SUMMARY OF AIR TOXICS EMISSIONS TESTING AT SIXTEEN UTILITY POWER PLANTS

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SECTION 1.0 INTRODUCTION

Background

The U.S. Department of Energy performed comprehensive assessments of toxic emissions from nine selected coal-fired electric utility units. A similar assessment was also carried out at seven power plants which are hosts to demonstration projects carried out under the Clean Coal Technology Program. These data are being collected in response to the Clean Air Act Amendments of 1990, which require that EPA conduct a study of the emissions of hazardous air pollutants (HAPs) from electric utility power plants, and that these emissions be evaluated for potential health risks. The data have been compiled and combined with similar data collected as part of the Field Chemical Emissions Monitoring program sponsored by the Electric Power Research Institute (EPRI) and furnished to the U.S. Environmental Protection Agency for emissions factor and health risk determinations.

The assessments of emissions involve the collection and analysis of samples from all major input and output streams of the selected power plants for selected hazardous pollutants contained in Title III of the Clean Air Act.

Objectives

The specific objectives of this program were:

- To collect and subsequently analyze representative solid, liquid, and gas samples of all specified input and output streams of the selected power plants for selected hazardous air pollutants listed in Title III of the 1990 Clean Air Act Amendments and to assess the potential level of release (concentration) of these pollutants;

- To determine the removal efficiencies of pollution control subsystems for selected pollutants at the power plants;

- To determine material balances for selected pollutants in specified subsystems of the power plant and an overall material balance for the power plants;

- To determine the concentration as a function of particle size of the pollutants associated with the particulate fraction of the flue gas streams;

- To determine the concentration of the pollutants associated with the particulate and vapor-phase fractions of the specified flue gas streams;

- To determine the concentrations of toxic substances on the surfaces of fly ash particles;

- To provide data for EPA for use in risk assessments and in updating publication AP-42;

- To determine hexavalent chromium stack emissions at selected plants; and

- To compare Method 29 vapor-phase mercury results with those obtained via charcoal absorption.

Scope of This Report

Table 1-1 lists the chemical substances analyzed during this project. Not all of these compounds were measured at each power plant.

Report Structure

These results are reported in two sections. First (Section 2), corresponding data for each of the plants are presented in a way to allow comparisons to be made easily. Including:

- Select information about equipment and operation of each plant.
- Coal analyses: ultimate, trace metals, and anions.
- Stack concentration of trace elements.
- Overall ranges of removal efficiencies.

Second (Section 3), more specific data for each individual plant are presented separately. Including

- Description of each plant, with flowsheet.
- Flow rates of trace metals at various locations in the plants.
- Distribution of trace metals in the output streams.
- Removal efficiencies of the control devices.
- Temperatures at various points in the plant.

Uncertainties

Emission factors, removal efficiencies, and other results presented in this report rely on measurement data that vary with time and/or may be near the limit of detection or below it for many of the

Table 1-1 Target Analysis

Trace Elements

Antimony	Boron	Copper	Molybdenum
Arsenic	Cadmium	Lead	Nickel
Barium	Chromium total	Manganese	Selenium
Beryllium	Cobalt	Mercury	Vanadium

Radionuclides

Hexavalent Chromium

Mercury Speciation/Comparison

Anions

Chloride (HCl)
Fluoride (HF)
Sulfates
Phosphates

Reduced Species

Ammonia
Cyanide

Organics

Formaldehyde
Dioxins
Furans

Volatile Organics

Benzene	Methyl Chloroform (1,1,1-Trichloroethane)
Bromoform	Methyl Ethyl Ketone (2-Butanone)
Carbon Disulfide	Methylene Chloride (Dichloromethane)
Carbon Tetrachloride	Propylene Dichloride (1,2-Dichloropropane)
Chlorobenzene	Styrene
Chloroform	1,1,2,2-Tetrachloroethane
1,4-Dichlorobenzene	Tetrachloroethene
cis-,1,3-Dichloropropene	Toluene
trans-1,3-Dichloropropene	1,1,2-Trichloroethane
Ethyl Benzene	Trichloroethene
Ethyl Chloride (Chloroethane)	Vinyl Acetate
Ethylene Dichloride (1,2,-Dichloroethane)	Vinyl Chloride
Ethylidene Dichloride (1,1-Dichloroethane)	Vinylidene Chloride (1,1-Dichloroethene)
Methyl Bromide (Bromomethane)	m,p-Xylene
Methyl Chloride (Chloromethane)	o-Xylene

Semivolatile Organics

Acenapthene	Indeno(1,2,3-cd)pyrene	7,12-Dimethylbenz(a)anthracene
Acenaphthalene	Isophorone	Dimethylphenethylamine
Acetophenone	Methyl Methanesulfonate	2,4-Dimethylphenol
4-Aminobiphenyl	3-Methylchlolanthrene	Dimethylphthalate
Aniline	2-Methylnaphthalene	4,6-Dinitro-2-methylphenol
Anthracene	2-Methylphenol (o-cresol)	2,4-Dinitrophenol
Benzidine	4-Methylphenol (p-cresol)	2,4-Dinitrotoluene
Benzo(a)anthracene	N-Nitroso-di-n-butylamine	2,6-Dinitrotoluene
Benzo(a)pyrene	N-Nitrosodimethylamine	Diphenylamine
Benzo(b)fluoranthene	N-Nitrosodiphenylamine	1,2-Diphenylhydrazine
Benzo(g,h,i)perylene	N-Nitrosopropylamine	Ethyl Methanesulfonate
Benzo(k)fluoranthene	N-Nitrosopiperidine	2-Nitrophenol
Benzoic Acid	Naphthalene	4-Nitrophenol
Benzyl Alcohol	1-Naphthylamine	Pentachlorobenzene

Table 1-1 (Continued)

Semivolatile Organics (continued)

4-Bromophenyl Phenyl Ether	2-Naphthylamine	Pentachloronitrobenzene
Butylbenzylphthalate	2-Nitroaniline	Pentachlorophenol
4-Chloro-3-Methylphenol	3-Nitroaniline	Phenacetin
p-Chloraniline	4-Nitroaniline	Phenanthrene
bis(2-Chloroethoxy)methane	Nitrobenzene	Phenol
bis(2-Chloroethyl)ether	Di-n-octylphthalate	2-Picoline
bis(2-Chloroisopropyl)ether	Dibenz(a,h)anthracene	Pronamide
1-Chloronaphthalene	Dibenz(a,j)acridine	Pyrene
2-Chloronaphthalene	Dibenzofuran	Pyridine
2-Chlorophenol	Dibutylphthalate	1,2,4,5-Tetrachlorobenzene
4-Chlorophenyl Phenyl Ether	1,2-Dichlorobenzene	2,3,4,6-Tetrachlorophenol
Chrysene	1,3-Dichlorobenzene	1,2,24-Trichlorobenzene
bis(2-Ehtylhexyl)phthalate	1,4-Dichlorobenzene	2,4,5-Trichlorophenol
Fluoranthene	3,3'-Dichlorobenzidine	2,4,6-Trichlorophenol
Fluorene	2,4-Dichlorophenol	2-Fluorobiphenyl
Hexachlorobenzene	2,6-Dichlorophenol	2-Fluorophenol
Hexachlorobutadiene	2,6-Dichlorophenol	Nitrobenzene
Hexachlorocyclopentadiene	Diethylphthalate	Phenol
Hexachloroethane	p-Dimethylaminoazobenzene	Terphenyl
		2,4,6-Tribromophenol

Additional Elements

Aluminum	Magnesium	Silicon	Zinc
Calcium	Potassium	Strontium	Uranium (coal only)
Iron	Sodium	Titanium	Thorium (coal only)

substances of interest. In this summary report, highly uncertain results have been flagged in the tables. For a more comprehensive examination of uncertainties associated with this data, the reader is referred to a companion report, "A Comprehensive Assessment of Toxic Emissions from Coal-Fired Power Plants: Statistical Correlations from the Combined DOE and EPRI Field Test Data" or the complete testing reports for each power plant listed in the Appendix.

SECTION 2.0 EXECUTIVE SUMMARY

This report is a summary of sixteen separate test projects sponsored by the U.S. Department of Energy in collaboration with the Electric Power Research Institute. Its purpose is to present, in a concise form, the results of those tests. To the maximum extent possible, results were taken directly from the reports. Calculations were performed only when necessary for the sake of comparison.

A summary of the results is presented in the following tables. These results are organized to allow plant-by-plant comparisons. Compounds that could have been measured by the techniques used but were not detected are not included in this report. If more information is needed, the reader is asked to consult the individual reports for each power station.

Table 2-1 summarizes information about each plant. Table 2-2 lists the conventions used by each contractor for reporting volumetric gaseous data. Table 2-3 presents the ultimate analyses for the feed coals at the test sites while Table 2-4 presents the coal analyses for minor and trace elements. Emission factors are presented in Tables 2-5 and 2-6 for organic materials and for trace/minor elements, respectively. Table 2-7 presents the stack concentrations of trace elements. Tables 2-8.1 and 2-8.2 show the range and average of trace element removal efficiencies at the test sites equipped with particulate removal devices. These data are shown graphically in Figures 2-1, 2-2, and 2-3. Finally, Table 2-9 summarizes the sampling and analytical procedures used at each site.

Non-Detects

Non-detects are samples in which the particular chemical compound being analyzed for was not detected. In a great many instances, the compounds of interest were present in the samples at concentrations near, at, or below the limits of the analytical procedures to detect them. When a compound is not detected, it is uncertain whether it is present or not. A non-detect does not guarantee that the compound in question is absent. If it is present in the sample, it is at a concentration below the detection limit of the measurement technique.

In some cases, where multiple samples were taken or multiple analyses were conducted on the same sample, a combination of non-detects and measurable results was observed. A convention was adopted to interpret data that included non-detects. This convention is used in the majority of the sixteen reports summarized here. The method used is described below and those plants that used different or unspecified methods are identified.

The commonly used method for handling non-detects in calculating emission rates and material balances is:

- If there are no non-detects, then the arithmetic average of the three or four samples is used.

- If there are both measurable quantities and non-detects, then one-half the detection limit is used for the non-detects in calculating averages. However, if the resulting average is calculated to be less than the highest detection limit, then the value is reported as "less than" the highest detection limit.

- If all values are non-detects, then the average is reported as "less than" the average of the detection limits.

Most of the reports used these conventions. Two exceptions are Plant Smith and Nelson Dewey Station. A description of the manner in which non-detects were handled was not found in the Smith report. In the Nelson Dewey report, mass balance calculations involving non-detects were carried out using the detection limit for the value.

In the tables that follow, flags are used to classify the data. The flags and their definitions are:

All samples used to calculate the average shown are non-detects. That is, the compound was not observed in any of the measurements.

A One of the samples is a non-detect, and measurable quantities were observed for the others.

B Two of the samples are non-detects and at least one measurable quantity was observed.

C More than two non-detects observed. When three samples are being reported using an average value, as many as six results could be involved in determining the average value. For example, in some samples, the entrained particulate phase and the gas phase were analyzed separately providing two results for each sample.

Uncertainty Analysis

Collecting and analyzing stream samples in an operating power plant is very difficult. Load changes and natural variations in operation result in changing conditions over the duration of the test, which normally require several hours to complete. Because of this variability, similar runs on different days would not be expected to be exact replicates. Therefore, the limits of uncertainty have been calculated for emission factors and some of the other results. The technique used is described in the publication, ANSI/ASME PTC 19.1 - 1985, "Measurement Uncertainty."

The result is a 95 percent confidence interval based on the standard deviation of the samples and the Student's "t" probability distribution function.

Uncertainty analyses were carried out in the same fashion in the majority of the reports. Two exceptions were Plant Smith and Nelson Dewey Station. In the Smith report, uncertainty appears to be simply the standard deviation of the three sample values. In the Nelson Dewey report, no description of Uncertainty Analysis was found.

In the tables in Section 2, rather than list the calculated uncertainty values from the original reports, uncertainties greater than 100 percent have been flagged as follows:

U Values with uncertainties greater than ±100 percent. For example, if a value of 10 is flagged, the true value is expected to lie somewhere within a range equal to or greater than 0-20, 95 percent of the time, for runs made at the same operating conditions.

N An uncertainty limit is either not known or not calculated.

Table 2-1 Power Plant Descriptions

Power Plant	Operator	Contractor	Boiler Type	Size, MWe	Coal	Control Technology		
						SO_2	NO_x	Particulates
Coal Creek	Cooperative Power	Battelle	Tangential-Fired	550	Lignite	Lime Scrubber	Over-Fire Air	ESP
Boswell	Minnesota Power	Weston	Drum	69	Subbituminous	None	None	Baghouse
Springerville	Tucson Electric Co.	Southern Research Institute	Corner-Fired	397	Subbituminous	Spray Dryer Absorber	Over-Fired Air	Baghouse
Cardinal	Ohio Power Co.	Energy and Environmental Corp.	Cell Burner	615	Bituminous	None	None	ESP
Baldwin	Illinois Power	Weston	Cyclone	568	Bituminous	None	None	ESP
Niles	Ohio Edison	Battelle	Cyclone	108	Bituminous	None	None	ESP
SNOX (Niles)	Asea Brown Boveri	Battelle	Cyclone	35 (A)	Bituminous	Catalytic System (B,C)	SCR	Baghouse
Yates	Georgia Power	Radian	Tangential-Fired	100	Bituminous	Limestone Scrubber (C,D)	None	ESP
Bailly	Northern Indiana Public Serv Co.	Southern Research Institute	Cyclone	528	Bituminous	Advanced FGD (C,E)	None	ESP
Nelson Dewey	Wisconsin Power & Light	Acurex Environmental Corp.	Cyclone	100	Bituminous	None	Reburn (C)	ESP
Hammond	Southern Company Services	Radian	Opposed Wall-Fired	500	Bituminous	None	Low-NO_x Burners	ESP
Smith	Southern Company Services	Southern Research Institute	Tangential-Fired	196	Bituminous	None	Low-NO_x Burners (C)	ESP
Burger	Babcock & Wilcox	Radian	Wall-Fired	160	Bituminous	SNRB (C,F)	SNRB	Baghouse ESP
Arapahoe	Public Service Co. of Colorado	Carnot	Roof-Fired	117	Bituminous	None	Low-NO_x Burners Over-Fire Air SNCR (C,G)	Baghouse
TIDD	Ohio Power	Radian	Pressurized Fluidized Bed	70	Bituminous	Hot Gas Cleanup (C)	None	ESP
GSA Pilot Plant (Shawnee)	AirPol Inc.	Energy and Environmental Research Corp.		10 (H)	(Slipstream reconstituted) (I)	Gas Suspension Absorption (C)	None	ESP and/or Baghouse (J)

A. Slipstream from Niles unit
B. Converts SO_2 and SO_3; removed as sulfuric acid
C. Innovative Clean Coal Technology Project
D. Chiyoda Wet Limestone Scrubber
E. Pure Air's Wet Limestone Scrubber
F. SOx-NOx-ROx-BOx Process
G. Selective Non-Catalytic Reduction
H. Slipstream from Shawnee Unit
I. Feed to GSA unit: Some removed flyash was reinjected to simulate composition of the flue gas stream leaving the boiler
J. Can be configured either as series or parallel flow

Table 2-2 Definition of Normal and Standard Volumetric Units for Each Plant

Pressure is 1.0 atmosphere for all plants			
	Nm^3	dscm	dscfm
Coal Creek	Dry, 0°C, 3% O2	Dry, 20°C	
Boswell	0°C		Dry
Springerville	Dry, 20°C, 3% O2		Dry, 0°C
Cardinal	0°C	Dry, 20°C	
Baldwin	0°		Dry
Niles	Dry, 0°C, 3% O2		
SNOX	Dry, 0°C, 3% O2	Dry, 20°C	
Yates	0°C		Dry, 20°C
Bailly	Dry, 20°C, 3% O2		Dry, 0°C
Nelson Dewey			
Hammond	Dry, 0°C		Dry, 20°C
Smith	4% O2		
Burger	0°C		Dry, 15.6°C
Arapahoe	Dry, 0°C		Dry, 20°C
TIDD	0°C		Dry, 20°C
GSA (Shawnee)	0°C	Dry, 20°C	

Nm^3: Normal cubic meters
dscm: Dry standard cubic meters
dscfm: Dry standard cubic feet per minute

Table 2-3 Average Coal Analyses for Plants

	Coal Creek	Boswell	Springerville	Cardinal	Baldwin	Niles	SNOX	Yates	Bailly
Analysis, Weight Percent									
Carbon	50.85	51.33	55.23	69.24	59.39	67.12	67.68	72.0	61.21
Hydrogen	3.36	3.50	4.35	5.61	4.12	4.47	4.51	4.83	4.45
Nitrogen	0.76	0.72	1.0	0.81	1.11	1.40	1.41	1.52	1.05
Sulfur	0.86	0.70	0.64	3.11	2.88	2.61	2.44	2.74	3.15
Oxygen	15.51	10.53	11.07	8.54	7.23	6.71	6.77	7.74	9.32
Chlorine		0.000028	0.039	0.08	0.07			0.14	0.1
Fluorine		0.000028	0.0073	<0.01	0.000097			0.01	0.0094
Ash	14.65	8.39	22.18	11.2	10.23	11.19	11.28	11.1	10.36
Moisture	14.00	24.82	5.53	1.4	14.97	6.5	5.9	0	10.35
Total	100.00	100.00	100.05	100.01	100.00	100.00	100.00	99.93	100.00
HHV, Btu/lb	8,203	10,474	9,814	11,964	10,626	12,090	12,258	12,697	11,103

Table 2-3 Average Coal Analyses for Plants, (continued)

	Nelson Dewey		Hammond		Smith		Burger
	Baseline	Reburn	OFA*	LNB*	Baseline	Low NO_x	SNRB*
Weight, Percent							
Carbon	61.41	62.86			65.90	67.12	
Hydrogen	4.33	4.45			4.40	4.54	
Nitrogen	1.10	1.02			1.37	1.46	
Sulfur	1.47	1.32	1.5	1.6	2.90	2.85	3.4
Oxygen	8.78	10.06			6.46	6.50	
Chlorine					0.19	0.17	
Fluorine					0.0080	0.0059	
Ash	7.32	7.82	9.5	9.1	9.05	8.29	12.0
Moisture	15.59	12.48	4.7	3.8	9.83	9.24	2.05
	100.00	100.01			100.09	100.18	
HHV, Btu/lb	11,387	11,688	13,056	13,276	11,882	12,062	12,620

*OFA = Over-fire Air
LNB = Low NO_x Burner
SNRB = SO_x, NO_x, RO_x, BO_x

Table 2-3 Average Coal Analyses for Plants, (continued)

	Arapahoe Plant		TIDD Plant	AirPol GSA Shawnee Plant			
				Series		Parallel	
	Baseline	SNCR*		Baseline	Demo	Baseline	Demo
Weight, Percent							
Carbon	62.88	65.10		63.9	64.8	65.8	64.8
Hydrogen	4.41	4.57		4.7	4.7	4.8	4.4
Nitrogen	1.59	1.66		1.2	1.3	1.3	1.3
Sulfur	0.43	0.44	3.4	2.6	2.6	2.5	2.6
Oxygen	10.67	10.04		4.9	5.3	6.1	6.0
Ash	8.81	8.58	12.0	11.4	11.2	9.5	12.0
Moisture	11.2	9.6		11.2	10.0	10.0	9.0
Total	100.000	100.000		99.9	99.9	100.0	100.1
HHV, Btu/lb	12,565	12,638	12,700	11,244	11,516	11,779	11,518

*Selective Non-Catalytic Reduction

Table 2-4 Average Coal Analyses for Plants - Trace Elements

	Coal Creek	Boswell	Springerville	Cardinal	Baldwin	Niles	SNOX	Yates	Bailly
Minor/Trace Elements, ppm									
Antimony	ND< 37 #	0.37	1.5 B	21 A	0.49	1.1	0.9	0.61	0.64
Arsenic	9.4	1.4	2.9	13	2.6	33	34	2.3	2.8
Barium	330	320	321	22	51	55	63	80	42
Beryllium	0.67	0.18	1.1	1.3	1.0	1.9	2.3	1.1	1.7
Boron	140	230	100	96	160	72	53	100	201
Cadmium	ND< 0.9 #	0.06	ND< 0.5 #	0.12	0.54	ND< 0.3 #	ND<0.3 #	0.30	2.7
Chromium	8.2	3.2	9.2	18	25	16	15	25	42
Cobalt	2.2	1.0	3.5	4.4 A	3.1	6.3	5.4	3.5	2.5
Copper	7.0	5.2	13	8.9	8.3	15	14	36.0 AU	9.4
Lead	7.3	3.9	ND< 5.0 #	6.6	9.3	13	13	8.0	7.6
Manganese	97	102	81	56	40	25	27	23	29
Mercury	0.08	0.05	0.037	0.048	0.06	0.21	0.26	0.077	0.10
Molybdenum	2.3	4.1	2.2	3.2 A	6.2	ND< 3 B	ND< 3 A	22	7.2
Nickel	2.6	2.1	5.7	14	16	18	15	30	23
Selenium	ND< 1.3 #	0.66	0.86 A	23	3.2	ND< 0.6 #	0.90	2.3	1.3
Vanadium	15	6.3	27	32	29	28	26	39	48
Chloride								1,400	1,000
Fluoride								100	94
Sulfate									
Phosphorus		103			120			84	119

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-4 Average Coal Analyses for Plants - Trace Elements, (continued)

	Nelson Dewey		Hammond		Smith		Burger
	Baseline	Reburn	OFA	LNB	Baseline	Low NO_x	
Minor/Trace Elements, ppm							
Antimony			1.4	1.5	1.2	1.5	ND< 1.0 #
Arsenic	10	7.1	17	23	4.2	3.6	5.0
Barium			170	99	54	57	47
Beryllium	3.1	2.9	1.4	2.2	ND< 10	ND< 10	0.67
Boron							
Cadmium	32.0 A	41.0 A	ND< 0.11 BN	ND< 2.6 #	ND< 2	2.0	ND< 0.3 #
Chromium	9.4	8.2	22	17	17	17	15
Cobalt			8.3	6.1	3.0	2.5	2.3
Copper			38	34	14	13	
Lead	31	14	5.1	7.3	18	20	5.3
Manganese	22	24	17	14	33	16	19
Mercury	ND< 0.10 #	ND< 0.10 #	0.15	0.14	0.064	0.077	0.13
Molybdenum			3.2 AU	ND< 3.6 AN	8.6	11	
Nickel	23	40	27	17	6.7	6.8	8.0
Selenium	ND< 1.0 #	ND< 1.0 #	3.8	3.7	2.3	1.6	2.7
Vanadium			37	26	53	78	22
Chloride	29 C	45 C	410	340			370
Fluoride	ND< 4.4 #	ND< 3.4 #	70	91			70
Sulfate							
Phosphorus			240	140	92	73	

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-4 Average Coal Analyses for Plants - Trace Elements, (continued)

	Arapahoe		TIDD Plant	AirPol GSA, Shawnee			
				Series		Parallel	
	Baseline	SNCR		Baseline	Demo	Baseline	Demo
Minor/Trace Elements, ppm							
Antimony		.	0.48	ND 0.5	ND 0.5	ND 0.5	ND 0.05
Arsenic	0.48	0.64	45	4.0	4.0	5.0	5.0
Barium	419	339	54	115	612	58	64
Beryllium	0.22	0.55 U	1.6	0.6	1.1	0.8	1.1
Boron			55.0 AU				
Cadmium	ND<0.05 BN	<0.06 BN	0.11 U	0.04	0.1	0.09	ND 0.05
Chromium	1.1	1.4 U	16	14	17	16	17
Cobalt	0.9	1.3	3.9	4.0	4.0	4.0	5.0
Copper	2.7	3.7	7.0				
Lead	2.1	2.2	6.3	4.0	5.0	5.0	5.0
Manganese	4.2	5.2	26	17	32	31	24
Mercury	0.021	0.019 U	0.15	0.075	0.065	0.075	0.065
Molybdenum	0.1 BU	0.5	0.58				
Nickel	0.6	1.0	13	9.0	7.0		12
Selenium	0.82	1.5 U	1.8	1.0	3.0	2.0	2.0
Vanadium	3.0	4.3	24	26	29	30	47
Chloride	22	16.0 N	1,200	200	200	200	200
Fluoride	84		110				
Sulfate							
Phosphorus	410	317	96				

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N *Uncertainty limit not known or not calculated.*

Table 2-5.1 Emission Factors, Aldehydes and Ketones

	Coal Creek	Boswell	Springerville	Cardinal	Baldwin	Niles	SNOX	Yates	Bailly
				Non Soot Blowing	Non Soot Blowing				
Units: lb/10^{12} Btu									
Acetone	NC	1100. BU		31. BN	ND< 1.0 #	NC	NC		8.4 AN
Acetaldhyde	67.	ND< 1.1 #	ND< 0.4 #	ND < 4.8 AN	14	89. U	390	8.6 U	ND< 0.89 AN
Acrolein	ND<2.2 #	ND< 3.4 A			3.5 U	41. U	8.3		
Benzaldehyde		5.8 U			16				
2,5-Dimethyl benzaldehyde		15. AU			14				
n-Butyraldehyde		19. AU			ND< 7.2 A				
2-Butanone (Methyl ethyl ketone)	9.8 U	ND< 5.0 #		48. BN	3.7 U	5.1 BU	ND< 8.3 #		
Crotonaldehyde		ND< 7.1 #			ND< 6.3 B				
Formaldehyde	ND<1.8 BU	ND< 1.7 #	1.4 BN	60. AN	ND< 1.7 BU	3.9 AU	57	24. U	11. N
Hexaldehyde		ND< 6.6 B			9.9				
2-Hexanone	12. U					7.8 BU	19. AU		
4-Methyl-2-Pentanone	6.0 BU					ND< 5.0 BU	ND< 5.8 #		
Propanal (Propionaldehyde)	12. U	ND< 1.7 #			6.0 BU	25. U	13. U		
o-Tolualdehyde		ND< 2.0 #			8.7 AU				
m/p-Tolualdehyde		1.8 A			5.8				
Valeraldehyde		11. BU			5.2 U				
iso-Valeraldehyde		ND< 4.6 #			ND< 4.0 #				
1,4-Benzoquinone				ND< 5.2 #					

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confidence Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.
NC Not calculated.

Table 2-5.1 **Emission Factors, Aldehydes and Ketones, (continued)**

	Nelson Dewey		Hammond		Smith		Burger	
	Baseline	Reburn	OFA	LNB	Baseline	Low NO_x	Baseline	SNRB
Units: lb/10^{12} Btu								
Acetone						4.1 N		
Acetaldhyde	2.7 BN	ND< 2.5 #	ND< 4.8 AN	4.3 U				
Acrolein			ND< 5.8 #					
Benzaldehyde								
2,5-Dimethyl benzaldehyde								
n-Butyraldehyde								
2-Butanone (Methyl ethyl ketone)								
Crotonaldehyde								
Formaldehyde	2.0 BN	ND< 2.5 #	ND< 4.0 BN	1.3 U		7.8 N		
Hexaldehyde								
2-Hexanone								
4-Methyl-2-Pentanone								
Propanal (Propionaldehyde)								
o-Tolualdehyde								
m/p-Tolualdehyde								
Valeraldehyde								
iso-Valeraldehyde								
1,4-Benzoquinone								

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confidence Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.1 Emission Factors, Aldehydes and Ketones, (continued)

	Arapahoe		TIDD Plant	Air Pol (Shawnee)		
	Baseline	SNCR		GSA+ESP	GSA+FF	GSA+ESP+FF
Units: lb/10^{12} Btu						
Acetone			ND< 3.3 N			
Acetaldhyde						
Acrolein						
Benzaldehyde						
2,5-Dimethyl benzaldehyde						
n-Butyraldehyde						
2-Butanone (Methyl ethyl ketone)			ND< 3.3 N			
Crotonaldehyde						
Formaldehyde	17 U		5.1			
Hexaldehyde						
2-Hexanone			ND< 3.3 N			
4-Methyl-2-Pentanone			ND< 3.3 N			
Propanal (Propionaldehyde)						
o-Tolualdehyde						
m/p-Tolualdehyde						
Valeraldehyde						
iso-Valeraldehyde						
1,4-Benzoquinone						

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confidence Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.2 Emission Factors, Dioxins

	Coal Creek	Boswell	Springerville	Cardinal	
Units: lb/10^{12} Btu				Non Soot Blowing	Soot Blowing (Only One Sample Taken)
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND< 2.0e-06 #	8.1e-07 AU		ND< 1.6e-06 #	ND< 4.3e-07 #
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND< 2.4e-06 #	ND< 1.4e-06 A		ND< 1.7e-06 #	ND< 2.0e-06 #
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND< 2.1e-06 #	ND< 2.8e-06 BU		ND< 1.9e-06 #	6.0e-07 N
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ND< 3.2e-06 #	ND< 1.4e-06 A		ND< 1.3e-06 #	ND< 2.7e-06 #
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ND< 3.3e-06 #	ND< 1.4e-06 B		ND< 1.1e-06 #	ND< 2.7e-06 #
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	3.2e-06 U	ND< 1.4e-06 B		2.3e-06 AN	2.3e-06 N
Octachlorodibenzo-p-dioxin	1.5e-05 U	ND< 1.1e-05 BU		2.0e-05 N	1.9e-05 N
Total Tetrachlorodibenzo-p-dioxin		9.3e-06		ND< 5.23-05 AN	1.7e-06 N
Total Pentachlorodibenzo-p-dioxin		4.6e-06		ND< 3.0e-05 #	ND< 2.3e-05 #
Total Hexachlorodibenzo-p-dioxin		2.1e-06 U		ND< 2.2e-05 BN	6.0e-07 N
Total Heptachlorodibenzo-p-dioxin		ND< 1.9e-06 #		ND< 7.6e-06 AN	2.3e-06 N
Total PCDD		2.03-05			
Total Dioxins and Furans			ND< 6e-06 #		

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confidence Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.2 Emission Factors, Dioxins, (continued)

	Baldwin	Niles	SNOX	Yates	Bailly
Units: lb/10^{12} Btu					
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND< 2.5e-06 BU	ND< 2.1e-06 #			
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND< 4.2e-07 #	ND< 2.9e-06 #			
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND< 4.2e-07 #	ND< 3.4e-06 #			
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ND< 3.2e-07 #	3.0e-06 BU			
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ND< 4.2e-07 #	2.9e-06 BU			
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	ND< 1.3e-06 A	1.7e-05 U			
Octachlorodibenzo-p-dioxin	ND< 8.9e-06 AU	1.9e-05 U			
Total Tetrachlorodibenzo-p-dioxin	1.3e-06				
Total Pentachlorodibenzo-p-dioxin	ND< 7.4e-07 B				
Total Hexachlorodibenzo-p-dioxin	9.6e-07 U				
Total Heptachlorodibenzo-p-dioxin	2.5e-06 AU				
Total PCDD	1.1e-05 U				
Total Dioxins and Furans					

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confidence Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.2 Emission Factors, Dioxins, (continued)

	Nelson Dewey	Hammond	Smith	Burger	
Units: lb/10^{12} Btu				Baseline	SNRB
2,3,7,8-Tetrachlorodibenzo-p-dioxin				3.4e-06 BU	ND< 1.9e-06 BN
1,2,3,7,8-Pentachlorodibenzo-p-dioxin				ND< 3.3e-06 #	1.7e-05 BU
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin				ND< 3.3e-06 #	4.1e-05 BU
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin				ND< 3.3e-06 #	4.4e-05 BU
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin				ND< 4.1e-06 BN	8.9e-05 AU
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin				9.4e-06	5.2e-04 AU
Octachlorodibenzo-p-dioxin				2.6e-05 U	1.4e-03 U
Total Tetrachlorodibenzo-p-dioxin				3.4e-06 BU	1.0e-05 BU
Total Pentachlorodibenzo-p-dioxin				ND< 3.3e-06 BN	6.3e-05 BU
Total Hexachlorodibenzo-p-dioxin				2.8e-06 BU	3.2e-04 AU
Total Heptachlorodibenzo-p-dioxin				1.6e-05	9.2e-04 AU
Total PCDD					
Total Dioxins and Furans					

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confidence Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.2 Emission Factors, Dioxins, (continued)

	Arapahoe	TIDD Plant	AirPol GSA (Shawnee)
Units: lb/10^{12} Btu			
2,3,7,8-Tetrachlorodibenzo-p-dioxin		ND< 2.0e-06 -N	
1,2,3,7,8-Pentachlorodibenzo-p-dioxin		ND< 3.5e-06 -N	
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin		ND< 4.8e-06 #	
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin		ND< 3.9e-06 -N	
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin		ND< 4.4e-06 -N	
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin		7.3e-06	
Octachlorodibenzo-p-dioxin		7.7e-05	
Total Tetrachlorodibenzo-p-dioxin		ND< 1.8e-06 AN	
Total Pentachlorodibenzo-p-dioxin		ND< 3.5e-06 N	
Total Hexachlorodibenzo-p-dioxin		ND< 4.1e-06 N	
Total Heptachlorodibenzo-p-dioxin		1.4e-05	
Total PCDD			
Total Dioxins and Furans			

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confidence Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.3 Emission Factors, Furans

	Coal Creek	Boswell	Springerville	Cardinal		Baldwin
Units: lb/10^{12} Btu				Non Soot Blowing	Soot Blowing (Only One Sample Taken)	Non Soot Blowing
2,3,7,8-Tetrachlorodibenzofuran	9.9e-06	6.0e-06		6.6e-07 BU	ND< 1.8e-06 #	ND< 1.3e-06 AU
1,2,3,7,8-Pentachlorodibenzofuran	ND< 4.3e-06 #	5.6e-06		ND< 1.0e-06 #	ND< 2.3e-06 #	ND< 7.4e-07 A
2,3,4,7,8-Pentachlorodibenzofuran	ND< 3.7e-06 #	5.1e-06		ND< 1.3e-06 #	ND< 3.1e-06 #	1.8e-06
1,2,3,4,7,8-Hexachlorodibenzofuran	ND< 3.8e-06 #	6.5e-06		ND< 1.7e-06 #	ND< 2.5e-06 #	2.4e-06
1,2,3,6,7,8-Hexachlorodibenzofuran	ND< 3.1e-06 #	2.2e-06		ND< 1.3e-06 #	8.4e-07 N	8.0e-07
1,2,3,7,8,9-Hexachlorodibenzofuran	ND< 5.3e-06 #	ND< 1.4e-06 B		ND< 1.4e-06 #	ND< 2.3e-06 #	ND< 3.2e-07 #
2,3,4,6,7,8-Hexachlorodibenzofuran	ND< 1.9e-06 #	2.3e-06		ND< 1.9e-06 BN	ND< 2.9e-06 #	ND< 1.5e-06 B
1,2,3,4,6,7,8-Heptachlorodibenzofuran	ND< 2.3e-05 #	4.6e-06		2.0e-06 AU	ND< 2.3e-06 #	1.5e-06
1,2,3,4,7,8,9-Heptachlorodibenzofuran	ND< 3.8e-06 #	ND< 2.8e-06 A		ND< 1.9e-06 #	ND< 2.5e-06 #	ND< 4.6e-07 #
Octachlorodibenzofuran	6.3e-06 A	1.9e-06 U		1.1e-05 U	7.8e-06 N	4.2e-06 U
Total Tetrachlorodibenzofuran		6.0e-05		ND< 3.5e-05 AN	ND< 7.0e-05 #	ND< 3.8e-06 B
Total Pentachlorodibenzofuran		4.7e-05 U		2.8e-06 U	ND< 7.6e-05 #	4.0e-06
Total Hexachlorodibenzofuran		2.2e-05		ND< 2.5e-05 AN	3.9e-06 N	5.6e-06 U
Total Heptachlorodibenzofuran		7.0e-06		2.7e-06 AU	ND< 9.8e-06 #	3.2e-06
Total PCDF		1.4e-04				1.8e-05
Total Dioxins and Furans			ND< 6e-06 #			

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N *Uncertainty limit not known or not calculated.*

Table 2-5.3 Emission Factors, Furans, (continued)

	Niles	SNOX	Yates	Bailly	Nelson Dewey	Hammond
Units: lb/10^{12} Btu						
2,3,7,8-Tetrachlorodibenzofuran	4.8e-06 BU					
1,2,3,7,8-Pentachlorodibenzofuran	ND< 3.4e-06 #					
2,3,4,7,8-Pentachlorodibenzofuran	3.2e-06 BU					
1,2,3,4,7,8-Hexachlorodibenzofuran	9.6e-06 BU					
1,2,3,6,7,8-Hexachlorodibenzofuran	3.8e-06 BU					
1,2,3,7,8,9-Hexachlorodibenzofuran	6.5e-06 AU					
2,3,4,6,7,8-Hexachlorodibenzofuran	ND< 2.5e-06 #					
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1.7e-05 AU					
1,2,3,4,7,8,9-Heptachlorodibenzofuran	3.6e-06 BU					
Octachlorodibenzofuran	2.0e-05 U					
Total Tetrachlorodibenzofuran						
Total Pentachlorodibenzofuran						
Total Hexachlorodibenzofuran						
Total Heptachlorodibenzofuran						
Total PCDF						
Total Dioxins and Furans						

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A *Of the calculations contributing to the average value shown, one includes a non-detect measurement.*
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.3 Emission Factors, Furans, (continued)

	Smith	Burger		Arapahoe	TIDD	AirPol (Shawnee)
Units: lb/10^{12} Btu		Baseline	SNRB			
2,3,7,8-Tetrachlorodibenzofuran		ND< 2.5e-06 AN	4.1e-05 U		ND< 2.0e-06 BN	
1,2,3,7,8-Pentachlorodibenzofuran		ND< 3.3e-06 #	3.3e-05 BU		ND< 2.2e-06 BN	
2,3,4,7,8-Pentachlorodibenzofuran		ND< 4.9e-06 #	6.1e-05 U		ND< 2.2e-06 BN	
1,2,3,4,7,8-Hexachlorodibenzofuran		ND< 4.9e-06 #	3.4e-06 N		5.6e-06	
1,2,3,6,7,8-Hexachlorodibenzofuran		1.2e-06 N	1.1e-06 AN		ND< 2.2e-06 BN	
1,2,3,7,8,9-Hexachlorodibenzofuran		3.7e-06	2.2e-04 U		ND< 3.5e-06 -N	
2,3,4,6,7,8-Hexachlorodibenzofuran		ND< 2.5e-06 #	1.4e-05 BU		4.4e-06	
1,2,3,4,6,7,8-Heptachlorodibenzofuran		ND< 1.1e-04 #	1.2e-03 BU		6.4e-06 A	
1,2,3,4,7,8,9-Heptachlorodibenzofuran		ND< 8.2e-06 AN	1.6e-04 AU		ND< 5.0e-06 #	
Octachlorodibenzofuran		2.1e-05	7.0e-04 U		1.2e-05 A	
Total Tetrachlorodibenzofuran		6.8e-06 U	9.0e-05 U		ND< 2.0e-06 BN	
Total Pentachlorodibenzofuran		ND< 3.3e-06 BN	2.8e-04 U		4.3e-06 A	
Total Hexachlorodibenzofuran		1.6e-05 U	2.3e-03 U		1.4e-05	
Total Heptachlorodibenzofuran		9.0e-06	1.6e-03 AU		4.5e-06 A	
Total PCDF						
Total Dioxins and Furans						

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
A Of the calculations contributing to the average value shown, one includes a non-detect measurement.
B Of the calculations contributing to the average value shown, two include a non-detect measurement.
U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.4 Emission Factors, Volatile Organic Compounds (VOC)

	Coal Creek	Boswell	Springerville	Cardinal	Baldwin	Niles	SNOX
Units: lb/10^{12} Btu				Non Soot			
Carbon Disulfide	3.4 B	18 U		ND< 51 AN	0.14 AU	5.9 AU	5.4 B
Bromomethane (Methyl Bromide)	4.3 AU			15 AU	0.97 BU	ND< 6.5 #	9.6 A
1,2-Dibromomethane				ND< 2.0 #			
Bromodichloromethane	ND< 6.5 #			ND< 3.1 #		ND< 5.1 #	ND< 5.8 #
Dibromochloromethane	ND< 6.5 #			ND< 3.1 #		ND< 5.1 #	ND< 5.8 #
Dibromoethane (Ethylene Dibromide)		0.066 BU					
Tribromomethane (Bromoform)	3.1 B			ND< 10 #		ND< 4.9 #	ND< 5.8 #
Chloromethane	106	2.5		6.4 AU		4.9 BU	218 U
Dichloromethane (Methylene Chloride)	NC	11		ND< 13 N	18		
Trichlorofluoromethane		1.8 U		15	2.6		
Trichloromethane (Chloroform)	ND< 6.5 #			2.9 A		ND< 5.1 #	ND< 5.8 #
Carbon Tetrachloride	ND< 6.5 #			ND< 3.1 #		ND< 5.1 #	ND< 5.8 #
Iodomethane				9.6 B	0.43 BU		
Bromoethene				ND< 12 #			
Chloroethane (Ethyl Chloride)	ND< 6.5 #	2.5 AU		ND< 10 #		ND< 5.1 #	3.4 B
1,1-Dichloroethane (Ethylidene Dichloride)	ND< 6.5 #			ND< 1.8 #		ND< 5.1 #	ND< 5.8 #
1,2-Dichloroethane	3.2 B			ND< 3.1 #		ND< 5.1 #	ND< 5.8 #
1,1,1-Trichloroethane (Methyl Chloroform)	ND< 6.5 #			ND< 13 #		ND< 5.1 #	ND< 5.8 #
1,1,2-Trichloroethane	ND< 6.5 #			ND< 2.2 #		ND< 4.9 #	4.9 BU
1,1,2,2-Tetrachloroethane	ND< 6.5 #			ND< 10 #		ND< 5.1 #	ND< 5.8 #
1,1-Dichloroethene	ND< 6.5 #			ND< 12 #		ND< 5.1 #	ND< 5.8 #
cis-1,2-Dichloroethene				ND< 3.1 #			
Trans-1,2-Dichloroethene (Ethylene	ND< 6.5 #			ND< 3.1 #		ND< 5.1 #	ND< 5.8 #
Tetrachloroethene	ND< 6.5 #	0.56 BU		ND< 3.1 BN		3.1 B	ND< 5.8 #
Trichloroethene	ND< 6.5 #			ND< 3.1 #		ND< 5.1 #	ND< 5.8 #
Chloromethyl Methyl Ether				ND< 13 #			
2-Chloroethylvinylether	ND< 6.5 #					ND< 5.1 #	ND< 5.8 #
Vinyl Chloride	ND< 6.5 #			ND< 10 #		ND< 5.1 #	ND< 5.8 #
Vinyl Acetate	ND< 6.5 #	0.43 BU		ND< 4.5 #		ND< 5.1 #	ND< 5.8 #
1,2-Dibromo-3-chloropropane	ND< 6.5 #			ND< 12 #			
1,2-Dichloropropane (Propylene Dichloride)				ND< 1.8 #		ND< 5.1 #	ND< 5.8 #
Methyl Methacrylate		1.1 BU		ND< 2.4 #			
Ethyl Acrylate				ND< 2.6 #			
3-Chloropropylene	ND< 6.5 #						
cis-1,3-Dichloropropene	ND< 6.5 #			ND< 1.8 #		ND< 5.1 #	ND< 5.8 #

Table 2-5.4 Emission Factors, Volatile Organic Compounds (VOC), (continued)

	Coal Creek	Boswell	Springerville	Cardinal	Baldwin	Niles	SNOX
Units: lb/10^{12} Btu				Non Soot			
trans-1,3-Dichloropropene				ND< 6.9 #		ND< 5.1 #	ND< 5.8 #
1,2-Epoxybutane	41			ND< 7.6 #			
1,3-Butadiene				ND< 18 #			
2-Chloro-1,3-Butadiene (Chloroprene)				ND< 41 #			
n-Hexane		1.5 U		6.5 A	0.16 U		
2,2,4-Trimethylpentane				ND< 1.6 #			
Benzene		100 U	170 N	3.4 A	120 U	7.9	5.6
1,2,4-Trimethylbenzene	ND< 6.5 #						
1,3,5-Trimethylbenzene	3.3 B						
Ethyl Benzene		0.43 U		ND< 2.2 #	0.13 BU	ND< 5.1 #	ND< 5.8 #
Styrene	3.3 B	1.8 U		ND< 3.1 #	0.20 AU	ND< 5.1 #	ND< 5.8 #
Iso-propyl Benzene (Cumene)		0.30 U		ND< 3.0 #			
Chlorobenzene		0.16 BU		ND< 2.2 #		ND< 5.1 #	ND< 5.8 #
1,2-Dichlorobenzene				ND< 3.1 #			
1,3-Dichlorobenzene	24			ND< 3.1 #			
1,4-Dichlorobenzene				ND< 3.1 #			
1,2,4-Trichlorobenzene	3.5 A						
Toluene		5.7	3.6 N	5.2 U	2.0 U	3.5 BU	3.9 AU
4-Ethyl Toluene							
Xylenes						ND< 5.1 #	ND< 5.8 #
m,p-Xylenes		2.2	0.65 BN	3.0 AU	0.97 U		
o-Xylene		0.28 U		ND< 3.1 #	0.52		
Methyl Hydrazine				6.6 BU			
Methyl tert-Butyl Ether				1.4 B			
Acrylonitrile				ND< 12 #			
Allyl Chloride				ND< 12 #			
Propylene Oxide				ND< 12 #			

ND< Value shown is detection limit.
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C Of the calculations contributing to the average value shown, more than two include a non-detect measurement.
U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.4 Emission Factors, Volatile Organic Compounds (VOC), (continued)

	Yates	Bailly	Nelson Dewey		Hammond		Smith	
			Baseline	Reburn	OFA	LNB	Baseline	Low NO_x
Units: $lb/10^{12}$ Btu								
Carbon Disulfide	2.2					ND< 0.51		
Bromomethane (Methyl Bromide)					ND< 0.49 #	0.72 BU		
1,2-Dibromomethane								
Bromodichloromethane								
Dibromochloromethane								
Dibromoethane (Ethylene Dibromide)								
Tribromomethane (Bromoform)								
Chloromethane								
Dichloromethane (Methylene Chloride)					3.8 AU	14 U		
Trichlorofluoromethane								
Trichloromethane (Chloroform)								
Carbon Tetrachloride								
Iodomethane								
Bromoethene								
Chloroethane (Ethyl Chloride)								
1,1-Dichloroethane (Ethylidene Dichloride)								
1,2-Dichloroethane								
1,1,1-Trichloroethane (Methyl Chloroform)					ND< 0.49 #			
1,1,2-Trichloroethane								
1,1,2,2-Tetrachloroethane								
1,1-Dichloroethene								
cis-1,2-Dichloroethene								
Trans-1,2-Dichloroethene (Ethylene Dichloride)								
Tetrachloroethene								
Trichloroethene								
Chloromethyl Methyl Ether								
2-Chloroethylvinylether								
Vinyl Chloride								
Vinyl Acetate								
1,2-Dibromo-3-chloropropane								
1,2-Dichloropropane (Propylene Dichloride)								
Methyl Methacrylate								
Ethyl Acrylate								

Table 2-5.4 Emission Factors, Volatile Organic Compounds (VOC), (continued)

	Yates	Bailly	Nelson Dewey		Hammond		Smith	
			Baseline	Reburn	OFA	LNB	Baseline	Low NO_x
Units: $lb/10^{12}$ Btu								
3-Chloropropylene								
cis-1,3-Dichloropropene								
trans-1,3-Dichloropropene								
1,2-Epoxybutane								
1,3-Butadiene								
2-Chloro-1,3-Butadiene (Chlorprene)								
n-Hexane								
2,2,4-Trimethylpentane								
Benzene	1.3		2.0 N	0.59 N	1.4 U	ND< 0.51	920 N	1000 N
1,2,4-Trimethylbenzene								
1,3,5-Trimethylbenzene								
Ethyl Benzene							59 N	
Styrene							19 N	
Iso-propyl Benzene (Cumene)								
Chlorobenzene								
1,2-Dichlorobenzene							ND< 3.7 #	ND< 3.7 #
1,3-Dichlorobenzene								
1,4-Dichlorobenzene							ND< 3.7 #	ND< 3.7 #
1,2,4-Trichlorobenzene							ND< 4.3 #	ND< 4.5 #
Toluene	2.0		1.1 N	1.2 N	ND< 0.49 #	0.7	17 N	5.5 N
4-Ethyl Toluene								
Xylenes							3.6 N	
m,p-Xylenes								
o-Xylene								
Methyl Hydrazine								
Methyl tert-Butyl Ether								
Acrylonitrile								
Allyl Chloride								
Propylene Oxide								

ND< Value shown is detection limit.
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N Uncertainty limit not known or not calculated.

Table 2-5.4 Emission Factors, Volatile Organic Compounds (VOC), (continued)

	Burger		Arapahoe		TIDD	AirPol (Shawnee)		
	Baseline	SNRB	Baseline	SNCR		GSA+ESP	GSA+FF	GSA+ESP+FF
Units: lb/10^{12} Btu								
Carbon Disulfide					1.0			
Bromomethane (Methyl Bromide)					ND< 0.7 BN			
1,2-Dibromomethane	7.0 N	4.4 BU						
Bromodichloromethane					ND< 0.7 BN			
Dibromochloromethane					ND< 0.7 N			
Dibromoethane (Ethylene Dibromide)								
Tribromomethane (Bromoform)					ND< 0.7 #			
Chloromethane					4.4 B			
Dichloromethane (Methylene Chloride)	ND< 1.6 #	410. BU			3.6			
Trichlorofluoromethane					ND< 0.7 N			
Trichloromethane (Chloroform)	7.9 N	ND< 2.5 #			ND< 0.7 BN			
Carbon Tetrachloride					ND< 0.7 N			
Iodomethane								
Chloroethane (Ethyl Chloride)					ND< 0.7 BN			
1,1-Dichloroethane (Ethylidene Dichloride)	10. N	ND< 2.1 AN						
1,2-Dichloroethane					8.7			
1,1,1-Trichloroethane (Methyl Chloroform)	3.4 N	ND< 2.8 BN			16			
1,1,2-Trichloroethane								
1,1,2,2-Tetrachloroethane								
1,1-Dichloroethene								
trans-1,2-Dichloroethene (Ethylene Dichloride)					ND< 0.7 N			
Tetrachloroethene					ND< 0.7 N			
Trichloroethene					ND< 0.7 N			
2-Chloroethylvinylether								
Vinyl Chloride					ND< 0.7 N			
Vinyl Acetate, lb/10^{12} Btu					ND< 3.3 N			
1,2-Dichloropropane (Propylene Dichloride)								
Methyl Methacrylate								
3-Chloropropylene	9.5 N	8.3 AU						
cis-1,3-Dichloropropene	6.5 N	ND< 2.3 BN			ND< 0.7 N			
trans-1,3-Dichloropropene	ND< 2.0 #	2.5 BU			ND< 0.7 N			

Table 2-5.4 Emission Factors, Volatile Organic Compounds (VOC), (continued)

	Burger		Arapahoe		TIDD	AirPol (Shawnee)		
	Baseline	SNRB	Baseline	SNCR		GSA+ESP	GSA+FF	GSA+ESP+FF
Units: lb/10^{12} Btu								
n-Hexane								
Benzene	26 N	7.0 U	2.6		6.6	2.6		
1,2,4-Trimethylbenzene	ND< 2.2 #	ND< 2.5 #			:			
1,3,5-Trimethylbenzene	6.2 N	ND< 2.5 #						
Ethyl Benzene	29 N	9.5 BU			ND< 0.7 N			
Styrene	ND< 1.9 #	6.2 BU			ND< 0.7 N			
Iso-propyl Benzene (Cumene)								
Chlorobenzene					ND< 0.7 N			
1,3-Dichlorobenzene	260 N	19 BU						
1,4-Dichlorobenzene	360 N	27 BU						
1,2,4-Trichlorobenzene	230 N	83 BU						
Toluene	ND< 1.7 #	ND< 1.9 BN	105		1.4	105		
Benzyl Chloride	110 N	19 BU						
4-Ethyl Toluene	6.2 N	ND< 2.5 #						
Xylenes								
m,p-Xylenes	4.3 N	8.4 BU			ND< 0.7 N			
o-Xylene	3.1 N	ND< 2.2 #			ND< 0.7 N			
Methyl Hydrazine								
Methyl tert-Butyl Ether								

ND< Value shown is detection limit.
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U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.5 Emission Factors, Semi-Volatile Organic Compounds (SVOC)

	Coal Creek	Boswell	Springerville	Cardinal	Baldwin	Niles	SNOX
Units: lb/10^{12} Btu							
Acetophenone	0.54 U	0.71		ND< 140 BN	1.2	0.64 U	0.30 U
2-Chloroacetophenone	0.13			ND< 54 #		0.29 U	ND<0.0055 #
Biphenyl	0.023	ND<0.18 #		ND< 5.6 BN	ND<0.88 #	0.13 U	0.0060 AU
Dibenzofuran	0.052			ND< 22 #		0.065 U	0.013
2,4-Dinitrotoluene	0.0065 AU			ND< 22 #		0.020 AU	0.0038 B
2,6-Dinitrotoluene	ND<0.0017 #			ND< 22 #		0.55	ND<0.0055 #
Isophorone				23 BU	26 U		
Quinoline	ND<0.017 #			ND< 5.6 BN			
Hexachloroethane	ND<0.0017 #			ND< 22 #		ND<0.012 #	ND<0.0055 #
Bis(2-Chloroisopropyl) Ether							
n-Nitrosodimethylamine		ND<0.89 #		ND< 22 #			
Phenol		0.43 A		ND< 22 #	ND<1.2 A		
2-Nitrophenol				ND< 22 #			
Benzyl Chloride	0.0057 BU			87 N		ND<0.012 #	0.025 AU
Hexachlorobenzene	ND<0.0017 #			ND< 22 #		ND<0.012 #	ND<0.0055 #
Hexachloroethane				ND< 22 #			
Hexachlorobutadiene	ND<0.0017 #			ND< 22 #		ND<0.012 #	ND<0.0055 #
Hexachlorocyclopentadiene	ND<0.0017 #			ND< 22 #		ND<0.012 #	ND<0.0055 #
2-Methylphenol (o-Cresol)		1.0 AU		ND< 22 #	1.8 BU		
4-Methylphenol (p-Cresol)		0.65 AU		ND< 22 #	0.78 BU		
Pentachlorophenol	ND<0.0017 #			ND< 54 #		ND<0.012 #	0.0032 B
Benzoic Acid							
Benzyl Alcohol							
Butylbenzylphthalate				ND< 22 #			
Dibutylphthalate		ND<1.9 #		ND< 22 #	ND<3.0 B		
Diethylphthalate				ND< 22 #			
Dimethylphthalate				ND< 22 #			
Bis(2-Ethylhexyl)phthalate		ND<1.7 B		ND< 22 #	4.6 U		
Dimethyl Sulfate				1.8 BU			
Total SVOCs, PAHs							

ND< Value shown is detection limit.
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U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.5 Emission Factors, Semi-Volatile Organic Compounds (SVOC), (continued)

	Yates	Bailly	Nelson Dewey		Hammond		Smith	
			Baseline	Reburn	OFA	LNB	Baseline	Low NO_x
Units: lb/10^{12} Btu								
Acetophenone	3.2							
2-Chloroacetophenone								
Biphenyl								
Dibenzofuran							ND< 3.7 #	ND< 3.7 #
2,4-Dinitrotoluene							ND< 2.2 #	ND< 2.2 #
2,6-Dinitrotoluene								
Isophorone							ND< 3.7 #	ND< 3.7 #
Quinoline								
Hexachloroethane								
Bis(2-Chloroisopropyl) Ether								ND< 1.5 #
n-Nitrosodimethylamine								
Phenol	9.2				5.5 BU		29. BN	18. N
2-Nitrophenol								5.4 N
Benzyl Chloride								
Hexachlorobenzene							ND< 5.8 #	ND< 6.0 #
Hexachloroethane							ND< 2.2 #	ND< 2.2 #
Hexachlorobutadiene							ND< 2.2 #	ND< 2.2 #
Hexachlorocyclopentadiene							ND< 3.7 #	ND< 3.7 #
2-Methylphenol (o-Cresol)	2.9 U							
4-Methylphenol (p-Cresol)	0.95 AU							
Pentachlorophenol							ND< 5.8 #	ND< 6.0 #
Benzoic Acid	120						61. N	37. CN
Benzyl Alcohol	2.8 BU							
Butylbenzylphthalate								
Dibutylphthalate					ND< 4.8 #			
Diethylphthalate								
Dimethylphthalate							ND< 2.2 #	ND< 2.2 #
Bis(2-Ethylhexyl)phthalate					6.2 AU			
Dimethyl Sulfate								
Total SVOCs, PAHs								

ND< Value shown is detection limit.
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U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.5 **Emission Factors, Semi-Volatile Organic Compounds (SVOC), (continued)**

	Burger		Arapahoe		TIDD	AirPol (Shawnee)		
	Baseline	SNRB	Baseline	SNCR		GSA+ESP	GSA+FF	GSA+ESP+FF
Units: lb/10^{12} Btu								
Acetophenone					3.9			
2-Chloroacetophenone								
Biphenyl	0.0030	0.012						
Dibenzofuran								
2,4-Dinitrotoluene								
2,6-Dinitrotoluene								
Isophorone					21 AU			
Quinoline								
Hexachloroethane								
Bis(2-Chloroisopropyl) Ether								
n-Nitrosodimethylamine								
Phenol					1.2 CU			
2-Nitrophenol								
Benzyl Chloride	110	19						
Hexachlorobenzene								
Hexachloroethane								
Hexachlorobutadiene								
Hexachlorocyclopentadiene								
2-Methylphenol (o-Cresol)								
4-Methylphenol (p-Cresol)								
Pentachlorophenol								
Benzoic Acid					160			
Benzyl Alcohol								
Butylbenzylphthalate								
Dibutylphthalate								
Diethylphthalate								
Dimethylphthalate								
Bis(2-Ethylhexyl)phthalate								
Dimethyl Sulfate								
Total SVOCs, PAHs								

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.
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B Of the calculations contributing to the average value shown, two include a non-detect measurement.
C Of the calculations contributing to the average value shown, more than two include a non-detect measurement.
U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.6 Emission Factors, Polynuclear Aromatic Hydrocarbons (PAH)

	Coal Creek	Boswell	Springer-ville	Cardinal	Baldwin	Niles	SNOX
Units: lb/10^{12} Btu							
Acenaphthylene	0.01 U	0.0053 U		ND<22 #	0.032 U	0.0068 AU	0.0042 U
Acenaphthene	0.017 U	0.041 U		ND<22 #	ND<0.0063 #	0.027 U	0.0053 U
Anthracene	0.015	0.0062 U		ND<22 #	ND<0.0026 AU	0.021 U	0.0036 U
Benzo(a)anthracene	0.0021	0.0047 U		ND<22 #	ND<0.0012 #	0.0037 AU	0.0021
Benzo(b & k)anthracene							
Benzo(b & k)fluoranthene	0.0045			ND<22 #		0.007 AU	0.0039
Benzo(b) fluoranthene		0.0027 U		ND<22 #	ND<0.0026 #		
Benzo(k)fluoranthene		0.00033 U		ND<22 #	ND<0.0013 BU		
Benzo(e)pyrene	0.0011	0.0023 U			ND<0.0017 #	0.0021 BU	0.0011 BU
Chrysene	0.0053 U	0.012 U		ND<22 #	ND<0.0021 B	0.0089 U	0.0021 AU
5-Methyl Chrysene							
Naphthalene	0.25	0.23 AU	ND< 0.12 N	1.9 U	ND<0.39 AU	0.22 U	0.060 U
1-Methylnaphthalene	0.015					0.016 U	0.011 U
2-Methylnaphthalene	0.041	0.032		ND<22 #	ND<0.034 B	0.038 U	0.020 U
2-Chloronaphthalene		0.00063		ND<22 #	0.00035 U		
Fluoranthene	0.042	0.083 U		ND<22 #	0.017 U	0.027 U	0.0069
Fluorene	0.042 U	0.0088 U		ND<22 #	ND<0.0049 B	0.031 U	0.00060 BU
Phenanthrene	0.31 U	0.21 U		ND<22 #	0.057	0.078 U	0.024 U
Pyrene	0.016	0.037 U		ND<22 #	ND<0.0028 BU	0.014 U	0.0012 AU
Benzo(g,h,i)perylene	0.00059 AU	ND<0.00052 #		ND<22 #	ND<0.0011 #	ND<0.0024 #	0.00093 B
Benzo(a)pyrene	0.00086 AU	ND<0.00021 B		ND<22 #	ND<0.00054 #	ND<0.0024 #	0.00094 B
Dibenzo(a,h)anthracene	0.00072	ND<0.00012 B		ND<22 #	ND<0.00029 #	ND<0.0024 #	0.00071 B
Indeno(1,2,3-c,d)pyrene	0.00063 AU	ND<0.00034 BU		ND<22 #	ND<0.0011 #	ND<0.0024 #	0.0010 BU
Perylene		0.08 BU			ND<0.00027 #		
17H-Dibenzo(c,g)carbazole							
Dibenzo(a,e)pyrene							
Dibenzo(a,j)pyrene							
Dibenzo(a,h)acridine							
Dibenzo(a,i)acridine							

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U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.6 Emission Factors, Polynuclear Aromatic Hydrocarbons, (continued)

	Yates	Bailly	Nelson Dewey		Hammond		Smith	
			Baseline	Reburn	OFA	LNB	Baseline	Low NO_x
Units: $lb/10^{12}$ Btu								
Acenaphthylene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.0030		
Acenaphthene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.0081		
Anthracene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.0037 U		
Benz(a)anthracene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.0070 U		
Benz(b & k) anthracene								
Benzo(b & k) fluoranthene						0.0015 U		
Benzo(b)fluoranthene			ND< 9.0 #	ND< 12 #				
Benzo(k)fluoranthene			ND< 9.0 #	ND< 12 #				
Benzo(e) pyrene								
Chrysene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.0018 U		
5-Methyl Chyrsene						ND<0.0009 BN		
Naphthalene	1.5		ND< 9.0 #	ND< 12 #			ND< 2.2 #	ND< 1.5 #
1-Methylnaphthalene								
2-Methylnaphthalene								ND< 1.5 #
2-Chloronaphthalene								
Fluoranthene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.01 U		
Fluorene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.0099 U		
Phenanthene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.044 U		
Pyrene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	0.011 U		
Benzo(g,h,i)perylene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	ND<0.0031 BN		
Benzo(a)pyrene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	ND<0.0041 BN		
Dibenzo(a,h)anthracene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	ND<0.0037 #		
Indeno(1,2,3-c,d)pyrene			ND< 9.0 #	ND< 12 #	ND< 5.0 #	ND<0.0027 AN		
Perylene								
17H-Dibenzo(c,g)carbazole						ND<0.016 #		
Dibenzo(a,e)pyrene						ND<0.0030 #		
Dibenzo(a,h)pyrene						ND<0.0032 #		
Dibenzo(a,i)pyrene						ND<0.0042 #		
Dibenzo(a,h)acridine						ND<0.0016 #		
Dibenzo(a,i)acridine						ND<0.0042 #		

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U Uncertainty (= 95% Confident Limit): Equal to or greater than 100 percent of value.
N Uncertainty limit not known or not calculated.

Table 2-5.6 Emission Factors, Polynuclear Aromatic Hydrocarbons, (continued)

	Burger (116)		Arapahoe (PSC CO)		TIDD	AirPol (Shawnee)		
	Baseline	SNRB	Baseline	SNCR		GSA+ESP	GSA+FF	GSA+ESP+ FF
Units: lb/10^{12} Btu								
Acenaphthylene	0.0032 U	0.0024 U			0.12			
Acenaphthene	0.0078 U	0.011 AU						
Anthracene	0.0068	0.0088 U						
Benz(a)anthracene	0.013 U	0.0084						
Benz(b & k)anthracene								
Benzo(b & k)fluoranthene	0.019 U	0.021						
Benzo(b)fluoranthene								
Benzo(k)fluoranthene								
Benzo(e)pyrene	0.0074	0.0082 U						
Chrysene	0.043 U	0.015						
5-Methyl Chyrsene								
Naphthalene	0.061 U	0.4 U	0.26					
1-Methylnaphthalene	0.0029	0.011 U						
2-Methylnaphthalene	0.0073	0.022 U	0.027 U					
2-Chloronaphthalene					0.0012			
Fluoranthene	0.066	0.068 U						
Fluorene	0.017	0.063 U						
Phenanthrene	0.11 U	0.15 U						
Pyrene	0.031	0.028 U						
Benzo(g,h,i)perylene	0.009	0.012 U						
Benzo(a)pyrene	0.02 U	0.012						
Dibenzo(a,h)anthracene	0.0061	0.0096 U						
Indeno(1,2,3,-c,d)pyrene	0.009 U	0.011 U						
Perylene								
17H-Dibenzo(c,g)carbazole								
Dibenzo(a,e)pyrene								
Dibenzo(a,h)pyrene								
Dibenzo(a,i)pyrene								
Dibenzo(a,h)acridine								
Dibenzo(a,i)acridine								

ND< Value shown is detection limit.
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N Uncertainty limit not known or not calculated.

Table 2-6.1 Emission Factors, Trace Metals

Plants	Coal Creek	Boswell	Springer-ville	Cardinal		Baldwin		Niles	SNOX	Yates
				Non-Soot Blowing	Soot Blowing	Non-Soot Blowing	Soot Blowing			
Units: lb/10^{12} Btu										
Antimony	0.18	ND< 0.68 #	0.040 AU	2.4 AN	1.4 CN	1.5	2.1	ND< 0.36 #	ND< 0.50 #	0.06
Arsenic	1.2	ND< 0.32 B	0.14 BU	3.5 CN	1.7 AN	13 U	12	42.	ND< 0.50 #	1.2
Barium	160	82 U	13	0.89 N	0.59 BN	5.3	3.4	5.4 U	0.17 BU	2.8 AU
Beryllium	ND< 1.7 #	ND< 0.13 #	ND< 0.04 #	0.067 CN	0.038 CN	1.4	1.7	0.19	0.17 AU	0.10 AU
Boron	19 U	610 U	580	1,910 BN	1,750 N	7,700	8,600			
Cadmium	ND< 3.2 #	ND< 0.65 #	0.026 U	0.85 N	0.66 N	3.0	4.5	0.07 BU	0.092 BU	0.60 AU
Chromium	10 N	2.0	0.10 BU	7.5 N	2.2 N	51	68	3.0	3.9 N	5.3 AU
Cobalt	1.5 BU	0.70	ND< 0.3 #	0.63 N	0.31 CN	6.8	10	ND< 0.12 #	ND< 0.22 BN	0.70 U
Copper	1.5 AN	2.4	0.93	1.4 N	1.1 N	19 U	33	4.0	0.89	2.0 U
Lead	0.69	2.4 AU	0.67	3.8 N	3.6 N	29	48	1.6	0.53 BU	0.60 AU
Manganese	30	18 U	11	15 N	20 N	22	32	3.4	2.6 U	7.2 U
Mercury	9.5	1.9	4.0	0.44 CN	0.78 CN	3.8	5.4	14.	22.	3.0
Molybdenum	0.51 N	1.3 U	1.4	0.59 CN	0.27 CN	34	41	2.3	5.4	1.5 U
Nickel	5.1 N	2.0 U	ND< 0.3 #	4.8 N	1.8 N	22	31	0.55 U	2.2 N	40. U
Selenium	8.3	3.2	ND< 0.038 BN	93 N	65 N	130	140 U	62. U	0.67 U	27 U
Vanadium	4.4	1.5 U	1.0 U	1.6 CN	0.72 CN	100	220 U	2.5	ND< 0.11 #	2.1

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N Uncertainty limit not known or not calculated.

Table 2-6.1 Emission Factors, Trace Metals, (Continued)

Plants	Bailly	Nelson-Dewey		Hammond		Smith		Burger	
		Baseline	Reburn	OFA	LNB	Baseline	Low NOx	Baseline	SNRB
Units: lb/10^{12} Btu									
Antimony	0.28 U			ND< 25 #	23 C	ND< 7.6 #	2.2 CN	0.10	0.76 U
Arsenic	1.1 U	7.9 N	8.6 N	94. U	110	1.1 N	9.6 N	2.9 U	1.2 U
Barium	1.3			220	140	3.7 N	19 N	1.2 BU	0.18 AU
Beryllium	ND< 0.07 AN	2.4 N	1.0 N	3.7 U	3.1	ND< 0.53 #	ND< 0.60 #	ND< 13 #	ND< 15 #
Boron	910.								
Cadmium	0.42	2.8 N	1.7 N	0.50 U	3.6	0.99 AN	ND< 2.2 CN	ND< 13 #	0.64 AU
Chromium	2.7	15. N	5.2 N	38	21	8.2 N	22 N	1.0 AU	5.3 AU
Cobalt	ND< 0.07 AN			11. U	6.5	4.9 BN	43 N	ND< 16 #	ND< 18 AN
Copper	1.7 U			41. U	30	4.4 N	1.0 BN		
Lead	1.6 U	92. N	59. N	33. U	11	7.6 N	16 N	ND< 0.22 BN	0.53 AU
Manganese	3.1	22. N	16. N	25.	21	5.0 N	105 N	10 U	0.81 AU
Mercury	2.1	4.9 N	4.0 N	6.4	4.8	0.07 N	0.40 N	9.2	14 U
Molybdenum	3.4			ND< 12 B	12	5.7 BN	35 N		
Nickel	2.2	82. N	35. N	24.	17	5.5 AN	7.4 N	ND< 16 #	49 AU
Selenium	190 U	250. N	150. N	130.	140	14 N	27 N	31 U	ND< 0.32 #
Vanadium	2.8			72.	41	12 AN	37 N	ND< 14 AN	ND< 16 #

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N Uncertainty limit not known or not calculated.

Table 2-6.1 Emission Factors, Trace Metals, (Continued)

Plants	Arapahoe		TIDD	AirPol GSA (Shawnee)					
				No Lime Injection (Baseline)			Lime Injection (Demonstration)		
	Baseline	SNCR		Parallel ESP	Parallel FF	Series ESP+FF	Parallel ESP	Parallel FF	Series ESP+FF
Units: lb/10^{12} Btu									
Antimony			ND< 2.6 #	ND< 0.058 #	ND< 0.075 #	ND< 0.071 #	ND< 0.062 #	ND< 0.062 #	ND< 0.058 #
Arsenic	0.75 U	0.15	1.2	5.1	0.71	0.07 BU	14 U	0.08 BU	ND< 0.041 #
Barium	1.1 U	1.1 U	0.92	ND< 3.2 #	ND< 4.1 #	ND< 3.9 #	47 U	ND< 3.4 #	ND< 3.2 #
Beryllium	ND< 0.02 #	ND< 0.02 #	0.26 B						
Boron			210				0.42 U		0.22 A
Cadmium	0.12 AU	ND< 0.07 #	2.2	0.86	2.2	0.47	20 AU	1.4	ND< 1.9 #
Chromium	0.66	0.30	4.6	6.4	ND< 2.4	ND< 2.2 #	4.5 AU	ND< 2.0 #	ND< 0.82 #
Cobalt	ND< 0.21 #	ND< 0.23 #	ND< 2.4 #	1.1	ND< 1.1 #	ND< 1.0 #		ND< 0.88 #	
Copper	1.1	1.3	5.3				13 U		0.27
Lead	0.44	0.4	0.80 B	3.8	0.94	0.61	26 U	0.59 U	1.4
Manganese	1.0 U	0.89 U	8.5	8.7 U	3.2	2.2 U	1.3	5.1 U	0.12 AU
Mercury	ND< 0.29 #	0.41 AU	18	0.46	1.1 AU	0.11 U		0.74 U	
Molybdenum	0.17	0.27 U	0.31 A						
Nickel	1.5 U	0.45	7.4				ND< 0.047 #	ND< 0.047 #	ND< 0.044 #
Selenium	0.36 U	ND< 0.060 #	49	13 U	ND< 0.057 #	1.2 U	42 AU	ND< 6.6 #	ND< 6.2 #
Vanadium	0.24 U	0.29	1.2	ND< 6.1 BU	ND< 7.9 #	ND< 7.5 #			

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Table 2-6.2 Emission Factors, Inorganics

Plants	Coal Creek	Boswell	Springer-ville	Cardinal		Baldwin	Niles	SNOX	Yates
				Non-Soot Blowing	Soot Blowing				
Units: lb/10^{12} Btu									
Anions									
Chloride (HCl)	1,340	1,100	ND< 176 BN	24,400 N		78,000	132,000	82,400	742
Fluoride (HF)	4,126	2,800	ND< 92 #	1,900 N		9,500	8,930	6,800	122
Phosphates	7.8 AU			ND< 920 BN			111 AU	ND< 2.0 BU	
Sulfates	1,220 U			800,000 N			12,280	56,600. U	
Reduced Species									
Ammonia	ND< 3.7 #	ND< 17 B		41 N		ND< 17 B	70 BU	56 N	
Cyanide	51	3.7 U		ND< 0.59 #		ND< 2.2 #	180 U	157	

Plants	Bailly	Nelson-Dewey		Hammond		Smith		Burger	
		Baseline	Reburn	OFA	LNB	Baseline	Low NOx	Baseline	SNRB
Units: lb/10^{12} Btu									
Anions									
Chloride (HCl)	1,020.	4,500. N	6,100. N	19,000	15,000	150,000. N	170,000. N	33,000	770 U
Fluoride (HF)	ND< 420. #	67. N	89. N	6,200	5,100	4,700. N	4,000. N	5,500	39 U
Phosphates	ND< 2,200. #					ND< 95. #	160. N		
Sulfates	590,000. N								
Reduced Species									
Ammonia									
Cyanide									

Table 2-6.2 Emission Factors, Inorganics (Continued)

Plants	Arapahoe (PSC Colorado)		TIDD	AirPol GSA (Shawnee)					
				No Lime Injection (Baseline)			Lime Injection (Demonstration)		
	Baseline	SNCR		ESP	FF	ESP+FF	ESP	FF	ESP+FF
Units: $lb/10^{12}$ Btu									
Anions									
Chloride (HCl)	630	720	83,000		18,140	18,440		ND< 7.3 #	ND< 210. #
Fluoride (HF)	4,300 U	4,800	5,600		1,530	4,210		ND< 23. #	ND< 21. #
Phosphates									
Sulfates									
Reduced Species									
Ammonia		4,300-8,900	140						
Cyanide	ND< 8 BN	ND< 9 #	610						

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N Uncertainty limit not known or not calculated.

Table 2-7 Stack Concentrations

	Coal Creek	Boswell	Springerville	Cardinal		Baldwin		Niles	SNOX	Yates
				Non-Soot Blowing	Soot Blowing	Non-Soot Blowing	Soot Blowing			
Units: µg/Nm³										
Antimony	0.25 N	ND< 0.91 #	0.058 AN	3.1 A	1.8 C	2.1	2.8	ND< 0.60 #	ND< 0.69 #	0.065
Arsenic	1.7 N	ND< 0.44 BU	0.21 BN	4.5 C	2.2 A	18	17	70 N	ND< 0.69 #	1.2
Barium	217 N	110 N	20 N	1.1	0.75 B	7.2	4.6	8.8 N	0.24 BN	2.9 AU
Beryllium	ND< 2.3 #	ND< 0.17 #	ND< 0.05 #	0.09 C	0.049 C	1.9	2.3	0.31 N	0.23 AN	0.099 AU
Boron	26 N	800 N	865 N	2,470 B	2,250	10,000	12,000		--	440
Cadmium	ND< 4.3 #	ND< 0.86 #	0.037 N	1.1	0.86	4.1	6	ND< 0.10 BN	ND< 0.16 BN	0.63 AU
Chromium	13 N	2.7 N	0.15 BN	9.8	2.8	69	92	5.1 N	5.4 N	5.4 AU
Cobalt	ND< 2.2 BN	0.93 N	ND< 0.4 #	0.82	0.39 C	9.3	13	ND< 0.20 #	ND< 0.30 BN	0.74 U
Copper	ND< 2.7 AN	3.2 N	1.4 N	1.8	1.4	26	44	6.7 N	1.2 N	2.0
Lead	0.92 N	3.2 AN	1.0 N	5.0	4.6	39	64	2.7 N	0.73 BN	0.61 A
Manganese	40 N	25 N	16 N	19	26	30	43	5.6 N	3.6 N	7.3 U
Mercury	13 N	2.6 N	9.64 N	0.56 C	1.0 C	5.2	7.2	24 N	30 N	3.1
Molybdenum	0.68 N	1.7 N	2.04 N	0.76 C	0.35 C	46	56	3.7 N	7.5 N	1.5 U
Nickel	6.9 N	2.6 N	ND< 0.4 #	6.2	2.3	30	42	0.90 N	3.0 N	41 U
Selenium	11 N	4.3 N	ND< 0.054 BN	120	83	180	190	102 N	0.92 N	27 U
Vanadium	5.9 N	2.0 N	1.5 N	2.1 C	0.92 C	140	300	4.2 N	ND< 0.15 #	2.2

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Table 2-7 Stack Concentrations, (continued)

	Bailly	Nelson-Dewey		Hammond		Smith		Burger	
		Baseline	Reburn	OFA	OFA/LNB	Baseline	Low NOx	Baseline	SNRB
Units: μg/Nm³									
Antimony	0.38 N			ND< 29 #	2.6	ND< 25 #	5.6 CN	0.13	0.82 U
Arsenic	1.4 N	11	12	110 U	120	1.8 N	13 N	3.6 U	1.3 U
Barium	1.7 N			260	160	5.6 N	25 N	1.4 BU	0.20 AU
Beryllium	ND< 0.10 AN	3.6	1.3	4.3 U	3.5	ND< 1.4 #	ND< 1.3 #	ND< 16 #	ND< 16 #
Boron	1,230 N								
Cadmium	0.57 N	4.0	2.4	0.59 U	4.2	1.4 AN	ND< 4.0 CN	ND< 16 #	0.68 AU
Chromium	3.7 N	21	7.4	44	24	18 N	41 N	1.3 AU	5.6 AU
Cobalt	ND< 0.10 AN			13 U	7.5	8.6 BN	4.0 N	ND< 19 #	ND< 19 AN
Copper	2.3 N			48	35	14 N	6.5 BN		
Lead	2.1 N	130	78	39	13	21 N	23 N	ND< 0.27 BN	0.56 AU
Manganese	4.2 N	31	23	29	24	71 N	21 N	13 U	0.86 AU
Mercury	2.8 N	6.9	5.7	7.5	5.5	0.76 N	0.97 N	11	15. U
Molybdenum	4.6 N			ND< 14 CN	14	2.3 BN	41 N		
Nickel	2.9 N	120	50	28	19	12 AN	8.3 N	ND< 19 #	52. A
Selenium	261. N	360	220	150	160	64 N	170 N	38 U	ND< 0.34 #
Vanadium	3.8 N			84	47	16 AN	1.4 N	ND< 17 AN	ND< 17 #

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Table 2-7 Stack Concentrations, (continued)

	Arapahoe		TIDD	AirPol GSA					
				No Lime Injection (Baseline)			Lime Injection (Demonstration)		
	Baseline	SNCR		Parallel ESP	Parallel FF	Series ESP+FF	Parallel ESP	Parallel FF	Series ESP+FF
Units: $\mu g/Nm^3$									
Antimony			ND< 2.1 #	ND< 0.09 #	ND< 0.10 #	ND< 0.095 #	ND< 0.09 #	ND< 0.09 #	ND< 0.079 #
Arsenic	0.97 U	0.19	1.0	8.2	0.98	ND< 0.090 BU	19 U	0.12 BU	ND< 0.056 #
Barium	1.5 U	1.3 U	0.74 U	ND< 5.1 #	ND< 5.6 #	ND< 5.2 #	66 U	ND< 4.7 #	ND< 4.3 #
Beryllium	ND< 0.03 #	ND< 0.03 #	0.021 BU						
Boron			170						
Cadmium	0.15 AU	ND< 0.09 #	1.8 U	1.4	3.0	0.63	0.59 U	1.9	0.30 A
Chromium	0.85	0.37	3.7 U	10	ND< 3.3 #	ND< 3.0 #	27 AU	ND< 2.7 #	ND< 2.5 #
Cobalt	ND< 0.28 #	ND< 0.29 #	ND< 0.19 #	1.8	ND< 1.5 #	ND< 1.3 #	6.2 AU	ND< 1.2 #	ND< 1.1 #
Copper	1.4	1.7	4.1 U						
Lead	0.56	0.50	0.65 BU	6.2	1.3	0.82	18 U	0.82 U	0.37
Manganese	1.3 U	1.1 U	6.9 U	15 U	4.4	3.0 U	36 U	7.0 U	1.9
Mercury	ND< 0.45 #	0.52 AU	15	0.75	1.5 AU	0.15 U	1.7	1.0 U	0.16 AU
Molybdenum	0.22	0.34 U	0.25 AU						
Nickel	1.9 U	0.56	6.0 U						
Selenium	0.47 U	ND< 0.08 #	39	21 U	ND< 0.08 #	1.6 U	ND< 0.07 #	ND< 0.07 #	ND< 0.061 #
Vanadium	0.31	0.35	1.0	ND< 9.8 BU	ND< 11 #	ND< 10 #	58 AU	ND< 9.1 #	ND< 8.4 #

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Table 2-8.1 Removal Efficiencies of ESPs and Baghouses

	ESP				Baghouse			
	Inlet Conc Range	Removal Efficiencies, Percent			Inlet Conc Range	Removal Efficiencies, Percent		
		Min	Max	Mean		Min	Max	Mean
Units: µg/Nm³								
Antimony	12-298	89.6	99.97	97.3	9-94	88.2	99.7	96.7
Arsenic	47-2274	85.2	99.9	96.8	16-3270	98.8	99.98	99.5
Barium	240-24500	92.7	99.84	98.8	241-95700	98.1	99.98	99.5
Beryllium	9-130	25.4	99.93	92.4	9-385	58.1	99.98	91.3
Boron	200-74000	19.4	98.7	62.2	35000-43200	97.6	98	97.8
Cadmium	3-166	44.0	97.3	89.7	3-726	78.7	99.995	93.2
Chromium	130-2900	94.7	100.14	97.7	64-2710	99.2	99.994	99.5
Cobalt	23-442	68.8	99.95	93.3	33-1030	85.7	99.96	97.2
Copper	11-1100	62.0	99.7	94.7	258-3710	99.3	99.96	99.7
Lead	73-1440	92.1	99.8	97.2	57-888	98.7	99.95	99.4
Manganese	140-11100	89.5	99.85	96.9	111-26100	99.0	99.93	99.5
Mercury	2-28	0	72.7	22.2	2-16	0	77.9	49.8
Molybdenum	3-1100	86.0	99.5	95.9	15-1100	97.7	99.8	99.0
Nickel	57-2100	89.2	99.9	96.5	37-16130	83.7	99.97	96.3
Selenium	0.3-408	7.6	99.8	53.9	0.2-423	17.0	99.98	80.3
Vanadium	120-4900	90.1	99.93	97.1	151-8140	98.2	100	99.5

PLANTS INCLUDED: (ESPs)

Bailly
Baldwin, Non-soot-blowing
Baldwin, Soot-blowing
Burger
Cardinal
Coal Creek
Hammond
Nelson Dewey
Niles
AirPol GSA
Smith
TIDD
Yates

PLANTS INCLUDED: (Baghouses)

Arapahoe
Boswell
Burger, SNRB
SNOX
AirPol GSA
Springerville

Table 2-8.2 Removal Efficiencies in Scrubbers

	Wet Scrubbers				Dry Scrubber/Baghouse		
	Inlet Conc	Removal Efficiencies, %			Inlet Conc	Removal Efficiencies, %	
Units: $\mu g/Nm^3$		Min*	Max	Mean		Scrubber	Overall
Antimony	0.41-43	-58	84	34	6.8	0	99.3
Arsenic	1.8-132	29	93	60	186	0	99.9
Barium	75-1920	-14	96	57	35000	0	99.95
Beryllium	1.7-99	53	93	78	112	0	> 99.96
Boron	202-17400	71	94	85	7350	0	90.5
Cadmium	1.3-163	46	90	61	264	0	99.99
Chromium	11-2080	30	77	56	935	0	99.99
Cobalt	2-191	45	85	70	380	0	> 99.9
Copper	5.6-958	70	88	77	1320	0	99.9
Lead	0.83-1440	27	97	69	140	0	99.0
Manganese	33-1200	5.1	78	49	6890	0	99.8
Mercury	4.2-12	-8.9	53	30	8.35	0	(Negative)
Molybdenum	1.4-760	50	83	62	161	0	98
Nickel	6.2-1240	-76	70	-0.8	593	0	> 99.9
Selenium	15-408	-16	67	30	118	0	> 99.96
Vanadium	5.1-2590	9.6	96	61	2920	0	99.96

__PLANTS INCLUDED:__ Bailly, Coal Creek, Yates

* Negative removal efficiency occurs when some of the material brought in with the recycled wash is entrained in the flue gas stream.

__PLANTS INCLUDED:__ Springerville

(Note: Spray Dryer has no solids removal. All solids are carried into baghouse.)

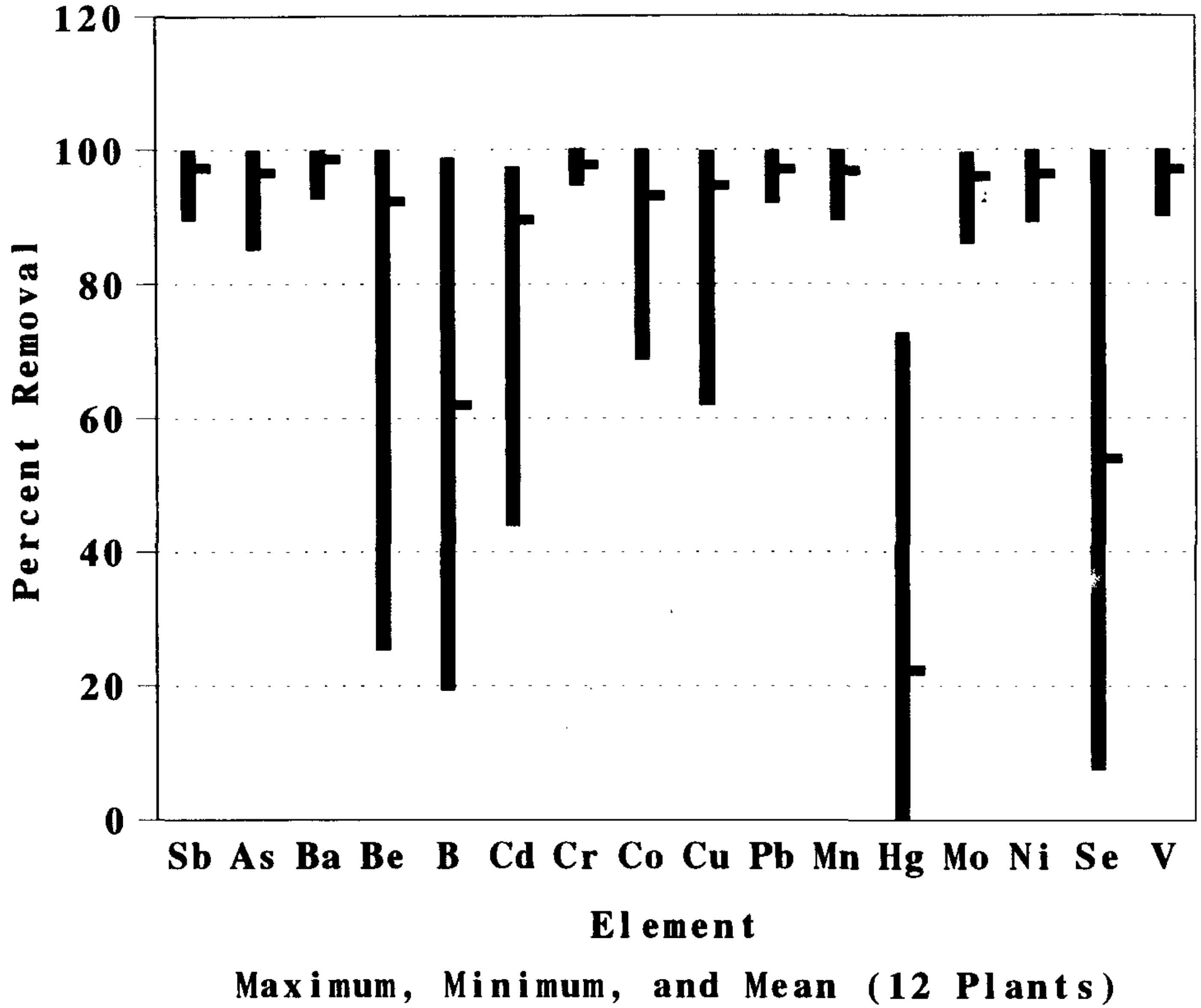

FIGURE 2-1. ESP REMOVAL EFFICIENCIES

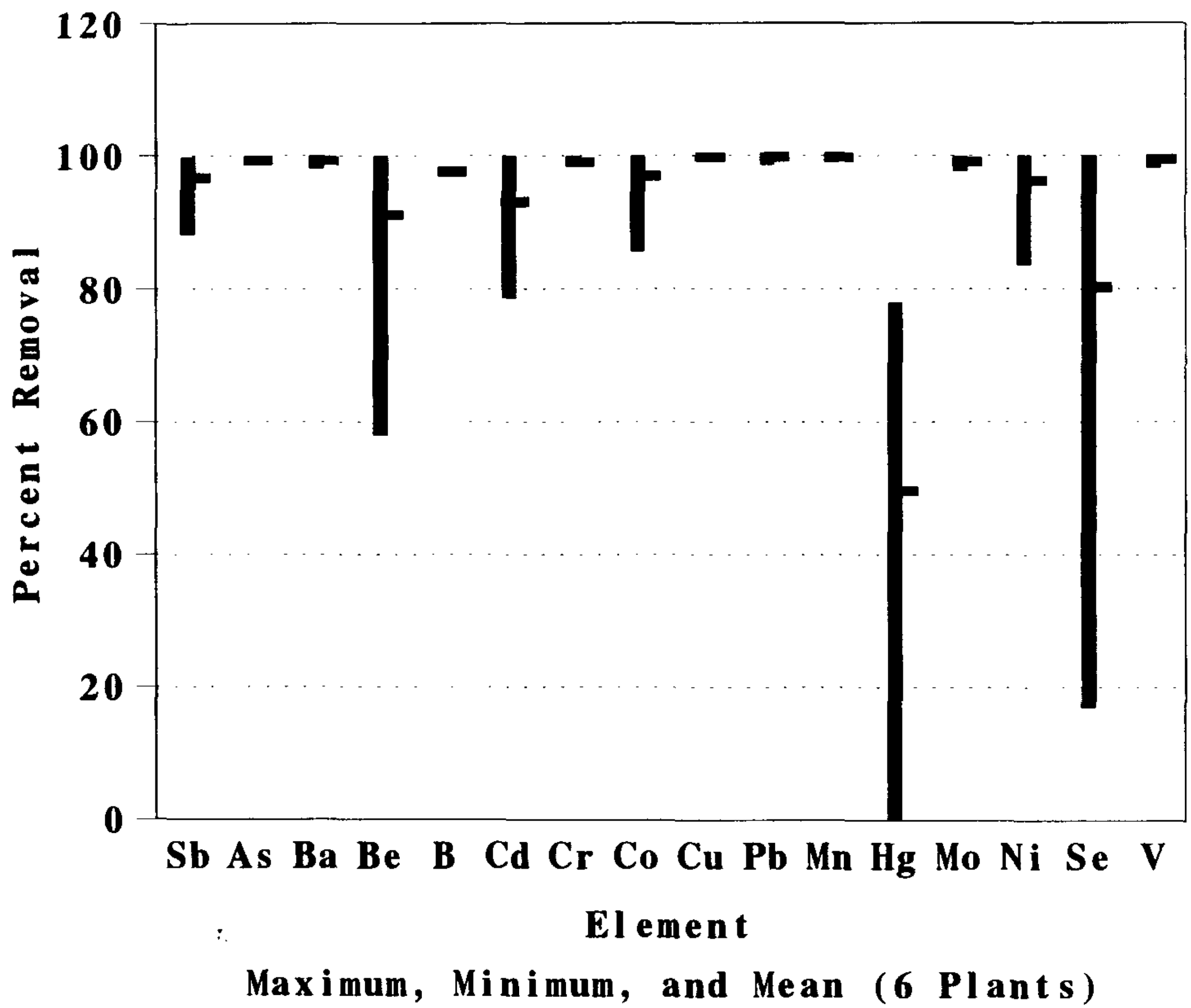

FIGURE 2-2. BAGHOUSE REMOVAL EFFICIENCIES

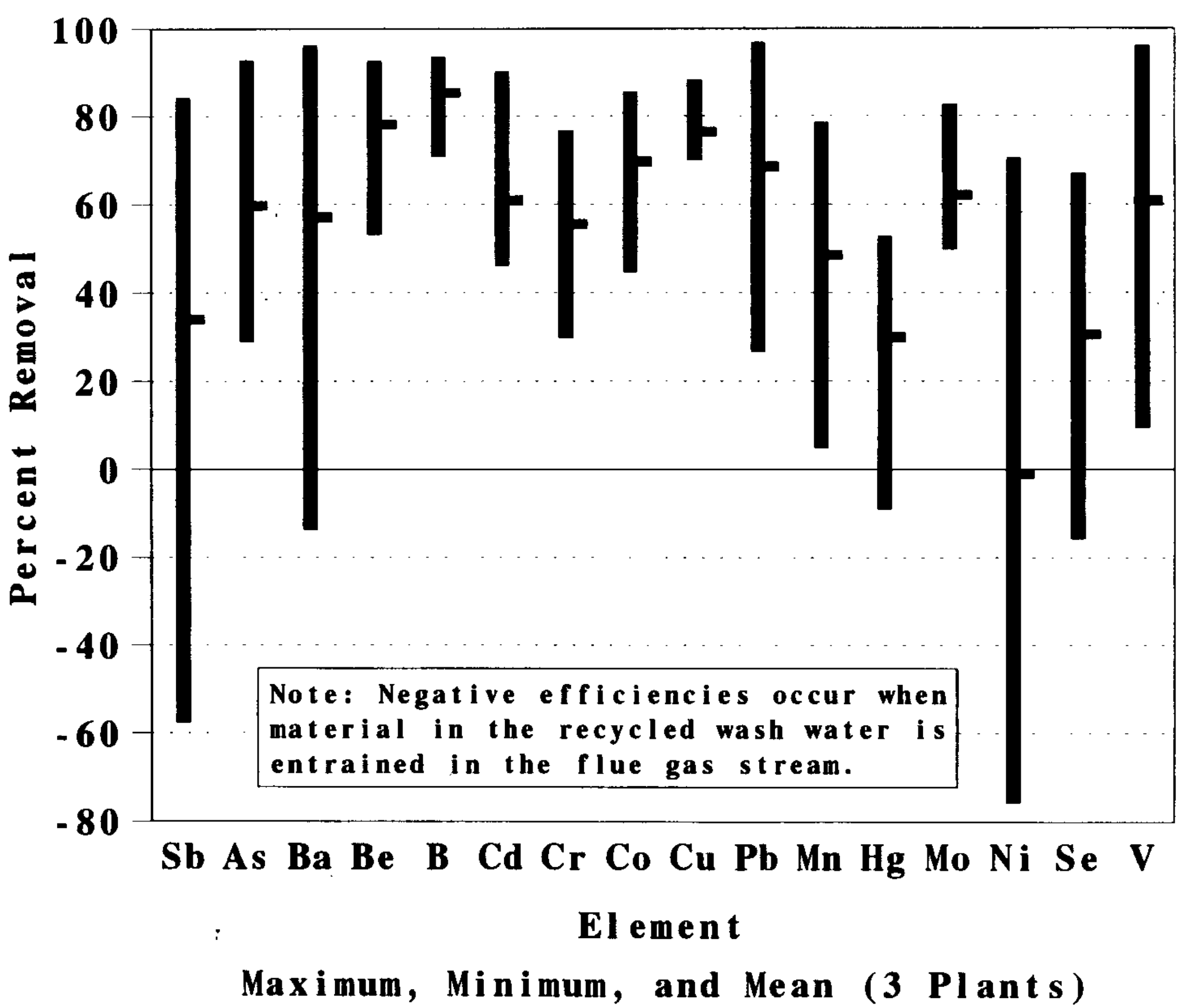

FIGURE 2-3. WET SCRUBBER EFFICIENCIES

Table 2-9 Flue Gas Sampling Methods for Hazardous Air Pollutants

Site/ Contractor	Particulate	Particle Size Distribution	Minor & Trace Elements (Including Mercury)	Halide Gasses[c] and NH_3 & HCN	Aldehydes and Ketones	Semi-Volatile Organic Compounds[c]	Volatile Organic Compounds
Baldwin/Roy F. Weston, Inc.	EPA Method 5/26A EPA Method 5/17/26A	EPA Method 201A (modified[a] by addition of a 3-Stage cyclonic separator) Malvern Particle Size Analyzer	EPA Draft Method 29 (modified by EPA Method 17) Bloom Method	EPA Method 17/26A EPA Method 5/26A HCN - Modified 26A NH_3 - Modified 26A	EPA Method SW-846 0011/0011A	EPA Method SW-846 0010/8270 EPA Method 23	EPA Method SW-846 0030/5040 (VOST)
Niles/Battelle (Columbus)	EPA Draft Method 29	Cascade Impactors	EPA Draft Method 29 HEST	EPA Method 26A HCN - APHA-808 NH_3 - APHA-401	EPA Method TO-5 EPA Method SW-846 0011 APHA 122	Modified EPA Method 23 EPA Method 23	EPA Method SW-846 0030/5040 (VOST) Summa Canister
Site 110/ Southern Research Institute	EPA Draft Method 29	Cyclonic Separation Cascade Impactors (University of Washington, Mark V)	EPA Draft Method 29 Bloom Method	Radian Corporation's Modified EPA Method 26A (includes NH_3 & HCN)	Radian Corporation's Modified EPA Method SW-846 0011	EPA Method SW-846 0010 (no analysis for Dioxins and Furans)	EPA Method SW-846 0030 (VOST)
Boswell/ Roy F. Weston, Inc.	EPA Method 5/26A EPA Method 5/17/26A	EPA Method 201A (modified by addition of a 3-stage cyclonic separator) Malvern Particle Size Analyzer	EPA Draft Method 29 (modified by EPA Method 17) Bloom Method	EPA Method 17/26A EPA Method 5/26A HCN - Modified 26A NH_3 - Modified 26A	EPA Method SW-846 0011	EPA Method SW-846 0010/8270 EPA Method 23	EPA Method SW-846-0030/5040 (VOST)
Site 116 (SNRB)/ Radian Corporation	EPA Method 26A	(Not Performed)	EPA Draft Method 29 Bloom Method	EPA Method 26A (NH_3 & HCN not sampled)	EPA Methods SW-846 0011/TO-11	EPA Method SW-846 0010 EPA Method 23	EPA Method 18/TO-14
Nelson Dewey/ Acurex Environmental Corporation	EPA Method 5 EPA Method 17	(Not Performed)	EPA Method SW-846 0012	CARB Method 421 (NH_3 & HCN not sampled)	CARB Method 430	EPA Method SW-846 0010/8270 (no analysis for Dioxins and Furans)	EPA Method SW-846 0030 (modified w/carbon molecular sieve sorbent)
Springerville/ Southern Research Institute	EPA Method 17	EPA Method 5 with Cyclones and Cascade Impactors	EPA Draft Method 29 Bloom Method	EPA Method SW-846-0050 (modified for HCN & NH_3)	Modified EPA Method SW-846-0011 EPA Method TO-5	EPA Method SW-846 0010/8270 (and Modified 0010)	EPA Method SW-846 0030 (VOST)

Table 2-9 Flue Gas Sampling Methods for Hazardous Air Pollutants, (continued)

Site/ Contractor	Particulate	Particle Size Distribution	Minor & Trace Elements (Including Mercury)	Halide Gasses[1] and NH_3 & HCN	Aldehydes and Ketones	Semi-Volatile Organic Compounds[2]	Volatile Organic Compounds
Yates/Radian Corporation	EPA Method 5 EPA Method 17	Cascade Impactors (in-stack)	EPA Draft Method 29 Bloom Method	Radian Corporation's Modified EPA Method 26A (includes NH_3 & HCN)	Modified EPA Method SW-846-0011	EPA Method SW-846 0010 Modified EPA Method 23	EPA Method SW-846 0030 (VOST)
Coal Creek/ Battelle (Columbus)	EPA Method 5	Glass Cyclones	EPA Draft Method 29 HEST	EPA Method 26A CARB Method 421 HCN - APHA-808 NH_3 - APHA-401	APHA 122 EPA Method TO-5	Modified EPA Method 23 EPA Method 23	EPA Method SW-846 0030 (VOST) Summa Canister
SNOX/Battelle (Columbus)	EPA Method 5	Glass Cyclones	EPA Draft Method 29 HEST	EPA Method 26A CARB Method 421 HCN - APHA-808 NH_3 - APHA-401	APHA 122 EPA Method TO-5	Modified EPA Method 23 EPA Method 23	EPA Method SW-846 0030 (VOST) Summa Canister
Site 16/Radian Corporation	EPA Method 5	Cascade Impactors (University of Washington, Mark V)	EPA Draft Method 29 Bloom Method	Radian Corporation's Modified EPA Method 26A (NH_3 & HCN not sampled)	EPA Method SW-846-0011	EPA Method SW-846 0010 (no analysis for Dioxins and Furans)	EPA Method SW-846 0030 (VOST)
Cardinal/ Energy and Environmental Research Corporation	EPA Method 5	In-situ 5-stage cyclonic separation In-situ Anderson Cascade Impactors	EPA Draft Method 29 Charcoal Traps	EPA Method 26A (with modifications for NH_3 and HNC)	Modified EPA Method SW-846-0011	EPA Method SW-846 0010 EPA Method 23	EPA Method SW-846 0030 (VOST) Charcoal Tubes
Bailly/ Southern Research Institute	EPA Method 17	Cyclone Trains and Impactors	EPA Draft Method 29 Carbon Traps Bloom Method	EPA Method SW-846 0050 (with modifications for NH_3 and HNC)	Modified EPA Method SW-846 0011	EPA Method SW-846 0010/8270 (and Modified 0010)	EPA Method SW-846 0030 (VOST)
TIDD PFBC/ Radian Corporation	EPA Method 5	Cascade Impactors	EPA Draft Method 29	Radian Corporation's Modified EPA Method 26A (includes NH_3 & HCN)	EPA Method SW-846 0011/0011A	Modified EPA Method SW-846 0010 Modified EPA Method 23	EPA Method SW-846 0030/5040 (VOST)
Shawnee Unit #9/ Energy and Environmental Research Corporation	EPA Draft Method 5	(Not Performed)	EPA Draft Method 29	EPA Method 26A (NH_3 & HCN not sampled)	(Not Performed)	(Not Performed)	(Not Performed)

Table 2-9 Flue Gas Sampling Methods for Hazardous Air Pollutants, (continued)

Site/ Contractor	Particulate	Particle Size Distribution	Minor & Trace Elements (Including Mercury)	Halide Gasses[1] and NH_3 & HCN	Aldehydes and Ketones	Semi-Volatile Organic Compounds[2]	Volatile Organic Compounds
Arapahoe Unit #4/ Public Service Company of Colorado	EPA Method 5	(Not Performed)	EPA Draft Method 29 Bloom Method	CARB Method 421 HCN - CARB-426 NH_3 - Modified EPA-26A	CARB Method 430	CARB Method 429 EPA Method 23	CARB Method 422(Tedlar Bags)/TO-14

FOOTNOTES

1. *The presence of halogen gasses (X_2) in coal flue gas is controversial as is their determination by EPA Method 26A.*

2. *Analyses for dioxins and furans were preformed except where otherwise indicated.*

3. *Only major modifications such as structural changes to sampling trains, for example the addition of cyclonic separators, and procedural changes such as an extraction step that might distinguish the analytes specific to, for example, the very similar EPA Method SW-846 0010 and EPA Method 23 will be noted as modifications to the standard procedures.*

ACRONYMS and TERMINOLOGY

APHA	American Public Health Association Method.
Bloom Method	Mercury chemical speciation method developed by Nicholas Bloom and workers.
CARB	California Air Resources Board.
EPA	U. S. Environmental Protection Agency.
HEST	Hazardous Emissions Sampling Train, developed by John Cooper and workers.

SECTION 3.0 INDIVIDUAL SITE RESULTS

This section contains selected results from each plant site. The data given here are reported in the units used in the individual reports except where calculations were necessary. Units may differ slightly. For example, gas stream concentrations for all plant sites are reported in *micro-grams/normal cubic meter* (μg/Ncm). Some contractors, however, reported results on a dry basis (μg/dscm, micro-grams/dry standard cubic meter), and some did not. Some concentrations were corrected to 3 percent oxygen, and some were not.

The stream numbers on the plant schematics correspond to the column numbers in the tables of stream flow rates.

Section 3.1 Coal Creek Station

The Coal Creek Station is located about 50 miles north of Bismarck, North Dakota, near Underwood, North Dakota. Coal Creek Station is a two-unit, zero discharge, 1,100 MWe, mine-mouth plant located in a lignite field. The two units are identical. The study described in this report was conducted on Unit No. 1. Each unit has a tangentially fired, water walled, dry bottom furnace, with a Combustion Engineering Controlled Circulation boiler. The furnace is fueled by lignite that is conveyed into the plant from the Falkirk mine located adjacent to the plant. Coal is fed to the boiler through eight pulverizers, of which seven are in operation at any one time. Each unit is equipped with an electrostatic precipitator (ESP) for particulate removal, and with a wet flue gas desulfurization unit (FGD, denoted as scrubber) for sulfur dioxide (SO_2) removal. Each of these components is described below.

Lignite is supplied to the plant from the nearby Falkirk mine by a conveyer system over 3 miles long. A series of conveyers and silos allows for supply of the plant, and for movement of coal in and out of yard storage supplies. The lignite is crushed, prior to being supplied to eight silos in each unit of the plant. The crushed lignite from the silos is then pulverized in eight bowl mills, which grind the coal to a fineness of 65 percent through 200 mesh. Only seven of the eight mills are in operation at any time. The pulverizing process also reduces the moisture content of the coal by about half. The pulverized lignite is transported to the furnace pneumatically, and injected into the furnace through tangential nozzles at eight levels in the windbox registers in the front and rear furnace walls.

Coal Creek Unit 1 is designed to achieve low NO_x production by means of the tangential firing, which produces a vortex in the furnace, causing mixing of the fuel and air streams throughout the furnace. Internal recirculation of gas within the furnace vortex provides low NO_x production, and results in a long residence time for combustion, favoring low hydrocarbon and CO emissions. Reduction of NO_x is also achieved by addition of overfire air.

Soot blowing at Unit 1 is conducted continuously on at least some portion of the furnace, using a total of 262 steam soot blowers installed in the furnace.

The flue gas leaving the Unit 1 boiler travels through an economizer and then through two parallel air preheaters (not shown) on its way to the two parallel halves of the ESP. The two halves of the ESP are shown as ESP #1 and ESP #2 in Figure 3.1-1. Gas leaving the preheaters is divided into four ducts, two of which connect to each half of the ESP. The ESP is constructed as two separate shells or halves, permitting operation with one shell under reduced load conditions.

The ESP provides a specific collecting area of 599 square feet per 1000 actual cubic feet per minute of gas flow. ESP is rated at a removal efficiency of 99.5 percent at inlet particulate loadings of greater than 1.16 grains per actual cubic foot (2.65 grams per actual cubic meter). At lower inlet loadings, the outlet particulate loading is rated to be no higher than 0.0058 grains per actual cubic foot (0.013 grams per actual cubic meter).

Ash from the hoppers is removed by a pressurized pneumatic system that dumps two hoppers at a time. Flue gas leaves the ESP in four ducts which connect to four induced draft fans. The gas flow from these fans recombines into two ducts that connect to the Unit 1 scrubber system.

The Coal Creek Unit 1 scrubber is a Combustion Engineering Air Quality Control System (AQCS), which removes SO_2 from the flue gas by means of four countercurrent spray towers using an alkali slurry. The system is designed to remove 90 percent of the SO_2

from up to 60 percent of the flue gas flow. The unscrubbed (bypassed) flue gas is recombined with the scrubbed gas to reheat it. Flexibility in responding to variations in fuel sulfur content is provided by the variable gas bypass flow, and by the capability of operating with fewer than four spray towers at a time.

In the scrubber, alkaline slurry is pumped to the spray towers from two slurry reaction tanks (not shown), and drains back after collection at the bottom of the scrubber. The scrubber slurry is maintained at a pH of about 7 by intermittent automatic introduction of lime slurry into the reaction tanks. The lime slurry is made up as needed from commercial pebble lime and scrubber makeup water, to a nominal solids content of 15 percent. This slurry is added to the reaction tanks, along with scrubber makeup water for tank level control. Scrubber makeup water also enters the system as an intermittent flow of mist eliminator wash water (not shown).

The scrubber bypass flow can be adjusted by means of dampers in the flow line. The bypass flow results from the convergence (from opposite directions) of the two combined flow streams downstream of the four induced draft fans at the outlet of the ESP. At the convergence point, the combined bypass flows turn vertically to meet the scrubbed flue gas flow exiting the scrubber. As a result of the contorted bypass flow path, the gas velocity profile in the bypass duct is highly non-uniform.

During the six days of measurement in this study, the scrubber was operated in a normal manner. As a result, scrubber operation varied in response to variations in the sulfur content of the feed coal. Because of this factor, all four of the scrubber spray towers were in service on the first, fifth, and sixth days of measurements, but only three were in service on the second, third, and fourth days. Changeover between the two modes of operation was done after the completion of flue gas measurements on each day.

A schematic flow diagram is shown in Figure 3.1-1 and Figure 3.1-2 shows the partitioning results for the trace elements. Tables 3.1-1 and 3.1-2 present the trace element flow rates and concentration/removal efficiency information for this plant. Table 3.1-3 gives the stream temperatures at various points in the plant.

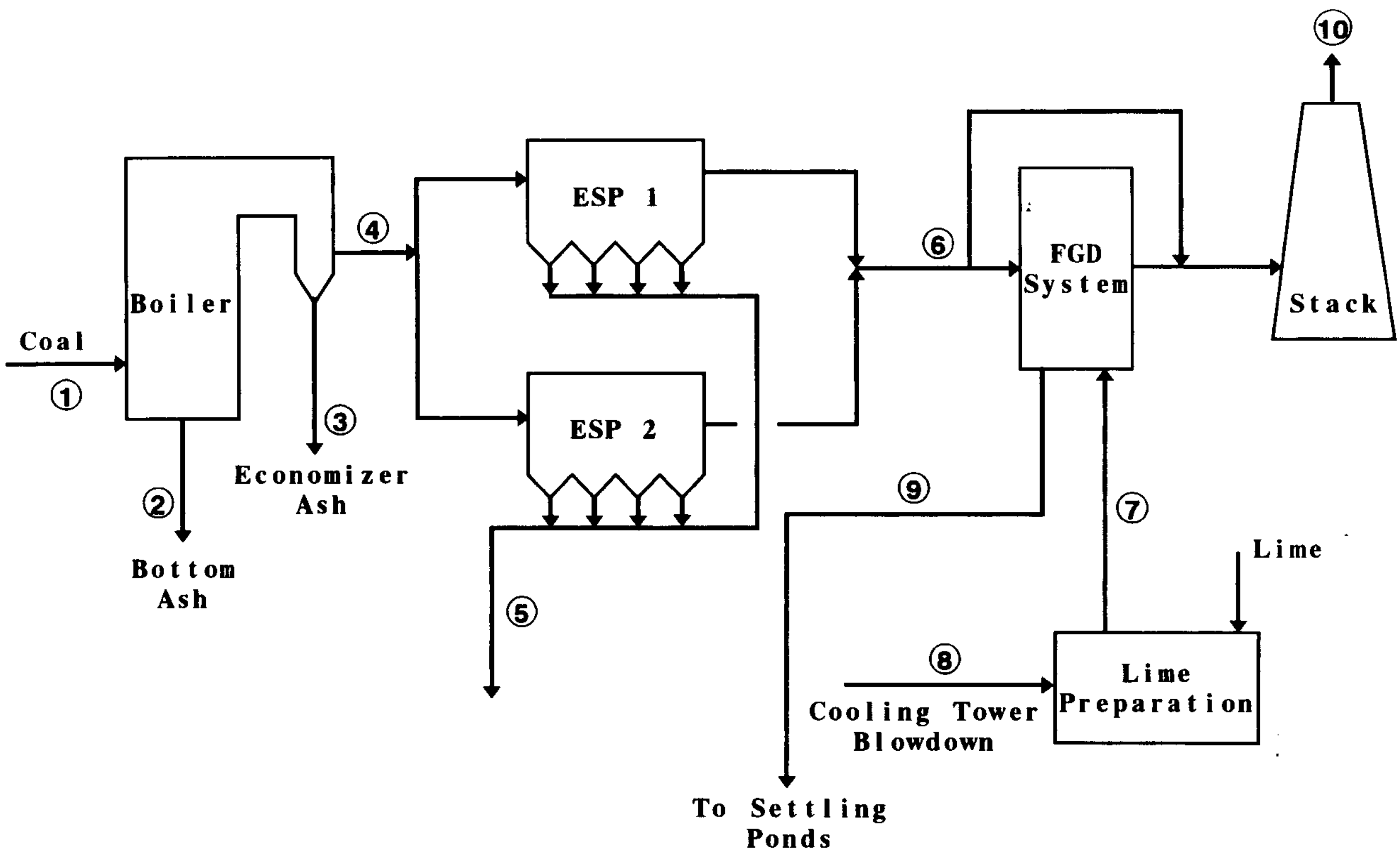

FIGURE 3.1-1. COAL CREEK STATION UNIT NO.1 FLOW DIAGRAM

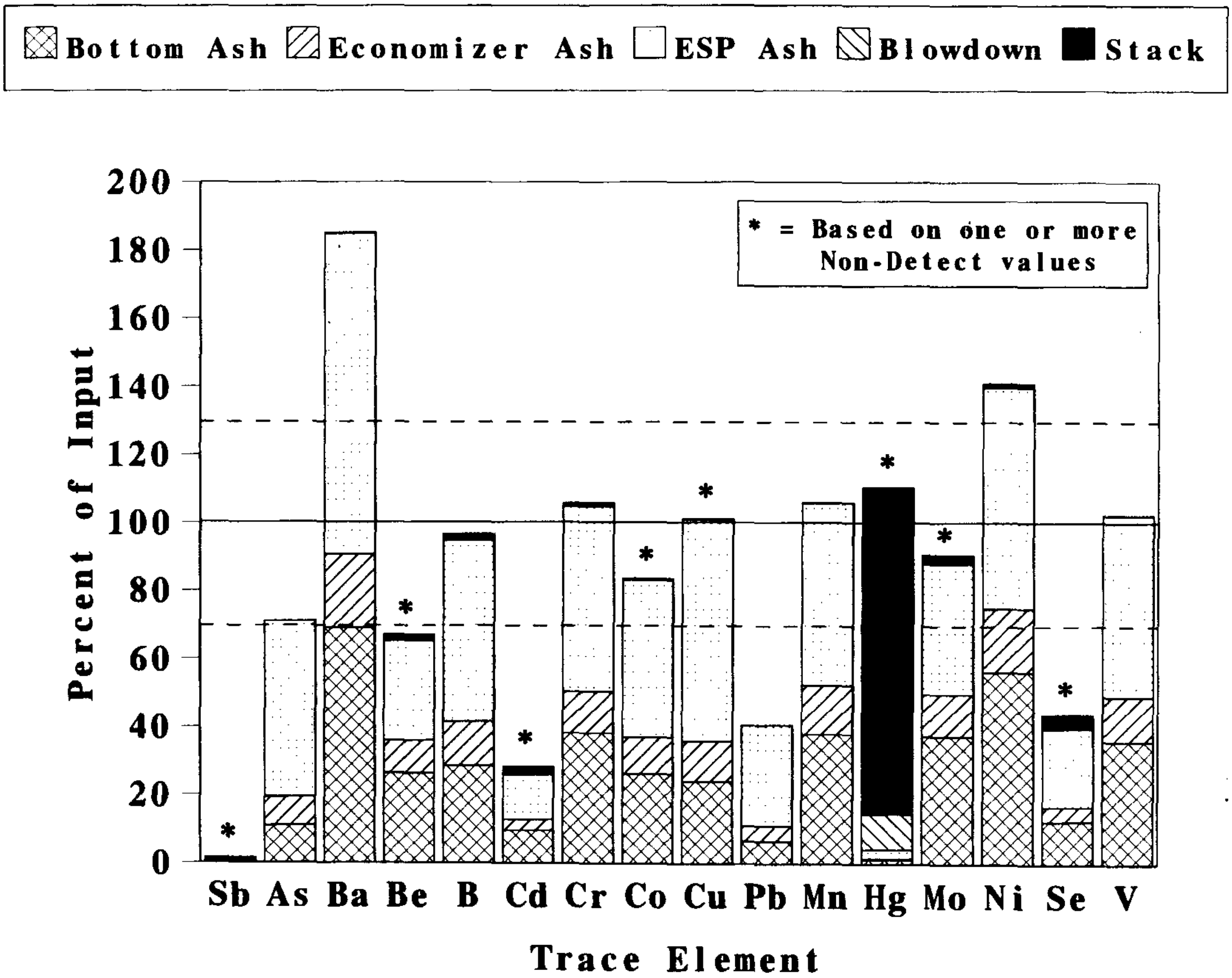

FIGURE 3.1-2 TRACE ELEMENTS IN OUTPUT STREAMS COAL CREEK STATION

Table 3.1-1 Trace Element Flow Rates, Coal Creek Station

	(1) Coal	(2) Bottom Ash	(3) Economizer Ash	(4) ESP Inlet	(5) ESP Catch	(6) ESP Out, Scrubber In	(7) Lime Reagent	(8) Recycle/ Makeup Water	(9) Srubber Blowdown	(10) Stack
Units: lb/hr										
Antimony	ND< 24.8 #	ND< 0.136 #	ND< 0.0451 #	0.310	0.185[C]	0.0062	ND< 0.208 #	ND< 0.0059 #	ND< 0.0025 #	0.0010
Arsenic	6.30	0.712	0.541	4.64	3.37	0.010	ND< 0.208 #	ND< 0.0059 #	0.0110	0.0069
Barium	218	152	47.4	90.3	207	1.07	1.25	0.0439	0.265	0.876
Beryllium	0.449	0.146	0.053	0.170	0.163	ND< 0.012 #	ND< 0.104 #	ND< 0.0015 #	ND< 0.0006 #	ND< 0.0093 #
Boron	95.8	28.0	12.9	57.5	52.4	0.97	ND< 2.61 #	3.22	1.39	0.105
Cadmium	ND< 0.603 #	ND< 0.0678 #	ND< 0.0226 #	0.0737	ND< 0.0924 #	ND< 0.021 #	0.104[B]	0.0015[A]	0.0006[B]	ND< 0.0174 #
Chromium	5.49	2.14	0.688	3.83	3.05	0.048 [A]	0.104[B]	0.0044	0.0101	0.0525
Cobalt	1.47	0.441	0.180	0.969	0.779	ND< 0.012 #	ND< 0.208 #	ND< 0.0029 #	0.0013[A]	ND< 0.0089[B]
Copper	4.69	1.15	0.564	2.50	3.13	0.0315	ND< 0.104 #	ND< 0.0015 #	0.0067	ND< 0.0109[A]
Lead	4.89	0.339	0.226	1.52	1.51	0.0044	ND< 0.208 #	ND< 0.0059 #	0.0025[A]	0.0037
Manganese	65.0	28.9	11.0	40.9	40.7	0.163	11.1	0.0322	0.480	0.161
Mercury	0.0536	ND< 0.0007 #	0.0002[B]	0.0516	0.0014	0.0811	ND< 0.0010 #	ND< 0.00006 #	0.0058	0.0525
Molybdenum	1.54	ND< 1.36 #	0.451[B]	0.829	ND< 1.39 #	0.0068	ND< 2.08 #	0.173	0.0783	0.0027
Nickel	1.74	1.19	0.395[A]	2.48	1.37	0.0274[B]	0.365[A]	ND< 0.0029 #	0.0139	0.0278
Selenium	ND< 0.871 #	ND< 0.136 #	ND< 0.0451 #	0.413	0.249[A]	0.087	ND< 0.209 #	0.0059[B]	ND< 0.0025 #	0.0444
Vanadium	10.1	3.73	1.38	4.05	5.53	0.0287	0.3336	0.0129	0.0189	0.0238

ND< Value shown is detection limit
A Includes one non-detect measurement
B Includes two non-detect measurements
C Includes five non-detect measurements (parallel sampling of two streams)
Non-detectible in all samples

Table 3.1-2 Concentrations and Collection Device Removal Efficiencies, Coal Creek Station

	ESP In, µg/Nm³	Scrubber In, µg/Nm³	Stack µg/Nm³	ESP Removal Efficiency, Percent	Scrubber Removal Efficiency, Percent
Antimony	69.8	1.65	0.25	97.2	76.1
Arsenic	1,046	2.12	1.7	99.8	29.1
Barium	20,348	205	217	98.8	-13.6
Beryllium	38.2	2.35	ND< 2.3	96.5	> 53.3
Boron	12,956	237	26	98.3	71.0
Cadmium	16.6	4.11	ND< 4.3	81.4	> 46.2
Chromium	864	12.9	13	98.5	29.9
Cobalt	218	2.35	ND< 2.2	99.4	> 44.7
Copper	563	6.58	ND< 2.7	98.8	> 71.4
Lead	342	0.976	0.92	99.7	26.7
Manganese	9,219	38.8	40	99.6	5.1
Mercury	11.6	14.1	13	-64.9	-8.9
Molybdenum	187	1.65	0.68	99.1	54.1
Nickel	558	7.29	6.9	98.8	2.7
Selenium	93.0	17.6	11	79.2	39.7
Vanadium	914	6.00	5.9	99.3	9.6

Table 3.1-3 Stream Temperatures, Coal Creek Station

Temperature, deg F	
Steam, Superheater Outlet	1004
Steam, Reheater Outlet	1005
ESP Inlet	340
ESP Outlet, Scrubber Inlet	317
Scrubber Outlet (To Stack)	230

Section 3.2 Boswell Energy Center

Plant Description

The Boswell Energy Center is located in Cohasset, Minnesota, and is owned and operated by Minnesota Power Company. The power plant comprises four coal-fired units numbered 1 through 4. Units 1 and 2 are each rated at 69 MWe, Unit 3 is rated at 350 MWe, and Unit 4 is rated at 500 MWe. Unit 2, built in 1957, was studied in this program. This unit, equipped with a Riley Stoker front-fired boiler, burns western subbituminous coal delivered to the station by train from the Powder River Basin area of Montana and Wyoming, primarily from the Rosebud seam. Average coal characteristics for this study were 8.4% ash, 0.70% sulfur, 24.8% moisture, and approximately 8,800 Btu/lb higher heating value.

Unit 2 is operated from a control room which is common to both Units 1 and 2. At Unit 2, coal is transferred from storage bunkers through feeders directly into four pulverizers located on the ground floor. Pulverized coal is transported via primary air through 9 burners on the front of the furnace. Secondary combustion air is introduced to the furnace through a windbox. The combustion gases leave the furnace and enter the convective pass section of the boiler which is composed of vertically divided superheater and reheater sections. Main and reheat steam temperatures are controlled primarily by dampers at the outlets of the superheater and reheater sections, and/or by a superheater/reheater bypass duct. Superheater and reheater attemperation sprays are available, but seldom used.

Next, the combustion gases are directed through an economizer section followed by an air preheater section. Some entrained particulate (i.e., ash) is deposited on various boiler wall and tube surfaces. Unit 2 is equipped with a series of sootblowers to remove this slagging and fouling material. The sootblowers are used on an irregular basis. That is, when heat transfer patterns change, the sootblowers are used to clean the contaminated surfaces and regain optimum steam temperature control and thermal efficiency. Selected sootblowing sequences are normally executed at least once per shift, but not necessarily at the same time during each shift.

At this unit, the economizer hoppers are maintained full, resulting in the carryover of overhead ash (i.e., fly ash) to downstream collection equipment.

Unit 2 uses a baghouse for particulate control. The original mechanical particulate collector has been removed, although the housing remains as part of the ductwork leading to the retrofitted baghouse. The baghouse consists of eight compartments containing a total of 1,920 Teflon-coated fiberglass bags (240 bags per compartment), has an air-to-cloth ratio of 1.974:1, and uses reverse air for cleaning. It is designed for 99.7% particulate collection efficiency. The flue gas exit temperature is 300-400°F under normal operating conditions. Boswell Unit 2 has no other air pollution control equipment currently installed.

Flue gas is discharged from Units 1, 2, and 3 via a common stack. Maintenance is effected by directing gas flow from the common stack to an adjacent 250-foot stack using dampers in the breaching of each unit. The 250-foot stack originally served Units 1 and 2 prior to the construction of Unit 3. Since there are no provisions for emission measurement on the 250-foot stack, a suitably configured and equipped section of ductwork located downstream of the Unit 2 baghouse and upstream of an induced draft (ID) fan was selected for flue gas discharge characterization.

All overhead ash collected in the baghouse hoppers is removed from the plant site via truck.

Furnace bottom ash is sluiced to a common bottom ash pond for Units 1, 2, 3 and 4. Supernatant from the pond is used as return water for all four units, and a portion of it is blown down. The blowdown is a part of the combined supernatant from the pond; it is not specific to each unit.

A process flow diagram of Boswell Unit 2 is shown in Figure 3.2-1. Partitioning results for trace elements are presented in Figure 3.2-2. Tables 3.2-1 and 3.2-2 give the trace element flow rates and concentration/removal efficiency information for the Boswell Plant. Table 3.2-3 gives the stream temperatures at various points in the plant.

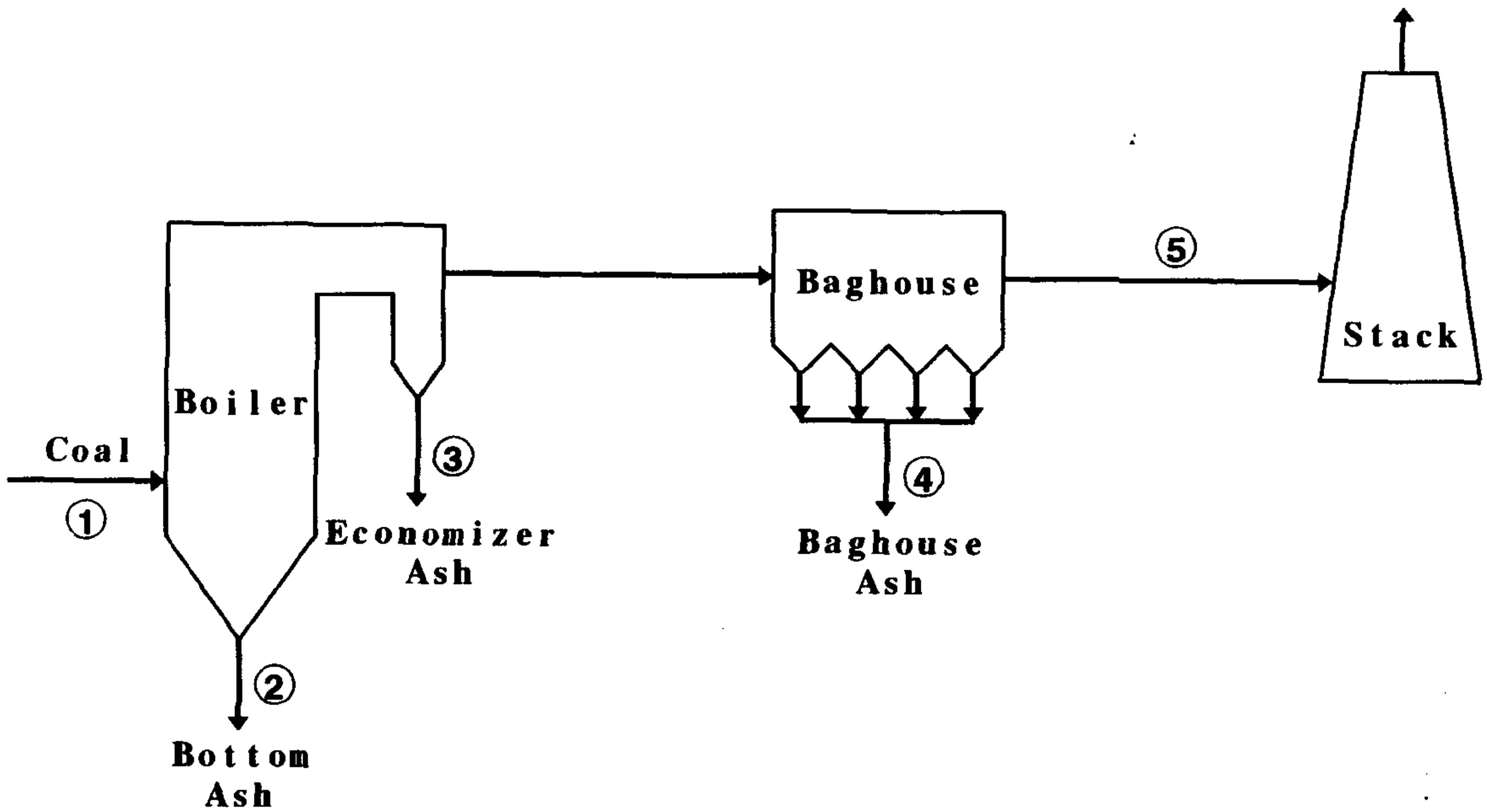

FIGURE 3.2-1. BOSWELL ENERGY CENTER UNIT NO. 2 FLOW DIAGRAM

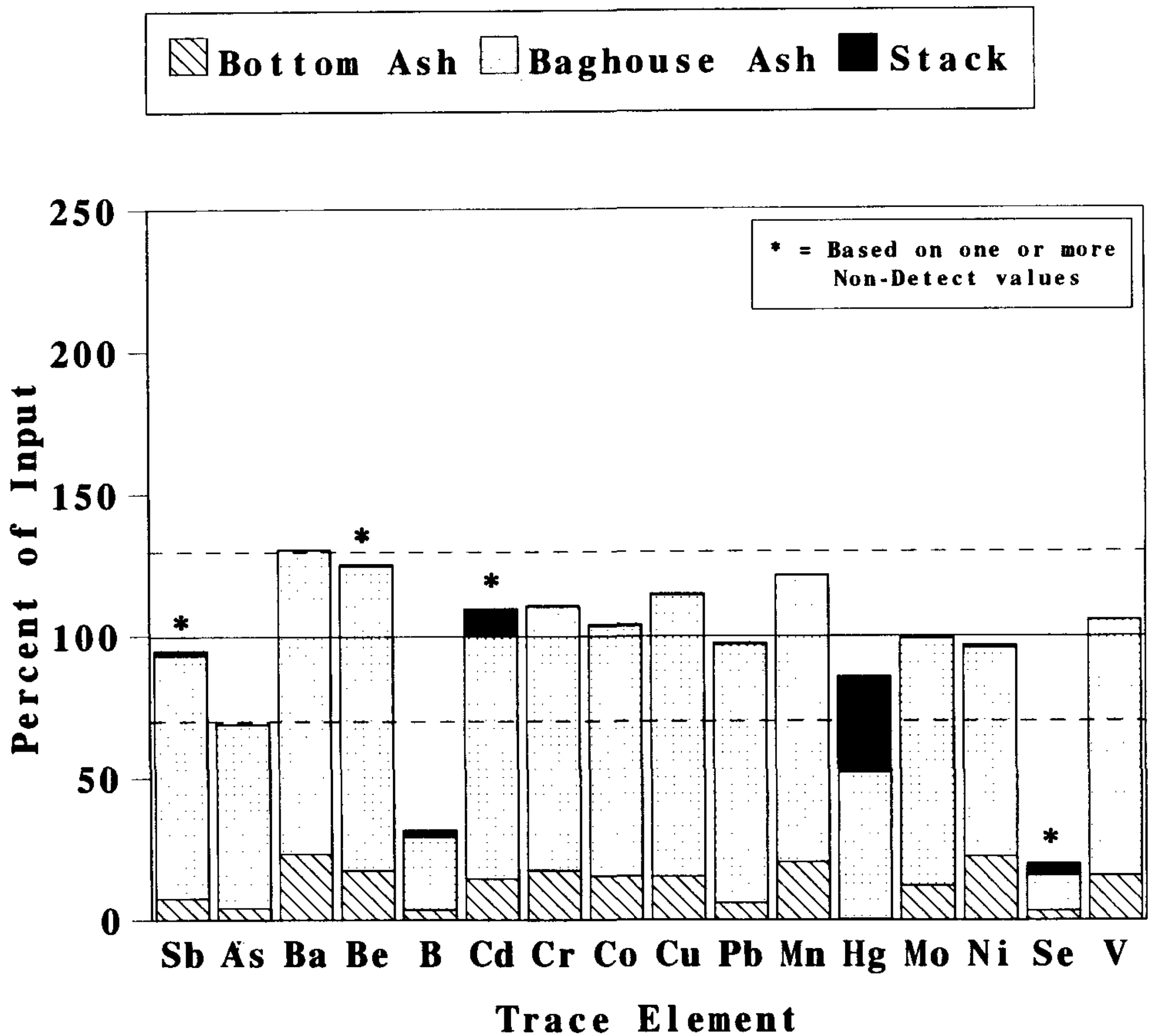

FIGURE 3.2-2. TRACE ELEMENTS IN OUTPUT STREAMS BOSWELL ENERGY CENTER

Table 3.2-1 Trace Element Flow Rates, Boswell Energy Center

	(1) Coal Input	(2) Bottom Ash	(3) Baghouse Inlet	(4) Baghouse Ash	(5) Stack
Units: lb/hr					
Antimony	0.028	0.002	0.016	0.024	ND< 0.00044 #
Arsenic	0.10	0.004	0.024	0.06	0.00021[B]
Barium	23.3	5.4	2.8	25.0	0.053
Beryllium	0.013	0.002	0.0078	0.014	ND< 0.000084 #
Boron	16.7	0.60	17	4.3	0.39
Cadmium	0.004	ND< 0.0006 #	0.0074	0.004	ND< 0.00042 #
Chromium	0.2	0.04	0.28	0.21	0.0013
Cobalt	0.07	0.012	0.07	0.066	0.00045
Copper	0.38	0.06	0.4	0.38	0.0016
Lead	0.29	0.018	0.12	0.26	0.0016[A]
Manganese	7.5	1.5	4.3	7.59	0.012
Mercury	0.004	0.000012[A]	0.003	0.0020	0.0013
Molybdenum	0.30	0.037	0.56	0.26	0.00084
Nickel	0.16	0.03	0.17	0.11	0.0013
Selenium	0.05	ND< 0.002 #	0.0061	0.006	0.0021
Vanadium	0.5	0.07	0.43	0.42	0.001

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
Non-detectible in all samples

Table 3.2-2 Concentrations and Collection Device Removal Efficiencies, Boswell Energy Center

	Baghouse Inlet, µg/Nm³	Baghouse Outlet, µg/Nm³	Removal Efficiency, Percent
Antimony	32	ND< 0.91	> 97.2
Arsenic	47	ND< 0.44	> 99.1
Barium	5,400	110	98.1
Beryllium	16	ND< 0.17	> 98.9
Boron	35,000	800	97.6
Cadmium	15	ND< 0.86	> 94.3
Chromium	610	2.7	99.5
Cobalt	150	0.93	99.3
Copper	850	3.2	99.6
Lead	240	3.2	98.7
Manganese	8,600	25	99.7
Mercury	6.4	2.6	59.8
Molybdenum	1,100	1.7	99.8
Nickel	360	2.6	99.2
Selenium	14	4.3	65.6
Vanadium	900	2.0	99.8

Table 3.2-3 Stream Temperatures, Boswell Energy Center

Temperature, deg F	
Baghouse Inlet	350
Baghouse Outlet (To Stack)	332

Section 3.3 Springerville Station

Springerville Generating Station Unit No. 2 is owned and operated by the Tucson Electric Power Company (TEP) and is located near Springerville, Arizona. The plant is a zero-discharge design, burning subbituminous coal from the Lee Ranch Mine in New Mexico. The coal has an average sulfur content of 0.7% and an ash content of 19%. Typical gross electrical generation at full load is 397 MWe, and the net generating capacity is approximately 360 MWe. (During testing, Unit No. 2 was operated at maximum capacity, with 422 MWe gross and 383 MWe net electrical output.)

The Unit No. 2 boiler is a corner-fired, balanced-draft design with overfire air for reducing NO_x emissions. Coal is fed to the boiler through bowl mill pulverizers. Pyrite is separated from the coal in the pulverizers. At full load, five or six pulverizers feed about 200 tons per hour of coal into 24 burners and produce 2.6 million pounds per hour of steam. Approximately 22% of the coal ash is retained as bottom ash in the boiler. The bottom ash is removed by a sluice. Soot blowers for the boiler walls are operated on a continuous cycle, and the air heater soot blowers are operated once per shift (twice daily). Pulverizer reject (pyrite) and bottom and economizer ash (sluice) are pumped to dewatering bins, surface water is passed through screens in the bins, and returned back for sluicing operations. The dewatered solids are trucked to the ash disposal area.

Unit No. 2 uses one cooling tower with 13 cells and one dual-pressure, single-shell condenser. The condensate is treated and recirculated. All makeup water for the unit is obtained from a storage pond supplied by seven nearby wells, or other waste water streams of the unit. Waste water is also treated on site and either sent to evaporation ponds or used as makeup water for other unit processes.

Unit No. 2 uses a Dry Flue Gas Desulfurization (FGD) system. The system has three spray dryer absorber (SDA) modules and one atomizer per absorber. A small portion of the flue gas (about 15% at full load) bypasses the SDA modules. Under normal conditions, at operation above 60% capacity, all three SDA modules are in service. Fresh lime from Chemstar Lime of Nelson, AZ, is slaked in ball mills at the plant. The fresh lime milk has a lag time of one to two hours from the lime milk storage tank to the injection through the atomizers. Solids content for the fresh lime slurry is maintained at 24%. The FGD system uses sorbent/ash recycle from the baghouse to supplement the fresh lime slurry. Recycle feed rate is adjusted to control the temperature of the flue gases leaving the SDA modules to 71 C (160°F). Solids content of the slurry feed at the atomizers is kept at about 50%. Air is entrained into the bottoms of the SDA modules to limit solids dropout in the modules. All of the fly ash and slurry residue pass through the SDA absorbers into the baghouse inlet ducts.

The baghouse system consists of two baghouses with 14 compartments each that withdraw flue gas from a common manifold. Filtered flue gases are pulled from the two baghouses into separate induced draft fans before being exhausted through the 152.4-m tall stack that is exclusive to Unit No. 2. Fly ash/sorbent is either recycled to the mix tank to be used in the FGD system or transported to a fly ash silo and then trucked to an ash disposal area.

Figure 3.3-1 is a schematic process flow diagram for Unit No. 2 and partitioning results for trace elements are presented in Figure 3.3-2. Tables 3.3-1 and 3.3-2 give the trace element flow rates and concentration/removal efficiency information for the Springerville Station. Table 3.3-3 gives the stream temperatures at various points in the plant.

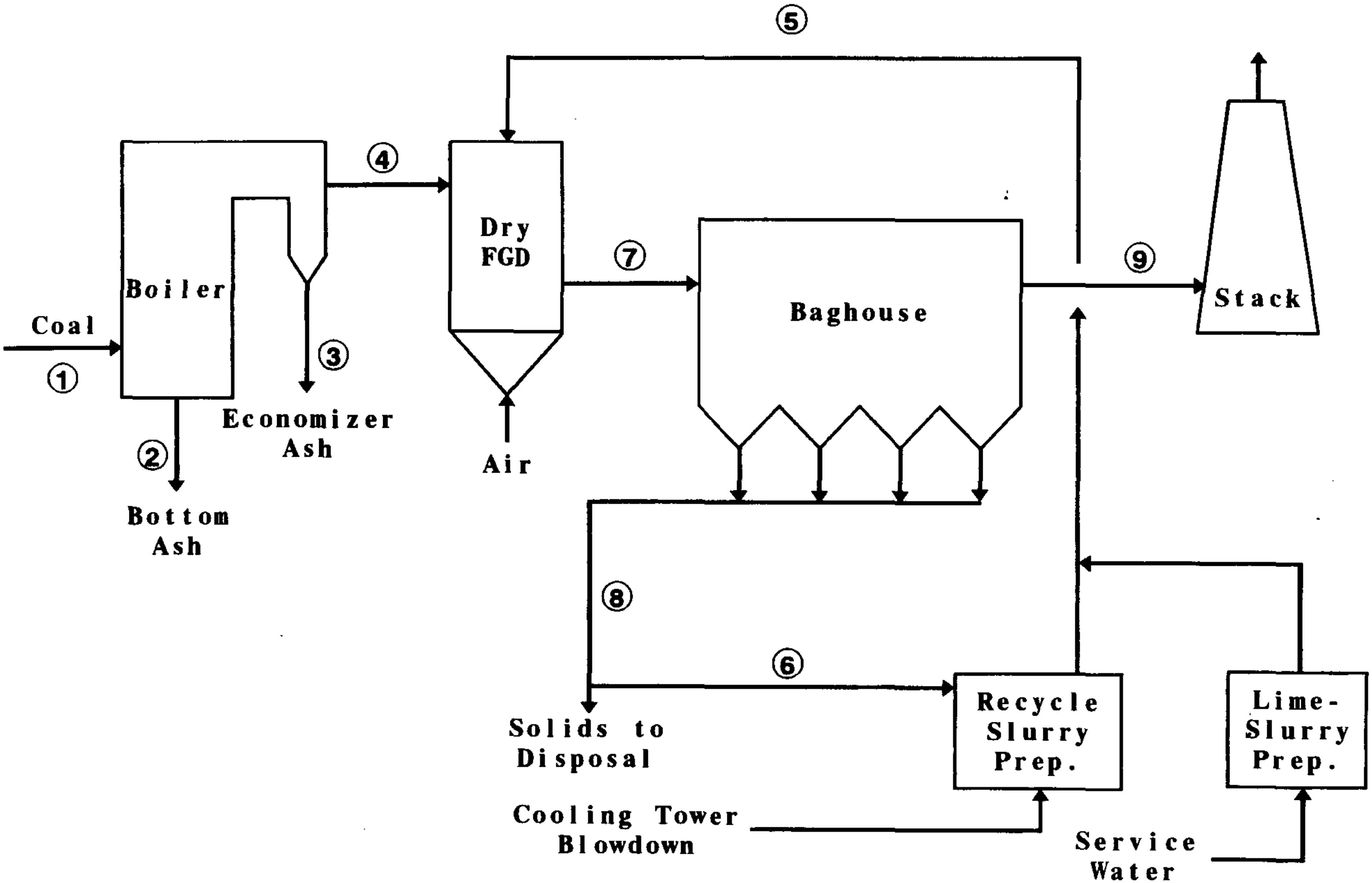

FIGURE 3.3-1. SPRINGERVILLE GENERATING STATION UNIT NO. 2 FLOW DIAGRAM

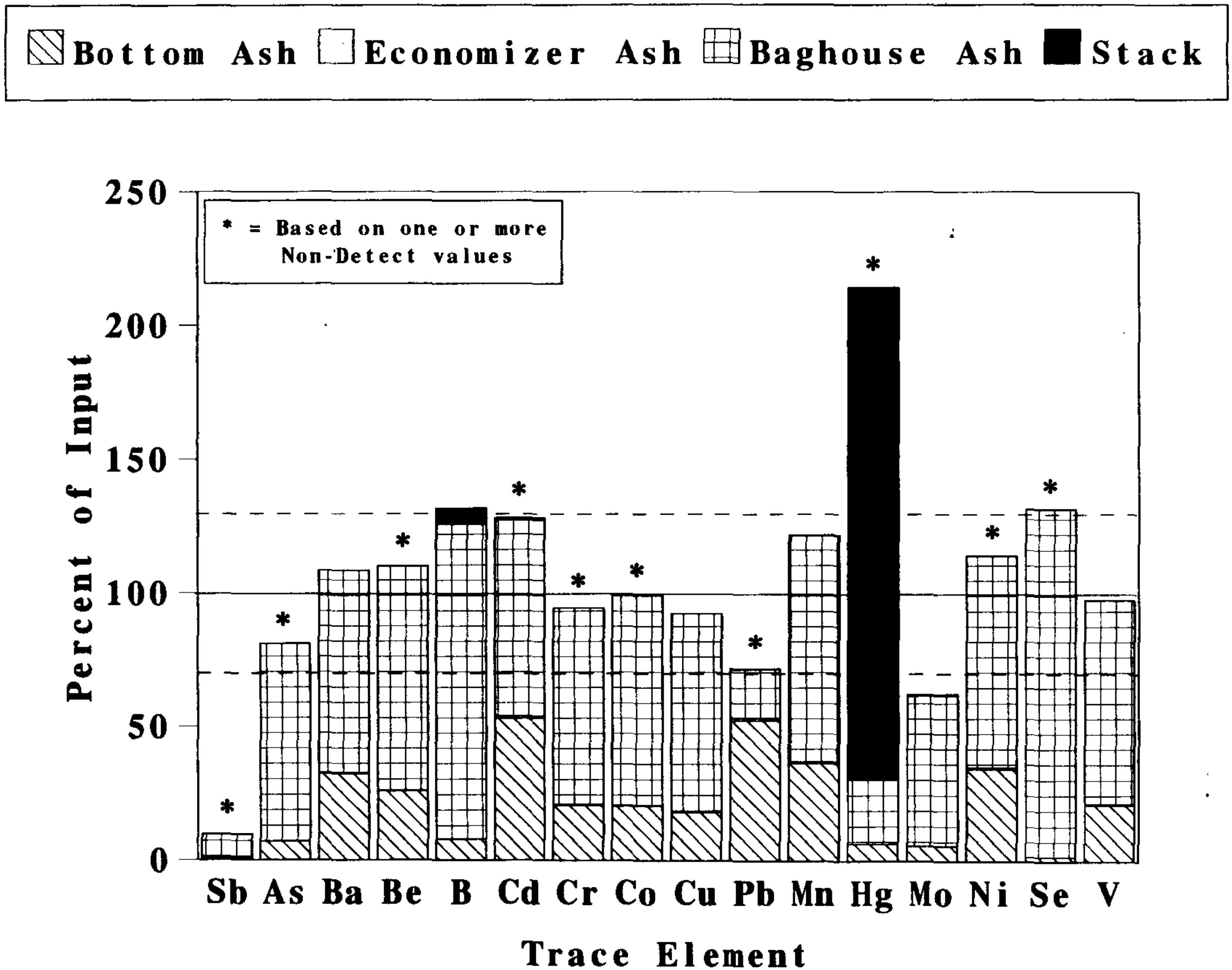

FIGURE 3.3-2. TRACE ELEMENTS IN OUTPUT STREAMS SPRINGERVILLE STATION

Table 3.3-1 Trace Element Flow Rates, Springerville Station

	(1) Coal	(2) Bottom Ash	(3) Economizer Ash	(4) Spray Dryer Inlet	(5) Lime Input	(6) Baghouse Recycle	(7) Baghouse Inlet	(8) Baghouse Ash	(9) Stack
Units: lb/hr									
Antimony	0.592	ND< 0.00586 #	ND< 0.000059 #	0.0190	ND< 0.000435 #	0.0726[B]	0.0509	0.125[B]	0.000161[A]
Arsenic	1.13	0.0783	0.00266	0.350	0.0256	1.33	2.47	2.18	ND< 0.000569 #
Barium	125.	40.5	0.433	95.2	0.0618	147.	267.	242.	0.0549
Beryllium	0.437	0.113	0.00128	0.406	ND< 0.00173 #	0.567	1.07	0.937	ND< 0.000137 #
Boron	39.1	3.07	0.0568	20.6	0.803	72.1	121.	119.	2.37[A]
Cadmium	ND< 0.0976 #	0.0518	0.000913	0.738	0.00292	0.115	2.02	0.190	ND< 0.00079 #
Chromium	3.60	0.740	0.0157	2.60	0.0562	4.14	7.55	6.84	ND< 0.000409 #
Cobalt	1.37	0.280	0.00340	1.06	0.00347	1.67	2.87	2.75	ND< 0.000546 #
Copper	4.91	0.889	0.0107	3.67	0.0493	5.67	10.4	9.37	0.00393
Lead	ND< 0.976 #	0.511	0.00944	0.390	0.00902	ND< 0.286 #	0.857	ND< 0.472 #	0.00281
Manganese	31.6	11.5	0.160	24.1	0.599	42.5	72.8	69.8	0.0708
Mercury	0.0143	0.000913	0.000001[A]	0.0233	ND< 0.000018 #	0.00533	0.0449	0.00881	ND< 0.0263 #
Molybdenum	0.857	0.0484	0.000575	0.448	0.0034	0.738	1.32	1.22	0.00556
Nickel	2.24	0.769	0.01	1.65	0.0321	2.79	4.55	4.60	ND< 0.000546 #
Selenium	0.338[A]	ND< 0.00587 #	ND< 0.000059 #	0.329	ND< 0.000435 #	0.687	1.18	1.13	0.00029[A]
Vanadium	10.4	2.20	0.0260	8.10	0.0927	12.4	22.7	20.4	0.00418

ND< Value shown is detection limit
A Includes one non-detect measurement
B Includes two non-detect measurements
Non-detectible in all samples

Table 3.3-2 Concentrations and Removal Efficiencies, Springerville Station

	SDA Inlet, µg/Nm³	SDA Out Baghouse Inlet, µg/Nm³	Baghouse Outlet, µg/Nm³	Baghouse Removal Efficiencies, Percent	Overall Removal Efficiencies, Percent
Antimony	6.8	18.2	0.058	99.7	99.3
Arsenic	186	885	0.21	99.97	99.9
Barium	35,000	95,700	20	99.98	99.95
Beryllium	112	385	ND< 0.05	> 99.98	> 99.96
Boron	7,350	43,200	865	98	90.5
Cadmium	264	726	0.037	99.995	99.99
Chromium	935	2,710	0.15	99.994	99.99
Cobalt	380	1,030	ND< 0.4	> 99.96	> 99.91
Copper	1,320	3,710	1.4	99.96	99.91
Lead	140	307	1	99.7	99.4
Manganese	6,890	26,100	16	99.93	99.8
Mercury	8.35	16.1	9.64	62	--
Molybdenum	161	473	2.04	99.54	98.1
Nickel	593	16,130	ND< 0.4	> 99.97	> 99.94
Selenium	118	423	ND< 0.054	> 99.98	> 99.96
Vanadium	2,920	8,140	1.5	99.98	99.96

Table 3.3-3 Stream Temperatures, Springerville Station

Temperature, deg F	
SDA Inlet	290
SDA Outlet	167
Baghouse Inlet	179
Baghouse Outlet	177

Section 3.4 Cardinal Station

Ohio Power Company's Cardinal Station is located in Brilliant, Ohio, along the Ohio River. It has three coal-fired boilers and is adjacent to the TIDD pressurized fluidized bed combustor (PFBC) demonstration plant. Unit 1, the host site, is considered to be representative of older coal-fired power plants without NO_x or SO_2 controls and was operated at maximum capacity (606 MWe average) during the tests. Further, this unit is considered to be representative of cell burner boiler designs utilizing an electrostatic precipitator to control particulate emissions. These units are presently exempt from Phase 1 acid rain controls because the effectiveness of existing NO_x control technologies for this application is not well known. Babcock and Wilcox is the only manufacturer of cell burner units. This design was sold from 1960 to 1970.

The only atypical feature of the Cardinal boiler design is that the upper row of burners employs only a single nozzle. This feature is likely due to the lack of a spare pulverizer (all five must be in service to achieve full load) on this unit. Since NO_x emissions from the host unit are fairly typical of other cell burner units, it is believed that combustion conditions within the furnace are representative of most cell burner units despite this difference.

The plant fires a high-sulfur bituminous coal. This is typical of coals normally fired at the plant. The coal is a Pittsburgh No. 8 coal and is typical of medium volatile bituminous coals. The coal is shipped to the station by rail, barge, or truck. Coal is unloaded and stored at the plant in piles located between Units 1 and 2, and Unit 3. The coal for Unit 1 is delivered to five 600-ton bunkers by a series of conveyors without additional size reduction. At maximum firing rate, Unit 1 burns approximately 225 U.S. tons per hour. Coal from the bunkers is delivered to five bowl-mill pulverizers. The pulverized coal is pneumatically conveyed by the primary air to the boiler. Rejects (mainly pyrites and other hard mineral matter) from the pulverizers are collected in bins at the base of the pulverizers.

The boiler is a forced-draft cell burner unit with two stages of reheat, manufactured by Babcock and Wilcox. Cell burner boilers are characterized by relatively small furnaces, resulting in a heat release per unit furnace volume of 6.7 MW/cubic meter. Downstream of the pulverizers, the air/coal mixture from each pipe is split into two pipes, either feeding separate burners at the top burner level or the two nozzles of a cell burner. Gaseous combustion products and entrained solids pass through the boiler and a single convective pass prior to splitting off to two vertical-axis regenerative rotary air preheaters.

Downstream of the air heaters are two Research-Cottrell ESPs (identified as A and B) arranged in parallel for particulate control. Each ESP has 10 fields in series. The ESP is moderately sized and has a design-specific collection area of 83 $m^2/m^3/sec$ (424 $ft^2/1000$ acfm). Electromechanical rappers are employed for discharge and collecting electrodes. Underneath each of the ESPs are three rows of six hoppers for collection of captured fly ash. Flue gas is exhausted to the atmosphere from a single round stack with a height exceeding 800 feet.

Ash Handling and Disposal

Bottom ash falls into the ash hopper at the base of the boiler. The bottom ash hoppers are sluiced by water four times a day forming a slurry of ash and water. The sluice cycle lasts one to two hours. Water for the slurry is supplied from the ash water recirculating pump pond from the Ohio River, and the slurry discharges to the bottom ash pond.

The fly ash collected in the ESP hoppers is removed with a vacuum pneumatic conveying system. A vacuum line from a water-driven eductor (hydroveyor) runs to all the hoppers. Each row of hoppers can be isolated by an automated valve at the head of each line.

The fly ash hoppers are evacuated sequentially in a continuous automatic cycle. The air is removed from the fly ash slurry downstream of the hydroveyor in an air/water separator tank. The slurry is then pumped from the tank and discharged to the fly ash settling pond.

A schematic flow diagram is shown in Figure 3.4-1 while Figure 3.4-2 presents the trace element partitioning. Tables 3.4-1 and 3.4-2 show the trace element flow rates and concentration/removal efficiencies for plant equipment. Table 3.4-3 gives the stream temperatures at various points in the plant.

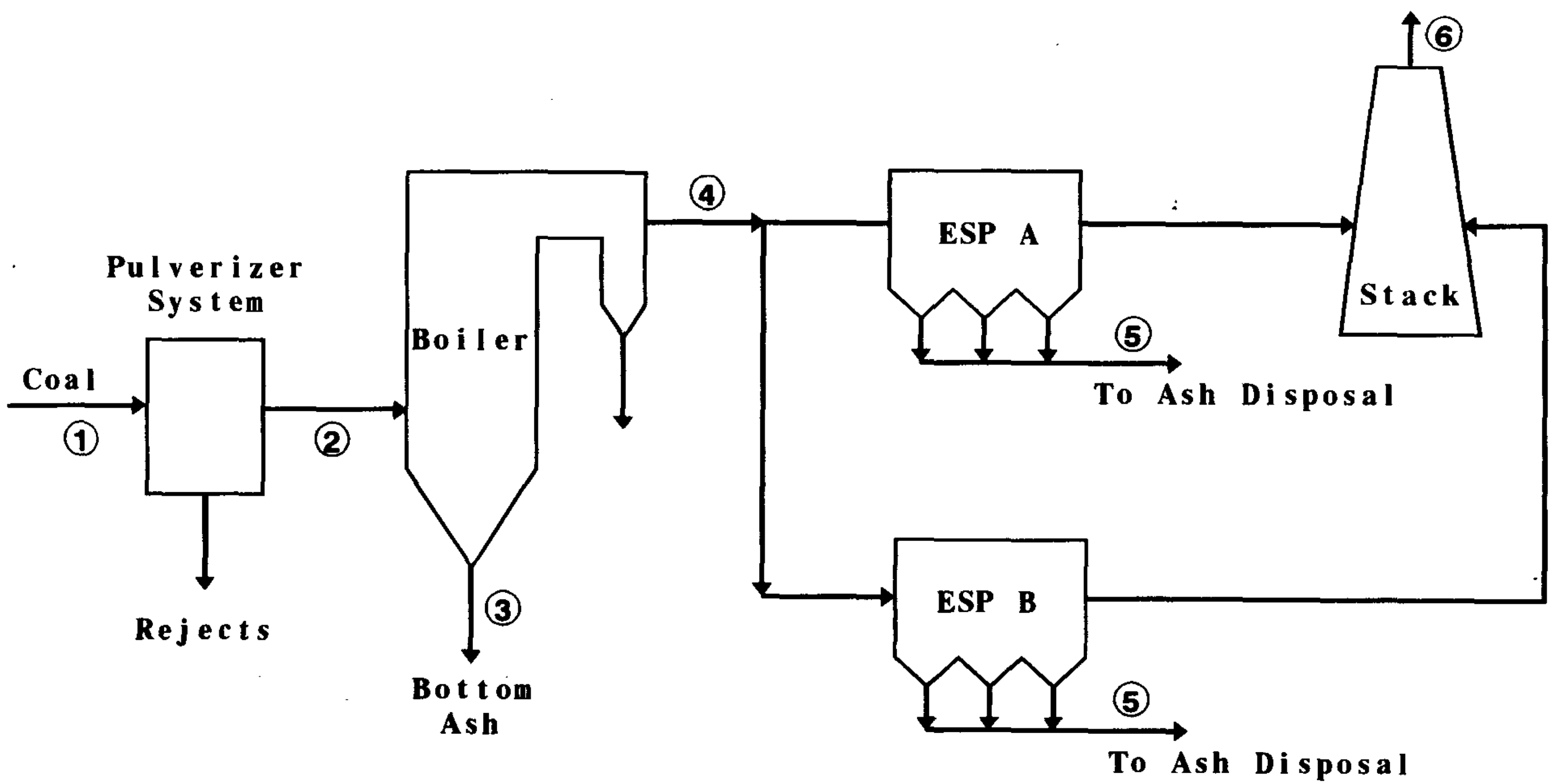

FIGURE 3.4-1. UNIT 1 FLOW DIAGRAM - CARDINAL STATION

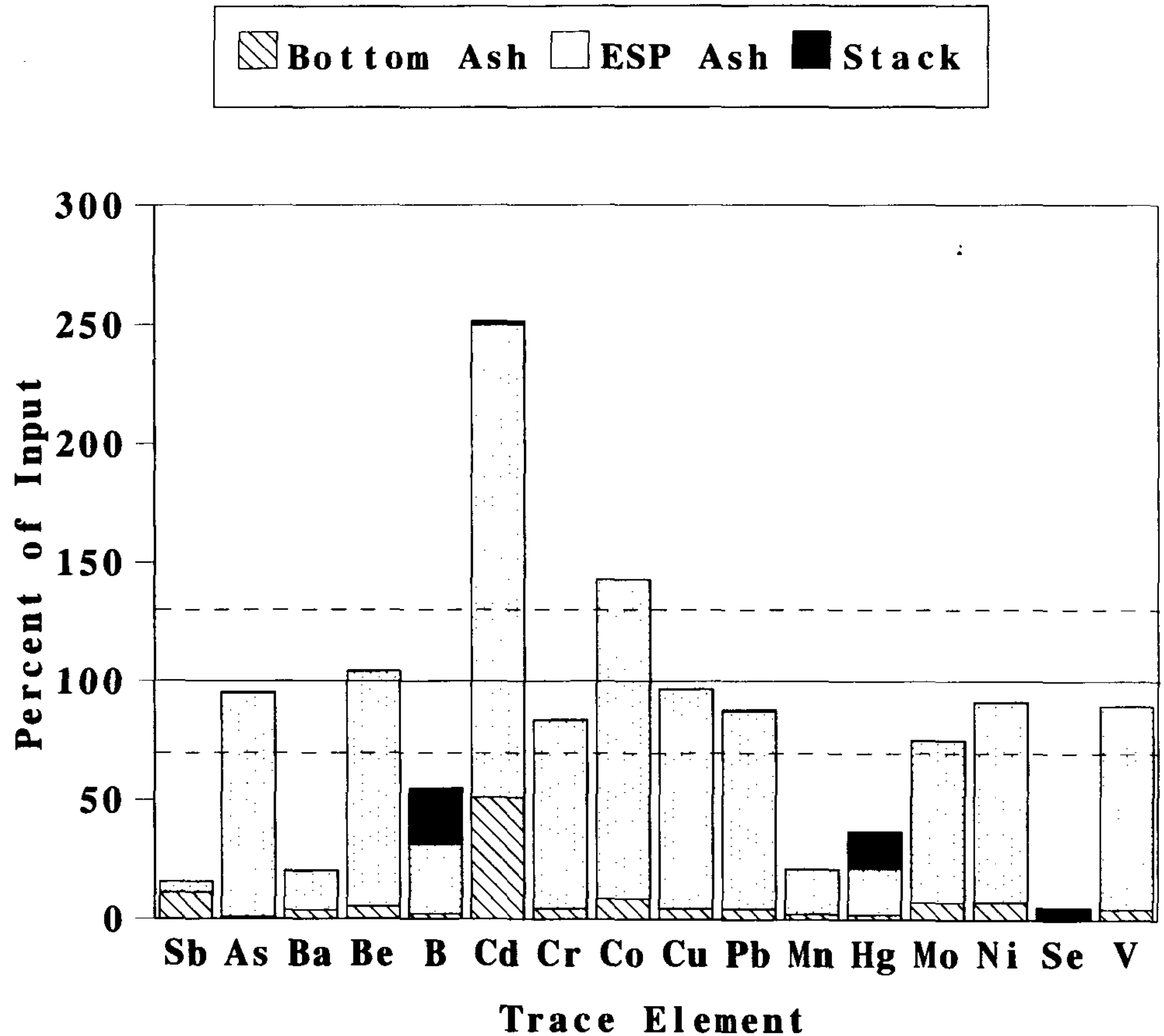

FIGURE 3.4-2. TRACE ELEMENTS IN OUTPUT STREAMS CARDINAL STATION

Table 3.4-1 Trace Elements Flow Rates, Cardinal Station

	(1) Coal Feed	(2) Bottom Ash	(3) Sluice Input	(4) ESP In	(5) ESP Ash	(6) Stack
Units: lb/hr						
Antimony	8.86	1.01	0.147	0.763	0.401	0.0100
Arsenic	5.38	0.057	0.059	5.31	5.06	0.0137
Barium	9.37	0.364	0.112	3.05	1.56	0.0039
Beryllium	0.55	0.030	0.0015	0.580	0.549	0.0003
Boron	41.0	0.908	0.227	24.1	12.1	9.6
Cadmium	0.254*	0.130	0.0006	0.168	0.507	0.0040
Chromium	7.52	0.340	0.0047	5.09	5.94	0.0255
Cobalt	1.87	0.165	0.015	1.96	2.53	0.0025
Copper	3.81	0.177	0.032	1.73	3.54	0.0065
Lead	2.82	0.129	0.013	3.22	2.35	0.0196
Manganese	24.0	0.586	0.175	6.90	4.50	0.0927
Mercury	0.02	0.0004	0.0003	0.0062	0.0040	0.0032
Molybdenum	1.35	0.101	0.015	0.831	0.925	0.0023
Nickel	5.95	0.452	0.040	4.89	5.01	0.0172
Selenium	9.63	0.015	0.0045	0.688	0.076	0.4145
Vanadium	13.5	0.604	0.0076	11.2	11.5	0.0061

*Calculated from crushed coal analysis.

Table 3.4-2 Concentration and Removal Efficiencies, Cardinal Station

	ESP A Inlet, µg/Nm³	ESP B Inlet, µg/Nm³	Stack, µg/Nm³	ESP Removal Efficiencies, Percent
Antimony	157	196	3.06	98.46
Arsenic	1,140	1,320	4.49	99.67
Barium	410	1,020	1.14	99.84
Beryllium	130	137	0.0899	99.93
Boron	5,590	5,510	2,470	56.30
Cadmium	17.1	62.3	1.1	97.18
Chromium	1,200	1,140	9.76	99.07
Cobalt	442	462	0.815	99.82
Copper	409	387	1.79	99.55
Lead	724	761	4.96	99.43
Manganese	2,220	928	19.3	96.82
Mercury	1.87	0.951	0.563	18.60
Molybdenum	192	189	0.758	99.53
Nickel	1,110	1,140	6.15	99.37
Selenium	135	183	120	19.03
Vanadium	2,470	2,700	2.05	99.93

Table 3.4-3 Stream Temperatures, Cardinal Station

Temperature, deg F	
Steam	994
ESP	330
Stack	327

Section 3.5 Baldwin Station

Plant Description

The Baldwin Power Station is located in Baldwin, Illinois, and is owned and operated by Illinois Power Company. The power plant is composed of three coal-fired units numbered 1 through 3. All three units are rated at 568 MWe. Unit 2 was studied in this program. This Babcock & Wilcox cyclone furnace unit, built in 1973, burns high-sulfur Illinois bituminous coal that is delivered to the station by train. Average coal characteristics for this study were 10.2% ash, 2.9% sulfur, 15.0% moisture, and 10,600 Btu/lb higher heating value.

Unit 2 is operated from a control room which is common to all three units. At Unit 2, coal is transferred from storage bunkers through feeders directly into 14 cyclones. The boiler is opposed-fired with a bottom row of four cyclones and a top row of three cyclones on each side. The combustion gases exit the furnace and enter the convective pass section of the boiler which includes superheater and reheater sections. Main and reheat steam temperatures are controlled primarily by flue gas recirculation and combustion air flow, and attemperation sprays for secondary control. Next, the combustion gases are directed through an economizer section.

Some entrained particulate (i.e., soot) is deposited on various boiler wall and tube surfaces. Unit 2 is equipped with a series of soot blowers to remove this slagging and fouling material. The soot blowers are used on a regular basis, once per shift. Supplemental soot blowing is performed to clean surfaces and regain optimum steam temperature control and thermal efficiency when heat absorption patterns change.

Some overhead particulate is collected at the economizer outlet and is conveyed to an ash pond via a water sluice system. Final particulate control is effected by an electrostatic precipitator (ESP). The ESP ash is also sluiced to an ash pond.

The ESP consists of six chambers and each chamber is four fields deep. The ESP has a specific collection area of 179.8 ft^2/1,000 cfm and uses weighted wire electrodes. The collecting plates are spaced 9 inches apart. Unit 2 has no other pollution control equipment.

The unit has its own stack. Ports at the ESP inlet and outlet (stack) were used for flue gas emission sampling/testing purposes.

The unit's condenser system is a tube heat exchanger. The average intake rate of condenser water is 50 ft^3/s. This system is served by a cooling reservoir (Baldwin Lake) covering an area of 2,000 acres and containing 22,000 acre feet of water.

The bottom ash, economizer hopper ash, and ESP hopper ashes are sluiced to an on-site ash pond system. The bottom ash is sluiced to its own primary and secondary ponds. The economizer and ESP hopper ashes are sluiced to common primary and secondary ponds. The supernatant from both secondary ponds overflows to a single tertiary pond. The effluent from the tertiary pond is discharged to the nearby Kaskaskia River. All of the bottom ash is sold for commercial use.

A process flow diagram of Baldwin Unit 2 is shown in Figure 3.5-1. Figures 3.5-2 and 3.5-3 give the partitioning results for non-soot-blowing and soot-blowing periods. Tables 3.5-1 and 3.5-2 present trace element flow rates for both periods. Table 3.5-3 presents the concentration and removal efficiency results for both periods. Table 3.5-4 gives stream temperatures at various points in the plant.

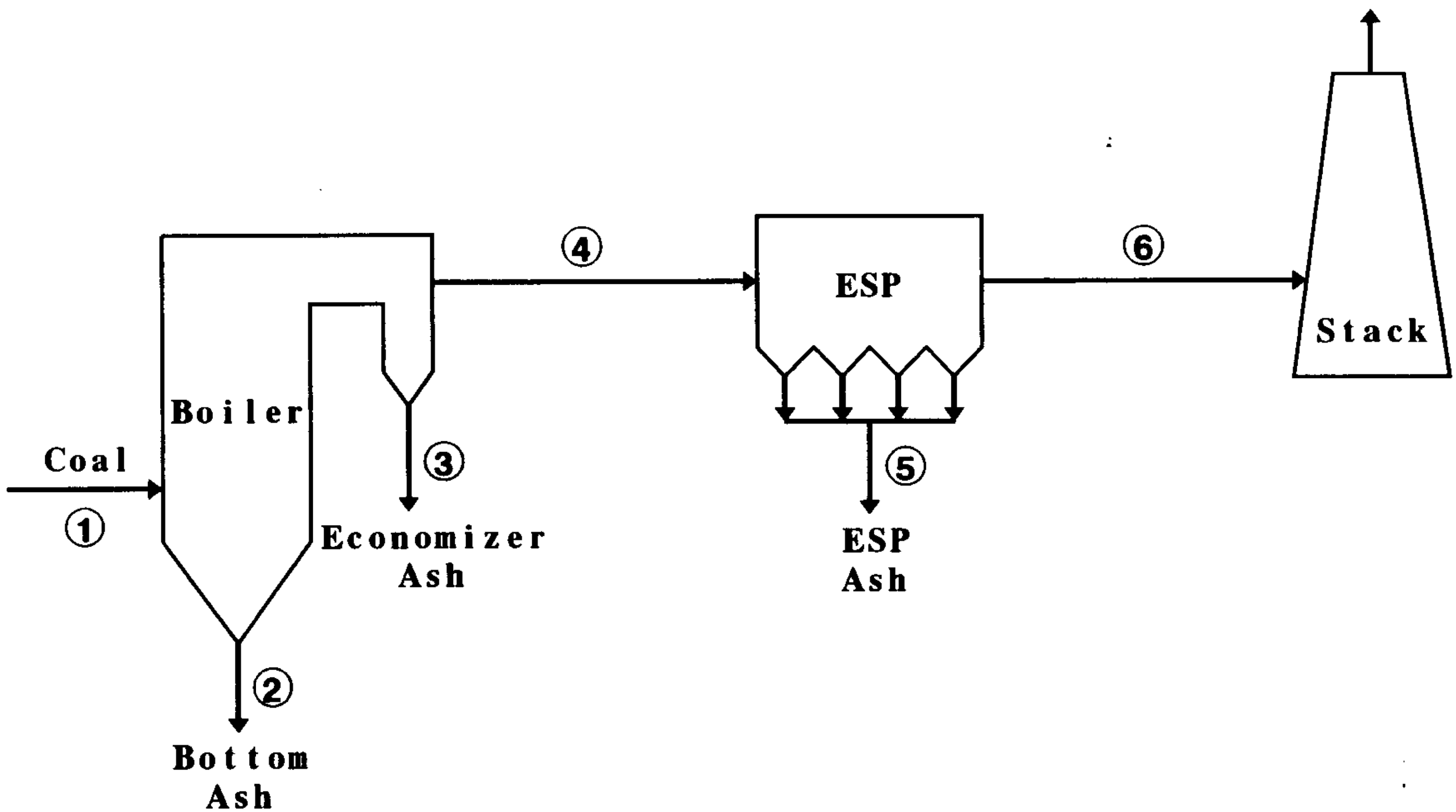

FIGURE 3.5-1. BALDWIN POWER STATION UNIT NO. 2 FLOW DIAGRAM

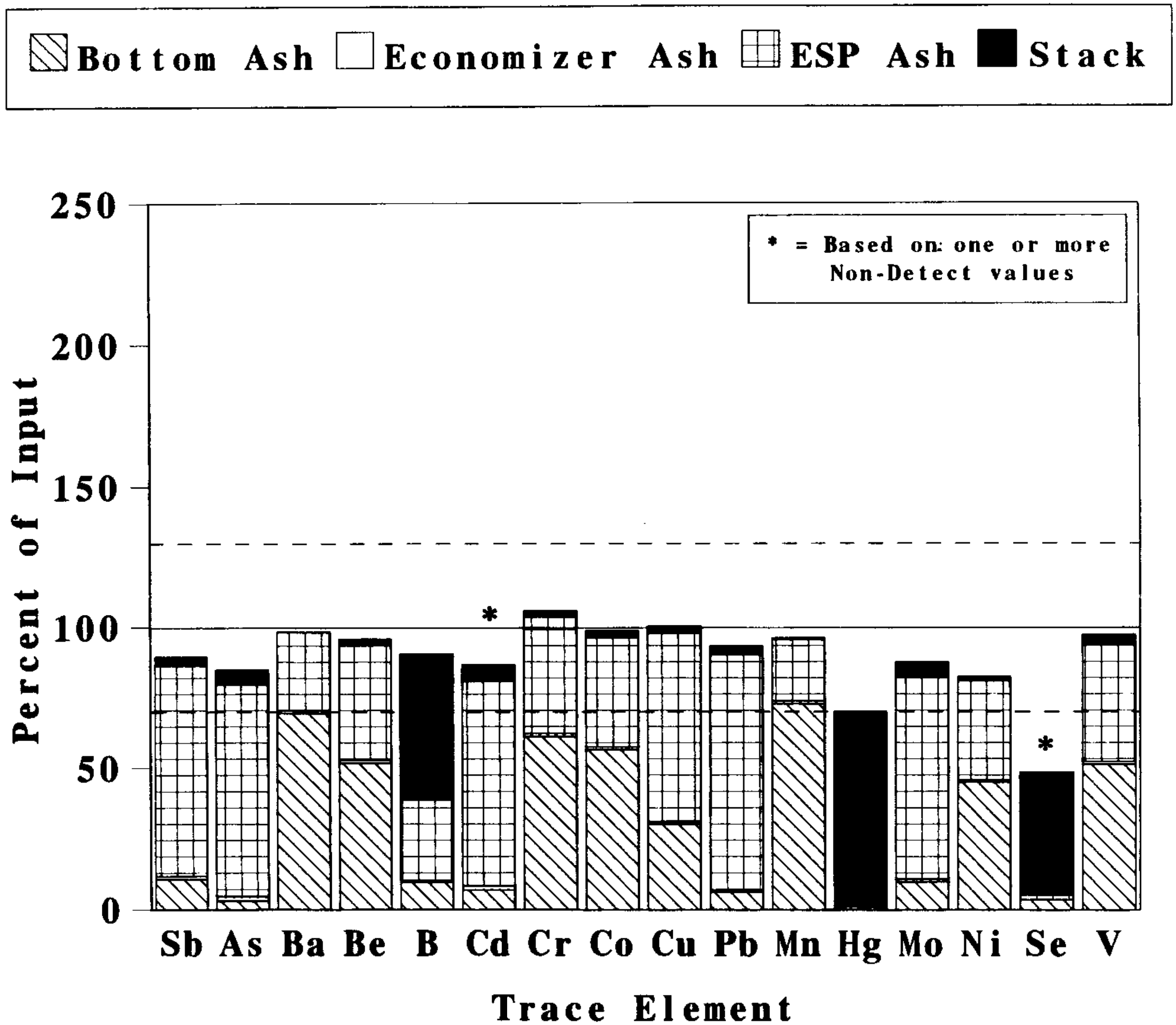

FIGURE 3.5-2. TRACE ELEMENTS IN OUTPUT STREAMS BALDWIN STATION, NON-SOOT BLOWING TESTS

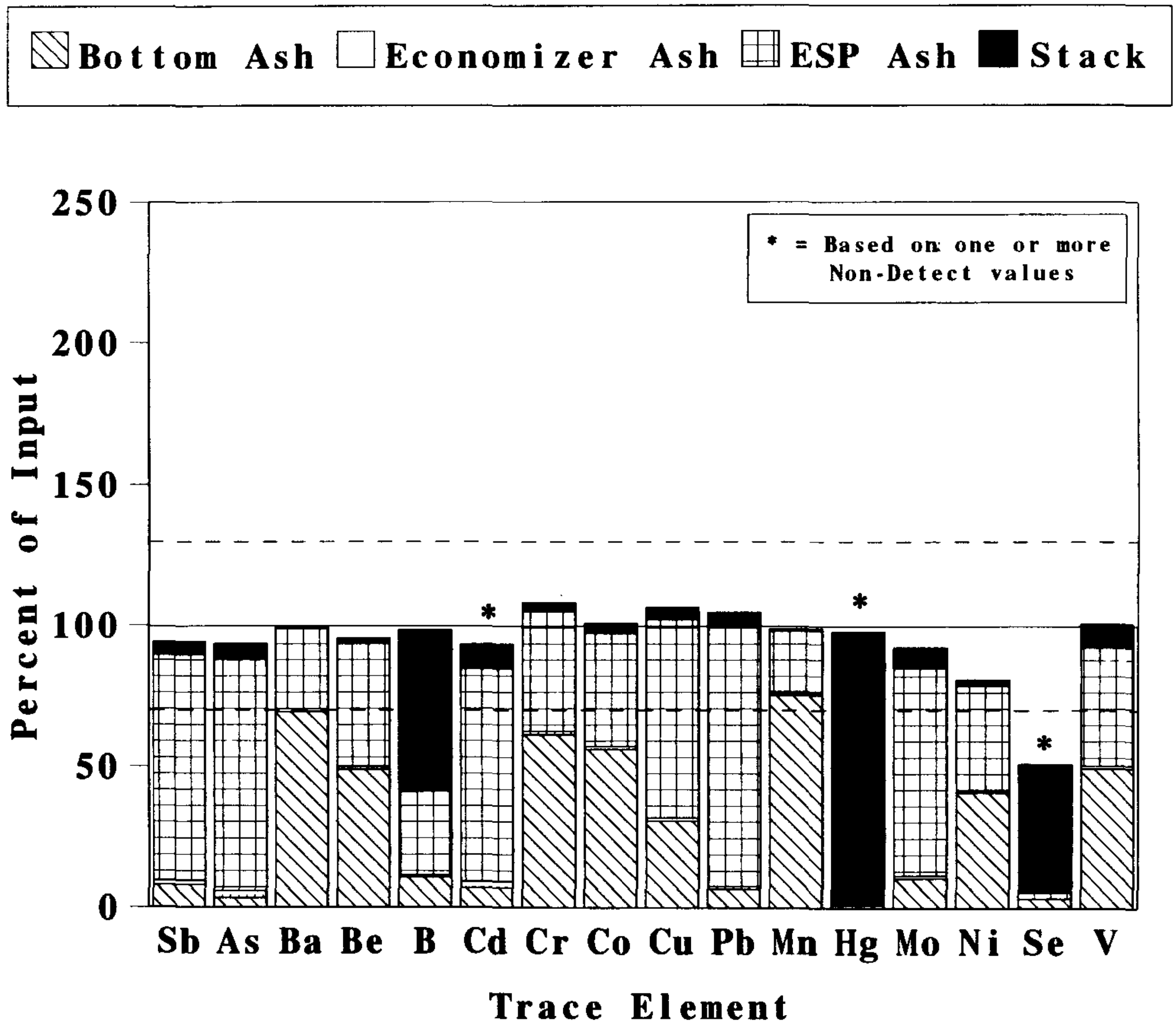

FIGURE 3.5-3. TRACE ELEMENTS IN OUTPUT STREAMS BALDWIN STATION, SOOT BLOWING TESTS

Table 3.5-1 Trace Element Flow Rates, Baldwin Station, Non-Soot Blowing Period

	(1) Coal Input	(2) Bottom Ash	(3) Economizer Ash	(4) ESP Inlet	(5) ESP Ash	(6) Stack
Units: lb/hr						
Antimony	0.263	0.028	0.0028	0.084	0.196	0.0087
Arsenic	1.43	0.044	0.024	5.7	1.07	0.077
Barium	27.6	19.2	0.288	5.9	7.671	0.030
Beryllium	0.539	0.279	0.0055	0.24	0.224	0.0081
Boron	85.2	8.22	0.527	220	24.3	44.
Cadmium	0.290	ND< 0.020 #	0.0044	0.38	0.210	0.017
Chromium	13.3	8.11	0.156	5.5	5.48	0.29
Cobalt	1.68	0.948	0.017	0.81	0.654	0.039
Copper	4.48	1.35	0.042	2.8	2.99	0.11
Lead	5.02	0.320	0.037	2.7	4.17	0.16
Manganese	21.7	15.8	0.232	4.4	4.72	0.13
Mercury	0.032	0.0004[B]	0.00001	0.030	0.0002[A]	0.022
Molybdenum	3.38	0.333	0.031	2.1	2.40	0.19
Nickel	8.39	3.76	0.071	3.6	2.94	0.13
Selenium	1.72	ND< 0.061 #	ND< 0.001 #	0.071	ND< 0.029 #	0.74
Vanadium	15.6	8.00	0.157	7.6	6.46	0.57

ND< Value shown is detection limit
A Includes one non-detect measurement
B Includes two non-detect measurements
Non-detectible in all samples

Table 3.5-2 Trace Element Flow Rates, Baldwin Station, Soot Blowing Period

	(1) Coal Input	(2) Bottom Ash	(3) Economizer Ash	(4) ESP Inlet	(5) ESP Ash	(6) Stack
Units: lb/hr						
Antimony	0.263	0.021	0.0040	0.220	0.210	0.012
Arsenic	1.43	0.049	0.034	7.90	1.18	0.070
Barium	27.6	19.1	0.292	9.80	7.89	0.019
Beryllium	0.539	0.263	0.0056	0.380	0.236	0.010
Boron	85.2	9.00	0.701	320	25.1	49.0
Cadmium	0.290	ND< 0.020 #	0.0067	0.670	0.219	0.025
Chromium	13.3	8.11	0.181	9.50	5.65	0.390
Cobalt	1.68	0.941	0.018	1.40	0.678	0.057
Copper	4.48	1.37	0.050	4.80	3.16	0.190
Lead	5.02	0.331	0.054	5.20	4.60	0.270
Manganese	21.7	16.4	0.237	7.30	4.72	0.180
Mercury	0.032	ND< 0.0004 #	0.00001	0.040	0.0002[A]	0.031
Molybdenum	3.38	0.350	0.035	3.30	2.48	0.240
Nickel	8.39	3.42	0.080	6.20	3.09	0.180
Selenium	1.72	ND< 0.060 #	ND< 0.0010 #	0.080	0.028[C]	0.780
Vanadium	15.6	7.70	0.173	13.0	6.55	1.30

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes five non-detect measurements (parallel sampling in two hoppers)
Non-detectible in all samples

Table 3.5-3 Concentrations and Collection Device Removal Efficiencies, Baldwin Station

	Non-Soot Blowing			Soot Blowing		
	ESP Inlet, µg/Nm³	ESP Outlet, µg/Nm³	Removal Efficiency, Percent	ESP Inlet, µg/Nm³	ESP Outlet, µg/Nm³	Removal Efficiency, Percent
Antimony	19	2.1	89.6	50	2.8	94.6
Arsenic	1,300	18	98.7	1,900	17	99.1
Barium	1,400	7.2	99.5	2,300	4.6	99.8
Beryllium	55	1.9	96.6	89	2.3	97.4
Boron	50,000	10,000	79.8	74,000	12,000	84.8
Cadmium	88	4.1	95.5	160	6.0	96.2
Chromium	1,300	69	94.7	2,200	92	95.9
Cobalt	190	9.3	95.2	320	13	95.8
Copper	650	26	96.1	1,100	44	96.1
Lead	610	39	93.9	1,200	64	94.7
Manganese	1,000	30	97.1	1,700	43	97.5
Mercury	6.8	5.2	26.0	9.5	7.2	24.4
Molybdenum	490	46	90.9	780	56	92.9
Nickel	840	30	96.5	1,400	42	97.1
Selenium	16	180		18	190	
Vanadium	1,800	140	92.4	3,000	300	90.1

Table 3.5-4 Stream Temperatures, Baldwin Station

Temperature, deg F	
Non-Soot Blowing	
ESP Inlet	336
ESP Outlet (To Stack)	336
Soot Blowing	
ESP Inlet	329
ESP Outlet (To Stack)	332

Section 3.6 Niles Station

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 MWe. 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 higher heating value 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 SO_2 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 economizer, passes through an air heater (not shown), 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. 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.

Characteristic of cyclone boilers, 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, typically 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, an ICCT 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 as part of another program on 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 3.6-1. Figure 3.6-2 presents the partitioning of the elements which give the trace element flow rates. Table 3.6-2 shows concentrations and removal efficiencies at key points in the plant. Gas stream concentrations are reported on a dry basis, corrected to 3% oxygen. Table 3.6-3 gives stream temperatures at various points in the plant.

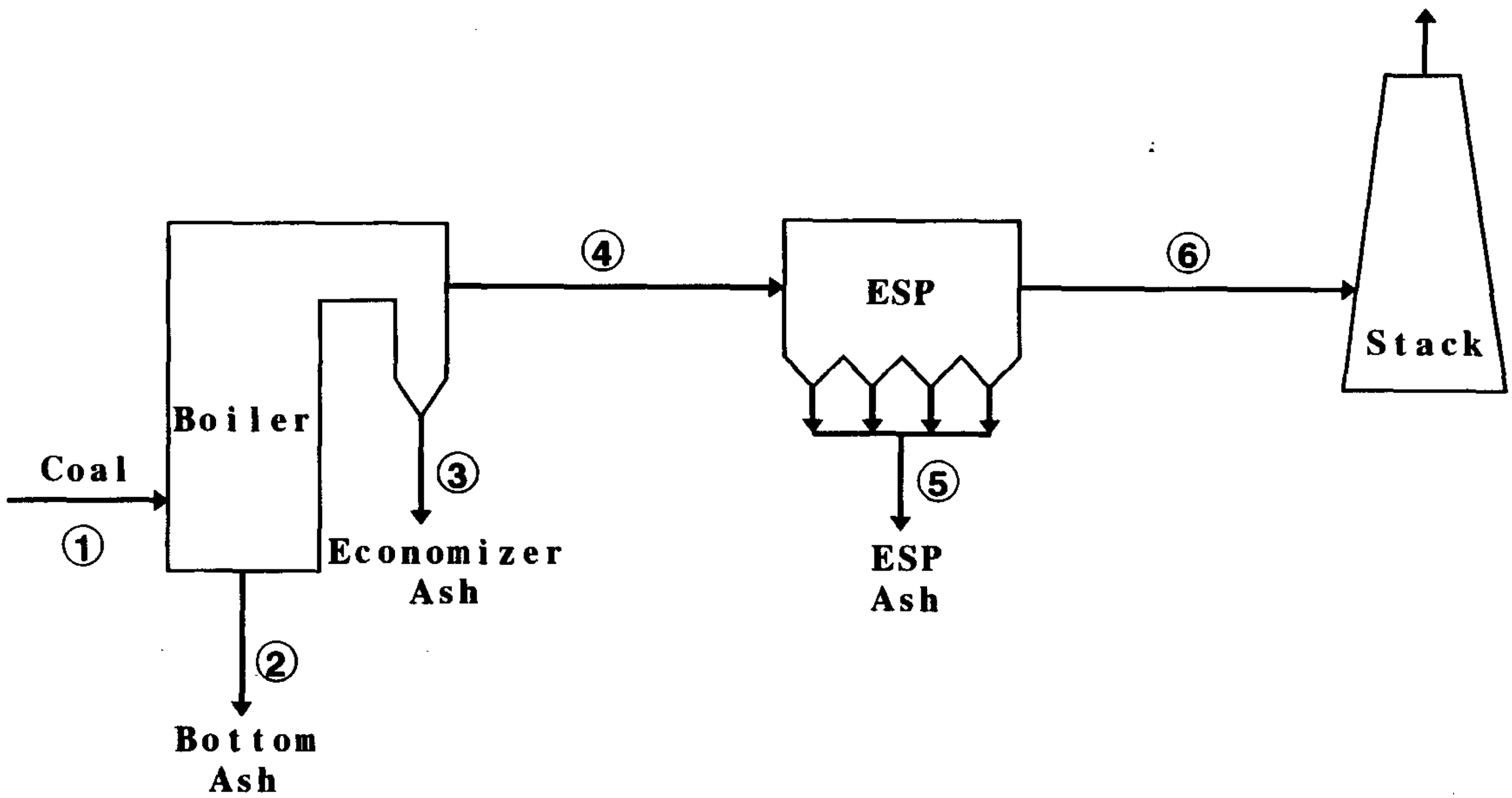

FIGURE 3.6-1. NILES STATION BOILER NO. 2 FLOW DIAGRAM

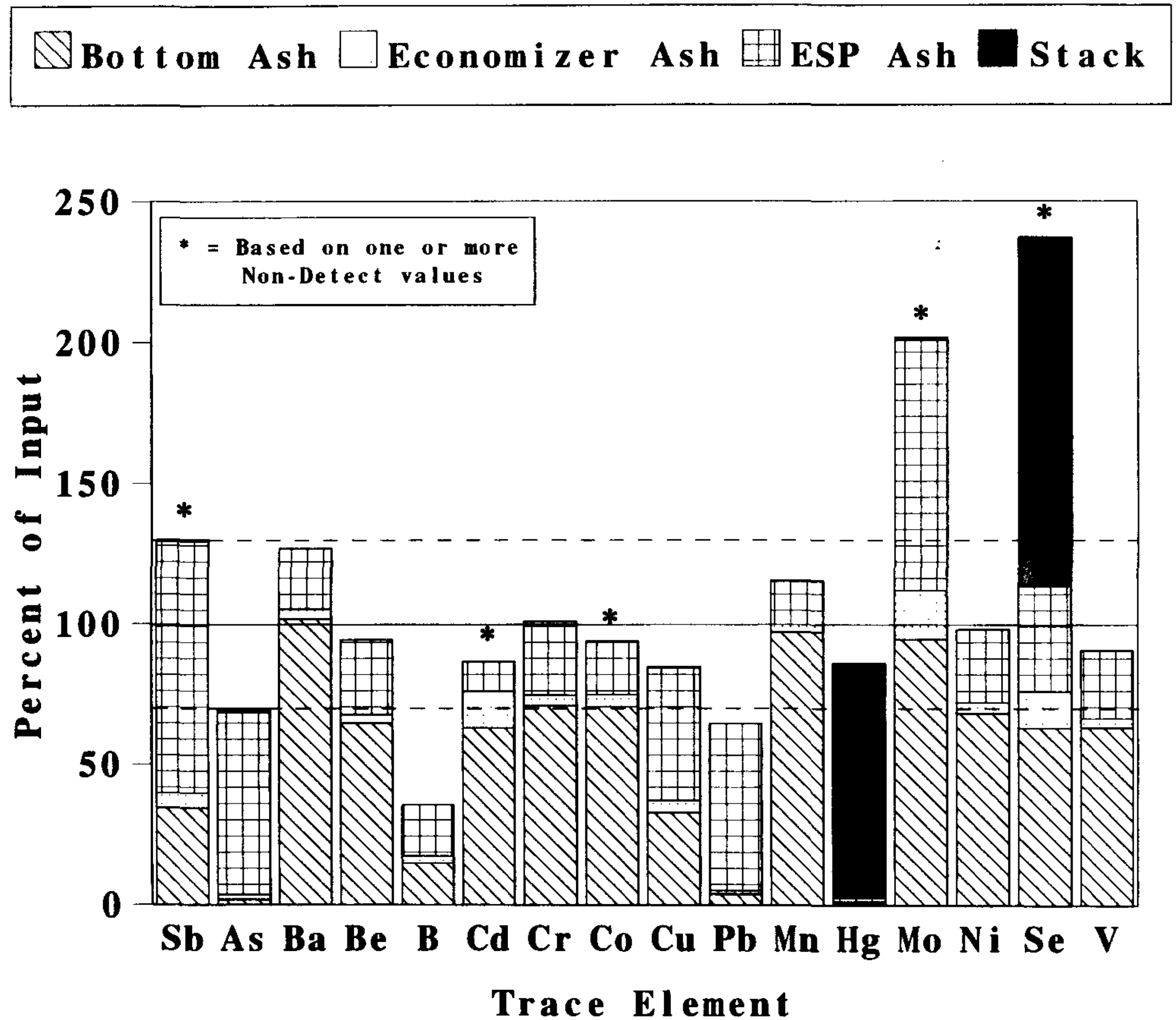

FIGURE 3.6-2. TRACE ELEMENTS IN OUTPUT STREAMS NILES STATION

Table 3.6-1 Trace Element Flow Rates, Niles Station

	(1) Coal	(2) Bottom Ash	(3) Economizer Ash	(4) ESP Inlet	(5) ESP Ash	(6) ESP Out, Stack
Units: lb/hr						
Antimony	0.104	ND< 0.0356 #	ND< 0.0055 #	0.126	ND< 0.0930 #	ND< 0.0004 #
Arsenic	3.11	0.0569	0.0566	1.88	2.01	0.0479
Barium	5.18	5.27	0.183	0.933	1.11	0.0060
Beryllium	0.179	0.116	0.0055	0.0487	0.0474	0.0002
Boron	6.78	1.00	0.170	N/A	1.23	N/A
Cadmium	ND< 0.0282 #	ND< 0.0178 #	ND< 0.0037 #	0.0031	ND< 0.0029 #	ND< 0.00007[B]
Chromium	1.51	1.07	0.0566	0.435	0.394	0.0035
Cobalt	0.593	0.418	0.0256	0.124	0.113	ND< 0.0001 #
Copper	1.41	0.462	0.0603	0.687	0.667	0.0046
Lead	1.22	0.0471	0.0152	0.704	0.726	0.0018
Manganese	2.35	2.29	0.0621	0.383	0.366	0.0038
Mercury	0.0198	0.0002[B]	0.0001	0.0231	0.0003	0.0164[B]
Molybdenum	ND< 0.282 #	ND< 0.267 #	ND< 0.0493 #	0.135	ND< 0.251 #	0.0025
Nickel	1.69	1.16	0.0658	0.511	0.439	0.0006
Selenium	ND< 0.0565 #	ND< 0.0356 #	0.0073[B]	0.0752	0.0212[B]	0.0698
Vanadium	2.64	1.66	0.0859	0.668	0.636	0.0029

ND< Value shown is detection limit
A Includes one non-detect measurement
B Includes two non-detect measurements
\# Non-detectible in all samples
N/A Not analyzed

Table 3.6-2 Concentrations and Removal Efficiencies, Niles Station

	ESP Inlet, µg/Nm³	Stack, µg/Nm³	ESP Removal Efficiency, Percent
Antimony	152	ND< 0.60 #	99.8
Arsenic	2,274	70	97.4
Barium	1,129	8.8	99.3
Beryllium	59	0.31	99.6
Boron			
Cadmium	3.7	ND< 0.10[B]	97.1
Chromium	526	5.1	99.2
Cobalt	150	ND< 0.20 #	99.95
Copper	831	6.7	99.3
Lead	852	2.7	99.7
Manganese	463	5.6	99.0
Mercury	28	24	29.9
Molybdenum	163	3.7	98.1
Nickel	618	0.9	99.9
Selenium	91	102	7.6
Vanadium	808	4.2	99.6

A Includes one non-detect measurement
B Includes two non-detect measurements
Non-detectible in all samples

Table 3.6-3 Stream Temperatures, Niles Station

Temperature, deg F	
Steam, Superheater Outlet	1000
Steam, Reheater Outlet	987
ESP Inlet	304
ESP Outlet (To Stack)	293

Section 3.7 SNOX Process

Niles Station of Ohio Edison is located in Niles, Ohio. The Niles Boiler No. 2 is a cyclone boiler burning bituminous coal with a net generating capacity of 100 MWe. The boiler has four cyclone burners, each fed by a separate feeder. Nominal sulfur content of the coal is 2.8 percent. The coal comes from several local sources and is blended in the coal yard to meet 24-hour and 30-day rolling averages for SO_2 content of flue gas.

The flue gas leaves the boiler, passes through an air heater (not shown), and enters an electrostatic precipitator (ESP) with five fields, each with two hoppers. The flue gas leaving the ESP is vented through a 120-m (393-foot) tall stack.

The SNOX process takes a slipstream of flue gas ahead of the ESP, cleans the slipstream, and returns it to the flue gas after the ESP and before the stack. All flue gas sampling was conducted on the slipstream of the SNOX process. Therefore, operation of the ESP had no effect on the measurements summarized in this report.

This ICCT project is the Wet Gas Sulfuric Acid (WSA)-Selective Catalytic Reduction of NO_x (SNOX) demonstration by ABB Environmental Systems (*Comprehensive Report to Congress, Clean Coal Technology Program, WSA-SNOX Flue Gas Cleaning Demonstration Project*, U.S. Department of Energy Report No. DOE/FE-0151, November 1989). Cosponsors are DOE, Ohio Coal Development Office, Ohio Edison, and Snamprogetti, USA. The SNOX process combines selective catalytic reduction and wet sulfuric acid technologies to remove both nitrogen and sulfur oxides from flue gas.

A 35-MWe equivalent slip of flue gas from the Niles Boiler No. 2 is taken after the air preheater and before the ESP to demonstrate the SNOX process. The SNOX system pulls a constant load from Boiler No. 2 as the total load on the boiler fluctuates about full load.

The flue gas entering the SNOX process from Boiler No. 2 first passes through a support burner (not shown) to increase its temperature. The support burner is fueled with natural gas. The combustion air flow is steady, and the flow of natural gas is varied to maintain the temperature of the flue gas. The heated flue gas travels to a baghouse to remove particulate matter. After the flue gas leaves the baghouse, ammonia is added to the particulate-free flue gas. The flue gas then passes through the selective catalytic reduction (SCR) unit, where oxides of nitrogen are reduced to free nitrogen and water vapor. The flue gas then passes through the SO_2 reactor where SO_2 is oxidized catalytically to sulfur trioxide and subsequently recovered as sulfuric acid in a wet gas sulfuric acid condenser. The flue gas then rejoins the flue gas from the boiler downstream of the ESP, and exits through the stack.

The SNOX baghouse removes particulate matter from the flue gas stream prior to the SO_2 catalyst. This allows the catalyst, which collects and retains over 90 percent of the particulate matter reaching it, to be used for longer periods of time before cleaning.

The SNOX baghouse was manufactured by ABB Environmental Systems. With a gross air-to-cloth ratio of 3.76 (4.51 net), it has six compartments containing a total of 1,596 Gore-Tex bags. The bags are 431 cm long (169.75 inches) and 15.2 cm (6 inches) in diameter. The bag material is Teflon on fiberglass. New bags were installed in the baghouse several days before sampling began.

Collected particulate matter is dislodged from the bags by pulse jet cleaning several times an hour. The pulse pressure is 3.4-4.8 x 10^5 kPa (50-70 psi). This is automatically initiated by pressure drop sensors. The ash falls into one of six hoppers. The hoppers are dumped once a shift after the ESP hoppers are dumped. The Niles Station hydro-vac system first empties the ESP hoppers and then automatically empties the SNOX baghouse hoppers. Ash is drawn out of the baghouse hoppers into a sluice line until the low vacuum limit is reached.

After the flue gas leaves the baghouse, it passes through a gas-gas heat exchanger (not shown), increasing the flue gas temperature. Ammonia is added to the flue gas on a local scale throughout the cross section of the duct through a matrix of nozzles. An additional 22.65 scm/min (800 scfm) of air flow is added to the flue gas with the ammonia addition. The ammonia/flue gas mixture enters the SCR and contacts the monolithic catalyst. The catalyst reduces the NO to nitrogen and water vapor. The local concentration ratio of ammonia/nitrogen oxides can be slightly greater than stoichiometric because any unreacted ammonia that passes out of the SCR is oxidized to NO, water and nitrogen further downstream in the SO_2 reactor. Throughout this portion of the SNOX process, the temperature of the flue gas is above the dew point of ammonium sulfate and ammonium bisulfate. Therefore, no sulfate particulate matter is generated in the flue gas from the ammonia.

The flue gas leaving the SCR is heated to increase its temperature for optimum conversion of SO_2 in the SO_2 reactor. The SO_2 is oxidized to SO_3 as it passes through a sulfuric acid catalyst.

The flue gas then passes through the gas-gas heat exchanger where SO_3 is hydrated to sulfuric acid. The sulfuric acid vapor is condensed in the WSA condenser. This is a tube and shell falling film condenser with ambient air used as a cooling medium on the shell side. The condenser has 7,200 glass tubes.

The condensed sulfuric acid is fed into an acid conditioning and storage system.

A flow diagram is shown in Figure 3.7-1. Figure 3.7-2 shows the partitioning of the trace elements. Tables 3.7-1 and 3.7-2 present the trace element flow rates and concentrations/removal efficiencies, respectively. Table 3.7-3 gives the stream temperatures at various points in the plant.

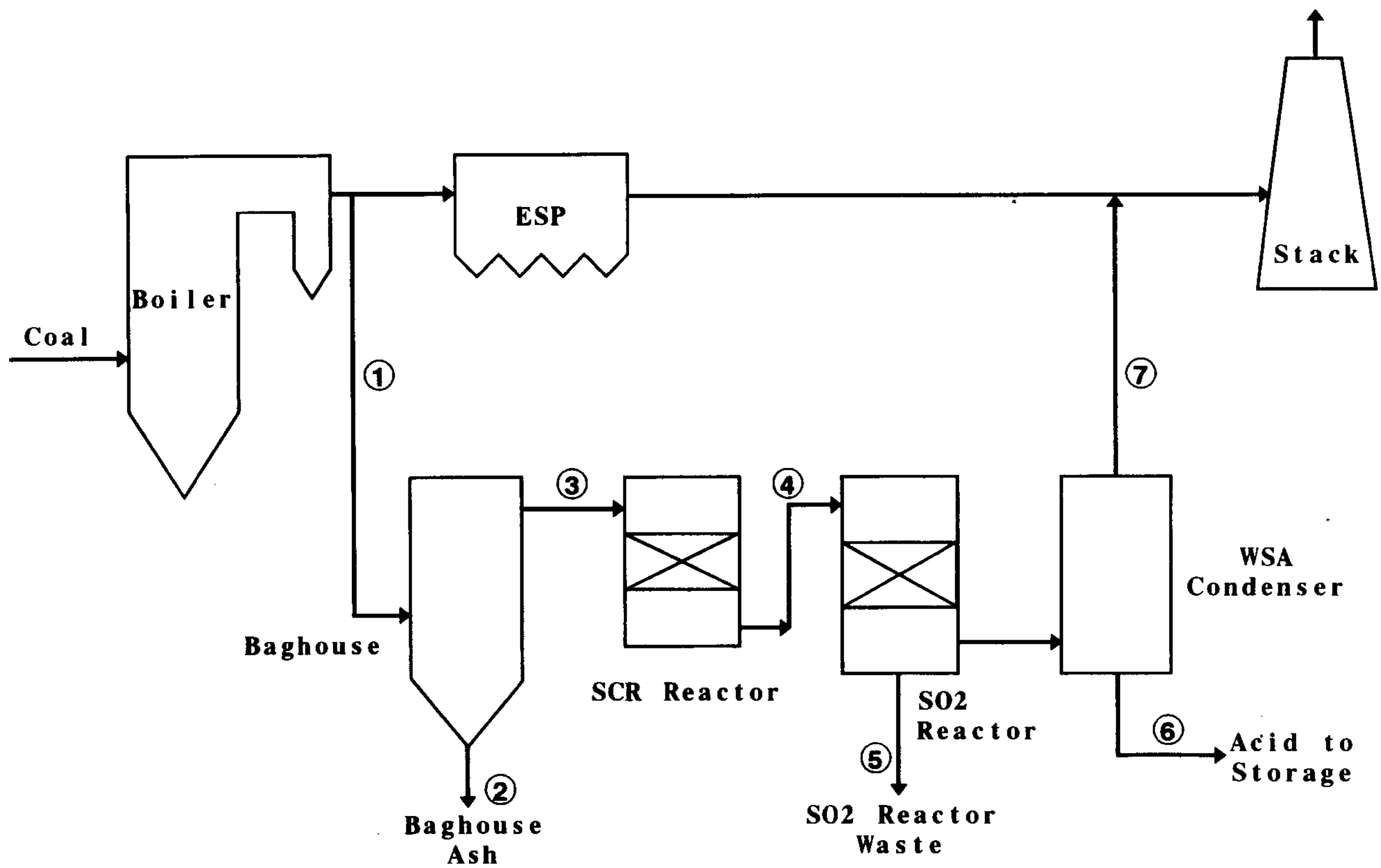

FIGURE 3.7-1. SNOX FLOW DIAGRAM

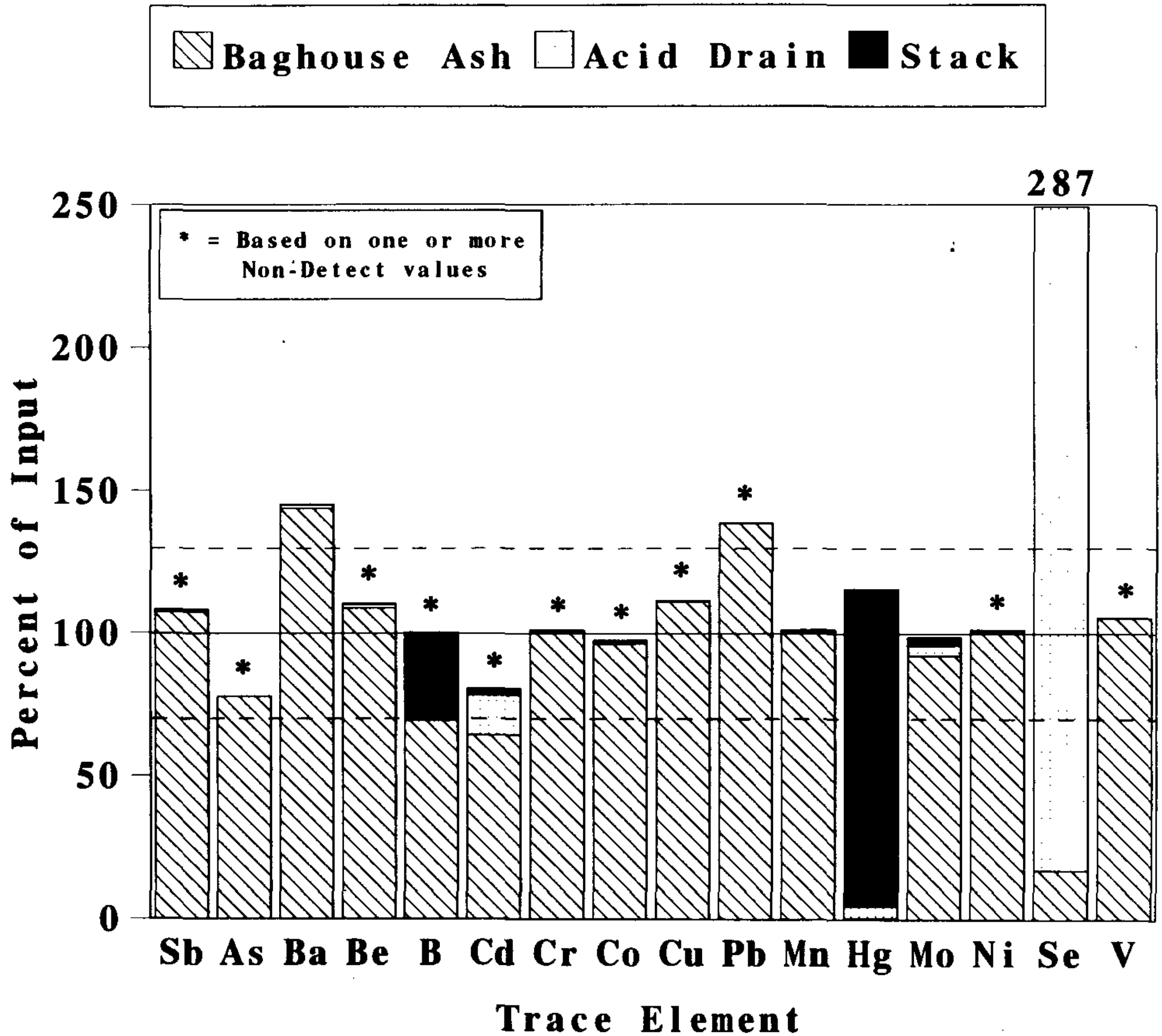

FIGURE 3.7-2. TRACE ELEMENTS IN OUTPUT STREAMS NILES STATION, SNOX PROCESS

Table 3.7-1 Trace Element Flow Rates, SNOX Process (Niles Station)

	(1) Slip Stream Inlet	(2) Baghouse Ash	(3) Baghouse Outlet	(4) SCR Outlet	(5) SO_2 Reactor Waste	(6) H_2SO_4 Drain	(7) Stack
Units: lb/hr							
Antimony	0.0213	0.0229	ND< 0.00011 #	ND< 0.00012 #	0	ND< 0.00004	ND< 0.00016 #
Arsenic	0.742	0.575	0.0029	0.0003[A]	0	0.0003	ND< 0.00016 #
Barium	0.302	0.434	0.0004	0.0002	0	0.0040	0.00006[B]
Beryllium	0.0175	0.0190	0.000018[B]	ND< 0.00004 #	0	ND< 0.00021 #	0.00005[A]
Boron	N/A	0.369	N/A	N/A	0	0.163	N/A
Cadmium	0.0015	0.0010[A]	ND< 0.00002 #	0.00004[B]	0	ND< 0.0002 #	ND< 0.00004[B]
Chromium	0.137	0.136	0.0004	0.0016	0	ND< 0.0002 #	0.0013
Cobalt	0.0461	0.0443	0.00004[B]	0.00009[B]	0	ND< 0.0004 #	ND< 0.00007[B]
Copper	0.199	0.221	0.0004	0.0038	0	ND< 0.0002 #	0.0003
Lead	0.201	0.279	0.0001[B]	0.0001[B]	0	ND< 0.00004 #	0.0002[B]
Manganese	0.133	0.133	0.0007	0.0019	0	0.0002[A]	0.0008
Mercury	0.0064	0.00004	0.0063	0.0070	0	0.0003	0.0070
Molybdenum	0.0608	0.0560	0.0005	0.0022	0	0.0021[B]	0.0018
Nickel	0.152	0.153	0.0001[A]	0.0006	0	ND< 0.0004 #	0.0007
Selenium	0.0236	0.0040	0.0192	0.0232	0	0.0635	0.0002
Vanadium	0.205	0.216	0.000009[B]	0.0001	0	ND< 0.0002 #	ND< 0.00004 #

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
Non-detectible in all samples
N/A Not Available

Table 3.7-2 Concentrations and Removal Efficiencies, SNOX Process (Niles Station)

	Baghouse Inlet, µg/Nm³	Baghouse Outlet, µg/Nm³	Stack, µg/Nm³	Baghouse Removal Efficiencies, Percent	SNOX Removal Efficiencies, Percent
Antimony	94	ND< 0.48	ND< 0.69	99.7	99.6
Arsenic	3,270	13	ND< 0.69	99.6	99.99
Barium	1,330	1.7	0.24	99.9	99.98
Beryllium	77	ND< 0.08	0.23	99.9	99.7
Boron					
Cadmium	6.7	ND< 0.09	ND< 0.16	99.0	97.9
Chromium	602	1.7	5.4	99.3	99.1
Cobalt	203	ND< 0.17	ND< 0.30	99.96	99.9
Copper	875	1.6	1.2	99.8	99.9
Lead	888	0.52	0.73	99.95	99.9
Manganese	584	3.1	3.6	99.4	99.3
Mercury	28	28	30	--	--
Molybdenum	268	2.4	7.5	99.0	96.9
Nickel	669	0.31	3	99.95	99.6
Selenium	104	85	0.92	17	99.1
Vanadium	904	ND< 0.04	ND< 0.15	100	99.99

Table 3.7-3 Stream Temperatures, SNOX Process

Temperature, deg F	
Steam, Superheater Outlet	998
Steam, Reheater Outlet	974
Baghouse Inlet	387
Baghouse Outlet	379
SCR Oultet	663
WSA Condenser Inlet	505
WSA Condenser Outlet (To Stack)	196

Section 3.8 Plant Yates

The Plant Yates Unit No. 1 is a bituminous coal-fired steam electricity-generating unit with a net generating capacity of 100 MWe. Located in Newnan, Georgia, the station is owned and operated by Georgia Power Company. Unit 1 includes a tangentially fired CE boiler that burns a 2.5 % sulfur blend of Illinois No. 5 and Illinois No. 6 bituminous coals, an electrostatic precipitator for particulate control, and the CT-121 flue gas desulfurization system for sulfur dioxide (SO_2) emissions control during the ICCT demonstration.

Flue gas flows through a single duct into the ESP, which is four chambers wide and three rows of chambers deep; however, only the first two rows of chambers are energized. The ESP has a separate row of hoppers to collect the fly ash from each field, i.e., one row of hoppers per field. After the ESP, the flue gas flows through a single ID fan and then to the CT-121 system. The flue gas exiting the CT-121 unit is vented to the atmosphere through a 250-foot exhaust stack. No other units at the station use this stack.

The CT-121 is a second-generation FGD process and employs a unique absorber design, called a jet bubbling reactor (JBR), to combine conventional SO_2 absorption, neutralization, sulfite oxidation, and gypsum crystallization in one reaction vessel. The process is designed to operate in a pH range (3 to 5) where the driving force for limestone dissolution is high, resulting in nearly complete reagent utilization. Oxidation of sulfite to sulfate is also promoted at the lower pH because of the increased solubility of innate oxidation catalysts such as iron (Fe). Because all of the absorbed SO_2 is oxidized, there is sufficient surface area for gypsum crystal growth to prevent the slurry from becoming significantly supersaturated with calcium sulfate. This significantly reduces the potential for gypsum scaling, a problem that frequently occurs in natural-oxidation FGD systems. Since much of the crystal attrition and secondary nucleation associated with the large centrifugal pumps in conventional FGD systems is also eliminated in the CT-121 design, large, easily dewatered gypsum crystals can be produced.

Flue gas from the boiler passes through the ESP and is pressurized by the Unit 1 ID fan. From the fan, the flue gas enters the gas-cooling section. Here, the flue gas is cooled and saturated with a mixture of JBR slurry, makeup water, and pond water. The quench slurry is sprayed into the gas at a liquid-to-gas ratio of about 10 gal/1000 acf at full boiler load using two centrifugal gas cooling pumps. The suction for the gas cooling pumps is located near the bottom of the JBR.

From the gas-cooling section, the flue gas enters the JBR. The JBR is the central feature of the CT-121 process. The gas enters an enclosed plenum chamber formed by an upper deck plate and a lower deck plate. Sparger tube openings in the lower deck plate force the gas into the slurry contained in the jet bubbling (froth) zone of the JBR vessel. After bubbling through the slurry, the gas flows upward through gas risers which pass through both the lower and upper deck plates. Entrained liquor in the gas disengages in a second plenum above the upper deck plate, and the cleaned gas passes to the mist eliminator.

The slurry in the JBR can be divided into two zones: the jet bubbling or froth zone and the reaction zone. SO_2 absorption occurs in the froth zone, while neutralization, sulfite oxidation, and crystal growth occur in both the froth and reaction zones.

The froth zone is formed when the untreated gas is accelerated through the sparger tubes in the lower deck and bubbled beneath the surface of the slurry at a depth of 6 to 16 inches. The froth zone provides the gas-liquid interfacial area for SO_2 mass transfer to the slurry. The bubbles in the froth zone are continually collapsing and reforming to generate new and fresh interfacial area and to transport reaction products away from the froth zone to the reaction zone. The amount of interfacial area can be varied by changing the level in the JBR and, consequently, the injection depth of flue gas. The deeper the gas is injected into the slurry, the greater the interfacial area for mass transfer and the greater the SO_2 removal. In addition, at deeper sparger depths, there is an increase in the gas-phase residence time. SO_2 removal can also be increased by increasing the pH of the slurry in the froth zone. The pH is controlled by the amount of limestone fed to the reaction zone of the JBR.

The solids concentration in the JBR is maintained at a constant level by removing a slurry stream from the bottom of the reaction zone and pumping this stream to a holding tank (gypsum slurry transfer tank), where it is diluted with pond water before being pumped to the gypsum stack. This is done to keep the velocity high over a range of operating conditions.

The oxygen which reacts with absorbed SO_2 to produce sulfate is provided to some extent by oxygen diffusion from the flue gas, but the predominant source is air bubbled into the reaction zone of the JBR. The oxidation air lines enter through the very top of the JBR vessel, penetrate the upper and lower deck plates, and introduce the air near the bottom of the JBR. Oxygen diffuses from the air into the slurry as the bubbles rise to the froth zone of the JBR. Excess air mixes with the flue gas and exits the JBR to the mist eliminator. Before the oxidation air enters the JBR, it is saturated with service water to prevent a wet-dry interface at the discharge of the oxidation air lines.

Plant Yates uses an ash settling and storage area consisting of one ash-settling pond. Bottom ash from the boiler and pyrites from the pulverizers are sluiced together and are disposed of in the ash-settling pond. The ESP ash, economizer ash, and air preheater ash are also sluiced together and disposed of in the same ash-settling pond. Water from the Chattahoochee River is used for cooling water in a once-through type steam condenser.

The ESP is a conventional weighted wire configuration typical of many of the older ESPs found on coal-fired utility boilers in the Midwest and Eastern parts of the United States. The specific collection area (SCA) is 210 ft^2/kacfm at full load.

The Plant Yates ESP uses a Forry Rapper Control System programmed to operate vibrators on the high voltage wire frames and electromechanical rappers on the collector plate assemblies. The rapping cycles are offset so that only one section of the plates is rapped at any single period of time. This rapping procedure results in smaller but more frequent spikes in opacity.

A Plant Yates process flow diagram is presented in Figure 3.8-1 and Figure 3.8-2 presents the trace element partitioning in the plant. Tables 3.8-1 and 3.8-2 present the trace element flow rates and concentration/removal efficiency information at key points in the power plant. Table 3.8-3 gives the stream temperatures at various points in the plant.

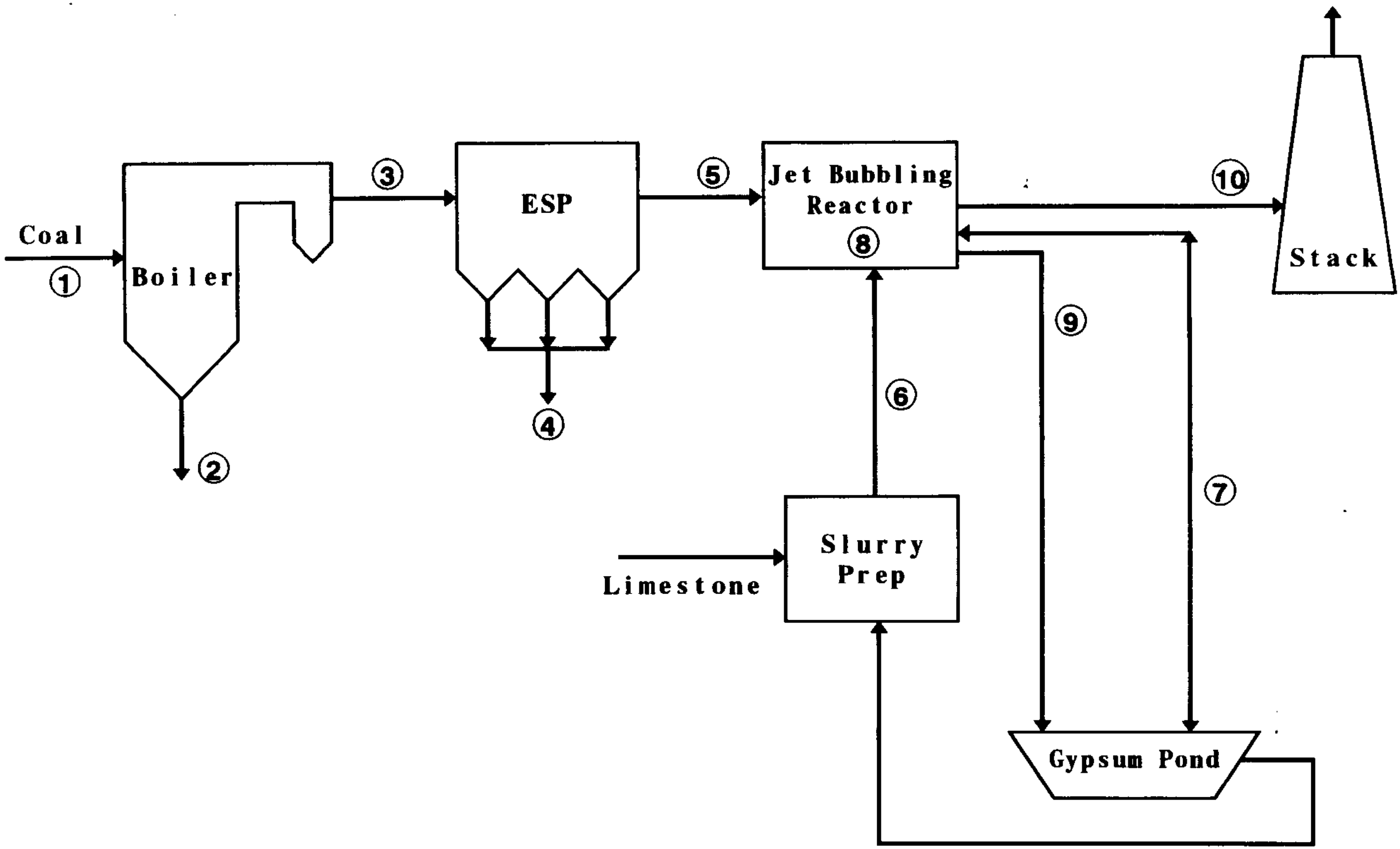

FIGURE 3.8-1. POWER PLANT YATES FLOW DIAGRAM

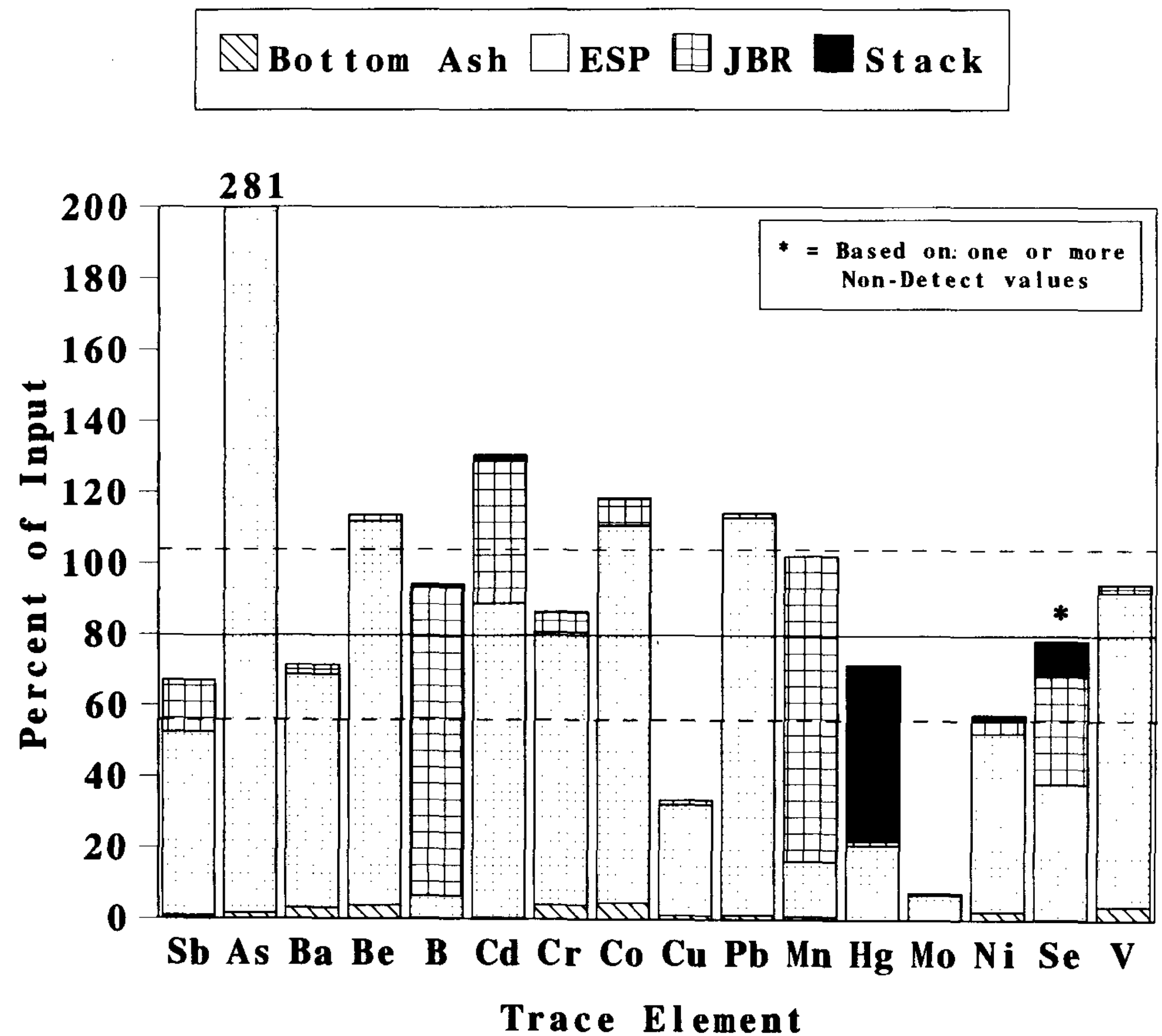

FIGURE 3.8-2. TRACE ELEMENTS IN OUTPUT STREAMS PLANT YATES

Table 3.8-1 Trace Element Flow Rates, Plant Yates

	(1) Coal In	(2) Bottom Ash	(3) Boiler Out, ESP In	(4) Collected Ash	(5) ESP Out, JBR In	(6) Limestone Reagent	(7) Recycle	(8) Accumu-lation	(9) JBR Blowdwn	(10) JBR Out, Stack
Units: lb/hr										
Antimony	0.049	0.0005	0.0327	0.0296	0.0004	0.0038[C]	ND< 0.0046 #	0.00006[C]	0.0084[C]	0.00006
Arsenic	0.184	0.0032	0.407	0.533	0.017	0.0038[C]	0.0080[C]	0.0002[C]	0.0116[C]	0.0012
Barium	6.42	0.20	4.37	4.33	0.074	0.10	0.077	0.0019	0.175	0.0029
Beryllium	0.0882	0.0034	0.0923	0.0969	0.0017	0.0013[A]	0.0002[A]	0.00004	0.0014	0.0001
Boron	8.02	0.123	6.5	4.10	6.85	23.0	33.9	0.438	56.4	0.442
Cadmium	0.0241	0.0001	0.0238	0.0358	0.0013	0.0053	0.0111	0.0002	0.0162	0.0006
Chromium	1.99	0.084	2.88	1.62	0.023	0.116	0.0047	0.0032	0.117	0.0054
Cobalt	0.281	0.014	0.274	0.322	0.0050	0.014	0.0090	0.0004	0.0227	0.0007[A]
Copper	2.89	0.0339	0.764	0.908	0.0169	0.0324	0.0034	0.0008	0.0350	0.0020
Lead	0.642	0.0088	0.704	0.725	0.0188	0.0084	0.0005[A]	0.0002	0.0086	0.0006
Manganese	1.88	0.119	2.10	2.14	0.034	4.29	7.72	0.099	11.9	0.0073
Mercury	0.0062	0.000005[B]	0.0129	0.0013	0.0057	0.00001[A]	0.00002	0.00005	0.00007	0.0031[A]
Molybdenum	1.79	0.0013[B]	0.317	0.122[A]	0.0086	0.0052	0.0059	0.0004	0.0107	0.0015
Nickel	2.41	0.0576	2.08	1.25	0.0238	0.0470	0.0398	0.0012	0.0856	0.0412
Selenium	0.184	ND< 0.0004 #	0.132	0.105	0.0794	0.0738	0.0170	0.0074[A]	0.0833[A]	0.0271
Vanadium	3.16	0.122	2.75	2.85	0.0546	0.0601	0.0141	0.0029	0.0713	0.0022

[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes three non-detect measurements
Non-detectible in all samples

Table 3.8-2 Concentrations and Removal Efficiencies, Plant Yates

	ESP Inlet, µg/Nm³	ESP Outlet JBR Inlet, µg/Nm³	JBR Outlet, µg/Nm³	ESP Removal Efficiencies, Percent	JBR Removal Efficiencies, Percent
Antimony	33	0.41	0.065	98.8	84.1
Arsenic	410	17	1.2	95.9	92.7
Barium	4,400	75	2.9	98.3	96.1
Beryllium	93	1.7	0.099	98.1	92.6
Boron	6,600	6,900	440	34.3	93.5
Cadmium	24	1.3	0.63	95.1	46.2
Chromium	2,900	23	5.4	98.7	76.6
Cobalt	276	5	0.74	98.2	85.3
Copper	770	17	2.0	97.8	88.1
Lead	710	19	0.61	97.4	96.7
Manganese	2,120	34	7.3	98.4	78.4
Mercury	13	5.7	3.1	16.5	45.9
Molybdenum	320	8.7	1.5	97.2	82.5
Nickel	2,100	24	41	98.8	-75.5
Selenium	133	80	27	38.1	66.9
Vanadium	2,770	55	2.2	98	96

Table 3.8-3 Stream Temperatures, Plant Yates

Temperature, deg F	
ESP Inlet	304
ESP Outlet	280
JBR Scrubber	---
Stack	129

Section 3.9 Bailly Station

The Bailly Generating Station is owned and operated by the Northern Indiana Public Service Company (NIPSCO). The plant is located on the shores of Lake Michigan near Chesterton, Indiana. This project involved the two coal-fired units of the Bailly Generating Station with a combined capacity of 528 MWe; Unit No. 7 has a gross capacity of 183 MWe and Unit No. 8 has a gross capacity of 345 MWe.

Each unit is equipped with a Babcock & Wilcox cyclone boiler and a steam turbine generator. Both units burn an Illinois/Indiana basin high-sulfur bituminous coal (2.5% to 4.5% sulfur). Unit 7 has four cyclone burners, and Unit 8 has eight cyclone burners. Full load on each unit usually varies by ± 3MW. There is no control technology for NO_x emissions.

Electrostatic precipitators (ESPs) are used on both units for particulate control. There are two ESPs on Unit 8 and one ESP on Unit 7. The two ESPs of Unit No. 8 are identical to the Unit No. 7 ESP. Each ESP is two shells wide and has 12 electrical fields. In addition, there are three rows of hoppers to collect fly ash from the 12 fields of each ESP. Thus, there are three hoppers in the direction of gas flow along any given lane of the ESP.

Ammonia is injected at a rate to yield 15 ppm concentration prior to the Unit No. 7 ESP and prior to each of the two Unit No. 8 ESPs for the control of SO_3 to prevent acid mist emissions. There are separate ammonia injection systems for the two units.

The Bailly Station Unit No. 7 flue gas flows through a single duct into the ESP. The flue gas stream exits the ESP and subsequently connects downstream of the ESP with the flue gas duct from the combined outlets of the two ESPs of Unit No. 8. These two flue gas streams then join to form a single stream.

There are various ash disposal systems for Units No. 7 and No. 8 at the Bailly Station. Based on four years of records of waste disposal from the plant, nominally 63% of the ash in the coal is collected as bottom ash and the remaining 37% is fly ash. Wet bottom ash is transferred to a slag tank where the ash is sluiced to an ash settling pond. The slag tank is dumped every six hours. The water from the settling pond is recycled back for the sluicing of the bottom ash. Economizer ash is not accumulated or evacuated in sufficient quantity or frequency to be considered as a separate waste stream. Makeup water is obtained from on-site facilities. Fly ash from the precipitators from both units is conveyed dry to an ash silo where it is trucked away to a landfill or sold.

Both units use Lake Michigan water as a once-through cooling medium.

Sulfur dioxide in the combined flue gas stream from the two units of the Bailly Generating Station is treated by the Advanced Flue Gas Desulfurization (AFGD) demonstration project managed by Pure Air of Allentown, Pennsylvania, (a joint venture of Air Products, Inc. and Mitsubishi Heavy Industries, Ltd.) under the Department of Energy's Clean Coal Technology program. The scrubber is owned and operated by Pure Air on the Lake. Pure Air's AFGD system is using wet limestone flue gas desulfurization (FGD) technology to achieve a high level of SO_2 removal (90 to 95+ percent capability) on high sulfur U.S. coals.

A feature of the AFGD process is the purchase and direct injection of powdered limestone in lieu of on-site limestone milling operations. This project includes an in-situ oxidation absorber module that produces high-quality gypsum from a range of high sulfur coals. These features serve to decrease facility size and costs for both installation and operation of the process. High-quality, by-product gypsum (93+ percent purity) is being produced and sold to a wallboard manufacturer. This by-product utilization eliminates the problem of solid waste disposal and also contributes to the cost-effectiveness of the technology.

The flue gas stream from the AFGD process is vented to the atmosphere through a 480-foot stack.

Figure 3.9-1 is a flow diagram of Bailly Station Units 7 and 8. Figure 3.9-2 presents the trace element partitioning. Tables 3.9-1 and 3.9-2 comprise the trace element flow rates and concentration/removal efficiency results. Table 3.9-3 gives stream temperatures at various points in the plant.

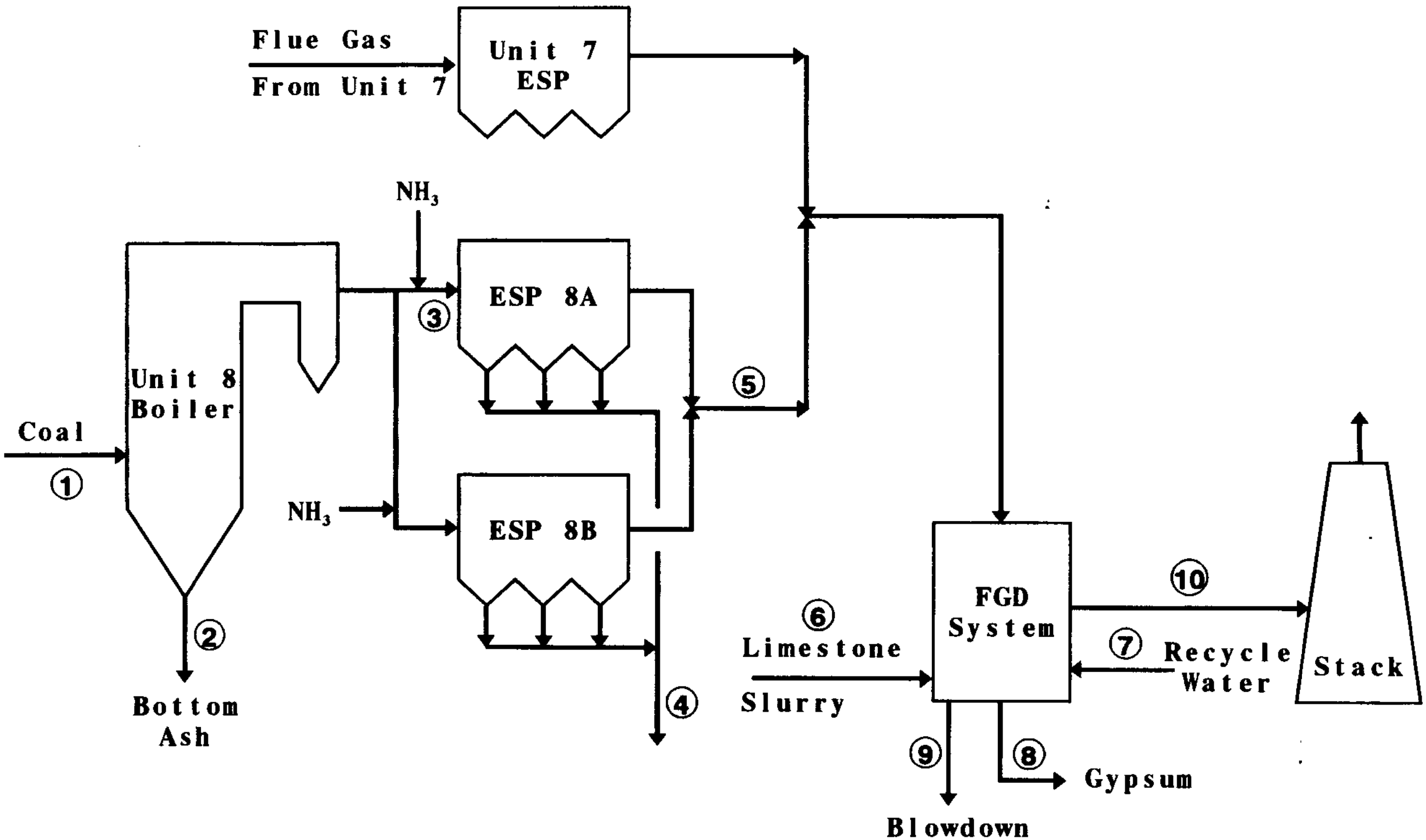

FIGURE 3.9-1. UNIT 7 & 8 FLOW DIAGRAM - BAILLY GENERATING STATION

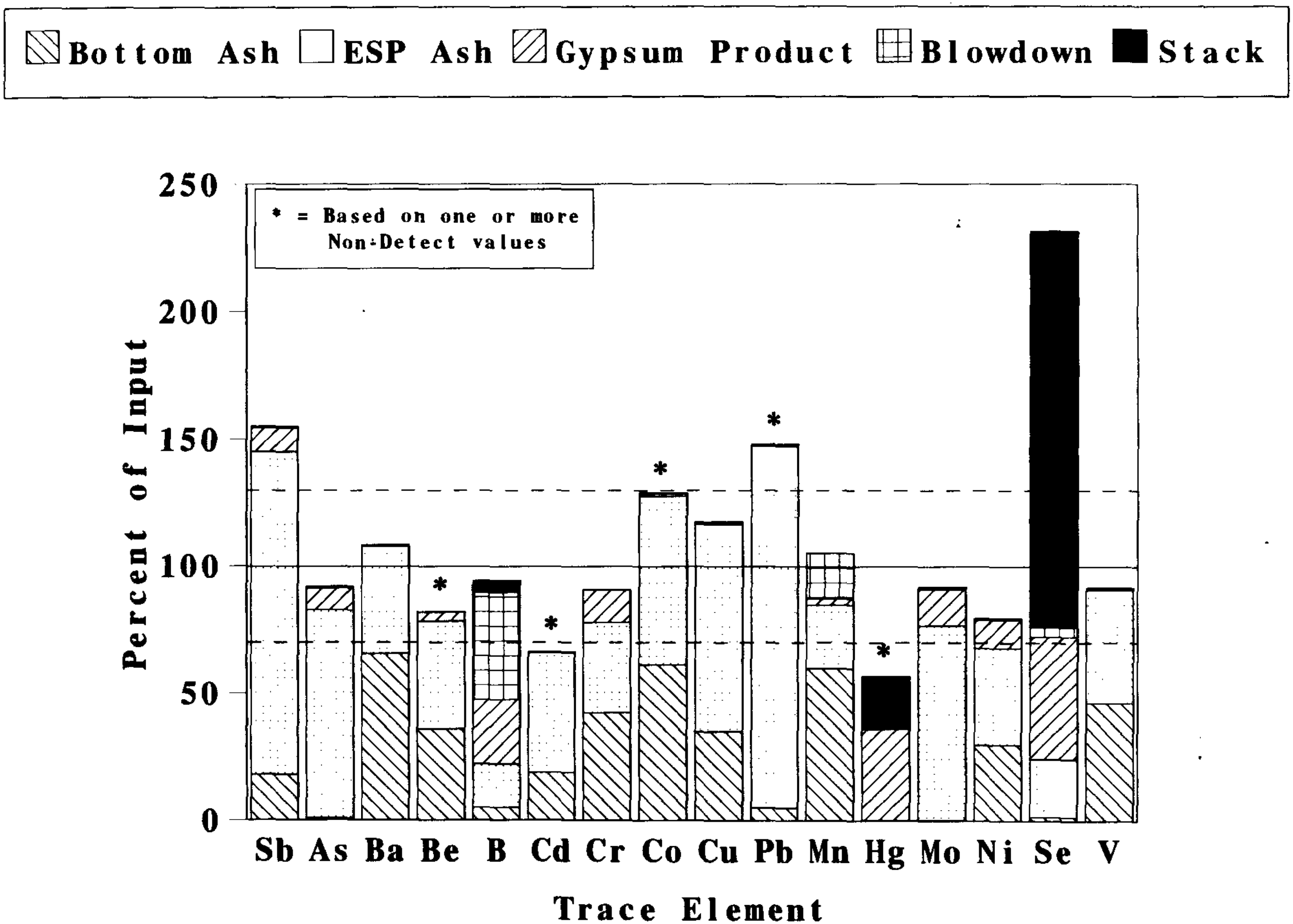

FIGURE 3.9-2. TRACE ELEMENTS IN OUTPUT STREAMS BAILLY STATION

Table 3.9-1 Trace Element Flow Rates, Bailly Station

	(1) Coal	(2) Bottom Ash	(3) ESP 8 Inlet	(4) ESP 8 Hopper Ash	(5) Scrubber In (ESP 8 Only)	(6) Lime Reagent	(7) Scrubber/ Makeup Water	(8) Scrubber Gypsum	(9) Scrubber Blowdown	(10) Stack
Units: lb/hr										
Antimony	0.200	0.042	0.091	0.298	0.00059	0.035	ND< 0.00013 #	0.022	0.00030	0.00094
Arsenic	0.873	0.0076	0.551	0.721	0.0051	0.010	ND< 0.00007 #	0.077	0.00055	0.0050
Barium	13.0	8.57	4.13	5.49	0.0139	0.048	0.0081	0.056	0.0100	0.0044
Beryllium	0.534	0.191	0.213	0.226	0.00020[A]	ND< 0.00014 #	ND< 0.00011 #	0.019	ND< 0.00001 #	ND< 0.00026[A]
Boron	62.5	3.35	37.5	11.5	33.2	4.55	ND< 0.0140 #	16.9	28.4	3.01
Cadmium	0.825	0.156	0.349	0.389	0.0094	ND< 0.0012[B]	0.00055	ND< 0.00047 #	0.0018	0.0014
Chromium	13.0	5.49	4.44	4.63	0.0190	0.021	ND< 0.0013 #	1.67	0.00023	0.0091
Cobalt	0.779	0.483	0.412	0.522	0.00061	0.010	0.00085	ND< 0.0070 #	0.0039	0.00036
Copper	2.93	1.05	2.05	2.45	0.0083	0.080	0.0024	0.020	0.00041	0.0057
Lead	2.37	0.121	3.11	3.37	0.0111	ND< 0.0022 #	ND< 0.0011 #	ND< 0.012 #	ND< 0.00012 #	0.0053
Manganese	8.97	6.83	2.56	2.82	0.0032	2.44	0.0023	0.284	2.05	0.0077
Mercury	0.032	ND< 0.00003[B]	0.0090	0.0001	0.0098	ND< 0.00004 #	0.00004	0.012	0.00002	0.0068
Molybdenum	2.25	0.0089[B]	1.63	1.72	0.0117	0.013	0.0109	0.320	0.0058	0.0113
Nickel	7.19	2.17	2.63	2.77	0.0153	0.090	0.0023	0.807	0.0354	0.0067
Selenium	0.407	0.0065	0.873	0.093	0.418	ND< 0.0018 #	0.00056	0.196	0.0148	0.636
Vanadium	14.8	6.90	5.56	6.61	0.0099	0.127	ND< 0.00067 #	0.099	0.00058	0.0091

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
\# Non-detectible in all samples

Table 3.9-2 Concentrations and Removal Efficiencies, Bailly Station

	ESP-8 Inlet, μg/Nm³	ESP-8 Outlet, μg/Nm³	ESP-7 Outlet, μg/Nm³	Scrubber Inlet, μg/Nm³	Stack, μg/Nm³	ESP-8 Removal Efficiencies, Percent	ESP-7 Removal Efficiencies, Percent	Scrubber Removal Efficiencies, Percent
Antimony	43	0.235	0.416	0.310	0.38	99.97	98.83	-57.5
Arsenic	132	2.1	6.4	3.65	1.43	98.41	95.05	58.26
Barium	1,920	5.66	23.7	12.1	1.71	99.7	98.75	89.18
Beryllium	99	ND< 0.09	1.38	0.542	ND< 0.10	99.92	98.58	88.7
Boron	17,400	13,600	13,300	13,481	1,230	19.43	20.8	91.16
Cadmium	163	3.81	9.45	5.82	0.57	97.33	93.78	90.15
Chromium	2,080	7.75	35.4	14.9	3.7	100.14	98.97	60.98
Cobalt	191	0.158	2.18	0.903	ND< 0.10	99.62	98.29	79.3
Copper	958	3.4	15.1	7.51	2.33	99.64	98.36	70.11
Lead	1,440	4.57	23.4	11.2	2.13	99.68	98.34	82.35
Manganese	1,200	1.73	10.7	4.05	4.16	99.85	99.22	62.45
Mercury	4.2	4.02	4.21	4.09	2.8	-5.10	8.22	52.68
Molybdenum	760	4.57	16.9	9.05	4.61	99.38	97.72	49.92
Nickel	1,240	6.5	17	6.92	2.92	99.45	98.63	70.34
Selenium	408	171	347	232	261	57.73	11.71	-15.68
Vanadium	2,590	4.32	38.2	16.0	3.81	99.83	98.49	76.92

Table 3.9-3 Stream Temperatures, Bailly Station

Temperature, deg F	
Unit 7	
Economizer Inlet	815
Steam, as throttle	655
ESP Outlet	296
Unit 8	
Economizer Inlet	942
Economizer Outlet	613
ESP Outlet	313
AFGD Inlet	319
AFGD Outlet	131

Section 3.10 Nelson Dewey Station

Plant Description

The site for this test was Unit 2 of the Nelson Dewey Station, which is owned and operated by Wisconsin Power and Light. This unit is equipped with three cyclone burners and is a forced draft unit with a nominal capacity of 100 MWe. The test unit burns an Indiana bituminous coal.

Environmental controls consist of an ESP for particulate control and a coal-fired reburn system for NO_x control. The reburn system was recently retrofitted to this unit and consists of the pulverizer, reburn burners in the upper furnace, overfire air ports, and modifications to the control system. The unit could be operated in either the baseline mode without the reburn burners or in the low-NO_x mode with approximately 20 percent of the heat input from the reburn burners. Under low NO_x reburn operation, the existing cyclone burners are fired with 70 to 80 percent of the total coal feed as crushed coal. The cyclones are operated at around 110 percent excess air in the main combustion zone. The reburn burners are fired with the remaining 20 to 30 percent of the coal feed as pulverized coal. These reburn burners are operated fuel rich at a reducing stoichiometry of 0.85 to 0.95. This reducing condition converts the nitrogen oxides formed in the cyclone burners to molecular nitrogen, thereby reducing NO_x. The balance of air required to complete combustion is added in the burnout zone above the reburn zone through the use of overfire air ports.

The standard baseline coal which was used throughout the development of the reburn system was a bituminous Indiana Lamar coal with a heating value of about 11,500 Btu/lb, a sulfur level of about 1.6 percent, and ash content of about 9 percent. The plant was converting to subbituminous western coal as the standard fuel after the test. As a result, the remaining supply of Lamar coal was very limited and the plant totally consumed the residual Lamar supply during the HAP testing. Some decisions on test priorities, sequencing, and duration of runs were structured around the need to stretch out the coal supply. To conserve coal, the unit was normally operated at low load between tests. During testing, and 2 hours before, the unit was operated at full load. At other times, however, the unit was fired at the lowest practical load to conserve remaining coal and maximize the flexibility for test run times.

Figure 3.10-1 shows a schematic flow diagram of the test unit. Figures 3.10-2 and 3.10-3 show trace element partitioning results during baseline operation and during reburn testing. Tables 3.10-1 and 3.10-2 present the trace element flow rates during these two periods. Table 3.10-3 gives trace element concentrations and removal efficiencies for both periods. Table 3.10-4 gives stream temperatures at various points in the plant.

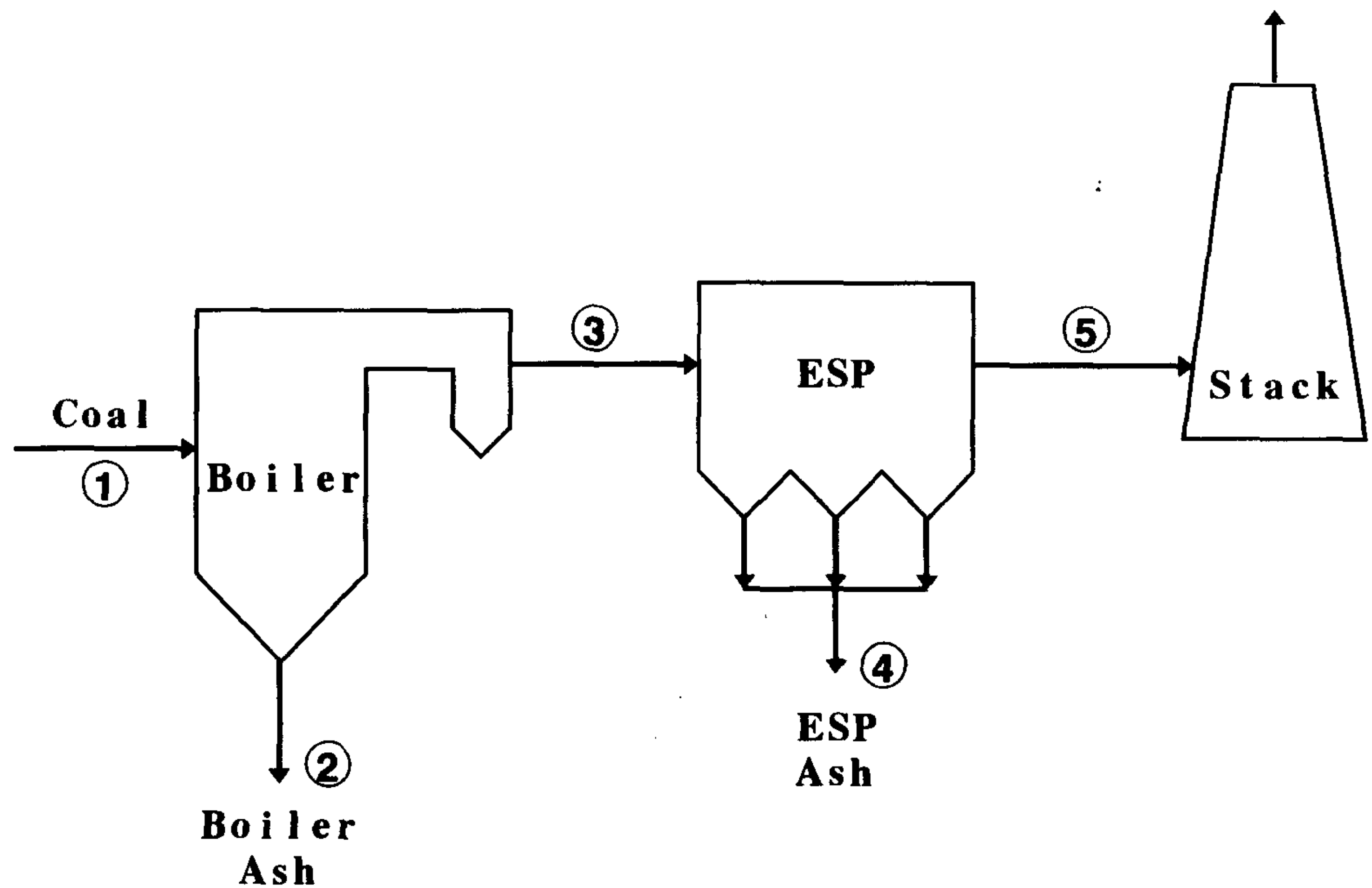

FIGURE 3.10-1. NELSON DEWEY STATION

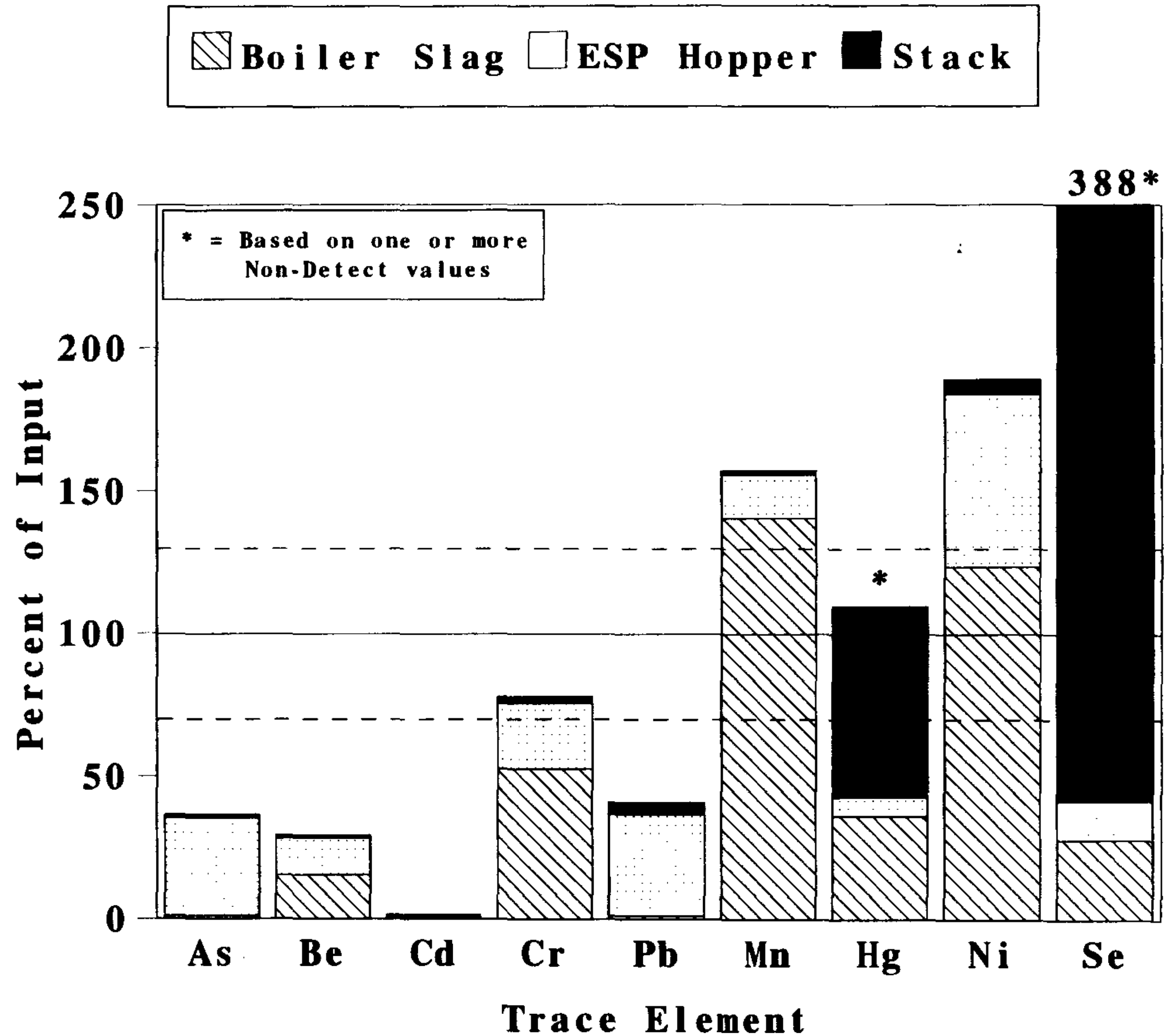

FIGURE 3.10-2. TRACE ELEMENTS IN OUTPUT STREAMS NELSON DEWEY STATION, BASELINE TESTS

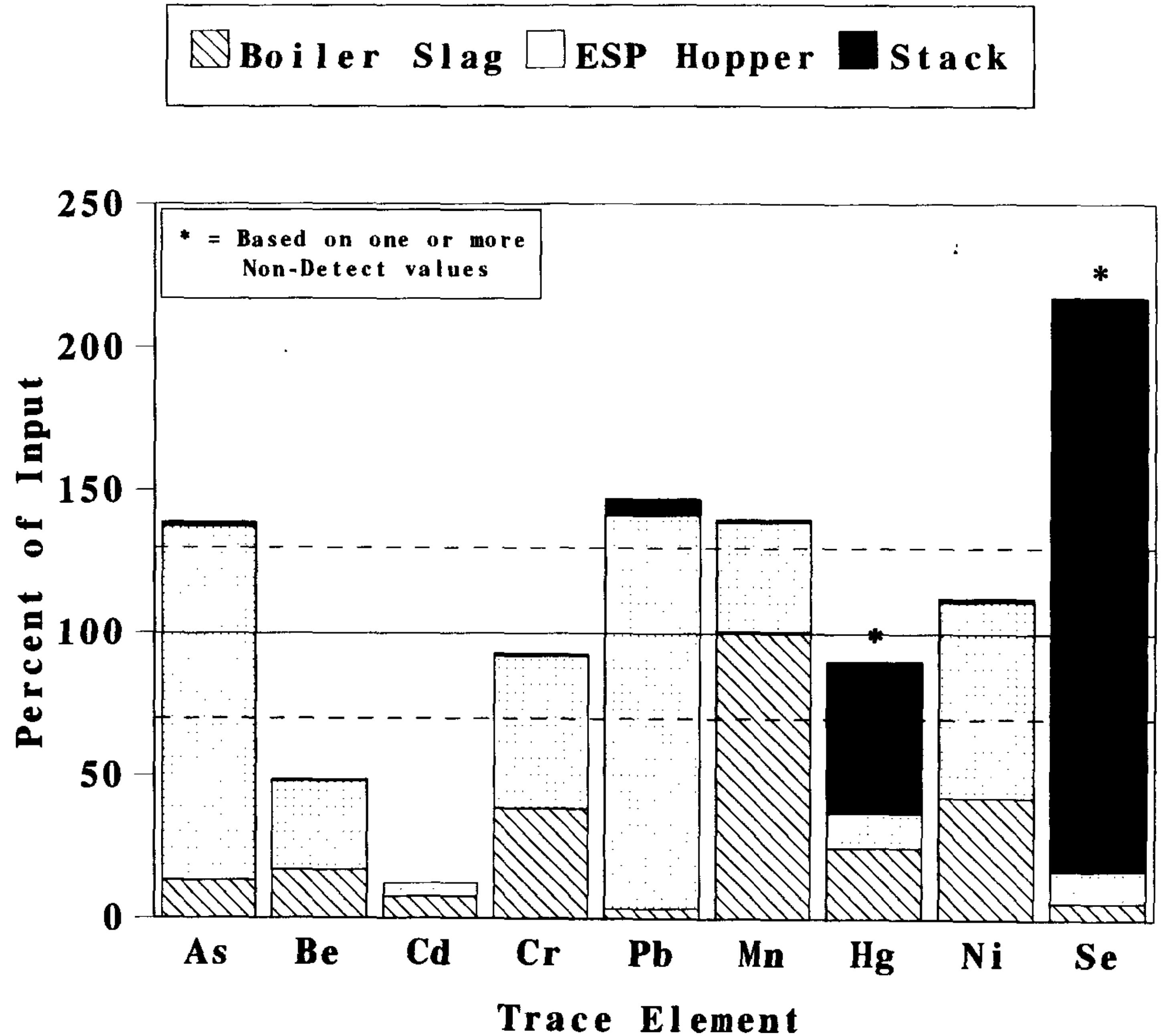

FIGURE 3.10-3. TRACE ELEMENTS IN OUTPUT STREAMS NELSON DEWEY STATION, REBURN TESTS

Table 3.10-1 Trace Element Flow Rates, Nelson Dewey Station, Baseline Data

	(1) Coal Input	(2) Boiler Slag	(3) ESP Inlet	(4) ESP Ash	(5) Stack
Units: lb/hr					
Arsenic	0.955	0.0106[B]	0.188	0.326	0.0103
Beryllium	0.286	0.044	0.056	0.037	0.0032
Cadmium	3.0[A]	0.025	0.030	0.0156[A]	0.0037
Chromium	0.892	0.468	0.338	0.206	0.019
Lead	2.88	0.037[A]	1.91	1.02	0.121
Manganese	2.09	2.94	0.543	0.318	0.029
Mercury	ND< 0.0095 #	ND< 0.0034 #	0.010	ND< 0.00063 #	0.0063
Nickel	2.14	2.65	1.91	1.30	0.107
Selenium	ND< 0.095 #	0.0265[B]	0.0331	ND< 0.013 #	0.330

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
Non-detectible in all samples

Table 3.10-2 Trace Element Flow Rates, Nelson Dewey Station, Reburn Data

	(1) Coal	(2) Slag	(3) ESP in	(4) Hopper Ash	(5) ESP out, Stack
Units: lb/hr					
Arsenic	0.672	0.088^{B}	0.198	0.833	0.011
Beryllium	0.275	0.047^{A}	0.047	0.085	0.0013
Cadmium	3.95^{A}	0.300^{A}	0.033	0.179^{B}	0.0021
Chromium	0.791	0.304	0.212	0.421	0.0066
Lead	1.30	0.046	1.29	1.78	0.075
Manganese	2.26	2.28	0.484	0.865	0.021
Mercury	ND< 0.0095 #	ND< 0.0024 #	0.0066	0.0012^{B}	0.0050
Nickel	3.86	1.64	0.543	2.65	0.044
Selenium	ND< 0.095 #	ND< 0.0056 #	0.132	0.011^{A}	0.191

ND< Value shown is detection limit.
^{A} Includes one non-detect measurement
^{B} Includes two non-detect measurements
Non-detectible in all samples

Table 3.10-3 Concentrations and Removal Efficiencies, Nelson Dewey Station

	Baseline			Reburn		
	ESP In, µg/dscm	ESP Out, µg/dscm	Removal Efficiencies, Percent	ESP In, µg/dscm	ESP Out, µg/dscm	Removal Efficiencies, Percent
Arsenic	196	11.0	94.4	218	12.1	94.5
Beryllium	57.0	3.61	93.7	52.1	1.31	97.5
Cadmium	30.9	3.98	87.1	36.4	2.37	93.5
Chromium	347	20.5	94.1	234	7.40	96.8
Lead	1,953	127	93.5	1,426	78.0	94.5
Manganese	560	31.2	94.4	535	23.1	95.7
Mercury	10.2	6.87	32.7	7.45	5.66	24.0
Nickel	2,034	117	94.3	599	49.7	91.7
Selenium	34.9	357	--	146	218	--

Table 3.10-4 Stream Temperatures, Nelson Dewey Station

Temperature, deg F	
ESP Inlet	513
Stack	492

Section 3.11 Plant Hammond

Plant Description

The unit tested, Plant Hammond, has a generating capacity of approximately 500 MWe. The opposed wall-fired, subcritical boiler was designed by Foster Wheeler. A partial vertical dividing plate within the furnace creates two combustion zones, and very little mixing of the flue gas occurs between the A and B sides.

The plant burns a combination of bituminous coals that have a typical sulfur content of 1.6% and a typical ash content of 10%. Bottom ash is removed from the boiler by an ash sluicing system. Electrostatic precipitators (ESPs) remove fly ash from the flue gases. The flue gas treatment and ash removal facilities are described in greater detail below.

The flue gas exiting each side of the furnace flows into a separate duct, designated the A or B side. Two ESPs, one each for the A and B sides, remove particulate matter from the flue gas. The unit is equipped with a conditioning system capable of injecting SO_3 or NH_3 into the flue gas upstream of the ESPs to improve ESP performance. The conditioning system was not in use during the Over-Fire Air (OFA) testing. During the Over-Fire Air/Low NO_x Burner (OFA/LNB) test, NH_3 was injected at a rate of approximately 25 scfm, which is equivalent to a concentration of about 20 ppmv in the flue gas entering the ESPs. The NH_3 injection was used because of plant concerns about complying with particulate matter emission limits.

Dry ash collected in the economizer and ESP hoppers is pneumatically transported to a tank where it is mixed with water and sluiced to a settling pond. Bottom ash from the boiler is sluiced to a separate settling pond. The water used for ash sluicing is recycled water from the settling ponds.

Overfire air ports were installed during a four-week outage in the spring of 1990 by Foster Wheeler Energy Corporation (FWEC). The design includes four overfire air ports on each side of the boiler directly above the top row of burners. Overfire air is diverted from the secondary air ductwork. At full load, approximately 20% of the secondary air is introduced through the overfire air ports.

The low-NO_x burners were installed during a seven-week outage in the spring of 1991. The FWEC burners are of the controlled flow/split flame (CFSF) design. The 24 burners are arranged on opposing walls, with three rows of four burners on each wall. The low-NO_x burners replaced the previous pre-NSPS Intervane burners that were in place during the OFA test.

The Plant Hammond flow diagram is shown in Figure 3.11-1. Partitioning results for the two test periods are given in Figure 3.11-2 and 3.11-3. Tables 3.11-1 and 3.11-2 present trace element flow rates for both (overfire air and low-NO_x burner) test periods. Table 3.11-3 shows trace element concentrations and removal efficiency data for both test periods. Table 3.11-4 gives stream temperatures at various points in the plant.

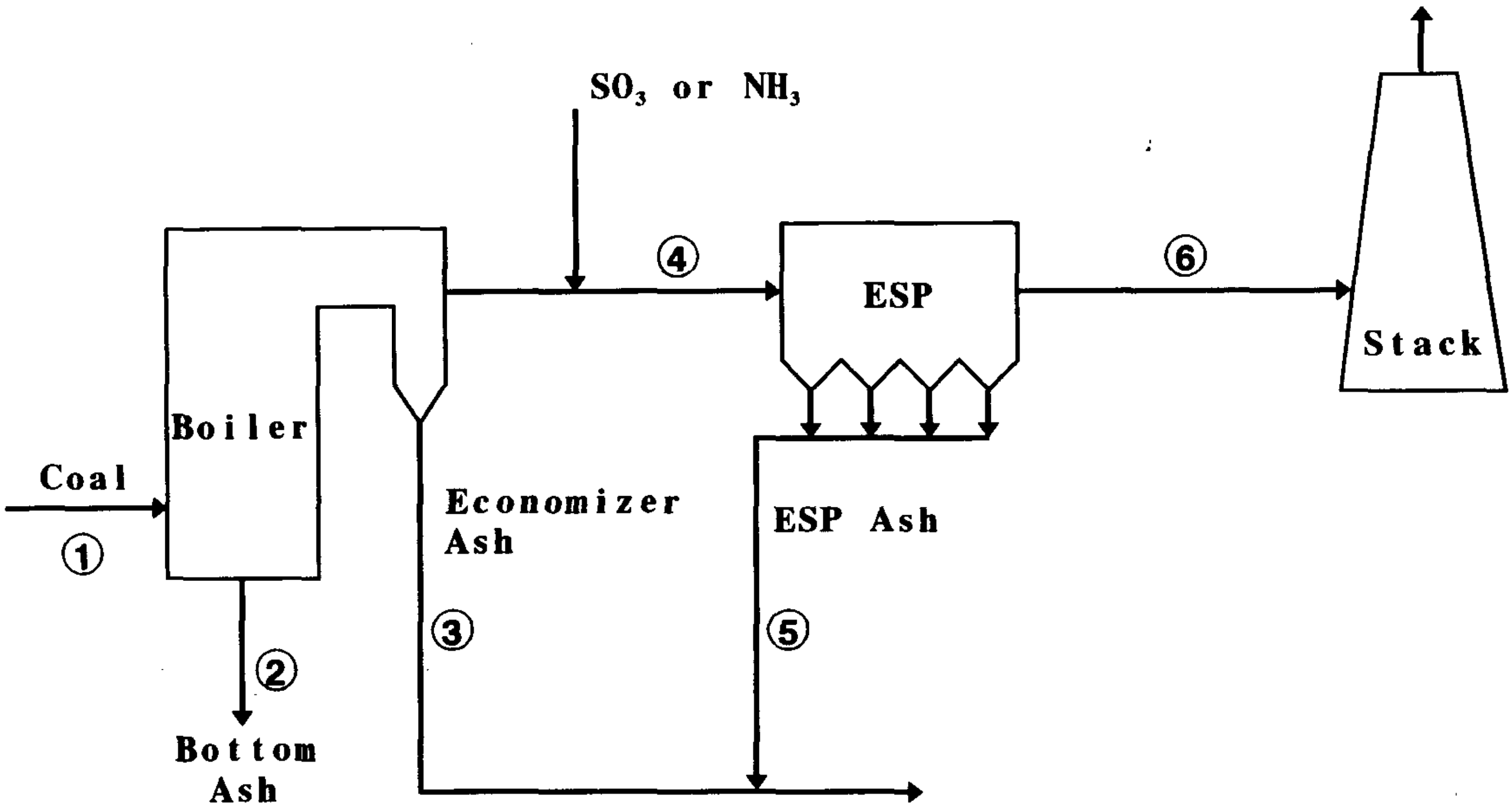

FIGURE 3.11-1. PLANT HAMMOND FLOW DIAGRAM

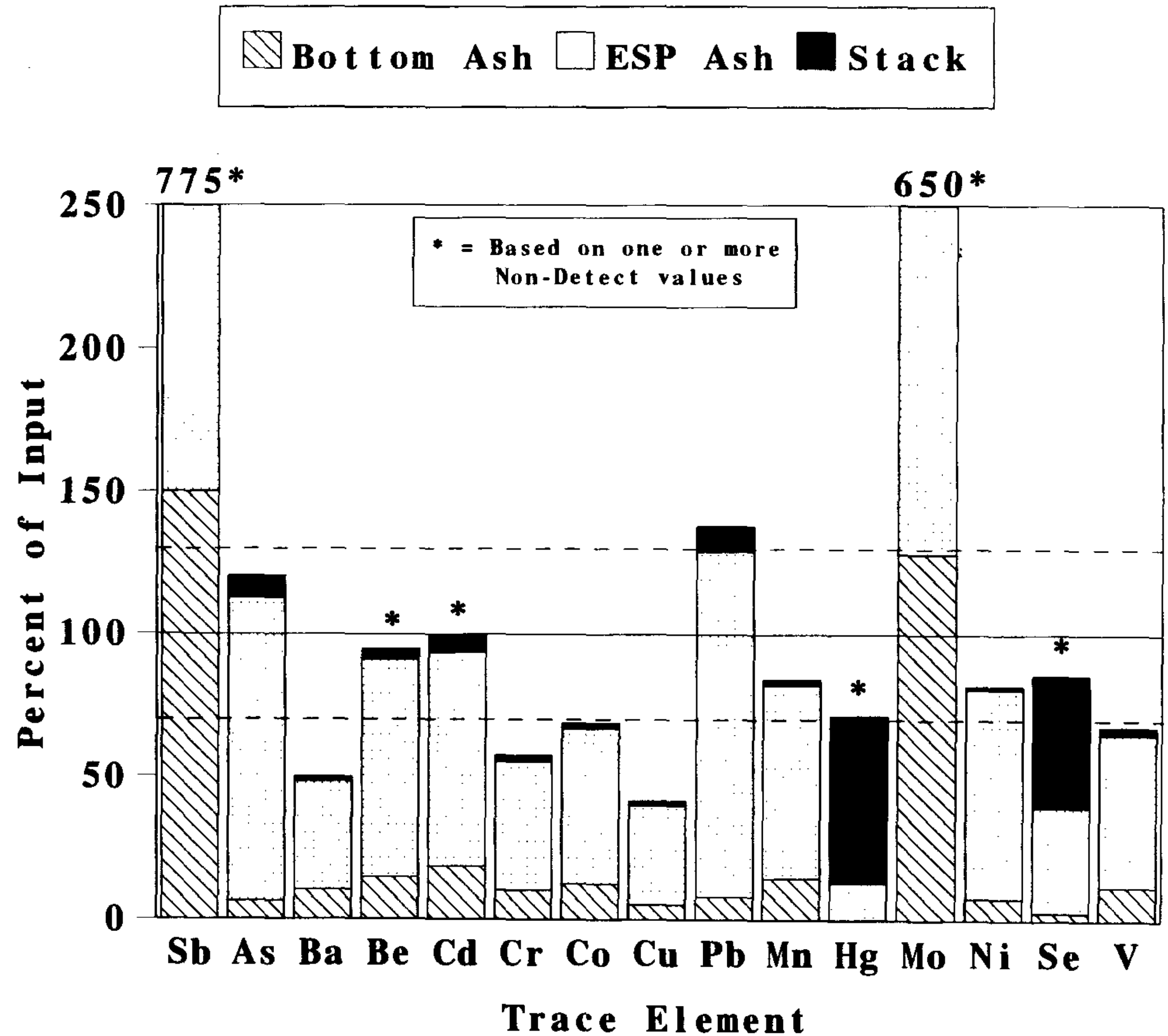

FIGURE 3.11-2. TRACE ELEMENTS IN OUTPUT STREAMS PLANT HAMMOND, OVER FIRE AIR

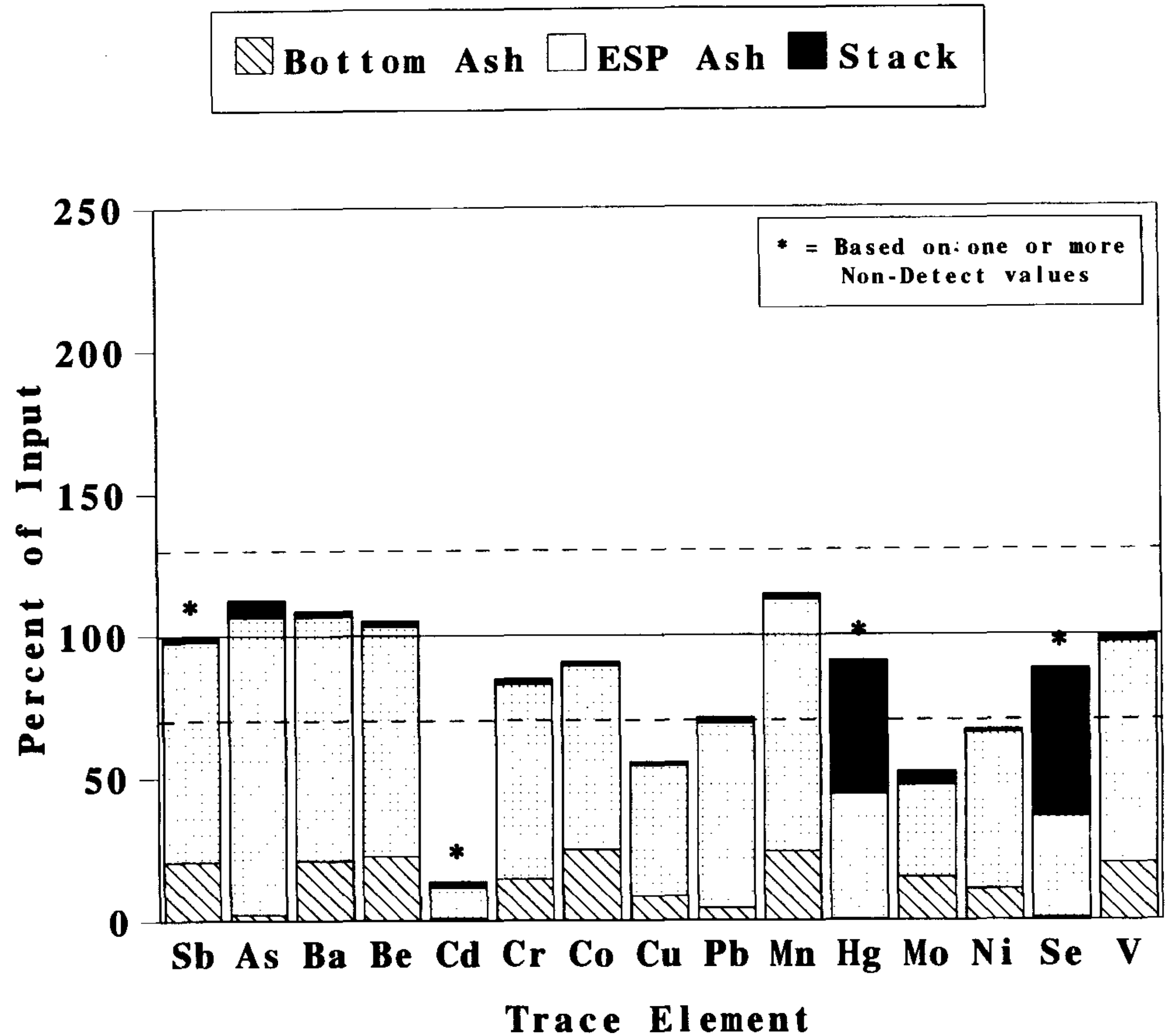

FIGURE 3.11-3. TRACE ELEMENTS IN OUTPUT STREAMS PLANT HAMMOND, LOW NOx BURNER

Table 3.11-1 Trace Element Flow Rates, Plant Hammond, Over-Fire Air Tests

	(1) Coal	(2) Bottom Ash	(3) ESP Inlet	(4) ESP Ash	(5) Stack
Units: lb/hr					
Antimony	0.452	ND< 0.677 #	ND< 2.65 #	ND< 2.71 #	ND< 0.122 #
Arsenic	5.61	0.352	8.10	5.96	0.424
Barium	56.1	5.82	28.3	21.1	1.00
Beryllium	0.462	0.0677	0.490	0.352	ND< 0.0166 #
Cadmium	0.0363[B]	ND< 0.0068 #	0.0495[A]	ND< 0.0271 #	ND< 0.0023 #
Chromium	7.26	0.745	4.23	3.25	0.170
Cobalt	2.74	0.339	1.66	1.49	0.0502
Copper	12.5	0.657	5.40	4.34	0.185
Lead	1.68	0.135	1.98	2.03	0.150
Manganese	5.61	0.812	3.37	3.79	0.112
Mercury	0.0495	ND< 0.00014 #	0.0319	0.0062	0.0289
Molybdenum	1.06[A]	ND< 1.35 #	ND< 1.304 #	5.42	0.054[C]
Nickel	8.91	0.677	2.97	6.50	0.108
Selenium	1.25	ND< 0.0339 #	2.11	0.461	0.579
Vanadium	12.2	1.42	8.10	6.50	0.324

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Non-detectible in all but one sample
Non-detectible in all samples

Table 3.11-2 Trace Element Flow Rates, Plant Hammond, Low-NO_x Burner Tests

	(1) Coal	(2) Bottom Ash	(3) ESP Inlet	(4) ESP Ash	(5) Stack
Units: lb/hr					
Antimony	0.47	0.097[B]	ND< 0.38 #	ND< 0.36 #	0.010
Arsenic	7.25	0.162	7.86	7.53	0.452
Barium	31.2	6.50	26.2	26.7	0.603
Beryllium	0.693	0.155	0.567	0.559	0.013
Cadmium	ND< 0.819 #	ND< 0.0071 #	0.092	0.087	0.016
Chromium	5.36	0.777	3.67	3.65	0.114
Cobalt	1.92	0.473	1.27	1.24	0.028
Copper	10.7	0.918	4.80	4.86	0.132
Lead	2.30	0.099	1.48	1.48	0.049
Manganese	4.41	1.06	3.88	3.89	0.090
Mercury	0.044	ND< 0.0001 #	0.048	0.019	0.021
Molybdenum	1.13[A]	0.169[A]	0.375[A]	0.365	0.053
Nickel	5.36	0.579	2.88	2.92	0.072
Selenium	1.17	ND< 0.0085 #	0.432	0.413	0.603
Vanadium	8.19	1.62	6.55	6.32	0.177

ND< Value shown is detection limit
A Includes one non-detect measurement
B Includes two non-detect measurements
\# Non-detectible in all samples

Table 3.11-3 Concentrations and Removal Efficiencies, Plant Hammond

	Over Fire Air Tests			Low NOx Burner Tests		
	ESP Inlet, $\mu g/Nm^3$	Stack, $\mu g/Nm^3$	OFA Removal Efficiencies, Percent	ESP Inlet, $\mu g/Nm^3$	Stack, $\mu g/Nm^3$	OFA/LNB Removal Efficiencies, Percent
Antimony	ND< 590	ND< 29	NC	ND< 87	2.6	NC
Arsenic	1,800	110	95	1,800	120	94
Barium	6,300	260	96	6,000	160	98
Beryllium	109	4.3	97	130	3.5	98
Boron						
Cadmium	ND< 11	0.59	NC	21	4.2	83
Chromium	940	44	96	840	24.	98
Cobalt	370	13	97	290	7.5	98
Copper	1,200	48	97	1,100	35	98
Lead	440	39	92	340	13	97
Manganese	750	29	97	890	24	98
Mercury	7.1	7.5	9	11	5.5	55
Molybdenum	ND< 290	ND< 14	NC	86	14	86
Nickel	660	28	96	660	19	98
Selenium	470	150	72	99	160	0
Vanadium	1,800	84	96	1,500	47	97

NC = Not Calculated.

Table 3.11-4 Stream Temperatures, Plant Hammond

Temperature, deg F	
ESP Inlet	303
ESP Outlet (To Stack)	305

Section 3.12 Plant Smith

Plant Description

There are two units at Plant Smith. Unit 1 is rated at 175 MWe and Unit 2, the test unit, at 196 MWe. Both units have tangentially-fired boilers. Originally, both units were equipped with cold-side ESPs; in 1977, however, when the units were converted to balanced draft operation, both units were also retrofitted with hot-side ESPs. Both units continue to operate with a hot-side and a cold-side ESP in tandem. Flue gas leaving the two cold-side ESPs is vented to the atmosphere through a common stack.

Over the years, the fuel supply at the test site has varied. About 10 years ago, for example, a low-sulfur coal from South Africa was employed. During the past year or longer, on the other hand, coals from Southern Illinois and Western Kentucky containing about 3% sulfur have been used as the fuel. A 3% sulfur Western Kentucky coal, purchased on the spot market was burned during both of the test occasions described in this report. There is no provision at the test site for the removal of sulfur from the flue gas in a scrubber of any type; however, a portion of the sulfur present in the coal as pyrite is removed during the pulverization process prior to combustion and is discharged as a waste stream.

During the first half of 1991, the furnace of Unit 2 began to undergo modification with the installation of low NO_x burners. This report includes the measurement of rates of toxic organic and inorganic substances in the flue gas both before and after the burner modifications were made. The measurements prior to the final adoption of modified combustion conditions were conducted during the period September 17-22, 1991; however, the baseline study was performed after certain structural changes in the furnace had been completed. The subsequent measurements with burner modifications in place were made during the period January 14-17, 1992.

Figure 3.12-1 shows the flow arrangement for Plant Smith. Figures 3.12-2 and 3.12-3 give partitioning results for baseline and Low-NO_x test periods. Trace element flow rates are given for both periods in Tables 3.12-1 and 3.12-2. Table 3.12-3 gives concentrations and removal efficiencies for trace elements during both periods. Table 3.12-4 gives stream temperatures at various points in the plant.

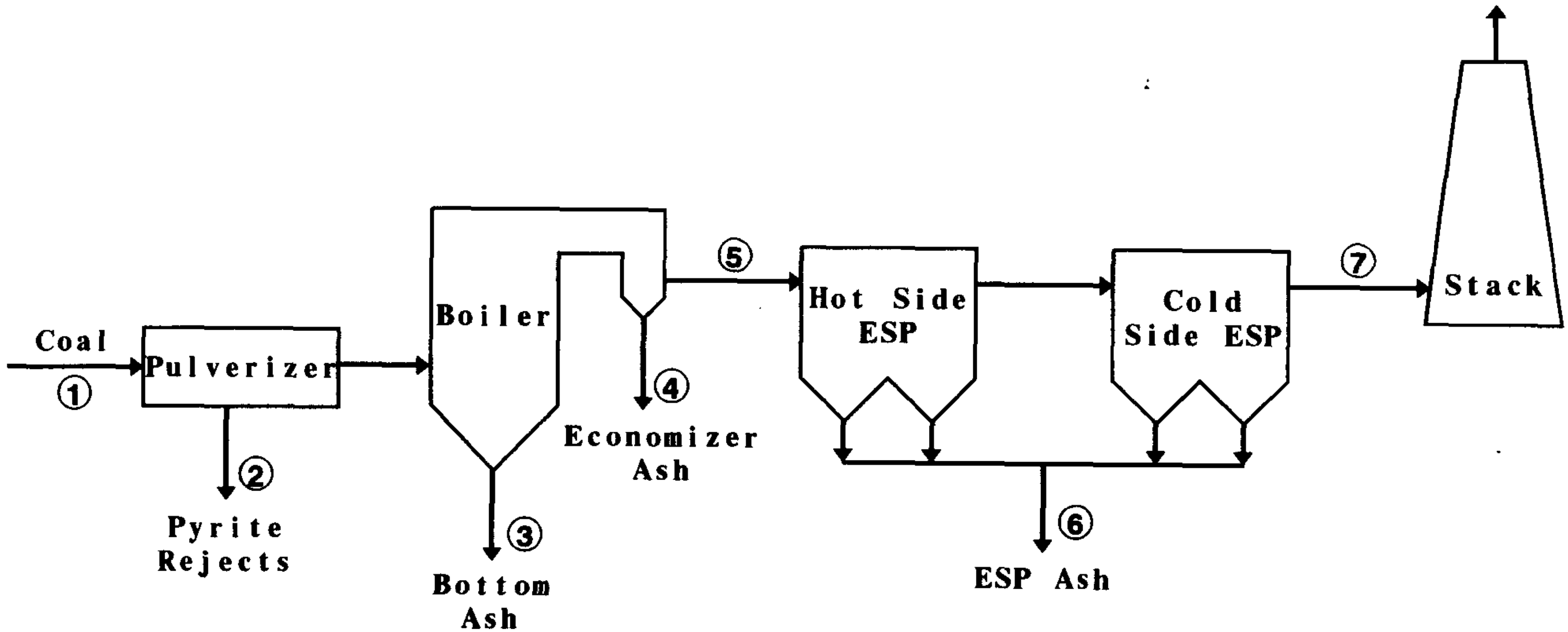

FIGURE 3.12-1. PLANT SMITH FLOW DIAGRAM

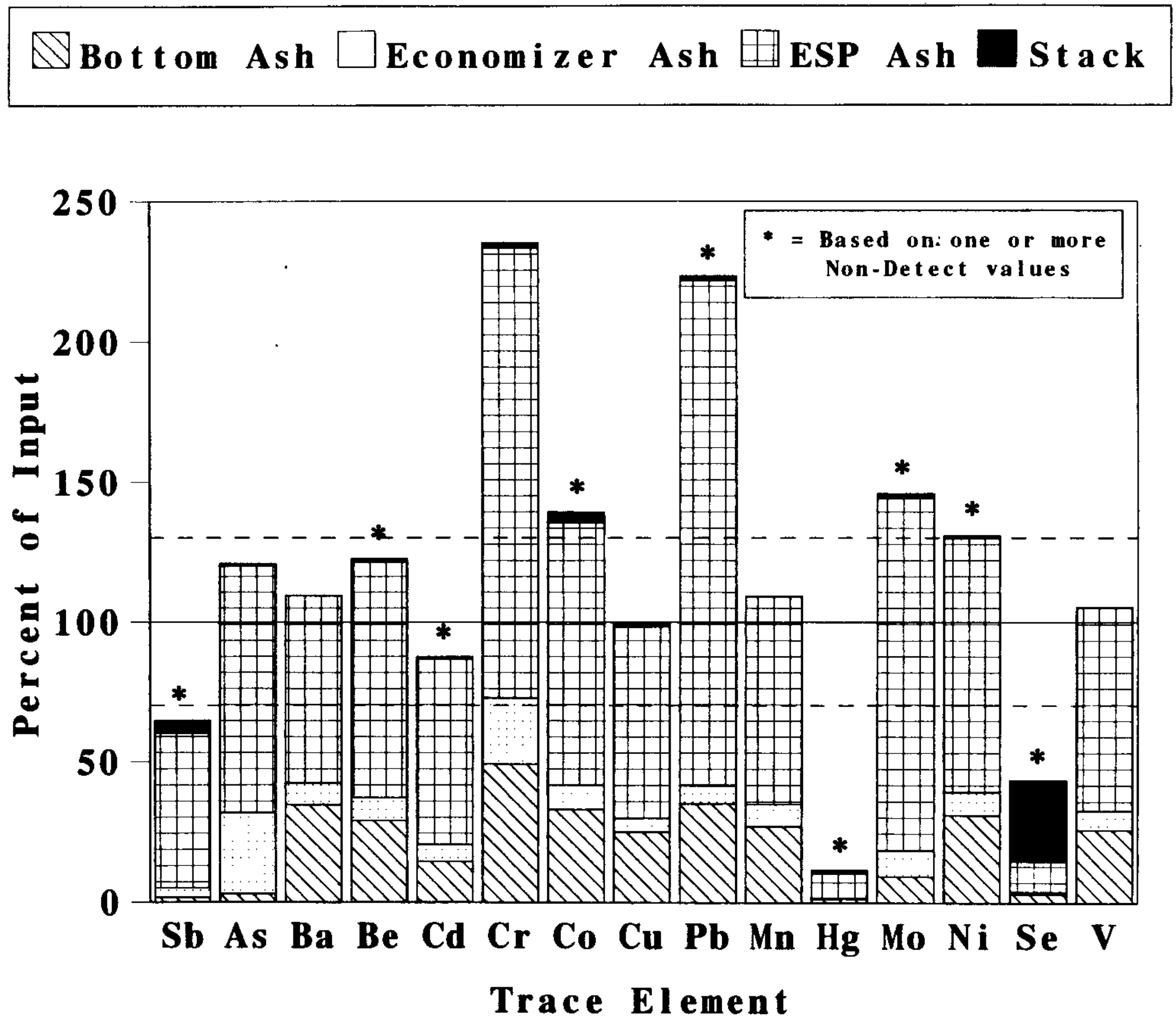

FIGURE 3.12-2. TRACE ELEMENTS IN OUTPUT STREAMS PLANT SMITH, BASELINE TESTS

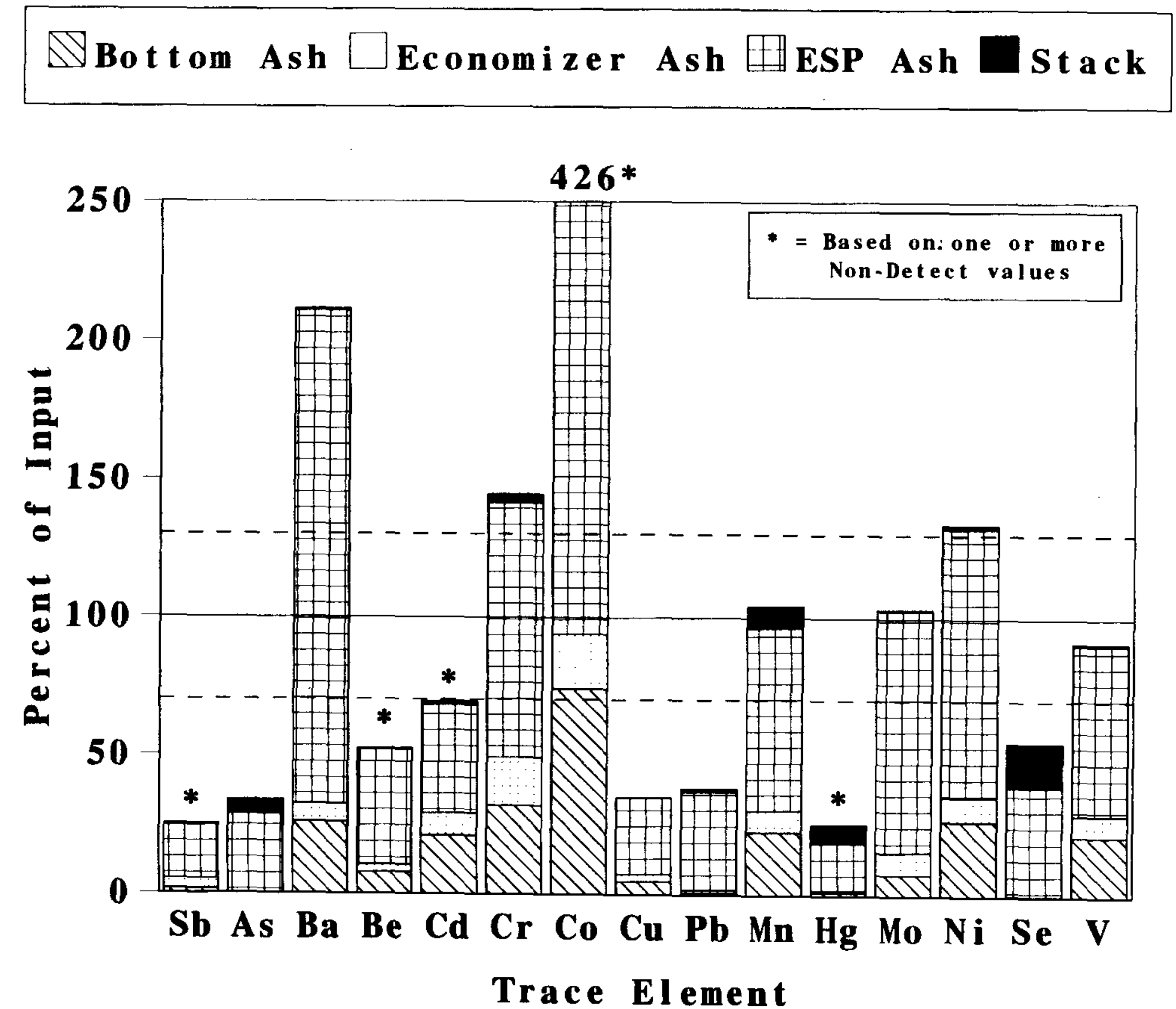

FIGURE 3.12-3. TRACE ELEMENTS IN OUTPUT STREAMS PLANT SMITH, LOW NOx TESTS

Table 3.12-1 Trace Element Flow Rates, Plant Smith, Baseline Tests

	(1) Raw Coal	(2) Pyrite Rejects	(3) Bottom Ash	(4) Economizer Ash	(5) ESP Inlet	(6) ESP Ash	(7) Stack
Units: lb/hr							
Antimony	ND< 0.337 #	0.0072[A]	ND< 0.0061 #	0.0114	0.193	0.185[B]	ND< 0.0152 #
Arsenic	0.319	0.339	0.0092	0.0922	0.296	0.282	0.0022[A]
Barium	4.55	0.338	1.58	0.351	3.19	3.04	0.0074[A]
Beryllium	0.105[A]	ND< 0.034 #	0.0304	0.0087	0.0920	0.0884	ND< 0.0011 #
Cadmium	0.277	0.091[A]	0.0402	0.0164	0.935	0.184	ND< 0.0020 #
Chromium	0.921	0.122[A]	0.453	0.217	1.56	1.48	0.0164
Cobalt	0.268	0.165	0.0885	0.0234	0.261	0.251	ND< 0.0098 #
Copper	0.967	0.0924	0.242	0.0482	0.699	0.661	0.0087
Lead	0.98[C]	1.010	0.344	0.0629	1.83	1.76	ND< 0.0152 #
Manganese	2.82	0.249	0.763	0.224	2.34	2.09	0.0099
Mercury	0.0108	0.0024	ND< 0.00015 #	ND< 0.00004 #	0.0036	ND< 0.0009 #	0.00013
Molybdenum	0.750	0.0391	0.0698	0.0688	0.983	0.944	ND< 0.0114 #
Nickel	1.13	0.789	0.351	0.0935	1.07	1.03	0.011[B]
Selenium	0.096	0.0040[A]	ND< 0.0030 #	0.0008[C]	0.0577	ND< 0.0102 #	0.0276
Vanadium	7.86	0.341	2.03	0.545	5.91	5.67	0.0238[A]

[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes three non-detect measurements
Non-detectible in all samples

Table 3.12-2 Trace Element Flow Rates, Plant Smith, Low NO_x Tests

	(1) Raw Coal	(2) Pyrite Rejects	(3) Bottom Ash	(4) Economizer Ash	(5) ESP Inlet	(6) ESP Ash	(7) Stack
Units: lb/hr							
Antimony	ND< 0.653 #	0.014[C]	ND< 0.0108 #	0.0227	0.442	0.125	0.0044[C]
Arsenic	0.383[B]	0.010[C]	N/A	N/A	0.131	0.109	0.019
Barium	5.84	0.284	1.50	0.378	10.7	10.4	0.037
Beryllium	0.214	0.018[A]	0.0167	0.0061	0.093	0.090	ND< 0.0012 #
Cadmium	0.340	0.032	0.0708	0.0272	0.246	0.134	ND< 0.0044[C]
Chromium	1.47	0.207	0.467	0.257	1.53	1.36	0.043
Cobalt	ND< 0.082 #	0.004[C]	0.0605	0.0162	0.279	0.187	0.085
Copper	2.53	0.096	0.121	0.0691	0.709	0.685	0.002[B]
Lead	2.77	0.039	0.021	0.0307	1.03	0.975	0.031
Manganese	2.68	0.124	0.601	0.210	2.06	1.77	0.208
Mercury	0.013	0.00021[B]	ND< 0.00016 #	ND< 0.00010 #	0.0029	0.0021	0.0008
Molybdenum	1.47	0.310	0.113	0.117	1.39	1.28	0.0069
Nickel	1.11	0.127	0.295	0.0958	1.11	1.08	0.015[C]
Selenium	0.336	0.0082	0.00066[A]	0.00027	0.289	0.131	0.053
Vanadium	11.3	1.47	2.41	0.858	7.22	6.94	0.074

[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes three non-detect measurements
\# Non-detectible in all samples
N/A Not analyzed.

Table 3.12-3 Concentrations and Removal Efficiencies, Plant Smith

	Baseline			Low NOx		
	ESP Inlet, µg/Nm³	ESP Outlet, µg/Nm³	Baseline Removal Efficiency, Percent	ESP Inlet, µg/Nm³	ESP Out, Stack, µg/Nm³	Low NOx Removal Efficiency, Percent
Antimony	128	ND< 24.8 #	> 91.8	298	5.6	> 96.5
Arsenic	195	1.82	99.1	88.4	12.9	85.2
Barium	2,106	5.60	99.6	7,228	24.9	99.6
Beryllium	60.7	ND< 1.35 #	> 98.8	62.4	ND< 1.3 #	> 98.7
Cadmium	618	1.4	> 98.9	166	4.0	> 96.7
Chromium	1,027	17.8	99.1	1,027	41.	97.2
Cobalt	173	8.6	> 96.1	188	4.0	68.8
Copper	461	13.8	98.6	477	6.5	> 99.7
Lead	1,212	21.4	99.1	695	23.	97.0
Manganese	1,544	70.9	99.4	1,383	21.	89.3
Mercury	2.40	0.760	85.7	1.97	0.97	62.5
Molybdenum	649	23.	> 98.8	933	41.	94.9
Nickel	705	12.	> 98.9	745	8.3	98.6
Selenium	38.1	63.7	26.9	195	170.	71.1
Vanadium	3,905	16.	> 99.6	4,858	1.4	98.9

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.

Table 3.12-4 Stream Temperatures, Plant Smith

Temperature, deg F	
Hot-Side ESP Inlet	702
Cold-Side ESP Outlet (To Stack)	330

Section 3.13 R.E. Burger Station

Testing was performed on Boiler #8 of Ohio Edison's R.E. Burger Station located in Dilles Bottom, Ohio, and having a gross generating capacity of 160 MWe. The boiler was designed by Babcock and Wilcox and has been in operation since 1955. Testing was conducted during April and May of 1993. The boiler is wall-fired and burns a medium sulfur (3.5%) bituminous coal from Ohio. The coal burned during the test period averaged about 2% moisture and 12% ash.

Bottom ash is removed from the boiler by an ash sluicing system, and fly ash is removed by a cold-side electrostatic precipitator (ESP) with a design efficiency of 99.35%. Flue gas exiting the ESP is discharged through the stack.

The SNRB™ process was on site as part of a test program being performed by Babcock and Wilcox (B&W) under DOE's Innovative Clean Coal Technology Program. The SNRB™ unit draws a 5-MW (equivalent) slipstream from the boiler. This corresponds to approximately 2% of the total flue gas. The SNRB™ process removes particulates, nitrogen oxides (NO_x), and sulfur oxides (SO_x) from the flue gas. The flue gas exiting the SNRB™ process is then rejoined with flue gas exiting the boiler prior to entering the ESP.

In this process, both dry sorbent (lime) and ammonia are injected upstream of a fabric filter (baghouse). A catalyst for the selective catalytic reduction (SCR) of NO_x is mounted inside the filter bags, providing for the destruction of NO_x as the flue gas/ammonia mixture passes over the catalyst. Sulfur oxides are adsorbed by the sorbent both in the flue gas duct and on the filter bags in the baghouse. Because the NO_x and SO_x removal processes require operation at elevated temperature (550-900°F), special high temperature fabric filter bags are used.

The baghouse consists of six individual modules each containing 42 bag/catalyst assemblies. The baghouse is designed to handle about 48,000 ft^3/min (actual) of flue gas. Flue gas heaters are located at the inlet and outlet of the baghouse to simulate the economizer and the air heater sections, respectively.

Figure 3.13-1 is a process flow diagram of the site while Figure 3.13-2 gives information on trace element partitioning. Tables 3.13-1 and 3.13-2 present trace element flow rates and concentration/removal efficiency data respectively Table 3.13-3 gives stream temperatures at various points in the plant.

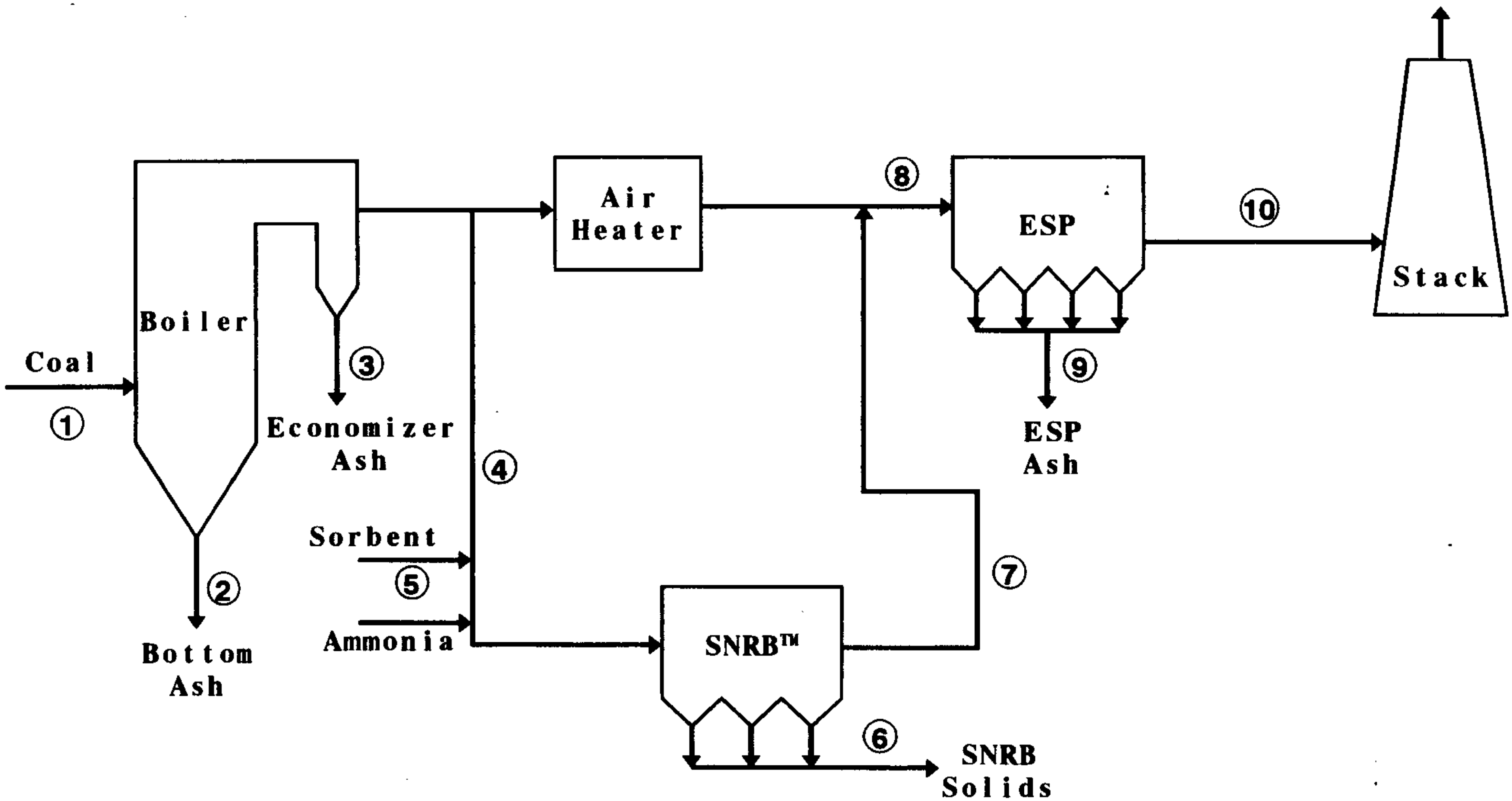

FIGURE 3.13-1. SNRB FLOW DIAGRAM, R.E. BURGER STATION

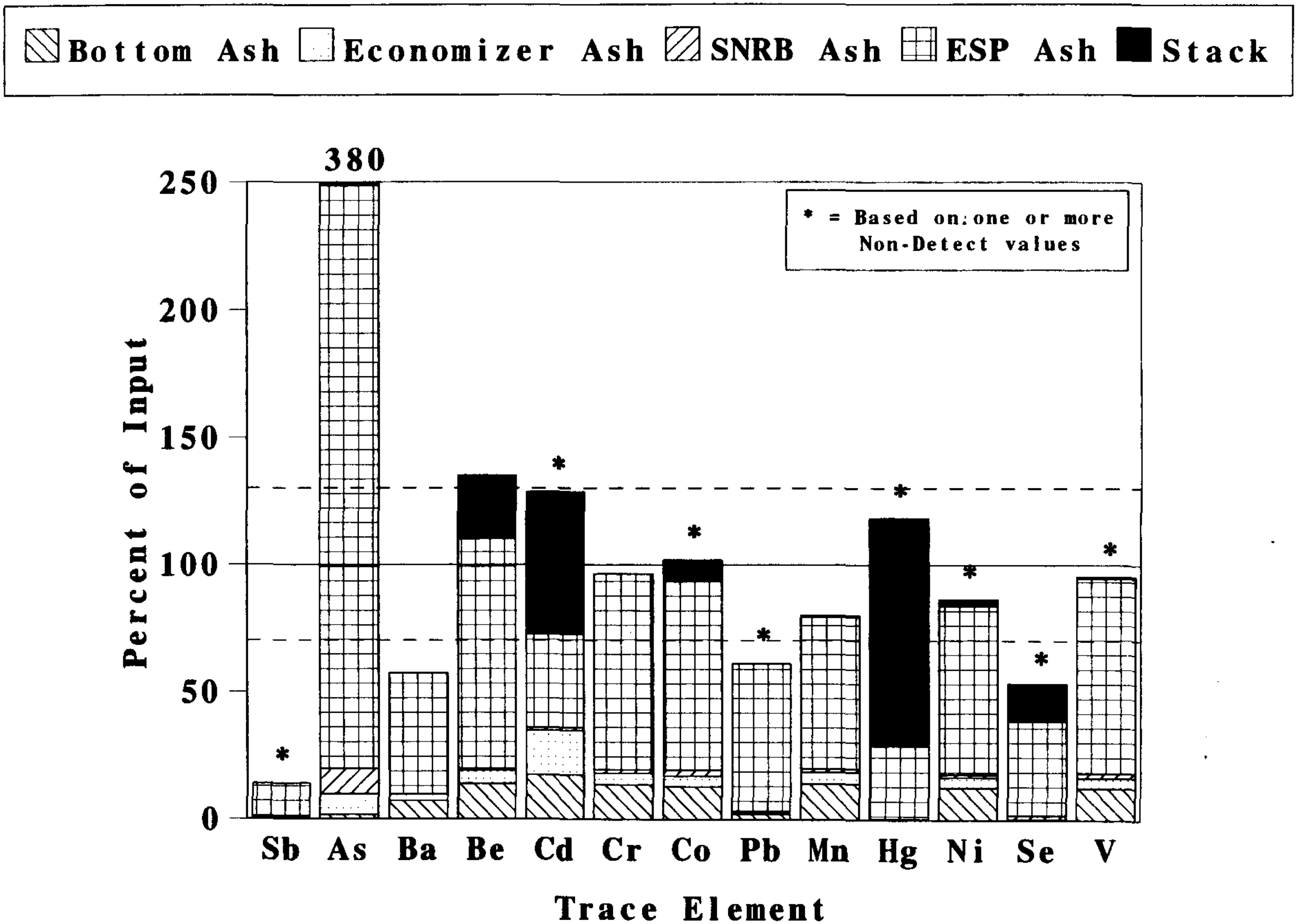

FIGURE 3.13-2. TRACE ELEMENTS IN OUTPUT STREAMS R. E. BURGER STATION, SNRB

Table 3.13-1 Trace Element Flow Rates, R.E. Burger Station, SOx-NOx-ROx-BOx (SNRB)

	(1) Coal Inlet	(2) Bottom Ash	(3) Economizer Ash	(4) SNRB Inlet	(5) Lime Input	(6) SNRB Solids	(7) SNRB Outlet	(8) ESP Inlet	(9) ESP Ash	(10) Stack
Units: lb/hr										
Antimony	ND< 0.124 #	ND< 0.00069^B	0.00028^B	0.00023	0.00014	0.00047	0.000028^B	0.0144^A	0.0159	0.00017
Arsenic	0.618	0.0108	0.0509	0.0130	0.0007	0.0607	0.000043	0.431	2.22	0.0047
Barium	5.81	0.415	0.145	0.0431	0.0063	0.0068	0.000007^A	0.850	2.76	0.0018
Beryllium	0.0828	0.0115	0.0043	0.0013	ND< 0.00019 #	0.00065^A	ND< 0.000513 #	0.0287^A	0.0749	ND< 0.0209 #
Cadmium	ND< 0.0371 #	0.0065	0.0064	0.00021	ND< 0.00023 #	ND< 0.00040 #	0.000023^A	0.0043^A	0.0138	ND< 0.0209 #
Chromium	1.85	0.252	0.0917	0.0222	ND< 0.00037^B	0.0264	0.00019^B	0.503^A	1.42	0.0017
Cobalt	0.284	0.0367	0.0120	0.0045	0.0013	0.0068	ND< 0.00062^B	0.0862^B	0.211	ND< 0.0248 #
Lead	0.655	0.0141	0.0040	0.0053	ND< 0.00014 #	0.0032	0.000019^A	0.168^A	0.378	ND< 0.00035^B
Manganese	2.35	0.330	0.110	0.0221	0.0023	0.0291	0.000029^A	0.503	1.40	0.0170^A
Mercury	0.0161	ND< 0.00005 #	ND< 0.00002^B	0.00028	ND< 0.000009 #	ND< 0.00002 #	0.00050^A	0.0156^A	0.0046	0.0144
Nickel	0.989	0.124	0.0403	0.0107	ND< 0.00009 #	0.0116	0.0018^A	0.227^A	0.654	ND< 0.0248 #
Selenium	0.334	ND< 0.0011 #	ND< 0.00038 #	0.0042	ND< 0.0002 #	0.0047	ND< 0.00001 #	0.156^A	0.123	0.0497
Vanadium	2.72	0.339	0.112	0.0317	0.0016	0.0487	ND< 0.0005 #	0.802^A	2.08	ND< 0.0222^A

ND< Value shown is detection limit
^{A} Includes one non-detect measurement
^{B} Includes two non-detect measurements
\# Non-detectible in all samples

Table 3.13-2 Concentrations and Removal Efficiencies, R.E. Burger Station

	SNRB			ESP		
	SNRB Inlet, µg/Nm³	SNRB Outlet, µg/Nm³	Removal Efficiencies, Percent	ESP Inlet, µg/Nm³	Stack, µg/Nm³	Removal Efficiencies, Percent
Antimony	8.7	0.815	88.2	12	0.13	98.8
Arsenic	493	1.26	99.7	360	3.6	98.9
Barium	1630	0.195	99.98	710	1.4	99.8
Beryllium	48.3	ND< 16. #	> 58.1	24	ND< 16. #	> 25.4
Boron						
Cadmium	7.76	0.685	88.9	3.6	ND< 16. #	Neg
Chromium	839	5.64	99.2	420	1.3	99.7
Cobalt	170	ND< 19. #	> 85.7	72	ND< 19. #	> 70.9
Copper						
Lead	199	0.563	99.6	140	ND< 0.27 #	> 99.8
Manganese	837	0.86	99.9	420	13	96.7
Mercury	10.6	14.5	Neg	13	11	3.1
Nickel	404	52.5	83.7	190	ND< 19. #	> 89.2
Selenium	157	ND< 0.34 #	> 99.7	130	38	67.8
Vanadium	1200	ND< 17. #	> 98.2	670	ND< 17. #	> 97.2

ND< Value shown is detection limit.
Of the calculations contributing to the average value shown, all include a non-detect measurement.

Table 3.13-3 Stream Temperatures, R.E. Burger Station

Temperature, deg F	
SNRB Inlet	639
Baghouse Inlet	865
SNRB Outlet	793
ESP Inlet	317
ESP Outlet	321

Section 3.14 Arapahoe Station

Plant Description

The Public Service of Colorado's Arapahoe Station was used for this test. The boiler for the test unit is a 115 MWe, roof-fired boiler that was fired on a western bituminous coal during the test period. This particular boiler is also capable of burning natural gas.

Low NO_x burners and overfire air ports have been installed for NO_x control. The test unit is also equipped with a selective non-catalytic reduction (SNCR) unit that utilizes a urea injection system. The SNCR unit was operated during one phase of the test program. Particulate removal is accomplished with a fabric filter dust collector (FFDC) having an air-to-cloth ratio of 2. The design of the FFDC calls for particulate removal down to 0.007 grains/dry standard cubic foot. No SO_2 removal system was used during the test period, although this unit will use sorbent injection upstream of the FFDC in the future.

Bottom ash consists of the larger ash particles, including those removed from the boiler surfaces during soot blowing. The bottom ash is discharged to a hopper from which it is sluiced into the ash pit water box and grinder. From there it is transported to the settling pond. Solids are periodically removed from the settling pond and transported off-site for disposal. Fly ash is discharged into a series of hoppers and is then pneumatically conveyed to a flyash silo. It is then transported off-site for disposal.

A schematic flow diagram is presented in Figure 3.14-1. Figures 3.14-2 and 3.14-3 present partitioning results for the trace elements during these same periods. Tables 3.14-1 and 3.14-2 present trace element flow rates results during baseline operation and SNCR testing, respectively. Table 3.14-3 gives trace element concentrations and removal efficiencies during both periods. Temperature data was not available at this plant.

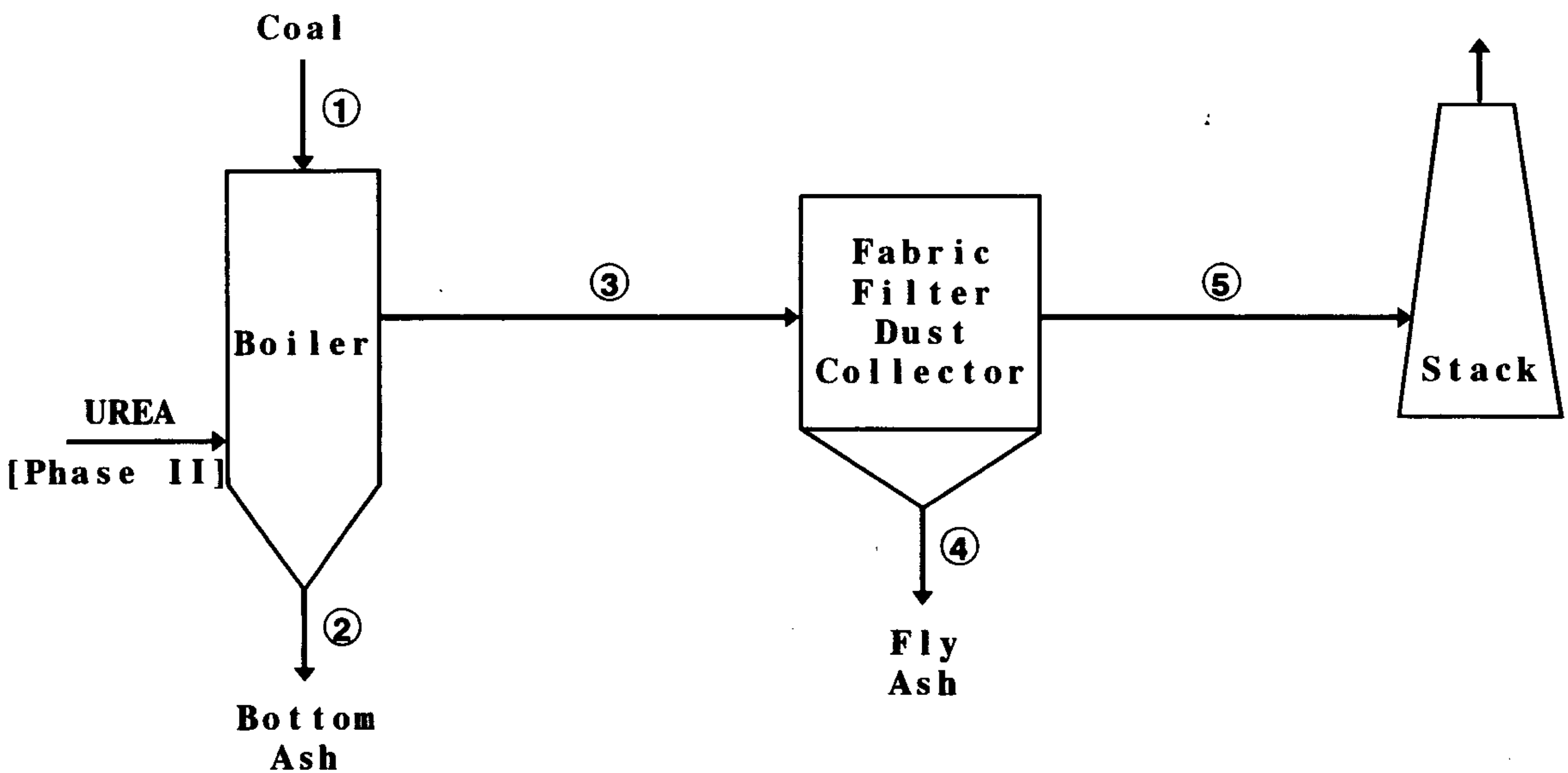

FIGURE 3.14-1. PUBLIC SERVICE OF COLORADO ARAPAHOE STATION FLOW DIAGRAM

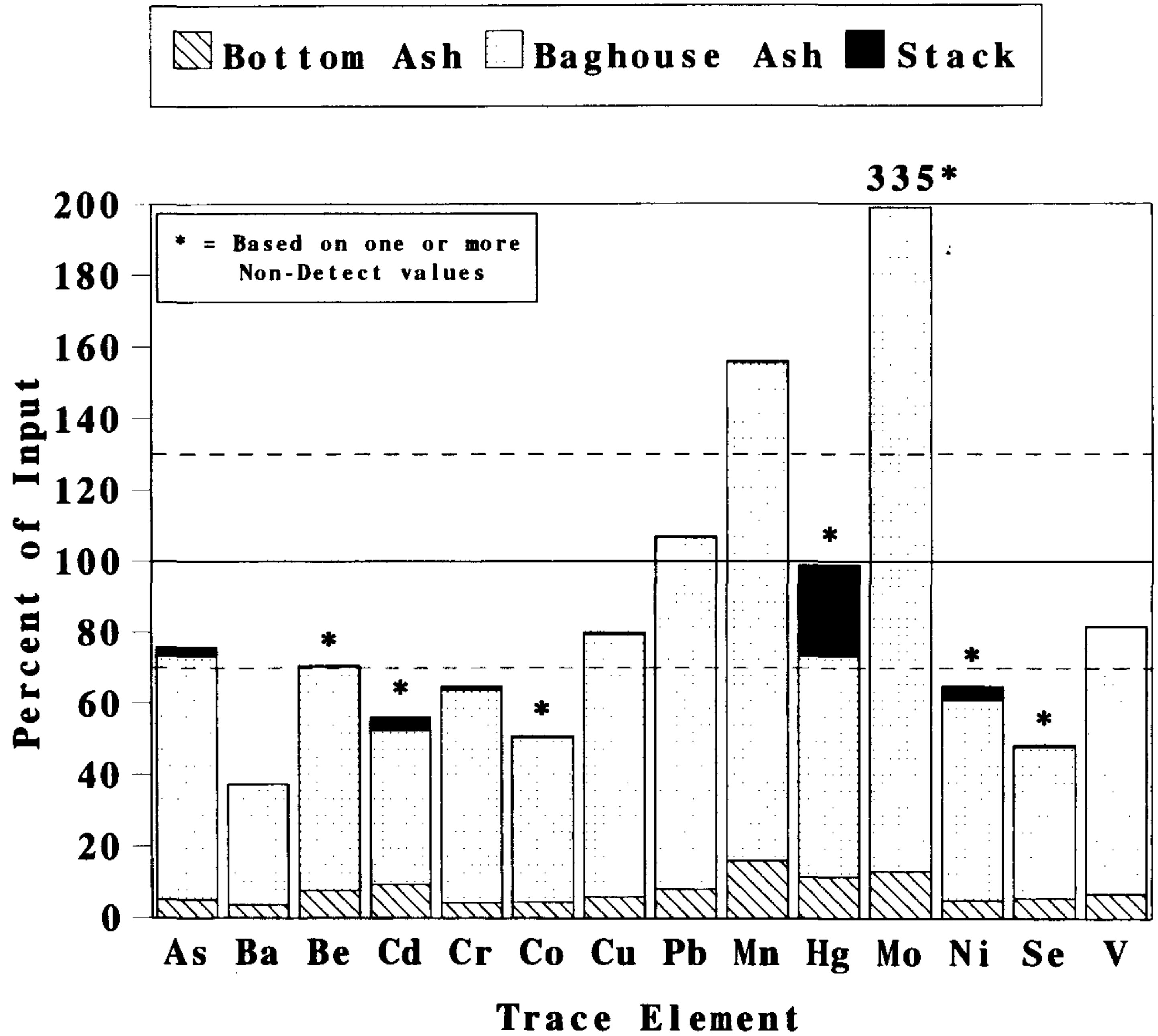

FIGURE 3.14-2. TRACE ELEMENTS IN OUTPUT STREAMS ARAPAHOE STATION, BASELINE TESTS

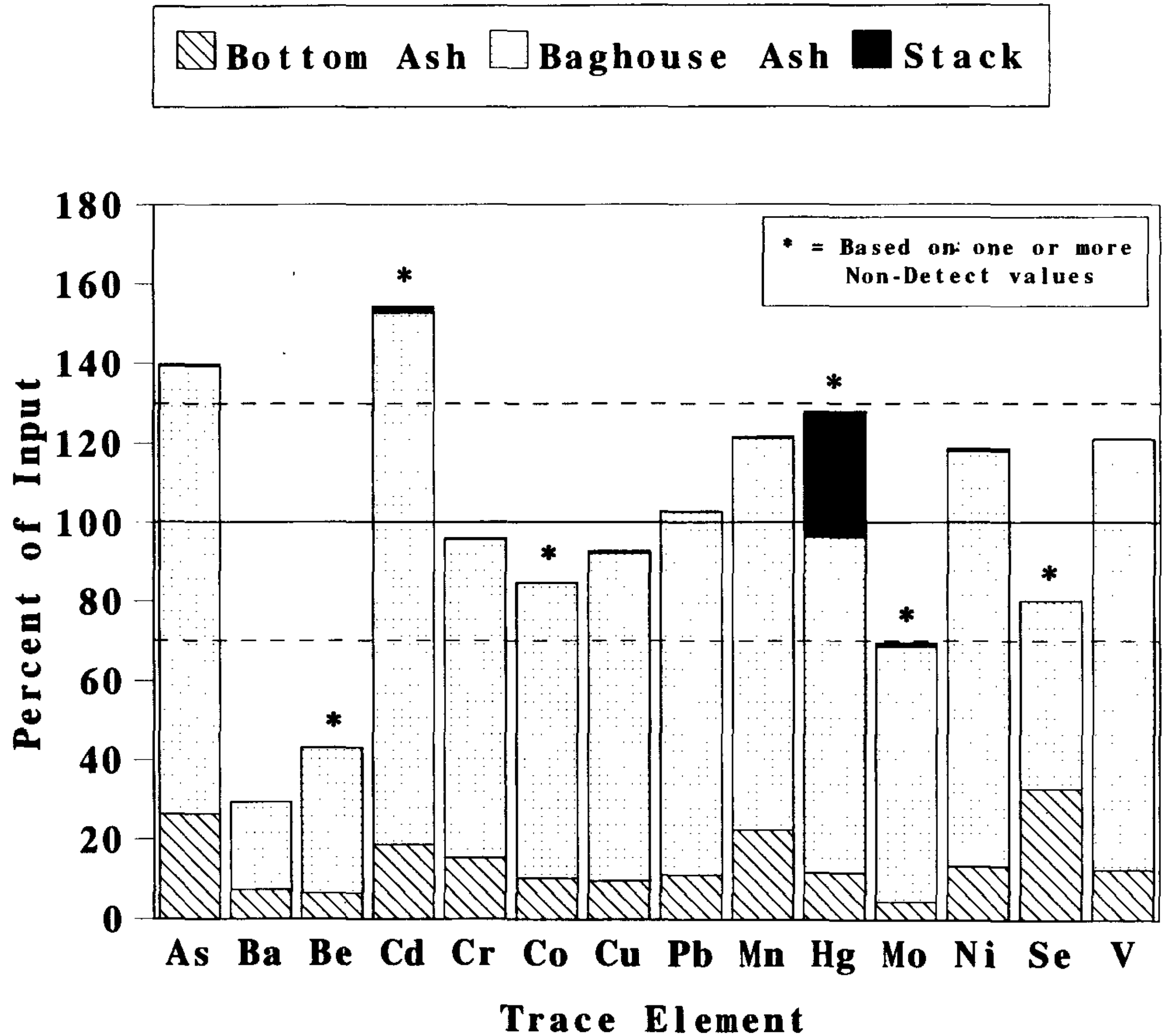

FIGURE 3.14-3. TRACE ELEMENTS IN OUTPUT STREAMS ARAPAHOE STATION, SNCR

Table 3.14-1 Trace Element Flow Rates, Arapahoe Station, (Baseline)

	(1) Coal In	(2) Bottom Ash	(3) Baghouse Inlet	(4) Baghouse Ash	(5) Stack
Units: lb/hr					
Arsenic	0.0376	0.0019	0.0281	0.0256	0.00091
Barium	32.8	1.22	0.285	11.0	0.00136
Beryllium	0.0172	0.0013	0.0109	0.0108	ND< 0.000028 #
Cadmium	ND< 0.0039[B]	ND< 0.00037 #	0.0028	ND< 0.0017[B]	0.00014
Chromium	0.0861	0.0037	0.0608	0.0513	0.00080
Cobalt	0.0705	0.0031	0.0363	0.0324	ND< 0.00026 #
Copper	0.211	0.0127	0.206	0.155	0.00133
Lead	0.164	0.0134	0.0775	0.162	0.00053
Manganese	0.329	0.0531	0.236	0.459	0.00121
Mercury	0.0016	0.00019[B]	0.0016	0.0010[A]	ND< 0.00042 #
Molybdenum	0.0078[B]	ND< 0.0010[A]	0.0131	0.0250	0.00021
Nickel	0.0470	ND< 0.0024[B]	0.0368	0.0263	0.00179
Selenium	0.0642	ND< 0.0037 #	0.0272	0.0270	0.00044
Vanadium	0.235	0.0162	0.165	0.175	0.00029

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
Non-detectible in all samples

Table 3.14-2 Trace Element Flow Rates Arapahoe Station, (SNCR)

	(1) Coal In	(2) Bottom Ash	(3) Baghouse Inlet	(4) Baghouse Ash	(5) Stack
Units: lb/hr					
Arsenic	0.0538	0.0142	0.0154	0.0608	0.00018
Barium	28.5	2.12	0.229	6.23	0.00126
Beryllium	0.0462	0.0030	0.0089	0.0169	ND< 0.000029 #
Cadmium	ND< 0.0050 #	ND< 0.00094 #	0.0024	ND< 0.0068 #	ND< 0.000087 #
Chromium	0.118	0.0181	0.0605	0.0946	0.00036
Cobalt	0.109	0.0113	0.0313	0.0811	ND< 0.00028 #
Copper	0.311	0.0302	0.245	0.257	0.00164
Lead	0.185	0.0208	0.0541	0.169	0.00048
Manganese	0.437	0.0981	0.105	0.432	0.00106
Mercury	0.0016	ND< 0.00019 #	0.0023	0.0014	0.00050[A]
Molybdenum	0.0420	ND< 0.0019 #	0.0141	0.0270	0.00033
Nickel	0.0840	0.0113	0.0350	0.0878	0.00058
Selenium	0.126	ND< 0.0415 #	0.0142	ND< 0.0594[B]	ND< 0.000077 #
Vanadium	0.361	0.0453	0.143	0.392	0.00034

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
Non-detectible in all samples

Table 3.14-3 Concentrations and Removal Efficiencies, Arapahoe Station

	Baseline			SNCR		
	Baghouse Inlet, µg/Nm³	Baghouse Outlet, µg/Nm³	Removal Efficiencies, Percent	Baghouse Inlet, µg/Nm³	Baghouse Outlet, µg/Nm³	Removal Efficiencies, Percent
Arsenic	30	0.97	96.8	16.2	0.19	98.8
Barium	304.7	1.45	99.5	241	1.31	99.5
Beryllium	11.7	ND< 0.03 #	> 99.7	9.4	ND< 0.03 #	> 99.8
Cadmium	2.96	0.15	94.9	2.5	ND< 0.09 #	> 98.2
Chromium	65	0.85	98.7	63.7	0.37	99.4
Cobalt	38.8	ND< 0.28 #	> 99.3	33	ND< 0.29 #	> 99.6
Copper	220	1.42	99.4	258	1.7	99.3
Lead	82.9	0.56	99.3	57	0.5	99.1
Manganese	252.8	1.29	99.5	111	1.1	99.0
Mercury	1.72	ND< 0.45 #	> 73.7	2.4	0.52	77.9
Molybdenum	14	0.22	98.4	14.8	0.34	97.7
Nickel	39.3	1.9	95.1	36.8	0.6	98.5
Selenium	29.1	0.47	98.4	15	ND< 0.08 #	> 99.7
Vanadium	176	0.31	99.8	151	0.35	99.8

ND< Value shown is detection limit.
\# Of the calculations contributing to the average value shown, all include a non-detect measurement.

Section 3.15 TIDD PFBC Demonstration

Plant Description

The TIDD PFBC demonstration, located in Brilliant, Ohio, is operated by Ohio Power Company, a subsidiary of American Electric Power (AEP). The boiler at the TIDD site is a bubbling-bed, pressurized fluidized bed combustor (PFBC) rated at 70 MWe full load. Total plant load during the test period was 45 to 46 MW; 37 MW was produced by a steam turbine generator and 8 MW was produced by depressurizing the hot flue gases through a gas turbine generator. The process operating conditions for the unit were selected by AEP and represent typical long-term operating conditions for the process.

Crushed coal (Pittsburgh No. 8, bituminous) is combined with water from a nearby river to produce a coal paste which was approximately 25 weight percent moisture. The paste is fed to the combustion chambers along with crushed dolomite. The material is fluidized by high velocity combustion air in the water-cooled boiler. Mean bed temperatures in the combustion chambers were controlled at approximately 1500°F during the test period. As the coal is combusted, the calcium carbonate in the dolomite or limestone is calcined to form quicklime which then reacts with the SO_2 and oxygen in the combustion gases to form solid calcium sulfate. This reaction removes SO_2 from the combustion gases, thus controlling SO_2 emissions. Test data from this program show approximately 90% removal of sulfur dioxide in the combustor. Formation of nitrogen oxides (NO_x) is minimized because of the relatively low combustion temperature of the PFBC process.

After releasing heat to the in-bed, water-cooled boiler tubes, the particulate-laden combustion gases flow into seven parallel, two-step cyclones. These cyclones remove approximately 93% of the entrained solids (primarily sulfated lime, unreacted lime, ash, and unburned carbon) from the gases. The combustion gases then flow to the gas turbine where they are expanded and then exit through the turbine exhaust gas economizer. Final particulate removal from the gases is achieved in an electrostatic precipitator (ESP) before the gases are released to the atmosphere.

Bed ash, which comprises about 45% of the total ash produced, is periodically removed from the bottom of the combustor through a lock hopper system. Solids collected by the primary cyclone are transported to a storage silo. Secondary cyclone solids are combined with the material collected in the ESP. All solids are transported by truck off site for disposal.

A research feature of the TIDD facility is a demonstration-scale hot gas cleanup (HGCU) system. Treated gas from one of the seven cyclone systems (approximately one-seventh of the total gas flow from the combustor) is diverted to a ceramic barrier, advanced particle filter (APF) and back-up cyclone, and directed back to the outlet header of the secondary cyclones. The APF uses silicon carbide candles in a cluster/plenum arrangement developed by Westinghouse Corporation to filter the gas. Tempering air was added to the system during the test period to control ash bridging within the APF system, reducing the APF inlet gas temperature from 1500°F to approximately 1350°F. Entrained solids removed in the APF system are collected and transported by truck off site for disposal.

Figure 3.15-1 shows a simple schematic of the unit. Figure 3.15-2 shows trace element partitioning results. Table 3.15-1 and 3.15-2 present the trace element flow rates and concentration/removal efficiency results. Table 3.15-3 gives stream temperatures at various points in the plant.

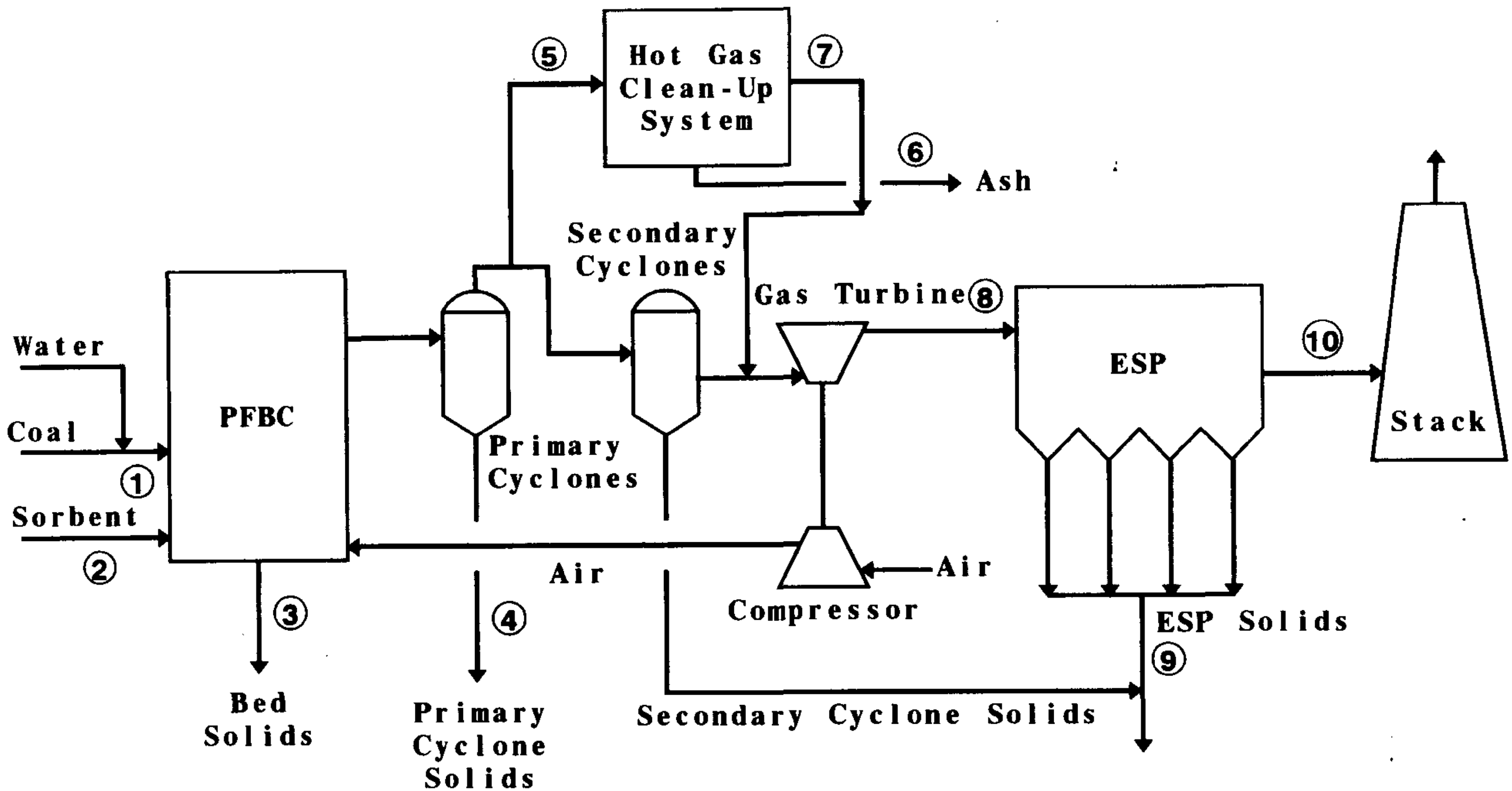

FIGURE 3.15-1. TIDD PFBC DEMONSTRATION FLOW DIAGRAM

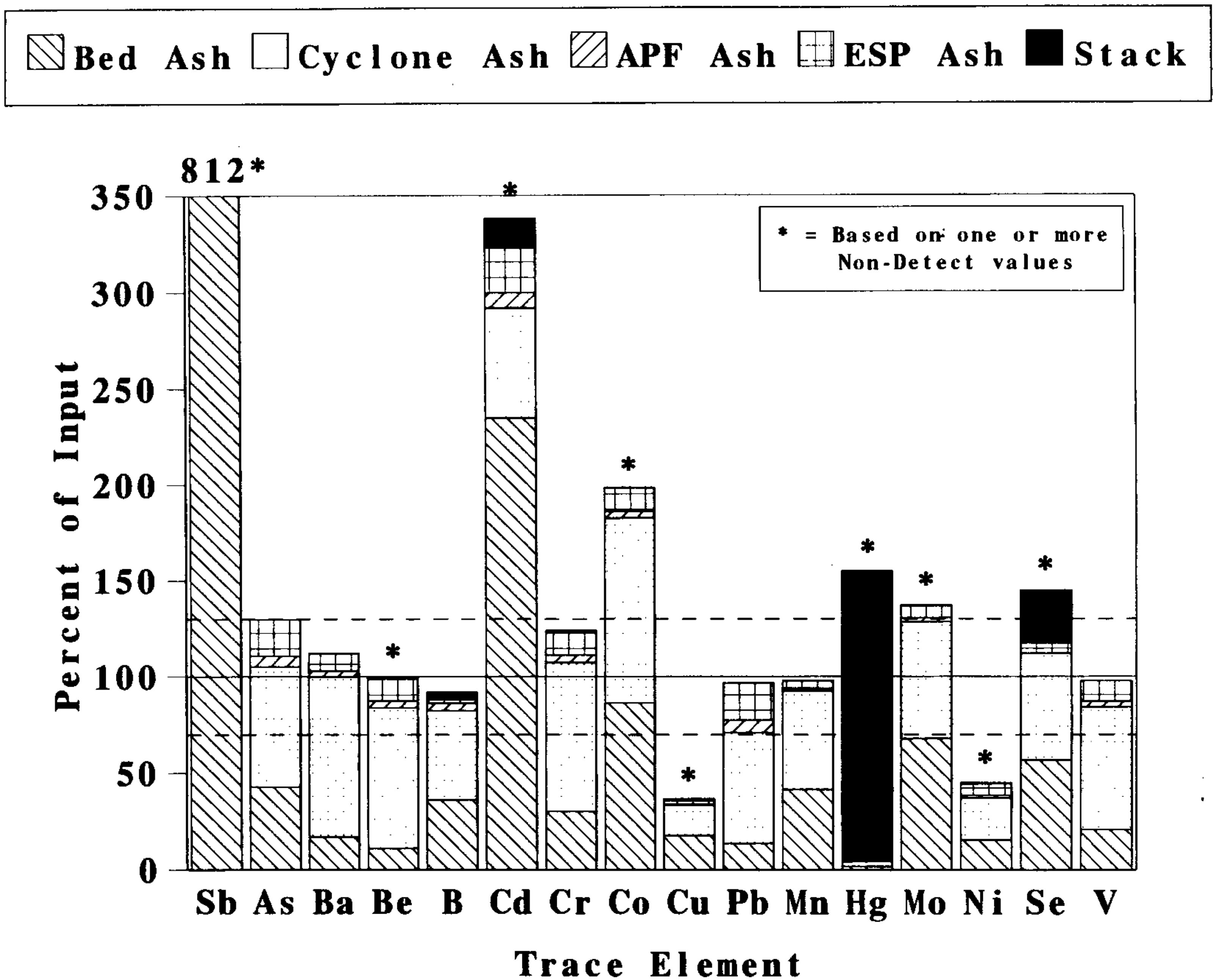

FIGURE 3.15-2. TRACE ELEMENTS IN OUTPUT STREAMS PLANT TIDD, PFBC

Table 3.15-1 Trace Element Flow Rates, TIDD PFBC Demonstration

	(1) Coal Paste	(2) Limestone	(3) Bed Ash	(4) Cyclone Ash	(5) APF In	(6) APF Ash	(7) APF OuT	(8) ESP In	(9) ESP Ash	(10) Stack
Units: lb/hr										
Antimony	0.016	ND< 0.105 #	ND< 0.502	ND< 0.414	ND< 0.00007 #	ND< 0.0157 #	ND< 0.00003 #	ND< 0.044 #	ND< 0.046	ND< 0.0011 #
Arsenic	1.51	0.036	0.661	0.962	0.083	0.085	0.00029	0.245	0.295	0.00053
Barium	1.81	0.067	0.316	1.55	0.065	0.063	0.000003	0.140	0.171	0.00039
Beryllium	0.054	ND< 0.00059[B]	0.0060	0.039	0.0020	0.0020	0.000002	0.0050	0.0062	0.00001[B]
Boron	1.84[A]	0.627	0.893	1.14	0.017	0.097	0.027	0.117	0.047	0.089
Cadmium	0.0037	0.0027	ND< 0.015	0.0036	ND< 0.0005 #	0.0005	ND< 4e-7 #	0.0019	0.0015	0.00095
Chromium	0.535	0.0532	0.177	0.455	0.039	0.023	0.0045	0.076	0.073	ND< 0.0019 #
Cobalt	0.130	ND< 0.0095[B]	0.121	0.134	0.0053	0.0050	0.00002	0.013	0.017	0.00010
Copper	0.234	ND< 0.0089 #	ND< 0.043	ND< 0.038	0.011	ND< 0.0013	0.00006	0.0064[A]	0.0050	0.0022
Lead	0.211	0.131	0.047	0.196	0.018	0.022	0.000002	0.043	0.065	0.00034[B]
Manganese	0.870	1.37	0.931	1.14	0.035	0.031	0.00061	0.082	0.085	0.0036[A]
Mercury	0.0050	ND< 0.00023 #	ND< 0.00009	ND< 0.00012	0.0012	ND< 0.000004	0.0011	0.0093	ND< 0.000009	0.0079
Molybdenum	0.019	0.029	ND< 0.033	ND< 0.029	0.0019	ND< 0.0010	0.00068	ND< 0.0020 #	ND< 0.0029	0.00013[A]
Nickel	0.435	0.228	ND< 0.102	0.145	0.0165	0.0091	0.0038	0.033	0.039	0.0032
Selenium	0.060	0.015	0.043	0.041	0.0050	ND< 0.00031	0.0037	0.036	0.0038	0.021
Vanadium	0.803	0.093	0.186	0.569	0.029	0.027	0.00015	0.070	0.093	0.00053

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
\# Non-detectible in all samples

Table 3.15-2 Concentrations and Control Device Removal Efficiencies, TIDD PFBC Demonstration

	APF In, µg/Nm³	APF Out, µg/Nm³	ESP In, µg/Nm³	Stack, µg/Nm³	APF Removal Efficiency, Percent	ESP Removal Efficiency, Percent
Antimony	0.96	ND< 0.36	ND< 76. #	ND< 2.1 #	> 65	NC
Arsenic	1,100	3.9	420	1.0	99.6	99.8
Barium	860	0.038	240	0.74	99.996	99.7
Beryllium	27	0.02	8.6	0.021	> 99.9	99.8
Boron	220	360	200	170	NC	NC
Cadmium	6.8	ND< 0.005	3.2	1.8	> 99.9	44
Chromium	520	60	130	3.7	89[A]	97.2
Cobalt	70	0.3	23	ND< 0.19 #	99.6	> 99.2
Copper	150	0.8	11	4.1	99.5	62
Lead	240	0.029	73	0.65	99.99	99.1
Manganese	460	8.1	140	6.9	98.2[A]	95.2
Mercury	16	15	16	15	9	4
Molybdenum	25	9.1	ND< 3.4 #	0.25	63[A]	NC
Nickel	220	51	57	6	77[A]	90
Selenium	67	49	62	39	27	37
Vanadium	390	2	120	1.0	99.5	99.2

A May not be representative of actual APF performance.
NC Not calculated. Substance was not detected in the inlet gas stream.
> Indicates the reported removal efficiency is a lower limit. Detection limit was used to estimate a lower limit for the removal efficiency.
ND< Value shown is detection limit.
Of the calculations contributing to the average value shown, all include a non-detect measurement.

Table 3.15-3 Stream Temperatures, TIDD PFBC Demonstration

Temperature, deg F	
Pressurized Fluid Bed	1500
Hot Gas Cleanup Unit	1350
Gas Turbine	---
ESP Inlet	---
Stack	404

Section 3.16 AirPol GSA System

Plant Description

A flexible pilot plant was constructed at TVA's National Center for Emissions Research to demonstrate the AirPol Gas Suspension Absorption (GSA) process. Flue gas for the pilot plant is drawn from a pulverized coal-fired boiler at the TVA's Shawnee Power Plant. A 9.43 Nm^3/sec (21,463 scfm) slipstream of flue gas from the boiler (approximately 10 MWe equivalent) is taken downstream of a mechanical particulate collector. The slipstream passes through a cross-flow preheater to allow control over the flue gas temperature at the demonstration plant inlet. Fly ash removed in the mechanical collector is reinjected into the demonstration plant to simulate various inlet particulate loadings.

The main components of the GSA pilot plant are the following:

- Slurry preparation system;
- Reactor;
- Cyclone separator;
- Electrostatic precipitator;
- Pulse-jet baghouse.

The lime slurry is prepared from hydrated lime in a batch mixer and pumped to a storage tank. The slurry is pumped from the storage tank to the GSA reactor, where it is injected upward through a two-fluid atomizer near the bottom of the reactor. The quantity of lime used is based on the SO_2 content of the flue gas and the amount of SO_2 removal required. Trim water is added to cool the gas to the design temperature of approximately 62 to 68°C (145-155°F).

The SO_2-laden flue gas from the preheater enters the bottom of the GSA reactor and flows upward. Most of the water in lime slurry droplets, heated by the flue gas, evaporates in the reactor, decreasing the gas temperature and leaving semi-dry solids. At a gas temperature close to the adiabatic saturation temperature, SO_2 (and to a lesser extent HCl and SO_3) is absorbed by the lime. The resulting solids and unreacted lime are entrained in the flue gas along with the fly ash from the boiler. The flue gas passes up through the reactor and exits at the top into a cyclone-type mechanical collector. The cyclone removes most of the particles from the flue gas (90+ percent), and nearly all of these solids are recycled to the reactor via a screw conveyor, thereby increasing lime utilization. The remaining solids are discharged in the form of a dry by-product. The absorption reactions are thought to take place primarily in the thin layer of fresh lime slurry coating the dry recycle solids; thus the surface area added by the recycled fly ash enhances both the SO_2 removal and the drying process in the reactor. The system is relatively forgiving to atomizer problems (e.g., pluggage, erosion) since SO_2 removal continues to occur via the recycled solids for short periods of time even when the atomizer is removed for maintenance. The high concentration of solids (approximately 200-800 grains/scf) is thought to simultaneously clean the inner surface of the reactor.

The flue gas from the cyclone flows to an electrostatic precipitator for final particulate removal. The solids collected in the ESP are conveyed mechanically to a waste silo. In addition, a slipstream (approximately 1 MWe equivalent or approximately 10%) of the flue gas from the main GSA/ESP plant may be removed from the ESP inlet or outlet, passed through a pulsed-jet baghouse, and returned to the main plant ductwork downstream of the ESP. The baghouse has a nominal air-to-cloth ratio of 4.0 acfm/ft^2 and the bags are cleaned by a low-pressure, high-volume, ambient air stream delivered by a rotating manifold. The solids collected in the baghouse are conveyed pneumatically to the waste silo. The treated flue gas is passed to an induced draft fan, reheated, and discharged to the atmosphere through a stack.

Tests were run during four periods:

- Baseline tests (no sorbent) - ESP/baghouse in series
- Demonstration tests - ESP/baghouse in series
- Baseline tests - ESP/baghouse in parallel

- Demonstration tests - ESP/baghouse in parallel

Two slightly different modes of operation were employed during demonstration tests. During the series configuration demonstration tests, the input calcium-to-sulfur ratio (Ca/S) was held constant at 1.4 and the SO_2 removal was allowed to vary. During the parallel configuration demonstration tests, Ca/S was varied to maintain overall SO_2 removal constant at approximately 90 percent. The target approach to saturation temperature was 6.7°C (12°F) for both demonstration test configurations.

Figure 3.16-1 shows the flow diagram for the GSA System and Figures 3.16-2 through 3.16-5 show partitioning results for the four periods described previously. Tables 3.16-1 through 3.16-4 show trace elements flow rates for the four periods. Tables 3.16-5 and 3.16-6 present concentration and removal efficiency data for trace elements during these periods. Table 3.16-7 gives stream temperatures at various points in the plant.

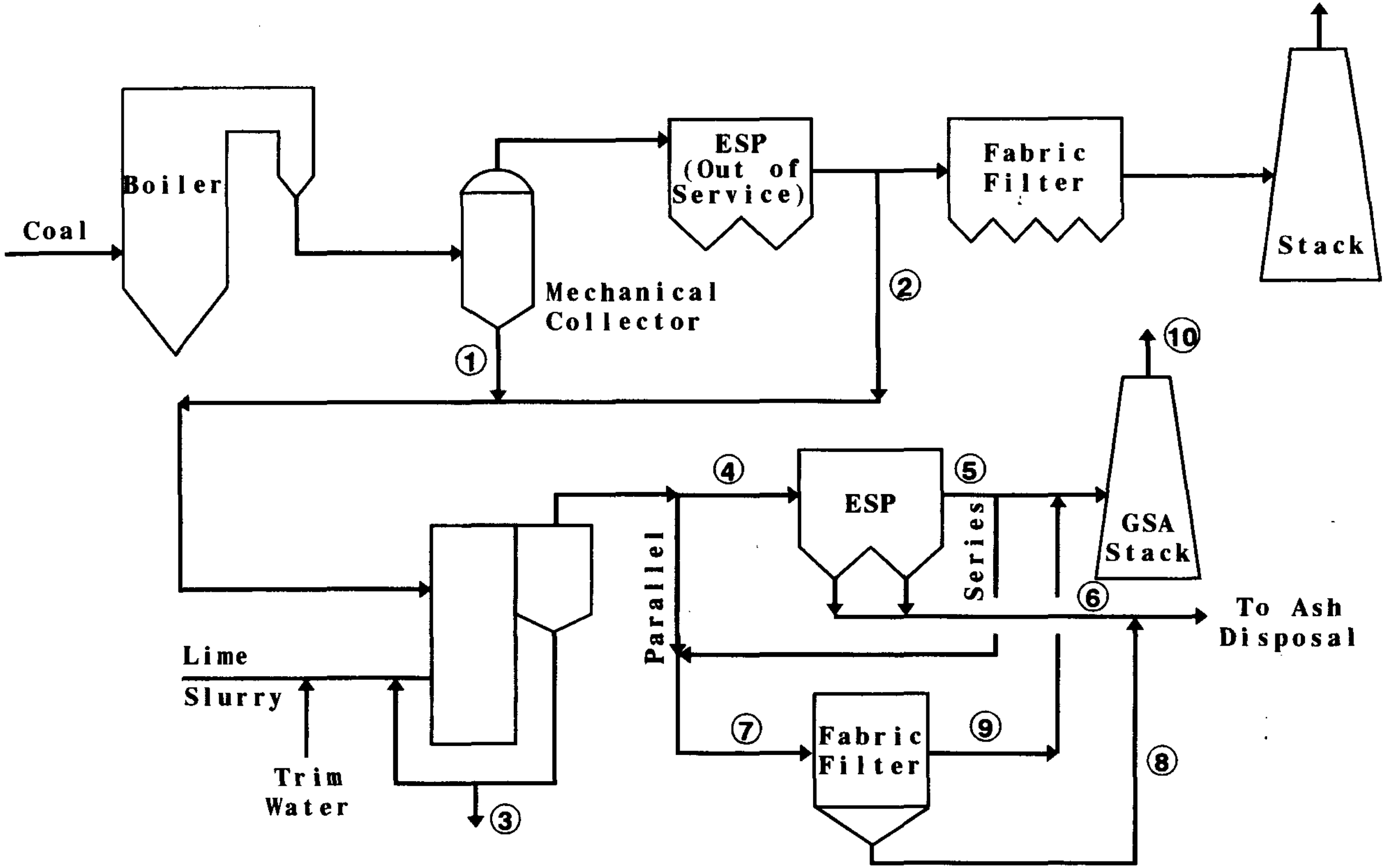

FIGURE 3.16-1. GAS SUSPENSION ABSORPTION SYSTEM AT SHAWNEE POWER PLANT

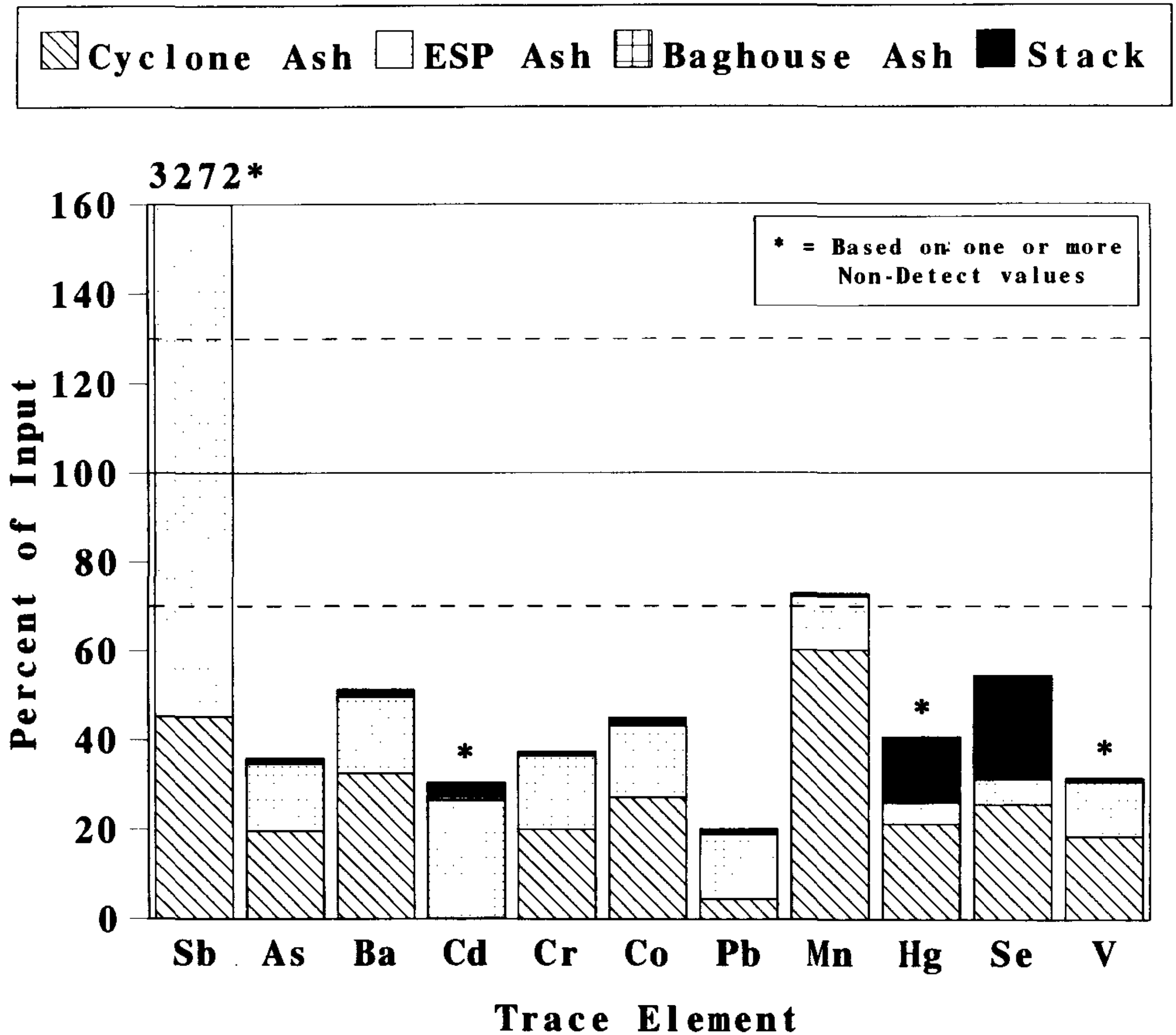

FIGURE 3.16-2. TRACE ELEMENTS IN OUTPUT STREAMS AIRPOL GSA SYSTEM, SERIES CONFIGURATION, BASELINE TESTS

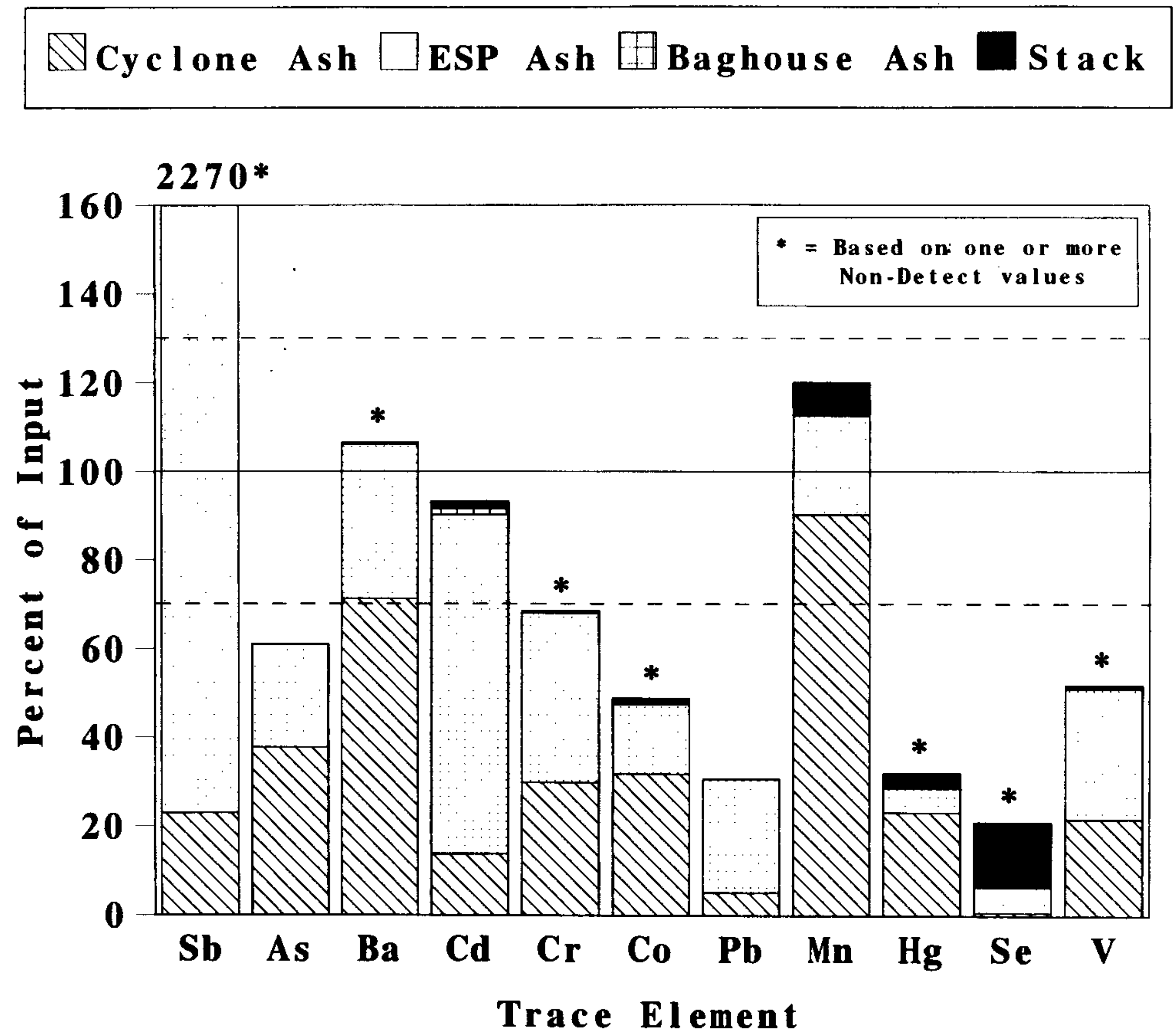

FIGURE 3.16-3. TRACE ELEMENTS IN OUTPUT STREAMS AIRPOL GSA SYSTEM, SERIES CONFIGURATION, DEMONSTRATION TESTS

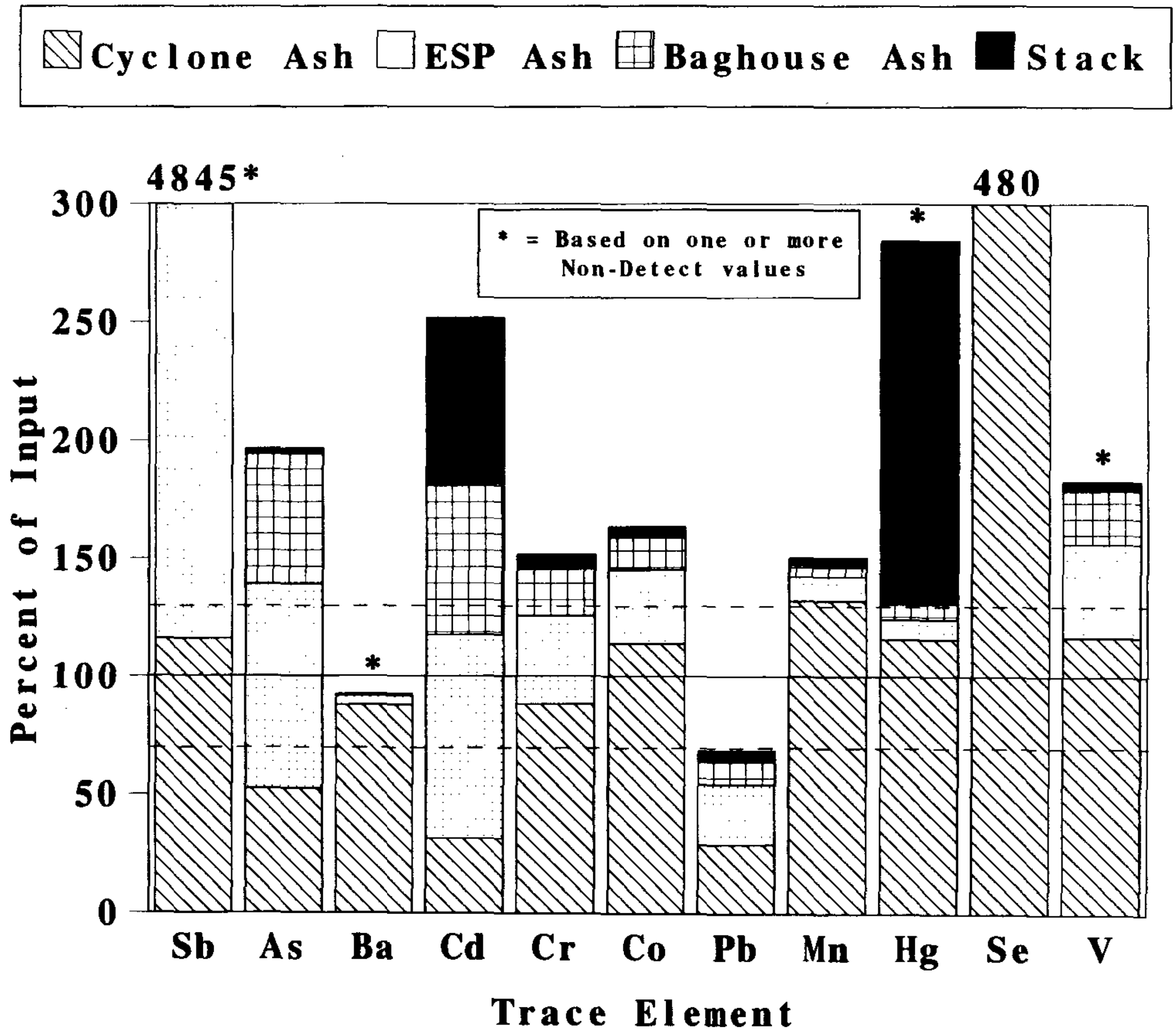

FIGURE 3.16-4. TRACE ELEMENTS IN OUTPUT STREAMS AIRPOL GSA SYSTEM, PARALLEL CONFIGURATION, BASELINE TESTS

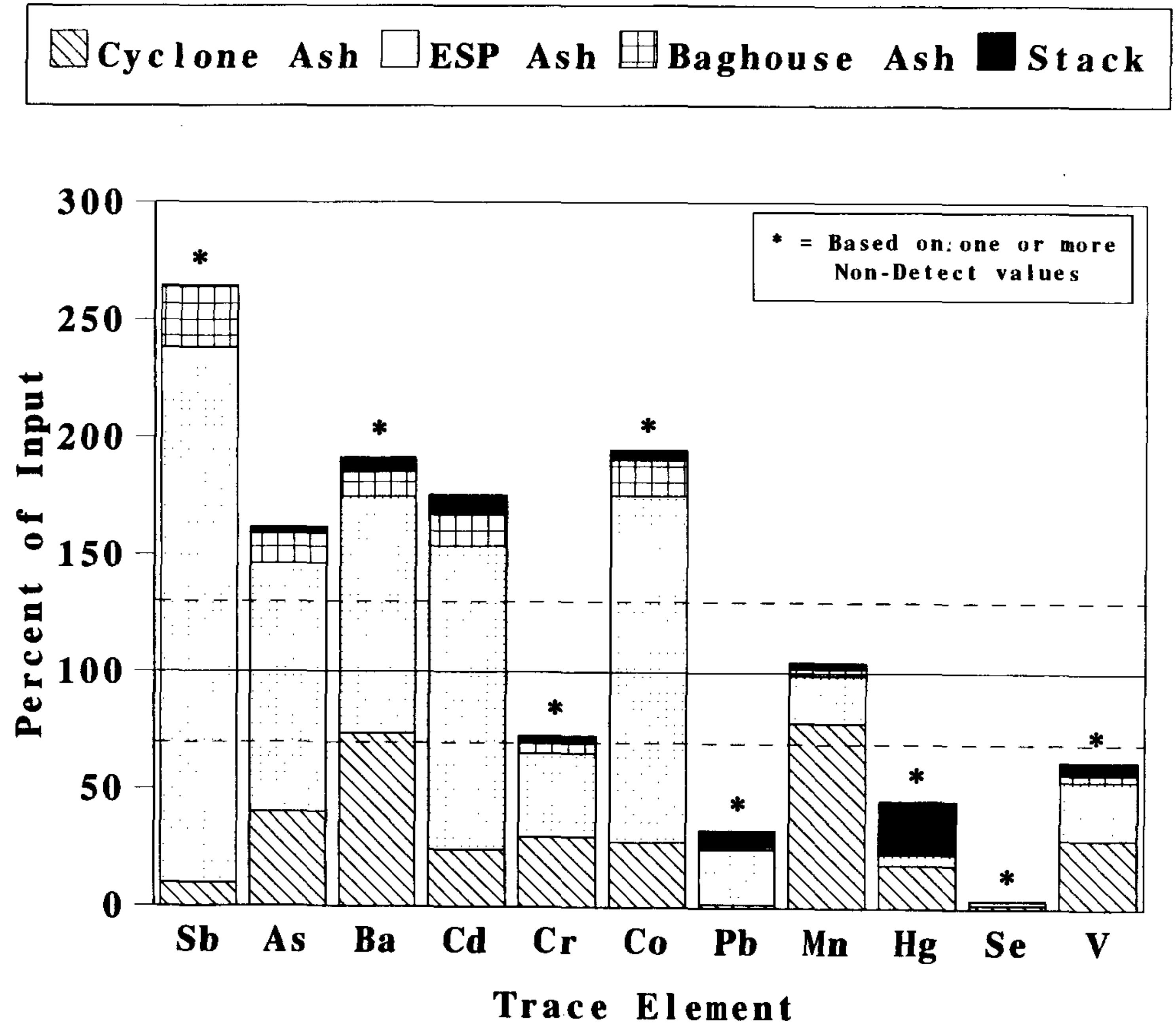

FIGURE 3.16-5. TRACE ELEMENTS IN OUTPUT STREAMS AIRPOL GSA SYSTEM, PARALLEL CONFIGURATION, DEMONSTRATION TESTS

Table 3.16-1 Trace Element Flow Rates, AirPol GSA, Shawnee Power Plant, Series Configuration, Baseline Tests

	(1) Reinjected Fly Ash	(2) GSA Slip Stream	(3) Cyclone Solids	(4) ESP In	(5) ESP Outlet
Units: lb/hr					
Antimony	ND< 0.00003 #	0.00004[B]	ND< 0.00003 #	0.00023	ND< 0.000005 #
Arsenic	0.019	0.015	0.0068	0.023	0.00043
Barium	0.048	0.058	0.034	0.113	0.0016
Cadmium	0.00012	0.00057	ND< 0.000002 #	0.00073	0.00001
Chromium	0.021	0.036	0.011	0.054	0.00050
Cobalt	0.0020	0.0047	0.0018	0.0098	0.00009
Lead	0.0068	0.011	0.00079	0.019	0.00020
Manganese	0.040	0.058	0.059	0.069	0.00068
Mercury	ND< 0.00004 #	0.00016	ND< 0.00004 #	0.00017	0.000026
Selenium	0.0014	0.011	0.0031	0.0085	0.0028
Vanadium	0.015	0.070	0.016	0.087	0.00061[B]

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes five non-detect measurements (parallel sampling of two streams)
Non-detectible in all samples

Table 3.16-1 Trace Element Flow Rates, AirPol GSA, Shawnee Power Plant, Series Configuration, Baseline Tests, (continued)

	(6) ESP Ash	(7) Baghouse In	(8) Baghouse Ash	(9) Baghouse Out	(10) Stack
Units: lb/hr					
Antimony	ND< 0.0024	ND< 0.000002 #	ND< 0.000003 #	ND< 0.000001 #	ND< 0.000007 #
Arsenic	0.0052	0.000038	0.000006	0.000001[B]	0.00043[B]
Barium	0.018	0.00042	0.000014	ND< 0.000065 #	0.0017
Cadmium	0.00018[A]	0.000004	0.000005	0.000008	0.000023
Chromium	0.0092	0.00020	0.000008	ND< 0.000038 #	0.00053
Cobalt	0.0011	0.000040	0.000001	ND< 0.000017 #	0.00011[C]
Lead	0.0025	0.000035	0.000004	0.000010	0.00021
Manganese	0.0119	0.00017	0.000024	0.000037	0.00072
Mercury	0.000009[C]	0.000001[B]	0.0000002[A]	0.000002	0.000028
Selenium	0.00068[C]	0.00012	0.000002	0.000020	0.0028
Vanadium	0.0103[C]	ND< 0.00020 #	0.000027	ND< 0.00013 #	0.00074

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes five non-detect measurements (parallel sampling of two streams)
Non-detectible in all samples

Table 3.16-2 Trace Element Flow Rates, AirPol GSA, Shawnee Power Plant, Series Configuration, Demonstration Tests

	(1) Reinjected Fly Ash	(2) GSA Slip Stream	(11) Lime Slurry	(12) Trim Water	(4) ESP In	(3) Cyclone Solids
Units: lb/hr						
Antimony	ND< 0.00004 #	0.00008[A]	ND< 0.00020 #	ND< 0.00001 #	0.00007[B]	ND< 0.00007 #
Arsenic	0.0276	0.0149	0.00235	ND< 0.000003 #	0.0111	0.017
Barium	0.0633	0.0139	0.00350	0.00011	0.109	0.058
Cadmium	0.00013	0.00057	0.00003	ND< 0.000002 #	0.00066	0.00010[A]
Chromium	0.0078	0.028	0.0110	ND< 0.00002 #	0.0431	0.0139
Cobalt	0.0020	0.0039	ND< 0.00086 #	ND< 0.00003 #	0.0065	0.0022
Lead	0.0084	0.0078	ND< 0.00009 #	ND< 0.000003 #	0.0131	0.00085
Manganese	0.0365	0.0308	0.0114	ND< 0.000003 #	0.0654	0.0712
Mercury	ND< 0.00004 #	0.00010	ND< 0.00024 #	ND< 0.000001 #	0.0001	ND< 0.00009 #
Selenium	0.0010	0.0069	0.0036	ND< 0.0000003 #	0.0141	ND< 0.00009 #
Vanadium	0.0119	0.0638	0.0055	ND< 0.00003 #	0.0615	0.0176

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes five non-detect measurements (parallel sampling of two streams)
Non-detectible in all samples

Table 3.16-2 Trace Element Flow Rates, AirPol GSA, Shawnee Power Plant, Series Configuration, Demonstration Tests, (continued)

	(5) ESP Outlet	(6) ESP Ash	(7) Baghouse In	(8) Baghouse Ash	(9) Baghouse Out	(10) Stack
Units: lb/hr						
Antimony	0.00001[B]	ND< 0.0070 #	ND< 0.000002 #	ND< 0.000004 #	ND< 0.000001 #	0.000015[B]
Arsenic	0.00001	0.0104	0.000002[B]	0.000013	ND< 7.56e-07 #	0.000014[C]
Barium	ND< 0.00028 #	0.0282[A]	ND< 0.000104 #	0.000019	ND< 0.000059 #	ND< 0.000335 #
Cadmium	0.000008[A]	0.00056[A]	0.000004	0.00001	0.000004[A]	0.000012
Chromium	ND< 0.00016 #	0.0177	ND< 0.00006 #	0.000016	ND< 0.000034 #	ND< 0.000195 #
Cobalt	ND< 0.00007 #	0.0011[C]	ND< 0.000027 #	0.000002	ND< 0.000015 #	ND< 0.000086 #
Lead	0.00002[B]	0.0041[A]	0.000023	0.000006	0.000005	0.000021[B]
Manganese	0.0057	0.0176	0.00003	0.000046	0.000025	0.005753
Mercury	0.00001	ND< 0.000021 #	0.000003	4.21e-07	0.000002[A]	0.000013[A]
Selenium	0.0017	0.00066[C]	0.000002[B]	ND< 4.63e-08 #	ND< 8.23e-07 #	0.001663
Vanadium	ND< 0.00053 #	0.0238[C]	ND< 0.0002 #	0.000018[A]	ND< 0.000114 #	ND< 0.000648 #

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes five non-detect measurements (parallel sampling of two streams)
Non-detectible in all samples

Table 3.16-3 Trace Element Flow Rates, AirPol GSA, Shawnee Power Plant Parallel Configuration, Baseline Tests

	(1) Reinjected Fly Ash	(2) GSA Slip Stream	(3) Cyclone Solids	(4) ESP In	(5) ESP Outlet
Units: lb/hr					
Antimony	ND< 0.00003 #	N/A	ND< 0.00004 #	0.00071	ND< 0.000005 #
Arsenic	0.021	N/A	0.0108	0.019	0.00047
Barium	0.050	N/A	0.044	0.031	ND< 0.00029 #
Cadmium	0.00017	N/A	0.000054[B]	0.00063	0.00008
Chromium	0.011	N/A	0.010	0.031	0.00059
Cobalt	0.0027	N/A	0.0031	0.0057	0.00011
Lead	0.0075	N/A	0.0022	0.015	0.00035
Manganese	0.031	N/A	0.041	0.027	0.00083
Mercury	ND< 0.00004 #	N/A	ND< 0.00005 #	0.00001[B]	0.000043
Selenium	0.0017	N/A	0.0058	ND< 0.00001 #	0.0012
Vanadium	0.019	N/A	0.022	0.031[A]	ND< 0.00056[B]

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes five non-detect measurements (parallel sampling of two streams)
Non-detectible in all samples
N/A Not Analyzed

Table 3.16-3 Trace Element Flow Rates, AirPol GSA, Shawnee Power Plant Parallel Configuration, Baseline Tests, (continued)

	(6) ESP Ash	(7) Baghouse In	(8) Baghouse Ash	(9) Baghouse Out	(10) Stack
Units: lb/hr					
Antimony	ND< 0.0012 #	0.00025	ND< 0.00039 #	ND< 0.000001 #	ND< 0.000006 #
Arsenic	0.0178	0.00585	0.0113	0.000013	0.00048
Barium	0.0018[C]	0.0167	ND< 0.00012 #	ND< 0.000073 #	ND< 0.0004 #
Cadmium	0.00015	0.00009	0.00011	0.000039	0.000119
Chromium	0.0040	0.0084	0.0021	ND< 0.000042 #	0.00064
Cobalt	0.00085	0.0015	0.00037	ND< 0.000019 #	0.00012
Lead	0.0019[A]	0.0048	0.00070	0.000017	0.00037
Manganese	0.0032	0.0074	0.0016	0.000058	0.00089
Mercury	ND< 0.000003[C]	0.00002	0.000003[A]	0.000020[A]	0.000063
Selenium	0.00069[A]	0.00006[B]	0.00050	ND< 0.000001 #	0.0012
Vanadium	0.0073[B]	0.0164	0.0043	ND< 0.00014 #	ND< 0.00070[C]

ND< Value shown is detection limit
A Includes one non-detect measurement
B Includes two non-detect measurements
C Includes five non-detect measurements (parallel sampling of two streams)
Non-detectible in all samples
N/A Not Analyzed

Table 3.16-4 Trace Element Flow Rates, AirPol GSA, Shawnee Power Plant Parallel Configuration, Demonstration Tests

	(1) Reinjected Fly Ash	(2) GSA Slip Stream	(11) Limestone Slurry	(12) Trim Water	(4) ESP Inlet	(3) Cyclone Solids
Units: lb/hr						
Antimony	ND< 0.00003 #	0.00048	ND< 0.00026 #	N/A	0.0017	ND< 0.00008 #
Arsenic	0.0172	0.0220	0.0017	N/A	0.0319	0.016
Barium	0.0556	0.0049	0.0044	N/A	0.164	0.048
Cadmium	0.00014	0.00051	0.00006	N/A	0.00082	0.00018[A]
Chromium	0.0122	0.0272	0.0118	N/A	0.0427	0.0152
Cobalt	0.0028	0.0052	ND< 0.0011 #	N/A	0.0084	0.0025
Lead	0.0057	0.0101	ND< 0.00011 #	N/A	0.0212	0.00025[A]
Manganese	0.0352	0.0216	0.0174	N/A	0.0423	0.0582
Mercury	ND< 0.00004 #	0.00016	ND< 0.00032 #	N/A	0.00028	ND< 0.00010 #
Selenium	0.0015	0.00082[A]	0.0032	N/A	ND< 0.00002 #	ND< 0.00010 #
Vanadium	0.0184	0.0492	0.0071	N/A	0.0841	0.0219

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes five non-detect measurements (parallel sampling of two streams)
Non-detectible in all samples
N/A Not Analyzed

Table 3.16-4 Trace Element Flow Rates, AirPol GSA, Shawnee Power Plant Parallel Configuration, Demonstration Tests, (continued)

	(5) ESP Outlet	(6) ESP Ash	(7) Baghouse Inlet	(8) Baghouse Ash	(9) Baghouse Outlet	(10) Stack
Units: lb/hr						
Antimony	ND< 0.00001 #	ND< 0.0085 #	0.00017	ND< 0.00095 #	ND< 0.000001 #	ND< 0.000006 #
Arsenic	0.0011	0.0434	0.0029	0.0053	0.000002[B]	0.0011[B]
Barium	0.0038	0.0657	0.0087	0.0069	ND< 0.00007 #	0.0038[C]
Cadmium	0.00003	0.00093	0.00004	0.00009	0.00003	0.00006
Chromium	0.0016[A]	0.0182	0.0028	0.0022	ND< 0.00004 #	0.0016[C]
Cobalt	0.00035[A]	0.0136	0.00060	0.0014	ND< 0.00002 #	0.00037[C]
Lead	0.0010	0.0037[B]	0.0011	ND< 0.00022 #	0.00001	0.0010
Manganese	0.0020	0.0152	0.0037	0.0021	0.00010	0.0021
Mercury	0.00010	ND< 0.00003 #	0.00002	0.000003 #	0.00001	0.00011
Selenium	ND< 0.000004 #	ND< 0.00009 #	ND< 0.000003 #	ND< 0.00001 #	ND< 0.0000010 #	ND< 0.000005 #
Vanadium	0.0033[A]	0.0186[C]	0.0062	0.0025[A]	ND< 0.00013 #	0.0035[C]

ND< Value shown is detection limit
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
[C] Includes five non-detect measurements (parallel sampling of two streams)
\# Non-detectible in all samples
N/A Not Analyzed

Table 3.16-5 Concentrations and Removal Efficiencies, AirPol GSA Pilot Plant, Series Tests

	Series Baseline						Series Demonstration					
	ESP Inlet, µg/dNm³	ESP Outlet, µg/dNm³	Baghouse Inlet, µg/dNm³	Baghouse Outlet, µg/dNm³	ESP Removal Efficiencies, Percent	ESP plus Baghouse Removal Efficiencies, Percent	ESP Inlet, µg/dNm³	ESP Outlet, µg/dNm³	Baghouse Inlet; µg/dNm³	Baghouse Outlet, µg/dNm³	ESP Removal Efficiencies, Percent	ESP plus Baghouse Removal Efficiencies, Percent
Antimony	2.85	ND< 0.09 #	< 0.172 #	ND< 0.095 #	89.7	89.7	0.87	0.243	ND< 0.16 #	ND< 0.079 #	84.7	95.0
Arsenic	283	7.13	3.55	ND< 0.09 #	98.7	99.98	147	0.216	0.126	ND< 0.056 #	99.96	99.99
Barium	1,370	26.5	39.1	ND< 5.22 #	98.4	99.7	1,439	ND< 4.66 #	ND< 8.60 #	ND< 4.35 #	99.6	99.7
Cadmium	8.91	0.249	0.405	0.634	97.4	94.0	8.75	0.129	0.293	0.30	98.7	97.4
Chromium	658	8.27	18.4	ND< 3.03 #	99.1	99.7	567	ND< 2.71 #	ND< 4.99 #	ND< 2.52 #	99.5	99.7
Cobalt	120	1.57	3.67	ND< 1.35 #	98.4	98.7	86.2	ND< 1.20 #	ND< 2.22 #	ND< 1.12 #	98.7	99.1
Lead	234	3.31	3.25	0.823	98.8	99.7	173	0.27	1.93	0.374	99.9	99.9
Manganese	835	11.4	15.4	2.99	99.2	99.8	862	96.7	2.48	1.85	92.4	99.9
Mercury	2.03	0.441	0.095	0.153	79.2	99.9	1.43	0.178	0.25	0.161	88.3	90.2
Selenium	103	46.9	10.9	1.59	73.1	99.1	185	28.1	0.189[a]	ND< 0.061 #	76.9	99.96
Vanadium	1,060	10.2[a]	ND<18.18 #	ND< 10.1 #	98.7	99.2	809	ND< 9.03 #	ND< 16.7 #	ND< 8.41 #	99.2	99.5

ND< Value shown is detection limit.
Of the calculations contributing to the average value shown, all include a non-detect measurement.

Table 3.16-6 Concentrations and Removal Efficiencies, AirPol GSA Pilot Plant, Parallel Tests

	Parallel Baseline						Parallel Demonstration					
	ESP Inlet, μg/dNm³	ESP Outlet, μg/dNm³	Baghouse Inlet, μg/dNm³	Baghouse Outlet, μg/dNm³	ESP Removal Efficiencies, Percent	Baghouse Removal Efficiencies, Percent	ESP Inlet, μg/dNm³	ESP Outlet, μg/dNm³	Baghouse Inlet, μg/dNm³	Baghouse Outlet, μg/dNm³	ESP Removal Efficiencies, Percent	Baghouse Removal Efficiencies, Percent
Antimony	8.61	ND< 0.09 #	23.0	ND< 0.10 #	96.6	96.7	20.1	ND< 0.09 #	13.7	ND< 0.09 #	98.8	98.7
Arsenic	237	8.23	541	0.98	98.4	99.8	388	19.2	228	0.12[B]	96.4	99.98
Barium	380	ND< 5.07 #	1,550	ND< 5.6 #	99.5	99.5	1,990	66.0	691	ND< 4.7 #	92.7	99.5
Cadmium	7.70	1.39	8.55	3.02	85	71.4	9.91	0.59	2.98	1.86	93.3	78.7
Chromium	379	10.4	781	ND< 3.3 #	98.1	99.5	519	27.3[A]	222	ND< 2.7 #	95.1	99.5
Cobalt	69.5	1.84	138	ND< 1.45 #	98.1	98.7	103	6.19[A]	47.5	ND< 1.2 #	94.3	98.9
Lead	183	6.19	442	1.29	97.3	99.5	258	17.7	86.2	0.82	92.1	99.6
Manganese	325	14.6	687	4.42	98.5	99.6	515	35.7	294	7.04	95.6	99.1
Mercury	0.13[B]	0.75	1.47	1.53[A]	62.5	32	3.35	1.74	1.84	1.02	-38.9	49.2
Selenium	ND< 0.18 #	20.5	5.94[B]	ND< 0.08 #	79.7	99.9	ND< 0.30 #	ND< 0.07 #	ND< 0.2 #	ND< 0.07 #	99.8	99.8
Vanadium	375. A	ND< 9.81[B]	1,520	ND< 10.8 #	98.8	99.1	1,020	58.5	491	ND< 9.1 #	93.4	99

ND< Value shown is detection limit.
[A] Includes one non-detect measurement
[B] Includes two non-detect measurements
\# Non-detectible in all samples

Table 3.16-7 Stream Temperatures, AirPol GSA System

Temperature, deg F		
	Baseline	Demonstration
GSA Inlet	290	294
ESP Outlet	243	146

SECTION 4.0 MERCURY SPECIATION

Section 4.1 Speciation Results

The following three tables summarize the test results for mercury speciation at the test facilities described in Section 3.0 of this report. Efforts are continuing to validate a method to quantitatively speciate mercury forms.

Table 4.1-1 Comparison of Mercury Measuring Techniques at Plant Stack

Plant	Concentrations, µg/Nm³							
	Bloom Method			Method 29			Carbon Trap	HEST
	Ionic[a]	Elemental	Total	Ionic[a]	Elemental	Total	Total	Total
Baldwin	5.0	2.1	7.2	---	---	5.2		
Boswell	2.5	0.7	3.1	---	---	2.6		
Arapahoe	ND	0.06	0.07					
Burger	4.3	4.2	8.5					
Hammond	3.0	3.6	6.6					
Smith (Baseline)	6.9	1.6	8.5					
Smith (Low NO_x)	6.1	0.6	6.7					
Bailly	0.1	3.5	3.6	2.6	0.14	2.8		
Yates	0.5	2.8	3.3	1.5	1.5	3.0		
Niles				20.6	3.2	23.8		16.4
SNOX				20.6	9.7	30.3		22.8
Coal Creek				4.4	8.3	12.7		5.4
Springerville	---	---	5.9	1.4		9.6		
Cardinal						0.45	9.21	

a - Filter and probe mercury are included with ionic.

Table 4.1-2 Mercury Speciation Using the Bloom Train

	Concentrations $\mu g/Nm^3$			
	Elemental	Ionic	Filter & Probe	Total
Baldwin				
ESP Inlet	4.7	2.6	0.89	8.3
ESP Outlet	2.1	4.7	0.33	7.2
Boswell				
Baghouse Inlet	3.7	2.1	0.70	6.5
Baghouse Outlet	0.71	2.3	0.19	3.1
Arapaho				
FFDC Inlet	0.34	6.91	---	7.24
FFDC Outlet	4.16	4.32	---	8.48
Hammond				
Stack	3.6	3.0	---	6.6
Smith-Baseline				
ESP Inlet	1.7	1.9	0.12	3.8
ESP Outlet	1.6	6.9	---	8.5
Smith-Low-NO_x				
ESP Inlet	---	---	---	<0.03
ESP Outlet	0.6	6.1	0.02	6.7
Bailly				
ESP8 Inlet	1.86	4.99	---	6.85
ESP8 Outlet	3.22	4.15	---	7.37
ESP7 Outlet	2.08	4.90	---	6.98
Stack	3.46	0.09	---	3.55
Yates (CT-121)				
ESP Inlet	2.0	4.4	---	6.4
ESP Outlet	2.5	4.8	---	7.3
Stack	2.8	0.47	---	3.3

Table 4.1-3 Method 29 Mercury Speciation

Plant/Sample Point	Concentrations µg/Nm^3					
	H_2O_2 Impinger	$KMnO_4$ Impinger	Probe	Filter	Filter/Probe Combined	Total
Niles						
ESP Inlet	22.5	4.2	0.9	0.7	---	28.3
ESP Outlet	20.6	3.2	0.02	0.0	---	23.8
SNO_x						
Baghouse Inlet	19.6	6.3	1.1	0.6	---	27.7
Baghouse Outlet	24.5	3.5	0.02	0.0	---	28.0
SCR Unit Outlet	26.0	4.2	0.2	0.5	---	30.9
WSA Condenser Outlet	18.9	9.7	1.7	0.02	---	30.3
Coal Creek						
ESP Inlet	4.2	9.4	0.02	0.04	---	13.6
ESP Outlet	7.6	4.3	0.02	0.0	---	11.9
Scrubber Outlet	4.4	8.3	0.0	0.0	---	12.7
Baldwin						
ESP Inlet	---	---	---	---	---	6.8
ESP Outlet	---	---	---	---	---	5.2
Boswell						
Baghouse Inlet	---	---	---	---	---	6.4
Baghouse Outlet	---	---	---	---	---	2.6
Bailly						
ESP8 Inlet	1.04	2.87	---	0.27	---	4.2
ESP8 Outlet	1.23	2.76	---	0.03	---	4.0
ESP7 Outlet	1.40	2.76	---	0.05	---	4.2
Stack	0.14	2.65	---	0.02	---	2.8
Yates						
ESP Inlet	0.35	5.1	---	---	7.1	12.5
ESP Outlet	0.98	4.6	---	---	0.13	5.7
Stack	1.5	1.5	---	---	0.006	3.0
Springerville						
SDA Inlet	3.7	---	---	---	1.4	7.4
SDA Outlet	0.37	---	---	---	3.1	11.5
Stack	1.4	---	---	---	---	9.6
Stack Diluter	2.9	0.09	---		0.1	8.0

APPENDIX - REFERENCES AND REPORT CONTENT SUMMARY

1. "A Study to Toxic Emissions from a Coal-Fired Power Plant Utilizing and ESP/Wet FGD System" by Battelle, July 1994 (Coal Creek Station)

Volume 1: Site description, sampling, sample analysis, results, data analyses, special topics

Volume 2: Appendices including log sheets, auditing, sampling protocol data sheets, QA/QC, analytical protocol, uncertainty analysis

2. "A Study of Toxic Emissions from a Coal-Fired Power Plant - Niles Station Boiler No. 2" by Battelle, June 1994

Volume 1: Site description, sampling, sample analysis, results, data analyses, special reports

Volume 2: Appendices including log sheets, auditing, sampling protocol data sheets, QA/QC, analytical protocol, uncertainty analysis

3. "A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing the **SNOX** Innovative Clean Coal Technology Demonstration" by Battelle, July 1994 (Niles Station)

Volume 1: Site description, sampling, sample analysis, results, data analyses, special topics

Volume 2: Appendices including log sheets, auditing, sampling protocol data sheets, QA/QC, analytical protocol, uncertainty analysis

4. "Gas Suspension Absorption (GSA) Demonstration Plant Air Toxics Characterization" by Energy and Environmental Research Corporation, September 1994 (Draft), (Shawnee Power Plant)

One Volume: Process/plant description, sampling and analytical procedures, results, mass balances, removal efficiency, emission factors, QA/QC, uncertainty analysis

5. "Assessment of Toxic Emissions from a Coal-Fired Power Plant Utilizing an ESP" by Energy and Environmental Research Corporation, December 1994 (Cardinal Station)

Main Report: Site description, sample collection, sample analysis, results, data analysis, special topics

Appendix A - External Quality Assurance

Appendix B - Sampling Protocol

Appendix C - Sampling Data Sheets

Appendix D - Internal Quality Assurance

Appendix E - Analytical Protocol

Appendix F - Uncertainty Analysis

Appendix G - Gas Run Data

Appendix H - Liquid Run Data

Appendix I - Solids Run Data

6. "Characterizing Toxic Emissions from a Coal-Fired Power Plant Demonstrating the AFGD ICCT Project and a Plant Utilizing a Dry Scrubber/Baghouse System - Springerville Generating

Station Unit 2 and Dry Scrubber/Baghouse System" by Southern Research Institute, June 1994

Main Report: Site description, sampling,, sample analysis, analytical results, data analysis, special topics

Appendices: Auditing, sampling protocol bunker coal analyses, analytical protocol, QA/QC, analytical calculations, uncertainty analyses, sampling data sheets

7. "Toxic Assessment Report - Illinois Power Company Baldwin Power Station" by Roy F. Weston, Inc., July 1994

Volume I: Unit description, study design and execution, flue gas stream results, process streams, QA/QC activities

Volume II: Process operations data, detailed test results, raw test data

Volume III: Laboratory reports

Volume IV: QA/QC audit report, QC oversight report, QA/QC activities and results, equipment calibration records, sample calculations

8. "Toxics Assessment Report - Minnesota Power Company Boswell Energy Center" by Roy F. Weston, Inc., July 1994

Volume I: Unit description, study design and execution, flue gas stream results, process streams, QA/QC activities

Volume II: Process operations data, detailed test results, raw test data

Volume III: Laboratory reports

Volume IV: QA/QC audit report, QC oversight report, QA/QC activities and results, equipment calibration records, sample calculations

9. "Characterizing Toxic Emissions from a Coal-Fired Power Plant Demonstrating the AFGD ICCT Project and Utilizing a Dry Scrubber/Baghouse System - Bailly Station Units 7 and 8 and AFGD ICCT Project" by Southern Research Institute, October, 1994.

Main Report: Site description, sampling, sample analysis, analytical results, data analysis, special topics

Appendices: Auditing, sampling protocol bunker coal analyses, analytical protocol, QA/QC, analytical calculations, uncertainty analyses, sampling data sheets

10. "A Study of Hazardous Air Pollutants at the TIDD PFBC Demonstration Plant" by Radian Corporation, October 1994.

Volume I: Site description, results, data evaluation, sample calculations

Volume II: Appendices - Sample collection and pretreatment, analytical procedures, data, QA/QC results, data trend plots, equipment calibration records, field data sheets, uncertainty formulas

11. "A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing an ESP While Demonstrating the ICCT CT-121 FGD Project" by Radian Corporation, June 1994 (Plant Yates)

One Volume: Site description, results, data evaluation, sample calculations, sample collection and pretreatment, analytical procedures, detailed analytical data, sampling data, QA/QC results data trends, plots, equipment calibration records, field data sheets, uncertainty formulas

12. "Field Chemical Emissions Monitoring Project Site 115 emissions Report" by Carnot, November 1994 (Preliminary Draft)

One Volume: Site description, results, chromium and mercury speciation results, data evaluation, sample calculations, sampling and analytical concentrations, unused data, flow rates, process operation, uncertainty analyses, QA/QC, analytical and blank correction data

13. "Hazardous Air Pollution Monitoring: Demonstration of Coal Reburning for Cyclone NO_x Boiler Control" by Acurex Environmental Corporation, June 1993

One Volume: Facility description, test plan, tests results

14. "Field Chemical Emissions Monitoring Project: site 116 Emissions Report" by Radian Corporation, July 1994 (Plant Burger)

One Volume: Site description, results, data evaluation, special topics, sample calculations, sampling and analytical methods, process and sampling data, QA/QC data

15. "Measurement of Chemical Emissions Under the Influence of Low-NO_x Combustion Modifications" by Southern Research Institute, October 1993 (Plant Smith)

One Volume: Site description, sampling and measurement procedures, physical characterizations, chemical analyses results, material balance data, particle size data, special topics QA/QC

16. "Field Chemical Emissions Monitoring: Overfire Air and Overfire Air/Low NO_x Burner Operation" by Southern Company Services, Inc., November 1993 (Plant Hammond)

One Volume: Site description, results, data evaluation, sample calculations, sample collection and analysis, analytical data, QA/QC results, process stream data