

Air



Chromium Screening Study Test Report

Coal Fired Boiler
Adolph Coors
Golden,
Colorado

EMISSION TEST REPORT
METHOD DEVELOPMENT AND TESTING
FOR CHROMIUM
Coal-Fired Boiler No. 4
Adolph Coors Company
Golden, Colorado

ESED Project No. 85/2
(EMB No. 85-CHM-6)

by

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Mr. Dennis Holzschuh, Emission Measurement Branch (EMB) Task Manager, provided overall project coordination and guidance and observed the test program. Mr. Dwight Atkinson, representing Midwest Research Institute (MRI) (an EPA contractor), monitored process operation throughout the test period. Mr. Charles Bruffey was the PEI Project Manager. Principal authors were Messrs. Charles Bruffey and Thomas Wagner.

SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is currently evaluating several potentially toxic metals and their compounds. One of these toxic metals is chromium. Neither New Source Performance Standards (NSPS) for stationary sources nor National Emissions Standards for Hazardous Air Pollutants (NESHAPS) currently include chromium emissions. Available data on the emission of chromium and its impact on air quality are limited.

The Emission Measurement Branch (EMB) of EPA's Environmental Standards and Engineering Division (ESED) requires contractor assistance in obtaining representative chromium emissions data from several source categories so that an accurate assessment of the potential problems can be made and appropriate regulatory action developed.

PEI Associates, Inc. (under contract to ESED-EMB) performed a series of atmospheric emission tests on the No. 4 pulverized-coal boiler operated by the Adolph Coors Company in Golden, Colorado. All testing took place during the period of March 18 through 21, 1985.

Triplicate tests were conducted simultaneously at the inlet and outlet of a fabric filter (baghouse) used to control particulate emissions from the boiler to determine the concentrations and mass emission rates of particulate matter, hexavalent chromium (Cr^{+6}), and total chromium (Cr). In addition, particle size distribution tests were conducted during the particulate/chromium tests at each location, and process samples (coal, boiler bottom ash,

and baghouse hopper ash) were collected and analyzed for Cr^{+6} and total chromium. Unofficial opacity (visible emission) data were also obtained during each particulate/chromium test.

At the completion of the particulate/chromium tests, a single test was conducted simultaneously at each location to determine the concentration and mass emission rate of inorganic arsenic.

Section 2 summarizes and discusses the test results; Section 3 addresses quality assurance considerations specific to this project; Section 4 describes the sampling locations and test procedures; and Section 5 describes source operation. Appendix A presents sample calculations and computer printouts; Appendices B and C contain the field data sheets and laboratory analytical results, respectively; Appendix D details the sampling and analytical procedures; Appendix E summarizes equipment calibration procedures and results; Appendix F presents a project quality assurance summary; Appendix G contains a list of project participants and a sampling log; and Appendices H and I contain the basic sample and analytical methodology used to determine hexavalent and total chromium content.

It should be noted that EPA performed the total chromium analysis of collected samples by neutron activation analysis (NAA). These data are included in Section 2 of this report.

SECTION 2

SUMMARY AND DISCUSSION OF TEST RESULTS

This section details the results of the sampling program. Subsections are used to identify results from each test type (i.e., particulate/Cr⁺⁶, particle size distribution, etc.), and results are expressed in both metric and English units where applicable.

2.1 TEST PROTOCOL

Table 2-1 presents the sampling and analytical protocol followed throughout this project, the test identification, and the sampling times for each specific test type.

In summary, EPA Method 5* sampling trains were used for simultaneous extraction of samples from the baghouse inlet and outlet test locations. Samples were collected over a 6-hour period by isokinetic, cross-sectional traverse techniques.

A total of six samples (three in and three out) were collected for determination of particulate, Cr⁺⁶, and total Cr concentrations. Method 5 analytical procedures were followed for the particulate analysis, and procedures recently developed by EPA for determination of Cr⁺⁶ content in source emission samples were used for the Cr⁺⁶ analysis. These latter procedures entail extraction of the sample fractions (probe residue and filter particulate) with an alkaline solution followed by the diphenylcarbazide colorimetric

* 40 CFR 60, Appendix A, Reference Method 5, July 1984.

TABLE 2-1. SAMPLING AND ANALYTICAL PARAMETERS, NO. 4 BOILER, ADOLPH COORS COMPANY

Run No.	Date (1985) and time (24-h)	Test or sample type	Sampling location	Sample parameters					Analytical parameters				
				Particulate Methods 1-5	Particle size dis- tribution	Cr ⁺⁶	Total Cr	Arsenic Method 108	Particulate Method 5	Particle size dis- tribution	Cr ⁺⁶	Total Cr	Arsenic Method 108
PCI-1	3/18 - 0925-1525	Particulate Cr ⁶ Total Cr	Inlet	X	-	X	X	-	X	-	X	X	-
PCO-1	3/18 - 0925-1543		Outlet	X	-	X	X	-	X	-	X	-	-
PCI-2	3/19 - 0810-1736		Inlet	X	-	X	X	-	X	-	X	X	-
PCO-2	3/19 - 0810-1802		Outlet	X	-	X	X	-	X	-	X	X	-
PCI-3	3/20 - 0820-1405	Particle size distribution	Inlet	X	-	X	X	-	X	-	X	X	-
PCO-3	3/20 - 0821-1435		Outlet	X	-	X	X	-	X	-	X	X	-
PSI-1	3/18 - 1610-1740		Inlet	-	X	X	X	-	-	X	-	-	-
PSO-1	3/18 - 1012-1715		Outlet	-	X	X	X	-	-	X	X	-	-
PSI-2	3/19 - 1131-1301	Arsenic	Inlet	-	X	X	X	-	-	X	X	X	-
PSO-2	3/19 - 0715-1830		Outlet	-	X	X	X	-	-	X	X	-	-
PSI-3	3/20 - 1105-1235		Inlet	-	X	X	X	-	-	X	-	-	-
PSO-3	3/20 - 0753-1755		Outlet	-	X	X	X	-	-	X	X	-	-
PSI-4	3/21 - 1220-1350	Process samples	Inlet	-	X	X	X	-	-	X	-	-	-
PSO-4	3/21 - 0815-1815		Outlet	-	X	X	X	-	-	X	X	X	-
AM-1	3/21 - 1415-1515		Outlet	-	X	X	X	-	-	X	-	-	-
AM-2	3/21 - 1605-1705		Outlet	-	X	X	X	-	-	X	-	-	-
AI-1	3/21 - 0850-1200	Mills A&B Boiler 4 No. 7 com- partment	Inlet	-	-	-	-	X	-	-	-	-	X
AO-2	3/21 - 0856-1200		Outlet	-	-	-	-	X	-	-	-	-	X
PCI(1-3)	3/18-21		Coal	-	-	-	-	-	-	-	X	X	-
PCO(1-3)			Bottom ash	-	-	-	-	-	-	-	X	X	-
AI-1		Baghouse ash	-	-	-	-	-	-	-	X	X	-	
AO-1													

method.* Neutron activation analysis was used to determine the total chromium content of selected samples. These data are summarized in Subsection 2.6.

Particle size distribution measurements were made at each site during the particulate/Cr⁺⁶ tests with an Andersen heavy grain loading impactor (HGLI). Three samples were collected at the baghouse inlet and four were collected at the baghouse outlet. Two additional samples were collected at the baghouse outlet with a standard Andersen Mark III in-stack impactor to validate the HGLI results. Particle size fractions were analyzed gravimetrically, and size distribution curves were developed for each site. At the completion of the gravimetric analysis, a single run from the inlet test site was analyzed for Cr⁺⁶ by individual stage. The analytical procedures used were similar to those for the particulate/Cr⁺⁶ samples. Three of the four sample runs at the baghouse outlet were composited by stage cut-point and analyzed for Cr⁺⁶.

At the completion of the particulate/Cr⁺⁶ and particle size tests, a single test was conducted simultaneously at each location according to procedures described in EPA Reference Method 108.** Method 108 provides both filterable and gaseous arsenic concentration. This test was conducted for 3 hours at each location by isokinetic, cross-sectional traverse techniques. Total arsenic content was then determined by atomic absorption (AA) analysis.

Process samples (pulverized coal, baghouse hopper fly ash, and boiler bottom ash) that were collected during each day of testing were composited by sample type and analyzed for Cr⁺⁶ and total chromium.

The following subsections detail the results of the sampling program.

* Test Methods for Evaluating Solid Waste. U.S. EPA SW-846, 2nd ed., July 1982.

** 40 CFR 60, Appendix A, Reference Method 108, July 1984.

2.2 PARTICULATE, HEXAVALENT CHROMIUM, AND ARSENIC TEST RESULTS

Simultaneous Method 5* tests were conducted at the baghouse inlet and outlet test locations. These samples were analyzed for particulate and Cr^{+6} concentrations, and the resulting data were used to characterize the removal efficiency across the baghouse. In addition, a single test was conducted simultaneously at each location (by EPA Method 108 sampling and analytical procedures) to characterize uncontrolled and controlled arsenic emissions from this type of source. During all testing, the boiler load was at least 80 percent of rated capacity (see Section 5).

Table 2-2 summarizes pertinent sample and flue gas data for the particulate/ Cr^{+6} and arsenic tests, and Table 2-3 presents the reported particulate and Cr^{+6} emission results. All data have been blank-corrected.

Volumetric flow rates are expressed in cubic meters per minute (m^3/min) and actual cubic feet per minute (acfm) at stack conditions. Flow rates corrected to standard conditions [20°C and 760 mmHg (68°F and 29.92 in.Hg) and zero percent moisture] are expressed as dry normal cubic meters per minute (dNm^3/min) and dry standard cubic feet per minute (dscfm).

Filterable particulate concentrations are expressed in milligrams per dry normal cubic meter (mg/dNm^3) and grains per dry standard cubic foot (gr/dscf). Filterable particulate represents that material collected in the sample probe and on the sample filter, which were both maintained at approximately 121°C (250°F). Hexavalent chromium concentrations are expressed in micrograms per gram ($\mu\text{g}/\text{g}$) and micrograms per dry normal cubic meter ($\mu\text{g}/\text{dNm}^3$). Mass emission rates are reported in kilograms per hour and pounds per hour.

* 40 CFR 60, Appendix A, Reference Method 5, July 1984.

TABLE 2-2. SUMMARY OF SAMPLE AND FLUE GAS DATA FOR PARTICULATE/CR⁺⁶ AND ARSENIC TESTS

Run No.	Date (1985)	Sampling duration, min	Sample volume,		Isokinetic sample rate, %	Volumetric flow rate ^a				Temperature		Moisture content, %	Gas composition, %			Gas velocity ^c		Static pressure, in.H ₂ O
						Actual		Standard					O ₂ CO ₂ CO					
			dNm ³	dscf		m ³ /min	acfm	dNm ³ /min	dscfm	°C	°F		mps	fps				
PCI-1	3/18	360	3.79	133.67	106.3	3730	131,700	1784	63,000	153	307	13.8	6.5	13.2	0	11.2	36.6	-7.5
PCO-1	3/18	360	7.93	279.99	102.9	4577	161,600	2223	78,500	158	317	13.2	6.8	12.8	0	10.4	34.0	-0.02
PCI-2	3/19	180	2.95	104.20	97.9	3911	138,100	1869	66,000	152	305	13.5	7.4	12.0	0	11.7	38.4	-7.5
PCO-2	3/19	360	7.95	280.895	101.8	4656	164,400	2257	79,700	159	318	12.8	7.2	13.5	0	10.5	34.6	-0.02
PCI-3	3/20	180	3.11	109.90	94.1	4143	146,300	2050	72,400	154	309	10.6	7.1	12.9	0	12.4	40.6	-7.5
PCO-3	3/20	360	7.98	281.31	100.0	4710	166,300	2300	81,200	161	321	12.4	8.3	12.9	0	10.7	35.0	-0.02
PCI (Inlet) average			3.28	115.92	99.4	3928	138,700	1901	67,100	153	307	12.6	7.0	13.1	0	11.8	38.5	-7.5
PCO (Outlet) average			7.95	280.73	101.6	4648	164,100	2260	79,800	159	319	12.8	7.4	13.1	0	10.5	34.5	-0.02
AI-1 (Arsenic)	3/21	180	3.15	111.095	100.0	4118	145,400	1951	68,900	156	313	14.0	7.95	12.55	0	12.3	40.4	-7.5
AO-1	3/21	180	3.94	138.993	98.2	4608	162,700	2314	81,700	162	323	9.8	7.3	13.0	0	10.4	34.2	-0.02

^aStandard conditions: 20°C (68°F), 760 mmHg (29.94 in.Hg) and zero percent moisture.

^bGas composition as determined from integrated bag samples collected during each test. Analysis performed with an Orsat gas analyzer.

^cMeasured flue gas velocity in meters per second and feet per second.

TABLE 2-3. SUMMARY OF PARTICULATE AND HEXAVALENT CHROMIUM EMISSIONS DATA

Run No.	Date (1985)	Filterable concentration ^a						Mass emission rate ^b				Collection efficiency, % Particulate Cr ⁺⁶	
		Total filterable weight, grams	Particulate		Cr ⁺⁶ (blank corrected)		Particulate		Cr ⁺⁶				
					Total Cr ⁺⁶ /								
			mg/dNm ³	gr/dscf	μg/g	sample, μg	μg/dNm ³	kg/h	lb/h	kg/h	lb/h		
PCI-1	3/18	54.269	14,319	6.3	0.40	21.7	5.7	1534	3382	0.00045	0.001	99.5	99.6
PCO-1	3/18	0.6075	76.6	0.034	0.30	0.18	0.02	10.2	22.5	-	<0.0001		
PCI-2	3/19	42.39	14,369	6.3	0.22	9.3	3.2	1610	3550	0.00036	0.0008	99.4	99.6
PCO-2	3/19	0.6985	87.9	0.038	0.20	0.14	0.02	11.9	26.2	-	<0.0001		
PCI-3	3/20	47.011	15,116	6.6	0.22	10.3	3.3	1858	4097	0.0004	0.0009	99.4	99.8
PCO-3	3/20	0.7706	96.7	0.042	0.10	0.08	0.01	13.3	29.4	-	<0.0001		

^aStandard conditions: 20°C (68°F), 760 mmHg (29.94 in.Hg) and zero percent moisture.

^bCollection efficiency: $\frac{\text{Inlet concentration} - \text{Outlet concentration}}{\text{Inlet concentration}} \times 100$.

As reported in Table 2-2, sample volumes were generally consistent, ranging from 2.95 to 3.79 dNm³ for the inlet trains and from 7.93 to 7.97 dNm³ for the outlet trains. The inlet sampling times were adjusted after Test PCI-1 to account for the heavy particulate loading at this site. Test PCI-1 was conducted for 6 hours at a reduced sampling rate of approximately 0.01 dNm³/min (0.37 scfm). Tests PCI-2 and 3 were conducted for 3 hours by sampling 30 minutes every hour on the hour for 6 hours. A sampling rate of approximately 0.02 dNm³/min (0.58 scfm) was realized for these tests. Iso-kinetic sampling rates ranged between 94.1 and 106.3 percent, which is within the acceptable range of 90 to 110 percent.

Volumetric gas flow rates at the baghouse inlet ranged from 3730 to 4143 m³/min (131,700 to 146,300 acfm) and averaged 3928 m³/min (138,700 acfm) for the three particulate/Cr⁺⁶ tests. The average volumetric flow at standard conditions was 1901 dNm³/min (67,100 dscfm). Flue gas temperatures ranged from 152° to 154°C (305° to 309°F) and averaged 153°C (307°F). The moisture content of the gas stream averaged 12.6 percent, and the average oxygen (O₂) and carbon dioxide (CO₂) contents were 7.0 and 13.1 percent, respectively.

Arsenic sample and flue gas data reported in Table 2-2 are comparable to data associated with the particulate/Cr⁺⁶ tests with the exception of the outlet moisture content. The measured moisture content (9.8 percent) is approximately 23 percent lower than the average moisture content (12.8 percent) determined during the particulate/Cr⁺⁶ tests. There were no leakage problems associated with this run, and calculations were rechecked to preclude calculation error as a source of the low bias. An error in recording the weight of each impinger might have occurred for this run; however, the overall effect on sample results is believed to be negligible.

As shown in Table 2-3, inlet particulate concentrations ranged from 14,319 to 15,116 mg/dNm³ (6.3 to 6.6 gr/dscf) and averaged 14,601 mg/dNm³ (6.4 gr/dscf). The average mass emission rate for the three tests was 1667 kg/h (3676 lb/h).

The inlet hexavalent chromium concentration ranged from 0.22 to 0.40 µg/g (3.2 to 5.7 µg/dNm³) and averaged 0.28 µg/g (4.1 µg/dNm³) for the three tests. The average Cr⁺⁶ mass emission rate was 0.0004 kg/h (0.0009 lb/h). The total quantity of Cr⁺⁶ per sample ranged from 9.3 to 21.7 µg.

At the baghouse outlet, volumetric gas flow rates ranged from 4577 to 4710 m³/min (161,600 to 166,300 acfm) and averaged 4648 m³/min (164,100 acfm). The average gas flow rate at standard conditions was 2260 dNm³/min (79,800 dscfm). Flue gas temperatures ranged from 158° to 161°C (317° to 321°F) and averaged 159°C (319°F). The moisture content of the gas stream averaged 12.8 percent, and the average O₂ and CO₂ contents were 7.4 and 13.1 percent, respectively.

Outlet particulate concentrations ranged between 76.6 and 96.7 mg/dNm³ (0.034 and 0.042 gr/dscf) and averaged 87.1 mg/dNm³ (0.038 gr/dscf). The average mass emission rate for the three tests was 11.8 kg/h (26.0 lb/h). The outlet Cr⁺⁶ concentrations ranged between 0.08 and 0.30 µg/g (0.01 and 0.02 µg/dNm³), and the total quantity of Cr⁺⁶ per sample was less than 0.20 µg. An approximate detection limit of 0.1 µg/g Cr⁺⁶ was established for the outlet samples, based on a 25-ml sample volume. Accordingly, the reported Cr⁺⁶ results are essentially at the detection limit of the analytical method (see Section 3).

The back-half or impinger solutions from Tests PCI and PCO-1 were also analyzed for Cr⁺⁶ content. PCI-1 (inlet) back-half Cr⁺⁶ content was 0.7 µg

in 690 ml of sample, or 0.001 $\mu\text{g/ml}$. PCO-1 (outlet) back-half Cr^{+6} content was 0.3 μg in 1145 ml of sample, or 0.0003 $\mu\text{g/ml}$. Average blank reagent values were less than 0.006 $\mu\text{g/ml}$, which indicates that the reported values for each location are essentially at the detection limit of the analytical method.

The particulate-removal efficiency of the baghouse was greater than 99 percent based on both the measured inlet and outlet particulate concentrations and mass emission rates. Hexavalent chromium collection efficiencies based on the measured Cr^{+6} concentrations and the total quantity of Cr^{+6} collected in the filterable fraction (probe and filter) were comparable to the particulate collection efficiency.

No major problems were encountered during the particulate/ Cr^{+6} tests. Extended sampling times were necessary to assure collection of sufficient sample so that Cr^{+6} levels could be quantified. The 3.05-m (10-ft), glass-lined, sampling probe that PEI used at the inlet location was not of sufficient length to reach the final traverse point in the 4 x 6 sampling point matrix established for this site. Therefore, Traverse Point 5 was sampled twice in each port because the velocity head and gas temperature at this point were comparable to the average gas velocity and temperature in the duct.

A 3.05-m (10-ft) glass-lined probe was used at both sites to preclude possible biases in Cr^{+6} and total Cr measurements, which might have resulted from the use of a stainless-steel-lined probe. Previous test experience has shown that the use of glass liners longer than 3.05 m results in excessive breakage and leakage problems.

Table 2-4 summarizes the arsenic emissions data obtained at this source.

TABLE 2-4. ARSENIC EMISSIONS DATA

Run No.	Date (1985)	Sampling location	Concentration			Arsenic collection efficiency, %
			Total filterable arsenic sample weight, μg	$\mu\text{g}/\text{dNm}^3$	mg/dNm^3	
AI-1	3/21	Inlet	525	167	0.17	>99.0
AO-1	3/21	Outlet	6.4	1.6	0.002	

Arsenic was found exclusively in the filterable fraction (probe and filter) of each sampling train. The inlet sample showed a total arsenic weight of 525 μg or 167 $\mu\text{g}/\text{dNm}^3$ compared with 6.4 μg (1.6 $\mu\text{g}/\text{dNm}^3$) for the outlet sample. This single test indicated an arsenic collection efficiency of more than 99 percent.

2.3 PARTICLE SIZE DISTRIBUTION TEST RESULTS

At each site, an Andersen HGLI was used to measure particle size distribution during each particulate/ Cr^{+6} test. This in-stack impactor consists of two single-jet impaction chambers followed by a third-stage cyclone and a backup thimble. Although this impactor normally would not be used to extract samples from a gas stream with a low particulate concentration, its use was advantageous in this case because it contains no filter media (except the backup thimble). This eliminates the need for filter blank corrections for Cr^{+6} and permits a more accurate quantification of Cr^{+6} size distribution. A total of three inlet samples (designated PSI) were collected over a 90-minute period at a single point representing the average gas velocity and temperature in the duct.

Four samples were collected at the baghouse outlet over an 8- to 10-hour sampling period to assure sufficient sample in each stage for both gravimetric and Cr^{+6} analysis. These samples (designated PS0) were collected from

two separate sampling points, each representing the average gas velocity and temperature in the duct.

For validation of the outlet particle size results, two additional measurements (designated AM) were made with a standard Andersen Mark III multistage impactor.

Each particle size test was conducted according to the procedures described in the HGLI operations manual. Isokinetic sampling rates were set initially, and constant cut-point characteristics were maintained throughout the sampling period. Specifications state that the gas flow rate through the impactor at stack conditions should be maintained between 0.3 and 0.7 acfm to avoid distortion of individual stage cut-points. With the exception of Test PS0-2 (outlet), this criterion was met. Isokinetic sampling rates ranged from 112 to 116 percent for the inlet tests and 96 to 103 percent for the outlet tests.

Cumulative size distribution curves representing the total weight of particulate matter smaller than the indicated aerodynamic particle diameter [in micrometers (μm)] were established for each test location. The cut-points for each HGLI test were determined graphically from information supplied by the manufacturer, and all particle size results are based on a particle density of 1 g/cm³. Data reduction for the HGLI runs was performed by computer programming with moisture, molecular weight, and temperature data obtained from the particulate/Cr⁺⁶ tests. The HGLI data reduction and intermediate calculations are presented in Appendix A of this report.

Figures 2-1 and 2-2 present the best-fit curves for the inlet and outlet particle size distribution tests. Table 2-5 presents a comparison of

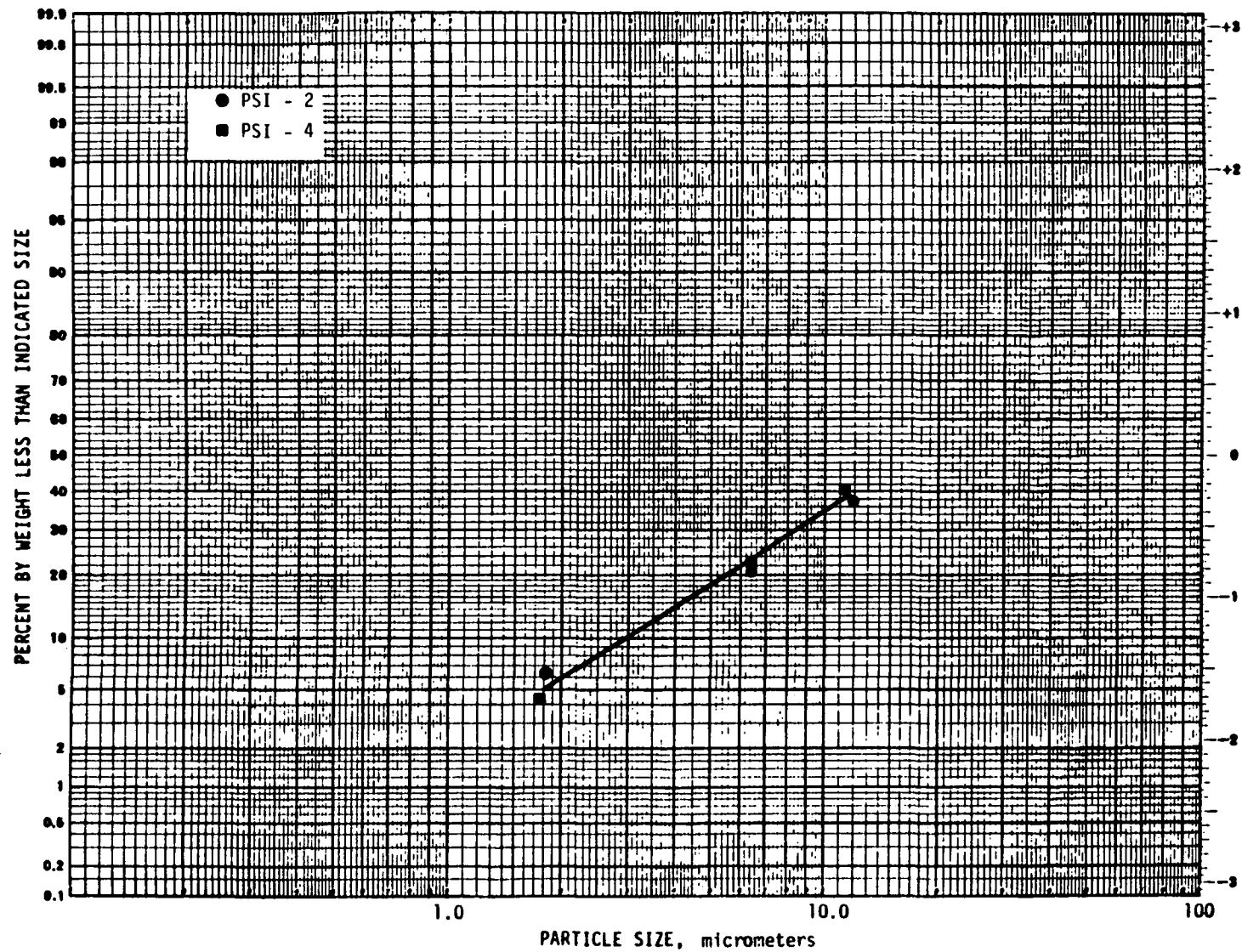


Figure 2-1. Particle size distribution tests PSI-2 and -4 at the baghouse inlet.

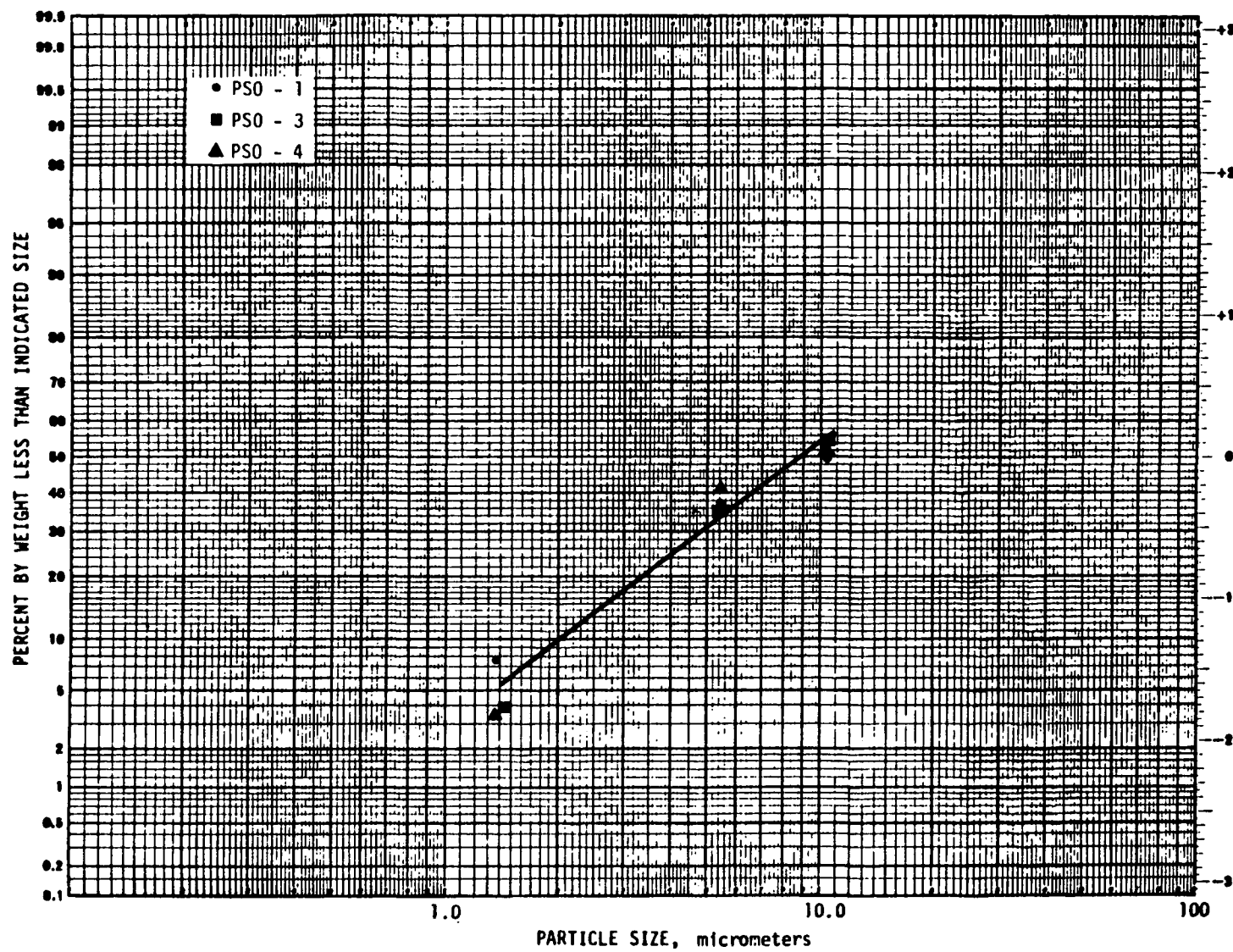


Figure 2-2. Particle size distribution tests PS0-1, -3 and -4 at the baghouse outlet.

TABLE 2-5. COMPARISON OF PARTICULATE CONCENTRATIONS AS MEASURED BY
EPA METHOD 5 VERSUS PARTICLE SIZE DISTRIBUTION IMPACTORS

Run No.	Test location	Sample type	Particulate concentration	
			mg/dNm ³	gr/dscf
PSI-2 PCI-1	Baghouse inlet	Particle size - HGLI	18,413	8.1
		Method 5 - Particulate	14,319	6.3
PSI-3 ^a PCI-2		Particle size - HGLI	8,385	3.7
		Method 5 - Particulate	14,369	6.3
PSI-4 PCI-3		Particle size - HGLI	18,216	7.9
		Method 5 - Particulate	15,116	6.6
PSO-1	Baghouse outlet	Particle size - HGLI	63.1	0.028
PSO-2 PCO-1		Particle size - HGLI	64.8	0.028
		Method 5 - Particulate	76.6	0.034
PSO-3 PCO-2		Particle size - HGLI	91.8	0.04
		Method 5 - Particulate	87.9	0.038
PSO-4 PCO-3		Particle size - HGLI	88.5	0.039
		Method 5 - Particulate	96.7	0.042

^aSample biased low; results not used in development of inlet size distribution curves.

particulate concentrations obtained from the particle size tests with those obtained by Method 5 tests.

One test from each location was excluded from the data used to plot the curves. Test PSI-3 (inlet) was voided because of an apparent loss of sample during removal of the assembly from the duct. Because this site was under a 7.5-in. (water) negative pressure, a small flow had to be maintained through the sampling train during removal of the impactor from the stack to prevent the sample from being drawn out of the impactor through the sample nozzle.

The particulate concentration data from this run were about 55 percent lower than the data from Tests PSI-2 and PSI-4, which indicates some loss of samples. Thus, data were not used in developing the inlet size distribution curve. As mentioned previously, results of Test PS0-2 (outlet) were voided because the calculated flow rate through the impactor (≈ 1.0 cfm) exceeded the manufacturer's recommended maximum value of 0.7 cfm. Therefore, data from Runs PS0-1, -3, and -4 were used to develop the outlet size distribution curves.

For the two inlet runs (PSI-2 and -4), the size distribution curve showed that about 40 percent by weight of the particles had a nominal diameter of 12 micrometers or less. The calculated average particulate concentration for these runs was 18,315 mg/dNm³ (8.0 gr/dscf) compared with a three-test Method 5 average of 14,601 mg/dNm³ (6.4 gr/dscf). This indicates about a 20 percent difference in average values between the two measurements. The percentage difference between the methods is acceptable according to the applicable criterion in the Inhalable Particulate (IP) protocol.* This

* Procedures Manual for Inhalable Particulate Samplers Operation, prepared by Southern Research Institute for EPA, Contract No. 68-02-3118, November 1979.

protocol states that a comparison of the total mass concentrations between particle size and Method 5 sample runs should not differ from the means by more than 50 percent.

The HGLI Stages 1, 2, and 3 cut-points for Test PSI-2 were 11.8, 6.2, and 2.0 μm , respectively. Thirty-eight percent of the particles were less than 11.8 μm , 22 percent were less than 6.2 μm , and 6 percent were less than 2 μm . The stage cut-points for Test PSI-4 were 11.6, 6.2, and 2 μm . Forty percent of the particles were less than 11.6 μm , 23 percent were less than 6.2 μm , and 4 percent were less than 2 μm .

The size distribution curves for the three outlet tests (PSO-1, -3, and -4) showed that about 55 percent by weight of the particles had a nominal diameter of 10.5 μm or less. The average calculated particulate concentration for these runs was 81.1 mg/dNm^3 (0.03 gr/dscf) compared with a three-test Method 5 average of 87.1 mg/dNm^3 (0.038 gr/dscf). This indicates less than a 10 percent difference between the two measurements.

The stage cut-points for Test PSO-1 were 10.4, 5.4, and 1.5 μm , respectively. Fifty percent of the particles were less than 10.4 μm , 36 percent were less than 5.4 μm , and 7 percent were less than 1.5 μm . For Test PSO-3, the stage cut-points were identical to those established for PSO-1. Fifty-five percent of the particles were less than 10.4 μm , 35 percent were less than 5.4 μm , and 4 percent were less than 1.5 μm . Test PSO-4 exhibited similar characteristics; 53 percent of the particles less than 10.5 μm , 40 percent were less than 5.5 μm , and 4 percent were less than 1.5 μm .

The outlet results are considered representative of particle size distribution in the gas stream at the time of testing. The data consistency and comparability to the average Method 5 results substantiate this conclusion.

The inlet results are somewhat suspect because only two sets of valid data were available for evaluation; however, the data reproducibility and overall comparability with the Method 5 results indicate these results are representative of particle size distribution in the gas stream during testing.

Figure 2-3 depicts the size distribution curve developed from data collected by a standard Andersen Mark III multistage impactor. Two 60-minute tests were conducted at the conclusion of the test program to validate the HGLI results. The results from these tests compared favorably with the HGLI tests in which approximately 45 to 55 percent of the particles were less than 10.5 μm .

In an effort to characterize Cr^{+6} size distribution, select particle size samples from each location were analyzed for Cr^{+6} by procedures similar to those used on the Method 5 samples. Inlet Test PSI-2 was analyzed by individual stage, whereas outlet Samples PS0-1, -2, and -3 were composited by stage cut-point and analyzed for Cr^{+6} . Table 2-6 presents the results of the Cr^{+6} size distribution analysis.

The size distribution Cr^{+6} concentrations presented in Table 2-6 are generally consistent with the Method 5 Cr^{+6} data. The inlet Cr^{+6} concentration determined for Stage 1 (11.8- μm cut-point) was 0.24 $\mu\text{g/g}$; for Stage 2 (6.2- μm cut-point), it was 2.85 $\mu\text{g/g}$; and for Stage 3 (2.0- μm cut-point), it was 2.15 $\mu\text{g/g}$. Based on a total particulate weight of 12.449 g, the quantity of Cr^{+6} in this sample was 11.9 μg , with a corresponding concentration of 0.95 $\mu\text{g/g}$.

The outlet Cr^{+6} concentration for the composite Stage 1 (10.4- μm cut-point) sample was 0.32 $\mu\text{g/g}$; for Stage 2 (5.4- μm cut-point), it was 1.1 $\mu\text{g/g}$; and for Stage 3 (1.5- μm cut-point), it was 0.65 $\mu\text{g/g}$. Based on a total

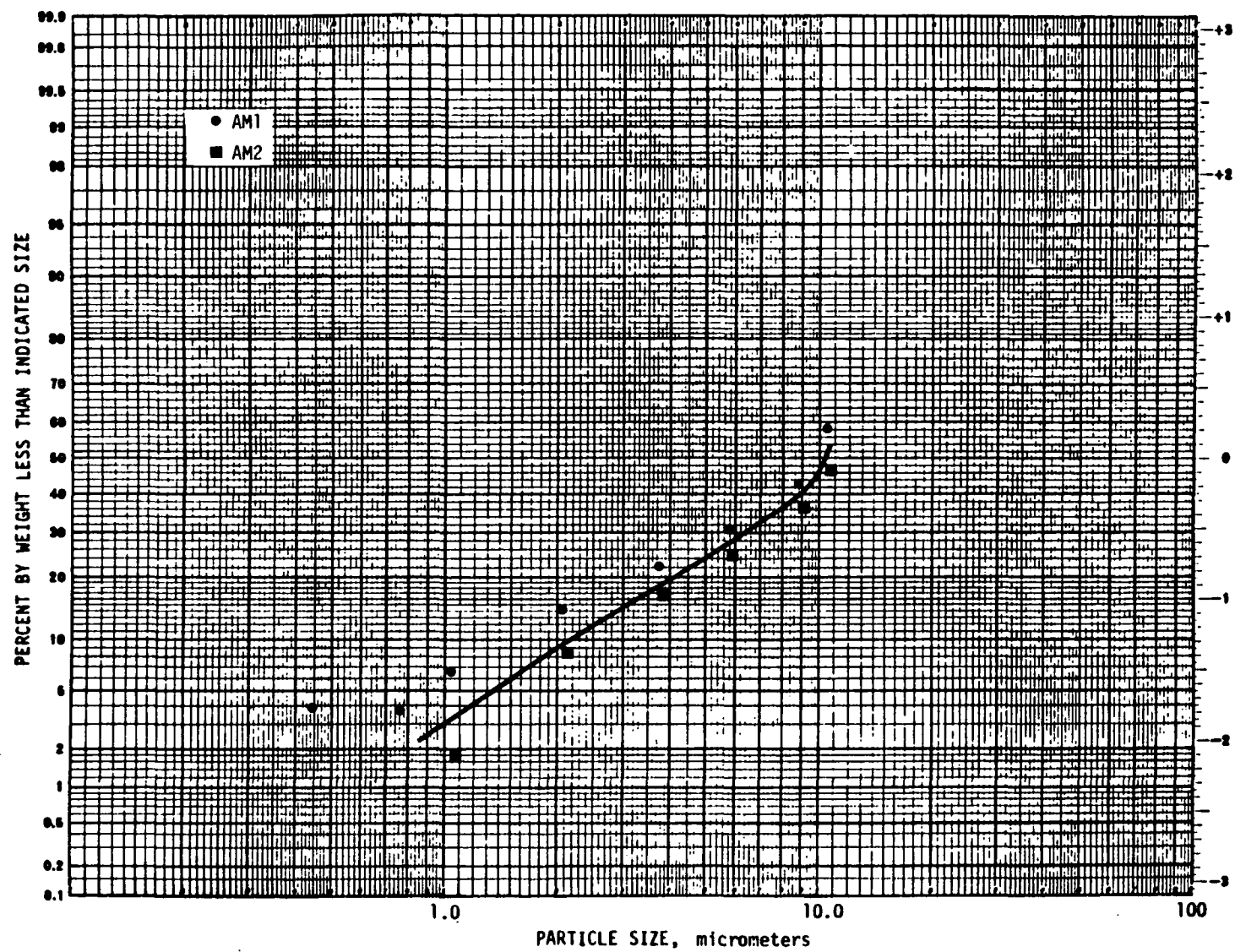


Figure 2-3. No. 4 boiler baghouse outlet particle size distribution.
(Andersen Mark III Impactor - Runs AM-1 and -2)

TABLE 2-6. SUMMARY OF HEXAVALENT CHROMIUM SIZE DISTRIBUTION DATA

Location	Run No.	Sample description	Stage cut-point, μm	Particulate weight per stage, g	Total Cr^{+6} , μg	Cr^{+6} concentration, ^a $\mu\text{g/g}$
Inlet	PSI-2	Stage 1/acetone residue	11.8	7.6694	1.85	0.24
	PSI-2	Stage 2/acetone residue	6.2	2.004	5.73	2.85
	PSI-2	Stage 3/acetone residue	2.0	2.003	4.30	2.15
	PSI-2	Backup thimble	<2.0	0.7719	Nonde-tectable ^b	-
	PSI-2	Total	-	12.449	11.88	0.95
Outlet	PS0(1-3)	Stage 1/acetone residue	10.4	0.6269	0.20	0.32
	PS0(1-3)	Stage 2/acetone residue	5.4	0.2095	0.22	1.1
	PS0(1-3)	Stage 3/acetone residue	1.5	0.3516	0.23	0.65
	PS0(1-3)	Backup thimble/residue	<1.5	0.0194	Nonde-tectable ^b	-
	PS0(1-3)	Total	-	1.233 ^c	0.65	0.53

^aReported results are blank-corrected.

^bLess than or equal to the thimble blank.

^cIncludes total thimble weight for PS0-1, -2, and -3.

particulate weight of 1.233 g, the quantity of Cr^{+6} in the composited sample was 0.65 μg with a corresponding concentration of 0.53 $\mu\text{g/g}$.

The Cr^{+6} analytical results from the inlet Method 5 samples ranged from 0.2 to 0.4 $\mu\text{g/g}$. The inlet Method 5 samples were analyzed in an identical manner as the particle size samples; i.e., weighed quantities of loose particulate were extracted and analyzed, which precluded the need for a Cr^{+6} blank filter corrections. Baghouse hopper fly ash samples also were collected during the test period, and Cr^{+6} levels of approximately 0.7 $\mu\text{g/g}$ were reported. These data are presented in Subsection 2.4 of this report. Based on the overall comparability of the inlet Method 5, baghouse hopper fly ash, and size distribution Cr^{+6} data, and considering the low levels of Cr^{+6} at this source, the Cr^{+6} size distribution data appear to be representative of actual gas stream conditions during the test period. These data do show that most of the Cr^{+6} emissions are concentrated in Stages 2 (6 to 7 μm) and 3 (1.5 to 2.0 μm) at both sites.

2.4 PROCESS SAMPLE ANALYTICAL RESULTS

Table 2-7 summarizes Cr^{+6} analytical results from pulverized coal, boiler bottom ash, and baghouse hopper and samples collected during each day of testing. Grab samples of each were collected at least once an hour over an 8-hour testing period. Samples were placed in separate polyethylene containers and sent to our Cincinnati laboratory, where they were composited by sample type into a single, representative sample. Weighed portions of each sample type were then extracted and analyzed for Cr^{+6} by procedures similar to those used in analyzing the emission test samples.

TABLE 2-7. PROCESS SAMPLE ANALYTICAL RESULTS

Sample type	Laboratory ID	Particulate weight analyzed, g	Total Cr ⁺⁶ , µg	Cr ⁺⁶ concentration, µg/g
Baghouse dust (composite for 3/18 to 3/21)	EE836-EE840	10.298	7.0	0.68
Boiler bottom ash (composite for 3/18 to 3/21)	EE841-EE844	10.9213	0.9	0.08
Pulverized coal ^a	EE845-EE849			
Coal		44.1519	-	0.014
Ash (composite for 3/18 to 3/21)		5.0044	0.61	0.12

^aThe coal samples were "ashed" prior to analysis. The ash content of the coal was approximately 11 percent.

The total Cr⁺⁶ content of the composite boiler bottom ash and sample was 0.9 µg, with a corresponding concentration of 0.08 µg/g. As noted in the previous section, the composite baghouse hopper fly ash sample showed a total Cr⁺⁶ content of 7.0 µg, with a corresponding concentration of 0.68 µg/g. Pulverized coal samples showed a Cr⁺⁶ concentration of 0.014 µg/g.

2.5 VISIBLE EMISSION OBSERVATIONS

Unofficial visible emission observations were made by the EPA Task Manager during each particulate/Cr⁺⁶ test. Opacity readings were consistently less than 5 percent for each test. Raw data sheets are contained in Appendix B of this report.

2.6 TOTAL CHROMIUM TEST RESULTS

Table 2-8 summarizes the total Cr content of selected emission samples analyzed by NAA. Analytical data as received from EPA are included in Appendix C of this report along with example calculations.

In summary, NAA is an analytical technique dependent on the measurement of the number and energy of gamma and X-rays emitted by the radioactive isotopes produced in the sample matrix by irradiation with thermal neutrons from a nuclear reactor. Typically, the sample matrix plus appropriate standards of the element(s) of interest are irradiated for a selected time period in the neutron flux core region of a research nuclear reactor. After irradiation and appropriate radioactive decay, a gamma-count energy spectrum is obtained by counting the sample on a nuclear detection system.

As reported in Table 2-8, inlet Method 5 samples designated PCI 1 through 3 and outlet Method 5 samples designated PCO 2 and 3 were submitted for analysis. In addition, inlet particle size Run PSI-2 and outlet particle size Run PSO-4 were submitted for analysis by individual stage cut point. Composite process samples (coal, boiler bottom ash, and baghouse hopper fly ash) were also analyzed for total Cr content.

The total Cr content of the inlet samples on a $\mu\text{g/g}$ basis ranged between 62 and 97 $\mu\text{g/g}$. Total Cr concentrations on a $\mu\text{g/dNm}^3$ basis ranged between 936 and 1385 $\mu\text{g/dNm}^3$ with corresponding mass emission rates ranging between 0.11 kg/h (0.25 lb/h) and 0.14 kg/h (0.3 lb/h).

The total Cr content of the outlet samples on a $\mu\text{g/g}$ basis ranged between 89 and 110 $\mu\text{g/g}$. The total Cr concentration in a $\mu\text{g/dNm}^3$ basis ranged between 7.8 and 10.6 $\mu\text{g/dNm}^3$ with corresponding mass emission rates of

TABLE 2-8. SUMMARY OF TOTAL Cr EMISSION DATA

Run No.	Sample type and location	Total ^a particulate collected, g	Particulate ^b sample weight analyzed by NAA, g	Total Cr ^c results by NAA, µg	Total Cr ^d concentration by NAA, µg/g	Total Cr ^e content of sample, µg	Total Cr concentration, µg/dNm ³
PCI-1	Filterable particulate baghouse inlet	54.269	0.5041	48.7	96.7	5248	1385
PCI-2	Filterable particulate baghouse inlet	42.390	0.1052	8.8	83.7	3546	1202
PCI-3	Filterable particulate baghouse inlet	47.011	0.1231	7.62	61.9	2910	936
PCO-2	Filterable particulate baghouse outlet	0.6985	0.3322	29.7	89.4	62.4	7.8
PCO-3	Filterable particulate baghouse outlet	0.7706	0.407	44.7	109.8	84.6	10.6
PSI-2	Particle size baghouse inlet						
	Stage 1 (11.8 µm)	7.669	0.100	8.70	87.0	667	
	Stage 2 (6.2 µm)	2.004	0.1062	11.79	111.0	222	
	Stage 3 (2.0 µm)	2.003	0.1147	7.23	63.0	126	
						1015	1504
PSO-4	Particle size baghouse outlet						
	Stage 1 (10.5 µm)	0.2407	0.0988	31.18	315.6	76.0	
	Stage 2 (5.5 µm)	0.0638	0.0533	12.38	232.3	14.8	
	Stage 3 (1.5 µm)	0.1858	0.0952	22.56	237.0	44.0	
						134.8	23.5
-	Baghouse dust composite	-	0.2721	12.55	46.1	-	-
-	Boiler bottom ash composite	-	0.1514	7.36	48.6	-	-
-	Coal composite	-	0.277	2.22	8.01	-	-

^aTotal particulate (probe residue and filter) collected during sample run.^bParticulate weight analyzed by NAA.^cTotal Cr results by NAA.^dTotal Cr(C) divided by particulate weight analyzed by NAA(b).^eTotal Cr concentration (µg/g) multiplied by total particulate weight collected(a).

0.001 kg/h (0.003 lb/h) and 0.001 kg/h (0.003 lb/h), respectively. These data generally follow the particulate and Cr^{+6} emission data in that greater than 98 percent of the total Cr is effectively removed by the baghouse control device.

The inlet particle size distribution data for total Cr showed Cr concentrations of 87 $\mu\text{g/g}$ for Stage 1 (11.8 μm), 111.0 $\mu\text{g/g}$ for Stage 2 (6.2 μm), and 63 $\mu\text{g/g}$ for Stage 3 (2.0 μm). An overall Cr concentration of 1504 $\mu\text{g/dNm}^3$ was determined for this sample, which is generally comparable to the total Cr concentration determined from the Method 5 samples.

The outlet particle size distribution data for total Cr showed Cr concentrations of 316 $\mu\text{g/g}$ for Stage 1 (10.5 μm), 232 $\mu\text{g/g}$ for Stage 2 (5.5 μm), and 237 $\mu\text{g/g}$ for Stage 3 (1.5 μm). An overall Cr concentration of 24 $\mu\text{g/dNm}^3$ was determined for this sample. It should be noted that thimble samples from both particle-size runs were submitted for analysis. The total Cr content of blank thimbles submitted with the actual samples was highly variable, however, making a quantitative analysis of total Cr less than 2 μm impossible.

Process samples analyzed for total Cr yielded the following results:

- Baghouse dust: 46.1 $\mu\text{g/g}$
- Boiler bottom ash: 48.6 $\mu\text{g/g}$
- Coal: 8.0 $\mu\text{g/g}$

These data were determined from composited samples collected during each test day.

SECTION 3

PROJECT QUALITY ASSURANCE

The application of quality assurance procedures to source emission measurements ensures accurate emission-testing results. Quality assurance guidelines provide the detailed procedures and actions necessary for defining and producing acceptable data. In this project, five documents were used in the preparation of a source-specific test plan that would ensure the collection of acceptable data: 1) the EPA Quality Assurance Handbook Volume II, EPA-600/4-77-0271; the PEI Emission Test Quality Assurance Plan; the PEI Laboratory Quality Assurance Plan; Determination of Hexavalent Chromium Emissions From Stationary Sources, December 13, 1984; and EPA Protocol for Emissions Sampling for Both Hexavalent and Total Chromium, February 22, 1985. Two of these are PEI's general guideline manuals and define the company's standard operating procedures followed by the company's emission testing and laboratory groups.

In this specific test program, which was reviewed by EPA's Emission Measurement Branch, the following steps were taken to ensure that the testing and analytical procedures produced quality data:

- ° A sample of the No. 4 boiler baghouse hopper catch was obtained during the February pretest survey and analyzed for Cr^{+6} content. These data were used to define sampling times and rates so that a quantifiable level of Cr^{+6} was collected.
- ° Prior to the field test, several filter media commonly used in source sampling (glass fiber, paper, and Teflon) were analyzed for Cr^{+6} content to establish background levels of Cr^{+6} , as the source levels were expected to be in the microgram range. Glass-fiber

filters were selected for sampling because of their proven durability under the expected source conditions (temperature) and the extended sampling times (6 hours) required at this source.

- Calibration of all field sampling equipment.
- Checks of train configuration and calculations.
- Onsite quality assurance checks, such as leak checks of the sampling train, pitot tube, and Orsat line and onsite quality assurance checks of all test equipment prior to use.
- Use of designated analytical equipment and sampling reagents.
- Internal and external audits to ensure accuracy in sampling and analysis.

Table 3-1 lists the specific sampling equipment used to perform the particulate/ Cr^{+6} , particle size distribution, and arsenic tests as well as the calibration guidelines and limits. In addition to the pre- and post-test calibrations, a field audit was performed on the metering systems and temperature-measurement devices used during sampling. These data are summarized in Table 3-1, and copies of the field audit data sheets are presented in Appendix B of this report.

The PEI project manager performed the onsite sample calculations, and computer programming was used to validate the data upon return to PEI's Cincinnati laboratory. Minor discrepancies between the hand calculations and computer printouts are due primarily to rounding off of values. Computerized example calculations are presented in Appendix A.

The following subsections summarize the quality assurance activities performed during the analytical phase of this project. As a check of the gravimetric analytical procedure, blank filter and reagent (acetone) were analyzed in a fashion similar to that used for the actual field samples. Table 3-2 summarizes the blank analysis data. These data indicate good analytical technique.

TABLE 3-1. FIELD EQUIPMENT CALIBRATION.

Equipment	ID No.	Calibrated against	Allowable error	Actual error	Within allowable limits	Comments
Meter box	FB-8 FB-9 FB-10 FB-11	Wet test meter	$\Delta H @ \pm 0.15$ (Y ± 0.5 Y post-test)	+0.09; -0.02 +0.04; +0.5 -0.11; -0.2 -0.08; -1.05	X X X X	Y = 0.997; Audit $\Delta H @ 1.88$ Y = 0.971; Audit $\Delta H @ 2.03$ Y = 0.976; Audit $\Delta H @ 1.67$ Y = 0.997; Audit $\Delta H @ 1.24$ (Field audit results)
Pitot tube	T-002 187	Standard pitot tube	Cp ± 0.01	0.84 0.84	X X	From Geometric Spec. 40 CFR Appendix A; Reference Method 2
Digital indicator	386 126	Millivolt signals	0.5%	0.40 0.41	X X	Field audit results = +0.23% Field audit results = +0.5%
Thermocouple and stack thermometer	121 257	ASTM-3F	1.5% ($\pm 2\%$ saturated)	+0.19 +0.19	X X	Maximum Maximum
Orsat analyzer	141	Standard gas	$\pm 0.5\%$	0 (O ₂) 0 (CO ₂)	X X	Audit value O ₂ and CO ₂ - 5.0%
Impinger thermometer	1-1 1-2	ASTM-3F	$\pm 2^\circ\text{F}$	+1 $^\circ\text{F}$ +1 $^\circ\text{F}$	X X	
Trip balance	Mettler No. 743985	Type S weights	± 0.5 g	+0.5	X	Maximum deviation
Barometer	Plant	NBS traceable barometer	± 0.10 in.Hg (0.20 post-test)	-	-	Plant barometer (high altitude)
Dry gas thermometer	FB-8 FB-9 FB-10 FB-11	ASTM-3F	$\pm 5^\circ\text{F}$	In - +4 $^\circ\text{F}$; Out - +3 $^\circ\text{F}$ In - +2 $^\circ\text{F}$; Out - +3 $^\circ\text{F}$ In - -1 $^\circ\text{F}$; Out - 0 $^\circ\text{F}$ In - -1 $^\circ\text{F}$; Out - +4 $^\circ\text{F}$	X X X X	Maximum deviations Maximum deviations Maximum deviations Maximum deviations
Probe nozzle	6-101 5-111 6-107 Part. size	Caliper	Dn ± 0.004 in.	0.003 0.001 0.0 0.002 0.001	X X X X X	Inlet Outlet

TABLE 3-2. EXAMPLE FILTER AND REAGENT BLANK
ANALYSIS FOR PARTICULATE

Sample type and filter number	Original tare weight, mg	Blank weight, mg	Net weight, mg
Particulate - 8510126 Reeve Angel 934 AH	363.8	364.2	0.4
Acetone blank ^a	99661.5 ^b	99669.0	7.5 (0.054 mg/g)
	100869.0 ^{c,d}	100872.8	3.8 (0.034 mg/g)
Water blank	NA ^e	NA	NA

^a177 ml evaporated and desiccated before weighing.

^bParticle size acetone blank (0.01 mg/g used in calculations).

^cMethod 5 acetone blank (0.01 mg/g used in calculations).

^d142 ml evaporated and desiccated before weighing.

^eNA = Not applicable.

Table 3-3 presents the results of the blank filter analysis for Cr^{+6} . Glass-fiber, ceramic, silica-fiber, paper filters, and Teflon filters were evaluated. Hexavalent chromium background levels ranged from 0.8 μg for the silica-fiber thimble to 100 μg for ceramic thimbles. PEI utilized Reeve Angel 934 AH glass-fiber filters (0.9 μg Cr^{+6}) for this study because of their proven durability at the temperatures required for sampling and the extended sampling times needed to assure collection of sufficient sample for Cr^{+6} analysis.

The blank filter data in conjunction with Cr^{+6} data from the pretest survey sample were used to formulate a workable test plan to quantify the low Cr^{+6} levels at this source.

Emission and process samples were analyzed in two separate batches. The baghouse inlet samples and process samples were analyzed on April 3, 1985, and the remaining samples on April 11, 1985. Table 3-4 summarizes the linear regression data of the spectrophotometer calibration for these samples.

The detection limit established for the April 3 sample batch was less than 0.009 $\mu\text{g}/\text{ml}$ for an absorbance 0.005. For samples analyzed on April 11, a detection limit of less than 0.005 $\mu\text{g}/\text{ml}$ was established at an absorbance of 0.005.

Because the concentration of hexavalent chromium in these solid samples were extremely low, the amount of alkaline extraction solution and the final dilution volume of this extract were kept at a minimum consistent with Method 3060 from Test Methods for Evaluating Solid Waste.* This proportion is 4 ml of alkaline extraction solution per gram of solid diluted to a final volume of 10 ml. Filters and thimbles require larger amounts of extraction solution

* U.S. EPA SW846, 2nd ed., July 1982.

TABLE 3-3. RESULTS OF PRELIMINARY Cr⁺⁶ ANALYSIS ON BLANK FILTER MEDIA

Type of filter media	Weight of filter media, g	Cr ⁺⁶ , $\mu\text{g/g}$	Total Cr ⁺⁶ , μg
Glass-fiber thimble (BGI)	2.54	1.0	2.5
Alundum (ceramic) thimble	37.6	2.9	100
Silica-fiber thimble (BGI)	3.36	0.23	0.8
S+S glass-fiber thimble	2.14	0.78	1.7
Glass-fiber filter (RA934AH)	0.34	2.5	0.9
Paper filter (Whatman)	0.61	1.8	1.1
Teflon (2.0- μg pore size)	0.0830	2.5	0.21

TABLE 3-4. LINEAR REGRESSION DATA SPECTROPHOTOMETER CALIBRATION

Sample description	Date (1985)	Cr ⁺⁶ standard concentration, $\mu\text{g/ml}$	Absorbance ^a	Y-Intercept	Slope ^a	Correlation coefficient
PCI 1-3 Process samples	4/3	0	0.0	-0.0020	0.8049	0.99990
		0.1	0.077			
		0.2	0.159			
		0.3	0.236			
		0.4	0.322			
		0.5	0.401			
PCI 1-3 All particle size fraction PCI-1 and PCO-1 back halves	4/11	0	0.0	-0.0016	1.3531	0.99995
		0.1	0.134			
		0.2	0.268			
		0.3	0.403			
		0.4	0.536			
		0.5	0.679			

^aDifferent cells used on each day. Flow-through cells were used on April 3; standard cells were used on April 11.

to cover the volume of material being extracted. This physical requirement increased the analytical detection limit.

Because the back-half impinger volumes were larger (690 to 1145 ml) than the final dilution of the extracted front-half particulate, the impinger contents had to be concentrated by factors of 10 or 100 to give comparable detection limits.

Table 3-5 presents the blank filter and reagent Cr^{+6} data. Filter, acetone, and water blanks were collected in the field and analyzed in the same manner as the emission samples.

Except for the filter/acetone fraction of the outlet samples and the thimble fraction of the inlet and outlet particle size samples, blank corrections were minimal. Because of the large particulate sample collected at the inlet, representative particulate samples of 10 g each were analyzed without blank interference from the filter. The first three stages of the particle size sampler do not use a sampling media; therefore, no blank interference was present. The three outlet particulate samples contained approximately 1, 1.5, and 2 times the filter blank, which contributes to the variability of the hexavalent chromium concentration in these samples. The amount of hexavalent chromium in the particle size thimble fraction was indistinguishable from the blank. Duplicate analyses (extraction and colorimetric determination) were performed on the inlet particulate of Run 1, the composite of the baghouse dust, the composite coal sample, and the Mill B coal sample. Also, the first stage of the inlet particle size sample from Run 2 was checked by method of additions, and a liquid audit sample supplied by EPA was analyzed. The results for these samples are presented in Table 3-6.

TABLE 3-5. BLANK DATA FOR Cr⁺⁶ ANALYSIS

Sample type	Volume, ml	Hexavalent chromium content, µg	Hexavalent chromium concentration, µg/ml
Method 5			
Filter/acetone	25	0.34	-
Impinger water	690	0.05 ^a	-
Impinger water	1145	0.09 ^a	-
Particle size thimble	100	3.5	-
Particle size	10	<0.08	-
Reagent blanks			
Particulate	100	<0.9 (inlet)	-
Filter/acetone	25	<0.2 (outlet)	-
Particle size	-	-	<0.005

^aBased on concentrated sample.

TABLE 3-6. RESULTS OF QC SAMPLES

Sample	QC type	Results
Particulate PCI-1	Duplicate	0.38, 0.42 µg/g
Baghouse dust (composite)	Duplicate	0.68, 0.63 µg/g
Coal (composite)	Duplicate	0.014, 0.015 µg/g
Coal (Mill B)	Duplicate	0.012, 0.012 µg/g
Particulate (PSI-2)	Spike	85% recovery
-	Audit ^a	100 ppm

^a100 ppm accepted value.

One problem was encountered in the analysis of the coal samples. When raw coal samples were extracted, a dark brown solution was obtained that could not be analyzed by the colorimetric procedure. The color was removed from this solution by using activated charcoal, but the recovery of spiked amounts of hexavalent chromium was negligible. This problem resulted from the extraction of highly colored organic material from the coal. The values reported for the coal samples were obtained from the ash after the coal samples had been heated to 900°C in a muffle furnace to eliminate the interference from organic matter. Lowering the temperatures did not eliminate all of the organic interference.

Table 3-7 presents QC data relative to the total Cr analysis by NAA. Duplicate, audit, and blank data are presented.

TABLE 3-7. QC DATA FOR TOTAL Cr BY NAA

LAB No.	Sample type	Results, total Cr
Run PCI-1 EE802/810	Duplicate analysis	7.11 μg ; 5.93 μg
Baghouse dust EE836/840	Duplicate analysis	6.9/ μg ; 5.64 μg
Coal EE845/849	Duplicate analysis	0.93 μg ; 1.29 μg
NBS coal	Audit	24.5 μg (34.4 $\mu\text{g/g}$ Cr accepted value)
NBS fly ash	Audit	198 μg (196 $\mu\text{g/g}$ Cr accepted value)
Alkaline extract	Blank	0 Cr
Type I H ₂ O	Blank	1.05 μg Cr (10X concentration)
Method 5 filter Acetone	Blank	15.7 μg Cr
Particle size Thimble	Blank	29.5 μg Cr

SECTION 4

SAMPLING LOCATIONS AND TEST PROCEDURES

This section describes the sampling sites and the test methods used to characterize particulate and chromium emissions from Boiler 4.

4.1 SAMPLING LOCATIONS

Flue gas samples were extracted from existing sampling ports prior to and after the baghouse that controls particulate emissions from Boiler 4. Figures 4-1 and 4-2 show the test locations.

At the baghouse inlet, four 8.9-cm ($3\frac{1}{2}$ -in.) i.d. sampling ports were located approximately 3.4 equivalent duct diameters (EDD) downstream and 0.85 EDD upstream from the nearest flow disturbances in a rectangular duct with an i.d. of 1.5 m x 3.7 m (5 ft x 12 ft). At the baghouse outlet, 8.9-cm ($3\frac{1}{2}$ -in.) i.d. sampling ports were located approximately 3.5 EDD downstream and 1.4 EDD upstream of the nearest flow disturbances in a rectangular duct with an i.d. of 3.3 m x 2.2 m (10 ft 9 in. x 7 ft 2 $\frac{1}{2}$ in.). Both locations conformed to the minimum requirements for sampling port locations specified in Method 1 of the Federal Register.*

4.2 PARTICULATE AND HEXAVALENT CHROMIUM SAMPLE EXTRACTION AND ANALYSIS

Flue gas samples were simultaneously collected at the baghouse inlet and outlet test locations according to procedures outlined in EPA Reference Method 5.**

* 40 CFR 60, Appendix A, Reference Method 1, July 1984.

** 40 CFR 60, Appendix A, Reference Method 5, July 1894.

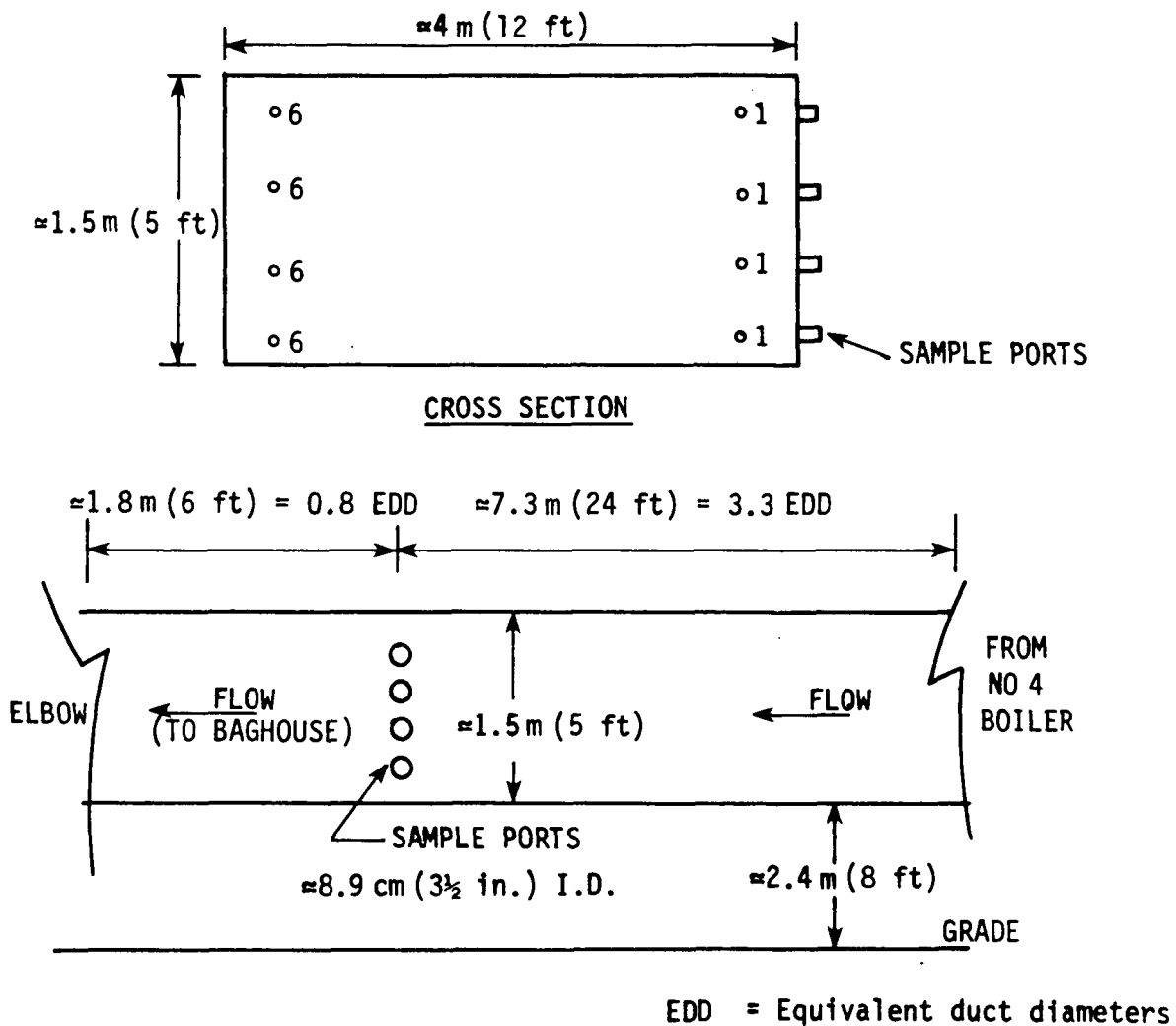


Figure 4-1. Boiler 4 baghouse inlet test location (no scale).

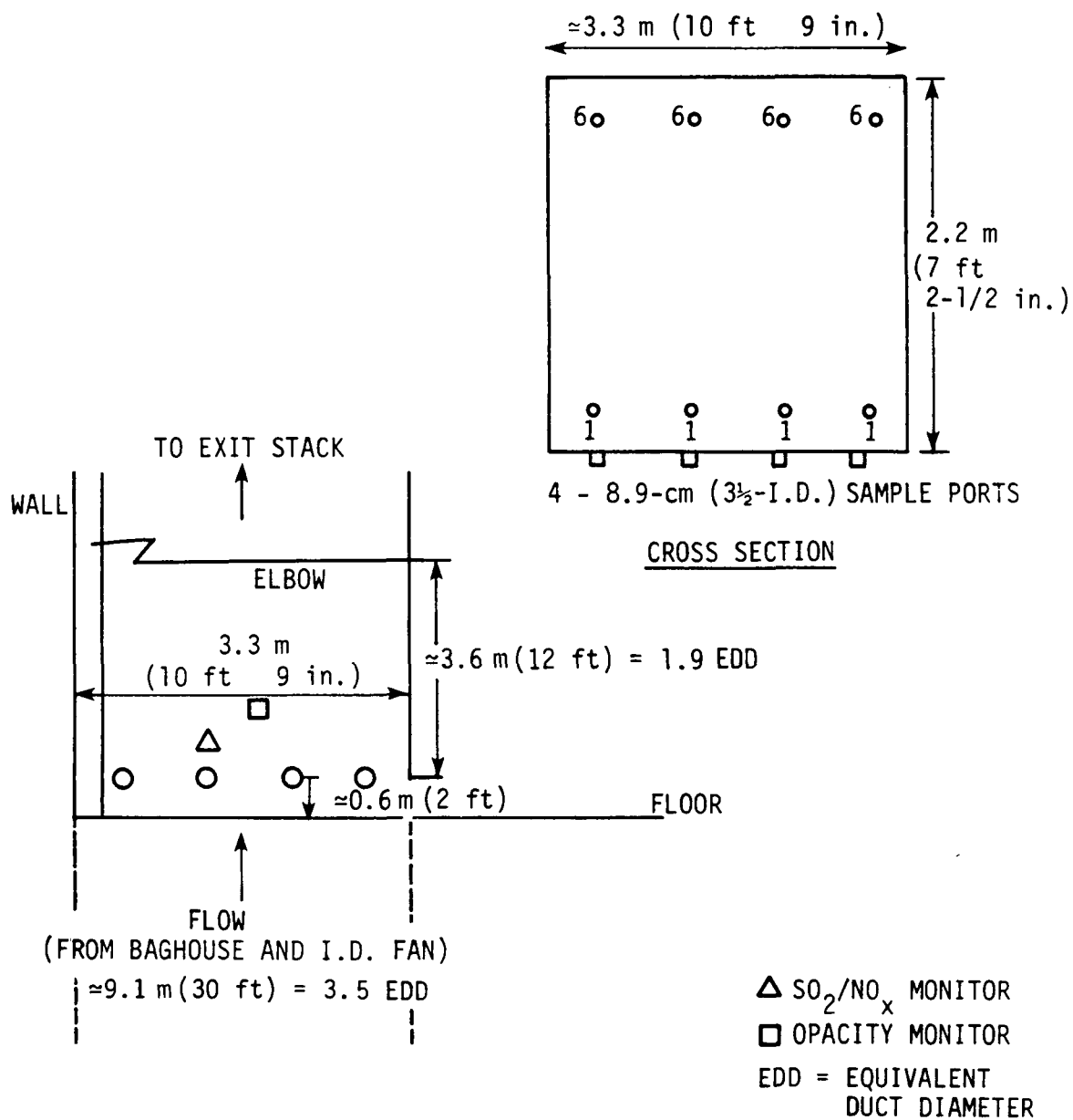


Figure 4-2. Boiler 4 baghouse outlet test location (no scale).

Initially, the collected samples were analyzed gravimetrically by Method 5 to determine particulate concentration and mass emission rates. At the completion of the gravimetric analysis, the samples were prepared and analyzed for Cr^{+6} according to procedures described in a draft EPA method entitled "Determination of Hexavalent Chromium Emissions From Stationary Sources." A copy of the draft method is contained in Appendix H of this report.

Before sampling began, velocity, static pressure, molecular weight, moisture content, and temperature were measured to define sampling rates and nozzle sizes are described in EPA Reference Methods 1 through 4.* The degree of turbulent flow at each location also was assessed according to procedures described in EPA Reference Method 2.* In this method, the face opening of the Type-S pitot tube is aligned perpendicularly to the duct cross-sectional plane, designated "0-degree reference." Null (zero) pitot readings obtained at a 0-degree reference indicate an acceptable flow condition at a given point.

If the pitot reading is not zero at 0-degree reference, the pitot is rotated (up to 90 degrees \pm yaw angle) until a null reading is obtained. The value of the rotation angle (yaw) is recorded for each point and averaged across the duct. Method 2 criteria stipulate that average angular rotations greater than ± 10 degrees indicate turbulent (nonaxial) flow conditions in the duct(s). This procedure was used to check several traverse points at each location. In each case, null pitot readings were observed at the 0-degree reference. These data, together with the velocity and temperature profiles established for each location, indicated acceptable flow patterns that would enable the extraction of representative samples at each site.

* 40 CFR 60, Appendix A, Reference Methods 1 through 4, July 1984.

A total of 24 sampling points were used to traverse the cross-sectional area of the duct(s) at each location. At the baghouse outlet, each point was isokinetically sampled for 15 minutes, which yielded a total test time of 360 minutes. At the inlet location, two different sampling approaches were used. During Test PCI-1, each point was sampled for 15 minutes for a total test time of 360 minutes. An undersized sample nozzle diameter was used to maintain a sample rate of less than 0.5 cfm to prevent overloading of the filter because of the heavy particulate loading. For the remaining two tests, the nozzle diameter was increased, which resulted in a sample rate of approximately 0.8 cfm. Each point was sampled for 7.5 minutes, which yielded a total test time of 180 minutes. Although these sampling trains started and stopped with the outlet trains, they sampled for 30 minutes every hour on the hour for 6 hours to preclude overloading the sample filter.

Only five of six traverse points per port were sampled at the inlet. Point No. 5, which exhibited a velocity pressure approximately equal to the average velocity pressure in the duct, had to be sampled twice in each port because of the type and length of sampling probe used. PEI used a 3.05-m (10-ft) glass-lined probe to preclude possible biases in Cr^{+6} and total Cr measurements that the use of a stainless-steel lined probe could cause. Previous test experience has shown that the use of glass-lined probes longer than 3.05 m (10 ft) results in excessive breakage and subsequent leakage problems.

The test and analytical procedures used are described briefly here, and detailed procedures are presented in Appendix D.

4.2.1 Velocity and Gas Temperature

A Type-S pitot tube and an inclined draft gauge manometer were used to measure the gas velocity pressures at the test sites. Velocity pressures were measured at each sampling point across the duct to determine an average value. Measurements were taken in the manner prescribed in Reference Method 2 of the Federal Register.^{*} The temperature at each sampling point was measured with a thermocouple and digital readout.

4.2.2 Molecular Weight

Flue gas composition was determined in accordance with the basic procedures described in Reference Method 3.^{*} Grab samples were collected prior to the start of any sampling to establish baseline contents of oxygen, carbon dioxide, and carbon monoxide. Integrated bag samples were collected during each test and were analyzed with an Orsat gas analyzer. The gas composition at each test site remained consistent throughout the test series.

4.2.3 Particulate/Cr⁺⁶ and Total Cr

Particulate, Cr⁺⁶, and total Cr samples were collected as specified in EPA Reference Method 5.^{*} All tests were conducted isokinetically by regulating the sample flow rate relative to the gas velocity in the duct (as measured by the pitot tube and thermocouple attached to the sample). The basic sampling train consisted of a heated glass-lined probe, a heated 7.6-cm (3-in.) diameter glass-fiber filter (Whatman Reeve Angel 934 AH), and a series of five Greenburg-Smith impingers followed by a vacuum line, vacuum gauge, leak-free vacuum pump, dry gas meter, thermometers, and a calibrated orifice.

For determination of particulate concentration, the nozzle, probe, and filter holder portions were rinsed with acetone at the end of each applicable

^{*} 40 CFR 60, Appendix A, Reference Methods 2, 3, and 5, July 1984.

test. The acetone rinse and particulate caught on the filter media were dried at room temperature, desiccated to a constant weight, and weighed on an analytical balance. Total filterable particulate matter was determined by adding these two values.

Upon completion of the gravimetric analysis, the sample fractions were prepared and analyzed for Cr^{+6} according to procedures recently developed by EPA. In summary, the samples were digested in an alkaline solution and analyzed by the diphenylcarbazide colorimetric method.* Selected samples were then shipped to EPA, where total chromium content of the samples was determined by NAA.

The volume of water collected in the impinger section of the sampling train(s) was measured at the end of each sample run to determine the moisture content of the flue gas. The contents of the impingers were transferred to a polyethylene container. The impingers and all connecting glassware, including the back half of the filter holder, were rinsed with distilled water and the rinse was added to the container. The impinger contents from Run PCI-1 were then analyzed for Cr^{+6} and later for total chromium by NAA. The remaining samples are being held in case EPA wishes further analysis.

4.3 PARTICLE SIZE DISTRIBUTION

Samples for particle-size distribution measurements were collected at the baghouse inlet and outlet by an Andersen HGLI. This in-stack impactor consists of two single-jet impaction chambers followed by a third-stage cyclone and a backup filter. The sampled gas stream enters the system

*Test Methods for Evaluating Solid Waste. U.S. Environmental Protection Agency, SW-846, 2nd ed., July 1982.

through the Stage 1 acceleration jet. Particles with sufficient inertia are impacted against the bottom of the Stage 1 impaction chamber. Smaller particles flow with the gas stream and exit the impaction chamber through three vent tubes.

Stage 2 of the HGLI is simply a scaled-down version of Stage 1 in which the jet nozzle diameter and the distance from jet exit to impaction surface have been designed for the proper Stage 2 cut-point.

Stage 3 of the HGLI is a small cyclone of the Southern Research Institute design. A high-efficiency glass-fiber filter removes all particles remaining in the gas stream downstream of the cyclone.

The Andersen HGLI was used at the inlet because of expected heavy particulate concentration, which would overload a standard multistage impactor. Although this impactor normally would not be used to extract samples from a baghouse outlet where particulate concentrations are low, it was used here because it contains no filter media (except the backup filter), which eliminates the need for filter blank corrections to Cr^{+6} and total chromium.

Three samples were collected at the baghouse inlet and four were collected at the baghouse outlet. The inlet samples were collected from a single point in the duct that was representative of the average velocity and temperature. These tests were run for 90 minutes. At the baghouse outlet, samples were collected from two different sampling ports and points, each of which represented the average gas velocity and temperature in the duct. The use of two sampling points was necessary to allow movement of the particulate/ Cr^{+6} sampling train, which was run concurrently with the particle size train. Test No. PS0-1 was conducted for 7 hours, and Tests PS0-2 through -4

were conducted for 10 hours each. Isokinetic sampling rates were set initially, and constant cut-point characteristics were maintained throughout the sampling period.

At the completion of each test, the impactor samples were recovered in accordance with procedures described in the HGLI operations manual.

Each recovered fraction was then subjected to a gravimetric analysis in accordance with EPA Reference Method 5 criteria. Size distribution curves representing the total weight percent of particulate matter smaller than the indicated aerodynamic particle diameter (in micrometers) were established for each run.

The three cut-points for each Andersen HGLI test were determined graphically from information supplied by the manufacturer. All particle size results are based on a particle density of 1 g/cm³. Data reduction and intermediate result calculations were performed by CIDRS programs with moisture contents and gas composition data obtained from the particulate/Cr⁺⁶ tests.*

Following the size distribution gravimetric analysis, individual stages from Test PSI-2 (inlet) were analyzed for Cr⁺⁶ in an effort to characterize the Cr⁺⁶ size distribution. The Cr⁺⁶ analysis for each individual stage was performed by the same procedures used in the analysis of the particulate/Cr⁺⁶ samples (Subsection 4.2 and Appendix D). Portions of each stage from this run were retained for total chromium analysis by NAA. Samples from individual stages of Runs PSO-1 through -3 (outlet) were composited and analyzed for

*Southern Research Institute. A Computer-Based Cascade Impactor Data Reduction System. Prepared for U.S. Environmental Protection Agency under Contract No. 68-022-131. March 1978.

Cr⁺⁶. The compositing of samples from individual stages was necessary to assure adequate sample weights for quantification of Cr⁺⁶. Samples from Run PSO-4 were retained for total chromium analysis by NAA.

Besides the Andersen HGLI size distribution tests, two additional tests were conducted at the baghouse outlet with a standard Andersen Mark III multistage impactor. Size distribution data from these runs were used to validate the HGLI size distribution data.

4.4 PROCESS SAMPLES

During the particulate/chromium tests, the following process samples were collected:

- ° Coal
- ° Boiler bottom ash
- ° Baghouse hopper ash

Grab samples of each test were collected every 60 to 90 minutes or four to six times during a 6-hour test run. The grab samples from each test were composited so that one representative sample of each sample type per test was available for analysis. Solid samples were extracted and analyzed for Cr⁺⁶ in accordance with procedures similar to those used for the Cr⁺⁶ analysis of the particulate samples. The analyses of the boiler bottom ash and baghouse hopper catch were relatively straightforward and no problems were encountered. Coal samples were "ashed" in a muffle furnace at 900°C prior to their analysis to eliminate interference from organic material in the coal sample. When raw coal samples were extracted, a dark brown solution was generated that could not be analyzed by the colorimetric Cr⁺⁶ procedure. A weighed quantity of raw coal was placed in a muffle furnace and heated to 900°C in an effort to eliminate the organic interferent. The remaining coal "ash" was

then analyzed for Cr^{+6} content. Composite process samples were also analyzed for total Cr content.

4.5 ARSENIC

Arsenic concentrations were measured by EPA Reference Method 108.* All tests were conducted isokinetically by regulating the sample flow rate to correspond to the gas velocity in the duct (as measured by the pitot tube and thermocouple attached to the sample probe). The basic sampling train consisted of a heated glass-lined probe, a heated 7.6-cm (3-in.) diameter glass-fiber filter (Whatman Reeve Angel 934 AH), and a series of five Greenburg-Smith impingers followed by a vacuum line, vacuum gauge, leak-free vacuum pump, dry gas meter, thermometers, and a calibrated orifice.

For determination of arsenic concentrations, the nozzle, probe, and filter holder portions were rinsed with 0.1 N NaOH at the end of each applicable test.

The filter and solids contained in the 0.1 N NaOH rinse of the front half of the sampling train were prepped, combined, and analyzed for arsenic (by atomic absorption).

The volume of water collected in the impinger section of the sampling train was measured at the end of each sampling run to determine the moisture content of the flue gas. The contents of the impingers were transferred to a polyethylene container. The impingers and all connecting glassware (including the back half of the filter holder) were rinsed with 0.1 N NaOH, and the rinse was added to the container. The contents of the impingers and 0.1 N NaOH rinse also were analyzed for arsenic by atomic absorption.

* 40 CFR 61, Appendix B, Reference Method 108, July 1984.

SECTION 5

PROCESS DESCRIPTION

The following source description and summary of process data were prepared by Midwest Research Institute (MRI), the EPA New Source Performance Standard (NSPS) contractor. Personnel from MRI were on site during the test program to monitor and record all pertinent boiler and baghouse operational data.

During the period from March 18-21, 1985, source emission tests were conducted on Boiler 4 at the Adolph Coors Company plant in Golden, Colorado. The tests were conducted by a five-person crew, headed by Chuck Bruffey, from PEI Associates. Dennis Holzschuh of the Emission Measurement Branch was present during the testing to observe emission testing procedures. The process was monitored by Dwight Atkinson from MRI. Paul Adams of the Adolph Coors Company coordinated testing with plant personnel.

5.1 PROCESS DESCRIPTION/SAMPLING PROGRAM

Boiler 4 is a tangentially-fired, vertical, upright unit manufactured by Combustion Engineering and installed in 1976. It has a rated capacity of 91.1 megawatts (311×10^6 Btu/h) and can produce 113,000 kilograms of steam per hour (250,000 pounds per hour). It operates on a base-load basis at approximately 80 percent of capacity, 24 hours per day, 7 days per week.

Coal for Boiler 4 typically comes from a Coors-owned mine in Keenesburg, Colorado. It has a maximum sulfur content of 0.4 percent and a typical ash content of 10 percent.

Particulate emissions are controlled by a baghouse manufactured by Wheelabrator-Frye. Design and operating characteristics of the baghouse are given in Table 5-1.

Table 5-2 outlines the tests conducted on Boiler 4. All tests were conducted when the boiler was operating at approximately 80 percent of capacity.

5.2 PROCESS CONDITIONS DURING TESTING

All processes were operated normally during emission testing. The following parameters were recorded every 15 minutes during testing: feed water flow, superheater temperature, drum pressure, economizer temperature, percent excess oxygen, volumetric air flow to boiler, steam flow, steam temperature, baghouse pressure drop, baghouse inlet gas temperature, SO₂ concentration, NO concentration, stack gas opacity, mill amperage, mill exhaust temperature, and coal feed rate. The SO₂ and NO concentrations were read from a Lear Siegler Model SM 810. The opacity monitor was a Lear Siegler Model RM-41. Tables 5-3 through 5-6 present results of the above observations.

Testing was halted twice during the four runs, both times during Run 2. On the first occasion, the inlet and outlet Method 5 trains were stopped 30 minutes into the run due to a ruptured filter disk on the inlet train. The filter disk was replaced, and testing was resumed in 31 minutes. On the second occasion, a temporary outage by the local power company tripped Boiler 4 and resulted in its being down for approximately 2 hours and 20 minutes. Testing was resumed when normal operation was reestablished after a total elapsed time of 3 hours and 12 minutes.

TABLE 5-1. BAGHOUSE DESIGN AND OPERATING CHARACTERISTICS

Boiler No.	4
Baghouse manufacturer	Wheelabrator-Frye
No. of compartments	8
No. of bags per compartment	180
Air-to-cloth ratio	2.6:1
Bag size, ft x ft	0.6 x 22
Bag material	Woven glass ^a
Cleaning method	Reverse air/shake ^b
Pressure drop, in. of water	4 to 8

^aCoated with silicon graphite.

^bOff-line cleaning. On-line cleaning by low pressure drop, 7.5 psig, pulse jet.

TABLE 5-2. SUMMARY OF TESTS CONDUCTED ON BOILER 4,
ADOLPH COORS COMPANY, GOLDEN, COLORADO^a

Sampling point	Test type	Test Method	Number per run
Baghouse inlet	Particulate concentration	EPA Method 5	1
	Particle size	Andersen HGLI ^b	1
Baghouse outlet	Particulate concentration	EPA Method 5	1
	Particle size	Andersen HGLI	1
	Particle size	Andersen Mark III	2 ^c
Outside observation point	Visible emissions	EPA Method 9	~4 ^d
Coal bin	Coal sample	Grab	~6
Bottom ash hopper	Bottom ash	Grab	~6
Baghouse dust hopper	Fly ash	Grab	~6

^aTests consisted of four runs, one each day on 3/18, 3/19, 3/20, and 3/21/ Method 5 samples on the fourth day were gathered for arsenic analyses, all other samples to be analyzed for particulate, total chromium, chromium⁺⁶, and cadmium.

^bHGLI = heavy grain loading impactor.

^cConducted during day 4, March 21, only.

^dEach observation period was 6 minutes in duration. These data were collected to support transmissometer data.

TABLE 5-3. PROCESS DATA FOR RUN 1--ADOLPH COORS COMPANY, BOILER 4, MARCH 18, 1985

Time	Feed- water flow gpm	Super heater temp., °F	Drum pres. psi	Econo- mizer temp., °F	Percent excess O ₂ , %	Air- flow to boiler, x1,000 acfm	Steam flow, x1,000 lb/h	Steam temp., °F	Bag- house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag- house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
8:45	460	807	870	220	1.9	118	200	827	7.2	280	160	4	290	27 24	125 123	16 18
9:25	500	803	870	220	1.7	118	205	825	7.3	275	160	1	290	28 24	125 124	16.3 18.3
9:25	start outlet M5 and Andersen and inlet M5															
9:40	500	803	870	220	1.9	118	200	825	8.4	270	160	1.5	290	28 24	125 124	16.3 18.3
9:55	500	802	875	225	2.3	120	205	825	8.2	260	160	2	290	28 24	125 124	16.3 18.3
10:10	500	805	867	220	2.1	120	200	825	8.2	270	165	2	290	28 24	125 125	16.3 18.3
10:25	500	803	870	220	2.1	120	205	825	7.7	265	165	2.5	290	28 24	126 125	16.3 18.3
10:40	490	805	870	220	2.1	122	205	825	8.4	275	165	1.5	285	28 24	126 125	16.3 18.3
10:55	500	805	870	220	2.2	122	205	825	8.0	260	165	1	290	28 24	126 125	16.3 18.3
11:00	soot blowing started															
11:10	500	797	870	220	2.3	122	205	820	9.0	250	165	4	290	28 24	125 124	16.3 18.3
11:25	480	809	870	220	2.2	122	205	825	9.1	260	165	3	290	28 24	125 124	16.3 18.3
11:40	480	804	870	218	2.1	122	200	830	8.6	255	165	4	285	28 24	124 123	16.3 18.3
11:55	500	799	875	218	2.2	122	205	820	9.0	260	165	4	285	28 24	124 123	16.3 18.3
12:10	485	804	875	212	2.2	122	207	825	7.5	240	170	2	285	28 24	123 122	16.3 18.3
12:18	finished soot blowing															
12:25	500	802	875	210	2.1	120	205	825	8.4	250	165	2.5	280	28 24	123 122	16.3 18.3
12:40	500	803	870	212	2.2	122	205	825	7.1	245	165	1	280	28 24	123 122	16.3 18.3
12:55	500	807	875	212	2.6	120	205	830	8.8	240	165	2	285	28 24	123 122	16.3 18.3
1:10	500	810	870	212	2.8	122	205	830	8.0	260	165	2	280	28 24	123 123	16.3 18.3
1:25	490	815	870	215	2.8	120	205	830	8.7	240	170	2.5	285	28 24	124 123	16.3 18.3
1:40	490	803	870	215	2.0	120	207	825	6.6	260	165	3	280	28 24	124 123	16.5 18.3
1:55	500	806	870	215	1.9	120	207	825	7.0	260	165	1	280	28 24	124 123	16.3 18.3

(continued)

TABLE 5-3. (continued)

Time	Feed-water flow gpm	Super heater temp., °F	Drum pres. psi	Econo-mizer temp., °F	Percent excess O ₂ , %	Air-flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag-house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag-house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
2:10	490	806	870	218	1.9	120	207	825	7.5	250	165	1	280	28 24	124 123	16.3 18.3
2:25	500	806	870	218	1.7	120	207	825	8.0	260	165	1	285	28 24	124 123	16.3 18.3
2:40	510	804	870	220	1.8	120	210	825	6.8	245	165	1	280	28 24	124 123	16.3 18.3
2:55	480	807	870	220	2.0	120	205	825	7.2	250	165	1	280	28 24	124 123	16.3 18.3
3:10	500	807	870	220	1.8	120	210	827	7.6	250	165	1	285	28 24	124 123	16.3 18.3
3:25	465	805	870	220	1.8	120	210	827	7.3	250	165	2	285	28 24	124 123	16.3 18.3
3:40	480	805	870	220	1.8	120	210	827	7.0	240	165	1	285	28 24	124 124	16.3 18.3
3:40	stop M5 inlet and outlet (test ended)															
3:55	490	806	870	220	1.9	120	205	825	7.4	265	165	1	285	28 24	124 124	16.3 18.3
4:10	start Andersen on inlet															
4:10	500	803	870	222	1.9	122	207	825	8.4	260	165	2	285	28 24	124 124	16.5 18.3
4:25	490	804	865	220	1.8	120	210	825	8.0	250	165	2	285	28 24	124 124	16.5 18.3
4:40	500	803	875	222	1.7	120	210	825	7.1	250	165	1	290	28 24	125 124	16.5 18.3
4:55	500	805	875	222	1.7	120	210	825	7.6	250	165	1	290	28 24	124 124	16.5 18.3
5:10	490	801	870	225	2.6	120	200	825	8.1	230	165	2	290	27 23	126 125	15.3 18.3
5:15	outlet Andersen stopped - test ended															
5:25	490	805	870	225	2.5	122	200	825	6.8	240	170	1	290	27 23	126 125	15.3 18.0
5:40	inlet Andersen stopped - test ended															
5:40	490	807	870	222	2.4	120	200	828	7.2	230	170	1	290	27 23	126 125	15.3 18.0

TABLE 5-4. PROCESS DATA FOR RUN 2--ADOLPH COORS COMPANY, BOILER 4, MARCH 19, 1985

Time	Feed- water flow gpm	Super heater temp., °F	Drum pres. psi	Econo- mizer temp., °F	Percent excess O ₂ , %	Air- flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag- house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag- house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
7:15	start Andersen outlet															
7:15	490	807	890	220	2.1	120	200	830	7.1	260	170	1	290	27 23	126 124	15.3 18.3
7:30	500	795	870	222	3.5	120	180	820	8.0	260	170	1	290	26 22	128 126	14.3 17.3
7:45	485	801	865	222	3.6	118	180	820	7.6	240	170	2	290	26 23	127 125	14.8 17.3
8:00	470	808	865	220	2.7	118	195	828	7.0	265	170	1	290	27 23	126 125	15.8 18.3
8:10	start M5 inlet and outlet															
8:15	460	814	870	220	2.4	122	195	825	8.7	255	170	2	290	27 24	126 125	15.8 18.3
8:30	480	803	865	220	2.4	118	195	825	7.8	255	180	2.5	290	27 23	126 125	15.8 18.3
8:40	stop testing (inlet and outlet M5) due to inlet sampling train failure (ruptured filter holder) (outlet Andersen kept running)															
8:45	460	808	870	220	2.4	120	202	828	7.0	260	170	2	290	27 23	127 125	15.8 18.3
9:00	480	806	860	220	2.5	120	198	830	8.3	250	170	1.5	290	27 23	126 125	15.8 18.3
9:11	restart inlet and outlet M5															
9:15	460	811	865	222	2.5	118	200	830	7.8	250	170	2	290	27 23	126 125	15.8 18.3
9:30	490	802	865	222	2.4	118	200	825	7.0	270	170	2	290	27 23	126 125	15.8 18.3
9:45	490	806	870	220	2.5	118	200	825	8.0	250	170	3	290	27 23	126 125	15.8 18.3
10:00	480	807	870	220	2.3	120	200	825	6.8	250	170	2	290	27 23	126 125	15.8 18.3
10:15	470	807	875	222	2.2	120	200	825	7.4	250	170	1.5	290	27 23	127 125	15.8 18.3
10:30	480	809	880	220	2.2	120	202	828	7.5	260	170	2	290	27 23	127 125	15.8 18.3
10:45	480	808	865	220	2.5	120	200	825	6.8	265	170	3	290	27 23	127 125	15.8 18.3
11:00	480	811	865	220	2.3	118	200	830	7.3	250	170	1.5	290	27 23	127 126	15.8 18.3
11:15	460	807	875	220	2.4	118	200	828	7.9	250	170	2	290	27 23	127 125	15.8 18.3
11:25	started soot blowing															

(continued)

TABLE 5-4. (continued)

Time	Feed- water flow gpm	Super heater temp., °F	Drum pres. psi	Econo- mizer temp., °F	Percent excess O ₂ , %	Air- flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag- house HP, in. H ₂ O	SO ₂ , ppm	NO _x , ppm	Opacity, %	Bag- house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
11:30	Inlet Andersen begins															
11:30	480	804	870	220	2.1	122	205	822	7.1	265	170	5	290	27 23	127 125	15.8 18.3
11:45	480	806	870	218	2.3	120	200	825	8.8	265	170	6.5	290	27 24	126 125	15.8 18.3
12:00	460	803	870	218	2.3	118	200	830	8.4	260	170	5	290	27 23	125 124	15.8 18.3
12:15	470	807	868	208	2.2	120	195	830	8.0	250	170	3	285	27 23	125 123	15.8 18.3
12:30	480	802	868	205	2.5	120	195	825	7.1	250	170	3	285	27 23	124 123	15.8 18.3
12:40	stopped soot blowing															
12:45	470	804	865	205	2.6	118	200	825	8.2	265	170	2	285	27 23	124 122	15.8 18.3
1:00	Inlet Andersen ended															
1:00	500	799	865	208	2.9	120	200	820	6.8	265	170	1	285	27 23	124 123	15.8 18.3
1:15	490	805	870	218	3.4	122	200	825	7.3	260	170	2	285	27 23	124 123	15.8 18.3
1:18	Boiler down due to power outage at Public Service Plant - Comanche Plant. All testing stopped.															
3:40	Boiler back up on gas/coal															
3:55	Boiler running on all coal															
4:15	490	802	870	218	2.7	122	195	825	6.9	not functioning properly			285	27 24	121 120	15.8 18.0
4:30	resume test															
4:30	485	804	865	215	2.7	210	198	825	7.3	not functioning properly			285	27 23	122 121	15.8 18.2
4:45	470	805	870	212	2.7	120	195	825	8.0	not functioning properly			285	27 23	123 121	15.8 18.2
5:00	480	805	870	212	2.5	120	200	825	7.6	not functioning properly			285	27 23	123 122	15.8 18.2
5:15	480	801	870	215	2.6	122	195	825	8.7	not functioning properly			285	27 23	123 122	15.8 18.1
5:30	475	807	870	215	2.6	122	200	825	7.5	not functioning properly			285	27 23	123 122	15.8 18.1
5:39	Inlet M5 ended															
5:45	470	811	870	215	2.5	120	195	825	7.1	not functioning properly			285	27 23	124 123	15.8 18.1

(continued)

TABLE 5-4. (continued)

Time	Feed- water flow gpm	Super heater temp., °F	Drum pres. psi	Econo- mizer temp., °F	Percent excess O ₂ , %	Air- flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag- house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag- house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B			
6:00	475	803	870	218	2.7	120	198	825	8.1	not functioning properly			285	27	23	124	123	15.8	18.1
6:02	outlet M5 ended																		
6:15	475	809	865	218	2.9	122	195	825	7.7	not functioning properly			285	27	23	124	123	15.8	18.1
6:30	480	804	870	218	2.7	122	200	825	7.1	not functioning properly			285	27	23	124	123	15.8	18.1
6:30	outlet Andersen ended																		

TABLE 5-5. PROCESS DATA FOR RUN 3--ADOLPH COORS COMPANY, BOILER 4, MARCH 20, 1985

Time	Feed- water flow gpm	Super heater temp., °F	Drum pres. psi	Econo- mizer temp., °F	Percent excess O ₂ , %	Air- flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag- house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag- house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
7:53	start Andersen outlet															
8:00	460	819	870	220	2.7	124	205	840	7.5	260	170	1	285	27 24	122 122	15.8 18.3
8:15	500	820	870	220	2.8	122	205	825	8.5	260	170	3	285	27 24	124 123	15.8 18.3
8:20	start M5 outlet/inlet															
8:30	470	820	870	222	3.0	120	200	840	8.9	240	170	1	290	27 24	124 123	15.8 18.3
8:45	470	823	870	225	3.1	124	202	840	8.5	250	170	2	285	27 24	124 123	15.8 18.4
9:00	490	822	870	225	3.2	124	202	838	7.3	260	170	1	290	27 24	125 124	15.8 18.4
9:15	480	821	870	225	3.1	124	200	838	8.4	260	170	2	290	27 24	125 124	15.8 18.4
9:30	470	818	870	228	2.9	124	200	835	7.2	250	170	1	285	27 24	125 124	15.8 18.4
9:45	490	821	870	228	3.1	124	200	840	8.3	255	170	3	290	27 24	125 124	15.8 18.4
10:00	490	819	870	228	3.2	124	200	835	7.2	250	170	1.5	290	27 24	125 124	16.0 18.4
10:15	480	822	870	228	3.1	124	200	835	7.7	230	175	3	290	27 24	126 124	16.0 18.4
10:30	490	817	865	228	3.1	124	200	835	8.4	260	170	2.5	290	27 24	126 124	16.0 18.4
10:45	490	821	875	230	2.9	124	205	835	7.5	270	170	4	290	27 24	126 124	16.0 18.4
11:00	460	827	870	230	2.8	124	205	840	8.2	260	175	3	290	27 24	126 124	16.0 18.4
11:05	start Andersen on inlet															
11:15	500	815	870	230	2.9	124	205	830	7.5	260	170	2	290	27 24	126 125	16.0 18.4
11:30	470	823	870	228	2.9	124	200	840	9.1	235	170	2.5	290	27 24	126 125	16.0 18.4
11:45	490	819	865	228	2.8	124	202	840	7.4	260	170	2	290	27 24	126 125	16.0 18.4
12:00	460	823	870	230	3.1	124	200	840	8.5	260	180	0	290	27 24	126 125	16.0 18.4
12:15	490	821	875	232	3.0	124	200	840	7.4	250	170	2	295	27 24	126 125	16.0 18.4
12:30	480	814	865	232	3.3	124	198	835	8.5	255	170	0	290	27 24	126 125	16.0 18.4
12:35	inlet Andersen ended															

(continued)

TABLE 5-5. (continued)

Time	Feed-water flow gpm	Super heater temp., °F	Drum pres. psl	Econo- mizer temp., °F	Percent excess O ₂ , %	Air-flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag-house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag-house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
12:45	470	820	870	232	3.0	124	205	840	7.4	265	170	2	285	27 24	127 125	16.0 18.4
12:50	start soot blowing															
1:00	490	825	870	230	3.0	124	200	840	8.7	260	170	4	290	27 24	126 125	16.0 18.4
1:15	480	826	865	230	2.9	124	200	840	9.1	255	170	4.5	295	27 24	125 124	16.0 18.4
1:30	470	818	865	228	2.7	124	205	835	8.5	250	170	4.5	290	27 24	125 124	16.0 18.4
1:45	480	818	875	222	2.8	124	205	835	8.5	250	170	2.5	285	27 24	124 123	16.0 18.4
2:00	finished soot blowing															
2:00	490	818	870	222	3.1	124	200	835	8.6	235	170	6	285	27 24	124 123	16.0 18.4
2:05	inlet M5 ended															
2:15	440	823	880	222	3.2	124	205	835	8.6	250	170	3	285	27 24	124 122	16.0 18.4
2:30	500	818	870	222	3.9	124	200	835	8.8	250	170	6	290	27 24	124 123	16.0 18.4
2:35	outlet M5 ended															
2:45	490	818	865	228	4.0	124	200	835	8.4	245	190	5	285	27 24	125 123	16.0 18.4
3:00	470	818	875	228	3.2	124	202	835	8.0	250	175	2	285	27 24	124 123	16.0 18.4
3:15	470	818	870	225	3.3	125	198	835	8.2	250	175	3	290	27 23	124 123	16.0 18.4
3:30	490	816	870	225	3.1	125	202	835	7.7	250	170	3	285	28 24	124 122	16.0 18.4
3:45	475	818	870	228	3.2	124	198	835	8.5	245	180	3	285	28 24	125 123	16.0 18.4
4:00	480	819	875	225	3.0	124	200	840	8.5	255	170	3	285	28 24	125 123	16.0 18.4
4:15	490	816	870	225	3.2	124	200	840	7.8	240	170	3	290	28 24	124 122	16.0 18.4
4:30	475	816	870	228	3.0	124	202	835	7.2	250	170	4	290	28 24	124 122	16.0 18.4
4:45	470	821	870	230	3.1	124	200	840	8.4	250	170	4	290	27 24	124 123	16.0 18.4
5:00	480	813	870	228	3.2	124	200	830	8.0	220	170	3	285	27 24	124 123	16.0 18.4
5:15	450	824	870	222	3.2	124	200	840	7.4	250	170	4	285	28 24	124 123	16.1 18.4

(continued)

TABLE 5-5. (continued)

Time	Feed- water flow gpm	Super heater temp., °F	Drum pres. psi	Econo- mizer temp., °F	Percent excess O ₂ , %	Air- flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag- house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag- house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
5:30	470	821	865	222	2.9	124	200	835	8.3	245	170	3	285	28 24	124 123	16.1 18.4
5:45	490	817	870	222	3.0	124	200	835	7.1	260	170	3	285	28 24	125 123	16.2 18.4
5:55	end Andersen outlet															

TABLE 5-6. PROCESS DATA FOR RUN 4--ADOLPH COORS COMPANY, BOILER 4, MARCH 21, 1985

Time	Feed-water flow gpm	Super heater temp., °F	Drum pres. psi	Econo-mizer temp., °F	Percent excess O ₂ , %	Air-flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag-house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag-house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
8:15	begin Andersen outlet Note: A Mill running Keenesburg coal and B Mill running Colowyo coal (see Attachments 1 and 2).															
8:15	530	808	870	220	3.0	120	200	830	7.3	230	170	2	290	25 22	127 136	13.3 16.9
8:30	500	806	870	220	3.0	119	200	830	7.0	220	170	2	295	25 22	127 136	13.5 16.3
8:45	460	819	870	218	2.8	120	200	835	7.3	250	170	2	290	25 22	128 136	13.5 16.3
8:50	begin outlet and inlet M5															
9:00	470	820	865	215	3.1	120	200	840	8.3	225	170	3	280	25 22	128 134	13.5 16.3
9:15	500	815	870	218	2.9	120	200	835	6.9	260	170	2.5	285	25 22	128 134	13.8 16.3
9:30	470	817	865	218	3.0	120	198	835	7.3	250	170	2	290	25 22	128 133	13.8 16.5
9:45	460	821	870	218	3.0	120	195	835	8.2	245	170	2.5	290	25 22	128 132	13.8 16.4
10:00	480	822	870	218	2.6	118	200	835	7.0	250	170	2	295	25 22	128 131	14.3 16.7
10:15	450	823	870	218	2.6	118	198	835	8.6	250	170	3	295	25 22	128 130	14.3 16.8
10:30	490	814	865	218	2.7	120	200	835	7.1	255	170	3	290	25 23	128 130	14.3 16.8
10:45	480	818	870	218	2.7	120	200	835	7.0	260	170	2	295	26 23	127 130	14.3 16.8
11:00	460	821	870	220	2.7	120	200	835	8.7	260	170	3.5	295	26 23	127 129	14.3 16.8
11:15	480	816	870	220	2.8	120	200	835	8.2	260	170	3	300	26 23	128 129	14.4 17.0
11:30	480	814	870	220	2.9	120	200	835	8.2	245	170	3	295	26 23	127 129	14.4 17.0
11:45	460	814	865	220	3.1	120	195	835	7.9	245	170	3	295	26 23	128 129	14.4 17.0
12:00	460	815	870	222	3.0	120	195	835	7.0	240	170	2	295	26 23	127 127	14.4 17.0
12:00	end inlet and outlet M5 essentially all Colowyo coal burned															
12:15	430	823	870	225	3.2	120	195	840	7.0	235	170	1	295	26 23	127 127	14.5 17.0
12:20	begin Andersen on inlet															
12:30	460	813	870	228	3.2	122	192	840	7.2	270	170	3	295	26 23	128 128	14.5 17.0

(continued)

TABLE 5-6. (continued)

Time	Feed- water flow gpm	Super heater temp., °F	Drum pres. psi	Econo- mizer temp., °F	Percent excess O ₂ , %	Air- flow to boiler, x1,000 acfm	Steam flow x1,000 lb/h	Steam temp., °F	Bag- house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag- house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, x1,000 lb/h A B
12:30	soot blowing begins															
12:45	460	810	865	222	3.4	122	187	830	7.8	260	170	3	295	26 23	127 127	14.5 17.0
1:00	450	808	870	222	3.0	122	195	830	8.5	250	170	5	295	26 23	126 125	15.2 17.6
1:15	480	818	875	222	3.2	124	200	840	9.2	225	170	8	295	27 23	125 124	15.2 17.6
1:30	480	816	865	220	3.2	124	195	835	8.6	250	175	7	295	27 23	125 123	15.2 17.6
1:45	440	814	870	220	3.8	124	198	835	8.7	240	170	8	285	27 23	124 123	15.2 17.6
1:48	soot blowing ends															
1:50	end Andersen on Inlet															
2:00	480	818	865	220	4.5	122	195	835	8.3	245	190	5	285	27 23	124 123	15.2 17.6
2:15	460	812	870	222	3.5	124	198	830	8.2	250	180	2	280	27 23	124 122	15.5 17.6
2:15 - 3:15	first Mark 3-Andersen on outlet															
2:30	460	816	870	222	3.5	122	198	835	8.0	240	190	6	280	27 23	124 122	15.2 17.6
2:45	450	817	870	220	3.5	124	195	835	8.0	240	180	5	280	27 23	124 122	15.3 17.6
3:00	460	813	870	220	3.2	124	200	835	7.2	220	190	2	280	27 23	124 122	15.6 17.6
3:15	450	818	865	220	3.3	124	195	835	8.2	215	170	3	280	27 23	124 122	15.5 17.6
3:30	480	817	870	222	3.2	124	195	835	8.3	250	170	1	285	27 23	124 122	15.5 17.6
3:45	450	818	875	225	3.1	125	200	835	8.4	220	170	2	285	27 23	125 122	15.5 17.6
4:00	470	816	870	225	3.3	125	195	835	8.3	245	170	1	285	27 23	125 122	15.4 17.6
4:15	460	819	870	225	3.2	123	195	835	8.2	240	170	2.5	285	27 23	125 123	15.4 17.6
4:30	460	813	865	228	3.3	123	195	835	7.1	260	170	1	285	27 23	125 123	15.4 17.6
4:35 - 5:05	second Mark 3-Andersen on outlet															
4:45	470	816	870	228	3.3	123	197	835	8.1	250	170	2.5	285	27 23	125 123	15.4 17.6

(continued)

TABLE 5-6. (continued)

Time	Feed- water flow gpm	Super heater temp., °F	Drum pres. psi	Econo- mizer temp., °F	Percent excess O ₂ , %	Air- flow to boiler, xl,000 acfm	Steam flow xl,000 lb/h	Steam temp., °F	Bag- house ΔP, in. H ₂ O	SO ₂ , ppm	NO, ppm	Opacity, %	Bag- house inlet stack gas temp., °F	Mill current, amps A B	Mill exhaust temp., °F A B	Coal feed rate, xl,000 lb/h A B
5:00	460	820	870	228	3.2	123	198	835	7.2	240	180	1	285	27 23	125 123	15.4 17.6
5:15	470	815	870	230	3.3	123	198	835	8.2	235	170	3	285	27 23	125 123	15.4 17.6
5:30	480	816	865	225	3.3	124	195	835	8.2	235	170	2	285	27 23	125 123	15.4 17.6
5:45	450	819	870	228	3.3	124	195	835	8.2	260	175	2	285	27 23	126 124	15.4 17.6
6:00	450	815	870	230	3.4	123	195	835	8.0	250	180	2	285	27 23	126 125	15.5 17.6
6:15	end Andersen on outlet															

During Runs 1 through 3, Boiler 4 operated entirely on coal mined from Coors' Kennesburg Mine. During the first 4 hours of Run 4, coal supplied to Boiler 4 via the B mill was from a different mine operated by Colowyo Coal Company. A mill coal for the entire run and B mill coal for the remainder of the run came from the Keenesburg Mine. Samples of the coal from the two mills were segregated during Run 4. Figure 5-1 presents results of coal analytical data performed on March 15, 1985.

5.3 CONCLUSIONS

Personnel at the Adolph Coors Company were very cooperative. Boiler 4 and its baghouse operated normally during emission testing.



Hazen Research, Inc.
4601 Indiana St. • Golden, Colo. 80403
Tel: (303) 279-4501 • Telex 45-860

DATE March 15 1985
HRI PROJECT 009-18
HRI SERIES NO. 29716-1
DATE RECD 3/7/85
CUST P.O.# CE-01609-K

REPORT OF ANALYSIS
Coors Energy Company
Nancy Hawkins
Post Office Box 467
Golden Colorado 80402-0467

SAMPLE IDENTIFICATION:
Keenesburg
2/25-3/3/85
-

REPORTING BASIS >	AS RECD	DRY	EQM	AIR DRY
----------------------	---------	-----	-----	---------

PROXIMATE (%)

MOISTURE	29.38	0.00		18.10
ASH	11.33	16.04		13.14
VOLATILE				
FIXED C				

TOTAL

SULFUR	0.41	0.59		0.48
BTU/LB	7572	10722		8781
NMF BTU/LB		12984		
MAF BTU/LB		12771		
AIR DRY LOSS (%)		13.77		

ULTIMATE (%)

MOISTURE
CARBON
HYDROGEN
NITROGEN
SULFUR
ASH
OXYGEN*

TOTAL
CHLORINE**

FORMS OF SULFUR (AS S,%)

SULFATE
PYRITIC
ORGANIC

TOTAL	0.41	0.59
-------	------	------

HGI= e % MOISTURE
AS REC'D SP. GR. (G/CC)
FREE SWELLING INDEX

REPORT PREPARED BY:

WATER SOLUBLE ALKALIES (%)

NA2O
K2O

JUDITH H. FIFE
COAL LABORATORY MANAGER

* OXYGEN BY DIFFERENCE.

** NOT USUALLY REPORTED AS PART OF THE ULTIMATE ANALYSIS

Figure 5-1. Coal analytical data.

COLOWYO COAL COMPANY

PLEASE ADDRESS ALL CORRESPONDENCE TO:

QUALITY CONTROL LABORATORY
COLOWYO COAL COMPANY
5731 STATE HIGHWAY 13
MEEKER, COLORADO 81641
(303) 824-4451

TO: COORS ENERGY COMPANY
P.O. BOX 467
GOLDEN, COLORADO 80402
ATTN: NANCY HAWKINS

DATE: 30685

SAMPLE DESCRIPTION:
COORS - STOKER
16
8 CARS
SHIPPED 30485

DATE SAMPLED: 30485 BY: LOSHBAUGH

RECEIVED BY LAB: 30585

LAB SAMPLE NUMBER: 850305.01

SHORT PROXIMATE ANALYSIS

	AS RECEIVED	DRY BASIS	DRY ASH FREE
%MOISTURE	16.26	XXXXXXXXXX	XXXXXXXXXXXXXX
%ASH	3.03	3.62	XXXXXXXXXXXXXX
%SULFUR	.46	.55	XXXXXXXXXXXXXX
BTU/LB	11015.	13154.	13648.

OTHER

AIR DRY LOSS 9.88%
POUNDS SO2 PER MILLION BTU .84

DON PINGS
CHIEF CHEMIST BY: LL

DISTRIBUTION: 1.CUSTOMER 2.TRAFFIC 3.ACCOUNTING
4.PRODUCTION 5.ENGINEERING 6.LABORATORY

Figure 5-1 (continued)