
FINAL REPORT

VOLUME 1 of 2 - SAMPLING/

RESULTS/SPECIAL TOPICS

A Study of Toxic Emissions

from a Coal-Fired Power

Plant - Niles Station

Boiler No. 2

Contract DE-AC22-93PC93251

To

U.S. Department of Energy

Pittsburgh Energy Technology Center

June 1994

FINAL REPORT

VOLUME 1 of 2 - SAMPLING/RESULTS/SPECIAL TOPICS

on

**A STUDY OF TOXIC EMISSIONS FROM A
COAL-FIRED POWER PLANT -
NILES STATION BOILER NO. 2**

Contract No. DE-AC22-93PC93251

Prepared for

**DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER**

by

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EXECUTIVE SUMMARY

This document is the Technical Note on the project titled "A Study of Toxic Emissions from a Coal-Fired Power Plant: Niles Station Boiler No. 2". This study was conducted for the U.S. Department of Energy, Pittsburgh Energy Technology Center (DOE-PETC), under Contract DE-AC22-93PC93251. The present study was one of a group of assessments of toxic emissions from coal-fired power plants, conducted for DOE-PETC during 1993. The motivation for those assessments was the mandate in the 1990 Clean Air Act Amendments that a study be made of emissions of hazardous air pollutants (HAPs) from electrical utilities. The results of this study will be used by the U.S. Environmental Protection Agency to evaluate whether regulation of HAPs emissions from utilities is warranted.

This report is organized in two volumes. Volume 1: Sampling/Results/Special Topics describes the sampling effort conducted as the basis for this study, presents the concentration data on toxic chemicals in the several power plant streams, and reports the results of evaluations and calculations conducted with those data. The Special Topics section of Volume 1 reports on issues such as comparison of sampling methods and vapor/particle distributions of toxic chemicals. Volume 2: Appendices include field sampling data sheets, quality assurance results, and uncertainty calculations.

This study involved measurements of a variety of toxic chemicals in solid, liquid, and gaseous samples from input, output, and process streams at a coal-fired power plant equipped with an electrostatic precipitator (ESP). The host plant for this study was the Niles Station Boiler No. 2, operated by Ohio Edison, in Niles, Ohio. Niles Boiler No. 2 is equipped with four cyclone burners, and burns bituminous coal of nominal sulfur content of 2.7 percent to achieve a net generating capacity of 108 MW. Measurements were conducted at Niles Boiler No. 2 on July 26-31, 1993. During the measurements, Ohio Edison provided reproducible conditions for sampling by maintaining Boiler No. 2 at full load and stable operating conditions.

The chemicals measured at Niles Boiler No. 2 were the following:

1. Five major and 16 trace elements, including mercury, chromium, cadmium, lead, selenium, arsenic, beryllium, and nickel.
2. Acids and corresponding anions (HCl, HF, chloride, fluoride, phosphate, sulfate).
3. Ammonia and cyanide.
4. Elemental carbon.
5. Radionuclides.

6. Volatile organic compounds (VOC).
7. Semivolatile compounds (SVOC) including polynuclear aromatic hydrocarbons (PAH), and polychlorinated dioxins and furans.
8. Aldehydes.

Some or all of these constituents were measured in solid, liquid, and gaseous input and output streams of the plant, and in flue gas at key points within the plant. In addition, particle size distributions were determined for flue gas particulate matter and for collected solid samples such as ESP ash. The measurement data are presented in Volume 1, Section 5.

The measurement data from this study were used to address several objectives:

1. To assess the emission levels of selected HAPs.
2. To determine for selected HAPs (a) the removal efficiency of the ESP, (b) material balances in individual components of the plant, and (c) material balances for the plant as a whole.
3. To determine the particle size distribution of selected HAPs in the flue gas particulate.
4. To determine the vapor/particle phase distribution of selected HAPs in flue gas streams.
5. To determine the concentrations and vapor/particle distributions of HAPs, under conditions simulating dilution and cooling of the stack plume in the atmosphere.

These objectives were addressed by comparisons and calculations using the HAPs concentration data obtained during the field measurements, along with plant characteristics and operating data provided by Ohio Edison. The main results of this study in each of these areas are summarized below.

The emission levels of the measured HAPs were calculated based on the stack gas flow rate and the concentrations measured in the stack gas. Not unexpectedly, emission rates differed widely among the various types of HAPs. The emission rates, which are reported in Volume 1, Section 6.2, are summarized in Tables ES-1 to ES-9. Emission rates in these tables are in units of pounds per 10^{12} Btu ($\text{lb}/10^{12}$ Btu) except for radionuclides, which are in milliCuries per 10^{12} Btu ($\text{mCi}/10^{12}$ Btu). Those tables, and the corresponding tables in Section 6.2, include an estimate of the total uncertainty (\pm) associated with each emission factor. The uncertainty values, which are 95 percent confidence intervals, include the effects of both precision and bias uncertainties; the emission factors should not be used without consideration of the associated uncertainty values. No emission factor is shown for silicon in Table ES-1 due to availability of partial data for this element (see Sections 5.1 and 6.2).

Removal efficiencies and material balances were calculated for the major and trace elements. Removal efficiencies for these elements were calculated for the ESP, and the average values (and standard deviations) are summarized in Table ES-10. Removal efficiencies for 15 of the elements exceeded 97 percent, and for 18 of the elements exceeded 93 percent. However, for mercury and selenium removal efficiencies of 30 and 8 percent, respectively, were found. The mercury result is consistent with the volatility of that element. The selenium results showed considerable variability, due to the difficulty in sampling and analyzing for this element. Removal efficiency results are presented in Volume 1, Section 6.3.

Material balances for elements were calculated across both individual plant components (i.e., the boiler; the ESP) and across the whole plant (i.e., boiler and ESP). Average mass balance results for the boiler; for the ESP; and for the combination of the boiler and ESP are shown in Table ES-11 for each element. Mass balance results (i.e., outputs/inputs) were within ± 25 percent of balance for the majority of the elements, and within ± 50 percent for almost all the elements. For instance, for the entire plant 17 of the elements considered showed mass balance results between 50 and 150 percent. However, a few elements exhibited low or high mass balances in one or more plant components. The reasons for the latter results include uncertainties in the measured HAPs concentrations in the pertinent streams, and the necessity of making assumptions about the mass flows in some streams. The mass balance results are presented in Volume 1, Section 6.1.

The particle size distribution of elements in flue gas particulate matter was evaluated, and is presented as a Special Topic in Volume 1, Section 7.3. That evaluation shows that for most elements the great majority of the mass of the element in flue gas particulate occurs in the size range greater than 10 micrometers (μm) aerodynamic diameter, which comprises the bulk of flue gas particulate. However, for a few elements, notably antimony, arsenic, cadmium, molybdenum, and lead, a substantial portion of the total flue gas loading is present in the size range less than 5 μm diameter. This effect occurs because the elemental composition of flue gas particulate differs among different size ranges. These results indicate that the effectiveness of toxic element removal by particulate removal equipment may vary from one element to another.

The vapor/particle phase distributions of elements, PAH/SVOC, and dioxins/furans were determined, and are presented as a Special Topic in Volume 1, Section 7.2. That evaluation shows that most of the elements measured exist almost entirely in the particle phase under all flue gas conditions encountered at Niles Boiler No. 2. However, some elements, such as antimony, arsenic, lead, sodium, potassium, and manganese, were found to be distributed between the vapor and particle phase. Mercury alone was found almost entirely in the vapor phase at both flue gas locations where it was measured. Most PAH and SVOC compounds were found largely in the vapor phase, consistent with their volatility and the flue gas temperatures. Benzo[a]pyrene and other PAHs having five or more aromatic rings in their molecular structure were rarely detected, so no phase distributions could be determined for such compounds. The one exception was benzo[e]pyrene, which existed 70 percent in the particulate phase in stack gas. Relatively few dioxin/furan compounds could be detected in flue gas. Those that were detected were present predominantly in the vapor

phase, consistent with their volatility. Thus the element, PAH/SVOC, and dioxin/furan data appear to provide a coherent and credible picture of the phase distributions of these species in the flue gas.

Simulated plume conditions were achieved using the Plume Simulating Dilution Sampler (PSDS) at the Niles stack. The PSDS extracts a flow of hot stack gas, and dilutes and cools it with a much larger flow of high purity air. The resulting gas is then sampled with the same methods used for the hot flue gas. Comparison of results from measurements made on hot stack gas with those made using the PSDS is presented as a Special Topic in Volume 1, Section 7.1. On an absolute basis, the concentration measurements made with the PSDS generally do not agree closely with those made on the hot gas. However, the PSDS is primarily designed to address the relative effects of plume dilution on pollutants, and of necessity has certain features which increase the uncertainty of absolute concentration measurements. The results in Section 7.1 illustrate the potential utility of the PSDS approach, but also indicate that further evaluation is needed of the absolute measurement capabilities of that approach.

Four other special topics were addressed in this study. First, measurements of vapor phase mercury, arsenic, and selenium in flue gas by EPA Method 29 were compared to parallel measurements using the Hazardous Element Sampling Train (HEST). The HEST is a novel approach that uses carbon-impregnated filters to collect vapor phase metals. Mercury results from the two methods showed excellent agreement. The HEST filters showed some degradation due to acid mist formation in sampling at the Boiler No. 2 stack; further work on preventing such an effect may be needed. HEST and Method 29 results showed poor agreement for arsenic and selenium, probably due to the sensitivity of vapor/particle distributions for these species to the temperature during sampling. This result indicates further work may be needed to define the range of conditions in which the HEST (and Method 29) are applicable. The HEST/Method 29 comparison is presented in Section 7.4 of Volume 1.

In another Special Topic, measurements of VOC in flue gas were made by two distinct methods: collection on solid sorbents using a Volatile Organic Sampling Train (VOST), and collection of whole flue gas in Summa sampling canisters. Comparison of VOC results from the two methods is presented in Section 7.5 of Volume 1. Most VOC were below or near the detection limit with both methods. For those VOC that were detected, agreement between methods was only within about a factor of four, and no consistent bias between methods could be discerned. Based on these results, it is not possible to select one method over the other; further evaluation is needed of methods for VOC in flue gas.

The effect of soot blowing on element concentrations in flue gas is presented as a Special Topic in Section 7.6 of Volume 1. This subject was addressed by high volume particulate sampling in the stack, both during soot blowing and during normal operations. The high volume results showed no substantial differences between element concentrations during soot blowing and normal conditions. However, several inconsistencies exist in the data. The soot blowing results indicate lower particulate loadings in stack gas than do the

results from normal conditions, contrary to expectations. Also, the high volume sampling in both soot blowing and normal conditions indicates much lower concentrations of elements in stack gas than do full traversing measurements using EPA Method 29. These inconsistencies cast doubt on any comparisons made with the high volume data, and indicate that the issue of element emissions during soot blowing must be studied further.

Finally, the mercury data from each component and sample fraction of the Method 29 train are considered separately, rather than collectively, in Section 7.7 of Volume 1. The purpose of this Special Topic was to assess the separation of mercury in the components of the Method 29 train. That evaluation showed that nearly all mercury is collected in the impinger portion of the Method 29 train, due to the predominance of the vapor form of this element in flue gas. The peroxide impinger solutions collected an average of 83 percent of the total mercury, and the permanganate impingers (located downstream in the Method 29 train) collected an average of 14 percent of the mercury.

TABLE ES-1. EMISSION FACTORS FOR ELEMENTS (lb/10¹² BTU)

Analyte	Emission Factor	Uncertainty
Aluminum	3280 a	NC
Potassium	2040 a	NC
Sodium	266 b	NC
Titanium	23	20
Antimony	ND < 0.36 #	0.06
Arsenic	42	19
Barium	5.4	9.3
Beryllium	0.19	0.05
Boron	NA	NA
Cadmium	0.07 ##	0.16
Chromium	3.0	1.2
Cobalt	ND < 0.12 #	0.02
Copper	4.0	2.2
Lead	1.6	1.2
Manganese	3.4	3.1
Mercury	14	6.4
Molybdenum	2.3	1.3
Nickel	0.55	0.69
Selenium	62	67
Vanadium	2.5	0.85

Uncertainty = 95% confidence limit.

NA = Not analyzed.

ND < = Analyte not detected.

NC = Not calculated.

= Average emission factor includes three non-detects out of three measurements.

= Average emission factor includes one or two non-detects out of three measurements.

a = Emission factor based on one set of measurements due to outliers.

b = Emission factor based on two sets of measurements due to outliers.

TABLE ES-2. EMISSION FACTORS FOR AMMONIA/CYANIDE (lb/10¹² BTU)

<u>Analyte</u>	<u>Emission Factor</u>	<u>Uncertainty</u>
Ammonia	70 ##	298
Cyanide	180	288

Uncertainty = 95 % confidence limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE ES-3. EMISSION FACTORS FOR ANIONS (lb/10¹² BTU)

<u>Analyte</u>	<u>Emission Factor</u>	<u>Uncertainty</u>
Hydrogen Chloride	132000	25300
Hydrogen Fluoride	8921	2455
Chloride (Particulate) **	19	21
Fluoride (Particulate) **	11	18
Phosphate (Particulate) **	111 ##	215
Sulfate (Particulate) **	12280	4298

Uncertainty = 95 % confidence limit.

= Average emission factor includes one or two non-detects out of three measurements.

** Sampling for anions was conducted at a single point in the duct; traverses were not made.

TABLE ES-4. EMISSION FACTORS FOR VOC (lb/10¹² BTU)

Analyte	Emission Factor	Uncertainty
Chloromethane	4.9 ##	10
Bromomethane	ND< 6.5 #	6.4
Vinyl Chloride	ND< 5.1 #	0.9
Chloroethane	ND< 5.1 #	0.9
Methylene Chloride	NC	NC
Acetone	NC	NC
Carbon Disulfide	5.9 ##	8.0
1,1-Dichloroethene	ND< 5.1 #	0.9
1,1-Dichloroethane	ND< 5.1 #	0.9
Trans-1,2-Dichloroethene	ND< 5.1 #	0.9
Chloroform	ND< 5.1 #	0.9
1,2-Dichloroethane	ND< 5.1 #	0.9
2-Butanone	5.1 ##	11
1,1,1-Trichloroethane	ND< 5.1 #	0.9
Carbon Tetrachloride	ND< 5.1 #	0.9
Vinyl Acetate	ND< 5.1 #	0.9
Bromodichloromethane	ND< 5.1 #	0.9
1,2-Dichloropropane	ND< 5.1 #	0.9
cis-1,3-Dichloropropylene	ND< 5.1 #	0.9
Trichloroethene	ND< 5.1 #	0.9
Dibromochloromethane	ND< 5.1 #	0.9
1,1,2-Trichloroethane	ND< 4.9 #	1.1
Benzene	7.9	5.7
trans-1,3-Dichloropropylene	ND< 5.1 #	0.9
2-Chloroethylvinylether	ND< 5.1 #	0.9
Bromoform	ND< 4.89 #	1.1
4-Methyl-2-Pentanone	5.0 ##	11
2-Hexanone	7.8 ##	23
Tetrachloroethene	3.1 ##	2.6
1,1,2,2-Tetrachloroethane	ND< 5.08 #	0.9
Toluene	3.5 ##	7.3
Chlorobenzene	ND< 5.08 #	0.9
Ethylbenzene	ND< 5.08 #	0.9
Styrene	ND< 5.08 #	0.9
Xylenes (Total)	ND< 5.08 #	0.9

Uncertainty = 95% confidence limit.

ND< = Analyte not detected.

NC = Not calculated, measurements in field affected by contamination.

= Average emission factor includes three non-detects out of three measurements.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE ES-5. EMISSION FACTORS FOR PAH/SVOC (lb/10¹² BTU)

Analyte	Emission Factor	Uncertainty
Benzylchloride	ND < 0.0119 #	0.0221
Acetophenone	0.6360	0.7425
Hexachloroethane	ND < 0.0119 #	0.0221
Naphthalene	0.2153	0.2500
Hexachlorobutadiene	ND < 0.0119 #	0.0221
2-Chloroacetophenone	0.2879	0.5166
2-Methylnaphthalene	0.0375	0.0905
1-Methylnaphthalene	0.0157	0.0372
Hexachlorocyclopentadiene	ND < 0.0119 #	0.0221
Biphenyl	0.1257	0.3563
Acenaphthylene	0.0068 ##	0.0233
2,6-Dinitrotoluene	0.5544	0.2437
Acenaphthene	0.0265	0.0833
Dibenzofuran	0.0654	0.1264
2,4-Dinitrotoluene	0.0197 ##	0.0266
Fluorene	0.0313	0.0895
Hexachlorobenzene	ND < 0.0119	0.0221
Pentachlorophenol	ND < 0.0119	0.0221
Phenanthrene	0.0776	0.1722
Anthracene	0.0207	0.0696
Fluoranthene	0.0270	0.0449
Pyrene	0.0139	0.0272
Benz(a)anthracene	0.0037 ##	0.0095
Chrysene	0.0089	0.0206
Benzo(b & k)fluoranthene	0.0070 ##	0.0243
Benzo(e)pyrene	0.0021 ##	0.0056
Benzo(a)pyrene	ND < 0.0024 #	0.0044
Indeno(1,2,3-c,d)pyrene	ND < 0.0024 #	0.0044
Dibenz(a,h)anthracene	ND < 0.0024 #	0.0044
Benzo(g,h,i)perylene	ND < 0.0024 #	0.0044

Uncertainty = 95 % confidence limit.

ND < = Analyte not detected.

= Average emission factor includes three non-detects out of three measurements.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE ES-6. EMISSION FACTORS FOR ALDEHYDES (lb/10¹² BTU)

<u>Analyte</u>	<u>Emission Factor</u>	<u>Uncertainty</u>
Formaldehyde	3.9 ##	8.7
Acetaldehyde	89	184
Acrolein	41	151
Propionaldehyde	25	52

Uncertainty = 95% confidence limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE ES-7. EMISSION FACTORS FOR RADIONUCLIDES (mCi/10¹² BTU)

<u>Analyte</u>	<u>Emission Factor</u>	<u>Uncertainty</u>
Pb-212	ND < 15 #	21
Tb-234	ND < 123 #	171
Pb-210	ND < 161 #	185
Pb-211	ND < 237 #	361
Ra-226	ND < 18 #	36
Ra-228	ND < 48 #	68
Th-229	ND < 92 #	123
Th-230	ND < 878 #	1009
U-234	ND < 3710 #	5430
U-235	ND < 39 #	59

Uncertainty = 95% confidence limit.

ND < = Analyte not detected.

= Average emission factor includes three non-detects out of three measurements.

TABLE ES-8. EMISSION FACTORS FOR PARTICULATE MATTER (lb/10¹² BTU)

Analyte	Emission Factor	Uncertainty
Particulate Matter	19600	19800

Uncertainty = 95% confidence limit.

TABLE ES-9. EMISSION FACTORS FOR DIOXINS/FURANS (lb/10¹² BTU)

Analyte	Emission Factor	Uncertainty
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND < 2.10E-06 #	1.50E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND < 2.85E-06 #	2.50E-06
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND < 3.39E-06 #	4.98E-06
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	2.96E-06 ##	8.04E-06
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	2.85E-06 ##	8.64E-06
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	1.71E-05	4.31E-05
Octachlorodibenzo-p-dioxin	1.89E-05	7.46E-05
2,3,7,8-Tetrachlorodibenzofuran	4.76E-06 ##	1.20E-05
1,2,3,7,8-Pentachlorodibenzofuran	ND < 3.40E-06 #	5.25E-06
2,3,4,7,8-Pentachlorodibenzofuran	3.22E-06 ##	5.64E-06
1,2,3,4,7,8-Hexachlorodibenzofuran	9.61E-06 ##	3.17E-05
1,2,3,6,7,8-Hexachlorodibenzofuran	3.84E-06 ##	9.91E-06
1,2,3,7,8,9-Hexachlorodibenzofuran	6.53E-06 ##	1.35E-05
2,3,4,6,7,8-Hexachlorodibenzofuran	ND < 2.50E-06 #	2.49E-06
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1.72E-05 ##	4.98E-05
1,2,3,4,7,8,9-Heptachlorodibenzofuran	3.62E-06 ##	8.66E-06
Octachlorodibenzofuran	1.95E-05	2.43E-05

Uncertainty = 95% confidence limit.

ND < = Analyte not detected.

= Average emission factor includes three non-detects out of three measurements.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE ES-10. AVERAGE ESP REMOVAL EFFICIENCIES FOR ELEMENTS (Percent)

Analyte	Average Removal Efficiency	Standard Deviation
Aluminum	97.11	0.24
Potassium	93.37	1.01
Silicon	96.65 ##	1.03
Sodium	93.71	8.12
Titanium	99.73	0.06
Antimony	99.80 #	0.10
Arsenic	97.41	0.44
Barium	99.34	0.43
Beryllium	99.56	0.10
Boron	NA	NA
Cadmium	97.11 ##	3.22
Chromium	99.20	0.02
Cobalt	99.95 #	0.01
Copper	99.32	0.19
Lead	99.72	0.13
Manganese	98.98	0.37
Mercury	29.92	6.59
Molybdenum	98.09	0.08
Nickel	99.88	0.06
Selenium	7.60	35.77
Vanadium	99.56	0.11

Calculation includes three non-detects out of three measurements.

Calculation includes one or two non-detects out of three measurements.

NA = Not analyzed.

TABLE ES-11. AVERAGE MASS BALANCE RESULTS FOR ELEMENTS IN NILES UNIT NO. 2 AND IN PLANT COMPONENTS (Percent)

Analyte	Average Mass Balance (Std. Dev.)		
	Boiler	ESP	Entire Plant
Aluminum	96.7 (1.4)	99.7 (9.0)	96.7 (1.9)
Potassium	98.5 (7.4)	82.9 (1.7)	95.5 (7.2)
Silicon	96.7 (1.6)	147.8 (45.8)	99.5 (1.5)
Sodium	82.7 (29.2)	63.8 (39.1) ##	63.5 (10.4)
Titanium	93.1 (1.2)	87.5 (15.9)	91.4 (1.2)
Antimony	79.7 (37.2) #	67.3 (38.8) #	47.6 (9.1) #
Arsenic	63.7 (13.4)	81.4 (10.6)	52.7 (12.6)
Barium	123.4 (3.8)	94.9 (9.2)	122.6 (3.1)
Beryllium	92.6 (7.5)	82.4 (1.2)	87.8 (7.0)
Boron	NA	NA	NA
Cadmium	181.3 (11.7) #	57.9 (3.5) #	163.9 (7.0) #
Chromium	103.4 (2.6)	74.5 (2.9)	96.1 (2.4)
Cobalt	96.2 (7.3)	79.3 (7.6) #	91.8 (7.2) #
Copper	87.0 (7.8)	76.6 (2.2)	75.4 (7.4)
Lead	63.6 (17.1)	82.3 (5.0)	53.6 (15.7)
Manganese	114.7 (10.2)	81.8 (8.8)	111.8 (8.9)
Mercury	125.3 (36.3) ##	72.1 (6.2)	90.2 (26.3) ##
Molybdenum	73.1 (8.1) #	132.5 (16.1) #	83.3 (5.7) #
Nickel	100.7 (8.7)	73.8 (2.0)	93.1 (8.8)
Selenium	43.7 (5.0) #	112.4 (30.6) ##	48.2 (14.1) #
Vanadium	91.4 (5.5)	77.1 (3.4)	85.6 (6.1)

Calculation includes three non-detects out of three measurements.

Calculation includes one or two non-detects out of three measurements.

NA = Not analyzed.

RECOMMENDATIONS

The experience gained in studying emissions of hazardous air pollutants (HAPs) from the Niles Boiler No. 2 led to the following recommendations for future studies at similar power plants utilizing a cyclone boiler and an electrostatic precipitator (ESP):

(1) **Nonrepresentative Flue Gas Sampling**

The coarse size characteristics and consequent settling of the particulate matter in the flue gas upstream of the ESP made it impossible to collect a flue gas particulate sample that represented the material collected in the entire ESP. Battelle recommends that in similar circumstances a better sampling location should be found if possible (i.e., a vertical rather than a horizontal duct), or that the ash mass balance calculations should be modified as in this study to take into account the effects of nonrepresentative sampling.

(2) **Extractive Sampling with Cyclones**

Flue gas sampling at the ESP inlet employed glass cyclones located outside the duct to determine the particle size distribution of flue gas particulate matter. Because of the coarse size characteristics of the particulate matter, most of the particulate mass was collected in the sampling probe and flexible line, upstream of the cyclones. As a result, little size distribution information was obtained. Although such extractive sampling has provided reasonable size distribution data in instances where flue gas particulate is relatively fine, Battelle recommends that in-stack cyclones be used instead in sampling at plants that exhibit a coarse particulate size distribution.

(3) **Hazardous Element Sampling Train**

The HEST sampler shows promise for measurement of mercury in flue gas, but comparisons of arsenic and selenium results from HEST to those from EPA Method 29 do not show good agreement. The sensitivity of As and Se vapor/ particle distributions to temperature, and the differences in sampling conditions between the HEST and Method 29 procedures may be the cause of the latter difference. Battelle recommends comparison of data from this study with other HEST data sets, followed by further evaluation of the HEST method.

(4) **Plume Simulating Dilution Sampler**

- a. Many HAPs could not be measured using the PSDS in one day of sampling, because their concentrations in the diluted flue gas were below their detection limits for a single day of sampling. Battelle

recommends that results of this project be combined with experience in using the PSDS to measure HAPs generated in a laboratory-scale combustion facility (with higher concentrations of HAPs), to design a power plant study specifically tailored to evaluating the efficacy of the PSDS for measuring HAPs emitted from power plants. Significantly longer sampling times will likely be required.

- b. Because the flow rate of diluted flue gas to be passed through an adsorbent material or impinger solution cannot be as large as that passed through the filter in the PSDS, the detection limits of vapor- and solid-phase substances differ greatly. Special consideration should be given to collecting diluted vapor samples in parallel to lower the detection limit for vapor species to an acceptable level.

(5) Collection of Volatile Organic Compounds

- a. Battelle recommends that an investigation be made of the variability in results of measurements by both the canister method of collecting and analyzing VOC and the volatile organic sampling train (VOST) method. The use of internal standards spiked on the Tenax adsorbent or into the evacuated canister prior to sampling would aid in determining if reactions are occurring with the VOCs following sample collection. Battelle recommends that a continuous (or near continuous) instrument for monitoring one or more of the VOCs be used to assess fluctuation of VOC concentrations in flue gas. For example, an automated gas chromatograph with a photoionization or mass selective detector could provide data on one or two key VOC at intervals of 30 minutes or less.
- b. Dichloromethane and acetone, used as solvents for other sampling, were found in both the VOST and canister samples. Battelle recommends that VOC sampling apparatus be kept away from these compounds if either is to be measured. The need for measuring (e.g.) dichloromethane must be balanced against the cost and extra effort to ensure that the VOC samples are not contaminated by this solvent in the field.

(6) Soot Blowing

The efforts made in this study to determine the effect of soot blowing on element concentrations in flue gas were inconclusive. Battelle recommends that further measurements be made, preferably using traversing sampling with EPA Method 29 for metals, to address this issue.

(7) Sample Digestion

For better quantification of major and trace elements in a single sample, separate aliquots of the sample should be digested for analysis if possible. Separate digestions will allow dilutions typically necessary for accurate determination of major elements without affecting detection of trace elements.

(8) SVOC Sample Treatment

When sufficient data have been obtained on the vapor/particulate distribution of semivolatile organic analytes (PAH/SVOC and dioxins/furans) in coal-fired emissions, in future work, vapor and solid phase samples for semivolatile organic compounds should be combined for analysis as a single sample to improve detection limits.

(9) Boron Analysis

The use of HF-resistant instrumentation for element analysis is recommended. This type of instrumentation will eliminate the need to complex HF-digested samples with boric acid, which prevented the determination of boron in some samples in this study.

(10) CO₂ and Oxygen

The oxygen content of flue gas in the stack was calculated in this study based on CO₂ measured by the plant. Measurements of both CO₂ and O₂ at all flue gas sampling locations may be useful in future studies in evaluating air leakage.

(11) Detection Limits in Coal

Care should be taken in selecting and applying an appropriate analysis technique for determining trace elements in coal to ensure that meaningful detection limits are achieved. This is especially critical in determining selenium, molybdenum, and cadmium, which were not detected in coal analyses performed in this study. If possible, required detection limits needed to accurately perform calculations (i.e., mass balances) should be determined to enable selection of an appropriate analytical technique.

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LIST OF ABBREVIATIONS AND ACRONYMS

μg	microgram, i.e., 1×10^{-6} gram
μl or μL	microliter, i.e., 1×10^{-6} liter
μm	micrometer, i.e., 1×10^{-6} meter
ALD	aldehydes
ASTM	American Society for Testing and Materials, and techniques specified by that organization
BCO	Battelle Columbus Operations
Btu	British thermal unit
C or $^{\circ}\text{C}$	degrees Centigrade
C6	hexane
CAAA	1990 Clean Air Act Amendments
CN	cyanide
CTE	Commercial Testing and Engineering Company
CTE-Denver	Commercial Testing and Engineering Company, Denver, CO, Laboratory
CV-AAS	cold vapor atomic absorption spectrometry
D_{50} percent	particle size for which the collection efficiency of a device or stage is 50 percent
DCM	dichloromethane (i.e., methylene chloride)
Dioxins	see PCDD
DL Ratio	detection limit ratio, indicates the portion of a result that is contributed by non-detect values
DNPH	2,4-Dinitrophenylhydrazine, reagent used for aldehyde sampling
DOE-PETC	Department of Energy, Pittsburgh Energy Technology Center

EA	Element Analysis Corporation
E	emission factor
EPA	U.S. Environmental Protection Agency
ESP	electrostatic precipitator
F or °F	degrees Fahrenheit
F	filter
FGD	flue gas desulfurization
Furans	see PCDF
g	gram
GC/HRMS	gas chromatography/high resolution mass spectrometry
GC/MS	gas chromatography/mass spectrometry
GF-AAS	graphite furnace atomic absorption spectrometry
HAPs	hazardous air pollutants
HEST	hazardous Element Sampling Train
HPLC/UV	high performance liquid chromatography with ultraviolet absorption detection
hr	hour
IC	ion chromatography
ICCT	Innovative Clean Coal Technology
ICP/AES	inductively coupled plasma atomic emission spectrometry
ID	identification (of a sample)
in. Hg	inches of mercury (Hg); unit of pressure, one inch of mercury equals 0.4898 pound per square inch
ISE	ion selective electrode
IT	International Technology Corporation

K	degrees Kelvin, i.e., absolute temperature
kg	kilogram, i.e., 1×10^3 g (1 kg = 2.20 lb)
klb	kilo-pounds, i.e., 1×10^3 pounds
kPa	kilo Pascals, i.e., 1×10^3 Pascals; a unit of pressure (6,892.9 Pascals = 1 pound per square inch)
L	liter
lb	pound
mCi	milli-Curie, i.e., 1×10^{-3} Curie (one Curie equals 3.7×10^{10} radioactive disintegrations per second)
MEOH	methanol
MFR	mass flow rate
mg	milligram, i.e., 1×10^{-3} gram
min	minute
MJ	mega Joules, i.e., 1×10^6 Joules (1055 Joules equal one Btu)
ml or mL	milliliter, i.e., 1×10^{-3} liter
MMD	mass median diameter
MM5	Modified Method 5
MUM	Multi-Metals Train (EPA Method 29)
MW	megawatts
NA	data not available, sample not available, or sample not analyzed
NC	not calculated
Ncm	Normal cubic meter (standard conditions are dry, 32°F (0°C), and 29.92 in Hg). Except as specially indicated, all values in Ncm are also normalized to 3 percent O ₂ content.
ND	not detected (generally accompanied by indication of the detection limit, e.g., ND < 4.0)

NDIR	non-dispersive infrared
ng	nanogram, i.e., 1×10^{-9} gram
Nm ³	see Ncm
NO _x	oxides of nitrogen (nitric oxide, NO, and nitrogen dioxide, NO ₂)
PAH	polynuclear aromatic hydrocarbons
PCDD	polychlorinated dibenzo-p-dioxins; congener classes include tetra-, (TCDD); penta-, (PeCDD); hexa-, (HxCDD); hepta-, (HpCDD); and octa-, (OCDD) chlorinated species
PCDF	polychlorinated dibenzofurans; congener classes include tetra-, (TCDF); penta-, (PeCDF); hexa-, (HxCDF); hepta-, (HpCDF); and octa-, (OCDF) chlorinated species
pCi	pico-Curie, i.e., 1×10^{-12} Curie (one Curie equals 3.7×10^{10} radioactive disintegrations per second)
pg	picogram, i.e., 1×10^{-12} gram
PIXE	proton induced X-ray emission spectrometry
ppbv	part per billion by volume, i.e., 1×10^{-9} v/v, measure of gaseous concentration in air
ppm	part per million, i.e., 1×10^{-6} by volume (generally of a pollutant in air or stack gas)
PSDS	Plume Simulating Dilution Sampler
psi or psig	pounds per square inch (gauge); i.e., pressure above atmospheric pressure
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Program Plan
RAD	radionuclide analyses
RE	removal efficiency
RTI	Research Triangle Institute, quality assurance auditors for the project
s	second (of time)

SD	standard deviation
SNOX	selective catalytic reduction of NO _x
SO ₂	sulfur dioxide
SVOC	semivolatile organic compounds
TU	total uncertainty
VOC	volatile organic compounds
VOST	Volatile Organic Sampling Train
WSA	wet gas sulfuric acid
X	XAD resin, for SVOC collection in Modified Method 5 train

1.0 INTRODUCTION

The Clean Air Act Amendments (CAAA) of 1990 direct that a study be made of emissions of hazardous air pollutants (HAPs) from electric utilities. Results of the study will be used by the United States Environmental Protection Agency (EPA) to evaluate whether or not regulation of emissions of HAPs from this industrial sector is warranted. If a finding is made that regulation is warranted for specific HAPs, rulemaking activities will proceed. In addition, control strategies must be developed for those HAPs that are to be regulated.

This report presents information from a project that is a part of the study identified above. This project was conducted for the U.S. Department of Energy's Pittsburgh Energy Technology Center as one of a group of assessments of toxic emissions from coal-fired power plants. This project is a "Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing a Cyclone Boiler and an ESP System." The host power plant for this project was Ohio Edison's Niles Station Boiler No. 2. The pollution control technology employed by the plant consists of an electrostatic precipitator (ESP). The WSA-SNOX Innovative Clean Coal Technology (ICCT) Demonstration Project set up at Boiler No. 2 was shut down for the period of the study reported here.

1.1 Objectives

The objectives of this project are:

- (1) To collect and analyze representative solid, liquid, and gas samples of input and output streams of the power plant for selected hazardous air pollutants (HAPs) that are listed in Title III of the 1990 Clean Air Act Amendments, and to assess the emission level of these pollutants.
- (2) To determine for selected HAPs (a) the removal efficiencies of pollution control subsystems at the power plant, (b) material balances in specified process streams, and (c) an overall material balance for the power plant.
- (3) To determine the concentration of selected HAPs associated with the particulate fraction of the flue gas stream as a function of particle size.

- (4) To determine the distribution of selected HAPs associated with the vapor and particulate phase fractions at sequential points in the flue gas streams while assessing the emission levels of these pollutants.
- (5) To determine the concentration of selected HAPs associated with the vapor and particulate phase fractions under simulated plume conditions at the power plant while assessing the emission level of these pollutants.

1.1.1 Objectives of DOE and EPA

The U.S. DOE will use the results of this project in its Flue Gas Cleanup Program to provide technology options that will allow for existing and future coal use in a manner that is environmentally acceptable. Under this program, control systems are being developed for airborne emissions of HAPs from coal-fired power plants. Results of this project along with the other projects in the assessment of toxic emissions will provide a database on the efficacy of a variety of control systems for HAPs generated by combustion of a variety of coals.

The U.S. EPA will use the results of this project along with other data to help fulfill the mandate in the CAAA for the Utility Toxics Study. Data on emissions along with results on removal efficiencies will be used to assess whether or not regulation of HAPS is warranted for the electric utility industry.

1.1.2 Substances Measured

To meet the objectives of the project, measurements were made of the concentrations of a comprehensive set of substances. The analytes that were measured are listed in Tables 1-1 through 1-8.

Major and trace elements are listed in Table 1-1. The major elements were measured to provide additional parameters to be used in the material balance calculations. Because these elements exist at much higher concentrations in coal and fly ash than do the trace elements that are classified as HAPs, they are expected to have less uncertainty in their determination. Hence they can serve as benchmarks for the material balance calculations of trace elements. Five major elements along with sulfur were measured. Sixteen trace elements were measured.

Other inorganic substances that were measured include the anions chloride, fluoride, phosphate, and sulfate. These anions were measured in solid, liquid, and flue gas process streams. In addition, ammonia and cyanide were measured in liquid and flue gas process streams. Elemental carbon was measured in flue gas streams. The ten radionuclides listed in Table 1-1 were also measured.

Organic substances that were measured include semivolatile organic compounds (SVOC), volatile organic compounds (VOC), and aldehydes. Semivolatile organic compounds include polycyclic aromatic hydrocarbons (PAH), other SVOC, and polychlorinated dioxins and furans. Table 1-2 lists PAH and other SVOC that were measured in flue gas and solid process streams. These compounds were measured in both the vapor and particle phases of the flue gas streams. Table 1-3 lists PAH and other SVOC that were measured in liquid process streams. Dioxins/furans that were measured are listed in Table 1-4. These compounds were measured only in selected flue gas streams.

Volatile organic compounds were measured in both flue gas and liquid process streams. Table 1-5 contains a list of VOC that were measured in flue gas streams using a volatile organic sampling train (VOST). Canisters were used to collect VOC from flue gas streams as an alternative collection method for comparison. The compounds measured in canister samples are listed in Table 1-6. Table 1-7 lists VOC measured in liquid process streams.

Measurements were made of four aldehydes in flue gas and liquid process streams. These compounds are listed in Table 1-8.

1.1.3 Target Detection Limits

Target detection limits for the substances cited in Section 1.1.2 were developed based upon the intended use of the data by the DOE and EPA subject to resource and schedule constraints of the project. Target detection limits account for the planned volume of sample to be collected and the analytical detection limit for an analyte in a given quantity of sample. The target detection limits for the project are listed in Tables 1-9 and 1-10. For some of the analytes listed in Table 1-9, the analytical method is noted. The right hand column in Table 1-9 gives the target detection limits in nanograms for each analyte in a sample. Using this

information, the target
1-10. Target detection
these elements were p

The greatest cl
collecting sufficient m
in turn depended prin
streams. The samplin
detection limits show

- Measuring the distribution of elements and SVOC between the vapor and particle phases.
- Collecting samples using a plume simulating dilution sampler (PSDS) at the stack, and comparing the dilute sampling results to hot stack sampling results.
- Measuring the concentration of elements and selected organic compounds in three particle size ranges.
- Measuring volatile elements (mercury, arsenic, selenium) using a hazardous element sampling train (HEST) for comparison to U.S. EPA Method 29 measurements.
- Collecting VOC in canisters to compare results with samples collected with a volatile organic sampling train (VOST).
- Conducting high-volume filter sampling in the stack to assess emissions of elements during soot blowing relative to those during normal operations.
- Comparison of mercury results from individual components of the Method 29 trains, to assess the potential for mercury speciation.

1.3 Quality Assurance Audits

A quality assurance program was implemented to evaluate adherence to planned sampling and analytical procedures in the project Quality Assurance Project Plan (QAPP). Internal audits conducted by Battelle were supplemented by external audits conducted by Research Triangle Institute (RTI) under contract to the U.S. EPA.

1.3.1 Internal Audits

Battelle conducted an internal quality assurance/quality control (QA/QC) program for the project that was described in the QAPP. Internal QA/QC was the direct responsibility of the field sampling team and laboratory personnel at all levels. Battelle assigned a QA project officer to the project. She conducted both field and laboratory audits to document Battelle's adherence to the QAPP.

1.3.2 External Audits

The external QA program included a review of the QAPP for the project by RTI and both performance evaluation audits and technical systems audits at the power plant. Performance evaluation audits consisted of RTI challenging monitors with calibration gases and spiking adsorbent material and filters with analytes. Technical systems audits consisted of RTI observing the procedures for sampling and handling samples to evaluate adherence to procedures in the QAPP.

1.4 Project Organization

Several organizations contributed to the project. An organization chart is shown in Figure 1-1. Battelle was the prime contractor and reported to DOE. Battelle worked directly with the host utility, Ohio Edison, through a Host Site Agreement. Ohio Edison shared in the costs of the project through in-kind support, including modifications of sampling locations, provision of on-site utilities, and dedication of plant staff during the period of the study.

The external QA program was conducted by RTI under contract to the U.S. EPA. The DOE and EPA coordinated the external audit activities.

A round robin program for coal analysis was coordinated by Consol, Inc. under contract to DOE. For this program, coal samples from eight power plants and a quality control sample were sent to Battelle and the other prime contractors in DOE's program.

Battelle used a major subcontractor, Chester Environmental, for sampling and some analyses. Chester conducted both hot flue gas sampling and sampling using its PSDS. Chester analyzed HEST samples for mercury and VOST samples for VOC. Zande Environmental Services analyzed liquid samples for VOC. Commercial Testing & Engineering Company (CTE) generated composite samples from solid process samples and analyzed coal samples. Flue gas samples were analyzed for elements by CTE. International Technology Corporation provided radionuclide analyses. Element Analysis Corporation analyzed coal samples for elements.

1.5 Organization of the Report

This report consists of two volumes. Volume 1 consists of Sections 1 through 7; Section 1 is this Introduction. The host utility site is described in Section 2, along with plant operating parameters during the test.

In Section 3 the schedule for sampling is summarized along with information on the samples that were collected. Mass balance results for ash content and sulfur content of the process streams are presented. Oxygen content of the flue gas at several locations is presented to estimate the infiltration of air into the flue gas. Included in Section 3 are problems encountered, and solutions or modifications devised to address them. Occurrences or problems resulting in deviations from the sampling plan¹ are also noted.

Section 4 of the report lists the analytical and sample preparation methods used to analyze samples. The analytical results are presented in Section 5, in several subsections that each focus on a particular class of analytes.

Section 6 provides analysis and interpretation of the data. These results are presented in three ways: (1) material balance calculations for the plant and individual process components, (2) emission factors, and (3) calculated removal efficiencies for trace elements by control equipment.

Special topics that were investigated in this study are summarized in Section 7 of Volume 1. Those topics are:

- Comparison of measurements made in hot stack gas with those made by Plume Simulating Dilution Sampling.
- Distribution of elements and PAH/SVOC between the vapor and particle phases.
- Particle size distribution of elements in flue gas particulate matter.

¹Study of Toxic Emissions from a Coal-Fired Power Plant Demonstrating the ICCT WSA-SNOX Project and a Plant Utilizing an ESP/Wet FGD System, Management Plan on DOE Contract DE-AC22-93PC93251, Section 5: Niles Site-Specific Plans. Prepared for DOE-PETC by Battelle, Columbus, Ohio, July 17, 1993.

- Comparison of measurements of mercury, arsenic, and selenium made by Method 29 sampling with those made using a hazardous element sampling train (HEST).
- Comparison of measurements of VOC using VOST and canister methods.
- Comparison of trace element concentrations in stack gas during normal operation and during soot-blowing.
- Comparison of mercury analytical results for individual components of the Method 29 train.

Volume 2 of this report contains several Appendices. Appendix A shows the process data log sheets provided by Niles and Ohio Edison staff during the field study. Appendices B, C, and D present QA auditing results, field sampling protocols, and field sampling data sheets, respectively. Appendix E presents internal QA/QC results, and Appendix F describes the analytical protocols used for sample analysis. Appendix G shows an uncertainty analysis used to derive the uncertainty limits for emission factors.

TABLE 1-1. INORGANIC SUBSTANCES MEASURED IN SOLID, LIQUID,
AND GAS PROCESS STREAMS

<u>Major Elements</u>	<u>Trace Elements</u>
Al, K, Ti, Si, Na	As, Se, Hg, Cd, Cr, Mo, B, Sb, Ba, Be, Pb, Mn, Ni, V, Cu, Co
<u>Anions</u>	<u>Other</u>
Cl ⁻ , F ⁻ , PO ₄ ⁼ , SO ₄ ⁼	NH ₃ , CN ⁻ , C
<u>Radionuclides</u>	
U ²³⁴ , U ²³⁵ , Th ²²⁹ , Th ²³⁰ , Th ²³⁴ , Ra ²²⁶ , Ra ²²⁸ , Pb ²¹⁰ , Pb ²¹¹ , Pb ²¹²	

TABLE 1-2. PAH AND OTHER SVOC MEASURED IN FLUE GAS
AND SOLID PROCESS STREAMS

<u>PAH</u>	<u>SVOC</u>
Naphthalene	Acetophenone
1-Methylnaphthalene	Benzyl chloride
2-Methylnaphthalene	2-Chloroacetophenone
Biphenyl	Dibenzofuran
Acenaphthene	2,4-Dinitrotoluene
Acenaphthylene	2,6-Dinitrotoluene
Phenanthrene	Hexachlorobenzene
Anthracene	Hexachlorobutadiene
Fluorene	Hexachlorocyclopentadiene
Fluoranthene	Hexachloroethane
Pyrene	Pentachlorophenol
Benz[a]anthracene	
Chrysene	
Benzo[e]pyrene	
Benzo[a]pyrene	
Benzo[b and k]fluoranthene	
Indeno[1,2,3-c,d]pyrene	
Benzo[g,h,i]perylene	
Dibenzo[a,h]anthracene	

TABLE 1-3. PAH AND OTHER SVOC MEASURED IN LIQUID PROCESS STREAMS

Acetophenone	Bis-(2-ethylhexyl)phthalate
Biphenyl	2-Chloroacetophenone
2-Methylphenol ^(a)	Dibenzofuran
3-Methylphenol	1,2-Dichlorobenzene ^(b)
4-Methylphenol	1,3-Dichlorobenzene
Dibutylphthalate	1,4-Dichlorobenzene
4,6-Dinitro-o-cresol	2,4-Dinitrophenol
2,4-Dinitrotoluene	2,6-Dinitrotoluene
Hexachlorobenzene	Hexachlorobutadiene
Hexachlorocyclopentadiene	Hexachloroethane
Nitrobenzene	4-Nitrophenol
Pentachloronitrobenzene	Pentachlorophenol
Phenol	Quinoline
2,4,5-Trichlorophenol	2,4,6-Trichlorophenol
Naphthalene	2-Methylnaphthalene
Acenaphthene	Acenaphthylene
Fluorene	Fluoranthene
Phenanthrene	Anthracene
Pyrene	Benz[a]anthracene
Chrysene	Benzo[a]pyrene
Benzo[e]pyrene	Indeno[1,2,3-cd]pyrene
Benzo[g,h,i]perylene	Dibenzo[a,h]anthracene

(a) 2-Methyl-, 3-Methyl-, 4-Methylphenol = o,m,p-Cresol, respectively.

(b) 1,2-, 1,3-, 1,4-Dichlorobenzene = o,m,p-Dichlorobenzene, respectively.

TABLE 1-4. DIOXINS AND FURANS MEASURED IN FLUE GAS
PROCESS STREAMS

<u>Dioxins</u>	<u>Furans</u>
2,3,7,8-TCDD ^(a)	2,3,7,8-TCDF ^(b)
1,2,3,7,8-PeCDD	1,2,3,7,8-PeCDF
1,2,3,4,7,8-HxCDD	2,3,4,7,8-PeCDF
1,2,3,6,7,8-HxCDD	1,2,3,4,7,8-HxCDF
1,2,3,7,8,9-HxCDD	1,2,3,6,7,8-HxCDF
1,2,3,4,6,7,8-HpCDD	1,2,3,7,8,9-HxCDF
OCDD	2,3,4,6,7,8-HxCDF
Total TCDD	1,2,3,4,6,7,8-HpCDF
Total PeCDD	1,2,3,4,7,8,9-HpCDF
Total HxCDD	OCDF
Total HpCDD	Total TCDF
	Total PeCDF
	Total HxCDF
	Total HpCDF

(a) TCDD = tetrachloro-dibenzo-p-dioxin; PeCDD = pentachloro-DD;
HxCDD = hexachloro-DD; HpCDD = heptachloro-DD;
OCDD = octachloro-DD.

(b) TCDF = tetrachloro-dibenzofuran; PeCDF = pentachloro-DF;
HxCDF = hexachloro-DF; HpCDF = heptachloro-DF;
OCDF = octachloro-DF.

TABLE 1-5. VOC COLLECTED BY VOST FROM FLUE GAS PROCESS STREAMS

Chloromethane	Chloroform	Dibromochloromethane
Bromomethane	1,2-Dichloroethane	1,1,2-Trichloroethane
Vinyl chloride	2-Butanone	Benzene
Chloroethane	1,1,1-Trichloroethane	trans-1,3-Dichloropropene
Methylene chloride	Carbon tetrachloride	2-Chloroethylvinylether
Acetone	Vinyl acetate	Bromoform
Carbon disulfide	Bromodichloromethane	4-Methyl-2-pentanone
1,1-Dichloroethene	1,2-Dichloropropane	2-Hexanone
1,1-Dichloroethane	cis-1,3-Dichloropropene	Tetrachloroethene
trans-1,2-Dichloroethene	Trichloroethylene	Toluene
1,1,2,2-Tetrachloroethane	Chlorobenzene	Ethylbenzene
Styrene	Xylenes (Total)	Hexane

TABLE 1-6. VOC COLLECTED IN CANISTERS FROM
FLUE GAS PROCESS STREAMS

Dichlorodifluoromethane (Freon-12)	cis-1,3-dichloropropene
Methyl chloride	trans-1,3-dichloropropene
1,2-Dichloro-1,1,2,2-tetra- fluoroethane (Freon-114)	1,1,2-Trichloroethane
Vinyl chloride	Toluene
Methyl bromide	1,2-Dibromoethane
Ethyl chloride	Tetrachloroethene
Trichlorofluoromethane (Freon-11)	Chlorobenzene
1,1-Dichloroethene	Ethylbenzene
Methylene chloride	m+p-xylene
3-Chloropropene	Styrene
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113)	1,1,2,2-Tetrachloroethane
1,1-Dichloroethane	o-xylene
cis-1,2-Dichloroethene	4-Ethyltoluene
Trichloromethane	1,3,5-Trimethylbenzene
1,2-Dichloroethane	1,2,4-Trimethylbenzene
1,1,1-Trichloroethane	Benzyl chloride
Benzene	m-dichlorobenzene
Carbon tetrachloride	p-dichlorobenzene
1,2-Dichloropropane	o-dichlorobenzene
Trichloroethylene	1,2,4-Trichlorobenzene
	Hexachlorobutadiene

TABLE 1-7. VOC MEASURED IN LIQUID PROCESS STREAMS

Acrylonitrile	1,4-Dioxane
Benzene	Ethylbenzene
Bromoform	Iodomethane
Bromomethane	Methyl methacrylate
2-Butanone	4-Methyl-2-pentanone
Carbon disulfide	Methylene chloride
Carbon tetrachloride	Styrene
Chlorobenzene	Toluene
Chloroethane	1,1,1-Trichloroethane
Chloromethane	1,1,2-Trichloroethane
Chloroprene	Trichloroethylene
Cumene	Vinyl acetate
1,2-Dibromoethane	Vinyl bromide
1,1-Dichloroethane	Vinyl chloride
1,2-Dichloroethane	m+p-Xylene
cis-1,3-Dichloropropene	o-Xylene
trans-1,3-Dichloropropene	

TABLE 1-8. ALDEHYDES MEASURED IN FLUE GAS AND LIQUID PROCESS STREAMS

Formaldehyde
 Acetaldehyde
 Acrolein
 Propionaldehyde

TABLE 1-9. TARGET ANALYTICAL DETECTION LIMITS

Target Analyte	Estimated Instrument Detection Limit, ng/mL	Final Sample Volume, mL	Estimated Detection Limit, ng
Elements^(c)			
Mo (ICP-AES)	25 ^(a)	450, or 25 ^(b)	11250, or 625 ^(b)
B (ICP-AES)	20	450, or 25	9000, or 500
Sb (GF-AAS)	5	450, or 25	2250, or 125
As (GF-AAS)	1	450, or 25	450, or 25
Ba (ICP-AES)	5	450, or 25	2250, or 125
Be (ICP-AES)	5	450, or 25	2250, or 125
Cd (GF-AAS)	5	450, or 25	2250, or 125
Cr (ICP-AES)	20	450, or 25	9000, or 500
Pb (GF-AAS)	1	450, or 25	450, or 25
Mn (ICP-AES)	5	450, or 25	2250, or 125
Hg (CV-AAS)	0.5	450, or 25	225, or 12.5
Ni (ICP-AES)	20	450, or 25	9000, or 500
Se (GF-AAS)	2	450, or 25	900, or 50
V (ICP-AES)	10	450, or 25	4500, or 250
Cu (ICP-AES)	10	450, or 25	4500, or 250
Co (ICP-AES)	15	450, or 25	6750, or 375
Volatile Elements^(d)			
As	1.6 ng/cm ²		16
Se	1.9 ng/cm ²		19
Hg	2.5 ng/cm ²		25
Ammonia	500 ^(a)		225000
Cyanide	250 ^(a)		112500
Anions			
F ⁻	10 ^(a)		4500 or 100 ^(b)
Cl ⁻	10		4500 or 100
PO ₄ ⁼	100		45000 or 1000
SO ₄ ⁼	25		11250 or 250
VOC - Liquid Samples	5-100 µg/L of sample		

ng = nanogram; µg = microgram; L = liter; cm = centimeter; pCi = picoCurie; g = grams; ppbv = parts per billion by volume.

TABLE 1-9. (Continued)

Target Analyte	Estimated Instrument Detection Limit, ng/mL	Final Sample Volume, mL	Estimated Detection Limit, ng
SVOC - Liquid Samples	5-100 µg/L of sample		
SVOC/PAH - Gas and Solid Samples	10-100	0.1-1	1-100
VOC - Canister		15	2 ppbv
VOC-VOST			25
Dioxin/Furan			
TCDD/TCDF	10	0.02	0.2
PeCDD/PeCDF	20	0.02	0.4
HxCDD/HxCDF	20	0.02	0.4
HpCDD/HpCDF	20	0.02	0.4
OCDD/OCDF	30	0.02	0.6
Aldehydes	6	20	120
Radionuclides	0.2 pCi/g		

- (a) Instrument detection limit is also equal to the detection limit in liquid samples.
- (b) The first number applies to the gas sample, and the second number applies to the solid sample. Except as noted, detection limits are the product of the instrument detection limit and the final sample volume.
- (c) Acronym within parentheses refers to analysis method for elements: ICP-AES = inductively coupled plasma atomic emission spectrometry; GF-AAS = graphite furnace atomic absorption spectrometry; and CV-AAS = cold vapor atomic absorption spectrometry.
- (d) Samples are analyzed by direct X-ray fluorescence of carbon-impregnated filters. Sample volume is not applicable.

TABLE 1-10. TARGET GASEOUS EMISSION DETECTION LIMITS

Element	Analytical Detection Limit (ng)	Gas Volume Sampled (Ncm)	Emission Detection Limit ($\mu\text{g}/\text{Ncm}$)
Mo	11250	7.6	1.5
B	9000	7.6	1.2
Sb	2250	7.6	0.3
As	450	7.6	0.06
Ba	2250	7.6	0.3
Be	2250	7.6	0.3
Cd	2250	7.6	0.3
Cr	9000	7.6	1.2
Pb	450	7.6	0.06
Mn	2250	7.6	0.3
Hg	225	7.6	0.03
Ni	9000	7.6	1.2
Se	900	7.6	0.12
V	4500	7.6	0.6
Cu	4500	7.6	0.6
Co	6750	7.6	0.9
Ammonia	225000	0.3	750
Cyanide	112500	0.59	191
Anions			
F ⁻	4500	1.5	3
Cl ⁻	4500	1.5	3
PO ₄ ⁼	45000	1.5	30
SO ₄ ⁼	11250	1.5	7.5
PAH/SVOC ^(a)	1-100	7.6	0.1-10 ^(c)
Dioxins/Furans			
TCDD/TCDF	0.2	7.6	0.03 ^(c)
PeCDD/PeCDF	0.4	7.6	0.053 ^(c)
HxCDD/HxCDF	0.4	7.6	0.053 ^(c)
HpCDD/HpCDF	0.4	7.6	0.053 ^(c)
OCDD/OCDF	0.6	7.6	0.08 ^(c)
Aldehydes	120	0.06	2
VOC - Canister	2 ppbv	NA ^(b)	6
VOC - VOST	25	0.003-0.018	1.4-8.3

(a) Calculated target emission detection limit will range from 0.1 to 10 ng/Ncm depending upon SVOC compound and matrix.

(b) NA = Not applicable.

(c) Detection limits for SVOC and dioxins/furans are in ng/Ncm.
ppbv = parts per billion by volume.

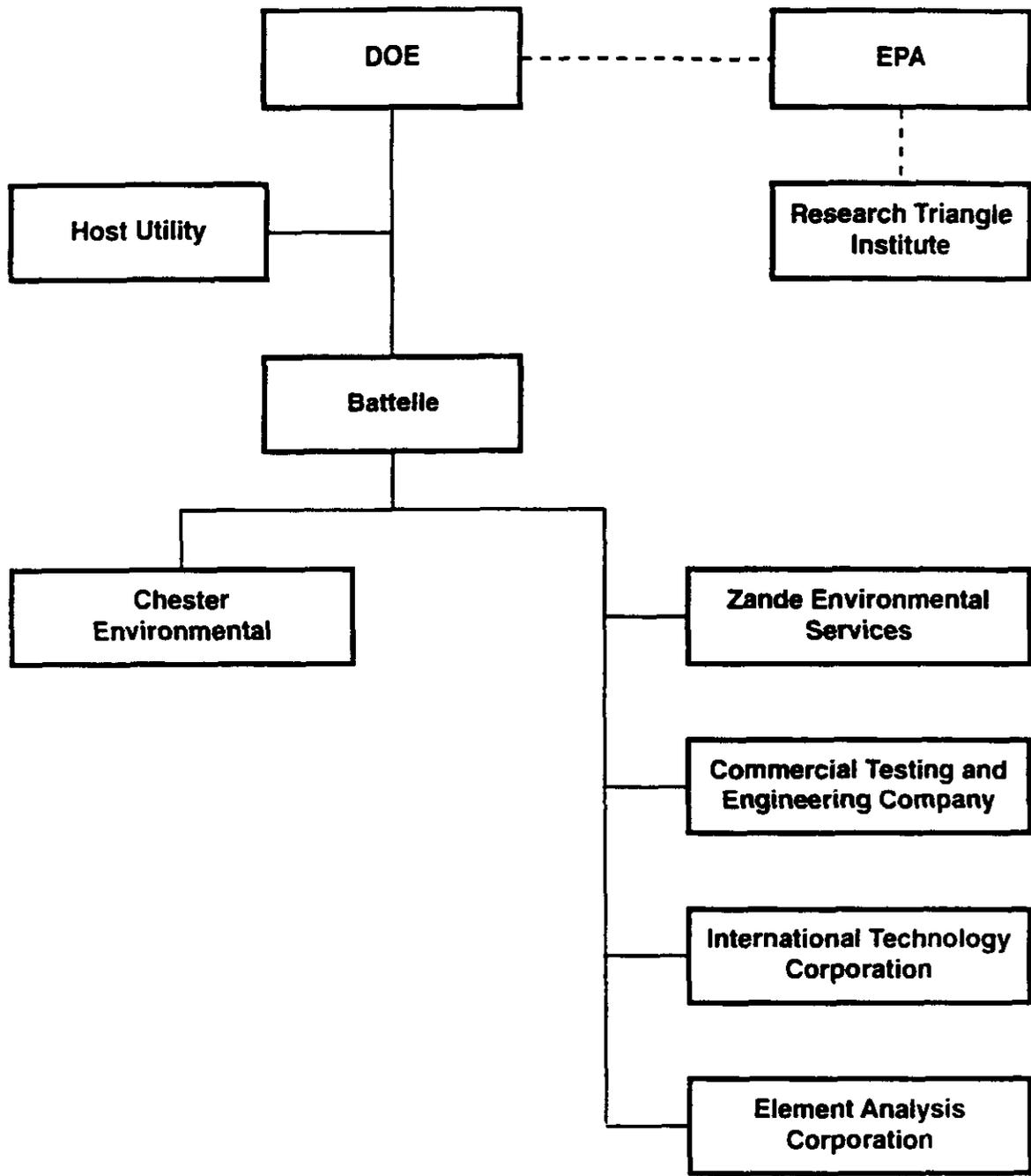


Figure 1-1. Project Organization

2.0 SITE DESCRIPTION

The host site for this study was Ohio Edison's Niles Station Boiler No. 2. The site is described in this section of the report as follows. The configuration of the boiler is described followed by a description of the process stream locations at which samples were collected. Finally, the expected and actual operating conditions of the boiler during the study are summarized.

2.1 Plant Configuration

2.1.1 Description of the Plant

Niles Station of Ohio Edison is located in Niles, Ohio, on the bank of the Mahoning River. The Niles Boiler No. 2 is a Babcock & Wilcox cyclone boiler burning bituminous coal with a net generating capacity of 108 megawatts. The furnace gas temperature at full load upstream of the superheater is about 1900°F. The boiler has four cyclone burners, each fed by a separate feeder. The Niles Plant uses coal with a low ash fusion temperature to allow the majority of the ash to drop out in the furnace cyclone combustors and to avoid carry-over into the boiler. The coal is mined in eastern Ohio and western Pennsylvania and is received in the respective proportions of about 70/30. Coal mined in Ohio comes principally from coal seams Nos. 6 and 7. The Pennsylvania mined coal comes also from seams Nos. 6 and 7, and from the Kittanning/Freeport seam. All the coal burned at the plant is from spot market purchases which are provided by up to a dozen different suppliers. The nominal contents of sulfur, ash, and heat are 2.7 percent, 10-12 percent, and 12,000 Btu/lb, respectively. The coal is blended in the coal yard at the plant to meet 24-hour and 30-day rolling averages for SO₂ content of flue gas. The feed rate of crushed coal to the four cyclone burners is determined by Ohio Edison from the quantity of coal on the four conveyor belts delivering the coal to the burners, along with the speed of travel of the belts. Each belt holds approximately 45 kg/m (30 lb/ft) of coal. The lag time for coal on each of the four conveyor belts to reach the cyclone burners and be fired is a few minutes.

The flue gas leaves the boiler, passes through an air heater, and enters an electrostatic precipitator (ESP) with five fields, each with two hoppers. The first row of hoppers is

deactivated and acts to passively collect coarse ash leaving the air heater. The fourth row of hoppers was also deactivated during this study, but was sampled. The ESP hoppers are dumped about every 4 hours; hopper sampling in this study was adapted to that schedule. The proportions of ash collected in each row of hoppers were estimated during this study by timing of the dumping cycle of the ESP; those results are described in Section 3.3.1. Collected ESP ash is transported to a settling pond by a water sluice. The flue gas leaving the ESP is vented through a 120-m (393-foot) tall stack.

It is characteristic of cyclone boilers that a large fraction of the ash from coal combustion is collected as bottom ash, and relatively little as fly ash. For Niles Boiler No. 2, it is typical that about 85 percent of the total ash is collected as bottom ash and air heater ash (of that portion the great majority is bottom ash), and only about 15 percent of the total ash is collected in the ESP. The fly ash produced by a cyclone boiler typically is relatively coarse and has a larger carbon content than does such ash from other boiler designs. The typical average carbon content of the ash collected in the entire ESP is about 40 percent at Niles Boiler No. 2. The coarse nature of the fly ash is the reason that the row 1 ESP hoppers are operated as passive (i.e., deenergized) collectors.

A 35-megawatt equivalent slipstream of flue gas from the Niles Boiler No. 2 is normally taken after the air heater and before the ESP to demonstrate the SNOX process. This ICCT demonstration is the Wet Gas Sulfuric Acid (WSA)-Selective Catalytic Reduction of NO_x (SNOX) demonstration by ABB Combustion Engineering. The SNOX process was shut down during the sampling period described here so that 100 percent of the Boiler No. 2 flue gas passed through the ESP before venting through the stack.

Ammonia is normally added to the flue gas upstream of the ESP at a rate of 0.1-0.2 m^3/min (4-6 cubic feet per minute) to achieve a concentration of about 18 ppm. This is done to control acid mist fallout from the stack, and does not appreciably affect ESP performance. However, during the course of this project ammonia was not added to the flue gas, to assure consistency with separate measurements made at the SNOX process in which ammonia was not added.

Normally, soot blowing occurs once each shift. To accommodate measurements of the effect of soot blowing on flue gas element concentrations, Ohio Edison altered the schedule for soot blowing during the field study. Soot blowing was conducted over a 2-hour

period (approximately 6-8 a.m.) before sampling began each day and again after all sampling was completed each day. Soot blowing is conducted automatically using 18 lances sequentially, one at a time. Seventeen of the lances are located in the furnace gas convection path, and one is located at the top of the air heater. Compressed air is used for soot blowing.

A schematic of the Niles Boiler No. 2 process flow is shown in Figure 2-1. In this figure, the sampling locations are indicated, and are numbered as listed in Table 2-1, which identifies the sample locations used for this study. For consistency in sample handling, a single numbering scheme was applied to three separate field studies conducted by Battelle for DOE-PETC, one of which was the Niles Boiler No. 2. Thus (e.g.) location number 1 was Boiler Feed Coal for all three field studies. A result of this numbering system was that location numbering at the Niles Boiler No. 2 was nonconsecutive, as shown in Table 2-1. Figure 2-1 and Table 2-1 distinguish three types of sampling locations: flue gas/particulate sampling locations, designated G; solid sample collection points, designated S; and liquid sample collection points, designated L.

2.1.2 Continuous Emission Monitoring

The Niles Station uses a continuous emission monitoring (CEM) system called Ecoprobe, which was installed by KVB of Irvine, California. The complete system is comprised of two subsystems with one subsystem serving as the primary measurement system and the other as the secondary system. Sulfur dioxide is measured with a Teco 43H pulsed fluorescence analyzer. Nitrogen oxides are measured with a Teco 42 chemiluminescence monitor, and carbon dioxide is measured with a Teco 41H gas filter correlation monitor. The flue gas is diluted by a factor of 150:1 before measurement. There are two flow monitors for the system. The primary system is a Dietrich anubar system, and the secondary system is a Parametrics CEM68 system. The CEMs are calibrated once a day automatically. The primary system is calibrated between 0630 and 0700, and the secondary system is calibrated around noon each day. It was not possible for Research Triangle Institute (RTI) to conduct a performance audit on these CEMs. Oxygen was measured at the furnace outlet by

the plant; calibration of this sensor was conducted once during these measurements. Oxygen was not measured at the stack, but was calculated from the CEM stack CO₂ measurements.

2.2 Process Streams

Nine flue gas, solid, and liquid process streams were sampled during the study. The streams are described below in two parts.

2.2.1 Flue Gas Streams

At Boiler No. 2, flue gas sampling was conducted outdoors at the ESP inlet (Location 4, Figure 2-1) and in the stack at the 61-meter (200-ft) level (Locations 5a, 5b). The SNOX process was shut down for the week of sampling at Boiler No. 2, so that 100 percent of the unit's flue gas was passing through the ESP. At the ESP inlet (Location 4), only two 3-in.-diameter sampling ports were available, one horizontal and one vertical. At that location, platform area and the small number of ports made coordination of multiple methods difficult. The duct sampled at Location 4 was a horizontal round duct 12 feet in diameter. This location was only a few duct diameters downstream of the nearest flow disturbance, which was an abrupt change from a square to a round duct. Settling of coarse particles in this duct was indicated by a layer of ash in the bottom of the duct, which was encountered during the vertical traverse in initial gas velocity measurements. The presence of this ash required that vertical traverses be stopped short of the last several inches of the duct diameter, to avoid clogging the sampling nozzle.

Flue gas sampling in the stack was conducted from two levels of platforms in the annular space between the outer stack and the two inner flues. This location provided ample room, and a total of eight ports (four at 90 degrees apart at each of two levels). This location was at least eight flue diameters above the nearest upstream flow disturbance, which was the entrance duct for flue gas from the ESP. Sampling at this location was conducted both by conventional hot stack methods (Location 5a) and by Plume Simulating Dilution Sampling (PSDS) (Location 5b). The latter approach involves diluting a flow of stack gas

with clean air to simulate dilution in the atmosphere. Measurements made with the PSDS are reported as a Special Topic in Section 7.1.

Table 2-2 summarizes the flue gas characteristics at Locations 4 and 5a on each of the sampling days at Niles Boiler No. 2. This table indicates consistent flue gas characteristics at both Locations 4 and 5a. The average flue gas flow rates measured at Locations 4 and 5a agreed within less than 4 percent when calculated at actual oxygen content. However, when normalized to 3 percent oxygen, the Location 5a flows are substantially lower than those at Location 4. This suggests an error in flow measurement at one or the other location. The measurements at Location 5a are considered more accurate, due to the close upstream flow disturbance at Location 4. Flue gas oxygen values are higher at Location 5a than at Location 4; comparisons of various oxygen measurements at the plant are presented in Section 3.3.3. The flue gas particle loading data in Table 2-2 indicate an average ESP removal efficiency for particulate of about 98.5 percent, a reasonable value. The particle loading and moisture data at Location 4 show significant variation. Review of flue gas sampling records, coal composition, and plant operating data has not disclosed any underlying cause for the variations observed, nor any indication that plant operations were anything other than normal.

2.2.2 Solid and Liquid Streams

Solid process samples collected included boiler feed coal (Location 1), bottom ash (Location 2), air heater ash (Location 3), and ESP ash (Location 8). Niles staff collected the boiler feed coal by taking equal quantities of coal every half hour during each day's measurements from each of the four coal feeders on Boiler No. 2. The collected portions were then composited by ASTM methods, and a single composite sample of about 3 kg was provided to Battelle. Bottom ash samples were collected three times a day by Niles staff from two hoppers located below the boiler. Air heater ash was collected from two hoppers located below the air heater three times a day. The ESP ash was collected from ten hoppers (five rows of 2 each). Hoppers in rows 1, 2, and 3 were sampled twice a day while hoppers in rows 4 and 5 were sampled once a day.

Liquid process samples collected included river make-up water (Location 9) and pond water (Location 10). River water samples were collected once a day from the river behind the plant. Pond water was collected from the outflow of one of the holding ponds located across the road from the plant. One sample of coal pile runoff (Location 13) was collected during the study.

2.3 Plant Operating Conditions

The design of the sampling at Boiler No. 2 was based in part on the expected operating conditions of the unit. These conditions are summarized in this section followed by a report of the actual condition that were encountered. The last part of this section provides plots of plant operating conditions as a function of time during each sampling day.

2.3.1 Nominal Conditions

As a result of consultation with Niles Station staff and review of information about the plant before the field study, expected plant operating conditions and allowable ranges of those conditions were established. Table 2-3 lists those operating conditions.

2.3.2 Actual Operating Conditions

An effort was made to compile information on all pertinent plant operating data listed in Table 4.5 of the Statement of Work for this project. Data on operating parameters measured during the study are presented below. Some operating parameters are not routinely measured, but are reported in the plant description in Section 2.1.1. Examples of such data include furnace gas temperature; feeder-to-furnace lag time; ESP dumping procedures; and soot blowing procedures. Some operating conditions, including air feed rate and stack CO content, are not measured and cannot be reported.

In order to document operating conditions at Niles Boiler No. 2, a variety of data were collected. Instantaneous plant process data were collected approximately hourly by plant staff on data sheets provided by Battelle. In addition, hourly average stack CO₂ values

and 6-minute average opacity data were obtained from plant records. Copies of the Battelle process data sheets are contained in Appendix A.

Table 2-4 presents average values, ranges, and standard deviations for actual plant operating conditions on each test day for Niles Boiler No. 2. The operating conditions that are reported are:

- Coal feed rate, klb/hr
- Gross load, MW
- Steam generation rate, klb/hr
- Drum steam pressure, psi gauge
- Steam temperature, superheater outlet, °F
- Steam temperature, reheater outlet, °F
- Excess O₂ at the furnace outlet, wet basis, percent
- CO₂ at the stack (hourly average), wet basis, percent
- SO₂ emissions, lb/10⁶ Btu
- NO_x emissions, lb/10⁶ Btu
- Opacity, percent
- Barometric pressure, inches of Hg.

Only the data for the actual daily test periods were used in calculating daily average values for plant operating conditions.

The daily average coal feed rate ranged from 89.6 to 96.7 klb/hr, a range of 7.6 percent of the average coal feed rate. The gross daily average load ranged from 116.6 to 117.5 MW, a range of 0.8 percent of the actual load. The daily average steam generation rate ranged from 109-111 kg/s (863 to 881 klb/hr), a range of 2.1 percent of the actual steam generation rate.

Steam temperatures and pressure were very stable throughout the study. Drum steam pressure daily averages ranged from 1528 to 1536 psig, a range of only 0.5 percent of the daily values. Steam temperature at the superheater outlet showed essentially no variation, and daily average steam temperature at the reheater outlet varied from 982 to 991 °F, a range of 0.6 percent of the absolute temperature.

The daily average excess oxygen readings at the furnace outlet ranged from 1.29 to 2.07 percent, a range of 46 percent of the excess oxygen. Although these values are lower than were initially expected (Table 2-3), Ohio Edison staff reported that these values are within their normal range of firing conditions and that there is appreciable variation in furnace O₂ levels from one operator to another. Ohio Edison staff also reported recalibrating

the furnace O₂ sensor near the end of this sampling period, and finding that it read 0.5 percent too low. Thus the difference between expected and actual oxygen levels was not in fact as large as first indicated. The conclusion reached is that Niles Boiler No. 2 operated normally but that the expected range of furnace oxygen values may have been set slightly higher than is typical for the Niles plant.

The daily average CO₂ readings from the CEM system at the stack ranged from 13.47 to 13.81 percent, a range of 2.5 percent of the CO₂ value.

The daily average SO₂ emissions based on CEM data at the stack ranged from 2.22 to 2.65 lb/10⁶ Btu (0.95-1.14 g/MJ), a range of 15 percent of the average SO₂ emissions value. The daily average NO_x emissions ranged from 1.29 to 1.38 lb/10⁶ Btu (0.55 to 0.59 g/MJ), a range of 6.7 percent of the average NO_x emissions value.

The daily average opacity based on 6-minute average values ranged from 3.0 to 3.5 percent, a range equal to 16 percent of the overall daily average opacity value. Barometric pressure varied gradually from day to day; good weather conditions predominated throughout the study.

Comparing the data reported in Table 2-4 to the expected operating conditions given in Table 2-3 shows that for most parameters the expected values were achieved. The furnace oxygen data shown in Table 2-4 are generally lower than the expected range shown in Table 2-3. However, this difference is partially resolved by the finding that the plant O₂ sensor read low, as noted above. In addition, plant personnel have indicated that the measured furnace O₂ data are in line with normal plant practice. Thus, all indications are that Boiler No. 2 operated in a stable and normal manner throughout this study.

The operating parameters of the ESP are shown in Tables 2-5 through 2-8, which list values of the primary current (amperes), primary voltage (volts), secondary current (milliamperes), and secondary voltage (kilovolts), respectively, for each bus (i.e., hopper) in each field (i.e., row of hoppers). Each of these tables shows the average and standard deviation of these parameters, for each field on each sampling day. The averages and standard deviations were calculated from values of the four parameters recorded by plant personnel every hour during flue gas sampling on each of the 6 test days. Copies of the log sheets on which these data were recorded are included in Appendix A of this report. No data are shown for hopper rows 1 and 4, since these were deactivated during this study.

Reading across each row of Tables 2-5 through 2-8 indicates the day-to-day variability in ESP conditions. All ESP parameters exhibited good stability during the study.

A final example of plant operating conditions is shown in Table 2-9, which presents coal analysis data provided by the plant for the 6 study days. These data were obtained on coal samples from bunkers at the plant, and represent the composition of coal burned about one day after sampling. This fact is footnoted in Table 2-9. The data in the table illustrate that the coal supplied to Boiler No. 2 was reasonably uniform throughout the present study. In particular, Table 2-9 indicates no unusual characteristics of the coal burned on July 31 (i.e., the coal sampled on July 30) that would have caused the relatively low particulate loading measured at Location 4 on July 31 (Table 2-2). A comparison of the data in Table 2-9 to corresponding data for the period June 30-July 24, 1993, also confirmed that the characteristics of coal burned during this study were typical of the coal routinely supplied to Boiler No. 2. Note that the coal analyses shown in Table 2-9 were not used in mass balance calculations; results from analysis of coal samples taken directly from the coal feeders on each sampling day were used for that purpose.

The only problems encountered in plant operation at Niles were in operation of the coal feeders. As Table 2-3 shows, operation with all four feeders and cyclone burners was required for the sampling effort. This requirement arises because load could drop substantially if one feeder failed. As a result, all flue gas sampling was stopped whenever a feeder was out of service. The most common feeder failure was breakage of a shear pin. This occurred a few times during the study, but resulted in sampling interruptions of no more than 15 minutes at a time. Thus this problem caused no deviation from the planned sampling. A list of the shear pin occurrences is provided in Section 3.1.3 of this report.

2.3.3 Process Trends Graphs

Figures 2-2 through 2-11 are plots of key operating conditions shown in Table 2-4 against time of day on each test day. When plant staff recorded data for periods longer than the actual sampling period (e.g., generally data was recorded from 7:00 am while sampling began about 9:00 or 10:00 am), all of the data are shown on the plots. Figures 2-2 through 2-11 each show values of plant operating conditions for three of the six test days. The

grouping of days is based on the fact that on July 26, 28, and 30 primarily organic constituents of the flue gas were measured, and on July 27, 29, and 31 primarily inorganic constituents were measured. Further detail on the sampling schedule is presented in Section 3.1 of this report. Figures 2-2 and 2-3 show hourly values of coal feed rate; Figures 2-4 and 2-5 show megawatt load and steam flow rate; Figures 2-6 and 2-7 show excess oxygen at the furnace and CO_2 at the stack; Figures 2-8 and 2-9 show SO_2 and NO_x emission rates; and Figures 2-10 and 2-11 show hourly average opacity data. As can be seen from Figures 2-2 to 2-11 and the low values for the standard deviations for operating conditions reported in Table 2-4 (with the exception of the oxygen value at the furnace outlet), Niles Boiler No. 2 was operated at nearly constant conditions for the period of the test.

TABLE 2-1. IDENTIFICATION OF SAMPLING POINTS

Location ^(a)	Description	Niles Boiler No. 2
1	Boiler feed coal	S
2	Bottom ash	S
3	Air heater ash	S
4	ESP inlet	G
5	ESP outlet	G
8	ESP ash	S
9	Make-up water	L
10	Outlet of pond	L
13	Coal pile runoff	L

- (a) See Figure 2-1 for locations in the process streams at Niles Boiler No. 2.
 (b) S = solid stream, G = flue gas stream, L = liquid stream.

TABLE 2-2. FLUE GAS CHARACTERISTICS AT SAMPLING LOCATIONS

Flue Gas Characteristics							
Location ^a / Test Day	Temp. (°F)	Pressure (in Hg)	Percent Moisture	Percent Oxygen	Particle Loading (mg/Ncm) ^b	Duct Flow (Ncm/min) ^b	Duct Flow (Ncm/min) ^c
Location 4							
7/26/93	310	0.05	8.4	4.0		6,007	6,363
7/27/93	301	0.05	14.4	4.1	2,239	6,103	6,503
7/28/93	282	0.05	11.8	4.4		6,365	6,905
7/29/93	292	0.05	12.3	4.0	2,583	6,074	6,434
7/30/93	296	0.05	9.3	4.1		6,225	6,633
7/31/93	282	0.05	7.9	4.4	1,581	6,562	7,118
Location 5a							
7/26/93	294	-0.07	9.2	7.5		4,763	6,362
7/27/93	294	-0.07	9.2	6.0	43.4	5,316	6,386
7/28/93	292	-0.09	9.1	7.0		5,038	6,488
7/29/93	293	-0.08	9.4	6.5	19.4	5,093	6,331
7/30/93	286	-0.09	8.4	6.0		5,373	6,454
7/31/93	291	-0.08	9.4	6.5	34.3	5,120	6,365

(a) Location 4 = ESP inlet; 5a = ESP outlet (stack).

(b) Normalized to 3 percent O₂ in flue gas.

(c) Flow rate at actual O₂ content (i.e., not normalized to 3 percent O₂).

TABLE 2-3. EXPECTED OPERATING CONDITIONS AND PERMITTED DEVIATION

Parameter ^(a)	Nominal Expected Value	Allowable Range
Boiler Operating Conditions		
Coal	Constant source, if possible	
Load, MW (gross)	115	110-115
Cyclones in operation	4	4
Flue gas oxygen monitor readings, percent	2.5-3.0	1.8-3.0
Steam temperature at superheater outlet, °F	1000	980-1010
Steam temperature at reheater outlet, °F	1000	950-1010
Drum steam pressure, psig	1470	1460-1480
Throttle steam flow, lb/hr	850,000- 900,000	800,000- 1,000,000
Preheater dumping	Arranged schedule	
ESP dumping	Arranged schedule	
Emissions		
Stack opacity, 6-min. average, percent	3-10	< 20
Stack SO ₂ , ppm	1900	1800-2200
Stack NO _x , ppm	600-650	500-810

- (a) 950 °F = 783 K
 980 °F = 800 K
 1,000 °F = 811 K
 1,010 °F = 816 K
 1,460 psig = 1.01 x 10⁷ kPa
 1,470 psig = 1.01 x 10⁷ kPa
 1,480 psig = 1.02 x 10⁷ kPa
 800,000 lb/hr = 101 kg/s
 850,000 lb/hr = 107 kg/s
 900,000 lb/hr = 114 kg/s
 1,000,000 lb/hr = 126 kg/s

TABLE 2-4. ACTUAL PLANT OPERATING CONDITIONS
DURING SAMPLING

Date	Average	Range	Standard Deviation
Coal Feed Rate, klb/hr			
July 26, 1993	89.6	88.4-90.1	0.6
July 27, 1993	91.5	89.7-93.5	1.5
July 28, 1993	93.8	91.5-95.9	1.6
July 29, 1993	94.2	92.6-96.6	1.3
July 30, 1993	94.4	93.4-95.2	0.6
July 31, 1993	96.7	95.2-98.1	1.1
Gross Load, MW			
July 26, 1993	116.7	116-117	0.5
July 27, 1993	116.6	116-117	0.2
July 28, 1993	117.1	116-118	0.7
July 29, 1993	116.6	116-117	0.5
July 30, 1993	116.7	116-117	0.5
July 31, 1993	117.5	117-118	0.6
Steam Generation Rate, klb/hr			
July 26, 1993	877	874-881	2
July 27, 1993	877	875-879	1
July 28, 1993	881	868-886	5
July 29, 1993	866	862-868	2
July 30, 1993	863	859-865	2
July 31, 1993	870	866-875	3
Drum Steam Pressure, psig			
July 26, 1993	1536	1535-1537	1.0
July 27, 1993	1534	1532-1537	1.4
July 28, 1993	1535	1533-1537	1.1
July 29, 1993	1534	1532-1535	1.0
July 30, 1993	1533	1529-1535	2.1
July 31, 1993	1528	1500-1536	11.9
Steam Temperature, Superheater Outlet, °F			
July 26, 1993	1000	1000-1001	0.5
July 27, 1993	1000	1000-1000	0.0
July 28, 1993	1000	999-1001	0.5
July 29, 1993	1000	999-1001	0.6
July 30, 1993	1000	999-1000	0.5
July 31, 1993	1000	999-1001	0.5

TABLE 2-4. (Continued)

Date	Average	Range	Standard Deviation
Steam Temperature Reheater Outlet, °F			
July 26, 1993	982	977-987	4.1
July 27, 1993	986	981-990	2.9
July 28, 1993	988	979-995	5.8
July 29, 1993	988	986-993	2.6
July 30, 1993	991	986-995	3.0
July 31, 1993	989	983-996	4.6
Excess O ₂ at Furnace Outlet, percent ^(a) (wet basis)			
July 26, 1993	1.29	1.18-1.54	0.13
July 27, 1993	1.65	1.34-2.18	0.23
July 28, 1993	1.65	1.34-1.83	0.16
July 29, 1993	1.72	1.42-1.96	0.21
July 30, 1993	2.07	1.82-2.17	0.13
July 31, 1993	1.90	1.76-2.06	0.11
CO ₂ at Stack, percent (wet basis)			
July 26, 1993	13.81	13.74-13.92	0.11
July 27, 1993	13.64	13.49-13.75	0.09
July 28, 1993	13.57	13.43-13.77	0.13
July 29, 1993	13.45	13.37-13.52	0.05
July 30, 1993	13.45	13.35-13.75	0.15
July 31, 1993	13.65	13.55-13.89	0.11
SO ₂ Emissions, lb/10 ⁶ Btu			
July 26, 1993	2.22	2.05-2.31	0.09
July 27, 1993	2.56	2.23-2.78	0.22
July 28, 1993	2.62	2.49-2.74	0.09
July 29, 1993	2.48	2.20-2.71	0.17
July 30, 1993	2.65	2.59-2.82	0.08
July 31, 1993	2.38	2.30-2.43	0.05
NO _x Emissions, lb/10 ⁶ Btu			
July 26, 1993	1.29	1.25-1.39	0.05
July 27, 1993	1.38	1.33-1.45	0.04
July 28, 1993	1.32	1.25-1.37	0.04
July 29, 1993	1.31	1.29-1.34	0.02
July 30, 1993	1.33	1.24-1.40	0.06
July 31, 1993	1.37	1.29-1.46	0.06

TABLE 2-4. (Continued)

Date	Average	Range	Standard Deviation
Opacity, percent			
July 26, 1993	3.1	2.8-3.7	0.2
July 27, 1993	3.2	2.8-3.9	0.2
July 28, 1993	3.0	2.6-6.7	0.4
July 29, 1993	3.2	3.0-3.7	0.2
July 30, 1993	3.5	3.2-3.9	0.2
July 31, 1993	3.3	2.9-3.8	0.2
Barometric Pressure, in. Hg			
July 26, 1993	29.00	--(b)	--
July 27, 1993	28.83	28.82-28.84	0.01
July 28, 1993	28.81	28.78-28.84	0.04
July 29, 1993	28.77	28.76-28.77	0.01
July 30, 1993	28.79	28.77-28.80	0.02
July 31, 1993	28.93	28.92-28.93	0.01

(a) Values not corrected for 0.5 percent offset in furnace O₂ sensor.

(b) No variation.

TABLE 2-5. NILES UNIT 2 ESP, PRIMARY CURRENT (Amperes)

	July 26	July 27	July 28	July 29	July 30	July 31
Field	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:
1	Out of Service					
2A	50.7 4.27	43 5	50 0	50 0	54 9.27	50 0
2B	70 0	70 0	70 0	70 0	70 0	70 0
3A	90 0	90 0	90 0	90 0	88.8 2.17	90 0
3B	105 7.07	109 5.34	106 2	105 0	105 0	106 2
4A	Off					
4B	Off					
5A	136 1.86	135 0	135 0	135 0	135 0	135 0
5B	144 4.49	145 0	143 4	145 0	145 0	145 0

TABLE 2-6. NILES UNIT 2 ESP, PRIMARY VOLTAGE (Volts)

	July 26	July 27	July 28	July 29	July 30	July 31
Field	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:
1	Out of Service					
2A	197 15.2	184 28.3	191 27.3	214 6.5	213 13	204 23.3
2B	256 8.37	250 5.77	249 6.63	235 6.12	233 2.5	240 3.16
3A	254 6.07	262 3.73	263 4	263 2.5	260 0	268 2.45
3B	258 6.87	261 1.86	262 2.45	266 2.17	260 0	266 3.74
4A	Off					
4B	Off					
5A	277 2.36	277 2.36	279 2	280 0	279 3.17	280 0
5B	278 2.35	280 0	280 0	280 0	280 0	280 0

TABLE 2-7. NILES UNIT 2 ESP, SECONDARY CURRENT (milliamperes)

	July 26	July 27	July 28	July 29	July 30	July 31
Field	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:
1	Out of Service					
2A	113 9.43	110 10	112 9.8	145 43.3	153 39	120 0
2B	218 3.73	220 0	220 0	220 0	220 0	220 0
3A	275 0	275 0	275 0	269 10.8	275 0	275 0
3B	292 18.6	300 0	300 0	300 0	300 0	300 0
4A	Off					
4B	Off					
5A	467 74.5	500 0	500 0	500 0	500 0	500 0
5B	542 18.6	550 0	550 0	550 0	550 0	550 0

TABLE 2-8. NILES UNIT 2 ESP, SECONDARY VOLTAGE (kilovolts)

	July 26	July 27	July 28	July 29	July 30	July 31
Field	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:	Avg.: SD:
1	Out of Service					
2A	43.3 1.7	44.5 3.15	44.8 1.94	45.3 1.3	43.5 0.87	45 1.55
2B	50.3 2.05	48.3 1.37	48.4 0.49	47 1	45.3 0.83	47 0.89
3A	47.2 1.07	48.2 0.37	49.4 0.49	49.5 0.5	49.3 0.43	50.8 0.75
3B	48.2 0.37	48.2 0.37	48 0	48.5 0.5	48 0	48.8 0.75
4A	Off					
4B	Off					
5A	48 0	48.2 0.37	48.6 0.49	49 0	49 0	49 0
5B	47.5 0.5	47.8 0.37	48 0	48 0	48 0	48 0

TABLE 2-9. RESULTS OF ANALYSIS OF BUNKER COAL SAMPLES

Day of Coal Sample ^(a)	Coal Analysis - As Received			
	Moisture (percent)	Ash (percent)	Sulfur (percent)	Heat Value (Btu/lb)
July 25, 1993	6.91	11.52	2.58	11,964
July 26, 1993	4.47	10.67	2.68	12,504
July 27, 1993	4.57	11.15	2.74	12,397
July 28, 1993	5.36	11.77	2.57	12,139
July 29, 1993	6.39	11.32	2.51	12,031
July 30, 1993	6.92	11.21	2.40	12,068

(a) Coal in bunker is burned about 1 day after sample is collected. Thus data shown represent coal burned on study days of July 26-31, 1993.

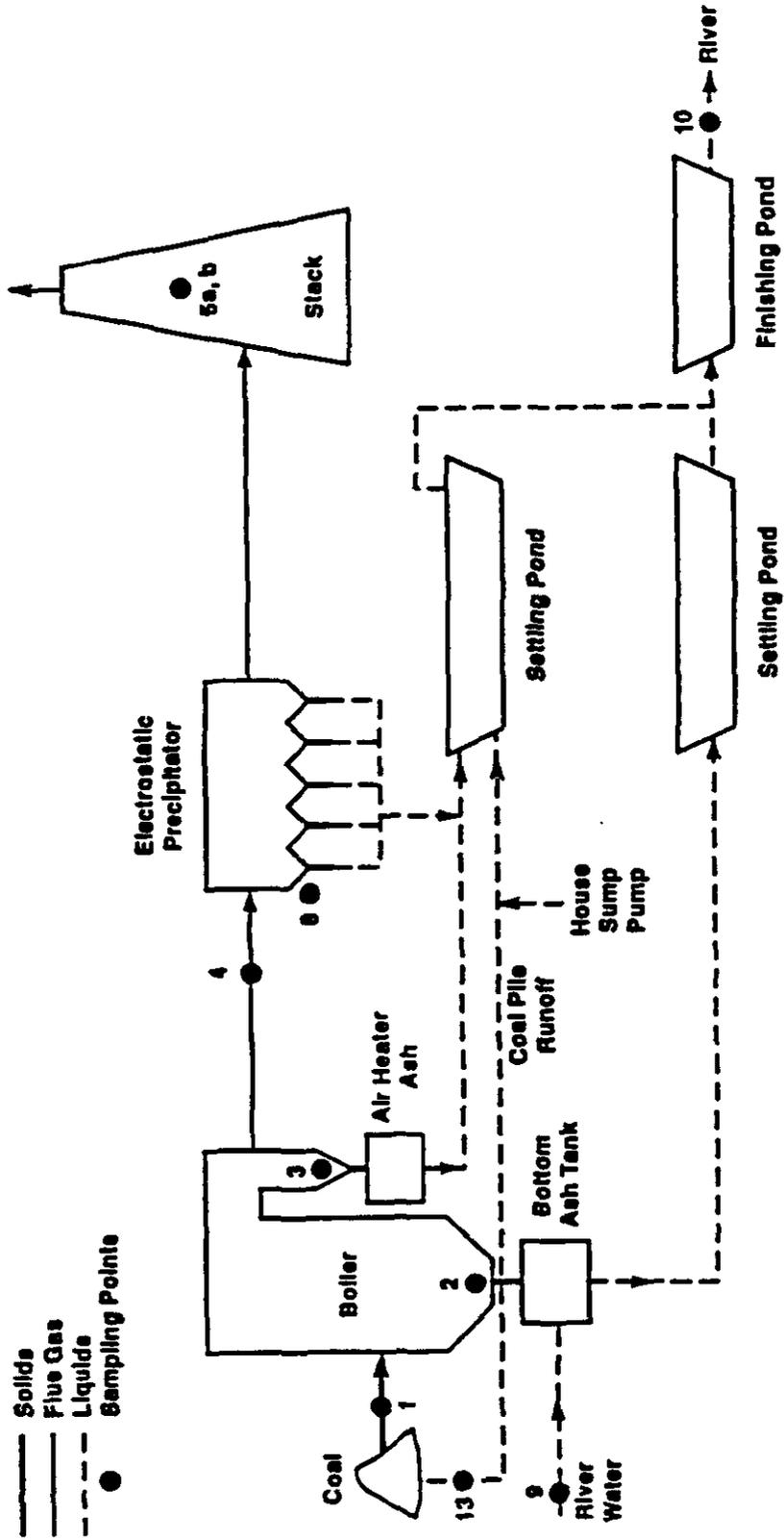


Figure 2-1. Process flow diagram and sampling locations for Niles Station Boiler No. 2

Niles No. 2

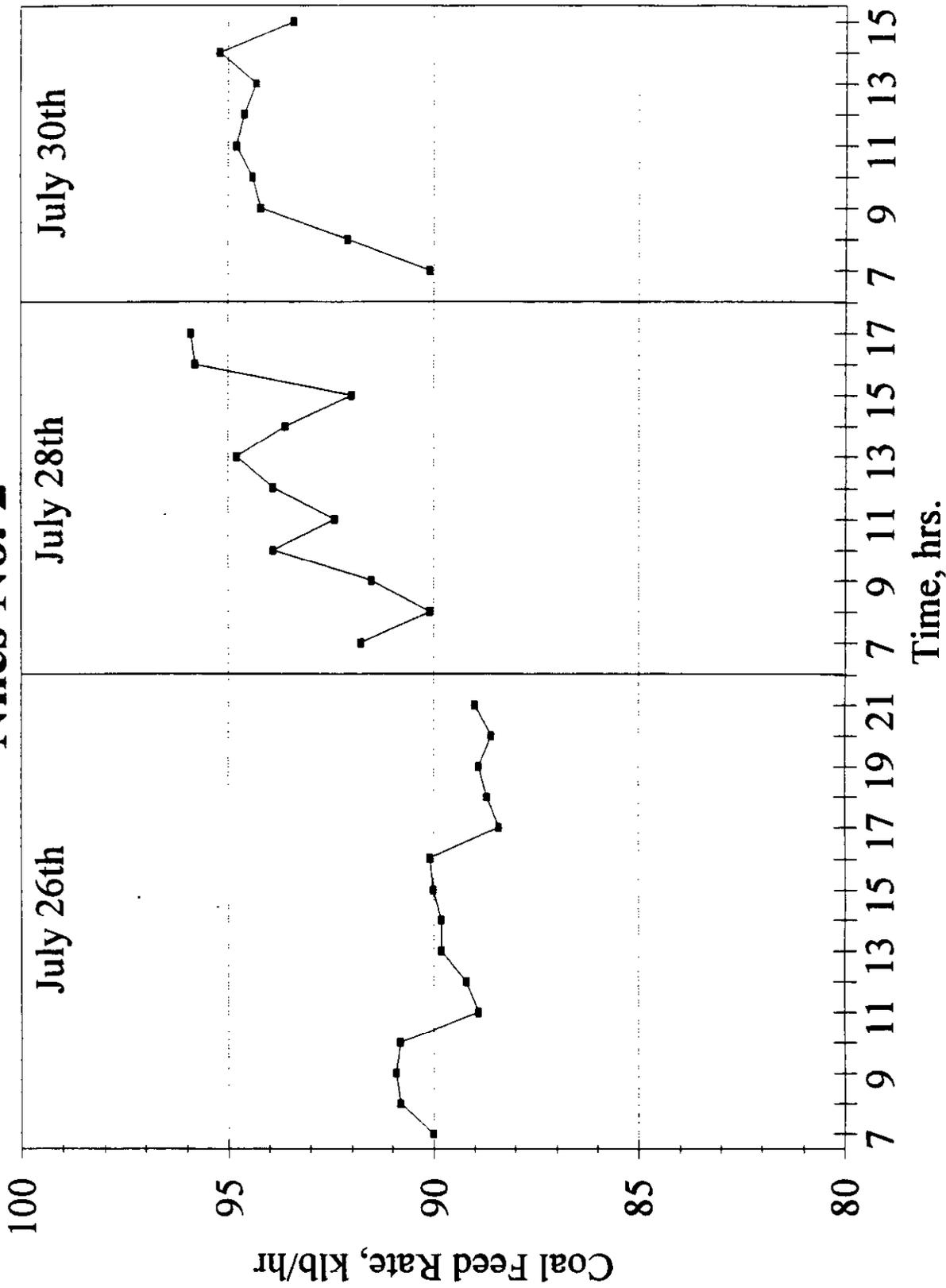


Figure 2-2. Coal feed rate, July 26, July 28, and July 30, 1993

Niles No. 2

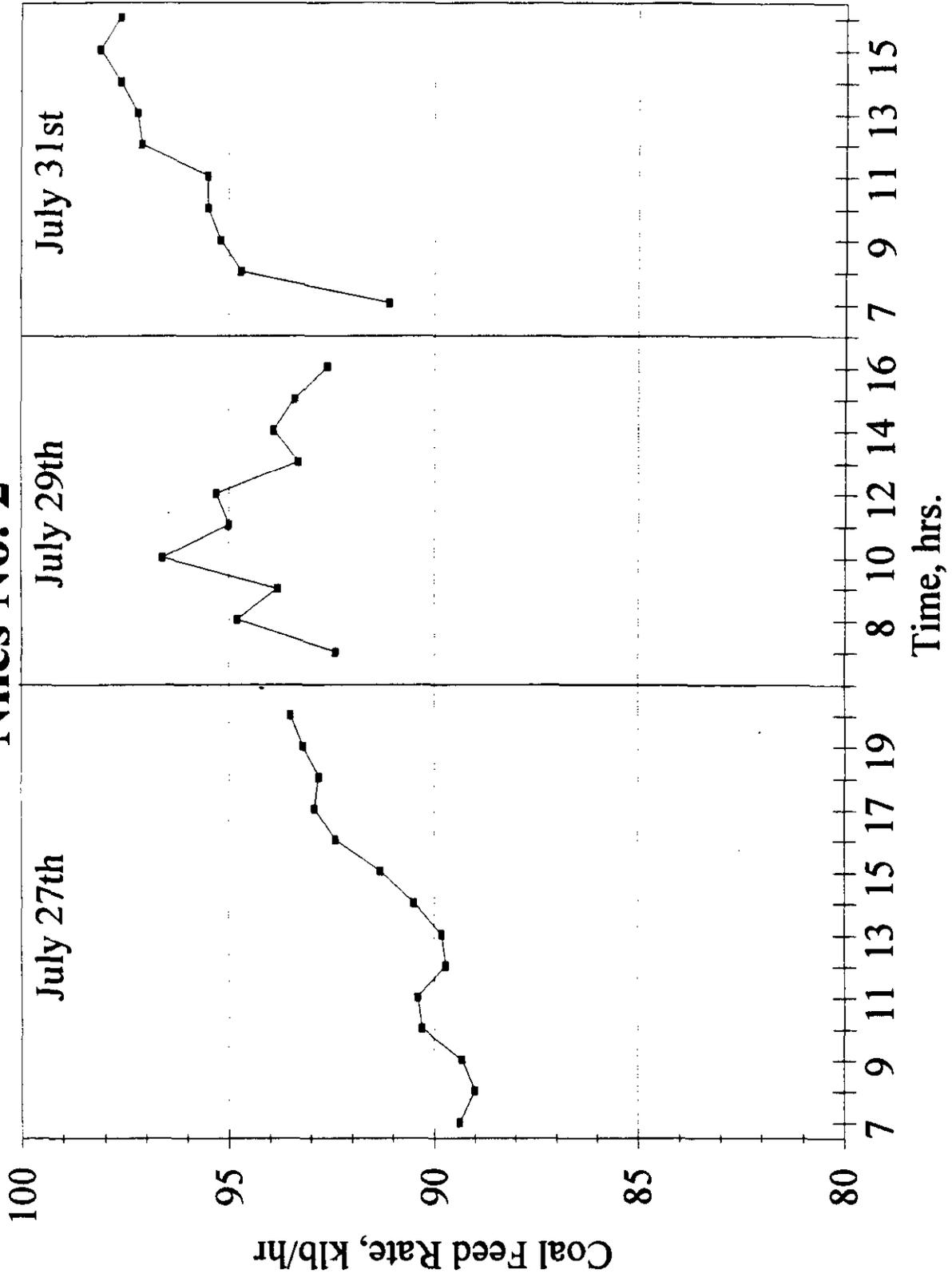


Figure 2-3. Coal feed rate, July 27, July 29, and July 31, 1993

Niles No. 2

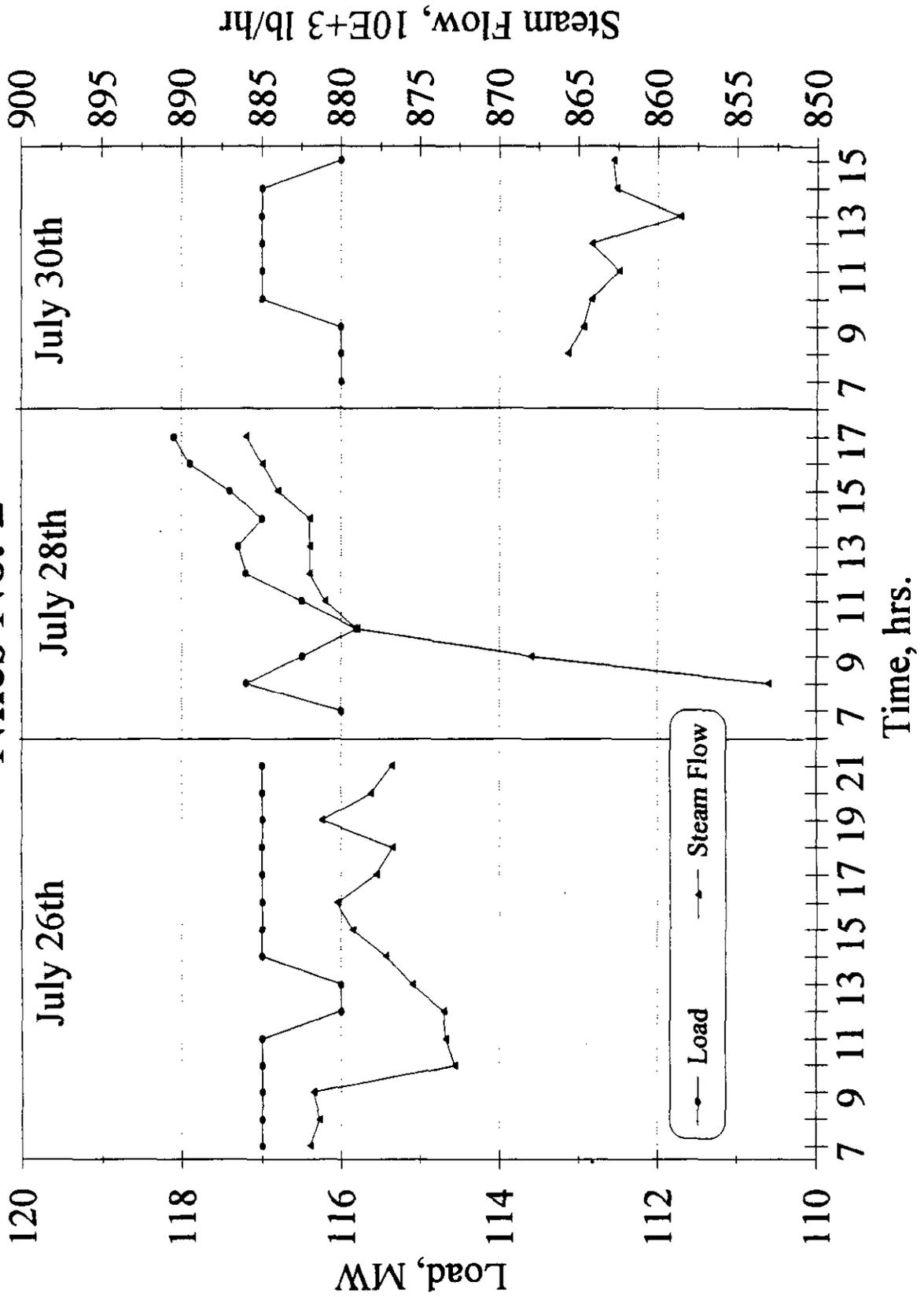


Figure 2-4. Load and steam generation rates, July 26, July 28, and July 30, 1993

Niles No. 2

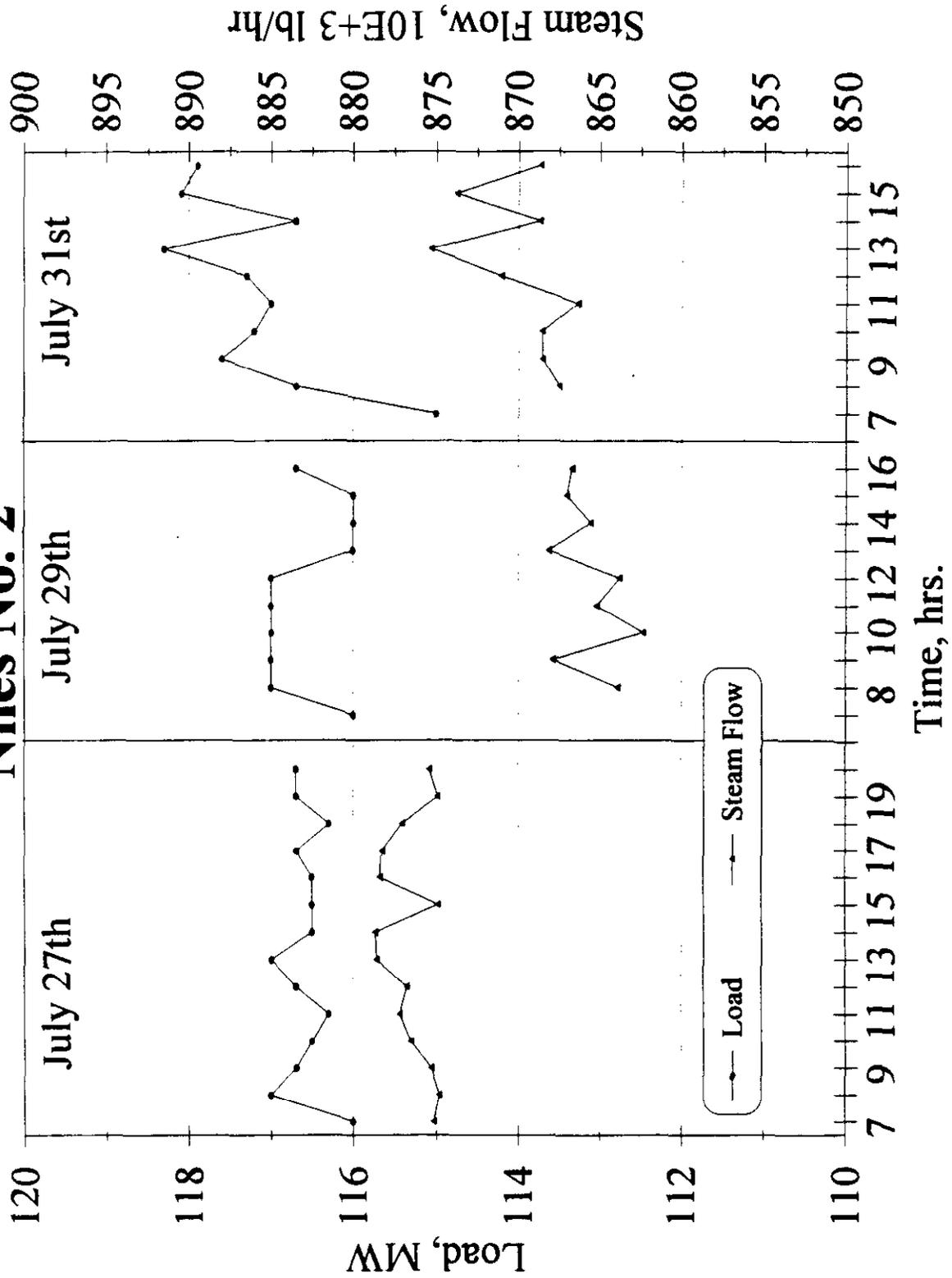


Figure 2-5. Load and steam generation rates, July 27, July 29, and July 31, 1993

Niles No. 2

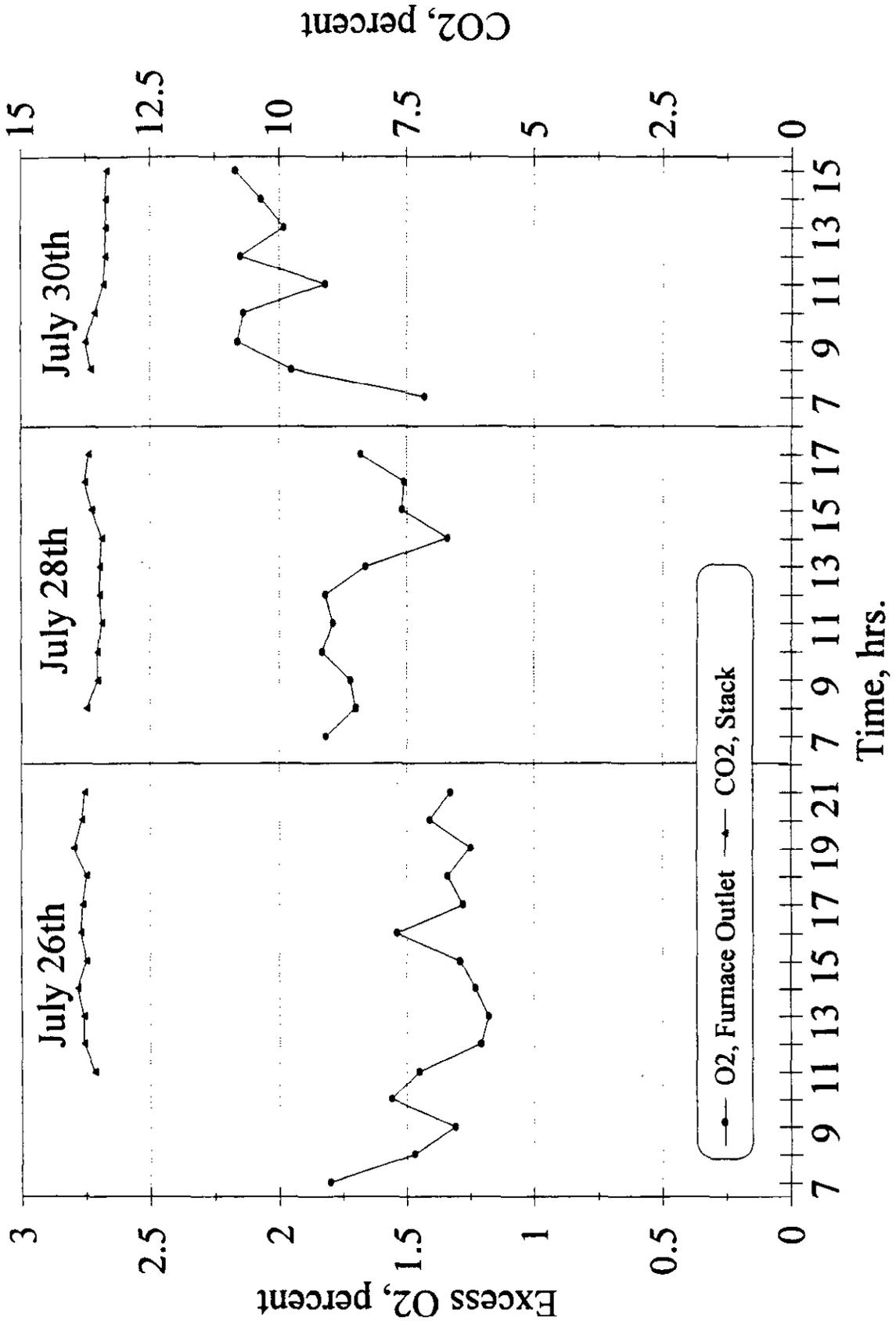


Figure 2-6. Furnace outlet O₂ and stack CO₂, July 26, July 28, and July 30, 1993

Niles No. 2

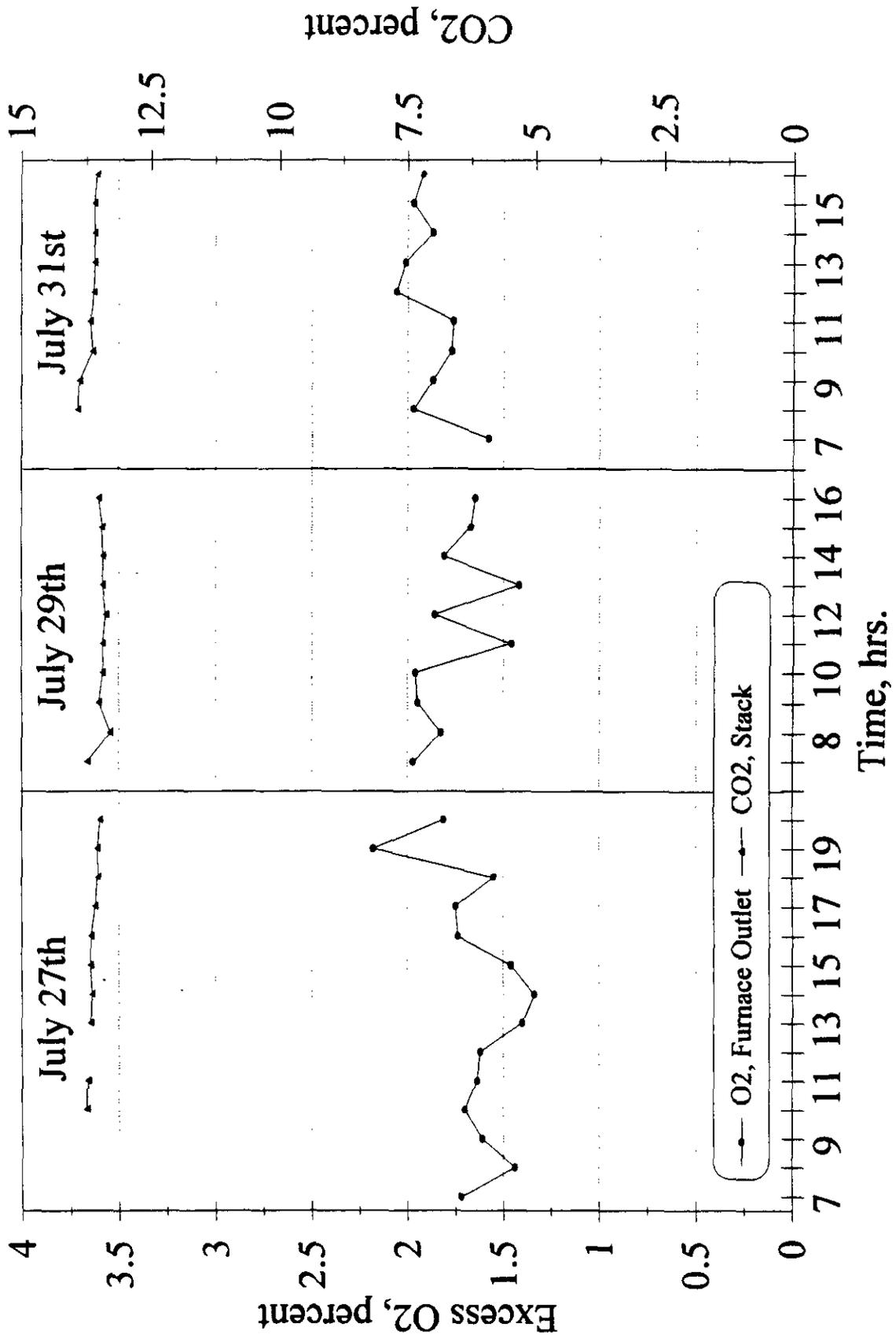


Figure 2-7. Furnace outlet O₂ and stack CO₂, July 27, July 29, and July 31, 1993

Niles No. 2

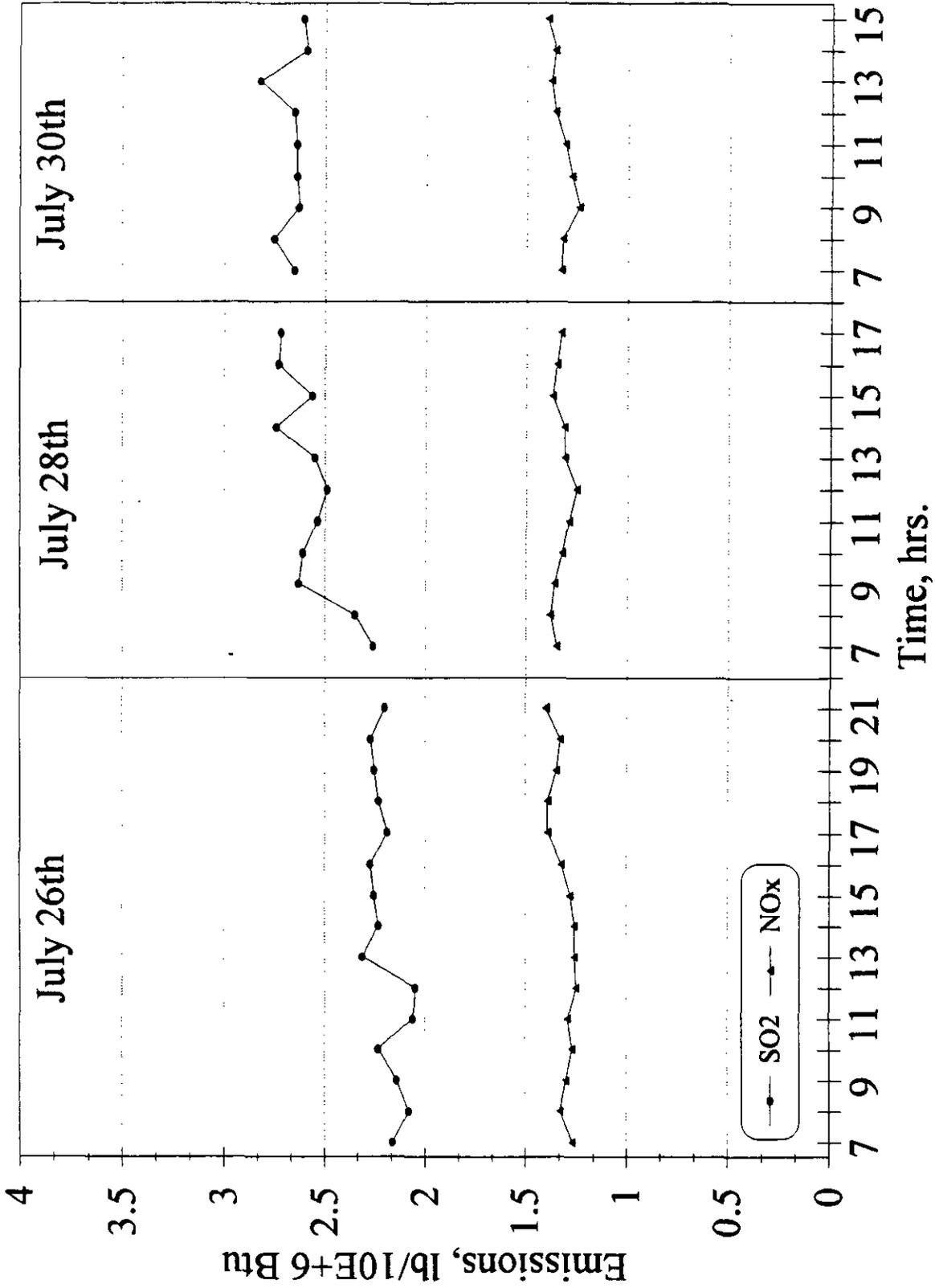


Figure 2-8. Unit No. 2 SO₂ and NO_x emissions, July 26, July 28, and July 30, 1993

Niles No. 2

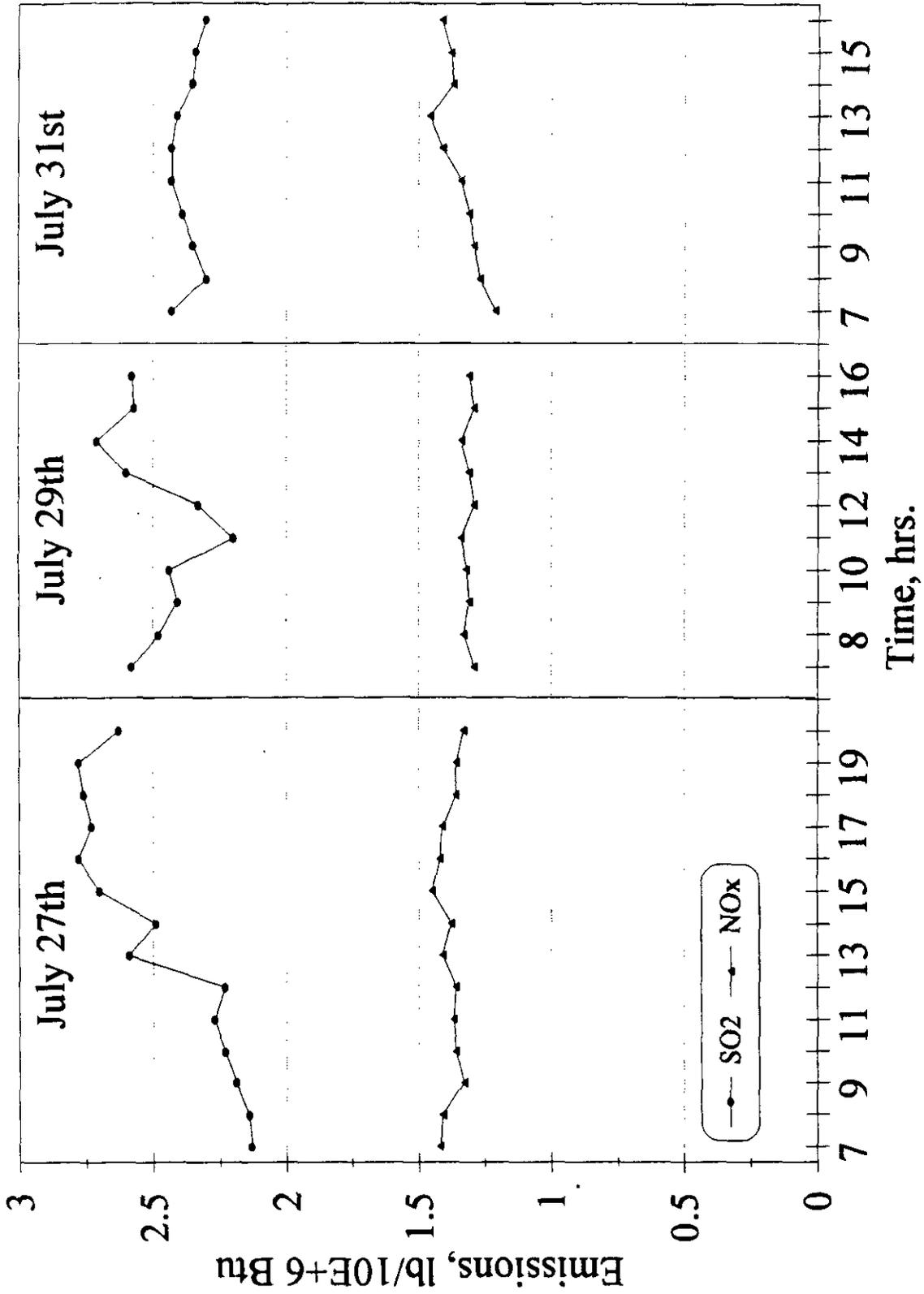


Figure 2-9. Unit No. 2 SO₂ and NO_x emissions, July 27, July 29, and July 31, 1993

NILES No. 2

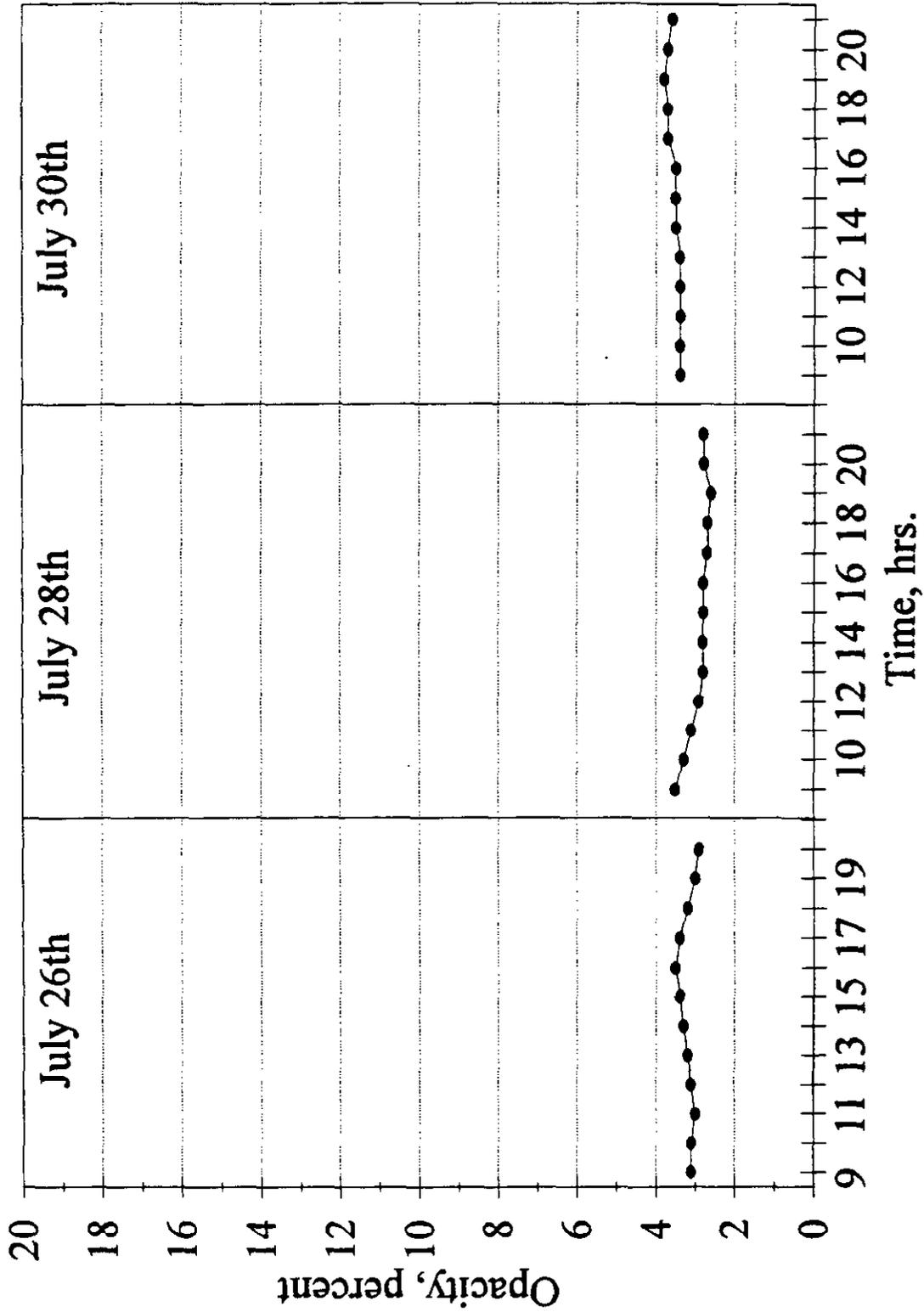


Figure 2-10. Unit No. 2 Opacity, July 26, July 28, and July 30, 1993

NILES No. 2

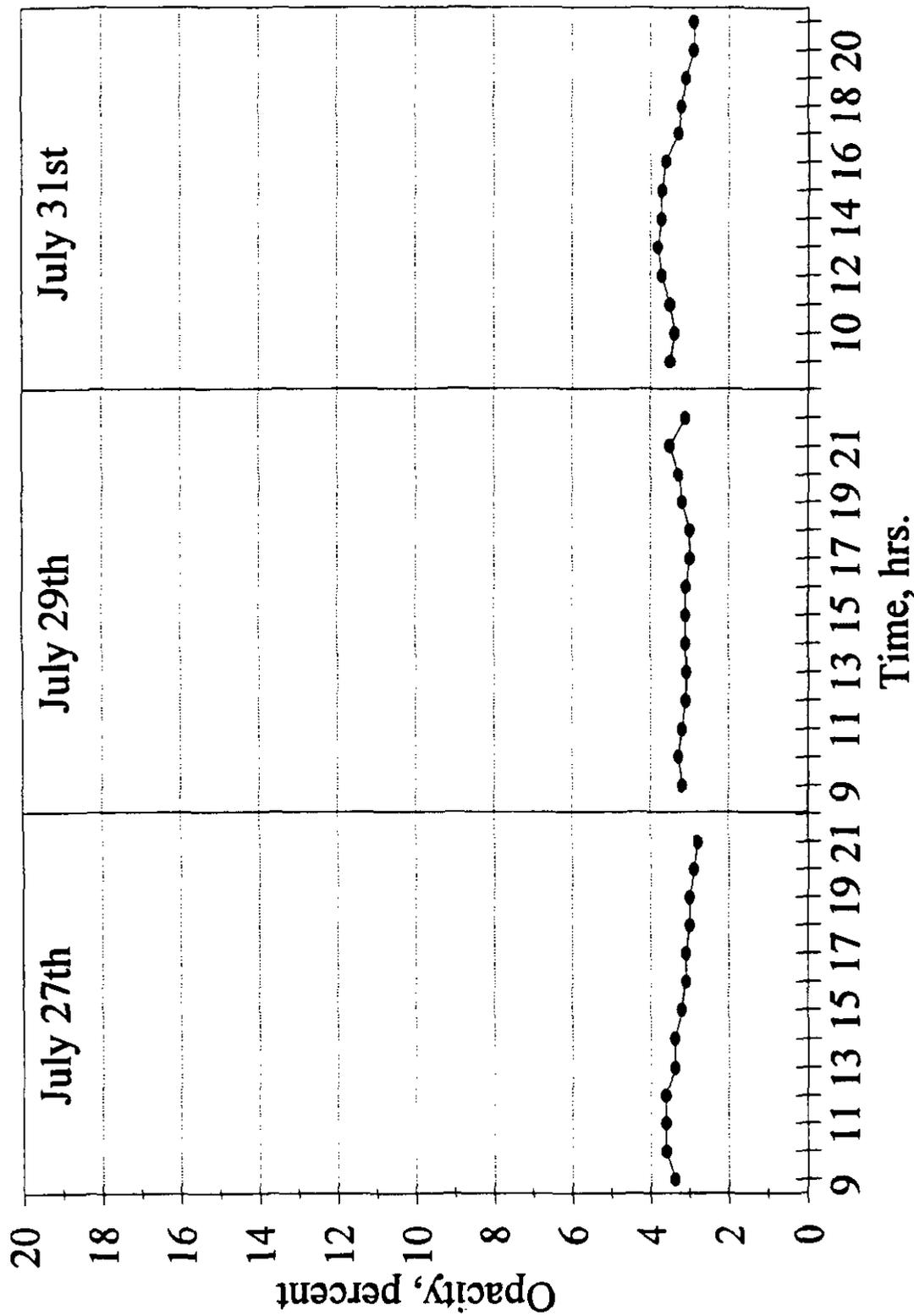


Figure 2-11. Unit No. 2 Opacity, July 27, July 29, and July 31, 1993

3.0 SAMPLING

The sampling activities at Boiler No. 2 are summarized in this section in three parts. First the schedule for sampling is summarized. Then the types and numbers of samples that were collected are reviewed. Finally, data on mass flows of ash and sulfur are presented.

3.1 Field Schedule

3.1.1 Overall Schedule

The overall schedule of the field effort at Niles Boiler No. 2 is illustrated in Table 3-1, which lists the dates and activities for the entire period that project staff were on site. As Table 3-1 indicates and as noted in Section 2, the actual sampling days at Boiler No. 2 were July 26-31. That 6-day period consisted of three 2-day sampling sets. Within each 2-day set, flue gas sampling on the first day was devoted to measurement of organic constituents, and on the second day to measurement of inorganic constituents. At Niles Boiler No. 2 the "organic" days were July 26, 28, and 30; the "inorganic" days were July 27, 29, and 31.

Details on the types of sampling conducted and the number of samples obtained are presented in the next section of this report. The collection of process (i.e., solid and liquid) samples did not vary from day to day, but the analyses subsequently conducted on those samples did vary. Process samples collected on "organic" days were analyzed for organic constituents, those collected on "inorganic" days were analyzed for inorganic constituents.

3.1.2 Daily Schedules

On each organic sampling day, sampling was conducted for semivolatile organic compounds (SVOC) for approximately 6 hours while traversing the duct. Three canister samples were collected for volatile organic compounds (VOC) at each flue gas location for about 30 minutes each. A set of three volatile organic sampling train (VOST) samples was also collected in parallel with the canister collections, for 5, 10, and 30 minutes. An impinger train was used to collect samples for aldehydes for 1 hour.

On the inorganic days, sampling was conducted for both gas and solid phase elements for approximately 6 hours while traversing the duct. In the same time period, a hazardous element sampling train (HEST) was used to collect vapor phase arsenic, selenium, and mercury over a 4-hour period by a carbon impregnated filter. Meanwhile at another port three impinger trains were used consecutively to collect acid gases/anions, ammonia, and cyanide. Cascade impactors were run on the inorganic sampling days at Locations 5a and 5b. High-volume sampling was conducted on the inorganic days during soot blowing, and again later in the day after soot blowing, at Location 5a only.

The sampling plan described planned daily sampling schedules that were coordinated among all the sampling locations, so that flue gas methods were conducted simultaneously at all locations. In practice, strict coordination of sampling methods in the field is difficult, because of the different constraints in sampling at different locations, difficulties in communications, and the need to conduct multiple sampling methods at each site simultaneously. Nevertheless, reasonable coordination of flue gas methods was achieved at Niles Boiler No. 2. Figures 3-1a to 3-1f show the actual schedules of sampling on the six sampling days at Boiler No. 2. The daily schedules are arranged chronologically, i.e., Figures 3-1a to 3-1f correspond to sampling days July 26-31, respectively.

The corresponding daily schedules of solid/liquid sample collection are shown in Figures 3-2a through 3-2f, which illustrate July 26-31, respectively. Boiler feed coal was collected throughout the period of flue gas sampling on each sampling day, as indicated in the figures. ESP ash, air heater ash, and bottom ash hoppers were all emptied on the morning of each sampling day before sampling began. Thus the ash samples from each sampling day represent ash collected in the hoppers over at most a few hours during the sampling period.

3.1.3 Deviations and Modifications to Schedule

The start of sampling at Niles Boiler No. 2 on July 26 was delayed somewhat, while Ohio Edison staff finished preparations of that site. Battelle staff requested that flanges be prepared to allow proper mating of the sampling probes to the ports at Location 4 and that accumulated solids be cleaned out of those ports. Those operations were completed the

morning of July 26; sampling started about noon that day. No deviations from the sampling plan occurred as a result of this delay.

Small interruptions in sampling occurred due to breakage of shear pins on the feeders of Boiler No. 2. Because loss of a feeder due to a broken shear pin affects plant load and operating conditions, sampling was stopped when a pin was sheared and was resumed once plant conditions were restabilized; i.e., about 5 minutes after the pin was replaced and the feeder brought back on line. Such interruptions were of little real consequence since they typically lasted no more than 10 minutes. Table 3-2 summarizes the shear pin occurrences during sampling at Niles.

3.2 Samples Collected

3.2.1 Types and Numbers of Samples

The primary kinds of substances that were measured in various flue gas, solid, and liquid samples from Boiler No. 2 are summarized in Table 3-3. The substances measured are shown, along with indications of the sample matrices from which samples were collected. More detail on the sampling and analysis conducted is given in Table 3-4, which shows the constituents measured in samples from the Boiler No. 2 field effort. In Table 3-4, flue gas locations are distinguished from solid and liquid sampling locations. All locations are numbered as indicated in Figure 2-1 and Table 2-1.

The methods used to collect samples from flue gas streams at Boiler No. 2 are summarized in Table 3-5. Size-fractionated particle samples were collected in the Multi-Metals and Modified Method 5 trains at Location 4. Glass cyclones with designed aerodynamic particle diameter cut points of 10 μm and 5 μm were fabricated for this project and were used ahead of the filter in each of these sampling trains at Location 4. The cyclones were used in an extractive mode, i.e., outside of the duct. A flexible, heated Teflon line of smooth inner bore connected the sampling probe to the cyclones, which were installed in the heated filter box of the sampling trains. The effect of this approach on determining particle size distributions is discussed in Section 5.11 of this report.

The daily sampling schedule on both organic and inorganic days was essentially the same at all flue gas locations. Thus the numbers of samples collected at each site were nominally the same. The actual numbers of samples of various types taken at Boiler No. 2 flue gas locations are shown in Table 3-6.

The number of solid/liquid samples collected on each sampling day are shown in Table 3-7. The number of samples of ESP ash and air heater ash varied somewhat from day to day depending on the availability of samples from the various hoppers. These variations are noted as deviations from the sampling plan, in Section 3.2.4.

3.2.1.1 Flue Gas Streams. Flue gas sampling at Boiler No. 2 took place at two parts of the plant, the ESP inlet (Location 4) and ESP outlet in the stack (Locations 5a and 5b). Location 5a consisted of hot flue gas sampling from the stack, and Location 5b consisted of sampling with Chester Environmental's Plume Simulating Dilution Sampler (PSDS). For this project PSDS sampling involved withdrawing hot flue gas at about 0.35 dry standard liters per second (0.75 dscfm), diluting by a factor of 25 to 30 with an oxygen/nitrogen mixture, and then sampling with the various collection trains. The O₂/N₂ mixture was at a ratio of 21:79 to simulate pure air. The same measurements were made at Location 5b by PSDS as in the flue gas itself at Location 5a, however, the PSDS is an isokinetic non-traversing method. Comparisons of hot and dilute (i.e., PSDS) sampling results from the stack are reported in Section 7.1. Particle size distributions were measured at Locations 5a and 5b by cascade impactors. In addition, Table 3-4 shows that elements originating in the stack gas from soot blowing were measured at Location 5a only. This measurement consisted of a 2-hour high-volume filter run during soot blowing at Boiler No. 2 (typically starting about 6 a.m.), followed by a second such sample later in the day when soot blowing was not being conducted.

3.2.1.2 Solid and Liquid Streams. Solid and liquid sample collection at Niles Boiler No. 2 (Table 3-4) was quite extensive. Boiler feed coal (Location 1) was collected and composited by OE personnel as described in Section 2.2.2. Bottom ash samples (Location 2) were collected three times daily by Niles Station personnel from one of the sluice tanks at the bottom of Boiler No. 2. Air heater ash (Location 3) was collected from

each of two hoppers three times each day by a combination of Battelle and Niles staff. The collection of ESP ash (Location 8) was done by Battelle staff from all five hopper rows (ten hoppers total). Samples were collected twice each day from rows 1-3, and once each day from rows 4 and 5. Make-up water (Location 9) and pond outlet water (Location 10) were collected once each day by Battelle staff. One sample of coal pile runoff (Location 13) was collected on July 29.

3.2.2 Compositing Procedures

Solid samples were obtained at Niles Boiler No. 2 in multiple collections during each sampling day, as described above. The purpose of this approach was to obtain samples representative of the range of plant operating conditions that occurred during each sampling day. The multiple samples collected at each solid sampling location on each day were then composited into a single daily sample. Portions of the resulting daily composite samples were then distributed to the various analytical laboratories as needed.

Solid samples were taken at four locations for Boiler No. 2: boiler feed coal (Location 1), bottom ash (Location 2), air heater ash (Location 3), and electrostatic precipitator ash (Location 8). Compositing of a day's samples taken at Locations 1, 2, and 3 was accomplished by taking equal amounts from the samples taken during that day. For Location 8 (the electrostatic precipitator) daily composites were made for each row of the ESP by taking equal amounts from each of the samples taken from that row during the day. The number of samples taken from any row during the day ranged from one to four. In the former case there was no compositing; the single sample was divided into portions for analysis as far as the available amount would go.

With the exception of the boiler feed coal samples (Location 1), all compositing was done by the Commercial Testing and Engineering Company (CTE) in Conneaut, Ohio. The boiler feed coal samples were collected during the period of sampling on each study day by Ohio Edison personnel under the direction of Battelle staff. Ohio Edison personnel used standard ASTM procedures to compile a composite sample of about 3 kg, and provided that composite to Battelle. Distribution of the feed coal for analysis was then done by Battelle personnel in Columbus, Ohio.

Battelle prepared a set of instructions, in the form of tables, for the compositing and apportioning of the samples. These instructions are shown in Table 3-8. Each page of Table 3-8 addresses a different type of solid sample, beginning with the boiler feed coal, then proceeding through Locations 2, 3, and 8 in order. Shown in these tables are the sample identification, dates, and sample apportioning procedures.

During the compositing the system for identifying the samples was altered, and a composite sample ID was established. Those composite IDs are shown in Table 3-8. The date was kept, although in a slightly different format; however, the sampling site number was replaced with a term descriptive of the source of the sample. Examples of the two sets of IDs are shown in Table 3-9.

Solid samples taken on organic days were analyzed for SVOC. Thus only two portions were made from the samples on these days -- one for the SVOC analysis and the other for an archive. On the inorganic days four to six portions were made from the composites. Analyses for metals were required for the samples taken from each of the sampling sites. Most of these analyses were performed by CTE at its laboratory in Denver (CTE-Denver). Metals analysis for the coal samples was shared by CTE-Denver (beryllium and boron) and Element Analysis Corporation (EA) (the remaining metals). Analyses covering ultimate/proximate, moisture, heat, carbon, sulfur, and particle size were performed by the Conneaut laboratory of CTE. Analyses for chlorine, fluorine, phosphate, and sulfate were performed by Battelle's Columbus Operations (BCO). The International Technology (IT) Corporation ran the radiological (RAD) analysis of the samples for gamma-emitting isotopes. Sample portions analyzed by each of these laboratories are indicated in Table 3-8.

In general, a portion of sample overly sufficient for each analysis was taken from the composite. If the composite contained only a limited amount of material, the amounts allocated for analysis were cut down to the minimum amounts required. If there was insufficient material for even the minimum requirements, then radionuclide analysis and particle size determination, in that order, were dropped from the analysis schedule.

3.2.3 Number of Analyses

The number and type of analyses conducted on the collected gas, solid, and liquid samples are listed in Table 3-10 according to sampling location and sampling method. The number of samples collected is provided for reference and discrepancies between number of samples collected and number of samples analyzed is noted as appropriate.

3.2.4 Problems and Deviations in Sampling

No deviations from the sampling plan occurred in the scheduling of flue gas sampling at Boiler No. 2. Minor deviations occurred in the collection of solid and liquid samples, and in some analyses. The specific deviations were:

- (1) July 26 - No ESP ash sample was obtained from Hopper 1-1 during the first collection of the day due to problems with the extraction tool. Also no ESP ash sample was collected from row 4, and from one hopper in row 5 during the second collection period due to lack of material in the hoppers. No air heater ash sample was collected from Hopper 3 due to plugging of the exit port during the first collection period.
- (2) July 27 - No ESP ash sample was obtained from Hopper 1-1 during the second collection period due to plugging of the exit port. Also sample was obtained from row 5 hoppers but not from row 4 hoppers. No air heater ash sample was obtained from Hopper 4 due to plugging of the exit port during the first collection period.
- (3) July 28 - No ESP ash samples were collected from Hoppers 4-2, 5-1, and 5-2 due to lack of material during the second collection period. No air heater ash sample was collected from Hopper 4 due to plugging of the exit port during the first sampling period.
- (4) July 29 - No ESP ash samples were collected from Hoppers 4-1, 4-2, 5-1, and 5-2 due to lack of material during the second collection period. Air heater ash was collected during only two time periods due to the short run day. No air heater ash samples could be collected from Hopper 4.
- (5) July 30 - No ESP ash sample was collected from Hopper 4-2 due to lack of material during the second sampling period. Air heater ash was collected during only two time periods due to the short run day.

- (6) July 31 - No precipitator ash sample was collected from Hopper 4-2 due to lack of material during the second sampling period. Economizer ash was collected during only two time periods due to the short run day.
- (7) The PSDS used a single 20-cm x 25-cm (8-in. x 10-in.) filter upstream of all the sampling trains at Location 5b. The low particulate loadings on those filters limited the chemical analyses that could be done on the collected particulate. As a result, PSDS filters from the inorganic sampling days were analyzed for elements and anions, but not for carbon and radionuclides as had been planned.
- (8) Although one sample of coal pile runoff was collected, no analyses were conducted on it since the sampling personnel questioned the representativeness of the sample obtained. This deviation has no effect on calculated mass balances or on any other aspect of the study.
- (9) Analyses for silicon and boron could not be conducted on flue gas particulate samples collected in the cyclones or on the filter. Silicon analysis was conducted on the particulate collected in the Teflon sampling line upstream of the cyclones (i.e., the probe wash particulate). The impact of this deviation on mass balances for these elements is noted in Section 6.1.
- (10) Boiler feed coal samples were provided by Niles Station personnel in polyethylene bags, rather than in polyethylene bottles as stated in the Sampling Plan.
- (11) The plan assumed that a single sample would be collected of each liquid stream once each day. In practice, for the purposes of various analyses, multiple containers of each liquid sample were collected simultaneously. At each liquid sample location, the following samples were collected:
- 1 - 4-liter bottle for SVOC analysis (organic days only)
 - 1 - 40-mL vial for anions analysis (inorganic days only)
 - 4 - 500-mL bottles for elements, NH₃, and CN analysis
 - 3 - VOA vials for VOC analysis.
- (12) Because of interference from SO₂ and water, chromatographic analysis of canister samples could not be done for six early-eluting VOC. The six VOC for which analyses could not be done are the first six listed in the left column of Table 1-6. In addition, hexane was not analyzed in the VOST samples (Table 1-5).

3.3 Mass Flows

3.3.1 Ash Mass Balance

Using the data produced by the sampling at Niles Boiler No. 2, ash mass balances were performed on the boiler, the ESP, and the combined boiler and ESP. Separate mass balances were calculated for each of the three inorganic sampling days.

Assumptions. In performing these calculations, the following assumptions were made:

General:

- It was assumed that the coal fired during each day of the test was of uniform composition.
- It was assumed that the boiler was operating at constant conditions. This assumption is supported by the plant process data which verify that the plant operated at as nearly constant conditions as practical.
- For each test day, it was assumed that samples collected from flue gas streams at any specific time were representative of the flue gas stream being sampled at all times. Thus, only one metals/particulate sample was collected over several hours at each location on each test day, and those samples were assumed to be representative of conditions throughout the day. Considering the stability of the fuel and the boiler operating conditions, this assumption is reasonable. Also, considering the cost of collecting all samples simultaneously, and the fact that different samples require different sampling periods, this assumption was necessary.
- For each test day, it was assumed that samples collected from solid and liquid process streams at any specific time were representative of the process stream being sampled at all times. Thus, only a few process samples were collected each test day from each process stream, and these samples were assumed to be representative of conditions throughout the day. Considering the stability of the fuel and the boiler operating conditions, this assumption is reasonable. Also, considering the cost of collecting all samples simultaneously, and more frequently, this assumption was necessary.
- It was assumed that samples collected from both the flue gas streams and the process streams were representative of the stream from which they were sampled. In some cases there is reason to doubt this assumption. For example, particulate samples collected from flue gas flowing in a horizontal

duct where large particles are present (as at Location 4) may not contain a representative fraction of the large particles. The ash deposits found in the bottom of the duct at Location 4a (see Section 2.2.1) show that particle settling is significant at that location. However, when the only available sampling site is in a horizontal duct, sampling must be done there.

Boiler ash balance:

- The plant system provides no practical means for measuring the flow of materials exiting the boiler as bottom ash and as air heater hopper ash. Knowing that the material flow into and out of the boiler must be in balance, it was assumed that the combined flow rates of materials exiting the furnace as bottom ash and air heater hopper ash was equal to the difference between (1) the ash entering the furnace with the coal and (2) the particulate exiting the boiler.
- Based on generally accepted industry estimates for cyclone fired wet-bottom boilers, the quantity of ash exiting the boiler as bottom ash was assumed to account for 95 percent of the combined flow of bottom ash and air heater hopper ash.
- Based on generally accepted industry estimates for cyclone-fired wet-bottom boilers, the quantity of ash exiting the boiler as air heater hopper ash was assumed to account for 5 percent of the combined flow of bottom ash and air heater hopper ash.

ESP ash balance:

- The plant system provides no practical means for measuring the flow of material exiting the ESP as collected fly ash. Knowing that the material flow into and out of the ESP must be in balance, it was assumed that the total flow rate of the material from the ESP hoppers was equal to the difference between (1) the particulate entering the ESP with the flue gas and (2) the particulate exiting the ESP with the flue gas.
- The distribution of fly ash catch among the various ESP hopper fields was assumed to be proportional to the time required to dump the hoppers. Hopper dumping times were recorded for four different hopper dumping cycles on two different days during this study, and the percentage of time required to dump hoppers from each row was determined. Then, the average percentage time was determined for the four sets of data. The average values were used in compositing the ash samples collected from the various hoppers. The compositing was done mathematically using results from separate analyses of the samples from each hopper. Based on the timing data, it was determined that the sample proportions from each row of hoppers were 35.05, 40.93, 14.96, 5.39, and 3.67 percent, respectively.

Based on these assumptions, ash mass balances were calculated as shown in Figure 3-3, which illustrates the average ash flows and mass balance from the 3 inorganic days. It can be seen from this figure that the ash balance for the ESP does not show closure. The total of ash exiting the ESP as fly ash and as ash in the ESP catch equals only about 68 percent of the ash entering the ESP. The cause of this imbalance was traced to the difference between the measured carbon content of flue gas particulate at the ESP inlet (i.e., 4.3 percent) and that of the ESP catch (i.e., weighted average 35 percent) (see Section 5.9). Obviously, 35 percent carbon ash cannot be captured from a stream containing 4.3 percent carbon ash. Nevertheless, as noted in Section 5.9, the 35 percent average carbon value for the ESP catch is close to the typical value of 40 percent carbon reported by the plant staff.

In an effort to understand these data, an analysis was made of the fraction of the coal ash and of the ash flow at Location 4 that is accounted for by the five major ash elements sampled. Table 3-11 shows the results of this analysis for coal ash and for the average of the Location 4 samples. From Table 3-11 it can be seen that over 75 percent of the ash in the coal (i.e., 750,000 $\mu\text{g/g}$) is accounted for by the oxides of the five major elements measured. Conversely, only about 50 percent of the ash in the particulate collected at Location 4 is accounted for by the five major elements, even after correcting for the 4.3 percent carbon content of the collected particulate. However, if the carbon content of the particulate passing Location 4 were higher, the five major element oxides would account for a higher percentage of the ash sampled at that point. (The ash is determined as particulate minus carbon, so a larger carbon value results in a lower ash value.) Assuming a 35 percent carbon content of the particulate at Location 4, as measured in the ESP catch (see Section 5-9, Table 5-56), the five major element oxides would account for 74 percent (744,000 $\mu\text{g/g}$) of the ash sampled at that location. This value agrees closely with that expected based on the major element oxides in coal ash, and strongly indicates that a 35 percent carbon content should be characteristic of Location 4 fly ash.

An important point is that although particulate for elemental analysis was collected at the ESP inlet (Location 4) by full isokinetic traversing, the particulate sample used for carbon content determination was collected at a single point near the top of the duct. Considerable stratification of the particulate occurred at that location, as noted in Section 2.2.1. Thus the sample used for carbon content determination at Location 4 likely did not

represent the bulk particulate passing that location and entering the ESP. This supposition is supported not only by the ash major element data shown in Table 3-11, but also by comparisons of minor element data and carbon content for bottom ash, air heater ash, ESP catch, and flue gas particulate in Sections 5.1 and 5.9 of this report. Based on these several lines of argument, a value of 35 percent carbon was assumed for particulate at the ESP inlet, rather than the measured value of 4.3 percent. The 35 percent value was used in all element mass balance calculations presented in Section 6. Mass balance results for ash are presented in this section based on both the measured 4.3 percent and the assumed 35 percent carbon content, for comparison.

Ash Mass Balance Calculations. Tables 3-12 and 3-13 show the mass balance calculation spreadsheets for ash for the three inorganic test days. The comments column for each table gives details regarding the calculations.

Table 3-12 shows the emissions calculations for particulate matter; results calculated in this table served as input to the overall ash mass balance calculation shown in Table 3-13. Note that in these tables M-1, M-2, M-3 refer to the three days of inorganic measurements (i.e., the three inorganic sampling days).

Table 3-13 shows the mass balance calculations for ash for the three inorganic test days. Separate calculations are shown for the boiler, the ESP, and the combined boiler and ESP. Results from the mass balance calculation shown in this table served as input for the element mass balance calculations shown in Section 6. Tables 3-14 and 3-15 show the values of major stream flows at Niles Boiler No. 2 that factor into the mass balance calculations. Table 3-14 shows stream flow values for the three inorganic sampling days, i.e., the days for which mass balance calculations were done. Table 3-15 shows similar information for the organic sampling days. Values for several streams are missing in Table 3-15, because particulate loading in flue gas was not determined on the organic sampling days.

Ash Mass Balance Results. Tables 3-16 and 3-17 summarize the ash mass balance results, based on the measured (4.3 percent) and assumed (35 percent) carbon content of ash at the ESP inlet, respectively. Figure 3-4 also depicts the average revised ash mass balance, using the assumed 35 percent carbon value. Thus Table 3-17 and Figure 3-4 are directly

comparable to Table 3-16 and Figure 3-3, respectively. In both cases, the ash mass balance for the boiler is 100 percent; this result was forced by the assumptions noted above, and should not be taken as an indicator of the quality of the measurements. Comparison of the two tables shows that assumption of a reasonable 35 percent carbon content for ash at the ESP inlet greatly improves the mass balances for the ESP. As noted above, this assumed carbon content was used in all element mass balance calculations presented in Section 6.

3.3.2 Sulfur Mass Balances

Sulfur mass balances were performed on the boiler, the ESP, and the combined boiler and ESP. Separate mass balances were calculated for each test run and for the average of the three runs.

Assumptions. Assumptions necessary for calculating the sulfur mass balance were identical to those required for the ash mass balance (Section 3.3.1). However, in addition it was assumed that:

- The plant process data for emissions of SO₂ were used as the measure of the gaseous SO₂ emissions from the boiler and the stack. Since there was no SO₂ removal system on this unit, this is a suitable assumption.

Sulfur Mass Balance Calculations. Table 3-18 shows the mass balance calculations for sulfur for the three inorganic sampling days. The comments column at the right of the table gives details regarding the calculations. Assumptions regarding the bottom ash and air heater hopper ash flows have little effect on these results.

Sulfur Mass Balance Results. Table 3-19 summarizes the mass balance results for sulfur. It can be seen that a close sulfur balance was not achieved for the boiler and for the overall unit. Review of the coal analysis data from the Niles plant suggests that the calculated imbalances may originate with the plant process data used as the basis for SO₂ calculations. Firing 2.5 percent sulfur, 12,200 Btu/lb coal should produce about 4.1 lb of SO₂ per 10⁶ Btu, not the approximately 2.5 lb/10⁶ Btu reported for SO₂ by the plant CEM

instrumentation. A later check with plant personnel showed no SO₂ values officially reported for the test period. This suggests that utility personnel concluded that SO₂ values measured during the test period were erroneous.

3.3.3 Flue Gas Oxygen

Table 3-20 gives the daily average flue gas O₂ levels at the furnace outlet (ahead of the air heater) and in the stack for the three runs for which coal analyses were available. The O₂ values at the furnace outlet are from plant instrumentation, corrected for recalibration. The O₂ values (wet basis) for the stack were calculated from the daily average CO₂ values (wet basis) measured at the stack. Also shown in Table 3-20 are the daily average total air values corresponding to the listed O₂ values.

These data suggest that the total air increased by about 10 percent as the flue gas passed through the air heater and the ESP. Although the Niles plant has tubular air heaters, plant staff reported that they suspect that there are holes (and thus air leakage) in the air heater. Thus, the 10 percent air leakage across the air heater and the ESP appears believable.

Table 3-21 compares the plant-based O₂ data to O₂ values reported from the flue gas particulate sampling, both on a dry basis. The data for the furnace exit location as measured by plant instrumentation and for the ESP inlet (Location 4) as measured for the particulate sampling show, as expected, that there was significant air leakage at the air heater (which was between these two locations). However, the O₂ data from the sampling at the ESP inlet and at the stack also suggest that there was some leakage across the ESP. Given the near-neutral flue gas static pressures at the ESP inlet (Location 4) and the slightly negative static pressures at the stack (Location 5a) shown in Table 2-2, air leakage across the ESP is possible.

There was some initial concern regarding the difference between the O₂ value calculated from plant CO₂ data and the O₂ value measured at the stack sampling position. However, as noted elsewhere, plant SO₂ data for the sampling period are suspect, and CO₂ analyses are determined from the same system. A later inquiry into plant CO₂ values for full-load operation produced an answer of 11.4 to 11.5 percent. The O₂ value calculated

from this CO₂ level is about 6.3 percent, which is in the range of the O₂ values measured during the test. If the stack O₂ value was close to 6 percent, as this suggests, then a greater air leakage would be inferred relative to that indicated in Table 3-20, i.e., a stack O₂ value of 6 percent would imply roughly 20 percent total air leakage, rather than the 10 percent indicated in Table 3-20.

TABLE 3-6. NUMBER OF SAMPLES AT
FLUE GAS SAMPLING LOCATIONS

Run Type	Location		
	4	5a	5b ^(a)
Organic			
Modified Method 5	3	3	3
VOC: canisters ^(b)	9	9	9
VOC: VOST ^(b)	9	9	9
Aldehydes	3	3	3
Inorganic			
Multi-Metals Train	3	3	3
HEST Sampler	3	3	3
Anion Train	3	3	3
Ammonia	3	3	3
Cyanide	3	3	3
Carbon	3	3	
Radionuclides	3	3	
Elements - Soot Blowing		3	
Particle Size Distribution		3	3

- (a) All samples collected using Plume Simulating Dilution Sampler (PSDS).
 (b) Each canister run used three canisters; each VOST run used three sets of VOST cartridges.

TABLE 3-7. NUMBER OF SOLID/LIQUID SAMPLES COLLECTED

Location #	Date					
	7/26/93	7/27/93	7/28/93	7/29/93	7/30/93	7/31/93
1 Boiler Feed Coal ^(a)	1	1	1	1	1	1
2 Bottom Ash	6	6	6	6	6	6
3 Air heater Ash	5	5	5	2	4	4
8 ESP Ash	12	13	13	12	15	15
9 River Water	1	1	1	1	1	1
10 Pond Water	1	1	1	1	1	1
13 Coal Pile Runoff	0	0	0	1	0	0

(a) One daily composite sample provided by plant personnel.

TABLE 3-8. SAMPLE COMPOSITING AND SPLITTING SCHEDULE (BY DAY)

BOILER FEED COAL								
Sample #	Bag Number	Matrix	Sample Date	Compositing Instructions	Composite ID	Splits	Minimum Split Wt.	Analyzing Laboratory
N-1-PRS-726	1	BOFEED	Jul 26, 1993	Equal amounts from each sample	JL2693BOFED	Archive		BCO
	2	ORG						
N-1-PRS-727	1	BOFEED	Jul 27, 1993	Equal amounts from each sample	JL2793BOFED	Metals	20 g	EA
	2	INORG				ULTI/PROX.	200 g	CTE
						MOIST.HEAT		
						CL/F/PO4	20 g	BCO
						RAD	1300 g	IT
						Be,B	50 g	CTE-Denver
						Archive		BCO
N-1-PRS-728	1	BOFEED	Jul 28, 1993	Equal amounts from each sample	JL2893BOFED	Archive		BCO
	2	ORG						
N-1-PRS-729	1	BOFEED	Jul 29, 1993	Equal amounts from each sample	JL2993BOFED	Metals	20 g	EA
	2	INORG				ULTI/PROX.	200 g	CTE
						MOIST.HEAT		
						CL/F/PO4	20 g	BCO
						RAD	1300 g	IT
						Be,B	50 g	CTE-Denver
						Archive		BCO
N-1-PRS-730	1	BOFEED	Jul 30, 1993	Equal amounts from each sample	JL3093BOFED	Archive		BCO
	2	ORG						
N-1-PRS-731	1	BOFEED	Jul 31, 1993	Equal amounts from each sample	JL3193BOFED	Metals	20 g	EA
	2	INORG				ULTI/PROX.	200 g	CTE
						MOIST.HEAT		
						CL/F/PO4	20 g	BCO
						RAD	1300 g	IT
						Be,B	50 g	CTE-Denver
						Archive		BCO

Acronyms and Abbreviations used in Table 3-8:

AIRHEAT - sample of air heater ash; Archive - remainder of sample after compositing and aliquotting have been done; B - analysis for boron; Be - analysis for beryllium; BOFED and BOFEED - boiler feed coal sample; BOTT - bottom ash sample; C - analysis for carbon; CL/F/PO₄(SO₄) - analysis for chloride, fluoride, phosphate (and sulfate); ESP - electrostatic precipitator; ESP ASH - sample of fly ash from electrostatic precipitators; ESP1(2,3,4,5) - sample from row 1(2,3,4,5) of the electrostatic precipitator; HASH - sample of air heater ash; HEAT - analysis of coal for Btu/lb; INORG - inorganic sampling day; JL - July; Metals - analyses for major and trace elements; MOIST - moisture analysis; ORG - organic sampling day; PRS - process solid sample; RAD - radiological analysis by gamma scan; Size - analysis of sample for particle size distribution; SVOC - analysis for semivolatile organic compounds; ULTI/PROX - ultimate/proximate analysis.

TABLE 3-8. (Continued)

BOTTOM ASH										
Sample #	Hopper/Time	Matrix	Sample Date	Compositing Instructions	Composite ID	Splits	Minimum Split Wt.	Analyzing Laboratory		
N-2-PRS-726	3/1130	BOTT	Jul 26, 1993	Equal amounts from each sample	JL2693BOTT	SVOC	20 g	BCO		
	3/1415					Archive		BCO		
	3/1655	ORG								
	4/1115									
	4/1440									
	4/1720									
N-2-PRS-727	3/1230	BOTT	Jul 27, 1993	Equal amounts from each sample	JL2793BOTT	Metals	20 g	CTE-Denver		
	3/1440					RAD		600 g	IT	
	3/1715	INORG						C	25 g	CTE
	4/1200							F/CL/PO4/SO4	25 g	BCO
	4/1500							Archive		BCO
	4/1735									
N-2-PRS-728	3/1145	BOTT	Jul 28, 1993	Equal amounts from each sample	JL2893BOTT	SVOC	20 g	BCO		
	3/1420					Archive		BCO		
	3/1630	ORG								
	4/1125									
	4/1445									
	4/1720									
N-2-PRS-729	3/1125	BOTT	Jul 29, 1993	Equal amounts from each sample	JL2993BOTT	Metals	20 g	CTE-Denver		
	3/1430					RAD		600 g	IT	
	3/1740	INORG						C	25 g	CTE
	4/1150							F/CL/PO4/SO4	25 g	BCO
	4/1455							Archive		BCO
	4/1805									
N-2-PRS-730	3/1205	BOTT	Jul 30, 1993	Equal amounts from each sample	JL3093BOTT	SVOC	20 g	BCO		
	3/1355					Archive		BCO		
	3/1730	ORG								
	4/1210									
	4/1415									
	4/1800									
N-2-PRS-731	3/1145	BOTT	Jul 31, 1993	Equal amounts from each sample	JL3193BOTT	Metals	20 g	CTE-Denver		
	3/1340					RAD		600 g	IT	
	3/1635	INORG						C	25 g	CTE
	4/1215							F/CL/PO4/SO4	25 g	BCO
	4/1400							Archive		BCO
	4/1620									

TABLE 3-8. (Continued)

AIR PREHEATER ASH									
Sample #	Hopper/ Time	Matrix	Sample Date	Compositing Instructions	Composite ID	Splits	Minimum Split Wt.	Analyzing Laboratory	
N-3-PRS-726	3/1800	AIRHEAT	Jul 26, 1993	Equal amounts from each sample	JL2693HASH	SVOC	20 g	BCO	
	3/2000	ORG				Archive		BCO	
	4/300								
	4/1800								
	4/2000								
N-3-PRS-727	3/1300	AIRHEAT	Jul 27, 1993	Equal amounts from each sample	JL2793HASH	Metals	20 g	CTE-Denver	
	3/1750					RAD		600 g	IT
	3/2100	INORG				C		25 g	CTE
	4/1750					F/CL/PO4/SO4		25 g	BCO
	4/2100					Archive			BCO
N-3-PRS-728	3/1300	AIRHEAT	Jul 28, 1993	Equal amounts from each sample	JUL2893HASH	SVOC	20 g	BCO	
	3/1700					Archive			BCO
	3/2100	ORG							
	4/1700								
	4/2100								
N-3-PRS-729	3/1300	AIRHEAT	Jul 29, 1993	Equal amounts from each sample	JL2993HASH	Metals	20 g	CTE-Denver	
	3/1630	INORG				RAD		600 g	IT
	3/1740					C		25 g	CTE
	4/1150					F/CL/PO4/SO4		25 g	BCO
	4/1455					Archive			BCO
N-3-PRS-730	3/1300	AIRHEAT	Jul 30, 1993	Equal amounts from each sample	JL3093HASH	SVOC	20 g	BCO	
	3/1700					Archive			BCO
	4/1300	ORG							
	4/1655								
N-3-PRS-731	3/1255	AIRHEAT	Jul 31, 1993	Equal amounts from each sample	JL3193HASH	Metals	20 g	CTE-Denver	
	3/1620					RAD		600 g	IT
	4/1255	INORG				C		25 g	CTE
	4/1620					F/CL/PO4/SO4		25 g	BCO
						Archive		BCO	

TABLE 3-8. (Continued)

ESP FLY ASH									
Sample #	Matrix	Sample Date	Row/Time	Row Comp.	Wt. of Row Comp.	Day Composite ID	Splits	Minimum Split Wt.	Analyzing Laboratory
N-8-PRS-726	ESP ASH ORG	Jul 26, 1993	1-2/1230	Row 1 ESP	Equal amounts of each of three samples	JL2693ESP1	SVOC Archive	20 g	BCO BCO
			1-1/1630						
			1-2/1630						
			2-1/1230	Row 2 ESP	Equal amounts of each of four samples	JL2693ESP2			
			2-2/1230						
2-1/1630									
2-2/1630									
N-8-PRS-727	ESP ASH INORG	Jul 27, 1993	1-1/1130	Row 1 ESP	Equal amounts from each of three samples	JL2793ESP1	Metals RAD C F/Cl/PO4/SO4 Size Archive	20 g 1000 g 25 g 20 g 200 g	CTE-Denver IT CTE BCO CTE BCO
			1-2/1130						
			1-2/1600						
			2-1/1130	Row 2 ESP	Equal amounts from each of four samples	JL2793ESP2			
			2-2/1130						
2-1/1600									
2-2/1600									
N-8-PRS-728	ESP ASH ORG	Jul 28, 1993	1-1/1200	Row 1 ESP	Equal amounts from each of four samples	JL2893ESP1	SVOC Archive	20 g	BCO BCO
			1-2/1200						
			1-1/1600						
			1-2/1600	Row 2 ESP	Equal amounts from each of four samples	JL2893ESP2			
			2-1/1200						
2-2/1200									
2-1/1600									
2-2/1600									
N-8-PRS-728	ESP ASH ORG	Jul 28, 1993	3-1/1200	Row 3 ESP	Equal amounts from each of four samples	JL2893/ESP3	SVOC Archive	20 g	BCO BCO
			3-2/1200						
			3-1/1600						
			3-2/1600	Row 4 ESP	Entire sample	JL2893ESP4			
			4-1/1600						

TABLE 3-8. (Continued)

ESP FLY ASH (Continued)										
Sample #	Matrix	Sample Date	Row/Time	Row Comp.	Wt. of Row Comp.	Day Composite ID	Splits	Minimum Split Wt.	Analyzing Laboratory	
N-8-PRS-729	ESP ASH INORG	Jul 29, 1993	1-1/1300	Row 1 ESP	Equal amounts from each of four samples	JL2993ESP4	Metals	20 g	CTE-Denver IT CTE BCO CTE BCO	
			1-2/1300				RAD	1000 g		
			1-1/1600				C	25 g		
			1-2/1600				F/Cl/PO4/SO4 Size Archive	20 g 200 g		
			2-1/1300	Row 2 ESP	Equal amounts from each of four samples	JL2993ESP2	Metals	20 g	CTE-Denver IT CTE BCO CTE BCO	
			2-2/1300				RAD	1000 g		
			2-1/1600				C	25 g		
			2-2/1600				F/Cl/PO4/SO4 Size Archive	20 g 200 g		
			3-1/1300	Row 3 ESP	Equal amounts from each of four samples	JL2993ESP3	Metals	20 g	CTE-Denver IT CTE BCO CTE BCO	
			3-2/1300				RAD	1000 g		
			3-1/1600				C	25 g		
			3-2/1600				F/Cl/PO4/SO4 Size Archive	20 g 200 g		
N-8-PRS-730	ESP ASH ORG	Jul 30, 1993	1-1/1300	Row 1 ESP	Equal amounts from each of four samples	JL3093ESP1	SVOC Archive	20 g	BCO BCO	
			1-2/1300							
			1-1/1620	Row 2 ESP	Equal amounts from each of four samples	JL3092ESP2				
			1-2/1620							
			2-1/1620							
2-2/1620	Row 3 ESP	Equal amounts from each of four samples	JL3093ESP3							
3-1/1620										
3-2/1620	Row 4 ESP	Entire sample	JL3093ESP4							
	5-1/1620	Row 5 ESP	Equal amounts from each of two samples	JL3093ESP5						
	5-2/1620									
N-8-PRS-731	ESP Ash INORG	Jul 31, 1993	1-1/1200	Row 1 ESP	Equal amounts from each of four samples	JL3193ESP1	Metals	20 g	CTE-Denver IT CTE BCO CTE BCO	
			1-2/1200				RAD	1000 g		
			1-1/1600				C	25 g		
			1-2/1600				F/Cl/PO4/SO4 Size Archive	20 g 200 g		
			2-1/1200	Row 2 ESP	Equal amounts from each of four samples	JL3193ESP2	Metals	20 g	CTE-Denver IT CTE BCO CTE BCO	
			2-2/1200				RAD	1000 g		
			2-1/1620				C	25 g		
			2-2/1620				F/Cl/PO4/SO4 Size Archive	20 g 200 g		
			3-1/1200	Row 3 ESP	Equal amounts from each of four samples	JL3193ESP3	Metals	20 g	CTE-Denver IT CTE BCO CTE BCO	
			3-2/1200				RAD	1000 g		
			3-1/1620				C	25 g		
			3-2/1620				F/Cl/PO4/SO4 Size Archive	20 g 200 g		
			4-1/1600	Row 4 ESP	Entire sample	JL3193ESP4	Metals C F/Cl/PO4/SO4 Archive	5 g 10 g 5 g	CTE-Denver CTE BCO BCO	
			5-1/1600	Row 5 ESP	Equal amounts from each of two samples	JL3193ESP5	Metals	5 g	CTE-Denver CTE BCO BCO	
			5-2/1600				C F/Cl/PO4/SO4 Archive	10 g 5 g		

TABLE 3-9. EXAMPLES OF SAMPLE AND COMPOSITE IDs

Description of Sample	Example of Sample ID	Composite ID made up of the corresponding samples
Coal Feed into Boiler	N-1-PRS-727	JL2793BOFED
Bottom Ash	N-2-PRS-727	JL2793BOTT
Air Heater Ash	N-3-PRS-727	JL2793HASH
ESP Ash	N-8-PRS-727 (Hopper 8-1-1)	JL2793ESP1

TABLE 3-10. (Continued)

NILES - BOILER NO. 2 NUMBER OF PROCESS SAMPLES ANALYZED (10/12/83)	Number Samples Collected	NUMBER OF ANALYSES																		
		VOC-Summa	VOC-VOST	VOC-Liquid	Aldehydes	Gas/Solid SVOC	Liquid SVOC	Dioxin/ Furans	As, Hg, Se	Elementary NH4	CF	PO4	SO4	Cn	Rad	C	Mass Loading	PSD	UnProx	
1 Boiler Feed Coal	3#																			
2 Bottom Ash	3#																			
3 Air Heater Ash	3#																			
6 ESP Ash	12#																			
9 Makeup Water	3																			
10 Pond Outlet	3																			
13 Coal Pile Runoff	1#																			
#Number of composite samples generated																				
#Elementary analyses for liquid samples (excluding sulfuric acid) Includes dissolved (filtrate) and total (unfiltered) analyses																				
#Only one coal pile runoff sample collected on inorganic test day (7/29/83)																				
TOTAL NUMBER OF PROCESS SAMPLE ANALYSES FOR NILES - BOILER NO. 2		0	0	6	6	18	6	0	0	35	7	28	25	7	21	18	0	12	3	
TOTAL NUMBER OF GAS AND PROCESS SAMPLE ANALYSES FOR NILES - BOILER NO. 2:		27	27	6	23	98	6	12	8	74	18	46	37	16	27	24	16	18	3	

TABLE 3-11. ANALYSIS OF MAJOR ELEMENT COMPOSITION OF COAL ASH AND OF FLY ASH COLLECTED AT THE ESP INLET (LOCATION 4)

Coal	Element, $\mu\text{g/g}$ in Coal ^(a)	Oxide, $\mu\text{g/g}$ in Coal ^(b)	Oxide, $\mu\text{g/g}$ in Ash ^(c)
Aluminum	14,067	26,580	239,888
Silicon	24,567	52,558	474,347
Sodium	300	404	3,650
Potassium	2,067	2,490	22,472
Titanium	800	1,334	12,044
Total			752,400

Fly Ash, Location 4	Element, $\mu\text{g/g}$ in Sample ^(d)	Oxide, $\mu\text{g/g}$ in Sample ^(b)	Oxide in Sample Adjusted for 4.3% Carbon in Sample, $\mu\text{g/g}$ ^(e)
Aluminum	72,386	136,773	142,919
Silicon	143,203	306,363	320,127
Sodium	5,237	7,059	7,377
Potassium	19,813	23,867	24,939
Titanium	5,747	9,586	10,017
Total		483,648	505,379

(a) Based on average coal analysis data; Section 5.1.2.

(b) Assumes most common oxide, e.g., Al_2O_3 for Al.

(c) Based on average ash content of coal; Section 5.10.

(d) Based on particulate composition data; Section 5.1.1.

(e) Based on average carbon content; Section 5.9.

TABLE 3-12. PARTICULATE EMISSION CALCULATIONS FOR NILES BOILER

Particulate Emissions: Metals Runs		M-1	M-2	M-3	Average	Comments
Test Date		7/27/93	7/29/93	7/31/93		
Boiler Outlet (Location 4)						
1. Gas flow rate, dry	Ncu/min	6563	6434	7118		From particulate sampling (Appen. D-12)
2. Particulate loading	mg/Ncu	2181.7	2438.4	1457.6		From particulate sampling (Appen. D-12)
3a. Particulate emissions	kg/hr	826.8413	941.3199	622.5118		#2*#1+60/(1000000)
3b. Particulate emissions	lb/hr	1888.191	2075.618	1372.639		#3a*2.265
Stack (Location 5)						
4. Gas flow rate, dry	Ncu/min	6386	6331	6365		From particulate sampling (Appen. D-12)
5. Particulate loading	mg/Ncu	36.1	15.6	27.6		From particulate sampling (Appen. D-12)
6a. Particulate emissions	kg/hr	13.83288	6.928816	18.64844		#5*#4+60/(1000000)
6b. Particulate emissions	lb/hr	30.49973	13.86842	23.24167		#6a*2.265
<hr/>						
Coal Firing Rate						
7. Coal feed rate	lb/hr	91588	94288	98788	94133.33	From Table 2-4
8. Coal heating value	Btu/lb	12269	12188	11892	12889.67	From Table 5-58
9a. Firing rate	10 ⁶ Btu/hr	1122.614	1148.574	1149.956	1137.715	#7*#8/1000000
9b. Firing rate	MJ/hr	1184367.	1263365.	1213284.	1288289.	#9a*1865
Particulate Emission Factors						
Boiler emissions						
10a. Particulate emissions	kg/hr	826.8413	941.3199	622.5118		#3a
10b. Particulate emissions	lb/hr	1888.191	2075.618	1372.639		#3b
11a. Particulate emission factor	g/MJ	.6923935	.7822787	.5131139	.6026954	(#10a/#9b)+1000
11b. Particulate emission factor	lb/10 ⁶ Btu	1.618698	1.619795	1.193644	1.541379	#10b/#9a
ESP emissions						
12a. Particulate emissions	kg/hr	13.83288	6.928816	18.64844		#6a
12b. Particulate emissions	lb/hr	30.49973	13.86842	23.24167		#6b
13a. Particulate emission factor	g/MJ	.0116798	.0849246	.0688881	.0884386	(#12a/#9b)+1000
13b. Particulate emission factor	lb/10 ⁶ Btu	.0271685	.0114568	.0282189	.0196118	#12b/#9a
Removal Efficiencies						
14. ESP	percent	98.31325	99.37848	98.38679	98.66358	(#11b-#13b)+100/#11b

TABLE 3-13. ASH MASS BALANCE CALCULATIONS FOR NILES BOILER

Ash Mass Balances for Niles Boiler Test

Test Date	M-1 7/27/93	M-2 7/29/93	M-3 7/31/93	Average	Comments
Boiler Furnace					
1. Coal feed	91586	94266	96768		From Table 2-4
2. Moisture in feed coal	6.86	6.33	7.85	8.548867	From Table 5-58
3. Coal feed, dry	88321.1	88237.14	89382.45	87953.56	#1+((100-#2)/100)
4. Ash in feed coal, dry basis	11.74	11.99	11.99		From Table 5-58
5. Ash in feed coal	10134.16	10579.63	10787.36	10473.76	#3+((#4/100)
6. Furnace particulate emissions	1898.191	2076.618	1372.639	1752.147	From particulate sampling (Appen. D-12)
7. Comb. carbon in furnace part.	35.66988	36.65912	33.73339	35.16413	100-#7
8. Ash in furnace particulate	64.93812	63.34889	68.26681		#6+8/100
9. Ash in furnace particulate	1174.661	1314.718	969.6811	1132.791	Assume 95% of #5-#9
10. Bottom ash, as ash	8512.835	8881.677	9387.875	8873.862	From Table 5-56
11. Comb. carbon in bottom ash	.16	.4	.1	.22	100-#11
12. Ash in bottom ash	99.84	99.6	99.9		#10/(#12/100)
13. Bottom ash, total material	8525.676	8837.825	9317.192	8893.297	Assume 5% of #5-#9
14. Economizer hopper ash, as ash	448.8818	463.2462	489.8881	467.8454	From Table 5-56
15. Comb. carbon in hopper ash	78.69	74.69	72.43	74.48333	100-#15
16. Ash in economizer hopper ash	23.91	25.31	27.57		#14/(#16/100)
17. Econ. hopper waste, total	1873.781	1838.289	1776.888	1826.959	#9+10+14
18. Total ash out	18134.16	18579.63	18787.36		#5-#18
19. Ash in - Ash out	0	0	0	0	#18/#5
20. Ash out/ash in	1	1	1	1	
ESP					
21. ESP inlet particulate	1888.191	2075.618	1372.639		From particulate sampling (Appen. D-12)
22. Comb. carbon in ESP inlet	35.66988	36.65912	33.73339		From Table 5-57
23. Ash in ESP inlet	64.93812	63.34889	66.26681		100-#22
24. Ash in ESP inlet	1174.661	1314.718	969.6811	1132.791	#21+25/100
25. ESP outlet emissions	38.49973	13.86642	23.24167	22.26927	From particulate sampling (Appen. D-12)
26. Comb. carbon in ESP out. emis.	.18	.85	.85	.8965667	From Table 5-57
27. Ash in ESP outlet emissions	99.61	99.95	99.95		100-#26
28. Ash in ESP outlet emissions	36.44178	13.85989	23.23885	22.24391	#25+27/100
29. ESP hopper particulate	1777.691	2062.544	1349.397	1729.877	#21-#25
30. Comb. carbon in ESP particulate	35.66988	36.65912	33.73339	35.16413	From Table 5-56
31. Ash in ESP particulate catch	64.93812	63.34889	68.26681		100-#30
32. Ash in ESP particulate catch	1164.257	1386.434	894.1996	1118.297	#29+31/100
33. Total ash out	1184.899	1319.494	917.4296		#28+32
34. Ash in - Ash out	-16.6383	-4.78358	-7.82858	-7.75812	#24-#33
35. Ash out/ash in	1.009861	1.003838	1.008687	1.007182	#33/#24
Boiler and ESP					
36. Ash to furnace	18134.16	18579.63	18787.36		#5
37. Bottom ash, as ash	8512.835	8881.677	9387.875		#10
38. Economizer hopper ash, as ash	448.8818	463.2462	489.8881		#14
39. Ash in ESP particulate catch	1164.257	1386.434	894.1996		#32
40. Ash in ESP outlet emissions	36.44178	13.85989	23.23885		#28
41. Total ash out	18144.74	18584.42	18715.19		#37+38+39+40
42. Ash in - Ash out	-16.6383	-4.78358	-7.82858	-7.75812	#36-#41
43. Ash out/ash in	1.001858	1.000452	1.000731	1.000744	#41/#36

TABLE 3-14. MAJOR STREAM FLOWS FOR INORGANIC SAMPLING DAYS

Stream	Units	Date		
		July 27	July 29	July 31
Coal feed	lb/hr	91,500	94,200	96,700
Bottom ash ^(a)	lb/hr	8,526	8,837	9,317
Air heater ash ^(a)	lb/hr	1,874	1,830	1,777
Flue gas flow at ESP inlet	Ncm/min	6,103	6,074	6,562
Flue gas flow at ESP outlet	Ncm/min	5,316	5,093	5,120
Particulate at ESP inlet	lb/hr	1,808	2,075	1,372
Particulate at ESP outlet	lb/hr	31	13	23
ESP catch ^(b)	lb/hr	1,778	2,063	1,350

(a) Estimated total material flow at these locations.

(b) By difference.

TABLE 3-15. MAJOR STREAM FLOWS FOR ORGANIC SAMPLING DAYS

Stream	Units	Date		
		July 26	July 28	July 30
Coal feed	lb/hr	89,600	93,800	94,400
Bottom ash	lb/hr	NC	NC	NC
Air heater ash	lb/hr	NC	NC	NC
Flue gas flow at ESP inlet	Ncm/min	6,007	6,365	6,225
Flue gas flow at ESP outlet	Ncm/min	4,763	5,038	5,373
Particulate at ESP inlet	lb/hr	NM	NM	NM
Particulate at ESP outlet	lb/hr	NM	NM	NM
ESP catch	lb/hr	NC	NC	NC

NM = Not measured.

NC = Not calculable because particulate sampling was not conducted.

TABLE 3-16. ASH MASS BALANCE RESULTS (percent) BASED ON
4 PERCENT CARBON IN PARTICULATE AT THE ESP INLET

	7/27/93	7/29/93	7/31/93	Average
Boiler	100	100	100	100
ESP ^(a)	68.3	67.7	68.6	68.2
Boiler & ESP	94.6	94.0	96.1	94.9

(a) See text for discussion of these results.

TABLE 3-17. ASH MASS BALANCE RESULTS (percent) BASED ON ASSUMED
35 PERCENT CARBON IN PARTICULATE AT THE ESP INLET

	7/27/93	7/29/93	7/31/93	Average
Boiler	100	100	100	100
ESP ^(a)	101	100	101	101
Boiler & ESP	100	100	100	100

(a) See text for discussion of these results.

TABLE 3-18. SULFUR MASS BALANCE CALCULATIONS FOR NILES BOILER

Material Balance: Sulfur		M-1	M-2	M-3	Average	Comments
Test Date		7/27/93	7/29/93	7/31/93		
Flue gas loadings						
Boiler Outlet (Location 4)						
1. Gas flow rate, dry, 3% O ₂	Ncm/min	6183	6074	6562		From Appendix D-12
2. Sulfur loading	ug/Ncm	27688.84	38037.64	24652.62	27459.78	From data in Table 5-19
3a. Sulfur emissions	g/hr	10139.10	10946.92	9706.229		#1+#2+#6#/1000000
3b. Sulfur emissions	lb/hr	22.35251	24.13342	21.39821		#3a/#53.6
4. Boiler SO ₂ emissions	lb/10 ⁶ Btu	2.56	2.48	2.38	2.473333	From Table 2-4
5. Boiler SO ₂ emissions	lb/hr	2873.891	2828.623	2736.898		#4+#44a
6a. Boiler sulfur emissions as SO ₂	lb/hr	1438.291	1416.636	1369.738		#5+#32.06/#64.86
6b. Boiler sulfur emissions as SO ₂	g/hr	652408.9	642132.5	621369.5		#6a+#53.6
7a. Total boiler sulfur emissions	lb/hr	1466.644	1439.769	1391.128		#3b+#6a
7b. Total boiler sulfur emissions	g/hr	662548.8	653879.4	631616.7		#3a+#6b
Stack (Location 5)						
8. Gas flow rate, dry, 3% O ₂	Ncm/min	5316	5893	6128		From Appendix D-12
9. Sulfur loading	ug/Ncm	5924.495	4779.644	5916.972	5546.378	From data in Table 5-19
10a. Sulfur emissions	g/hr	1889.677	1468.564	1817.694		#4+#5+#8#/1000000
10b. Sulfur emissions	lb/hr	4.165954	3.219937	4.067262		#6a/#53.6
11. Stack SO ₂ emissions	lb/10 ⁶ Btu	2.56	2.48	2.38	2.473333	From Table 2-4
12. Stack SO ₂ emissions	lb/hr	2873.891	2828.623	2736.898		#11+#44a
13a. Stack sulfur emissions as SO ₂	lb/hr	1438.291	1416.636	1369.738		#12+#32.06/#64.86
13b. Stack sulfur emissions as SO ₂	g/hr	652408.9	642132.5	621369.5		#13a+#53.6
14a. Total stack sulfur emissions	lb/hr	1442.467	1418.866	1373.737		#10b+#13a
14b. Total boiler sulfur emissions	g/hr	654298.5	643593.8	623127.1		#10a+#13b
Sulfur mass balances						
Boiler Furnace						
15. Fuel fired	lb/hr	91600	94200	96700		From Table 2-4
16. Sulfur in coal	ug/g	25900	26500	26100	25833.33	From Table 5-58
17. Sulfur in coal	lb/hr	2369.86	2498.3	2427.17		#15+#16/#1000000
18. Furnace sulfur emissions	lb/hr	1468.644	1439.769	1391.128		#3b
19. Bottom ash	lb/hr	8625.676	8837.825	9317.192		From Table 3-13
20. Sulfur in bottom ash	ug/g	12.91611	16.85436	7.669494	12.45999	From data in Table 5-23
21. Sulfur in bottom ash	lb/hr	.1181186	.1489424	.6788991		#19+#20/#1000000
22. Preheater hopper ash	lb/hr	1873.781	1838.289	1776.888		From Table 3-13
23. Sulfur in hopper ash	ug/g	347.8997	324.4847	487.2746	366.2597	From data in Table 5-24
24. Sulfur in hopper ash	lb/hr	.6583610	.6937544	.8658326		#22+#23/#1000000
25. Total sulfur out	lb/hr	1461.404	1446.512	1392.865		#18+#21+#24
26. Sulfur in - Sulfur out	lb/hr	908.4459	1055.788	1035.106		#17+#25
27. Sulfur out/sulfur in		.6166653	.6778589	.6735341	.6898861	#25/#17

TABLE 3-18. (Continued)

28.	ESP inlet sulfur emissions	lb/hr	1468.644	1439.769	1391.128	#3b	
29.	ESP outlet sulfur emissions	lb/hr	1442.457	1418.856	1373.737	#10b	
30.	ESP hopper particulate	lb/hr	1777.691	2082.544	1349.397	From Table 3-13	
31.	Sulfur in ESP part. catch	ug/g	12274.72	12878.99	13354.12	From data in Table 5-25a	
32.	Sulfur in ESP part. catch	lb/hr	21.82067	26.54513	18.02088	#30*#31/1000000	
33.	Total sulfur out	lb/hr	1464.278	1445.481	1391.757	#28-#32	
34.	Sulfur in - Sulfur out	lb/hr	-3.63411	-5.63165	-6.29054	#28-#32	
35.	Sulfur out/sulfur in		1.002488	1.003911	1.000462	#33/#28	
Boiler and ESP							
36.	Sulfur in coal	lb/hr	2369.85	2496.3	2427.17	#27	
37.	Sul. out, boiler process streams	lb/hr	7884798	7428969	9387317	#21-#24	
38.	Total sulfur out, ESP	lb/hr	1464.278	1445.481	1391.757	#33	
39.	Total sulfur out	lb/hr	1465.858	1446.144	1392.694	#37-#38	
40.	Sulfur in - Sulfur out	lb/hr	984.8117	1058.156	1034.476	#30-#39	
41.	Sulfur out/sulfur in		.6181987	.5793149	.5737933	#39/#38	

Sulfur Emission Factors							
Firing Rate							
42.	Coal feed rate (Loc. 1)	lb/hr	91588	94288	96788	From Table 2-4	
43.	Coal heating value (Loc. 1)	Btu/lb	12259	12188	11892	From Table 5-58	
44a.	Firing rate	10 ⁶ Btu/hr	1122.614	1148.674	1149.956	#42*#43/1000000	
44b.	Firing rate	MJ/hr	1184357.	1203305.	1213284.	#44a*1055	
Boiler emissions							
45a.	Sulfur emissions	g/hr	652548.8	663079.4	631016.7	#3a	
45b.	Sulfur emissions	lb/hr	1468.644	1439.769	1391.128	#3b	
46a.	Sulfur emissions factor	ug/MJ	659416.6	642738.8	628123.3	#45a*1000000/#44b	
46b.	Sulfur emissions factor	lb/10 ¹² Btu	1381116.	1282328.	1289722.	#45b*1000000/#44a	
ESP emissions							
47a.	Sulfur emissions	g/hr	654298.5	643593.6	623127.1	#18a	
47b.	Sulfur emissions	lb/hr	1442.457	1418.856	1373.737	#10b	
48a.	Sulfur emissions factor	ug/MJ	552458.3	534864.4	513821.1	#47a*1000000/#44b	
48b.	Sulfur emissions factor	lb/10 ¹² Btu	1284918.	1243904.	1194599.	#47b*1000000/#44a	
Removal Efficiencies							
49.	ESP	percent	1.245186	1.452558	1.258133	1.315932	(#46b-#48b)*100/#46b

TABLE 3-19. SULFUR MASS BALANCE RESULTS (percent)

	7/27/93	7/29/93	7/31/93	Average
Boiler	61.7	57.7	57.4	58.9
ESP	100.2	100.4	100.0	100.2
Boiler & ESP	61.8	57.9	57.4	59.0

TABLE 3-20. FLUE GAS OXYGEN RESULTS

	July 27, 1993	July 29, 1993	July 31, 1993
Measured O ₂ value at furnace outlet, wet basis, percent ^(a)	2.15	2.22	2.40
Calculated O ₂ value at stack ^(b) , wet basis, percent	3.60	3.84	3.59
Total air at furnace outlet, percent	112	113	114
Total air at stack, percent	123	124	123
Change in total air across ESP, percent	11	11	9
Air leakage as a percentage of total air at furnace outlet, percent	10	10	8

(a) These values include an increase of 0.5 percent O₂ as correction for plant recalibration of sensor (see Section 2.3.2).

(b) Based on CO₂ content in the stack.

TABLE 3-21. COMPARISON OF FLUE GAS OXYGEN VALUES
(Values in percent, dry basis)

	July 27, 1993	July 29, 1993	July 31, 1993
Measured O ₂ value at furnace outlet, plant instrumentation ^(a)	2.35	2.43	2.62
O ₂ value at ESP inlet from particulate sampling	4.1	4.0	4.4
Calculated O ₂ value at stack ^(a)	3.93	4.18	3.91
O ₂ value at stack from particulate sampling	6.0	6.5	6.5

(a) Calculated from O₂ on wet basis in Table 3-20.

Niles Boiler No. 2 Sampling Times 7/26/93

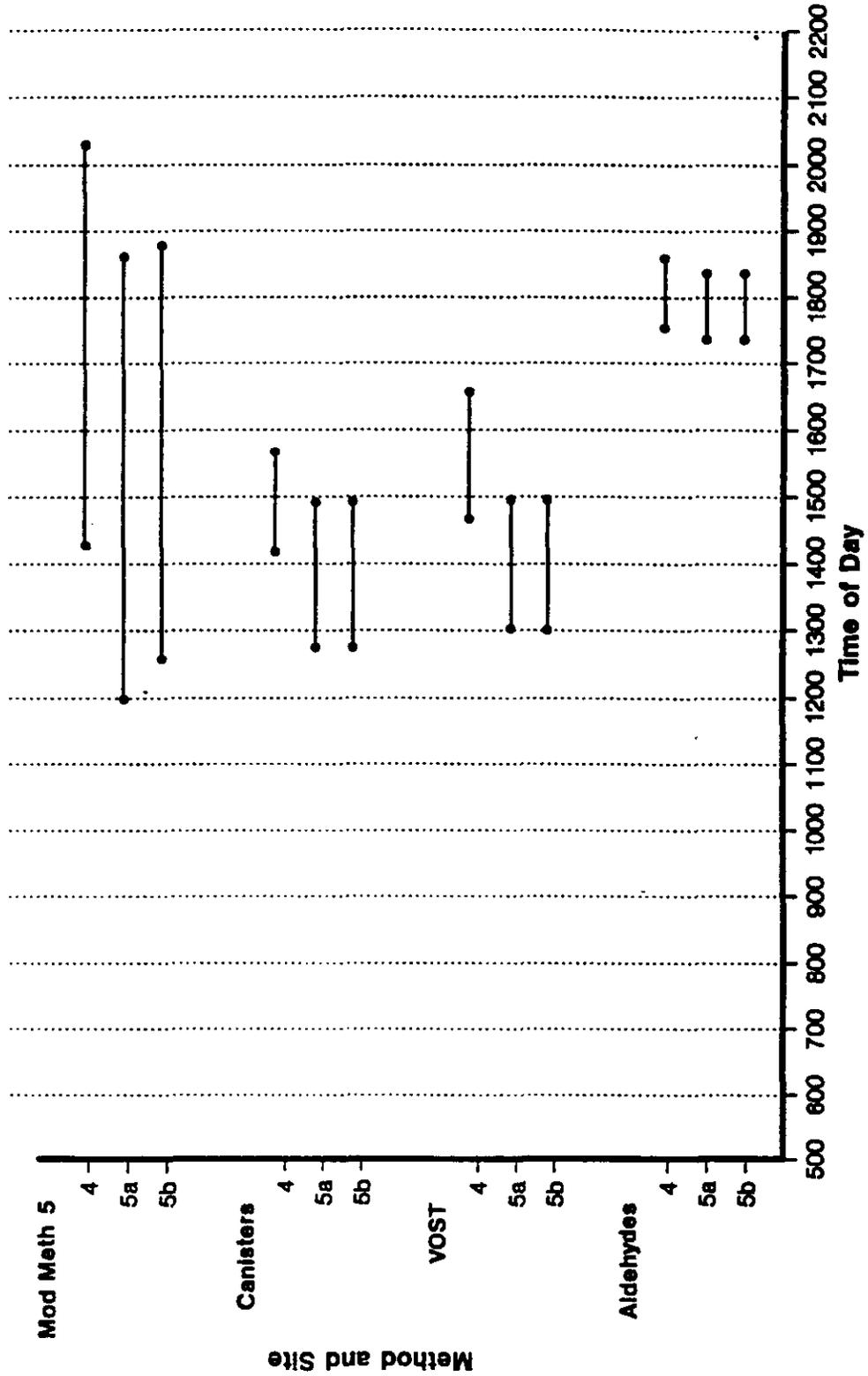


Figure 3-1a. Schedule of flue gas sampling conducted at Niles Boiler No. 2, July 26, 1993

Niles Boiler No. 2 Sampling Times 7/27/1993

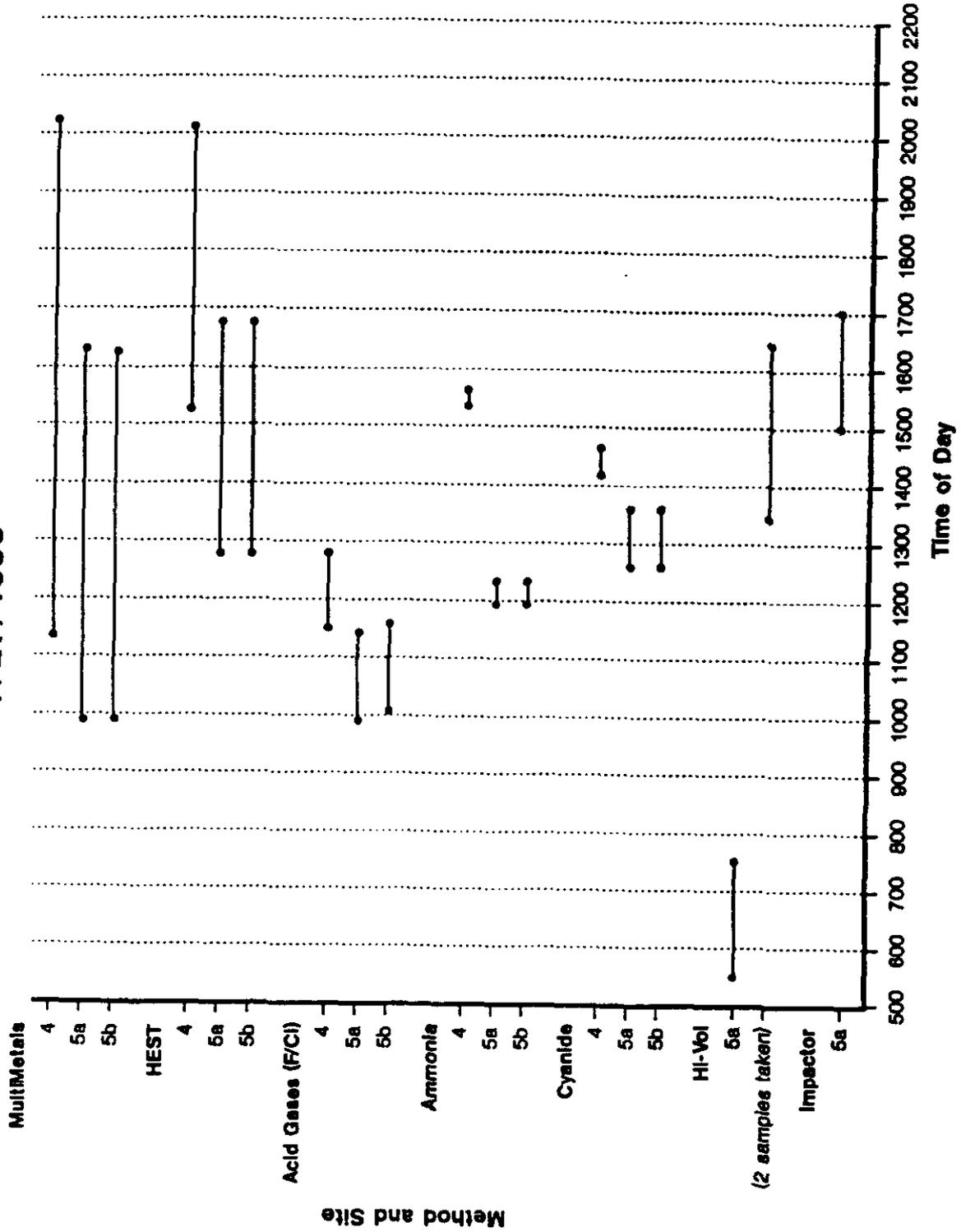


Figure 3-1b. Schedule of flue gas sampling conducted at Niles Boiler No. 2, July 27, 1993

Niles Boiler No. 2 Sampling Times 7/28/93

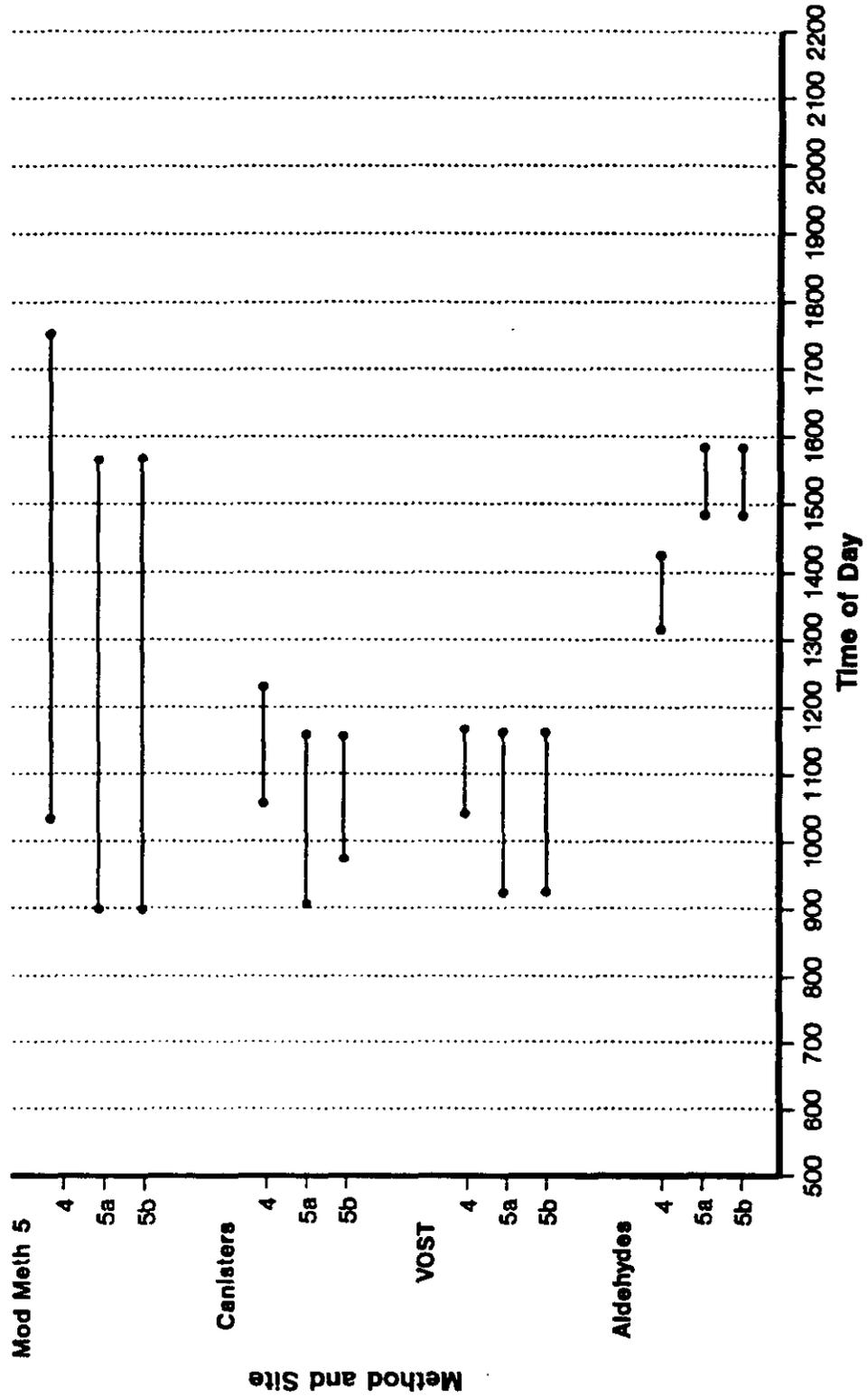


Figure 3-1c. Schedule of flue gas sampling conducted at Niles Boiler No. 2, July 28, 1993

Niles Boiler No. 2 Sampling Times 7/29/1993

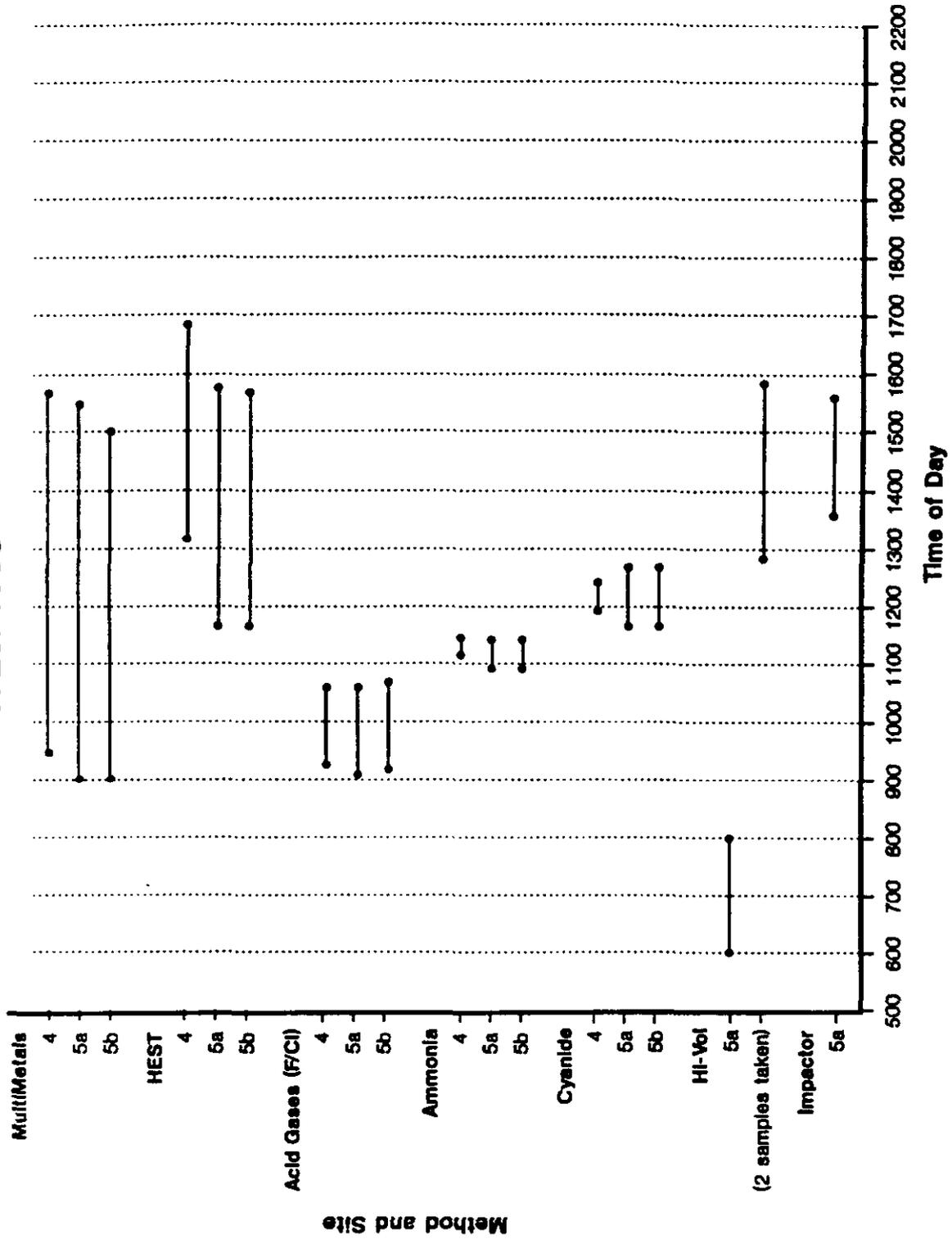


Figure 3-1d. Schedule of flue gas sampling conducted at Niles Boiler No. 2, July 29, 1993

Niles Boiler No. 2 Sampling Times 7/30/93

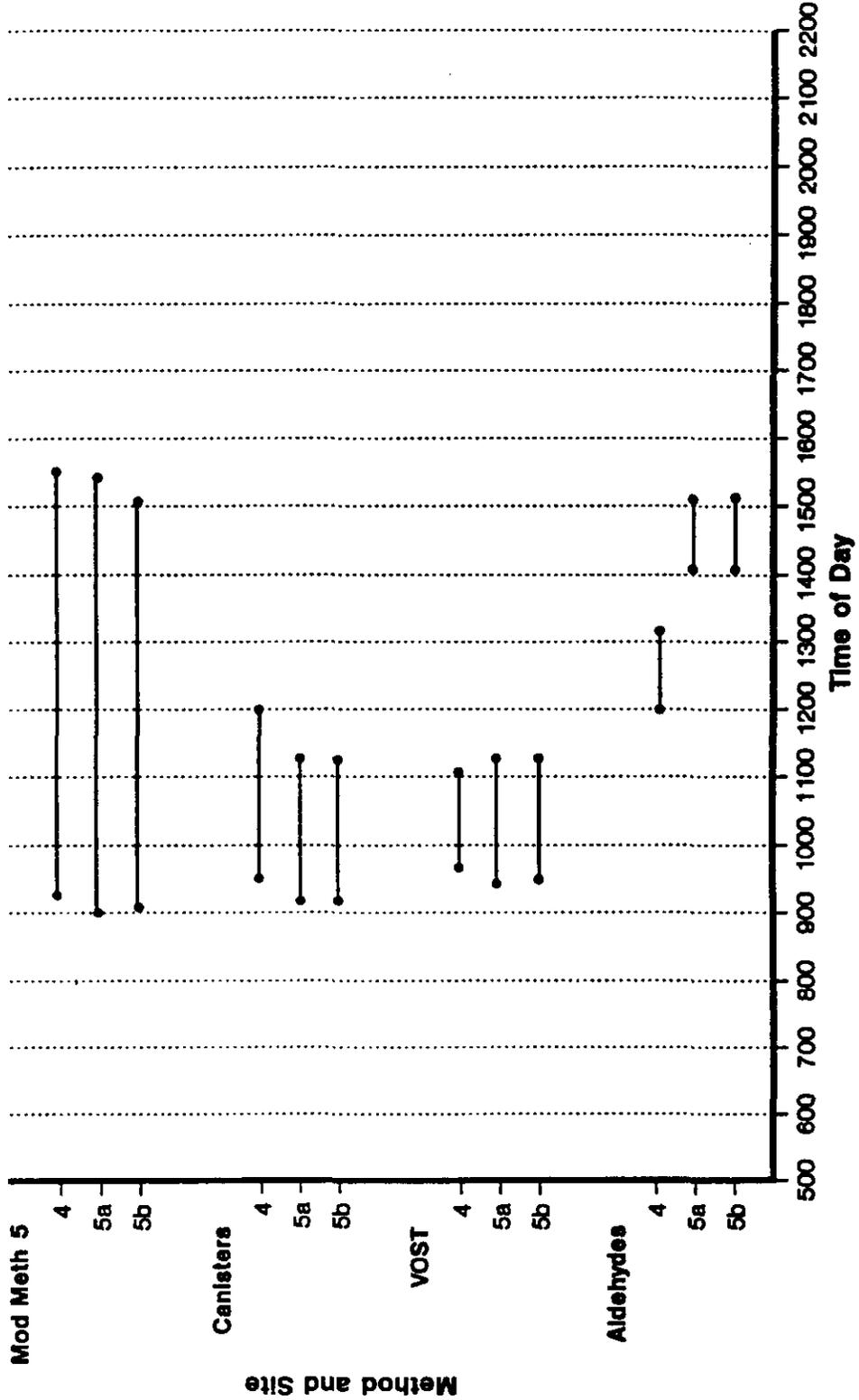


Figure 3-1e. Schedule of flue gas sampling conducted at Niles Boiler No. 2, July 30, 1993

Niles Boiler No. 2 Sampling Times 7/31/1993

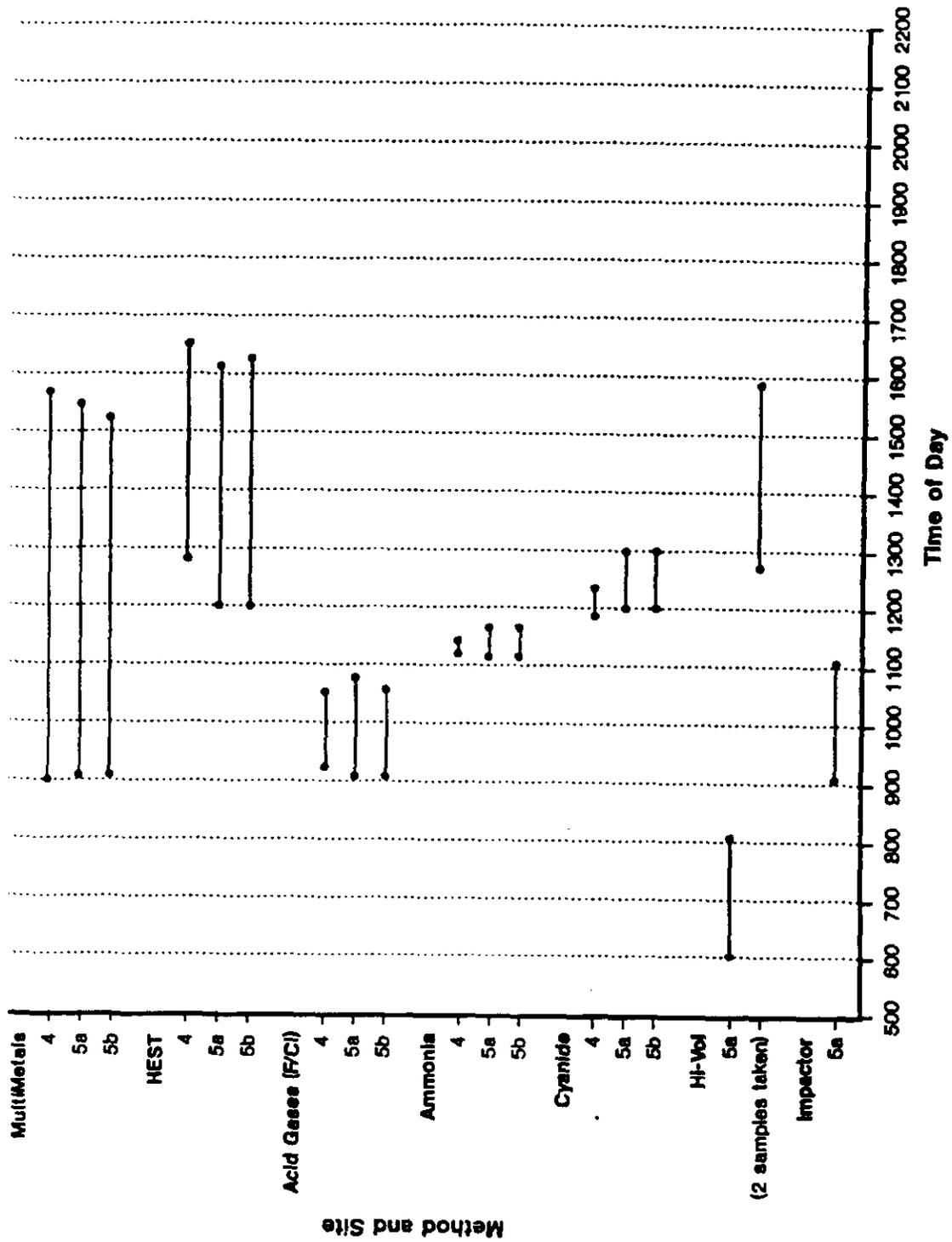
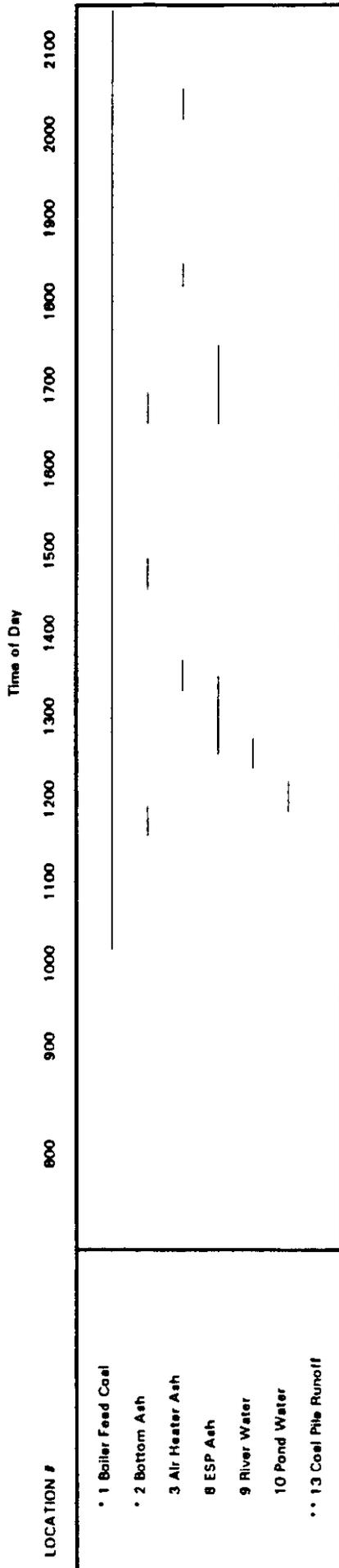


Figure 3-1f. Schedule of flue gas sampling conducted at Niles Boiler No. 2, July 31, 1993

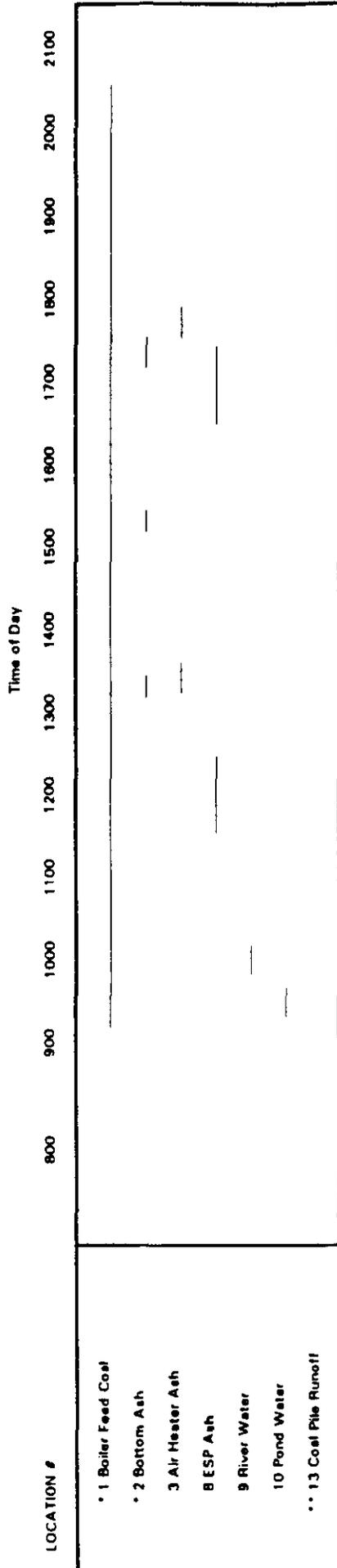
Process Sampling Day Schedule Niles Boiler 7/26/93



• = Sample taken by Niles Staff
 .. = Sample not taken

Figure 3-2a. Schedule of solid/liquid sample collections at Niles Boiler No. 2, July 26, 1993

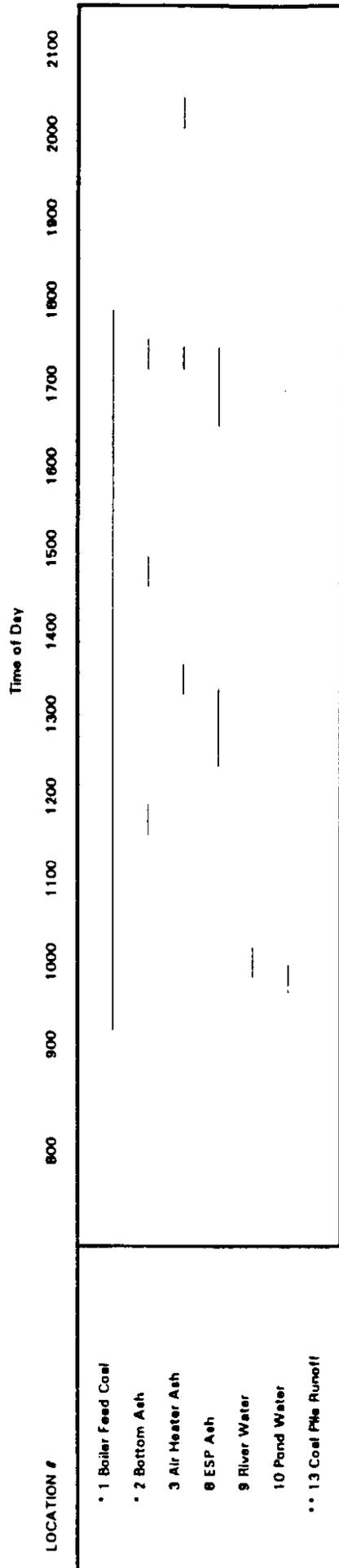
Process Sampling Day Schedule Niles Boiler 7/27/93



* Sample taken by Niles Staff
 .. Sample not taken

Figure 3-2b. Schedule of solid/liquid sample collections at Niles Boiler No. 2, July 27, 1993

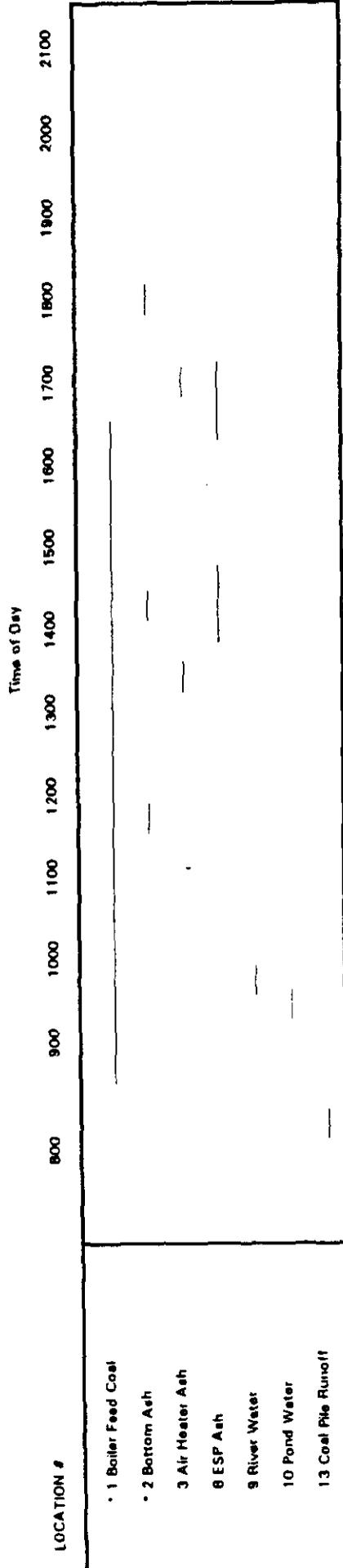
Process Sampling Day Schedule Niles Boiler 7/28/93



• = Sample taken by Niles Staff
 .. = Sample not taken

Figure 3-2c. Schedule of solid/liquid sample collections at Niles Boiler No. 2, July 28, 1993

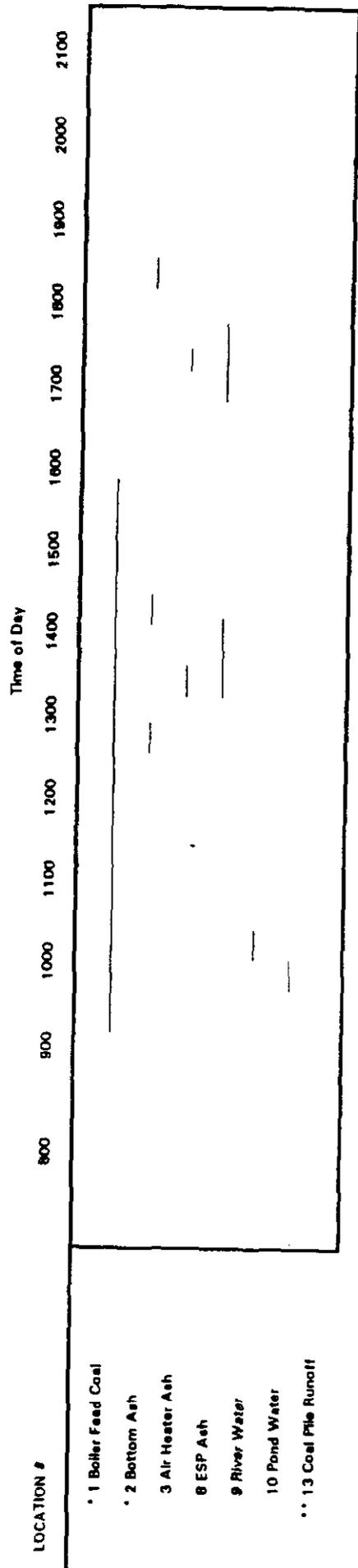
Process Sampling Day Schedule Niles Boiler 7/29/93



• = Sample taken by Niles Staff
 .. = Sample not taken

Figure 3-2d. Schedule of solid/liquid sample collections at Niles Boiler No. 2, July 29, 1993

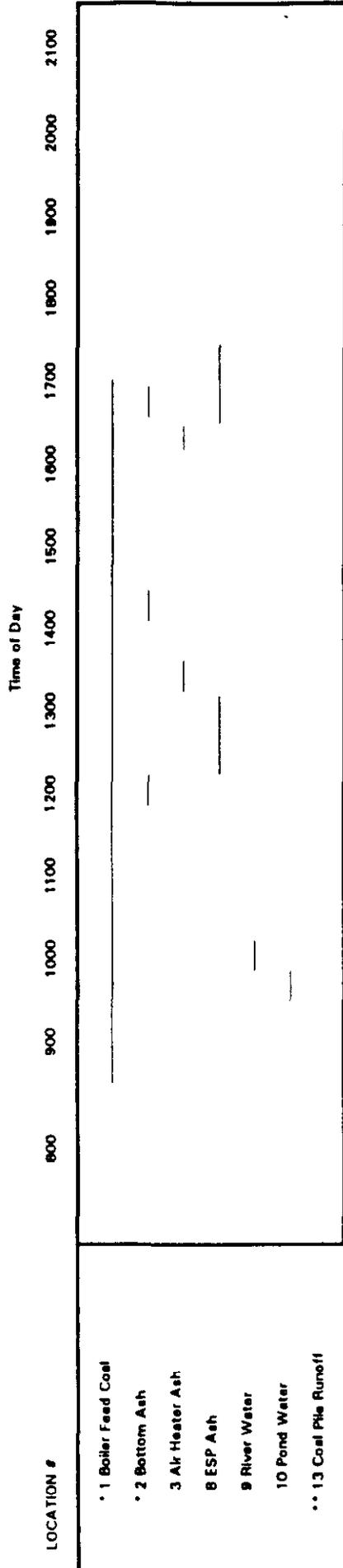
**Process Sampling Day Schedule Niles Boiler
7/30/93**



* = Sample taken by Niles Staff
 ** = Sample not taken

Figure 3-2e. Schedule of solid/liquid sample collections at Niles Boiler No. 2, July 30, 1993

Process Sampling Day Schedule Niles Boiler 7/31/93



* = Sample taken by Niles Staff
 ** = Sample not taken

Figure 3-2f. Schedule of solid/liquid sample collections at Niles Boiler No. 2, July 31, 1993

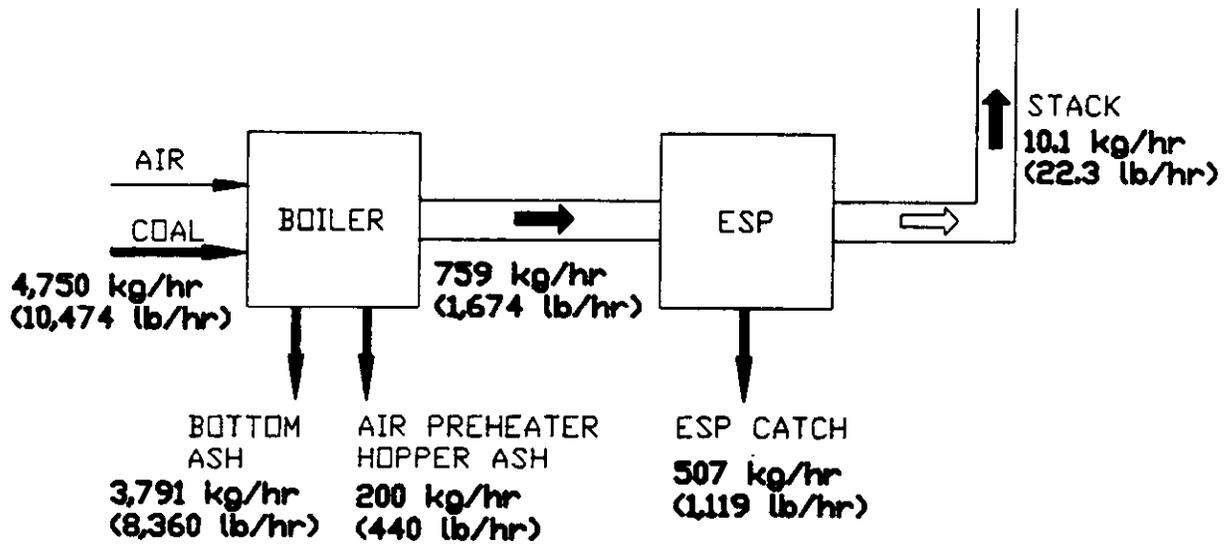


Figure 3-3. Schematic of average ash flows and mass balance, based on 4 percent carbon in particulate at the ESP inlet.

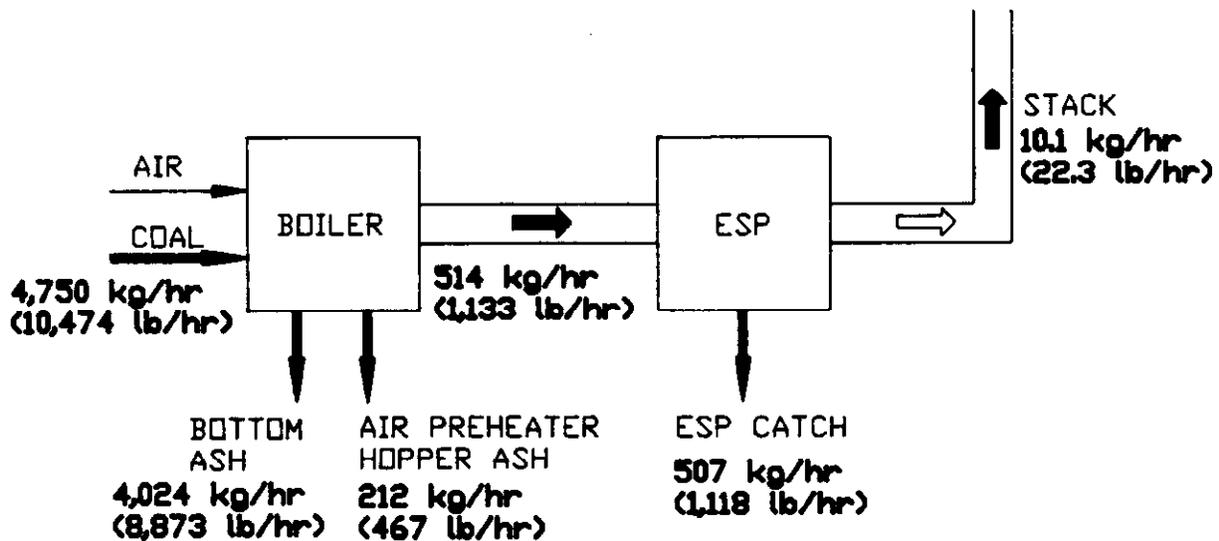


Figure 3-4. Schematic of revised average ash flows and mass balance, based on assumed 35 percent carbon in particulate at the ESP inlet.

4.0 SAMPLE ANALYSIS

4.1 Analytical Methods

A summary of the sample preparation procedures and analytical techniques used to analyze the gas, solid, and liquid samples collected on this project are listed in Table 4-1 along with the identity of the laboratory conducting the analyses. Specific details of the analytical procedures are provided in the **Analytical Plan*** prepared for this study. Any deviations from the analytical procedures cited in the Analytical Plan are described in Appendix F, and QA/QC data associated with the analyses are summarized in Appendix E. Requirements for the preservation and storage of samples after collection are detailed in Table C-2, Appendix C.

***Study of Toxic Emissions from a Coal-Fired Power Plant Demonstrating the ICCT WSA-SNOX Project and a Plant Utilizing an ESP/Wet FGD System, Management Plan on DOE Contract DE-AC22-93PC93251, Section 5: Niles Site-Specific Plans. Prepared for DOE-PETC by Battelle, Columbus, Ohio, July 17, 1993.**

TABLE 4-1. LABORATORY ANALYTICAL PROCEDURES

Sample Matrix	Analyte Class	Sample Preparation Procedure	Analytical Technique	Analytical Laboratory	
Gas ^(a) (includes particulate in gas stream)	Elements Ba, Be, Cr, Co, Mn, Ni, V, B, Mo, Cu, Al, Si, Ti, K, Na As, Sb, Se, Pb, Cd Hg Ammonia/Cyanide Anions VOC ^(a) PAH/SVOC Dioxins/Furans Aldehydes Radionuclides	Acid digestion ^(b) Acid digestion ^(b) Acid/KMnO ₄ digestion ^(b) None CO ₃ ²⁻ /HCO ₃ ⁻ Extraction ^(c) None Solvent Extraction Solvent Extraction None	ICP-AES GF-AAS CV-AAS ISE IC GC/MS GC/MS GC/HRMS HPLC/UV Gamma radiation ASTM	CTE CTE Battelle ^(d) Battelle Battelle Chester Battelle Battelle Battelle IT CTE	
	Solid	Ultimate/Proximate and Related Analyses	-	-	CTE
		Elements Ba, Be, Cr, Co, Mn, Ni, V, B, Mo, Cu, Al, Si, Ti, K, Na As, Sb, Se, Pb, Cd Hg Anions PAH/SVOC Radionuclides	Acid digestion Acid digestion Acid/KMnO ₄ digestion CO ₃ ²⁻ /HCO ₃ ⁻ extraction Solvent extraction	ICP-AES GF-AAS CV-AAS IC GC/MS Gamma radiation ASTM	CTE CTE CTE Battelle Battelle IT CTE
		Ultimate/Proximate and Related Analyses	-	-	CTE

TABLE 4-1. (Continued)

Sample Matrix	Analyte Class	Sample Preparation Technique	Analytical Technique	Analytical Laboratory
Liquid	Elements Ba, Be, Cr, Co, Mn, Ni, V, B, Mo, Cu, Al, Si, Ti, K, Na As, Sb, Se, Pb, Cd Hg Ammonia/Cyanide Anions VOC PAH/SVOC Aldehydes	Acid digestion Acid digestion KMnO ₄ digestion None None Helium purge Solvent extraction DNPH derivatization	ICP-AES GF-AAS CV-AAS ISE IC GC/MS HPLC/UV	CTE CTE CTE Battelle Battelle Zande Battelle Battelle

VOC = Volatile organic compounds.

PAH/SVOC = Polynuclear aromatic hydrocarbons and other semivolatile organic compounds.

ICP-AES = Inductively coupled plasma atomic emission spectrometry.

GF-AAS = Graphite furnace atomic absorption spectrometry.

CV-AAS = Cold vapor atomic absorption spectrometry.

ISE = Ion selective electrode.

IC = Ion chromatography.

GC/MS = Gas chromatography/mass spectrometry

GC/HRMS = Gas chromatography/high resolution mass spectrometry.

HPLC/UV = High performance liquid chromatography/ultraviolet detection.

ASTM = ASTM-specified techniques.

CTE = Commercial Testing and Engineering Laboratory.

IT = International Technology, Inc.

(a) Does not include HEST samples and VOC-canister samples for which procedures and results are presented in Section 7.

(b) As specified in Method 29.

(c) For anions in gas samples, impinger solutions were analyzed directly without preparation; particulate filters were extracted with carbon/bicarbonate (CO₃²⁻/HCO₃⁻) eluent, and the extract solution was analyzed.

(d) Filters were analyzed for Hg by CTE.

5.0 ANALYTICAL RESULTS

Analytical results are presented in Section 5. Analytical data were reduced according to specifications provided by DOE. These specifications are reproduced exactly below (with Battelle interpretation in italics):

"TREATMENT OF NON-DETECTS, VALUES OUTSIDE OF THE CALIBRATION RANGE AND BLANKS

Treatment of non-detects (analytical results for which the concentration of the species of interest is below the detection limit of the method) and blank values is of critical importance in this program because detection levels and blank concentrations are often on the same order of magnitude as sample values. When the results are then used for risk assessments or policy decisions, treatment of the data becomes important. This discussion describes how blank and non-detect values are to be treated in presenting/developing reported results.

Non-Detects

The discussion presented below explains how averages, sums, and reported emission values are to be calculated for all species given various combinations of detected and non-detected values.

All values detected. The arithmetic average or sum is taken, as appropriate. No special techniques required.

All values below the detection limit. For individual test runs or species, the data are to be reported as "ND < (detection limit)." For cases where all three runs (*or multiple species*) are below the detection limit, the average is reported as non-detected less than the average detection limit of the three runs (*species*).

Some values are detected and some are non-detects. As an approximation, half of the detection limit for nondetect values and the actual value for detects will be used to determine reported values. As an example of averaging, an average for three test runs with results of 10, 8, and ND < 6 would be 7. As an example for summing (such as for mercury fractions), individual species values of 50, ND < 1 and ND < 2 would be summed to provide a value of $50 + .5 + 1$ or 51.5. In reporting these types of sums or averages no "<" sign is used. The only exception to this rule occurs when the average (*or sum*) is less than the highest detection limit of the non-detected values. In this case, the averages or sums is reported as "ND < (the highest detection limit)." For example, 5, ND < 4 and ND < 3 would be reported as "ND < 4."

This approach is also used to obtain test train totals which required analyses of separate fractions for each individual run. Specifically, the volatile, metals, and anion test train totals for each run are obtained by addition of test train fractions which were analyzed separately.

Fractions from the volatile test train included separate analyses of the tenax and tenax/charcoal tubes for each sample period. Separate analyses were conducted on the filterable and gaseous test train components for both the metals and anion test trains.

Detection limit ratio. These methods of treating the data may result in some loss of information in going from raw data to final values. Specifically, what is often lost is the amount of a final emission value that is attributable to detection limits and the amount that is attributable to measured values. In order to quantify and present this information, all results in this report are presented along with the "Detection Limit Component Ratio," (*DL Ratio*) which is calculated as the ratio of the contribution of detection limit values to a final emission result.

For example, a set of three values of 16, ND < 6, and ND < 5 should be reported as 7, with a detection limit ratio of 26% $((3+2.5)/(16+3+2.5))$, while a set of values of 12, ND < 6, and 9 should be reported as 8, with a detection limit ratio of 13%. The different ratios provide insight as to the extent something is "really there," and hopefully can help provide better information to those making decisions on risk and policy issues.

Values Outside the Calibration Range

It is possible that the reported lab data will be outside the calibration range of the instrument. Data reported below the lower detection limit will be flagged with a qualifier (e.g., "J"). Data with the "J" flag will have been tentatively identified and tentatively quantified. Data reported above the upper detection limit will be flagged with a qualifier (e.g., "E"). Data with the "E" flag will have been positively identified and tentatively quantified. Data with both qualifiers will be estimates. Consider J and E values to be quantitatively representative when calculating averages. Neither flag should cause a value to be weighted more or less important. The J and E data qualifiers should appear in the respective laboratory analytical report. The data qualifiers need not appear on the calculated data summaries.

Blank Values

The level and treatment of blank values is important in interpreting data, since in some cases species are detected but not at levels significantly higher than blanks. In these cases measured values may not represent emissions, but rather just limitations of the method. However, most of the test methods used in this program either do not allow subtraction of blanks or are silent on how to treat blank values.

When a method does not specify how the sample will be blank corrected, the appropriate blank train values should be subtracted. Laboratory and site/reagent blanks will be analyzed and the results evaluated for identification of contamination. If a sample compound is blank corrected the data will be flagged by a "B". If the value is blank corrected below the detection limit it should be reported as "ND < (detection limit) BC." A "C" flag indicates that the blank value was greater than the sampled value. In no case should the blank corrected values be reported below the method detection limit."

Gas samples and train blanks were corrected for field reagent blanks, where available. After field reagent blank corrections, samples were corrected for train blanks. These blank corrections are designated in footnotes to the Section 5 tables rather than flagged with a "B" as indicated in the above DOE specifications. Any additional flags used to qualify the analytical data are included as appropriate in the Section 5 tables with defining footnotes in each table where used. The spreadsheet program used to prepare the Section 5

tables does not allow ready control of significant figures. As a result, the reader is requested to be tolerant of excessive significant figures in some values.

Averages were calculated for the three samples collected at a single location on each of the three sampling days (i.e., inorganic or organic). Specifications provided by DOE, as reproduced above, were used to calculate averages. A standard deviation (SD) was calculated for the three sampling days using a sample population (i.e., using N-1 in the denominator). It must be noted that results from the three individual measurements shown in Section 5 tables were used to conduct three separate calculations of mass balances, removal efficiencies, and power plant emissions, in Section 6. The average result of those three separate calculations was then calculated. The average concentrations shown in Section 5 were not used in such calculations.

It should be noted that DL Ratio values were calculated and are shown in subsequent tables only when a detected value is shown for the average, not when the average is a non-detect value. In other words, an average value which is itself a non-detect (i.e., ND <), whether based entirely or partially on individual non-detect values, is not shown with an associated DL Ratio value. This approach eliminates unnecessary repetition of high DL Ratio values for results which are already indicated as non-detect values.

In parts of Section 5 blank values for analytes in flue gas are shown, in units of (e.g.) $\mu\text{g}/\text{dscm}$. The blank results shown were calculated from blank samples using a representative or average sampled flue gas volume; as such they are for illustration only. Blank subtraction from actual samples was always done by subtracting the mass of analyte in the blank, then dividing by the sampled flue gas volume appropriate for each sample.

In a few instances, individual measured values were found which appeared to be outliers. Those values are footnoted in the Section 5 data tables, and are excluded from the calculation of mass balances, removal efficiencies, and emission factors. Average values for the accepted data were substituted in place of the outliers in such calculations. Where pertinent, the reasons for considering individual values as outliers are noted.

Finally, one exception was made to the use of half the detection limit value for non-detects. When calculating the emission factor for a species for which all three values are non-detects, the non-detect values, rather than half those values, were used. This approach avoids underestimating both the magnitude and the uncertainty of the emissions.

5.1 Elements

5.1.1 Elements in Flue Gas Samples

Tables 5-1 through 5-5 show the concentrations of elements measured in flue gas samples from Locations 4 and 5a at Niles Boiler No. 2. Tables 5-1 and 5-3 show the element concentrations in flue gas particulate matter from Locations 4 and 5a, respectively, in units of micrograms per gram of collected particulate ($\mu\text{g/g}$). Tables 5-2 and 5-4 show the total (i.e., particle plus vapor) element concentrations in flue gas at Locations 4 and 5a, respectively, in units of micrograms of analyte per normal cubic meter of flue gas ($\mu\text{g}/\text{Nm}^3$). Thus the concentrations in Tables 5-2 and 5-4 include the particulate element data in Tables 5-1 and 5-3, reckoned relative to flue gas volume rather than to particulate mass. Note that silicon was determined only in the probe rinse particulate, which comprised about 59 percent of the total particulate catch at the ESP inlet (Location 4), and 92 percent at the ESP outlet (Location 5a).

Table 5-5 shows train blank values representative of elements in flue gas, and reported in $\mu\text{g}/\text{Nm}^3$ units.

Aluminum, sodium, and potassium values in flue gas showed a large degree of variability, attributable in part to high blank values, possibly due to filter contamination (see footnote to Table 5-5). Such filter contamination is not unexpected, even with quartz filters as used in this study (see, e.g., Berg et al., *Atmos. Environ.*, Vol. 27A, p. 2435, 1993). Subtraction of large blank values for these elements led to substantial uncertainty in the flue gas concentrations, particularly at Location 5a where particulate loading was low, and filter blank values were consequently more important. Outlier values are noted in Tables 5-3 and 5-4 for these three elements, and arise primarily from the blank values noted above. The exception is the sodium value in Table 5-3 from 7/27, which appears to be from sample contamination. Emission factor tables elsewhere in this report are also footnoted to indicate the exclusion of outlier data at the stack (Location 5a).

TABLE 5-1. ELEMENTS IN PARTICULATE MATTER FROM ESP INLET (LOCATION 4) ($\mu\text{g/g}$)

Analyte	N-4-MUM-727	N-4-MUM-729	N-4-MUM-731	AVERAGE	DL RATIO	SD
Aluminum	72295	63016	81847	72386		9416
Potassium	19812	18255	21371	19813		1558
Silicon	149309	98146	182156	143203		42337
Sodium	5150	7740	2821	5237		2461
Titanium	6274	4476	6491	5747		1106
Antimony	39.5	48.9	53.1	47		7.0
Arsenic	1223	876	1118	1072		178
Barium	527	482	611	540		66
Beryllium	28.8	25.7	29.8	28		2.2
Cadmium	1.61	1.81	1.77	1.7		0.11
Chromium	247	232	270	249		19
Cobalt	67.9	63.3	85.7	72		12
Copper	374	376	431	394		32
Lead	405	391	405	400		8
Manganese	207	193	245	215		27
Mercury	0.809	0.772	0.764	0.78		0.024
Molybdenum	84.5	69.0	76.7	77		7.7
Nickel	265	294	319	293		27
Selenium	42.0	31.1	38.9	37		5.6
Vanadium	370	356	429	385		39

DL Ratio = Detection limit ratio.

SD = Standard deviation.

Samples corrected for train blank.

Silicon value refers to probe rinse only.

TABLE 5-2. ELEMENTS IN GAS SAMPLES FROM ESP INLET (LOCATION 4) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-4-MUM-727	N-4-MUM-729	N-4-MUM-731	AVERAGE	DL RATIO	SD
Aluminum	161715	163287	129293	151432		19189
Potassium	45943	47645	33760	42449		7573
Silicon	184110	150409	187281	173933		20434
Sodium	11731	21666	4491	12629		8622
Titanium	14034	11550	10254	11946		1921
Antimony	88.6	127	242	152		80
Arsenic	2772	2264	1786	2274		493
Barium	1179	1244	966	1129		146
Beryllium	64.6	66.3	47.1	59		11
Boron	NA	NA	NA	NA		NA
Cadmium	3.64	4.71	2.84	3.7		0.94
Chromium	552	599	426	526		89
Cobalt	152	163	135	150		14
Copper	837	972	683	831		145
Lead	906	1010	639	852		191
Manganese	473	507	410	463		49
Mercury	31.7	28.4	24.9	28		3.4
Molybdenum	189	179	122	163		36
Nickel	594	757	504	618		129
Selenium	102	91.7	80.2	91		11
Vanadium	829	918	678	808		121

DL Ratio = Detection limit ratio.

SD = Standard deviation.

NA = Not analyzed.

Samples corrected for train blank.

Silicon not determined in cyclones and filter.

TABLE 5-3. ELEMENTS IN PARTICULATE MATTER FROM ESP OUTLET (LOCATION 5a) ($\mu\text{g/g}$)

Analyte	N-5a-MUM-727		N-5a-MUM-729		N-5a-MUM-731		AVERAGE	DL RATIO	SD
Aluminum	27763		749 #		634 #		27763		NC
Potassium	19409	ND <	86.2 #		616 #		19409		NC
Silicon	173007		28491		70589		90696		74326
Sodium	37390 #	ND <	2654		1510	ND <	2654		NC
Titanium	797		1473		1010		1093		345
Antimony	ND <	15.3	ND <	34.5	ND <	20.1	ND <	23	10
Arsenic		1746		3045		1966		2252	695
Barium		185		237		175		199	34
Beryllium		5.33		12.8		7.99		8.7	3.8
Cadmium	ND <	2.76	ND <	6.00		6.21	ND <	6.0	2.5
Chromium		90.0		268		111		156	98
Cobalt	ND <	5.51	ND <	12.0	ND <	7.05	ND <	8.2	3.4
Copper		132		265		183		193	67
Lead		55.3		85.5		94.5		78	21
Manganese		61.0		92.9		54.0		69	21
Mercury		2.15	ND <	1.03	ND <	0.614	ND <	1.0	1.0
Molybdenum		87.9		214		75.3		126	77
Nickel		27.7		45.0		11.9		28	17
Selenium		2817		2004		2968		2596	518
Vanadium		85.7		206		142		144	60

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NC = Not calculated.

= Outlier value, not used in calculations.

Samples corrected for train blank.

Silicon value refers to probe rinse only.

TABLE 5-4. ELEMENTS IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-MUM-727	N-5a-MUM-729	N-5a-MUM-731	AVERAGE	DL RATIO	SD		
Aluminum	5238	14.6 #	90.7 #	5238		NC		
Potassium	3257	ND<	1.45 #	125 #		NC		
Silicon	9529	5363	6101	6997		2223		
Sodium	7604 #	ND<	51.3	891	458	3% NC		
Titanium	51.2	28.6	36.2	39		11.5		
Antimony	ND<	0.59	ND<	0.60	ND<	0.60	0.0	
Arsenic	79.4	59.6	70.3	70		9.9		
Barium	15.4	4.63	6.45	8.8		5.8		
Beryllium	0.31	0.28	0.33	0.31		0.0		
Boron	NA	NA	NA	NA		NA		
Cadmium	ND<	0.10	ND<	0.10	0.24	ND<	0.10	0.11
Chromium	4.92	5.89	4.37	5.1		0.77		
Cobalt	ND<	0.20	ND<	0.19	ND<	0.20	0.0	
Copper	7.78	5.37	6.83	6.7		1.2		
Lead	2.62	1.89	3.47	2.7		0.79		
Manganese	7.66	4.09	5.07	5.6		1.8		
Mercury	27.4	21.2	23.2	24		3.1		
Molybdenum	4.09	4.27	2.87	3.7		0.76		
Nickel	1.32	0.93	0.47	0.90		0.43		
Selenium	136	56.1	113	102		41		
Vanadium	3.74	4.02	4.88	4.2		0.59		

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

NA = Not analyzed.

NC = Not calculated.

= Outlier value, not used in calculations.

Samples corrected for train blank.

Silicon not determined in cyclones and filter.

TABLE 5-5. ELEMENTS IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

Analyte	TRAIN BLANK N-5a-MUM-726
Aluminum	7862
Potassium	4753
Silicon	11674
Sodium	11600
Titanium	23.9
Antimony	ND < 0.689
Arsenic	2.69
Barium	12.8
Beryllium	ND < 0.114
Boron	NA
Cadmium	ND < 0.114
Chromium	ND < 0.114
Cobalt	ND < 0.228
Copper	0.464
Lead	2.64
Manganese	2.55
Mercury	ND < 0.028
Molybdenum	3.01
Nickel	3.07
Selenium	ND < 0.689
Vanadium	ND < 0.114

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

Silicon not determined in cyclones and filter.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

<u>Analyte</u>	<u>Average Table 5-6 Result ($\mu\text{g/g}$, as received)</u>	<u>Round-Robin Result Used in Mass Balance Calculations ($\mu\text{g/g}$, dry)</u>
Cadmium	ND < 0.3	0.085
Molybdenum	ND < 3	4.54
Selenium	ND < 0.6	2.56

In general, the relative percent difference between the average results for detected elements in the boiler feed coal presented in Table 5-6 and the average result obtained for Niles coal (designated Samples F and O) by the five laboratories participating in the round-robin study was less than 30 percent. Antimony and nickel were the only two elements with relative percent differences above 30 percent, at 56 percent and 38 percent, respectively. The average antimony result from the round-robin result ($2.1 \mu\text{g/g}$ dry, versus $1.1 \mu\text{g/g}$ as received, in Table 5-6) was therefore used in the mass balance calculation. The average nickel result from the round-robin study ($28.2 \mu\text{g/g}$, dry, versus $18 \mu\text{g/g}$, as received, in Table 5-6) was not used in the mass balance calculations because the percent relative standard deviation of nickel results in the round-robin study was relatively high (average of 33.1 percent), as was the range of results in comparison to the other elements. This suggested that the round-robin result was not more accurate than the result presented in Table 5-6.

5.1.2 Elements in Solid Samples

Tables 5-6 through 5-9 present analytical results for elements in solid samples. All results are shown in μg of analyte per gram of sample ($\mu\text{g/g}$). Tables 5-6 through 5-9, respectively, show data for elements in boiler feed coal (Location 1), bottom ash (Location 2), air heater ash (Location 3), and ESP ash (Location 8). Each table shows results for individual daily composite samples, and the average and standard deviation of those results. The composite sample identification scheme and compositing procedures are described in Section 3.2.2. Note that the data for ESP ash are presented in five parts, Tables 5-9a through 5-9e, corresponding to ash samples from ESP hopper rows 1 through 5, respectively.

Comparison of the elemental composition of air heater ash (Table 5-8) to that of the various ESP ash samples (Table 5-9) shows that the air heater ash composition closely resembles that of the ESP row 1 ash (Table 5-9a), but differs markedly from that of ash from later rows of the ESP (Tables 5-9b-e). The ash from the later ESP rows closely resembles flue gas particulate from Location 4 (Table 5-1) in elemental composition. These factors confirm the conclusion reached in Section 3.3.1, that the Location 4 particulate samples may represent the fine particulate collected in later rows of the ESP, but they are not comparable to the coarse ash collected passively in the deactivated hoppers of row 1 of the ESP. (See also Section 5.9, Carbon Analyses.)

One outlier in the solid sample element data is the value of 27,000 $\mu\text{g/g}$ for sodium in bottom ash on 7/29 (Table 5-7). That value differs widely from all other sodium data in all types of solid samples. No cause has been identified for that extreme outlier.

Results from the coal analysis round-robin study coordinated by Consol, Inc. for DOE/PETC are presented in Appendix B Auditing of this report. For the elements not detected in boiler feed coal (Table 5-6), results from the round-robin study were used instead in mass balance calculations presented later in this report. The round-robin results that were adopted include the following:

TABLE 5-6. ELEMENTS IN BOILER FEED COAL (LOCATION 1) ($\mu\text{g/g}$)

Analyte	JL2793-BOFED	JL2993-BOFED	JL3193-BOFED	AVERAGE	DL RATIO	SD	
Aluminum	14000	13900	14300	14067		208	
Potassium	2100	2000	2100	2067		58	
Silicon	24500	24300	24900	24567		306	
Sodium	300	300	300	300		0	
Titanium	800	800	800	800		0	
Antimony	0.8	1.5	1.1	1.1		0.35	
Arsenic	33	32	35	33		1.5	
Barium	54	55	56	55		1.0	
Beryllium	1.7	2.3	1.8	1.9		0.32	
Boron	72	76	67	72		4.5	
Cadmium	ND<	0.3	ND<	0.3	ND<	0.3	0
Chromium	15	17	16	16		1.0	
Cobalt	5.4	8.0	5.5	6.3		1.5	
Copper	14	15	15	15		0.58	
Lead	11	14	14	13		1.7	
Manganese	25	27	24	25		1.5	
Mercury	0.19	0.17	0.27	0.21		0.053	
Molybdenum	3.9	ND<	3	ND<	3	1.4	
Nickel	17	22	16	18		3.2	
Selenium	ND<	0.6	ND<	0.6	ND<	0.6	0
Vanadium	26	29	29	28		1.7	

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-7. ELEMENTS IN BOTTOM ASH (LOCATION 2) ($\mu\text{g/g}$)

Analyte	JL2793-BOTT	JL2993-BOTT	JL3193-BOTT	AVERAGE	DL RATIO	SD
Aluminum	121000	123600	124900	123167		1986
Potassium	16300	17700	16500	16833		757
Silicon	222500	225100	226400	224667		1986
Sodium	1600	27000 #	1000	1300		NC
Titanium	6400	6400	6400	6400		0
Antimony	ND< 4	ND< 4	ND< 4	ND< 4		0
Arsenic	5.1	6	8.2	6.4		1.6
Barium	560	600	620	593		191
Beryllium	11	14	13	13		1.5
Boron	120	140	80	113		31
Cadmium	ND< 2	ND< 2	ND< 2	ND< 2		0
Chromium	110	130	120	120		10
Cobalt	43	57	40	47		9.1
Copper	41	58	56	52		9.3
Lead	5.5	5.8	4.7	5.3		0.57
Manganese	240	260	270	257		15
Mercury	0.02	ND< 0.02	ND< 0.02	ND< 0.02		0.0058
Molybdenum	ND< 30	ND< 30	ND< 30	ND< 30		0
Nickel	110	150	130	130		20
Selenium	ND< 4	ND< 4	ND< 4	ND< 4		0
Vanadium	160	210	190	187		25

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

NC = Not calculated.

= Outlier value, not used in calculations.

TABLE 5-8. ELEMENTS IN AIR HEATER ASH (LOCATION 3) ($\mu\text{g/g}$)

Analyte	JL2793-HASH		JL2993-HASH		JL3193-HASH		AVERAGE	DL RATIO	SD
Aluminum	30800		32600		35000		32800		2107
Potassium	3200		3800		4200		3733		503
Silicon	50000		51700		55300		52333		2706
Sodium	600		1000		900		833		208
Titanium	1700		1900		1900		1833		115
Antimony	ND<	3	ND<	4	ND<	2	ND<	3	1.0
Arsenic	25		24		44		31		11
Barium	82		98		120		100		19
Beryllium	2.8		2.7		3.5		3		0.44
Boron	100		80		100		93		12
Cadmium	ND<	1.5	ND<	2	ND<	1.5	ND<	2	0.29
Chromium	27		30		37		31		5.1
Cobalt	12		19		12		14		4.0
Copper	25		34		39		33		7.1
Lead	9.8		7.6		7.6		8.3		1.3
Manganese	31		36		35		34		2.6
Mercury	0.03		0.04		0.04		0.037		0.0058
Molybdenum	ND<	30	ND<	30	ND<	20	ND<	27	5.8
Nickel	28		43		36		36		7.5
Selenium	4.3		ND<	4	ND<	4	ND<	4.0	1.3
Vanadium	39		42		59		47		11

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-9a. ELEMENTS IN ESP ASH ROW 1 (LOCATION 8) ($\mu\text{g/g}$)

Analyte	JL2793-ESP1	JL2993-ESP1	JL3193-ESP1	AVERAGE	DL RATIO	SD
Aluminum	25600	25800	28500	26633		1620
Potassium	2800	2600	3300	2900		361
Silicon	40100	38000	43200	40433		2616
Sodium	500	500	600	533		58
Titanium	1400	1400	1600	1467		115
Antimony	ND< 4	ND< 4	ND< 3	ND< 3.7		0.58
Arsenic	149	153	160	154		5.6
Barium	78	80	120	93		24
Beryllium	2.8	2.9	4.7	3.5		1.1
Boron	160	69	170	133		56
Cadmium	ND< 2.0	ND< 2.0	ND< 1.5	ND< 1.8		0.29
Chromium	35	27	38	33		5.7
Cobalt	6.8	10	15	11		4.1
Copper	25	25	40	30		8.7
Lead	19	170	22	70		86
Manganese	44	30	42	39		7.6
Mercury	0.29	0.23	0.34	0.29		0.055
Molybdenum	ND< 30	ND< 30	ND< 20	ND< 27		5.8
Nickel	19	37	48	35		15
Selenium	11	7.9	6.3	8.4		2.4
Vanadium	39	40	60	46		12

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-9b. ELEMENTS IN ESP ASH ROW 2 (LOCATION 8) (µg/g)

Analyte	JL2793-ESP2	JL2993-ESP2	JL3193-ESP2	AVERAGE	DL RATIO	SD
Aluminum	95000	85200	95200	91800		5717
Potassium	22000	18300	20700	20333		1877
Silicon	162000	143000	156400	153800		9763
Sodium	3500	3300	3400	3400		100
Titanium	6700	5900	6600	6400		436
Antimony	50	45	43	46		3.6
Arsenic	1140	870	860	957		159
Barium	680	550	640	623		67
Beryllium	33	26	32	30		3.8
Boron	640	680	640	653		23
Cadmium	ND< 2	ND< 2	ND< 2	ND< 2		0
Chromium	240	210	240	230		17
Cobalt	82	63	80	75		10
Copper	360	360	440	387		46
Lead	438	340	390	389		49
Manganese	240	190	240	223		29
Mercury	0.32	0.4	0.36	0.36		0.040
Molybdenum	110	80	150	113		35
Nickel	280	270	310	287		21
Selenium	5.8	ND< 4	ND< 4	ND< 4		2.2
Vanadium	360	350	410	373		32

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-9c. ELEMENTS IN ESP ASH ROW 3 (LOCATION 8) ($\mu\text{g/g}$)

Analyte	JL2793-ESP3	JL2993-ESP3	JL3193-ESP3	AVERAGE	DL RATIO	SD
Aluminum	101100	99300	101800	100733		1290
Potassium	25200	24900	25700	25267		404
Silicon	173000	167300	170800	170367		2875
Sodium	4600	4500	4300	4467		153
Titanium	7400	7700	7500	7533		153
Antimony	70	75	70	72		2.9
Arsenic	1650	1414	1415	1493		136
Barium	900	900	820	873		46
Beryllium	40	39	38	39		1.0
Boron	830	990	900	907		80
Cadmium	ND< 2	ND< 2	ND< 2	ND< 2		0
Chromium	300	320	310	310		10
Cobalt	91	97	96	95		3.2
Copper	450	530	560	513		57
Lead	595	520	560	558		38
Manganese	270	330	280	293		32
Mercury	0.13	0.15	0.15	0.14		0.012
Molybdenum	180	190	170	180		10
Nickel	320	350	380	350		30
Selenium	7.9	24	7.0	13		9.6
Vanadium	450	510	530	497		42

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-9d. ELEMENTS IN ESP ASH ROW 4 (LOCATION 8) ($\mu\text{g/g}$)

<u>Analyte</u>	<u>JL3193ESP4</u>
Aluminum	96500
Potassium	26000
Silicon	159800
Sodium	4300
Titanium	7800
Antimony	81
Arsenic	1830
Barium	910
Beryllium	40
Boron	1100
Cadmium	ND < 2
Chromium	360
Cobalt	96
Copper	640
Lead	670
Manganese	380
Mercury	0.08
Molybdenum	230
Nickel	410
Selenium	22
Vanadium	600

ND < = Not detected, value following ND < is detection limit.

TABLE 5-9e. ELEMENTS IN ESP ASH ROW 5 (LOCATION 8) ($\mu\text{g/g}$)

Analyte	JL2793-ESP5	JL3193-ESP5	AVERAGE	DL RATIO	SD
Aluminum	91300	88300	89800		2121
Potassium	26900	27500	27200		424
Silicon	160100	153200	156650		4879
Sodium	4200	4500	4350		212
Titanium	7300	7700	7500		283
Antimony	100	116	108		11
Arsenic	2140	2443	2292		214
Barium	1190	1210	1200		14
Beryllium	44	48	46		2.8
Boron	1160	1470	1315		219
Cadmium	ND< 2	ND< 2	ND< 2		0
Chromium	350	420	385		49
Cobalt	100	100	100		0
Copper	560	760	660		141
Lead	692	787	740		67
Manganese	280	300	290		14
Mercury	0.14	0.02	0.08		0.085
Molybdenum	250	330	290		57
Nickel	350	420	385		49
Selenium	23	40	32		12
Vanadium	550	670	610		85

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

5.1.3 Elements in Liquid Samples

Tables 5-10 through 5-13 show the analytical results for elements in liquid samples. All results are reported in milligrams per liter of sample (mg/L). Results are shown for make-up water (Location 9), and pond outlet water (Location 10), in that order. For each type of sample, an even-numbered table (e.g., 5-10) shows total element results, and an odd-numbered table (e.g., 5-11) shows dissolved element results. Each table shows the individual sample results as well as the average and standard deviation. Comparison of the two sample sets shows that most element concentrations are higher in pond outlet water than in the river water used for plant make-up. This is as expected since the pond outlet water has been used to sluice ESP ash and other solids into the pond.

TABLE 5-10. TOTAL ELEMENTS IN MAKE-UP WATER (LOCATION 9) (mg/L)

Analyte	N-9-PRL-727	N-9-PRL-729	N-9-PRL-731	AVERAGE	DL RATIO	SD
Aluminum	0.584	1.36	0.693	0.88		0.42
Potassium	3.26	3.02	3.88	3.4		0.44
Silicon	3.80	7.15	4.35	5.1		1.8
Sodium	21.5	23.6	25.5	24		2.0
Titanium	0.014	0.042	0.015	0.024		0.016
Antimony	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02		0
Arsenic	0.029	ND< 0.020	ND< 0.020	ND< 0.020		0.0095
Barium	0.029	0.224	0.037	0.097		0.11
Beryllium	ND< 0.005	ND< 0.005	ND< 0.005	ND< 0.005		0
Boron	0.19	0.13	0.07	0.13		0.060
Cadmium	ND< 0.005	ND< 0.005	ND< 0.005	ND< 0.005		0.0014
Chromium	ND< 0.005	0.028	ND< 0.005	0.011	15%	0.015
Cobalt	ND< 0.010	ND< 0.010	ND< 0.010	ND< 0.010		0
Copper	0.006	0.011	0.007	0.0080		0.0026
Lead	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02		0
Manganese	0.159	0.262	0.210	0.21		0.052
Mercury	ND< 0.0002	ND< 0.0002	ND< 0.0002	ND< 0.0002		0
Molybdenum	ND< 0.05	ND< 0.05	ND< 0.05	ND< 0.050		0.017
Nickel	ND< 0.010	0.145	ND< 0.010	0.052	6%	0.081
Selenium	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02		0
Vanadium	ND< 0.005	ND< 0.005	ND< 0.005	ND< 0.005		0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-11. DISSOLVED ELEMENTS IN MAKE-UP WATER (LOCATION 9) (mg/L)

Analyte	N-9-PRL-727	N-9-PRL-729	N-9-PRL-731	AVERAGE	DL RATIO	SD
Aluminum	0.07	0.18	0.18	0.14		0.06
Potassium	3.54	2.50	4.07	3.37		0.80
Silicon	3.74	3.86	4.40	4.00		0.35
Sodium	25.8	26.1	25.3	26		0.40
Titanium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	0.00
Antimony	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04	0.00
Arsenic	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04	0.00
Barium	0.20	0.20	0.16	0.18		0.02
Beryllium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	0.00
Boron	0.94	0.93	0.74	0.87		0.12
Cadmium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	0.00
Chromium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	0.00
Cobalt	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02	0.00
Copper	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	0.00
Lead	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04	0.00
Manganese	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	0.00
Mercury	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02	0.00
Molybdenum	ND< 0.10	ND< 0.10	ND< 0.10	ND< 0.10	ND< 0.10	0.00
Nickel	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02	0.00
Selenium	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04	0.00
Vanadium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01	0.00

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-12. TOTAL ELEMENTS IN OUTLET OF POND (LOCATION 10) (mg/L)

Analyte	N-10-PRL-727		N-10-PRL-729		N-10-PRL-731		AVERAGE	DL RATIO	SD	
Aluminum		2.14		2.13		30.8		12	17	
Potassium		10.8		13.6		17.3		14	3.3	
Silicon		4.20		4.40		12.5		7.0	4.7	
Sodium		58.6		72.4		88.5		73	15	
Titanium		0.017	ND <	0.005		0.257		0.092	1%	0.14
Antimony	ND <	0.02	ND <	0.02	ND <	0.02	ND <	0.02		0
Arsenic		0.07		0.04		0.61		0.24		0.32
Barium		0.109		0.140		0.196		0.15		0.044
Beryllium	ND <	0.005	ND <	0.005		0.036		0.014	12%	0.019
Boron		0.83		0.97		1.15		0.98		0.16
Cadmium		0.006	ND <	0.005		0.014		0.0075	11%	0.0059
Chromium		0.011		0.011		0.338		0.12		0.19
Cobalt		0.013		0.022		0.047		0.027		0.018
Copper		0.114		0.164		1.42		0.57		0.74
Lead	ND <	0.02	ND <	0.02		0.20		0.07	9%	0.11
Manganese		0.256		0.931		0.922		0.70		0.39
Mercury	ND <	0.0002	ND <	0.0002	ND <	0.0002	ND <	0.0002		0
Molybdenum	ND <	0.05	ND <	0.05	ND <	0.05	ND <	0.05		0.029
Nickel		0.042		0.078		0.242		0.12		0.11
Selenium	ND <	0.02	ND <	0.02	ND <	0.02	ND <	0.02		0.0058
Vanadium	ND <	0.005	ND <	0.005		0.082		0.029	6%	0.046

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-13. DISSOLVED ELEMENTS IN OUTLET OF POND (LOCATION 10) (mg/L)

Analyte	N-10-PRL-727	N-10-PRL-729	N-10-PRL-731	AVERAGE	DL RATIO	SD
Aluminum	0.17	0.26	0.22	0.22		0.05
Potassium	9.48	10.5	9.47	9.8		0.59
Silicon	4.36	4.56	3.89	4.3		0.34
Sodium	53.3	64.3	67.9	62		7.6
Titanium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01		0.00
Antimony	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04		0.00
Arsenic	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04		0.00
Barium	0.12	0.04	0.07	0.08		0.04
Beryllium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01		0.00
Boron	1.48	1.56	1.86	1.63		0.20
Cadmium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01		0.00
Chromium	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01		0.00
Cobalt	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02		0.00
Copper	ND< 0.01	ND< 0.01	ND< 0.01	ND< 0.01		0.00
Lead	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04		0.00
Manganese	0.19	0.73	ND< 0.24	0.35	11%	0.33
Mercury	ND< 0.02	ND< 0.02	ND< 0.02	ND< 0.02		0.00
Molybdenum	ND< 0.10	ND< 0.10	ND< 0.10	ND< 0.10		0.00
Nickel	ND< 0.02	ND< 0.02	ND< 0.03	ND< 0.02		0.00
Selenium	ND< 0.04	ND< 0.04	ND< 0.04	ND< 0.04		0.00
Vanadium	ND< 0.01	0.01	ND< 0.01	ND< 0.01		0.01

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

5.2 Ammonia and Cyanide

5.2.1 Ammonia and Cyanide in Flue Gas Samples

Tables 5-14 through 5-16 show ammonia (NH₃) and cyanide (CN) results from flue gas samples from Locations 4 and 5a, and from blank samples, respectively. These two species were measured in the gas phase only. In Tables 5-14 through 5-16, all results are shown in micrograms of analyte per normal cubic meter of flue gas ($\mu\text{g}/\text{Nm}^3$). Individual sample results, and the average and standard deviation, are shown.

Large variability was found in both NH₃ and CN levels in flue gas. As a result, it is not possible to reach a conclusion about removal of these species in the ESP.

TABLE 5-14. AMMONIA/CYANIDE IN GAS SAMPLES FROM ESP INLET (LOCATION 4) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-4-NH4-727	N-4-NH4-729	N-4-NH4-731	AVERAGE	DL RATIO	SD
	N-4-CN-727	N-4-CN-729	N-4-CN-731			
Ammonia	79.1	122	52.0	84		35
Cyanide	173	151	710	345		317

DL Ratio = Detection limit ratio.

SD = Standard deviation.

Sample results corrected for train blank.

TABLE 5-15. AMMONIA/CYANIDE IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-NH4-727		N-5a-NH4-729		N-5a-NH4-731		AVERAGE	DL RATIO	SD
	N-5a-CN-727		N-5a-CN-729		N-5a-CN-731				
Ammonia	ND<	1.15	352	ND<	1.21		118	0%	203
Cyanide		115	280		513		303		200

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

TABLE 5-16. AMMONIA/CYANIDE IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

TRAIN BLANK		
N-5a-NH4-725		
Analyte	N-5a-CN-725	
Ammonia	ND <	1.30
Cyanide		3.87

ND < = Not detected, value following ND < is detection limit.
Sample results corrected for field reagent blank.

5.2.2 Ammonia and Cyanide in Liquid Samples

Tables 5-17 and 5-18 show ammonia and cyanide results for samples of make-up water (Location 9), and pond outlet water (Location 10), respectively. All results are in micrograms of analyte per milliliter of sample ($\mu\text{g/ml}$). Tables 5-17 and 5-18 show individual sample results, plus the average and standard deviation. Ammonia was elevated in pond outlet water by over a factor of ten, relative to its concentrations in makeup water. Cyanide was only detected in one sample, and shows no difference between the two water streams.

TABLE 5-17. AMMONIA/CYANIDE IN MAKE-UP WATER (LOCATION 9) ($\mu\text{g/ml}$)

<u>Analyte</u>	<u>N-9-PRL-727</u>	<u>N-9-PRL-729</u>	<u>N-9-PRL-731</u>	<u>AVERAGE</u>	<u>DL RATIO</u>	<u>SD</u>
Ammonia	0.109	0.893	0.597	0.53		0.40
Cyanide	0.080	ND < 0.020	ND < 0.020	0.033	20%	0.040

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-18. AMMONIA/CYANIDE IN OUTLET OF POND (LOCATION 10) ($\mu\text{g/ml}$)

<u>Analyte</u>	<u>N-10-PRL-727</u>	<u>N-10-PRL-729</u>	<u>N-10-PRL-731</u>	<u>AVERAGE</u>	<u>DL RATIO</u>	<u>SD</u>
Ammonia	9.03	10.1	7.97	9.0		1.0
Cyanide	ND < 0.02	ND < 0.02	ND < 0.02	ND < 0.02		0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

5.3 Anions

5.3.1 Anions in Flue Gas Samples

Tables 5-19 through 5-21 show analytical results for gaseous (HCl, HF) and particulate (chloride, fluoride, phosphate, sulfate) species in flue gas streams. Results shown in Tables 5-19 to 5-21 include individual samples, average, and standard deviation, for samples from Locations 4 and 5a, and from blank samples, respectively. In Tables 5-19 to 5-21, all results are in micrograms per normal cubic meter of flue gas ($\mu\text{g}/\text{Nm}^3$).

Tables 5-19 and 5-20 indicate that the great majority of the chloride and fluoride present in flue gas was in the form of the gaseous acids, HCl and HF. The HCl and HF concentrations in the two tables indicate that the ESP is completely ineffective at removing HCl and HF from the flue gas.

Considering the particulate concentrations in Tables 5-19 and 5-20, removal of particulate chloride, fluoride, and sulfate by the ESP is apparently reasonably efficient. Removal efficiencies of 95.0 percent, 95.1 percent, and 76.8 percent for chloride, fluoride, and sulfate, respectively, can be derived based on the average values for these species. The lower removal efficiency for sulfate relative to the other two species may indicate that sulfate is present in smaller particles than are chloride and fluoride. Interestingly, phosphate levels appear to increase across the ESP, though all the phosphate levels shown are quite low.

TABLE 5-19. ANIONS IN GAS SAMPLES FROM ESP INLET (LOCATION 4) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-4-FCL-727	N-4-FCL-729	N-4-FCL-731	AVERAGE	DL RATIO	SD
Hydrogen Chloride	193740	178585	191525	187950		8186
Hydrogen Fluoride	9408	9957	11495	10287		1082
Chloride	280	978.7	617	626		349
Fluoride	229	355	569	385		172
Phosphate	3.77	6.74	10.88	7.1		3.6
Sulfate	88389	95325	80128	87947		7608

DL Ratio = Detection limit ratio.

SD = Standard deviation.

Sample results corrected for train blank.

TABLE 5-20. ANIONS IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-FCL-727	N-5a-FCL-729	N-5a-FCL-731	AVERAGE	DL RATIO	SD
Hydrogen Chloride	221302	218101	218635	219346		1715
Hydrogen Fluoride	12767	15731	16095	14864		1826
Chloride	14.1	39.3	40.2	31		15
Fluoride	8.27	15.9	32.1	19		12.2
Phosphate	ND< 39.0	249	293	187	3%	147
Sulfate	21325	17800	22037	20388		2269

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

TABLE 5-21. ANIONS IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

Analyte	TRAIN BLANK	
	N-5a-FCL-725	
Hydrogen Chloride		26.9
Hydrogen Fluoride		4.83
Chloride		4.89
Fluoride		0.550
Phosphate	ND <	1.83
Sulfate		26.6

ND < = Not detected, value following ND < is detection limit.
Sample results corrected for field reagent blank.

5.3.2 Anions in Solid Samples

Tables 5-22 through 5-25 present analytical results for anionic species (chloride, fluoride, phosphate, sulfate) in samples of boiler feed coal (Location 1), bottom ash (Location 2), air heater ash (Location 3), and ESP ash (Location 8), respectively. All results are in micrograms of analyte per gram of sample ($\mu\text{g/g}$). Shown are results for individual daily composite samples, as well as the average and standard deviation of those results. The composite sample identification numbers, and the procedures for preparing composite samples, are described in Section 3.2.2. Table 5-22 shows anions in boiler feed coal, and lists both total fluoride and chloride (average values from the coal analysis round robin, Appendix B) and soluble fluoride and chloride (from aqueous extraction of pulverized coal). The total anion results are on a dry basis, whereas all other results in Tables 5-22 through 5-25 are on an as-received basis. Note that Table 5-25, parts a through e, show results for composite samples from rows 1 through 5 of the ESP, respectively.

Some interesting trends are evident in these data, in progressing along the flow path from the boiler to the air heater and through the successive ESP rows. For example, chloride predominates over fluoride in coal (Table 5-22), bottom ash (Table 5-23), air heater ash (Table 5-24), and in row 1 ESP ash (Table 5-25a). However, the chloride and fluoride concentrations generally increase in ash from successive ESP hopper rows, and the proportions change. ESP row 3 ash (Table 5-25c) contains about 3 times as much fluoride as chloride and for row 5 ash (Table 5-25e) the two species are about equal in concentration. These variations are probably due to the chemical forms and particle sizes in which these species are present. Sulfate content increases uniformly in successive samples from air heater ash (Table 5-24) through ESP row 5 ash (Table 5-25e), probably due to the increasing proportion of fine sulfate-containing particles collected in these successive ash fractions. Phosphate was detected at significant levels only in row 5 ESP ash (Table 5-25e).

TABLE 5-22. ANIONS IN BOILER FEED COAL (LOCATION 1) ($\mu\text{g/g}$)

Analyte	JL2793BOFED		JL2993BOFED		JL3193BOFED		AVERAGE	DL RATIO	SD
Fluoride (soluble)	0.909		0.804		1.37		1.0		0.30
Fluoride (total) *							81		
Chloride (soluble)	3.37		4.92		3.28		3.9		0.92
Chloride (total) *							1400		
Phosphate	ND <	1.00	ND <	1.00	ND <	1.00	ND <	1.0	0
Sulfate	NA		NA		NA				

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

* Total fluoride and chloride results are averages for Niles coal (samples F and O) from five laboratories in the coal analysis round robin. Total fluoride and chloride are on a dry basis, all others are as received. "Soluble" chloride and fluoride are from aqueous extraction of pulverized coal, which provides an incomplete measurement.

TABLE 5-23. ANIONS IN BOTTOM ASH (LOCATION 2) ($\mu\text{g/g}$)

Analyte	JL2793BOTT		JL2993BOTT		JL3193BOTT		AVERAGE	DL RATIO	SD
Fluoride	ND <	0.100	ND <	0.100	ND <	0.100	ND <	0.10	0
Chloride	3.74		3.59		2.74		3.4		0.54
Phosphate	ND <	0.500	ND <	0.500	ND <	0.500	ND <	0.50	0
Sulfate	38.7		50.5		22.8		37		14

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-24. ANIONS IN AIR HEATER ASH (LOCATION 3) ($\mu\text{g/g}$)

Analyte	JL2793HASH	JL2993HASH	JL3193HASH	AVERAGE	DL RATIO	SD
Fluoride	0.796	1.18	1.50	1.2		0.35
Chloride	11.9	15.9	14.6	14		2.0
Phosphate	2.16	0.486	ND < 0.500	1.0	9%	1.0
Sulfate	1040	972	1460	1157		264

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-25a. ANIONS IN ESP ASH ROW 1 (LOCATION 8) ($\mu\text{g/g}$)

Analyte	JL2793ESP1	JL2993ESP1	JL3193ESP1	AVERAGE	DL RATIO	SD
Fluoride	1.65	2.68	11.0	5.1		5.1
Chloride	14.3	20.9	24.0	20		5.0
Phosphate	ND < 1.00	ND < 1.00	ND < 1.00	ND < 1.0		0
Sulfate	5460	5340	7440	6080		1179

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-25b. ANIONS IN ESP ASH ROW 2 (LOCATION 8) ($\mu\text{g/g}$)

Analyte	JL2793ESP2	JL2993ESP2	JL3193ESP2	AVERAGE	DL RATIO	SD
Fluoride	19.2	13.1	17.9	17		3.2
Chloride	23.4	21.7	2.0	16		12
Phosphate	ND< 5.00	ND< 5.00	ND< 5.00	ND< 5.0		0
Sulfate	35600	35600	39900	37033		2483

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-25c. ANIONS IN ESP ASH ROW 3 (LOCATION 8) ($\mu\text{g/g}$)

Analyte	JL2793ESP3	JL2993ESP3	JL3193ESP3	AVERAGE	DL RATIO	SD
Fluoride	48.2	61.8	49.7	53		7.5
Chloride	9.78	24.7	20.0	18		7.6
Phosphate	ND< 5.00	ND< 5.00	ND< 5.00	ND< 5.0		0
Sulfate	60600	71700	63600	65300		5742

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-25d. ANIONS IN ESP ASH ROW 4 (LOCATION 8) ($\mu\text{g/g}$)

Analyte	JL3193ESP4	
Fluoride		84.8
Chloride		42.9
Phosphate	ND <	5.00
Sulfate		98700

ND < = Not detected, value following ND < is detection limit.

TABLE 5-25e. ANIONS IN ESP ASH ROW 5 (LOCATION 8) ($\mu\text{g/g}$)

Analyte	JL2793ESP5	JL3193ESP5	AVERAGE	DL RATIO	SD
Fluoride	50.7	90.1	70		28
Chloride	70.2	79.7	75		6.7
Phosphate	64.8	91.2	78		19
Sulfate	161000	170000	165500		6364

DL Ratio = Detection limit ratio.

SD = Standard deviation.

5.3.3 Anions in Liquid Samples

Tables 5-26 and 5-27 present analytical results for anions (chloride, fluoride, phosphate, sulfate) in samples of make-up water (Location 9), and pond outlet water (Location 10), respectively. All results are in micrograms of analyte per milliliter of sample ($\mu\text{g}/\text{ml}$). For make-up water (Table 5-26) and pond outlet water (Table 5-27), individual sample results are shown along with the average and standard deviation of those results.

The only significant difference in the two types of water samples is in the sulfate content. Sulfate concentrations in pond outlet water (Table 5-27) are about five times higher than in make-up water (Table 5-26).

TABLE 5-26. ANIONS IN MAKE-UP WATER (LOCATION 9) ($\mu\text{g/ml}$)

Analyte	N-9-PRL-727	N-9-PRL-729	N-9-PRL-731	AVERAGE	DL RATIO	SD
Chloride	40.5	33.9	39.7	38		3.6
Fluoride	0.290	0.360	0.308	0.32		0.036
Phosphate	0.202	0.395	ND < 0.800	ND < 0.80		0.11
Sulfate	54.0	49.4	66.6	57		8.9

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-27. ANIONS IN OUTLET OF POND (LOCATION 10) ($\mu\text{g/ml}$)

Analyte	N-10-PRL-727	N-10-PRL-729	N-10-PRL-731	AVERAGE	DL RATIO	SD
Chloride	41.1	39.3	40.1	40		0.90
Fluoride	0.363	0.357	0.514	0.41		0.089
Phosphate	ND < 0.200	ND < 0.200	ND < 0.800	ND < 0.40		0.35
Sulfate	224	322	310	285		53

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

5.4 Volatile Organic Compounds (VOC)

5.4.1 VOC in Flue Gas Samples

Tables 5-28 through 5-30 present analytical results for VOC in flue gas samples from Locations 4 and 5a, and for blank gas samples, respectively. These results are from VOST sampling for VOC; data from VOC sampling by canisters is presented as a special topic in Section 7.5. In Tables 5-28 through 5-30, each table shows results in micrograms of analyte per normal cubic meter of flue gas ($\mu\text{g}/\text{Nm}^3$). Note that each daily VOST sample shown is the average of three VOST runs that day, i.e., each day's VOST sampling consisted of triplicate runs.

Only a few VOC were detected in flue gas samples. Methylene chloride and acetone were found in the VOST samples at highest concentrations, but the measured levels of these compounds are believed to be due largely to contamination, not to actual flue gas content. Both methylene chloride and acetone were used as solvents for probe rinses in the field, and their presence in the VOST samples at high concentrations is likely due to that source. Footnotes to the tables indicate that fact. Other VOC detected include chloromethane, carbon disulfide, 2-butanone, and benzene. The occasional detected values for these latter species are not thought to arise from contamination, though breakdown of the Tenax sorbent during VOST sampling is always a possibility. In any case, the data do not strongly indicate significant concentrations of VOC in flue gas. The detected values are sparse, but comparison of Tables 5-28 and 5-29 suggests that VOC in flue gas are unaffected by passage through the ESP.

TABLE 5-28. VOC IN GAS SAMPLES FROM ESP INLET (LOCATION 4) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-4-VOS-726	N-4-VOS-728	N-4-VOS-730	AVERAGE	DL RATIO	SD
Chloromethane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Bromomethane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Vinyl Chloride	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Chloroethane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Methylene Chloride*	105	39.3	142	95		52
Acetone*	678	27.6	8.38	238		381
Carbon Disulfide	5.13	ND < 9.51	8.41	ND < 9.5		2.0
1,1-Dichloroethene	50.2	ND < 5.54	ND < 5.16	19	10%	27
1,1-Dichloroethane	ND < 2.13	ND < 5.54	ND < 5.16	ND < 4.3		1.9
Trans-1,2-Dichloroethene	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Chloroform	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
1,2-Dichloroethane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
2-Butanone	13.8	ND < 5.54	ND < 5.16	8.2	28%	6.4
1,1,1-Trichloroethane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Carbon Tetrachloride	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Vinyl Acetate	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Bromodichloromethane	ND < 8.66	ND < 5.54	ND < 5.16	ND < 6.5		1.9
1,2-Dichloropropane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
cis-1,3-Dichloropropylene	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Trichloroethene	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Dibromochloromethane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
1,1,2-Trichloroethane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Benzene	6.96	ND < 9.51	7.69	ND < 9.5		1.5
trans-1,3-Dichloropropylene	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
2-Chloroethylvinylether	ND < 8.66	ND < 5.54	ND < 5.16	ND < 6.5		1.9
Bromoform	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
4-Methyl-2-Pentanone	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
2-Hexanone	ND < 4.83	ND < 5.54	ND < 8.95	ND < 6.4		2.2
Tetrachloroethene	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
1,1,2,2-Tetrachloroethane	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Toluene	ND < 4.52	ND < 9.51	ND < 4.92	ND < 6.3		2.8
Chlorobenzene	ND < 4.83	ND < 5.54	ND < 8.95	ND < 6.4		2.2
Ethylbenzene	ND < 8.66	ND < 5.54	ND < 5.16	ND < 6.5		1.9
Styrene	ND < 4.83	ND < 5.54	ND < 5.16	ND < 5.2		0.35
Xylenes (Total)	ND < 8.66	ND < 5.54	ND < 5.16	ND < 6.5		1.9

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

* Measured values are affected by use of these chemicals as solvents in the field study.

TABLE 5-29. VOC IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-VOS-726	N-5a-VOS-728	N-5a-VOS-730	AVERAGE	DL RATIO	SD
Chloromethane	16.5	ND < 8.83	ND < 7.85	ND < 8.8		7.1
Bromomethane	ND < 8.89	ND < 16.07	ND < 7.85	ND < 11		4.5
Vinyl Chloride	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Chloroethane	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Methylene Chloride*	50.0	35.9	16.0	34		17.1
Acetone*	36.5	17.8	71.4	42		27.2
Carbon Disulfide	ND < 9.01	10.4	14.5	9.8	15%	5.0
1,1-Dichloroethene	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
1,1-Dichloroethane	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Trans-1,2-Dichloroethene	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Chloroform	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
1,2-Dichloroethane	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
2-Butanone	ND < 8.89	17.4	ND < 7.85	8.9	32%	7.6
1,1,1-Trichloroethane	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Carbon Tetrachloride	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Vinyl Acetate	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Bromodichloromethane	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
1,2-Dichloropropane	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
cis-1,3-Dichloropropylene	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Trichloroethene	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Dibromochloromethane	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
1,1,2-Trichloroethane	ND < 8.89	ND < 7.85	ND < 7.85	ND < 8.2		0.60
Benzene	10.3	17.6	11.7	13		3.9
trans-1,3-Dichloropropylene	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
2-Chloroethylvinylether	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Bromoform	ND < 8.89	ND < 7.85	ND < 7.85	ND < 8.2		0.60
4-Methyl-2-Pentanone	ND < 8.89	17.0	ND < 7.85	ND < 8.9		7.4
2-Hexanone	ND < 8.89	31.1	ND < 7.85	13	21%	16
Tetrachloroethene	7.38	ND < 8.83	ND < 7.85	ND < 8.8		1.9
1,1,2,2-Tetrachloroethane	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Toluene	11.7	ND < 7.85	ND < 4.19	ND < 7.9		5.1
Chlorobenzene	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Ethylbenzene	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Styrene	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58
Xylenes (Total)	ND < 8.89	ND < 8.83	ND < 7.85	ND < 8.5		0.58

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

* Measured values are affected by use of these chemicals as solvents in the field study.

TABLE 5-30. VOC IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

Chloromethane	ND <	3.21
Bromomethane	ND <	3.21
Vinyl Chloride	ND <	3.21
Chloroethane	ND <	3.21
Methylene Chloride*		22.4
Acetone*		24.3
Carbon Disulfide	ND <	3.21
1,1-Dichloroethene	ND <	3.21
1,1-Dichloroethane	ND <	3.21
Trans-1,2-Dichloroethene	ND <	3.21
Chloroform	ND <	3.21
1,2-Dichloroethane	ND <	3.21
2-Butanone	ND <	3.21
1,1,1-Trichloroethane	ND <	3.21
Carbon Tetrachloride	ND <	3.21
Vinyl Acetate	ND <	3.21
Bromodichloromethane	ND <	3.21
1,2-Dichloropropane	ND <	3.21
cis-1,3-Dichloropropylene	ND <	3.21
Trichloroethene	ND <	3.21
Dibromochloromethane	ND <	3.21
1,1,2-Trichloroethane	ND <	3.21
Benzene	ND <	3.21
trans-1,3-Dichloropropylene	ND <	3.21
2-Chloroethylvinylether	ND <	3.21
Bromoform	ND <	3.21
4-Methyl-2-Pentanone	ND <	3.21
2-Hexanone	ND <	3.21
Tetrachloroethene	ND <	3.21
1,1,2,2-Tetrachloroethane	ND <	3.21
Toluene	ND <	3.21
Chlorobenzene	ND <	3.21
Ethylbenzene	ND <	3.21
Styrene	ND <	3.21
Xylenes (Total)	ND <	3.21

ND < = Not detected, value following ND < is detection limit.

Sample results not corrected for train blank values.

Assumes gas sample volume of $.0079 \text{ Nm}^3$.

* Blank values are affected by the use of these chemicals as solvents in the field study.

5.4.2 VOC in Liquid Samples

Tables 5-31 through 5-33 present analytical results for VOC in make-up water (Location 9), pond outlet water (Location 10), and blank samples, respectively. All results are in micrograms of analyte per liter of sample ($\mu\text{g/L}$). Tables 5-31 and 5-32 show results for individual samples, and the average and standard deviation of those results. None of the target VOC were detected in any of the water samples.

TABLE 5-31. VOC IN MAKE-UP WATER (LOCATION 9) (µg/L)

Analyte	N-9-PRL-726	N-9-PRL-728	N-9-PRL-730	AVERAGE	DL RATIO	SD
Acrylonitrile	ND< 10	ND< 10	ND< 10	ND< 10		0
Benzene	ND< 5	ND< 5	ND< 5	ND< 5		0
Bromomethane	ND< 5	ND< 5	ND< 5	ND< 5		0
Bromoform	ND< 5	ND< 5	ND< 5	ND< 5		0
2-Butanone	ND< 50	ND< 50	ND< 50	ND< 50		0
Carbon disulfide	ND< 10	ND< 10	ND< 10	ND< 10		0
Carbon tetrachloride	ND< 5	ND< 5	ND< 5	ND< 5		0
Chlorobenzene	ND< 5	ND< 5	ND< 5	ND< 5		0
Chloroethane	ND< 5	ND< 5	ND< 5	ND< 5		0
Chloromethane	ND< 5	ND< 5	ND< 5	ND< 5		0
Chloroprene	ND< 5	ND< 5	ND< 5	ND< 5		0
Cumene	ND< 5	ND< 5	ND< 5	ND< 5		0
1,2-Dibromoethane	ND< 5	ND< 5	ND< 5	ND< 5		0
1,1-Dichloroethane	ND< 5	ND< 5	ND< 5	ND< 5		0
1,2-Dichloroethane	ND< 5	ND< 5	ND< 5	ND< 5		0
<i>cis</i> -1,3-Dichloropropylene	ND< 5	ND< 5	ND< 5	ND< 5		0
<i>trans</i> -1,3-Dichloropropylene	ND< 5	ND< 5	ND< 5	ND< 5		0
1,4-Dioxane	ND< 50	ND< 50	ND< 50	ND< 50		0
Ethylbenzene	ND< 5	ND< 5	ND< 5	ND< 5		0
Iodomethane	ND< 5	ND< 5	ND< 5	ND< 5		0
Methylene chloride	ND< 5	ND< 5	ND< 5	ND< 5		0
Methyl methacrylate	ND< 10	ND< 10	ND< 10	ND< 10		0
4-Methyl-2-pentanone	ND< 10	ND< 10	ND< 10	ND< 10		0
Styrene	ND< 5	ND< 5	ND< 5	ND< 5		0
Toluene	ND< 5	ND< 5	ND< 5	ND< 5		0
1,1,1-Trichloroethane	ND< 5	ND< 5	ND< 5	ND< 5		0
1,1,2-Trichloroethane	ND< 5	ND< 5	ND< 5	ND< 5		0
Trichloroethylene	ND< 5	ND< 5	ND< 5	ND< 5		0
Vinyl acetate	ND< 10	ND< 10	ND< 10	ND< 10		0
Vinyl bromide	ND< 5	ND< 5	ND< 5	ND< 5		0
Vinyl chloride	ND< 5	ND< 5	ND< 5	ND< 5		0
<i>o</i> -Xylene	ND< 5	ND< 5	ND< 5	ND< 5		0
<i>m</i> + <i>p</i> -Xylene	ND< 10	ND< 10	ND< 10	ND< 10		0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-32. VOC IN OUTLET OF POND (LOCATION 10) (µg/L)

Analyte	N-10-PRL-726		N-10-PRL-728		N-10-PRL-730		AVERAGE	DL RATIO	SD
Acrylonitrile	ND<	10	ND<	10	ND<	10	ND<	10	0
Benzene	ND<	5	ND<	5	ND<	5	ND<	5	0
Bromomethane	ND<	5	ND<	5	ND<	5	ND<	5	0
Bromoform	ND<	5	ND<	5	ND<	5	ND<	5	0
2-Butanone	ND<	50	ND<	50	ND<	50	ND<	50	0
Carbon disulfide	ND<	10	ND<	10	ND<	10	ND<	10	0
Carbon tetrachloride	ND<	5	ND<	5	ND<	5	ND<	5	0
Chlorobenzene	ND<	5	ND<	5	ND<	5	ND<	5	0
Chloroethane	ND<	5	ND<	5	ND<	5	ND<	5	0
Chloromethane	ND<	5	ND<	5	ND<	5	ND<	5	0
Chloroprene	ND<	5	ND<	5	ND<	5	ND<	5	0
Cumene	ND<	5	ND<	5	ND<	5	ND<	5	0
1,2-Dibromoethane	ND<	5	ND<	5	ND<	5	ND<	5	0
1,1-Dichloroethane	ND<	5	ND<	5	ND<	5	ND<	5	0
1,2-Dichloroethane	ND<	5	ND<	5	ND<	5	ND<	5	0
cis-1,3-Dichloropropylene	ND<	5	ND<	5	ND<	5	ND<	5	0
trans-1,3-Dichloropropylene	ND<	5	ND<	5	ND<	5	ND<	5	0
1,4-Dioxane	ND<	50	ND<	50	ND<	50	ND<	50	0
Ethylbenzene	ND<	5	ND<	5	ND<	5	ND<	5	0
Iodomethane	ND<	5	ND<	5	ND<	5	ND<	5	0
Methylene chloride	ND<	5	ND<	5	ND<	5	ND<	5	0
Methyl methacrylate	ND<	10	ND<	10	ND<	10	ND<	10	0
4-Methyl-2-pentanone	ND<	10	ND<	10	ND<	10	ND<	10	0
Styrene	ND<	5	ND<	5	ND<	5	ND<	5	0
Toluene	ND<	5	ND<	5	ND<	5	ND<	5	0
1,1,1-Trichloroethane	ND<	5	ND<	5	ND<	5	ND<	5	0
1,1,2-Trichloroethane	ND<	5	ND<	5	ND<	5	ND<	5	0
Trichloroethylene	ND<	5	ND<	5	ND<	5	ND<	5	0
Vinyl acetate	ND<	10	ND<	10	ND<	10	ND<	10	0
Vinyl bromide	ND<	5	ND<	5	ND<	5	ND<	5	0
Vinyl chloride	ND<	5	ND<	5	ND<	5	ND<	5	0
o-Xylene	ND<	5	ND<	5	ND<	5	ND<	5	0
m+p-Xylene	ND<	10	ND<	10	ND<	10	ND<	10	0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-33. VOC IN LIQUID BLANK SAMPLES ($\mu\text{g/L}$)

Analyte	TRIP BLANK	FIELD BLANK
Acrylonitrile	ND < 10	ND < 10
Benzene	ND < 5	ND < 5
Bromomethane	ND < 5	ND < 5
Bromoform	ND < 5	ND < 5
2-Butanone	ND < 50	ND < 50
Carbon disulfide	ND < 10	ND < 10
Carbon tetrachloride	ND < 5	ND < 5
Chlorobenzene	ND < 5	ND < 5
Chloroethane	ND < 5	ND < 5
Chloromethane	ND < 5	ND < 5
Chloroprene	ND < 5	ND < 5
Cumene	ND < 5	ND < 5
1,2-Dibromoethane	ND < 5	ND < 5
1,1-Dichloroethane	ND < 5	ND < 5
1,2-Dichloroethane	ND < 5	ND < 5
cis-1,3-Dichloropropylene	ND < 5	ND < 5
trans-1,3-Dichloropropylene	ND < 5	ND < 5
1,4-Dioxane	ND < 50	ND < 50
Ethylbenzene	ND < 5	ND < 5
Iodomethane	ND < 5	ND < 5
Methylene chloride	ND < 5	ND < 5
Methyl methacrylate	ND < 10	ND < 10
4-Methyl-2-pentanone	ND < 10	ND < 10
Styrene	ND < 5	ND < 5
Toluene	ND < 5	ND < 5
1,1,1-Trichloroethane	ND < 5	ND < 5
1,1,2-Trichloroethane	ND < 5	ND < 5
Trichloroethylene	ND < 5	ND < 5
Vinyl acetate	ND < 10	ND < 10
Vinyl bromide	ND < 5	ND < 5
Vinyl chloride	ND < 5	ND < 5
<i>o</i> -Xylene	ND < 5	ND < 5
<i>m</i> + <i>p</i> -Xylene	ND < 10	ND < 10

ND < = Not detected, value following ND < is detection limit.

5.5 PAH/SVOC

5.5.1 PAH/SVOC in Flue Gas Samples

Tables 5-34 through 5-36 show results for PAH/SVOC in flue gas samples from Locations 4 and 5a, and in blank samples, respectively. Individual results plus the average and standard deviation are shown. In Tables 5-34 to 5-36, the results are presented in nanograms of analyte per normal cubic meter of flue gas (ng/Nm³).

Several PAH/SVOC were detected at both sampling locations. For most compounds detected, concentrations at Location 5a are lower than or about equal to those at Location 4. This result indicates partial to no removal of these compounds in the ESP, consistent with the predominance of these compounds in the vapor phase (see Section 7.2). Those PAH expected to be predominantly in the particle phase were generally not detected, so no conclusion can be reached about removal in the ESP. However, for a few SVOC compounds (e.g., acetophenone and 2,6-dinitrotoluene) concentrations increased between Location 4 (Table 5-34) and Location 5a (Table 5-35). This result suggests that production of these compounds may be occurring in the hot flue gas. An alternative explanation for the presence of acetophenone and 2,6-dinitrotoluene is degradation or contamination of the sampling materials, since both compounds were found in the train blank (Table 5-36). However, these compounds were also found in solid samples (see Section 5.5.2), for which such issues are not pertinent. Furthermore, laboratory method blanks did not show these compounds. Thus there is strong evidence that these SVOC were present in the flue gas.

TABLE 5-34. PAH/SVOC IN GAS SAMPLES FROM ESP INLET (LOCATION 4) (ng/Nm³)

Analyte	N-4-MM5- F+X-726	N-4-MM5- F+X-728	N-4-MM5- F+X-730	AVERAGE	DL RATIO	SD
Benzylchloride	ND< 8.70	ND< 12.7	ND< 13.0	ND< 11		2.4
Acetophenone	672	43.4	71.4	262		355
Hexachloroethane	ND< 8.70	ND< 12.7	ND< 13.0	ND< 11		2.4
Naphthalene	224	10.5	15.0	83		122
Hexachlorobutadiene	ND< 8.70	ND< 12.7	ND< 13.0	ND< 11		2.4
2-Chloroacetophenone	103	130	440	224		188
2-Methylnaphthalene	57.4	32.5	49.3	46		13
1-Methylnaphthalene	29.9	14.1	13.9	19		9.2
Hexachlorocyclopentadiene	ND< 8.70	ND< 12.7	ND< 13.0	ND< 11		2.4
Biphenyl	249	304	87.8	214		112
Acenaphthylene	4.95	18.7	46.9	24		21
2,6-Dinitrotoluene	111	115	45.8	91		39
Acenaphthene	22.1	43.4	83.0	49		31
Dibenzofuran	416	757	135	436		312
2,4-Dinitrotoluene	46.6	77.1	43.5	56		19
Fluorene	148	252	27.9	143		112
Hexachlorobenzene	ND< 8.70	ND< 12.7	ND< 13.0	ND< 11		2.4
Pentachlorophenol	ND< 8.70	ND< 12.7	ND< 13.0	ND< 11		2.4
Phenanthrene	374	602	121	366		241
Anthracene	34.4	36.3	29.6	33		3.4
Fluoranthene	91.2	106	49.1	82		29
Pyrene	23.7	31.5	11.1	22		10
Benz(a)anthracene	6.49	37.1	95.5	46		45
Chrysene	31.2	60.8	84.6	59		27
Benzo(b & k)fluoranthene	5.65	8.88	3.63	6.1		2.6
Benzo(e)pyrene	ND< 1.74	ND< 2.54	ND< 2.61	ND< 2.3		0.48
Benzo(a)pyrene	ND< 1.74	ND< 2.54	ND< 2.61	ND< 2.3		0.48
Indeno(1,2,3-c,d)pyrene	ND< 1.74	ND< 2.54	ND< 2.61	ND< 2.3		0.48
Dibenz(a,h)anthracene	ND< 1.74	ND< 2.54	ND< 2.61	ND< 2.3		0.48
Benzo(g,h,i)perylene	ND< 1.74	ND< 2.54	ND< 2.61	ND< 2.3		0.48

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

The reported F+X data (ng/Nm³) were the sum of the corrected filter data and the corrected XAD-2 data.

The corrected filter and XAD-2 data were obtained by dividing the corrected total amount (ng) with the corresponding sample volume (Nm³).

TABLE 5-35. PAH/SVOC IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) (ng/Nm³)

Analyte	N-5a-MM5- F+X-726	N-5a-MM5- F+X-728	N-5a-MM5- F+X-730	AVERAGE	DL RATIO	SD
Benzylchloride	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Acetophenone	1518	1223	493 E	1078		528
Hexachloroethane	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Naphthalene	526	395	174 E	365		178
Hexachlorobutadiene	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
2-Chloroacetophenone	792	588	92.7	491		360
2-Methylnaphthalene	136	37.3	18.4	64		63
1-Methylnaphthalene	56.2	17.4	6.78	27		26
Hexachlorocyclopentadiene	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Biphenyl	102	494	44.7	213		245
Acenaphthylene	30.3	ND < 5.75	1.58	ND < 5.8		16
2,6-Dinitrotoluene	1135	851	808 E	931		178
Acenaphthene	111	22.9	2.29	45		58
Dibenzofuran	212	75.2	46.0	111		89
2,4-Dinitrotoluene	51.0	ND < 28.8	33.6	ND < 29		18
Fluorene	125	21.2	13.8	53		62
Hexachlorobenzene	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Pentachlorophenol	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Phenanthrene	267	93.1	36.4	132		120
Anthracene	91.0	12.0	3.28	35		48
Fluoranthene	79.2	42.1	16.5	46		32
Pyrene	42.8	23.7	4.77	24		19
Benz(a)anthracene	13.9	ND < 5.75	1.97	6.2	15%	6.6
Chrysene	31.8	8.04	5.74	15		14
Benzo(b & k)fluoranthene	31.5	ND < 5.75	1.79	ND < 5.8		17
Benzo(e)pyrene	7.90	ND < 5.75	ND < 0.520	ND < 5.8		3.9
Benzo(a)pyrene	ND < 5.88	ND < 5.75	ND < 0.520	ND < 4.1		3.1
Indeno(1,2,3-c,d)pyrene	ND < 5.88	ND < 5.75	ND < 0.520	ND < 4.1		3.1
Dibenz(a,h)anthracene	ND < 5.88	ND < 5.75	ND < 0.520	ND < 4.1		3.1
Benzo(g,h,i)perylene	ND < 5.88	ND < 5.75	ND < 0.520	ND < 4.1		3.1

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

The reported F+X data (ng/Nm³) were the sum of the corrected filter data and the corrected XAD-2 data.

The corrected filter and XAD-2 data were obtained by dividing the corrected total amount (ng) with the corresponding sample volume (Nm³).

TABLE 5-36. PAH/SVOC IN BLANK GAS SAMPLES (ng/Nm³)

Analyte	N-5a-MM5-		TRAIN BLANK	
	F-725	X-725	N-5a-MM5-	F+X-725
Benzylchloride	ND<	2.80	ND<	2.80
Acetophenone		25.3		111
Hexachloroethane	ND<	2.80	ND<	2.80
Naphthalene		3.29		123
Hexachlorobutadiene	ND<	2.80	ND<	2.80
2-Chloroacetophenone	ND<	2.80		51.4
2-Methylnaphthalene		2.75		6.38
1-Methylnaphthalene		1.28		2.91
Hexachlorocyclopentadiene	ND<	2.80	ND<	2.80
Biphenyl		0.84		1.51
Acenaphthylene	ND<	0.56		0.60
2,6-Dinitrotoluene		35.2		21.8
Acenaphthene		1.46		4.08
Dibenzofuran	ND<	2.80		4.51
2,4-Dinitrotoluene	ND<	2.80	ND<	2.80
Fluorene		2.11		4.00
Hexachlorobenzene	ND<	2.80	ND<	2.80
Pentachlorophenol	ND<	2.80	ND<	2.80
Phenanthrene		7.28		17.6
Anthracene	ND<	0.56		1.60
Fluoranthene		2.32		7.92
Pyrene		0.86		2.83
Benz(a)anthracene	ND<	0.56	ND<	0.56
Chrysene		0.56		1.02
Benzo(b & k)fluoranthene		0.63		0.93
Benzo(e)pyrene	ND<	0.56	ND<	0.56
Benzo(a)pyrene	ND<	0.56	ND<	0.56
Indeno(1,2,3-c,d)pyrene	ND<	0.56	ND<	0.56
Dibenz(a,h)anthracene	ND<	0.56	ND<	0.56
Benzo(g,h,i)perylene	ND<	0.56	ND<	0.56

ND< = Not detected, value following ND< is detection limit.
 Sample results corrected for field reagent blank.

5.5.2 PAH/SVOC in Solid Samples

Tables 5-37 through 5-39 show PAH/SVOC results in samples of bottom ash (Location 2), air heater ash (Location 3), and ESP ash (Location 8), respectively. All results are in nanograms of analyte per gram of sample (ng/g). Note that Table 5-39 consists of five parts (a-e), corresponding to samples from ESP hopper rows 1 through 5, respectively.

Most of the PAH/SVOC were detected in at least some of the solid samples. Most of the detected species were present at average levels of about 1 ng/g or less. Of the few species present at higher levels, 2,6-dinitrotoluene and biphenyl were the most prevalent, especially in the ESP ash (Table 5-39). Considerable variability was observed in PAH/SVOC concentrations. Laboratory method blanks for PAH/SVOC were clean, indicating that the presence of 2,6-dinitrotoluene and other compounds was not due to contamination.

TABLE 5-37. PAH/SVOC IN BOTTOM ASH (LOCATION 2) (ng/g)

Analyte	JL2693BOTT	JL2893BOTT	JL3093BOTT	AVERAGE	DL RATIO	SD
Benzylchloride	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Acetophenone	0.369	1.00	0.424	0.60		0.35
Hexachloroethane	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Naphthalene	3.16	1.68	5.38	3.4		1.9
Hexachlorobutadiene	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
2-Chloroacetophenone	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
2-Methylnaphthalene	4.05	2.19	8.55	4.9		3.3
1-Methylnaphthalene	3.05	1.19	6.58	3.6		2.7
Hexachlorocyclopentadiene	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Biphenyl	1.00	0.251	2.20	1.2		0.98
Acenaphthylene	0.192	0.0910	0.367	0.22		0.14
2,6-Dinitrotoluene	13.5	5.63	5.09	8.1		4.7
Acenaphthene	0.544	0.325	0.685	0.52		0.18
Dibenzofuran	1.58	1.23	3.30	2.0		1.1
2,4-Dinitrotoluene	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Fluorene	1.24	1.34	3.05	1.9		1.0
Hexachlorobenzene	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Pentachlorophenol	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Phenanthrene	3.95	2.01	9.06	5.0		3.6
Anthracene	0.856	0.451	1.90	1.1		0.75
Fluoranthene	1.14	0.921	3.39	1.8		1.4
Pyrene	0.928	0.665	2.82	1.5		1.2
Benz(a)anthracene	0.791	0.428	2.10	1.1		0.88
Chrysene	1.08	0.531	2.68	1.4		1.1
Benzo(b & k)fluoranthene	0.855	0.606	2.66	1.4		1.1
Benzo(e)pyrene	0.572	0.415	1.72	0.90		0.71
Benzo(a)pyrene	0.740	0.398	2.16	1.1		0.94
Indeno(1,2,3-c,d)pyrene	0.401	0.272	1.45	0.71		0.65
Dibenz(a,h)anthracene	0.302	0.165	1.08	0.52		0.49
Benzo(g,h,i)perylene	1.05	0.606	3.15	1.6		1.4

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-38. PAH/SVOC IN AIR HEATER ASH (LOCATION 3) (ng/g)

Analyte	JL2693HASH	JL2893HASH	JL3093HASH	AVERAGE	DL RATIO	SD
Benzylchloride	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Acetophenone	1.21	1.98	0.989	1.4		0.52
Hexachloroethane	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Naphthalene	4.89	15.7	6.20	8.9		5.9
Hexachlorobutadiene	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
2-Chloroacetophenone	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
2-Methylnaphthalene	1.08	1.96	1.01	1.3		0.53
1-Methylnaphthalene	0.545	1.11	0.511	0.72		0.34
Hexachlorocyclopentadiene	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Biphenyl	2.23	14.9	5.34	7.5		6.6
Acenaphthylene	0.0530	0.299	0.0770	0.14		0.14
2,6-Dinitrotoluene	9.13	34.8	8.31	17		15
Acenaphthene	0.205	0.643	0.348	0.40		0.22
Dibenzofuran	0.596	2.16	1.02	1.3		0.81
2,4-Dinitrotoluene	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Fluorene	1.02	5.29	1.33	2.5		2.4
Hexachlorobenzene	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Pentachlorophenol	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Phenanthrene	0.539	3.19	0.821	1.5		1.5
Anthracene	0.0860	0.514	0.183	0.26		0.22
Fluoranthene	0.347	1.77	0.412	0.84		0.80
Pyrene	0.182	0.768	0.223	0.39		0.33
Benz(a)anthracene	ND< 0.050	0.123	ND< 0.050	0.058	29%	0.057
Chrysene	0.072	0.177	0.0830	0.11		0.058
Benzo(b & k)fluoranthene	0.085	0.143	0.0720	0.10		0.038
Benzo(e)pyrene	ND< 0.050	ND< 0.10	0.105	ND< 0.10		0.041
Benzo(a)pyrene	ND< 0.050	ND< 0.10	0.0880	ND< 0.10		0.032
Indeno(1,2,3-c,d)pyrene	ND< 0.050	ND< 0.10	0.0640	ND< 0.10		0.020
Dibenz(a,h)anthracene	ND< 0.050	ND< 0.10	ND< 0.050	ND< 0.067		0.029
Benzo(g,h,i)perylene	ND< 0.050	0.105	0.192	0.11	8%	0.084

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-39a. PAH/SVOC IN ESP ASH ROW 1 (LOCATION 8) (ng/g)

Analyte	JL2693ESP1	JL2893ESP1	JL3093ESP1	AVERAGE	DL RATIO	SD
Benzylchloride	ND< 0.25	ND< 0.25	ND< 0.25	ND< 0.25		0
Acetophenone	0.592	1.07	0.341	0.67		0.37
Hexachloroethane	ND< 0.25	ND< 0.25	ND< 0.25	ND< 0.25		0
Naphthalene	2.28	2.70	1.14	2.0		0.81
Hexachlorobutadiene	ND< 0.25	ND< 0.25	ND< 0.25	ND< 0.25		0
2-Chloroacetophenone	ND< 0.25	ND< 0.25	ND< 0.25	ND< 0.25		0
2-Methylnaphthalene	1.37	1.25	0.788	1.1		0.31
1-Methylnaphthalene	0.636	0.546	0.291	0.49		0.18
Hexachlorocyclopentadiene	ND< 0.25	ND< 0.25	ND< 0.25	ND< 0.25		0
Biphenyl	0.610	5.70	1.01	2.4		2.8
Acenaphthylene	ND< 0.05	0.0810	0.0740	0.060	14%	0.031
2,6-Dinitrotoluene	20.5	4.30	7.36	11		8.6
Acenaphthene	0.253	0.211	0.334	0.27		0.063
Dibenzofuran	0.598	0.723	0.678	0.67		0.063
2,4-Dinitrotoluene	ND< 0.25	ND< 0.25	ND< 0.25	ND< 0.25		0
Fluorene	2.88	0.640	1.19	1.6		1.2
Hexachlorobenzene	ND< 0.25	ND< 0.25	ND< 0.25	ND< 0.25		0
Pentachlorophenol	ND< 0.25	ND< 0.25	ND< 0.25	ND< 0.25		0
Phenanthrene	0.725	0.939	0.967	0.88		0.13
Anthracene	0.147	0.181	0.153	0.16		0.018
Fluoranthene	0.350	0.547	0.553	0.48		0.12
Pyrene	0.196	0.322	0.190	0.24		0.075
Benz(a)anthracene	ND< 0.05	0.08	ND< 0.05	ND< 0.05		0.029
Chrysene	0.080	0.126	ND< 0.05	0.077	11%	0.051
Benzo(b & k)fluoranthene	0.096	0.147	ND< 0.05	0.089	9%	0.061
Benzo(e)pyrene	ND< 0.05	0.0660	ND< 0.05	ND< 0.05		0.024
Benzo(a)pyrene	ND< 0.05	0.0870	ND< 0.05	ND< 0.05		0.036
Indeno(1,2,3-c,d)pyrene	0.06	0.0550	ND< 0.05	ND< 0.05		0.020
Dibenz(a,h)anthracene	ND< 0.05	ND< 0.05	0.0880	ND< 0.05		0.036
Benzo(g,h,i)perylene	ND< 0.05	0.0540	ND< 0.05	ND< 0.05		0.017

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-39b. PAH/SVOC IN ESP ASH ROW 2 (LOCATION 8) (ng/g)

Analyte	JL2693ESP2	JL2893ESP2	JL3093ESP2	AVERAGE	DL RATIO	SD
Benzylchloride	ND < 0.50	ND < 0.25	ND < 0.25	ND < 0.33		0.14
Acetophenone	2.68	1.12	1.06	1.6		0.92
Hexachloroethane	ND < 0.50	ND < 0.25	ND < 0.25	ND < 0.33		0.14
Naphthalene	3.91	1.71	3.19	2.9		1.1
Hexachlorobutadiene	ND < 0.50	ND < 0.25	ND < 0.25	ND < 0.33		0.14
2-Chloroacetophenone	ND < 0.50	ND < 0.25	ND < 0.25	ND < 0.33		0.14
2-Methylnaphthalene	3.86	0.917	1.69	2.2		1.5
1-Methylnaphthalene	2.09	0.543	0.98	1.2		0.80
Hexachlorocyclopentadiene	ND < 0.50	ND < 0.25	ND < 0.25	ND < 0.33		0.14
Biphenyl	2.39	84.4	15.2	34		44
Acenaphthylene	0.29	0.12	0.08	0.16		0.11
2,6-Dinitrotoluene	28.9	1.22	3.23	11		15
Acenaphthene	0.78	0.253	0.305	0.45		0.29
Dibenzofuran	2.62	2.05	1.80	2.2		0.42
2,4-Dinitrotoluene	ND < 0.50	ND < 0.25	ND < 0.25	ND < 0.33		0.14
Fluorene	1.94	0.917	1.22	1.4		0.53
Hexachlorobenzene	ND < 0.50	ND < 0.25	ND < 0.25	ND < 0.33		0.14
Pentachlorophenol	ND < 0.50	ND < 0.25	ND < 0.25	ND < 0.33		0.14
Phenanthrene	4.83	1.55	0.809	2.4		2.1
Anthracene	0.553	0.204	0.118	0.29		0.23
Fluoranthene	1.84	0.545	0.500	0.96		0.76
Pyrene	0.989	0.210	0.189	0.46		0.46
Benz(a)anthracene	0.273	ND < 0.05	ND < 0.05	0.11	15%	0.14
Chrysene	0.240	0.0650	0.05	0.12		0.10
Benzo(b & k)fluoranthene	0.350	0.080	ND < 0.05	0.15	5%	0.17
Benzo(e)pyrene	ND < 0.10	ND < 0.05	ND < 0.05	ND < 0.067		0.029
Benzo(a)pyrene	0.136	ND < 0.05	ND < 0.05	0.062	27%	0.064
Indeno(1,2,3-c,d)pyrene	ND < 0.10	ND < 0.05	ND < 0.05	ND < 0.067		0.029
Dibenz(a,h)anthracene	0.143	ND < 0.05	ND < 0.05	0.064	26%	0.068
Benzo(g,h,i)perylene	ND < 0.10	ND < 0.05	ND < 0.05	ND < 0.067		0.029

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-39c. PAH/SVOC IN ESP ASH ROW 3 (LOCATION 8) (ng/g)

Analyte	JL2693ESP3	JL2893ESP3	JL3093ESP3	AVERAGE	DL RATIO	SD
Benzylchloride	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Acetophenone	0.736	2.34	0.402	1.2		1.0
Hexachloroethane	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Naphthalene	1.31	8.82	1.29	3.8		4.3
Hexachlorobutadiene	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
2-Chloroacetophenone	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
2-Methylnaphthalene	1.03	10.8	1.32	4.4		5.6
1-Methylnaphthalene	0.531	8.87	0.955	3.5		4.7
Hexachlorocyclopentadiene	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Biphenyl	37.3	243	40.2	107		118
Acenaphthylene	0.166	1.43	0.349	0.65		0.68
2,6-Dinitrotoluene	1.54	84.8	3.79	30		47
Acenaphthene	0.218	3.27	0.529	1.3		1.7
Dibenzofuran	1.90	ND< 0.50	3.32	1.8	5%	1.5
2,4-Dinitrotoluene	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Fluorene	0.701	5.50	0.890	2.4		2.7
Hexachlorobenzene	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Pentachlorophenol	ND< 0.25	ND< 0.50	ND< 0.25	ND< 0.33		0.14
Phenanthrene	1.72	7.04	2.22	3.7		2.9
Anthracene	0.225	2.24	0.300	0.92		1.1
Fluoranthene	0.455	4.85	1.13	2.1		2.4
Pyrene	0.173	2.16	0.318	0.88		1.1
Benz(a)anthracene	ND< 0.05	0.424	ND< 0.05	0.16	11%	0.23
Chrysene	0.0540	0.553	0.144	0.25		0.27
Benzo(b & k)fluoranthene	ND< 0.05	0.592	ND< 0.05	0.21	8%	0.33
Benzo(e)pyrene	ND< 0.05	0.108	ND< 0.05	0.053	32%	0.048
Benzo(a)pyrene	ND< 0.05	0.234	0.0550	0.10	8%	0.11
Indeno(1,2,3-c,d)pyrene	ND< 0.05	0.116	ND< 0.05	0.055	30%	0.053
Dibenz(a,h)anthracene	ND< 0.05	ND< 0.10	ND< 0.05	ND< 0.067		0.029
Benzo(g,h,i)perylene	ND< 0.05	0.125	ND< 0.05	0.058	29%	0.058

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-39d. PAH/SVOC IN ESP ASH ROW 4 (LOCATION 8) (ng/g)

Analyte	JL2893ESP4	JL3093ESP4	AVERAGE	DL RATIO	SD
Benzylchloride	ND< 0.25	ND< 0.55	ND< 0.40		0.21
Acetophenone	0.873	1.65	1.3		0.55
Hexachloroethane	ND< 0.25	ND< 0.55	ND< 0.40		0.21
Naphthalene	2.49	1.74	2.1		0.53
Hexachlorobutadiene	ND< 0.25	ND< 0.55	ND< 0.40		0.21
2-Chloroacetophenone	ND< 0.25	ND< 0.55	ND< 0.40		0.21
2-Methylnaphthalene	3.74	2.67	3.2		0.76
1-Methylnaphthalene	1.88	1.01	1.4		0.62
Hexachlorocyclopentadiene	ND< 0.25	ND< 0.55	ND< 0.40		0.21
Biphenyl	0.605	1.11	0.86		0.36
Acenaphthylene	0.121	0.226	0.17		0.074
2,6-Dinitrotoluene	5.78	88.0	47		58
Acenaphthene	0.392	0.832	0.61		0.31
Dibenzofuran	1.69	1.98	1.8		0.21
2,4-Dinitrotoluene	ND< 0.25	ND< 0.55	ND< 0.40		0.21
Fluorene	1.59	2.53	2.1		0.66
Hexachlorobenzene	ND< 0.25	ND< 0.55	ND< 0.40		0.21
Pentachlorophenol	ND< 0.25	ND< 0.55	ND< 0.40		0.21
Phenanthrene	2.11	2.99	2.6		0.62
Anthracene	0.241	0.437	0.34		0.14
Fluoranthene	0.541	1.28	0.91		0.52
Pyrene	0.252	0.686	0.47		0.31
Benz(a)anthracene	ND< 0.05	ND< 0.11	ND< 0.08		0.042
Chrysene	ND< 0.05	0.369	0.197	6%	0.24
Benzo(b & k)fluoranthene	ND< 0.05	0.111	0.068	18%	0.061
Benzo(e)pyrene	ND< 0.05	ND< 0.11	ND< 0.08		0.042
Benzo(a)pyrene	ND< 0.05	ND< 0.11	ND< 0.08		0.042
Indeno(1,2,3-c,d)pyrene	ND< 0.05	ND< 0.11	ND< 0.08		0.042
Dibenz(a,h)anthracene	ND< 0.05	ND< 0.11	ND< 0.08		0.042
Benzo(g,h,i)perylene	ND< 0.05	ND< 0.11	ND< 0.08		0.042

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-39e. PAH/SVOC IN ESP ASH ROW 5 (LOCATION 8) (ng/g)

Analyte	JL2693ESP5	JL3093ESP5	AVERAGE	DL RATIO	SD
Benzylchloride	ND < 0.25	ND < 0.47	ND < 0.36		0.16
Acetophenone	0.937	2.20	1.6		0.89
Hexachloroethane	ND < 0.25	ND < 0.47	ND < 0.36		0.16
Naphthalene	1.45	2.51	2.0		0.75
Hexachlorobutadiene	ND < 0.25	ND < 0.47	ND < 0.36		0.16
2-Chloroacetophenone	ND < 0.25	ND < 0.47	ND < 0.36		0.16
2-Methylnaphthalene	1.49	2.24	1.9		0.53
1-Methylnaphthalene	0.723	1.18	0.95		0.32
Hexachlorocyclopentadiene	ND < 0.25	ND < 0.47	ND < 0.36		0.16
Biphenyl	3.32	0.637	2.0		1.9
Acenaphthylene	0.129	0.204	0.17		0.053
2,6-Dinitrotoluene	1.83	69.3	36		48
Acenaphthene	0.168	0.758	0.46		0.42
Dibenzofuran	1.21	1.23	1.2		0.016
2,4-Dinitrotoluene	ND < 0.25	16.6	8.4	1%	12
Fluorene	0.776	2.51	1.6		1.2
Hexachlorobenzene	ND < 0.25	ND < 0.47	ND < 0.36		0.16
Pentachlorophenol	ND < 0.25	ND < 0.47	ND < 0.36		0.16
Phenanthrene	2.22	4.62	3.4		1.7
Anthracene	0.338	0.718	0.53		0.27
Fluoranthene	0.738	1.72	1.2		0.69
Pyrene	0.496	0.863	0.68		0.26
Benz(a)anthracene	0.0670	0.138	0.10		0.050
Chrysene	0.165	0.408	0.29		0.17
Benzo(b & k)fluoranthene	0.0540	0.216	0.14		0.11
Benzo(e)pyrene	ND < 0.05	0.118	0.072	17%	0.066
Benzo(a)pyrene	ND < 0.05	ND < 0.094	ND < 0.072		0.031
Indeno(1,2,3-c,d)pyrene	ND < 0.05	0.162	0.094	13%	0.10
Dibenz(a,h)anthracene	ND < 0.05	ND < 0.097	ND < 0.074		0.033
Benzo(g,h,i)perylene	ND < 0.05	0.134	0.080	16%	0.077

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

5.5.3 PAH/SVOC in Liquid Samples

Tables 5-40 through 5-42 present analytical results for PAH/SVOC in samples of make-up water (Location 9), pond outlet water (Location 10), and blank samples, respectively. All results are in micrograms of analyte per liter of sample ($\mu\text{g/L}$). In Tables 5-40 and 5-41, individual samples are shown along with the average and standard deviation. Di-n-butyl phthalate was the only PAH/SVOC detected in the water samples.

TABLE 5-40. PAH/SVOC IN MAKE-UP WATER (LOCATION 9) (µg/L)

Analyte	N-9-PRL 726	N-9-PRL 728	N-9-PRL 730	AVERAGE	DL RATIO	SD
Phenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
1,3-Dichlorobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
1,4-Dichlorobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
1,2-Dichlorobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
3-Methylphenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2-Methylphenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
4-Methylphenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Acetophenone	ND < 9	ND < 9	ND < 9	ND < 9	9	0
Hexachloroethane	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Nitrobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Naphthalene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Hexachlorobutadiene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Quinoline	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2-Chloroacetophenone	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2-Methylnaphthalene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Hexachlorocyclopentadiene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,4,6-Trichlorophenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,4,5-Trichlorophenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Biphenyl	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Acenaphthylene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Acenaphthene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,4-Dinitrophenol	ND < 50	ND < 50	ND < 50	ND < 50	50	0
4-Nitrophenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Dibenzofuran	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,4-Dinitrotoluene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,6-Dinitrotoluene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Fluorene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
4,6-Dinitro-2-methylphenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Hexachlorobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Pentachloronitrobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Pentachlorophenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Phenanthrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Anthracene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Di-n-butylphthalate	8 J	7 J	2 J	6		3
Fluoranthene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Pyrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Benz(a)anthracene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Bis(2-ethylhexyl)phthalate	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Chrysene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Benzo(e)pyrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Benzo(a)pyrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Indeno(1,2,3-c,d)pyrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Dibenz(a,h)anthracene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Benzo(g,h,i)perylene	ND < 10	ND < 10	ND < 10	ND < 10	10	0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

J = Concentration detected below calibration range.

TABLE 5-41. PAH/SVOC IN OUTLET OF POND (LOCATION 10) (µg/L)

Analyte	N-10-PRL 726	N-10-PRL 728	N-10-PRL 730	AVERAGE	DL RATIO	SD
Phenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
1,3-Dichlorobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
1,4-Dichlorobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
1,2-Dichlorobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
3-Methylphenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2-Methylphenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
4-Methylphenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Acetophenone	ND < 9	ND < 9	ND < 9	ND < 9	9	0
Hexachloroethane	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Nitrobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Naphthalene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Hexachlorobutadiene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Quinoline	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2-Chloroacetophenone	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2-Methylnaphthalene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Hexachlorocyclopentadiene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,4,6-Trichlorophenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,4,5-Trichlorophenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Biphenyl	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Acenaphthylene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Acenaphthene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,4-Dinitrophenol	ND < 50	ND < 50	ND < 50	ND < 50	50	0
4-Nitrophenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Dibenzofuran	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,4-Dinitrotoluene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
2,6-Dinitrotoluene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Fluorene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
4,6-Dinitro-2-methylphenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Hexachlorobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Pentachloronitrobenzene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Pentachlorophenol	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Phenanthrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Anthracene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Di-n-butylphthalate	11	4 J	1 J	5	5	5
Fluoranthene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Pyrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Benz(a)anthracene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Bis(2-ethylhexyl)phthalate	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Chrysene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Benzo(e)pyrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Benzo(a)pyrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Indeno(1,2,3-c,d)pyrene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Dibenz(a,h)anthracene	ND < 10	ND < 10	ND < 10	ND < 10	10	0
Benzo(g,h,i)perylene	ND < 10	ND < 10	ND < 10	ND < 10	10	0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

J = Concentration detected below calibration range.

TABLE 5-42. PAH/SVOC IN LIQUID BLANK SAMPLES ($\mu\text{g/L}$)

Analyte	FIELD BLANK		TRIP BLANK		METHOD BLANK		METHOD BLANK	
	N-9-PRL-730	N-9-PRL-730	N-9-PRL-730	N-9-PRL-730	07/30/93(a)	07/30/93(a)	08/04/93(b)	08/04/93(b)
Phenol	ND <	10	ND <	10	ND <	10	ND <	10
1,3-Dichlorobenzene	ND <	10	ND <	10	ND <	10	ND <	10
1,4-Dichlorobenzene	ND <	10	ND <	10	ND <	10	ND <	10
1,2-Dichlorobenzene	ND <	10	ND <	10	ND <	10	ND <	10
3-Methylphenol	ND <	10	ND <	10	ND <	10	ND <	10
2-Methylphenol	ND <	10	ND <	10	ND <	10	ND <	10
4-Methylphenol	ND <	10	ND <	10	ND <	10	ND <	10
Acetophenone	ND <	9	ND <	9	ND <	9	ND <	9
Hexachloroethane	ND <	10	ND <	10	ND <	10	ND <	10
Nitrobenzene	ND <	10	ND <	10	ND <	10	ND <	10
Naphthalene	ND <	10	ND <	10	ND <	10	ND <	10
Hexachlorobutadiene	ND <	10	ND <	10	ND <	10	ND <	10
Quinoline	ND <	10	ND <	10	ND <	10	ND <	10
2-Chloroacetophenone	ND <	10	ND <	10	ND <	10	ND <	10
2-Methylnaphthalene	ND <	10	ND <	10	ND <	10	ND <	10
Hexachlorocyclopentadiene	ND <	10	ND <	10	ND <	10	ND <	10
2,4,6-Trichlorophenol	ND <	10	ND <	10	ND <	10	ND <	10
2,4,5-Trichlorophenol	ND <	10	ND <	10	ND <	10	ND <	10
Biphenyl	ND <	10	ND <	10	ND <	10	ND <	10
Acenaphthylene	ND <	10	ND <	10	ND <	10	ND <	10
Acenaphthene	ND <	10	ND <	10	ND <	10	ND <	10
2,4-Dinitrophenol	ND <	50	ND <	50	ND <	50	ND <	50
4-Nitrophenol	ND <	10	ND <	10	ND <	10	ND <	10
Dibenzofuran	ND <	10	ND <	10	ND <	10	ND <	10
2,4-Dinitrotoluene	ND <	10	ND <	10	ND <	10	ND <	10
2,6-Dinitrotoluene	ND <	10	ND <	10	ND <	10	ND <	10
Fluorene	ND <	10	ND <	10	ND <	10	ND <	10
4,6-Dinitro-2-methylphenol	ND <	10	ND <	10	ND <	10	ND <	10
Hexachlorobenzene	ND <	10	ND <	10	ND <	10	ND <	10
Pentachloronitrobenzene	ND <	10	ND <	10	ND <	10	ND <	10
Pentachlorophenol	ND <	10	ND <	10	ND <	10	ND <	10
Phenanthrene	ND <	10	ND <	10	ND <	10	ND <	10
Anthracene	ND <	10	ND <	10	ND <	10	ND <	10
Di-n-butylphthalate	ND <	10	ND <	10	ND <	10	ND <	10
Fluoranthene	ND <	10	ND <	10	ND <	10	ND <	10
Pyrene	ND <	10	ND <	10	ND <	10	ND <	10
Benz(a)anthracene	ND <	10	ND <	10	ND <	10	ND <	10
Bis(2-ethylhexyl)phthalate	ND <	10	ND <	10	ND <	10	ND <	10
Chrysene	ND <	10	ND <	10	ND <	10	ND <	10
Benzo(e)pyrene	ND <	10	ND <	10	ND <	10	ND <	10
Benzo(a)pyrene	ND <	10	ND <	10	ND <	10	ND <	10
Indeno(1,2,3-c,d)pyrene	ND <	10	ND <	10	ND <	10	ND <	10
Dibenz(a,h)anthracene	ND <	10	ND <	10	ND <	10	ND <	10
Benzo(g,h,i)perylene	ND <	10	ND <	10	ND <	10	ND <	10

ND < = Not detected, value following ND < is detection limit.

(a) = blank correlates with all -726 & -728 samples.

(b) = blank correlates with all -730 samples.

5.6 Dioxins/Furans

Dioxins and furans were measured only in flue gas samples at Location 5a. Results for dioxins/furans at Location 5a are shown in Table 5-43, and from blank samples in Table 5-44. These results are in picograms per normal cubic meter of flue gas (pg/Nm^3). Shown for Location 5a are individual sample results, plus the average and standard deviation of those results.

Several individual dioxin/furan isomers and most congener classes were detected in flue gas at Location 5a. Measured concentrations were highest in the first sampling run, on June 26. The individual isomers present at highest concentrations included 1,2,3,4,6,7,8-HpCDD, OCDD, 1,2,3,4,6,7,8-HpCDF, and OCDF. The furan congener classes were generally present at higher concentrations than were the dioxin congener classes, with the exception of total HpCDD.

TABLE 5-43. DIOXINS/FURANS IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) (pg/Nm³)

Analyte	N-5a-MM5-726*	N-5a-MM5-728	N-5a-MM5-730	AVERAGE DL RATIO	SD
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND < 4.77	ND < 2.89	ND < 2.94	ND < 3.5	1.1
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND < 6.87	ND < 3.90	ND < 3.62	ND < 4.8	1.8
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND < 9.79	ND < 4.08	ND < 3.37	ND < 5.7	3.5
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	11.5 J	ND < 3.80	ND < 3.42	5.0	24%
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	11.8 J	ND < 2.34	ND < 3.20	4.9	19%
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	63.7	9.74 J	13.5 J	29	30
Octachlorodibenzo-p-dioxin	92.2 K	1.9 K	3.2 K	32	52
2,3,7,8-Tetrachlorodibenzofuran	17.8	3.63 J	ND < 5.85	8.1	12%
1,2,3,7,8-Pentachlorodibenzofuran	ND < 9.85	ND < 2.75	ND < 4.60	ND < 5.7	3.7
2,3,4,7,8-Pentachlorodibenzofuran	ND < 18.6	ND < 3.04	5.36 J	ND < 19	2.8
1,2,3,4,7,8-Hexachlorodibenzofuran	41.9	ND < 5.25	ND < 9.43	16	15%
1,2,3,6,7,8-Hexachlorodibenzofuran	14.5 J	ND < 3.77	ND < 6.41	ND < 5.0	6.9
1,2,3,7,8,9-Hexachlorodibenzofuran	21.6 J	ND < 7.13	7.87 J	11	11%
2,3,4,6,7,8-Hexachlorodibenzofuran	ND < 6.06	ND < 2.64	ND < 3.89	ND < 4.2	1.7
1,2,3,4,6,7,8-Heptachlorodibenzofuran	69.2	11.4 J	ND < 14.3	29	8%
1,2,3,4,7,8,9-Heptachlorodibenzofuran	13.1 J	ND < 4.62	ND < 5.98	ND < 6.1	6.1
Octachlorodibenzofuran	52.5 J	20.5 J	25.8 J	33	17
Total Tetrachlorodibenzo-p-dioxin	21.8	ND < 2.89	13.4	12	4%
Total Pentachlorodibenzo-p-dioxin	9.46	ND < 3.90	ND < 3.62	4.4	28%
Total Hexachlorodibenzo-p-dioxin	49.6	ND < 4.08	ND < 3.42	18	7%
Total Heptachlorodibenzo-p-dioxin	102	15.1	18.7	45	49
Total Tetrachlorodibenzofuran	81.6	2.18	ND < 5.85	29	3%
Total Pentachlorodibenzofuran	87.3	ND < 3.04	10.4	33	2%
Total Hexachlorodibenzofuran	107	ND < 7.13	5.29	39	3%
Total Heptachlorodibenzofuran	89.2	5.25	ND < 14.3	34	7%

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

Total sample non detect values are the average detection limit from the XAD and Filter fractions.

Total sample values from XAD and filter fractions containing one hit and one non detect were calculated as : hit + (non detect/2).

Total congener class results do not include any contribution from non detects. Detection limits are considered to be the same as for 2,3,7,8-substituted isomers.

J = Concentration detected below calibration range.

K = total value in the calibration range, but individual values from the XAD or filter fraction or both were below the calibration range.

Method Blank values are average of the Filter Method Blank and XAD Method Blank results.

Continuing calibration response factor for 23478-PeCDF-13C12 slightly below 30% from initial calibration at end of analysis day for N-5a-MM5-725 and N-5a-MM5-726 filters.

Continuing calibration response factor for 1234678-HpCDF-13C12 slightly above 30% from initial calibration at end of analysis day for N-5a-MM5-728 and N-5a-MM5-730 filters.

* = several isotope ratios in the continuing calibration were slightly out of the theoretical range on the day these samples were analyzed.

TABLE 5-44. DIOXINS/FURANS IN BLANK GAS SAMPLES (pg/Nm³)

Analyte	5a TRAIN BLANK * N-5a-MM5-725
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND < 3.07
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND < 3.52
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND < 3.92
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ND < 3.48
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ND < 4.56
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	ND < 10.6
Octachlorodibenzo-p-dioxin	74.7 K
2,3,7,8-Tetrachlorodibenzofuran	ND < 2.24
1,2,3,7,8-Pentachlorodibenzofuran	ND < 3.47
2,3,4,7,8-Pentachlorodibenzofuran	ND < 4.19
1,2,3,4,7,8-Hexachlorodibenzofuran	ND < 3.93
1,2,3,6,7,8-Hexachlorodibenzofuran	ND < 3.55
1,2,3,7,8,9-Hexachlorodibenzofuran	ND < 6.83
2,3,4,6,7,8-Hexachlorodibenzofuran	ND < 3.60
1,2,3,4,6,7,8-Heptachlorodibenzofuran	ND < 17.9
1,2,3,4,7,8,9-Heptachlorodibenzofuran	ND < 5.46
Octachlorodibenzofuran	ND < 11.8

Total Tetrachlorodibenzo-p-dioxin

Total Pentachlorodibenzo-p-dioxin

Total Hexachlorodibenzo-p-dioxin

Total Heptachlorodibenzo-p-dioxin

Total Tetrachlorodibenzofuran

Total Pentachlorodibenzofuran

Total Hexachlorodibenzofuran

Total Heptachlorodibenzofuran

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Total sample non detect values are the average detection limit from the XAD and Filter fractions.

Total sample values from XAD and filter fractions containing one hit and one non detect were calculated as :

hit + (non detect/2).

Total congener class results do not include any contribution from non detects. Detection limits are considered to be the same as for 2,3,7,8-substituted isomers.

K = total value in the calibration range, but individual values from the XAD or filter fraction or both were below the calibration range.

Method Blank values are average of the Filter Method Blank and XAD Method Blank results.

Continuing calibration response factor for 23478-PeCDF-13C12 slightly below 30% from initial calibration at end of analysis day for N-5a-MM5-725 and N-5a-MM5-726 filters.

Continuing calibration response factor for 1234678-HpCDF-13C12 slightly above 30% from initial calibration at end of analysis day for N-5a-MM5-728 and N-5a-MM5-730 filters.

* = several isotope ratios in the continuing calibration were slightly out of the theoretical range on the day these samples were analyzed.

5.7 Aldehydes

5.7.1 Aldehydes in Flue Gas Samples

Tables 5-45 through 5-47 show analytical results for aldehydes in flue gas samples from Locations 4 and 5a, and in blank samples, respectively. For each set of samples, results are shown in micrograms of analyte per normal cubic meter of flue gas ($\mu\text{g}/\text{Nm}^3$). Results for Locations 4 and 5a include individual sample results plus the average and standard deviation of those results.

All four target aldehydes were detected in at least some samples. Acetaldehyde was present at concentrations higher than those of the other three aldehydes. The most striking feature of the aldehyde results is that much higher aldehyde levels were measured at Location 5a (Table 5-46) than at the upstream Location 4 (Table 5-45). Concentrations at both locations are quite variable, however the increase in aldehyde concentrations at Location 5a relative to Location 4 suggests that formation of these compounds in the hot flue gas may be occurring.

TABLE 5-45. ALDEHYDES IN GAS SAMPLES FROM ESP INLET (LOCATION 4) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-4-ALD-726	N-4-ALD-728	N-4-ALD-730	AVERAGE DL RATIO	SD
Formaldehyde	1.53 J	3.91	ND< 2.29	ND< 2.3	1.5
Acetaldehyde	6.71	7.59	ND< 2.29	5.1 7%	3.5
Acrolein	ND< 2.27	ND< 2.33	ND< 2.29	ND< 2.3	0.0
Propionaldehyde	3.39	2.50	ND< 2.29	2.3 16%	1.1

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

J = Concentration detected below calibration range.

The DNPH solution for sample N-4-ALD-730 was light in color when received.

TABLE 5-46. ALDEHYDES IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-ALD-726	N-5a-ALD-728	N-5a-ALD-730	AVERAGE DL RATIO	SD
Formaldehyde	13.3	5.54	ND< 2.58	6.7 6%	6.1
Acetaldehyde	120	292	43.8	152	127
Acrolein	6.87	189	11.5	69	104
Propionaldehyde	53.9	70.8	1.73 J	42	36

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

J = Concentration detected below calibration range.

The DNPH solution for samples N-5A-ALD-728 and N-5A-ALD-730 was light in color when received.

TABLE 5-47. ALDEHYDES IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

Analyte	TRAIN BLANK		DNPH BLANK		ACETONITRILE BLANK	
	N-5a-ALD-725		N-4-ALD-RB		N-4-ALD-RB	
Formaldehyde	ND <	2.54	ND <	2.54	ND <	2.54
Acetaldehyde		1.67 J	ND <	2.54	ND <	2.54
Acrolein	ND <	2.54	ND <	2.54	ND <	2.54
Propionaldehyde	ND <	2.54	ND <	2.54	ND <	2.54

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for field reagent blank.

J = Concentration detected below calibration range.

The gas volume used for calculating the blank values was 0.0472 dscm.

5.7.2 Aldehydes in Liquid Samples

Tables 5-48 and 5-49 show analytical results for aldehydes in samples of make-up water (Location 9) and pond outlet water (Location 10), respectively. Individual sample results, as well as the average and standard deviation, are shown. All results are in micrograms per liter of sample ($\mu\text{g/L}$). Only formaldehyde was detected, and only in samples of the pond outlet water.

TABLE 5-48. ALDEHYDES IN MAKE-UP WATER (LOCATION 9) ($\mu\text{g/L}$)

Analyte	N-9-PRL-726		N-9-PRL-728		N-9-PRL-730		AVERAGE	DL RATIO	SD
Formaldehyde	ND<	6.00	ND<	6.00	ND<	6.00	ND<	6.0	0.0
Acetaldehyde	ND<	6.00	ND<	6.00	ND<	6.00	ND<	6.0	0.0
Acrolein	ND<	6.00	ND<	6.00	ND<	6.00	ND<	6.0	0.0
Propionaldehyde	ND<	6.00	ND<	6.00	ND<	6.00	ND<	6.0	0.0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-49. ALDEHYDES IN OUTLET OF POND (LOCATION 10) ($\mu\text{g/L}$)

Analyte	N-10-PRL-726		N-10-PRL-728		N-10-PRL-730		AVERAGE	DL RATIO	SD
Formaldehyde		11.0		3.12 J		9.38		7.8	4.2
Acetaldehyde	ND<	6.00	ND<	6.00	ND<	6.00	ND<	6.0	0
Acrolein	ND<	6.00	ND<	6.00	ND<	6.00	ND<	6.0	0
Propionaldehyde	ND<	6.00	ND<	6.00	ND<	6.00	ND<	6.0	0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

J = Concentration detected below calibration range.

5.8 Radionuclides

5.8.1 Radionuclides in Flue Gas Samples

Tables 5-50 through 5-52 show analytical results for radionuclides in flue gas particulate samples. These results are from analysis of particulate filter samples collected during the full duration of the ammonia and cyanide sampling runs. Tables 5-50 through 5-52 present results from Locations 4 and 5a, and from a blank sample, respectively. For the data from Locations 4 and 5a, individual samples and the average and standard deviation are shown. For each of the three sets of samples (4, 5a, blank) results are shown in pico-Curies per normal cubic meter of flue gas (pCi/Nm³).

Only Th-234, Pb-210, and U-235 were detected, each in a single sample from Location 4 (Table 5-50). No radionuclides were detected in samples from Location 5a (Table 5-51).

TABLE 5-50. RADIONUCLIDES IN GAS SAMPLES FROM ESP INLET (LOCATION 4) (pCi/Nm³)

Analyte	N-4-NH4CN-727	N-4-NH4CN-729	N-4-NH4CN-731	AVERAGE	DL RATIO	SD
Pb-212	ND< 36	ND< 43	ND< 35	ND< 38		4.3
Th-234	539	ND< 381	ND< 324	ND< 381		210
Pb-210	ND< 568	423	ND< 548	ND< 568		84
Pb-211	ND< 671	ND< 737	ND< 673	ND< 694		38
Ra-226	ND< 41	ND< 428	ND< 70	ND< 180		216
Ra-228	ND< 152	ND< 117	ND< 152	ND< 140		21
Th-229	ND< 310	ND< 309	ND< 242	ND< 287		39
Th-230	ND< 3098	ND< 2854	ND< 2740	ND< 2897		183
U-234	ND< 12390	ND< 12606	ND< 11459	ND< 12152		610
U-235	ND< 119	95	ND< 130	ND< 130		19

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

TABLE 5-51. RADIONUCLIDES IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) (pCi/Nm³)

Analyte	N-5a-NH4CN-727	N-5a-NH4CN-729	N-5a-NH4CN-731	AVERAGE	DL RATIO	SD
Pb-212	ND< 85	ND< 38	ND< 36	ND< 53		28
Th-234	ND< 712	ND< 299	ND< 322	ND< 444		232
Pb-210	ND< 854	ND< 359	ND< 544	ND< 585		250
Pb-211	ND< 1423	ND< 538	ND< 604	ND< 855		493
Ra-226	ND< 123	ND< 40	ND< 36	ND< 66		49
Ra-228	ND< 280	ND< 120	ND< 121	ND< 173		92
Th-229	ND< 522	ND< 199	ND< 282	ND< 334		168
Th-230	ND< 4744	ND< 2391	ND< 2416	ND< 3184		1352
U-234	ND< 21824	ND< 7769	ND< 10671	ND< 13421		7420
U-235	ND< 232	ND< 80	ND< 111	ND< 141		81

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

TABLE 5-52. RADIONUCLIDES IN BLANK GAS SAMPLES (pCi/Nm³)

<u>Analyte</u>	<u>TRAIN BLANK</u>	
	<u>N-5a-NH4CN-725</u>	
Pb-212	ND <	37.3
Th-234	ND <	373
Pb-210	ND <	439
Pb-211	ND <	593
Ra-226	ND <	52.7
Ra-228	ND <	136
Th-229	ND <	263
Th-230	ND <	2854
U-234	ND <	9878
U-235	ND <	108

ND < = Not detected, value following ND < is detection limit.
Sample results corrected for field reagent blank.

5.8.2 Radionuclides in Solid Samples

Tables 5-53 through 5-55 show results for radionuclides in daily composite samples of boiler feed coal (Location 1), bottom ash (Location 2), and air heater ash (Location 3), respectively. The composite sample identification scheme and compositing procedures are presented in Section 3.2.2. In these tables, all results are shown in pico-Curies per gram of sample (pCi/g). Individual sample results are shown, as well as the average and standard deviation of those results, for boiler feed coal and bottom ash. One sample of air heater ash was analyzed, as shown in Table 5-55. Insufficient sample was available to conduct radionuclide analysis on ESP ash, or on air heater ash except for the one sample shown.

In coal (Table 5-53), Th-234 and Pb-210 were the principal radionuclides detected. In bottom ash, Pb-210 was not detected, but Th-234 was the principal radionuclide found, with Pb-212, Ra-226, and Ra-228 also found in all samples at similar levels (Table 5-54). Th-234 was also the radionuclide found at highest levels in air heater ash (Table 5-55), with Ra-226, Pb-210, Ra-228, and Pb-212 also present.

TABLE 5-53. RADIONUCLIDES IN BOILER FEED COAL (LOCATION 1) (pCi/g)

Analyte	JL2793-BOFED	JL2993-BOFED	JL3193-BOFED	AVERAGE	DL RATIO	SD
Pb-210	2.21	1.59	1.38	1.7		0.43
Pb-212	0.330	0.383	0.332	0.35		0.030
Ra-226	0.477	0.543	0.453	0.49		0.047
Ra-228	ND< 0.470	0.265	ND< 0.330	ND< 0.47		0.051
Th-234	2.33	2.95	3.03	2.8		0.38
Pb-211	ND< 1.60	ND< 1.40	ND< 1.40	ND< 1.5		0.12
Th-229	ND< 0.580	ND< 0.580	ND< 0.570	ND< 0.58		0.0058
Th-230	ND< 5.20	ND< 6.90	ND< 6.50	ND< 6.2		0.89
U-234	ND< 19.0	ND< 23.0	ND< 23.0	ND< 22		2.3
U-235	ND< 0.220	ND< 0.220	ND< 0.230	ND< 0.22		0.0058

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-54. RADIONUCLIDES IN BOTTOM ASH (LOCATION 2) (pCi/g)

Analyte	JL2793-BOTT	JL2993-BOTT	JL3193-BOTT	AVERAGE	DL RATIO	SD
Pb-210	ND< 0.810	0.630	1.18	ND< 0.81		0.40
Pb-212	1.85	2.06	2.38	2.1		0.27
Ra-226	2.62	3.36	3.27	3.1		0.40
Ra-228	1.87	2.04	1.94	2.0		0.085
Th-234	3.02	3.81	3.52	3.5		0.40
Pb-211	ND< 1.10	ND< 1.20	ND< 1.40	ND< 1.2		0.15
Th-229	ND< 0.530	ND< 0.610	ND< 0.600	ND< 0.58		0.044
Th-230	ND< 5.80	7.40	ND< 6.70	ND< 6.7		2.5
U-234	16.3	ND< 21.0	30.7	ND< 21		10
U-235	0.210	ND< 0.220	0.220	ND< 0.22		0.061

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-55. RADIONUCLIDES IN AIR HEATER ASH (LOCATION 3) (pCi/g)

<u>Analyte</u>	<u>JL3193-HASH</u>
Pb-210	0.884
Pb-212	0.810
Ra-226	1.53
Ra-228	0.888
Th-234	1.77
Pb-211	ND< 1.60
Th-229	ND< 0.760
Th-230	ND< 8.10
U-234	ND< 35.0
U-235	ND< 0.520

ND< = Not detected, value following ND< is detection limit.

5.9 Carbon Analyses

Table 5-56 shows the results of analyses for carbon in composite daily samples of bottom ash (Location 2), air heater ash (Location 3), and ESP fly ash (Location 8). For the ESP ash, results are shown for samples from hopper rows 1 through 5. The average value for carbon in the total ESP catch is also shown in Table 5-56. That value is a weighted average based on the results from each row, using the time required for dumping the hoppers in each row as the weighting factor. All results are in percent carbon by weight on a dry basis, and results are shown for individual samples, as well as the average and standard deviation of those results. The composite sample identification scheme and compositing procedures are presented in Section 3.2.2.

Table 5-57 shows the results for carbon in flue gas particulate samples, collected during the full duration of the single-point, isokinetic ammonia and cyanide runs on a given sampling day. Results are shown for both Locations 4 and 5a. The results in Table 5-57 are the percent of carbon in flue gas particulate on a dry weight basis.

The data shown in Tables 5-56 and 5-57 have been discussed in Section 3.3.1, in the context of the comparability of flue gas particulate and ESP ash. It is clear from comparison of the data in these tables that the carbon content of air heater ash and ESP row 1 ash are very similar to each other, but distinctly different from the carbon content of ESP rows 2-5 ash or Location 4 (ESP inlet) particulate. This latter difference is apparently due to the presence of coarse particles in the duct at Location 4, which are collected in the ESP row 1 hoppers but which were not adequately sampled by the single-point sampling used to determine the carbon content of particulate at Location 4. Consideration of other factors as well, such as the elemental composition of these solid samples, has led to use of an ESP-average carbon value of about 35 percent to represent Location 4 particulate in mass balance calculations. The basis and impact of adopting this carbon content value for Location 4 particulate are presented in Section 3.3.1. The measured carbon content values from Location 4 are footnoted in Table 5-57 to indicate that the single-point sampling did not properly represent the coarse bulk particulate in the duct at that location.

TABLE 5-56. CARBON IN BOTTOM ASH, AIR PRE-HEATER ASH, AND ESP ASH (% BY WEIGHT, DRY BASIS)

Analyte	JL2793	JL2993	JL3193	AVERAGE DL RATIO	SD
Bottom Ash	0.16	0.4	0.1	0.22	0.16
Air Pre-heater Ash	76.1	74.7	72.4	74	1.8
ESP Fly Ash: Row 1	79.6	80.2	77.5	79	1.4
ESP Fly Ash: Row 2	14.7	18.2	13.4	15	2.5
ESP Fly Ash: Row 3	6.06	5.94	5.59	5.9	0.24
ESP Fly Ash: Row 4	NA	NA	3.27	NA	NA
ESP Fly Ash: Row 5	1.89	NA	1.88	1.9	0.0071
Calculated ESP Average*	35.1	36.7	33.7	35	1.5

DL Ratio = Detection limit ratio.

SD = Standard deviation.

NA = Sample not available, sample not analyzed, or data not available.

* Weighted average carbon content of entire ESP catch.

TABLE 5-57. CARBON IN FLUE GAS PARTICULATE SAMPLES (% dry)

Location	7/27	7/29	7/31	AVERAGE	DL RATIO	SD
4*	4.1	6.06	2.64	4.3		1.7
5a	0.19	0.05	0.05	0.097		0.081

DL Ratio = Detection limit ratio.

SD = Standard deviation.

* Carbon content determined by single-point isokinetic sampling is not representative of coarse, stratified particulate in the duct. Weighted average carbon content for ESP ash of about 35 percent was assumed to represent Location 4 particulate in mass balance calculations (see Section 3.3.1).

5.10 Ultimate/Proximate and Related Solid Sample Analyses

Table 5-58 shows the results of ultimate/proximate analyses of daily composite samples of boiler feed coal (Location 1). Results for individual samples are shown, along with the average and standard deviation. The units of the analytical results are shown in the table.

Table 5-59 shows results for moisture in boiler feed coal, in percent by weight. The individual results, average, and standard deviation are shown.

Inspection of Tables 5-58 and 5-59 shows that the composition of the coal was reasonably uniform. The results shown here for percent ash, percent sulfur, percent moisture, and heat content in Btu/lb are all in good agreement with the corresponding values for bunker coal samples in Table 2-9.

TABLE 5-58. ULTIMATE/PROXIMATE RESULTS FOR BOILER FEED COAL (LOCATION 1)

Analyte	JL2793BOFED	JL2993BOFED	JL3193BOFED	AVERAGE	DL RATIO	SD
Proximate Analysis (as received), percent						
Moisture	5.66	6.33	7.65	6.5		1.0
Ash	11.1	11.2	11.1	11		0.10
Volatile matter	34.5	34.9	33.6	34		0.64
Fixed Carbon (diff) *	48.7	47.6	47.7	48		0.64
Sulfur	2.59	2.65	2.51	2.6		0.07
Ultimate Analysis (dry), percent						
Carbon	72.0	72.0	71.7	72		0.18
Hydrogen	4.83	4.8	4.75	4.8		0.04
Nitrogen	1.46	1.49	1.51	1.5		0.03
Sulfur	2.75	2.83	2.72	2.8		0.06
Ash	11.7	12.0	12.0	12		0.14
Oxygen (diff) *	7.23	6.88	7.34	7.2		0.24
Heating Value, Btu/lb						
As received	12269	12108	11892	12090		189
Dry	13005	12926	12877	12936		65
MAF	14735	14687	14631	14684		52

DL Ratio = Detection limit ratio.

SD = Standard deviation.

MAF = Moisture and ash free.

* diff = Calculated by difference.

TABLE 5-59. MOISTURE IN BOILER FEED COAL (percent)

Analyte	JL2793-BOFED	JL2993-BOFED	JL3193-BOFED	AVERAGE	DL RATIO	SD
Moisture	5.66	6.33	7.65	6.5		1.0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

5.11. Particulate Size Distribution

Particulate size distribution was determined for two different sample types: ESP ash, and flue gas particulate collected at Locations 4 and 5a. These results are shown in Tables 5-60 to 5-62.

Table 5-60 shows the size distribution results for ESP ash from hopper rows 1, 2, and 3. This table shows the cumulative percent of sample mass retained in successively smaller size stages. As was discussed in Section 3.3.1, ash from ESP row 1 was much coarser than ash from subsequent rows. As a result, row 1 ash was sized using a different technique than those used for rows 2 and 3 ash. As indicated in Table 5-60, row 1 ESP ash was sized using a series of standard sieves; the sieve opening sizes are listed below for each of the sieve designations in Table 5-60:

Sieve No.	Opening Size
16	1,180 μm
20	850 μm
30	600 μm
40	425 μm
50	300 μm
70	212 μm
100	150 μm
140	106 μm
200	75 μm
325	45 μm

Ash from rows 2 and 3 of the ESP was sized using two different techniques, screening for the larger particle sizes, and a Coulter counter for the finer sizes. The cut sizes for each stage of these two techniques are shown in Table 5-60, in μm . Note that the screens provide a geometric sizing of the particles, whereas the Coulter counter is based on a volumetric measurement of particle size.

Table 5-60 shows that the ESP row 1 ash exhibited a mass median diameter of about 850 μm (i.e., about 50 percent of the mass was retained by a number 20 sieve), and nearly all the mass was in particles greater than 75 μm in diameter (i.e., retained by a number 200 sieve). Row 2 and row 3 ESP ash was much finer. For row 2 ash, only 15 percent of the mass, on average, was in particles larger than 75 μm , and the mass median volumetric diameter from the Coulter counter was about 12 μm . About 59 percent

of the mass of row 2 ash was in particles larger than 10 μm volumetric diameter, and about 7 percent was in particles smaller than 5 μm volumetric diameter. For row 3 ash, only 3.6 percent of the mass was in particles larger than 75 μm , and the mass median volumetric diameter was about 9 μm . Approximately 47 percent of the mass of row 3 ash was in particles larger than 10 μm volumetric diameter, and about 13 percent was in particles smaller than 5 μm volumetric diameter. The differences in particle size distribution in these samples parallel the differences noted previously in elemental composition (Section 5.1.2) and carbon content (Section 5.9).

The particle size distribution of flue gas particulate was determined in two ways. Two glass cyclones were used with the Multi-Metals (Method 29) and Modified Method 5 trains at Location 4, and a cascade impactor was used at Location 5a. The glass cyclones were designed for this study, and were installed in the heated filter box of the train during sampling. The designed aerodynamic cut points of the cyclones were 10 μm and 5 μm ; insufficient time was available to test the cut points before the study. A Teflon flex line connected the sampling probe to the cyclones, as described in Section 3.2.1. The impactor used at Location 5a was a Pilat Mark III Source Test cascade impactor with glass fiber impaction stages and backup filter. The glass fiber material was Reeve Angel 934H; this material is reported to minimize weight gain from SO_2/SO_3 adsorption.

Table 5-61 shows the particle size distribution data from Location 4, the ESP inlet. Because the cyclones were used outside the duct, the probe wash particulate catch is included in Table 5-61. As this table shows, the probe and flexible line collected the majority of particulate in the metals sampling at Location 4. About 20 percent of the particulate mass was collected in the coarse cyclone ($>10 \mu\text{m}$), and about an equal amount was collected on the filter ($<5 \mu\text{m}$ size). Very little of the particulate was collected in the fine cyclone (5-10 μm range). Loss of particles in the probe is likely to be most important for the largest particles, but the sizes of particles collected in this fraction must be considered as unknown. Thus the data in Table 5-61 suggest that the great majority (ca. 75 percent) of the flue gas particulate mass at Location 4 is in particles greater than 10 μm aerodynamic diameter, but with considerable uncertainty. Only about 20 percent of the particulate mass at this location is in particles smaller than 5 μm aerodynamic diameter.

In principle, the particulate size distribution of ESP ash should be comparable to that of the particulate at the ESP inlet. For reasons discussed in Section 3.3.1, it is certain that the flue gas particulate collected at Location 4 was not representative of all the material collected in the ESP. In addition, it is clear that the extractive sampling with cyclones did not provide fully valid size distribution information at the ESP inlet (Table 5-61). It can be concluded, however, that the flue gas particulate collected at Location 4 (Table 5-61) is much closer to the ESP rows 2 and 3 ash, in terms of fraction of mass $> 10 \mu\text{m}$ and fraction of mass $< 5 \mu\text{m}$, than it is to the ESP row 1 ash. This conclusion is consistent with *comparison of elemental composition (Section 5.1.2) and carbon content (Section 5.9)*.

Table 5-62 shows the particle size distribution results from cascade impactor runs at Location 5a. Shown in this table are the impactor stage designation, the corresponding aerodynamic cut size (D_{50}), the percent mass retained in that stage, and the cumulative percent mass through successive stages. Table 5-62 shows that the impactor cut sizes were consistent over all three runs, and that the flue gas particulate size distribution was determined with good precision. The particulate at Location 5a exhibited a mass median aerodynamic diameter of just over $2 \mu\text{m}$, based on the average mass results in Table 5-62. The mass at particle sizes below $2 \mu\text{m}$ was relatively evenly distributed among the impactor stages. The finest size range ($< 0.20 \mu\text{m}$) contained an average 15 percent of the particle mass. This is a surprisingly large mass fraction for such fine particles, and likely results in part from the condensation of sulfuric acid in the sampling process. The possibility of this effect is discussed further in Section 7.1, in the context of impactor results from cooled, diluted stack gas at Location 5b.

TABLE 5-60. PARTICULATE SIZE DISTRIBUTION OF ESP ASH (CUMULATIVE PERCENT MASS RETAINED)

Sieve No.	JL2793-ESP1			JL2993-ESP1			JL3193-ESP1			JL3193-ESP2			JL2793-ESP2			JL2993-ESP2			JL3193-ESP2			JL2793-ESP3			JL2993-ESP3			JL3193-ESP3									
	Average	SD	Micron Size*																																		
0.25	8.38		210	5.67	4.70	210	6.65	6.70	4.83	6.06	1.07	210	0.84	0.78	0.81	0.04	210	0.84	0.78	0.81	0.04	210	0.84	0.78	0.81	0.04	210	0.84	0.78	0.81	0.04						
16	14.2	25.7	106	22.1	6.94	106	14.3	12.3	9.16	11.9	2.58	106	2.71	2.24	2.48	0.33	106	2.71	2.24	2.48	0.33	106	2.71	2.24	2.48	0.33	106	2.71	2.24	2.48	0.33						
20	39.1	51.3	75	46.8	6.76	75	18.6	15.2	11.5	15.1	3.55	75	3.83	3.31	3.57	0.37	75	3.83	3.31	3.57	0.37	75	3.83	3.31	3.57	0.37	75	3.83	3.31	3.57	0.37						
30	62.9	72.2	45	67.6	4.67	45	27.9	19.8	15.8	21.1	6.19	45	6.17	5.46	5.82	0.50	45	6.17	5.46	5.82	0.50	45	6.17	5.46	5.82	0.50	45	6.17	5.46	5.82	0.50						
40	78.2	85.4	40.3	81.1	3.78	40.3	28.6	20.7	16.5	21.9	6.17	40.3	6.97	7.49	7.23	0.37	40.3	6.97	7.49	7.23	0.37	40.3	6.97	7.49	7.23	0.37	40.3	6.97	7.49	7.23	0.37						
50	87.8	92.0	32.0	88.7	3.01	32.0	29.4	22.1	17.4	22.9	6.04	32.0	7.97	9.52	8.75	1.10	32.0	7.97	9.52	8.75	1.10	32.0	7.97	9.52	8.75	1.10	32.0	7.97	9.52	8.75	1.10						
70	93.1	95.6	25.4	93.1	2.42	25.4	32.0	24.7	19.5	25.4	6.27	25.4	11.8	11.0	11.4	0.52	25.4	6.27	25.4	11.8	11.0	11.4	0.52	25.4	6.27	25.4	11.8	11.0	11.4	0.52	25.4	6.27	25.4	11.8	11.0	11.4	0.52
100	95.7	97.2	20.2	95.5	1.76	20.2	37.0	28.8	22.3	29.3	7.36	20.2	17.2	16.0	16.6	0.89	20.2	7.36	20.2	17.2	16.0	16.6	0.89	20.2	7.36	20.2	17.2	16.0	16.6	0.89	20.2	7.36	20.2	17.2	16.0	16.6	0.89
140	97.1	98.0	16.0	97.0	1.17	16.0	43.8	35.5	29.9	36.4	7.00	16.0	26.4	21.6	24.0	3.39	16.0	7.00	16.0	26.4	21.6	24.0	3.39	16.0	7.00	16.0	26.4	21.6	24.0	3.39	16.0	7.00	16.0	26.4	21.6	24.0	3.39
200	98.4	98.7	12.7	98.3	0.59	12.7	54.1	45.6	42.3	47.3	6.10	12.7	38.9	29.1	34.0	6.89	12.7	6.10	12.7	38.9	29.1	34.0	6.89	12.7	6.10	12.7	38.9	29.1	34.0	6.89	12.7	6.10	12.7	38.9	29.1	34.0	6.89
325	100	100	10.1	100	0.00	10.1	64.7	57.7	55.8	59.4	4.71	10.1	53.5	40.3	46.9	9.36	10.1	4.71	10.1	53.5	40.3	46.9	9.36	10.1	4.71	10.1	53.5	40.3	46.9	9.36	10.1	4.71	10.1	53.5	40.3	46.9	9.36
			8.00			8.00	75.6	70.5	70.9	72.3	2.84	8.00	68.9	53.8	61.4	10.7	8.00	2.84	8.00	68.9	53.8	61.4	10.7	8.00	2.84	8.00	68.9	53.8	61.4	10.7	8.00	2.84	8.00	68.9	53.8	61.4	10.7
			6.35			6.35	85.9	81.8	84.5	84.1	2.12	6.35	82.9	67.4	75.2	11.0	6.35	2.12	6.35	82.9	67.4	75.2	11.0	6.35	2.12	6.35	82.9	67.4	75.2	11.0	6.35	2.12	6.35	82.9	67.4	75.2	11.0
			5.05			5.05	93.6	90.9	94.2	92.9	1.78	5.05	93.3	80.4	86.9	9.14	5.05	1.78	5.05	93.3	80.4	86.9	9.14	5.05	1.78	5.05	93.3	80.4	86.9	9.14	5.05	1.78	5.05	93.3	80.4	86.9	9.14
			4.00			4.00	97.9	96.4	98.7	97.7	1.15	4.00	98.5	90.6	94.6	5.57	4.00	1.15	4.00	98.5	90.6	94.6	5.57	4.00	1.15	4.00	98.5	90.6	94.6	5.57	4.00	1.15	4.00	98.5	90.6	94.6	5.57
			3.17			3.17	99.7	98.8	99.8	99.4	0.55	3.17	99.9	97.3	98.6	1.82	3.17	0.55	3.17	99.9	97.3	98.6	1.82	3.17	0.55	3.17	99.9	97.3	98.6	1.82	3.17	0.55	3.17	99.9	97.3	98.6	1.82
			2.52			2.52	99.9	99.4	99.9	99.7	0.28	2.52	100	99.4	99.7	0.41	2.52	0.28	2.52	100	99.4	99.7	0.41	2.52	0.28	2.52	100	99.4	99.7	0.41	2.52	0.28	2.52	100	99.4	99.7	0.41
			2.00			2.00	99.9	99.5	99.9	99.8	0.26	2.00	100	100	100	0.01	2.00	0.26	2.00	100	100	100	0.01	2.00	0.26	2.00	100	100	100	0.01	2.00	0.26	2.00	100	100	100	0.01
			1.00			1.00	100	100	100	100	0.00	1.00	100	100	100	0.00	1.00	0.00	1.00	100	100	100	0.00	1.00	0.00	1.00	100	100	100	0.00	1.00	0.00	1.00	100	100	100	0.00

SD = Standard deviation.
 * Screen analysis used for micron size 45-210.
 Coulter counter used for micron size 1-40.3.

TABLE 5-61. PARTICLE SIZE DISTRIBUTION DATA (CYCLONES) AT ESP INLET (LOCATION 4)

Particulate Fraction	Sampling Day						Average Percent Mass (Std.Dev.)
	July 27		July 29		July 31		
	Mass (g)	Fraction (%)	Mass (g)	Fraction (%)	Mass (g)	Fraction (%)	
Probe Wash	4.6650	54.26	5.7838	57.95	4.0267	64.18	58.80 (5.01)
> 10 $\mu\text{m}^{(a)}$	1.9099	22.22	2.3726	23.77	0.8140	12.97	19.65 (5.84)
5-10 $\mu\text{m}^{(b)}$	0.3040	3.54	0.0720	0.72	0.0101	0.16	1.47 (1.81)
< 5 $\mu\text{m}^{(c)}$	1.7181	19.98	1.7517	17.55	1.4230	22.68	20.07 (2.57)
Total	8.5970	100.00	9.9801	100.00	6.2738	100.00	

(a) From coarse cyclone (10 μm cut).

(b) From fine cyclone (5 μm cut).

(c) From filter.

TABLE 5-62. PARTICULATE SIZE DISTRIBUTION (IMPACTOR) AT ESP OUTLET (LOCATION 5a)

Impactor Stage	Sampling Day												Average % Mass by Stage (Std. Dev.)
	July 27			July 29			July 31			Cumulative % Mass	Cumulative % Mass	Cumulative % Mass	
	Aerodynamic Cut D_{50} (μm)	% Mass	Cumulative % Mass	Aerodynamic Cut D_{50} (μm)	% Mass	Cumulative % Mass	Aerodynamic Cut D_{50} (μm)	% Mass	Cumulative % Mass				
RAPC ^(a)	7.82	13.73	13.73	7.74	6.63	6.63	7.65	5.22	5.22	5.22	5.22	8.53 (4.56)	
3	3.92	29.41	43.14	3.87	33.13	39.76	3.83	38.06	43.28	38.06	43.28	33.53 (4.34)	
4	2.05	15.69	58.83	2.02	12.05	51.81	1.99	10.45	53.73	10.45	53.73	12.73 (2.69)	
5	1.16	11.76	70.59	1.15	11.45	63.26	1.12	10.45	64.18	10.45	64.18	11.22 (0.68)	
6	0.56	11.76	82.35	0.55	10.84	74.10	0.54	6.72	70.9	6.72	70.9	9.77 (2.68)	
7	0.20	10.78	93.13	0.20	8.43	82.53	0.20	7.46	78.36	7.46	78.36	8.89 (1.71)	
Filter		6.86	100.00		17.47	100.00		21.64	100.0	21.64	100.0	15.32 (7.62)	

(a) Right angle pre-collector.

6.0 DATA ANALYSIS AND INTERPRETATION

6.1 Element Mass Balances

Figures 6-1 and 6-2 show the boundaries for the mass balance calculations and the plant components included in the calculations, as follows:

Figure 6-1. Mass balances on each of the boiler and ESP

Figure 6-2. Mass balance on the combined boiler and ESP.

6.1.1 Element Mass Balance Calculations

Assumptions necessary for calculating the element mass balances were identical to those required for the ash mass balances (Section 3.3.1), including the assumption of 35 percent carbon content in particulate at the ESP inlet. However, in addition it was assumed that:

- When "less than" values were reported for element analyses, a value equal to one-half of the detection limit was used in the element mass balance calculations.
- For antimony, cadmium, molybdenum, and selenium, the average results from the round-robin analyses of the coal were used for mass balance calculations (see Section B-6 in Appendix B).
- For aluminum, potassium, and sodium, certain outliers in the analytical data were replaced with the average of the remaining values (see Section 5.1).

Table 6-1 shows an example spreadsheet, illustrating the mass balance calculations for one of the 21 elements of interest, aluminum. A mass balance for each of the elements was performed in the same way, using a separate but identical spreadsheet for each element. Separate mass balance calculations are shown for the boiler, the ESP, and the combined boiler and ESP. The comments column at the right of Table 6-1 gives details regarding the calculations.

6.1.2 Element Mass Balance Results

Figures 6-3 through 6-23 show the average mass flows and results of the mass balances for each element in graphical form. Table 6-2 lists the results of the mass balance calculations for the 21 elements of interest. Separate mass balance results are shown for the boiler, the ESP, and the combined boiler and ESP. The three individual daily results are shown, along with the average and standard deviation of those results. The following paragraphs summarize the results for each element. Note that shaded areas of Table 6-2 and subsequent tables indicate results calculated on the basis of one or more non-detect values. Also, a few results are excluded from calculations of average values, because they result from marked outliers or suspect values in the analytical data. Such instances are noted in the subsequent paragraphs.

Aluminum. The aluminum content of the three streams exiting the boiler equalled 95 to 98 percent (average 97 percent) of the measured aluminum content of the coal being fired in the boiler.

The aluminum content of the two streams exiting the ESP equalled 91 to 109 percent (average 100 percent) of the aluminum content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the aluminum content of the four streams exiting the unit equalled 95 to 99 percent (average 97 percent) of the aluminum content of the coal fired in the boiler.

Two outlier values for aluminum, in particulate at the ESP outlet on July 29 and July 31, were excluded from the calculations. Those values were replaced with the corresponding value from July 27 (see Section 5.1.1).

Potassium. The potassium content of the three streams exiting the boiler equalled 94 to 107 percent (average 99 percent) of the measured potassium content of the coal being fired in the boiler.

The potassium content of the two streams exiting the ESP equalled 81 to 84 percent (average 83 percent) of the potassium content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the potassium content of the four streams exiting the unit equalled 91 to 104 percent (average 96 percent) of the potassium content of the coal fired in the boiler.

Two outlier values for potassium, in particulate at the ESP outlet on July 29 and July 31, were excluded from the calculations. Those values were replaced with the corresponding value from July 27 (see Section 5.1.1).

Titanium. The titanium content of the three streams exiting the boiler equalled 92 to 94 percent (average 93 percent) of the measured titanium content of the coal being fired in the boiler.

The titanium content of the two streams exiting the ESP equalled 78 to 106 percent (average 88 percent) of the titanium content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the titanium content of the four streams exiting the unit equalled 90 to 93 percent (average 91 percent) of the titanium content of the coal fired in the boiler.

Silicon. A complete mass balance could not be performed for silicon because some components of the sampling trains (the cyclone and the filter catch) were not analyzed for silicon. A mass balance was performed using the available data, which account for most of the particulate silicon (Section 5.1.1).

The silicon content of the bottom ash and preheater hopper ash exiting the boiler and of that portion of the sampling train that was analyzed for silicon equalled 95 to 98 percent (average 97 percent) of the measured silicon content of the coal being fired in the boiler.

Based on the portions of the sampling train that were analyzed for silicon, the silicon content of the two streams exiting the ESP equalled 101 to 193 percent (average 148 percent) of the silicon content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the silicon content of the four streams exiting the unit equalled 99 to 101 percent (average 100 percent) of the silicon content of the coal fired in the boiler. Although some portions of the sampling trains were not analyzed for silicon, the amount of error for the entire unit is small because only a tiny fraction (e.g., 0.5 percent) of the silicon would be expected to exit the ESP as fly ash.

Sodium. The sodium content of the three streams exiting the boiler equalled 51 to 109 percent (average 83 percent) of the measured sodium content of the coal being fired in the boiler. The analytical result for sodium in bottom ash on 7/29/93 (Table 5-7) is far out of line with the other results. For this reason, the 7/29/93 bottom ash sodium was not used and the average bottom ash analyses of the other two tests was used in mass balance calculations.

The sodium content of the two streams exiting the ESP equalled 31 to 107 percent (average 64 percent) of the sodium content of the flue gas stream entering the ESP. The variable analytical results for sodium, discussed in Section 5.1.1, led to the observed variability in mass balances. One outlier, for sodium in flue gas at the ESP outlet on 7/27, was excluded and replaced with the average from the other two days.

Considering the boiler and the ESP together, the sodium content of the four streams exiting the unit equalled 52 to 72 percent (average 64 percent) of the sodium content of the coal fired in the boiler. In addition to the bottom-ash value noted above, one other outlier for sodium was excluded from the calculations, that being the high sodium value in particulate at the ESP outlet on July 27 (Section 5.1.1).

Mercury. The mercury content of the three streams exiting the boiler equalled 83 to 149 percent (average 125 percent) of the measured mercury content of the coal being fired in the boiler.

The mercury content of the two streams exiting the ESP equalled 65 to 77 percent (average 72 percent) of the mercury content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the mercury content of the four streams exiting the unit equalled 62 to 114 percent (average 90 percent) of the mercury content of the coal fired in the boiler.

Selenium. The selenium content of the three streams exiting the boiler equalled 40 to 49 percent (average 44 percent) of the measured selenium content of the coal being fired in the boiler. This result is based on Se data from the round-robin coal analysis.

The selenium content of the two streams exiting the ESP equalled 78 to 137 percent (average 112 percent) of the selenium content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the selenium content of the four streams exiting the unit equalled 35 to 63 percent (average 48 percent) of the selenium content of the coal fired in the boiler.

Arsenic. The arsenic content of the three streams exiting the boiler equalled 50 to 77 percent (average 64 percent) of the measured arsenic content of the coal being fired in the boiler.

The arsenic content of the two streams exiting the ESP equalled 74 to 93 percent (average 81 percent) of the arsenic content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the arsenic content of the four streams exiting the unit equalled 38 to 60 percent (average 53 percent) of the arsenic content of the coal fired in the boiler.

Cadmium. The cadmium content of the three streams exiting the boiler equalled 172 to 194 percent (average 181 percent) of the measured cadmium content of the coal being fired in the boiler. This result is based on the Cd results from the round-robin coal analysis.

The cadmium content of the two streams exiting the ESP equalled 55 to 62 percent (average 58 percent) of the cadmium content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the cadmium content of the four streams exiting the unit equalled 158 to 172 percent (average 164 percent) of the cadmium content of the coal fired in the boiler.

Chromium. The chromium content of the three streams exiting the boiler equalled 100 to 105 percent (average 103 percent) of the measured chromium content of the coal being fired in the boiler.

The chromium content of the two streams exiting the ESP equalled 71 to 77 percent (average 75 percent) of the chromium content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the chromium content of the four streams exiting the unit equalled 94 to 98 percent (average 96 percent) of the chromium content of the coal fired in the boiler.

Molybdenum. The molybdenum content of the three streams exiting the boiler equalled 64 to 79 percent (average 73 percent) of the measured molybdenum content of the coal being fired in the boiler. This result is based on the round-robin coal analysis.

The molybdenum content of the two streams exiting the ESP equalled 117 to 149 percent (average 132 percent) of the molybdenum content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the molybdenum content of the four streams exiting the unit equalled 77 to 87 percent (average 83 percent) of the molybdenum content of the coal fired in the boiler.

Boron. A mass balance could not be performed for boron because the flue gas sampling trains were not analyzed for boron.

Antimony. The antimony content of the three streams exiting the boiler equalled 51 to 122 percent (average 80 percent) of the measured antimony content of the coal being fired in the boiler. This result is based on Sb results from the round-robin coal analysis.

The antimony content of the two streams exiting the ESP equalled 24 to 99 percent (average 67 percent) of the antimony content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the antimony content of the four streams exiting the unit equalled 37 to 55 percent (average 48 percent) of the antimony content of the coal fired in the boiler.

All the antimony results included at least one non-detect value in their calculation.

Barium. The barium content of the three streams exiting the boiler equalled 119 to 126 percent (average 123 percent) of the measured barium content of the coal being fired in the boiler.

The barium content of the two streams exiting the ESP equalled 84 to 101 percent (average 95 percent) of the barium content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the barium content of the four streams exiting the unit equalled 119 to 125 percent (average 123 percent) of the barium content of the coal fired in the boiler.

Beryllium. The beryllium content of the three streams exiting the boiler equalled 84 to 97 percent (average 93 percent) of the measured beryllium content of the coal being fired in the boiler.

The beryllium content of the two streams exiting the ESP equalled 81 to 83 percent (average 82 percent) of the beryllium content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the beryllium content of the four streams exiting the unit equalled 80 to 92 percent (average 88 percent) of the beryllium content of the coal fired in the boiler.

Lead. The lead content of the three streams exiting the boiler equalled 45 to 79 percent (average 64 percent) of the measured lead content of the coal being fired in the boiler.

The lead content of the two streams exiting the ESP equalled 77 to 87 percent (average 82 percent) of the lead content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the lead content of the four streams exiting the unit equalled 36 to 66 percent (average 54 percent) of the lead content of the coal fired in the boiler.

Manganese. The manganese content of the three streams exiting the boiler equalled 109 to 126 percent (average 115 percent) of the measured manganese content of the coal being fired in the boiler.

The manganese content of the two streams exiting the ESP equalled 72 to 87 percent (average 82 percent) of the manganese content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the manganese content of the four streams exiting the unit equalled 107 to 122 percent (average 112 percent) of the manganese content of the coal fired in the boiler.

Nickel. The nickel content of the three streams exiting the boiler equalled 94 to 111 percent (average 101 percent) of the measured nickel content of the coal being fired in the boiler.

The nickel content of the two streams exiting the ESP equalled 72 to 76 percent (average 74 percent) of the nickel content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the nickel content of the four streams exiting the unit equalled 87 to 103 percent (average 93 percent) of the nickel content of the coal fired in the boiler.

Vanadium. The vanadium content of the three streams exiting the boiler equalled 88 to 98 percent (average 91 percent) of the measured vanadium content of the coal being fired in the boiler.

The vanadium content of the two streams exiting the ESP equalled 75 to 81 percent (average 77 percent) of the vanadium content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the vanadium content of the four streams exiting the unit equalled 82 to 93 percent (average 86 percent) of the vanadium content of the coal fired in the boiler.

Copper. The copper content of the three streams exiting the boiler equalled 82 to 96 percent (average 87 percent) of the measured copper content of the coal being fired in the boiler.

The copper content of the two streams exiting the ESP equalled 74 to 78 percent (average 77 percent) of the copper content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the copper content of the four streams exiting the unit equalled 70 to 84 percent (average 75 percent) of the copper content of the coal fired in the boiler.

Cobalt. The cobalt content of the three streams exiting the boiler equalled 89 to 104 percent (average 96 percent) of the measured cobalt content of the coal being fired in the boiler.

The cobalt content of the two streams exiting the ESP equalled 71 to 85 percent (average 79 percent) of the cobalt content of the flue gas stream entering the ESP.

Considering the boiler and the ESP together, the cobalt content of the four streams exiting the unit equalled 86 to 100 percent (average 92 percent) of the cobalt content of the coal fired in the boiler.

6.1.3 Discussion of Element Mass Balance Results

Tables 6-3 through 6-5 report the mass balance results in a way that is more useful, by organizing results according to the units of the plant. Tables 6-3 to 6-5 show results for the boiler; the ESP; and the boiler plus ESP, respectively. Part a of the tables reports the mass balance results in order based on the ratio of the output to the input. For convenience, Part b of each table also presents the same results in alphabetical order for the elements.

Tables 6-3a and 3b show the mass balances for the boiler. The average mass balance for all elements was 95.4 percent; for the five major elements it was 93.5 percent. It can be seen that balances within ± 50 percent (based on average values) were achieved for 18 of the 20 elements and that balances within ± 30 percent were achieved for 16 of the elements. For one element (selenium), the quantity of the element found in the exit streams was less than half that reported entering the boiler and for two elements (lead and arsenic) less than two-thirds of the element contained in the coal was found in streams exiting the boiler. The fact that reasonably good mass balances were achieved for 16 of the elements suggests that sampling and flow measurement procedures were satisfactory, and that assumptions used in the calculations were reasonable. This leaves recovery of the element from the sample stream, and analytical problems associated with the low concentrations of the elements, as the most likely causes of poor mass balance results. For all five of the major elements (aluminum, potassium, silicon, sodium, and titanium), the balance for the boiler was within $+0/-20$ percent.

Tables 6-4a and 4b show the mass balances for the ESP. The average mass balance for all elements was 86.4 percent; for the five major elements it was 96.3 percent. It can be seen that balances within ± 50 percent (based on average values) were achieved for all 20 of the elements and that balances within ± 30 percent were achieved for 15 of the elements. Three of the five major elements (aluminum, potassium, and titanium) produced mass balances within $+0/-20$ percent.

Tables 6-5a and 5b show the mass balances for the combined boiler and the ESP. The average mass balance for all elements was 87.5 percent, for the five major elements it was 89.3 percent. Conducting a mass balance for this combination of devices eliminates the effect of any sampling problems at the exit of the boiler (entrance to the ESP) because this stream drops out of the calculation. It can be seen that balances within ± 50 percent were achieved for 18 of the 20 elements and the balances were within ± 30 percent for 14 of the elements. Four of the five major elements produced mass balances within $+0/-15$ percent.

Results for the combined boiler and ESP (Table 6-5) tended to parallel the results for the boiler alone (Table 6-3). That is, for the same three elements (lead, selenium, and arsenic), less than 70 percent of the material reported going into the boiler was found in the exit streams, and for the same element (cadmium), the quantity of the element found in the exit streams was appreciably more than that reported entering the boiler.

In general, the mass balance results show good accounting for nearly all elements in the plant streams. However, it was noted that the mass balance values for the boiler and for the combined boiler and ESP tended to be lower for some (but not all) of the more volatile elements, especially selenium, arsenic, sodium, and lead. This may suggest a problem with capturing or recovering the vapor phase component of these elements.

6.2 Emission Factor Determinations

6.2.1 Emission Factor Calculations

Emission factors (E) were calculated as follows:

$$E, \text{ lb}/10^{12} \text{ Btu} = \frac{\text{Loading, } \mu\text{g}/\text{Ncm} \times \text{stack gas flow rate, Ncm}/\text{min} \times 60 \text{ min}/\text{hr}}{1,000,000 \mu\text{g}/\text{g} \times 453.6 \text{ g}/\text{lb} \times \text{Firing rate, } 10^{12} \text{ Btu}/\text{hr}}$$

and

$$E, \mu\text{g}/\text{MJ} = \frac{\text{Loading, } \mu\text{g}/\text{Ncm} \times \text{stack gas flow rate, Ncm}/\text{min} \times 60 \text{ min}/\text{hr}}{\text{Firing rate, MJ}/\text{hr}}$$

where the firing rate in MJ/hr equals the firing rate in 10^{12} Btu/hr times 1.055×10^9 .

In these equations, the term loading means the concentration in flue gas of an analyte or of particulate matter. Radionuclide emission factors were calculated from concentration data in pCi/Ncm, producing E values in pCi/MJ and mCi/10¹² Btu.

An example emission factor calculation is shown below, indicating both the calculation procedure and the location of the primary data within this report. This example calculation is for aluminum on July 27, 1993.

Example:

$$\text{Aluminum loading in stack gas} = 5,238 \mu\text{g/Ncm (Table 5-4, page 5-8)}$$

$$\text{Stack gas flow rate} = 5,316 \text{ Ncm/min (Table 2-2, page 2-12)}$$

$$\text{Coal feed rate} = 91,500 \text{ lb/hr (Table 2-4, page 2-14)}$$

$$\text{Firing rate} = 91,500 \text{ lb/hr} \times 12,269 \text{ Btu/lb (Table 5-58, p. 5-81)}$$

$$= 1.123 \times 10^9 \text{ Btu/hr}$$

$$= 1.123 \times 10^{-3} (10^{12} \text{ Btu/hr}).$$

Therefore the aluminum EF is

$$\text{EF} = \frac{5,238 \mu\text{g/Ncm} \times 5,316 \text{ Ncm/min} \times 60 \text{ min/hr}}{1 \times 10^6 \mu\text{g/g} \times 453.6 \text{ g/lb} \times 1.123 \times 10^{-3} (10^{12} \text{ Btu/hr})}$$

$$\text{EF} = 3,280 \text{ lb}/10^{12} \text{ Btu}$$

This result can be found at the top of the first data column in Table 6-6, which shows emission factors for elements. The same emission rate can be calculated in $\mu\text{g}/\text{mJ}$ by converting the firing rate to MJ/hr, i.e.

$$\text{Firing rate} = 1.123 \times 10^{-3} (1.055 \times 10^9)$$

$$= 1.184 \times 10^6 \text{ MJ/hr}$$

Then

$$\text{EF} = \frac{5,238 \mu\text{g/Ncm} \times 5,316 \text{ Ncm/min} \times 60 \text{ min/hr}}{1.184 \times 10^6 \text{ MJ/hr}}$$

$$\text{EF} = 1,410 \mu\text{g}/\text{MJ}$$

This value can be found at the top of the first data column in Table 6-7.

6.2.2 Emission Factor Results

Tables 6-6 through 6-23 present the emission factor results for all analytes, calculated as described above. Individual sample results are shown, along with the average of the three individual results. In each of these tables, the emission factors are shown with associated total uncertainty (TU) values. The TU values, which are 95 percent confidence intervals, indicate the total \pm contribution of precision and bias effects, as described in Appendix G. The emission factors should not be used without consideration of their associated TU values. When an average emission factor in Tables 6-6 through 6-23 is the result of three values all of which are based on non-detects at the Niles stack, then in that case only the full value of the detection limits is used to calculate emission factors. In all other cases, i.e., with a mixture of detect and non-detect values, one-half the detection limit is used in calculations. The latter cases are denoted by an asterisk (*) and a footnote in the tables.

6.3 Removal Efficiencies

6.3.1 Removal Efficiency Calculations

Removal efficiencies were calculated for each element, for each inorganic run. Calculations were made only for the ESP, as the only emission control device at Niles Boiler No. 2. The calculation for removal efficiency (RE) in the ESP was:

$$\text{RE, percent} = \frac{(\text{MFR, ESP inlet} - \text{MFR, ESP outlet}) \times 100}{\text{MFR, ESP inlet}}$$

The term MFR means the mass flow rate of an analyte in lb/hr. A sample calculation of ESP removal efficiency for aluminum is included in the sample mass balance calculation shown in Table 6-1.

6.3.2 Removal Efficiency Results

Table 6-24 presents the ESP removal efficiencies for each of the elements. Table 6-24a presents the results in order of removal efficiency of the elements, and Table 6-24b presents the same results in alphabetical order by element.

Table 6-24 shows that average removal efficiencies in the ESP for 10 of the 20 elements were greater than 99 percent, removal efficiencies for 12 of the 20 elements were greater than 98 percent, and removal efficiencies for 18 of the 20 elements were greater than 90 percent. Only mercury and selenium gave low removal efficiencies, 30 and 8 percent, respectively. The results for mercury were similar across the three test days, and the low removal efficiency is consistent with the predominance of vapor over particulate-phase mercury (see Section 7.2). No removal efficiency could be calculated for boron, due to lack of measurements of this element in flue gas particulate. In general, these results are consistent with the expected and measured ESP removal efficiency for flue gas particulate matter (see Section 2.2.1), and with the known volatility of certain elements (e.g., mercury). Note that the removal efficiency calculations exclude a few outliers for individual elements in particulate at the ESP outlet on 7/27/93 (sodium), 7/29/93 (aluminum and potassium), and 7/31/93 (aluminum and potassium), as described in Section 5.1.1.

TABLE 6-1. SAMPLE METAL MASS BALANCE CALCULATION FOR NILES BOILER: ALUMINUM

Metals Calculations: Aluminum		M-1	M-2	M-3	Average	Comments
Test Date		7/27/93	7/29/93	7/31/93		
Flue gas loadings						
Boiler Outlet (Location 4)						
1. Gas flow rate, dry, 3% O2	Ncm/min	6163	6874	6562		From Table 2-2
2. Metal loading	ug/Ncm	161714.91	163287.7	129292.8		From Table 5-2
3a. Metal emissions	g/hr	59216.767	59588.56	58984.85		#1*#2*68/1000000
3b. Metal emissions	lb/hr	130.54843	131.1917	112.2241	124.6547	#3a/453.6
Stack (Location 5)						
4. Gas flow rate, dry, 3% O2	Ncm/min	5316	5893	5128		From Table 2-2
5. Metal loading	ug/Ncm	5237.5428	6237.543	5237.543		From Table 5-4 (Run 1 only)
6a. Metal emissions	g/hr	1676.5667	1688.488	1688.973		#4*#5*68/1000000
6b. Metal emissions	lb/hr	3.6829871	3.528413	3.547119	3.586146	#6a/453.6
Metal mass balances						
Boiler Furnace						
7. Fuel fired	lb/hr	91568	94288	98788		From Table 2-4
8. Metal in coal	ug/g	14888	13988	14388		From Table 5-6
9. Metal in coal	lb/hr	1281	1399.38	1362.81	1324.397	#7*#8/1000000
10. Furnace metal emissions	lb/hr	138.54843	131.1917	112.2241	124.6547	#3b
11. Bottom ash	lb/hr	8626.8757	8637.825	9317.192		From Table 3-13
12. Metal in bottom ash	ug/g	121888	123688	124988		From Table 5-7
13. Metal in bottom ash	lb/hr	1831.8888	1692.256	1163.717	1895.868	#11*#12/1000000
14. Preheater hopper ash	lb/hr	1873.7888	1839.289	1776.888		From Table 3-13
15. Metal in hopper ash	ug/g	38888	32888	35888		From Table 5-8
16. Metal in hopper ash	lb/hr	57.788988	69.66742	62.19189	69.86617	#14*#15/1000000
17. Total metal out	lb/hr	1219.8652	1283.115	1338.132		#18*#13*#16
18. Metal in - Metal out	lb/hr	61.134829	26.26457	44.67755		#9-#17
19. Metal out/metal in		.95227578	.9799412	.9878988	.9866359	#17/#9
ESP						
20. ESP inlet metal emissions	lb/hr	130.54843	131.1917	112.2241	124.6547	#3b
21. ESP outlet metal emissions	lb/hr	3.6829871	3.528413	3.547119	3.586146	#6b
22. ESP hopper particulate	lb/hr	1777.6914	2882.544	1349.397		From Table 3-13
23. Metal in ESP particulate	ug/g	71532.92	67267.55	72625.85	70475.44	From data in Table 6-9(A-E)
24. Metal in ESP part. catch	lb/hr	127.16346	138.7423	98.89189	121.3823	#22*#23/1000000
25. Total metal out	lb/hr	130.84638	142.2787	181.5482		#21*#24
26. Metal in - Metal out	lb/hr	-.2979322	-11.8798	16.87589		#28-#25
27. Metal out/metal in		1.0822822	1.084449	.9846899	.9972883	#25/#28

TABLE 6-1. (Continued)

Boiler and ESP							
28.	Metal in coal	lb/hr	1281	1309.38	1382.01	#19	
29.	Metal out, boiler process streams	lb/hr	1089.3167	1151.924	1225.988	#13-#16	
30.	Total metal out, ESP	lb/hr	130.84036	142.2707	161.5482	#25	
31.	Total metal out	lb/hr	1220.1631	1294.194	1327.457	#29-#30	
32.	Metal in - Metal out	lb/hr	68.83697	15.18559	55.35344	#28-#31	
33.	Metal out/metal in		.96259828	.9884925	.9599703	#31/#28	

Metal Emission Factors							
Firing Rate							
34.	Coal feed rate	lb/hr	91500	94200	96700		From Table 2-4
35.	Coal heating value	Btu/lb	12269	12100	11892		From Table 5-58
36a.	Firing rate	10 ⁶ Btu/hr	1122.6135	1140.574	1149.956		#34-#36/1000000
36b.	Firing rate	MJ/hr	1184357.2	1283305.	1213254.		#36a/1055
Boiler emissions							
37a.	Metal emissions	g/hr	59216.767	59500.56	59904.85		#3a
37b.	Metal emissions	lb/hr	130.54843	131.1917	112.2241		#3b
38a.	Metal emission factor	ug/MJ	49999.075	49454.20	41959.02		#37a*1000000/#36b
38b.	Metal emission factor	lb/10 ¹² Btu	110289.74	115022.6	97589.88		#37b*1000000/#36a
ESP emissions							
39a.	Metal emissions	g/hr	1670.5667	1690.480	1690.973		#6a
39b.	Metal emissions	lb/hr	3.6829071	3.528413	3.547119		#6b
40a.	Metal emission factor	ug/MJ	1410.5200	1330.977	1326.218		#39a*1000000/#36b
40b.	Metal emission factor	lb/10 ¹² Btu	3200.6545	3003.543	3084.500		#39b*1000000/#36a
Removal Efficiencies							
41.	ESP	percent	97.170006	97.31049	96.83925	97.10955	(#38b-#40b)*100/#38b

TABLE 6-2. MASS BALANCE RESULTS FOR METALS (percent)^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Aluminum					
Boiler	95.2	98.0	96.8	96.7	1.4
ESP	100.2	108.4	90.5	99.7	9.0
Boiler & ESP	95.3	98.8	96.0	96.7	1.9
Potassium					
Boiler	94.7	107.0	93.8	98.5	7.4
ESP	83.6	84.2	81.0	82.9	1.7
Boiler & ESP	91.6	103.8	91.1	95.5	7.2
Titanium					
Boiler	94.4	92.0	92.9	93.1	1.2
ESP	79.3	105.9	77.5	87.5	15.9
Boiler & ESP	91.2	92.7	90.4	91.4	1.2
Silicon					
Boiler	95.4	96.3	98.4	96.7	1.6
ESP	149.0	192.9	101.3	147.8	45.8
Boiler & ESP	98.7	101.2	98.5	99.5	1.5
Sodium					
Boiler	88.3	108.7	51.1	82.7	29.2
ESP	53.7	30.8	107.0	63.8	39.1
Boiler & ESP	72.3	66.1	52.0	63.5	10.4
Mercury					
Boiler	148.8	143.6	83.4	125.3	36.3
ESP	76.8	65.1	74.6	72.1	6.2
Boiler & ESP	114.5	93.7	62.4	90.2	26.3
Selenium					
Boiler	49.3	42.2	39.7	43.7	5.0
ESP	136.6	78.0	122.7	112.4	30.6
Boiler & ESP	63.1	35.0	46.6	48.2	14.1
Arsenic					
Boiler	77.1	63.6	50.4	63.7	13.4
ESP	77.4	93.4	73.5	81.4	10.6
Boiler & ESP	60.4	59.6	38.2	52.7	12.6

TABLE 6-2. (Continued)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Cadmium					
Boiler	178.0	194.3	171.7	181.3	11.7
ESP	61.8	55.3	56.6	57.9	3.5
Boiler & ESP	162.5	171.5	157.7	163.9	7.0
Chromium					
Boiler	104.5	105.2	100.4	103.4	2.6
ESP	75.7	76.6	71.2	74.5	2.9
Boiler & ESP	96.6	98.2	93.5	96.1	2.4
Molybdenum					
Boiler	79.4	76.0	64.0	73.1	8.1
ESP	117.3	130.7	149.4	132.5	16.1
Boiler & ESP	86.2	87.0	76.7	83.3	5.7
Boron					
Boiler	NA	NA	NA	NA	NA
ESP	NA	NA	NA	NA	NA
Boiler & ESP	NA	NA	NA	NA	NA
Antimony					
Boiler	50.9	66.5	121.6	79.7	37.2
ESP	99.0	78.9	24.0	67.3	38.8
Boiler & ESP	50.5	54.9	37.4	47.6	9.1
Barium					
Boiler	119.0	125.1	126.1	123.4	3.8
ESP	100.8	99.6	84.3	94.9	9.2
Boiler & ESP	119.1	125.0	123.7	122.6	3.1
Beryllium					
Boiler	97.2	84.0	96.6	92.6	7.5
ESP	83.1	83.0	81.1	82.4	1.2
Boiler & ESP	91.5	79.8	92.2	87.8	7.0
Lead					
Boiler	79.1	66.4	45.2	63.6	17.1
ESP	82.1	87.4	77.4	82.3	5.0
Boiler & ESP	66.1	58.7	35.9	53.6	15.7

TABLE 6-2. (Continued)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Manganese					
Boiler	108.7	108.9	126.4	114.7	10.2
ESP	87.4	86.2	71.7	81.8	8.8
Boiler & ESP	106.6	106.7	122.1	111.8	8.9
Nickel					
Boiler	94.4	97.1	110.7	100.7	8.7
ESP	76.0	72.0	73.5	73.8	2.0
Boiler & ESP	87.1	88.9	103.2	93.1	8.8
Vanadium					
Boiler	88.5	97.8	87.8	91.4	5.5
ESP	75.1	81.0	75.2	77.1	3.4
Boiler & ESP	81.5	92.6	82.6	85.6	6.1
Copper					
Boiler	83.7	95.9	81.6	87.0	7.8
ESP	74.1	78.2	77.5	76.6	2.2
Boiler & ESP	70.0	83.9	72.4	75.4	7.4
Cobalt					
Boiler	103.6	88.9	96.1	96.2	7.3
ESP	84.7	82.6	70.6	79.3	7.6
Boiler & ESP	99.8	85.9	89.6	91.8	7.2

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

TABLE 6-3a. MASS BALANCE RESULTS FOR BOILER, BY PERCENTAGE IN BALANCE^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Boron	NA	NA	NA	NA	NA
Selenium	49.3	42.2	39.7	43.7	5.0
Lead	79.1	66.4	45.2	63.6	17.1
Arsenic	77.1	63.6	50.4	63.7	13.4
Molybdenum	79.4	76.0	64.0	73.1	8.1
Antimony	50.9	66.5	121.6	79.7	37.2
Sodium	88.3	108.7	51.1	82.7	29.2
Copper	83.7	95.9	81.6	87.0	7.8
Vanadium	88.5	97.8	87.8	91.4	5.5
Beryllium	97.2	84.0	96.6	92.6	7.5
Titanium	94.4	92.0	92.9	93.1	1.2
Cobalt	103.6	88.9	96.1	96.2	7.3
Aluminum	95.2	98.0	96.8	96.7	1.4
Silicon	95.4	96.3	98.4	96.7	1.6
Potassium	94.7	107.0	93.8	98.5	7.4
Nickel	94.4	97.1	110.7	100.7	8.7
Chromium	104.5	105.2	100.4	103.4	2.6
Manganese	108.7	108.9	126.4	114.7	10.2
Barium	119.0	125.1	126.1	123.4	3.8
Mercury	148.8	143.6	83.4	125.3	36.3
Cadmium	178.0	194.3	171.7	181.3	11.7

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

TABLE 6-3b. MASS BALANCE RESULTS FOR BOILER, ALPHABETICALLY^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Aluminum	95.2	98.0	96.8	96.7	1.4
Antimony	50.9	66.5	121.6	79.7	37.2
Arsenic	77.1	63.6	50.4	63.7	13.4
Barium	119.0	125.1	126.1	123.4	3.8
Beryllium	97.2	84.0	96.6	92.6	7.5
Boron	NA	NA	NA	NA	NA
Cadmium	178.0	194.3	171.7	181.3	11.7
Chromium	104.5	105.2	100.4	103.4	2.6
Cobalt	103.6	88.9	96.1	96.2	7.3
Copper	83.7	95.9	81.6	87.0	7.8
Lead	79.1	66.4	45.2	63.6	17.1
Manganese	108.7	108.9	126.4	114.7	10.2
Mercury	148.8	143.6	83.4	125.3	36.3
Molybdenum	79.4	76.0	64.0	73.1	8.1
Nickel	94.4	97.1	110.7	100.7	8.7
Potassium	94.7	107.0	93.8	98.5	7.4
Selenium	49.3	42.2	39.7	43.7	5.0
Silicon	95.4	96.3	98.4	96.7	1.6
Sodium	88.3	108.7	51.1	82.7	29.2
Titanium	94.4	92.0	92.9	93.1	1.2
Vanadium	88.5	97.8	87.8	91.4	5.5

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

TABLE 6-4a. MASS BALANCE RESULTS FOR ESP, BY PERCENTAGE IN BALANCE^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Boron	NA	NA	NA	NA	NA
Cadmium	61.8	55.3	56.6	57.9	3.5
Sodium	53.7	30.8	107.0	63.8	39.1
Antimony	99.0	78.9	24.0	67.3	38.8
Mercury	76.8	65.1	74.6	72.1	6.2
Nickel	76.0	72.0	73.5	73.8	2.0
Chromium	75.7	76.6	71.2	74.5	2.9
Copper	74.1	78.2	77.5	76.6	2.2
Vanadium	75.1	81.0	75.2	77.1	3.4
Cobalt	84.7	82.6	70.6	79.3	7.6
Arsenic	77.4	93.4	73.5	81.4	10.6
Manganese	87.4	86.2	71.7	81.8	8.8
Lead	82.1	87.4	77.4	82.3	5.0
Beryllium	83.1	83.0	81.1	82.4	1.2
Potassium	83.6	84.2	81.0	82.9	1.7
Titanium	79.3	105.9	77.5	87.5	15.9
Barium	100.8	99.6	84.3	94.9	9.2
Aluminum	100.2	108.4	90.5	99.7	9.0
Selenium	136.6	78.0	122.7	112.4	30.6
Molybdenum	117.3	130.7	149.4	132.5	16.1
Silicon	149.0	192.9	101.3	147.8	45.8

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

TABLE 6-4b. MASS BALANCE RESULTS FOR ELECTROSTATIC PRECIPITATOR, ALPHABETICALLY^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Aluminum	100.2	108.4	90.5	99.7	9.0
Antimony	99.0	78.9	24.0	67.3	38.8
Arsenic	77.4	93.4	73.5	81.4	10.6
Barium	100.8	99.6	84.3	94.9	9.2
Beryllium	83.1	83.0	81.1	82.4	1.2
Boron	NA	NA	NA	NA	NA
Cadmium	61.8	55.3	56.6	57.9	3.5
Chromium	75.7	76.6	71.2	74.5	2.9
Cobalt	84.7	82.6	70.6	79.3	7.6
Copper	74.1	78.2	77.5	76.6	2.2
Lead	82.1	87.4	77.4	82.3	5.0
Manganese	87.4	86.2	71.7	81.8	8.8
Mercury	76.8	65.1	74.6	72.1	6.2
Molybdenum	117.3	130.7	149.4	132.5	16.1
Nickel	76.0	72.0	73.5	73.8	2.0
Potassium	83.6	84.2	81.0	82.9	1.7
Selenium	136.6	78.0	122.7	112.4	30.6
Silicon	149.0	192.9	101.3	147.8	45.8
Sodium	53.7	30.8	107.0	63.8	39.1
Titanium	79.3	105.9	77.5	87.5	15.9
Vanadium	75.1	81.0	75.2	77.1	3.4

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

TABLE 6-5a. MASS BALANCE RESULTS FOR BOILER & ESP, BY PERCENTAGE
IN BALANCE^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Boron	NA	NA	NA	NA	NA
Antimony	50.5	54.9	37.4	47.6	9.1
Selenium	63.1	35.0	46.6	48.2	14.1
Arsenic	60.4	59.6	38.2	52.7	12.6
Lead	66.1	58.7	35.9	53.6	15.7
Sodium	72.3	66.1	52.0	63.5	10.4
Copper	70.0	83.9	72.4	75.4	7.4
Molybdenum	86.2	87.0	76.7	83.3	5.7
Vanadium	81.5	92.6	82.6	85.6	6.1
Beryllium	91.5	79.8	92.2	87.8	7.0
Mercury	114.5	93.7	62.4	90.2	6.2
Titanium	91.2	92.7	90.4	91.4	1.2
Cobalt	99.8	85.9	89.6	91.8	7.2
Nickel	87.1	88.9	103.2	93.1	8.8
Potassium	91.6	103.8	91.1	95.5	7.2
Chromium	96.6	98.2	93.5	96.1	2.9
Aluminum	95.3	98.8	96.0	96.7	1.9
Silicon	98.7	101.2	98.5	99.5	1.5
Manganese	106.6	106.7	122.1	111.8	8.9
Barium	119.1	125.0	123.7	122.6	3.1
Cadmium	162.5	171.5	157.7	163.9	7.0

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

TABLE 6-5b. MASS BALANCE RESULTS FOR BOILER & ESP, ALPHABETICALLY^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Aluminum	95.3	98.8	96.0	96.7	1.9
Antimony	50.5	54.9	37.4	47.6	9.1
Arsenic	60.4	59.6	38.2	52.7	12.6
Barium	119.1	125.0	123.7	122.6	3.1
Beryllium	91.5	79.8	92.2	87.8	7.0
Boron	NA	NA	NA	NA	NA
Cadmium	162.5	171.5	157.7	163.9	7.0
Chromium	96.6	98.2	93.5	96.1	2.9
Cobalt	99.8	85.9	89.6	91.8	7.2
Copper	70.0	83.9	72.4	75.4	7.4
Lead	66.1	58.7	35.9	53.6	15.7
Manganese	106.6	106.7	122.1	111.8	8.9
Mercury	114.5	93.7	62.4	90.2	6.2
Molybdenum	86.2	87.0	76.7	83.3	5.7
Nickel	87.1	88.9	103.2	93.1	8.8
Potassium	91.6	103.8	91.1	95.5	7.2
Selenium	63.1	35.0	46.6	48.2	14.1
Silicon	98.7	101.2	98.5	99.5	1.5
Sodium	72.3	66.1	52.0	63.5	10.4
Titanium	91.2	92.7	90.4	91.4	1.2
Vanadium	81.5	92.6	82.6	85.6	6.1

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

TABLE 6-6. EMISSION FACTORS FOR ELEMENTS (lb/10¹² BTU)

Analyte	N-5a-MUM-727		N-5a-MUM-729		N-5a-MUM-731		AVERAGE		TU
Aluminum	3280		#		#		3280		NC
Potassium	2040		#		#		2040		NC
Sodium	#		ND <	15.1 *	525		266 ##		NC
Titanium	32.1		16.9		21.4		23		20
Antimony	ND <	0.371	ND <	0.355	ND <	0.361	ND <	0.36	0.06
Arsenic	49.7		35.2		41.4		42		19
Barium	9.69		2.73		3.79		5.4		9.3
Beryllium	0.194		0.165		0.196		0.19		0.05
Boron	NA		NA		NA		NA		NA
Cadmium	ND <	0.032 *	ND <	0.028 *	0.141		0.07 ##		0.16
Chromium	3.08		3.48		2.58		3.0		1.2
Cobalt	ND <	0.121	ND <	0.110	ND <	0.118	ND <	0.12	0.02
Copper	4.87		3.17		4.02		4.0		2.2
Lead	1.65		1.12		2.04		1.6		1.2
Manganese	4.80		2.42		2.99		3.4		3.1
Mercury	17.1		12.5		13.7		14		6.4
Molybdenum	2.56		2.52		1.69		2.3		1.3
Nickel	0.824		0.551		0.275		0.55		0.69
Selenium	85.6		33.1		66.4		62		67
Vanadium	2.34		2.37		2.88		2.5		0.85

TU = Total uncertainty (95% confidence limit).

NA = Not analyzed.

ND < = Analyte not detected.

NC = Not calculated.

* = Emission factor calculated using one half of the detection limit.

= Outlier data (see section 5), not used in calculation.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-7. EMISSION FACTORS FOR ELEMENTS ($\mu\text{g}/\text{MJ}$)

Analyte	N-5a-MUM-727	N-5a-MUM-729	N-5a-MUM-731	AVERAGE	TU
Aluminum	1410	#	#	1410	NC
Potassium	877	#	#	877	NC
Sodium	#	ND< 6.50 *	226	114 ##	NC
Titanium	13.8	7.25	9.19	10	8.5
Antimony	ND< 0.160	ND< 0.153	ND< 0.154	ND< 0.16	0.03
Arsenic	21.4	15.1	17.8	18	8.3
Barium	4.17	1.18	1.63	2.3	4.0
Beryllium	0.083	0.071	0.084	0.08	0.02
Boron	NA	NA	NA	NA	NA
Cadmium	ND< 0.014 *	ND< 0.012 *	0.061	0.03 ##	0.07
Chromium	1.33	1.50	1.11	1.3	0.53
Cobalt	ND< 0.052	ND< 0.047	ND< 0.051	ND< 0.05	0.01
Copper	2.09	1.36	1.73	1.7	0.95
Lead	0.708	0.481	0.878	0.69	0.51
Manganese	2.06	1.04	1.28	1.5	1.3
Mercury	7.36	5.39	5.88	6.2	2.7
Molybdenum	1.10	1.08	0.726	1.0	0.55
Nickel	0.354	0.237	0.118	0.24	0.29
Selenium	36.8	14.2	28.5	27	29
Vanadium	1.01	1.02	1.24	1.1	0.36

TU = Total uncertainty (95% confidence limit).

NA = Not analyzed.

ND< = Analyte not detected.

NC = Not calculated.

* = Emission factor calculated using one half of the detection limit.

= Outlier data (see section 5), not used in calculation.

TABLE 6-8. EMISSION FACTORS FOR AMMONIA/CYANIDE (lb/10¹² BTU)

Analyte	N-5a-NH4-727	N-5a-NH4-729	N-5a-NH4-731	AVERAGE	TU
	N-5a-CN-727	N-5a-CN-729	N-5a-CN-731		
Ammonia	ND < 0.359 *	208	ND < 0.356 *	70 ##	298
Cyanide	72.1	165	302	180	288

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-9. EMISSION FACTORS FOR AMMONIA/CYANIDE (µg/MJ)

Analyte	N-5a-NH4-727	N-5a-NH4-729	N-5a-NH4-731	AVERAGE	TU
	N-5a-CN-727	N-5a-CN-729	N-5a-CN-731		
Ammonia	ND < 0.154 *	89.5	ND < 0.153 *	30 ##	128
Cyanide	31.0	71.0	130	77	124

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-10. EMISSION FACTORS FOR ANIONS (lb/10¹² BTU)

Analyte	N-5a-FCL-727	N-5a-FCL-729	N-5a-FCL-731	AVERAGE	TU
Hydrogen Chloride	138600	128800	128800	132000	25300
Hydrogen Fluoride	7995	9290	9479	8921	2455
Chloride (Particulate) **	8.85	23.2	23.6	19	21
Fluoride (Particulate) **	5.18	9.41	18.9	11	18
Phosphate (Particulate) **	ND <	12.2 *	147	173	111 ##
Sulfate (Particulate) **	13360	10510	12980	12280	4298

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

** Sampling for anions was conducted at a single point in the duct; traverses were not made.

TABLE 6-11. EMISSION FACTORS FOR ANIONS (µg/MJ)

Analyte	N-5a-FCL-727	N-5a-FCL-729	N-5a-FCL-731	AVERAGE	TU
Hydrogen Chloride	59596	55383	55365	56781	10863
Hydrogen Fluoride	3438	3995	4076	3836	1056
Chloride (Particulate) **	3.81	10.0	10.2	8.0	9.1
Fluoride (Particulate) **	2.23	4.05	8.13	4.8	7.5
Phosphate (Particulate) **	ND <	5.25 *	63.2	74.3	48 ##
Sulfate (Particulate) **	5743	4520	5580	5281	1848

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

** Sampling for anions was conducted at a single point in the duct; traverses were not made.

TABLE 6-12. EMISSION FACTORS FOR VOC (lb/10¹² BTU)

Analyte	N-5a-VOS-726	N-5a-VOS-728	N-5a-VOS-730	AVERAGE	TU
Chloromethane	9.60	ND < 2.59 *	ND < 2.44 *	4.9 ##	10
Bromomethane	ND < 5.17	ND < 9.44	ND < 4.88	ND < 6.5	6.4
Vinyl Chloride	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Chloroethane	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Methylene Chloride	NC	NC	NC	NC	NC
Acetone	NC	NC	NC	NC	NC
Carbon Disulfide	ND < 2.62 *	6.14	9.05	5.9 ##	8.0
1,1-Dichloroethene	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
1,1-Dichloroethane	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Trans-1,2-Dichloroethene	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Chloroform	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
1,2-Dichloroethane	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
2-Butanone	ND < 2.58 *	10.21	ND < 2.44 *	5.1 ##	11
1,1,1-Trichloroethane	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Carbon Tetrachloride	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Vinyl Acetate	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Bromodichloromethane	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
1,2-Dichloropropane	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
cis-1,3-Dichloropropylene	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Trichloroethene	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Dibromochloromethane	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
1,1,2-Trichloroethane	ND < 5.17	ND < 4.61	ND < 4.88	ND < 4.9	1.1
Benzene	5.97	10.36	7.28	7.9	5.7
trans-1,3-Dichloropropylene	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
2-Chloroethylvinylether	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Bromoform	ND < 5.17	ND < 4.61	ND < 4.88	ND < 4.9	1.1
4-Methyl-2-Pentanone	ND < 2.58 *	9.96	ND < 2.44 *	5.0 ##	11
2-Hexanone	ND < 2.58 *	18.3	ND < 2.44 *	7.8 ##	23
Tetrachloroethene	4.29	ND < 2.59 *	ND < 2.44 *	3.1 ##	2.6
1,1,2,2-Tetrachloroethane	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Toluene	6.80	ND < 2.31 *	ND < 1.30 *	3.5 ##	7.3
Chlorobenzene	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Ethylbenzene	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Styrene	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9
Xylenes (Total)	ND < 5.17	ND < 5.19	ND < 4.88	ND < 5.1	0.9

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

NC = Not calculated, measurements in field affected by contamination.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-13. EMISSION FACTORS FOR VOC ($\mu\text{g}/\text{MJ}$)

Analyte	N-5a-VOS-726	N-5a-VOS-728	N-5a-VOS-730	AVERAGE	TU
Chloromethane	4.13	ND < 1.12 *	ND < 1.05 *	2.1 ##	4.4
Bromomethane	ND < 2.22	ND < 4.06	ND < 2.10	ND < 2.8	2.8
Vinyl Chloride	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Chloroethane	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Methylene Chloride	NC	NC	NC	NC	NC
Acetone	NC	NC	NC	NC	NC
Carbon Disulfide	ND < 1.13 *	2.64	3.90	2.6 ##	3.5
1,1-Dichloroethene	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
1,1-Dichloroethane	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Trans-1,2-Dichloroethene	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Chloroform	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
1,2-Dichloroethane	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
2-Butanone	ND < 1.11 *	4.39	ND < 1.05 *	2.2 ##	4.8
1,1,1-Trichloroethane	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Carbon Tetrachloride	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Vinyl Acetate	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Bromodichloromethane	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
1,2-Dichloropropane	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
cis-1,3-Dichloropropylene	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Trichloroethene	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Dibromochloromethane	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
1,1,2-Trichloroethane	ND < 2.22	ND < 1.98	ND < 2.10	ND < 2.1	0.45
Benzene	2.57	4.46	3.13	3.4	2.5
trans-1,3-Dichloropropylene	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
2-Chloroethylvinylether	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Bromoform	ND < 2.22	ND < 1.98	ND < 2.10	ND < 2.1	0.45
4-Methyl-2-Pentanone	ND < 1.11 *	4.29	ND < 1.05 *	2.1 ##	4.6
2-Hexanone	ND < 1.11 *	7.86	ND < 1.05 *	3.3 ##	9.7
Tetrachloroethene	1.85	ND < 1.12 *	ND < 1.05 *	1.3 ##	1.1
1,1,2,2-Tetrachloroethane	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Toluene	2.93	ND < 0.99 *	ND < 0.56 *	1.5 ##	3.1
Chlorobenzene	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Ethylbenzene	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Styrene	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40
Xylenes (Total)	ND < 2.22	ND < 2.23	ND < 2.10	ND < 2.2	0.40

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

NC = Not calculated, measurements in field affected by contamination.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-14. EMISSION FACTORS FOR PAH/SVOC (lb/10¹² BTU)

Analyte	N-5a-MM- F+X-726	N-5a-MM- F+X-728	N-5a-MM- F+X-730	AVERAGE	TU
Benzylchloride	ND < 0.0171	ND < 0.0169	ND < 0.0016	ND < 0.0119	0.0221
Acetophenone	0.8829	0.7183	0.3070	0.6360	0.7425
Hexachloroethane	ND < 0.0171	ND < 0.0169	ND < 0.0016	ND < 0.0119	0.0221
Naphthalene	0.3056	0.2323	0.1080	0.2153	0.2500
Hexachlorobutadiene	ND < 0.0171	ND < 0.0169	ND < 0.0016	ND < 0.0119	0.0221
2-Chloroacetophenone	0.4607	0.3452	0.0577	0.2879	0.5166
2-Methylnaphthalene	0.0791	0.0219	0.0115	0.0375	0.0905
1-Methylnaphthalene	0.0327	0.0102	0.0042	0.0157	0.0372
Hexachlorocyclopentadiene	ND < 0.0171	ND < 0.0169	ND < 0.0016	ND < 0.0119	0.0221
Biphenyl	0.0590	0.2904	0.0278	0.1257	0.3563
Acenaphthylene	0.0176	ND < 0.0017 *	0.0010	0.0068 ##	0.0233
2,6-Dinitrotoluene	0.6602	0.4998	0.5031	0.5544	0.2437
Acenaphthene	0.0646	0.0135	0.0014	0.0265	0.0833
Dibenzofuran	0.1234	0.0442	0.0286	0.0654	0.1264
2,4-Dinitrotoluene	0.0296	ND < 0.0084 *	0.0209	0.0197 ##	0.0266
Fluorene	0.0729	0.0125	0.0086	0.0313	0.0895
Hexachlorobenzene	ND < 0.0171	ND < 0.0169	ND < 0.0016	ND < 0.0119	0.0221
Pentachlorophenol	ND < 0.0171	ND < 0.0169	ND < 0.0016	ND < 0.0119	0.0221
Phenanthrene	0.1554	0.0547	0.0227	0.0776	0.1722
Anthracene	0.0529	0.0070	0.0020	0.0207	0.0696
Fluoranthene	0.0461	0.0247	0.0103	0.0270	0.0449
Pyrene	0.0249	0.0139	0.0030	0.0139	0.0272
Benz(a)anthracene	0.0081	ND < 0.0017 *	0.0012	0.0037 ##	0.0095
Chrysene	0.0185	0.0047	0.0036	0.0089	0.0206
Benzo(b & k)fluoranthene	0.0183	ND < 0.0017 *	0.0011	0.0070 ##	0.0243
Benzo(e)pyrene	0.0046	ND < 0.0017 *	ND < 0.0002 *	0.0021 ##	0.0056
Benzo(a)pyrene	ND < 0.0034	ND < 0.0034	ND < 0.0003	ND < 0.0024	0.0044
Indeno(1,2,3-c,d)pyrene	ND < 0.0034	ND < 0.0034	ND < 0.0003	ND < 0.0024	0.0044
Dibenz(a,h)anthracene	ND < 0.0034	ND < 0.0034	ND < 0.0003	ND < 0.0024	0.0044
Benzo(g,h,i)perylene	ND < 0.0034	ND < 0.0034	ND < 0.0003	ND < 0.0024	0.0044

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-15. EMISSION FACTORS FOR PAH/SVOC ($\mu\text{g}/\text{MJ}$)

Analyte	N-5a-MM- F+X-726	N-5a-MM- F+X-728	N-5a-MM- F+X-730	AVERAGE	TU
Benzylchloride	ND < 0.0074	ND < 0.0073	ND < 0.0007	ND < 0.00511	0.0095
Acetophenone	0.3800	0.3092	0.1321	0.27375	0.3196
Hexachloroethane	ND < 0.0074	ND < 0.0073	ND < 0.0007	ND < 0.00511	0.0095
Naphthalene	0.1315	0.1000	0.0465	0.09266	0.1076
Hexachlorobutadiene	ND < 0.0074	ND < 0.0073	ND < 0.0007	ND < 0.00511	0.0095
2-Chloroacetophenone	0.1983	0.1486	0.0248	0.1239	0.2224
2-Methylnaphthalene	0.0341	0.0094	0.0049	0.01614	0.0390
1-Methylnaphthalene	0.0141	0.0044	0.0018	0.00676	0.0160
Hexachlorocyclopentadiene	ND < 0.0074	ND < 0.0073	ND < 0.0007	ND < 0.00511	0.0095
Biphenyl	0.0254	0.1250	0.0120	0.05411	0.1533
Acenaphthylene	0.0076	ND < 0.0007 *	0.0004	0.00291 ##	0.0100
2,6-Dinitrotoluene	0.2841	0.2151	0.2165	0.23859	0.1049
Acenaphthene	0.0278	0.0058	0.0006	0.0114	0.0359
Dibenzofuran	0.0531	0.0190	0.0123	0.02815	0.0544
2,4-Dinitrotoluene	0.0128	ND < 0.0036 *	0.0090	0.00846 ##	0.0114
Fluorene	0.0314	0.0054	0.0037	0.01348	0.0385
Hexachlorobenzene	ND < 0.0074	ND < 0.0073	ND < 0.0007	ND < 0.00511	0.0095
Pentachlorophenol	ND < 0.0074	ND < 0.0073	ND < 0.0007	ND < 0.00511	0.0095
Phenanthrene	0.0669	0.0235	0.0098	0.03339	0.0741
Anthracene	0.0228	0.0030	0.0009	0.0089	0.0300
Fluoranthene	0.0198	0.0106	0.0044	0.01163	0.0193
Pyrene	0.0107	0.0060	0.0013	0.0060	0.0117
Benz(a)anthracene	0.0035	ND < 0.0007 *	0.0005	0.0016 ##	0.0041
Chrysene	0.0080	0.0020	0.0015	0.0038	0.0089
Benzo(b & k)fluoranthene	0.0079	ND < 0.0007 *	0.0005	0.0030 ##	0.0104
Benzo(e)pyrene	0.0020	ND < 0.0007 *	ND < 0.0001 *	0.0009 ##	0.0024
Benzo(a)pyrene	ND < 0.0015	ND < 0.0015	ND < 0.0001	ND < 0.0010	0.0019
Indeno(1,2,3-c,d)pyrene	ND < 0.0015	ND < 0.0015	ND < 0.0001	ND < 0.0010	0.0019
Dibenz(a,h)anthracene	ND < 0.0015	ND < 0.0015	ND < 0.0001	ND < 0.0010	0.0019
Benzo(g,h,i)perylene	ND < 0.0015	ND < 0.0015	ND < 0.0001	ND < 0.0010	0.0019

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-16. EMISSION FACTORS FOR DIOXINS/FURANS (lb/10¹² BTU)

Analyte	N-5a-MM5-726	N-5a-MM5-728	N-5a-MM5-730	AVERAGE	TU
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND < 2.78E-06	ND < 1.70E-06	ND < 1.83E-06	ND < 2.10E-06	1.50E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND < 3.99E-06	ND < 2.29E-06	ND < 2.26E-06	ND < 2.85E-06	2.50E-06
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND < 5.69E-06	ND < 2.40E-06	ND < 2.09E-06	ND < 3.39E-06	4.98E-06
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	6.69E-06	ND < 1.12E-06 *	ND < 1.06E-06 *	2.96E-06 ##	8.04E-06
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	6.86E-06	ND < 6.90E-07 *	ND < 1.00E-06 *	2.85E-06 ##	8.64E-06
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	3.70E-05	5.72E-06	8.43E-06	1.71E-05	4.31E-05
Octachlorodibenzo-p-dioxin	5.36E-05	1.14E-06	2.01E-06	1.89E-05	7.46E-05
2,3,7,8-Tetrachlorodibenzofuran	1.03E-05	2.14E-06	ND < 1.82E-06 *	4.76E-06 ##	1.20E-05
1,2,3,7,8-Pentachlorodibenzofuran	ND < 5.73E-06	ND < 1.62E-06	ND < 2.87E-06	ND < 3.40E-06	5.25E-06
2,3,4,7,8-Pentachlorodibenzofuran	ND < 5.42E-06 *	ND < 8.90E-07 *	3.34E-06	3.22E-06 ##	5.64E-06
1,2,3,4,7,8-Hexachlorodibenzofuran	2.43E-05	ND < 1.54E-06 *	ND < 2.93E-06 *	9.61E-06 ##	3.17E-05
1,2,3,6,7,8-Hexachlorodibenzofuran	8.42E-06	ND < 1.11E-06 *	ND < 1.99E-06 *	3.84E-06 ##	9.91E-06
1,2,3,7,8,9-Hexachlorodibenzofuran	1.26E-05	ND < 2.09E-06 *	4.90E-06	6.53E-06 ##	1.35E-05
2,3,4,6,7,8-Hexachlorodibenzofuran	ND < 3.53E-06	ND < 1.55E-06	ND < 2.42E-06	ND < 2.50E-06	2.49E-06
1,2,3,4,6,7,8-Heptachlorodibenzofuran	4.03E-05	6.71E-06	ND < 4.45E-06 *	1.72E-05 ##	4.98E-05
1,2,3,4,7,8,9-Heptachlorodibenzofuran	7.63E-06	ND < 1.36E-06 *	ND < 1.86E-06 *	3.62E-06 ##	8.66E-06
Octachlorodibenzofuran	3.05E-05	1.20E-05	1.61E-05	1.95E-05	2.43E-05

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-17. EMISSION FACTORS FOR DIOXINS/FURANS (ug/MJ)

Analyte	N-5a-MM5-726	N-5a-MM5-728	N-5a-MM5-730	AVERAGE	TU
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND < 1.20E-06	ND < 7.32E-07	ND < 7.88E-07	ND < 9.04E-07	6.46E-07
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND < 1.72E-06	ND < 9.86E-07	ND < 9.73E-07	ND < 1.23E-06	1.08E-06
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND < 2.45E-06	ND < 1.03E-06	ND < 9.00E-07	ND < 1.46E-06	2.14E-06
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	2.88E-06	ND < 4.82E-07 *	ND < 4.56E-07 *	1.27E-06 ##	3.46E-06
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	2.95E-06	ND < 2.97E-07 *	ND < 4.30E-07 *	1.23E-06 ##	3.72E-06
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	1.59E-05	2.46E-06	3.63E-06	7.34E-06	1.85E-05
Octachlorodibenzo-p-dioxin	2.31E-05	4.91E-07	8.65E-07	8.14E-06	3.21E-05
2,3,7,8-Tetrachlorodibenzofuran	4.45E-06	9.21E-07	ND < 7.83E-07 *	2.05E-06 ##	5.16E-06
1,2,3,7,8-Pentachlorodibenzofuran	ND < 2.47E-06	ND < 6.97E-07	ND < 1.24E-06	ND < 1.46E-06	2.26E-06
2,3,4,7,8-Pentachlorodibenzofuran	ND < 2.33E-06 *	ND < 3.83E-07 *	1.44E-06	1.39E-06 ##	2.43E-06
1,2,3,4,7,8-Hexachlorodibenzofuran	1.05E-05	ND < 6.63E-07 *	ND < 1.26E-06 *	4.14E-06 ##	1.37E-05
1,2,3,6,7,8-Hexachlorodibenzofuran	3.62E-06	ND < 4.78E-07 *	ND < 8.56E-07 *	1.65E-06 ##	4.27E-06
1,2,3,7,8,9-Hexachlorodibenzofuran	5.42E-06	ND < 9.00E-07 *	2.11E-06	2.81E-06 ##	5.81E-06
2,3,4,6,7,8-Hexachlorodibenzofuran	ND < 1.52E-06	ND < 6.67E-07	ND < 1.04E-06	ND < 1.08E-06	1.07E-06
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1.73E-05	2.89E-06	ND < 1.92E-06 *	7.38E-06 ##	2.14E-05
1,2,3,4,7,8,9-Heptachlorodibenzofuran	3.28E-06	ND < 5.85E-07 *	ND < 8.01E-07 *	1.56E-06 ##	3.73E-06
Octachlorodibenzofuran	1.31E-05	5.17E-06	6.91E-06	8.41E-06	1.05E-05

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-18. EMISSION FACTORS FOR ALDEHYDES (lb/10¹² BTU)

Analyte	N-5a-ALD-726	N-5a-ALD-726	N-5a-ALD-726	AVERAGE	TU
Formaldehyde	7.73	3.26	ND < 0.803 *	3.9 ##	8.7
Acetaldehyde	69.9	171	27.3	89	184
Acrolein	3.99	111	7.18	41	151
Propionaldehyde	31.3	41.6	1.08	25	52

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-19. EMISSION FACTORS FOR ALDEHYDES (µg/MJ)

Analyte	N-5a-ALD-726	N-5a-ALD-726	N-5a-ALD-726	AVERAGE	TU
Formaldehyde	3.32	1.40	ND < 0.345 *	1.7 ##	3.8
Acetaldehyde	30.0	73.7	11.7	38	79
Acrolein	1.72	47.8	3.09	18	65
Propionaldehyde	13.5	17.9	0.462	11	23

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-20. EMISSION FACTORS FOR RADIONUCLIDES (mCi/10¹² BTU)

Analyte	N-5a-NH4CN-727		N-5a-NH4CN-729		N-5a-NH4CN-731		AVERAGE	TU
Pb-212	ND <	24.3	ND <	10.1	ND <	9.68	ND < 15	21
Th-234	ND <	202	ND <	80.0	ND <	86.0	ND < 123	171
Pb-210	ND <	243	ND <	96.0	ND <	145	ND < 161	185
Pb-211	ND <	404	ND <	144	ND <	161	ND < 237	361
Ra-226	ND <	35.0	ND <	10.7	ND <	9.68	ND < 18	36
Ra-228	ND <	79.5	ND <	32.0	ND <	32.3	ND < 48	68
Th-229	ND <	148	ND <	53.4	ND <	75.3	ND < 92	123
Th-230	ND <	1348	ND <	640	ND <	645	ND < 878	1009
U-234	ND <	6199	ND <	2081	ND <	2850	ND < 3710	5430
U-235	ND <	66.0	ND <	21.3	ND <	29.6	ND < 39	59

TU = Total uncertainty (95 % confidence limit).

ND < = Analyte not detected.

TABLE 6-21. EMISSION FACTORS FOR RADIONUCLIDES (pCi/MJ)

Analyte	N-5a-NH4CN-727		N-5a-NH4CN-729		N-5a-NH4CN-731		AVERAGE	TU
Pb-212	ND <	23.0	ND <	9.61	ND <	9.17	ND < 14	19
Th-234	ND <	192	ND <	75.9	ND <	81.6	ND < 116	162
Pb-210	ND <	230	ND <	91.0	ND <	138	ND < 153	175
Pb-211	ND <	383	ND <	137	ND <	153	ND < 224	342
Ra-226	ND <	33.2	ND <	10.1	ND <	9.17	ND < 17	34
Ra-228	ND <	75.4	ND <	30.3	ND <	30.6	ND < 45	64
Th-229	ND <	140	ND <	50.6	ND <	71.4	ND < 87	117
Th-230	ND <	1277	ND <	607	ND <	612	ND < 832	957
U-234	ND <	5875	ND <	1972	ND <	2701	ND < 3516	5147
U-235	ND <	62.6	ND <	20.2	ND <	28.0	ND < 37	56

TU = Total uncertainty (95 % confidence limit).

ND < = Analyte not detected.

TABLE 6-22. EMISSION FACTORS FOR PARTICULATE MATTER (lb/10¹² BTU)

Analyte	N-5a-MUM-727	N-5a-MUM-729	N-5a-MUM-731	AVERAGE	TU
Particulate Matter	27210	11500	20190	19640	19780

TU = Total uncertainty (95 % confidence limit).

TABLE 6-23. EMISSION FACTORS FOR PARTICULATE MATTER (µg/MJ)

Analyte	N-5a-MUM-727	N-5a-MUM-729	N-5a-MUM-731	AVERAGE	TU
Particulate Matter	11700	4946	8683	8443	8505

TU = Total uncertainty (95 % confidence limit).

TABLE 6-24a. ESP REMOVAL EFFICIENCIES BY PERCENTAGE REMOVAL^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Boron	NA	NA	NA	NA	NA
Selenium	(16.25)	48.73	(9.68)	7.60	35.77
Mercury	25.06	37.42	27.28	29.92	6.59
Potassium	93.82	94.07	92.21	93.37	1.01
Sodium	96.71	99.90	84.51	93.71	8.12
Silicon	95.49	97.01	97.46	96.65	1.03
Aluminum	97.18	97.31	96.84	97.11	0.24
Cadmium	98.76	99.17	93.40	97.11	3.22
Arsenic	97.50	97.79	96.93	97.41	0.44
Molybdenum	98.11	97.99	98.15	98.09	0.08
Manganese	98.59	99.32	99.03	98.98	0.37
Chromium	99.22	99.17	99.20	99.20	0.02
Copper	99.19	99.54	99.22	99.32	0.19
Barium	98.86	99.69	99.48	99.34	0.43
Beryllium	99.58	99.65	99.45	99.56	0.10
Vanadium	99.61	99.63	99.44	99.56	0.11
Lead	99.75	99.84	99.58	99.72	0.13
Titanium	99.68	99.79	99.72	99.73	0.06
Antimony	99.71	99.80	99.90	99.80	0.10
Nickel	99.81	99.90	99.93	99.88	0.06
Cobalt	99.94	99.95	99.94	99.95	0.01

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

TABLE 6-24b. ESP REMOVAL EFFICIENCY, ALPHABETICALLY BY ELEMENT^(a)

Element	7/27/93	7/29/93	7/31/93	Average	Standard Deviation
Aluminum	97.18	97.31	96.84	97.11	0.24
Antimony	99.71	99.80	99.90	99.80	0.10
Arsenic	97.50	97.79	96.93	97.41	0.44
Barium	98.86	99.69	99.48	99.34	0.43
Beryllium	99.58	99.65	99.45	99.56	0.10
Boron	NA	NA	NA	NA	NA
Cadmium	98.76	99.17	93.40	97.11	3.22
Chromium	99.22	99.17	99.20	99.20	0.02
Cobalt	99.94	99.95	99.94	99.95	0.01
Copper	99.19	99.54	99.22	99.32	0.19
Lead	99.75	99.84	99.58	99.72	0.13
Manganese	98.59	99.32	99.03	98.98	0.37
Mercury	25.06	37.42	27.28	29.92	6.59
Molybdenum	98.11	97.99	98.15	98.09	0.08
Nickel	99.81	99.90	99.93	99.88	0.06
Potassium	93.82	94.07	92.21	93.37	1.01
Selenium	(16.25)	48.73	(9.68)	7.60	35.77
Silicon	95.49	97.01	97.46	96.65	1.03
Sodium	96.71	99.90	84.51	93.71	8.12
Titanium	99.68	99.79	99.72	99.73	0.06
Vanadium	99.61	99.63	99.44	99.56	0.11

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NA = Not analyzed.

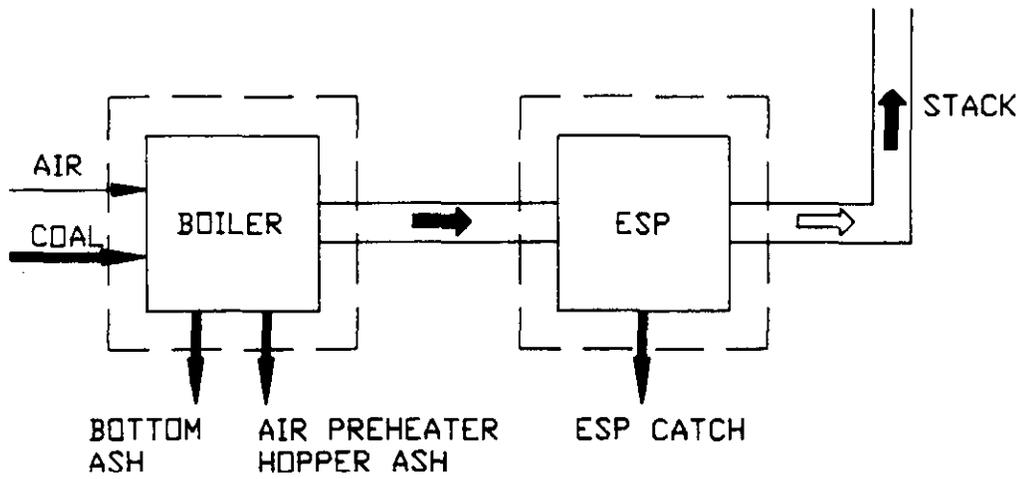


Figure 6-1. Boundaries for Mass Balance on Boiler and ESP.

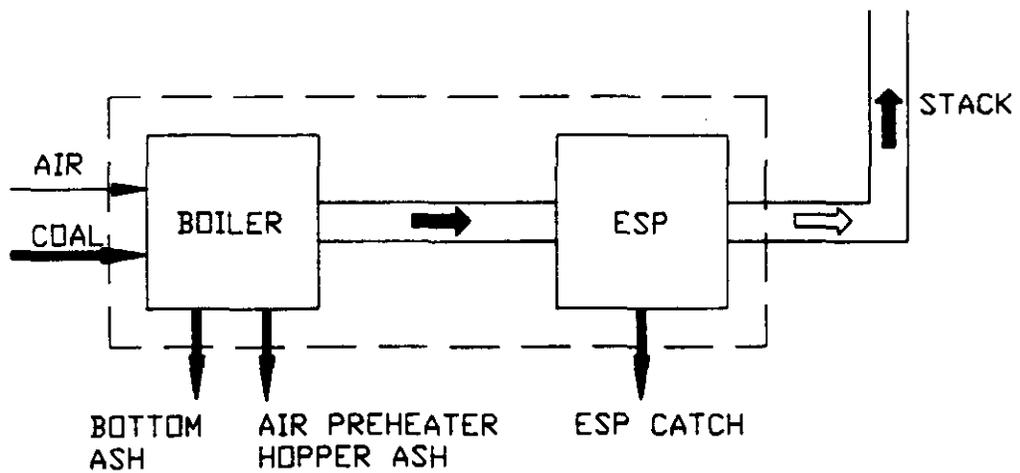


Figure 6-2. Boundary for Mass Balance on Combined Boiler and ESP.

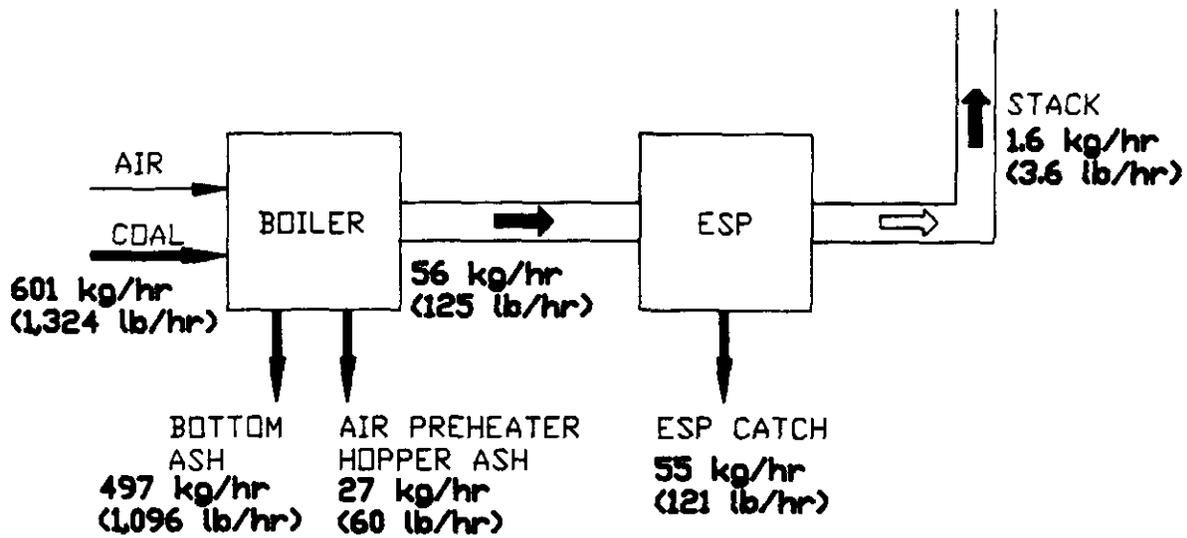


Figure 6-3. Aluminum Balance for Niles Boiler.

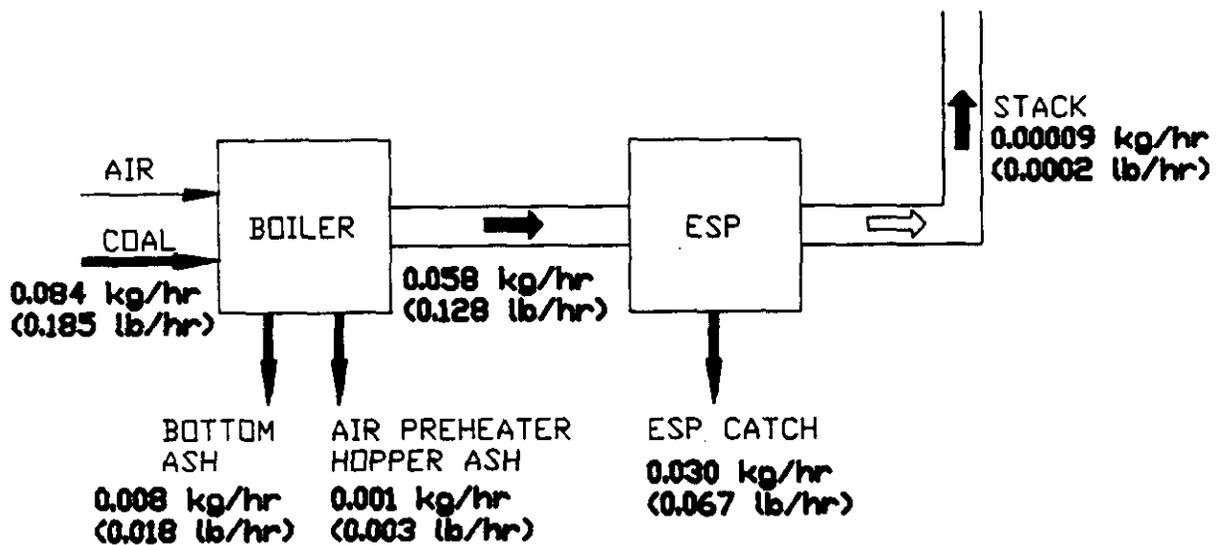


Figure 6-4. Antimony Balance for Niles Boiler.

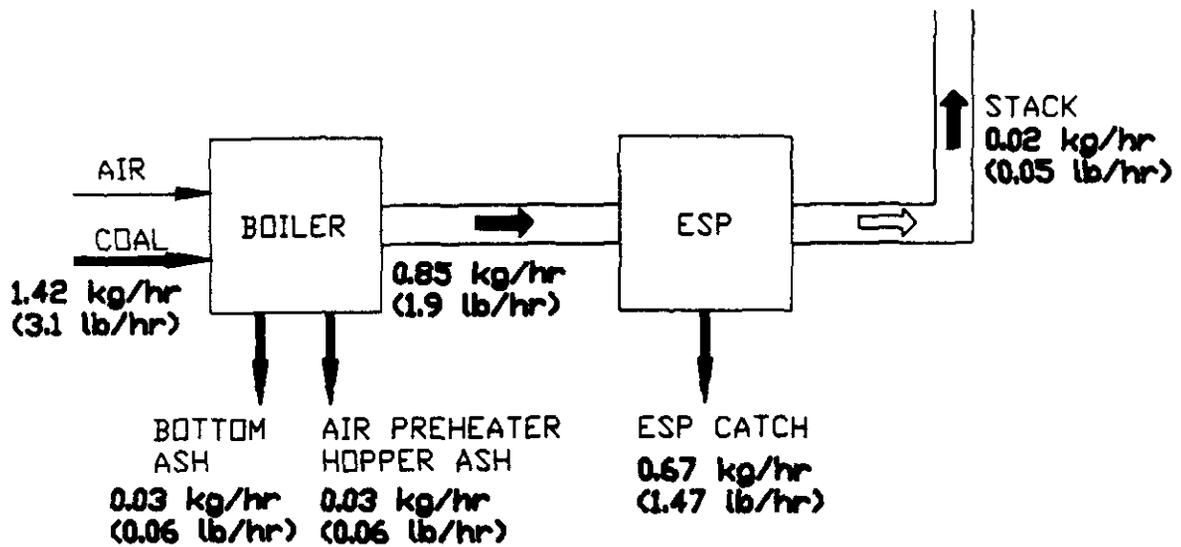


Figure 6-5. Arsenic Balance for Niles Boiler.

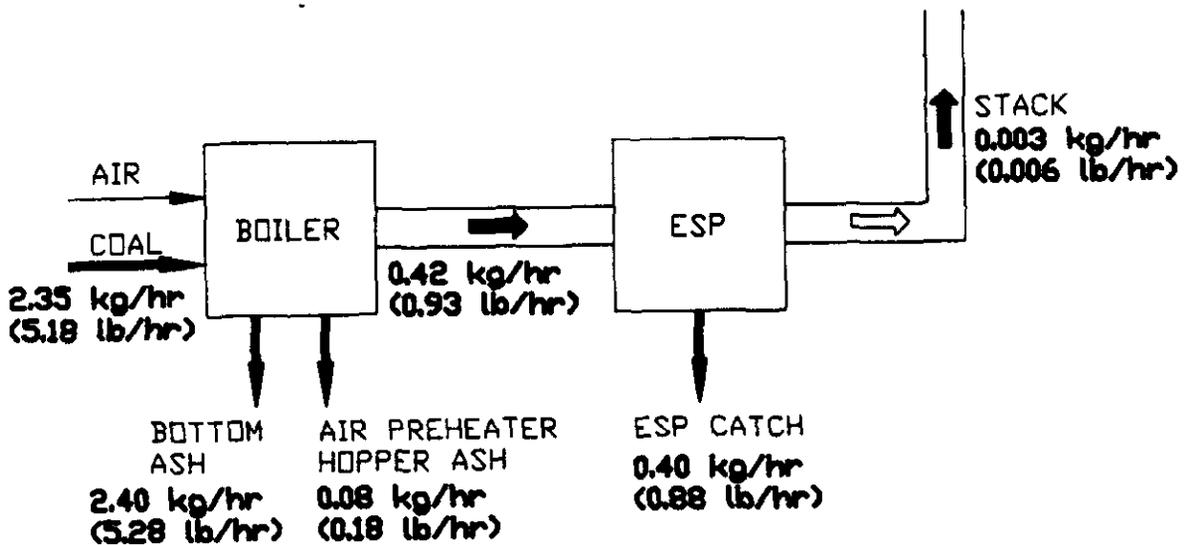


Figure 6-6. Barium Balance for Niles Boiler.

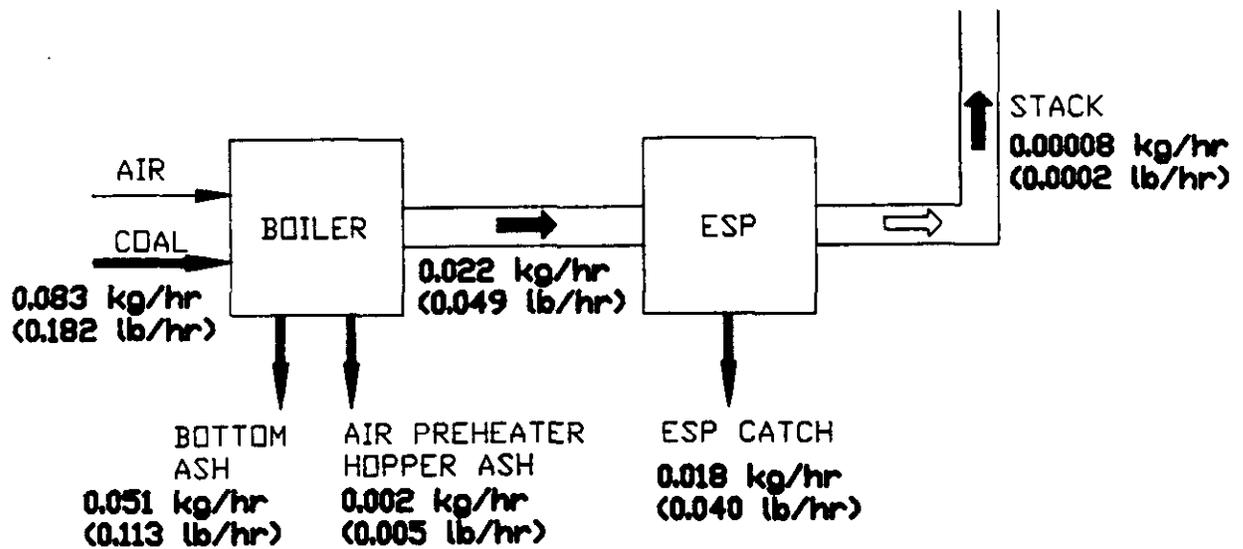


Figure 6-7. Beryllium Balance for Niles Boiler.

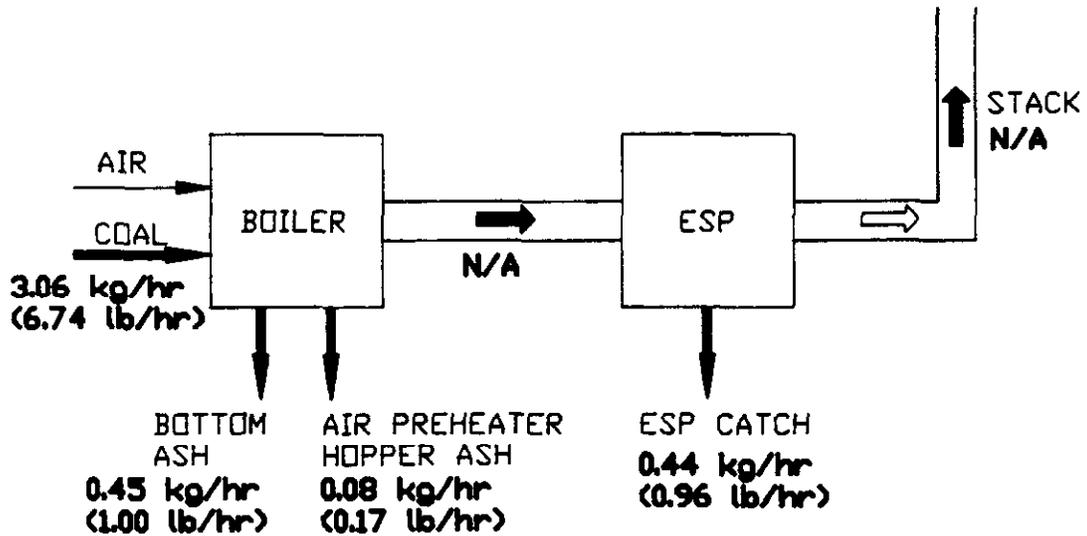


Figure 6-8. Boron Balance for Niles Boiler.

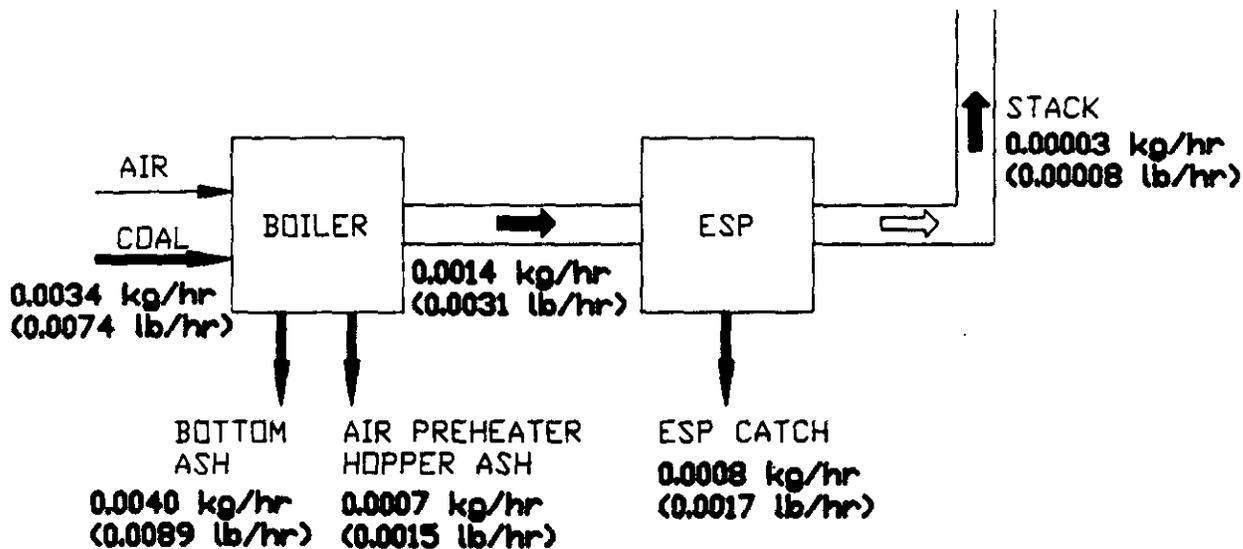


Figure 6-9. Cadmium Balance for Niles Boiler.

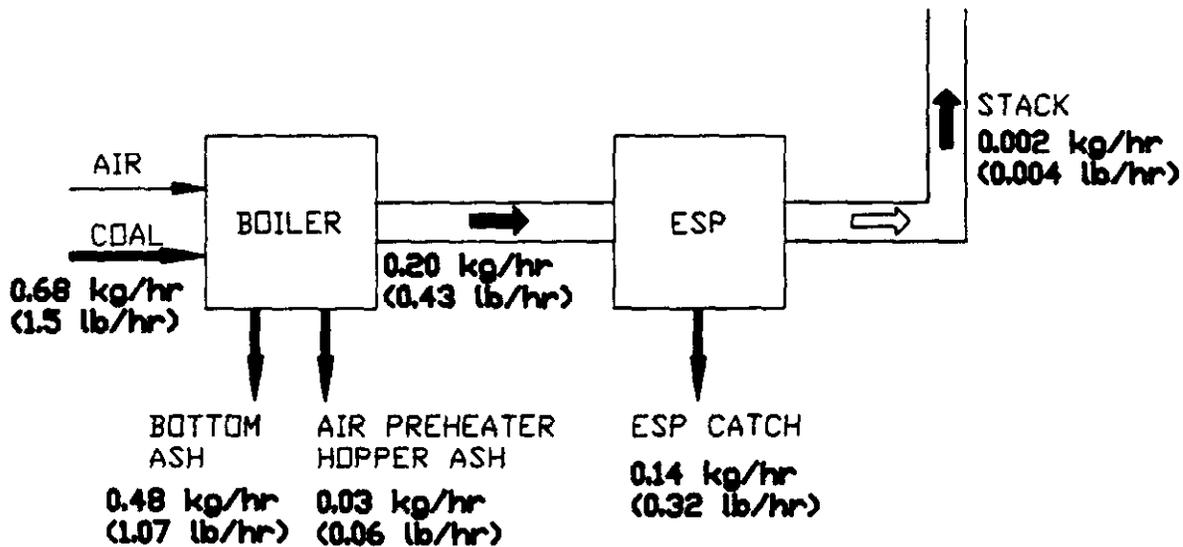


Figure 6-10. Chromium Balance for Niles Boiler.

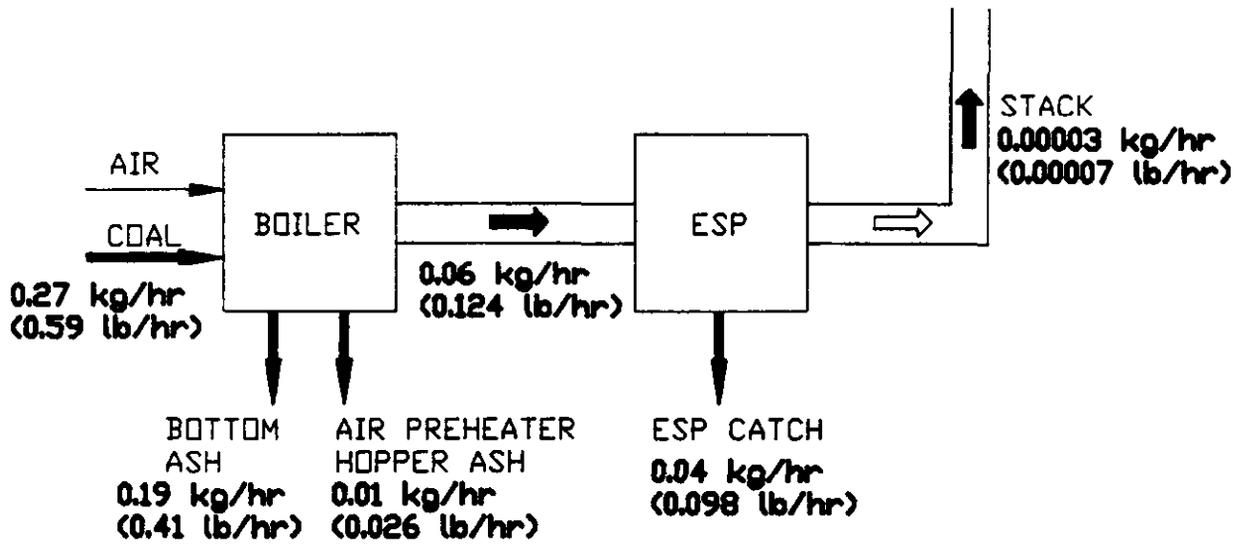


Figure 6-11. Cobalt Balance for Niles Boiler.

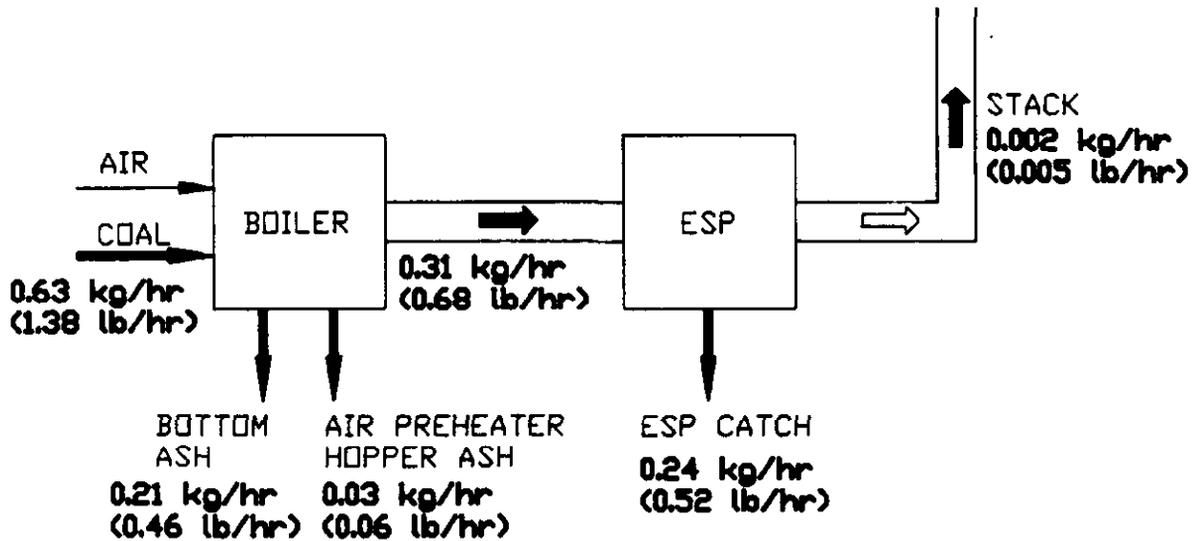


Figure 6-12. Copper Balance for Niles Boiler.

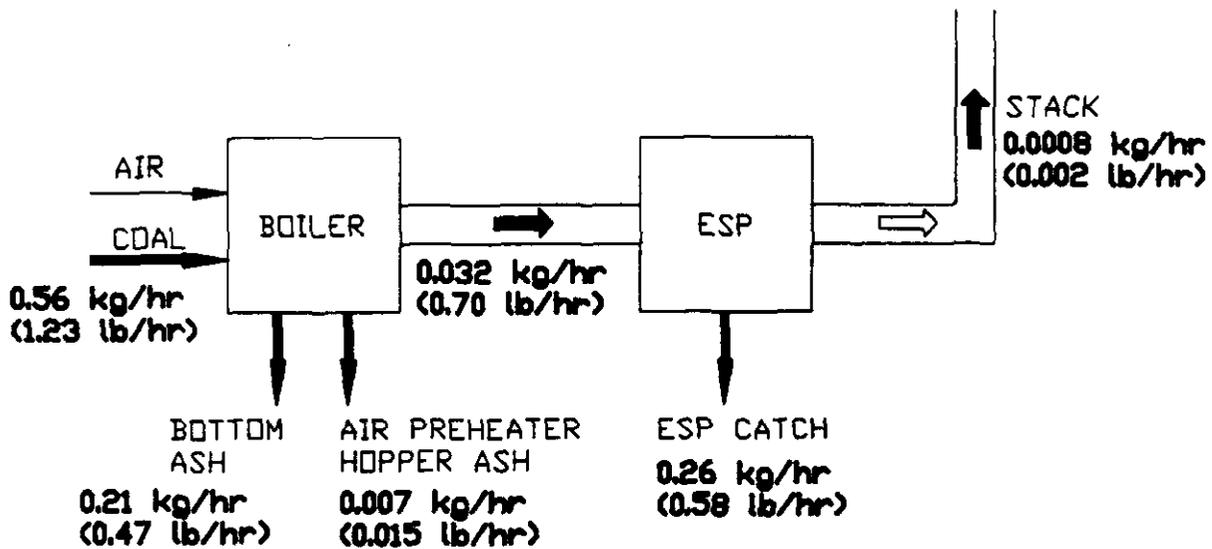


Figure 6-13. Lead Balance for Niles Boiler.

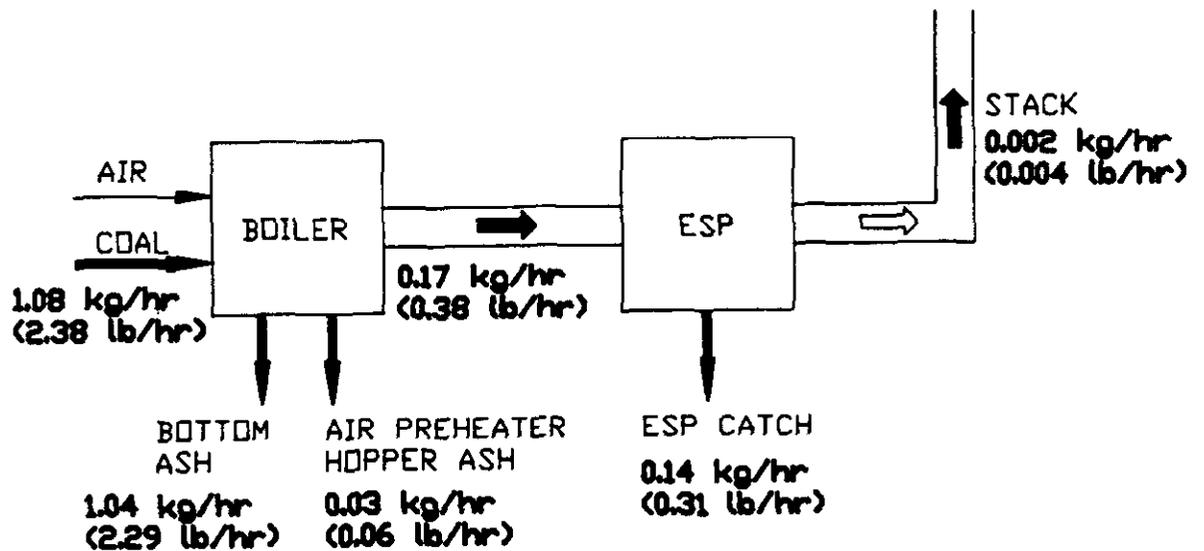


Figure 6-14. Manganese Balance for Niles Boiler.

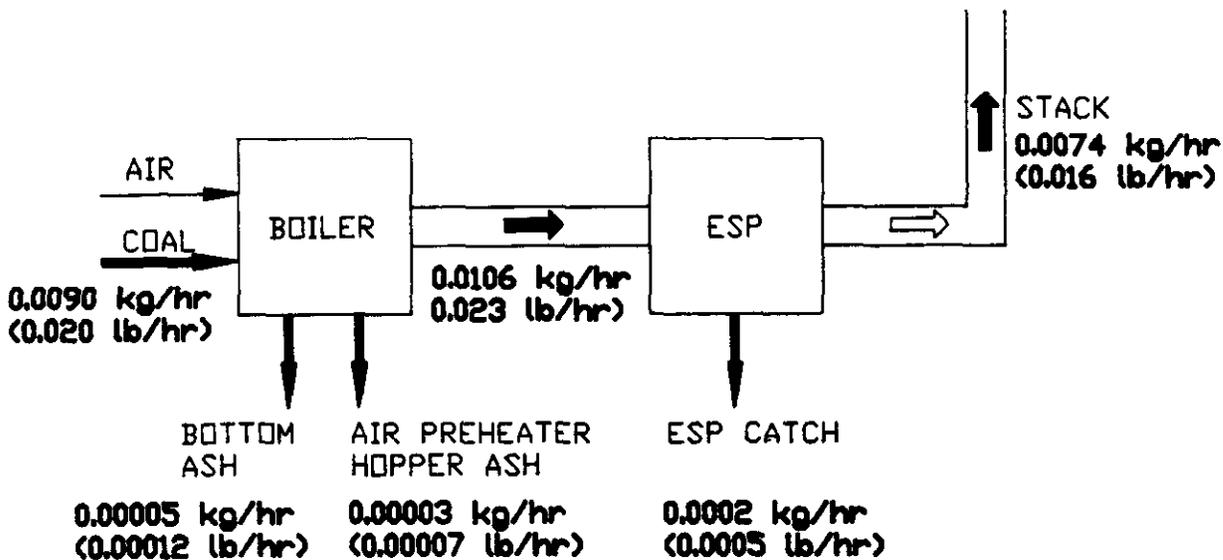


Figure 6-15. Mercury Balance for Niles Boiler.

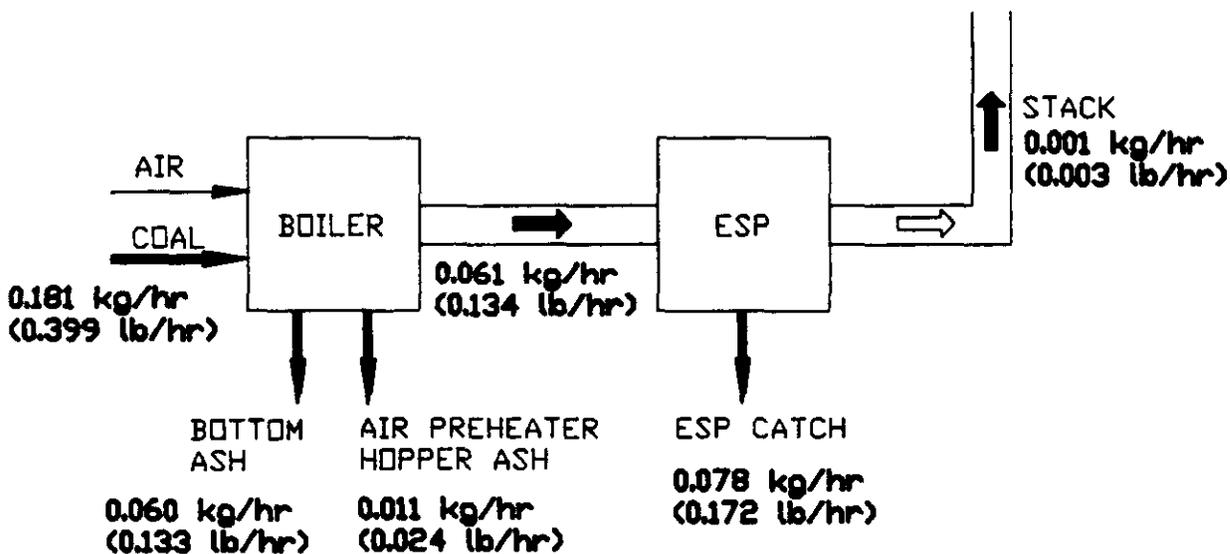


Figure 6-16. Molybdenum Balance for Niles Boiler.

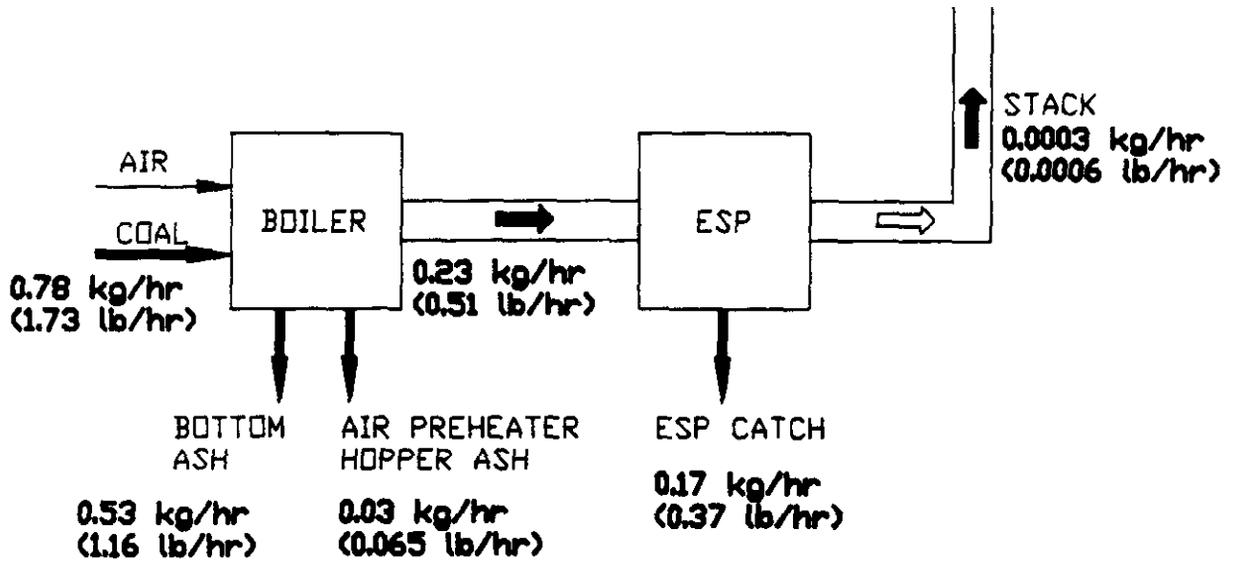


Figure 6-17. Nickel Balance for Niles Boiler.

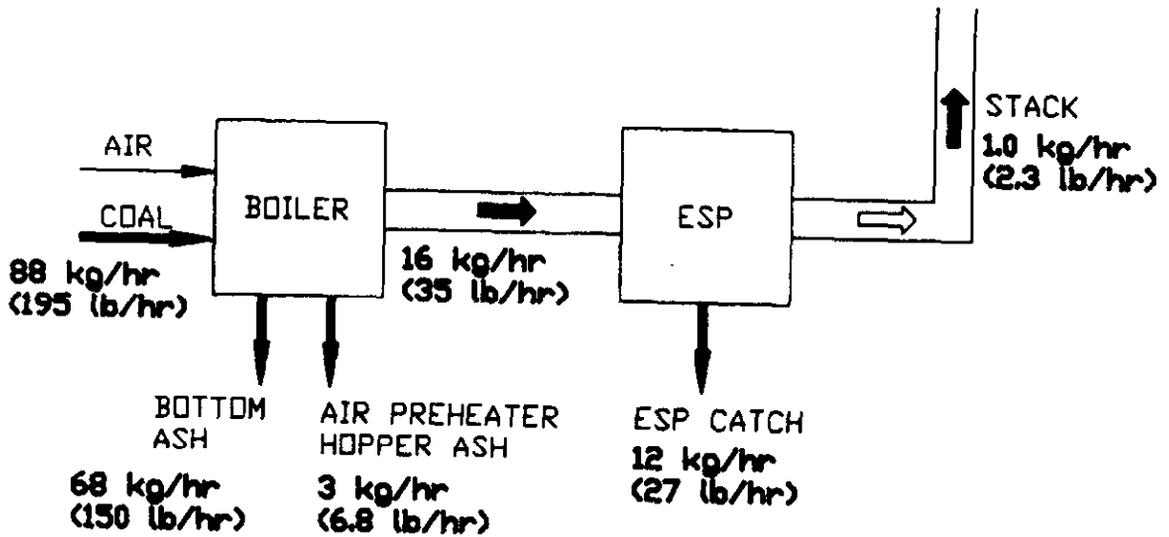


Figure 6-18. Potassium Balance for Niles Boiler.

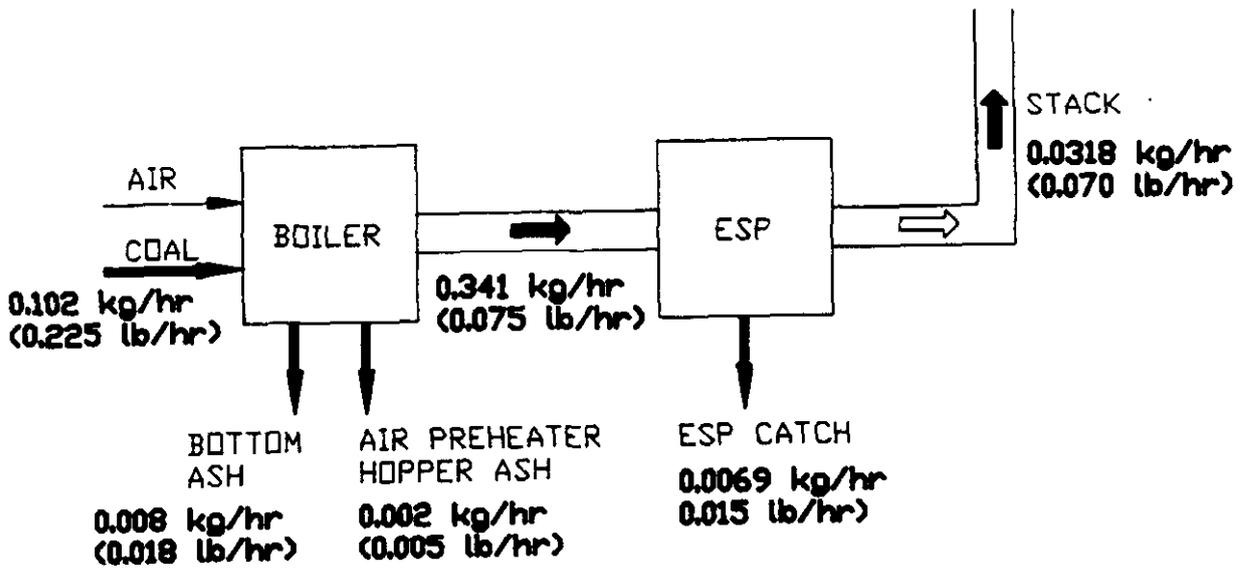


Figure 6-19. Selenium Balance for Niles Boiler.

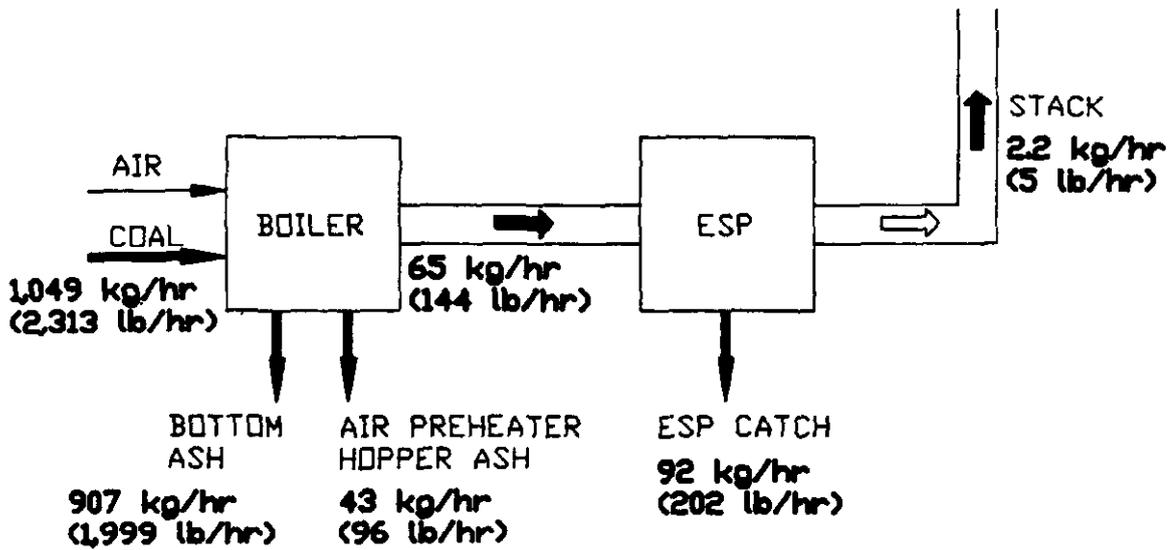


Figure 6-20. Silicon Balance for Niles Boiler.

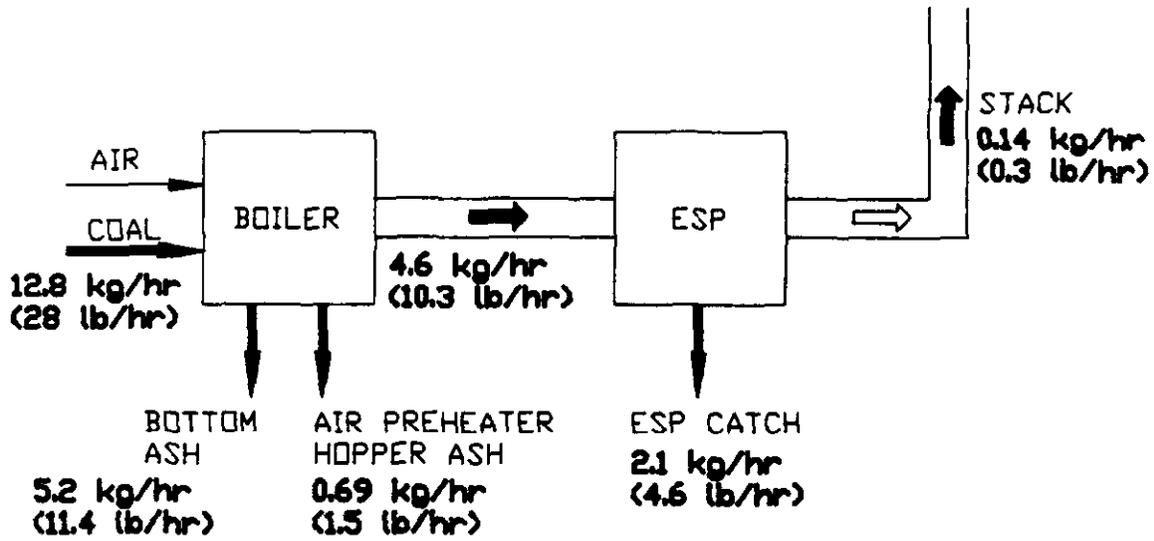


Figure 6-21. Sodium Balance for Niles Boiler.

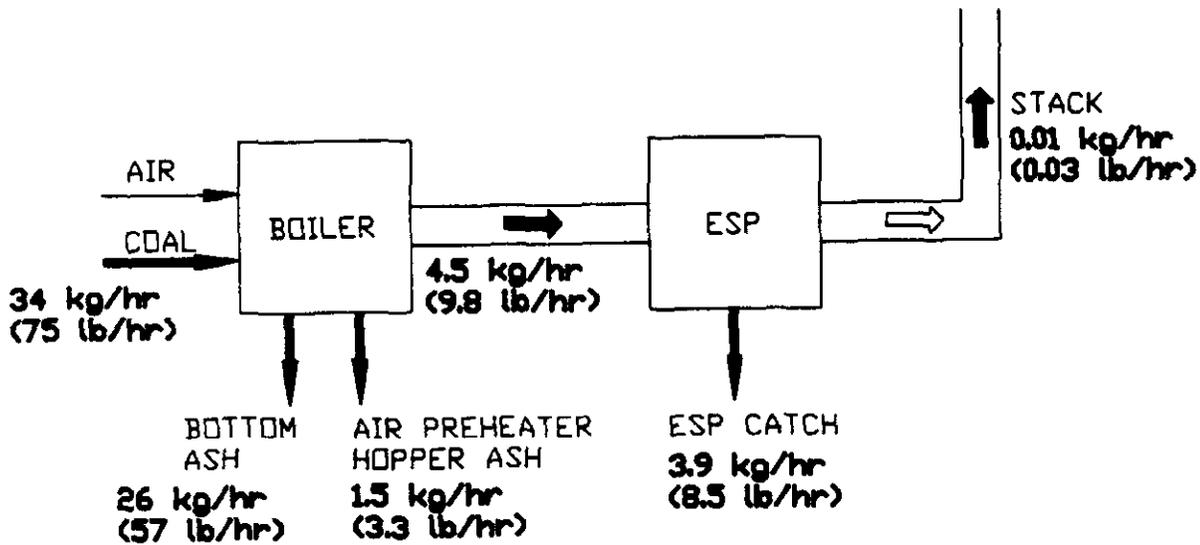


Figure 6-22. Titanium Balance for Niles Boiler.

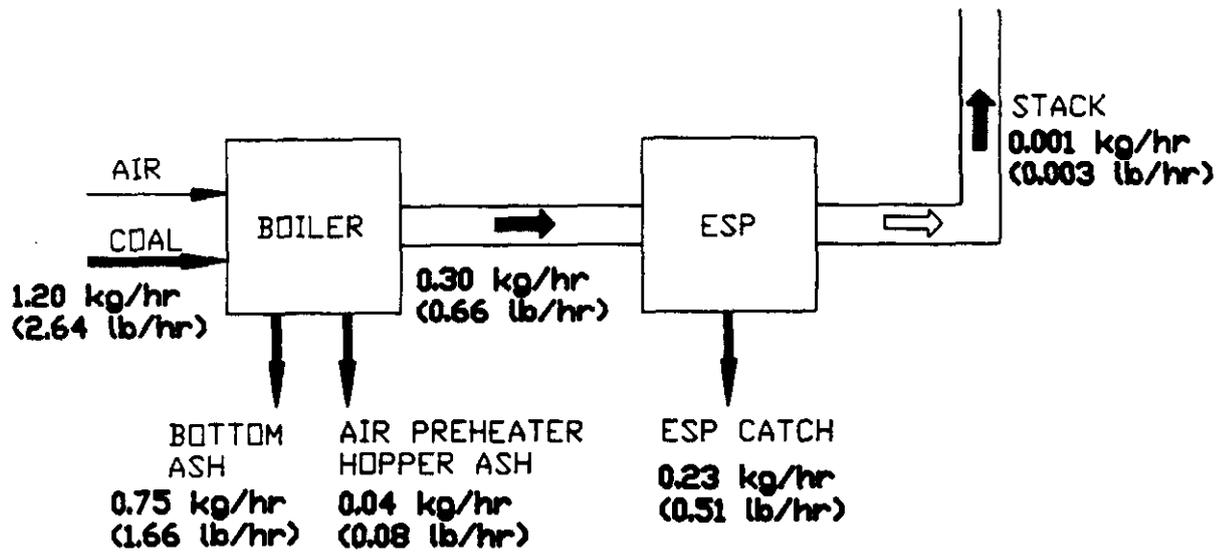


Figure 6-23. Vanadium Balance for Niles Boiler.

7.0 SPECIAL TOPICS

This section of the report presents comparison and discussion of various aspects of the data, or of comparable data obtained by different methods. Six subjects are presented as Special Topics in this section:

- (1) Comparison of results obtained on hot stack gas at the Boiler No. 2 stack (Location 5a) to those obtained on cooled, diluted stack gas (Location 5b) using the Plume Simulating Dilution Sampler (PSDS).
- (2) Evaluation of the vapor/particle phase distribution of elements, PAH/SVOC, and dioxins/furans in flue gas streams.
- (3) Discussion of the distribution of individual elements among various size fractions of the particulate matter in flue gas streams.
- (4) Comparison of results for volatile metals in flue gas obtained with the Multi-Metals (Method 29) train, to those obtained with the Hazardous Element Sampling Train (HEST).
- (5) Comparison of VOC results obtained in flue gas using the Volatile Organic Sampling Train (VOST) to those obtained using Summa canisters.
- (6) Comparison of elemental data from high-volume filters at Location 5a during soot-blowing operations to those obtained during normal operations.
- (7) Comparison of mercury results from individual components and sample fractions of the Method 29 trains.

7.1 Plume Simulating Dilution Sampling (PSDS)

7.1.1 Introduction

Dilution sampling was included in the original scope of work at the stack location for the purposes of observing the probable plume effects of dilution and cooling on the stack emissions. Condensation and secondary reactions within the plume can cause the character and chemistry of the emission to be quite different at points of exposure than at the stack. By comparing the results of simultaneously conducted hot and dilute sampling, insight to these differences and their implications regarding air toxics exposures may be gained.

In this Special Topics section the dilution sampling and analytical methods are discussed, and the results presented. Finally, the dilution sampling results are compared with the conventional hot stack sampling results from the same location.

7.1.2 Sampling

7.1.2.1 Location and Schedule. Both the dilution sampling (Location 5b) and conventional hot sampling (Location 5a) were conducted at the ESP outlet. The sampling was performed at the 200 foot level (about mid-elevation) in the stack serving Boiler No. 2. The sampling area is on two levels of the annular space between the outer stack wall and two stack inner flues, and is accessed by an external elevator. The inner stacks are both of brick/mortar construction having an inside diameter of 11.7 feet.

All hot sampling was conducted through four test ports spaced at 90° intervals on the stack circumference. The ports are 3-in. MPT nipples mounted about 36 in. above the floor grating. This sampling location meets EPA Reference Method 1 criteria as the ports are situated about eight stack diameters above the nearest upstream disturbance and many diameters below the exit. Dilution sampling was conducted through a fifth port (3-in. MPT nipple) which was on the inner stack wall at 36 in. above the floor grating on a second level in the sampling area. The dilution sampler was rigidly coupled to this port and remained stationary for all sampling.

Two diluent gas tube trailers were located on ground level at the base of the stack. Samples and sampling trains were shuttled between the lab and the sampling decks in the elevator as required. The diluent gas was delivered from the tube trailers, through a pressure regulating manifold mounted at ground level, up to the sampling deck through a 0.75 in. Teflon line. Communication between ground level and the sampling deck was by two-way radio.

The dilution sampling schedule was virtually identical to the hot stack (5a) sampling schedule as described in Section 3.1. The primary difference was with the dilute particulate sampling times, which were no less than eight hours each day for both the 8-in. x 10-in. filter and the cascade impactor.

7.1.2.2 Description. The following types of sampling were conducted at the dilution sampling Location 5b:

- SVOC*
 - PAH/SVOC
 - Dioxins/Furans
- VOC
- Aldehydes
- Elements*
- Anions*
- Cyanide
- Ammonia
- Particle Mass
- Particle Size Distribution

* These substances were measured by methods which distinguish between vapor phase and particle phase.

All of the dilute gas samples were taken with Chester Environmental's plume simulating dilution sampler (PSDS) at the ESP outlet Location 5b as described previously. The sampling configuration is shown schematically in Figure 7.1-1. The flue gas sample was

removed from the stack through a single port, without traversing (traversing is prohibited by the size and configuration of the PSDS and peripherals). After dilution, mixing and aging, particle samples were taken onto an 8-in. x 10-in. quartz filter for mass and the appropriate chemical analyses, and into a cascade impactor for size distribution measurements. Gas phase samples were taken from a common gas sampling manifold following the 8-in. x 10-in. particle filter.

The major components of the PSDS are the inlet nozzle, transfer tube, mixing and aging (dilution) chamber, and the various particle and gas phase sampling apparatus. All of the wetted surfaces in the sampler are stainless steel, Teflon or Viton. A brief description of these major components and the general operating procedures is provided in the following paragraphs.

Inlet Nozzle. A conventional Method 5 buttonhook sampling nozzle was installed on the transfer tube to extract a hot flue gas sample isokinetically. The nozzle was sized on-site to match sample flow with stack gas velocity within the targeted range of diluent gas rate (~20-25 scfm) and dilution ratio (~25-35:1).

Transfer Tube. The sample entering the inlet nozzle passes through the transfer tube and into the dilution chamber for dilution, aging and collection, along with secondary particles formed in the dilution process. The transfer tube is maintained at stack temperature to prevent premature condensation. An S-type pitot tube and a thermocouple are installed on the transfer tube to monitor stack gas velocity and temperature. The flow rate through the transfer tube is established by the difference between the total stack pressure at the inlet nozzle and the static pressure in the dilution chamber. This pressure difference, monitored with a magnehelic gage installed between the upstream port of the pitot and the dilution chamber, is referred to as chamber pressure. The chamber pressure - flow relationship is established by calibration of the nozzle/transfer tube assembly as an integrated unit. The operating chamber pressure was determined on-site using this calibration with the appropriate temperature and pressure corrections for the actual stack conditions encountered.

Dilution Chamber. The dilution chamber facilitates mixing of the flue gas with dilution gas, cooling and aging of this mixture to simulate the dilution processes occurring in a plume, and distribution of the aged mixture to the various sampling devices. The chamber flows were balanced by throttling the dilution gas (supplied under pressure) as required to establish the operating chamber pressure (for the specified flue gas flow rate through the transfer tube) while maintaining the necessary sampling device flow rates (withdrawn under vacuum).

The dilution sampler was operated according to Chester Environmental's PSDS Standard Operating Procedure, as modified to accommodate the special requirements of this project. The appropriate operating points for balancing source gas and dilution gas flows within prescribed targets were established and maintained on-site, using a calculation spreadsheet and a portable computer. The spreadsheet contains calibration constants for all of the appropriate dilution sampler components (transfer tube/nozzle combinations, flow metering orifice) and accepts operator inputs for actual ambient, stack, and sampling parameters. At start-up, initial operating points were calculated using inputs estimated from prior tests or default values. Over the course of each day's testing, the spreadsheet was updated with actual operating conditions and the appropriate operating points maintained. The operating parameters were manually recorded at 15 minute intervals on special field data sheets designed for this project.

Particle Sampling. Dilute particle samples were collected with an 8-in. x 10-in. high-purity quartz fiber filter and with a Pilat Mark 3 cascade impactor from two parallel circuits exiting the dilution chamber.

In one circuit the impactor was used to collect particles in eight size ranges. Particles in each size range were collected on pre-weighed glass fiber substrates for gravimetric (mass distribution) analyses. The sample flow was established and maintained at a rate of about 0.75 cubic feet per minute with a Method 5 type pump and meter box.

The second circuit was used to provide bulk particulate sample quantities across the entire size range. The circuit consisted of an 8-in. x 10-in. filter holder containing a pre-weighed 8-in. x 10-in. high purity quartz filter which was analyzed for mass, elements and anions for inorganic days, and for PAH/SVOC and dioxin/furans for organic days. A dilute

sample flow rate of about 15 scfm was maintained by a high-volume centrifugal blower, controlled with a Variac. The flow rate was monitored with a calibrated sharp-edged orifice installed downstream of the filter.

Because of the low concentrations after dilution ($< 1 \text{ mg/m}^3$), particulate samples were collected for as long as the dilution sampler was operated on any given sampling day. This ranged from 8 - 10 hours, as required to complete the daily sampling schedules. Because of the combination of low concentration and low flow rate, the cascade impactor was operated for two consecutive days without changing substrates. This provided for three runs of 16-20 hour duration.

Gas Phase Sampling. All of the dilute gas phase samples were taken from a common gas sampling manifold installed downstream of the 8-in. x 10-in. filter between the metering orifice and the blower. Samples were taken for the same analyses as for the hot gas phase samples, with equipment and methods of essentially the same description (back-half only). The dilute samples were each taken from the manifold through a separate shut-off valve and Teflon tube into the appropriate sample collection means. The dilute gas sampling rates were generally higher than the corresponding hot sampling rates (except VOST and SUMMA), but still within the range of conventional Method 5 equipment (0.8 - 1 scfm). However, after accounting for dilution, the actual stack gas volumes sampled by various methods were generally lower than those in the hot gas sampling.

7.1.2.3 Conditions. The dilute gas sampling conditions result from the mixing of the source gas with the dilution gas, at a dilution ratio of 25:1 or more (dilution ratio is defined as the volumes of dilution gas per volume of source gas, at wet standard conditions). Accordingly, the composition of the dilution gas is of controlling significance. The purpose of the dilution gas is to simulate atmospheric plume cooling and condensation, while minimizing artifact formation and without adding background contamination.

The targeted dilute sample gas conditions are near ambient temperatures and < 30 percent relative humidity, after 2 seconds residence time. These conditions are considered appropriate to provide adequate condensation and equilibration of analyte species and to minimize artifact formation due to acidic condensate on sample substrates. The residence

time is achieved by configuring the dilution chamber. In order to achieve the temperature and relative humidity objectives the dilution gas should be delivered at ambient temperature (or less) and virtually bone dry, i.e. less than 5 ppm.

A cryogenically pure mixture of 21 percent oxygen/79 percent nitrogen (by volume) was used for the dilution gas. This composition is preferred over 100 percent nitrogen, for this project, in order to insure that the formation of specific oxygenated-PAH compounds is not inhibited by low oxygen levels within the dilution chamber, relative to the actual ambient plume environment. Because both component gases were of cryogenic origin, maximum dryness and organic background purity were insured. The dilution gas was delivered pre-mixed to the test site in high volume (40,000 scf) compressed gas tube-trailers. A delivery manifold on the trailer provided pressure regulation (25-30 psig) and activated carbon filtration of the gas prior to delivery to the sampling location. The gas was delivered to the sampling location through Teflon line to a control manifold connected to the inlet of the dilution chamber. The control manifold consists of a rate control valve, temperature and pressure instrumentation, and final HEPA filtration.

The targeted dilute gas sampling conditions, and the actual conditions realized for each sampling day are shown in Table 7.1-1.

7.1.3 Analytical

The analytical methods and the analytical QA/QC applied to the samples collected with the PSDS were the same as those described in Section 4 for like analytes in flue gas samples. The only noteworthy exception is with the range of analyses performed on the dilute particulate samples (8-in. x 10-in. filter) collected on inorganic days. The dilute particulate samples were not analyzed for carbon or radionuclides.

7.1.4 Results

The analytical results for the samples collected with the PSDS are shown in Tables 7.1-2 through 7.1-10. Each table presents, for each analyte being reported, the results for each of three replicate sample runs plus the associated average and standard deviation. The

results are presented as "whole train" results without distinction between particulate and vapor phases. Section 7.2 presents separate particulate (front half) and vapor phase (back half) results for runs which were so configured. All results are corrected for train blanks as appropriate. For the purpose of this Special Topic, some of the results in Tables 7.2-2 through 7.2-10 were calculated differently than were the corresponding results in Section 5. Specifically, individual sample fraction results that were below detection limits were set equal to zero, in the present evaluation. This procedure applies only to those measurements that produced multiple sample fractions from each run, i.e., PAH/SVOC, dioxin/furan, and trace element sampling methods. For those types of analyses, two sets of results are shown here. One set is the PSDS results from Location 5b, calculated as indicated above. The other is the hot sampling results from Location 5a, calculated as described above, and shown here for direct comparison to the Location 5b results. Data for PAH/SVOCs, dioxins/furans, and elements are shown in Tables 7.1-2 through 7.1-7.

All concentration results, which are reported in units of mass/Ncm, were calculated using the source gas volume (Ncm) associated with the actual diluted gas volume which was sampled from the PSDS. Therefore, these results can be compared directly with the hot sampling results on a concentration basis.

7.1.5 Data Analysis

In the following paragraphs, the dilution sampling results (Location 5b) are compared with the hot stack sampling results (Location 5a). The comparisons are made on a concentration basis by analyte group. Before proceeding with data comparisons some of the constraints of the PSDS methods relative to the conventional reference methods should be discussed.

The current configuration of the PSDS was originally conceived and designed for the purpose of developing PM_{10} source profiles or "fingerprints" to be used in chemical mass balance receptor modeling studies. These source measured profiles had to represent the source chemistry as it would impact a downwind ambient receptor. Therefore, the PSDS was configured for high dilution and residence time and to accept ambient PM_{10} sampling

devices. The result was a large stationary sampler exhibiting the following limitations relative to conventional reference methods:

- Single point versus traversing operation
- No flow totalizer (dry gas meter) is used for source gas flow
- Sample recoveries are incomplete (no probe or dilution chamber rinse).

These factors are of little consequence to the original PSDS objective of "relative chemistry", but should be recognized when comparing results with the more "absolute" reference methods. Accordingly, there is more uncertainty with PSDS sample volumes (10-15 percent for individual primary flow measurements, 25-40 percent propagated through dilution ratio calculation and secondary flow measurements). Also, concentration measurements may be biased low due to unrecovered sample. It is difficult to quantify these sample loss effects on a case by case basis, but it should be noted that PM_{10} and mercury vapor transmission efficiencies have been tested at over 90 percent.

7.1.5.1 PAH/SVOC. The PAH/SVOC results from Locations 5a and 5b are shown in Tables 7.1-2A and -2B, respectively. The comparison of the PAH/SVOC results is rather curious, as it shows the PSDS (Location 5b) concentrations to be higher than the hot concentrations (Location 5a) by a factor of almost 6, as an average across all species reported. The total PAH/SVOC concentrations/standard deviations are about 21,430/10,700 ng/Ncm and 3,690/1340 ng/Ncm for the PSDS and hot stack samples, respectively. These concentrations represent total recoveries (particulate plus vapor). Both the hot and PSDS profiles are similar in that acetophenone, naphthalene, chloroacetophenone, and 2,6-dinitrotoluene are the dominant species. The 3,690 ng/Ncm measured at the hot location is within the range of total PAH stack concentrations indicated by previous work^{1,2,3}. The PSDS concentrations are expected to be enriched in the particulate phase, but this degree of total PAH enrichment seems high. Contamination of the PSDS recoveries would cause them to be artificially high, but the consistency of the trend from day to day and the similarity of the speciation profiles suggest a more systematic process. Even a propagated error in PSDS sample volumes of 40-50 percent would not account for these differences.

It appears as if the compounds are being formed in the dilution process. Although unexpected it is conceivable, particularly among the oxygenated, nitrated, and halogenated

compounds. Given the presence of oxides of nitrogen, hydrogen chloride, hydrogen fluoride and the addition of excess oxygen, a variety of gas phase and cross-phase reactions may be occurring within the dilution chamber. 2,4-Dinitrotoluene is enriched by a factor of 24 over the hot samples, and 2-methylnaphthalene and acetophenone by factors of 12 and 11, respectively. Still, this degree of enrichment seems quite high for the 3- to 4-second residence times realized in the dilution chamber.

It should be noted that there is considerable variability in the individual and total PAH/SVOC concentrations from day to day at all locations. Standard deviations up to 140 percent of the three run average occurred, with 75-100 percent not uncommon.

The most consistent indication across the runs is the phase distribution of the recovered compounds. On the average less than 1 percent of the total PAH/SVOC recovered from the PSDS samples was in the particulate phase, compared with about 7 percent for the hot samples (see Section 7.2). This indication is counter to the expectation for particle phase enrichment during the dilution and cooling process. Unrecovered particle loss to the PSDS nozzle and transfer tube could account for some of this difference, as could in-stack stratification of particle loading (PSDS was not traversed).

7.1.5.2 Dioxins/Furans. Dioxin/furan results are shown in Tables 7.1-3A and -3B. The dioxin/furan results for both the PSDS and hot samples are dominated by non-detects and show considerable variability, particularly the PSDS samples. Accordingly, the real value of any comparison is questionable, but some observations may be noteworthy.

The most significant levels were detected in the first of three samples (day one) from both the hot stack and PSDS locations. On that day, the total concentrations for all of the detected compounds are about 670 pg/Ncm at the hot stack location and 1650 pg/Ncm at the PSDS location. The hot stack total consists of a variety of compounds at concentrations of about 10-100 pg/Ncm, while the PSDS total comes from only three compounds at concentrations in the range of 100-1000 pg/Ncm. The dissimilarity of the two profiles suggests that they may not be of common (source) origin, but the effects of low source gas sample volume associated with the PSDS vapor (XAD) samples may be the key factor. Relative to the hot samples, the low volume associated with the PSDS XAD sample will increase source detection limits and magnify any background contamination, in terms of

pg/Ncm of source gas. It should also be noted that virtually 100 percent of the compounds detected in these first day's samples were detected in the vapor phase (XAD) samples.

In the second and third days' samples the detected compounds are reported at levels which are on the same order as the detection limits (~ 10-100 pg/Ncm for PSDS samples and ~ 1-20 pg/Ncm for hot samples). Also, fewer compounds were detected and the total concentrations were considerably lower in the second and third days' samples than in the first day. The only compound appearing above detection level in these PSDS samples was octachlorodibenzofuran and it appeared only in the particle phase at 13 and 43 pg/Ncm. The corresponding concentrations reported for the hot samples were 20.5 pg/Ncm (~ 70 percent particulate) and 16.4 pg/Ncm (100 percent vapor).

7.1.5.3 Aldehydes. Aldehyde results from Location 5b are shown in Table 7.1-4. The aldehyde results show that, on the average, the PSDS samples are enriched in formaldehyde (22.7 versus 6.7 $\mu\text{g}/\text{Ncm}$) and depleted in acetaldehyde (18.4 versus 152 $\mu\text{g}/\text{Ncm}$), relative to samples from Location 5a (see Section 5.7.1). Acrolein and propionaldehyde were not detected in any of the PSDS samples, but average 69 and 42 $\mu\text{g}/\text{Ncm}$, respectively, in the hot samples. From prior similar work³, it is expected that the PSDS samples would be enriched in all of the aldehyde species, presumably due to their formation in the acidic environment within the dilution chamber. It is not clear why these results are inconsistent, but variation among samples is considerable with standard deviations ranging from about 60-150 percent of the average.

7.1.5.4 VOC. VOC results from VOST samples at Location 5b are shown in Table 7.1-5. Only the VOC results from the VOST samples will be considered in this section. The SUMMA canister results are compared with the VOST results for all locations in Section 7.5. Note that the daily VOST results are the averages of three VOST runs per day, and that the VOST results are not blank corrected.

The only VOC compounds reported above detection limit in both the PSDS and hot stack sample sets are chloromethane, methylene chloride, acetone, and carbon disulfide. Methylene chloride and acetone were used as probe rinse solvents in the field, and their presence in VOST samples and blanks is believed to be due to contamination. The

corresponding average total VOC concentration ($\mu\text{g}/\text{Ncm}$)/standard deviation over all runs are about 175/100 for the PSDS samples and 110/63 for the hot stack samples, respectively. Excluding methylene chloride and acetone, chloromethane dominates the PSDS total at 78 $\mu\text{g}/\text{Ncm}$ followed by 1,1,1-trichloroethane and carbon disulfide at concentrations of 17 and 10 $\mu\text{g}/\text{Ncm}$, respectively. The hot samples contain benzene, carbon disulfide, and 2-butanone at 13, 10, and 9 $\mu\text{g}/\text{Ncm}$, respectively.

Carbon disulfide levels in both the PSDS and hot samples are, on the average, equal. Chloromethane is enriched in the PSDS samples by a factor of at least 9, and 1,1,1-trichloroethane by a factor of at least 2, over the hot sample results. Benzene and 2-butanone average concentrations in the hot samples are very close to or below the corresponding PSDS detection levels.

Given the variability in the data and the relatively high PSDS detection limits, the hot and PSDS results compare reasonably well. However, the reason for consistent enrichment of chloromethane in the PSDS samples is not clear.

7.1.5.5 Elements. The results for the elements are presented in Tables 7.1-6 and 7.1-7. Because they are inert to chemical change the total concentration of each element is expected to be essentially the same in the PSDS and the hot stack samples, excluding any sampling or analytical error. Depending on the particulate loading and size distribution in the stack, the PSDS samples might be expected to compare low due to unrecoverable particle losses in the nozzle and transfer tube. The phase distribution is expected to change for the more volatile elements because the PSDS is operated at near ambient temperatures. Accordingly, particle phase enrichment is expected for some elements in the PSDS samples.

Relative to these expectations, the averaged elemental results for most compounds do not compare well. For aluminum, barium, beryllium, copper, potassium, selenium, sodium, and titanium, the differences between the average PSDS and hot concentrations are within one standard deviation. However, variability in the data is considerable with standard deviations typically exceeding the average. The average aluminum, potassium, and sodium concentrations for the PSDS samples are enriched by factors of 3-100 over the hot stack concentrations, and due entirely to very high vapor phase concentrations on the third test day. This suggests contamination and calls the data into question.

Arsenic, chromium, manganese, copper, and vanadium average levels are depleted in the PSDS samples by factors of 0.13, 0.25, 0.08, 0.5, and 0.16, respectively. Lead, mercury, and molybdenum concentrations are enriched by factors of 1.6, 1.3, and 6.2, respectively. The run-to-run concentrations of all of these elements do not show enough variability to account for the average differences and, with the exception of nickel and vanadium, the levels measured are consistently above the detection limits. However, lead and mercury concentrations are close enough that the differences may be within the normal range of sampling and analytical error, particularly considering the uncertainty of mercury measurements by Draft Method 29. The reason for depletion/enrichment of these elements in the PSDS samples is not clear.

Particle/vapor phase distribution of the elements are discussed in section 7.2 and the results of arsenic, mercury, and selenium vapor phase measurements by the HEST method and Method 29 are compared in Section 7.4.

7.1.5.6 Anions. Anion results from the PSDS sampling are shown in Table 7.1-8. The anion results show gas phase hydrogen chloride (HCl) and hydrogen fluoride (HF) and particle phase chlorides, fluorides, sulfates, and phosphates. Comparing the average concentrations, the PSDS samples are depleted slightly in HCl and HF by factors of 0.89 and 0.94, respectively, relative to the hot samples (Section 5.3.1). The corresponding average concentrations ($\mu\text{g}/\text{Ncm}$)/standard deviations are 195,902/16,931 and 14,014/256 for HCl and HF respectively, in the PSDS samples and 219,346/1,715 and 14,864/1,826 in the hot samples. These vapor phase results compare reasonably well considering the variability relative to the differences between the PSDS and hot averages.

Of the particulate anions, chloride average results are virtually identical (32 $\mu\text{g}/\text{Ncm}$ PSDS versus 31 $\mu\text{g}/\text{Ncm}$ hot). Fluoride, phosphate, and sulfate particulate are depleted in the PSDS samples by factors of 0.14, 0.69, and 0.61, respectively. Normally, particulate anions are expected to be somewhat enriched during the dilution process, which is not evidenced in these results. However, the variability of the hot stack fluoride and phosphate measurements is fairly high. Also, unrecovered losses to the PSDS nozzle and probe may be a factor, particularly for sulfate as sulfuric acid mist. Given the SO_x concentrations prevailing in the stack the acid dew point is likely to be relatively high.

7.1.5.7 Ammonia and Cyanide. Ammonia and cyanide results from the PSDS are shown in Table 7.1-9. Ammonia was detected in only the third of the PSDS samples (N-5B-NH4-731) at a concentration of 192 $\mu\text{g}/\text{Ncm}$, and in the second of the hot stack samples (N-5A-NH4-729) at a concentration of 352 $\mu\text{g}/\text{Ncm}$ (Section 5.2.1). The corresponding averages/standard deviations are 73/103 and 118/203, respectively. The cyanide results indicate average concentrations($\mu\text{g}/\text{Ncm}$)/standard deviations of 190/218 for the PSDS samples and 303/200 for the hot stack samples. For both analytes the differences between the average PSDS and hot stack concentrations fall within the range of variability. However, the high degree of variability and uncertainty brings the value of this comparison into question.

7.1.5.8 Particle Size Distribution. The results of the particle size distributions as measured by cascade impactors at the hot stack and the PSDS are shown in Tables 7.1-10A and 7.1-10B, respectively. The indicated average mass median diameters (classic aerodynamic D_{50}) are about 2.9 μm for the hot stack and 0.1 μm for the PSDS. A shift toward the smaller diameter in the PSDS is expected, due to the loss of some larger particles in the PSDS nozzle and transfer tube, plus the enrichment of fine particles due to condensation/nucleation processes within the dilution chamber. However, a mass median diameter of 0.1 μm appeared too low and called for a closer inspection of the PSDS impactor data.

The majority (75-80 percent) of mass deposited in the PSDS impactor runs was found consistently on the backup filters. The corresponding weight gains of these filters (17-26 mg) were confirmed by a secondary reweighing conducted about two months after the original analysis. It was noted that the backup filters were discolored with a brown-orange cast which was not apparent on any of the impaction substrates which are of the same materials and specification (Reeve-Angel 934AH, glass mat). It appears that the weight gain of the filters is real, but the discoloration suggests that it may be due to artifact formation within the filter substrate. As to why a similar artifact was not apparent in the impaction substrates or in the hot stack impactor runs, the differences in flow configuration (through versus across) and operating environment, respectively, are all that can be offered.

Another check was made by comparing the total particulate loading indicated by the impactor mass with that indicated by the 8-in. x 10-in. filter mass. The average dilution chamber particle loading indicated by the impactor weight gains is 1.9 mg/Ncm compared with 0.67 mg/Ncm based on the 8-in. x 10-in. weight gains. This further supports the artifact theory, as the high-purity quartz 8-in. x 10-in. substrate is relatively inert to gas phase reaction.

Assuming the artifact theory is true, and adjusting the backup filter weight gains to bring the impactor based particle loading into agreement with the 8-in. x 10-in. based loading, the average dilute mass median diameter increases into the 0.5-0.6 μm range.

It should also be noted that the uncertainty of individual impactor stage mass measurements is 0.1 mg. The reported weight gains for individual impactor stages varied widely from 0.0 to 25.5 mg, and total impactor weight gains range from 4.3 to 73.0 mg. Aside from the first stage measurements for the PSDS runs, mass uncertainties are less than 25 percent.

7.1.6 Recommendations

To address some of the inherent limitations of the PSDS discussed in the beginning of Section 7.1.5 and some of the questions raised in the preceding data analysis, the following recommendations are offered regarding design/operating aspects of the PSDS and further study:

- Improve means for source gas and dilute gas sample flow measurement/validation by monitoring source and dilute gas CO_2 concentrations and by using a calibrated positive displacement (Roots) blower for maintaining and measuring the total diluted exhaust flow.
- Modify design to accommodate a glass probe/nozzle assembly and to facilitate daily probe/nozzle sample recovery without excessive time and physical difficulty. (Note that recovered sample will not have been subjected to the dilution process.)
- Design and conduct further studies on the issue of PAH/SVOC enrichment in dilute samples. This enrichment is indicated consistently in both the Coal Creek and Niles studies and, if real, could have significant implications

regarding the associated emission factors and subsequent risk assessment. Elements of study would include:

- Simultaneous hot sampling from the same fixed point in the stack
 - Daily filter and XAD method (train) blanks
 - A dilution gas XAD blank
 - Field spiking
 - *Adaptation of ambient XAD sampling equipment to allow a significantly increase sampling in the dilute sampling rate.*
- Consider similar additional study on other reactive species such as formaldehyde
 - Analyze the cascade impactor backup filters from the Niles dilute (5b) location by microscopy and, possibly, by XRF and ion chromatography to confirm the source of the excess mass.

7.1.7 References

1. K. Warman. "PAH Emissions from Coal Fired Plants." Studsvik Energiteknik AB, Report No. Studsvik-EB-84-8, January, 1984.
2. R. Meij, L.H.J.M. Janssen, and J. van der Kooij. "Air Pollutant Emissions from Coal- Fired Power Stations." Kema Scientific and Technical Reports, 4, 1986.
3. Topical Report to U.S. Department of Energy, "Characterization of Air Toxics from a Laboratory Coal-Fired Combustor." Battelle Contract No. DE-AC22-91PC90366, September, 1993.

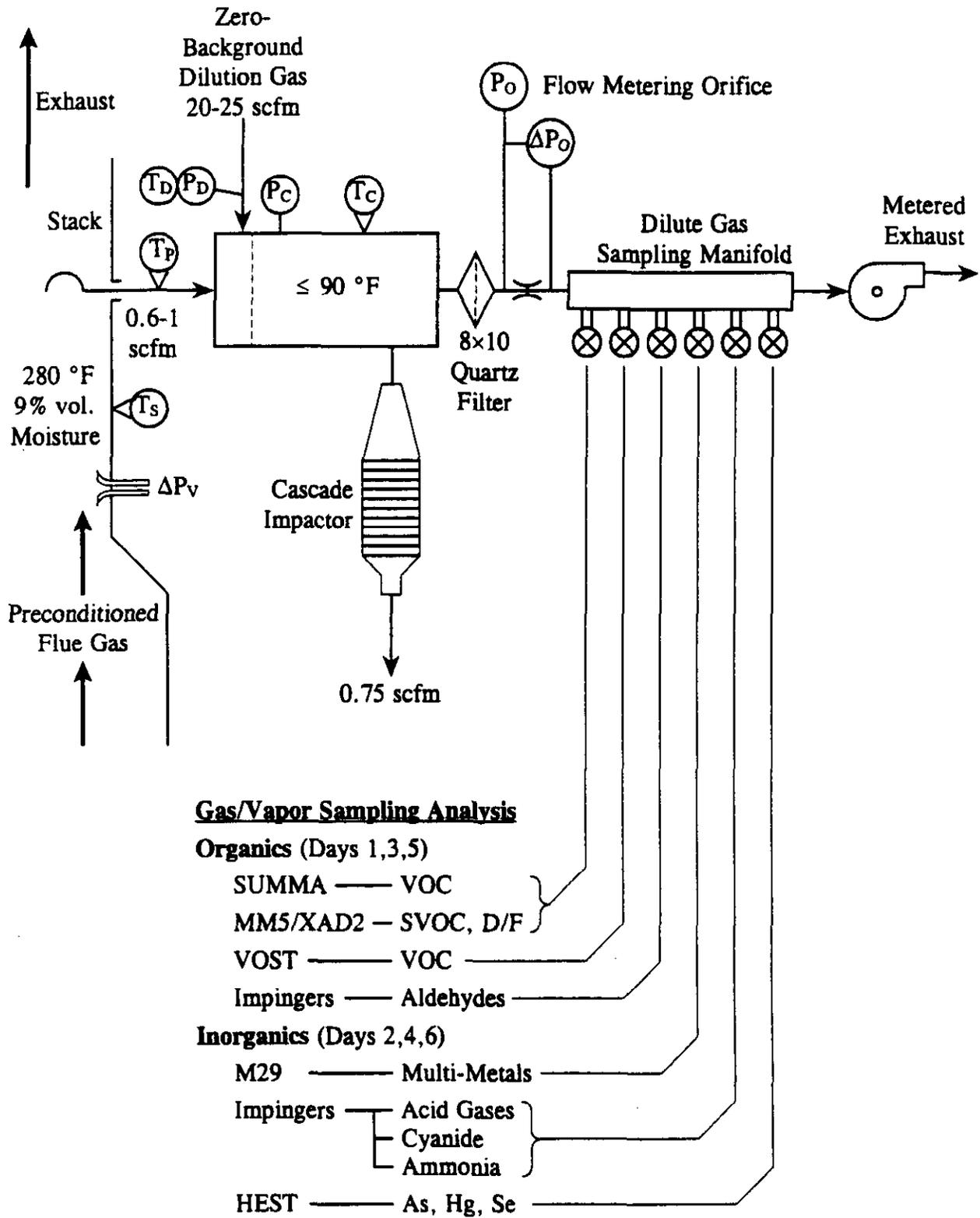


Figure 7.1-1. Dilute Sampling Schematic

TABLE 7.1-1. PSDS SAMPLING CONDITIONS

Niles, Ohio Location 5b

	Dilution Sampling Parameters				Dilution Chamber Conditions			Stack Conditions		Volume Sampled (Nem source gas)		
	Source Gas Rate (scfm)	Diluent Gas Rate (scfm)	Dilution Ratio	Isokinetic Ratio (%)	Sampling Time (min)	Temp (°F)	Moisture (% vol)	Particle conc. (mg/Nem)	Temp (°F)	Moisture (% vol)	8" x 10" filter	Cascade Impactor
Targeted	0.6-1.0	20-25	25-35:1	100	480	= < 90	< 1%	< 1	285	8.9		
Daily avg												
N-5B-726	0.50	14.96	30.05	102.0	480	111	0.30		290	9.2	4.284	0.212
N-5B-727	0.50	14.88	29.88	102.0	510	105	0.30	0.700	290	9.2	5.064	0.180
N-5B-728	0.50	14.84	29.86	101.7	488	106	0.29		290	8.9	4.524	0.222
N-5B-729	0.49	14.60	29.97	102.0	480	100	0.30	0.690	290	9.4	4.489	0.236
N-5B-730	0.50	15.06	30.19	101.8	480	92	0.27		287	8.4	4.814	0.245
N-5B-731	0.49	14.61	29.81	102.0	480	94	0.31	0.609	285	9.4	4.523	0.243

TABLE 7.1-2A. PAH/SVOC IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) (ng/Nm³)

Analyte	N-5A-MM5- F+X-726	N-5A-MM5- F+X-728	N-5A-MM5- F+X-730	AVERAGE	DL RATIO	SD
Benzylchloride	4.92	ND < 28.8	ND < 2.60	6.9	72%	6.8
Acetophenone	1517	1223	492 E	1077		528
Hexachloroethane	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Naphthalene	526	395	174 E	365		178
Hexachlorobutadiene	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
2-Chloroacetophenone	791	588	92.7	490		359
2-Methylnaphthalene	136	37.3	18.2	64		63
1-Methylnaphthalene	55.9	17.4	6.52	27		26
Hexachlorocyclopentadiene	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Biphenyl	102	494	44.7	213		245
Acenaphthylene	30.0	2.42	1.32	11		16
2,6-Dinitrotoluene	1134	851	807 E	930		177
Acenaphthene	111	22.9	2.29	45		58
Dibenzofuran	212	75.2	46.0	111		89
2,4-Dinitrotoluene	51.0	ND < 28.8	32.3	33	15%	18
Fluorene	125	21.2	13.8	53		62
Hexachlorobenzene	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Pentachlorophenol	ND < 29.4	ND < 28.8	ND < 2.60	ND < 20		15
Phenanthrene	267	93.1	36.4	132		120
Anthracene	91.0	12.0	3.28	35		48
Fluoranthene	79.2	42.1	16.5	46		32
Pyrene	42.8	23.7	4.77	24		19
Benz(a)anthracene	13.9	0.687	1.71	5.4		7.3
Chrysene	31.8	8.04	5.48	15		15
Benzo(b & k)fluoranthene	31.5	1.25	1.79	12		17
Benzo(e)pyrene	7.90	0.623	ND < 0.520	2.9	4%	4.3
Benzo(a)pyrene	ND < 5.88	ND < 5.75	ND < 0.520	ND < 4.1		3.1
Indeno(1,2,3-c,d)pyrene	ND < 5.88	ND < 5.75	ND < 0.520	ND < 4.1		3.1
Dibenz(a,h)anthracene	ND < 5.88	ND < 5.75	ND < 0.520	ND < 4.1		3.1
Benzo(g,h,i)perylene	ND < 5.88	ND < 5.75	ND < 0.520	ND < 4.1		3.1

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

TABLE 7.1-2B. PAH/SVOC IN DILUTE GAS SAMPLES FROM ESP OUTLET (LOCATION 5b) (ng/Nm³)

Analyte	N-5B-MM5- F+X-726	N-5B-MM5- F+X-728	N-5B-MM5- F+X-730	AVERAGE	DL RATIO	SD
Benzylchloride	ND < 120	ND < 62.8	ND < 56.1	ND < 80		35
Acetophenone	19143	7813	8563	11840		6336
Hexachloroethane	ND < 120	ND < 62.8	ND < 56.1	ND < 80		35
Naphthalene	2106	608	833	1182		808
Hexachlorobutadiene	ND < 120	ND < 62.8	ND < 56.1	ND < 80		35
2-Chloroacetophenone	8232	3532	726	4164		3792
1-Methylnaphthalene	972	243	32.6	416		493
2-Methylnaphthalene	663	219	75.7	319		306
Hexachlorocyclopentadiene	ND < 120	ND < 62.8	ND < 56.1	ND < 80		35
Biphenyl	233	162	88.9	161		72
Acenaphthylene	59.2	25.6	ND < 11.2	30	6%	27
2,6-Dinitrotoluene	1792	257	1423	1157		801
Acenaphthene	109	17.2	0.964	43		58
Dibenzofuran	249	98.0	4.77	117		124
2,4-Dinitrotoluene	1517	576	316	803		632
Fluorene	586	207	46.6	280		277
Hexachlorobenzene	ND < 120	ND < 62.8	ND < 56.1	ND < 80		35
Pentachlorophenol	ND < 120	ND < 62.8	ND < 56.1	ND < 80		35
Phenanthrene	1060	472	6.44	513		528
Anthracene	218	103	26.0	116		96
Fluoranthene	392	91.6	37.4	174		191
Pyrene	86.3	43.4	15.8	49		35
Benz(a)anthracene	72.0	15.3	2.16	30		37
Chrysene	69.4	35.9	0.463	35		34
Benzo(b & k)fluoranthene	109	0.587	ND < 11.2	38	5%	61
Benzo(e)pyrene	0.785	0.504	0.434	0.57		0.19
Benzo(a)pyrene	0.657	0.481	ND < 11.2	2.2	83%	2.9
Indeno(1,2,3-c,d)pyrene	0.884	0.618	ND < 11.2	2.4	79%	2.8
Dibenz(a,h)anthracene	1.125	0.786	0.420	0.78		0.35
Benzo(g,h,i)perylene	0.858	0.523	ND < 11.2	2.3	80%	2.8

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 7.1-3A. DIOXINS/FURANS IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) (pg/Nm³)

Analyte	N-5A-MMS-726	N-5A-MMS-728	N-5A-MMS-730	AVERAGE	DL RATIO	SD
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND < 4.77	ND < 2.88	ND < 2.94	ND < 3.5		1.1
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND < 6.87	ND < 3.89	ND < 3.62	ND < 4.8		1.8
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND < 9.79	ND < 4.07	ND < 3.37	ND < 5.7		3.5
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	10.2 J	ND < 3.80	ND < 3.42	4.6	26%	4.8
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	9.99 J	ND < 2.33	ND < 3.19	4.3	22%	5.0
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	59.6	9.74 J	10.3 J	27		29
Octachlorodibenzo-p-dioxin	91.8 K	2.35 J	11.5 J	35		49
2,3,7,8-Tetrachlorodibenzofuran	16.8	2.18 J	ND < 5.85	7.3	13%	8.2
1,2,3,7,8-Pentachlorodibenzofuran	ND < 9.85	ND < 2.75	ND < 4.60	ND < 5.7		3.7
2,3,4,7,8-Pentachlorodibenzofuran	ND < 18.6	ND < 3.03	4.10 J	5.0	73%	4.0
1,2,3,4,7,8-Hexachlorodibenzofuran	40.3	ND < 5.25	ND < 9.42	16	15%	21
1,2,3,6,7,8-Hexachlorodibenzofuran	13.1 J	ND < 3.77	ND < 6.40	6.1	28%	6.1
1,2,3,7,8,9-Hexachlorodibenzofuran	18.5 J	ND < 7.13	5.29 J	9.1	13%	8.2
2,3,4,6,7,8-Hexachlorodibenzofuran	ND < 6.06	ND < 2.63	ND < 3.89	ND < 4.2		1.7
1,2,3,4,6,7,8-Heptachlorodibenzofuran	63.5	5.28 J	ND < 14.3	25	9%	33
1,2,3,4,7,8,9-Heptachlorodibenzofuran	10.9 J	ND < 4.61	ND < 5.98	5.4	33%	4.8
Octachlorodibenzofuran	48.0 J	20.5 J	16.4 J	28		17
Total Tetrachlorodibenzo-p-dioxin	21.8		13.4	12		11
Total Pentachlorodibenzo-p-dioxin	9.46			3.2		5.5
Total Hexachlorodibenzo-p-dioxin	49.6			17		29
Total Heptachlorodibenzo-p-dioxin	102	15.1	18.7	45		49
Total Tetrachlorodibenzofuran	81.6	2.18		28		46
Total Pentachlorodibenzofuran	87.3		10.4	33		48
Total Hexachlorodibenzofuran	107		5.29	37		60
Total Heptachlorodibenzofuran	89.2	5.25		31		50

** Total sample non detect values are the average detection limit from the XAD and Filter fractions.
 Total results do not include any contribution from non detects.
 J = value detected below the calibration range.
 K = total value in the calibration range, but individual values from the XAD or filter fraction or both were below the calibration range.
 L = isotope ratio slightly outside theoretical range.
 C = indicates the blank value was greater than the sample value.
 Continuing calibration response factor for 23478-PeCDF-13C12 slightly below 30% from initial calibration at end of analysis day for N-5
 Continuing calibration response factor for 1234678-HpCDF-13C12 slightly above 30% from initial calibration at end of analysis day for
 ** = several isotope ratios in the continuing calibration were slightly out of the theoretical range on the day these samples were analyzed.

TABLE 7.1-3B. DIOXINS/FURANS IN DILUTE GAS SAMPLES FROM ESP OUTLET (LOCATION 5b) (pg/Nm³)

Analyte	**		**		AVERAGE	DL RATIO	SD		
	N-5B-MM5-726	N-5B-MM5-728	N-5B-MM5-730	N-5B-MM5-730					
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND <	56.4	ND <	28.5	ND <	26.7	ND <	37	17
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND <	93.4	ND <	32.5	ND <	28.0	ND <	51	37
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND <	132	ND <	68.5	ND <	31.7	ND <	78	51
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ND <	115	ND <	71.0	ND <	30.6	ND <	72	42
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ND <	178	ND <	89.5	ND <	26.2	ND <	98	76
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	ND <	316	ND <	171	ND <	75.0	ND <	187	121
Octachlorodibenzo-p-dioxin	1010 K		ND <	750 C	ND <	700 C		578	374
2,3,7,8-Tetrachlorodibenzofuran	ND <	44.6	ND <	26.3	ND <	20.3	ND <	30	13
1,2,3,7,8-Pentachlorodibenzofuran	ND <	138	ND <	30.9	ND <	28.9	ND <	66	62
2,3,4,7,8-Pentachlorodibenzofuran	ND <	178	ND <	53.6	ND <	22.5	ND <	85	82
1,2,3,4,7,8-Hexachlorodibenzofuran	ND <	144	ND <	46.7	ND <	17.1	ND <	69	66
1,2,3,6,7,8-Hexachlorodibenzofuran	ND <	105	ND <	40.3	ND <	15.3	ND <	53	46
1,2,3,7,8,9-Hexachlorodibenzofuran	ND <	77.9	ND <	113	ND <	56.4	ND <	83	29
2,3,4,6,7,8-Hexachlorodibenzofuran	ND <	142	ND <	87.7	ND <	31.3	ND <	87	55
1,2,3,4,6,7,8-Heptachlorodibenzofuran	169 J		ND <	149	ND <	38.5		88	76
1,2,3,4,7,8,9-Heptachlorodibenzofuran	ND <	216	ND <	146	ND <	38.6	ND <	133	89
Octachlorodibenzofuran	508 J		ND <	12.8 J		42.6		188	277
Total Tetrachlorodibenzo-p-dioxin									
Total Pentachlorodibenzo-p-dioxin									
Total Hexachlorodibenzo-p-dioxin									
Total Heptachlorodibenzo-p-dioxin									
Total Tetrachlorodibenzofuran									
Total Pentachlorodibenzofuran									
Total Hexachlorodibenzofuran									
Total Heptachlorodibenzofuran									

Total sample non detect values are the average detection limit from the XAD and Filter fractions.
 Total results do not include any contribution from non detects.
 J = value detected below the calibration range.
 K = total value in the calibration range, but individual values from the XAD or filter fraction or both were below the calibration range.
 L = isotope ratio slightly outside theoretical range.
 C = indicates the blank value was greater than the sample value.
 Continuing calibration response factor for 23478-PeCDF-13C12 slightly below 30% from initial calibration at end of analysis day for N-5A-
 Continuing calibration response factor for 1234678-HpCDF-13C12 slightly above 30% from initial calibration at end of analysis day for N-5
 ** = several isotope ratios in the continuing calibration were slightly out of the theoretical range on the day these samples were analyzed.

TABLE 7-1-4. ALDEHYDES IN DILUTE GAS SAMPLES FROM ESP OUTLET (LOCATION 5b) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5B-ALD-726		N-5B-ALD-728		N-5B-ALD-730		AVERAGE	DL RATIO	SD
Formaldehyde		39.6		15.9		12.6		22.7	14.7
Acetaldehyde		11.0		12.3		31.8		18.4	11.7
Acrolein	ND <	2.87	ND <	2.76	ND <	2.58	ND <	2.74	0.15
Propionaldehyde	ND <	2.87	ND <	2.76	ND <	2.58	ND <	2.74	0.15

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 7.1-5. VOC IN DILUTE GAS SAMPLES FROM ESP OUTLET (LOCATION 5b) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5B-VOS-726	N-5B-VOS-728	N-5B-VOS-730	AVERAGE	DL RATIO	SD		
Chloromethane		121	64.5	47.6	78	33		
Bromomethane	ND <	10.7	ND <	15.3	ND <	14	9.0	
Vinyl Chloride	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Chloroethane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Methylene Chloride		57.2	70.2	17.9	48	36		
Acetone		38.0	11.6	19.7	23	10		
Carbon Disulfide	ND <	18.4	17.1	ND <	7.31	ND <	18	9.0
1,1-Dichloroethene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
1,1-Dichloroethane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Trans-1,2-Dichloroethene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Chloroform	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
1,2-Dichloroethane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
2-Butanone	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
1,1,1-Trichloroethane	ND <	10.7	40.1	ND <	9.77	17	20%	22
Carbon Tetrachloride	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Vinyl Acetate	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Bromodichloromethane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
1,2-Dichloropropane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
cis-1,3-Dichloropropane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Trichloroethene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Dibromochloromethane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
1,1,2-Trichloroethane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Benzene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
trans-1,3-Dichloropropane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
2-Chloroethylvinylether	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Bromoform	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
4-Methyl-2-Pentanone	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
2-Hexanone	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Tetrachloroethene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
1,1,2,2-Tetrachloroethane	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Toluene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Chlorobenzene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Ethylbenzene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Styrene	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7
Xylenes (Total)	ND <	10.7	ND <	15.3	ND <	9.77	12	7.7

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 7.1-6. ELEMENTS IN GAS SAMPLES FROM ESP OUTLET (LOCATION 5a) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-MUM-727	N-5a-MUM-729	N-5a-MUM-731	AVERAGE	DL RATIO	SD	
Aluminum	5238	14.6 #	90.7 #	5238		NC	
Potassium	3257	ND <	1.45 #	125 #	3257	NC	
Silicon *	9529	5363	6101	6997		2223	
Sodium	7604 #	ND <	51.3	891	458	3% NC	
Titanium	51.2	28.6	36.2	39		11.5	
Antimony	ND <	0.59	ND <	0.60	ND <	0.60	0.0
Arsenic	79.4	59.6	70.3	70		9.9	
Barium	15.4	4.63	6.45	8.8		5.8	
Beryllium	0.31	0.28	0.33	0.31		0.0	
Boron	NA	NA	NA	NA		NA	
Cadmium	ND <	0.10	ND <	0.10	ND <	0.10	0.11
Chromium	4.92	5.89	4.37	5.1		0.77	
Cobalt	ND <	0.20	ND <	0.19	ND <	0.20	0.0
Copper	7.78	5.37	6.83	6.7		1.2	
Lead	2.62	1.89	3.47	2.7		0.79	
Manganese	7.66	4.09	5.07	5.6		1.8	
Mercury	27.4	21.2	23.2	24		3.1	
Molybdenum	4.09	4.27	2.87	3.7		0.76	
Nickel	1.32	0.93	0.47	0.90		0.43	
Selenium	136	56.1	113	102		41	
Vanadium	3.74	4.02	4.88	4.2		0.59	

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Not analyzed.

NC = Not calculated.

= Outlier value, not used in calculations.

Samples corrected for train blank.

Silicon not determined in cyclones and filter.

TABLE 7.1-7. ELEMENTS IN DILUTE GAS SAMPLES FROM ESP OUTLET (LOCATION 5b) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5b-MUM-727		N-5b-MUM-729		N-5b-MUM-731		AVERAGE	DL RATIO	SD
Aluminum	ND <	5.71	ND <	6.32		50679	16895	0%	29258
Potassium	ND <	24.1	ND <	25.9		40681	13569	0%	23480
Silicon *		105557	ND <	332		250291	118671	0%	125577
Sodium	ND <	803	ND <	839		105150	35324	1%	60471
Titanium		15.6		15.8		132	55		67
Antimony	ND <	7.77	ND <	8.18	ND <	7.59	ND <	7.8	0.30
Arsenic		8.09		9.16		10.0		9.1	0.97
Barium		0.487	ND <	1.30		66.1		22	1% 38
Beryllium	ND <	1.10	ND <	1.17		2.07	ND <	1.2	0.87
Boron		NA		NA		NA		NA	NA
Cadmium	ND <	1.10	ND <	1.17	ND <	1.09	ND <	1.1	0.04
Chromium		1.20		1.65		0.993		1.3	0.34
Cobalt	ND <	2.20	ND <	2.34	ND <	2.65	ND <	2.4	0.23
Copper		7.98		1.12		1.02		3.4	4.0
Lead		3.79		4.48		4.72		4.3	0.48
Manganese		0.515		0.407		0.406		0.44	0.06
Mercury		30.2		34.8		31.6		32	2.4
Molybdenum		28.0		18.0		22.4		23	5.0
Nickel	ND <	2.20		0.204	ND <	2.19	ND <	2.2	0.52
Selenium		98.2		27.2		75.0		67	36
Vanadium		0.906	ND <	1.40		1.11	ND <	1.4	0.21

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

* Silicon not determined in filter portion of samples.

TABLE 7.1-8. ANIONS IN DILUTE GAS SAMPLES FROM ESP OUTLET (LOCATION 5b) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5B-MUM-727	N-5B-MUM-729	N-5B-MUM-731	AVERAGE	DL RATIO	SD
Hydrogen Chloride	215201	188963	183543	195902		16931
Hydrogen Fluoride	13771	14281	13989	14014		256
Chloride	28	39	28.7	32		6.0
Fluoride	2.65	2.96	2.50	2.7		0.24
Phosphate	163	136	82.7	127		41
Sulfate	13348	11919	12048	12439		790

DL Ratio = Detection limit ratio.

SD = Standard deviation.

TABLE 7.1-9. AMMONIA/CYANIDE IN DILUTE GAS SAMPLES FROM ESP OUTLET (LOCATION 5b) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5B-NH4-727		N-5B-NH4-729		N-5B-NH4-731		AVERAGE	DL RATIO	SD
	N-5B-CN-727		N-5B-CN-729		N-5B-CN-731				
Ammonia	ND <	28.8	ND <	27.0		192	73	13%	103
Cyanide		92.2		37.5		440	190		218

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 7.1-10A. CASCADE IMPACTOR DATA TABLE: LOCATION 5a

Stage No.	Run - 1		Run - 2		Run - 3	
	Cut point D50 μm	% Mass retained	Cut point D50 μm	% Mass retained	Cut point D50 μm	% Mass retained
RAPC	7.82	13.73	7.74	6.63	7.65	5.22
3	3.92	29.41	3.87	33.13	3.83	38.06
4	2.05	15.69	2.02	12.05	1.99	10.45
5	1.16	11.76	1.15	11.45	1.12	10.45
6	0.56	11.76	0.55	10.84	0.54	6.72
7	0.20	10.78	0.20	8.43	0.20	7.46
filter		6.86		17.47		21.64
		100		100		100

TABLE 7.1-10B. CASCADE IMPACTOR DATA TABLE: LOCATION 5b

Stage No.	Run - 1		Run - 2		Run - 3	
	Cut point D50 μm	% Mass retained	Cut point D50 μm	% Mass retained	Cut point D50 μm	% Mass retained
INLET	8.19	0.90	8.27	0.32	8.12	0.79
3	3.67	5.88	3.70	3.15	3.64	4.74
4	1.86	1.81	1.88	1.58	1.84	1.58
5	1.04	1.36	1.05	2.84	1.03	2.37
6	0.51	5.88	0.52	4.42	0.50	5.93
7	0.20	7.24	0.20	7.26	0.20	7.51
filter		76.92		80.44		77.08
		100		100		100

7.2 Vapor/Particulate Comparisons

7.2.1 Introduction

This section discusses the distribution of selected chemicals between the vapor and particulate phases in flue gas samples collected at various sampling locations at the Niles - Boiler No. 2 flowstream. As detailed earlier in this report, samples were collected from flue gas streams at the: (1) ESP Inlet - Location 4, (2) ESP Outlet; Hot Flue - Location 5a, and (3) ESP Outlet; Dilute Flue - Location 5b. The standard sampling methods used at these locations separated the vapor- and particulate-phases of the pollutants present in the flue gas streams so as to allow separate analyses of the concentrations in the two phases.

Vapor- and particulate-phase samples collected from the various sampling locations were analyzed individually for the target air toxics within three specific groups of species, namely, elements, PAH/SVOC, and dioxins/furans. The results of these analyses are presented subsequently in this section. For each group of species, the vapor- and particulate-phase concentrations of individual air toxics in the sampled flue gas are presented. Concentration data are provided separately for each of the four sampling locations. For each group of species, the vapor and particulate-phase concentrations measured in blank gas samples and/or method blanks are also presented.

The phase distribution results obtained are discussed briefly within each group of species. Differences in phase distribution of individual air toxics among the various sampling locations are examined. The potential for sampling artifacts to arise during the separation of the vapor and particulate phases is noted where applicable.

Samples with different detection limits for vapor- and particulate-phase air toxics concentrations are also identified in the discussions presented in this section. Specifically, samples collected at Location 5b (ESP outlet; diluted and cooled) using the PSDS suffered from the serious problem of widely differing sample collection volumes for the two phases. The particulate-phase samples collected at this location had typical flue gas sample volumes of ~6 Ncm, whereas vapor-phase flue gas sample volumes were ~0.2 Ncm. The disproportionately different flue gas sample volumes between the particulate and vapor phase samples resulted in widely different detection limits. Thus, particulate phase species were

detected at Location 5b at much smaller levels and with less uncertainty than the vapor-phase species. Comparisons of vapor and particulate-phase compositions at this location are therefore skewed by the large differences in the corresponding detection limits. In this section, these comparisons are omitted for species present in the vapor phase at levels close to the vapor-phase detection limit. Comparisons are only provided for cases where the vapor-phase levels were sufficiently high to be detected with a reasonable degree of confidence.

Each subsection also presents a table of the average distribution of individual species concentrations between the vapor and particulate phases in the flue gas at the various sampling locations. This table provides a summary of the differences in composition of the vapor and particulate phases for each group of species. Note that the average phase distributions for the various species at each sampling location have been calculated using zero values for the non-detected particulate or vapor phase concentrations in individual samples. Outliers are also flagged where appropriate in the data tables.

7.2.2 Elements

Table 7.2-1 shows a summary of the average percentage phase distribution of the various elements at each sampling location. The data in Table 7.2-1 were derived by averaging the phase distributions measured in the sets of three samples collected at each location. The vapor- and particulate-phase concentrations (in $\mu\text{g}/\text{Ncm}$) of elements determined from flue gas samples are presented in Tables 7.2-2 through 7.2-4. Table 7.2-5 shows the corresponding vapor- and particulate-phase concentrations of the individual elements in train blank samples.

Tables 7.2-1 and 7.2-2 show that at Location 4, the ESP Inlet, all the elements, except for mercury, were present almost entirely in the particulate phase, with little variability among the three samples (evidenced by the low standard deviations in Table 7.2-1). The only two elements with > 10 percent of the total concentration present in the vapor phase are antimony and selenium. Table 7.2-1 and Table 7.2-2 reveal that at Location 4, mercury is predominantly (> 94 percent) present in the vapor phase, results which are consistent with the vapor pressure characteristics of mercury.

The phase distributions of the elements at the sampling location downstream of Location 4 are similar to each other in a number of respects. These absolute vapor and particulate phase concentrations at Location 5a and 5b, hot flue and cooled, diluted flue, respectively, at the outlet of the ESP are presented in Tables 7.2-3 and 7.2-4.

At Location 5a and 5b, the particulate phase flue gas concentrations of the various elements were significantly lower in magnitude than the corresponding concentrations at Location 4. This result is consistent with the operation of the ESP. However, the vapor phase concentrations of many elements were similar both at the inlet and outlet of the ESP. Consequently, the average percentage phase distributions in Table 7.2-1 for the outlet of the ESP show greater fractions of elements in the vapor phase than upstream of the ESP at Location 4. Two elements, antimony and cobalt, were not detected in either phase at both Locations 5a and 5b.

Most of the elements continue to remain largely in the particulate phase at both Locations 5a and 5b. These elements include arsenic, barium, beryllium, cadmium, chromium, copper, lead, molybdenum, nickel, selenium, titanium, and vanadium. These results are consistent with the vapor pressure characteristics of these elements.

For a few elements, the particulate phase concentrations at either Location 5a or 5b were below the detection limit in one or more of the three samples at each location, thus yielding a predominantly vapor phase percentage distribution. Elements with such a result include aluminum, barium, manganese, potassium, and sodium. Again, these phase distribution results are a consequence of the removal of particulate matter by the ESP to elemental concentration levels below the particulate phase detection limits.

At Location 5b compared with Location 5a, there is typically greater variability in the average percentage phase distribution results for a number of elements, as evidenced by the standard deviations in Table 7.2-1. Elements with a significant variability in the average phase distributions at Location 5b include arsenic, copper, molybdenum, selenium, and titanium. These results are a consequence of the higher particle and vapor phase elemental detection limits for samples collected at Location 5b compared with the corresponding detection limits for samples collected at Location 5a. Tables 7.2-2 through 7.2-4 show that a greater number of elements were not detected at Location 5b, either in the particulate or

vapor phase or in both phases, compared with elements in corresponding samples at Location 5a.

In summary, the elements, arsenic, beryllium, chromium, lead, molybdenum, nickel, selenium, titanium and vanadium were all present at >70 percent levels in the particulate phase at all three sampling locations.

Mercury remains predominantly in the vapor phase even downstream of the ESP, at Locations 5a and 5b. Note that there is very little variability in this predominantly vapor-phase distribution at both locations, as indicated by the standard deviations shown for the average mercury phase distribution in Table 7.2-1. Overall, these results are consistent with the vapor pressure characteristics of mercury.

7.2.3 PAH/SVOC

Table 7.2-6 shows a summary of the average percentage phase distribution of PAH/SVOC compounds at each sampling location. The data in Table 7.2-6 were derived by averaging the phase distributions measured in the sets of three samples collected at each location. The particulate and vapor phase PAH/SVOC concentrations (in ng/Ncm) measured in individual samples at each location are presented in Tables 7.2-7 through 7.2-9. Results from blank samples are shown in Table 7.2-10. Table 7.2-6 provides a convenient means of following trends in the phase distribution of individual PAH/SVOC compounds. The average phase distribution data in Table 7.2-6 and the individual concentrations shown in Table 7.2-7 show that at Location 4 (ESP Inlet), most of the PAH/SVOC species are only in the vapor phase. These include compounds such as acetophenone, biphenyl, acenaphthene, and dibenzofuran.

Among the PAH, the three-ring and four-ring compounds are predominantly in the vapor phase at Location 4. The 5-ring compounds benzo(b and k)fluoranthene were present in both the particulate and vapor phases. No average phase distribution results are shown for benzo(a)pyrene, benzo(e)pyrene, and the remainder of the ≥ 5 -ring PAH compounds in Table 7.2-6. Some of these species were detected in one or more of the particulate phase samples from Location 4, but none were ever detected in the corresponding vapor phase samples. Average phase distribution results are not shown in Table 7.2-6 because the

particulate-phase concentrations of these PAH, when detected, were on the order of one-tenth of the vapor-phase detection limit. Qualitatively, it may be stated that benzo(e)pyrene, benzo(a)pyrene, and the remainder of the ≥ 5 -ring PAH compounds in Table 7.2-6 were only detected in the particulate phase. In general, the phase distributions observed are largely consistent with the vapor pressure characteristics of the various PAH/SVOC compounds and the ~ 300 F temperature of the flue gas at this location.

The PAH/SVOC phase distributions at Locations 5a and 5b, at the outlet of the ESP, are shown in Table 7.2-6 (average percent) and Tables 7.2-8 and 7.2-9 (concentrations). The average phase distributions at Location 5a, ESP Outlet - hot flue, shown in Table 7.2-6 are very variable for all detected species, as indicated by the standard deviation values in the table. Typically, the standard deviation in the average phase distribution for detected species at Location 5a was between 40-50 percent. This result may be a consequence of sample contamination artifacts or other currently unidentified problems with the sampling and/or analysis. However, the large variability in the phase distributions for the detected species makes it difficult to adequately interpret the results at this location. Table 7.2-8 does reveal, however, that benzo(a)pyrene, and the remainder of the ≥ 5 -ring PAH compounds were not detected in the vapor or particulate phase in any of the three samples at Location 5a.

At Location 5b, there is considerably less variability in the average phase distributions, compared with the corresponding results at Location 5a. As expected, a number of SVOC/PAH species such as acetophenone, naphthalene and dibenzofuran are predominantly or exclusively present in the vapor phase.

Among the PAH, the three-ring and four-ring compounds are predominantly in the vapor phase at Location 5b. As was the case for Location 4, no average phase distribution results are shown for benzo(a)pyrene, benzo(e)pyrene, and the remainder of the ≥ 5 -ring PAH compounds in Table 7.2-6. Some of these species were detected in one or more of the particulate phase samples from Location 5b, but none were ever detected in the corresponding vapor phase samples. Average phase distribution results are not shown in Table 7.2-6 because the particulate-phase concentrations of these PAH, when detected, were on the order of one-tenth of the vapor-phase detection limit. Qualitatively, it may be stated

that benzo(e)pyrene, benzo(a)pyrene, and the remainder of the ≥ 5 -ring PAH compounds in Table 7.2-6 were only detected in the particulate phase.

Finally, it must be noted that the reference sampling method (Method 23) utilized for this group of species may yield an artifactual bias toward higher vapor-phase concentrations. This sampling artifact arises from the possibility of desorption of PAH/SVOC adsorbed on the surface of fly-ash collected on the filter, during the course of sampling. The compounds desorbed from the particulate matter would then be collected in the XAD resin trap, and analyzed as vapor-phase constituents. This desorption artifact is also referred to as "blow-off" in the literature and is commonly observed in ambient air sampling. However, the use of a heated and temperature-equilibrated filter for source sampling in Method 23 reduces the likelihood of desorption-related sampling artifacts. The conclusions derived above regarding the phase distribution of PAH/SVOC are therefore likely to be largely accurate.

7.2.4 Dioxins/Furans

Table 7.2-11 shows a summary of the average percentage phase distribution of dioxins/furans at the two locations where sampling for these species was conducted, namely, Locations 5a and 5b. The data in Table 7.2-11 were derived by averaging the phase distributions measured in the sets of three samples collected at each location. The particulate and vapor phase dioxin/furan concentrations (in pg/Ncm) measured in individual samples at each location are presented in Tables 7.2-12 and 7.2-13. The corresponding concentrations in the blank train samples are shown in Table 7.2-14.

For this group of air toxics, samples were collected only at two locations: (1) ESP Outlet; hot flue - Location 5a, and (2) ESP Outlet; diluted, cooled flue - Location 5b. The concentrations and average phase distribution data presented for dioxins/furans in the tables include both individual congeners and total congener classes in the upper and lower portions of the various tables, respectively.

Table 7.2-11 provides a convenient means of following trends in the phase distribution of individual dioxins/furans. The results shown in Table 7.2-11, combined with the concentration data shown in Tables 7.2-12 and 7.2-13, reveal that the vapor and particulate-phase concentrations of most dioxin and furan compounds in the flue gas sampled

were below the detection limit. A greater number of dioxin/furan compounds were detected at Location 5a than at Location 5b. The latter result is to some extent a consequence of one vapor-phase sample (N-5A-MM5-726 in Table 7.2-12) with relatively high concentrations for all total congener classes as well as many of the individual congeners.

At Location 5a, Table 7.2-11 shows that most of the detected dioxins/furans were predominantly present in the vapor phase. A few of the higher chlorinated species, namely, heptachlorodibenzo-p-dioxin, heptachlorodibenzofuran, octachlorodibenzo-p-dioxin, and octachlorodibenzofuran, had small to appreciable fractions in the particulate phase. This result is consistent with typical distributions of the higher chlorinated species between both the particulate and vapor phases. The detection limits for vapor and particulate phases were similar, to within a factor of five, for most dioxins/furans in the three samples collected at Location 5a. Therefore, it may be reasonably concluded that at this location, most dioxins and furans were typically present at less than detectable levels in both phases, and when detected were present mostly in the vapor phase.

At Location 5b, where cooled and diluted flue gas was sampled, very few dioxin/furan species were detected in any of the three samples, as shown in Table 7.2-11. This result is consistent with the higher vapor phase detection limits for these samples because of the low sample collection volumes, as discussed in the introduction to this section. The few species detected consisted of the higher chlorinated species, which were found in both particulate and vapor-phases. A single congener of heptachlorodibenzofuran, as well as octachlorodibenzo-p-dioxin and octachlorodibenzofuran were detected in one or more of the three samples.

Although phase distribution results for the detected species are presented in Table 7.2-11 for Location 5b, these results must be interpreted with caution because the samples at Location 5b typically had a ten- to fifty-fold higher detection limit for vapor-phase concentrations compared with the detection limit for particulate concentrations. The detection limits for particulate concentrations in the samples collected at Location 5b were, however, very similar to the particulate concentration detection limits for samples collected at Location 5a. In the case of the two species that were detected at Location 5b in primarily the vapor-phase, namely, heptachlorodibenzofuran and octachlorodibenzo-p-dioxin, it can be concluded that these species were present mainly in the vapor-phase even after the flue gas

from the ESP is cooled. However, in the case of the third species detected at Location 5b, octachlorodibenzofuran, a firm conclusion regarding the phase distribution is not possible.

The potential for sampling artifacts from the desorption of vapor from particulate matter was discussed previously for PAH/SVOC. Such sampling artifacts may also arise for dioxins and furans. However, as stated previously, the use a heated and temperature-equilibrated filter for source sampling in Method 23 reduces the likelihood of desorption-related sampling artifacts. The conclusions derived above regarding the phase distribution of dioxins and furans are therefore likely to be largely accurate.

TABLE 7.2-1. SUMMARY OF AVERAGE PHASE DISTRIBUTIONS OF ELEMENTS AT EACH SAMPLING LOCATION

SPECIES	Percentage Phase Distribution; P: Particulate; V: Vapor											
	Location 4				Location 5a				Location 5b			
	ESP Inlet	±SD			ESP Outlet	±SD			ESP Outlet - Dilute	±SD		
P	V			P	V			P	V			
<i>Elements</i>												
Aluminum	99.9	0.1	0.3		48.9	51.1	44.2		0	100		
Antimony	78.2	21.8	37.8		ND	ND	ND		ND	ND		ND
Arsenic	99.1	0.9	0.6		96.7	3.3	2		100	0		0
Barium	100	0	0.1		81.6	18.4	25.9		50.5	49.5		70.1
Beryllium	100	0	0		81.7	18.3	16.8		0	100		-
Cadmium	100	0	0		100	0	ND		ND	ND		ND
Chromium	99.9	0.1	0.1		84.8	15.2	4.9		100	0		0
Cobalt	100	0	0		ND	ND	ND		ND	ND		ND
Copper	99.8	0.2	0.1		87	13	11.6		70.1	29.9		51.8
Lead	100	0	0.1		100	0	0		100	0		0
Manganese	96.8	3.2	2.1		38.3	61.7	5		100	0		0
Molybdenum	100	0	0		99.1	0.9	1.5		51.3	48.7		24.3
Nickel	100	0	0		96.9	3.1	5.4		100	0		-
Potassium	98.4	1.6	1.6		21.1	78.9	6.6		0	100		-
Selenium	85.3	14.7	7.8		83.1	16.9	11.9		66.1	33.9		34.5
Silicon	-	-	-		-	-	-		-	-		-
Sodium	96.7	3.3	4.2		10.6	89.4	15.1		0	100		-
Titanium	100	0	0		87.7	12.3	17.6		71.3	28.7		49.7
Vanadium	100	0	0		100	0	0		100	0		0
Mercury	5.6	94.4	1		0.1	99.9	0.1		0	100		0

P,V,SD: Averages and standard deviation derived from the three samples at each location

ND: Not detected in all three samples at this location or otherwise not interpretable

-: SD not available; detected in only one of three samples at this location. Data for silicon not available

TABLE 7.2-2. VAPOR/PARTICULATE DISTRIBUTION FOR ELEMENTS FROM ESP INLET (LOCATION 4) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-4-MUM-727			N-4-MUM-729			N-4-MUM-731		
	VAPOR	SOLID	TOTAL	VAPOR	SOLID	TOTAL	VAPOR	SOLID	TOTAL
Aluminum	0.000	161715	161715	711	162576	163287	0.000	129293	129293
Potassium	1626	44317	45943	549	46881	47430	0.000	33760	33760
Silicon	2878	181232	184110	3668	146741	150409	2597	184685	187281
Sodium	211	10869	11081	1696	19322	21019	0.000	3827	3827
Titanium	0.000	14034	14034	3.55	11547	11550	0.000	10254	10254
Antimony	0.000	86.8	86.8	0.000	125	125	158	83.5	242
Arsenic	35.8	2737	2772	3.88	2261	2264	20.3	1766	1786
Barium	0.000	1179	1179	1.62	1242	1244	0.000	966	966
Beryllium	0.000	64.5	64.5	0.000	66.2	66.2	0.000	46.9	46.9
Boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	0.000	2.21	2.21	0.000	3.93	3.93	0.000	1.84	1.84
Chromium	0.325	552	552	0.969	598	599	0.315	426	426
Cobalt	0.000	152	152	0.000	163	163	0.000	135	135
Copper	1.30	836	837	1.45	970	972	2.05	681	683
Lead	0.000	905	905	0.000	1009	1009	0.000	639	639
Manganese	10.4	463	473	9.53	498	507	23.1	387	410
Mercury	30.0	1.75	31.7	26.4	1.85	28.2	23.6	1.16	24.8
Molybdenum	0.000	178	178	0.000	164	164	0.000	112	112
Nickel	0.325	593	594	0.000	757	757	0.000	503	503
Selenium	8.46	93.9	102	11.3	79.4	90.7	18.7	61.2	79.9
Vanadium	0.000	829	829	0.000	918	918	0.000	678	678

NA = Sample not available, sample not analyzed, or data not available.

Silicon missing from filter and cyclone analyses.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

Sample results corrected for N-5a-MUM-726 train blank.

TABLE 7.2-3. VAPOR/PARTICULATE DISTRIBUTION FOR ELEMENTS FROM ESP OUTLET (LOCATION 5a) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-MUM-727		N-5a-MUM-729		N-5a-MUM-731				
	VAPOR	SOLID	TOTAL	VAPOR	SOLID	TOTAL	VAPOR	SOLID	TOTAL
Aluminum	4035	1203	5238	0.000	14.4	14.4 #	69.0	21.6	90.6 #
Potassium	2416	841	3257	0.000	0.000	0.000 #	103	20.4	124 #
Silicon	2667	6862	9529	4854	508	5363	3875	2226	6101
Sodium	5984	1619	7603 #	0.000	0.000	0.000	839	0.000	839
Titanium	16.6	34.5	51.2	0.000	28.6	28.6	1.61	34.6	36.2
Antimony	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arsenic	3.76	75.7	79.4	0.572	59.1	59.6	2.87	67.4	70.3
Barium	7.41	8.02	15.4	0.000	4.61	4.61	0.460	5.99	6.45
Beryllium	0.080	0.162	0.242	0.000	0.183	0.183	0.057	0.204	0.262
Boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.143
Chromium	1.03	3.90	4.92	0.687	5.21	5.89	0.575	3.79	4.37
Cobalt	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Copper	2.05	5.72	7.78	0.229	5.14	5.37	0.575	6.26	6.83
Lead	0.000	2.40	2.40	0.000	1.66	1.66	0.000	3.24	3.24
Manganese	5.01	2.64	7.66	2.29	1.80	4.09	3.22	1.85	5.07
Mercury	27.2	0.064	27.3	20.5	0.000	20.5	23.3	0.000	23.3
Molybdenum	0.000	3.30	3.30	0.114	4.15	4.27	0.000	2.58	2.58
Nickel	0.114	1.10	1.21	0.000	0.87	0.87	0.000	0.307	0.307
Selenium	14.0	122	136	17.2	38.9	56.1	11.0	102	113
Vanadium	0.000	3.72	3.72	0.000	3.99	3.99	0.000	4.85	4.85

NA = Sample not available, sample not analyzed, or data not available.
 Silicon missing from filter and cyclone analyses.
 Possible contamination of aluminum, potassium, and sodium in filter analyses.
 Sample results corrected for N-5a-MUM-726 train blank.
 # = This sample considered an outlier for this element; see Section 5.1.1.

TABLE 7.2-4. VAPOR/PARTICULATE DISTRIBUTION FOR ELEMENTS FROM ESP OUTLET - DILUTE (LOCATION 5b) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5b-MUM-727		N-5b-MUM-729		N-5b-MUM-731		TOTAL
	VAPOR	SOLID	VAPOR	SOLID	VAPOR	SOLID	
Aluminum	0.000	0.000	0.000	0.000	50679	0.000	50679
Potassium	0.000	0.000	0.000	0.000	40681	0.000	40681
Silicon	10557	NA	0.000	NA	250291	NA	250291
Sodium	0.000	0.000	0.000	0.000	105150	0.000	105150
Titanium	0.000	15.6	0.000	15.8	114	18.5	132
Antimony	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	8.09	0.000	9.16	0.000	10.0	10.0
Barium	0.000	0.487	0.000	0.000	65.5	0.599	66.1
Beryllium	0.000	0.000	0.000	0.000	2.07	0.000	2.07
Boron	NA	NA	NA	NA	NA	NA	NA
Cadmium	0.000	0.00	0.000	0.000	0.000	0.000	0.000
Chromium	0.000	1.20	0.000	1.65	0.000	0.993	0.993
Cobalt	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Copper	7.16	0.824	0.000	1.12	0.000	1.02	1.02
Lead	0.000	3.79	0.000	4.48	0.000	4.72	4.72
Manganese	0.000	0.515	0.000	0.407	0.000	0.406	0.406
Mercury	30.2	0.000	34.8	0.000	31.6	0.000	31.6
Molybdenum	17.9	10.1	3.74	14.3	13.8	8.66	22.4
Nickel	0.000	0.000	0.000	0.204	0.000	0.000	0.000
Selenium	32.2	66.0	0.000	27.2	51.7	23.3	75.0
Vanadium	0.000	0.906	0.000	0.000	0.000	1.11	1.11

NA = Sample not available, sample not analyzed, or data not available.
 Silicon missing from filter and cyclone analyses.
 Possible contamination of aluminum, potassium, and sodium in filter analyses.
 Sample results corrected for N-5a-MUM-726 train blank.

TABLE 7.2-5. VAPOR/PARTICULATE DISTRIBUTION FOR ELEMENTS IN BLANK GAS SAMPLES (LOCATION 5a) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-MUM-726		
	VAPOR	SOLID	TOTAL
Aluminum	3661	4201	7862
Potassium	2379	2373	4752
Silicon	401	11273	11674
Sodium	5666	5933	11599
Titanium	10.6	13.3	23.9
Antimony	0.000	0.000	0.000
Arsenic	0.000	1.95	1.95
Barium	5.88	6.65	12.5
Beryllium	0.000	0.000	0.000
Boron	NA	NA	NA
Cadmium	0.000	0.000	0.000
Chromium	0.000	0.000	0.000
Cobalt	0.000	0.000	0.000
Copper	0.267	0.119	0.386
Lead	0.000	2.14	2.14
Manganese	1.20	1.35	2.55
Mercury	0.000	0.000	0.000
Molybdenum	0.000	1.90	1.90
Nickel	0.000	2.85	2.85
Selenium	0.000	0.000	0.000
Vanadium	0.000	0.000	0.000

NA = Sample not available, sample not analyzed, or data not available.

Silicon missing from filter and cyclone analyses.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

TABLE 7.2-6. SUMMARY OF AVERAGE PHASE DISTRIBUTIONS OF PAH/SVOC AT EACH SAMPLING LOCATION

SPECIES	Percentage Phase Distribution; P: Particulate; V: Vapor								
	Location 4.			Location 5a			Location 5b		
	ESP Inlet			ESP Outlet			ESP Outlet - Dilute		
	P	V	±SD	P	V	±SD	P	V	±SD
<i>PAH/SVOC</i>									
Benzylchloride	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acetophenone	0	100	0	33.9	66.1	57.2	0	100	0
Hexachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	67.6	32.4	56.2	34.9	65.1	55.8	0	100	0
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloroacetophenone	5.1	94.9	5.9	33.7	66.3	56.7	0.3	99.7	0.4
1-Methylnaphthalene	19.7	80.3	1.3	42.6	57.4	51.5	0	100	0
2-Methylnaphthalene	30.2	69.8	7.8	41.1	58.9	52.3	0	100	0
Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Biphenyl	6.8	93.2	7.3	72.9	27.1	35.2	56.6	43.4	20
Acenaphthylene	6.2	93.8	5.9	66.7	33.3	57.7	ND	ND	ND
2,6-Dinitrotoluene	5.4	94.6	9.4	34	66	57.1	0.1	99.9	0.1
Acenaphthene	9.8	90.2	4.9	43.4	56.6	47.7	35.1	64.9	56.2
Dibenzofuran	6	94	5.4	44	56	46.5	35.4	64.6	55.9
2,4-Dinitrotoluene	4.5	95.5	2.3	ND	ND	ND	0	100	0
Fluorene	10.5	89.5	12.1	49.7	50.3	46.4	1.8	98.2	2.1
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	13.6	86.4	12.1	50.9	49.1	47.9	33.9	66.1	57.2
Anthracene	7	93	3.4	42.8	57.2	46.6	3.9	96.1	4.6
Fluoranthene	14.3	85.7	6.8	49.1	50.9	42.9	5.1	94.9	5
Pyrene	22.6	77.4	19.1	47.8	52.2	45.1	9.4	90.6	7.1
Benz(a)anthracene	3.6	96.4	5.8	68.8	31.2	54	37.5	62.5	54.2
Chrysene	12.3	87.7	7.5	40.6	59.4	51.8	34.1	65.9	57.1
Benzo(b & k)fluoranthene	50.6	49.4	44	53	47	48.3	ND	ND	ND
Benzo(e)pyrene	ND	ND	ND	70.4	29.6	51.2	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND

P,V,SD: Averages and standard deviation derived from the three samples at each location

ND: Not detected in at least two of the three samples at this location or otherwise not interpretable (see text)

TABLE 7.2-7. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC FROM ESP INLET (LOCATION 4) (ng/Nm³)

Analyte	N-4-MM5- X-726		N-4-MM5- F-726		N-4-MM5- F+X-726		N-4-MM5- X-728		N-4-MM5- F-728		N-4-MM5- F+X-728		N-4-MM5- X-730		N-4-MM5- F-730		N-4-MM5- F+X-730		
	ND < 8.70	671	ND < 0.870	ND < 0.870	ND < 8.70	671	ND < 12.7	42.8	ND < 12.7	42.8	ND < 12.7	42.8	ND < 12.7	42.8	ND < 13.0	70.8	ND < 1.30	ND < 1.30	ND < 13.0
Benzylchloride	ND < 8.70	671	ND < 0.870	ND < 0.870	ND < 8.70	671	ND < 12.7	42.8	ND < 12.7	42.8	ND < 12.7	42.8	ND < 12.7	42.8	ND < 13.0	70.8	ND < 1.30	ND < 1.30	ND < 13.0
Acetophenone	ND < 8.70	671	ND < 0.870	ND < 0.870	ND < 8.70	671	ND < 12.7	42.8	ND < 12.7	42.8	ND < 12.7	42.8	ND < 12.7	42.8	ND < 13.0	70.8	ND < 1.30	ND < 1.30	ND < 13.0
Hexachloroethane	ND < 8.70	671	ND < 0.870	ND < 0.870	ND < 8.70	671	ND < 12.7	42.8	ND < 12.7	42.8	ND < 12.7	42.8	ND < 12.7	42.8	ND < 13.0	70.8	ND < 1.30	ND < 1.30	ND < 13.0
Naphthalene	218	218	6.12	6.12	224	224	ND < 2.54	2.54	ND < 2.54	2.54	9.18	9.18	ND < 2.61	2.61	2.61	13.7	13.7	13.7	13.7
Hexachlorobutadiene	ND < 8.70	90.7	ND < 0.870	ND < 0.870	ND < 8.70	103	ND < 12.7	129	ND < 12.7	129	ND < 12.7	129	ND < 13.0	13.0	424	16.6	16.6	ND < 13.0	ND < 13.0
2-Chloroacetophenone	90.7	90.7	11.9	11.9	103	103	ND < 12.7	129	ND < 12.7	129	ND < 12.7	129	ND < 13.0	13.0	424	16.6	16.6	ND < 13.0	ND < 13.0
2-Methylnaphthalene	45.3	45.3	12.0	12.0	57.4	57.4	26.1	26.1	6.38	6.38	32.5	32.5	40.3	40.3	40.3	9.07	9.07	49.3	49.3
1-Methylnaphthalene	21.9	21.9	8.03	8.03	29.9	29.9	10.6	10.6	3.47	3.47	14.1	14.1	8.43	8.43	8.43	5.42	5.42	13.9	13.9
Hexachlorocyclopentadiene	ND < 8.70	240	ND < 0.870	ND < 0.870	ND < 8.70	249	ND < 12.7	298	ND < 12.7	298	ND < 12.7	298	ND < 13.0	13.0	74.4	13.4	13.4	ND < 13.0	ND < 13.0
Biphenyl	240	240	8.35	8.35	249	249	298	298	5.90	5.90	304	304	74.4	74.4	74.4	13.4	13.4	87.8	87.8
Acenaphthylene	4.31	4.31	0.640	0.640	4.95	4.95	18.0	18.0	0.708	0.708	18.7	18.7	46.0	46.0	46.0	0.931	0.931	46.9	46.9
2,6-Dinitrotoluene	93.0	93.0	18.0	18.0	111	111	115	115	1.27	1.27	115	115	45.2	45.2	45.2	1.30	1.30	45.2	45.2
Acenaphthene	18.7	18.7	3.31	3.31	22.1	22.1	39.4	39.4	4.02	4.02	43.4	43.4	78.6	78.6	78.6	4.38	4.38	83.0	83.0
Dibenzofuran	403	403	13.1	13.1	416	416	738	738	19.5	19.5	757	757	118	118	118	16.4	16.4	135	135
2,4-Dinitrotoluene	44.2	44.2	2.42	2.42	46.6	46.6	75.6	75.6	1.52	1.52	77.1	77.1	40.7	40.7	40.7	2.74	2.74	43.5	43.5
Fluorene	142	142	5.88	5.88	148	148	244	244	8.07	8.07	252	252	21.0	21.0	21.0	6.81	6.81	27.9	27.9
Hexachlorobenzene	ND < 8.70	8.70	ND < 0.870	ND < 0.870	ND < 8.70	8.70	ND < 12.7	12.7	ND < 1.27	1.27	ND < 12.7	12.7	ND < 13.0	13.0	13.0	1.30	1.30	ND < 13.0	ND < 13.0
Pentachlorophenol	ND < 8.70	8.70	ND < 0.870	ND < 0.870	ND < 8.70	8.70	ND < 12.7	12.7	ND < 1.27	1.27	ND < 12.7	12.7	ND < 13.0	13.0	13.0	1.30	1.30	ND < 13.0	ND < 13.0
Phenanthrene	351	351	23.5	23.5	374	374	561	561	41.3	41.3	602	602	87.4	87.4	87.4	33.2	33.2	121	121
Anthracene	32.2	32.2	2.17	2.17	34.4	34.4	34.9	34.9	1.43	1.43	36.3	36.3	26.5	26.5	26.5	3.17	3.17	29.6	29.6
Fluoranthene	83.2	83.2	7.99	7.99	91.2	91.2	92.8	92.8	12.8	12.8	106	106	38.4	38.4	38.4	10.8	10.8	49.1	49.1
Pyrene	21.1	21.1	2.63	2.63	23.7	23.7	27.7	27.7	3.81	3.81	31.5	31.5	6.15	6.15	6.15	4.95	4.95	11.1	11.1
Benz(a)anthracene	5.82	5.82	0.670	0.670	6.49	6.49	36.9	36.9	ND < 0.254	0.254	36.9	36.9	95.1	95.1	95.1	0.441	0.441	95.5	95.5
Chrysene	27.7	27.7	3.51	3.51	31.2	31.2	48.5	48.5	12.4	12.4	60.8	60.8	80.0	80.0	80.0	4.63	4.63	84.6	84.6
Benzo(b & k)fluoranthene	4.76	4.76	0.890	0.890	5.65	5.65	5.68	5.68	3.20	3.20	8.88	8.88	2.61	2.61	2.61	2.33	2.33	2.33	2.33
Benzo(e)pyrene	ND < 1.74	1.74	ND < 0.251	0.251	0.251	0.251	ND < 2.54	2.54	0.628	0.628	0.628	0.628	2.61	2.61	2.61	0.523	0.523	0.523	0.523
Benzo(a)pyrene	ND < 1.74	1.74	ND < 0.174	0.174	ND < 1.74	1.74	ND < 2.54	2.54	ND < 0.254	0.254	ND < 2.54	2.54	2.61	2.61	2.61	1.13	1.13	1.13	1.13
Indeno(1,2,3-c,d)pyrene	ND < 1.74	1.74	ND < 0.220	0.220	0.220	0.220	ND < 2.54	2.54	0.305	0.305	0.305	0.305	2.61	2.61	2.61	0.396	0.396	0.396	0.396
Dibenz(a,h)anthracene	ND < 1.74	1.74	ND < 0.379	0.379	0.379	0.379	ND < 2.54	2.54	0.311	0.311	0.311	0.311	2.61	2.61	2.61	0.301	0.301	0.301	0.301
Benzo(g,h,i)perylene	ND < 1.74	1.74	ND < 0.312	0.312	0.312	0.312	ND < 2.54	2.54	ND < 0.254	0.254	ND < 2.54	2.54	2.61	2.61	2.61	0.315	0.315	0.315	0.315

ND < = Not detected, value following ND < is detection limit.
Sample results corrected for train blank.

TABLE 7.2-8. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC FROM ESP OUTLET (LOCATION 5a) (ng/Nm³)

Analyte	N-5a-MMS-		N-5a-MMS-		N-5a-MMS-		N-5a-MMS-		N-5a-MMS-		N-5a-MMS-		N-5a-MMS-		
	X-726	F-726	F+X-726	X-728	F-728	F+X-728	X-730	F-730	F+X-730	X-726	F-726	F+X-726	X-728	F-728	
Benzylchloride	ND <	29.4	4.92	ND <	28.8	ND <	2.88	ND <	2.60	ND <	2.60	ND <	2.60	ND <	2.60
Acetophenone	1517	ND <	2.94	1517	1201	ND <	22.0	1223	492 E	ND <	2.60	ND <	2.60	492 E	492 E
Hexachloroethane	ND <	29.4	2.94	ND <	28.8	ND <	2.88	ND <	2.60	ND <	2.60	ND <	2.60	ND <	2.60
Naphthalene	523	ND <	2.40	526	376	ND <	19.8	395	172 E	ND <	1.91	ND <	1.91	174 E	174 E
Hexachlorobutadiene	ND <	29.4	2.94	ND <	28.8	ND <	2.88	ND <	2.60	ND <	2.60	ND <	2.60	ND <	2.60
2-Chloroacetophenone	791	ND <	2.94	791	576	ND <	11.7	588	89.4	ND <	3.35	ND <	3.35	92.7	92.7
2-Methylnaphthalene	135	0.627	0.627	136	27.1	10.2	10.2	37.3	18.2	ND <	0.520	ND <	0.520	18.2	18.2
1-Methylnaphthalene	55.9	ND <	0.588	55.9	13.4	4.03	4.03	17.4	6.52	ND <	0.520	ND <	0.520	6.52	6.52
Hexachlorocyclopentadiene	ND <	29.4	2.94	ND <	28.8	ND <	2.88	ND <	2.60	ND <	2.60	ND <	2.60	ND <	2.60
Biphenyl	68.8	32.7	32.7	102	24.8	469	469	494	13.0	ND <	31.6	ND <	31.6	44.7	44.7
Acenaphthylene	30.0	ND <	0.588	30.0	5.75	2.42	2.42	2.42	1.32	ND <	0.520	ND <	0.520	1.32	1.32
2,6-Dinitrotoluene	1134	ND <	2.94	1134	833	18.0	18.0	851	807 E	ND <	2.60	ND <	2.60	807 E	807 E
Acenaphthene	110	0.810	0.810	111	15.0	7.91	7.91	22.9	1.45	ND <	0.842	ND <	0.842	2.29	2.29
Dibenzofuran	208	3.99	3.99	212	48.0	27.3	27.3	75.2	42.7	ND <	3.31	ND <	3.31	46.0	46.0
2,4-Dinitrotoluene	44.9	6.04	6.04	51.0	28.8	2.88	2.88	28.8	32.3	ND <	2.60	ND <	2.60	32.3	32.3
Fluorene	124	1.16	1.16	125	9.57	11.7	11.7	21.2	12.8	ND <	1.04	ND <	1.04	13.8	13.8
Hexachlorobenzene	ND <	29.4	2.94	ND <	28.8	ND <	2.88	ND <	2.60	ND <	2.60	ND <	2.60	ND <	2.60
Pentachlorophenol	ND <	29.4	2.94	ND <	28.8	ND <	2.88	ND <	2.60	ND <	2.60	ND <	2.60	ND <	2.60
Phenanthrene	264	2.87	2.87	267	41.8	51.3	51.3	93.1	34.1	ND <	2.32	ND <	2.32	36.4	36.4
Anthracene	89.9	1.15	1.15	91.0	7.92	4.07	4.07	12.0	2.67	ND <	0.606	ND <	0.606	3.28	3.28
Fluoranthene	74.8	4.45	4.45	79.2	21.0	21.1	21.1	42.1	13.8	ND <	2.69	ND <	2.69	16.5	16.5
Pyrene	41.1	1.67	1.67	42.8	13.0	10.8	10.8	23.7	3.74	ND <	1.03	ND <	1.03	4.77	4.77
Benz(a)anthracene	13.0	0.897	0.897	13.9	5.75	0.687	0.687	0.687	1.71	ND <	0.520	ND <	0.520	1.71	1.71
Chrysene	30.3	1.47	1.47	31.8	6.66	1.38	1.38	8.04	5.48	ND <	0.520	ND <	0.520	5.48	5.48
Benzo(b & k)fluoranthene	30.4	1.09	1.09	31.5	5.75	1.25	1.25	1.25	1.110	ND <	0.684	ND <	0.684	1.79	1.79
Benzo(e)pyrene	7.01	0.889	0.889	7.90	5.75	0.623	0.623	0.623	0.520	ND <	0.520	ND <	0.520	0.520	0.520
Benzo(a)pyrene	5.88	ND <	0.588	5.88	5.75	ND <	0.575	ND <	0.520	ND <	0.520	ND <	0.520	0.520	0.520
Indeno(1,2,3-c,d)pyrene	ND <	5.88	ND <	5.88	5.75	ND <	0.575	ND <	0.520	ND <	0.520	ND <	0.520	0.520	0.520
Dibenz(a,h)anthracene	ND <	5.88	ND <	5.88	5.75	ND <	0.575	ND <	0.520	ND <	0.520	ND <	0.520	0.520	0.520
Benzo(g,h,i)perylene	ND <	5.88	ND <	5.88	5.75	ND <	0.575	ND <	0.520	ND <	0.520	ND <	0.520	0.520	0.520

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

Sample results corrected for train blank.

TABLE 7.2-9. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC FROM ESP OUTLET- DILUTE (LOCATION 5b) (ng/Nm³)

Analyte	N-5b-MMS- X-726		N-5b-MMS- F-726		N-5b-MMS- F+X-726		N-5b-MMS- X-728		N-5b-MMS- F-728		N-5b-MMS- F+X-728		N-5b-MMS- X-730		N-5b-MMS- F-730		N-5b-MMS- F+X-730					
	ND <	120	ND <	2.33	ND <	120	ND <	62.8	ND <	2.21	ND <	62.8	ND <	56.1	ND <	2.08	ND <	56.1	ND <	2.08	ND <	56.1
Benzylchloride	ND <	120	ND <	2.33	ND <	120	ND <	62.8	ND <	2.21	ND <	62.8	ND <	56.1	ND <	2.08	ND <	56.1	ND <	2.08	ND <	56.1
Acetophenone	19143	19143	ND <	2.33	19143	19143	7813	7813	7813	2.21	7813	7813	8563	8563	8563	2.08	8563	8563	2.08	8563	2.08	8563
Hexachloroethane	ND <	120	ND <	2.33	ND <	120	ND <	62.8	ND <	2.21	ND <	62.8	ND <	56.1	ND <	2.08	ND <	56.1	ND <	2.08	ND <	56.1
Naphthalene	2106	2106	ND <	0.467	2106	2106	608	608	608	0.442	608	608	833	833	0.415	833	833	0.415	833	0.415	833	833
Hexachlorobutadiene	ND <	120	ND <	2.33	ND <	120	ND <	62.8	ND <	2.21	ND <	62.8	ND <	56.1	ND <	2.08	ND <	56.1	ND <	2.08	ND <	56.1
2-Chloroacetophenone	8229	8232	3.04	3.04	8232	8232	3532	3532	3532	2.21	3532	3532	721	721	5.42	721	721	5.42	721	5.42	721	726
2-Methylnaphthalene	972	972	ND <	0.467	972	972	243	243	243	0.442	243	243	32.6	32.6	0.415	32.6	32.6	0.415	32.6	0.415	32.6	32.6
1-Methylnaphthalene	663	663	ND <	0.467	663	663	219	219	219	0.442	219	219	75.7	75.7	0.415	75.7	75.7	0.415	75.7	0.415	75.7	75.7
Hexachlorocyclopentadiene	ND <	120	ND <	2.33	ND <	120	ND <	62.8	ND <	2.21	ND <	62.8	ND <	56.1	ND <	2.08	ND <	56.1	ND <	2.08	ND <	56.1
Biphenyl	147	233	86.1	86.1	233	233	71.1	71.1	162	90.7	162	162	20.6	20.6	68.3	20.6	20.6	68.3	68.3	68.3	88.9	88.9
Acenaphthylene	59.2	59.2	ND <	0.467	59.2	59.2	25.6	25.6	25.6	0.442	25.6	25.6	11.2	11.2	0.415	11.2	11.2	0.415	11.2	0.415	11.2	11.2
2,6-Dinitrotoluene	1792	1792	ND <	2.33	1792	1792	257	257	257	2.21	257	257	1420	1420	3.15	1420	1420	3.15	1420	3.15	1420	1423
Acenaphthene	108	109	1.75	1.75	109	109	16.6	16.6	17.2	0.618	17.2	17.2	11.2	11.2	0.964	11.2	11.2	0.964	11.2	0.964	11.2	0.964
Dibenzofuran	245	249	4.46	4.46	249	249	93.6	93.6	98.0	4.37	98.0	98.0	56.1	56.1	4.77	56.1	56.1	4.77	56.1	4.77	56.1	4.77
2,4-Dinitrotoluene	1517	1517	ND <	2.33	1517	1517	576	576	576	2.21	576	576	316	316	2.08	316	316	2.08	316	2.08	316	316
Fluorene	584	586	1.83	1.83	586	586	206	206	207	1.57	207	207	44.6	44.6	1.96	44.6	44.6	1.96	44.6	1.96	44.6	46.6
Hexachlorobenzene	ND <	120	ND <	2.33	ND <	120	ND <	62.8	ND <	2.21	ND <	62.8	ND <	56.1	ND <	2.08	ND <	56.1	ND <	2.08	ND <	56.1
Pentachlorophenol	ND <	120	ND <	2.33	ND <	120	ND <	62.8	ND <	2.21	ND <	62.8	ND <	56.1	ND <	2.08	ND <	56.1	ND <	2.08	ND <	56.1
Phenanthrene	1054	1060	5.20	5.20	1060	1060	465	465	472	6.12	472	472	11.2	11.2	6.44	11.2	11.2	6.44	6.44	6.44	6.44	6.44
Anthracene	216	218	1.26	1.26	218	218	101	101	103	1.99	103	103	23.6	23.6	2.35	23.6	23.6	2.35	23.6	2.35	23.6	26.0
Fluoranthene	388	392	4.01	4.01	392	392	88.3	88.3	91.6	3.27	91.6	91.6	33.5	33.5	3.96	33.5	33.5	3.96	33.5	3.96	33.5	37.4
Pyrene	83.9	86.3	2.41	2.41	86.3	86.3	39.8	39.8	43.4	3.65	43.4	43.4	13.2	13.2	2.67	13.2	13.2	2.67	13.2	2.67	13.2	15.8
Benz(a)anthracene	69.7	72.0	2.33	2.33	72.0	72.0	13.9	13.9	15.3	1.44	15.3	15.3	11.2	11.2	2.16	11.2	11.2	2.16	11.2	2.16	11.2	2.16
Chrysene	68.8	69.4	0.679	0.679	69.4	69.4	35.4	35.4	35.9	0.497	35.9	35.9	11.2	11.2	0.463	11.2	11.2	0.463	11.2	0.463	11.2	0.463
Benzo(b & k)fluoranthene	108	109	1.10	1.10	109	109	12.6	12.6	12.6	0.587	12.6	12.6	11.2	11.2	0.415	11.2	11.2	0.415	11.2	0.415	11.2	11.2
Benzo(e)pyrene	ND <	24.0	0.785	0.785	0.785	0.785	12.6	12.6	12.6	0.504	12.6	12.6	11.2	11.2	0.434	11.2	11.2	0.434	11.2	0.434	11.2	0.434
Benzo(a)pyrene	ND <	24.0	0.657	0.657	0.657	0.657	12.6	12.6	12.6	0.481	12.6	12.6	11.2	11.2	0.415	11.2	11.2	0.415	11.2	0.415	11.2	11.2
Indeno(1,2,3-c,d)pyrene	ND <	24.0	0.884	0.884	0.884	0.884	12.6	12.6	12.6	0.618	12.6	12.6	11.2	11.2	0.415	11.2	11.2	0.415	11.2	0.415	11.2	11.2
Dibenz(a,h)anthracene	ND <	24.0	1.13	1.13	1.13	1.13	12.6	12.6	12.6	0.786	12.6	12.6	11.2	11.2	0.420	11.2	11.2	0.420	11.2	0.420	11.2	0.420
Benzo(g,h,i)perylene	ND <	24.0	0.858	0.858	0.858	0.858	12.6	12.6	12.6	0.523	12.6	12.6	11.2	11.2	0.415	11.2	11.2	0.415	11.2	0.415	11.2	11.2

ND < = Not detected, value following ND < is detection limit.
Sample results corrected for train blank.

TABLE 7.2-10. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC IN BLANK GAS SAMPLES (ng/Nm³)

Analyte	N-5a-MM5- X-725		N-5a-MM5- F-725		TRAIN BLANK N-5a-MM5- F+X-725	
	ND <		ND <		ND <	
Benzylchloride	ND <	2.80	ND <	2.80	ND <	2.80
Acetophenone		111		25.3		136
Hexachloroethane	ND <	2.80	ND <	2.80	ND <	2.80
Naphthalene		123		3.29		126
Hexachlorobutadiene	ND <	2.80	ND <	2.80	ND <	2.80
2-Chloroacetophenone		51.4	ND <	2.80		52.8
2-Methylnaphthalene		6.38		2.75		9.12
1-Methylnaphthalene		2.91		1.28		4.20
Hexachlorocyclopentadiene	ND <	2.80	ND <	2.80	ND <	2.80
Biphenyl		1.51		0.844		2.36
Acenaphthylene		0.599	ND <	0.559		0.878
2,6-Dinitrotoluene		21.8		35.2		57.0
Acenaphthene		4.08		1.46		5.54
Dibenzofuran		4.51	ND <	2.80		5.91
2,4-Dinitrotoluene	ND <	2.80	ND <	2.80	ND <	2.80
Fluorene		4.00		2.11		6.11
Hexachlorobenzene	ND <	2.80	ND <	2.80	ND <	2.80
Pentachlorophenol	ND <	2.80	ND <	2.80	ND <	2.80
Phenanthrene		17.6		7.28		24.9
Anthracene		1.60	ND <	0.559		1.88
Fluoranthene		7.92		2.32		10.2
Pyrene		2.83		0.855		3.68
Benz(a)anthracene	ND <	0.559	ND <	0.559	ND <	0.559
Chrysene		1.02		0.563		1.59
Benzo(b & k)fluoranthene		0.934		0.631		1.57
Benzo(e)pyrene	ND <	0.559	ND <	0.559	ND <	0.559
Benzo(a)pyrene	ND <	0.559	ND <	0.559	ND <	0.559
Indeno(1,2,3-c,d)pyrene	ND <	0.559	ND <	0.559	ND <	0.559
Dibenz(a,h)anthracene	ND <	0.559	ND <	0.559	ND <	0.559
Benzo(g,h,i)perylene	ND <	0.559	ND <	0.559	ND <	0.559

ND < = Not detected, value following ND < is detection limit.
 Sample results corrected for field reagent blank.

TABLE 7.2-11. SUMMARY OF AVERAGE PHASE DISTRIBUTIONS OF DIOXINS/FURANS AT EACH SAMPLING LOCATION

SPECIES	Percentage Phase Distribution; P: Particulate; V: Vapor					
	Location 5a			Location 5b		
	ESP Out (Hot)			ESP Out (Diluted)		
	Particle	Vapor	±SD	Particle	Vapor	±SD
<i>Dioxins/Furans</i>						
2,3,7,8-Tetrachlorodibenzo-p-dioxin	-	-	-	-	-	-
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	-	-	-	-	-	-
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	-	-	-	-	-	-
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	0	100	-	-	-	-
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	0	100	-	-	-	-
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	17.1	82.9	29.6	-	-	-
Octachlorodibenzo-p-dioxin	34.1	65.9	12.6	2.3	97.7	0.8
2,3,7,8-Tetrachlorodibenzofuran	0	100	0	-	-	-
1,2,3,7,8-Pentachlorodibenzofuran	-	-	-	-	-	-
2,3,4,7,8-Pentachlorodibenzofuran	0	100	-	-	-	-
1,2,3,4,7,8-Hexachlorodibenzofuran	0	100	-	-	-	-
1,2,3,6,7,8-Hexachlorodibenzofuran	0	100	-	-	-	-
1,2,3,7,8,9-Hexachlorodibenzofuran	0	100	0	-	-	-
2,3,4,6,7,8-Hexachlorodibenzofuran	-	-	-	-	-	-
1,2,3,4,6,7,8-Heptachlorodibenzofuran	50	50	70.7	0	100	-
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0	100	-	-	-	-
Octachlorodibenzofuran	24.8	75.2	42.9	67.2	32.8	56.8
Total Tetrachlorodibenzo-p-dioxin	0	100	0	-	-	-
Total Pentachlorodibenzo-p-dioxin	0	100	-	-	-	-
Total Hexachlorodibenzo-p-dioxin	0	100	-	-	-	-
Total Heptachlorodibenzo-p-dioxin	11	89	19.1	-	-	-
Total Tetrachlorodibenzofuran	0	100	0	-	-	-
Total Pentachlorodibenzofuran	0	100	0	-	-	-
Total Hexachlorodibenzofuran	0	100	0	-	-	-
Total Heptachlorodibenzofuran	50	50	70.7	0	100	-

P,V,SD: Averages and standard deviation derived from the three samples at each location

- (Particle or Vapor): Not detected in all three samples at this location

- (±SD): Detected in only one or two of the three samples at this location

TABLE 7.2-13. VAPOR/PARTICULATE DISTRIBUTION FOR DIOXINS/FURANS FROM ESP OUTLET - DILUTE (LOCATION 5b) (pg/Nm³)

Analyte	N-5b-MMS-726*		N-5b-MMS-728*		N-5b-MMS-730		TOTAL				
	VAPOR	SOLID	VAPOR	SOLID	VAPOR	SOLID					
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND <	ND <	56.4	ND <	54.9	ND <	28.5	ND <	1.87	ND <	26.7
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND <	ND <	93.4	ND <	62.2	ND <	32.5	ND <	4.06	ND <	28.0
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND <	ND <	132	ND <	133	ND <	68.5	ND <	3.74	ND <	31.7
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ND <	ND <	115	ND <	138	ND <	71.0	ND <	3.31	ND <	30.6
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ND <	ND <	178	ND <	177	ND <	89.5	ND <	2.76	ND <	26.2
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	ND <	ND <	316	ND <	336	ND <	171	ND <	10.7	ND <	75.0
Octachlorodibenzo-p-dioxin	1008 J	2.87 J	1010 K	ND <	1457 C	ND <	750 C	ND <	41.5 C	ND <	700 C
2,3,7,8-Tetrachlorodibenzofuran	ND <	ND <	87.6	ND <	50.9	ND <	26.3	ND <	1.15	ND <	20.3
1,2,3,7,8-Pentachlorodibenzofuran	ND <	ND <	272	ND <	59.8	ND <	30.9	ND <	2.97	ND <	28.9
2,3,4,7,8-Pentachlorodibenzofuran	ND <	ND <	353	ND <	103	ND <	53.6	ND <	2.26	ND <	22.5
1,2,3,4,7,8-Hexachlorodibenzofuran	ND <	ND <	284	ND <	90.3	ND <	46.7	ND <	3.49	ND <	17.1
1,2,3,6,7,8-Hexachlorodibenzofuran	ND <	ND <	208	ND <	77.8	ND <	40.3	ND <	3.07	ND <	15.3
1,2,3,7,8,9-Hexachlorodibenzofuran	ND <	ND <	268	ND <	221	ND <	113	ND <	5.80	ND <	56.4
2,3,4,6,7,8-Hexachlorodibenzofuran	ND <	ND <	282	ND <	173	ND <	87.7	ND <	4.89	ND <	31.3
1,2,3,4,6,7,8-Heptachlorodibenzofuran	169 J	10.9	169 J	ND <	292	ND <	149	ND <	8.70	ND <	38.5
1,2,3,4,7,8,9-Heptachlorodibenzofuran	ND <	ND <	427	ND <	216	ND <	146	ND <	5.58	ND <	38.6
Octachlorodibenzofuran	499 J	8.57 J	508 J	ND <	511	ND <	12.8 J	ND <	42.6	ND <	42.6
Total Tetrachlorodibenzo-p-dioxin											
Total Pentachlorodibenzo-p-dioxin											
Total Hexachlorodibenzo-p-dioxin											
Total Heptachlorodibenzo-p-dioxin											
Total Tetrachlorodibenzofuran											
Total Pentachlorodibenzofuran											
Total Hexachlorodibenzofuran											
Total Heptachlorodibenzofuran											

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

Total sample non detect values are the average detection limit from the XAD and Filter fractions.

Total results do not include any contribution from non detects.

J = Concentration detected below detection/calibration range.

K = Total value in the calibration range, but individual values from the XAD or filter fraction or both were below the calibration range.

C = Blank-corrected concentration below detection/calibration limit.

Continuing calibration response factor for 23478-PeCDFE-13C12 slightly below 30% from initial calibration at end of analysis day for N-5a-MMS-725 filter, N-5b-MMS-726 filter, and N-5a-MMS-726 filter.

Continuing calibration response factor for 1234678-HpCDFE-13C12 slightly above 30% from initial calibration at end of analysis day for N-5b-MMS-730 filter, N-5a-MMS-728 filter, and N-5a-MMS-730 filter.

* = several isotope ratios in the continuing calibration were slightly out of the theoretical range on the day these samples were analyzed.

TABLE 7.2-14. VAPOR/PARTICULATE DISTRIBUTION FOR DIOXINS/FURANS IN BLANK GAS SAMPLES (pg/Nm³)

Analyte	5a TRAIN BLANK N-5a-MMS-725		5b TRAIN BLANK N-5b-MMS-725		TOTAL		METHOD BLANK*		TOTAL			
	VAPOR	SOLID	VAPOR	SOLID	VAPOR	SOLID	VAPOR	SOLID	VAPOR	SOLID		
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND <	3.07	ND <	3.07	ND <	3.07	ND <	4.74	ND <	1.68	ND <	3.21
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND <	3.82	ND <	3.22	ND <	3.52	ND <	15.2	ND <	5.06	ND <	10.1
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND <	4.63	ND <	3.19	ND <	3.91	ND <	12.0 J	ND <	6.33	ND <	12.0 J
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ND <	4.37	ND <	2.58	ND <	3.47	ND <	30.6	ND <	4.27	ND <	17.4
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ND <	4.56	ND <	4.56	ND <	4.56	ND <	11.1 J	ND <	7.14	ND <	11.1 J
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	ND <	10.6	ND <	10.6	ND <	10.6	ND <	23.1 J	ND <	16.0	ND <	23.1 J
Octachlorodibenzo-p-dioxin	40.7 J	34.0 J,L	74.7 K	1046 J	26.8 J,L	1073 K	111	34.9 J	146 K	2.42	ND <	2.42
2,3,7,8-Tetrachlorodibenzofuran	ND <	2.32	ND <	2.14	ND <	2.23	ND <	3.02	ND <	1.82	ND <	11.6
1,2,3,7,8-Pentachlorodibenzofuran	ND <	3.55	ND <	3.39	ND <	3.47	ND <	18.2	ND <	5.05	ND <	13.1
2,3,4,7,8-Pentachlorodibenzofuran	ND <	5.22	ND <	3.15	ND <	4.18	ND <	21.2	ND <	5.05	ND <	14.8
1,2,3,4,7,8-Hexachlorodibenzofuran	ND <	4.41	ND <	3.44	ND <	3.92	ND <	25.4	ND <	4.20	ND <	9.58
1,2,3,6,7,8-Hexachlorodibenzofuran	ND <	4.07	ND <	3.02	ND <	3.54	ND <	15.8	ND <	3.32	ND <	10.3 J
1,2,3,7,8,9-Hexachlorodibenzofuran	ND <	7.78	ND <	5.87	ND <	6.83	ND <	10.3 J	ND <	10.1	ND <	19.3
2,3,4,6,7,8-Hexachlorodibenzofuran	ND <	3.29	ND <	3.92	ND <	3.60	ND <	32.8	ND <	5.84	ND <	10.8 J
1,2,3,4,6,7,8-Heptachlorodibenzofuran	ND <	23.1	ND <	12.8	ND <	17.9	ND <	10.8 J	ND <	5.45	ND <	21.3 J
1,2,3,4,7,8,9-Heptachlorodibenzofuran	ND <	6.17	ND <	4.74	ND <	5.45	ND <	21.3 J	ND <	7.56	ND <	77.6 K
Octachlorodibenzofuran	ND <	12.2	ND <	11.3	ND <	11.8	ND <	68.8	8.79 J			
Total Tetrachlorodibenzo-p-dioxin												
Total Pentachlorodibenzo-p-dioxin												
Total Hexachlorodibenzo-p-dioxin												
Total Heptachlorodibenzo-p-dioxin												
Total Tetrachlorodibenzofuran												
Total Pentachlorodibenzofuran												
Total Hexachlorodibenzofuran												
Total Heptachlorodibenzofuran												

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for field reagent blank.

Total sample non detect values are the average detection limit from the XAD and Filter fractions.

Total results do not include any contribution from non detects.

J = Concentration detected below the calibration range.

K = Total value in the calibration range, but individual values from the XAD or filter fraction or both were below the calibration range.

L = Isotope ratio slightly outside theoretical range.

C = Blank-corrected concentration below detection/calibration limit.

Continuing calibration response factor for 23478-PeCDF-13C12 slightly below 30% from initial calibration at end of analysis day for N-5a-MMS-725 filter, N-5b-MMS-726 filter, and N-5a-MMS-728 filter. Continuing calibration response factor for 1234678-HpCDF-13C12 slightly above 30% from initial calibration at end of analysis day for N-5b-MMS-730 filter, N-5a-MMS-728 filter, and N-5a-MMS-730 filter.

* = several isotope ratios in the continuing calibration were slightly out of the theoretical range on the day these samples were analyzed.

7.3 Particulate Size Distribution of Elements in Flue Gas Streams

7.3.1 Introduction

This section discusses the distribution of elemental concentrations among the various particulate size fractions collected at Locations 4 and 5a at the Niles - Boiler No.2 flowstream. Three samples were collected at Locations 4 (ESP Inlet) and 5a (ESP Outlet) using a Multi-Metals sampling train. Various particulate size fractions were collected separately in the train, using glass cyclones upstream of the particulate filter. The large cyclone collected the $> 10 \mu\text{m}$ aerodynamic size particles, the small cyclone collected particles in the $5\text{-}10 \mu\text{m}$ aerodynamic size range, and the downstream quartz filter collected the $< 5 \mu\text{m}$ size fraction.

The sampling constraints of Locations 4 and 5a necessitated the use of a substantial length of heated flexible tubing to connect the sampling probe to the inlet of the large cyclone. The particulate fraction collected in this tubing, together with that in the sampling probe, were collectively analyzed and are referred to here as the Probe Rinse particulate fraction. Due to the length of the tubing and complexity of the flow path, the particulate size range collected as the Probe Rinse fraction is difficult to estimate. However, it is expected from aerosol dynamics that larger particles would be preferentially removed in the probe and tubing compared with smaller aerosols.

The various particulate fractions collected in the three samples at Location 4 were analyzed for elemental concentrations. No samples were collected in the cyclones at Location 5a. The discussions in this section are limited to the particulate size distributions at Location 4, because no information is available from the results from Location 5a. Table 7.3-1 provides the measured particulate-phase elemental concentrations of various elements in each of the three known size fractions at Location 4. Note that on average 58.8 percent of the particulate mass collected at Location 4 was in the Probe Rinse, 19.7 percent was in the Large $> 10 \mu\text{m}$ Cyclone, 1.5 percent was in the Small ($5\text{-}10 \mu\text{m}$) Cyclone, and 20.1 percent was collected on the filter (see Section 5.11).

7.3.2. Average Distribution of Elemental Concentrations

A more informative picture of the particulate size distribution of elemental pollutants in the flue gas is provided in Table 7.3-2. This table provides the average percentage distributions of elemental flue gas concentrations among the various size fractions at Location 4. The data in Table 7.3-2 have been derived by averaging the elemental concentrations measured in the respective particulate size fractions in each of the three samples collected at this sampling location. Zero values were used in the calculations for non-detected particulate fraction concentrations in individual samples. Each entry in Table 7.3-2 is the average percentage of the total flue gas loading of the indicated elements that is contributed by the indicated size fraction of particles. The sum of the percentages across the row for each element equals 100 percent. For example, in Table 7.3-2, aluminum in flue gas at Location 4 exists about 20.9 percent in $<5 \mu\text{m}$ particles, 1.6 percent in $5\text{-}10 \mu\text{m}$ particles, 6.1 percent in $>10 \mu\text{m}$ particles, and 71.4 percent in particles collected in the probe and flexible tubing. Table 7.3-2 thus provides a perspective on the distribution of individual elements among the various particulate fractions in the flue gas stream upstream of the ESP.

Table 7.3-2 shows that at Location 4, the Probe Rinse particulate fraction contained the largest proportion of the elemental concentrations for all of the elements, except antimony, arsenic, cadmium, molybdenum, and sodium. Except for these latter elements, the second-largest proportion of elemental concentrations were typically in the Filter ($<5 \mu\text{m}$ range). The Large Cyclone ($>10 \mu\text{m}$ range) fraction elemental concentrations were always smaller than the Probe Rinse and Filter fraction concentrations. The Small Cyclone ($5\text{-}10 \mu\text{m}$ range) fraction always contained the lowest proportion of elemental concentrations for all elements.

A few elements; namely, antimony, arsenic, molybdenum, and sodium, had >50 percent of their particulate-phase concentrations in the Filter ($<5 \mu\text{m}$ fraction). The remainder of the elements had typically between 25-45 percent of their particulate phase concentrations in the Filter fraction. Most elements has over 50 percent of their particulate-phase concentrations present in the Probe Rinse fraction. Aluminum, barium, beryllium, cobalt, manganese, nickel, selenium, and titanium had >60 percent of their particulate-

phase concentrations in the Probe rinse fraction. Only lead was present in similar proportions in the Filter and Probe Rinse fractions.

No individual trends in the particulate elemental distributions could be observed for any of the elements, either with increasing or decreasing particle size. The high proportions of elemental concentrations in the unknown size Probe Rinse fractions makes it difficult to identify the existence of any such trends.

7.3.3 Elemental Content Ratios

The elemental concentrations in Tables 7.3-1 can also be interpreted in terms of the elemental contents in each of the various particulate fractions. Table 7.3-3 shows the average elemental contents in the particulate matter collected in the four parts of the sampling train, as well as in the total particulate, at Location 4. The data in Tables 7.3-3 have been derived by averaging the elemental concentration data (in $\mu\text{g}/\text{Ncm}$) in the three samples at Location 4, multiplying the average concentrations by the average sample volume (in Ncm), and dividing by the average particulate mass (in g) collected of each size fraction. Thus the entries in Tables 7.3-3 show the elemental composition (in $\mu\text{g}/\text{g}$) of each particle size fraction, as well as of the total particulate mass.

Elemental content results are presented for the Filter, Large and Small Cyclones, and Probe Rinse fractions, and for the Total Particulate in Table 7.3-3. Note that there is a great degree of variability in elemental contents for many elements in the Small Cyclone fraction. This variability is a consequence of the low and variable levels of particulate mass collected in this part of the sampling train in the three samples at this location. Results for the Small Cyclone fraction must therefore be interpreted with caution.

The results in Table 7.3-3 show that the elemental contents in the Filter and Probe Rinse fractions are quite similar for a few elements. These results are observed for the elements aluminum, cobalt, manganese, selenium, and titanium. Many more elements, however, have higher elemental contents in the Filter fraction than in the other size fractions. Elements with such a result include antimony, arsenic, barium, chromium, copper, lead, nickel, and vanadium.

The elemental content ratios in the Large Cyclone fractions were generally smaller than the corresponding ratios in the Filter and Probe Rinse fractions, a result which is consistent with the relatively low percentage of the total particulate elemental concentration in the Large Cyclone fraction (see Table 7.3-2), despite the collection of about 20 percent of the particulate mass in the Large Cyclone.

For the majority of the elements, the elemental contents in the total particulate mass are about equal to the corresponding elemental contents in the Probe Rinse fraction. Notable exceptions are elements such as arsenic, molybdenum, and sodium, which have elemental contents in the total particulate mass that are higher than the corresponding contents in the Probe Rinse fraction.

A few elements have elemental contents that increase consistently with decreasing particle size, when considering the three size fractions of known particle size; namely, the Filter, Small Cyclone, and Large Cyclone fractions. Elements with such a result are antimony, barium, chromium, copper, lead, nickel, and vanadium. The variability in elemental contents in the Small Cyclone fraction, as discussed previously, does cast some doubts on this interpretation of the data.

TABLE 7.3-1. PARTICULATE SIZE DISTRIBUTION OF ELEMENTS IN ESP INLET (LOCATION 4) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-4-MUM-727			N-4-MUM-729			N-4-MUM-731		
	SMALL CYCLONE	LARGE CYCLONE	TOTAL FILTER	SMALL CYCLONE	LARGE CYCLONE	TOTAL FILTER	SMALL CYCLONE	LARGE CYCLONE	TOTAL FILTER
Aluminum	5015	12771	34670	1666	11653	37609	692	4304	23346
Potassium	1582	2932	15658	ND <	2269	19074	251	902	10323
Silicon	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sodium	281	328	10261	ND <	245	19077	290	215	3322
Titanium	538	1491	3132	164	1288	3216	31.8	389	2604
Antimony	1.50	ND <	56.7	1.86	6.13	85.6	ND <	7.99	45.3
Arsenic	114	283	1456	17.7	129	1159	0.636	59.4	999
Barium	31.6	64.6	415	12.8	60.1	408	2.98	24.6	286
Beryllium	2.69	5.47	20.0	0.744	4.54	19.6	3.31	1.48	15.3
Boron	NA	NA	NA	NA	NA	NA	ND <	NA	NA
Cadmium	ND <	0.237	2.21	ND <	0.920	2.13	ND <	0.254	1.84
Chromium	19.0	54.7	210	9.86	51.5	201	1.09	14.6	161
Cobalt	6.96	12.4	38.9	0.558	14.1	40.3	0.509	4.10	35.5
Copper	31.6	59.6	313	10.1	50.3	365	2.06	17.8	256
Lead	41.1	59.6	425	8.93	79.7	458	1.60	15.2	305
Manganese	16.6	37.3	129	7.44	35.6	131	1.45	12.1	103
Molybdenum	4.83	ND <	173	5.58	10.7	164	2.29	ND <	112
Nickel	23.7	49.7	167	6.89	55.8	213	0.509	13.5	144
Selenium	3.24	6.96	29.2	1.86	3.68	16.4	ND <	4.30	16.6
Vanadium	30.8	74.5	302	11.7	73.6	327	0.636	22.5	256
			408			412	2.21		280

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

TABLE 7.3-2. AVERAGE DISTRIBUTION OF ELEMENTS IN THE PARTICULATE MATTER COLLECTED IN THE FOUR PARTS OF THE SAMPLING TRAIN AT LOCATION 4

SPECIES	Percentage Elemental Distribution						
	Filter ≤ 5 μm % ±SD%	Small Cyclone 5 - 10 μm % ±SD%	Large Cyclone >10 μm % ±SD%	Probe Rinse Unknown size % ±SD%			
Elements							
Aluminum	20.9	2.6	1.6	1.4	6.1	2.5	71.4
Antimony	61.4	6.9	1.3	0.5	5.9	3.2	31.4
Arsenic	53.7	2.7	1.7	2.2	6.5	3.6	38.2
Barium	32.6	2.8	1.4	1.2	4.3	1.5	61.8
Beryllium	31	1.4	1.9	1.9	6.2	2.7	60.9
Cadmium	45	5	7.4	2.7	16.3	5.1	31.4
Chromium	38.5	2.5	1.8	1.6	7.3	3.4	54.4
Cobalt	25.5	0.7	1.8	2.4	6.6	3.1	66.1
Copper	37.6	0.1	1.7	1.8	5	2.3	55.7
Lead	46.7	1.2	1.9	2.3	5.6	2.9	45.8
Manganese	27	0.9	1.8	1.6	6.1	2.6	65.1
Molybdenum	80	9.5	2.2	0.6	4	1.6	13.8
Nickel	28.3	0.2	1.7	2.1	6.1	3	63.9
Potassium	35.4	4.9	1.7	1.6	4.7	2	58.2
Selenium	26	5.5	2.3	1.2	6.3	1.6	65.4
Silicon	-	-	-	-	-	-	-
Sodium	83.7	15.9	2.6	2.9	2.8	1.5	10.8
Titanium	25.2	2.8	1.9	1.8	8.5	4.1	64.4
Vanadium	36.6	1.1	1.8	1.8	6.8	3	54.9

-: Particulate data not available for silicon

TABLE 7.3-3. AVERAGE CONTENT OF INDIVIDUAL ELEMENTS IN PARTICULATE MATTER COLLECTED IN THE FOUR PARTS OF THE SAMPLING TRAIN AND IN THE TOTAL PARTICULATE AT LOCATION 4

SPECIES	Elemental Content									
	Filter ≤ 5 μm μg/g ± SD		Small Cyclone 5 - 10 μm μg/g ± SD		Large Cyclone > 10 μm μg/g ± SD		Probe Rinse Unknown Size μg/g ± SD		Total Particulate μg/g ± SD	
Elements										
Aluminum	87407	20651	69121	63784	25210	12110	101599	31244	72386	9416
Potassium	41183	12094	21199	20329	5356	2725	22795	6956	19840	1517
Silicon										
Sodium	29853	21652	5373	4596	692	154	1273	871	5378	2418
Titanium	8183	910	6877	7384	2780	1543	7184	1875	5747	1106
Antimony	171	57	38	18	15	7	29	9	48	7
Arsenic	3303	636	1262	1695	414	302	806	232	1072	178
Barium	1014	198	448	406	131	58	653	159	540	66
Beryllium	50	7	35	36	10	5	34	8	28	2
Boron										
Cadmium	6	1	10	5	2	1	1	0	2	0
Chromium	524	72	281	252	106	59	267	63	249	19
Cobalt	105	7	75	104	27	14	92	18	72	12
Copper	854	150	410	430	112	58	430	94	394	32
Lead	1087	221	484	591	136	87	364	97	400	8
Manganese	332	43	239	215	75	37	273	62	215	27
Molybdenum	410	89	119	49	21	11	22	5	90	20
Nickel	479	96	292	337	104	60	368	100	293	27
Selenium	57	20	54	37	13	5	47	19	38	5
Vanadium	809	99	420	410	150	78	414	84	385	39

- : Particulate data not available

7.4 Comparison of HEST and Method 29 Methods for Volatile Elements

7.4.1 Introduction

Volatile trace elements (mercury, selenium, arsenic) were measured at three locations in the boiler flue and stack gas using both Chester Environmental's Hazardous Element Sampling Train (HEST) and EPA's Draft Method 29 (Method 29). The objective was to provide two independent measurements for these elements as well as provide data to evaluate the HEST.

7.4.2 Experimental

Method 29: The Method 29 sampling train is illustrated in Figure 7.4-1. This sampling train was modified to collect size fractionated particle samples for multimetals analysis by adding a multistage-Pyrex impactor inside the heated box preceding the heated filter. The vapor phase samples were trapped in the impinger downstream of the quartz fiber particle filter. The Method 29 vapor phase results are based on the analysis of the impinger solution and the rinse solution of all glass surfaces downstream of the particulate quartz fiber filter including the filter support disks.

Particles were separated from the flue gas with cyclones and a quartz fiber filter. Method 29 requires that filtration take place in a box heated to 393 K ($248 \pm 25^\circ\text{F}$) to prevent condensation of moisture. The temperature of the air inside the box, however, is not necessarily the temperature of the flue or stack gas at the time of filtration. Flue or stack samples that are substantially higher than 248°F , for example, may not reach this recommended temperature prior to filtration. This may represent a particular problem with vapor phase species such as SeO_2 that can have a dew point in this same temperature range. Even if the stack gas temperatures approach the method specific temperature range, the particle and vapor phase ratio may not be representative of in situ conditions, if, as is the case of SeO_2 , its dew point is likely to be near this temperature range.

The Method 29 samples were used to determine both the particle and gas phase concentration of elements. As such, collection of Method 29 samples included an isokinetic traverse of the stack or flue.

HEST Method: The HEST is illustrated in Figure 7.4-2. Two versions of this sampling train were used. One version, referred to as the low ash HEST (LAH), was as illustrated in Figure 7.4-2 with a quartz fiber filter followed by two carbon impregnated filters (CIF), all of which were housed in a Teflon-coated stainless steel cartridge located at the end of the probe. In this LAH arrangement, the suspended particles were filtered at flue or stack gas temperatures. As such, particle and vapor phases were separated at in situ temperatures that accurately represent the process conditions.

The other HEST arrangement, referred to as the high ash HEST (HAH) was similar to the front half of the modified Method 29 with the particle phase being separated from the vapor phase with glass cyclones and a quartz fiber filter located outside the stack in a box heated to $248 \pm 24^{\circ}\text{F}$. The vapor phase elements were trapped on CIFs much like the LAH. The portion of the HAH downstream of the CIFs was similar to the back half of the LAH.

Only single point HEST samples were collected since only the vapor phase was determined by this method.

Plume Simulating Dilution Sampler (PSDS). Modified HEST and Method 29 samples were collected with the plume simulating dilution sampler. In this case, both the HEST cartridge and the Method 29 impingers were located downstream of the same 8 in. by 10 in. quartz fiber particle filter. The temperature of the filtered stack gas was the same for both samplers.

Sampling. Method 29 and HEST samples were collected from two different ports. The duration and flow rate of the HEST samples was generally less than that of Method 29 samples. The HEST sampling period typically overlapped about 40 to 50 percent of the Method 29 sampling period but at times was as low as about 30 percent.

The sampling conditions are summarized in Table 7.4-1.

7.4.3 Results

The HEST and Method 29 results are summarized in Tables 7.4-2 through 7.4-4. Selected particulate phase HEST results are presented to provide an estimate of the total concentration for comparison with the Method 29 total values. The HEST particle fraction represents only what was captured on the quartz fiber filter. This will be low by the amount of particulate fraction removed in the probe and cyclone in the HAH case. Both the HAH and LAH particle fractions will also be in error by the degree to which the single point sample is not representative and the degree to which the sample was nonisokinetic. These factors, however, should not affect the vapor phase concentrations.

7.4.4 Discussion

7.4.4.1 Overview. The HEST vapor phase mercury results were generally in good agreement with the Method 29 mercury results. The agreement between the two methods for vapor phase arsenic and selenium was poor. Differences in the arsenic and selenium vapor phase results ranged from two to over tenfold. The difference in the arsenic and selenium results are thought to be due to differences in temperature at the time the particle and vapor phases were separated. Some portion of the difference is due to the fact that the samples were not collected under identical conditions (different probes, different points in the stack, and differences in isokinetics), and the sampling times did not overlap completely.

These results have helped to define the dynamic range of applicability of the HEST. This comparison has also shown that Method 29 may be limited in its ability to define the in situ particle to vapor phase concentration ratios correctly for species that are near their dew point.

The HEST, like all methods has a dynamic range of applicability. It is recommended that the conditions (e.g., temperature range, moisture and acidity ranges, flow rates) in which the HEST is applicable be defined more precisely. It is also recommended that whenever in situ phase partitioning information is required, particle filtration should be done at the in situ temperature. In addition, to avoid artifacts from gas phase interaction with

filtered particles, denuders should be used to separate key gas phase components prior to filtration.

7.4.4.2 Mercury. The mercury results are compared in Table 7.4-2. In this table, "Part." means particle-phase element, "Gas-P" means vapor from the primary HEST filter, and "Gas-S" means vapor from the secondary HEST filter. Samples from Location 5a showed acid damage to the primary filter, and secondary filters were analyzed to check for breakthrough. The vapor phase mercury results are in reasonably good agreement, but the HEST results are consistently biased lower than the Method 29 results by about 20 percent. This bias in the case of the hot stack samples may be caused in part by sulfuric acid condensation and mercury breakthrough to the backup CIF. This was not the case, however, with the HEST samples collected before the ESP and from the PSDS. No breakthrough was detected with these latter samples.

The low mercury trapping efficiency of the HEST with the in-stack measurement appears to have been due to condensation of sulfuric acid. The filters from Location 5a appeared as though they had been exposed to a liquid and lost physical stability as might be expected after being exposed to sulfuric acid.

7.4.4.3 Selenium. Table 7.4-3 shows the selenium results. The HEST results for vapor phase selenium are generally more than tenfold greater than the Method 29 vapor phase selenium. The trapping efficiency of the primary CIF for selenium at the ESP inlet was greater than 99 percent. Significant breakthrough of selenium was observed with the samples collected in the stack where the CIFs appear to have been wet with sulfuric acid. The agreement between the HEST and Method 29 results was generally good between the samples collected from the PSDS; i.e. within experimental error.

The average total selenium results (i.e., considering particle plus vapor) were in better agreement than for the vapor alone at both the ESP inlet and the hot stack. In this particular case, the difference in reported vapor phase concentrations appears to be due mostly to differences in phase partitioning. Although similar front half sampling trains were used, it is quite possible that particle filtration took place at different temperatures. Since the dominant vapor phase selenium species has a dew point in the potential range of

filtration, it is quite likely that sampling temperature differences are responsible for differences in reported vapor phase selenium concentrations at Locations 4 and 5a.

Another indication that the Method 29 selenium vapor results do not correctly represent the in situ selenium concentration is the very low ESP particulate selenium removal efficiency (2.7 percent) based on Method 29 particle concentrations at the inlet and the hot stack. The ESP particulate selenium removal efficiency based on the HEST measurements was over 90 percent.

The low vapor phase selenium concentration at the inlet to the ESP relative to the outlet as determined by the HEST hot stack measurements may be due in part to gas phase removal by the thick particle deposit on the inlet filter.

7.4.4.4 Arsenic. Table 7.4-4 shows the arsenic results. The vapor phase arsenic HEST results are, like the selenium results, several fold greater than the vapor phase concentrations reported by Method 29. The arsenic trapping efficiency of the primary CIF was also greater than 99 percent except for the hot stack samples that were affected by sulfuric acid. Because such a large fraction of the arsenic was in the particulate phase much of it may have been removed in the probe and cyclones. Nevertheless, the total (i.e., particle plus vapor) As values show much better agreement than do the vapor only data.

Both methods show a significant reduction of the vapor phase arsenic downstream of the ESP relative to upstream. This may be due to exaggeration of the vapor phase concentrations at the upstream Location 4, by volatilization of a small portion of the large amount of arsenic particulate collected there. This would not have been the case with the selenium since it is dominated by the vapor phase.

7.4.5 Conclusion

The vapor phase mercury results reported by Method 29 may be more representative of the in situ conditions in the Niles Boiler flue gas stream than are the HEST results. The HEST results may be low because of reduced trapping efficiency of the primary CIF caused by condensation of sulfuric acid with the hot stack samples.

The HEST vapor phase selenium and arsenic results may be more representative of the in situ conditions than the Method 29 results. The difference, which was at times more than a factor of ten, is thought to be due to differences in phase partitioning and its high sensitivity to temperature. For both these elements, total (particle plus vapor) concentrations showed much better agreement than did vapor only values.

It is essential that phase separation be achieved at in situ temperatures, if it is important that accurate particulate and vapor phase partitioning be achieved. It is also important that potential artifacts such as vapor phase interaction with particulate deposits and potential volatilization of particle deposits be eliminated.

7.4.6 Recommendations

The HEST is an easy-to-use, low-cost sampling train that can provide accurate and reliable measurements of vapor phase mercury, arsenic, and selenium when operated within its dynamic range of applicability. Because this method is less than 2 years old, its dynamic range of applicability has not been completely defined. Prior to these measurements, it had not exceeded its range of applicability. The HEST's trapping efficiency depends on variables such as temperature, flow rate, analyte and interferant concentrations, sampling time, etc. As such, it is recommended that the dynamic range of the HEST be defined. It is further recommended that HEST samples be collected well above the dew point of sulfuric acid but below 350°F, preferably at about 300°F.

If accurate phase partitioning is required, it is recommended that phase separation take place at accurately controlled in situ temperatures.

If accurate phase partitioning is required, it is recommended that denuder methods be used to separate key vapor phase species prior to particle collection and vapor phase species be measured downstream of the particle filter to estimate particulate volatilization.

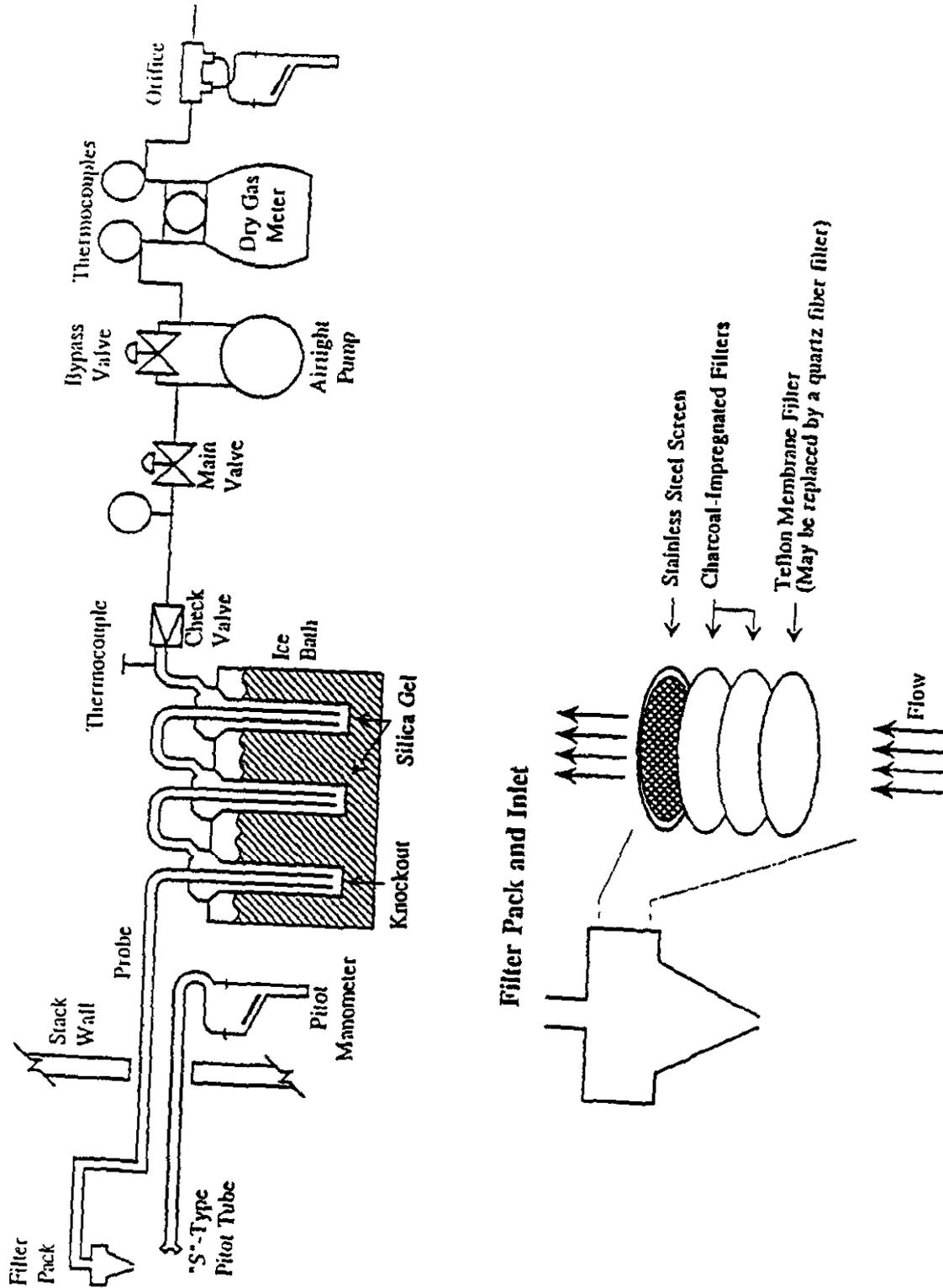


Figure 7.4-2. Hazardous Element Sampling Train

TABLE 7.4-1. SAMPLING CONDITIONS - NILES BOILER NO. 2

Location	Site	Date	Stack Temp. (°F)	Part. Conc. ^(a) (mg/Ncm)	SO ₂ /SO ₃ (ppm)	HEST Config.	CIF Temp. ^(b) (°F)	Moisture (%)	CIF Dia. (mm)	Flow (slpm/cm ²)	Sampling Overlap (%) ^(c)
ESP Inlet	N-4	7-27	310	2241	1217/<15	HAH	249	14.4	86	0.414	54
		7-29	300	2585	1170/<15	HAH	252	12.3	86	0.370	42
		7-31	302	1582	1020/<15	HAH	257	7.9	86	0.507	43
		Mean	304	2136	1136/<15		253	11.5		0.430	46
		Std	4.32	510	84/not def.		3.30	2.7		0.057	5
Stack	N-5a	7-27	299	43.5	1230/<15	LAH	299	9.2	47	1.40	54
		7-29	295	19.5	1190/<15	LAH	295	9.4	47	0.873	60
		7-31	285	34.3	1160/<15	LAH	285	9.4	47	1.75	53
		Mean	293	32.4	1193/<15		293	9.3		1.34	56
		Std	5.89	12.1	29/not def.		5.89	0.1		0.36	3
Stack Dilute	N-5b	7-27	105	0.700	40/<15	LAH	105	0.30	47	0.060	56
		7-29	100	0.690	38/<15	LAH	100	0.30	47	0.064	58
		7-31	94	0.609	38/<15	LAH	94	0.31	47	0.068	52
		Mean	100	0.666	39/<15		100	0.30		0.064	55
		Std	4.5	0.050	1/not def.		4.5	0.00		0.003	2

(a) Determined by Method 29.

(b) HAH = high ash HEST; LAH = low ash HEST.

(c) Percentage of M29 run during which the HEST was in use.

TABLE 7.4-2. MERCURY RESULTS - NILES BOILER NO. 2 ($\mu\text{g}/\text{Nm}^3$)

Location	Stack Temp.	Site I.D.	Date	HEST						Method 29			
				Type	Part.	Gas-P	Gas-S	Total ^(a)	Part.	Gas	Total		
ESP	310	N-4	7-27	HAH	ND 0.0 ^(b)	22.87	ND < 0.013	22.87	1.75	29.96	31.67		
Inlet	300		7-29	HAH	ND 0.0 ^(b)	23.99		23.99	1.85	26.37	23.19		
	302		7-31	HAH	ND 0.0 ^(b)	23.64		23.64	1.15	23.63	24.80		
Mean	304				ND 0.0 ^(b)	23.50		23.50	1.58	26.65	28.22		
SD	4				0.0	0.5		0.5	0.4	3.2	3.4		
Stack	299	N-5a	7-27	LAH	ND < 1.367	1.079 ^(c)		9.67 ^(c)	0.064	27.20	27.33		
	295		7-29	LAH	ND < 2.335	0.354 ^(c)		35.35 ^(c)	ND 0.0	21.21	21.21		
	285		7-31	LAH	ND < 0.459	3.615 ^(c)		12.90 ^(c)	ND 0.0	23.34	23.34		
Mean	293				ND < 1.39	1.68		19.3	0.021	23.9	24.0		
SD	6				0.94	1.71		14.0	0.037	3.0	3.1		
Stack	105	N-5b	7-27	LAH	ND < 0.605	27.3		ND < 0.014	ND 0.0	30.2	30.2		
Dilute	100		7-29	LAH	ND < 0.606	25.6			ND 0.0	34.8	34.8		
	94		7-31	LAH	ND < 0.556	24.0			ND 0.0	31.6	31.6		
Mean	100				ND < 59	25.7			ND 0.0	32.2	32.2		
SD	5				0.03	1.66			0.00	2.4	2.4		

- (a) A total is reported for whatever analyses were performed. HEST particulate and secondary carbon filters were analyzed selectively.
- (b) The detection limits for Location 4 mercury were high due to X-ray interference by germanium. "ND 0.0" is reported rather than a large non-detect so that the mercury total is not distorted.
- (c) When breakthrough occurred, the results were adjusted for X-ray absorption.

TABLE 7.4-3. SELENIUM RESULTS - NILES BOILER NO. 2 ($\mu\text{g}/\text{Nm}^3$)

Location	Stack Temp.	Site I.D.	Date	HEST						Method 29			
				Type	Part.	Gas-P	Gas-S	Total ^(a)	Part.	Gas	Total		
ESP	310	N-4	7-27	HAH	15.6	125	ND < 0.134	140.3	94.0	8.46	102.5		
Inlet	300		7-29	HAH	11.5	121		132.0	80.4	11.31	91.6		
	302		7-31	HAH	11.2	128		139.3	61.5	18.75	80.2		
Mean	304				12.7	124		137.2	78.6	12.84	91.4		
SD	4				2.5	4		4.5	16.3	5.31	11.1		
Stack	299	N-5a	7-27	LAH	0.680	236 ^(a)	36.9 ^(a)	273.4	122.1	14.05	136.7		
	295		7-29	LAH	1.322 ^(b)	415 ^(a)	83.8 ^(a)	500.3	38.8	17.21	56.0		
	285		7-31	LAH	2.268 ^(b)	160 ^(a)	15.7 ^(a)	177.4	101.7	11.03	112.7		
Mean	293				1.42	270	45.5	317.0	87.5	14.10	101.8		
SD	6				0.80	131	34.8	165.8	43.4	3.09	41.4		
Stack	105	N-5b	7-27	LAH	ND < 0.419	57.8	ND < 0.027	58.0	66.0	32.2	98.3		
Dilute	100		7-29	LAH	ND < 0.398	51.1		51.2	27.2	ND < 14.9 ^(d)	27.2 ^(d)		
	94		7-31	LAH	1.037	50.7		51.8	23.3	51.9	75.0		
Mean	100				0.618	53.2		53.7	38.9	33.0	66.8		
SD	5				0.363	4.0		3.8	23.6	18.5	36.2		

(a) A total is reported for whatever analyses were performed. HEST particulate and secondary carbon filters were analyzed selectively.
 (b) These filters were analyzed by ICP for As and Se because their uneven particle deposition made them unsuited to XRF analysis. ICP analysis for mercury was not performed because no mercury was expected. XRF was used for mercury to confirm this expectation.
 (c) When breakthrough occurred, the results were adjusted for X-ray absorption.
 (d) M29 non-detects at Location 5b are treated as zero to facilitate the hot stack/dilute stack comparison.

TABLE 7.4-4. ARSENIC RESULTS - NILES BOILER NO. 2 ($\mu\text{g}/\text{Nm}^3$)

Location	Stack Temp.	Site I.D.	Date	HEST						Method 29			
				Type	Part.	Gas-P	Gas-S	Total ^(e)	Part.	Gas	Total		
ESP	310	N-4	7-27	HAH	1506	89.3	ND < 0.014	1595	2736	35.8	2772		
Inlet	300		7-29	HAH	1369	72.0		1440	2261	3.9	2265		
	302		7-31	HAH	1620	72.4		1692	1766	20.3	1786		
Mean	304				1498	77.9		1576	2255	20.0	2274		
SD	4				126	9.9		127	485	16.0	493		
Stack	299	N-5a	7-27	LAH	25.3	49.0 ^(e)	0.20 ^(e)	74.5	75.7	3.77	79.4		
	295		7-29	LAH	16.4 ^(b)	63.8 ^(e)	1.96 ^(e)	82.2	60.3	0.57	60.8		
	285		7-31	LAH	31.5 ^(b)	10.2 ^(e)	5.83 ^(e)	47.5	67.4	2.87	70.3		
Mean	293				24.4	41.0	2.66	68.1	67.8	2.40	70.2		
SD	6				7.6	27.7	2.88	18.2	7.7	1.65	9.3		
Stack	105	N-5b	7-27	LAH	2.27	2.14	ND < 0.129	4.51	8.08	ND < 14.3 ^(d)	8.08 ^(d)		
Dilute	100		7-29	LAH	2.23	0.95		3.20	9.17	ND < 14.9 ^(d)	9.17 ^(d)		
	94		7-31	LAH	1.55	ND < 0.52		1.87	10.03	ND < 13.7 ^(d)	10.03 ^(d)		
Mean	100				2.01	1.20		3.19	9.09	ND < 14.3	9.09		
SD	5				0.41	0.84		1.32	0.98	0.60	0.98		

- (a) A total is reported for whatever analyses were performed. HEST particulate and secondary carbon filters were analyzed selectively.
- (b) These filters were analyzed by ICP for As and Se because their uneven particle deposition made them unsuited to XRF analysis. ICP analysis for mercury was not performed because no mercury was expected. XRF was used for mercury to confirm this expectation.
- (c) When breakthrough occurred, the results were adjusted for X-ray absorption.
- (d) M29 non-detects at Location 5b are treated as zero to facilitate the hot stack/dilute stack comparison.

7.5 Comparison of VOST and Summa Canisters For VOCs

7.5.1 Introduction

The purpose of this Special Topic is to compare the analytical results from two established techniques that have been frequently used for collecting and analyzing volatile organic compounds (VOCs) from various air matrices. The canister methodology made use of a flow orifice attached to the inlet of the evacuated canister, that permitted the collection of a time integrated flue gas sample once the canister valve was opened. The VOST methodology made use of two adsorbent tubes, Tenax and Tenax/Charcoal, a pump and flow controller assembly to actively sample the flue gas. Details on sampling and analysis with these methods are contained in the Management/Sampling and Analysis Plans, and elsewhere in this report and are not repeated here.

The target list of VOCs for the canister methodology included the 41 components that are listed in US EPA's TO-14 Methodology. Analytical results were obtained for 35 of those compounds; six early eluting compounds could not be measured due to interference from SO₂ in the sample. The target list for the VOST Methodology included 36 components and originates from SW-846, Method 5041 for VOCs. Thirty-five of those compounds were measured; hexane was not measured. Twenty compounds were common to both lists. The Method 5041 list contains 8 oxygenated species not on the TO-14 list. The TO-14 list includes several chlorinated and aromatic species not on the VOST target list.

For the Niles Boiler No. 2 program, samples were collected with both methods at three locations during three test days. The location descriptions and dates are as follows:

Location 4 - Gas samples from ESP Inlet

Sampling Dates - 7/26/93, 7/28/93, 7/30/93

Location 5a - Gas samples from ESP Outlet

Sampling Dates - 7/26/93, 7/28/93, 7/30/93

Location 5b - Dilute Gas samples from ESP Outlet

Sampling Dates - 7/26/93, 7/28/93, 7/30/93

At each sampling location, three samples were sequentially collected with each method for each test run. For the VOST sampling, each set was comprised of a 5-minute, 10-minute and 30-minute sample at a nominal flow rate of 0.5 L/min. The sampling was carried out in that order, i.e. from short to long sampling times. This distributive volume approach was used to determine if breakthrough had occurred for any species and to extend the detection level for those species not exhibiting breakthrough. Canister sampling was initiated close to the start of each VOST collection time. However, the canisters were fitted with an orifice designed to fill the canister over a fixed time period of 30 minutes. As a result, start and stop times for individual VOST and canister samples generally do not coincide.

Because of problems encountered during earlier power plant studies, i.e. rapid deterioration of the analytical columns and poor analytical precision, a preliminary sampling effort was carried out at the Niles Station prior to the full-scale study. Several canister samples were collected at the site and returned to Battelle for analysis. The preconcentration trap on the gas chromatograph/mass spectrometer had previously contained glass beads and was normally cooled to -160 C during sample collection. For the samples collected at Niles in this preliminary study, the cryo-trap was replaced with a two-component adsorbent trap (Supelco #2-0321). This type of trap is normally employed for the analyses of VOCs in water when using purge and trap procedures. Previous Battelle work has also shown that this adsorbent combination works well in capturing and releasing ambient concentrations of the TO-14 species. Purging the trap with zero air after sample collection to dry the trap reduces residual moisture so that column plugging does not occur.

The analytical results from repeated injections of the preliminary canister samples did show much better precision than earlier work with the cryo-trap; however, several large components were still found to elute from the analytical column. These peaks were subsequently identified as column bleed peaks by the mass spectrometer (e.g. siloxane mass fragments). Battelle suspected that sufficient acidic gases were still present in the vapor phase to cause this column stripping to occur. Several column manufacturers have concurred that the bonded phase on the fused silica columns will be readily stripped in the presence of strong acids.

Further efforts were carried out to test an air scrubber placed ahead of the adsorbent trap. Previous studies at Battelle had indicated that a sodium bicarbonate (NaHCO_3)

denuder worked very well in removing gaseous SO₂ from humidified air streams. The denuder system operated at flows of 10 to 20 liters/minute. At the low flow conditions required with the adsorbent trap (i.e. 15 cc/minute), a 10 cm long by 0.2 cm i.d. trap packed with 60/80 mesh NaHCO₃ was fabricated and placed in-line. Analytical results indicated much less peak artifacts. Results from the analyses of a 6 ppb standard mixture of TO-14 compounds with and without the NaHCO₂ scrubber also indicated reasonable agreement. No concentration differences were observed with benzene and toluene, however about a 20 percent loss was observed with the less volatile species such as hexachlorobutadiene. Battelle believes that the less volatile TO-14 compounds are more likely to adhere to the NaHCO₃ surface.

Based upon the positive results with the NaHCO₂ scrubber, this device was inserted in-line for the analyses of all canister samples from the SNOX process.

7.5.2 Data Analysis

A total of 26 VOST and 27 canister samples were analyzed. Tables 7.5-1 through 7.5-9 show the results from individual Summa can sample runs. Tables 7.5-10 through 7.5-18 show the results from the VOST sample runs. The latter values are not blank corrected. Each table contains the runs on the indicated date using the specified method (No VOST results are available for run #2 at Location 5a on 7/30/93). The "ND <" label indicates that the analyte was not detected. The detection level (DL) is indicated to the right of the label. For the VOST samples, the DL values changed as a function of the sampled volume. For the canister samples, the DL values remained constant because the same volume was always analyzed. In scanning the data it is evident that most of the target compounds were less than the detection level. It is also clear that the reported concentrations at several locations and on specific sampling days, vary somewhat from run to run with both methods. To further examine the data, three of the more frequently occurring compounds - dichloromethane, benzene and toluene - were selected and compared for the 27 runs. Table 7.5-19 shows these results. In viewing this table, a great deal of method run to run variability is evident for dichloromethane. However, for benzene and toluene, the method run to run concentration variability was reasonable, i.e., usually within a factor of two.

Agreement of concentrations between the VOST and canister methods was usually within a factor of four. Furthermore, there does not appear to be a consistent bias between methods.

Dichloromethane (DCM) (50/50 with methanol) was used in the field study as a solvent to rinse sampling apparatus. It is suspected that the unreasonably high concentrations of DCM in the samples are probably due to contamination from this source. However, we did not observe unreasonably high DCM in the field spike canister sample. In this case a portion of the trip spike was directed through the sampling manifold and into a second evacuated canister (i.e. field spike sample).

In order to better determine if a bias exists between methods, the individual values from the three daily runs for benzene and toluene were first averaged and then compared. Figure 7.5-1 shows the results in bar graph form. The upper bar graph contains the benzene data; the lower bar graph contains the toluene data. The VOST and Can benzene daily averages are generally within a factor of two, except for Location 5b (third day). At Location 5b the Can and VOST results were corrected for dilution gas flow (correction factor of 28.9). The Can results at Location 5b before dilution were approximately three times the DL on the third day, and less than the DL value on days 1 and 2. However, by incorporating the dilution factor the resulting values on day three appear abnormally high. The toluene concentrations were often near or less than the detection level for both methods (see Table 7.5-19). No trend between methods was observed for either compound.

The benzene and toluene daily averages at each location were then averaged and the results are shown in Figure 7.5-2. The benzene location averages are depicted on the upper bar graph; the toluene location averages are shown on the lower bar graph. The VOST benzene results are higher than the canister benzene values at Location 5a. The VOST benzene results at Location 4 are comparable to the canister values. Again the Can benzene values at Location 5b show the effect of using the 28.9 correction factor. The VOST toluene location averages were consistently higher than the Can toluene values at Locations 4, 5a, and 5b. However, this condition results primarily because the VOST DL values are higher than the Can DL values (see Table 7.5-19). The toluene location averages at 5b were less than the DL.

7.5.3 Conclusion

The following conclusions can be drawn from the above analyses:

- (1) Dichloromethane concentrations are artifact values and are probably due to contamination from DCM/methanol washing of the sampling manifold and associated equipment.
- (2) The VOCs, whether collected by VOST or canisters, were often either near the DL values or not detected. For those compounds with reported concentrations, the run to run concentration variability was usually less than a factor of two.
- (3) The VOST and canister collection methods generally agree within a factor of four. However, there does not seem to be a consistent trend between methods. This lack of a trend in the data may be due in part to the fact that the concentrations were quite low.

7.5.4 Recommendations

The following recommendations are made from the above analyses.

1. Greater care needs to be exerted to eliminate the solvent (dichloromethane) contamination or carry over into the sampling apparatus. This problem was consistently observed in both the VOST and canister sampling trains.
2. Battelle does not understand why both methods show such run-to-run variability. More internal QC checks may be helpful in focusing in on the problem. The use of internal standards spiked on the Tenax adsorbent or into the evacuated canister prior to sampling would aid in determining if reactions are occurring with the VOCs following sample collection.
3. The employment of an on-line continuous (or almost continuous) instrument (or almost continuous) for monitoring one or more of the VOCs would help a good deal in determining how much the VOC concentrations fluctuate in the flue gas stream. For example, an automated gas chromatograph with a *photonization or mass selective detector could provide data on one or two key VOC at intervals of 30 minutes or less.*

TABLE 7.5-1. VOC IN SUMMA GAS SAMPLES FROM ESP INLET (Location 4)-7/26/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-4-CAN-726-1	N-4-CAN-726-2	N-4-CAN-726-3	
Trichlorofluoromethane		4.49	5.27	6.39
1,1-Dichloroethene	ND<	2.46	ND<	2.46
Dichloromethane		3451.05 E	2424.72 E	2497.13 E
3-Chloropropene		100.51	63.65	65.05
1,1,2-Trichloro-1,2,2-trifluoroethane		21.28	25.37	30.76
1,1-Dichloroethane	ND<	2.51	ND<	2.51
cis-1,2-dichloroethene	ND<	2.46	ND<	2.46
Trichloromethane	ND<	3.02	ND<	3.02
1,2-Dichloroethane	ND<	2.51	ND<	2.51
1,1,1-Trichloroethane	ND<	3.38	ND<	3.38
Benzene		4.63	2.98	3.03
Carbon tetrachloride	ND<	3.91	ND<	3.91
1,2-Dichloropropane	ND<	2.87	ND<	2.87
Trichloroethene	ND<	3.33	ND<	3.33
cis-1,3-Dichloropropene	ND<	2.82	ND<	2.82
trans-1,3-Dichloropropene	ND<	2.82	ND<	2.82
1,1,2-Trichloroethane	ND<	3.38	ND<	3.38
Toluene	ND<	2.33	ND<	2.33
1,2-Dibromoethane	ND<	4.77	ND<	4.77
Tetrachloroethene	ND<	4.21	ND<	4.22
Chlorobenzene	ND<	2.87	ND<	2.87
Ethylbenzene	ND<	2.69	ND<	2.69
m+p-Xylene	ND<	2.69	ND<	2.69
Styrene	ND<	2.64	ND<	2.64
1,1,2,2-Tetrachloroethane	ND<	4.26	ND<	4.26
o-Xylene	ND<	2.69	ND<	2.69
4-Ethyl toluene	ND<	3.05	ND<	3.05
1,3,5-Trimethylbenzene	ND<	3.05	ND<	3.05
1,2,4-Trimethylbenzene	ND<	3.05	ND<	3.05
Benzyl chloride	ND<	3.22	ND<	3.22
m-Dichlorobenzene	ND<	3.73	ND<	3.73
p-Dichlorobenzene	ND<	3.73	ND<	3.73
o-Dichlorobenzene	ND<	3.73	ND<	3.73
1,2,4-Trichlorobenzene	ND<	4.59	ND<	4.59
Hexachlorobutadiene	ND<	6.62	ND<	6.62

ND< = not detected, value following ND< is the detection limit.

TABLE 7.5-2. VOC IN SUMMA GAS SAMPLES FROM ESP INLET (Location 4)-7/28/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-4-CAN-728-1		N-4-CAN-728-2		N-4-CAN-728-3	
Trichlorofluoromethane	ND	3.56	ND	3.56		6.93
1,1-Dichloroethene	ND	2.52	ND	2.52	ND	2.52
Dichloromethane		2501.95 E		1844.38 E		1691.44 E
3-Chloropropene		15.77		4.98		8.48
1,1,2-Trichloro-1,2,2-trifluoroethane		19.40		19.96		27.05
1,1-Dichloroethane	ND	2.57	ND	2.57	ND	2.57
cis-1,2-dichloroethene	ND	2.52	ND	2.52	ND	2.52
Trichloromethane	ND	3.09	ND	3.09		3.58
1,2-Dichloroethane	ND	2.57	ND	2.57	ND	2.57
1,1,1-Trichloroethane	ND	3.46	ND	3.46	ND	3.46
Benzene		3.10		4.92		5.32
Carbon tetrachloride	ND	4.00	ND	4.00	ND	4.00
1,2-Dichloropropane	ND	2.94	ND	2.94	ND	2.94
Trichloroethene	ND	3.41	ND	3.41	ND	3.41
cis-1,3-Dichloropropene		5.00	ND	2.88	ND	2.88
trans-1,3-Dichloropropene	ND	2.88	ND	2.88	ND	2.88
1,1,2-Trichloroethane	ND	3.46	ND	3.46	ND	3.46
Toluene	ND	2.39	ND	2.39	ND	2.39
1,2-Dibromoethane	ND	4.89	ND	4.89	ND	4.89
Tetrachloroethene	ND	4.31	ND	4.31	ND	4.32
Chlorobenzene	ND	2.94	ND	2.94	ND	2.94
Ethylbenzene	ND	2.76	ND	2.76	ND	2.76
m+p-Xylene	ND	2.76	ND	2.76	ND	2.76
Styrene	ND	2.70	ND	2.70	ND	2.70
1,1,2,2-Tetrachloroethane	ND	4.37	ND	4.37	ND	4.37
o-Xylene	ND	2.76	ND	2.76	ND	2.76
4-Ethyl toluene	ND	3.12	ND	3.12	ND	3.12
1,3,5-Trimethylbenzene	ND	3.12	ND	3.12	ND	3.12
1,2,4-Trimethylbenzene	ND	3.12		45.35		33.56
Benzyl chloride	ND	3.30		31.70		24.89
m-Dichlorobenzene	ND	3.82		10.66		8.14
p-Dichlorobenzene	ND	3.82		13.33		10.16
o-Dichlorobenzene	ND	3.82	ND	3.82	ND	3.82
1,2,4-Trichlorobenzene	ND	4.70	ND	4.70	ND	4.70
Hexachlorobutadiene	ND	6.78	ND	6.78	ND	6.78

TABLE 7.5-3. VOC IN SUMMA GAS SAMPLES FROM ESP INLET (Location 4) - 7/30/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-4-CAN-730-1	N-4-CAN-730-2	N-4-CAN-730-3	
Trichlorofluoromethane		5.10	3.65	3.69
1,1-Dichloroethene	ND*	2.48	ND*	2.48
Dichloromethane		660.75 E	164.13	136.79
3-Chloropropene		6.25	55.56	3.65
1,1,2-Trichloro-1,2,2-trifluoroethane		15.38	18.65	20.24
1,1-Dichloroethane	ND*	2.53	ND*	2.53
cis-1,2-dichloroethene	ND*	2.48	ND*	2.48
Trichloromethane	ND*	3.04	ND*	3.04
1,2-Dichloroethane	ND*	2.53	ND*	2.53
1,1,1-Trichloroethane	ND*	3.40	ND*	3.40
Benzene		15.65	17.77	20.47
Carbon tetrachloride	ND*	3.93	ND*	3.93
1,2-Dichloropropane	ND*	2.88	ND*	2.88
Trichloroethene	ND*	3.35	ND*	3.35
cis-1,3-Dichloropropene	ND*	2.83	ND*	2.83
trans-1,3-Dichloropropene	ND*	2.83	ND*	2.83
1,1,2-Trichloroethane	ND*	3.40	ND*	3.40
Toluene	ND*	2.35	ND*	2.35
1,2-Dibromoethane	ND*	4.80	ND*	4.80
Tetrachloroethene		10.93	12.70	12.66
Chlorobenzene	ND*	2.88	ND*	2.88
Ethylbenzene	ND*	2.71	ND*	2.71
m+p-Xylene	ND*	2.71	ND*	2.71
Styrene	ND*	2.65	3.64	2.65
1,1,2,2-Tetrachloroethane	ND*	4.29	ND*	4.29
o-Xylene	ND*	2.71	ND*	2.71
4-Ethyl toluene	ND*	3.06	14.07	3.06
1,3,5-Trimethylbenzene	ND*	3.06	ND*	3.06
1,2,4-Trimethylbenzene		91.32	80.91	73.58
Benzyl chloride		66.91	60.28	53.49
m-Dichlorobenzene		21.92	18.89	17.23
p-Dichlorobenzene		27.38	23.60	21.59
o-Dichlorobenzene	ND*	3.75	ND*	3.75
1,2,4-Trichlorobenzene	ND*	4.62	17.21	20.58
Hexachlorobutadiene	ND*	6.66	ND*	6.66

TABLE 7.5-4. VOC IN SUMMA GAS SAMPLES FROM ESP OUTLET (Location 5a) - 7/26/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-5A-CAN-726-1		N-5A-CAN-726-2		N-5A-CAN-726-3	
Trichlorofluoromethane		5.58		6.51		6.11
1,1-Dichloroethene	ND	3.11	ND	3.11	ND	3.11
Dichloromethane		887.36 E		416.26		320.76
3-Chloropropene		5.31		6.55		8.21
1,1,2-Trichloro-1,2,2-trifluoroethane		12.17		12.85		12.23
1,1-Dichloroethane	ND	3.17	ND	3.17	ND	3.17
cis-1,2-dichloroethene	ND	3.11	ND	3.11	ND	3.11
Trichloromethane	ND	3.81	ND	3.81	ND	3.81
1,2-Dichloroethane	ND	3.17	ND	3.17	ND	3.17
1,1,1-Trichloroethane	ND	4.26	ND	4.26	ND	4.26
Benzene		3.11		3.26		2.91
Carbon tetrachloride	ND	4.93	ND	4.93	ND	4.93
1,2-Dichloropropane	ND	3.62	ND	3.62	ND	3.62
Trichloroethene	ND	4.19	ND	4.19	ND	4.19
cis-1,3-Dichloropropene	ND	3.55	ND	3.55	ND	3.55
trans-1,3-Dichloropropene	ND	3.55	ND	3.55	ND	3.55
1,1,2-Trichloroethane	ND	4.26	ND	4.26	ND	4.26
Toluene	ND	2.94	ND	2.94	ND	2.94
1,2-Dibromoethane	ND	6.02	ND	6.02	ND	6.02
Tetrachloroethene	ND	5.31	ND	5.31	ND	5.32
Chlorobenzene	ND	3.62	ND	3.62	ND	3.62
Ethylbenzene	ND	3.40	ND	3.40	ND	3.40
m+p-Xylene	ND	3.40	ND	3.40	ND	3.40
Styrene	ND	3.33	ND	3.33	ND	3.33
1,1,2,2-Tetrachloroethane	ND	5.38	ND	5.38	ND	5.38
o-Xylene	ND	3.40	ND	3.40	ND	3.40
4-Ethyl toluene	ND	3.84	ND	3.84	ND	3.84
1,3,5-Trimethylbenzene	ND	3.84	ND	3.84	ND	3.84
1,2,4-Trimethylbenzene	ND	3.84	ND	3.84	ND	3.84
Benzyl chloride	ND	4.06	ND	4.06	ND	4.06
m-Dichlorobenzene	ND	4.70	ND	4.70	ND	4.70
p-Dichlorobenzene	ND	4.70	ND	4.70	ND	4.70
o-Dichlorobenzene	ND	4.70	ND	4.70	ND	4.70
1,2,4-Trichlorobenzene	ND	5.79	ND	5.79	ND	5.79
Hexachlorobutadiene	ND	8.35	ND	8.35	ND	8.35

TABLE 7.5--9. VOC IN DILUTE SUMMA GAS SAMPLES FROM ESP OUTLET (Location 5b) -7/30/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-5B-CAN-730-1	N-5B-CAN-730-2	N-5B-CAN-730-3
Trichlorofluoromethane	4.64	4.74	4.67
1,1-Dichloroethene	4.25 ND*	2.79 ND*	2.79
Dichloromethane	3191.86 E	1027.42 E	595.30
3-Chloropropene	27.42	34.01	19.65
1,1,2-Trichloro-1,2,2-trifluoroethane	14.54	15.29	15.12
1,1-Dichloroethane	ND*	2.85 ND*	2.85
cis-1,2-dichloroethene	ND*	3.04 ND*	2.79
Trichloromethane	ND*	3.43 ND*	3.43
1,2-Dichloroethane	ND*	2.85 ND*	2.85
1,1,1-Trichloroethane	ND*	3.83 ND*	3.83
Benzene	3.53	3.53	3.86
Carbon tetrachloride	ND*	4.43 ND*	4.43
1,2-Dichloropropane	ND*	3.25 ND*	3.25
Trichloroethene	ND*	3.77 ND*	3.77
cis-1,3-Dichloropropene	ND*	3.19 ND*	3.19
trans-1,3-Dichloropropene	ND*	3.19 ND*	3.19
1,1,2-Trichloroethane	ND*	3.83 ND*	3.83
Toluene	ND*	2.65 ND*	2.65
1,2-Dibromoethane	ND*	5.41 ND*	5.42
Tetrachloroethene	13.05	12.91	13.94
Chlorobenzene	ND*	3.25 ND*	3.25
Ethylbenzene	ND*	3.05 ND*	3.06
m+p-Xylene	ND*	3.05 ND*	3.06
Styrene	ND*	2.99 ND*	2.99
1,1,2,2-Tetrachloroethane	ND*	4.83 ND*	4.83
o-Xylene	ND*	3.05 ND*	3.06
4-Ethyl toluene	ND*	3.46 ND*	3.46
1,3,5-Trimethylbenzene	ND*	3.46 ND*	3.46
1,2,4-Trimethylbenzene	ND*	3.46 ND*	3.46
Benzyl chloride	ND*	3.65 ND*	3.65
m-Dichlorobenzene	ND*	4.23 ND*	4.23
p-Dichlorobenzene	ND*	4.23 ND*	4.23
o-Dichlorobenzene	ND*	4.23 ND*	4.23
1,2,4-Trichlorobenzene	ND*	5.21 ND*	5.21
Hexachlorobutadiene	ND*	7.51 ND*	7.51

Note! Concentrations need to be multiplied by average dilution factor of 28.9 for comparison with VOST sample.

TABLE 7.5-10. VOC IN VOST GAS SAMPLES FROM ESP INLET (Location 4) - 7/26/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N4VOS7261		N4VOS7262		N4VOS7263	
CHLOROMETHANE	ND	8.66	ND	4.52	ND	1.30
BROMOMETHANE	ND	8.66	ND	4.52	ND	1.30
VINYL CHLORIDE	ND	8.66	ND	4.52	ND	1.30
CHLOROETHANE	ND	8.66	ND	4.52	ND	1.30
METHYLENE CHLORIDE		257.17		50.63		6.91
ACETONE		1927.71		67.63		38.36
CARBON DISULFIDE		11.79	ND	4.52		1.35
1,1-DICHLOROETHENE		144.87		2.35 J		3.38
1,1-DICHLOROETHANE		3.47 J	ND	4.52	ND	1.30
TRANS-1,2-DICHLOROETHENE	ND	8.66	ND	4.52	ND	1.30
CHLOROFORM	ND	8.66	ND	4.52	ND	1.30
1,2-DICHLOROETHANE	ND	8.66	ND	4.52	ND	1.30
2-BUTANONE		38.47	ND	4.52	ND	1.30
1,1,1-TRICHLOROETHANE	ND	8.66	ND	4.52	ND	1.30
CARBON TETRACHLORIDE	ND	8.66	ND	4.52	ND	1.30
VINYL ACETATE	ND	8.66	ND	4.52	ND	1.30
BROMODICHLOROMETHANE	ND	8.66	ND	4.52		1.35
1,2-DICHLOROPROPANE	ND	8.66	ND	4.52	ND	1.30
CIS-1,3-DICHLOROPROPANE	ND	8.66	ND	4.52	ND	1.30
TRICHLOROETHENE	ND	8.66	ND	4.52	ND	1.30
DIBROMOCHLOROMETHANE	ND	8.66	ND	4.52	ND	1.30
1,1,2-TRICHLOROETHANE	ND	8.66	ND	4.52	ND	1.30
BENZENE		10.40		5.79		4.68
TRANS-1,3-DICHLOROPROPANE	ND	8.66	ND	4.52	ND	1.30
2-CHLOROETHYLVINYLEETHER	ND	8.66		7.41		5.98
BROMOFORM	ND	8.66	ND	4.52	ND	1.30
4-METHYL-2-PENTANONE	ND	8.66	ND	4.52	ND	1.30
2-HEXANONE	ND	8.66	ND	4.52	ND	1.30
TETRACHLOROETHENE	ND	8.66	ND	4.52	ND	1.30
1,1,2,2-TETRACHLOROETHANE	ND	8.66	ND	4.52	ND	1.30
TOLUENE		3.47 J	ND	4.52		1.92
CHLOROBENZENE	ND	8.66	ND	4.52	ND	1.30
ETHYLBENZENE	ND	8.66	ND	4.52		0.67 J
STYRENE	ND	8.66	ND	4.52	ND	1.30
XYLENES (TOTAL)	ND	8.66	ND	4.52		2.39

TABLE 7.5-11. VOC IN VOST GAS SAMPLES FROM ESP INLET (Location 4) - 7/28/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N4VOS7281		N4VOS7282		N4VOS7283	
CHLOROMETHANE	ND	9.51	ND	5.23	ND	1.87
BROMOMETHANE	ND	9.51	ND	5.23	ND	1.87
VINYL CHLORIDE	ND	9.51	ND	5.23	ND	1.87
CHLOROETHANE	ND	9.51	ND	5.23	ND	1.87
METHYLENE CHLORIDE		66.92		43.35		7.54
ACETONE		53.65		20.95		8.15
CARBON DISULFIDE	ND	9.51		5.24		3.43
1,1-DICHLOROETHENE	ND	9.51	ND	5.23	ND	1.87
1,1-DICHLOROETHANE	ND	9.51	ND	5.23	ND	1.87
TRANS-1,2-DICHLOROETHENE	ND	9.51	ND	5.23	ND	1.87
CHLOROFORM	ND	9.51	ND	5.23	ND	1.87
1,2-DICHLOROETHANE	ND	9.51	ND	5.23	ND	1.87
2-BUTANONE	ND	9.51	ND	5.23	ND	1.87
1,1,1-TRICHLOROETHANE	ND	9.51	ND	5.23	ND	1.87
CARBON TETRACHLORIDE	ND	9.51	ND	5.23	ND	1.87
VINYL ACETATE	ND	9.51	ND	5.23	ND	1.87
BROMODICHLOROMETHANE	ND	9.51	ND	5.23	ND	1.87
1,2-DICHLOROPROPANE	ND	9.51	ND	5.23	ND	1.87
CIS-1,3-DICHLOROPROPANE	ND	9.51	ND	5.23	ND	1.87
TRICHLOROETHENE	ND	9.51	ND	5.23	ND	1.87
DIBROMOCHLOROMETHANE	ND	9.51	ND	5.23	ND	1.87
1,1,2-TRICHLOROETHANE	ND	9.51	ND	5.23	ND	1.87
BENZENE	ND	9.51		10.26		7.25
TRANS-1,3-DICHLOROPROPANE	ND	9.51	ND	5.23	ND	1.87
2-CHLOROETHYL VINYLETHER	ND	9.51	ND	5.23	ND	1.87
BROMOFORM	ND	9.51	ND	5.23	ND	1.87
4-METHYL-2-PENTANONE	ND	9.51	ND	5.23	ND	1.87
2-HEXANONE	ND	9.51	ND	5.23	ND	1.87
TETRACHLOROETHENE	ND	9.51	ND	5.23	ND	1.87
1,1,2,2-TETRACHLOROETHANE	ND	9.51	ND	5.23	ND	1.87
TOLUENE	ND	9.51		2.10 J	ND	1.87
CHLOROBENZENE	ND	9.51	ND	5.23	ND	1.87
ETHYLBENZENE	ND	9.51	ND	5.23	ND	1.87
STYRENE	ND	9.51	ND	5.23	ND	1.87
XYLENES (TOTAL)	ND	9.51	ND	5.23	ND	1.87

TABLE 7.5-12. VOC IN VOST GAS SAMPLES FROM ESP INLET (Location 4) - 7/30/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N4VOS7301		N4VOS7302		N4VOS7303	
CHLOROMETHANE	ND	8.95	ND	4.92	ND	1.61
BROMOMETHANE	ND	8.95	ND	4.92	ND	1.61
VINYL CHLORIDE	ND	8.95	ND	4.92	ND	1.61
CHLOROETHANE	ND	8.95	ND	4.92	ND	1.61
METHYLENE CHLORIDE		396.10		26.62		3.90
ACETONE		21.86	ND	4.92	ND	1.61
CARBON DISULFIDE		11.82		9.66		3.75
1,1-DICHLOROETHENE	ND	8.95	ND	4.92	ND	1.61
1,1-DICHLOROETHANE	ND	8.95	ND	4.92	ND	1.61
TRANS-1,2-DICHLOROETHENE	ND	8.95	ND	4.92	ND	1.61
CHLOROFORM	ND	8.95	ND	4.92	ND	1.61
1,2-DICHLOROETHANE	ND	8.95	ND	4.92	ND	1.61
2-BUTANONE	ND	8.95	ND	4.92	ND	1.61
1,1,1-TRICHLOROETHANE	ND	8.95	ND	4.92	ND	1.61
CARBON TETRACHLORIDE	ND	8.95	ND	4.92	ND	1.61
VINYL ACETATE	ND	8.95	ND	4.92	ND	1.61
BROMODICHLOROMETHANE	ND	8.95	ND	4.92	ND	1.61
1,2-DICHLOROPROPANE	ND	8.95	ND	4.92	ND	1.61
CIS-1,3-DICHLOROPROPANE	ND	8.95	ND	4.92	ND	1.61
TRICHLOROETHENE	ND	8.95	ND	4.92	ND	1.61
DIBROMOCHLOROMETHANE	ND	8.95	ND	4.92	ND	1.61
1,1,2-TRICHLOROETHANE	ND	8.95	ND	4.92	ND	1.61
BENZENE		12.91		4.92		5.24
TRANS-1,3-DICHLOROPROPANE	ND	8.95	ND	4.92	ND	1.61
2-CHLOROETHYLVINYLEETHER	ND	8.95	ND	4.92	ND	1.61
BROMOFORM	ND	8.95	ND	4.92	ND	1.61
4-METHYL-2-PENTANONE	ND	8.95	ND	4.92	ND	1.61
2-HEXANONE	ND	8.95	ND	4.92		0.83 J
TETRACHLOROETHENE	ND	8.95	ND	4.92	ND	1.61
1,1,2,2-TETRACHLOROETHANE	ND	8.95	ND	4.92	ND	1.61
TOLUENE		5.74 J	ND	4.92		1.56 J
CHLOROBENZENE	ND	8.95	ND	4.92		0.64 J
ETHYLBENZENE	ND	8.95	ND	4.92	ND	1.61
STYRENE	ND	8.95	ND	4.92	ND	1.61
XYLENES (TOTAL)	ND	8.95	ND	4.92	ND	1.61

TABLE 7.5-13. VOC IN VOST GAS SAMPLES FROM ESP OUTLET (Location 5a) - 7/26/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N5AVOS7261		N5AVOS7262		N5AVOS7263	
CHLOROMETHANE	ND	14.79		40.71	ND	2.86
BROMOMETHANE	ND	14.79	ND	9.01	ND	2.86
VINYL CHLORIDE	ND	14.79	ND	9.01	ND	2.86
CHLOROETHANE	ND	14.79	ND	9.01	ND	2.86
METHYLENE CHLORIDE		137.45		11.22		1.37 J
ACETONE		84.13		18.37		7.09
CARBON DISULFIDE		8.89 J	ND	9.01		2.74 J
1,1-DICHLOROETHENE	ND	14.79	ND	9.01	ND	2.86
1,1-DICHLOROETHANE	ND	14.79	ND	9.01	ND	2.86
TRANS-1,2-DICHLOROETHENE	ND	14.79	ND	9.01	ND	2.86
CHLOROFORM	ND	14.79	ND	9.01	ND	2.86
1,2-DICHLOROETHANE	ND	14.79	ND	9.01	ND	2.86
2-BUTANONE	ND	14.79	ND	9.01	ND	2.86
1,1,1-TRICHLOROETHANE	ND	14.79	ND	9.01	ND	2.86
CARBON TETRACHLORIDE	ND	14.79	ND	9.01	ND	2.86
VINYL ACETATE	ND	14.79	ND	9.01	ND	2.86
BROMODICHLOROMETHANE	ND	14.79	ND	9.01	ND	2.86
1,2-DICHLOROPROPANE	ND	14.79	ND	9.01	ND	2.86
CIS-1,3-DICHLOROPROPANE	ND	14.79	ND	9.01	ND	2.86
TRICHLOROETHENE	ND	14.79	ND	9.01	ND	2.86
DIBROMOCHLOROMETHANE	ND	14.79	ND	9.01	ND	2.86
1,1,2-TRICHLOROETHANE	ND	14.79	ND	9.01	ND	2.86
BENZENE		16.00		8.29 J		6.52
TRANS-1,3-DICHLOROPROPANE	ND	14.79	ND	9.01	ND	2.86
2-CHLOROETHYLVINYLEETHER	ND	14.79	ND	9.01	ND	2.86
BROMOFORM	ND	14.79	ND	9.01	ND	2.86
4-METHYL-2-PENTANONE	ND	14.79	ND	9.01	ND	2.86
2-HEXANONE	ND	14.79	ND	9.01	ND	2.86
TETRACHLOROETHENE		14.22 J		6.48 J	ND	2.86
1,1,2,2-TETRACHLOROETHANE	ND	14.79	ND	9.01	ND	2.86
TOLUENE		27.84		5.76 J		1.49 J
CHLOROBENZENE	ND	14.79	ND	9.01	ND	2.86
ETHYLBENZENE	ND	14.79	ND	9.01	ND	2.86
STYRENE	ND	14.79	ND	9.01	ND	2.86
XYLENES (TOTAL)	ND	14.79	ND	9.01	ND	2.86

TABLE 7.5-14. VOC IN VOST GAS SAMPLES FROM ESP OUTLET (Location 5a) - 7/28/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N5AVOS7281		N5AVOS7282		N5AVOS7283	
CHLOROMETHANE	ND	16.07	ND	7.85	ND	2.58
BROMOMETHANE	ND	16.07		3.77 J	ND	2.58
VINYL CHLORIDE	ND	16.07	ND	7.85	ND	2.58
CHLOROETHANE	ND	16.07	ND	7.85	ND	2.58
METHYLENE CHLORIDE		43.07		61.25		3.50
ACETONE		44.36		7.22 J		1.85 J
CARBON DISULFIDE		21.86		6.60 J		2.89
1,1-DICHLOROETHENE	ND	16.07	ND	7.85	ND	2.58
1,1-DICHLOROETHANE	ND	16.07	ND	7.85	ND	2.58
TRANS-1,2-DICHLOROETHENE	ND	16.07	ND	7.85	ND	2.58
CHLOROFORM	ND	16.07	ND	7.85	ND	2.58
1,2-DICHLOROETHANE	ND	16.07	ND	7.85	ND	2.58
2-BUTANONE		46.93	ND	7.85	ND	2.58
1,1,1-TRICHLOROETHANE	ND	16.07	ND	7.85	ND	2.58
CARBON TETRACHLORIDE	ND	16.07	ND	7.85	ND	2.58
VINYL ACETATE	ND	16.07	ND	7.85	ND	2.58
BROMODICHLOROMETHANE	ND	16.07	ND	7.85	ND	2.58
1,2-DICHLOROPROPANE	ND	16.07	ND	7.85	ND	2.58
CIS-1,3-DICHLOROPROPANE	ND	16.07	ND	7.85	ND	2.58
TRICHLOROETHENE	ND	16.07	ND	7.85	ND	2.58
DIBROMOCHLOROMETHANE	ND	16.07	ND	7.85	ND	2.58
1,1,2-TRICHLOROETHANE		8.36 J	ND	7.85	ND	2.58
BENZENE		27.00		13.82		12.06
TRANS-1,3-DICHLOROPROPANE	ND	16.07	ND	7.85	ND	2.58
2-CHLOROETHYLVINYLEETHER	ND	16.07	ND	7.85	ND	2.58
BROMOFORM		12.86 J		7.85	ND	2.58
4-METHYL-2-PENTANONE		45.64	ND	7.85	ND	2.58
2-HEXANONE		88.07	ND	7.85	ND	2.58
TETRACHLOROETHENE	ND	16.07	ND	7.85	ND	2.58
1,1,2,2-TETRACHLOROETHANE	ND	16.07	ND	7.85	ND	2.58
TOLUENE		7.07 J	ND	7.85	ND	2.58
CHLOROBENZENE	ND	16.07	ND	7.85	ND	2.58
ETHYLBENZENE	ND	16.07	ND	7.85	ND	2.58
STYRENE	ND	16.07	ND	7.85	ND	2.58
XYLENES (TOTAL)	ND	16.07	ND	7.85	ND	2.58

TABLE 7.5-15. VOC IN VOST GAS SAMPLES FROM ESP OUTLET (Location 5a) - 7/30/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N5AVOS7301		N5AVOS7303	
CHLOROMETHANE	ND<	13.31	ND<	2.38
BROMOMETHANE	ND<	13.31	ND<	2.38
VINYL CHLORIDE	ND<	13.31	ND<	2.38
CHLOROETHANE	ND<	13.31	ND<	2.38
METHYLENE CHLORIDE		26.64		5.43
ACETONE		138.00		4.86
CARBON DISULFIDE		19.18		9.90
1,1-DICHLOROETHENE	ND<	13.31	ND<	2.38
1,1-DICHLOROETHANE	ND<	13.31	ND<	2.38
TRANS-1,2-DICHLOROETHENE	ND<	13.31	ND<	2.38
CHLOROFORM	ND<	13.31	ND<	2.38
1,2-DICHLOROETHANE	ND<	13.31	ND<	2.38
2-BUTANONE	ND<	13.31	ND<	2.38
1,1,1-TRICHLOROETHANE	ND<	13.31	ND<	2.38
CARBON TETRACHLORIDE	ND<	13.31	ND<	2.38
VINYL ACETATE	ND<	13.31	ND<	2.38
BROMODICHLOROMETHANE	ND<	13.31	ND<	2.38
1,2-DICHLOROPROPANE	ND<	13.31	ND<	2.38
CIS-1,3-DICHLOROPROPANE	ND<	13.31	ND<	2.38
TRICHLOROETHENE	ND<	13.31	ND<	2.38
DIBROMOCHLOROMETHANE	ND<	13.31	ND<	2.38
1,1,2-TRICHLOROETHANE	ND<	13.31	ND<	2.38
BENZENE		16.52		6.86
TRANS-1,3-DICHLOROPROPANE	ND<	13.31	ND<	2.38
2-CHLOROETHYLVINYLETHER	ND<	13.31	ND<	2.38
BROMOFORM	ND<	13.31	ND<	2.38
4-METHYL-2-PENTANONE	ND<	13.31	ND<	2.38
2-HEXANONE	ND<	13.31	ND<	2.38
TETRACHLOROETHENE	ND<	13.31	ND<	2.38
1,1,2,2-TETRACHLOROETHANE	ND<	13.31	ND<	2.38
TOLUENE	ND<	13.31		1.71 J
CHLOROBENZENE	ND<	13.31	ND<	2.38
ETHYLBENZENE	ND<	13.31	ND<	2.38
STYRENE	ND<	13.31	ND<	2.38
XYLENES (TOTAL)	ND<	13.31	ND<	2.38

TABLE 7.5-16. VOC IN DILUTE VOST GAS SAMPLES FROM ESP OUTLET (Location 5b) - 7/26/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N5BVOS7261		N5BVOS7262		N5BVOS7263
CHLOROMETHANE		239.68		122.71	ND*	3.17
BROMOMETHANE	ND*	18.42	ND*	10.55	ND*	3.17
VINYL CHLORIDE	ND*	18.42	ND*	10.55	ND*	3.17
CHLOROETHANE	ND*	18.42	ND*	10.55	ND*	3.17
METHYLENE CHLORIDE		120.58		45.54		5.58
ACETONE		78.67		29.10		6.08
CARBON DISULFIDE	ND*	18.42		4.64 J		2.92 J
1,1-DICHLOROETHENE	ND*	18.42	ND*	10.55	ND*	3.17
1,1-DICHLOROETHANE	ND*	18.42	ND*	10.55	ND*	3.17
TRANS-1,2-DICHLOROETHENE	ND*	18.42	ND*	10.55	ND*	3.17
CHLOROFORM	ND*	18.42	ND*	10.55	ND*	3.17
1,2-DICHLOROETHANE	ND*	18.42	ND*	10.55	ND*	3.17
2-BUTANONE	ND*	18.42	ND*	10.55	ND*	3.17
1,1,1-TRICHLOROETHANE	ND*	18.42	ND*	10.55	ND*	3.17
CARBON TETRACHLORIDE	ND*	18.42	ND*	10.55	ND*	3.17
VINYL ACETATE	ND*	18.42	ND*	10.55	ND*	3.17
BROMODICHLOROMETHANE	ND*	18.42	ND*	10.55	ND*	3.17
1,2-DICHLOROPROPANE	ND*	18.42	ND*	10.55	ND*	3.17
CIS-1,3-DICHLOROPROPANE	ND*	18.42	ND*	10.55	ND*	3.17
TRICHLOROETHENE	ND*	18.42	ND*	10.55	ND*	3.17
DIBROMOCHLOROMETHANE	ND*	18.42	ND*	10.55	ND*	3.17
1,1,2-TRICHLOROETHANE	ND*	18.42	ND*	10.55	ND*	3.17
BENZENE	ND*	18.42	ND*	10.55	ND*	3.17
TRANS-1,3-DICHLOROPROPANE	ND*	18.42	ND*	10.55	ND*	3.17
2-CHLOROETHYLVINYLEETHER	ND*	18.42	ND*	10.55	ND*	3.17
BROMOFORM	ND*	18.42	ND*	10.55	ND*	3.17
4-METHYL-2-PENTANONE	ND*	18.42	ND*	10.55	ND*	3.17
2-HEXANONE	ND*	18.42	ND*	10.55	ND*	3.17
TETRACHLOROETHENE	ND*	18.42	ND*	10.55	ND*	3.17
1,1,2,2-TETRACHLOROETHANE	ND*	18.42	ND*	10.55	ND*	3.17
TOLUENE	ND*	18.42	ND*	10.55	ND*	3.17
CHLOROBENZENE	ND*	18.42	ND*	10.55	ND*	3.17
ETHYLBENZENE	ND*	18.42	ND*	10.55	ND*	3.17
STYRENE	ND*	18.42	ND*	10.55	ND*	3.17
XYLENES (TOTAL)	ND*	18.42	ND*	10.55	ND*	3.17

TABLE 7.5-17. VOC IN DILUTE VOST GAS SAMPLES FROM ESP OUTLET (Location 5b) - 7/28/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N5BVOS7281		N5BVOS7282		N5BVOS7283
CHLOROMETHANE	ND	34.62		132.64		43.40
BROMOMETHANE	ND	34.62	ND	8.69	ND	2.60
VINYL CHLORIDE	ND	34.62	ND	8.69	ND	2.60
CHLOROETHANE	ND	34.62	ND	8.69	ND	2.60
METHYLENE CHLORIDE		178.29		25.41		6.77
ACETONE		24.88 J		7.31 J		2.50 J
CARBON DISULFIDE		45.61	ND	8.69	ND	2.60
1,1-DICHLOROETHENE	ND	34.62	ND	8.69	ND	2.60
1,1-DICHLOROETHANE	ND	34.62	ND	8.69	ND	2.60
TRANS-1,2-DICHLOROETHENE	ND	34.62	ND	8.69	ND	2.60
CHLOROFORM	ND	34.62	ND	8.69	ND	2.60
1,2-DICHLOROETHANE	ND	34.62	ND	8.69	ND	2.60
2-BUTANONE	ND	34.62	ND	8.69	ND	2.60
1,1,1-TRICHLOROETHANE		114.71	ND	8.69	ND	2.60
CARBON TETRACHLORIDE	ND	34.62	ND	8.69	ND	2.60
VINYL ACETATE	ND	34.62	ND	8.69	ND	2.60
BROMODICHLOROMETHANE	ND	34.62	ND	8.69	ND	2.60
1,2-DICHLOROPROPANE	ND	34.62	ND	8.69	ND	2.60
CIS-1,3-DICHLOROPROPANE	ND	34.62	ND	8.69	ND	2.60
TRICHLOROETHENE	ND	34.62	ND	8.69	ND	2.60
DIBROMOCHLOROMETHANE	ND	34.62	ND	8.69	ND	2.60
1,1,2-TRICHLOROETHANE	ND	34.62	ND	8.69	ND	2.60
BENZENE	ND	34.62	ND	8.69	ND	2.60
TRANS-1,3-DICHLOROPROPANE	ND	34.62	ND	8.69	ND	2.60
2-CHLOROETHYLVINYLETHER	ND	34.62	ND	8.69	ND	2.60
BROMOFORM	ND	34.62	ND	8.69	ND	2.60
4-METHYL-2-PENTANONE	ND	34.62	ND	8.69	ND	2.60
2-HEXANONE	ND	34.62	ND	8.69	ND	2.60
TETRACHLOROETHENE	ND	34.62	ND	8.69	ND	2.60
1,1,2,2-TETRACHLOROETHANE	ND	34.62	ND	8.69	ND	2.60
TOLUENE	ND	34.62	ND	8.69	ND	2.60
CHLOROBENZENE	ND	34.62	ND	8.69	ND	2.60
ETHYLBENZENE	ND	34.62	ND	8.69	ND	2.60
STYRENE	ND	34.62	ND	8.69	ND	2.60
XYLENES (TOTAL)	ND	34.62	ND	8.69	ND	2.60

TABLE 7.5-18. VOC IN DILUTE VOST GAS SAMPLES FROM ESP OUTLET (Location 5b)-7/30/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N5BVOS7301		N5BVOS7302		N5BVOS7303
CHLOROMETHANE		86.59		41.99		14.24
BROMOMETHANE	ND	15.78	ND	10.60		5.60
VINYL CHLORIDE	ND	15.78	ND	10.60	ND	2.92
CHLOROETHANE	ND	15.78	ND	10.60	ND	2.92
METHYLENE CHLORIDE		42.98		7.63 J		3.03
ACETONE		41.72		13.57		3.85
CARBON DISULFIDE		15.17 J	ND	10.60	ND	2.92
1,1-DICHLOROETHENE	ND	15.78	ND	10.60	ND	2.92
1,1-DICHLOROETHANE	ND	15.78	ND	10.60	ND	2.92
TRANS-1,2-DICHLOROETHENE	ND	15.78	ND	10.60	ND	2.92
CHLOROFORM	ND	15.78	ND	10.60	ND	2.92
1,2-DICHLOROETHANE	ND	15.78	ND	10.60	ND	2.92
2-BUTANONE	ND	15.78	ND	10.60	ND	2.92
1,1,1-TRICHLOROETHANE	ND	15.78	ND	10.60	ND	2.92
CARBON TETRACHLORIDE	ND	15.78	ND	10.60	ND	2.92
VINYL ACETATE	ND	15.78	ND	10.60	ND	2.92
BROMODICHLOROMETHANE	ND	15.78	ND	10.60	ND	2.92
1,2-DICHLOROPROPANE	ND	15.78	ND	10.60	ND	2.92
CIS-1,3-DICHLOROPROPANE	ND	15.78	ND	10.60	ND	2.92
TRICHLOROETHENE	ND	15.78	ND	10.60	ND	2.92
DIBROMOCHLOROMETHANE	ND	15.78	ND	10.60	ND	2.92
1,1,2-TRICHLOROETHANE	ND	15.78	ND	10.60	ND	2.92
BENZENE	ND	15.78	ND	10.60	ND	2.92
TRANS-1,3-DICHLOROPROPANE	ND	15.78	ND	10.60	ND	2.92
2-CHLOROETHYLVINYLETHER	ND	15.78	ND	10.60	ND	2.92
BROMOFORM	ND	15.78	ND	10.60	ND	2.92
4-METHYL-2-PENTANONE	ND	15.78	ND	10.60	ND	2.92
2-HEXANONE	ND	15.78	ND	10.60	ND	2.92
TETRACHLOROETHENE	ND	15.78	ND	10.60	ND	2.92
1,1,2,2-TETRACHLOROETHANE	ND	15.78	ND	10.60	ND	2.92
TOLUENE	ND	15.78	ND	10.60	ND	2.92
CHLOROBENZENE	ND	15.78	ND	10.60	ND	2.92
ETHYLBENZENE	ND	15.78	ND	10.60	ND	2.92
STYRENE	ND	15.78	ND	10.60	ND	2.92
XYLENES (TOTAL)	ND	15.78	ND	10.60	ND	2.92

TABLE 7.5-19. COMPARISON OF VOST AND CANISTER RESULTS FOR SELECT COMPOUNDS ($\mu\text{g}/\text{Nm}^3$)

Test Run I.D.	Dichloromethane		Benzene		Toluene		
	CAN	VOST	CAN	VOST	CAN	VOST	
N-4-726-1	3451.05 E	257.17	4.63	10.4	ND<	2.33	3.47 J
N-4-726-2	2424.72 E	50.63	2.98	5.79	ND<	2.33	ND< 4.52
N-4-726-3	2497.13 E	6.91	3.03	4.68	ND<	2.33	1.92
N-4-728-1	2501.95 E	66.92	3.10	ND<	ND<	2.39	ND< 9.51
N-4-728-2	1844.38 E	43.35	4.92	10.2	ND<	2.39	2.1 J
N-4-728-3	1691.44 E	7.54	5.32	7.25	ND<	2.39	ND< 1.87
N-4-730-1	660.75 E	396.1	15.65	12.9	ND<	2.35	5.74 J
N-4-730-2	164.13	26.62	17.77	4.92	ND<	2.35	ND< 4.92
N-4-730-3	136.79	3.9	20.47	5.24	ND<	2.35	1.56 J
N-5A-726-1	887.36 E	137.45	3.11	16	ND<	2.94	27.8
N-5A-726-2	416.26	11.22	3.26	8.29 J	ND<	2.94	5.76 J
N-5A-726-3	320.76	1.37 J	2.91	6.52	ND<	2.94	1.49 J
N-5A-728-1	8271.18 E	43.07	2.56	27	ND<	9.70	7.07 J
N-5A-728-2	2489.22 E	61.25	ND<	13.8	ND<	2.84	ND< 7.85
N-5A-728-3	1134.75 E	3.5	ND<	12.0	ND<	2.84	ND< 2.58
N-5A-730-1	5550.31 E	26.64	5.27	16.5	ND<	5.50	ND< 13.3
N-5A-730-2	5341.93 E	5.43	5.89	6.86	ND<	2.65	1.71 J
N-5A-730-3	6498.64 E	120.58	5.29	8.86	ND<	3.23	18.4
N-5B-726-1	266.747	45.54	ND<	18.4	ND<	2.94	ND< 10.5
N-5B-726-2	ND<	2.72	ND<	10.5	ND<	2.94	ND< 3.17
N-5B-726-3	404.6	5.58	ND<	3.17	ND<	2.94	ND< 34.6
N-5B-728-1	18986.4	178.29	ND<	34.6	ND<	2.84	ND< 8.69
N-5B-728-2	1781.10	25.41	ND<	8.69	ND<	2.84	ND< 2.6
N-5B-728-3	704.293	6.77	ND<	2.6	ND<	2.84	ND< 15.7
N-5B-730-1	92244.7 E	42.98	102.	15.7	ND<	2.65	ND< 10.6
N-5B-730-2	29692.4 E	7.63 J	102.	10.6	ND<	2.65	ND< 2.92
N-5B-730-3	17204.1	3.03	111.	2.92	ND<	2.65	ND< 2.92

ND< indicates that the compound was not detected.

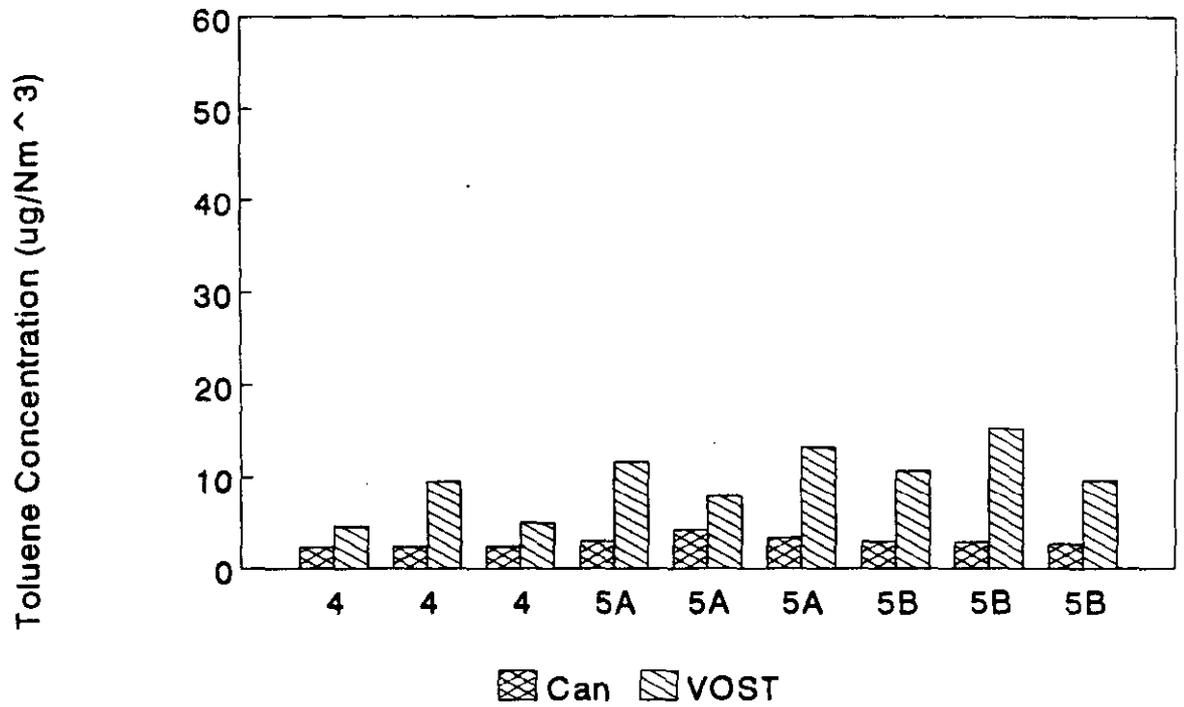
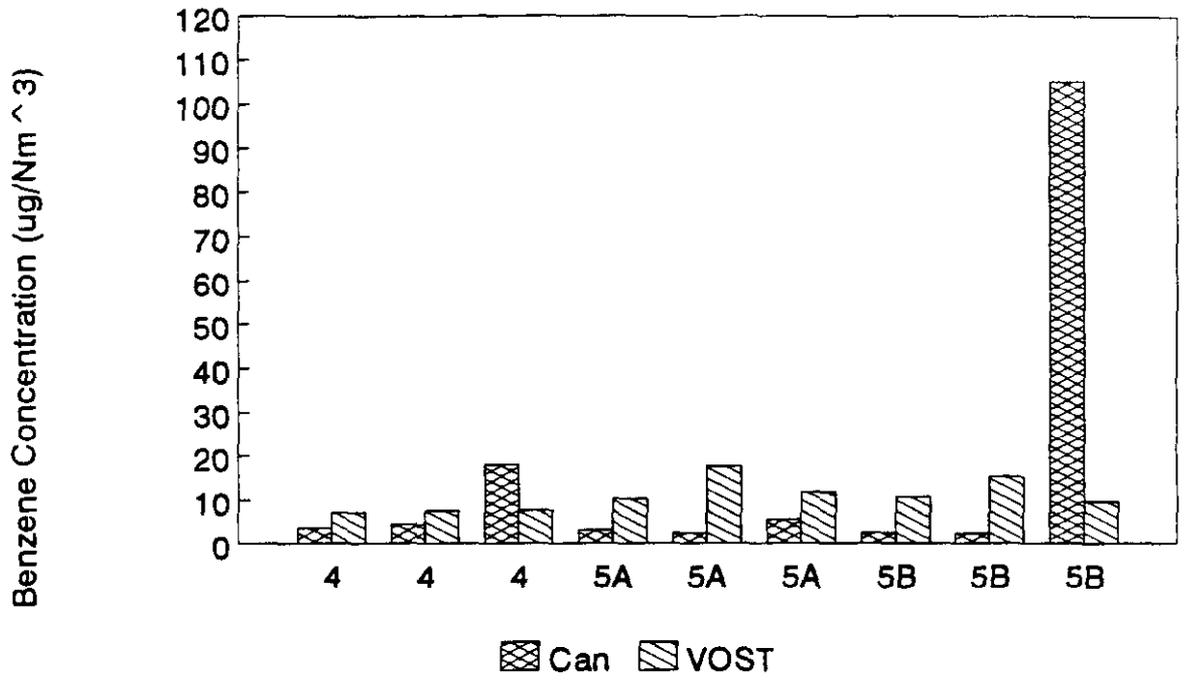


Figure 7.5-1. Can vs VOST comparison for benzene and toluene daily averages

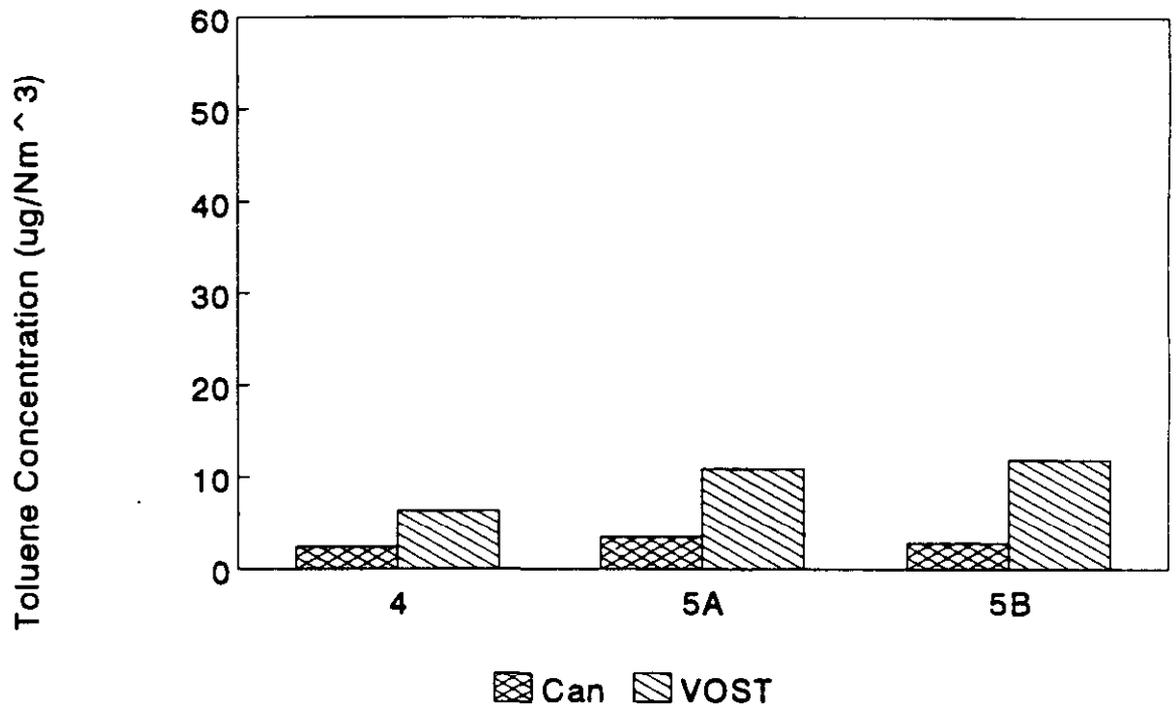
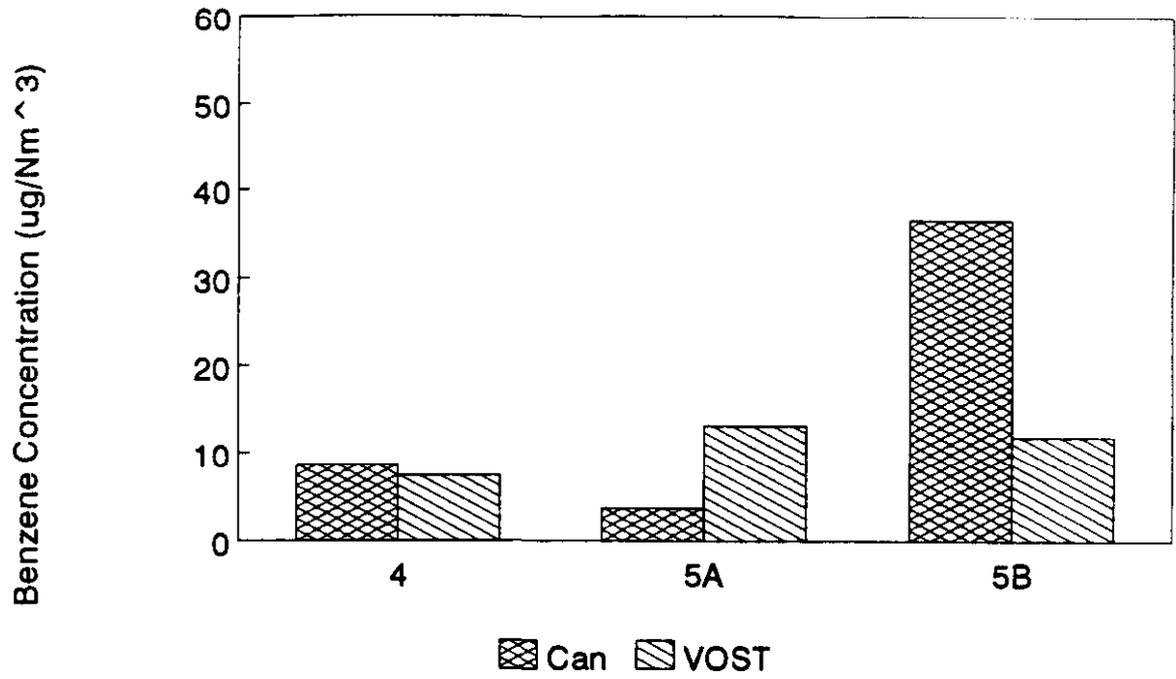


Figure 7.5-2. Can vs VOST comparison for benzene and toluene location averages

7.6 Effect of Soot Blowing on Element Concentrations in Stack Gas

7.6.1 Introduction

High volume (HV) sampling was originally added to the scope of work in order to evaluate the potential for increased arsenic emissions during soot blowing events. HV sampling was specified so that adequate sample volume could be obtained during the relatively short term (~2 hours) of each soot blowing event. As conducted, the HV sampling included two runs on each of the three inorganic sampling days, the recoveries from which were analyzed for the full complement of elements reported for the Multi-Metals (Method 29, M29) runs. All HV samples were taken at the hot stack (Location 5a).

The two HV samples collected on each inorganic sampling day consisted of a two hour sample taken during a soot blowing event (prior to the beginning of the regularly scheduled sampling), and a three hour sample taken during the period of regularly scheduled sampling under normal conditions, i.e., without soot blowing. Accordingly, six HV samples were taken; three during soot blowing, and three during normal operation.

Sampling was conducted according to the general provisions of Oregon Department of Environmental Quality (ODEQ) Method 8 (High Volume Sampling of Stationary Source Particulate Emissions), with modifications to accommodate the relatively severe flue gas conditions (temperature, moisture, SO₂) encountered at Niles. The sampling train consisted of an oversized (~0.88 inch I.D.) stainless steel nozzle and probe, a Teflon-lined 8-in. x 10-in. filter holder, a calibrated flow metering tube with a sharp edged orifice, a flexible exhaust line and a variable speed high volume blower. Samples were taken isokinetically from a single point in the stack at a rate of 10-15 scfm. The train was operated with the entire probe in-stack, and the filter holder was heated. Despite these efforts, there were signs of acid condensation within the sampling train on all runs. At the time of testing this was not considered to be prohibitive, because the analyte of interest (arsenic) is not a component of stainless steel. However, subsequent analyses for other elements typically alloyed with stainless steel (chromium, nickel, molybdenum, manganese) must be considered compromised.

The recovered sample from each run consisted of the 8-in. x 10-in. quartz filter, plus acetone and dilute nitric acid rinses of the nozzle, probe and filter holder front-half. The nitric acid rinse was not originally planned, but was considered necessary for complete recovery given the acid condensation problems encountered.

7.6.2 Data Analysis

The HV analytical results are presented in Tables 7.6-1 and 7.6-2 for the normal conditions and soot blowing, respectively. The results are in units of $\mu\text{g}/\text{Ncm}$ for each of the elements (as noted above, chromium, manganese, molybdenum, and nickel values may be compromised by the stainless steel probe).

Comparing the averages and standard deviations of the concentration results indicates no significant differences between the soot blowing and standard operating conditions, with the possible exception of a complete absence of sodium and potassium during soot blowing. Arsenic is consistently in the 8-15 $\mu\text{g}/\text{Ncm}$ range, averaging 13 $\mu\text{g}/\text{Ncm}$ for the soot blowing condition and 12 $\mu\text{g}/\text{Ncm}$ for the operating condition. The standard deviations of these results are 4.1 and 3.1, respectively. Considering these results and presuming the flue gas volumetric flow to be the same for both conditions (Niles plant personnel have confirmed full-load operation throughout both test periods) it might be concluded that soot blowing has no significant impact on the emission of any elements of interest. However, caution is indicated by also considering total particulate loading and elemental results from the M29 runs.

Total particulate loadings as measured by the HV sampling during the soot blowing and during normal operating conditions were quite the opposite of expectations. The average particulate loading from the soot blowing tests was only 5.4 mg/Ncm compared with an average of 28.4 mg/Ncm from the normal condition tests. Both conditions were tested with the same equipment, by the same procedures, through the same port, and at the same point in the duct. Sampling rates were very nearly the same, as dictated by stack velocity, and only the sampling times differed significantly (as described above) based on the expectation for lower loading during the standard condition. The total particulate loading as measured by the M29 runs (N-5A-MUM-727,729,731) averaged 32.4 mg/Ncm.

This is considered more accurate than the HV measurements because it is based on EPA Method 5 with full traversing. The agreement of particulate loading values from M29 and normal condition HV runs lends some credibility to the normal condition HV tests, particularly because they were conducted within the time frame of the M29 runs. Although the low loading indicated during the soot blowing tests is not impossible, it remains unexplained, and due caution is indicated.

Comparison of the M29 elemental results with those from the HV runs is also interesting. The M29 results indicate concentrations of virtually all of the elements analyzed which are greater than those measured by the HV methods (the M29 tests were all run during the normal operating conditions). Some of these differences are within the standard deviation, but most are outside of it. For example, the average arsenic concentration measured during soot blowing by the HV method is 13 $\mu\text{g}/\text{Ncm}$. This compares with 12 $\mu\text{g}/\text{Ncm}$ by the HV method, and 70 $\mu\text{g}/\text{Ncm}$ by the M29 method, both during normal operation. In terms of $\mu\text{g}/\text{gram}$ of total particulate, the concentrations are 2,216, 404, and 2,252, respectively. The same general trend is apparent across all of the detected elements (except those compromised as discussed above). Again, the greater confidence has to be placed with the M29 results.

Given the inconsistencies discussed above the HV results must be considered with due caution, and the issue of soot blowing's impact on the emission of trace metals needs further study.

7.6.3 Recommendations

Given the inconsistencies discussed above the HV results must be considered with due caution, and the issue of soot blowing's impact on the emission of trace metals needs further study. It is recommended that a separate study be conducted to assess the impact of soot blowing events on specific toxic metals emissions. Based on the M29 elemental concentrations measured at Location 5a, this same method could achieve adequate detection limits for most analytes (arsenic and selenium included) if run for 2 hours during a soot blow. This method is superior to the modified high volume method described above because it allows traversing, prevents condensation, provides all glass wetted surfaces, and

records total dry gas sample volume. Accordingly, all of the problems associated with adaptation of the above high volume method are avoided, without significantly sacrificing detection limits.

If further improvements in detection limits are deemed necessary, it is recommended that SASS (Source Assessment Sampling System) equipment be adapted to the sampling and analytical procedures of M29. The SASS train is capable of a 4 dcfm maximum sampling rate as compared with a 0.75 dcfm maximum rate associated with the M29 train, and provides the same advantages as described above.

TABLE 7.6-1. ELEMENTS IN GAS SAMPLES DURING NORMAL OPERATIONS ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5a-HVS-727	N-5a-HVS-729	N-5a-HVS-731	AVERAGE	SD
Aluminum	896	119	1006	673	483
Potassium	268	36.2	88.1	131	122
Silicon	NA	NA	NA	NA	NA
Sodium	557	81.0	147	262	258
Titanium	16.0	11.4	15.2	14	2.5
Antimony	0.482	0.461	0.596	0.51	0.07
Arsenic	14.3	8.29	12.5	12	3.1
Barium	4.42	2.37	2.69	3.2	1.1
Beryllium	0.00	0.00	0.072	0.02	0.04
Boron	NA	NA	NA	NA	NA
Cadmium	0.00	0.00	0.00	0.00	0.00
Chromium	101	2.99	23.5	43	52
Cobalt	0.928	0.424	0.106	0.49	0.41
Copper	1.48	0.806	1.05	1.1	0.34
Lead	4.51	3.49	3.46	3.8	0.60
Manganese	10.9	3.89	2.84	5.9	4.4
Molybdenum	19.3	0.636	7.04	9.0	9.5
Nickel	62.6	8.23	26.4	32	28
Selenium	55.3	39.5	35.9	44	10
Vanadium	1.24	0.640	1.54	1.1	0.46

SD = Standard deviation.

NA = Sample not available, sample not analyzed, or data not available.

TABLE 7.6-2. ELEMENTS IN GAS SAMPLES DURING SOOT BLOWING OPERATIONS ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-5A-HVS-727	N-5A-HVS-729	N-5A-HVS-731	AVERAGE	SD
Aluminum	0.00 C	786	89.4	292	430
Potassium	0.00 C	0.00 C	0.00	0.00	0.00
Silicon	NA	NA	NA	NA	NA
Sodium	0.00 C	0.00 C	0.00 C	0.00	0.00
Titanium	8.58	8.07	14.2	10	3.4
Antimony	0.383	0.291	0.489	0.39	0.10
Arsenic	15.7	8.40	15.4	13	4.1
Barium	0.369	0.00 C	1.26	0.54	0.65
Beryllium	0.052	0.00	0.079	0.04	0.04
Boron	NA	NA	NA	NA	NA
Cadmium	0.00	0.00	0.00	0.00	0.00
Chromium	9.37	187	33.1	76	96
Cobalt	0.00	1.24	0.852	0.70	0.63
Copper	0.492	0.796	2.75	1.3	1.2
Lead	3.01	1.98	1.83	2.3	0.64
Manganese	1.44	23.6	6.60	11	12
Molybdenum	3.01	3.13	32.7	13	17
Nickel	5.60	47.6	57.5	37	28
Selenium	45.1	24.6	23.7	31	12
Vanadium	0.632	1.62	1.27	1.2	0.50

SD = Standard deviation.

NA = Sample not available, sample not analyzed, or data not available.

C = Blank-corrected concentration below detection/calibration limit.

7.7 Mercury Results for Individual Method 29 Components

The individual components of the Method 29 (M29) train were analyzed separately for mercury at the request of DOE, rather than combining front-half and back-half components as is standard practice in Method 29 procedures. The results for these individual component analyses are presented in Table 7.7-1, for each of the three inorganic sampling days at both the ESP inlet (Location 4) and the ESP outlet (Location 5a).

The results in Table 7.7-1 show that at both locations the great majority of mercury was found in the impinger components of the M29 train. At the ESP inlet 93 to 95 percent was in the impingers, and at the ESP outlet 99 to 100 percent was in the impingers. At the inlet, the probe rinse, filter, and large cyclone captured small amounts of the total mercury, due to the high particulate loading at that location. In all cases, most of the mercury (73 to 94 percent, averaging 83 percent) was captured in the H₂O₂ impingers; the KMnO₄ impingers (which are located downstream of the H₂O₂ impingers in the Method 29 train) captured a smaller fraction of the mercury (5 to 22 percent, averaging 14 percent).

TABLE 7.7-1. RESULTS FOR MERCURY IN GAS SAMPLES FROM NILES-BOILER

Sample Component	ESP INLET						STACK (ESP OUTLET)					
	N-4-MUM-727		N-4-MUM-729		N-4-MUM-731		N-5A-MUM-727		N-5A-MUM-729		N-5A-MUM-731	
	$\mu\text{g}/\text{Ncm}$ of Total	Percent										
KMNO ₄ Impingers	6.84	22	3.39	12	2.34	9	1.43	5	3.59	17	4.86	21
H ₂ O ₂ Impingers	23.10	73	23.00	81	21.31	86	25.79	94	17.61	83	18.41	79
Acid Probe Rinse	0	0	0.01	0	0	0	0	0	0	0	0	0
Acetone Probe Rinse	0.87	3	1.09	4	0.70	3	0.06	<190	0	0	0	0
Filter	0.28	1	0	0	0	0	0	0	0	0	0	0
Large Cyclone	0.60	2	0.76	3	0.46	2	0	0	0	0	0	0
Small Cyclone	0	0	0	0	0	0	0	0	0	0	0	0
Total	31.7		28.4		24.9		27.4		21.2		23.2	