING

EPRI Project RP3177-1

October 1992

Prepared by:
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8501 Mo-Pac Boulevard
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Prepared For:

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

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DCN 92-213-152-26

FIELD CHEMICAL EMISSIONS MONITORING PROJECT: SITE 15 EMISSIONS REPORT

PRELIMINARY DRAFT REPORT

Prepared for:

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6 October 1992

EPRI
Electric Power
Research Institute *Leadership in Science and Technology*

October 15, 1992

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 is actively pursuing additional FCEM sampling programs, with at least 22 sites either completed or planned.

This site report presents a preliminary summary of data gathered during a sampling program conducted at one of the FCEM sampling programs - Site 15. Site 15 consists of a pulverized coal-fired boiler burning bituminous coal and an electrostatic precipitator. **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 conduct verification tests at this site. If 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 15 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 provides an assessment of the trace metals material balances, discusses the data quality, identifies suspect data, and offers possible explanations for the questionable data. Because the discussion only focuses upon the suspect or invalidated 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 15 with the results from previous utility sites. Generic conclusions and recommendations were not drawn concerning the effectiveness of the ESP as a potential control technology 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.

A thorough evaluation of the results from Site 15 revealed that some sampling and analytical errors may have occurred. The data have been qualified to note potential sampling or analytical errors, and where significant biases or inconsistencies were substantiated, the data were discarded. The most notable example was the flue gas measurements of mercury.

The Site 15 mercury measurements in flue gas are believed to be biased low due to incomplete recovery of mercury from the impinger solution prior to analysis. The material balance calculations indicated that approximately 25% of the mercury in the inlet streams could be accounted for in the outlet streams. The mercury data are included in the report, even though the data are suspect, because they do provide an approximation for mercury emissions. The reader is strongly advised to exercise good scientific judgment in using the flue gas mercury concentrations in any further evaluations.

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

Sincerely,

Paul Chu
Manager, Toxic Substances Control
Environment Division

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Section 1

INTRODUCTION

This report presents a summary of data gathered during a sampling program sponsored by the Electric Power Research Institute (EPRI). 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 (CAAA) of 1990. The plants studied during this project were chosen to reflect a cross section of the existing technologies for controlling air emissions. They were not chosen to represent "typical" fossil-fuel-fired power plant operation per se, nor should the solid or aqueous waste treatment systems used or discharge levels achieved be deemed representative of the industry as a whole.

The project examined the fate of selected substances found in the process streams at the host site. All of the relevant analytical data generated during the project are presented in the appendices. The body of the report presents information relative to the compositions of the coal and gas streams. Information on the gas streams is presented both as concentrations and as units of energy.

This report is one of a series being produced under the Field Chemical Emissions Monitoring (FCEM) project (RP 3177-1) sponsored by EPRI. The objective of this project has been to measure selected inorganic and organic substances in the process and discharge streams of power plants. Table 1-1 presents the list of substances of interest to the program. Data on additional substances detected by the analytical methods employed are presented in the appendix. By characterizing all streams of interest, information about the control and fate of these substances can be developed.

This report summarizes information about stack emissions from the operation of a divided-wall, tangentially fired boiler burning medium-sulfur bituminous coal. Sampling was conducted during October of 1990. **Note that the results presented in this report *should be considered preliminary.*** At present, we believe them to be correct; however, as information is obtained from other sites, samples are occasionally reanalyzed to obtain additional information. Plants also have been resampled when the initial results do not appear to be reasonable indicators of process performance.

The results reported in this document are of generally good quality and meet the objectives of the FCEM study. They provide a more accurate and comprehensive characterization of a power plant system than is often found in the published literature. The samples upon which the reported results are based have been collected in a careful manner using accepted and appropriate sampling and analytical methods. The sampling and analytical results have been subjected to an extensive QA/QC evaluation (a separate

Table 1-1

FCEM Substances

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

[a]Also referred to as semivolatile organic compounds, including polynuclear aromatic hydrocarbons (PAHs).

QA/QC report is provided in Appendix E). In this report, the data which are of satisfactory quality are simply reported and not extensively discussed. The focus of the discussions is, instead, on those results which are questionable, uncertain, or known to be of poor quality.

The technical approach used at each plant has been to employ "standard" sampling and analytical procedures to the extent possible (i.e., the FCEM program is not a methods development or research program designed to measure extremely low levels of emissions). The target detection level for the selected substances in gas streams was 20 $\mu g/Nm^3$ (as the FCEM project has progressed, lower levels of detection for some species have been sought to provide more detailed information). The sampling protocol is to obtain three sets of samples for the chemical analysis of each process stream. The results are presented both by individual run and averaged with a 95% confidence interval about the mean presented to demonstrate the process, sampling, and analytical variability.

Section 2 of this report presents a brief description of the plant and sample locations. Section 3 discusses the chemical analysis of the coal and the two gas streams sampled at the plant. Section 4 discusses the results in terms of both analytical and engineering considerations. Section 5 presents example calculations, and a glossary of terms is provided in Section 6. The appendices present sampling and analytical methods, stream concentrations, measured and calculated stream flows, particulate measurement results, QA/QC information, and blank correction data. In particular, Appendix B contains additional results of analyses for the substances listed in Table 1-1 using the preferred analytical methods. Appendix C includes results of testing for other substances and/or with alternate analytical methods.

Section 2

SITE DESCRIPTION

The FCEM project has a policy of providing a site code for each plant that is sampled. This plant has been designated Site 15. Descriptions of the test site and the sampling locations are given in this section.

Facility Information

One coal-fired steam electric generator, with a capacity of approximately 600 MWe, is located at Site 15. The unit began commercial operation in 1970. Figure 2-1 shows a process flow diagram of the plant.

Pulverized coal is burned in a tangentially fired, divided-wall furnace manufactured by Combustion Engineering. The boiler contains 40 burners placed on five elevations. Overfire air is not used.

Eastern bituminous coals are acquired on a spot market basis. Low-sulfur and medium-sulfur coals are segregated on delivery. During reclaim, the coals are blended to provide a fuel with approximately 1.5% sulfur by weight to control sulfur dioxide emissions. In addition, the boiler is equipped to substitute up to 16% of the heat input with natural gas to further reduce sulfur dioxide emissions, if necessary.

Bottom ash is removed from the boiler ash hoppers by an ash sluicing system. An electrostatic precipitator (ESP) system removes fly ash from the boiler flue gases, and the fly ash is removed from the ESP hopper system by an ash sluicing system. The flue gas treatment and ash removal facilities are described in greater detail below.

Flue Gas Treatment Facilities

The furnace flue gases flow through a duct system to two cold-side ESPs as illustrated in Figure 2-2. Separate ducts are used to direct flue gases from each half of the divided wall furnace to the ESP system. Air preheaters are located in each duct. Gas sampling ports are located approximately 50 feet downstream of the air preheaters in a wide, rectangular duct. The flue gases continue into a common triangularly shaped duct. The ESPs are located along each outer wall, and flow distribution vanes are located at the inlet and outlet of each ESP. The ESP gases are drawn through two induced draft fans and discharged through a common stack.

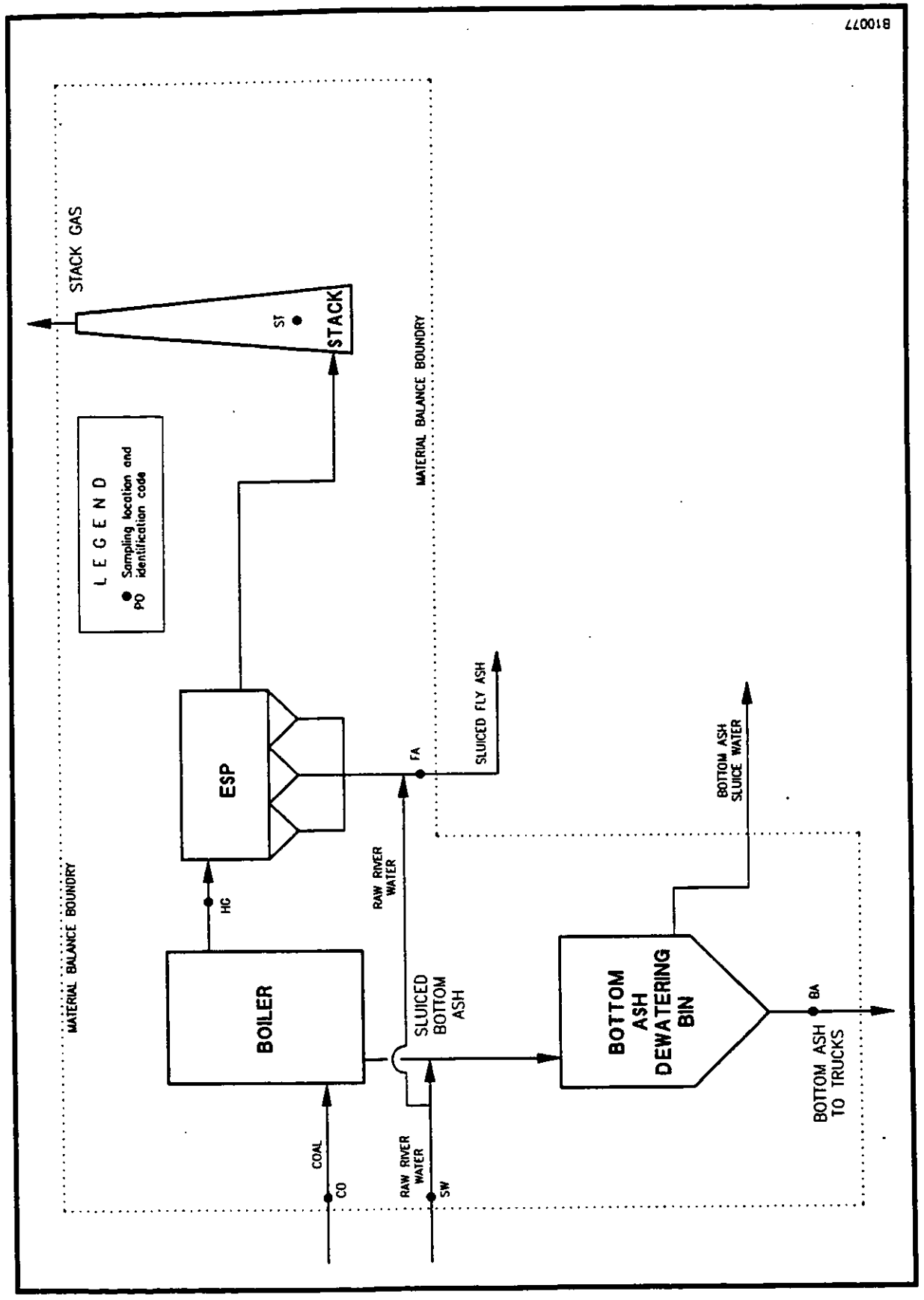

Figure 2-1. Process Flow Diagram for Site 15

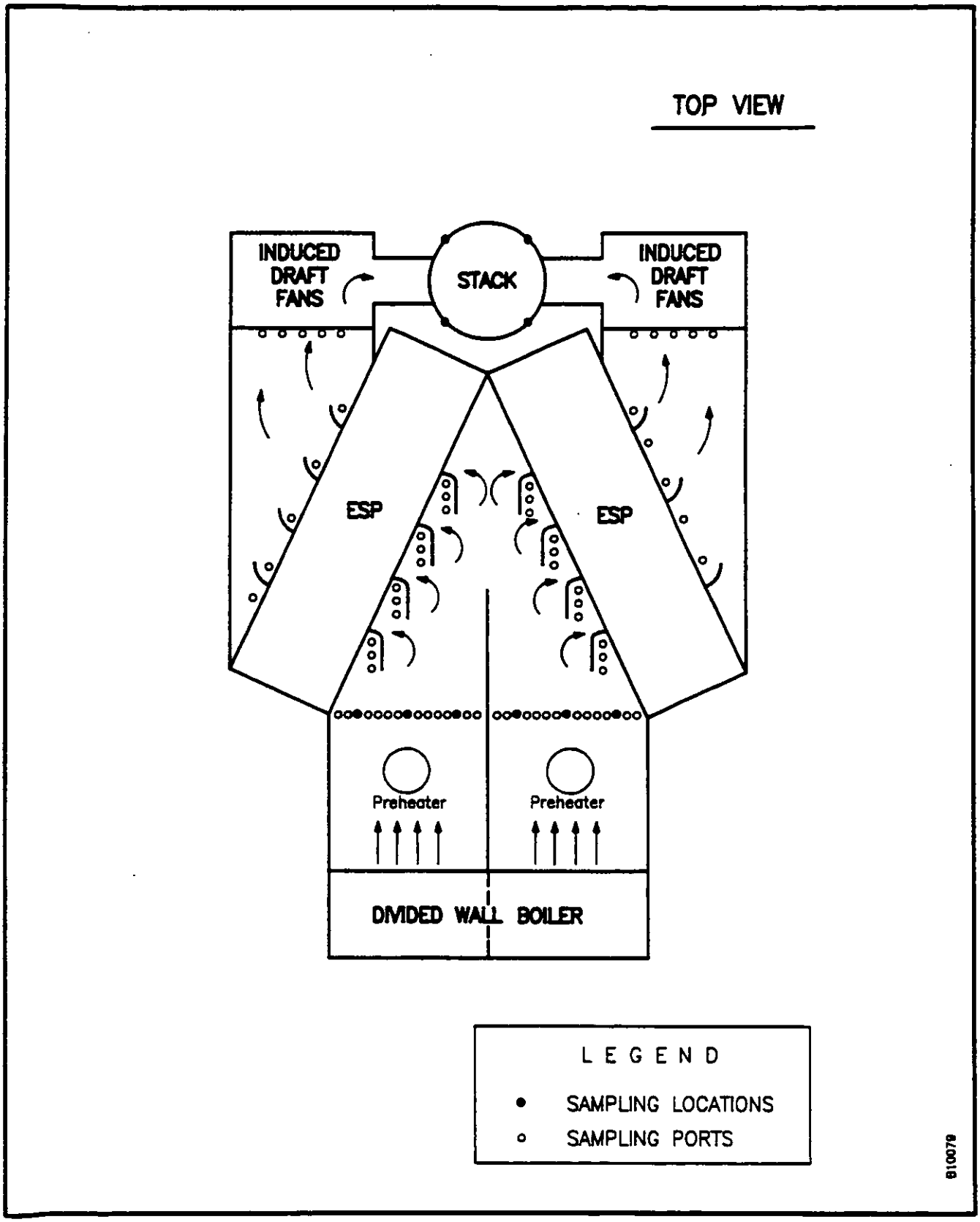

Figure 2-2. Diagram of Flue Gas Flow System for Site 15

Ash Removal Facilities

River water is used to sluice the bottom ash and fly ash. The water is chlorinated to control the growth of algae and bacteria in process lines.

Bottom ash is sluiced into one of two dewatering bins. After a period of dewatering, the bottom ash is trucked to an open storage area, where it is stockpiled for sale at a later date. (The weight of bottom ash trucked to storage during the test program was used to calculate the generation rate.) The associated sluice water is decanted into a settling pond. The sluiced fly ash is transported by pipeline to an abandoned mine.

Sampling Locations

Samples were collected at several locations in the plant. Two input streams were sampled: coal and river water. Intermediate process streams sampled include the inlet gas to the electrostatic precipitators and the fly ash slurry. The sampling points are identified in the process diagram, Figure 2-1. Following are brief descriptions of each stream and sampling location:

- Coal samples were collected from sampling ports located on the coal feed chutes to the five coal pulverizers;
- Service water samples were collected from a service water tap located in the power plant building;
- Flue gas entering the electrostatic precipitator system was sampled from ports located at the entrance duct to the ESP system (refer to Figure 2-2);
- Flue gas leaving the electrostatic precipitator system was sampled from ports located at the 150-foot level of the stack;
- Fly ash slurry samples were collected from the fly ash sump area during a fly ash sluicing event; and
- Bottom ash samples were collected at the bottom ash storage area while the trucks were emptying the storage bins.

The procedures for collecting, pretreating, and analyzing samples are discussed in Appendix A. Table 2-1 presents an overview of the types of analyses performed on these streams.

Table 2-1

Process Stream Analyses

Stream	Metals	Anions	Volatile Organic Compounds	Semivolatile Organic Compounds	Aldehydes
Coal	✓	✓			
Bottom Ash	✓	✓			
Collected Fly Ash	✓	✓			
ESP Inlet Gas	✓	✓	✓	✓	✓
Stack Gas	✓	✓	✓	✓	✓
Service Water	✓	✓			

Section 3

RESULTS

This section summarizes the results of the coal characterization and gas stream analyses.

Sampling Schedule

Site 15 was sampled in late October 1990. To obtain samples for analyzing the substances listed in Table 1-1, five sampling trains were used for sampling the ESP inlet and the stack. The multi-metals and semivolatile trains require full traversing of the ducts. The other three trains (VOST, anions, and aldehydes) are sampled at single points. Because of load demands, equipment failures, and manpower restrictions, it was not possible to complete all five trains on three successive days. Figure 3-1 presents the actual measurements schedule. To our knowledge, there is no reason to suspect that the operation of the plant during any test day was irregular and would, therefore, have resulted in a nonrepresentative data set. On October 25, 26, and 29, problems with the coal mills prevented sampling. The plant is constrained by opacity and SO_2 limits, measured in the stack, that has required co-firing with up to 15% natural gas at full load. Sampling was occasionally delayed until only coal was being fired. The plant operated generally in the range of 530-575 MWe during most of the testing.

As shown on Figure 3-1, five anion runs were taken. Two were voided when the filters ruptured, contaminating the impinger solutions. Coal samples were taken to coincide with metal and anion gas sampling events.

Data Treatment

Several conventions were developed 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 reportable concentrations in either (or both) phases required that conventions be developed for dealing with these data and formulating emission factors. 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 reporting limits.

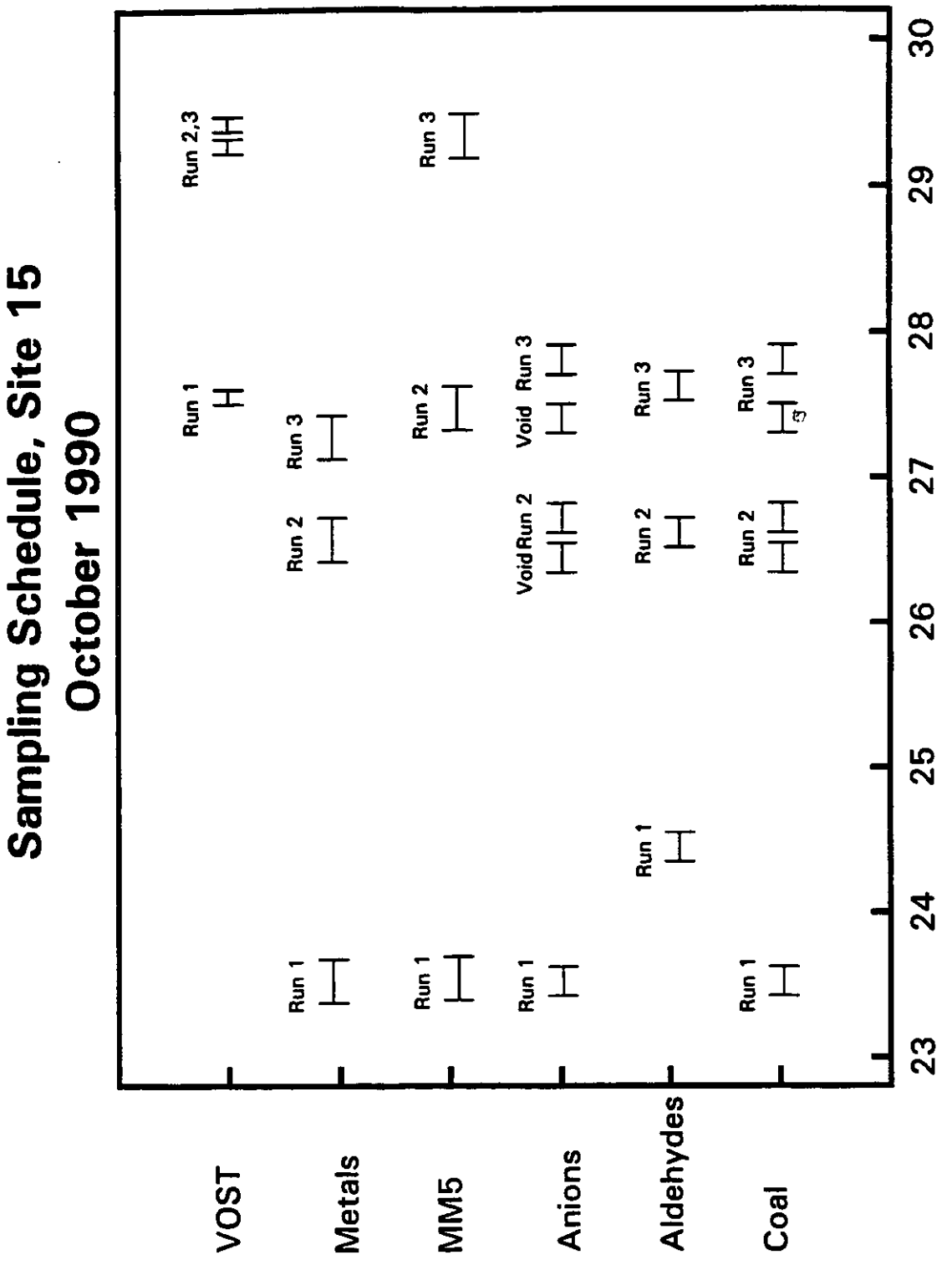

Figure 3-1. Summary of Gas Train Runs Completed

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

Case 3: The concentration in one phase is above the reporting limit, while the concentration in the other phase is below the reporting 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 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 selenium concentration in the ESP inlet gas is calculated as follows for Run 1:

Se in solid phase = 182 μg/Nm^3

Se in vapor phase = 5.9 μg/Nm^3

Total Se in ESP inlet gas = 187.9 μg/Nm^3

Case 2: The total concentration is considered to be the reporting limit in the solid phase.

For example, the cadmium concentration in the ESP inlet gas is calculated as follows for Run 3:

Cd in solid phase = NR(11 μg/Nm^3)

Cd in vapor phase = NR(0.5 μg/Nm^3)

where NR(11) indicates that the analytical result was below the reporting limit of 11 μg/Nm^3 (see footnote in Table 3-1 for additional details).

Total Cd in ESP inlet gas = NR(11 μg/Nm^3)

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 cobalt concentration in the stack gas is calculated as follows for Run 3:

Co in solid phase = 2.8 μg/Nm^3

Table 3-1

Site 15 Coal Analyses (mg/kg Unless Noted)

Substance	Run 1	Run 2	Run 3	Average	95% CI
Load (MWe)	545	565	565	558	30
Coal (lb/hr)	412,000	424,000	425,000	419,000	16,600
HHV - Btu/lb	13,100	13,000	13,000	13,000	140
Ash (% dry basis)	12.9	12.6	12.7	12.7	0.6
Sulfur (%)	1.74	1.54	1.52	1.6	0.3
Arsenic	15	11	12	13	5
Barium	204	128	253	195	157
Beryllium	1.3	0.9	1.0	1.1	0.5
Cadmium	NR(8) [a]	NR(7)	10	NR(8)	--
Chloride	932	765	894	864	217
Chromium	28	22	27	26	9
Cobalt	5.9	4.4	5.4	5	2
Copper	NR(90)	NR(81)	NR(83)	NR(90)	--
Fluoride	76 [b]	90 [b]	79 [b]	82	18
Lead	4.6	3.9	3.6	4	1.3
Manganese	28	30	26	28	5
Mercury	0.16	0.13	0.14	0.14	0.04
Molybdenum	NR(1)	NR(1)	NR(1)	NR(1.0)	--
Nickel	NR(20)	20	22	NR(20)	--
Phosphorus	231	234	232	232	4
Selenium	2.0	2.2	2.5	2.2	0.6
Vanadium	37	26	26	29	16

[a] NR = Below reporting limit; the reporting limit is shown in parentheses. The "reporting limit" is the concentration below which results are not routinely reported. The reporting limit is set at a concentration representing an upper tolerance for the method detection limit (MDL). As described in Appendix B to 40 CFR 136, the MDL is a value that is calculated from a series of measurements made at a particular point in time under a particular set of conditions; it is not an intrinsic characteristic of a method. Thus, for a given method, the numerical value of the MDL will vary somewhat with each determination. Likewise, MDLs would be expected to vary somewhat between instruments, between analysts, and between laboratories all using the same method. Thus, the reporting limit, as the upper tolerance for the MDL, represents a laboratory-specific value below which the MDL would be expected to fall for any determination in that particular laboratory, regardless of instrument, analyst, etc. The reporting limit does not necessarily have utility in regulatory application.

[b] Denotes concentration less than five times the reporting limit.

Co in vapor phase = NR(5 μg/Nm^3)

Total Co in stack gas = 2.8 μg/Nm^3

The above conventions are also in agreement 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 sites has 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 of different runs:

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

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

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

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

Analytical Values	Mean Value
5, NR(4), NR(3)	NR(4)

- When all analytical results for a given variable are less than the reporting limit, the value reported as the mean or average is NR(x), where x is the largest reporting limit. The bias estimate (used in calculating confidence intervals) is one-half of the reporting level, and no confidence interval is reported.

- Questionable analytical data have been excluded from all summary calculations. These include results that indicate a sampling bias, analytical interference, or the presence of organic compounds known to be common laboratory contaminants.

Concentrations were corrected against the blank where appropriate. Details of the blank corrections are provided in Appendix G.

Coal

Table 3-1 shows the results of analyses of the coal samples. Appendix A presents the analytical method reported for each combination of substance and stream. The concentrations reported here were measured using our choice of the best method for each matrix. For each substance, a mean concentration has been calculated, along with the 95% confidence interval about the mean. The confidence interval is the range about the calculated mean wherein the probability is 95% that the true mean lies. For example, it can be said, with a 95% certainty, that the true mean arsenic concentration in coal is between 8 and 18 mg/kg, based on the three results presented in Table 3-1. The calculation of this confidence interval is discussed in Section 5 and in Appendix E. Most of the substances in the table were analyzed using Inductively Coupled Argon Plasma Emission Spectroscopy (ICP-AES). Other analyses were made using Neutron Activation Analysis (NAA) and Graphite Furnace Atomic Absorption Spectroscopy (GFAAS). Mercury was measured using Double Gold Amalgamation (DGA) with Cold Vapor Atomic Absorption Spectroscopy (CVAAS). For those substances that could not be quantified, the notation "NR(x)" is presented. This term means "not reported at a concentration of x." The reporting limit can vary based on sample size, sample preparation, and analytical method (see footnote in Table 3-1 for additional details about the reporting limit).

ESP Inlet Gas

Table 3-2 summarizes the concentration measurements made on the gas exiting the air preheaters and entering the electrostatic precipitators at Site 15. In addition to the substances shown in this table, POMs were also analyzed; however, none were reported. The trace element and anion concentrations for both solid and vapor phase fractions are presented in Table 3-2. For the multi-metals train, the particulate filter, probe rinse, and nozzle rinse fractions were combined and analyzed. The laboratory reported the elemental result on a total weight basis, e.g., total milligrams of arsenic. When appropriate (i.e., if the substance was reported in the blank), this value was corrected against the blank. This total weight was divided by the total mass of particulate collected to obtain an elemental composition of the suspended ash. The suspended ash composition was also compared to the collected ash composition (ash removed by the ESP) as an additional verification of the consistency of the measured solids composition. The compositions generally agreed well.

The total suspended ash flow rate was calculated, by difference, as the amount of ash entering the boiler with the coal less that being removed as bottom ash (truck weigh scales were used to estimate the bottom ash generation rate over the sampling periods). (The suspended ash flow and composition were measured, but this is a difficult sampling location. The calculated suspended ash flow is a more reasonable estimate than the measured flow as indicated in Appendix, D, pp. D-4.) The suspended ash flow rate was multiplied by the elemental concentrations to obtain a solid phase substance mass rate. When divided by the gas flow rate, this value becomes the solid phase portion of the gas concentration. The multi-metals train impingers were analyzed directly for total

Table 3-2

ESP Inlet Gas Composition ($\mu g/Nm^3$ unless noted)

Substance	Solid Phase Run 1	Solid Phase Run 2	Solid Phase Run 3	Vapor Phase Run 1	Vapor Phase Run 2	Vapor Phase Run 3	Combined Average	95% CI
Gas Flow (scfm)	896,000	1,000,000	1,000,000				967,000	152,000
Particulate (lb/hr)	39,500	39,000	39,600				39,400	855
Particulate (gram/Nm^3)	12.5	11.0	11.2				11.5	2.0
Arsenic	1,200 [a]	828 [a]	874 [a]	NR(14) [b]	NR(12)	NR(3)	967	501
Barium	10,800	10,100	9,600	NR(5)	NR(5)	NR(5)	10,200	1,550
Beryllium	74 [c]	56 [c]	91 [c]	NR(1)	NR(1)	NR(1)	74	44
Cadmium	NR(12)	NR(11)	NR(11)	NR(0.5)	0.53 [c]	NR(0.5)	NR(12)	--
Chloride	598 [a]	1,140 [a]	NR(223) [a]	69,700	49,700	62,000	61,100	25,100
Chromium	2,090	1,790	1,750	NR(5)	NR(5)	NR(5)	1,880	463
Cobalt	666	559	525 [c]	NR(5)	NR(5)	NR(5)	583	183
Copper	1,162	970 [c]	852 [c]	NR(9)	NR(10)	NR(10)	990	389
Fluoride	286 [a]	165 [a]	748 [a]	5,113	3,120	3,034	4,160	3,020
Lead	1,420	1,280	1,230 [a]	NR(1)	2.7 [c]	NR(2)	1,310	197
Manganese	2,610	2,520	2,690	163	48	478	2,830	591
Mercury [d]	7 [c]	NR(2)	4 [c]	0.57	0.40 [c]	0.93	4.6	7.9
Molybdenum	3,350	2,900	2,430 [c]	NR(24)	NR(24)	NR(25)	2,890	1,150
Nickel	1,160 [c]	975 [c]	1,110 [c]	NR(9)	NR(10)	NR(10)	1,080	238
Phosphorus	24,400 [a]	21,500 [a]	22,300 [a]	NR(17)	NR(17)	NR(16)	22,800	3,700
Selenium	182 [c]	185 [c]	180 [c]	5.9 [c]	5.9 [c]	12.8	191	12
Vanadium	3,130	2,760	2,680	NR(9)	NR(10)	NR(10)	2,860	608
Benzene	--	--	--	8	6	7	7	2.2
Formaldehyde	--	--	--	NR(8)	NR(8)	NR(9)	NR(9)	--
Toluene	--	--	--	6	4	10	7	7.0

[a] Collected fly ash analysis used as an estimated concentration.
[b] NR = Below reporting limit. Reporting limit is shown in parentheses.
[c] Denotes concentration less than five times the reporting limit.
[d] The reported vapor phase mercury concentrations are suspected to be low. Problems were encountered in analyzing these samples (see discussion in Section 4).

elemental mass, corrected against the blank, and divided by the sampled gas volume to obtain the vapor phase concentration.

Several substances require a brief discussion regarding the derivation of their concentration values. The concentration determined using Hydride Generation for arsenic in the suspended particulate matter does not agree well with that determined by Graphite Furnace and Neutron Activation for collected fly ash (average of 14 vs. 96 mg/kg). With a coal arsenic concentration of 13 mg/kg and coal ash concentration of 12.7%, the collected fly ash levels appeared more realistic and were reported in Table 3-2.

Chloride, fluoride, and phosphorus determinations were not made on the suspended ash fraction. The solid phase gas concentrations in the ESP inlet gas, as presented in Table 3-2, are based on the analysis of the collected fly ash for these three substances. (Since greater than 99% of the ESP inlet particulate is collected in the ESP, the collected ash should have the same composition.) Also, the measured lead concentration in the suspended ash for Run 3 did not agree well with the collected fly ash concentration. The three suspended ash lead compositions were 114, 116, and 38 mg/kg, while the corresponding collected fly ash values were 110, 110, and 110 mg/kg. An average concentration of 110 mg/kg was, therefore, used for the suspended ash in the calculation for Run 3 and so denoted on the table. In addition, the reported molybdenum levels may be high by as much as an order of magnitude and, therefore, should be considered questionable (analyses appeared to be biased high because of matrix interferences). These issues are discussed in greater detail in Section 4 of this report.

Stack Gas

Table 3-3a and 3-3b present the concentration and unit-energy basis results of stack gas emission measurements from Site 15. The data are presented as solid and vapor phase concentrations with the mean and confidence interval corresponding to the combined phase. Concentrations in the particulate matter were corrected for reported concentrations of the substance in the blank sample. In such cases, the blank value was subtracted from the sample value. Since the particulate loading is 99% lower in the stack gas than in the ESP inlet gas, these blank corrections are more significant in the stack gas measurements.

Some of the solid phase concentrations for Run 3 appear to be questionable; however, there is no discernible reason to eliminate or substitute values other than the lead concentration of Run 3. As shown in Table 3-1, the coal lead level was consistent over the sampling period. As shown in Appendix B, the collected fly ash lead concentrations vary from 110 to 130 mg/kg over the test period. For the three emitted particulate measurements, the reported levels of lead were 112, 195, and 4,030 mg/kg. Since the stack particulate matter concentration (grain loading) was consistent over the test period, there is no explanation for such a tremendous discrepancy in the emitted particulate lead concentration for Run 3. Therefore, the average lead concentration in the stack gas was calculated using values from Runs 1 and 2 only. Cadmium shows a significant increase in Run 3 also; however, it was reported in the coal during this sampling period but had

Table 3-3a

Stack Gas Concentration ($\mu g/Nm^3$ Unless Noted)

Substance	Solid Phase Run 1	Solid Phase Run 2	Solid Phase Run 3	Vapor Phase Run 1	Vapor Phase Run 2	Vapor Phase Run 3	Combined Average	95% CI of Mean
Gas Flow (scfm)	1,140,000	1,170,000	1,170,000				1,160,000	38,000
Particulate (lb/hr)	158	176	123				152	67
Particulate (gram/Nm³)	0.039	0.042	0.030				0.037	0.016
Arsenic	16	21	16	NR(1) [a]	NR(1)	NR(14)	18	7.1
Barium	40	51	45	NR(3)	NR(3)	NR(5)	45	13
Beryllium	0.5	0.6	0.5 [b]	NR(0.5)	NR(0.6)	NR(1.1)	0.5	0.04
Cadmium	1.3 [b]	1.5	9.5	NR(0.3)	NR(0.3)	NR(0.5)	4.1	12
Chloride	-- [c]	-- [c]	-- [c]	67,200	59,000	61,300	62,500	10,500
Chromium	10	11	25	NR(3)	NR(3)	NR(5)	15	20
Cobalt	2.2	3.0	2.8 [b]	NR(3)	NR(3)	NR(5)	2.7	1.0
Copper	5.6	5.9	10.8	NR(5)	NR(6)	NR(11)	7.4	7.2
Fluoride	-- [c]	-- [c]	-- [c]	6,220	4,900	4,350	5,160	2,390
Lead	4.4	8.3	-- [d]	NR(0.8)	NR(0.9)	NR(1.6)	6.4	25
Manganese	8.3	12.2	14.0	NR(3)	NR(3)	NR(5)	11	7.2
Mercury [e]	0.047 [b]	0.071	0.169	1.4	1.7	0.72	1.4	1.2
Molybdenum	4.0 [b,f]	6.7 [b,f]	11 [b,f]	NR(13)	NR(15)	NR(27)	7.2	9.0
Nickel	6.2	7.8	9.7 [b]	NR(5)	NR(6)	NR(11)	7.9	4.4
Phosphorus	-- [c]	-- [c]	-- [c]	NR(18)	NR(16)	NR(16)	-- [c]	--
Selenium	71	106	89	4.2 [b]	18	23 [b]	104	50
Vanadium	15	21	20 [b]	NR(5)	NR(6)	NR(11)	19	7.5
Benzene	--	--	--	NR(1)	2.8	NR(0.6)	1.2	3.6
Formaldehyde	--	--	--	NR(7)	NR(7)	NR(7)	NR(7)	--
Toluene	--	--	--	18	1.0 [b]	2.1 [b]	7.0	24

[a] NR = Below reporting limit. Reporting limit is shown in parentheses.
[b] Denotes concentration less than five times the reporting limit.
[c] Not measured because of the small amount of particulate available for analysis.
[d] Lead concentration from Run 3 is unreasonably high and was not included in determining the average stack concentration.
[e] The reported vapor phase mercury concentrations are suspected to be low. Problems were encountered in analyzing these samples (see discussion in Section 4).
[f] Blank correction is greater than 50% of measured concentration.

Table 3-3b

Stack Gas Emission Factors (lb/10^{12} Btu Unless Noted)

Substance	Average Emission Factor	95% CI of Mean
Gas Flow (scfm)	1,160,000	38,000
Particulate (lb/hr)	152	67
Particulate (lb/MM Btu)	0.028	0.012
Arsenic	13	5.3
Barium	34	10
Beryllium	0.4	0.03
Cadmium	3.1	9
Chloride	46,700	7,640
Chromium	12	15
Cobalt	2.0	0.8
Copper	5.5	5.4
Fluoride	3,850	1,770
Lead	4.3	4.1
Manganese	8.6	5.4
Mercury	NC [a]	NC [a]
Molybdenum	5.3	6.7
Nickel	5.9	3.3
Phosphorus	NC [b]	NC [b]
Selenium	77	38
Vanadium	14	5.7
Benzene	0.8	2.7
Formaldehyde	NR(5) [c]	--
Toluene	5.2	18

[a]NC = Not calculated. The reported vapor phase mercury concentrations are suspected to be low. Problems were encountered in analyzing these samples (see discussion in Section 4).

[b]NC = Not calculated. Phosphorus in stack gas solids was not measured.

[c]NR = Below reporting limit. Reporting limit is shown in parentheses.

been below the reporting limit during the first two tests. Copper and chromium values for Run 3 are twice as high as in the first two runs; however, this is not considered to be an inordinate amount of variability. Again, the molybdenum values are considered suspect because of analytical interferences, as discussed in Section 4.

The small sample size of the emitted particulate matter precluded direct analysis for chloride, fluoride, and phosphate (particulate matter was analyzed for trace elements).

ESP Performance

Table 3-4 presents the average removal efficiency of the ESP calculated for various substances. The flow rates at the ESP inlet and stack gas were not equal (the inlet was about 85% of the stack flow) because of the in-leakage of air, so the concentrations in Tables 3-2 and 3-3a cannot be used directly to calculate removal efficiency. Instead, the mass flow rates of each substance in the ESP inlet gas and stack gas were calculated using the respective gas flow rates. These mass flow rates were then used to compute the removal efficiencies shown in Table 3-4.

The average particulate removal efficiency is 99.6 percent. Most of the trace elements are also removed quite effectively.

Other Species of Interest

Other chemicals not on the FCEM list (Table 1-1) which are listed in Title III of the CAAA of 1990 were also measured. These concentrations are listed in Appendix C. Measurements in which concentrations for at least one run were above the reporting limits are summarized in Table 3-5.

Phenol was reported in only one of three samples in both the ESP inlet gas and the stack gas. The phenol concentration of 77 $\mu g/Nm^3$ reported in the ESP inlet gas during Run 1 appears inordinately high, since the concentrations were either below the reporting limits of 6-10 $\mu g/Nm^3$ or close to these limits (9.0 $\mu g/Nm^3$ in the stack gas during Run 2) in both the ESP inlet gas and the stack gas. Although the phenol level of 77 $\mu g/Nm^3$ appears to be an outlier, in the absence of any other confirming data, this data point was not excluded when calculating the mean phenol concentration.

Table 3-4

ESP Removal of Selected Substances

Substance	Removal
Particulate	99.6%
Arsenic	99.8%
Barium	99.5%
Beryllium	99.1%
Cadmium	NC
Chloride	0*
Chromium	99.0%
Cobalt	99.5%
Copper	99.1%
Fluoride	0*
Lead	99.5%
Manganese	99.5%
Mercury	NA
Molybdenum	99.7%
Nickel	99.1%
Phosphorus	NC
Selenium	35.4%
Vanadium	99.2%
Benzene	80.6%
Formaldehyde	NC
Toluene	0*

*Calculated values were negative. Zero percent removal efficiency is shown in table.

NC = Not calculated (below reporting limit or not measured in either ESP inlet or stack).

NA = Not available. The reported vapor phase mercury concentrations are suspected to be low. Problems were encountered when analyzing these samples (see discussion in Section 4).

Table 3-5

Other Species of Interest

	μg/Nm³				
ESP Inlet	**Run 1**	**Run 2**	**Run 3**	**Mean**	**95% CI of Mean**
Substance					
Phenol	77	NR(7.2)[a]	NR(6.1)	28	106
Acrolein	21	NR(10)	NR(11)	NR(11)	--
Ethyl Benzene	1.1[b]	0.79[b]	1.4[b]	1.1[b]	0.76
m,p-Xylene	4.6	3.2	6.2	4.7	3.7
o-Xylene	1.0[b]	0.73[b]	2.2[b]	1.3[b]	1.9
Stack Gas					
Substance					
Phenol	NR(9.9)	9.0[b]	NR(6.0)	NR(9.9)	--
m,p-Xylene	13	0.67[b]	1.4[b]	5.0	17

[a]NR = Below the reporting limit. Reporting limit is shown in parentheses.

[b]Denotes a value less than five times the reporting limit.

Section 4

DATA ASSESSMENT

Several procedures can be used to evaluate the information developed during a field sampling program. Within the overall FCEM program, three methods are used to assess data quality. The first is the use of material balances. If closure of a substance material balance can be made within an acceptable percentage, the measurements that have been made should be representative of the process operation. Since material balances involve the summation and comparison of component mass flows in several streams, often sampled by different procedures and analyzed by different methods, good agreement indicates either accurate results or a statistically improbable degree of luck. The second data assessment method involves the traditional QA/QC protocols of laboratory analysis, i.e., duplicates, blanks, spike recovery, etc. For some elements, it is not possible to obtain a material balance, perhaps because of low concentration levels, so that QA/QC results are the only way to verify that the measurements were performed correctly. Finally, current results can be compared with literature information, where available.

Material Balance Results

At Site 15, four key streams define the overall plant material balance: coal, bottom ash, collected fly ash, and stack gas. For substances of interest, stream flow and concentration distributions (average and standard deviation) were used as the input to an error propagation model to estimate the uncertainty in the overall material balance closure. Closure is defined as the ratio of outlet to inlet mass. A 100% closure indicates perfect agreement. When trace substances are analyzed, a closure between 70 and 130% has been set as a goal for the FCEM project. This range reflects the typical level of uncertainty in the measurements and, therefore, permits one to interpret the inlet and outlet stream component mass flow rates as being statistically equivalent. Poor closures usually indicate measurement problems in one or more types of sample matrices. However, poor closures do not necessarily mean that emissions measurements are in error. Since the emission rate of many substances is less than 1% of the mass entering with the coal, the material balance closure is controlled by measurements of coal, bottom ash, and collected fly ash.

Table 4-1 presents the results of the material balance error propagation analysis. The detailed calculations are presented in Appendix E. All of the substances present at fairly high concentrations in the coal show closures in the desired range (aluminum, calcium, iron, magnesium, potassium, magnesium, sodium, titanium). This indicates that the flow rates for the streams and the chemical analyses for these substances are probably accurate.

Table 4-1

Material Balance Closure and Uncertainty

Substance	Closure	Uncertainty
Aluminum	111%	±8.7%
Arsenic	65%	±40%
Barium	74%	±52%
Beryllium	98%	±30%
Calcium	79%	±20%
Chloride	70%	±14%
Chromium	77%	±26%
Cobalt	106%	±30%
Fluoride	65%	±24%
Iron	81%	±44%
Lead	280%	±57%
Magnesium	83%	±7.8%
Manganese	109%	±18%
Mercury	26%*	±17%*
Phosphorus	101%	±19%
Potassium	124%	±45%
Selenium	78%	±23%
Sodium	96%	±27%
Titanium	112%	±18%
Vanadium	97%	±37%

*Measured mercury concentrations in the gas streams are considered to be unreliable because of difficulties encountered during analysis. For this reason, the calculated material balance closure is highly questionable.

The closures for some substances could not be calculated because their concentrations were not reported in a key stream. For example, cadmium, copper, nickel, and molybdenum were not reported in the coal; therefore, material balances could not be developed for these substances. For those substances showing closures between 70 and 130%, the data are considered valid and no further discussion is presented (barium, beryllium, chloride, chromium, cobalt manganese, phosphorus, selenium, and vanadium). Substances that did not or could not show acceptable closures, and the organic substances measured, are discussed below. Material balances were not attempted for organic species, since these species are not necessarily conserved in the plant (i.e., they can be created or destroyed by reaction as they pass through the plant).

Substance Discussion

Although closures are outside the desired range for some substances, the uncertainty associated with the closure is typically large and often encompasses 100 percent. For most substances the data are adequate in terms of describing the operation of Site 15. Those substances for which material balance closures are outside the 70 to 130% acceptable range, or for which material balances were not developed, are discussed below.

Arsenic

As shown in Table 4-1, the closure for arsenic is 65 $\pm$ 40 percent. The major contributors to the uncertainty are variabilities in the coal and fly ash compositions. An average closure under 100% indicates that the coal concentration is high and/or that the ash levels are low, since arsenic was not detected in the vapor phase of the stack gas. We suspect that the ash values are low, although the confidence interval includes 100% closure.

Arsenic concentrations in coal were measured using a fusion technique followed by HGAA and by NAA. The averages of the results were similar for these two methods, but there was much more variability in the NAA results (range from <5 to 23 mg/kg) than in the fusion/HGAA results.

All collected fly ashes and all bottom ashes were analyzed for arsenic by microwave digestion followed by both HGAA and GFAA. Only HGAA was used to analyze suspended ash (particulate matter entering the ESP) and emitted particulate (filter solids in the stack). One fly ash and one bottom ash sample were analyzed by NAA for method confirmation.

The bottom ash reporting limits were 5 mg/kg for microwave digestion HGAA and 4 mg/kg for GFAA and NAA. The arsenic concentration was below the reporting limit for all bottom ash samples analyzed. Because arsenic was not reported in the bottom ash using any of the three analytical procedures, we believe that the true value is less than 5 mg/kg.

The arsenic concentration in collected fly ash samples measured by HGAA averaged 10 mg/kg, which is slightly above the reporting limit of 5 mg/kg. Matrix spike recoveries were near 40%, and the arsenic recovery in the NBS standard fly ash was 85 percent. The arsenic recovery in a blind performance evaluation sample was only 8.3%, indicating a severe bias. One set of duplicate arsenic analyses in collected fly ash differed by 83 percent. Therefore, the HGAA analysis is suspect for not only the collected fly ash but also the ESP inlet and stack particulate matter.

The average arsenic concentration in collected fly ash measured by GFAA was 96 mg/kg which agrees very well with the NAA confirmation sample value of 97 mg/kg. The analytical value for suspended fly ash (i.e., particulate matter in the ESP inlet gas) should be essentially identical in composition to the collected fly ash. However, using HGAA, an average value of 14 mg/kg was reported for the suspended ash. Therefore, the GFAA values for the collected fly ash analysis were used to calculate the solid-phase arsenic level in the ESP inlet gas shown in Tables 3-2a and 3-2b.

There was a significant enrichment of arsenic seen in the emitted particulate matter (average arsenic concentration of about 500 mg/kg) using HGAA. The small sample volume precludes the use of alternative analytical methods to verify this value. Although HGAA did not produce acceptable results at lower concentrations in the bulk ash samples, at higher levels it may be suitable. Therefore, the stack gas particulate concentration is suspect, although no data exist from which to calculate a better value.

In both the ESP inlet and stack gas streams, the concentration of arsenic present in a vapor state was less than the reporting limit of about 1-14 $\mu g/Nm^3$.

Cadmium

An overall material balance could not be performed for cadmium because concentrations were below analytical reporting limits in the coal (using NAA) and in fly ash and bottom ash (using microwave digestion and GFAA). However, the cadmium mass rates in the emitted particulate matter could be measured. The calculated mass rate in the stack gas (solids) is on the order of 3 lb/trillion Btu of coal input to the boiler. With this low emission rate, additional efforts to quantify the incoming cadmium concentrations may not be warranted. The estimated coal concentration equivalent to this emission rate is 0.03 mg/kg.

Copper

The copper material balance could not be calculated because the copper concentration in the coal was below the NAA reporting limit (90 mg/kg). Copper concentrations in ashes indicated that the coal copper concentration should be 10% or less of the NAA reporting limit. No vapor phase copper was detected at levels of 5 to 11 $\mu g/Nm^3$ in the ESP inlet or stack gas streams.

Fluorine

The overall fluoride material balance closure was 65 ± 24 percent. However, the coal concentration values were less than five times the reporting limit, so the input mass is uncertain. Gas phase fluoride measured concentrations at the ESP inlet were lower than measured levels in the stack. This is not physically possible. Some concerns about the HF capture efficiency in the impingers were raised, but subsequent testing at a different site indicated that HF is effectively trapped in the anion train's impingers.

Appendix E contains information about the contribution of each stream to the fluorine material balance uncertainty.

Lead

The overall material balance for lead was 280 ± 57 percent. Analytical quality control data for the laboratory control sample and matrix spike recoveries do not indicate serious positive or negative interferences with either the coal or ash analyses. However, the lead recovery for the blind performance evaluation sample was 179%, indicating a possible positive interference. It is also possible that variations in lead concentrations in the feed coal were not adequately represented by the ash samples collected.

Mercury

The overall material balance closure for mercury was 26 ± 17 percent. However, it was discovered during later sampling efforts that a significant portion of the mercury present in the sampled gas was collected in the nitric acid impingers of the multi-metals sampling train. The contents of these impingers were not analyzed properly because insufficient permanganate (which reacts with hydrogen peroxide in the impinger solution) was added prior to analysis by CVAAS). Thus, the reported vapor phase mercury levels are believed to be lower than the actual concentrations. (At some subsequent test sites, the mercury balance closures have still been low, even when correct analytical procedures were used for impinger solutions. There remains a possibility that measured mercury concentrations in coal samples are high.)

Molybdenum

The molybdenum concentration in coal is below the NAA reporting limit (1.5 mg/kg). This reporting limit is near the low end of coal molybdenum concentrations reported for this coal type in the PISCES database. In addition, internally consistent analytical data could not be obtained for molybdenum in any of the ash streams prepared by microwave digestion and analyzed by ICP-AES. Molybdenum recovery from the NBS (NTIS) 1633a Standard Reference Material (coal fly ash) analyzed with the Site 15 samples was over 1000 percent. This bias can be attributed to spectral interferences from aluminum and iron in the ash matrix. The concentrations reported were less than five times the analytical reporting limit and less than three times the level in the digestion blank. The multi-element ICP-AES method developed for hazardous waste incinerators is not suited

for measuring low molybdenum concentrations in coal ash matrices. It is probable that similar interferences would be observed if coal were digested and analyzed by ICP-AES. Alternative methods should be identified for analysis of molybdenum in coals and their associated ashes.

Analysis by another analytical technique such as NAA can also be used to identify a systematic bias resulting from such a procedure. For the purposes of this study, one fly ash sample and one bottom ash sample were submitted for analysis by a standard NAA method for ashes. The molybdenum concentrations measured were below the NAA reporting limits; however, this reporting limit is an order of magnitude lower than the concentrations measured by ICP-AES (NR(11) mg/kg for NAA versus 160 mg/kg for ICP-AES). Therefore, the particulate phase molybdenum concentrations measured in the ESP inlet and outlet streams and presented in Tables 3-2 and 3-3 may be significantly higher (by as much as an order of magnitude) than the actual concentrations, since they are based on ICP-AES results. The amount of molybdenum in these streams is relatively small, however, compared to the quantities present in the ash streams. Thus, the effect on the material balance of biased molybdenum concentrations in the gas stream is small.

Benzene

Benzene was reported at 5-6 $\mu g/Nm^3$ in all three samples from the ESP inlet. It was only reported once at 2 $\mu g/Nm^3$ in the stack (2 values at <0.5 $\mu g/Nm^3$). No reason is evident for this apparent decrease across the ESP.

Toluene

Toluene was reported at 6 to 7 $\mu g/Nm^3$ at both the ESP inlet and stack for all six samples.

Formaldehyde

Formaldehyde levels were below reporting limits of about 7 $\mu g/Nm^3$ in any gas samples.

POMs

No polycyclic organic compounds, including polynuclear aromatic hydrocarbons (PAHs), were identified in any gas stream.

Section 5

EXAMPLE CALCULATIONS

This section presents the methodology and sample calculations used to develop the results presented in Sections 3 and 4. Specifically, the calculation of stream flow rates, unit-energy basis results, mean values, and confidence intervals are presented.

Stream Flows

Appendix D contains information about the stream flows measured or calculated at Site 15 during the sampling period. After receiving data from the laboratory on stream compositions, it became evident that not all of the measurements were consistent. Therefore, to present more accurately the distribution of substances, some realistic simplifications have been made where appropriate. Several flows have been used as measured, since there is no alternative method for determining them short of performing design basis calculations. These flows include the coal feed rate (taken from plant totalizers), the stack gas flow rate (measured during testing), and the bottom ash generation rate (estimated by truck weights during testing). Using these three flow rates and appropriate concentration measurements, a set of consistent stream flows were determined.

There were two stream flow rates that were very difficult to measure at Site 15: the ESP inlet ash flow rate and the collected fly ash flow rate. The collected fly ash was sluiced from hoppers on an irregular cycle. Since hopper volume varied, it was impossible to determine this flow directly. Similarly, the gas entering the ESP has a high dust load. The duct used for sampling was horizontal, which required vertical probe traverses. It is likely that stratification occurs both vertically and horizontally in the short transition duct between the air preheater and the ESP. As shown in Figure 2-2, only six of some 30 ports were used for sampling. Therefore, the corresponding gas flow and grain loading measured at this location could be unrepresentative. However, vapor phase samples and the composition of the ash collected were assumed to be unaffected by this potential bias. Since ash is a major source of most trace substances, a balanced ash distribution was used to estimate several flow rates. Table 5-1 presents the measured and calculated distribution of ash at Site 15 using data from October 23, 1990 (Run 1). The coal ash concentration multiplied by the coal consumption rate gives the total ash input. As described earlier, the bottom ash rate was measured by weighing trucks that were moving bottom ash to storage during the test period. By, difference, the suspended ash concentration can be calculated as 39,520 lb/hr, versus 45,600 lb/hr measured in the duct. Both the bottom ash and fly ash contained some material which was "lost on ignition", i.e., unburned carbon; therefore, a small adjustment was made in these streams to determine

Table 5-1

Ash Distribution for Run 1

Stream	Ash Concentration	Stream Flow (lb/hr) Measured	Stream Flow (lb/hr) Calculated	Ash Flow (lbs/hr)
Coal	12.9%	412,000		53,070
Bottom Ash	92%	16,930		15,480
Suspended Ash	96%		39,520	37,590
Emitted Particulate	100%	158		158
Collected Fly Ash	96%		38,990	37,430

the true "ash" flow. The grain loading measured at the stack was then subtracted from suspended ash to provide the collected fly ash rate. This calculation was duplicated for each test period. Average flows and standard deviations were used to perform the material balance calculations detailed in Appendix E.

The gas flow rates at the ESP inlet were calculated from the stack gas flow rates and the oxygen concentrations at the two locations. This was done because the measured flow rates at the ESP inlet were inconsistent with those measured at the stack, and the stack measurements were considered the more accurate. The ESP inlet flow rate was measured from duct ports located considerably less than the desired ten diameters upstream or two diameters downstream of flow disturbances.

A calculation was made for each run. For example, for Run 2, the stack gas flow rate was 1,170,000 dscfm, while the oxygen content was 9 percent. The ESP inlet oxygen content of 7% indicates a 15% in-leakage of air between the two locations. Therefore, the ESP inlet flow rate is calculated to be 85% of the stack flow rate, or 1,000,000 dscfm.

The calculation of the ESP inlet gas compositions shown in Table 3-2 requires the addition of the solid phase and gas phase concentrations. The gas phase concentrations were obtained by direct measurement, with the laboratory analysis of the collection impingers providing the total collected mass of a vapor phase substance, which is then divided by the gas volume measured during the sampling. The solid phase component of the gas stream was calculated by multiplying the ash elemental concentration (either suspended or emitted particulate matter) by the ash mass rate (calculated for suspended ash, measured for emitted ash) and dividing by the respective volumetric gas flow rate (ESP inlet or stack).

For example, the barium concentration in the suspended ash for Run 1 is 870 mg/kg. The ash flow, from Table 5-1, was 39,500 lb/hr, which gives a barium mass flow of 15.6 kg/hr. The ESP inlet gas flow for Run 1, corrected for the oxygen concentration, was 896,000 dscfm, which is equal to 1,440,000 Nm^3/hr (35.3 ft^3/m^3, 1.057 temperature correction). Dividing the mass rate by the gas flow produces the solid phase gas concentration of 10,800 $\mu g/Nm^3$ shown in Table 3-2. The vapor phase concentration is found directly in Appendix B as <5 $\mu g/Nm^3$.

The emitted particulate contribution to the stack emissions is obtained in the same fashion. However, instead of calculating the solids mass rate, the grain loading obtained during the testing is used. For Run 1, a mass of 158 lb/hr of particulate matter was emitted. The elemental barium concentration of 1,020 mg/kg in the particulate results in a mass flow of 0.073 kg/hr, which divided by the stack flow (1,140,000 dscfm = 1,800,000 Nm^3/hr), produces a concentration of 40 $\mu g/Nm^3$, as shown in Table 3-3a.

Unit Energy Calculation

In addition to the gas phase concentrations, a unit-energy basis emission rate has also been developed for each substance. These emission rates were determined by using the

average mass flow of a substance (as developed above) and dividing by the heat input to the boiler during testing. The heat input was obtained from the coal flow rate and the average higher heating value (HHV) of the fuel.

The average coal mass rate was 419,000 lb/hr with a HHV of 13,000 Btu/lb, for a heat input of 0.00545×10^{12} Btu/hr. Using arsenic as an example, the average stack gas flow of 1,160,000 scfm (1,830,000 Nm^3/hr) multiplied by the arsenic concentration of 18 $\mu g/Nm^3$ is equal to 0.073 lb/hr. Dividing by the heat input produces the average arsenic emission factor of 13 $lb/10^{12}$ Btu shown in Table 3-3b.

Example calculations of confidence intervals are presented in Appendix E.

Section 6

GLOSSARY

Btu	British Thermal Unit
CAAA	Clean Air Act Amendments
CFBC	Circulating Fluidized Bed Combustion
CVAAS	Cold Vapor Atomic Absorption Spectroscopy
DGA	Double Gold Amalgamation
dNm^3	Dry Normal Cubic Meter
DQO	Data Quality Objectives
dscfh	Dry Standard Cubic Feet per Hour
ESP	Electrostatic Precipitator
FCEM	Field Chemical Emissions Monitoring
GFAAS	Graphite Furnace Atomic Adsorption Spectroscopy
HGAAS	Hydride Generation Atomic Absorption Spectroscopy
HHV	Higher Heating Value
IC	Ion Chromatography
ICP (ICAP, ICAPES, ICP-AES)	Inductively Coupled Argon Plasma Emissions Spectroscopy
ID	Induced Draft
MDL	Method Detection Limit
MSD	Matrix Spike Duplicate
NAA	Neutron Activation Analysis
NBS	National Bureau of Standards
NC	Not Calculated
NR	Not Reported (below reporting limit)
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
TNMHC	Total Non-Methane Hydrocarbons
VOC	Volatile Organic Compound
VOST	Volatile Organic Sampling Train

Appendix A

Detailed Sample Collection/Preparation/Analysis Tables

Table A-1

Sample Collection, Preservation, and Handling Techniques for Site 15

Stream	Collection Method	Fraction Description	Sample Handling & Preservation	Comments
FLUE GAS				
ESP Inlet	SW 0030	VOST	Cooled to 4° C	Analyzed for volatile organic compounds.
	SW 0010	MM5-Thimble	Cooled to 4° C	Analyzed for semivolatile organic compounds.
		MM5-XAD Resin	Cooled to 4° C	
		MM5-PNR/Condensate	Cooled to 4° C	
	EPA Draft Method	"Metals" Probe and Nozzle Rinse	Acetone portion dried and weighed; nitric acid portion sealed and kept at ambient temperature.	Subsamples of the acetone probe and nozzle rinse were digested with a proportional subsample of the nitric acid probe and nozzle rinse, and the digest analyzed for "metals".
		"Metals" Filter	Desiccated at room temperature to constant weight.	A 0.100 g subsample of the filter catch was digested and analyzed for "metals".
		"Metals" - Impinger 1 & 2	Sealed and kept at ambient temperature.	Analyzed for "metals" except mercury.
		"Metals" - Impinger 3 & 4	Sealed and kept at ambient temperature.	Mercury analysis only.
	SW 0011	Formaldehyde Impinger	Rinsed with $MeCl_4$; cooled to 4° C.	Analyzed for aldehydes.
	Radian Method	Anion Train	Sealed and kept at ambient temperature.	Analyzed for chloride, fluoride, total P, and total S.
Stack	SW 0030	VOST	Cooled to 4° C.	Analyzed for volatile organic compounds.
	SW 0010	MM5-Filter	Cooled to 4° C.	Analyzed for semivolatile organic compounds.
		MM5-XAD Resin	Cooled to 4° C.	
		MM5-PNR/Condensate	Cooled to 4° C.	
	EPA Draft Method	"Metals" Probe and Nozzle Rinse	Acetone portion dried and weighted; nitric acid portion sealed and kept at ambient temperature.	Entire filter digested and combined with digested probe and nozzle rinses, and combined digest analyzed for "metals".
		"Metals" Filter	Desiccated at room temperature to constant weight.	
		"Metals" - Impinger 1 & 2	Sealed and kept at ambient temperature.	Analyzed for "metals" except mercury.
		"Metals" - Impinger 3 & 4	Sealed and kept at ambient temperature.	Mercury analysis only.
	SW 0011	Formaldehyde Impinger	Rinsed with $MeCl_4$; cooled to 4° C.	Analyzed for aldehydes.
	Radian Method	Anion Train	Sealed and kept at ambient temperature.	Analyzed for chloride, fluoride, total P, and total S.

Table A-1

(Continued)

Stream	Collection Method	Fraction Description	Sample Handling & Preservation	Comments
WATER, INCLUDING AQUEOUS PHASE OF SLURRIES				
Fly Ash Slurry Water	Decanted & Filtered	"Metals" Cl, F, SO_4 Total P	Nitric acid to pH <2 None Sulfuric acid to pH <2	Three samples of approximately three gallons each were taken during the sampling period and composited. Solids were allowed to settle before siphoning and filtering the water phase.
Bottom Ash Water	Decanted	"Metals" Chloride Fluoride Sulfate Total P	Nitric acid to pH <2 Thiosulfate HNO_3 to pH = 3 HNO_3 to pH = 3 Sulfuric acid to pH <2	Bottom ash sluice water was collected during active sluice periods that represented the gas tests. Ten gallon samples were collected and treated the same as fly ash sluice samples.
Service Water	Grab	"Metals" Chloride Fluoride Sulfate Total P	Nitric acid to pH <2 Thiosulfate HNO_3 to pH = 3 HNO_3 to pH = 3 Sulfuric acid to pH <2	Single grab samples during gas tests.
Treated Fly Ash Sluice Water (WE)	Grab	"Metals" Cl, F, SO_4 Total P	Nitric acid to pH <2 None Sulfuric acid to pH <2	Single grab samples.
Treated Bottom Ash Sluice Water (PO)	Grab	"Metals" Cl, F, SO_4 Total P	Nitric acid to pH <2 None Sulfuric acid to pH <2	Single grab samples.
SOLIDS, INCLUDING SOLID PHASE OF SLURRIES				
Coal	Grab/Composite	Ultimate Proximate "Metals" Cl, F, P	Kept in sealed container; submitted "as collected".	Multiple grab samples collected during the test period were composited directly into buckets and riffled to reduce sample size.
Bottom Ash Solids	Grab/Composite	"Metals" Cl, F Total P Total S	Placed in sealed container in field; dried at 105° C before analysis.	Grab samples composited from bottom ash trucks. Ash was sent to sample preparation for drying, grinding, and splitting.
Fly Ash Solids	Grab/Composite	"Metals" Cl, F Total P Total S	Placed in sealed container in field; dried at 105° C before analysis.	Same as bottom ash.

*U.S. Environmental Protection Agency, Environmental Monitoring Branch. "Methodology for the Determination of Metals Emissions in Exhaust Gases from Incineration Processes." Draft, October 1989.

Table A-2

Preparation Procedures and Chemical Analysis Methods Applied to Coal at Site 15

Component	Method Reference	Coal
ULTIMATE ANALYSIS OF COAL		
Ash	ASTM D 3174	X
Carbon	ASTM D 3178	X
Hydrogen	ASTM D 3178	X
Nitrogen	ASTM D 3179	X
Sulfur	ASTM D 4239	X
Heating Value	ASTM D 2015	X
PROXIMATE ANALYSIS OF COAL		
Moisture	ASTM D 3173	X
Ash	ASTM D 3174	X
Volatiles	ASTM D 3175	X
Fixed Carbon	Calculated	X
FCEM TARGET ELEMENTS BY INAA		
Preparation		None
Analysis by INAA		
Arsenic	Karr, Chapters 12 and 46	X
Barium	Karr, Chapters 12 and 46	X
Cadmium	Karr, Chapters 12 and 46	X
Chromium	Karr, Chapters 12 and 46	X
Chlorine	Karr, Chapters 12 and 46	X
Cobalt	Karr, Chapters 12 and 46	X
Copper	Karr, Chapters 12 and 46	X
Manganese	Karr, Chapters 12 and 46	X
Mercury	Karr, Chapters 12 and 46	X
Molybdenum	Karr, Chapters 12 and 46	X
Nickel	Karr, Chapters 12 and 46	X
Selenium	Karr, Chapters 12 and 46	X
Vanadium	Karr, Chapters 12 and 46	X

Table A-2

(Continued)

Component	Method Reference	Coal
BERYLLIUM, AND LEAD ANALYSIS IN COAL		
Preparation		
Oxygen Bomb Combustion	ASTM D 3684	X
Mixed Acid Residue Digestion	Lindahl and Bishop	X
Analysis by ICP-AES		
Beryllium	SW 6010	X
Analysis by GFAA		
Lead	SW 7421	X
ARSENIC AND SELENIUM ANALYSIS IN COAL		
Preparation		
Eschka Mixture Fusion	ASTM D 4606	X
Analysis by HGAA		
Arsenic	ASTM D 4606	X
Selenium	ASTM D 4606	X
CHLORINE AND FLUORINE ANALYSIS IN COAL		
Preparation		
Oxygen Bomb Digestion	ASTM D 2361/ASTM D 3761	X
Analysis by Ion Chromatography		
Chloride	SM 407C	X
Analysis by Ion Selective Electrode		
Fluoride	ASTM D 3761	X
TOTAL PHOSPHORUS ANALYSIS IN COAL		
Preparation		
Ash and Acid Digestion	ASTM D 2795	X
Spectrophotometric Analysis		
Total P, Spectrophotometric	ASTM D 2795	X
MERCURY ANALYSIS IN COAL		
Preparation		
Double Amalgamation	Karr, Chapter 14	X
Analysis by CVAA		
Mercury	Karr, Chapter 14	X

Table A-2

(Continued)

Component	Method Reference	Coal
ADDITIONAL INORGANIC ANALYTES IN COAL		
Preparation		None
Analysis by INAA		
Aluminum	Karr, Chapters 12 and 46	X
Calcium	Karr, Chapters 12 and 46	X
Iron	Karr, Chapters 12 and 46	X
Magnesium	Karr, Chapters 12 and 46	X
Potassium	Karr, Chapters 12 and 46	X
Sodium	Karr, Chapters 12 and 46	X
Titanium	Karr, Chapters 12 and 46	X
Zinc	Karr, Chapters 12 and 46	X

Karr, C. Jr., (ed)., "Analytical Methods for Coal and Coal Products".

SW is EPA SW-846, "Test Methods for Evaluating Solid Waste".

Lindahl, P.C. and A.M. Bishop. "Determination of Trace Elements in Coal by An Oxygen Bomb Combustion/Atomic Absorption Spectrophotometric Method." Fuel 61, (7), pp. 658-662 (1982).

Table A-3

Preparation Procedures and Chemical Analysis Methods for Inorganic Chemical Components in Non-Coal Solids, Aqueous Streams, and Flue Gas at Site 15

Component	Method Reference	Non-Coal Solids	Aqueous Streams	ESP Inlet Solids	Stack Solids	Metals Impingers 1 & 2	Metals Impingers 3 & 4	Anions Impingers (Combined)
FCEM TARGET ELEMENTS BY ICP-AES								
Preparation								
Water Digestion for ICP-AES	SW 3005		X			X		
MW Digestion for Solids	CEM-FA	X		X				
MW Digestion for Filters	CEM-F				X			
Analysis by ICP-AES								
Barium	SW 6010	X	X	X	X	X		
Beryllium	SW 6010	X	X	X	X	X		
Chromium	SW 6010	X	X	X	X	X		
Cobalt	SW 6010	X	X	X	X	X		
Copper	SW 6010	X	X	X	X	X		
Manganese	SW 6010	X	X	X	X	X		
Molybdenum	SW 6010	X	X	X	X	X		
Nickel	SW 6010	X	X	X	X	X		
Vanadium	SW 6010	X	X	X	X	X		
FCEM TARGET ELEMENTS BY HGAA								
Preparation								
MW Digestion for Solids	CEM-FA	X		X				
MW Digestion for Filters	CEM-F				X			
Analysis by HGAA								
Arsenic by HGAA	SW 7061	X	X	X	X	X		
Selenium by HGAA	SW 7741	X	X	X	X	X		
FCEM TARGET ELEMENTS BY GFAA								
Preparation								
Water Digestion for GFAA	CLP 3/90 D-5		X			X		
MW Digestion for Solids	CEM-FA	X		X				
MW Digestion for Filters	CEM-F				X			
Analysis by GFAA								
Arsenic	SW 7060	X						

Table A-3

(Continued)

Component	Method Reference	Non-Coal Solids	Aqueous Streams	ESP Inlet Solids	Stack Solids	Metals Impingers 1 & 2	Metals Impingers 3 & 4	Anions Impingers (Combined)
Cadmium	SW 7131	X	X	X	X	X		
Lead	SW 7421	X	X	X	X	X		
MERCURY BY CVAA								
Preparation								
MW Digestion for Solids	CEM-FA	X		X				
MW Digestion for Filters	CEM-F				X			
Analysis by CVAA								
Mercury	SW 7470	X	X	X	X		X	
FCEM ACID-FORMING ANIONS								
Aqueous Extraction of Solids	Radian	X						
Chloride by IC	EPA 300.0	X	X					X
Sodium Hydroxide Fusion	McQuaker and Gurney	X						
Fluoride by SIE	McQuaker and Gurney	X						
Fluoride by SIE	EPA 340.2		X					X
Total P Spectrophotometric	EPA 365.3		X					X
X-Ray Fluorescence for P	ASTM D 4326	X						
ADDITIONAL INORGANIC ANALYTES BY ICP-AES								
Preparation								
Water Digestion for ICP-AES	SW 3005		X			X		
MW Digestion for Solids	CEM-FA	X		X				
MW Digestion for Filters	CEM-F				X			
Analysis by ICP-AES								
Aluminum	SW 6010	X	X	X	X	X		
Calcium	SW 6010	X	X	X	X	X		
Iron	SW 6010	X	X	X	X	X		
Magnesium	SW 6010	X	X	X	X	X		
Potassium	SW 6010	X	X	X	X	X		
Titanium	SW 6010	X	X	X	X	X		
Zinc	SW 6010	X	X	X	X	X		

Table A-3

(Continued)

Component	Method Reference	Non-Coal Solids	Aqueous Streams	ESP Inlet Solids	Stack Solids	Metals Impingers 1 & 2	Metals Impingers 3 & 4	Anions Impingers (Combined)
MAJOR AND MINOR ELEMENTS BY X-RAY FLUORESCENCE								
Aluminum	ASTM D 4326	X						
Calcium	ASTM D 4326	X						
Iron	ASTM D 4326	X						
Magnesium	ASTM D 4326	X						
Potassium	ASTM D 4326	X						
Silicon	ASTM D 4326	X						
Sodium	ASTM D 4326	X						
Titanium	ASTM D 4326	X						
TOTAL SULFUR ANALYSIS								
Sulfate by IC (a)	EPA 300.0		X					X
Total Sulfur by Leco	ASTM D 4239	X		X	X			

ASTM is American Society for Testing and Materials.

EPA is EPA Methods for Chemical Analysis of Water and Wastes, 1983.

SW EPA is SW-846, "Test Methods for Evaluating Solid Waste", 3rd ed.

CEM-FA CEM Corporation, Matthews, NC Procedure for microwave digestion of coal fly ash.

CEM-F CEM Corporation, Matthews, NC Procedure for microwave digestion of glass or quartz filters.

CLP is EPA Contract Laboratory Program SOW 3/90.

McQuaker, N. R., and M. Gurney. "Determination of Total Fluoride in Soil and Vegetation Using An Alkali Fusion-Selective Ion Electrode Technique", Analytical Chemistry, Vol. 49, No. 1, January 1977, pp. 53-56.

Table A-4

Preparation Procedures and Chemical Analysis Methods Used to Measure Organic Chemical Components at Site 15

Component	Method Reference	Flue Gas
VOLATILE ORGANIC COMPOUNDS		
Sample Collection		
VOST	SW 0030	X
Analysis by GC/MS		
Benzene	SW 8240	X
Toluene	SW 8240	X
FORMALDEHYDE		
Sample Collection		
DNPH Impinger [a]	SW 0011	X
Analysis by HPLC		
Formaldehyde	TO5 [b]	X
POLYNUCLEAR AROMATIC ORGANIC COMPOUNDS		
Sample Collection		
MM5	SW 0010	X
Preparation		
Soxhlet Extraction	SW 3540	X
Analysis by GC/MS		
Acenaphthene	SW 8270	X
Acenaphthylene	SW 8270	X
Anthracene	SW 8270	X
Benzo(a)anthracene	SW 8270	X
Benzo(a)pyrene	SW 8270	X
Benzo(b)fluoranthene	SW 8270	X
Benzo(g,h,i)perylene	SW 8270	X
Benzo(k)fluoranthene	SW 8270	X
Chrysene	SW 8270	X
Dibenzo(a,h)anthracene	SW 8270	X
Fluoranthene	SW 8270	X
Fluorene	SW 8270	X
Indeno(1,2,3-cd)pyrene	SW 8270	X

Table A-4

(Continued)

Component	Method Reference	Flue Gas
Naphthalene	SW 8270	X
Phenanthrene	SW 8270	X
Pyrene	SW 8270	X
2-Methylnaphthalene	SW 8270	X
3-Methylcholanthrene	SW 8270	X
7,12-Dimethylbenz(a)anthracene	SW 8270	X

[a]DNPH is 2,4-dinitrophenylhydrazine.

[b]TO5 is EPA Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, EPA 600/4/84/041.

SW is EPA SW-846, "Test Methods for Evaluating Solid Waste".

Appendix B

Data Used in Calculations

Site 15 Data Used in Calculations

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3
ESP inlet gas	1-Chloronaphthalene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	1-Chloronaphthalene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	1-Naphthylamine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	1-Naphthylamine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	1,2-Diphenylhydrazine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	1,2-Diphenylhydrazine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2-Chloronaphthalene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2-Chloronaphthalene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2-Methylnaphthalene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2-Methylnaphthalene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2-Naphthylamine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2-Naphthylamine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	3-Methylcholanthrene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	3-Methylcholanthrene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	3,3'-Dichlorobenzidine	827SSNT1	mg/Nm3	< 0.022423	< 0.014404	< 0.012114
stack gas	3,3'-Dichlorobenzidine	827SSNT1	mg/Nm3	< 0.01977	< 0.011196	< 0.011991
ESP inlet gas	4-Aminobiphenyl	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	4-Aminobiphenyl	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	4-Bromophenyl phenyl ether	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	4-Bromophenyl phenyl ether	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	4-Chlorophenyl phenyl ether	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	4-Chlorophenyl phenyl ether	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	7,12-Dimethylbenz(a)anthracene	827SSNT1	mg/Nm3	< 0.028029	< 0.018006	< 0.015143
stack gas	7,12-Dimethylbenz(a)anthracene	827SSNT1	mg/Nm3	< 0.024713	< 0.013995	< 0.014988
ESP inlet gas	Acenaphthene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Acenaphthene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Acenaphthylene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Acenaphthylene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Aluminum	NAA	ug/g	14462	14797	14407
bottom ash	Aluminum	ICPSSN00	mg/kg	110000	120000	
suspended ash	Aluminum	ICPSSN00	mg/kg	147313.5	151346.3	135577.8
collected fly ash	Aluminum	ICPSSN00	mg/kg	130000	130000	120000
emitted particulates	Aluminum	ICPSSN00	mg/kg	96335.96 R	112286.5 R	160847.5 R
ESP inlet gas, vapor phase	Aluminum	ICPSWN00	mg/Nm3	0.110508 @	< 0.095587	< 0.100818
stack gas, vapor phase	Aluminum	ICPSWN00	mg/Nm3	< 0.050832	< 0.059403	< 0.109132
service water	Aluminum	ICPSWN00	mg/L	0.78 @	0.7 @	0.62 @
ESP inlet gas	Anthracene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Anthracene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Arsenic	HGAA	mg/kg	14.7	10.8	12.4
bottom ash	Arsenic	ASGSSA00	mg/kg	< 4	< 4	
collected fly ash	Arsenic	ASGSSA00	mg/kg	96.2	75.4	78.3
emitted particulates	Arsenic	ASHRSN00	mg/kg	417.1364	499.343	542.3729
ESP inlet gas, vapor phase	Arsenic	ASHRWA00	mg/Nm3	< 0.013924	< 0.011948	< 0.00252
stack gas, vapor phase	Arsenic	ASHRWA00	mg/Nm3	< 0.001271	< 0.001485	< 0.01355
service water	Arsenic	ASHRWA00	mg/L	< 0.005	< 0.005	< 0.005
coal	Ash	Proximat	% dry	12.88059	12.59307	13.10072
coal	Barium	NAA	ug/g	203.83	127.5	252.64
bottom ash	Barium	ICPSSN00	mg/kg	700	740	
suspended ash	Barium	ICPSSN00	mg/kg	870.6956	922.1116	860.1213
collected fly ash	Barium	D4326	mg/kg	1872.209	774.4306	1198.436
emitted particulates	Barium	ICPSSN00	mg/kg	1020.293 R	1189.225 R	1508.475 R
ESP inlet gas, vapor phase	Barium	ICPSWN00	mg/Nm3	< 0.004702	< 0.004779	< 0.005041
stack gas, vapor phase	Barium	ICPSWN00	mg/Nm3	< 0.002542	< 0.00297	< 0.005457
service water	Barium	ICPSWN00	mg/L	0.047 @	0.051	0.051
ESP inlet gas	Benzene	SW 8240	mg/Nm3	0.006233	0.005243	0.006203
stack gas	Benzene	SW 8240	mg/Nm3	< 0.000571	0.002858	< 0.000565
ESP inlet gas	Benzidine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Benzidine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Benzo(a)anthracene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Benzo(a)anthracene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Benzo(a)pyrene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Benzo(a)pyrene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Benzo(b)fluoranthene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Benzo(b)fluoranthene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Benzo(g,h,i)perylene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Benzo(g,h,i)perylene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Benzo(k)fluoranthene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Benzo(k)fluoranthene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Beryllium	ICP	mg/kg	1.3	0.87	0.96
bottom ash	Beryllium	ICPSSN00	mg/kg	5.4 @	5.6 @	
suspended ash	Beryllium	ICPSSN00	mg/kg	5.906956 @	5.101681 @	8.171856 @
collected fly ash	Beryllium	ICPSSN00	mg/kg	9.6 @	8 @	8.6 @
emitted particulates	Beryllium	ICPSSN00	mg/kg	13.52875	13.1406	18.30508 @
ESP inlet gas, vapor phase	Beryllium	ICPSWN00	mg/Nm3	< 0.00094	< 0.000956	< 0.001008
stack gas, vapor phase	Beryllium	ICPSWN00	mg/Nm3	< 0.000508	< 0.000594	< 0.001091
service water	Beryllium	ICPSWN00	mg/L	0.0023 @	< 0.002	0.0021 @
ESP inlet gas	Butylbenzylphthalate	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Butylbenzylphthalate	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Cadmium	NAA	ug/g	< 8.401	< 6.7975	10.449

Site 15 Data Used in Calculations

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3
bottom ash	Cadmium	CDGSSA00	mg/kg	< 1	< 1	
suspended ash	Cadmium	CDGSSA00	mg/kg	< 1	< 1	< 1
collected fly ash	Cadmium	CDGSSA00	mg/kg	< 1	< 1	< 1
emitted particulates	Cadmium	CDGSSA00	mg/kg	33.25817 @R	36.13666 R	316.9492 R
ESP inlet gas, vapor phase	Cadmium	CDGSWA00	mg/Nm3	< 0.00047	0.000529 @	< 0.000504
stack gas, vapor phase	Cadmium	CDGSWA00	mg/Nm3	< 0.000254	< 0.000297	< 0.000546
service water	Cadmium	CDGSWA00	mg/L	< 0.001	< 0.001	< 0.001
bottom ash	Calcium	D4326	mg/kg	7896.697	9029.022	
suspended ash	Calcium	ICPSSN00	mg/kg	10664.86	10080.83	9420.785
collected fly ash	Calcium	D4326	mg/kg	10186.08	8376.917	9904.655
emitted particulates	Calcium	ICPSSN00	mg/kg	12401.35 R	14454.66 R	23050.85 R
ESP inlet gas, vapor phase	Calcium	ICPSWN00	mg/Nm3	0.498795 @	< 0.477934	< 0.50409
stack gas, vapor phase	Calcium	ICPSWN00	mg/Nm3	< 0.254159	< 0.297013	< 0.54566
service water	Calcium	ICPSWN00	mg/L	15	17	16
coal	Carbon	Ultimate	% dry	73.60181	73.206	72.66403
coal	Chloride	CLPMSN00	mg/kg	932	765	894
bottom ash	Chloride	CLPMSN00	mg/kg	99.8 @	90.7 @	
collected fly ash	Chloride	CLPMSN00	mg/kg	47.8 @	104	< 20
ESP inlet gas, vapor phase	Chloride	CLIFWN00	mg/Nm3	69.74213	49.69263	61.99177
stack gas, vapor phase	Chloride	CLIFWN00	mg/Nm3	67.23722	59.03	61.29216
service water	Chloride	CLIFWN00	mg/L	8.23	8.73	8.26
coal	Chromium	NAA	ug/g	28.487	21.764	27.433
bottom ash	Chromium	ICPSSN00	mg/kg	120	130	
suspended ash	Chromium	ICPSSN00	mg/kg	168.1445	163.1379	157.1436
collected fly ash	Chromium	ICPSSN00	mg/kg	160	160	160
emitted particulates	Chromium	ICPSSN00	mg/kg	254.7914 R	270.6965 R	833.8983 R
ESP inlet gas, vapor phase	Chromium	ICPSWN00	mg/Nm3	< 0.004702	< 0.004779	< 0.005041
stack gas, vapor phase	Chromium	ICPSWN00	mg/Nm3	< 0.002542	< 0.00297	< 0.005457
service water	Chromium	ICPSWN00	mg/L	< 0.01	< 0.01	< 0.01
ESP inlet gas	Chrysene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Chrysene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Cobalt	NAA	ug/g	5.8644	4.3854	5.3748
bottom ash	Cobalt	ICPSSN00	mg/kg	39 @	33 @	
suspended ash	Cobalt	ICPSSN00	mg/kg	53.49323	50.88164	47.055 @
collected fly ash	Cobalt	ICPSSN00	mg/kg	47 @	41 @	44 @
emitted particulates	Cobalt	ICPSSN00	mg/kg	56.36979	69.6452	94.91525 @
ESP inlet gas, vapor phase	Cobalt	ICPSWN00	mg/Nm3	< 0.004702	< 0.004779	< 0.005041
stack gas, vapor phase	Cobalt	ICPSWN00	mg/Nm3	< 0.002542	< 0.00297	< 0.005457
service water	Cobalt	ICPSWN00	mg/L	< 0.01	< 0.01	< 0.01
coal	Copper	NAA	ug/g	< 89.808	< 81.061	< 83.107
bottom ash	Copper	ICPSSN00	mg/kg	32 @	32 @	
suspended ash	Copper	ICPSSN00	mg/kg	93.31888 @	88.36046 @	76.30571 @
collected fly ash	Copper	ICPSSN00	mg/kg	74 @	68 @	70 @
emitted particulates	Copper	ICPSSN00	mg/kg	142.0519 R	139.2904 R	359.322 R
ESP inlet gas, vapor phase	Copper	ICPSWN00	mg/Nm3	< 0.009404	< 0.009559	< 0.010082
stack gas, vapor phase	Copper	ICPSWN00	mg/Nm3	< 0.005083	< 0.00594	< 0.010913
service water	Copper	ICPSWN00	mg/L	0.021 @	0.022 @	0.039 @
ESP inlet gas	Dibenzofuran	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Dibenzofuran	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Dibenz(a,h)anthracene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Dibenz(a,h)anthracene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Dibenz(a,j)acridine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Dibenz(a,j)acridine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Diphenylamine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Diphenylamine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Fixed carbon	Proximat	% dry	53.68171	54.38653	54.38296
ESP inlet gas	Fluoranthene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Fluoranthene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Fluorene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Fluorene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Fluoride	F_SESA00	mg/kg	75.6 @	89.7 @	78.6 @
collected fly ash	Fluoride	F_SMSN	mg/kg	23.29 @R	15.11 JR	67.18 R
ESP inlet gas, vapor phase	Fluoride	F_SEWJ	mg/Nm3	5.11251	3.120005	3.033595
stack gas, vapor phase	Fluoride	F_SEWJ	mg/Nm3	6.22095	4.895177	4.349249
service water	Fluoride	F_SEWJ	mg/L	< 0.1	< 0.1	0.0607
ESP inlet gas	Formaldehyde	ALDELKAS	mg/Nm3	< 0.006391	< 0.006648	< 0.007604
stack gas	Formaldehyde	ALDELKAS	mg/Nm3	< 0.00669	< 0.007245	< 0.007005
coal	HHV	HHV	Btu/lb	13132.15	13036.58	12965.86
coal	Hydrogen	Ultimate	% dry	4.99892	4.953059	4.923472
ESP inlet gas	Indeno(1,2,3-cd)pyrene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Indeno(1,2,3-cd)pyrene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Iron	NAA	ug/g	17266	8677.3	14013
bottom ash	Iron	D4326	mg/kg	110938.4	87451.78	
suspended ash	Iron	ICPSSN00	mg/kg	67991.87	70523.87	68935.71
collected fly ash	Iron	D4326	mg/kg	70643.32	71765.78	74068.39
emitted particulates	Iron	ICPSSN00	mg/kg	46223.22 R	70959.26 R	101694.9 R
ESP inlet gas, vapor phase	Iron	ICPSWN00	mg/Nm3	0.014732 @	0.020952 @	< 0.020164
stack gas, vapor phase	Iron	ICPSWN00	mg/Nm3	< 0.010166	< 0.011881	< 0.021826
service water	Iron	ICPSWN00	mg/L	1.7	1.8	1.6

Site 15 Data Used in Calculations

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3
coal	Lead	GFAA	mg/kg	4.6	3.9	3.8
bottom ash	Lead	PBGSSA00	mg/kg	19	20	
suspended ash	Lead	PBGSSA00	mg/kg	113.9892	116.7182	37.89285
collected fly ash	Lead	PBGSSA00	mg/kg	110	110	110
emitted particulates	Lead	PBGSSA00	mg/kg	111.4994 R	195.6636 R	4030.169 R
ESP inlet gas, vapor phase	Lead	PBGSWA00	mg/Nm3	< 0.001411	0.002704 @	< 0.001512
stack gas, vapor phase	Lead	PBGSWA00	mg/Nm3	< 0.000762	< 0.000891	< 0.001637
service water	Lead	PBGSWA00	mg/L	0.014 @	0.0096 @	0.014 @
coal	Magnesium	NAA	ug/g	641.55	677.89	633.42
bottom ash	Magnesium	D4326	mg/kg	3744.448	3921.197	
suspended ash	Magnesium	ICPSSN00	mg/kg	4557.633 @	4573.235 @	4485.928 @
collected fly ash	Magnesium	D4326	mg/kg	4354.602	4171.341	4092.121
emitted particulates	Magnesium	ICPSSN00	mg/kg	4847.802 @	5519.054 @	12203.39 @
ESP inlet gas, vapor phase	Magnesium	ICPSWN00	mg/Nm3	< 0.470184	< 0.477934	< 0.50409
stack gas, vapor phase	Magnesium	ICPSWN00	mg/Nm3	< 0.254159	< 0.297013	< 0.54566
service water	Magnesium	ICPSWN00	mg/L	3.9 @	4.4 @	4.3 @
coal	Manganese	NAA	ug/g	27.749	30.278	26.239
bottom ash	Manganese	ICPSSN00	mg/kg	290	290	
suspended ash	Manganese	ICPSSN00	mg/kg	209.1418	229.4082	240.7643
collected fly ash	Manganese	ICPSSN00	mg/kg	200	220	220
emitted particulates	Manganese	ICPSSN00	mg/kg	211.9504 R	286.4652 R	467.7966 R
ESP inlet gas, vapor phase	Manganese	ICPSWN00	mg/Nm3	0.163475	0.047521	0.478168
stack gas, vapor phase	Manganese	ICPSWN00	mg/Nm3	< 0.002542	< 0.00297	< 0.005457
service water	Manganese	ICPSWN00	mg/L	0.26	0.32	0.31
coal	Mercury	DGA/CVAA	mg/kg	0.16	0.13	0.17
bottom ash	Mercury	HGC_SN00	mg/kg	< 0.045	< 0.045	
suspended ash	Mercury	HGC_SN00	mg/kg	0.582493 @	< 0.18	0.322153 @
collected fly ash	Mercury	HGC_SN00	mg/kg	0.43	0.16 @	0.36
emitted particulates	Mercury	HGC_SN00	mg/kg	1.200676 @R	1.662286 R	5.644068 R
ESP inlet gas, vapor phase	Mercury	HGC_WN00	mg/Nm3	0.000569 #	0.000395 @#	0.000934 #
stack gas, vapor phase	Mercury	HGC_WN00	mg/Nm3	0.001438 #	0.001666 #	0.000719 #
service water	Mercury	HGC_WN00	mg/L	< 0.0002	< 0.0002	< 0.0002
coal	Moisture	Proximat	% as receive	7.38	7.33	6.57
bottom ash	Moisture	oven dry	%	32.3	25.8	
collected fly ash	Moisture	oven dry	%	21.9	20.3	21
coal	Molybdenum	NAA	ug/g	< 1.3658	< 1.1027	< 1.2936
bottom ash	Molybdenum	ICPSSN00	mg/kg	150 @	150 @	
suspended ash	Molybdenum	ICPSSN00	mg/kg	269.1418	264.4815	217.535 @
collected fly ash	Molybdenum	ICPSSN00	mg/kg	160 @	160 @	150 @
emitted particulates	Molybdenum	ICPSSN00	mg/kg	101.4656 @R	157.6873 @R	372.8814 @R
ESP inlet gas, vapor phase	Molybdenum	ICPSWN00	mg/Nm3	< 0.023509	< 0.023897	< 0.025204
stack gas, vapor phase	Molybdenum	ICPSWN00	mg/Nm3	< 0.012708	< 0.014851	< 0.027283
service water	Molybdenum	ICPSWN00	mg/L	< 0.05	< 0.05	< 0.05
ESP inlet gas	Naphthalene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Naphthalene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Nickel	NAA	ug/g	< 19.9	19.785	21.689
bottom ash	Nickel	ICPSSN00	mg/kg	74 @	82 @	
suspended ash	Nickel	ICPSSN00	mg/kg	93.15267 @	88.76328 @	99.30571 @
collected fly ash	Nickel	ICPSSN00	mg/kg	76 @	80 @	81 @
emitted particulates	Nickel	ICPSSN00	mg/kg	157.8354	183.9685	325.4237 @
ESP inlet gas, vapor phase	Nickel	ICPSWN00	mg/Nm3	< 0.009404	< 0.009559	< 0.010082
stack gas, vapor phase	Nickel	ICPSWN00	mg/Nm3	< 0.005083	< 0.00594	< 0.010913
service water	Nickel	ICPSWN00	mg/L	< 0.02	< 0.02	< 0.02
coal	Nitrogen	Ultimate	% dry	1.511553	1.510737	1.498448
ESP inlet gas	N-Nitrosodiphenylamine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	N-Nitrosodiphenylamine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Oxygen	Ultimate	% dry	5.26884	6.194022	6.293482
ESP inlet gas	Particulate matter	Multimetal	mg/Nm3	12500	11000	11200
stack gas	Particulate matter	Multimetal	mg/Nm3	39	42	30
ESP inlet gas	Phenanthrene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Phenanthrene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Phosphorus	D3682-87	ug/g	231	234	232
bottom ash	Phosphorus	D4326	mg/kg	1315.089	1216.197	
collected fly ash	Phosphorus	D4326	mg/kg	2363.588	1886.765	1960.425
ESP inlet gas, vapor phase	Phosphorus	TPOEWJ	mg/Nm3	< 0.016812	< 0.017382	< 0.015701
stack gas, vapor phase	Phosphorus	TPOEWJ	mg/Nm3	< 0.017655	< 0.016412	< 0.015757
service water	Phosphorus	TPOEWJ	mg/L	0.0457 @	0.0457 @	0.051 @
coal	Potassium	NAA	ug/g	< 1701.9	1494.4	2030.9
bottom ash	Potassium	ICPSSN00	mg/kg	14000 @	15000	
suspended ash	Potassium	ICPSSN00	mg/kg	18997.29	18642.23	18822
collected fly ash	Potassium	ICPSSN00	mg/kg	18000	18000	17000
emitted particulates	Potassium	ICPSSN00	mg/kg	18038.33	19710.91	40677.97 @
ESP inlet gas, vapor phase	Potassium	ICPSWN00	mg/Nm3	< 1.410553	< 1.433802	1.371905 @
stack gas, vapor phase	Potassium	ICPSWN00	mg/Nm3	< 0.762476	< 0.89104	< 1.636979
service water	Potassium	ICPSWN00	mg/L	< 3	< 3	< 3
ESP inlet gas	Pyrene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Pyrene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Selenium	HGAA	mg/kg	2	2.17	2.45
bottom ash	Selenium	SEHRSN00	mg/kg	< 5.1	< 5.1	

Site 15 Data Used in Calculations

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3
suspended ash	Selenium	SEHRSN00	mg/kg	14.57633 @	16.88164 @	16.15285 @
collected fly ash	Selenium	SEHRSN00	mg/kg	< 5.1	5.9 @	6.4 @
emitted particulates	Selenium	SEHRSN00	mg/kg	1803.833	2496.715	2983.051
ESP inlet gas, vapor phase	Selenium	SEHRWN00	mg/Nm3	0.005941 @	0.00586 @	0.012782
stack gas, vapor phase	Selenium	SEHRWN00	mg/Nm3	0.004202 @	0.017703	0.023175 @
service water	Selenium	SEHRWN00	mg/L	< 0.005	< 0.005	< 0.005
coal	Sodium	NAA	ug/g	243.32	319.4	297.29
bottom ash	Sodium	D4326	mg/kg	2099.993	1929.55	
collected fly ash	Sodium	D4326	mg/kg	2255.6	2494.529	2198.007
ESP inlet gas, vapor phase	Sodium	ICPSWN00	mg/Nm3	< 0.470184	< 0.477934	< 0.50409
stack gas, vapor phase	Sodium	ICPSWN00	mg/Nm3	< 0.254159	< 0.297013	< 0.54566
service water	Sodium	ICPSWN00	mg/L	8.2	9.8	8.8
ESP inlet gas, vapor phase	Sulfate	SFIFWN00	mg/Nm3	4975.953	4188.311	4898.293
stack gas, vapor phase	Sulfate	SFIFWN00	mg/Nm3	4731.096	4027.804	4726.917
service water	Sulfate	SFIFWN00	mg/L	28.6	35.9	98.9
coal	Sulfur	Ultimate	% dry	1.738285	1.54311	1.519854
bottom ash	Sulfur	D4326	mg/kg	1023.686	743.9866	
collected fly ash	Sulfur	D4326	mg/kg	989.2879	615.5703	765.4815
coal	Titanium	NAA	ug/g	875.68	761.43	863.7
bottom ash	Titanium	D4326	mg/kg	6131.25	6571.352	
suspended ash	Titanium	TIESSN00	mg/kg	7598.916	7656.893	7322.928
collected fly ash	Titanium	D4326	mg/kg	7177.24	7314.741	7104.998
emitted particulates	Titanium	TIESSN00	mg/kg	6583.991 R	7936.925 R	11322.03 R
ESP inlet gas, vapor phase	Titanium	TIESWN00	mg/Nm3	< 0.023509	< 0.023897	< 0.025204
stack gas, vapor phase	Titanium	TIESWN00	mg/Nm3	< 0.012708	< 0.014851	< 0.027283
service water	Titanium	TIESWN00	mg/L	< 0.05	< 0.05	< 0.05
ESP inlet gas	Toluene	SW 8240	mg/Nm3	0.005195	0.003827	0.008788
stack gas	Toluene	SW 8240	mg/Nm3	0.018257	0.001009 @	0.002145 @
coal	Vanadium	NAA	ug/g	36.828	25.589	25.624
bottom ash	Vanadium	ICPSSN00	mg/kg	160	170	
suspended ash	Vanadium	ICPSSN00	mg/kg	251.6351	250.9011	239.7857
collected fly ash	Vanadium	ICPSSN00	mg/kg	230	230	230
emitted particulates	Vanadium	ICPSSN00	mg/kg	390.0789 R	494.0867 R	664.4068 R
ESP inlet gas, vapor phase	Vanadium	ICPSWN00	mg/Nm3	< 0.009404	< 0.009559	< 0.010082
stack gas, vapor phase	Vanadium	ICPSWN00	mg/Nm3	< 0.005083	< 0.00594	< 0.010913
service water	Vanadium	ICPSWN00	mg/L	< 0.02	< 0.02	< 0.02

Key to Data Flags

Flag	Description
@	Less than five times the reporting limit.
B	Reported in blank, not corrected in sample result.
E	Estimated analyte result greater than calibration range.
F	Sample result corrected for nonisokinetic sampling conditions.
I	Updated result.
J	Estimated analyte result less than the detection limit.
NA	Not analyzed.
R	Reported in blank, corrected in sample result.
S	Result obtained by using Method of Standard Additions.
<	Less than the reporting limit.
#	The reported mercury concentrations are suspected to be low due to analytical problems.

Methods Key

Method Code	Method Description
824SWNT1	Gas Chromatography/Mass Spectroscopy
827SSNT1	Gas Chromatography/Mass Spectroscopy
827SWNT1	Gas Chromatography/Mass Spectroscopy
AGESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
ALDELKAS	High Performance Liquid Chromatography
ALESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
ASGSSAOO	Graphite Furnace Atomic Absorption Spectrophotometry
ASHRWAOO	Hydride Generation Atomic Absorption Spectrophotometry
BAESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
BEESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
B_ESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
CAESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
CDGSSAOO	Graphite Furnace Atomic Absorption Spectrophotometry
CDGSWAOO	Graphite Furnace Atomic Absorption Spectrophotometry
CDGSWOOO	Graphite Furnace Atomic Absorption Spectrophotometry
CLIESNOO	Ion Chromatography
CLIFWNOO	Ion Chromatography
COESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
CRESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
CUESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
D2361	Parr Bomb Digestion/Potentiometric Titration
D2795	Parr Bomb Digestion/Visible Spectrophotometry
D3302	Oven Drying
D3761	Parr Bomb Digestion/Ion Selective Electrode
D4326	X-ray Fluorescence

Method Code	Method Description
FEESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
F_SESAOO	Ion Specific Electrode
GFAA	Graphite Furnace Atomic Absorption Spectrophotometry
HGAA	Hydride Generation Atomic Absorption Spectrophotometry
HGC_SNOO	Cold Vapor Atomic Absorption Spectrophotometry
HGC_WNOO	Cold Vapor Atomic Absorption Spectrophotometry
HHV	Adiabatic Bomb Calorimetry
HPLC	High Performance Liquid Chromatography
I39RWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
IC	Ion Chromatography
ICP	Inductively Coupled Argon Plasma Emission Spectrophotometry
ICPSSNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
ICPSWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
K_ESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
MGESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
MNESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
MOESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
NAA	Neutron Activation Analysis
NAESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
NIESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
NaOH FUS	Sodium Hydroxide Fusion/Ion Chromatography
PBGSSAOO	Graphite Furnace Atomic Absorption Spectrophotometry
PBGSWAOO	Graphite Furnace Atomic Absorption Spectrophotometry
PBGSWOOO	Graphite Furnace Atomic Absorption Spectrophotometry
P_ESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry

Method Code	Method Description
PROXIMAT	Oven Drying, Oven Heating, Ignition
SEHRSNOO	Hydride Generation Atomic Absorption Spectrophotometry
SEHRWNOO	Hydride Generation Atomic Absorption Spectrophotometry
SFIFWNOO	Ion Chromatography
SIESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
SNESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
SRESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
S_ESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
TIESSNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
TIESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
TPOESJ	Visible Spectrophotometry
TPOEWJ	Visible Spectrophotometry
TPORSNOO	Visible Spectrophotometry
TTSRSNOO	Leco Total Sulfur Analysis
ULTIMATE	Combustion/Gas Absorption, Digestion/Titration, Ignition
VSTSAOT2	Gas Chromatography/Mass Spectroscopy
V_ESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
ZNESWNOO	Inductively Coupled Argon Plasma Emission Spectrophotometry
AC DISS	Acid Dissolution/Ion Chromatography
AQ	Ion Specific Electrode
IMP	Ion Specific Electrode
OVEN DRY	Oven Drying

Appendix C

Data Not Used In Calculations

Site 15 Data Not Used in Calculations

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3
ESP inlet gas	1,1-Dichloroethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	1,1-Dichloroethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	1,1-Dichloroethene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	1,1-Dichloroethene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	1,1,1-Trichloroethane	SW 8240	mg/Nm3	0.001454 @	0.001625 @	0.002068 @
stack gas	1,1,1-Trichloroethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	1,1,2-Trichloroethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	1,1,2-Trichloroethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	1,1,2,2-Tetrachloroethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	1,1,2,2-Tetrachloroethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	1,2-Dichlorobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	1,2-Dichlorobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	1,2-Dichloroethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	1,2-Dichloroethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	1,2-Dichloropropane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	1,2-Dichloropropane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	1,2,4-Trichlorobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	1,2,4-Trichlorobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	1,2,4,5-Tetrachlorobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	1,2,4,5-Tetrachlorobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	1,3-Dichlorobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	1,3-Dichlorobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	1,4-Dichlorobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	1,4-Dichlorobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2-Butanone	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	2-Butanone	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	2-Chlorophenol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2-Chlorophenol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2-Hexanone	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	2-Hexanone	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	2-Methylphenol(o-cresol)	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2-Methylphenol(o-cresol)	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2-Nitroaniline	827SSNT1	mg/Nm3	< 0.056057	< 0.036011	< 0.030286
stack gas	2-Nitroaniline	827SSNT1	mg/Nm3	< 0.049425	< 0.027991	< 0.029977
ESP inlet gas	2-Nitrophenol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2-Nitrophenol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2-Picoline	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2-Picoline	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2,3,4,6-Tetrachlorophenol	827SSNT1	mg/Nm3	< 0.022423	< 0.014404	< 0.012114
stack gas	2,3,4,6-Tetrachlorophenol	827SSNT1	mg/Nm3	< 0.01977	< 0.011196	< 0.011991
ESP inlet gas	2,4-Dichlorophenol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2,4-Dichlorophenol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2,4-Dimethylphenol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2,4-Dimethylphenol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2,4-Dinitrophenol	827SSNT1	mg/Nm3	< 0.056057	< 0.036011	< 0.030286
stack gas	2,4-Dinitrophenol	827SSNT1	mg/Nm3	< 0.049425	< 0.027991	< 0.029977
ESP inlet gas	2,4-Dinitrotoluene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2,4-Dinitrotoluene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2,4,5-Trichlorophenol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2,4,5-Trichlorophenol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2,4,6-Trichlorophenol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2,4,6-Trichlorophenol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2,6-Dichlorophenol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2,6-Dichlorophenol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	2,6-Dinitrotoluene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	2,6-Dinitrotoluene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	3-Nitroaniline	827SSNT1	mg/Nm3	< 0.056057	< 0.036011	< 0.030286
stack gas	3-Nitroaniline	827SSNT1	mg/Nm3	< 0.049425	< 0.027991	< 0.029977
ESP inlet gas	4-Chloro-3-methylphenol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	4-Chloro-3-methylphenol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	4-Methyl-2-pentanone	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	4-Methyl-2-pentanone	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	4-Methylphenol(p-cresol)	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	4-Methylphenol(p-cresol)	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	4-Nitroaniline	827SSNT1	mg/Nm3	< 0.056057	< 0.036011	< 0.030286
stack gas	4-Nitroaniline	827SSNT1	mg/Nm3	< 0.049425	< 0.027991	< 0.029977
ESP inlet gas	4-Nitrophenol	827SSNT1	mg/Nm3	< 0.056057	< 0.036011	< 0.030286
stack gas	4-Nitrophenol	827SSNT1	mg/Nm3	< 0.049425	< 0.027991	< 0.029977
ESP inlet gas	4,6-Dinitro-2-methylphenol	827SSNT1	mg/Nm3	< 0.056057	< 0.036011	< 0.030286
stack gas	4,6-Dinitro-2-methylphenol	827SSNT1	mg/Nm3	< 0.049425	< 0.027991	< 0.029977
ESP inlet gas	Acetaldehyde	ALDELKAS	mg/Nm3	< 0.007722	< 0.008033	< 0.009188
stack gas	Acetaldehyde	ALDELKAS	mg/Nm3	< 0.008084	< 0.008754	< 0.008464
ESP inlet gas	Acetone	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Acetone	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Acetophenone	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Acetophenone	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Acrolein	ALDELKAS	mg/Nm3	0.020584 @	< 0.009695	< 0.011088
stack gas	Acrolein	ALDELKAS	mg/Nm3	< 0.009757	< 0.010566	< 0.010216
bottom ash	Aluminum	D4326	mg/kg	120529.6	127676.5	

Site 15 Data Not Used in Calculations

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3
collected fly ash	Aluminum	D4326	mg/kg	137835.8	137794.1	136271.8
ESP inlet gas	Aniline	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Aniline	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Antimony	NAA	ug/g	1.0791	0.4307	0.6781
bottom ash	Antimony	ICPSSN00	mg/kg	< 100	< 100	
suspended ash	Antimony	ICPSSN00	mg/kg	< 100.8311	< 101.4929	< 100.9786
collected fly ash	Antimony	ICPSSN00	mg/kg	< 100	< 100	< 100
emitted particulates	Antimony	ICPSSN00	mg/kg	< 112.7396	< 131.406	< 338.9831
ESP inlet gas, vapor phase	Antimony	ICPSWN00	mg/Nm3	< 0.047018	< 0.047793	< 0.050409
stack gas, vapor phase	Antimony	ICPSWN00	mg/Nm3	< 0.025416	< 0.029701	< 0.054566
service water	Antimony	ICPSWN00	mg/L	< 0.1	< 0.1	< 0.1
coal	Arsenic	NAA	ug/g	23.178	< 4.963	11.029
bottom ash	Arsenic	ASHRSN00	mg/kg	< 5.1	< 5.1	
suspended ash	Arsenic	ASHRSN00	mg/kg	15.57633 @	14.09011 @	18.055 @
collected fly ash	Arsenic	ASHRSN00	mg/kg	14 @	15 @	8.9 @
bottom ash	Barium	D4326	mg/kg	0	0	
collected fly ash	Barium	ICPSSN00	mg/kg	830	850	840
ESP inlet gas	Benzaldehyde	ALDELKAS	mg/Nm3	< 0.014912	< 0.015511	< 0.017742
stack gas	Benzaldehyde	ALDELKAS	mg/Nm3	< 0.015611	< 0.015094	< 0.016345
ESP inlet gas	Benzoic acid	827SSNT1	mg/Nm3	0.061663 @	0.216067	0.242287
stack gas	Benzoic acid	827SSNT1	mg/Nm3	0.072161 @	0.195937	< 0.029977
ESP inlet gas	Benzyl alcohol	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Benzyl alcohol	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	bis(2-Chloroethoxy)methane	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	bis(2-Chloroethoxy)methane	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	bis(2-Chloroethyl)ether	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	bis(2-Chloroethyl)ether	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	bis(2-Chloroisopropyl)ether	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	bis(2-Chloroisopropyl)ether	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	bis(2-Ethylhexyl)phthalate	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	bis(2-Ethylhexyl)phthalate	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
bottom ash	Boron	B_ESSN00	mg/kg	< 94	< 120	
collected fly ash	Boron	B_ESSN00	mg/kg	< 120	< 130	< 120
ESP inlet gas, vapor phase	Boron	ICPSWN00	mg/Nm3	2.648188	1.377191 @	2.493349
stack gas, vapor phase	Boron	ICPSWN00	mg/Nm3	1.313159	2.370871	2.356016
service water	Boron	ICPSWN00	mg/L	< 0.6	< 0.6	< 0.6
coal	Bromine	NAA	ug/g	14.778	17.631	19.644
ESP inlet gas	Bromodichloromethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Bromodichloromethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Bromoform	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Bromoform	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Bromomethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Bromomethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
coal	Calcium	NAA	ug/g	1366.7	1505.3	1686.4
bottom ash	Calcium	ICPSSN00	mg/kg	7500	6900	
collected fly ash	Calcium	ICPSSN00	mg/kg	9600	8200	8400
ESP inlet gas, vapor phase	Carbon	ULTRSN00	%	3.26	3.94	3.3
ESP inlet gas	Carbon disulfide	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Carbon disulfide	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Carbon tetrachloride	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Carbon tetrachloride	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
coal	Cerium	NAA	ug/g	17.409	14.295	19.786
coal	Cesium	NAA	ug/g	1.4308	0.9807	1.5825
coal	Chlorine	NAA	ug/g	984.67	567.65	684.28
ESP inlet gas	Chlorobenzene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Chlorobenzene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Chloroethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Chloroethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Chloroform	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Chloroform	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Chloromethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Chloromethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	cis-1,2-Dichloroethene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	cis-1,2-Dichloroethene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	cis-1,3-Dichloropropene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	cis-1,3-Dichloropropene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Dibromochloromethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Dibromochloromethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Dibutylphthalate	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Dibutylphthalate	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Diethylphthalate	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Diethylphthalate	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Dimethylphenethylamine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Dimethylphenethylamine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Dimethylphthalate	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Dimethylphthalate	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Di-n-octylphthalate	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Di-n-octylphthalate	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Ethyl benzene	SW 8240	mg/Nm3	0.001143 @	0.000786 @	0.001447 @

Site 15 Data Not Used in Calculations

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3
stack gas	Ethyl benzene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Ethyl methanesulfonate	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Ethyl methanesulfonate	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Europium	NAA	ug/g	0.3379	0.3112	0.3645
bottom ash	Fluoride	F_SMSN	mg/kg	14.57 JR	5.21 JR	
coal	Gold	NAA	ug/g	< 0.001	< 0.001	< 0.002
coal	Hafnium	NAA	ug/g	0.8781	0.6204	1.0308
ESP inlet gas	Hexachlorobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Hexachlorobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Hexachlorobutadiene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Hexachlorobutadiene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Hexachlorocyclopentadiene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Hexachlorocyclopentadiene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Hexachloroethane	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Hexachloroethane	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas, vapor phase	Hydrogen	ULTRSN00	%			0.02 @
coal	Iodine	NAA	ug/g	1.5143	< 1.0467	< 1.1184
bottom ash	Iron	ICPSSN00	mg/kg	100000	85000	
collected fly ash	Iron	ICPSSN00	mg/kg	66000	67000	67000
ESP inlet gas	Isophorone	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Isophorone	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Lanthanum	NAA	ug/g	9.4586	8.3223	12.104
coal	Lutetium	NAA	ug/g	0.2821	0.1104	0.1415
bottom ash	Magnesium	ICPSSN00	mg/kg	3500 @	3700 @	
collected fly ash	Magnesium	ICPSSN00	mg/kg	4300 @	4200 @	4100 @
bottom ash	Manganese	D4326	mg/kg	855.0572	869.835	
collected fly ash	Manganese	D4326	mg/kg	821.2757	830.4191	826.1222
coal	Mercury	NAA	ug/g	< 0.8886	< 0.7804	< 0.8344
ESP inlet gas	Methyl methanesulfonate	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Methyl methanesulfonate	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Methylene chloride	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Methylene chloride	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
coal	Moisture	D3302889a	%	4	2.81	3.08
bottom ash	Moisture	air dry	%	24.5	28.2	
collected fly ash	Moisture	air dry	%	22	20	21.4
ESP inlet gas	m,p-Xylene	SW 8240	mg/Nm3	0.004623	0.003198	0.006203
stack gas	m,p-Xylene	SW 8240	mg/Nm3	0.013122	0.000672 @	0.001355 @
coal	Neodymium	NAA	ug/g	10.036	6.6821	9.3492
ESP inlet gas	Nitrobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Nitrobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	N-Nitrosodimethylamine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	N-Nitrosodimethylamine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	N-Nitroso-di-n-butylamine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	N-Nitroso-di-n-butylamine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	N-Nitrosodipropylamine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	N-Nitrosodipropylamine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	N-Nitrosopiperidine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	N-Nitrosopiperidine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	o-Xylene	SW 8240	mg/Nm3	0.001039 @	0.000734 @	0.002223 @
stack gas	o-Xylene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	p-Chloroaniline	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	p-Chloroaniline	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	p-Dimethylaminoazobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	p-Dimethylaminoazobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Pentachlorobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Pentachlorobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Pentachloronitrobenzene	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Pentachloronitrobenzene	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Pentachlorophenol	827SSNT1	mg/Nm3	< 0.056057	< 0.036011	< 0.030286
stack gas	Pentachlorophenol	827SSNT1	mg/Nm3	< 0.049425	< 0.027991	< 0.029977
ESP inlet gas	Phenacetin	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Phenacetin	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Phenol	827SSNT1	mg/Nm3	0.077359	< 0.007202	< 0.006057
stack gas	Phenol	827SSNT1	mg/Nm3	< 0.009885	0.008957 @	< 0.005995
bottom ash	Potassium	D4326	mg/kg	15312.37	16348.15	
collected fly ash	Potassium	D4326	mg/kg	19009.21	19061.34	18724.68
ESP inlet gas	Pronamide	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Pronamide	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
ESP inlet gas	Pyridine	827SSNT1	mg/Nm3	< 0.011211	< 0.007202	< 0.006057
stack gas	Pyridine	827SSNT1	mg/Nm3	< 0.009885	< 0.005598	< 0.005995
coal	Rubidium	NAA	ug/g	14.69	9.3635	17.158
coal	Samarium	NAA	ug/g	1.8285	1.5044	1.8614
coal	Scandium	NAA	ug/g	5.1878	4.0723	4.5588
coal	Selenium	NAA	ug/g	3.1846	1.6242	2.6069
bottom ash	Silicon	D4326	mg/kg	219178.2	234603	
suspended ash	Silicon	ICPSSN00	mg/kg	956621.5	928365.8	404678.5
collected fly ash	Silicon	D4326	mg/kg	240586.7	248294.9	244240.2
emitted particulates	Silicon	ICPSSN00	mg/kg	< 11273.96 R	< 13140.6 R	< 33898.31 R
ESP inlet gas, vapor phase	Silicon	ICPSWN00	mg/Nm3	1.107932 @	0.395604 @	0.660373 @

Site 15 Data Not Used in Calculations

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3
stack gas, vapor phase	Silicon	ICPSWN00	mg/Nm3	0.63809 @	0.915338 @	0.738537 @
service water	Silicon	ICPSWN00	mg/L	3 @	3 @	2.8 @
coal	Silver	NAA	ug/g	< 0.6392	< 0.5707	< 0.605
bottom ash	Silver	ICPSSN00	mg/kg	< 10	< 10	
suspended ash	Silver	ICPSSN00	mg/kg	< 10.08311	< 10.14929	< 10.09786
collected fly ash	Silver	ICPSSN00	mg/kg	< 10	< 10	< 10
emitted particulates	Silver	ICPSSN00	mg/kg	< 11.27396	< 13.1406	< 33.89831
ESP inlet gas, vapor phase	Silver	ICPSWN00	mg/Nm3	< 0.004702	< 0.004779	< 0.005041
stack gas, vapor phase	Silver	ICPSWN00	mg/Nm3	< 0.002542	< 0.00297	< 0.005457
service water	Silver	ICPSWN00	mg/L	< 0.01	< 0.01	< 0.01
bottom ash	Sodium	ICPSSN00	mg/kg	< 1000	1400 @	
suspended ash	Sodium	ICPSSN00	mg/kg	52324.12	48656.89	1800421
collected fly ash	Sodium	ICPSSN00	mg/kg	26000	24000	2300 @
emitted particulates	Sodium	ICPSSN00	mg/kg	< 11273.96 R	< 13140.6 R	< 33898.31 R
coal	Strontium	NAA	ug/g	120.38	113.17	209.25
bottom ash	Strontium	D4326	mg/kg	2007.573	2120.818	
bottom ash	Strontium	ICPSSN00	mg/kg	730	680	
suspended ash	Strontium	ICPSSN00	mg/kg	967.3442	909.1257	890.1213
collected fly ash	Strontium	D4326	mg/kg	2972.731	1299.817	2505.364
collected fly ash	Strontium	ICPSSN00	mg/kg	980	840	820
emitted particulates	Strontium	ICPSSN00	mg/kg	967.3055 R	969.7766 R	1383.051 R
ESP inlet gas, vapor phase	Strontium	ICPSWN00	mg/Nm3	0.001524 @	< 0.001434	< 0.001512
stack gas, vapor phase	Strontium	ICPSWN00	mg/Nm3	< 0.000762	< 0.000891	< 0.001637
service water	Strontium	ICPSWN00	mg/L	0.061	0.074	0.071
ESP inlet gas	Styrene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Styrene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
bottom ash	Sulfur	TTSRSN00	%	0.209	0.196	
collected fly ash	Sulfur	TTSRSN00	%	0.0207 @	0.0214 @	0.0177 @
ESP inlet gas, vapor phase	Sulfur	TTSRSN00	%	0.141	0.16	0.143
coal	Tantalum	NAA	ug/g	0.2073	0.2158	0.2619
coal	Terbium	NAA	ug/g	0.2155	0.1606	0.2076
ESP inlet gas	Tetrachloroethene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Tetrachloroethene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
bottom ash	Thallium	ICPSSN00	mg/kg	< 100	< 100	
suspended ash	Thallium	ICPSSN00	mg/kg	< 100.8311	< 101.4929	< 100.9786
collected fly ash	Thallium	ICPSSN00	mg/kg	< 100	< 100	< 100
emitted particulates	Thallium	ICPSSN00	mg/kg	< 112.7396	< 131.406	< 338.9831
ESP inlet gas, vapor phase	Thallium	ICPSWN00	mg/Nm3	< 0.047018	< 0.047793	< 0.050409
stack gas, vapor phase	Thallium	ICPSWN00	mg/Nm3	< 0.025416	< 0.029701	< 0.054566
service water	Thallium	ICPSWN00	mg/L	< 0.1	< 0.1	< 0.1
coal	Thorium	NAA	ug/g	2.8517	2.1772	2.8651
coal	Tin	NAA	ug/g	< 15	< 15	< 15
bottom ash	Titanium	TIESSN00	mg/kg	5800	6300	
collected fly ash	Titanium	TIESSN00	mg/kg	7400	7300	7200
coal	Total moisture	D3302	%		6.22	6.79
ESP inlet gas	trans-1,2-Dichloroethene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	trans-1,2-Dichloroethene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	trans-1,3-Dichloropropene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	trans-1,3-Dichloropropene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Trichloroethene	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Trichloroethene	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Trichlorofluoromethane	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Trichlorofluoromethane	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
coal	Tungsten	NAA	ug/g	< 10	< 10	< 10
coal	Uranium	NAA	ug/g	2.0304	0.9892	0.8304
ESP inlet gas	Vinyl acetate	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Vinyl acetate	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
ESP inlet gas	Vinyl chloride	SW 8240	mg/Nm3	< 0.000519	< 0.000524	< 0.000517
stack gas	Vinyl chloride	SW 8240	mg/Nm3	< 0.000571	< 0.00056	< 0.000565
coal	Volatile carbon	Proximat	% dry	33.4377	33.02039	32.51632
coal	Ytterbium	NAA	ug/g	0.8588	0.7374	0.9769
coal	Zinc	NAA	ug/g	21.584	18.122	21.875
bottom ash	Zinc	ICPSSN00	mg/kg	< 20	< 20	
suspended ash	Zinc	ICPSSN00	mg/kg	< 20	< 20	36.69997 @
collected fly ash	Zinc	ICPSSN00	mg/kg	< 20	30 @	< 20
emitted particulates	Zinc	ICPSSN00	mg/kg	1059.752 @	617.6084 @	1694.915 @
ESP inlet gas, vapor phase	Zinc	ICPSWN00	mg/Nm3	< 0.009404	< 0.009559	< 0.010082
stack gas, vapor phase	Zinc	ICPSWN00	mg/Nm3	< 0.005083	< 0.00594	< 0.010913
service water	Zinc	ICPSWN00	mg/L	0.028 @	0.046 @	0.034 @
coal	Zirconium	NAA	ug/g	< 36.148	< 30.99	< 33.489

Appendix D

Measured and Calculated Process Stream Flows

Table D-1 summarizes process stream flow rates for Site 15. Additional tables summarize the gas stream characterization data. Process data that could not be accurately estimated from plant operating records were the makeup water utilization rate, the fly ash and bottom ash sluice system rates, and the collected fly ash production rate. These variables were determined mathematically from other measured variables. The calculation methods are briefly described below:

- The collected fly ash rate was calculated by computing an ash balance around the plant. The coal ash input less the bottom ash and emitted particulates was calculated as the collected fly ash rate.

- The ESP inlet gas flow was adjusted relative to the measured stack gas flow based on the measured oxygen concentrations.

Table D-1

Process Flow Rates

Stream	Source	UOM	10/23	10/26a	10/26b	10/27	10/29
Load (MWe)	M	MWe	545	565	--	565	530
Coal (dry basis)	M	lb/hr	412,034	424,272	423,804	425,062	402,840
Coal Ash	M	%	12.9%	12.6%	13.1%	12.7%	12.3%
Inlet Ash	C	lb/hr	53,070	53,416	55,518	53,940	49,428
Bottom Ash (dry)	M	lb/hr	16,930	17,134		17,309	
Bottom Ash ignited	M	%	91%	93%		92%*	
Actual Bottom Ash	C	lb/hr	15,484	15,943		15,924	
Actual Suspended Ash	C	lb/hr	39,518	38,977		39,617	
Suspended Ash Ignited	M	%	95%	96%	96%	96%	97%
Suspended Ash (dry)	C	lb/hr	37,586	37,473		38,016	
ESP Inlet Gas Flow (dry)	M	scfm	1,250,000	1,304,000		1,286,000	
ESP Grain Loading	M	gr/scf	4.25	2.48		3.88	
Suspended Ash (measured)	C	lb/hr	45,536	27,719		42,769	
ESP Inlet Oxygen	M	%	7%	7%		7%	
Collected Fly Ash	C	lb/hr	37,428	37,297		37,893	
Stack Gas Flow (dry)	M	scfm	1,140,000	1,170,000		1,170,000	
Stack Grain Loading	M	gr/scf	0.0162	0.0175		0.0123	
Emitted Ash	C	lb/hr	158	176		123	
Stack Oxygen	M	%	10%	9%		9%	
Adjusted ESP Inlet Flow	C	scfm	895,714	1,002,857		1,002,857	

M = Measured
C = Calculated
* = Assumed to be 92 percent.

VOST SAMPLING DATA

Run No.	Pair No.	Date	Start Time	Stop Time	Volume at Meter (l)	DGMCF	Meter Temp (deg F)	Probe Temp (deg F)	Bar. Pressure (in. Hg)	Gas Volume Collected (Std l)
Inlet Run 1	A	10/27/90	1730	1811	21.07	1.007	70	254	29.25	20.66
	B	10/27/90	1826	1837	5.81	1.007	69	262	29.25	5.71
	C	10/27/90	1852	1854	1.00	1.007	68	251	29.25	0.98
Inlet Run 2	A	10/29/90	2015	2053	20.00	1.007	54	263	29.6	20.47
	B	10/29/90	2101	2111	5.06	1.007	54	262	29.6	5.18
	C	10/29/90	2120	2122	1.05	1.007	54	257	29.6	1.07
Inlet Run 3	A	10/29/90	1705	1745	20.56	1.007	62	258	29.66	20.76
	B	10/29/90	1755	1805	5.50	1.007	62	250	29.66	5.55
	C	10/29/90	1820	1822	1.00	1.007	61	244	29.66	1.01
Stack Run 1	A	10/27/90	1740	1820	20.00	0.984	80	277	29.25	18.81
	B	10/27/90	1831	1841	5.00	0.984	84	285	29.25	4.67
	C	10/27/90	1852	1854	1.00	0.984	85	290	29.25	0.93
Stack Run 2	A	10/29/90	1705	1745	20.00	0.984	78	297	29.66	19.15
	B	10/29/90	1755	1805	5.00	0.984	83	295	29.66	4.74
	C	10/29/90	1821	1823	1.00	0.984	82	296	29.66	0.95
Stack Run 3	A	10/29/90	1836	1916	20.00	0.984	82	295	29.66	19.01
	B	10/29/90	1926	1936	5.00	0.984	83	293	29.66	4.74
	C	10/29/90	1948	1850	1.00	0.984	83	297	29.66	0.95

ANIONS

Date	Run No.	INLET Dry Standard Meter Volume	STACK Dry Standard Meter Volume
10/23/90	1	74.779 DSCF	73.542 DSCF
10/26/90	2	65.12 DSCF	68.146 DSCF
10/26/90	3	63.754 DSCF	61.043 DSCF
10/27/90	4	66.993 DSCF	65.618 DSCF
10/27/90	5	67.952 DSCF	77.004 DSCF

		Filter Weight Gain	Filter Weight Gain
10/23/90	1	0.0000 gms	0 gms
10/26/90	2	0.0000 gms	0.067 gms
10/26/90	3	12.9261 gms	0.1102 gms
10/27/90	4	15.3254 gms	0.1448 gms
10/27/90	5	14.0391 gms	0.1624 gms

		Impinger volume	Impinger volume
10/23/90	1	0 g	0 g
10/26/90	2	0.0 g	0 g
10/26/90	3	565.6 g	568.7 g
10/27/90	4	614.5 g	568.3 g
10/27/90	5	563 g	640.3 g

ALDEHYDES

		Dry Standard Meter Volume	Dry Standard Meter Volume
10/24/90	1	14.233 DSCF	13.596 DSCF
10/26/90	2	13.683 DSCF	12.555 DSCF
10/27/90	3	11.963 DSCF	12.985 DSCF

		Impinger volume	Impinger volume
10/24/90	1	573.7 g	554.6 g
10/26/90	2	505.5 g	488.1 g
10/27/90	3	466.9 g	494.8 g

MODIFIED METHOD 5

PARAMETER	INLET		STACK	
Date	10/23/90		10/23/90	
Dry Standard Meter Volume	33.805	DSCF	38.341	DSCF
Percent Flue Gas Moisture	8.36	%	7.49	%
Flue Gas Molecular Weight (wet)	29.40	g/g-mole	29.36	g/g-mole
Average Gas Velocity	56.98	ft/sec	89.89	ft/sec
Average Flue Gas Flow Rate	1,430,000	DSCFM	1,170,000	DSCFM
Adjusted Inlet Flue Gas Flow Rate	1,285,570	DSCFM		
Isokinetic Sampling Rate	102.9	%	99.6	%

PARAMETER	INLET		STACK	
Date	10/27/90		10/27/90	
Dry Standard Meter Volume	52.623	DSCF	67.701	DSCF
Percent Flue Gas Moisture	5.05	%	6.43	%
Flue Gas Molecular Weight (wet)	29.81	g/g-mole	29.49	g/g-mole
Average Gas Velocity	57.62	ft/sec	84.76	ft/sec
Average Flue Gas Flow Rate	1,540,000	DSCFM	1,130,000	DSCFM
Adjusted Inlet Flue Gas Flow Rate	1,384,460	DSCFM		
Isokinetic Sampling Rate	96.4	%	97.9	%

PARAMETER	INLET		STACK	
Date	10/29/90		10/29/90	
Dry Standard Meter Volume	62.571	DSCF	63.216	DSCF
Percent Flue Gas Moisture	7.00	%	6.70	%
Flue Gas Molecular Weight (wet)	29.57	g/g-mole	30.28	g/g-mole
Average Gas Velocity	52.37	ft/sec	83.12	ft/sec
Average Flue Gas Flow Rate	1,370,000	DSCFM	1,220,000	DSCFM
Adjusted Inlet Flue Gas Flow Rate	1,231,630	DSCFM		
Isokinetic Sampling Rate	100.8	%	110.3	%

MULTI-METALS

PARAMETER	INLET		STACK	
Date	10/23/90		10/23/90	
Dry Standard Meter Volume	43.665	DSCF	84.463	DSCF
Percent Flue Gas Moisture	8.36	%	7.49	%
Flue Gas Molecular Weight (wet)	29.4	g/g-mole	29.4	g/g-mole
Average Gas Velocity	54.76	ft/sec	86.34	ft/sec
Average Flue Gas Flow Rate	1,390,000	DSCFM	1,140,000	DSCFM
Adjusted Inlet Flue Gas Flow Rate	1,249,610	DSCFM		
Isokinetic Sampling Rate	99.8	%	91.6	%
Oxygen Concentration	7	%	10	%
Total Mass of Particulate Solids	12.0326	grams	0.0887	grams
Particulate Concentration	4.25	gr/DSCF	0.0162	gr/DSCF
Particulate Emissions	50,500	lb/hr	158.00	lb/hr
Adjusted Particulate Emissions	45,585	lb/hr		

PARAMETER	INLET		STACK	
Date	10/26/90		10/26/90	
Dry Standard Meter Volume	41.662	DSCF	67.286	DSCF
Percent Flue Gas Moisture	5.05	%	6.43	%
Flue Gas Molecular Weight (wet)	29.81	g/g-mole	29.49	g/g-mole
Average Gas Velocity	55.08	ft/sec	87.77	ft/sec
Average Flue Gas Flow Rate	1,450,000	DSCFM	1,170,000	DSCFM
Adjusted Inlet Flue Gas Flow Rate	1,303,550	DSCFM		
Isokinetic Sampling Rate	105.6	%	97.9	%
Oxygen Concentration	7	%	9	%
Total Mass of Particulate Solids	6.6982	grams	0.0761	grams
Particulate Concentration	2.48	gr/DSCF	0.0175	gr/DSCF
Particulate Emissions	30,800	lb/hr	175.00	lb/hr
Adjusted Particulate Emissions	23,463	lb/hr		

PARAMETER	INLET		STACK	
Date	10/27/90		10/27/90	
Dry Standard Meter Volume	40.698	DSCF	37.021	DSCF
Percent Flue Gas Moisture	7	%	6.70	%
Flue Gas Molecular Weight (wet)	29.57	g/g-mole	29.46	g/g-mole
Average Gas Velocity	55.84	ft/sec	87.54	ft/sec
Average Flue Gas Flow Rate	1,430,000	DSCFM	1,170,000	DSCFM
Adjusted Inlet Flue Gas Flow Rate	1,285,570	DSCFM		
Isokinetic Sampling Rate	104.1	%	101.8	%
Oxygen Concentration	7	%	9	%
Total Mass of Particulate Solids	10.219	grams	0.0295	grams
Particulate Concentration	3.88	gr/DSCF	0.0123	gr/DSCF
Particulate Emissions	47,700	lb/hr	123	lb/hr
Adjusted Particulate Emissions	42,732	lb/hr		

IMPINGER VOLUMES

		INLET		STACK	
10/23/90	IMP 1 & 2	541.7	gms	566.4	gms
	IMP 3 & 4	579.1	gms	488.6	gms
10/26/90	IMP 1 & 2	525.4	gms	527.3	gms
	IMP 3 & 4	556.5	gms	537.7	gms
10/27/90	IMP 1 & 2	541.3	gms	533.0	gms
	IMP 3 & 4	577.8	gms	553.7	gms

Appendix E

Error Analysis Tables

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.

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;
β_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:

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

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

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

$$S_r = \sqrt{\sum_{i=1}^{j} (\theta_i * S_{\overline{pi}})^2} \quad (3)$$

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:

$$S_{\bar{p}i} = \frac{S_{pi}}{\sqrt{N}} \quad (6)$$

The degrees of freedom for each parameter is found from

$$v_i = N_i - 1 \quad (7)$$

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

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

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, if a 15-minute average coal data are used to generate a mean coal feed rate for each of three days, the degrees of freedom in the average coal feed rate for the trip should reflect all of the 15 minute averages and not just the three daily averages. However, as another 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 and ash;
- No 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 detection limit may be especially large. Therefore, the uncertainty values calculated for this report should be used with care.

An example of the calculation of confidence intervals is shown below.

Confidence Interval Calculations

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

CIs for Stream Concentrations

For arsenic in the stack gas, the 95% CI is calculated using the equations presented above. The 95% CI about the total mean for the sum of two values can be represented by:

$$U_{r_{TOT}} = \sqrt{\left(U_{r_{PART}}\right)^2 + \left(U_{r_{VAPOR}}\right)^2} \quad (9)$$

where:

$U_{r\,TOT}$ = 95% CI for the total concentration;

$U_{r\,PART}$ = 95% CI for the particulate phase; and

$U_{r\,VAPOR}$ = 95% CI for the vapor phase.

The 95% CI for each phase is given by:

$$U_r = \sqrt{\beta^2 + \left(t * \frac{S_r}{\sqrt{N}}\right)^2} \quad (10)$$

where:

U_r = 95% CI for each phase;

β = Bias component;

t = Student's t factor for 97.5 percentile (one-tail) and N-1 degrees of freedom;

S_r = Standard deviation of the individual run measurements; and

N = Number of measurements.

The three sets of concentration data for arsenic in the stack gas shown in Table 3-3a were:

	Run 1	Run 2	Run 3
Particulate	16	21	16
Vapor	<1	<1	<14

For this set of data, the average value was calculated by adding zero to the particulate concentration and obtaining the mean (16 + 21 + 16)/3 = 18.

For the sum of each run, the standard deviation (S_R) equals 2.85. Since the sum for each run is greater than the reporting limit, there is no bias term.

$$N = 3$$

$$t_{N-1} = 4.3$$

$$U_R = \sqrt{(0)^2 + \left(4.3\ \frac{2.85}{\sqrt{3}}\right)^2} \qquad (11)$$

$$= 7.1$$

This is the 95% CI shown in Table 3-3a for arsenic. Similar calculations were performed to determine the confidence intervals for all other values.

In addition to the assumptions about bias errors referred to above, the calculations also assume that the population distribution of each measurement is normal 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.

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

The tables which follow this discussion are the computer-generated results from the material balance error propagation. Each table provides the results for an individual element (e.g., pp. E-10 provides error propagation results for aluminum). The tables present the material balance closure as the average value (110% for aluminum) with an absolute total uncertainty of 8.7 percent. The program sorts the input variables in decreasing order of error contribution. For aluminum, the coal and collected fly ash stream flows are the two largest sources of uncertainty. On subsequent calculations, concentration variability is usually responsible for most of the uncertainty.

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	110.6319	6.76E+00	5.45E+00	8.7E+00	2.37E+00	6.5E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	2.77E+01	-5.55E-04	9.49E+03	-
2)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.52E+01	4.63E-03	8.42E+02	-
3)	asccfa	fly ash aluminum	mg/kg	128000	PREC	1.39E+01	6.10E-04	1.06E+04	3
4)	ascba	ba aluminum	mg/kg	115000	PREC	7.48E+00	2.83E-04	1.67E+04	3
5)	ascc	coal aluminum	mg/kg	14555.3	PREC	4.72E+00	-7.54E-03	4.99E+02	3
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	2.91E+00	4.63E-03	2.55E+03	48
7)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	2.65E+00	4.16E-03	3.91E+02	-
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	7.19E-01	-5.55E-04	1.06E+04	48
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	1.95E-02	4.16E-03	2.33E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	64.54405	4.43E+00	3.94E+01	4.0E+01	3.18E+00	2.8E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	asccfa	fly ash arsenic	mg/kg	95.74	PREC	1.28E+03	6.55E-01	9.47E+01	3
2)	ascc	coal arsenic	mg/kg	13.56	PREC	2.65E+02	-4.38E+00	6.43E+00	3
3)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	9.82E+00	3.72E-03	8.42E+02	-
4)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	9.44E+00	-3.24E-04	9.49E+03	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	3.40E+00	3.72E-03	3.43E+03	48
6)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	4.43E-01	-3.24E-04	1.42E+04	48
7)	ascba	ba arsenic	mg/kg	2	BIAS	3.70E-01	3.04E-01	2.00E+00	-
8)	ascov	stack gas arsenic	ug/Nm3	17.9	PREC	1.32E-01	7.07E-02	8.91E+00	3
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	9.24E-04	7.77E-05	3.91E+02	-
10)	gas	GAS FLOW	Nm3/hr	1820393	PREC	6.02E-04	6.95E-07	6.12E+04	3
11)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	1.23E-05	7.77E-05	3.13E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	73.91513	4.64E+00	5.18E+01	5.2E+01	2.78E+00	3.8E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	asccfa	fly ash barium	mg/kg	1281.69	PREC	1.64E+03	4.56E-02	1.54E+03	3
2)	ascc	coal barium	mg/kg	194.66	PREC	1.05E+03	-3.20E-01	1.75E+02	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.24E+01	-3.71E-04	9.49E+03	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	8.54E+00	3.47E-03	8.42E+02	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	2.25E+00	3.47E-03	2.99E+03	48
6)	ascba	ba barium	mg/kg	720	PREC	9.22E-01	2.12E-02	7.85E+01	3
7)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	5.81E-01	1.95E-03	3.91E+02	-
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	4.42E-01	-3.71E-04	1.24E+04	48
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	5.90E-03	1.95E-03	2.73E+02	48
10)	ascov	stack gas barium	ug/Nm3	45.2	PREC	1.75E-03	4.93E-03	1.47E+01	3
11)	gas	GAS FLOW	Nm3/hr	1820393	PREC	1.41E-05	1.22E-07	5.34E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	98.09098	6.12E+00	2.92E+01	3.0E+01	2.78E+00	3.6E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal beryllium	mg/kg	1.06	PREC	5.80E+02	-8.44E+01	4.95E-01	3
2)	asccfa	fly ash beryllium	mg/kg	9.100001	PREC	2.68E+02	8.37E+00	3.39E+00	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	2.18E+01	-4.92E-04	9.49E+03	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.45E+01	4.52E-03	8.42E+02	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	3.82E+00	4.52E-03	2.99E+03	48
6)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	1.14E+00	2.73E-03	3.91E+02	-
7)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	7.78E-01	-4.92E-04	1.24E+04	48
8)	ascba	ba beryllium	mg/kg	5.5	PREC	7.77E-01	3.89E+00	3.93E-01	3
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	1.16E-02	2.73E-03	2.73E+02	48
10)	ascov	stack gas beryllium	ug/Nm3	.55	PREC	4.73E-04	9.05E-01	4.16E-02	3
11)	gas	GAS FLOW	Nm3/hr	1820393	PREC	7.11E-05	2.74E-07	5.34E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	79.27365	4.85E+00	1.98E+01	2.0E+01	2.78E+00	4.2E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	asccfa	fly ash calcium	mg/kg	9639.59	PREC	2.18E+02	5.84E-03	4.38E+03	3
2)	ascc	coal calcium	mg/kg	1519.47	PREC	1.60E+02	-4.92E-02	4.45E+02	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.42E+01	-3.98E-04	9.49E+03	-
4)	ascba	ba calcium	mg/kg	8462.859	PREC	1.21E+01	2.71E-03	2.22E+03	3
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	7.93E+00	3.34E-03	8.42E+02	-
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	2.09E+00	3.34E-03	2.99E+03	48
7)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	1.32E+00	2.93E-03	3.91E+02	-
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	5.08E-01	-3.98E-04	1.24E+04	48
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	1.34E-02	2.93E-03	2.73E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	70.17296	3.35E+00	1.32E+01	1.4E+01	2.78E+00	3.7E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	escc	coal chloride	mg/kg	863.6701	PREC	1.16E+02	-7.68E-02	2.43E+02	3
2)	escov	stack gas chloride	ug/Nm3	62522	PREC	5.69E+01	1.11E-03	1.18E+04	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.12E+01	-3.52E-04	9.49E+03	-
4)	gas	GAS FLOW	Nm3/hr	1820393	PREC	1.38E+00	3.81E-05	5.34E+04	3
5)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	3.98E-01	-3.52E-04	1.24E+04	48
6)	escfa	fly ash chloride	mg/kg	28.63	BIAS	8.64E-02	1.03E-02	2.86E+01	-
7)	escba	ba chloride	mg/kg	95.25	PREC	2.42E-03	4.77E-03	1.79E+01	3
8)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	5.17E-04	5.81E-05	3.91E+02	-
9)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	2.16E-04	1.75E-05	8.42E+02	-
10)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	5.70E-05	1.75E-05	2.99E+03	48
11)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	5.24E-06	5.81E-05	2.73E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	76.69228	4.71E+00	2.61E+01	2.6E+01	4.30E+00	2.5E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal chromium	mg/kg	25.8946	PREC	6.06E+02	-2.74E+00	1.56E+01	3
2)	asccfa	fly ash chromium	mg/kg	164	PREC	5.80E+01	3.43E-01	3.85E+01	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.33E+01	-3.85E-04	9.49E+03	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	7.90E+00	3.34E-03	8.42E+02	-
5)	ascba	ba chromium	mg/kg	125	PREC	7.82E+00	1.59E-01	3.04E+01	3
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	5.00E+00	3.34E-03	4.64E+03	48
7)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	1.14E+00	-3.85E-04	1.93E+04	48
8)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	9.90E-01	2.54E-03	3.91E+02	-
9)	ascov	stack gas chromium	ug/Nm3	15.5	PREC	5.83E-01	3.70E-02	3.57E+01	3
10)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	2.41E-02	2.54E-03	4.23E+02	48
11)	gas	GAS FLOW	Nm3/hr	1820393	PREC	2.27E-04	3.16E-07	8.27E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	106.3635	6.53E+00	2.89E+01	3.0E+01	3.18E+00	2.9E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal cobalt	mg/kg	5.2082	PREC	6.81E+02	-1.88E+01	2.40E+00	3
2)	asccfa	fly ash cobalt	mg/kg	45.4	PREC	1.11E+02	1.70E+00	1.07E+01	3
3)	ascba	ba cobalt	mg/kg	36	PREC	3.81E+01	7.92E-01	1.35E+01	3
4)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	2.56E+01	-5.34E-04	9.49E+03	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.50E+01	4.59E-03	8.42E+02	-
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	5.18E+00	4.59E-03	3.43E+03	48
7)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	2.03E+00	3.64E-03	3.91E+02	-
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	1.20E+00	-5.34E-04	1.42E+04	48
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	2.71E-02	3.64E-03	3.13E+02	48
10)	ascov	stack gas cobalt	ug/Nm3	2.67	PREC	1.83E-02	1.84E-01	1.27E+00	3
11)	gas	GAS FLOW	Nm3/hr	1820393	PREC	9.15E-05	2.71E-07	6.12E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	64.66241	3.08E+00	2.40E+01	2.4E+01	3.18E+00	3.3E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascov	stack gas fluoride	ug/Nm3	5156	PREC	4.36E+02	1.18E-02	3.06E+03	3
2)	ascc	coal fluoride	mg/kg	81.3	PREC	1.06E+02	-7.56E-01	2.36E+01	3
3)	asccfa	fly ash fluoride	mg/kg	35.193	PREC	3.15E+01	1.09E-01	8.91E+01	3
4)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	9.48E+00	-3.24E-04	9.49E+03	-
5)	gas	GAS FLOW	Nm3/hr	1820393	PREC	1.39E+00	3.34E-05	6.12E+04	3
6)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	4.44E-01	-3.24E-04	1.42E+04	48
7)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	3.69E-02	2.28E-04	8.42E+02	-
8)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	1.28E-02	2.28E-04	3.43E+03	48

* PRECISION COMPONENT = t*Srbar

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-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	81.40374	4.88E+00	4.35E+01	4.4E+01	3.18E+00	2.5E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal iron	mg/kg	13318.8	PREC	1.68E+03	-5.14E-03	1.38E+04	3
2)	asccfa	fly ash iron	mg/kg	76072.4	PREC	1.17E+02	6.66E-04	2.81E+04	3
3)	ascba	ba iron	mg/kg	99195.1	PREC	8.92E+01	3.10E-04	5.28E+04	3
4)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.50E+01	-4.08E-04	9.49E+03	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	6.43E+00	3.01E-03	8.42E+02	-
6)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	2.36E+00	3.92E-03	3.91E+02	-
7)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	2.22E+00	3.01E-03	3.43E+03	48
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	7.04E-01	-4.08E-04	1.42E+04	48
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	3.14E-02	3.92E-03	3.13E+02	48
10)	gas	GAS FLOW	Nm3/hr	1820393	PREC	5.89E-10	-6.88E-10	6.12E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	280.0545	1.86E+01	5.43E+01	5.7E+01	2.78E+00	3.9E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal lead	mg/kg	3.92	PREC	1.84E+03	-6.75E+01	1.10E+00	3
2)	asccfa	fly ash lead	mg/kg	114	PREC	1.05E+03	2.26E+00	2.48E+01	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.78E+02	-1.41E-03	9.49E+03	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.67E+02	1.53E-02	8.42E+02	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	4.39E+01	1.53E-02	2.99E+03	48
6)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	6.34E+00	-1.41E-03	1.24E+04	48
7)	ascba	ba lead	mg/kg	19.5	PREC	1.42E+00	1.05E+00	1.96E+00	3
8)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	1.05E+00	2.62E-03	3.91E+02	-
9)	ascov	stack gas lead	ug/Nm3	5.77	PREC	7.44E-01	2.45E-01	6.11E+00	3
10)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	1.07E-02	2.62E-03	2.73E+02	48
11)	gas	GAS FLOW	Nm3/hr	1820393	PREC	5.67E-04	7.73E-07	5.34E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	83.06948	5.08E+00	5.98E+00	7.8E+00	2.57E+00	4.8E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal magnesium	mg/kg	650.953	PREC	1.93E+01	-1.25E-01	6.09E+01	3
2)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.56E+01	-4.17E-04	9.49E+03	-
3)	asccfa	fly ash magnesium	mg/kg	4311.78	PREC	1.26E+01	1.36E-02	4.51E+02	3
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	8.64E+00	3.49E-03	8.42E+02	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	1.95E+00	3.49E-03	2.77E+03	48
6)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	1.47E+00	3.10E-03	3.91E+02	-
7)	ascba	ba magnesium	mg/kg	3832.82	PREC	1.38E+00	6.33E-03	3.21E+02	3
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	4.79E-01	-4.17E-04	1.15E+04	48
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	1.28E-02	3.10E-03	2.53E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	108.6868	6.49E+00	1.73E+01	1.8E+01	2.78E+00	4.1E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal manganese	mg/kg	28.089	PREC	1.48E+02	-3.71E+00	5.67E+00	3
2)	asccfa	fly ash manganese	mg/kg	208	PREC	1.46E+02	3.16E-01	6.63E+01	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	2.68E+01	-5.45E-04	9.49E+03	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.08E+01	3.90E-03	8.42E+02	-
5)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	4.53E+00	5.44E-03	3.91E+02	-
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	2.84E+00	3.90E-03	2.99E+03	48
7)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	9.56E-01	-5.45E-04	1.24E+04	48
8)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	4.59E-02	5.44E-03	2.73E+02	48
9)	ascov	stack gas manganese	ug/Nm3	11.5	PREC	2.55E-02	3.41E-02	8.11E+00	3
10)	gas	GAS FLOW	Nm3/hr	1820393	PREC	4.42E-05	2.16E-07	5.34E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	26.29691	1.63E+00	1.69E+01	1.7E+01	3.18E+00	3.1E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	asccfa	fly ash mercury	mg/kg	.28	PREC	2.24E+02	6.00E+01	4.32E-01	3
2)	ascov	stack gas mercury	ug/Nm3	1.37	PREC	3.54E+01	6.48E+00	1.59E+00	3
3)	ascc	coal mercury	mg/kg	.148	PREC	2.53E+01	-1.67E+02	5.22E-02	3
4)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.57E+00	-1.32E-04	9.49E+03	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	7.05E-01	9.97E-04	8.42E+02	-
6)	ascba	ba mercury	mg/kg	.0225	BIAS	3.93E-01	2.79E+01	2.25E-02	-
7)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	2.44E-01	9.97E-04	3.43E+03	48
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	7.35E-02	-1.32E-04	1.42E+04	48
9)	gas	GAS FLOW	Nm3/hr	1820393	PREC	2.97E-02	4.88E-06	6.12E+04	3
10)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	9.82E-04	8.01E-05	3.91E+02	-
11)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	1.31E-05	8.01E-05	3.13E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	54.53116	3.32E+00	4.08E+01	4.1E+01	3.18E+00	2.6E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	escc	coal nickel	mg/kg	20.458	PREC	1.46E+03	-2.08E+00	3.18E+01	3
2)	esccfa	fly ash nickel	mg/kg	88.6	PREC	2.04E+02	4.34E-01	5.70E+01	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	6.74E+00	-2.74E-04	9.49E+03	-
4)	escba	ba nickel	mg/kg	78	PREC	4.39E+00	2.02E-01	1.80E+01	3
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	3.69E+00	2.28E-03	8.42E+02	-
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	1.28E+00	2.28E-03	3.43E+03	48
7)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	6.18E-01	2.01E-03	3.91E+02	-
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	3.16E-01	-2.74E-04	1.42E+04	48
9)	escov	stack gas nickel	ug/Nm3	7.91	PREC	2.35E-02	4.69E-02	5.66E+00	3
10)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	8.23E-03	2.01E-03	3.13E+02	48
11)	gas	GAS FLOW	Nm3/hr	1820393	PREC	5.16E-05	2.04E-07	6.12E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	100.8621	6.29E+00	1.84E+01	1.9E+01	4.30E+00	2.3E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	asccfa	fly ash phosphorus	mg/kg	2040.479	PREC	3.13E+02	3.83E-02	8.01E+02	3
2)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	2.31E+01	-5.06E-04	9.49E+03	-
3)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.52E+01	4.63E-03	8.42E+02	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	9.64E+00	4.63E-03	4.64E+03	48
5)	ascba	ba phosphorus	mg/kg	1265.64	PREC	9.53E+00	1.78E-02	3.01E+02	3
6)	ascc	coal phosphorus	mg/kg	232	PREC	4.62E+00	-4.33E-01	8.61E+00	3
7)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	1.98E+00	-5.06E-04	1.93E+04	48
8)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	1.26E+00	2.87E-03	3.91E+02	-
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	3.08E-02	2.87E-03	4.23E+02	48
10)	ascov	stack gas phosphorus	ug/Nm3	73.3	PREC	1.55E-02	4.14E-03	5.21E+01	3
11)	gas	GAS FLOW	Nm3/hr	1820393	PREC	6.47E-05	1.68E-07	8.27E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	77.66811	1.57E+01	1.74E+01	2.3E+01	2.78E+00	3.9E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	asccfa	fly ash selenium	mg/kg	6.66	BIAS	2.12E+02	3.83E+00	3.80E+00	-
2)	ascov	stack gas selenium	ug/Nm3	104	PREC	1.76E+02	4.14E-01	5.55E+01	3
3)	ascc	coal selenium	mg/kg	2.316	PREC	1.25E+02	-3.18E+01	6.10E-01	3
4)	ascba	ba selenium	mg/kg	5.1	BIAS	1.98E+01	1.78E+00	2.50E+00	-
5)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	1.37E+01	-3.90E-04	9.49E+03	-
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.63E+00	1.51E-03	8.42E+02	-
7)	gas	GAS FLOW	Nm3/hr	1820393	PREC	5.31E-01	2.37E-05	5.34E+04	3
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	4.88E-01	-3.90E-04	1.24E+04	48
9)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	4.29E-01	1.51E-03	2.99E+03	48
10)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	2.06E-01	1.16E-03	3.91E+02	-
11)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	2.09E-03	1.16E-03	2.73E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	96.35342	5.87E+00	2.67E+01	2.7E+01	2.78E+00	4.1E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal sodium	mg/kg	286.67	PREC	3.82E+02	-3.12E-01	1.09E+02	3
2)	asccfa	fly ash sodium	mg/kg	2176.05	PREC	3.20E+02	3.10E-02	1.00E+03	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	2.10E+01	-4.83E-04	9.49E+03	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.13E+01	4.00E-03	8.42E+02	-
5)	ascba	ba sodium	mg/kg	2014.772	PREC	7.72E+00	1.44E-02	3.35E+02	3
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	2.99E+00	4.00E-03	2.99E+03	48
7)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	2.10E+00	3.70E-03	3.91E+02	-
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	7.51E-01	-4.83E-04	1.24E+04	48
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	2.13E-02	3.70E-03	2.73E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	111.6926	6.85E+00	1.63E+01	1.8E+01	2.78E+00	4.0E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal titanium	mg/kg	833.6	PREC	1.67E+02	-1.28E-01	1.74E+02	3
2)	asccfa	fly ash titanium	mg/kg	7539.44	PREC	8.77E+01	1.06E-02	1.52E+03	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	2.83E+01	-5.60E-04	9.49E+03	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.61E+01	4.76E-03	8.42E+02	-
5)	ascba	ba titanium	mg/kg	6351.3	PREC	6.09E+00	4.95E-03	8.64E+02	3
6)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	4.24E+00	4.76E-03	2.99E+03	48
7)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	2.47E+00	4.01E-03	3.91E+02	-
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	1.01E+00	-5.60E-04	1.24E+04	48
9)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	2.50E-02	4.01E-03	2.73E+02	48

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

OUTPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ABSOLUTE BIAS COMPONENT	ABSOLUTE PRECISION COMPONENT*	ABSOLUTE TOTAL UNC	STUDENT t	DEGREES OF FREEDOM
closet	total closure	%	96.38084	5.96E+00	3.70E+01	3.7E+01	3.18E+00	2.5E+00

	INPUT VARIABLE NAME	DESCRIPTION	UNITS	AVERAGE VALUE	ERROR TYPE	ABSOLUTE CONTRIBUTION **	ABSOLUTE SENSITIVITY (SIGMAp)	ABSOLUTE ERROR OF INPUT***	NUMBER OF SAMPLES
1)	ascc	coal vanadium	mg/kg	29.347	PREC	1.20E+03	-2.91E+00	2.06E+01	3
2)	asccfa	fly ash vanadium	mg/kg	240	PREC	1.54E+02	3.02E-01	7.12E+01	3
3)	coal	COAL FLOW RATE	kg/hr	189819.3	BIAS	2.11E+01	-4.84E-04	9.49E+03	-
4)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	BIAS	1.32E+01	4.31E-03	8.42E+02	-
5)	cfa	COLLECTED FLY ASH	kg/hr	16848.7	PREC	4.56E+00	4.31E-03	3.43E+03	48
6)	ascba	ba vanadium	mg/kg	165	PREC	3.33E+00	1.40E-01	2.25E+01	3
7)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	BIAS	1.34E+00	2.96E-03	3.91E+02	-
8)	coal	COAL FLOW RATE	kg/hr	189819.3	PREC	9.87E-01	-4.84E-04	1.42E+04	48
9)	ascov	stack gas vanadium	ug/Nm3	18.7	PREC	3.24E-02	3.27E-02	9.55E+00	3
10)	ba	BOTTOM ASH FLOW RATE	kg/hr	7825.99	PREC	1.79E-02	2.96E-03	3.13E+02	48
11)	gas	GAS FLOW	Nm3/hr	1820393	PREC	1.41E-04	3.36E-07	6.12E+04	3

* PRECISION COMPONENT = t*Srbar

** (Bp*SIGMAp)^2 FOR BIAS ERRORS; (t*Spbar*SIGMAp)^2 FOR PRECISION ERRORS
-WHERE Spbar=PRECISION INDEX OF THE MEAN, Sp/(NUMBER OF SAMPLES)^.5
-THE SQUARE ROOT OF THE SUM OF THE ABSOLUTE CONTRIBUTIONS IS EQUAL TO THE TOTAL UNCERTAINTY

*** Bp FOR BIAS ERRORS; Sp FOR PRECISION ERRORS

Appendix F

Quality Assurance/Quality Control Data

The objective of quality assurance and quality control (QA/QC) efforts associated with the Site 15 study is to ensure that all data collected are of known and sufficient quality to qualitatively and quantitatively characterize the various process streams. This section addresses the QA/QC associated with the chemical analyses of gas, solid, and aqueous sample from the program. The tables located at the end of this appendix contain details of the QA/QC analyses summarized in this text.

Summary of Data Quality and QA/QC Approach

Quality assurance and quality control procedures used for this program were consistent with those described in Table 4-10 of the Site 15 sampling and analytical plan, August 1990, and the Laboratory Quality Assurance Program Plan (QAPP, revision 2, February, 1990) 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 quality control check samples;
- Laboratory spiked samples;
- Duplicate samples; and
- Duplicate analyses.

Quality assurance/quality control data associated with the sampling and analytical procedures for this study indicate that, with a few exceptions to be discussed below, the data quality objectives were achieved for all variables. For this reason the data may be considered valid and usable for project needs.

Blank Samples

Blank samples consist of laboratory pure matrices that are subjected to routine sampling and analytical procedures. For this project, trip blanks, field blanks, and laboratory blanks were analyzed. Trip blanks consist of blank sampling media that are transported to the field but are not exposed to field conditions. Field blanks are blank sampling media that are placed in the sampling equipment, transported to the sampling location, leak checked, and then recovered immediately into sampling containers. Laboratory blanks consist of laboratory water or sampling media that are prepared and/or digested in the same manner as the samples. Laboratory blank samples are used to control laboratory contamination because corrective action is initiated when results are above acceptable limits. Field blank samples are used to assess sampling contamination.

One set of field blank samples was collected for each gas collection technique. (For the VOST sampling, field blanks were collected daily at each sampling site.) In addition, trip blanks were collected for many of the sampling trains. Laboratory blanks were analyzed at a frequency of 10% or with each batch of samples analyzed (whichever was greater). Blank results are compared with quality control (QC) limits which are set at 1.5 times the method reporting limit (MRL) for most organic analyses and are five times the method reporting limit (MRL) for metals and anions. (Method reporting limits are specified by the laboratory for each of the methods performed and are based on method, EPA, or other requirements. All instrument-specific method detection limits must be less than or equal to the corresponding method reporting limit.) Generally, if laboratory blank results are found above the QC limit, analytical procedures could be contaminating field samples. Similarly, field blank results above the QC limits indicate that sampling procedures may be contaminating field samples.

Table F-1 summarizes the laboratory blank and field blank results. This table shows the total number of blank samples for each method, any compounds detected, and the range of results detected in the blanks. Low levels of chloride, fluoride, and sulfate were found in one or more of the impinger field blanks at concentrations less than five times the

sample reporting limit (SRL). Fluoride was also found in the impinger trip blank and the laboratory blank analyzed with the solid samples. Aluminum, iron, manganese, strontium, and zinc were found in the field blanks and trip blanks analyzed by ICP-AES associated with the stack outlet samples. These analytes were reported at levels less than five times the SRL except for iron and zinc which were detected at levels greater than five times the SRL. Manganese and zinc were also found in the field blanks and trip blanks associated with the ESP inlet impinger samples. Cadmium and/or lead were found in the field blanks and trip blanks analyzed by GFAAS. No contaminating analytes were detected in the laboratory blanks associated with these analyses.

Aluminum, barium, chromium, copper, iron, lead, molybdenum, sodium, silicon, and strontium were found in the laboratory blanks associated with the probe and nozzle and filter samples from the metals sampling train. These analytes were mostly detected at low levels (less than five times the SRL) except for aluminum, sodium, and silicon that were found in significant levels. These contaminants were most likely contributed by the filter and the reagents used in the microwave digestion procedure. Aluminum, copper, molybdenum, sodium, and lead were also found in the preparation blanks analyzed with the solid samples.

Quality Control Check Samples

Quality control check samples (QCCS) are laboratory pure matrices to which known amounts of target analytes have been added. Results from QCCS analyses are used to calculate percent recoveries which are then compared to established acceptance limits to check instrument calibration and/or control analytical performance. Expressed as a percentage of the amount added, QCCS recovery provides a measure of the accuracy of the analysis. For a single sample, this includes the combined effects of bias, or systematic error, and variability due to imprecision. Averaging QCCS recoveries tends to "average out" the random error due to imprecision and provides an estimate of analytical bias. In addition, the laboratory may also analyze standard reference materials with

certified composition. NBS ash was used for this project. Percent recoveries for these materials are also used to indicate overall analytical efficiency.

Table F-2 summarizes the QCCS analyses for anions and metals performed with the sample analysis. The mean percent recovery shown in these tables represents analytical bias which was estimated to be within acceptance limits (90% to 110% recovery) for the compounds analyzed except for antimony, lead, selenium, silicon, silver, sodium, and zinc spiked into the probe and nozzle rinse and filter matrix and analyzed by ICP-AES. Results for lead and selenium spiked into this same matrix were within acceptable limits for analyses by AAS techniques.

Spiked Samples

Spiked samples are field samples to which known amounts of the analyte of interest have been added. A spiked and unspiked aliquot were analyzed for this project. The difference in the concentration between the spiked and unspiked aliquots are calculated and compared to the amount of spike added. Since actual samples are used for the determination, any matrix effects can be identified. Like QCCS analyses, spiked sample analyses may be used to estimate analytical bias. The bias estimate generated from the spiked sample analyses includes systematic bias contributed by the sample matrix.

Tables F-3, F-4, and F-5 summarize the spiked sample results. The mean percent recovery was within acceptable limits for all organic compounds except for 4-nitrophenol which showed recoveries above the acceptance limits for both the matrix spike and matrix spike duplicate. Phosphate spikes into the impinger solution used for the recovery of anions from the gas streams showed 0% recovery. This may be a matrix problem and will be investigated with samples from future sites. Spikes into solid samples (particulates from the gas streams) showed good recoveries except for aluminum, arsenic (ICP-AES and HGAAS), boron, iron, lead (GFAAS), selenium (ICP-AES and HGAAS), silver, and titanium. Arsenic (ICP-AES), boron, iron, lead (GFAAS), and titanium recoveries exceeded the 125% QC limits and recoveries for aluminum, arsenic

(HGAAS), selenium, and silver were below the 75% QC limits. Spikes into probe and nozzle rinses and filter samples from the metals sampling train showed good recoveries except for aluminum, antimony, copper, potassium, silver, sodium, and titanium analyzed by ICP-AES and arsenic analyzed by HGAAS. Sodium recoveries exceeded the QC acceptance limits while the other analytes were recovered below the acceptance limits. Matrix spikes into impinger samples showed good recoveries except for beryllium, potassium, and selenium analyzed by ICP-AES and mercury by CVAAS.

Spikes into the service water samples showed excellent recoveries for all analytes. Spikes into fly ash sluice water samples also showed excellent recoveries except for one spike that showed low recoveries for boron, calcium, potassium, sodium, and selenium.

Surrogate spiked samples are a special type of spiked sample used as a part of the analytical protocol for the organic analyses to maintain method performance for each sample. (Surrogate compounds are not expected to be found in the sample and are added to each sample, blank, and standard before sample extraction.) Surrogate spike results for the volatile organic analyses are summarized in Table F-4, and surrogate spikes for the semivolatile analyses are summarized in Table F-5. All surrogate recoveries were within the QC acceptance limits for all volatile and semivolatile analyses performed.

Duplicate Samples and Duplicate Analyses

Duplicate samples and duplicate analyses are used as indicators of measurement data precision. Precision is a measure of mutual agreement among individual measurements of the same property made under similar conditions. Variability among the measurements is attributable to random error. In the case of duplicate analyses, the analytical process is replicated for separate aliquots of a single sample with prescribed elements of the process held constant. For example, duplicate analyses are usually performed on the same day, by the same analyst, using the same instrument, and the same calibration.

Differences in results for duplicate analyses are attributable to random variability in the analytical process and are a measure of analytical precision.

Duplicate samples provide another measure of precision. Collecting and analyzing duplicate samples involves replicating sample collection (and associated sample handling activities) and analysis; therefore, precision estimates based on duplicate sample results take both sampling variability and analytical variability into account.

Both duplicate samples and duplicate analysis results provide data for precision estimates. Generally, however, duplicate sample data are used in different ways than the results for duplicate analyses. Since analytical precision is primarily a function of the analytical procedures used, precision data for duplicate analyses may be used as an ongoing quality control check, and corrective action can be initiated when results indicate that analytical precision is not within acceptable limits.

Results for duplicate samples, on the other hand, are more often used merely as a data quality assessment tool. There is a lag between sample collection and the availability of analytical results, and it is usually not possible to initiate corrective action based on duplicate sample data because the process would no longer be at the same conditions. Variability in duplicate sample results may also include a component of variability attributable to inherent nonhomogeneity of the sample matrix.

Both types of duplicate data are useful as indicators of the degree to which results may be expected to vary by chance alone. This information is important whenever comparisons are made between measured values. Without this information it is difficult to know when to attribute observed differences to measurement error and when to attribute them to real differences.

Precision estimates for field duplicate samples for the project are presented in Table F-6. The precision objective is expressed in terms of the relative percent difference (RPD) and represents the objective for analytical variability. Duplicate samples were collected

only for the solid slurry and liquid streams. The results for the duplicate analyses are also presented in Table F-6. The precision objectives were met for most analytes. Exceptions and limitations are discussed in the following section.

Summary of Quality Control Results

Semivolatile Organics

All surrogate recoveries associated with the semivolatile organics, except for phenol in one sample, were within control limits. Surrogate recoveries are summarized in Table F-5. These results show surrogate recoveries ranging from 75% to 104% and repeatability ranging from less than 1% to 12% as relative percent difference. Benzoic acid and phenol were the only target analytes detected in either of the gas streams analyzed for semivolatile organics. These compounds were not detected in any of the blank samples (trip, field, or lab).

Volatile Organics

During the VOST sampling, the target compounds were benzene and toluene. For these analyses, all surrogate recoveries and laboratory system blanks were within control ranges.

Benzene, toluene, and xylene were found in at least one sample set in both the ESP inlet and the stack outlet gas streams sampled by VOST. In addition, ethyl benzene and 1,1,1-trichloroethene were found in the ESP inlet stream, and 1,1,1-trichloroethene and 1,1,2-trichloroethene were found in the stack outlet stream. None of these compounds were detected in any of the blanks analyzed (trip, field, or lab).

A summary of surrogate spike recoveries for the volatile organic analyses is presented in Table F-4. These summaries indicate that the results are generally within control limits. None of the surrogate recoveries were outside the acceptance limits. Mean recoveries

ranged from 89% to 117% with a repeatability range from 3.3% to 24% relative percent difference.

Aldehydes

Acrolein was the only aldehyde compound detected in either of the two gas streams sampled. This was detected at the method reporting limits in only one sample collected at the ESP inlet. Matrix spike recoveries averaged 96% with a standard deviation of 7.8% for one formaldehyde matrix spike duplicate pair. Target aldehyde compounds were not detected in either of the two field blanks or the laboratory blank prepared and analyzed with the samples.

Anions

Quality control sample results for analyses of fluoride, chloride, sulfate, and phosphate show acceptable calibration and instrument control. Spike recoveries for aqueous samples averaged 102% for chlorides and 95% for sulfate. Spikes into impinger solutions showed 92% and 102% recoveries for chloride and sulfate, respectively. Results for duplicate sample and duplicate analyses showed good repeatability for water, impinger, and solid samples.

Metals

All quality control data for metals analyses point to accurate calibration and instrument control. Limitations based on matrix effects and sample preparation techniques are discussed below.

Fly Ash Slurry and Bottom Ash. Matrix spike results in the fly ash slurry solids were outside the 75% to 125% recovery objectives for boron, sodium, and silver by ICP-AES and arsenic by HGAAS. Results for boron were high (133%), while the recoveries for sodium, silver, and arsenic were low (0%, 16% and 40%, respectively). Duplicate RPDs

(relative percent differences) were within the 20% objective for all elements except sodium. A NBS 1633a fly ash sample analyzed as a blind performance evaluation sample showed good recoveries except for sodium (135%), zinc (40%), arsenic (8%), and lead (179%). In bottom ash samples, duplicate sample results were within the required 20% precision objectives for all elements except arsenic. Aluminum, iron, molybdenum, sodium, and lead were detected in the laboratory preparation blank. This could significantly affect results for lead, molybdenum, and sodium in the solid samples. Even though the blank results for aluminum (2000 mg/kg) and iron (74 mg/kg) were high, these levels are not significant compared to the sample results.

Metals Train Particulate Samples. A standard fly ash sample (1633a) obtained from the National Institute of Standards and Technology was digested and analyzed in conjunction with the analysis of particulates from the filter and probe and nozzle rinses out of the metals train. Recoveries of less than 75% for aluminum and magnesium (by ICP-AES) indicate that these metals may be biased low. Recoveries greater than 125% were observed for lead by ICP-AES but were within limits (87%) for the GFAAS analysis. Of particular concern were results for molybdenum (1600%), which were considered unreliable in these samples because there were spectral interferences from aluminum and iron. The molybdenum results were consistent with the results of seven replicate analyses of the NBS fly ash standard used to evaluate the effectiveness of the microwave digestion procedure developed for this program.

Matrix spike recoveries for a sample from the stack outlet train showed low levels of aluminum, antimony, iron, potassium, silver, and selenium and showed high levels for silicon and sodium. Blank filter spike results also showed low recoveries for antimony and silver. The results for the method blank showed aluminum, iron, molybdenum, silicon, and sodium at levels greater than five times the sample reporting limits. Barium, chromium, copper, lead, and strontium were reported at levels less than five times the sample reporting limits. The blank levels were most likely the background from the filter.

Metals Train Impinger Solutions. Average spike recoveries for silicon were outside control limits in the ESP inlet impinger samples. In addition, at least one result for boron, selenium (by ICP-AES), and lead (by GFAAS) were outside limits although the average recoveries for the spiked pair were within limits. Recoveries of silicon and boron were low, and recoveries of selenium and lead were high. Spike recoveries for spikes into a matrix blank sample were within limits for all elements. A review of laboratory calibration check results found that recoveries for all elements to be within acceptable quality control limits.

Aluminum, cadmium, iron, lead, manganese, strontium, and zinc were found in the stack outlet field and trip blanks. Cadmium, lead, manganese, and zinc were also found in the ESP inlet trip and field blanks. No contamination was found in any of the lab blanks analyzed with the impinger sample sets.

Service Water, Bottom Ash Sluice Water, Fly Ash Sluice Water, Ash Pond Outlet Water, and Wastewater Treatment Effluent. Copper was reported at less than five times the method reporting limit in the method blank. Calibration and interference check samples run with the water samples indicate that the laboratory was in good control at this time.

Spike recovery data for spikes prepared in laboratory pure water prior to sample digestion showed recoveries ranging from 94% to 101% for all elements analyzed by ICP-AES.

Table F-1

Summary of Blank Sample Results for Site 15

Method	Number of Blanks Analyzed	Number of Detects	Range of Compounds Detected	Reporting Limit
Semivolatile Organics				
Lab Blanks	1	0		
Field Blanks (MM5)	1	0		
Trip Blank (MM5)	1	0		
VOST				
Field Blank-ESP Inlet	3	0		
Field Blank-Stack	3	0		
Trip Blanks	1	0		
Lab Blanks	2	0		
Aldehydes				
Lab Blanks	1	0		
Field Blanks	2	0		
Chloride				
Field Blank-Impingers	2	2	0.837-0.851 mg/L	0.53 mg/L
Lab Blanks-Solids	1	0		
Lab Blanks-Impingers	1	0		
Lab Blanks-Waters	4	0		
Sulfate				
Field Blank-Impinger	2	2	1.49-1.52 mg/L	2.4 mg/L
Lab Blanks-Solids				
Lab Blanks-Impingers	1	0		
Lab Blanks-Waters	4	0		
Fluoride				
Lab Blanks-Impingers	1	0		
Field Blanks-Impinger	1	1	0.046 mg/L	0.05 mg/L
Trip Blank-Impinger	1	1	0.041 mg/L	0.05 mg/L
Lab Blanks-Solids	1	1	27.1 mg/kg	18 mg/kg
Phosphate				
Field Blanks-Impingers	2	0		
Lab Blanks-Waters	1	0		
Total Sulfur				
Lab Blanks	1	0		

Table F-1

(Continued)

Method	Number of Blanks Analyzed	Number of Detects	Range of Compounds Detected	Reporting Limit
Metals (ICP-AES) - Aqueous Samples				
Lab Blanks	1	0		
Metals (GFAAS, CVAAS) - Aqueous Samples				
Lab Blanks				
Arsenic	1	0		
Cadmium	1	0		
Selenium	1	0		
Lead	1	0		
Mercury	4	0		
Metals (ICP-AES) - Impinger Solutions				
Field Blank-Stack	1			
Aluminum		1	0.23 mg/L	0.20 mg/L
Iron		1	0.61 mg/L	0.04 mg/L
Manganese		1	0.096 mg/L	0.01 mg/L
Strontium		1	0.0044 mg/L	0.003 mg/L
Zinc		1	0.33 mg/L	0.02 mg/L
Field Blank-ESP Inlet	1			
Manganese		1	0.11 mg/L	0.01 mg/L
Zinc		1	0.040 mg/L	0.02 mg/L
Trip Blank-Stack	1			
Aluminum		1	0.34 mg/L	0.20 mg/L
Cadmium		1	1.2 mg/L	1.0 mg/L
Iron		1	0.13 mg/L	0.04 mg/L
Manganese		1	0.11 mg/L	0.01 mg/L
Strontium		1	0.0043 mg/L	0.003 mg/L
Zinc		1	0.091 mg/L	0.02 mg/L
Trip blank-ESP Inlet	1			
Manganese		1	0.10 mg/L	0.01 mg/L
Zinc		1	0.20 mg/L	0.02 mg/L
Lab Blanks	5	0		

Table F-1

(Continued)

Method	Number of Blanks Analyzed	Number of Detects	Range of Compounds Detected	Reporting Limit
Metals (GFAAS, CVAAS) - Impinger Solutions				
Field Blank-Stack	1			
Cadmium		1	0.0012 mg/L	0.001 mg/L
Lead		1	0.080 mg/L	0.006 mg/L
Field Blank-ESP Inlet	1			
Lead		1	0.0034 mg/L	0.006 mg/L
Trip blank-Stack	1			
Lead		1	0.0098 mg/L	0.003 mg/L
Trip Blank-ESP Inlet	1			
Cadmium		1	0.0018 mg/L	0.001 mg/L
Lead		1	0.0033 mg/L	0.003 mg/L
Lab Blanks				
Arsenic	7	0		
Cadmium	6	0		
Lead	5	0		
Mercury	11	0		
Selenium	6	0		
Metals (ICP-AES) - Probe & Nozzle Rinse plus Filter				
Field Blank				
Aluminum	1	1	380 µg	20 µg
Barium	1	1	18 µg	1 µg
Calcium	1	1	200 µg	100 µg
Chromium	1	1	5.4 µg	1 µg
Copper	1	1	3.4 µg	2 µg
Iron	1	1	100 µg	4 µg
Lead	1	1	22 µg	5 µg
Manganese	1	1	2.2 µg	2 µg
Molybdenum	1	1	39 µg	5 µg
Silicon	1	1	390,000 µg	1,000 µg
Sodium	1	1	160,000 µg	1,000 µg
Strontium	1	1	4.2 µg	0.3 µg

Table F-1

(Continued)

Method	Number of Blanks Analyzed	Number of Detects	Range of Compounds Detected	Reporting Limit
Titanium	1	1	6 µg	1 µg
Vanadium	1	1	2.4 µg	2 µg
Trip Blank				
Aluminum	1	1	330 µg	20 µg
Barium	1	1	21 µg	1 µg
Iron	1	1	100 µg	4 µg
Silicon	1	1	300,000 µg	1,000 µg
Sodium	1	1	193,000 µg	1,000 µg
Lab Blanks				
Aluminum	1	1	200 µg	20 µg
Barium	1	1	3.3 µg	1.0 µg
Chromium	1	1	2.0 µg	1.0 µg
Copper	1	1	2.0 µg	2.0 µg
Iron	1	1	23 µg	4.0 µg
Lead	1	1	16 µg	5.0 µg
Molybdenum	1	1	29 µg	5.0 µg
Sodium	1	1	110,000 µg	1,000 µg
Silicon	1	1	250,000 µg	1,000 µg
Strontium	1	1	0.80 µg	0.30 µg
Metals (GFAAS, CVAAS) - Probe & Nozzle Rinse plus Filter				
Field Blank				
Cadmium	1	1	0.25 µg	0.1 µg
Mercury	1	1	0.016 µg	0.01 µg
Lead	1	1	1.6 µg	0.3 µg
Trip Blank				
Mercury	1	1	0.011 µg	0.01 µg
Lead	1	1	0.62 µg	0.3 µg
Lab Blanks				
Lead	1	1	0.36 µg	0.30 µg

Table F-1

(Continued)

Method	Number of Blanks Analyzed	Number of Detects	Range of Compounds Detected	Reporting Limit
Metals (ICP-AES) - Solids				
Lab Blanks	5			
Aluminum		1	2,000 mg/kg	200 mg/kg
Copper		1	74 mg/kg	40 mg/kg
Molybdenum		1	67 mg/kg	50 mg/kg
Sodium		1	7,900 mg/kg	1,000 mg/kg
Metals (GFAAS, CVAAS) - Solids				
Lab Blanks				
Cadmium	4	0		
Arsenic	5	0		
Mercury				
Lead	5	1	8.1 mg/kg	3.0 mg/kg
Selenium	4	0		

Table F-2

Summary of Quality Control Check Sample Results for Site 15

Parameter	No. QCCS	Mean % Rec.	Std. Dev.
VOST:			
Benzene	2	104	7.8
Chrorobenzene	2	110	6.8
1,1-Dichloroethene	2	114	13.4
Toluene	2	108	7.8
Trichloroethene	2	96	12.0
Aldehydes:			
Formaldehyde	2	96	7.8
Anions:			
Chloride	1	100	-
Chlorine (NBS 1632A Coal)	1	101	-
Fluoride - Impinger	1	103	-
Fluoride - Waters	1	101	-
Phosphate - Impingers	2	105	0.57
Metals - Probe/Nozzle Rinse and Filter (ICP-AES-Predigest Spike into Blank Matrix):			
Aluminum	2	81	7.4
Antimony	2	66	9.1
Arsenic	2	90	2.2
Barium	2	88	3.4
Beryllium	2	92	3.1
Cadmium	2	81	2.5
Calcium	2	100	14
Chromium	2	84	3.6
Cobalt	2	82	3.7
Copper	2	80	5.0
Iron	2	84	2.4
Lead	2	74	6.9
Magnesium	2	79	2.5
Manganese	2	82	3.6
Molybdenum	2	87	2.3

Table F-2

(Continued)

Parameter	No. QCCS	Mean % Rec.	Std. Dev.
Nickel	2	83	2.4
Potassium	2	90	3.4
Selenium	2	0	NC
Silicon	2	0	NC
Silver	2	72	4.2
Sodium	2	0	NC
Strontium	2	87	2.3
Thallium	2	81	2.5
Titanium	2	89	2.2
Vanadium	2	84	3.6
Zinc	2	2	30
Metals - Probe/nozzle Rinse and Filter (GFAAS - Predigest Spike into Blank Matrix):			
Arsenic	2	114	2.6
Cadmium	2	106	3.8
Lead	2	114	5.3
Selenium	2	100	7
Metals - Probe/Nozzle Rinse and Filter (ICP-AES - NBS 1633A Fly Ash):			
Aluminum	1	50	-
Barium	1	78	-
Calcium	1	79	-
Chromium	1	106	-
Cobalt	1	101	-
Copper	1	91	-
Iron	1	80	-
Lead	1	387	-
Magnesium	1	65	-
Manganese	1	87	-
Molybdenum	1	1600	-
Nickel	1	88	-

Table F-2

(Continued)

Parameter	No. QCCS	Mean % Rec.	Std. Dev.
Strontium	1	80	-
Vanadium	1	86	-
Metals - Probe/Nozzle Rinse and Filter (GFAAS - NBS 1633A Fly Ash):			
Arsenic	1	86	-
Lead	1	87	-
Selenium	1	91	-
Metals - Impinger Solutions (ICP-AES - Predigestion Spike into Blank Matrix):			
Aluminum	1	96	NC
Antimony	1	96	NC
Arsenic	1	112	NC
Barium	1	99	NC
Beryllium	1	104	NC
Boron	1	101	NC
Cadmium	1	98	NC
Calcium	1	101	NC
Chromium	1	99	NC
Cobalt	1	99	NC
Copper	1	99	NC
Iron	1	97	NC
Lead	1	99	NC
Magnesium	1	97	NC
Manganese	1	99	NC
Molybdenum	1	102	NC
Nickel	1	99	NC
Potassium	1	95	NC
Selenium	1	100	NC
Silicon	1	91	NC
Silver	1	98	NC
Sodium	1	95	NC

Table F-2

(Continued)

Parameter	No. QCCS	Mean % Rec.	Std. Dev.
Strontium	1	99	NC
Thallium	1	97	NC
Titanium	1	100	NC
Vanadium	1	98	NC
Zinc	1	99	NC
Metals- Impinger Solutions (GFAAS/CVAAS - Predigest Spike of Blank Matrix):			
Cadmium		99	
Lead		100	
Metals - Solids Blind Performance Evaluation (ICP-AES - NBS 1633A Fly Ash):			
Aluminum	1	91	-
Barium	1	87	-
Beryllium	1	92	-
Calcium	1	90	-
Chromium	1	92	-
Cobalt	1	109	-
Copper	1	93	-
Iron	1	90	-
Lead	1	137	-
Magnesium	1	90	-
Manganese	1	95	-
Molybdenum	1	620	-
Nickel	1	94	-
Potassium	1	90	-
Sodium	1	135	-
Strontium	1	94	-
Titanium	1	100	-
Vanadium	1	94	-
Zinc	1	40	-

Table F-2

(Continued)

Parameter	No. QCCS	Mean % Rec.	Std. Dev.
Metals - Solids Blind Performance Evaluation (GFAAS - NBS 1633A Fly Ash):			
Arsenic	1	8.3	-
Cadmium	1	110	-
Lead	1	179	-
Selenium	1	91	-
Metals - NBS Coal 1632A (NAA):			
Aluminum	1	97	-
Antimony	1	99	-
Arsenic	1	99	-
Barium	1	98	-
Calcium	1	98	-
Chromium	1	98	-
Iron	1	98	-
Magnesium	1	106	-
Manganese	1	101	-
Nickel	1	107	-
Potassium	1	93	-
Selenium	1	98	-
Sodium	1	101	-
Titanium	1	109	-
Vanadium	1	100	-

Table F-3

Summary of Spiked Sample Results for Site 15

Compound	No. of Spikes	Mean % Recovery	Mean RPD Std. Dev.	No. Below Limits	No. Above Limits
Semivolatile Organics in Gas:					
Acenaphthene	2	68	0.7	0	0
4-Chloro-3-methylphenol	2	76	1.4	0	0
2-Chlorophenol	2	78	2.8	0	0
1,4-Dichlorobenzene	2	86	4.9	0	0
2,4-Dinitrotoluene	2	84	1.4	0	0
N-Nitrosodiprppylamine	2	66	2.1	0	0
4-Nitrophenol	2	158	11.3	0	2
Pentachlorophenol	2	74	3.5	0	0
Phenol	2	74	3.5	0	0
Pyrene	2	85	2.8	0	0
1,2,4-Trichlorobenzene	2	68	0	0	0
Anions in Gas:					
Chloride	1	92	NC	0	0
Fluoride	1	104	NC	0	0
Phosphate	1	0	NC	1	0
Sulfate	1	102	NC	0	0
Chloride and Sulfate in Solids:					
Chloride	2	100	0	0	0
Anions in Water:					
Chloride	6	102	1.1	0	0
Fluoride	2	80	0.71	2	0
Phosphate	1	98	NC	0	0
Sulfate	6	95	1.4	0	0
Metals by ICP-AES in ESP Inlet (Particulate):					
Aluminum	2	71	2.8	2	0
Antimony	2	86	2.3	0	0
Arsenic	2	127	3.1	0	1
Barium	2	104	1.9	0	0
Beryllium	2	92	1.1	0	0

Table F-3

(Continued)

Compound	No. of Spikes	Mean % Recovery	Mean RPD Std. Dev.	No. Below Limits	No. Above Limits
Boron	2	133	0	0	2
Cadmium	2	88	3.4	0	0
Calcium	2	98	11.3	0	2
Chromium	2	94	0	0	0
Cobalt	2	90	0	0	0
Copper	2	95	2.1	0	0
Iron	2	163	3.7	0	2
Lead	2	80	1.2	0	0
Magnesium	2	87	20.7	0	0
Manganese	2	93	0	0	0
Molybdenum	2	94	0	0	0
Nickel	2	90	1.1	0	0
Potassium	2	75	8	1	0
Selenium	2	30	30.5	2	0
Silver	2	7.8	41	2	0
Strontium	2	101	5.9	0	0
Thallium	2	91	4.4	0	0
Titanium	2	178	3.9	0	2
Vanadium	2	95	0	0	0
Zinc	2	84	10.6	0	0
Metals by GFAAS and CVAAS in ESP Inlet Gas (Particulate):					
Arsenic	2	45	4.4	0	1
Cadmium	2	118	13.6	0	0
Lead	2	138	2.9	1	0
Mercury	2	95	6.3	0	0
Selenium	2	70	4.2	0	0

Table F-3

(Continued)

Compound	No. of Spikes	Mean % Recovery	Mean RPD Std. Dev.	No. Below Limits	No. Above Limits
Metals by ICP-AES in Stack Gas (Probe/Nozzle Rinse and Filter):					
Aluminum	2	51	62.3	2	0
Antimony	2	70	9.9	2	0
Arsenic	2	93	4.3	0	0
Barium	2	83	9.6	0	0
Beryllium	2	84	3.6	0	0
Cadmium	2	82	1.2	0	0
Calcium	2	81	7.4	0	0
Chromium	2	84	3.6	0	0
Cobalt	2	81	1.2	0	0
Copper	2	80	5	0	0
Iron	2	59	33.9	2	0
Lead	2	76	0	0	0
Magnesium	2	76	3.9	0	0
Manganese	2	82	3.6	0	0
Molybdenum	2	86	5.8	0	0
Nickel	2	84	1.2	0	0
Potassium	2	71	8.4	2	0
Selenium	2	93	4.3	0	0
Silver	2	71	1.4	0	0
Sodium	2	130	30.8	0	2
Strontium	2	84	7.1	0	0
Thallium	2	76	9.3	1	0
Titanium	2	58	41	2	0
Vanadium	2	81	4.9	0	0
Zinc	2	98	1	0	0

Table F-3

(Continued)

Compound	No. of Spikes	Mean % Recovery	Mean RPD Std. Dev.	No. Below Limits	No. Above Limits
Metals by GFAAS and CVAAS in Stack Gas (Probe/Nozzle Rinse and Filter):					
Arsenic	2	84	14.3	1	0
Cadmium	2	120	6.7	0	0
Lead	2	87	1.1	0	0
Selenium	2	101	17.6	0	0
Metals by ICP-AES in ESP Inlet Gas (Impingers):					
Aluminum	4	94	2.9	0	0
Antimony	4	92	3.6	0	0
Arsenic	4	106	5.9	0	0
Barium	4	95	4.6	0	0
Beryllium	4	99	4.8	0	0
Boron	4	102	26.5	1	0
Cadmium	4	89	3.8	0	0
Calcium	4	99	3.7	0	0
Chromium	4	94	4.6	0	0
Cobalt	4	93	4.2	0	0
Copper	4	93	3.9	0	0
Iron	4	95	4.1	0	0
Lead	4	92	3	0	0
Magnesium	4	93	3.8	0	0
Manganese	4	93	4.6	0	0
Molybdenum	4	97	4.5	0	0
Nickel	4	94	3.7	0	0
Potassium	4	95	3.3	0	0
Selenium	4	111	22	0	1
Silicon	4	80	29.5	2	0
Silver	4	90	3.9	0	0
Sodium	4	94	2.9	0	0
Strontium	4	95	4.6	0	0

Table F-3

(Continued)

Compound	No. of Spikes	Mean % Recovery	Mean RPD Std. Dev.	No. Below Limits	No. Above Limits
Thallium	4	95	4.1	0	0
Titanium	4	96	3.7	0	0
Vanadium	4	93	4.1	0	0
Zinc	4	91	3.2	0	0
Metals by GFAAS and CVAAS in ESP Inlet Gas (Impingers):					
Cadmium	4	106	8.4	0	0
Lead	4	109	12.7	0	1
Mercury	4	102	6.9	0	0
Metals by GFAAS and CVAAS in Stack Gas (Impingers):					
Arsenic	4	102	6.2	0	0
Mercury	4	73	20.7	2	0
Metals by ICP-AES in Service Water:					
Aluminum	2	93	0	0	0
Antimony	2	90	0	0	0
Arsenic	2	106	3.8	0	0
Barium	2	92	1.1	0	0
Beryllium	2	94	1.1	0	0
Boron	2	96	0	0	0
Cadmium	2	90	1.1	0	0
Calcium	2	94	1.1	0	0
Chromium	2	90	0	0	0
Cobalt	2	90	0	0	0
Copper	2	90	0	0	0
Iron	2	90	1.1	0	0
Lead	2	88	2.3	0	0
Magnesium	2	92	0	0	0
Manganese	2	89	0	0	0
Molybdenum	2	90	1.1	0	0
Nickel	2	92	0	0	0

Table F-3

(Continued)

Compound	No. of Spikes	Mean % Recovery	Mean RPD Std. Dev.	No. Below Limits	No. Above Limits
Potassium	2	118	2.5	0	0
Selenium	2	82	0	0	0
Silicon	2	96	0	0	0
Silver	2	87	0	0	0
Sodium	2	94	7.4	0	0
Strontium	2	92	0	0	0
Thallium	2	92	0	0	0
Titanium	2	90	0	0	0
Vanadium	2	90	1.1	0	0
Zinc	2	92	3.3	0	0
Metals by GFAAS and CVAAS in Service Water:					
Arsenic	2	98	5.1	0	0
Cadmium	2	107	9.3	0	0
Lead	2	92	2.2	0	0
Mercury	2	118	5.9	0	0
Selenium	2	100	4	0	0
Metals by ICP-AES in Fly Ash Sluice Water:					
Aluminum	2	92	12	0	0
Antimony	2	92	5.4	0	0
Arsenic	2	110	13.7	0	0
Barium	2	96	15.7	0	0
Beryllium	2	98	12.2	0	0
Boron	2	86	46.5	1	0
Cadmium	2	92	10.9	0	0
Calcium	2	50	200	1	0
Chromium	2	93	12.9	0	0
Cobalt	2	93	10.8	0	0
Copper	2	92	15.2	0	0
Iron	2	92	9.8	0	0

Table F-3

(Continued)

Compound	No. of Spikes	Mean % Recovery	Mean RPD Std. Dev.	No. Below Limits	No. Above Limits
Lead	2	90	7.7	0	0
Magnesium	2	91	17.6	0	0
Manganese	2	92	16.4	0	0
Molybdenum	2	95	12.6	0	0
Nickel	2	92	9.7	0	0
Potassium	2	79	58	1	0
Selenium	2	91	8.8	0	0
Silicon	2	90	26.7	0	0
Silver	2	92	12	0	0
Sodium	2	86	31.6	1	0
Strontium	2	90	25.4	0	0
Thallium	2	96	9.4	0	0
Titanium	2	92	11.9	0	0
Vanadium	2	92	13	0	0
Zinc	2	92	14.2	0	0
Metals by GFAAS and CVAAS in Fly Ash Sluice Water:					
Arsenic	2	94	1	0	0
Cadmium	2	111	0	0	0
Lead	2	106	1.9	0	0
Mercury	2	110	15.3	0	0
Selenium	2	86	24.6	1	0

Table F-4

Summary of Surrogate Recoveries for Volatile Organic Analysis for Site 15

FCEM 15	No. of Analyses	Mean % Rec.	Std. Dev.	No. Below Limits	No. Above Limits	QC Limits %
ESP Inlet Gas (VOST):						
1,4-Bromofluorobenzene	8	106	6.3	0	0	50-150
1,2-Dichloroethane-d14	8	94	4.4	0	0	50-150
Toluene-d8	8	93	3.3	0	0	50-150
Stack Gas (VOST):						
1,4-Bromofluorobenzene	9	108	5.6	0	0	50-150
1,2-Dichloroethane-d14	9	92	3.9	0	0	50-150
Toluene-d8	9	95	8.4	0	0	50-150
VOST Field Blanks:						
1,4-Bromofluorobenzene	6	106	11.8	0	0	50-150
1,2-Dichloroethane-d14	6	96	4.1	0	0	50-150
Toluene-d8	6	91	6.6	0	0	50-150
VOST Trip Blanks:						
1,4-Bromofluorobenzene	1	111	NC	0	0	50-150
1,2-Dichloroethane-d14	1	101	NC	0	0	50-150
Toluene-d8	1	89	NC	0	0	50-150
VOST Lab Blanks:						
1,4-Bromofluorobenzene	2	117	24.0	0	0	50-150
1,2-Dichloroethane-d14	2	92	5.6	0	0	50-150
Toluene-d8	2	94	7.8	0	0	50-150

Table F-5

Summary of Surrogate Recoveries for Semivolatile Organic Analyses

FCEM 15	No. of Analyses	Mean % Rec.	Std. Dev.	No. Below Limits	No. Above Limits	QC Limits %
Gas:						
2-Fluorobiphenyl	8	96	2.1	0	0	30-115
2-Fluorophenol	8	85	4.4	0	0	25-121
Nitrobenzene-d5	8	98	0.8	0	0	23-120
Phenol-d5	8	101	11.8	0	1	24-114
Terphenyl-d14	8	104	7.7	0	0	18-137
2,4,6-Tribromophenol	8	98	6.8	0	0	19-122
Field Blanks - Gas Samples:						
2-Fluorobiphenyl	1	94	NC	0	0	30-115
2-Fluorophenol	1	75	NC	0	0	25-121
Nitrobenzene-d5	1	89	NC	0	0	23-120
Phenol-d5	1	88	NC	0	0	24-114
Terphenyl-d14	1	92	NC	0	0	18-137
2,4,6-Tribromophenol	1	80	NC	0	0	19-122
Reagent Blanks - Gas Samples:						
2-Fluorobiphenyl	1	88	NC	0	0	30-115
2-Fluorophenol	1	71	NC	0	0	25-121
Nitrobenzene-d5	1	86	NC	0	0	23-120
Phenol-d5	1	84	NC	0	0	24-114
Terphenyl-d14	1	101	NC	0	0	18-137
2,4,6-Tribromophenol	1	84	NC	0	0	19-122

Table F-5

(Continued)

FCEM 15	No. of Analyses	Mean % Rec.	Std. Dev.	No. Below Limits	No. Above Limits	QC Limits %
Lab Blanks - Gas Samples:						
2-Fluorobiphenyl	1	97	NC	0	0	30-115
2-Fluorophenol	1	80	NC	0	0	25-121
Nitrobenzene-d5	1	102	NC	0	0	23-120
Phenol-d5	1	95	NC	0	0	24-114
Terphenyl-d14	1	95	NC	0	0	18-137
2,4,6-Tribromophenol	1	90	NC	0	0	19-122

Table F-6

Summary of Duplicate Sample Results for Site 15

FCEM 15	No. of Pairs	Mean	RPD %
Total Hydrogen, Carbon, and Nitrogen in ESP Inlet Particulates (%):			
Hydrogen	1	0.03	0
Carbon	1	3.92	0.8
Nitrogen	1	0.07	0
Total Sulfur in ESP Particulates - Duplicate Analysis (%):			
Sulfur	1	0.1366	5.9
Total Sulfur in Fly Ash - Duplicate Analysis (%):			
Sulfur	1	0.0208	0.48
Total Sulfur in Bottom Ash (%):			
Duplicate Samples	1	0.145	70
Duplicate Analysis	1	0.09412	1.2
Anions in Bottom Ash Sluice Water (mg/L):			
Chloride	1	10.2	3.9
Fluoride	1	0.2	0.5
Phosphate	1	0.172	16.4
Anions in Service Water (mg/L):			
Chloride	1	8.6	3.1
Fluoride	1	0.0457	0
Phosphate	1	0.0668	1.5
Anions in Fly Ash Sluice Water (mg/L):			
Chloride	1	10.7	1.9
Fluoride	1	0.562	2.3
Phosphate	1	0.0702	7.6
Sulfate	1	168	2.4
Anions in Ash Settling Pond (mg/L):			
Chloride	1	17.8	7.9
Fluoride	1	0.16	3.1

Table F-6

(Continued)

FCEM 15	No. of Pairs	Mean	RPD %
Phosphate	1	0.0607	14.8
Sulfate	1	138	7.9
Anions in Wastewater Treatment Effluent (mg/L):			
Chloride	1	95.1	1.9
Fluoride	1	0.248	4
Phosphate	1	0.0054	12.8
Sulfate	1	966	0.2
Anions in Fly Ash (mg/kg):			
Chloride	1	<33.9	>82
Chloride and Sulfate in ESP Inlet Impingers (mg/L):			
Chloride	1	168	0.6
Sulfate	1	14,250	0.9
Anions - Duplicate Analyses:			
Fluoride- Waters (mg/L)	1	0.203	3.2
Fluoride- Waters (mg/L)	1	0.067	0
Fluoride- Solids (mg/kg)	1	15.18	3.3
Phosphate-Waters (mg/L)	1	0.724	26.3
ICP-AES Metals in Bottom Ash (mg/kg):			
Aluminum	1	120,000	0
Barium	1	740	0
Beryllium	1	6	13.3
Calcium	1	7,000	2.8
Chromium	1	125	8
Cobalt	1	36	16.7
Copper	1	32	0
Iron	1	86,000	1.2
Magnesium	1	3,700	0
Manganese	1	290	0
Molybdenum	1	150	0

Table F-6

(Continued)

FCEM 15	No. of Pairs	Mean	RPD %
Nickel	1	75.5	17.2
Potassium	1	15,000	0
Sodium	1	2,150	70
Strontium	1	685	1.4
Vanadium	1	170	0
Titanium	1	7,350	1.4
Metals by GFAAS and CVAAS in Fly Ash (mg/kg):			
Arsenic	1	10.6	83
Lead	1	115	8.7
Selenium	1	5.6	10.7
Metals by GFAAS and CVAAS in Fly Ash - Duplicate Analysis (mg/kg):			
Arsenic	1	8.7	4.6
Selenium	1	9.2	3.2
Mercury by CVAAS in Waters (mg/L):			
No target analyte detected in five duplicate pairs.			
ICP-AES Metals in Bottom Ash Sluice Water (mg/L):			
Aluminum	1	2	90
Barium	1	0.11	33.2
Beryllium	1	0.0026	11.8
Calcium	1	20	4.9
Copper	1	<0.020	>4.9
Iron	1	2	93
Magnesium	1	4.5	4.4
Manganese	1	0.32	6.2
Nickel	1	<0.022	>22.2
Silicon	1	4.4	34.5
Sodium	1	8.9	7.8
Strontium	1	0.18	27
Titanium	1	0.11	97
Zinc	1	0.026	3.8

Table F-6

(Continued)

FCEM 15	No. of Pairs	Mean	RPD %
Metals by GFAAS in Bottom Ash Sluice Water (mg/L):			
Arsenic	1	<0.0053	>11.3
Lead	1	0.0042	19
ICP-AES Metals in Fly Ash Sluice Water (mg/L):			
Aluminum	1	2.5	32
Barium	1	<0.33	>18.2
Beryllium	1	0.12	24
Boron	1	2.6	3.8
Cadmium	1	0.0073	2.7
Calcium	1	99	2
Chromium	1	0.042	41
Cobalt	1	0.015	13.3
Copper	1	0.13	31
Iron	1	0.9	22.2
Magnesium	1	6.9	5.6
Manganese	1	0.34	2.9
Molybdenum	1	0.12	24
Nickel	1	0.074	4
Potassium	1	16	6.1
Silicon	1	5.7	7
Silver	1	0.012	26.1
Sodium	1	16	6.4
Strontium	1	0.88	7.9
Vanadium	1	0.098	23.4
Zinc	1	0.18	11.1
Metals by GFAAS in Fly Ash Sluice Water (mg/L):			
Arsenic	1	0.48	20.8
Cadmium	1	0.0072	9.7
Lead	1	<0.003	>3.3
Selenium	1	0.015	13.3

Table F-6

(Continued)

FCEM 15	No. of Pairs	Mean	RPD %
ICP-AES Metals in Ash Settling Pond Outlet Water (mg/L):			
Aluminum	1	0.4	42
Barium	1	0.068	2.9
Beryllium	1	0.0024	0
Calcium	1	20	4.9
Iron	1	0.46	32
Magnesium	1	4.3	4.6
Manganese	1	0.24	0
Silicon	1	3	0
Sodium	1	9.4	1.1
Strontium	1	0.15	0
Metals by GFAAS in Ash Settling Pond Outlet Water (mg/L):			
Lead	1	0.0062	38.7
ICP-AES Metals in Service Water (mg/L):			
Aluminum	1	0.67	9
Barium	1	0.05	2
Beryllium	1	16	6.1
Calcium	1	0.024	12.8
Copper	1	1.7	11.8
Iron	1	4.4	0
Magnesium	1	0.32	3.2
Manganese	1	3	3.4
Silicon	1	<0.23	>11.3
Sodium	1	9	17.8
Strontium	1	0.073	2.7
Zinc	1	0.034	75
Metals by GFAAS in Service Water (mg/L):			
Lead	1	0.0103	13.6

Table F-6

(Continued)

FCEM 15	No. of Pairs	Mean	RPD %
ICP-AES Metals in Wastewater Treatment Effluent (mg/L):			
Calcium	1	100	1
Iron	1	0.52	9.5
Magnesium	1	31	0
Manganese	1	0.14	0
Potassium	1	6.8	2.9
Silicon	1	3.6	2.8
Sodium	1	495	
Strontium	1	1.5	0
Metals by GFAAS in Wastewater Treatment Effluent (mg/L):			
Lead	1	0.0042	57

Appendix G

Blank Correction Data

For most of the metallic elements of interest to this program, small traces are present in both the reagents and filter media used in sampling and analyses. In many instances, the total mass present in these materials prior to sampling is equivalent to that measured after sampling. Consequently, we routinely use a blank correction in the calculation of gas stream concentrations for metals and anions. Semivolatile gas analyses have not indicated the presence of semivolatile organic compounds in the blanks. Aldehyde samples occasionally require blank correction. In the following tables, the mass or concentrations reported by the laboratory are presented for those substances for which concentrations were reported in the blank. The ratio of the blank value to the measured value is then calculated. Measured values which are equal to or greater than 50% of the blank values are denoted with a "B". As shown in Appendix F, for the large majority of substances, the blank levels detected are within five times of the reporting limit indicating that the substance levels in the reagent and filter media are low.

Table G-1 presents the probe and nozzle rinse and filter blank, and anion corrections for Site 15. Ten substances were reported in the blanks. Of the 30 values (10 substances, 3 runs) which were blank corrected, corrections of 50% or more were only made to the levels of molybdenum measured in the stack.

Table G-2 presents the metal impinger blank corrections for Site 15. Three metals (cadmium, lead, and manganese) were detected in the blank impinger solution. Many of the sample train impingers had concentrations of cadmium and lead that were below the reporting limits. (Specific reporting limits vary based on the amount of liquid in each impinger analyzed, since the reporting limit for these instruments is expressed in mg/L). Of the 18 measurements shown on this table, the blank correction is less than 50% for only four.

Table G-1

Site 15 Anion and Filter Blank [a] Corrections

Stream	Substance	UOM	Run 1 [b]	Blank/ Run 1	Run 2 [b]	Blank/ Run 2	Run 3 [b]	Blank/ Run 3	Blank
Stack Gas, Solid Phase	Barium	µg	110	16%	110	16%	64	28%	18
Stack Gas, Solid Phase	Cadmium	µg	3.2	8%	3	8%	9.6	3%	0.25
Stack Gas, Vapor Phase	Chloride	mg/L	191	0%	216	0%	195	0%	0.837
ESP Inlet Gas, Vapor Phase	Chloride	mg/L	208	0%	169	0%	198	0%	0.837
Stack Gas, Solid Phase	Chromium	µg	28	19%	26	21%	30	18%	5.4
Stack Gas, Solid Phase	Copper	µg	16	21%	14	24%	14	24%	3.4
Stack Gas, Solid Phase	Lead	µg	11	15%	16	10%	120	1%	1.6
Stack Gas, Solid Phase	Manganese	µg	21	10%	24	9%	16	14%	2.2
Stack Gas, Solid Phase	Mercury	µg	0.12	13%	0.14	11%	0.18	9%	0.016
Stack Gas, Solid Phase	Molybde-num	µg	48 B [c]	81%	51 B	76%	50 B	78%	39
Stack Gas, Solid Phase	Vanadium	µg	37	6%	40	6%	22	11%	2.4

[a]Filter blanks include probe and nozzle rinse blanks.
[b]Blank corrected.
[c]Blank correction of 50% or more of the measured concentration.

Table G-2

Site 15 Metals Impinger Blank Corrections

Substance	Stream	Run 1, mg [a]	Blank/ Run 1	Run 2, mg [a]	Blank/ Run 2	Run 3, mg [a]	Blank/ Run 3	Blank, mg	Avg FB
Cadmium	ESP Inlet Gas, Vapor Phase	0.00073	41%	<0.0003 B[b]	100%	<0.0003 B	100%	0.0003	0.0012
Cadmium	Stack Gas, Vapor Phase	<0.0003 B	100%	<0.0003 B	100%	<0.0003 B	100%	0.0003	0.0012
Lead	ESP Inlet Gas, Vapor Phase	<0.0009 B	1247%	<0.0009 B	1247%	0.0019 B	591%	0.01123	0.0449
Lead	Stack Gas, Vapor Phase	<0.0009 B	1247%	<0.0009 B	1247%	<0.0009 B	1247%	0.01123	0.0449
Manganese	ESP Inlet Gas, Vapor Phase	0.2425 B	11%	0.108	24%	0.5779	4%	0.02575	0.103
Manganese	Stack gas, Vapor Phase	0.0466 B	55%	0.0506 B	51%	0.0511 B	50%	0.02575	0.103

[a] Blank corrected.

[b] B = Blank correction of 50% or more.