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RESULTS OF EMISSIONS TESTING WHILE
BURNING DENSIFIED REFUSE DERIVED FUEL
DORDT COLLEGE, SIOUX CENTER, IOWA

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Prepared for:

Council of Great Lakes Governors
Regional Biomass Energy Program
310 South Michigan Avenue
Chicago, Illinois 60604

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Prepared by:

Pacific Environmental Services, Inc.
4700 Duke Dr., Suite 150
Mason, Ohio 45040
(513)398-2556
Fax (513)398-3342

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SECTION 1

INTRODUCTION

Pacific Environmental Services, Inc. provided engineering and source testing services to the Council of Great Lakes Governors to support their efforts in promoting the development and utilization of densified refuse derived fuels (d-RDF) and pelletized wastepaper fuels in small steam generating facilities. The emissions monitoring program was designed to provide a complete air emissions profile while burning various refuse derived fuels.

The specific goal of this test program was to conduct air emissions tests at Dordt College located in Sioux Center, Iowa and to identify a relationship between fuel types and emission characteristics. Participants in the test program included: The Council of Great Lakes Governors located in Madison, Wisconsin; Dordt College located in Sioux Center, Iowa; Bio-Mass Energy located in Sioux Center, Iowa; Pacific Environmental Services, Inc. (PES) located in Mason, Ohio; Lundell Manufacturing, Inc. of Cherokee, Iowa and Waste Resource Recovery of Iowa Falls, Iowa.

The Council of Great Lakes Governors was represented by Mr. Fred Kuzel. Mr. Bernard Dewitt of Dordt College and Mr. Norlyn Van Beek of Bio-Mass Energy were present during the testing. Dordt College provided the site for the test burn and Bio-Mass Energy provided the fuel. The PES test team was under the technical direction of Mr. John Chehaske, Mr. Frank Meadows and Ms. Helen Owens coordinated the boiler operation with the testing activities. Ms. Helen Yoest was the designated QA/QC specialist and also performed on-site data reduction. Mr. David Wetmore, Mr. Timothy Miller and Mr. Bruce Gerber were responsible for conducting the sampling activities. Lundell Manufacturing, Inc. and Waste Resource Recovery provided shipment of fuel, but neither company was represented at the test site.

The sampling protocol was carried out June 12 through June 20, 1989 on boiler #4. This unit had been previously modified to burn d-RDF. The boiler was not equipped with any type of air pollution control device so the emissions samples were collected from the boiler exhaust stack on the roof of the boilerhouse. The emissions that were sampled included: particulate; PM_{10} particulates; hydrochloric acid; dioxins; furans; polychlorinated biphenyls (PCB); metals and continuous monitors for CO , CO_2 , O_2 , SO_x , NO_x and total hydrocarbons. Grab samples of the fuels were collected, composited and analyzed for heating value, moisture content, proximate and ultimate analysis, ash fusion

temperature, bulk density and elemental ash analysis. Grab samples of the boiler ash were also collected and analyzed for total hydrocarbons, total dioxins, total furans, total PCBs and heavy metals. Figures 1-1 through 1-9 present Gantt Charts which illustrate the approximate period of time that each parameter was measured under each condition.

During the field test it was necessary to deviate from the test plan as it was submitted to the Council. The changes to the test plan concerned the sampling methods for particulate, chlorides and metals. The specifics of these particular sampling procedures are presented later in this report.

The remainder of this report provides a summary of test results which are presented in Section 2, a description of the process and its operation during the test is presented in Section 3. Section 4 discusses the sampling locations, Section 5 discusses the sampling and analytical procedures and the Quality Assurance/Quality Control procedures are present in Section 6. All field data sheets, process data, test methodologies and other support data are presented in the Appendices.

* Estimated start time

Figure 1-1. Gantt Chart Illustrating Sample Times
Condition 1; Pelletized Municipal Refuse
Run A; June 14, 1989

Figure 1-2. Gantt Chart Illustrating Sampling Times
Condition 1; Pelletized Municipal Refuse
Run B; June 15, 1989.

Figure 1-3. Gantt Chart Illustrating Sampling times
Condition 1; Pelletized Municipal Refuse
Run C; June 15, 1989

* Estimated start time

Figure 1-4. Gantt Chart Illustrating Sampling Times
Condition 2; Pelletized Cardboard, <1% Plastic
Run A; June 16, 1989

Figure 1-5. Gantt Chart Illustrating Sampling Times
Condition 2, Pelletized Cardboard¹/₈ Plastic
Run B; June 16, 1989

Figure 1-6. Gantt Chart Illustrating Sampling Times
Condition 2; Pelletized Cardboard <1% Plastic
Run C; June 17, 1989

Figure 1-7. Gantt Chart Illustrating Sampling Times
 Condition 3; Pelletized Municipal Refuse, Reduced Plastic
 Run A; June 19, 1989

Figure 1-8. Gantt Chart Illustrating Sampling Times
 Condition 3; Pelletized Municipal Refuse, Reduced Plastics
 Run B; June 19, 1989

Figure 1-9. Gantt Chart Illustrating Sampling times
 Condition 3; Pelletized Municipal Refuse, Reduced Plastics
 Run C; June 20, 1989

SECTION 2

SUMMARY OF RESULTS

This section summarizes the results of the source testing program from the Dordt College boiler. The test program evaluated three conditions: 1) pelletized municipal waste, 2) pelletized cardboard with less than 1 percent plastics, and 3) pelletized municipal refuse with reduced plastics. These conditions are designated as Conditions 1, 2, and 3 respectively. There were three runs under each condition which were designated as Runs A, B, and C. The testing results are discussed in detail below. Any problems associated with the analytical methods are also discussed in order to qualify the data as necessary.

PARTICULATE EMISSIONS

A total of nine Method 5 samples were collected for front half particulate emissions and concentrations and back half organics. PES originally intended to analyze the back half for inorganic as well as organic analyses but we inadvertently forgot to request inorganic analysis on the analytical request form. By the time this oversight was discovered, the contract lab had discarded the samples, thus no inorganic analysis was performed. The results of all test runs for each condition are presented in two tables; one in english units and one in metric units. Tables 2-1A and 2-1B are the results for Condition 1, english units and metric units respectively. Tables 2-2A and 2-2B are the results for Condition 2, and Tables 2-3A and 2-3B are the results for Condition 3. All test runs were successful.

Condition 1

The average particulate concentration for Condition 1 was 0.2756 gr/dscf (0.6297 g/dncm). The average total particulate concentration including the backhalf organics was 0.2780 gr/dscf (0.6362 g/dncm).

The average particulate emission rate was 5.205 lb/hr (2.361 kg/hr). The average total particulate emission rate including the back half organics was 5.247 lb/hr (2.382 kg/hr). The back/half organics represent an insignificant portion, less than 1 percent, of the total particulate catch.

The heating value of the fuel was calculated based on both the actual rate the fuel was fed to the hopper and the F-factor method. The results show a good comparison. As you can see on Tables 2-1A and 2-1B, the F-Factor calculations and the calculations using actual fuel feedrates differ by less than 20%. In all cases, the F-factor value was lower than the calculated value using actual fuel feed rates.

Condition 2

The average particulate concentration for Condition 2 was 0.1335 gr/dscf (0.3055 g/dncm). The average total particulate concentration including the back half organics was 0.1344 gr/dscf (0.3076 g/dncm).

The average particulate emission rate was 2.4593 lb/hr (1.1199 kg/hr). The average total particulate emission rate including back half organics was 2.4757 lb/hr (1.1230 kg/hr). Again, the back half organics represent an insignificant portion of the total particulate catch of less than 1 percent.

The results comparing the heating value of the fuel calculated using actual fuel feed rates and the F-factor method showed a good comparison with less than 10 percent difference. There was a period during the test when the fuel flow backed up and there was no feed to the hopper. The total time with no feed has been estimated to be less than 14 minutes. We compared the heat value calculated using actual fuel feed rates and F-factor method for that run with the other runs during that condition and the results do not show a significant difference. Condition 2 differs from Condition 1 and 3 in that in Condition 2, the F-factor method produced higher values for all three runs than the calculated heat value using actual feed rates.

Condition 3

The average particulate concentration for Condition 3 was 0.2589 gr/dscf (0.5890 g/dncm). The average total particulate concentration including the back half organics was 0.2596 gr/dscf (0.5922 g/dncm).

The average particulate emission rate was 4.624 lb/hr (2.070 kg/hr). The average total particulate emission rate including back half organics was 4.637 lb/hr (2.104 kg/hr). The results comparing the heating value of the fuel calculated using actual fuel feed rates and the F-Factor method showed a good comparison with less than 10 percent difference.

In general, Condition 2 showed the lowest particulate concentrations and emission rates, on average more than 50 percent less, compared to Condition 1 and 3.

EMISSIONS OF SEMI-VOLATILE ORGANIC COMPOUNDS

Polychlorobiphenyl (PCB)

The PCB samples were analyzed and calculated as a concentration for congeners Mono through Deca. The test results are typically presented in metric units only and this is how we have presented these results.

In all but one case, no PCBs were found greater than the detection limit. Condition 2, Run A, tetra-PCB resulted in a concentration of 0.014 $\mu\text{g}/\text{Nm}^3$. Although this is a valid result, it is not considered a

resulting concentration is of a very low amount suggesting possible contamination. Table 2-4 presents the PCB results. We have calculated the results for both the minimum detection limit (MDL), the estimated maximum possible concentration (EMPC), and the actual concentration found in the one sample.

The MDL and the EMPC are both considered detection limits and are calculated as such (see Section 7 for quality assurance for PCB analyses). The MDL values are presented in brackets, [], the EMPC values are presented in parentheses, (). The concentrations greater than the detection limit are presented as the total for each congener.

Polychlorinated Dibenzodioxin (PCDD)

Tables 2-5A and 2-5B present the dioxin stack gas results as a concentration in ng/Nm^3 . Table 2-5A presents the total PCDD for isomers tetra through octa. Table 2-5B presents the PCDD data for the most toxic isomers, those with 2,3,7,8 configurations. There were dioxins present in the stack gas for the total dioxins tetra through octa. Condition 1 averaged $161.1 \text{ ng}/\text{Nm}^3$, Condition 2 averaged $137.1 \text{ ng}/\text{Nm}^3$, and Condition 3 averaged $96.1 \text{ ng}/\text{Nm}^3$.

Polychlorinated Dibenzofurans (PCDF)

Tables 2-6A and 2-6B present the PCDF stack gas results as a concentration in ng/Nm^3 . Table 2-6A presents the total PCDF for isomers tetra through octa. Table 2-6B presents the PCDF data for the most toxic isomers, those with 2,3,7,8 configurations. There were furans present in the stack gas. For the total furans tetra through octa, Condition 1 averaged $360.9 \text{ ng}/\text{Nm}^3$, Condition 2 averaged $206.7 \text{ ng}/\text{Nm}^3$, and Condition 3 averaged $225.6 \text{ ng}/\text{Nm}^3$.

METALS EMISSIONS

Tables 2-7A through 2-7C presents the metal emissions data in mg/dncm for Conditions 1, 2, and 3 respectively. Overall, Condition 2 values were lower than Conditions 1 and 3. Condition 3 appeared to be in the "mid-range" however, there was not a significant difference between Conditions 1 and 3.

HCl EMISSIONS

A total of nine (three test runs for each of three conditions) HCl samples were collected to determine the HCl emission rates from the d-RDF fueled boiler.

The results were as expected. The average emission rate for Condition 1 was 2.04 lb/hr (15.4 g/min). Condition 2 was 0.7392 lb/hr (5.6 g/min), and Condition 3, was 1.5502 lb/hr (11.7 g/min). Table 2-8 shows these averages as well as each individual test run. The table presents the emission rates for both english and metric units.

PM₁₀

Figures 2-1A through 2-1C illustrate the results of the PM₁₀ particle distribution for Condition 1, 2, and 3 respectively. Table 2-9A through 2-9C summarizes an interpretation of those results regarding the size distribution relative to certain cutpoints. Computer summaries of the particle size distribution data are presented in the appendices.

CONTINUOUS EMISSION MONITORING (CEMs)

Gas samples were continuously withdrawn from a single point for introduction to the continuous analyzers for analysis of oxygen (O₂), carbon dioxide (CO₂), carbon monoxide (CO), total hydrocarbons (THC), sulfur dioxide (SO₂), and oxides of nitrogen (NO_x). The analyzers were located in a truck near the boiler building. A heated Teflon™ line conveyed the stack gas from a single probe positioned in the stack to the CEM truck where the stack gas was conditioned and then manifolded to the individual analyzers. EPA Reference Methods were followed for all instrument methods. Reference Method 3A was used for O₂ and CO₂, Reference Method 10 for CO, Reference Method 25A for THC, Reference Method 6C for SO₂, and Reference Method 7E for NO_x.

During most of the testing, PES used an ACRO 2000 data acquisition system and an IBM compatible computer to collect the data continuously for 1 minute averages. Pen recorders were used as backup in case the computer system failed. This data acquisition system was used for part of Condition 1, Run B and was in full operation for Run C of the same Condition as well as for all runs in Conditions 2 and 3. Condition 1, Run A and part of Run B were recorded using strip chart recorders only. These two exceptions resulted in the data being reduced as a three minute average.

During the testing, a pattern was recognized at 26 and 56 minutes past each hour. The O₂, CO, and THC would rise and the CO₂, NO_x, and SO₂ would drop. This was later determined to be the result of the grate cleaning process. As a result, we have reduced the data with this in mind. We have broken the data into two distinct groups: 1) "with grate cleaning", where the data during the grate cleaning process was used in the averages, and 2) "without grate cleaning" where we recalculated the one-minute averages removing these outliers. Tables 2-10A through Tables 2-10C show the comparison of grate cleaning and non-grate cleaning parameter values and indicate the degree of change associated with the grate cleaning process. In our best judgement, the data reduced "with grate cleaning" is a true representation of the actual stack gas constituents during the testing program because this was what was actually occurring in the stack during the testing program. Therefore, all calculations which required stack gas constituent input used the "with grate cleaning" results. The CEM runs that were not monitored with the data acquisition system are represented "with grate cleaning" as well, since the data was reduced as a three minute average, taking into account the outliers generated during the grate cleaning process.

These CEM data were used for all calculations. Table 2-11 presents the results of the gas analyses.

Condition 1

Figures 2-2 through 2-13 graphically displays the O_2 , CO_2 , CO, NO_x and SO_2 concentrations for Condition 1. Run A shows just one graph for each constituent as discussed above. Runs B and C show each constituent graphed "with grate cleaning" and "without grate cleaning."

The THC analyzer was inoperable during Condition 1. The cell window in the SO_2 analyzer cracked and caused the analyzer to become inoperable during Condition 1, Run C. No fyrite analyses were performed during Condition 1.

Condition 2

Figures 2-14 through 2-28 graphically displays the gas constituents for Condition 2. The THC analyzer was inoperable during Run A, and the SO_2 analyzer was inoperable during Runs A and B. Fyrite analysis was performed on Run A only.

Condition 3

Figures 2-29 through 2-46 graphically displays the gas constituents for Condition 3. All analyzers were operational during this condition and Fyrite analyses were performed during each run.

The data used to create the graphs for all three Conditions can be found in the appendices as well as copies of the strip charts for each run.

FUEL ANALYSES

The results of the fuel analysis are presented in Table 2-12. In addition to the analytical results of the fuel samples, we have also added the nominal feed rate fed to the hopper.

The nominal feed rate is the calculated average feed rate based on the number of counts registered as the feed was fed to the hopper. The number of counts, along with the calibration factor of the counter, allowed the calculation of the nominal feed rate in pounds per hour. Table 2-13 breaks down the feed rates for each test run for particle, semi-volatile organic, metals, and HCl emissions.

ASH ANALYSES

Tables 2-14A and 2-14B present the analytical results of the ash analyses for each condition. Analyses were conducted for Loss on Ignition (Hydrocarbons), Metals, PCBs, Dioxins, and Furans. There were some metals present in the ash. The laboratory analyses found no PCBs. The analyses also found some dioxins and furans in some of the congeners in concentrations in the parts per billion range.

TABLE 2-1A
COUNCIL OF GREAT LAKE GOVERNORS, DORDT COLLEGE
METHOD 5 PARTICULATE RESULTS FOR CONDITION 1

Parameter	Units	Run		
		A	B	C
Sample Time	mins.	60	60	60
Sample Volume	ft ³	37.564	36.822	35.678
Stack Gas Velocity	fps	25.3	25.1	24.4
Stack Gas Volumetric Flowrate	acfm	4034	4009	3892
Stack Gas Volumetric Flowrate	dscfm	2261	2204	2147
Stack Gas Temperature	°F	372	395	394
Stack Gas Moisture	% vol.	7.8	7.3	7.1
Oxygen Concentration	%	14.9	13.2	14.1
Carbon Dioxide Conc.	%	5.9	7.8	6.8
Percent Isokinetic	%	96.0	96.6	96.1
Particulate Collected	gr	9.892	10.370	10.062
Particulate Conc.	gr/dscf	0.2633	0.2816	0.2820
Particulate Conc.	lb/1000dscf	0.0376	0.0402	0.0403
Total Particulate Conc. Including Backhalf Organics	gr/dscf	0.2659	0.2838	0.2838
Particulate Emission Rate	lb/hr.	5.103	5.321	5.190
Total Particulate ER Including Backhalf Organics	lb/hr.	5.153	5.362	5.223
Particulate Emission Heat Value: F-Factor	lb/MMBTU	1.141	0.951	1.072
Total Particulate Inc. Backhalf Organics: F-Factor Method	lb/MMBTU	1.152	0.958	1.078
Particulate Emission Heat Value: Fuel Feed Rate	lb/MMBTU	1.230	1.259	1.265

TABLE 2-1B
COUNCIL OF GREAT LAKE GOVERNORS, DORDT COLLEGE
METHOD 5 PARTICULATE RESULTS FOR CONDITION 1

Parameter	Units	Run		
		A	B	C
Sample Time	mins.	60	60	60
Sample Volume	m ³	1.0648	1.0428	1.0104
Stack Gas Velocity	m/sec.	7.71	7.65	7.44
Stack Gas Volumetric Flowrate	acm/min	114.2	113.5	110.2
Stack Gas Volumetric Flowrate	dncm/min	64.03	62.42	60.80
Stack Gas Temperature	°C	189	202	201
Stack Gas Moisture	% vol.	7.8	7.3	7.1
Oxygen Concentration	%	14.9	13.2	14.1
Carbon Dioxide Conc.	%	5.9	7.8	6.8
Percent Isokinetic	%	96.0	96.6	96.1
Particulate Collected	mg	641.0	672.0	652.0
Particulate Conc.	g/dncm	0.6025	0.6414	0.6453
Total Particulate Conc. Including Backhalf Organics	g/dncm	0.6084	0.6493	0.6493
Particulate Emission Rate	kg/hr.	2.315	2.414	2.355
Total Particulate ER Including Backhalf Organics	kg/hr.	2.338	2.433	2.369
Particulate Emission Heat Value: F-Factor	mg/kJ	0.491	0.409	0.461
Total Particulate Inc. Backhalf Organics: F-Factor Method	mg/kJ	0.4931	0.4101	0.4614
Particulate Emission Heat Value: Fuel Feed Rate	mg/kJ	0.529	0.542	0.544

TABLE 2-2A
COUNCIL OF GREAT LAKE GOVERNORS, DORDT COLLEGE
METHOD 5 PARTICULATE RESULTS FOR CONDITION 2

Parameter	Units	Run		
		A	B	C
Sample Time	mins.	60	60	60
Sample Volume	ft ³	37.441	36.701	36.458
Stack Gas Velocity	fps	24.8	24.4	24.3
Stack Gas Volumetric Flowrate	acfm	3950	3900	3873
Stack Gas Volumetric Flowrate	dscfm	2203	2134	2099
Stack Gas Temperature	°F	377	384	378
Stack Gas Moisture	% vol.	7.5	8.1	9.5
Oxygen Conc.	%	14.8	14.9	12.0
Carbon Dioxide Conc.	%	5.3	5.5	8.0
Percent Isokinetic	%	98.2	99.4	100.4
Particulate Collected	gr	5.572	4.463	4.747
Particulate Conc.	gr/dscf	0.1488	0.1216	0.1302
Total Particulate Conc. Including Backhalf Organics	gr/dscf	0.1502	0.1225	0.1306
Particulate Conc.	lb/1000dscf	0.0213	0.0174	0.0186
Particulate Emission Rate	lb/hr.	2.811	2.224	2.343
Total Particulate ER Including Backhalf Organics	lb/hr.	2.836	2.241	2.350
Particulate Emission Heat Value: F-Factor	lb/MMBTU	0.708	0.580	0.439
Total Particulate Inc. Backhalf Organics: F-Factor Method	lb/MMBTU	0.714	0.585	0.440
Particulate Emission Heat Value: Fuel Feed Rate	lb/MMBTU	0.782	0.646	0.541

TABLE 2-2B
COUNCIL OF GREAT LAKE GOVERNORS, DORDT COLLEGE
METHOD 5 PARTICULATE RESULTS FOR CONDITION 2

Parameter	Units	Run		
		A	B	C
Sample Time	mins.	60	60	60
Sample Volume	m ³	1.0603	1.0394	1.0325
Stack Gas Velocity	m/sec.	7.56	7.44	7.41
Stack Gas Volumetric Flowrate	acm/min.	111.9	110.5	109.7
Stack Gas Volumetric Flowrate	dncm/min.	62.42	60.41	59.45
Stack Gas Temperature	°C	192	196	192
Stack Gas Moisture	% vol.	7.5	8.1	9.5
Oxygen Conc.	%	14.8	14.9	12.0
Carbon Dioxide Conc.	%	5.3	5.5	8.0
Percent Isokinetic	%	98.2	99.4	100.4
Particulate Collected	mg	361.1	289.2	307.6
Particulate Conc.	g/dncm	.3405	.2782	.2979
Total Particulate Conc. Including Backhalf Organics	g/dncm	0.3437	0.2803	0.2989
Particulate Emission Rate	kg/hr.	1.280	1.013	1.067
Total Particulate ER Including Backhalf Organics	kg/hr.	1.286	1.017	1.066
Particulate Emission Heat Value: F-Factor	mg/kJ	0.304	0.249	0.187
Total Particulate Inc. Backhalf Organics: F-Factor Method	mg/KJ	0.307	0.251	0.189
Particulate Emission Heat Value: Fuel Feed Rate	mg/kJ	0.337	0.278	0.233

TABLE 2-3A
COUNCIL OF GREAT LAKE GOVERNORS, DORDT COLLEGE
METHOD 5 PARTICULATE RESULTS FOR CONDITION 3

Parameter	Units	Run		
		A	B	C
Sample Time	mins.	60	60	60
Sample Volume	ft ³	35.501	34.829	34.337
Stack Gas Velocity	fps	24.2	24.2	23.5
Stack Gas Volumetric Flowrate	acfm	3864	3866	3747
Stack Gas Volumetric Flowrate	dscfm	2110	2080	2050
Stack Gas Temperature	°F	386	393	374
Stack Gas Moisture	% vol.	8.5	9.2	9.1
Oxygen Concentration	%	11.2	11.3	11.7
Carbon Dioxide Conc.	%	9.2	9.0	8.4
Percent Isokinetic	%	97.3	96.8	96.8
Particulate Collected	gr	9.941	10.872	6.332
Particulate Conc.	gr/dscf	0.2800	0.3122	0.1844
Particulate Conc.	lb/1000dscf	0.0400	0.0446	0.0263
Total Particulate Conc. Including Backhalf Organics	gr/dscf	0.2806	0.3132	0.1849
Particulate Emission Rate	lb/hr.	5.065	5.567	3.240
Total Particulate ER Including Backhalf Organics	lb/hr.	5.076	5.586	3.250
Particulate Emission Heat Value: F-Factor	lb/MMBTU	0.819	0.922	0.568
Total Particulate Inc. Backhalf Organics: F-Factor Method	lb/MMBTU	0.820	0.925	0.570
Particulate Emission Heat Value: Fuel Feed Rate	lb/MMBTU	0.924	1.047	0.663

TABLE 2-3B
COUNCIL OF GREAT LAKE GOVERNORS DORDT COLLEGE
METHOD 5 PARTICULATE RESULTS FOR CONDITION 3

Parameter	Units	Run		
		A	B	C
Sample Time	mins.	60	60	60
Sample Volume	m ³	1.0053	0.98645	0.97242
Stack Gas Velocity	m/sec.	7.38	7.38	7.16
Stack Gas Volumetric Flowrate	acm/min	109.4	109.5	106.1
Stack Gas Volumetric Flowrate	dncm/min	59.76	58.91	58.06
Stack Gas Temperature	°C	197	201	190
Stack Gas Moisture	% vol.	8.6	9.2	9.1
Oxygen Concentration	%	11.2	11.3	11.7
Carbon Dioxide Conc.	%	9.2	9.0	8.4
Percent Isokinetic	%	97.3	96.8	96.8
Particulate Collected	mg	644.2	704.5	410.3
Particulate Conc.	g/dncm	0.6339	0.7123	0.4207
Total Particulate Conc. Including Backhalf Organics	g/dncm	0.6402	0.7146	0.4219
Particulate Emission Rate	kg/hr.	2.214	2.525	1.470
Total Particulate ER Including Backhalf Organics	kg/hr.	2.303	2.534	1.474
Particulate Emission Heat Value: F-Factor	mg/kJ	0.352	0.397	0.245
Total Particulate Inc. Backhalf Organics: F-Factor Method	mg/kJ	0.352	0.3974	0.2449
Particulate Emission Heat Value: Fuel Feed Rate	mg/kJ	0.398	0.457	0.285

Table 2-4

COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE

POLYCHLOROBIPHENYL (PCB) STACK GAS RESULTS
CALCULATIONS BASED ON MINIMUM DETECTION LIMITS

SAMPLING RUN	MONO	DI	TRI	TETRA	PENTA	HEXA	HEPTA	OCTA	NONA	DECA
PCB CONGENERS (ug/m ³)										
CONDITION 1										
RUN A	[0.325]	[0.756]	(0.062)	(0.084)	[0.569]	(0.114)	(0.099)	(0.200)	(0.216)	(0.227)
RUN B	[0.080]	[0.167]	[0.029]	[0.044]	[1.670]	(0.018)	(0.015)	[0.041]	[0.265]	(0.035)
RUN C	[0.012]	[0.255]	[0.041]	[0.072]	[0.961]	(0.041)	(0.036)	(0.074)	(0.079)	(0.084)
Avg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CONDITION 2										
RUN A	[0.048]	[0.062]	(0.018)	0.014	[0.569]	(0.023)	(0.019)	[0.118]	[0.223]	(0.045)
RUN B	[0.011]	[0.073]	(0.019)	[0.035]	[0.817]	(0.024)	(0.021)	[0.063]	(0.046)	(0.049)
RUN C	[0.017]	[0.080]	[0.052]	[0.035]	[1.550]	(0.021)	(0.018)	[0.128]	[0.115]	(0.042)
Avg	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND
CONDITION 3										
RUN A	[0.006]	[0.034]	(0.019)	[0.026]	[0.940]	(0.024)	(0.021)	[0.067]	[0.138]	(0.049)
RUN B	[0.010]	[0.029]	(0.028)	[0.060]	[1.020]	(0.034)	(0.030)	[0.099]	[0.275]	(0.069)
RUN C	[0.013]	[0.049]	[0.019]	[0.043]	[0.929]	(0.022)	(0.019)	[0.095]	[0.397]	(0.044)
TOTAL	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

() = Minimum Detection Limit (MDL)

[] = Estimated Maximum Possible Concentration (EMPC)

ND = Not Detected

NOTE: MDL and EMPC's are considered zeros for calculation in the TOTAL result.

TABLE 2-5A

COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE

TOTAL DIOXIN STACK GAS RESULTS

Sampling Run	DIOXIN ISOMER (ng/gram)					
	Total TCDD	Total PeCD	Total HxCd	Total HpCD	Total OCd	
Condition 1						
Run A	19.7	25.6	43.7	39.9	20.1	
Run B	15.7	27.3	64.7	77.9	58.0	
Run C	<u>7.46</u>	<u>12.0</u>	<u>21.0</u>	<u>28.9</u>	<u>23.1</u>	
Average	14.3	21.6	43.1	48.9	33.7	
Condition 2						
Run A	6.00	17.9	39.1	66.2	42.2	
Run B	2.56	5.70	13.6	19.3	11.5	
Run C	<u>25.2</u>	<u>41.1</u>	<u>65.1</u>	<u>48.3</u>	<u>14.0</u>	
Average	11.3	21.6	39.3	44.6	22.6	
Condition 3						
Run A	5.29	13.3	25.9	19.2	6.13	
Run B	6.78	12.8	33.9	45.4	31.2	
Run C	<u>7.78</u>	<u>15.5</u>	<u>26.0</u>	<u>25.3</u>	<u>13.6</u>	
Average	6.62	13.9	28.6	30.6	17.0	

TABLE 2-5B

COUNCIL OF GREAT LAKES GOVERNORS
DOROT COLLEGE

DIOXIN STACK GAS RESULTS

SAMPLING RUN	DIOXIN ISOMER (pg/K-33)						
	2378-TCDD	12378-PCDD	123478-HxCDD	123678-HxCDD	123789-HxCDD	1234678-HpCDD	OCDD
CONDITION 1							
RUN A	0.52	2.63	2.2	4.09	7.80	20.9	20.0
RUN B	0.36	2.58	3.41	5.48	4.35	39.1	58.0
RUN C	<u>0.23</u>	<u>0.79</u>	<u>0.83</u>	<u>2.0</u>	<u>2.8</u>	<u>14.8</u>	<u>23.1</u>
Avg	<u>0.37</u>	<u>2.00</u>	<u>2.2</u>	<u>3.9</u>	<u>5.0</u>	<u>24.9</u>	<u>33.7</u>
CONDITION 2							
RUN A	0.11	1.0	1.3	4.25	5.28	35.6	42.1
RUN B	(0.05)	0.23	0.37	1.2	1.3	9.61	11.5
RUN C	<u>0.73</u>	<u>2.94</u>	<u>2.0</u>	<u>5.50</u>	<u>8.25</u>	<u>25.5</u>	<u>13.9</u>
Avg	0.28	1.4	1.2	3.7	4.9	23.6	22.5
CONDITION 3							
RUN A	(0.062)	0.56	0.68	2.0	2.4	9.72	6.13
RUN B	(0.18)	1.2	1.4	2.95	4.65	24.3	31.1
RUN C	<u>0.27</u>	<u>1.3</u>	<u>1.3</u>	<u>2.3</u>	<u>4.14</u>	<u>13.3</u>	<u>13.5</u>
TOTAL	0.09	1.0	1.1	2.4	3.7	15.8	16.9

[] = Minimum Detection Limit (MDL)

() = Estimated Maximum Possible Concentration (EMPC)

ND = Not Detected

NOTE : MDL and EMPC's are considered zeros for calculation in the TOTAL result.

TABLE 2-6A

COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE

TOTAL PCDF STACK GAS RESULTS, ng/dtcm

Sampling Run	Total TCDF	Total PCDF	FURAN ISOMER (ng/dtcm)		Total HxCDF	Total HpCDF	Total OCDF
			Total	HxCDF			
Condition 1							
Run A	131	109	73.6		54.0		11.2
Run B	107	99.5	168		106		32.6
Run C	44.5 94.2	46.6 85.0	48.7 96.8		39.3 66.4		11.8 18.5
Average							
Condition 2							
Run A	43.7	49.9	54.6		55.3		23.3
Run B	17.2	19.4	16.2		14.7		4.40
Run C	127 62.6	82.5 50.6	48.9 39.9		20.2 30.1		3.89 10.5
Average							
Condition 3							
Run A	28.5	22.7	16.7		7.16		1.5
Run B	49.8	57.0	73.2		55.9		14.7
Run C	65.2 47.8	79.0 52.9	69.9 53.3		37.6 33.6		7.72 7.97
Average							

TABLE 2-6B

COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE

2378 ISOMER FURAN STACK GAS RESULTS

FURAN ISOMER (ng/Nm3)

SAMPLING RUN	2378-TCDF	12378-PeCDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	234678-HxCDF	123789-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
CONDITION 1										
RUN A	24.8	5.69	12.4	17.7	10.2	15.5	0.88	26.0	5.79	11.2
RUN B	20.0	4.18	12.9	30.4	14.2	26.1	1.5	55.3	8.26	32.6
RUN C	<u>8.67</u>	<u>1.8</u>	<u>4.49</u>	<u>8.11</u>	<u>4.52</u>	<u>8.93</u>	<u>0.23</u>	<u>21.9</u>	<u>(2.9)</u>	<u>11.8</u>
Avg	17.8	4.0	9.93	18.7	9.64	16.8	0.87	34.4	4.68	18.5
CONDITION 2										
RUN A	9.47	1.5	5.28	9.24	4.25	12.4	0.34	25.6	5.12	23.3
RUN B	3.81	0.50	1.8	2.8	1.3	3.43	(0.047)	7.26	1.0	4.40
RUN C	<u>26.0</u>	<u>3.854</u>	<u>10.0</u>	<u>9.03</u>	<u>4.55</u>	<u>8.40</u>	<u>0.35</u>	<u>9.47</u>	<u>1.8</u>	<u>3.89</u>
Avg	13.1	2.0	5.7	7.0	3.4	8.06	0.23	14.1	2.6	10.5
CONDITION 3										
RUN A	6.75	0.81	2.7	2.9	1.4	3.1	0.16	3.58	(0.81)	1.5
RUN B	10.2	2.9	6.51	12.8	6.81	14.1	0.54	31.1	(5.12)	14.7
RUN C	<u>11.4</u>	<u>3.92</u>	<u>8.25</u>	<u>12.1</u>	<u>6.90</u>	<u>11.0</u>	<u>0.47</u>	<u>19.4</u>	<u>3.39</u>	<u>7.72</u>
Avg	9.45	2.5	5.8	9.3	5.0	9.4	0.39	18.0	1.13	8.0

[] = Minimum Detection Limit (MDL)

() = Estimated Maximum Possible Concentration (EMPC)

ND = Not Detected

NOTE : MDL and EMPC's are considered zeros for calculation in the TOTAL result.

TABLE 2-7A
COUNCIL OF GREAT LAKES GOVERNORS, DORDT COLLEGE
METALS EMISSIONS, mg/dncm
CONDITION 1

	Detection Limit (ug/sample)	Run		
		A 6-14-89	B 6-15-89	C 6-15-89
Antimony, Sb	20	[0.0191]	0.0311	0.0159
Arsenic, As	50	[0.0478]	0.0673	0.0425
Barium, Ba	5	0.4370	0.3798	0.5881
Beryllium, Be	0.5	[0.0005]	[0.0003]	[0.0003]
Cadmium, Cd	1	0.1785	0.1670	0.1853
Chromium, Cr	1	0.0664	0.0554	0.5308
Copper, Cu	2	0.4256	0.4004	0.4782
Lead, Pb	10	3.661	3.889	4.567
Manganese, Mn	2	0.4393	0.3478	0.5354
Nickel, Ni	5	0.0526	0.0229	0.0252
Phosphorus, P	20	1.922	1.824	1.810
Selenium, Se	50	[0.0478]	[0.0259]	[0.0265]
Silver, Ag	1	0.0503	0.0526	0.0595
Thallium, Tl	50	[0.0478]	[0.0259]	[0.0265]
Zinc, Zn	2	10.07	7.09	8.47

[] = Minimum Detection Limit

TABLE 2-7B
COUNCIL OF GREAT LAKES GOVERNORS, DORDT COLLEGE
METALS EMISSIONS, mg/dncm
CONDITION 2

	Detection Limit (ug/sample)	Run		
		A 6-16-89	B 6-16-89	C 6-17-89
Antimony, Sb	20	[0.0098]	[0.0101]	[0.0099]
Arsenic, As	50	[0.0244]	[0.0254]	[0.0249]
Barium, Ba	5	0.2211	0.1442	0.1693
Beryllium, Be	0.5	[0.0002]	[0.0003]	[0.0002]
Cadmium, Cd	1	0.0229	0.0114	0.0160
Chromium, Cr	1	0.0444	0.0294	0.0343
Copper Cu	2	0.1853	0.1396	0.1533
Lead, Pb	10	0.6864	0.4576	0.4576
Manganese, Mn	2	0.4531	0.3295	0.4370
Nickel, Ni	5	0.0137	0.0069	0.0114
Phosphorus, P	20	1.4301	1.0855	1.4118
Selenium, Se	50	[0.0244]	[0.0254]	[0.0249]
Silver, Ag	1	0.0092	0.0069	0.0069
Thallium, Tl	50	[0.0244]	[0.0254]	[0.0249]
Zinc, Zn	2	1.6017	1.1441	1.1441

[] = Minimum Detection Limit (MDL)

TABLE 2-7C
COUNCIL OF GREAT LAKES GOVERNORS, DORDT COLLEGE
METALS EMISSIONS, mg/dncm
CONDITION 3

	Detection Limit (ug/sample)	Run		
		A 6-19-89	B 6-19-89	C 6-20-89
Antimony, Sb	20	0.0183	0.0155	0.0549
Arsenic, As	50	0.0343	0.0412	0.0503
Barium, Ba	5	0.2151	0.2242	0.4096
Beryllium, Be	0.5	[0.0002]	[0.0003]	[0.0003]
Cadmium, Cd	1	0.0686	0.3707	0.2425
Chromium, Cr	1	0.0366	0.1236	0.0618
Copper Cu	2	0.2425	0.4187	0.4073
Lead, Pb	10	1.8305	3.8898	3.6889
Manganese, Mn	2	0.3409	0.4027	0.3844
Nickel, Ni	5	0.0137	0.0183	0.0229
Phosphorus, P	20	1.5010	1.7344	2.0181
Selenium, Se	50	[0.0243]	[0.0258]	[0.0253]
Silver, Ag	1	0.0335	0.0664	0.0664
Thallium, Tl	50	[0.0243]	[0.0258]	[0.0253]
Zinc, Zn	2	3.4322	7.3220	7.0932

[] = Minimum Detection Limit (MDL)

TABLE 2-8
COUNCIL OF GREAT LAKES GOVERNORS, DORDT COLLEGE
SUMMARY OF CHLORIDE EMISSIONS AS HCl

Run Number	Sample Duration (min)	Sample Volume (dscf)	Stack Gas Flow Rate (dscf/min)	Mass Collected (mg)	Concentration as Cl- (mg/dscf)	Concentration as HCl (mg/dscf)	HCl Rate (g/min)	HCl Rate (lb/hr)
1A	25	0.673	2261	3.3	5.5000	5.6540	12.7837	1.6874
1B	30	0.795	2204	5.5	7.4206	7.6284	16.8130	2.2193
1C	30	0.795	2147	5.6	7.5464	7.7577	16.6557	<u>2.1986</u>
Average								2.0351
2A	30	0.795	2203	0.7	1.3834	1.4221	3.1330	0.4136
2B	30	0.783	2134	3.0	4.3427	4.4643	9.5267	1.2575
2C	30	0.782	2099	1.1	1.9183	1.9720	4.1393	<u>0.5464</u>
Average								0.7392
3A	30	0.782	2110	3.6	5.1147	5.2579	11.0943	1.4644
3B	30	0.770	2080	4.4	6.2310	6.4055	13.3234	1.7587
3C	30	0.779	2050	3.6	5.1317	5.2754	10.8146	<u>1.4275</u>
Average								1.5502

Figure 2-1A. Particle Size Distribution Data,
Council of Great Lakes Governors,
Dordt College, Condition 1,
Runs A, B, and C.

Figure 2-1B. Particle Size Distribution Data,
 Council of Great Lakes Governors,
 Dordt College, Condition 2,
 Runs A, B, and C.

TABLE 2-98

COUNCIL OF GREAT LAKES GOVERNORS, DORDT COLLEGE

SUMMARY OF PARTICLE SIZE DATA AS A LESS THAN 10 MICRON DISTRIBUTION

CONDITION 2

Particle Diameter (microns)	Cumulative Percent of Particle Smaller than the State Size (%)		
	A	Runs B	C
0.30	2.17	4.47	5.02
0.63	3.18	6.18	7.41
1.00	3.83	7.29	8.72
1.25	4.14	7.82	9.29
2.50	5.10	9.47	10.80
6.00	6.32	11.47	12.19
10.00	7.83	12.81	12.72

TABLE 2-9C

COUNCIL OF GREAT LAKES GOVERNORS, DODDT COLLEGE

SUMMARY OF PARTICLE-SIZE DATA AS A LESS THAN 10 MICRON DISTRIBUTION

CONDITION 3

Particle Diameter (microns)	Cumulative Percent of Particle Smaller than the State Size (%)		
	A	Runs B	C
0.30	6.03	6.42	7.03
0.63	7.73	8.84	10.67
1.00	9.19	10.52	12.71
1.25	9.98	11.36	13.60
2.50	12.84	14.11	16.03
6.00	17.34	17.90	18.38
10.00	20.42	20.28	19.3

Figure 2-1C. Particle Size Distribution Data,
Council of Great Lakes Governors,
Dordt College, Condition 3,
Run A, B, and C.

TABLE 2-9A

COUNCIL OF GREAT LAKES GOVERNORS, DORDT COLLEGE

SUMMARY OF PARTICLE SIZE DATA AS A LESS THAN 10 MICRON DISTRIBUTION

CONDITION 1

Particle Diameter (microns)	Cumulative Percent of Particle Smaller than the Stated Size (%) RUNS		
	A	B	C
0.30	2.13	2.57	3.57
0.63	3.05	3.71	4.80
1.00	3.60	4.44	5.74
1.25	3.86	4.78	6.23
2.50	4.61	5.85	7.93
6.0	5.47	7.21	10.45
10.0	5.93	8.88	12.11

TABLE 2-9C
COUNCIL OF GREAT LAKES GOVERNORS, DORDT COLLEGE
SUMMARY OF PARTICLE-SIZE DATA AS A LESS THAN 10 MICRON DISTRIBUTION
CONDITION 3

Particle Diameter (microns)	Cumulative Percent of Particle Smaller than the State Size (%)		
	A	Runs B	C
0.30	6.03	6.42	7.03
0.63	7.73	8.84	10.67
1.00	9.19	10.52	12.71
1.25	9.98	11.50	13.60
2.50	12.84	14.11	16.03
6.00	17.34	17.90	18.38
10.00	20.42	20.28	19.3

TABLE 2-10³

COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE
COMPARISON OF GRATE CLEANING AND NON-GRATE CLEANING PARAMETER VALUES
CONDITION 2

RUN A		O ₂	CO ₂	CO	THC	NOx	SO ₂
TEST VALUE WITHOUT GC		14.6	5.5	141.7	ND	53.1	ND
VALUE DURING GC		17	3.8	534.7	ND	23.8	ND
% CHANGE DUE TO GC		16	-31	277	NA	-55	NA
RUN B							
TEST VALUE WITHOUT GC		14.6	5.7	97.6	0.8	60.3	ND
VALUE DURING GC		17.4	2.9	415.3	9.6	23.6	ND
% CHANGE DUE TO GC		19	-49	326	1100	-61	NA
RUN C							
TEST VALUE WITHOUT GC		12	8.5	109.8	0	87.2	69.6
VALUE DURING GC		15.6	4.6	423.2	3.1	39.8	28.2
% CHANGE DUE TO GC		30	-46	285	NA	-54	-59

GC = GRATE CLEANING

TABLE 2-10C

COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE
COMPARISON OF GRATE CLEANING AND NON-GRATE CLEANING PARAMETER VALUES
CONDITION 3

RUN A	O ₂	CO ₂	CO	THC	NOX	SO ₂
TEST VALUE WITHOUT GC	10.9	9.5	78.5	0.2	133.6	124.7
VALUE DURING GC	15	5.2	540.2	4.6	55.2	52.5
% CHANGE DUE TO GC	38	-45	588	2200	-59	-58
RUN B						
TEST VALUE WITHOUT GC	10.9	9.4	58.4	0	156.3	116.4
VALUE DURING GC	15.6	4.9	528.4	1.4	77.2	58.4
% CHANGE DUE TO GC	43	-48	805	NA	-51	-50
RUN C						
TEST VALUE WITHOUT GC	11.3	8.7	83.4	0	131.6	101.2
VALUE DURING GC	16	4.4	588.9	4.2	80.2	40.2
% CHANGE DUE TO GC	42	-49	606	NA	-39	-60

GC = GRATE CLEANING

TABLE 2-11

COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE
GAS ANALYSIS (WITH GRATE CLEANING)

Parameters	Condition 1			Condition 2			Condition 3		
	A 6-14-89	B 6-15-89	C 6-15-89	A 6-16-89	B 6-16-89	C 6-17-89	A 6-19-89	B 6-19-89	C 6-20-89
O ₂ - CEM, %	14.9	13.2	14.1	14.8	14.8	12.3	11.2	11.3	11.7
O ₂ - Fyrite, %	NSP	NSP	NSP	13.5	NSP	NSP	11.5	12.0	12.5
CO ₂ - CEM, %	5.9	7.8	6.8	5.3	5.5	8.1	9.2	49.0	8.4
CO ₂ - Fyrite, %	NSP	NSP	NSP	8.0	NSP	NSP	9.0	9.5	8.5
CO - CEM, PPM	46	161	86	175	126	138	108	102	127
THC - CEM, PPM	NSP	NSP	NSP	NSP	1.5	0.3	0.5	0.1	0.5
NO _x - CEM, PPM	157	107	102	50	57	83	129	150	125
SO ₂ - CEM, PPM	31	255	NSP	NSP	NSP	65	121	111	96

NOTE: CEM - Continuous Emission Monitoring
NSP - No sample taken

**Figure 2-2. Graphic Representation of Three Minute Averages
for Condition 1, Run A for Oxygen and Carbon Dioxide**

Figure 2-3. Graphic Representation of Three Minute Averages for Condition 1, Run A for Carbon Monoxide and Oxides of Nitrogen

Figure 2-4. Graphic Representation of Three Minute Averages
for Condition 1, Run A for Sulfur Dioxide

100% WITH GRATE CLEANING DATA

100% WITHOUT GRATE CLEANING DATA

Figure 2-5. Graphic Representation of One Minute Averages for Condition 1, Run B for Oxygen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-6. Graphic Representation of One Minute Averages for Condition 1, Run B for Carbon Dioxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-7. Graphic Representation of One Minute Averages for Condition 1, Run B for Carbon Monoxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-8. Graphic Representation of One Minute Averages for Condition 1, Run B for Sulfur Dioxide, With Grate Cleaning and Without Grate Cleaning Data

OXIDES OF NITROGEN

JUNE 15, 1989 RUN 1-B

Figure 2-9. Graphic Representation of One Minute Averages for Condition 1, Run B for Oxides of Nitrogen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-10. Graphic Representation of One Minute Averages for Condition 1, Run C for Oxygen, With Grate Cleaning and Without Grate Cleaning Data

REPORT OF THE

DATE: 11/19/99 RUN: 1

Figure 2-11. Graphic Representation of One Minute Averages for Condition 1, Run C for Carbon Dioxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-12. Graphic Representation of One Minute Averages for Condition 1, Run C for Carbon Monoxide, With Grate Cleaning and Without Grate Cleaning Data

OXIDES OF NITROGEN

JUNE 15, 1989 RUN 1-1

Figure 2-13. Graphic Representation of One Minute Averages for Condition 1, Run C for Oxides of Nitrogen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-14. Graphic Representation of One Minute Averages for Condition 2, Run A for Oxygen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-15. Graphic Representation of One Minute Averages for Condition 2, Run A for Carbon Dioxide, With Grate Cleaning and Without Grate Cleaning Data

**Figure 2-16. Graphic Representation of One Minute Averages
for Condition 2, Run A for Carbon Monoxide, With Grate Cleaning and
Without Grate Cleaning Data**

Figure 2-17. Graphic Representation of One Minute Averages for Condition 2, Run A for Oxides of Nitrogen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-18. Graphic Representation of One Minute Averages for Condition 2, Run B for Oxygen, With Grate Cleaning and Without Grate Cleaning Data

CO₂ (%) WITH GRATE CLEANING DATA

CO₂ (%) WITHOUT GRATE CLEANING DATA

Figure 2-19 Graphic Representation of One Minute Averages for Condition 2, Run B for Carbon Dioxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-20 Graphic Representation of One Minute Averages for Condition 2, Run B for Carbon Monoxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-21 Graphic Representation of One Minute Averages for Condition 2, Run B for Total Hydrocarbon, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-22 Graphic Representation of One Minute Averages for Condition 2, Run B for Oxides of Nitrogen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-23 Graphic Representation of One Minute Averages for Condition 2, Run C for Oxygen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-24 Graphic Representation of One Minute Averages for Condition 2, Run C for Carbon Dioxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-25 Graphic Representation of One Minute Averages
for Condition 2, Run C for Carbon Monoxide, With Grate Cleaning and
Without Grate Cleaning Data

Figure 2-26 Graphic Representation of One Minute Averages
for Condition 2, Run C for Total Hydrocarbon, With Grate Cleaning and
Without Grate Cleaning Data

Figure 2-27 Graphic Representation of One Minute Averages
for Condition 2, Run C for Sulfur Dioxide, With Grate Cleaning and
Without Grate Cleaning Data

Figure 2-28 Graphic Representation of One Minute Averages for Condition 2, Run C for Oxides of Nitrogen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-29 Graphic Representation of One Minute Averages for Condition 3, Run A for Oxygen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-30 Graphic Representation of One Minute Averages for Condition 3, Run A for Carbon Dioxide, With Grate Cleaning and Without Grate Cleaning Data

CARBON MONOXIDE

JUNE 19, 1989 RUN 3-A

Figure 2-31 Graphic Representation of One Minute Averages for Condition 3, Run A for Carbon Monoxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-32 Graphic Representation of One Minute Averages for Condition 3, Run A for Total Hydrocarbon, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-33 Graphic Representation of One Minute Averages for Condition 3, Run A for Sulfur Dioxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-34 Graphic Representation of One Minute Averages for Condition 3, Run A for Oxides of Nitrogen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-35 Graphic Representation of One Minute Averages for Condition 3, Run B for Oxygen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-36 Graphic Representation of One Minute Averages for Condition 3, Run B for Carbon Dioxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-37 Graphic Representation of One Minute Averages
for Condition 3, Run B for Carbon Monoxide, With Grate Cleaning and
Without Grate Cleaning Data

Figure 2-38 Graphic Representation of One Minute Averages for Condition 3, Run B for Total Hydrocarbon, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-39 Graphic Representation of One Minute Averages for Condition 3, Run B for Sulfur Dioxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-40 Graphic Representation of One Minute Averages
for Condition 3, Run B for Oxides of Nitrogen, With Grate Cleaning and
Without Grate Cleaning Data

Figure 2-41 Graphic Representation of One Minute Averages for Condition 3, Run C for Oxygen, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-43 Graphic Representation of One Minute Averages for Condition 3, Run C for Carbon Monoxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-43 Graphic Representation of One Minute Averages for Condition 3, Run C for Carbon Monoxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-44 Graphic Representation of One Minute Averages for Condition 3, Run C for Total Hydrocarbon, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-45 Graphic Representation of One Minute Averages for Condition 3, Run C for Sulfur Dioxide, With Grate Cleaning and Without Grate Cleaning Data

Figure 2-46 Graphic Representation of One Minute Averages for Condition 3, Run C for Oxides of Nitrogen, With Grate Cleaning and Without Grate Cleaning Data

TABLE 2-12
DESCRIPTION OF FUEL STREAM

Parameter	Units	Condition 1	Condition 2	Condition 3
Type		d-RDF Pelletized Municipal Refuse	d-RDF Pelletized Cardboard with <1% Plastic	d-RDF Pelletized Municipal Refuse with Reduced Plastic
Type of Feed		Hopper	Hopper	Hopper
Nominal Feed Rate	lb/hr	541	583	658
Proximate Analysis, as Received				
Moisture	%	6.69	20.60	7.04
Volatile Matter	%	71.48	65.43	72.14
Ash	%	8.02	1.85	7.83
Sulfur	%	0.14	0.10	0.13
BTU/lb		7,642	6,585	8,060
Proximate Analysis, Dry Basis				
Volatile Matter	%	76.60	82.40	77.60
Ash	%	8.60	2.33	8.42
Sulfur	%	0.15	0.12	0.14
BTU/lb		8,190	8,260	8,670
Ultimate Analysis, Dry Basis				
Carbon	%	44.60	49.20	48.90
Hydrogen	%	5.90	6.50	6.55
Nitrogen	%	0.26	0.17	0.14
Chlorine	%	0.17	0.03	0.14
Sulfur	%	0.15	0.12	0.14
Ash	%	8.60	2.33	8.42
Oxygen	%	40.32	41.65	35.71
Ash Fusion Temperature				
Initial Deformation	°F	1990	1900	1990
Softening Temp.	°F	2080	1990	2090
Hemispheric Temp.	°F	2100	2050	2110
Fluid Temp.	°F	2130	2070	2190
Elemental Ash Analysis				
Sodium Oxide	%	8.15	14.30	5.85
Potassium Oxide	%	1.27	3.29	2.42
Magnesium Oxide	%	0.84	0.62	0.92
Calcium Oxide	%	10.90	12.20	14.30
Zinc	%	0.015	0.009	0.013
Ferric Oxide	%	3.86	2.08	2.37
Copper	%	0.08	0.03	0.12
Aluminum Oxide	%	21.30	22.10	16.95
Titanium Oxide	%	4.42	2.24	3.49
Silicon Dioxide	%	43.04	29.10	41.80

TABLE 2-13
COUNCIL OF GREAT LAKES GOVERNORS, DORDT COLLEGE
FUEL FEED RATES DURING SAMPLING^A, LB/HR

Run	Date	Average Feed Rate	M5 ^B	MM5 ^C	Metals ^D	HCl ^E
Condition 1						
A	6/14	547	543	545	543	543
B	6/15	542	553	555	561	553
C	6/15	553	537	533	526	533
Condition 2						
A	6/16	550	548	551	558	557
B	6/16	529	525	526	528	525
C	6/17	670	660	669	666	697
Condition 3						
A	6/19	668	680	663	661	654
B	6/19	677	660	676	680	684
C	6/20	630	606	638	641	645

A - 1b/hr of fuel fed over the specific series of tests including M5, MM5, Metals and HCl

B - 1b/hr of fuel fed during the Method 5 (particle) sampling

C - 1b/hr of fuel fed during the Modified Method 5 (semi-VOST) sampling

D - 1b/hr of fuel fed during the Metals sampling

E - 1b/hr of fuel fed during the Hydrogen Chloride sampling

TABLE 2-14A

COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE

ASH ANALYSES

Parameter	Units	Detection Limit	Condition 1	Condition 2	Condition 3
Loss on Ignition	%	--	1.28	0.79	1.16
Lead	PPM	10	200	300	100
Chromium	PPM	10	240	300	350
Cadmium	PPM	10	10	10	10
Arsenic	PPM	0.5	20	9.5	10.3
Beryllium	PPM	10	<10	<10	<10
Nickel	PPM	10	<10	<10	60
Manganese	PPM	5	2300	900	1550
Copper	PPM	5	700	1500	600
Zinc	PPM	5	1300	700	550
Selenium	PPM	0.5	<0.5	<0.5	<0.5
Total Phosphorus (as PO ₄ -P)	PPM	1	4350	3878	6010
Thallium	PPM	10	<10	<10	<10
Silver	PPM	5	50	25	15
Antimony	PPM	0.5	16.8	20.8	15.4
Barium	PPM	20	1350	1365	1350

TABLE 2-14B

COUNCIL OF GREAT LAKES GOVERNORS,
DORDT COLLEGE

ASH ANALYSES

Parameter	Units	Detection Limit	Condition 1	Condition 2	Condition 3
<u>PCBs</u>					
Total MONO PCB	ug	0.005	ND	ND	ND
Total DI PCB	ug	0.010	ND	ND	ND
Total TRI PCB	ug	0.020	ND	ND	ND
Total Tetra PCB	ug	0.028	ND	ND	ND
Total Penta PCB	ug	0.028	ND	ND	ND
Total Hexa PCB	ug	0.035	ND	ND	ND
Total Hepta PCB	ug	0.030	ND	ND	ND
Total Octa PCB	ug	0.062	ND	ND	ND
Total Nona PCB	ug	0.068	ND	ND	ND
Total Deca PCB	ug	0.070	ND	ND	ND
<u>Dioxin</u>					
2378-TCDD	ppb	0.001	ND	ND	0.02
12378-PeCDD	ppb	0.001	ND	ND	ND
123478-HxCDD	ppb	0.001	ND	ND	ND
123678-HxCDD	ppb	0.001	ND	ND	ND
123789-HxCDD	ppb	0.001	ND	ND	ND
1234678-HpCDD	ppb	0.001	(0.007)	0.01	0.004
OCDD	ppb	0.001	0.02	0.04	0.03
<u>Furan</u>					
2378-TCDF	ppb	0.001	0.004	(0.008)	0.02
12378-PeCDF	ppb	0.001	ND	ND	ND
23478-PeCDF	ppb	0.001	ND	ND	(0.002)
123478-HxCDF	ppb	0.001	0.002	(0.004)	0.002
123678-HxCDF	ppb	0.001	ND	0.002	0.001
234678-HxCDF	ppb	0.001	0.003	(0.004)	(0.002)
123789-HxCDF	ppb	0.001	ND	ND	ND
1234678-HpCDF	ppb	0.001	0.005	0.008	0.004
1234789-HpCDF	ppb	0.001	ND	ND	ND
OCDF	ppb	0.001	0.005	ND	0.003

() EMPC Estimated minimum possible concentration

SECTION 3

PROCESS DESCRIPTION AND OPERATION

PROCESS DESCRIPTION

The boiler tested at Dordt College was unit #4. This unit is a Kewanee 200 HP package boiler that was originally installed as a natural gas fired boiler and then modified to burn d-RDF. The modifications included the addition of a Sidewinder burner and pneumatic feeder.

Unit #4 is one of four boilers used to provide steam to the Dordt College Campus. This unit is rated at 6900 pounds of steam per hour (psph) and is operated at approximately 20 psi steam pressure. Figure 3-1 is a schematic of unit #4.

The process begins with the delivery of the pelletized fuel to the facility. The fuel is delivered by bulk truck similar to those used in the agriculture industry to transport bulk feedstock. The fuel is augered from the delivery truck to the fuel storage bin which is located adjacent to the boiler room. The fuel storage bin is an isolated area approximately 19' x 20' x 14' with a capacity of approximately 45 tons of fuel. The storage bin is equipped with augers to move the fuel from the storage bin to the feed hopper. Figure 3-2 is a schematic showing the auger configuration in the fuel storage bin. The feed hopper is equipped with a fuel level indicator that rotates freely when the fuel level is low. When the fuel level is low the indicator begins to rotate and activates the storage bin augers which in turn convey the fuel from the storage bin to the fuel feed hopper. When the fuel level in the hopper is sufficient to stop the rotation of the level indicator, the augers stop feeding the fuel to the feed hopper. This feed cycle usually occurs approximately once or twice every 5 minutes.

The fuel feed hopper is attached to the front of the boiler. The fuel feed system is calibrated so that the fuel charging rate can be determined on a pound of fuel charged per revolution of the auger. The following is a step-by-step procedure used to calibrate the fuel feed system.

1. Weigh 3 buckets of fuel to obtain an average weight.
2. With the fuel feed hopper empty, dump the known amount of fuel from the bucket into the hopper.
3. Take an initial reading on the revolution counter.

FIGURE 3-1 Simplified Schematic of Fuel Feed and Ash Disposal System, and Burner / Boiler System.

FIGURE 3-2 Fuel Storage Bin Auger Configuration.

4. When the hopper is empty, take a final reading from the revolution counter.
5. Divide the pounds of fuel dumped in the hopper by the number of revolutions required to charge all of the fuel to determine the pounds of fuel charged per revolution.

Example: 15 lb. fuel dumped in hopper, 12 revolutions required to charge the 15 lb. of fuel.

$$\frac{15 \text{ lb}}{12 \text{ rev.}} = 1.25 \text{ lb/revolution}$$

A photograph of the fuel hopper is presented in Figure 3-3. Prior to feeding the fuel to the ignition chamber, the fire is started in the chamber with matches and old newspaper. Once the flames are sufficient to support burning of the fuel, the fuel feeding process is started. The fuel feed process begins by augering the material from the hopper to where the fuel is dropped in front of the injector fan. The fuel is blown into the ignition chamber. Figure 3-4 is a photograph of the fuel hopper and injector fan system.

The boiler operating conditions are monitored using a steam pressure gauge, a boiler draft gauge and a stack temperature thermometer. Feedwater flow rate and temperature are also monitored. The primary chamber is equipped with a dampered fan to provide combustion air to the unit. Removal of the boiler ash (grate cleaning) is accomplished automatically by a timer on the fuel injection fan. The injection fan shuts off for a one (1) minute period during the preset time (in this case every one-half hour). The draft sensor senses a lack of draft and increases the air flow through the undergrate fan located on the back of the boiler. The increase in the draft blows the ash from the grate in the direction of the ash removal auger and is augered to a "dedicated" dumpster located outside the boiler room. This removal system is presented in Figures 3-5 and 3-6.

Boiler Operating Conditions

Boiler unit #4 at Dordt College is used to generate hot water and steam for the campus utilities. Normally, unit #4 burns d-RDF that is manufactured locally and consists of a cardboard pellet with <1% plastic. Under this test protocol the boiler was tested while burning three different types of fuels. No other changes were made to the "normal" operating conditions of the boiler. A discussion of each of the operating conditions is included in the following paragraphs.

Condition 1

Condition 1 consisted of burning pelletized municipal refuse. Figure 3-7 is a photograph of the fuel. The waste included all constituents found in municipal refuse such as plastics, paper products, pieces of metal, etc. The waste did not receive any special handling (sorting) during the processing of the pellets.

Figure 3-3. Fuel feed hopper

Figure 3-4. Fuel hopper and injector fan system

Figure 3-5. Ash auger unit from bottom of ignition chamber.

Figure 3-6. Ash collection dumpster located outside the boiler room.

Figure 3-7. Pelletized Municipal Refuse

Sampling under Condition 1 was conducted over a two day period. The steam pressure for day 1 averaged 15 psi and the boiler exhaust temperature averaged 418° F. On day 2 of Condition 1 the steam pressure average 19 psi and the boiler exhaust temperature averaged 440° F. Readings of the boiler conditions were taken at approximately 15 minute intervals over the course of the test day. The fuel feed system was calibrated as described previously. The calibration factor was determined to be 1.25 pounds of fuel per revolution. Table 3-1 presents a summary of the boiler operating conditions for Condition 1.

Condition 2

Boiler operating Condition 2 consisted of burning pelletized cardboard with <1% plastic. Figure 3-8 is a photograph of the fuel. In the processing stages of the cardboard, the raw material is delivered to the processing plant and the plastic material is manually separated from the fibrous material and then pelletized.

Sampling under Condition 2 was conducted over a two-day period. Two series of tests were conducted on day 1 of this condition and one series was conducted on day 2. On day 1 of Condition 2 the steam pressure averaged 19 psi and the boiler exhaust temperature averaged 425° F. On day 2 of Condition 2 the steam pressure averaged 13 psi and the boiler exhaust averaged 416° F. Readings of the boiler conditions were taken at approximately 15 minute intervals from the beginning of the day's sampling activities to the end of the test day. The fuel feed system was calibrated as described previously. The calibration factor was determined to be 1.5 pounds of fuel per revolution. Table 3-2 presents a summary of the hourly boiler readings for Condition 2.

Condition 3

Boiler operating Condition 3 consisted of burning municipal refuse with reduced plastic content. Figure 3-9 is a photograph of the fuel burned under Condition 3. In the processing stages the refuse was visually inspected and the larger plastic materials (jugs, bags, bottles, etc.) are manually removed to reduce the plastic content of the fuel.

Sampling under Condition 3 was conducted over a two-day period. Two series of tests were conducted on day 1 and one series was conducted on day 2 of this condition. On day 1 the steam pressure averaged 18 psi and the boiler exhaust temperature averaged 434° F. On day 2 the steam pressure averaged 20 psi and the boiler exhaust temperature averaged 422° F. A summary of the boiler conditions during Condition 3 are presented in Table 3-3. The fuel feed system was calibrated as described previously and the calibration factor was calculated to be 1.5 pounds of fuel per revolution.

TABLE 3-1
COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE

CONDITION 1

Date (1989)	Time	Lbs of Fuel Charged	Steam Pressure (PSIG)	Boiler Exhaust Temp (°F)	Draft (inches of water)
6/14	1220-1320	401	17	400	0.12
6/14	1320-1420	545	14	403	0.17
6/14	1420-1520	549	14	416	0.09
6/14	1520-1620	549	14	424	0.13
6/14	1620-1720	550	16	431	0.11
6/14	1720-1803	391	17	433	0.12
6/15	0930-1030	553	17	423	0.14
6/15	1030-1130	551	18	433	0.13
6/15	1130-1230	558	19	439	0.12
6/15	1230-1330	554	19	444	0.12
6/15	1330-1430	559	20	444	0.12
6/15	1430-1531	531	20	443	0.12
6/15	1531-1630	526	20	445	0.12
6/15	1630-1730	530	20	444	0.12
6/15	1730-1830	530	20	445	0.10
6/15	1830-1930	529	20	443	0.13
6/15	1930-1945	133	20	445	0.11

Fuel feed calibration = 1.25 pounds/revolution

The pounds of fuel charged were determined as follows:

$$(R_f - R_i) \text{ lbs/revolution} = \text{lbs of fuel charged}$$

Where: R_f = final feeder counter reading
 R_i = initial feeder counter reading

Figure 3-8. Cardboard Pellets less than
1% Plastic

TABLE 3-2
COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE
HOURLY AVERAGE OF BOILER CONDITIONS
CONDITION 2

Date (1989)	Time	Lbs of Fuel Charged	Steam Pressure (PSIG)	Boiler Exhaust Temp (°F)	Draft (inches of water)
6/16	0918-1030	788	17	412	0.15
6/16	1030-1130	653	20	423	0.14
6/16	1130-1230	629	20	426	0.14
6/16	1230-1336	717	20	431	0.13
6/16	1336-1431	575	20	429	0.15
6/16	1431-1530	630	19	413	0.21
6/16	1530-1630	608	20	430	0.16
6/16	1630-1730	614	20	434	0.14
6/16	1730-1748	186	20	438	0.12
6/17	1047-1145	644	13	407	0.16
6/17	1145-1245	672	13	409	0.16
6/17	1245-1347	707	14	419	0.15
6/17	1347-1456	759	14	421	0.14

Fuel feeder calibration = 1.5 pounds/revolution

Figure 3-9. Municipal Refuse Pellets reduced plastic.

TABLE 3-3
COUNCIL OF GREAT LAKES GOVERNORS
DORDT COLLEGE
HOURLY AVERAGE OF BOILER CONDITIONS
CONDITION 3

Date (1989)	Time	Lbs of Fuel Charged	Steam Pressure (PSIG)	Boiler Exhaust Temp (°F)	Draft (inches of water)
6/19	0839-0930	555	13	410	0.15
6/19	0930-1030	662	15	426	0.14
6/19	1030-1134	717	17	431	0.14
6/19	1134-1230	626	17	431	0.14
6/19	1230-1331	684	17	430	0.16
6/19	1331-1430	660	18	438	0.14
6/19	1430-1530	680	20	440	0.13
6/19	1530-1629	665	19	441	0.13
6/19	1629-1731	690	20	444	0.13
6/20	0815-0915	644	20	420	0.16
6/20	0915-1015	641	20	425	0.17
6/20	1015-1115	626	20	424	0.20
6/20	1115-1215	636	20	418	0.25
6/20	1215-1245	288	20	423	0.22

Fuel feeder calibration = 1.5 pounds/revolution

SECTION 4

SAMPLING LOCATIONS

The samples collected during the field test using manual methods included particulate emissions, PCB, dioxin, and furan emissions, PM₁₀ particle distributions, metals, HCl, and fuel and ash samples. Oxygen (O₂), carbon dioxide (CO₂), carbon monoxide (CO), total hydrocarbons (THC), sulfur dioxide (SO₂) and nitrogen oxide (NO_x) samples were collected using Continuous Emissions Monitors (CEMs). Stack gas emission samples (particulate, PCB, dioxins, furans, PM₁₀, metals, HCl and CEMs) were collected at several locations on the stack. These locations are addressed specifically in the following paragraphs. Fuel and boiler ash sample locations are also discussed. Figure 5-1 presents a diagram showing all of the sampling locations and adjacent equipment.

EMISSIONS SAMPLING LOCATION

Particulates, Metals, and HCl Sample Location

The emission samples were collected from the uncontrolled source at the boiler exhaust stack located on the roof of the boilerhouse. The existing port location did not conform to EPA Method 1 criteria, therefore, it was necessary to modify the duct with the addition of a stack extension so that the ports installed for previous testing could be utilized.

The rectangular duct measure 19.63" x 19.56". After installation of the stack extension, the distance from the ports to the nearest downstream disturbance (the atmosphere) was 58.5" (3.0 diameter equivalents) and the distance from the ports to the nearest upstream disturbance (induced draft fan) was 160" (8.2 diameter equivalents). Figure 5-2 shows the location of sample ports for this site. The sampling ports were 3" in diameter with a 3 15/16" nipple. Twelve sample traverse points were required using a 3 x 4 matrix to collect the samples. Figure 5-3 is a diagram showing the traverse point locations and the stack cross-sectional area at this location.

PM₁₀ Sampling Location

The PM₁₀ samples were collected from a 4" diameter port which was installed approximately 22 inches below the three ports used for the particulate, metals and HCl. This 4" port was installed to provide for smoother insertion and removal of the impactor from the stack. Figure 5-4 is a diagram showing the particle size sampling port and the cross-sectional area of the duct at this location. The PM₁₀ samples were collected from a single point of average velocity as determined from the preliminary velocity traverse.

LEGEND	
(A)	Stack gas emissions collection point (Particulate, metals, HCl, PM10 and Continuous Monitors)
(B)	Fuel collection point
(C)	Ash collection point

Figure 5.1. Sample Collection Locations and Adjacent Equipment.

Figure 4.2 Location of Sample Ports for the Particulate, Metals and HCl Samples.

Figure 4.3 Traverse Point Locations and Stack Dimensions.

Figure 4.4 Location of Sample Port and Cross-Sectional Area of Stack for PM₁₀ Sampling.

PCDD/PCDF/PCB Sampling Location

The PCDD/PCDF/PCB samples were collected from a 4" port which was installed approximately 115" (5.9 diameters) upstream of the particulate sampling ports on the opposite side of the stack. This port would allow the PCDD/PCDF/PCB sampling to be conducted concurrently with the particulate, metals and HCl sampling trains. This also permitted two series of samples to be collected during one test day. The PCDD/PCDF/PCB samples were collected from a single point of average velocity as determined from the preliminary velocity traverse. Figure 5-5 is a diagram showing the PCDD/PCDF/PCB sample port and stack cross-sectional area at this location.

Continuous Emissions Monitor Sample Location

The Continuous Emission Monitor (CEM) samples were collected from a 3" port which was installed approximately 94" upstream from the particulate sampling ports at a 90° angle. Figure 5-6 is a diagram showing the CEM sample port and stack cross-sectional area at this location.

Fuel Sampling Location

Samples of the fuel were collected from the fuel feed hopper. This sample location is presented in Figure 4.1 as item B.

Boiler Ash Sampling Location

Samples of the boiler ash were collected from the "dedicated" dumpster located outside of the boilerhouse. This sample location is presented in Figure 4.1 as item C.

Figure 4.5 Location of Sample Ports for the PCDD/PCDF/PCB and the Cross-Sectional Area of the Stack at this Location.

Figure 4.6 Location of Sample Ports for the CEM, a Stack Cross-Sectional Area.

SECTION 5
SAMPLING AND ANALYTICAL PROCEDURES

The sampling and analytical procedures were selected to determine the physical-chemical characteristics of the d-RDF feed materials, material feed rates, the composition and flow rates of the stack gases and the amount of pollutants discharged in the ash and stack gases.

The sampling and analytical procedures employed for sampling were as follows:

The Code of Federal Regulations (40 CFR 60)

- Method 1 - Sample and Velocity Traverses for Stationary Sources.
- Method 2 - Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S pitot tube).
- Method 3 - Gas Analysis for Oxygen, Carbon Dioxide, and Dry Molecular Weight.
- Method 3A- Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure).
- Method 4 - Determination of Moisture Content in Stack Gases.
- Method 5 - Determination of Particulate Emissions from Stationary Sources.
- Method 6C- Determination of Sulfur Dioxide Emissions from Stationary Sources (Instrumental Analyzer Procedure).
- Method 7E- Determination of Nitrogen Oxide Emissions from Stationary Sources (Instrumental Analyzer Procedure).
- Method 10- Determination of Carbon Monoxide Emissions from Stationary Sources.
- Method 25A- Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer.

In addition to the the Standard EPA Reference Methods, we used two EPA draft procedures. The hydrochloric acid sampling procedure used as a guideline was entitled "The Determination of HCl Emissions from Municipal and Hazardous Waste Incinerators" and the metal sampling method that was used is entitled "Methodology for the Determination of Metals Emissions in Exhaust Gases from Stationary Sources Combustion Processes."

Table 5-1 presents a listing of the methods used in the preparation, sampling and analysis of the MM5 sampling train. Table 5-2 presents a listing of the methods used in the analysis of the fuel.

TABLE 5.1
METHODS USED IN SAMPLING FOR
PCDD/PCDF/PCB

Method	Parameter	Detection Limit
Method 0010 ^a	Modified Method 5 Sample Train	N/A
Method 0010 ^a	Preparation of XAD-2 Sample Train	N/A
Method 8270 ^a	Gas Chromatography/ Mass Spectrometry for Semi-Volatile Organics: Capillary Column Headings	10-50 ug/l (cpd dependent)

^aTest Methods for Analysis of Solid Waste (SW-846)

TABLE 5.2
METHODS USED IN THE ANALYSIS OF THE FUEL

Method	Parameter	Detection Limit
D-644 ^a	Moisture	
D-209 ^a	Total Suspended Solids	0.1 mg/l
D-209 ^a	Total Dissolved Solids	0.1 mg/l
D-240 ^a	Heat Content	0.6 Btu/lb
D-202 (Procedure A) ^a	Ash Content	0.01%
1298 ^a	Density	0.2%
D3177 ^a , 3178 ^a , 3179 ^a	Elemental Composition	0.2%

^aAmerican Society for Testing Materials (ASTM)

SAMPLING PROCEDURES

Sampling Procedures for Particulate Emissions, Stack Gas Volumetric Flow Rate and Stack Gas Moisture Content.

The location and number of traverse points on the boiler exhaust stack were determined as specified in EPA Method 1, "Sample and Velocity Traverses for Stationary Sources" 40 CFR 60. A preliminary measurement of the stack gas flow rate was conducted as specified in EPA Method 2, "Determination of Stack Gas Velocity and Volumetric Flow Rate." The data collected from the preliminary velocity traverse was used to determine the size of the stainless steel nozzle to be used for the particulate traverse and to obtain a velocity profile to identify any unusual flow characteristics (extremely high or low flow). Following the preliminary measurements, the Method 2 determinations were conducted simultaneously with the particulate sampling. The moisture content of the stack gas was determined as specified in EPA Method 4, "Determination of Moisture Content in Stack Gases," and conducted simultaneously with the particulate emissions sampling.

The particulate emissions were determined as specified in the Iowa Department of Environmental Quality's Air Quality Compliance Sampling Manual, however, the calculations were performed using 68°F and 29.92 in. Hg to correct the gas volumes to standard conditions as specified in 40 CFR 60. Each Method 5 run was conducted over a 1 hour sampling period. There were a total of 12 traverse points that were sampled for 5 minutes per point. The volume of gas sampled for each Method 5 run was in excess of the required minimum gas sample volume of 30 dry standard cubic feet. Sample recovery was performed as specified in the method. A schematic of the Method 5 sample train is presented in Figure 5-1.

Sampling Procedures for PCDD/PCDF/PCB Emissions

Sampling for polychlorinated dibenzo-p-dioxin (PCDD), polychlorinated dibenzofurans (PCDF) and polychlorinated biphenyls (PCB) was conducted as specified in EPA SW-846 Method 0010, "Modified-Method 5 Sampling Train." A schematic of the Modified Method 5 (MM5) sample train is presented in Figure 5-2. The intent of using the Modified Method 5, or semi-VOST, was to sample for PCDD/PCDF/PCB only, therefore, the samples were collected isokinetically from a point of average velocity. The semi-VOST was set up using a cyclone for run SV-1-A and SV-1-B to prevent blinding of the filter. Prior to run SV-1-C, it was determined that the cyclone was not necessary because there was no visible amount of particulate matter that was collected in the cyclone during the first two runs. Therefore, on subsequent tests, the cyclone was eliminated from the sampling train. During the sample collection there were numerous problems with high vacuums which made it impossible to obtain the required delta H through the metering system. This difficulty was attributed to the filter plugging due to the high fine particulate concentration resulting from the longer sampling period. In order to avoid the high vacuum and anisokinetic sampling conditions, the filter was changed periodically during each run. These changes were noted on the field data sheets.

Figure 5.1 Method 5 Train Schematic.

Figure 5.2 . Semi-VOST Schematic.

Pyrex nozzles were used in sampling for the PCDD/PCDF/PCB. The largest nozzle size was selected that would allow isokinetic sampling conditions to be maintained, but would also allow the largest volume of sample to be collected in the 3 hour sampling timeframe. Sample recovery was performed as specified in the method.

Sampling Procedures for Metals Emissions

The sampling procedure used as a guideline for the collection of metals emissions is an EPA draft method entitled, "Methodology for the Determination of Metals Emissions in Exhaust Gases from Stationary Source Combustion Processes."

In this method, the gas was collected through a Pyrex nozzle and glass-lined probe then is passed through a Pallflex quartz fiber filter to remove particle material and then bubbled through a series of four impingers. The sampling procedures for this method are identical to those used for the Method 5. The first metals run, MTL-1-A, was conducted over a one hour timeframe, all subsequent runs were conducted over a two-hour timeframe. For the two hour runs, meter readings were taken every 5 minutes and the traverse points were changed every 10 minutes. Sample recovery was performed as specified in the method. Figure 5-3 presents a schematic of the metals sample train.

Sampling Procedures for Hydrochloric Acid Emissions

The procedure used as a guideline for collecting hydrochloric acid (HCl) emissions samples was the draft method currently under development by the EPA. The method is entitled, "The Determination of HCl Emissions from Municipal and Hazardous Waste Incinerators."

In this method, stack gas was passed through a heated glass-lined probe and a series of four midget impingers. The HCl sampling train was leak checked by plugging the inlet of the probe, turning on the pump to evacuate the system. The sample train was observed to verify any bubbling of the impinger solution. If bubbling occurred, the leak was found and repaired, then the leak check procedure was repeated. The sample was collected at a rate of 0.8 liters/minute from a single point over a 30 minute period. Run HCl-1-A was collected over a 25 minute period. Sample recovery was performed as specified in the method. Figure 5-4 is a schematic of the HCl sample train.

Sampling Procedures for PM₁₀ Particulate

The procedure for measuring the percent of PM₁₀ particle distribution was conducted using an Andersen 8-stage cascade impactor. The cascade impactor is usually assembled with the 8 stages configured with the largest cut diameter stage first and the smallest cut diameter stage last followed by the back-up filter. In this test program the configuration of the stages was modified so that only 3 stages and the back-up filter were used. The preseparator was used to remove particles >10 microns.

Plates 1, 2, and 3 and back-up were configured as the first 4 stages. The remaining plates were assembled behind the back-up stage to

Figure 5.3. Metals Train Schematic.

Figure 5.4. Schematic of HCl sample train.

assure proper spacing. No samples were collected from the stages behind the first four. Figure 5-5 is a schematic of the PM₁₀ particulate train. Figure 5-6 is a schematic of the Andersen 8-stage cascade impactor and preseparator.

The impactor was leak checked prior to sampling by plugging the nozzle and pulling a 15-inch vacuum on the system and recording the leak rate. If the leak rate exceeded 0.02 CFM, the leak was found and corrected, the leak procedure was then repeated.

Run PM-1-A was run for 5 minutes, Run PM-1-B was increased to 6 minutes, Runs PM-1-C and PM-2-A were both run for 8 minutes, all subsequent runs were conducted over a 12 minute timeframe.

When the impactor was cool enough to handle, the PM₁₀ samples were recovered. Each filter substrate was removed and placed in the aluminum pouch in which it was tared. Each aluminum pouch was placed in a larger aluminum pouch that was labeled and sealed.

Sampling Procedures for O₂, CO₂, CO, THC, SO₂, and NO_x

Stack gas samples were continuously withdrawn from the stack to the PES CEM trailer where we housed the analyzers. The trailer provided a clean environment for the analyzers.

The stack gas was conveyed through a sampling probe which was equipped with a 2-stage filter system to remove particulate matter. The 2-stage filter system consisted of an alundum filter followed by a 47 mm Gelman glass fiber filter. Once the stack gas was filtered, it passed through a heated Teflon line (heated to approximately 95°C) to maintain the integrity of the gas sample before the gas entered the sample gas conditioning system.

A Hankinson moisture removal system was used to condition the stack gas. The Hankinson system is a non-reactive, refrigeration dryer moisture removal device. A non-reactive, leak-free, Teflon lined sampling pump was used to pull the sample gas through the system at a flow sufficient to minimize transport delay. The gas sample was pumped to a stainless steel manifold which directed portions of the sample gas stream to the different analyzers. Figure 5-7 illustrates the CEM sampling system.

O₂ (Oxygen) Monitor

O₂ monitoring was conducted using a Teledyne Analytical Instruments Model 320P-4 Oxygen Analyzer. During the operation of this instrument, oxygen is sensed by a fuel cell which consumes oxygen from the atmosphere surrounding the measurement probe and generates a proportional electric current.

Figure 5.5. Schematic of the PM₁₀ particle sample train.

Figure 5.6. Schematic of Anderson 8-stage impactor and preseparator.

Figure 5.7. CEM sampling system.

CO₂ (Carbon Dioxide) Monitor

CO₂ monitoring was conducted using a Horiba Instruments Model PIR-2000 non-dispersive infrared (NDIR) analyzer. NDIR analyzers emit a specific wavelength of infrared radiation through the sample cell which is selectively absorbed by CO₂ molecules. The intensity of radiation which reaches the end of the sample cell is compared to the intensity of radiation through a CO₂-free reference cell. The reference cell is used to determine background absorbance which is subtracted from the sample absorbance. Absorbance is directly proportional to the CO₂ concentration in the gas.

CO (Carbon Monoxide) Monitor

CO monitoring was conducted using a Horiba Instrument, Model PIR-2000 NDIR analyzer. This instrument was identical to the instrument used for CO₂ monitoring except that a different wavelength of infrared radiation was used.

THC (Total Hydrocarbon) Monitor

The total hydrocarbons in the stack gas was monitored using a Ratfisch Total Hydrocarbon Analyzer. The analyzer utilized a hydrogen flame ionization detector (FID), which when burning hydrogen in air produces a hot, clean flame forming relatively few ions. When an impure gas stream is introduced to the flame, a cloud of ions is produced. A small current produced from the formation of ions can be amplified and directed to a strip chart.

SO₂ (Sulfur Dioxide) Monitor

The SO₂ concentration of the stack gas was monitored using a Thermo Environmental Corporation Model 40 analyzer which works on the principle of pulsed fluorescence. A pulsed source of ultraviolet radiation electronically excites the SO₂ molecules in the sample cell. The excited SO₂ molecules then decay back to their ground state by fluorescence, emitting a photon. Light emitted by the decaying SO₂ molecules has a different wavelength than the incident UV light. An optical filter selectively blocks the original incident UV light beam and allows only the emitted light to pass. Light which permeates the filter enters a photomultiplier tube which amplifies the signal and gives a response proportional to the SO₂ concentration.

NO_x (Nitrogen Oxides) Monitor

NO_x monitoring was conducted using a Thermo Electron Corporation Model 10AR analyzer. The operating principle of this instrument is the chemiluminescent reaction in which ozone (O₃) reacts with nitric oxide (NO) to form oxygen (O₂) and nitrogen dioxide (NO₂). The instrument is capable of analyzing total oxides of nitrogen (NO + NO₂) by thermally converting NO₂ to NO.

Sampling Procedures for Fuel

Grab samples of the fuel were collected once per hour during the test day directly from the fuel feed hopper. Each grab sample was then composited in a large plastic refuse bag. The composite sample consisted of grab samples collected during a specific boiler condition. At the completion of the testing of each condition, the fuel was mixed thoroughly in the plastic bag and a sample was collected in a "zip-lock"-type plastic bag for subsequent analysis. The sample times were documented on the boiler process data sheets which are included in the appendices.

Sampling Procedures for Boiler Ash

A single grab sample of the boiler ash was collected at the end of each test day. The ash was collected in a 1 liter glass jar.

Data Acquisition

All data was recorded using a strip chart recorder for each instrument. The recorders were connected directly to the continuous monitors. During the initial setup of the instruments, the response was adjusted to give appropriate responses, e.g., 1 volt = 1 ppm, 1 volt = .5 ppm. In addition to the recorders, PES used an ACRO 2000 data acquisition system and an IBM compatible computer to collect the data continuously for 1 minute averages. This data acquisition system was used for part of Condition 1, Run B and was in full operation for Run C of the same Condition as well as for all runs in Conditions 2 and 3. Condition 1, Run A and part of Run B were recorded using strip chart recorders only. These two exceptions resulted in the data being reduced as a three minute average.

ANALYTICAL PROCEDURES

Analytical Procedures for Stack Gas Moisture Content and Particulate Emissions

The moisture content of the stack gas was determined during recovery of the particulate sample train. The volume of water collected in the impingers was measured gravimetrically. From this data, the stack gas moisture content was calculated.

The front half (including filter) of the Method 5 sampling trains were retained in the PES Laboratory for analysis. The back half (impinger contents) of the sampling trains were submitted to DataChem located in Cincinnati, Ohio for analysis. For both sampling train components, the analytical procedures used followed the specifications in the Iowa Department of Environmental Quality's Air Quality Compliance Sampling Manual. In the procedure the front half rinses (nozzle, probe, filter holder and connecting glassware) were evaporated to dryness and weighed to a constant weight. The back half (back of filter holder, impinger 1-3 solutions and rinses, and connecting glassware) of the sample train was analyzed for organic particulate matter by extracting

the rinseate with ether/chloroform aliquots. The solvent extract was then evaporated to dryness, dessicated and weighed to a constant weight. All gravimetric results were reported to the nearest 0.1 milligrams (mg).

Analytical Procedures for PCDD/PCDF/PCB Emissions

The analyses of the PCDD/PCDF/PCB samples was conducted by Triangle Laboratories, Inc. (TLI) located in Research Triangle Park, North Carolina. These procedures were conducted as outlined in SW-846 Method 8270

Analytical Procedures for Metals Emissions

The metals analyses was performed by DataChem located in Cincinnati, Ohio. The samples were analyzed using inductively coupled argon plasma (ICAP) spectroscopy as outlined in the EPA draft method entitled "Methodology for the Determination of Metals Emissions in Exhaust Gases from Stationary Source Combustion Processes."

Analytical Procedures for Hydrochloric Acid Emissions

The HCl analyses were also performed by DataChem. The samples were analyzed using the ion chromatography (IC) procedures as outlined in the EPA draft method entitled "Draft Method for the Determination of HCl Emissions from Municipal and Hazardous Waste Incinerators."

Analytical Procedures for PM₁₀ Particulate

The PM₁₀ particulate samples were returned to the PES laboratory for gravimetric analysis. The rinseate from the nozzle and preseparator were evaporated to dryness in a tared beaker, dessicated and weighed to a constant weight. The filter substrates were dessicated and weighed to a constant weight. All of the gravimetric analytical results were reported to the nearest 0.01 mg.

Analytical Procedures for O₂, CO₂, CO, THC, SO₂, and NO_x

EPA reference methods were followed for all instrumental methods. The methods are as follows:

Oxygen and carbon dioxide	- EPA Method 3A, "Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)"
Carbon monoxide	- EPA Method 10, "Determination of Carbon Monoxide Emissions from Stationary Sources"
Total hydrocarbons	- EPA Method 25A, "Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer"

Sulfur dioxide	- EPA Method 6C, "Determination of Sulfur Dioxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)"
Nitrogen Oxides	- EPA Method 7E, "Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)"

Copies of the Methods as they appear in 40 CFR 60, Appendix A (July 1988) are included in the appendices.

The following is a brief description of each continuous analyzer's principle of operation:

Oxygen

Measurement Principle:	Zirconium oxide fuel cell
Manufacturer:	Teledyne 320P
Analysis Range:	0-25%
Calibration Gases:	O ₂ and N ₂ mix: 14.0%, 10.04% and zero air

Carbon Dioxide

Measurement Principle:	Nondispersive infrared absorption spectroscopy (NDIR)
Manufacturer:	ACS/Fuji 3300
Analysis Range:	0-10%
Calibration Gases:	CO ₂ in zero air mix: 10.01%, 5.985% and zero air

Carbon Monoxide

Measurement Principle:	Nondispersive infrared absorption spectroscopy (NDIR)
Manufacturer:	Horiba Dir-2000
Analysis Range:	0-1200 ppm
Calibration Gases:	274.6 ppm in zero air and zero air

Total Hydrocarbon

Measurement Principle:	Flame ionization detector (FID)
Manufacturer:	Ratfish R555
Analysis Range:	0-1000 ppm
Calibration Gases:	THC in HC free air mix: 84.7 ppm, 59.5 ppm and zero air

Sulfur Dioxide

Measurement Principle:	Ultra violet absorption
Manufacturer:	Western Research 721A
Analysis Range:	0-500 ppm
Calibration Gases:	SO ₂ in zero air mix: 272 ppm, 425 ppm and zero air

Nitrogen Oxide

Measurement Principle:	Chemiluminescence
Manufacturer:	Thermo-Electron Corporation
Analysis Range:	0-250 ppm, 0-1000 ppm
Calibration Gases:	137 ppm and 279 ppm in zero air and zero air

Analyzer Calibration

The analyzers were calibrated at the beginning of each test day and again at the end of the test day. The following is a description of the calibration procedures for each analyzer:

Oxygen

The oxygen analyzer was calibrated before each test with 3 ranges: zero air, 14.01%, 10.04%, in a N₂ mix. At the conclusion of each test, we conducted a post-test calibration using a mid level calibration gas that was closest observed during the sampling.

Carbon Dioxide

The CO₂ analyzer was calibrated before each test with 3 ranges: zero air, 5.985% and 10.01% in a N₂ mix. At the conclusion of each test, we conducted a post-test calibration using a mid level calibration gas that was closest observed during the sampling.

Carbon Monoxide

The CO analyzer was calibrated before each test with 2 ranges: zero air and 274.6 ppm. At the conclusion of the test, we conducted a post-test calibration check with the 274.6 ppm calibration gas.

Total Hydrocarbon

The THC analyzer was calibrated before each test with 3 ranges: zero air, 84.7 ppm and 599.5 ppm in a N₂ mix. At the conclusion of the test, we conducted a post-test calibration that was closest observed during the sampling.

Sulfur Dioxide

The SO₂ analyzer was calibrated before each test with 3 ranges: zero air, 272 ppm and 425 ppm. At the conclusion of the test, we conducted a post-test calibration using a mid-level calibration gas that was closest observed during the sampling.

Nitrogen Oxide

The NO_x analyzer was calibrated before each test with 2 ranges: 0-200 ppm and 0-1000 ppm. At the conclusion of the test, we conducted a

post-test calibration check using the calibration gas with the concentration that was closest to that observed during the sampling.

Analytical Procedures for Fuel

The fuel samples were submitted to Broeman Laboratories, Inc. located in Cincinnati, Ohio. The samples were analyzed for bulk density, ash fusion temperature, proximate and ultimate parameters, and elemental ash analysis. Each parameter was determined using American Society for Testing and Materials (ASTM) methodologies. The specific analytical method for the parameter measured is presented in Table 5.3.

TABLE 5.3
ASTM METHODS FOR FUEL ANALYSIS

<u>Parameter</u>	<u>ASTM Method</u>
Moisture	D-644
Ash	D-202 (Procedure A)
Volatile Matter	31-75
Sulfur Content	D-3177 (Method A)
Btu/lb	D-240
Carbon/Hydrogen	D-3178
Nitrogen	D-3179
Chlorine	D-2361 (Eschka Method)
Oxygen	calculation
Ash Fusion	D-1857
Bulk Density	D-202
Elemental Ash	D-2795

Analytical Procedures for Boiler Ash

The boiler ash samples were submitted to Triangle Laboratories to be analyzed for total dioxin, total furan, total PCB and metals. The analytical procedures for the organics are presented in SW-846, Method 8270 and Method 680. The metals analysis was performed as outlined in SW-846 for each metal.

SECTION 6

QUALITY ASSURANCE AND QUALITY CONTROL

SAMPLING EQUIPMENT PREPARATION

Glassware

Initially, all glassware was soaked in an caustic/acid bath to remove any residue. Subsequently, the glassware was rinsed three times with tap water followed by three deionized water rinses. Following the initial cleaning process, special preparation was given to the glassware to be used for the semi-VOST. Specifically, the semi-VOST glassware was heated for 2 hours at 450°F and rinsed three times with a 1:1 methanol/methylene chloride solution. The glassware was then capped with solvent-rinsed aluminum foil.

The glassware used for the particulates, metals and HCl sampling were rinsed three times with a 10% nitric acid solution, rinsed with tap water then deionized water followed by an acetone rinse for drying. The glassware was then capped with Parafilm and packed for shipment in a separate container from the semi-VOST glassware.

Emissions Sampling Equipment

The remaining preparation included calibration and leak checking for all the sampling train equipment. This included meter boxes, thermocouples, nozzles, pitot tubes, and umbilicals. Referenced calibration procedures were followed when available, and the results properly documented and retained. If a referenced calibration technique for a particular piece of apparatus was not available, then a state-of-the-art technique was used. A discussion of the techniques used to calibrate this equipment is presented below. The calibration data is presented in the appendices.

Type-S Pitot Tube Calibration

The EPA has specified guidelines concerning the construction and geometry of an acceptable Type-S pitot tube. If the specified design and construction guidelines are met, a pitot tube coefficient of 0.84 can be used. Information related to the design and construction of the Type-S pitot tube is presented in detail in 40 CFR 60, Appendix A. Only Type-S pitot tubes meeting the required EPA specifications were used during this project. Pitot tubes were visually inspected and documented as meeting EPA specifications prior to the field sampling.

Sampling Nozzle Calibration

Both stainless steel and quartz nozzles were used for isokinetic sampling. Calculation of the isokinetic sampling rate requires that the cross sectional area of the sampling nozzle be accurately and precisely known. All nozzles used on this project were thoroughly cleaned, visually inspected and calibrated according to the procedure outlined in 40 CFR 60, Appendix A.

Temperature Measuring Device Calibration

Accurate temperature measurements are required during source sampling. Bimetallic stem thermometers and thermocouple temperature sensors were calibrated using the procedure described in 40 CFR 60, Appendix A. Each temperature sensor was calibrated over the anticipated range of use against a NBS-traceable mercury-in-glass thermometer.

Dry Gas Meter Calibration

Dry gas meters (DGMs) were used in the particulate, metals, PM₁₀ and PCDD/PCDF/PCB sampling trains to measure the sample volume. All DGMs were calibrated to document the volume correction factor prior to the departure of the equipment to the field. Post-test calibration checks were performed upon return to the PES Laboratory. The calibrations were performed as specified in the EPA document "Quality Assurance Handbook for Air Pollution Measurement Systems," (EPA-600/9-76005b)

Continuous Emissions Monitors

The CEMs were calibrated using EPA protocol and certified gases. The monitors were calibrated in the expected concentration range of the stack gas.

GENERAL SAMPLING QC PROCEDURE

Semi-Vost

The semi-VOST was partially assembled and leak checked prior to transferring it to the sample location. Once in place at the sample site, the semi-VOST was assembled and the entire train was leak checked. The results of the leak checks, pretest and post-test, were documented on the data sheets.

All data during the tests were recorded on standard data sheets. At the end of the test day the data sheets were compiled and accounted for.

The equipment used for the PCDD/PCDF/PCB sampling such as the thermocouples, quartz nozzles, pitot tube and meter box were documented on the data sheets. All of the equipment was calibrated as described previously.

Particulates and Metals

The particulates and metals trains were assembled at the sampling location and allowed to heat. A leak check was conducted prior to and following the test. The results of the leak checks were documented on the data sheets.

All of the data collected during the test was recorded on standard forms. At the end of the test day the data sheets were compiled and accounted for.

The equipment used for the particulates and metals sampling such as the thermocouples, nozzle, pitot tube and meter box were documented on the data sheets. All of the equipment was calibrated as described previously.

HCl

The HCl train was leak checked prior to and following the sampling to ensure that no leaks occurred during the run. The data was recorded on data sheets that were compiled and accounted for at the end of the test day.

The gas metering device used in the HCl sampling was a calibrated orifice. The orifice number was recorded on data sheet.

PM₁₀ Particles

The PM₁₀ particle sample train was leak checked prior to sampling, however a post-test leak check was not conducted in order to prevent reentrainment of the particles.

The data was recorded on standard data sheets that were accounted for at the end of each test day. The equipment used in the PM₁₀ sampling such as the nozzle and dry gas meter were calibrated as described previously.

Continuous Emission Monitors

The CEMs were calibrated at the start of each test day and again at the end of each test day. The data was recorded on strip chart recorders as well as on an ACRO 2000 data log system.

SAMPLE RECOVERY

Semi-VOST

The semi-VOST recovery was conducted in an area that was isolated from the particulate, metals, HCl and PM₁₀ particulate recovery area. The samples were recovered into pre-labeled solvent rinsed amber bottles and glass petri dishes. All utensils that were used in the recovery of the samples were rinsed with solvent. The recovery solvent, a 1:1 mixture of distilled in glass-grade methylene chloride and methanol was prepared and stored in glass containers and poured into the Teflon wash

bottle as needed. After the samples were recovered, the liquid level was marked on the bottle and the openings were sealed with Teflon tape to prevent leakage. At the end of the test day the samples obtained were documented on the Chain-of-Custody data sheets. One set of blanks was set up and submitted to the laboratory for analysis along with the samples.

In the PES Laboratory, the samples were unpacked and visually inspected to verify if any leakage had occurred during shipment. The liquid level of all of the samples was the same as that marked on the bottle at the time of recovery. Each sample was logged in the sample log book and assigned a log number. The liquid samples were wrapped in plastic bags and bubble pack then packed in a cooler containing vermiculite. The resin traps were wrapped in plastic bags and bubble pack then packed in a cooler containing ice packs. All samples were shipped and received at the laboratory the following morning. All samples were received in good condition.

Particulate

Recovery of the particulate sampling train was performed in the recovery trailer. The samples were recovered into labeled borosilicate glass bottles and glass petri dishes. One set of blanks (filter, deionized water and acetone) was set-up in the field. Acetone was used to recover the particulates in the nozzle, probe and front half of the filter holder. The acetone was stored on site in the "as shipped" glass containers then dispensed into polyethylene wash bottles as needed. Deionized water was used to recover the back half of the train. The water was stored on site in polyethylene jugs. Following recovery of the samples, the liquid level on the sample bottles was marked and the opening of each bottle was sealed with Teflon tape to prevent leakage.

Following recovery, the sample train components (front half acetone rinse, filter and back half) were accounted for and stored. Prior to departure from the test site the samples were packed in a shipping container for shipment to the PES Laboratory.

Metals

Recovery of the metals sampling train was performed in the recovery trailer. Nitric acid (0.1 N) was used to recover the front half and the back half of the sampling train into separate borosilicate glass sample bottles. The 0.1 N HNO_3 was made from concentrated HNO_3 as required. The Pallflex filter was recovered into a glass petri dish. After the samples were recovered, the container openings were sealed with Teflon tape to prevent leakage during shipping. The liquid level of the samples was marked on each bottle. One set of blanks was set-up in the field, which included a blank for the impinger solution and the filter. Following recovery, the samples were accounted for and stored. Prior to departure the samples were packed in a shipping container for shipment to the PES Laboratory.

HCl

Recovery of the HCl sampling train was performed in the recovery trailer. Deionized water was used as the recovery solvent. The samples were recovered into polyethylene sample bottles. The sample bottles were labeled and the liquid level marked.

Following recovery, the samples were accounted for and stored. Prior to departure from the test site, the samples were packed for shipping to the PES Laboratory.

PM₁₀ Particles

The recovery of the PM₁₀ particle sampling train was performed in the recovery trailer. The impactor was maintained in an up-right position to prevent any particles from dislodging from the collection media. As soon as the impactor was cool enough to handle, the collection media was recovered. Each media stage was recovered into the foil pouch in which it was tared. The four stages that were recovered were placed in a larger foil pouch. The nozzle and cone section of the impactor were brushed and rinsed with acetone and collected in a polyethylene sample bottle. The bottle was labeled and the liquid level was marked on the bottle. The opening of the sample bottle was sealed with Teflon tape and stored. Prior to departure, the samples were packed for shipping to the PES Laboratory.

CEM

The CEM data was recovered in the field from the ACRO 2000 data acquisition system. An IBM-PC was used to recover the data from the ACRO system.

SAMPLE CUSTODY

Semi-VOST Samples

The semi-VOST samples were recovered and the samples packed for shipping to PES Laboratory. The samples remained in PES custody until they were shipped to Triangle Laboratories, Inc. (TLI). TLI acknowledged the receipt of the samples by returning PES' Chain-of-Custody sheets with a form describing the samples that were received, the condition and the project reference number. TLI's internal Chain-of-Custody was also documented on their Sample Management and Tracking Form.

Particulate Samples

The particulate samples were recovered and packed for shipment to PES' laboratory. The samples remained in PES' custody during shipping. After the samples were logged in, the filters and front half acetone rinses were retained for analysis by PES. The back half samples were submitted to DataChem located in Cincinnati, Ohio for the determination of organic and inorganic particulate. DataChem acknowledged the receipt

of the samples by signing PES' Chain-of-Custody data sheet and returning it to PES.

Metals and HCl Samples

The metals and HCl samples were recovered and packed for shipping to PES. The samples remained in PES custody during shipping. After the samples were logged in, they were transported to DataChem for analysis. DataChem acknowledged the receipt of the samples by signing the PES Chain-of-Custody data sheet and returning it to PES.

PM₁₀ Particles

The PM₁₀ particle samples were recovered and packed for transport to PES. The samples remained in PES custody during shipping. After the samples were logged in, the samples were retained by PES for analysis.

Process Samples

Fuel

The fuel samples remain in PES custody during transport from the test site. After the samples were logged in, they were submitted to Broeman Laboratories, Inc. located in Cincinnati. Broeman Labs acknowledged the receipt of the fuel samples by signing PES' Chain-of-Custody data sheet and returning it to PES.

Ash

The ash samples remained in PES custody during transport from the test site. After the samples were logged in, they were submitted to TLI for analysis. Triangle Labs acknowledged the receipt of the samples by returning PES' Chain-of-Custody sheet with a data form describing the samples, their condition upon arrival, and indicating the TLI project number.

Sample Analysis

The laboratories that provided analytical support to PES included DataChem, Broeman Laboratories, Inc. and Triangle Laboratories, Inc. all have internal QA/QC procedures that they must follow. However, it is not possible to present the QA/QC procedures for each laboratory in this report.

In order to demonstrate the quality of the data that was reported to us, the laboratories have provided us with data documenting the results of internal audits such as spikes, known concentration samples and duplicates. This information is provided in the appendices.

Data Documentation and Verification

All of the data that was collected in the field was recorded on standard data forms. The use of these data forms provided a means for process conditions, identification of run number, amount of sample

collected, time that sampling was conducted, etc. A portion of the raw data was calculated in the field using a computer program. The data that was calculated in the field included gas volumes, stack gas velocities and flow rates, stack gas moisture content and isokinetic sampling rates.

After the laboratory results were received and the final calculations were performed, the data was summarized. The data summaries were reviewed for any data that may be suspect (extremely high or low, not in range of similar data). If an error was found, the result was flagged then recalculated.

The calculated data was also reviewed to ensure that all raw information was input correctly. The inputted data was printed on a summary sheet and this data was compared with the data from the field data sheet.

Finally, this report was subjected to PES' internal review process.

Preparation of Samples for Analysis

The samples that were submitted to contract laboratories include the semi-VOST, Method 5 back half, metals, HCl and process samples. When the samples were submitted to the laboratory, they were accompanied by instructions as to what analysis were to be performed and the analytical method to be utilized.

The samples that were retained by PES included the Method 5 filters and front half acetone rinses, and PM₁₀ particle filters and acetone rinses. In preparation for analysis, the Method 5 filter numbers were recorded in the laboratory notebook along with the initial weight of that particular filter. The Method 5 front half acetone rinses were assigned a tared beaker in which they were to be evaporated. The sample number and tare weight of the beaker was recorded on a data sheet in a notebook. The same procedures were followed for the PM₁₀ particle collection media and impactor acetone rinses.

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