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EMISSIONS TEST REPORT
DIOXIN/FURAN EMISSION TESTING

REFUSE FUELS ASSOCIATES
LAWRENCE, MASSACHUSETTS

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TABLE OF CONTENTS

TABLE OF CONTENTS
(cont'd.)

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Radian Corporation, under contract to Refuse Fuels Associates (RFA), provided technical and sampling support for the evaluation of emissions from the RFA resource recovery facility located in Lawrence, Massachusetts. The objective of the program was to accurately determine the flue gas mass emission rates of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) from the RDF boiler. Also, the PCDD and PCDF concentration in the ESP ash and total ash discharge streams produced by the incinerator were determined. One test consisting of three sampling runs was performed at this facility.

The resource recovery facility consisted of a suspension fired incinerator with a waterwall boiler which produces superheated steam. The feed to the incinerator is refuse derived fuel (RDF) which consists of municipal solid waste which has been sorted and shredded to remove noncombustibles and reduced to a uniform consistency. Stack particulate emissions were controlled by an electrostatic precipitator (ESP). The overall test program included sampling for PCDD's and PCDF's following ASME/EPA procedures[1] at the induced draft (ID) fan outlet. Concurrently, samples of the ESP ash and total ash discharge (ESP ash, boiler/economizer fly ash, and incinerator bottom ash combined) were collected and analyzed for PCDD/PCDF.

The PCDD/PCDF analysis of the flue gas and ash samples were performed by Triangle Laboratories, Inc. located in Research Triangle Park, North Carolina. The samples were analyzed by gas chromatography followed by high resolution mass spectrometry. The specific PCDD/PCDF homologues which were determined are listed in Table 1-1.

Sampling was conducted over a two day period from September 15 to September 18. The MM5 train sampling time was 192 minutes per test run. Table 1-2 summarizes the sampling times for each parameter sampled during the test period and any problems which occurred during the sampling runs. The test participants and their responsibilities are listed in Table 1-3.

The test program was executed with emphasis on completeness and data quality. A quality assurance (QA) and quality control (QC) program was an

TABLE 1-1. LIST OF CHLORINATED ORGANIC COMPOUNDS FOR ANALYSIS

1.	Total Trichlorinated dibenzo dioxins (TrCDD)
2.	2,3,7,8 Tetrachloro dibenzo-p-dioxin (2,3,7,8 TCCD)
3.	Total Tetrachlorinated dibenzo dioxins (TCDD)
4.	1,2,3,7,8, Pentachloro dibenzo dioxin (1,2,3,7,8 PCDD)
5.	Total Pentachlorinated dibenzo dioxins (PCDD)
6.	1,2,3,4,7,8, Hexachloro dibenzo dioxin (1,2,3,4,7,8, HxCDD)
7.	1,2,3,6,7,8 Hexachloro dibenzo dioxin (1,2,3,6,7,8, HxCDD)
8.	1,2,3,7,8,9 Hexachloro dibenzo dioxin (1,2,3,7,8,9, HxCDD)
9.	Total Hexachlorinated dibenzo dioxins (HxCDD)
10.	Total Heptachlorinated dibenzo dioxins (HpCDD)
11.	Total Octachlorinated dibenzo dioxins (OCDD)
12.	Total Trichlorinated dibenzo furans (TrCDF)
13.	2,3,7,8 Tetrachloro dibenzo furans (2,3,7,8 TCDF)
14.	Total Tetrachlorinated dibenzo furans (TCDF)
15.	1,2,3,7,8 Pentachloro dibenzo furan (1,2,3,7,8, PCDF)
16.	2,3,4,7,8 Pentachloro dibenzo furan (2,3,4,7,8, PCDF)
17.	Total Pentachlorinated dibenzo furans (PCDF)
18.	1,2,3,4,7,8 Hexachloro dibenzo furan (1,2,3,4,7,8, HxCDF)
19.	1,2,3,7,8,9 Hexachloro dibenzo furan (1,2,3,7,8,9, HxCDF)
20.	2,3,4,6,7,8 Hexachloro dibenzo furan (2,3,4,6,7,8 HxCDF)
21.	Total Hexachlorinated dibenzo furans (HxCDF)
22.	Total Heptachlorinated dibenzo furans (HpCDF)
23.	Total Octachlorinated dibenzo furans (OCDF)
24.	Monochlorinated dibenzo dioxin (MCDD)
25.	Total dichlorinated dibenzo dioxins (DCDD)
26.	Monochlorinated dibenzo furan (MCDF)
27.	Total dichlorinated dibenzo furan (DCDF)

TABLE 1-2. RFA SAMPLING LOG

Date	Run	MM5 Train Sampling Time	Port[a]	Total Ash Discharge	ESP Ash	Notes
9-17-86	1	09:00-10:36 11:36-13:34	A B	09:45-13:25	10:01-13:31	Weather: Clear and cold.
9-17-86	2	14:22-16:51 17:14-18:48	A B	15:00-19:01	15:02-19:03	Midway thru Port A the incinerator grate became clogged and testing ceased while it was cleared. Weather: Clear and mild.
9-18-86	3	09:18-11:26 12:15-13:51	A B	10:30-13:59	10:32-13:32	When the test was initially started the grate became clogged and testing ceased while it was cleared. Weather: Clear and cool.

[a]Port A was the vertical traverse.

[b]Port B was the horizontal traverse.

TABLE 1-3. RFA DIOXIN/FURAN TEST PARTICIPANTS
September 15-18, 1986

Name	Affiliation	Responsibilities
Ashvin Patel	RFA	Test Program Coordinator
Joe Bacchi	RFA	Plant Manager
Dennis Knisley	Radian	Test Engineer
Mike Palazzolo	Radian	Ash Sampler
Lee Garcia	Radian	Stack Sampler
Gary Henry	Radian	Sample Recovery
Tom Natario	Massachusetts DEQE (Air Quality)	MM5 Sampling Observer
David Adams	Massachusetts DEQE (Solid Waste)	Ash Sampling Observer

integral part of Radian's test program. The goal of the QA/QC effort was to ensure that the data collected are of known precision and accuracy and that they are complete, representative and comparable. The results of the QA/QC activities are discussed in detail in Section 5.

2.0 SUMMARY OF RESULTS

The results of the sampling conducted at Refuse Fuels Associates (RFA) are summarized in Table 2-1. The results presented in this section are not corrected for blank results or surrogate recoveries which are presented in Section 5.0. The total average PCDD/PCDF concentration in the flue gas was 2719 ng/dscm. An average 76 percent of the total PCDD/PCDF was determined to be in the front half of the sampling train. The front half of the sampling train consists of the nozzle/probe rinse and the particulate on the filter. Dioxin/furans captured in this part of the train are generally considered to have condensed in or on the particulate matter in the flue gas. The dioxin/furans captured in the back half of the train, which includes the condenser coil, XAD^{R} trap, and the impinger catches, are considered to have been present in the gaseous phase. Corrected to 12 percent CO_2, the total average PCDD/PCDF concentration was 3341 ng/dscm at 12 percent CO_2 and the total average concentration in terms of 2378 TCDD equivalents was 43 ng/dscm of 2378 TCDD. The results of the ash sampling determined that the ESP ash contained an average of 6426 ng/g of total PCDD/PCDF. The total ash discharge sample contained an average of 1690 ng/g PCDD/PCDF over the three tests.

2.1 DIOXIN/FURAN ANALYSIS RESULTS

The dioxin/furan results for the flue gas, ESP ash and total ash discharge samples are presented in this section. The dioxin/furan flue gas samples were collected and analyzed according to the December 1984 Environmental Standards Workshop protocol for dioxin/furan sampling with several modifications which are discussed in Chapter 4. The protocol is included as Appendix A of this report.

2.1.1 Flue Gas Results

The dioxin/furan sampling trains were analyzed as front half and back half samples. The front half samples included the probe rinse, front half of the filter holder rinse and filter. Back half samples consisted of the back

TABLE 2-1. SUMMARY OF RFA TEST PROGRAM RESULTS FOR FLUE GAS AND ASH

Parameter	Average Concentrations		
FLUE GAS			
Dioxin/Furans	Average PCDD Concentration	Average PCDF Concentration	Total Average PCDD and PCDF Concentration
Front Half (ng/dscm)	1333	747	2080
Back Half (ng/dscm)	315	324	639
Total (ng/dscm)	1648	1071	2719
Fraction in front half (%)	81	70	76
Total concentration corrected to 12% CO_2 (ng/dscm)	2024	1317	3341
Total concentration as 2378-TCDD equivalents (ng/dscm)	33	10	43
Emission factors (10^{-9} lb/MMBtu)	NA	NA	NA
ASH			
ESP Ash			
Concentration (ng/g)	3780	2799	6574
Total ash discharge			
Concentration (ng/g)	1519	338	1857

half filter holder rinse, condenser rinse, XAD^R trap, and the contents and rinses from the first four impingers.

The total concentrations of the mono- through octa- dioxin/furan isomers (front half plus back half) for each test run are summarized in Table 2-2. The average total 2378-TCDD concentration was 6.4 ng/dscm and the average 2378-TCDF concentration was 23.8 ng/dscm. The average total PCDD concentration was 1648 ng/dscm and the average total PCDF concentration was 1071 ng/dscm. The average total PCDD/PCDF concentration was 2719 ng/dscm.

The front half and back half dioxin/furan results are presented in Table 2-3. The fraction of the PCDD/PCDF found in the front half of the train is presented in Table 2-4. More than 80 percent of the PCDD and greater than 69 percent of the PCDF was detected in the front half of the sample train. An average of 2080 ng/dscm of PCDD/PCDF was detected in the front half sample which is 76 percent of the total PCDD/PCDF captured. This indicated that most of the PCDD/PCDF captured in the MM5 sample were condensed in or on the particulate matter in the flue gas. Less than 25 percent of the flue gas PCDD/PCDF emissions were in the gaseous phase.

Dioxin/furan results corrected to 12 percent CO_2 are presented in Table 2-5. The concentrations are corrected for each test run by multiplying by the quotient of $12/CO_2$ measured. The measured value of CO_2 was determined by EPA Method 3 from an integrated bag sample using Orsat analysis. Corrected to 12 percent CO_2, the average 2378 TCDD concentration was 7.9 ng/dscm and the average 2378 TCDF concentration 29.4 ng/dscm. The average total PCDD concentration was 2024 ng/dscm and the average total PCDF concentration was 1317 ng/dscm. The average total PCDD/PCDF concentration at 12 percent CO_2 was 3341 ng/dscm.

The dioxin/furan results corrected to 12 percent CO_2 are expressed in terms of 2378 TCDD equivalents in Table 2-6. Each isomer has a 2378 TCDD toxicity equivalency factor[2], which is also contained in Table 2-6, that rates the toxicity of the isomers relative to 2378-TCDD. In terms of 2378 TCDD, the total PCDD concentration was 32.6 ng/dscm and the total PCDF concentration was 9.8 ng/dscm. The average total PCDD and PCDF concentration was 42.4 ng/dscm relative to 2378-TCDD.

TABLE 2-2. SUMMARY OF DIOXIN/FURAN FLUE GAS CONCENTRATIONS FOR RFA

ISOMER	CONCENTRATION (NG/DSCM, AS MEASURED) RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN				
Mono-CDD	0.0	0.0	0.0	0.0
Di-CDD	9.2	7.0	1.6	5.9
Tri-CDD	34.1	38.3	18.0	30.1
2378 TCDD	7.6	7.9	3.7	6.4
Other TCDD	61.2	110.2	48.9	73.4
12378 PCDD	13.0	28.7	13.4	18.3
Other PCDD	28.1	191.1	84.2	101.1
123478 HxCDD	28.2	36.5	21.3	28.7
123678 HxCDD	113.9	47.1	22.8	61.3
123789 HxCDD	283.1	87.5	47.6	139.4
Other HxCDD	394.7	381.7	202.9	326.4
Hepta-CDD	93.9	751.5	422.9	422.8
Octa-CDD	97.0	795.5	411.3	434.6
TOTAL PCDD	1164.0	2482.9	1298.4	1648.5
FURAN				
Mono-CDF	0.5	0.1	0.8	0.4
Di-CDF	7.8	17.4	17.5	14.2
Tri-CDF	126.5	174.6	134.2	145.1
2378 TCDF	19.1	18.8	33.5	23.8
Other TCDF	131.1	250.1	140.1	173.8
12378 PCDF	8.2	20.0	11.8	13.3
23478 PCDF	16.6	41.9	23.6	27.4
Other PCDF	57.9	142.5	72.2	90.9
123478 HxCDF	42.4	99.8	59.5	67.2
123678 HxCDF	17.2	45.8	25.4	29.5
123789 HxCDF	1.5	0.0	0.0	0.5
Other HXCDF	86.8	186.1	135.7	136.2
Hepta-CDF	209.9	420.1	250.7	293.6
Octa-PCDF	43.5	76.1	45.9	55.2
TOTAL PCDF	769.0	1493.2	950.8	1071.0
TOTAL PCDD/PCDF	1933.0	3976.1	2249.3	2719.5

TABLE 2-3. DIOXIN/FURAN RESULTS OF FRONT HALF/BACK HALF SAMPLES

ISOMER	CONCENTRATION (NG/DSCM, AS MEASURED) RUN 01 FRONT HALF	RUN 01 BACK HALF	RUN 02 FRONT HALF	RUN 02 BACK HALF	RUN 03 FRONT HALF	RUN 03 BACK HALF
DIOXIN						
Mono-CDD	0.00	0.00	0.00	0.00	0.00	0.00
Di-CDD	9.01	0.18	4.02	3.00	1.18	0.43
Tri-CDD	27.60	6.47	23.26	14.99	9.57	8.38
2378 TCDD	6.76	0.87	5.62	2.25	2.59	1.07
Other TCDD	47.87	13.34	73.41	36.81	32.45	16.40
12378 PCDD	10.47	2.51	20.80	7.85	9.86	3.56
Other PCDD	12.93	15.18	142.70	48.38	62.41	21.77
123478 HxCDD	24.76	3.46	27.56	8.94	16.52	4.79
123678 HxCDD	109.52	4.39	36.87	10.20	17.85	4.96
123789 HxCDD	275.74	7.37	69.31	18.22	37.80	9.75
Other HxCDD	359.69	35.02	290.76	90.90	158.45	44.45
Hepta-CDD	22.13	71.78	622.63	128.87	350.27	72.58
Octa-CDD	18.14	78.82	701.39	94.12	358.10	53.24
TOTAL PCDD	924.62	239.41	2018.36	464.54	1057.06	241.38
FURAN						
Mono-CDF	0.11	0.36	0.06	0.00	0.07	0.68
Di-CDF	7.81	0.00	11.10	6.29	0.00	17.51
Tri-CDF	70.19	56.31	94.05	80.54	70.59	63.66
2378 TCDF	19.11	0.00	0.00	18.75	21.73	11.81
Other TCDF	70.17	60.95	172.14	77.99	97.12	42.96
12378 PCDF	5.68	2.49	13.30	6.66	8.24	3.58
23478 PCDF	11.57	5.05	28.87	13.00	16.64	6.93
Other PCDF	38.79	19.11	95.38	47.12	48.10	24.11
123478 HxCDF	30.41	11.95	73.39	26.42	45.26	14.26
123678 HxCDF	12.07	5.17	33.41	12.39	19.72	5.64
123789 HxCDF	1.47	0.00	0.00	0.00	0.00	0.00
Other HXCDF	57.38	29.38	132.88	53.22	111.86	23.79
Hepta-CDF	158.89	51.05	324.65	95.49	200.11	50.55
Octa-PCDF	32.98	10.54	65.62	10.50	38.79	7.11
TOTAL PCDF	516.62	252.36	1044.84	448.38	678.21	272.61
TOTAL PCDD/PCDF	1441.24	491.77	3063.20	912.92	1735.27	513.99

TABLE 2-4. FRACTION OF TOTAL DIOXIN/FURAN IN THE FRONT HALF SAMPLE

ISOMER	FRACTION (%) RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN				
Mono-CDD	0.0	0.0	0.0	0.0
Di-CDD	98.1	57.2	73.4	76.3
Tri-CDD	81.0	60.8	53.3	65.0
2378 TCDD	88.6	71.5	70.8	76.9
Other TCDD	78.2	66.6	66.4	70.4
12378 PCDD	80.7	72.6	73.5	75.6
Other PCDD	46.0	74.7	74.1	64.9
123478 HxCDD	87.7	75.5	77.5	80.3
123678 HxCDD	96.1	78.3	78.3	84.2
123789 HxCDD	0.0	79.2	0.0	26.4
Other HxCDD	91.1	76.2	78.1	81.8
Hepta-CDD	23.6	82.9	82.8	63.1
Octa-CDD	18.7	88.2	87.1	64.6
TOTAL PCDD	79.4	81.3	81.4	80.7
FURAN				
Mono-CDF	22.8	100.0	9.1	44.0
Di-CDF	100.0	63.8	0.0	54.6
Tri-CDF	55.5	53.9	52.6	54.0
2378 TCDF	100.0	0.0	64.8	54.9
Other TCDF	53.5	68.8	69.3	63.9
12378 PCDF	69.5	66.6	69.7	68.6
23478 PCDF	69.6	69.0	70.6	69.7
Other PCDF	67.0	66.9	66.6	66.8
123478 HxCDF	71.8	73.5	76.0	73.8
123678 HxCDF	70.0	73.0	77.8	73.6
123789 HXCDF	0.0	0.0	0.0	0.0
Other HXCDF	66.1	71.4	82.5	73.3
Hepta-CDF	75.7	77.3	79.8	77.6
Octa-PCDF	75.8	86.2	84.5	82.2
TOTAL PCDF	67.2	70.0	71.3	69.5
TOTAL PCDD/PCDF	74.6	77.0	77.1	76.2

TABLE 2-5. DIOXIN/FURAN CONCENTRATIONS CORRECTED TO 12 PERCENT CO2

ISOMER	CONCENTRATION (NG/DSCM, CORRECTED TO 12% CO2) RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN				
Mono-CDD	0.0	0.0	0.0	0.0
Di-CDD	11.4	8.5	2.0	7.3
Tri-CDD	42.1	46.4	22.4	37.0
2378 TCDD	9.4	9.5	4.6	7.9
Other TCDD	75.7	133.6	61.1	90.1
12378 PCDD	16.1	34.7	16.8	22.5
Other PCDD	34.8	231.6	105.2	123.9
123478 HxCDD	34.9	44.2	26.6	35.3
123678 HxCDD	140.9	57.1	28.5	75.5
123789 HxCDD	350.2	106.1	59.4	171.9
Other HxCDD	488.3	462.6	253.6	401.5
Hepta-CDD	116.2	910.9	528.6	518.6
Octa-CDD	120.0	964.3	514.2	532.8
TOTAL PCDD	1440.0	3009.6	1623.0	2024.2
FURAN				
Mono-CDF	0.6	0.1	0.9	0.5
Di-CDF	9.7	21.1	21.9	17.5
Tri-CDF	156.5	211.6	167.8	178.6
2378 TCDF	23.6	22.7	41.9	29.4
Other TCDF	162.2	303.2	175.1	213.5
12378 PCDF	10.1	24.2	14.8	16.4
23478 PCDF	20.6	50.7	29.5	33.6
Other PCDF	71.6	172.7	90.3	111.5
123478 HxCDF	52.4	121.0	74.4	82.6
123678 HxCDF	21.3	55.5	31.7	36.2
123789 HxCDF	1.8	0.0	0.0	0.6
Other HXCDF	107.3	225.6	169.6	167.5
Hepta-CDF	259.7	509.3	313.3	360.8
Octa-PCDF	53.8	92.3	57.4	67.8
TOTAL PCDF	951.3	1810.0	1188.5	1316.6
TOTAL PCDD/PCDF	2391.4	4819.5	2811.6	3340.8

TABLE 2-6. DIOXIN/FURAN CONCENTRATION AS 2378-TCDD EQUIVALENTS (CORRECTED TO 12 PERCENT CO2)

ISOMER	2378 TCDD EQUIV. FACTORS	2378 TCDD EQUIVALENT CONCENTRATION (NG/DSCM) RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN					
Mono-CDD	0.0000	0.00	0.00	0.00	0.00
Di-CDD	0.0000	0.00	0.00	0.00	0.00
Tri-CDD	0.0000	0.00	0.00	0.00	0.00
2378 TCDD	1.0000	9.45	9.54	4.58	7.86
Other TCDD	0.0100	0.76	1.34	0.61	0.90
12378 PCDD	0.5000	8.03	17.37	8.38	11.26
Other PCDD	0.0050	0.17	1.16	0.53	0.62
123478 HxCDD	0.0400	1.40	1.77	1.07	1.41
123678 HxCDD	0.0400	5.64	2.28	1.14	3.02
123789 HxCDD	0.0400	14.01	4.24	2.38	6.88
Other HxCDD	0.0004	0.20	0.19	0.10	0.16
Hepta-CDD	0.0010	0.12	0.91	0.53	0.52
Octa-CDD	0.0000	0.00	0.00	0.00	0.00
TOTAL PCDD		39.76	38.79	19.32	32.62
FURAN					
Mono-CDF	0.0000	0.00	0.00	0.00	0.00
Di-CDF	0.0000	0.00	0.00	0.00	0.00
Tri-CDF	0.0000	0.00	0.00	0.00	0.00
2378 TCDF	0.1000	2.36	2.27	4.19	2.94
Other TCDF	0.0010	0.16	0.30	0.18	0.21
12378 PCDF	0.1000	1.01	2.42	1.48	1.64
23478 PCDF	0.1000	2.06	5.07	2.95	3.36
Other PCDF	0.0010	0.07	0.17	0.09	0.11
123478 HxCDF	0.0100	0.52	1.21	0.74	0.83
123678 HxCDF	0.0100	0.21	0.56	0.32	0.36
123789 HxCDF	0.0100	0.02	0.00	0.00	0.01
Other HXCDF	0.0001	0.01	0.02	0.02	0.02
Hepta-CDF	0.0010	0.26	0.51	0.31	0.36
Octa-PCDF	0.0000	0.00	0.00	0.00	0.00
TOTAL PCDF		6.69	12.54	10.27	9.83
TOTAL PCDD/PCDF		46.45	51.33	29.59	42.46

Dioxin/furan emission factors are summarized in Table 2-7. Emission factors express dioxin/furan emissions as pounds of an isomer emitted per million Btu of refuse derived fuel incinerated. The conversion is based on an F-factor (dscf of flue gas per million Btu of refuse derived fuel incinerated) that is characteristic of the fuel. The average emission factor for total PCDD's was 3.75×10^{-3} lb/MMBtu and 2.44×10^{-3} lb/MMBtu for total PCDF's. The total PCDD/PCDF average emission factor was 6.20×10^{-3} lb/MMBtu.

The dioxin/furan train sampling and flue gas parameters are summarized for each test run in Table 2-8. The average volumetric flowrate of the flue gas was 2,947 dscmm (103,974 dscfm) and the average moisture content was 12.3 percent by volume. The flue gas combustion products (O_2, CO_2) concentrations which are used in the isokinetic calculations and to correct the PCDD/PCDF results to 12 percent CO_2 were measured using EPA Method 3. The average oxygen concentration was 10.3 percent by volume and the average carbon dioxide concentration was 9.7 percent by volume. An average of 2.9 dscm (102 dscf) of flue gas was sampled at an average sampling rate of 0.015 dscmm (0.53 dscfm). For all the test runs, the sample volume met the 90 dscf minimum sample volume requirement. Isokinetics ranged from 98.1 to 99.9 percent which were within the quality assurance objectives of 100 $\pm$ 10 percent.

The distribution of the dioxin and furan isomers are shown in tabular form in Table 2-9 and in graphical form in Figures 2-1 and 2-2. The isomer coding key is shown in Table 2-10. The hexa- thru octa-PCDD isomers composed greater than 80 percent of the total PCDD detected in the flue gas. The tri- and tetra- PCDF isomers accounted for 40 percent of the total PCDF detected. Another 40 percent of the PCDF sample was composed of the hexa- and hepta-PCDF isomers.

2.1.2 ESP Ash Results

The ESP ash sample was collected at an intermediate transfer point at the start of the screw conveyor which transfers the ash to the total ash discharge point. The ESP ash is water quenched in this screw conveyor; however, the sample was taken before quenching occurred. A sample was collected every 30 minutes during flue gas sampling. Sampling began 45 minutes after the start of the flue gas sampling. Approximately four pounds of ESP ash was collected

TABLE 2-7. DIOXIN/FURAN EMISSION FACTORS FOR RFA

	EMISSION FACTORS (1E-6 lb/MMBtu)			
ISOMER	RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN				
Mono-CDD	0.00	0.00	0.00	0.00
Di-CDD	21.17	15.74	3.73	13.55
Tri-CDD	78.48	85.70	41.78	68.66
2378 TCDD	17.60	17.62	8.53	14.58
Other TCDD	141.05	246.92	113.65	167.20
12378 PCDD	29.91	64.19	31.20	41.77
Other PCDD	64.79	428.06	195.83	229.56
123478 HxCDD	65.03	81.78	49.57	65.46
123678 HxCDD	262.47	105.46	53.05	140.33
123789 HxCDD	652.35	196.09	110.62	319.69
Other HxCDD	909.48	854.99	472.01	745.49
Hepta-CDD	216.38	1683.49	983.69	961.19
Octa-CDD	223.42	1782.08	956.92	987.47
TOTAL PCDD	2682.13	5562.12	3020.59	3754.94
FURAN				
Mono-CDF	1.08	0.13	1.75	0.99
Di-CDF	18.00	38.96	40.73	32.56
Tri-CDF	291.46	391.10	312.31	331.62
2378 TCDF	44.02	42.01	78.03	54.69
Other TCDF	302.12	560.35	325.87	396.11
12378 PCDF	18.82	44.73	27.50	30.35
23478 PCDF	38.31	93.78	54.83	62.30
Other PCDF	133.42	319.23	167.98	206.88
123478 HxCDF	97.61	223.59	138.46	153.22
123678 HxCDF	39.73	102.60	59.00	67.11
123789 HxCDF	3.39	0.00	0.00	1.13
Other HXCDF	199.90	416.88	315.57	310.78
Hepta-CDF	483.74	941.19	583.12	669.35
Octa-PCDF	100.28	170.52	106.79	125.86
TOTAL PCDF	1771.87	3345.07	2211.93	2442.96
TOTAL PCDD/PCDF	4454.00	8907.18	5232.52	6197.90

TABLE 2-8. SUMMARY OF MM5 TRAIN SAMPLING AND FLUE GAS PARAMETERS AT RFA

Parameters	Run 01	Run 02	Run 03	Average
Flue Gas Combustion Products				
O_2 (Vol%)[a]	10.4	10.1	10.5	10.3
CO_2 (Vol%)[a]	9.7	9.9	9.6	9.7
Flue Gas Temperature				
(^oF)	396	408	403	402
(^oC)	202	209	206	206
Flue Gas Moisture Content				
(Vol%)	11.9	12.4	12.5	12.3
Flue Gas Volumetric Flowrate				
(dscfm)[b]	105,501	102,205	104,135	103,947
(dscmm)[c]	2,998	2,894	2,949	2,947
(acfm)[d]	191,758	189,599	191,958	191,105
(acmm)[e]	5,431	5,369	5,436	5,412
Volume of Flue Gas Sampled				
(dscf)[f]	102.2	99.6	102.8	101.5
(dscm)[g]	2.9	2.8	2.9	2.9
Average Sampling Rate				
(dscfm)[b]	0.53	0.51	0.54	0.53
(dscmm)[c]	0.015	0.015	0.015	0.015
Isokinetics				
(%)[h]	98.1	98.6	99.9	98.9

[a] EPA Method 3 by Orsat.
[b] Dry standard cubic ft/minute, standard conditions; 29.92 inches (760 mm) of mercury 68^oF (20^oC).
[c] Dry standard cubic meters per minute
[d] Actual cubic feet per minute at stack conditions.
[e] Actual cubic meters per minute at stack conditions.
[f] Dry standard cubic feet.
[g] Dry standard cubic meters.
[h] The quality assurance objective for EPA Method 5 testing is isokinetics of 100 $\pm$ 10%.

TABLE 2-9. DIOXIN/FURAN DISTRIBUTIONS IN THE FLUE GAS

	MOLE FRACTION			
ISOMER	RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN				
Mono-CDD	0.00	0.00	0.00	0.00
Di-CDD	0.01	0.00	0.00	0.01
Tri-CDD	0.04	0.02	0.02	0.03
2378 TCDD	0.01	0.00	0.00	0.01
Other TCDD	0.06	0.06	0.05	0.06
12378 PCDD	0.01	0.01	0.01	0.01
Other PCDD	0.03	0.09	0.07	0.06
123478 HxCDD	0.02	0.02	0.02	0.02
123678 HxCDD	0.10	0.02	0.02	0.05
123789 HxCDD	0.24	0.04	0.04	0.11
Other HxCDD	0.34	0.16	0.16	0.22
Hepta-CDD	0.07	0.29	0.32	0.23
Octa-CDD	0.07	0.29	0.28	0.21
FURAN				
Mono-CDF	0.00	0.00	0.00	0.00
Di-CDF	0.01	0.02	0.03	0.02
Tri-CDF	0.21	0.15	0.18	0.18
2378 TCDF	0.03	0.01	0.04	0.03
Other TCDF	0.19	0.19	0.17	0.18
12378 PCDF	0.01	0.01	0.01	0.01
23478 PCDF	0.02	0.03	0.03	0.03
Other PCDF	0.08	0.10	0.08	0.08
123478 HxCDF	0.05	0.06	0.06	0.06
123678 HxCDF	0.02	0.03	0.02	0.02
123789 HxCDF	0.00	0.00	0.00	0.00
Other HXCDF	0.10	0.12	0.13	0.12
Hepta-CDF	0.23	0.24	0.22	0.23
Octa-PCDF	0.04	0.04	0.04	0.04

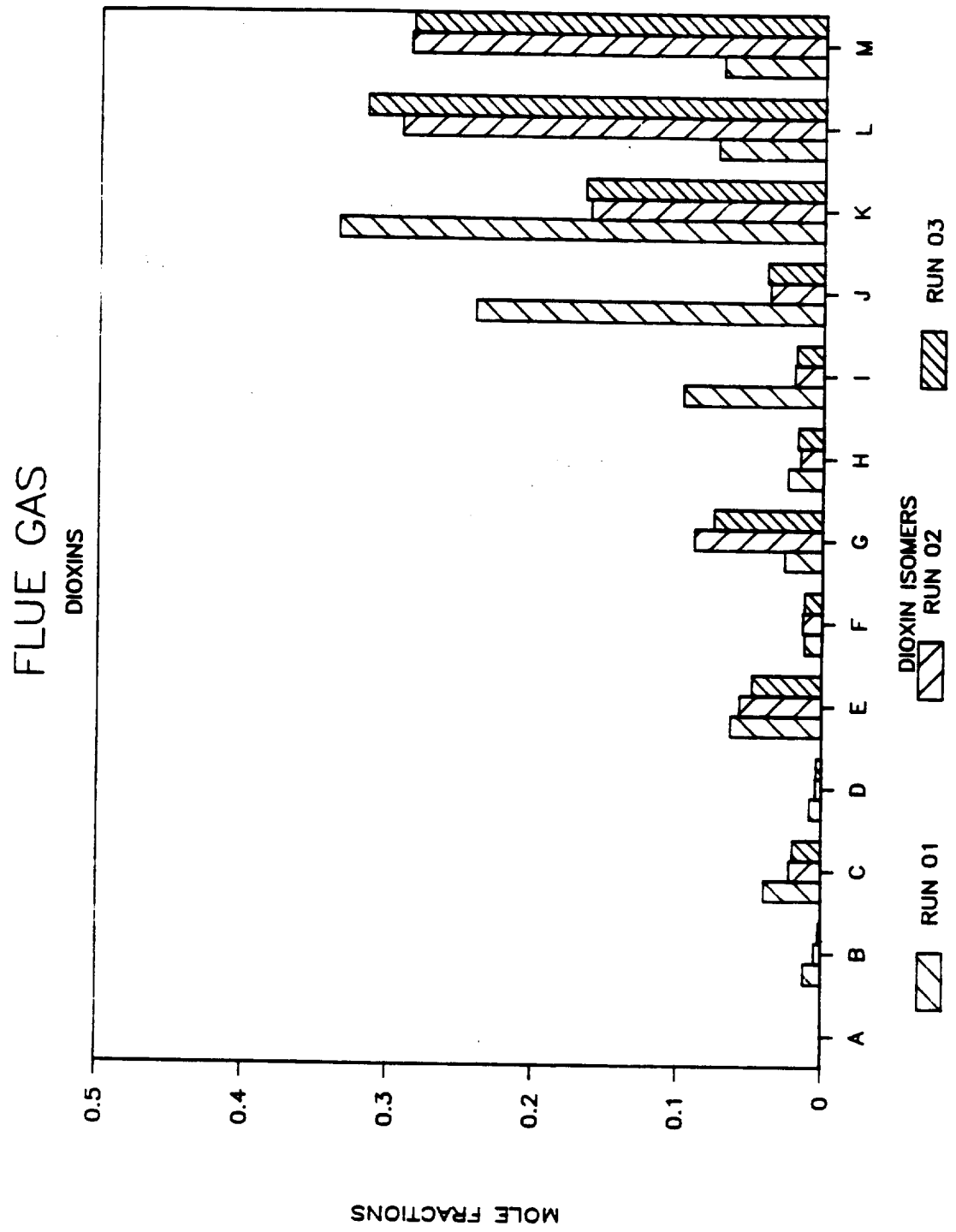


Figure 2-1. Dioxin homolog distribution in the flue gas.

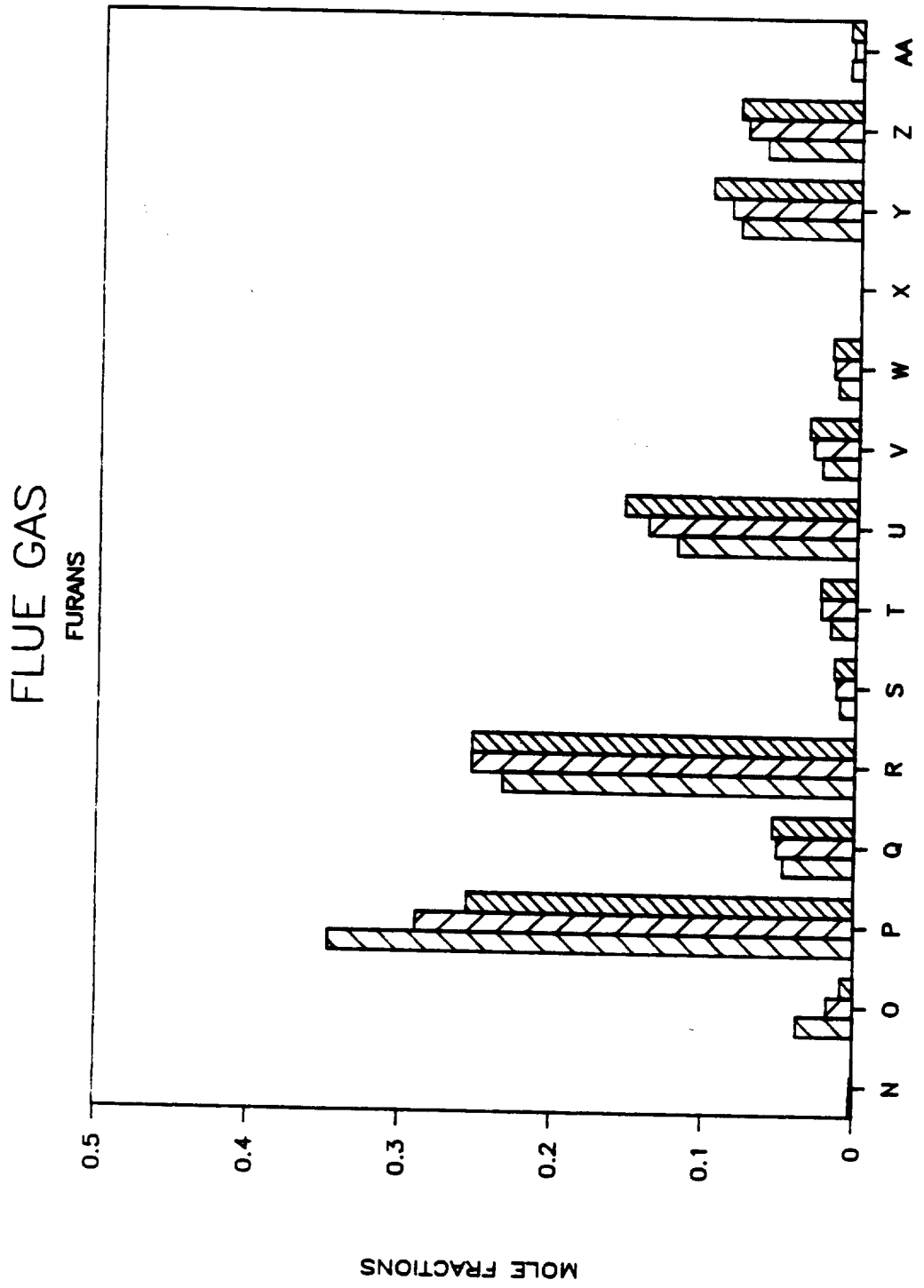


Figure 2-2. Furan homolog distribution in the flue gas.

TABLE 2-10. KEY TO ISOMER CODING FOR FIGURES 2-1 THROUGH 2-6.

CODE	ISOMER
	Dioxins
A =	Mono-CDD
B =	Di-CDD
C =	Tri-CDD
D =	2378-TCDD
E =	Other TCDD
F =	12378 PCDD
G =	Other PCDD
H =	123478 HxCDD
I =	123678 HxCDD
J =	123789 HxCDD
K =	Other HxCDD
L =	Hepta-CDD
M =	Octa-CDD
	Furans
N =	Mono-CDF
O =	Di-CDF
P =	Tri-CDF
Q =	2378-TCDF
R =	Other TCDF
S =	12378 PCDF
T =	Other PCDF
U =	123478 HxCDF
V =	123678 HxCDF
W =	123789 HxCDF
X =	Other HxCDF
Z =	Hepta-CDF
AA =	Octa-CDF

during each run which was composited and an aliquot was placed in a 950 ml amber glass bottle. Approximately 10 grams of this aliquot was extracted by Triangle Labs for PCDD/PCDF analysis.

The ESP ash samples contained high levels of PCDD/PCDF which caused some problems with the analysis of the samples. The maximum values for which the high resolution GC/MS was calibrated for each of the dioixn/furan isomers was as follows:

Homolog	Maximum Calibrated Value
Mono-through tetra-PCDD/PCDF	20 ng/g
Penta- through hepta-PCDD/PCDF	100 ng/g
Octa- PCDD/PCDF	400 ng/g

According to Triangle Laboratories, the reported values of the individual isomers should be relatively accurate up to twice the maximum calibrated value. Above this limit the accuracy is unknown and the reported values should be used as a minimum amount of PCDD/PCDF in the sample. Individual isomers in several of the samples analyzed were reported to be greater than 1000 ng/g PCDD or PCDF. Therefore, the results presented in the ash analysis sections should be considered to be a minimum value. The actual results could not be quantified because of the high levels of contamination.

The results of the ESP ash analyses are summarized in Table 2-11. The ESP ash sample from Run 02 was the most contaminated of the three samples analyzed. Several of the individual isomers were above the maximum concentration which could be quantified by the high resolution GC/MS analysis. The concentration of the octa-PCDD homolog was greater than 1,000 ng/g for each run. The concentration of the hepta-PCDD homolog was higher than the quantitation limit for the samples from Run 02 and 03 and the hexa-PCDD homolog concentration was greater than 1,000 ng/g for the Run 02 sample. The PCDF isomers were not as concentrated as the PCDD species. The hexa-, hepta- and octa-PCDF homologs were above the maximum quantitation limit for the Run 02 sample. The only other furan species which was above the quantitation limit was the hepta-PCDF homolog in Run 03. The average 2378-TCDD concentration was 6.24 ng/g and the average 2378-TCDF concentration was

TABLE 2-11. DIOXIN/FURAN RESULTS OF ESP ASH SAMPLES FOR RFA

ISOMER	CONCENTRATION (ng/g or ppb, mass basis) RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN				
Mono-CDD	0.00	0.00	0.00	0.00
Di-CDD	2.52	8.71	4.88	5.37
Tri-CDD	10.22	37.54	19.40	22.39
2378 TCDD	1.35	10.78	6.58	6.24
Other TCDD	20.80	120.45[a]	78.94[a]	73.40
12378 PCDD	7.56	40.60	28.78	25.65
Other PCDD	43.81	181.56	135.28	120.22
123478 HxCDD	22.04	81.05	68.10	57.06
123678 HxCDD	22.63	1000.00[a]	77.88	366.84
123789 HxCDD	51.55	1000.00[a]	200.85	417.47
Other HxCDD	191.73	1000.00[a]	608.22	599.98
Hepta-CDD	833.33[a]	1000.00[a]	1000.00[a]	944.44
Octa-CDD	1423.38[a]	1000.00[a]	1000.00[a]	1141.13
TOTAL PCDD	2630.92	5480.69	3228.91	3780.17
FURAN				
Mono-CDF	0.00	0.00	0.01	0.00
Di-CDF	0.00	0.00	4.81	1.60
Tri-CDF	32.39	50.59[a]	50.74	44.57
2378 TCDF	9.02	23.64	0.00	10.89
Other TCDF	42.37[a]	130.68[a]	148.45[a]	107.17
12378 PCDF	1.84	13.14	11.14	8.71
23478 PCDF	9.91	34.61	24.20	22.91
Other PCDF	38.67	81.65	88.46	69.59
123478 HxCDF	38.10	1000.00[a]	109.35	382.48
123678 HxCDF	14.68	1000.00[a]	57.02	357.23
123789 HxCDF	2.41	8.19	5.77	5.46
Other HxCDF	117.93	1000.00[a]	330.12	482.68
Hepta-CDF	289.86[a]	1000.00[a]	1020.46[a]	770.11
Octa-PCDF	152.27	1000.00[a]	437.88	530.05
TOTAL PCDF	749.45	5342.50	2288.40	2793.45
TOTAL PCDD/PCDF	3380.37	10823.19	5517.31	6573.62

[a] These values are greater than twice the maximum calibrated value and should be considered minimum values.

10.89 ng/g. The average total PCDD concentration was 3780 ng/g and the average total PCDF concentration 2794 ng/g. The average total PCDD/PCDF concentration was 6574 ng/g.

The dioxin/furan results for the ESP ash are expressed in terms of 2378 TCDD equivalents[2] in Table 2-12. In terms of 2378 TCDD, the average total PCDD concentration was 55.2 ng/g and the average total PCDF concentration 55.2 ng/g. The average total PCDD/PCDF concentration was 110.4 ng/g expressed as 2378 TCDD equivalents.

The distribution of the dioxin and furan homologs are presented in tabular form in Table 2-13 and in graphical form in Figures 2-3 and 2-4. The key for the isomer coding is shown in Table 2-10. Greater than 90 percent of the PCDD concentration is composed of the hexa-, hepta- and octa-PCDD homologs. These same homologs compose more than 80 percent of the PCDF isomers.

2.1.3 Total Ash Discharge Results

The total ash discharge sample included boiler bottom ash, ESP ash and boiler/economizer fly ash. The sample was collected at the exit chute which was immediately above the dump truck which is used to transport the ash to the landfill. A bucket was used to collect a representative sample of the total ash discharge at 15 minute intervals while flue gas testing was being conducted. The ash sampling did not begin until 45 minutes after the flue gas sampling began to ensure that the ash samples coincided with the flue gas samples. After the total sample was collected, the ash was mixed in a cement mixer and 2 samples were collected in 950 ml amber glass jars. One of the samples was returned to Radian Laboratories for moisture analysis and the other sample was sent to Triangle Labs for dioxin/furan analysis.

The moisture analyses of the total ash discharge samples are summarized in Table 2-14. The average percent solids content of the ash was 79 weight percent. The solids content ranged from 78 to 80 percent.

The results of the dioxin/furan analyses of the total ash discharge samples are summarized in Table 2-15. The average total PCDD concentration was 1519 ng/g and the average total PCDF concentration 338 ng/g. The average total PCDD and PCDF concentration in the total ash discharge sample was

TABLE 2-12. ESP ASH DIOXIN/FURAN RESULTS EXPRESSED AS 2378-TCDD EQUIVALENTS

ISOMER	2378 TCDD EQUIV. FACTORS	2378 TCDD EQUIVALENT CONCENTRATIO (ng/g or ppb, mass basis) RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN					
Mono-CDD	0.0000	0.00	0.00	0.00	0.00
Di-CDD	0.0000	0.00	0.00	0.00	0.00
Tri-CDD	0.0000	0.00	0.00	0.00	0.00
2378 TCDD	1.0000	1.35	10.78	6.58	6.24
Other TCDD	0.0100	0.21	1.20	0.79	0.73
12378 PCDD	0.5000	3.78	20.30	14.39	12.82
Other PCDD	0.0050	0.22	0.91	0.68	0.60
123478 HxCDD	0.0400	0.88	3.24	2.72	2.28
123678 HxCDD	0.0400	0.91	40.00	3.12	14.67
123789 HxCDD	0.0400	2.06	40.00	8.03	16.70
Other HxCDD	0.0004	0.08	0.40	0.24	0.24
Hepta-CDD	0.0010	0.83	1.00	1.00	0.94
Octa-CDD	0.0000	0.00	0.00	0.00	0.00
TOTAL PCDD		10.32	117.83	37.55	55.23
FURAN					
Mono-CDF	0.0000	0.00	0.00	0.00	0.00
Di-CDF	0.0000	0.00	0.00	0.00	0.00
Tri-CDF	0.0000	0.00	0.00	0.00	0.00
2378 TCDF	0.1000	0.90	2.36	0.00	1.09
Other TCDF	0.0010	0.04	0.13	0.15	0.11
12378 PCDF	0.1000	0.18	1.31	1.11	0.87
23478 PCDF	0.1000	0.99	3.46	2.42	2.29
Other PCDF	0.0010	0.04	0.08	0.09	0.07
123478 HxCDF	0.0100	0.38	10.00	1.09	3.82
123678 HxCDF	0.0100	0.15	10.00	0.57	3.57
123789 HxCDF	0.0100	0.02	0.08	0.06	0.05
Other HxCDF	0.0001	0.01	0.10	0.03	0.05
Hepta-CDF	0.0010	0.29	1.00	1.02	0.77
Octa-PCDF	0.0000	0.00	0.00	0.00	0.00
TOTAL PCDF		10.32	117.83	37.55	55.23
TOTAL PCDD/PCDF		20.63	235.67	75.10	110.47

TABLE 2-13. DIOXIN/FURAN ISOMER DISTRIBUTIONS IN THE ESP ASH

	ESP ASH			
	MOLE FRACTION			
ISOMER	RUN 08	RUN 09	RUN 10	AVERAGE
DIOXIN				
Mono-CDD	0.00	0.00	0.00	0.00
Di-CDD	0.00	0.00	0.00	0.00
Tri-CDD	0.01	0.01	0.01	0.01
2378 TCDD	0.00	0.00	0.00	0.00
Other TCDD	0.01	0.03	0.03	0.02
12378 PCDD	0.00	0.01	0.01	0.01
Other PCDD	0.02	0.04	0.05	0.04
123478 HxCDD	0.01	0.02	0.02	0.02
123678 HxCDD	0.01	0.19	0.03	0.07
123789 HxCDD	0.02	0.19	0.07	0.09
Other HxCDD	0.08	0.19	0.20	0.16
Hepta-CDD	0.32	0.17	0.30	0.27
Octa-CDD	0.51	0.16	0.28	0.32
FURAN				
Mono-CDF	0.00	0.00	0.00	0.00
Di-CDF	0.00	0.00	0.00	0.00
Tri-CDF	0.06	0.01	0.03	0.04
2378 TCDF	0.02	0.01	0.00	0.01
Other TCDF	0.07	0.03	0.08	0.06
12378 PCDF	0.00	0.00	0.01	0.00
23478 PCDF	0.01	0.01	0.01	0.01
Other PCDF	0.06	0.02	0.04	0.04
123478 HxCDF	0.05	0.19	0.05	0.10
123678 HxCDF	0.02	0.19	0.03	0.08
123789 HxCDF	0.00	0.00	0.00	0.00
Other HxCDF	0.16	0.19	0.15	0.17
Hepta-CDF	0.36	0.18	0.42	0.32
Octa-PCDF	0.18	0.16	0.17	0.17

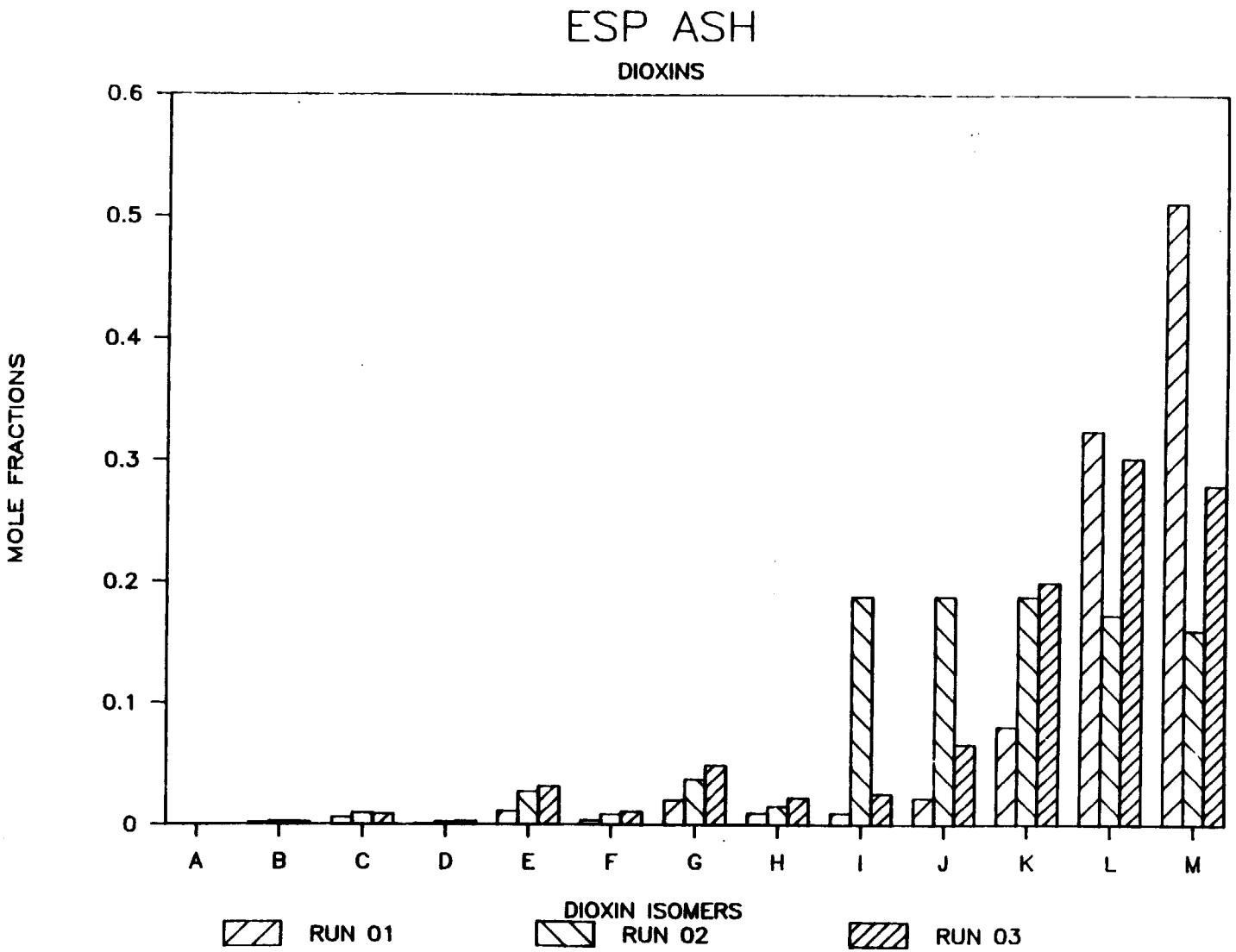


Figure 2-3. Dioxin homolog distribution in the ESP ash.

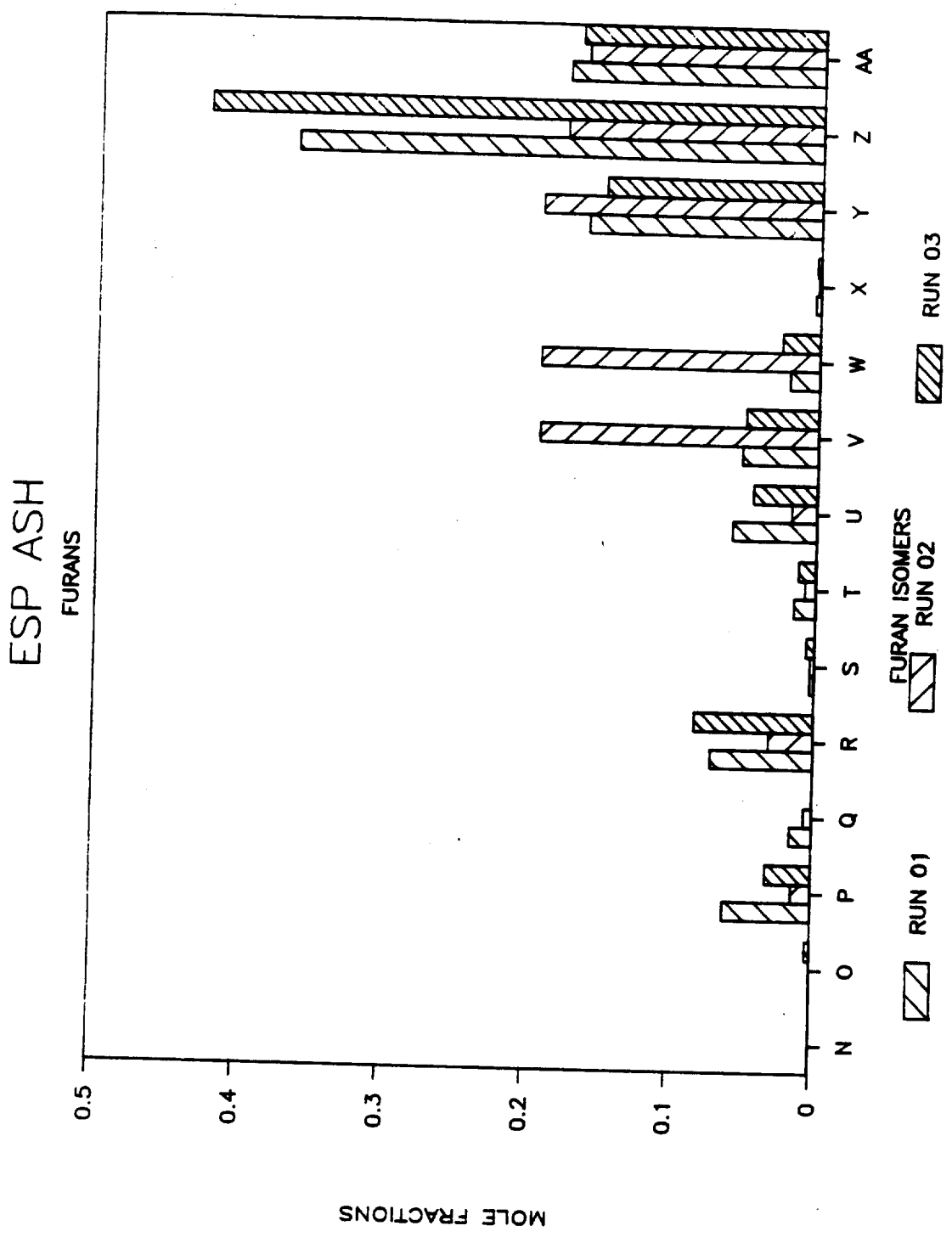


Figure 2-4. Furan homolog distribution in the ESP ash.

TABLE 2-14. RESULTS OF MOISTURE ANALYSIS FOR TOTAL ASH DISCHARGE

Run #	Percent solids, Mass basis
1	79
2	78
3	80
Average	79

TABLE 2-15. DIOXIN/FURAN RESULTS OF TOTAL ASH DISCHARGE SAMPLES FOR RFA

ISOMER	CONCENTRATION (ng/g or ppb, mass basis) RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN				
Mono-CDD	0.00	0.00	0.00	0.00
Di-CDD	0.74	1.53	0.49	0.92
Tri-CDD	3.85	9.24	2.53	5.21
2378 TCDD	1.28	2.78	0.99	1.68
Other TCDD	14.60	31.29[a]	11.57	19.15
12378 PCDD	4.85	8.98	5.25	6.36
Other PCDD	22.91	41.03	25.52	29.82
123478 HxCDD	11.65	16.38	11.98	13.34
123678 HxCDD	14.15	18.52	13.06	15.24
123789 HxCDD	31.03	44.75	30.93	35.57
Other HxCDD	103.81	137.42	95.01	112.08
Hepta-CDD	367.51[a]	402.29[a]	335.21[a]	368.34
Octa-CDD	735.55	1498.65[a]	499.87	911.36
TOTAL PCDD	1311.93	2212.86	1032.41	1519.07
FURAN				
Mono-CDF	0.00	0.00	0.00	0.00
Di-CDF	0.00	0.00	0.00	0.00
Tri-CDF	9.47	10.22	7.47	9.05
2378 TCDF	4.24	4.89	3.70	4.28
Other TCDF	20.54	29.71	18.23	22.83
12378 PCDF	1.84	2.95	1.89	2.23
23478 PCDF	3.91	5.34	4.05	4.43
Other PCDF	14.03	18.22	14.32	15.52
123478 HxCDF	17.54	23.18	16.30	19.01
123678 HxCDF	8.35	11.21	7.25	8.94
123789 HxCDF	0.00	0.00	0.00	0.00
Other HxCDF	57.27	69.73	51.15	59.38
Hepta-CDF	116.79	151.48	103.73	124.00
Octa-PCDF	51.90	116.42	35.05	67.79
TOTAL PCDF	305.88	443.35	263.14	337.46
TOTAL PCDD/PCDF	1617.81	2656.21	1295.55	1856.52

[a] These values are greater than twice the maximum calibrated value and should be considered minimum values.

1857 ng/g. These values are relatively high compared to the PCDD/PCDF concentrations detected in the total ash discharge from other municipal solid waste incinerators.

The dioxin/furan results for the total ash discharge are expressed in terms of 2378 TCDD equivalents[1] in Table 2-16. In terms of 2378 TCDD, the average total PCDD and PCDF concentration was 9.7 ng/g.

The dioxin and furan isomer distributions are presented in tabular form in Table 2-17 and in graphical form in Figures 2-5 and 2-6. The key for isomer coding is shown in Table 2-10. The hepta- and octa-CDD isomers composed about 80 percent of the PCDD species. The hepta- and octa-CDF isomers were also the most prevalent accounting for more than 50 percent of the PCDF species. The distribution in the ESP ash and total ash discharge samples was very similar.

2.2 INCINERATOR OPERATING DATA

The incinerator operating data which were monitored during each test run are summarized in Table 2-18. The values given for each test run are averages of 15 minute readings taken during the flue gas sampling interval. The original data sheets are shown in Appendix E.

The average steam production during the three test runs was 213,000 lb/hr. The undergrate air flow averaged 56,000 lb/hr while the overfire air flow was greater than 150,000 lb/hr. The oxygen level at the air heater averaged 9.4 percent in duct A and 7.1 percent in duct B, based on plant instrumentation.

During normal operation of the incinerator the grate is manually cleared of noncombustibles and ash every 60 to 90 minutes to prevent the grate and quench bath chute from becoming clogged. During the test program this was not done while flue gas sampling was being performed. There were several instances where testing was ceased while the grate was cleared. Otherwise, the operation of the boiler was conducted as normal.

TABLE 2-16. TOTAL ASH DISCHARGE DIOXIN/FURAN RESULTS EXPRESSED AS 2378-TCDD EQUIVALENTS

ISOMER	2378 TCDD EQUIV. FACTORS	2378 TCDD EQUIVALENT COCENTRATION (ng/g or ppb, mass basis) RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN					
Mono-CDD	0.0000	0.00	0.00	0.00	0.00
Di-CDD	0.0000	0.00	0.00	0.00	0.00
Tri-CDD	0.0000	0.00	0.00	0.00	0.00
2378 TCDD	1.0000	1.28	2.78	0.99	1.68
Other TCDD	0.0100	0.15	0.31	0.12	0.19
12378 PCDD	0.5000	2.43	4.49	2.63	3.18
Other PCDD	0.0050	0.11	0.21	0.13	0.15
123478 HxCDD	0.0400	0.47	0.66	0.48	0.53
123678 HxCDD	0.0400	0.57	0.74	0.52	0.61
123789 HxCDD	0.0400	1.24	1.79	1.24	1.42
Other HxCDD	0.0004	0.04	0.05	0.04	0.04
Hepta-CDD	0.0010	0.37	0.40	0.34	0.37
Octa-CDD	0.0000	0.00	0.00	0.00	0.00
TOTAL PCDD		6.65	11.43	6.47	8.18
FURAN					
Mono-CDF	0.0000	0.00	0.00	0.00	0.00
Di-CDF	0.0000	0.00	0.00	0.00	0.00
Tri-CDF	0.0000	0.00	0.00	0.00	0.00
2378 TCDF	0.1000	0.42	0.49	0.37	0.43
Other TCDF	0.0010	0.02	0.03	0.02	0.02
12378 PCDF	0.1000	0.18	0.30	0.19	0.22
23478 PCDF	0.1000	0.39	0.53	0.41	0.44
Other PCDF	0.0010	0.01	0.02	0.01	0.02
123478HxCDF	0.0100	0.18	0.23	0.16	0.19
123678 HxCDF	0.0100	0.08	0.11	0.07	0.09
123789 HxCDF	0.0100	0.00	0.00	0.00	0.00
Other HxCDF	0.0001	0.01	0.01	0.01	0.01
Hepta-CDF	0.0010	0.12	0.15	0.10	0.12
Octa-PCDF	0.0000	0.00	0.00	0.00	0.00
TOTAL PCDF		1.41	1.87	1.34	1.54
TOTAL PCDD/PCDF		8.06	13.30	7.81	9.72

TABLE 2-17. DIOXIN/FURAN ISOMER DISTRIBUTIONS IN THE TOTAL ASH DISCHARGE

	MOLE FRACTIONS			
ISOMER	RUN 01	RUN 02	RUN 03	AVERAGE
DIOXIN				
Mono-CDD	0.00	0.00	0.00	0.00
Di-CDD	0.00	0.00	0.00	0.00
Tri-CDD	0.00	0.01	0.00	0.00
2378 TCDD	0.00	0.00	0.00	0.00
Other TCDD	0.01	0.02	0.01	0.02
12378 PCDD	0.00	0.00	0.01	0.01
Other PCDD	0.02	0.02	0.03	0.02
123478 HxCDD	0.01	0.01	0.01	0.01
123678 HxCDD	0.01	0.01	0.01	0.01
123789 HxCDD	0.03	0.02	0.03	0.03
Other HxCDD	0.09	0.07	0.10	0.09
Hepta-CDD	0.29	0.19	0.33	0.27
Octa-CDD	0.53	0.65	0.45	0.54
FURAN				
Mono-CDF	0.00	0.00	0.00	0.00
Di-CDF	0.00	0.00	0.00	0.00
Tri-CDF	0.04	0.03	0.04	0.04
2378 TCDF	0.02	0.01	0.02	0.02
Other TCDF	0.08	0.09	0.09	0.09
12378 PCDF	0.01	0.01	0.01	0.01
23478 PCDF	0.01	0.01	0.02	0.02
Other PCDF	0.05	0.05	0.06	0.05
123478HxCDF	0.06	0.05	0.06	0.06
123678 HxCDF	0.03	0.03	0.03	0.03
123789 HxCDF	0.00	0.00	0.00	0.00
Other HxCDF	0.19	0.16	0.20	0.18
Hepta-CDF	0.36	0.33	0.37	0.35
Octa-PCDF	0.15	0.23	0.11	0.16

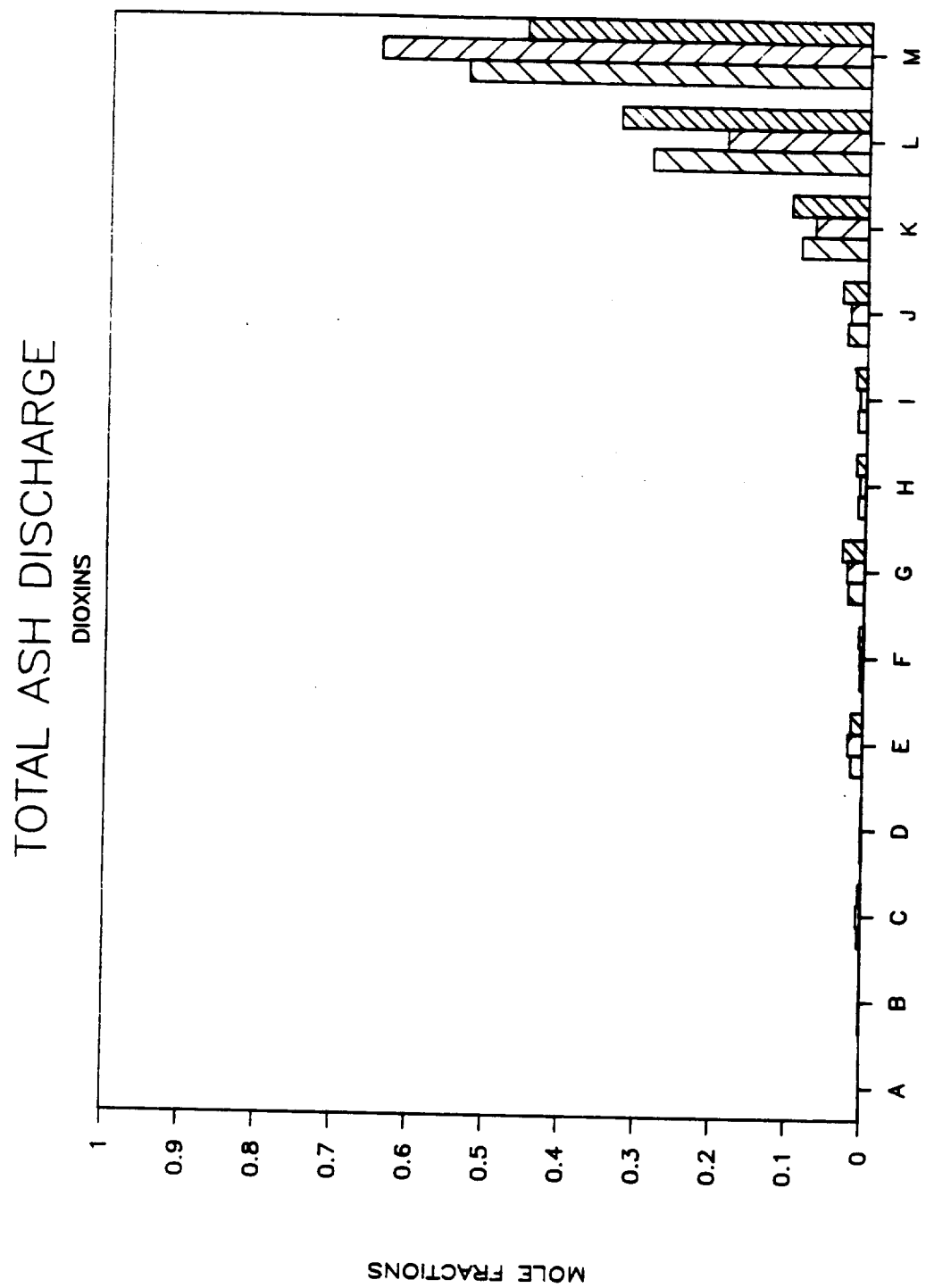


Figure 2-5. Dioxin homolog distribution in the total ash discharge.

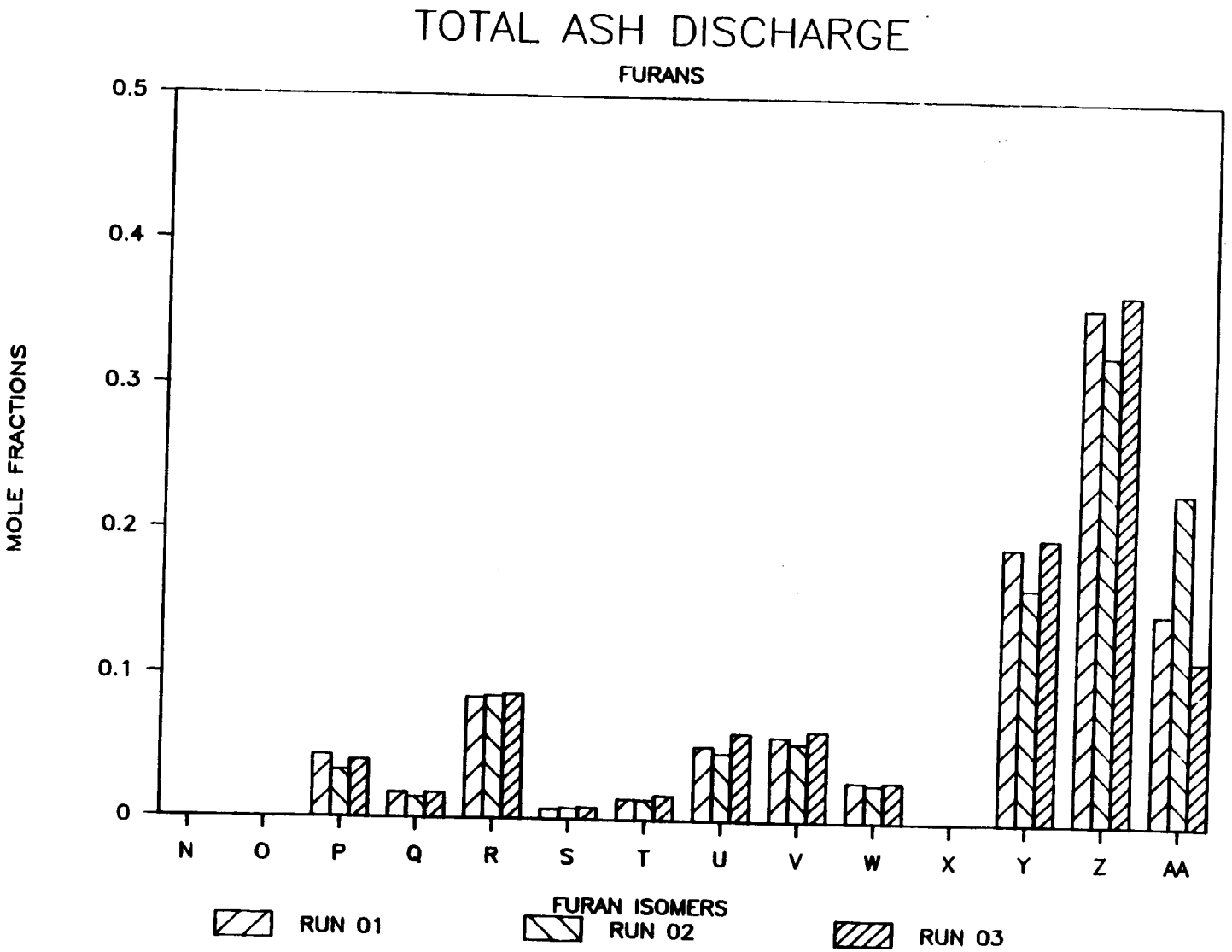


Figure 2-6. Furan homolog distribution in the total ash discharge.

TABLE 2-18. SUMMARY OF PROCESS DATA AT RFA's LAWRENCE, MA FACILITY

Parameter	Run 01	Run 02	Run 03	Average
Boiler				
Steam Production (10^{-3} lb/hr)	217	208	215	213
Superheater Outlet				
Steam Temperature (^{o}F)	701	698	700	700
Steam Pressure (PSIG)	632	640	586	619
Gas Temperature (^{o}F)	531	538	534	534
Exit Gas Temperature (^{o}F)	819	823	821	821
Undergrate Air Flow (10^{3} lb/hr)	56	56	55	56
Overfire Air Flow (10^{3} lb/hr)	>150	>150	>150	--
RDF Demand (%)	52	52	53	52
Economizer Exit Gas Temperature (^{o}F)	538	545	544	542
Air Heater				
Flue Gas Inlet Temperature (^{o}F)	511	521	518	517
Flue Gas Outlet Temperature (^{o}F)	344	354	349	349
Air Inlet Temperature (^{o}F)	90	95	94	93
Air Outlet Temperature (^{o}F)	354	366	358	359
Flue Gas				
Oxygen A (%)	9.3	9.5	9.5	9.4
Oxygen B (%)	7.3	7.0	7.1	7.1
Conductivity (u MHOS)	992	962	1192	1049

3.0 PROCESS DESCRIPTION

The Refuse Fuels facility located in Lawrence, Massachusetts, is a cogenerating plant consisting of a RDF boiler and three oil-fired boilers. The RDF boiler, a Babcock and Wilcox Sterling Power Boiler, is designed to fire both refuse derived fuel (RDF) and number 6 fuel oil. Operation of the boiler was limited to RDF firing during the testing period. A generalized schematic of the process line is presented in Figure 3-1.

The boiler at the RFA facility is a suspension fired boiler designed to produce 250,000 pounds of steam per hour. The RDF is introduced into the boiler above the moving grates and is ignited while suspended. The refuse is presorted and shredded before it arrives at the plant in dump trucks. It is loaded onto a conveyor by front-end loader then fed to the incinerator pneumatically through chutes. The burning mass of RDF then travels through the boiler at a predetermined speed on the moving grate. Noncombustibles and ash are discharged continuously to a quench bath. Normal operation includes clearing the grate of ash deposits and non-combustibles every 60 to 90 minutes to prevent the chute leading to the quench bath from being clogged.

Flue gas particulate emissions are controlled with a Belco hot side electrostatic precipitator (ESP). The ESP ash is discharged from hoppers to a screw conveyor. The ESP ash is combined with the bottom ash after the quench bath and the total discharge ash is landfilled at the Refuse Fuels facility in Haverhill.

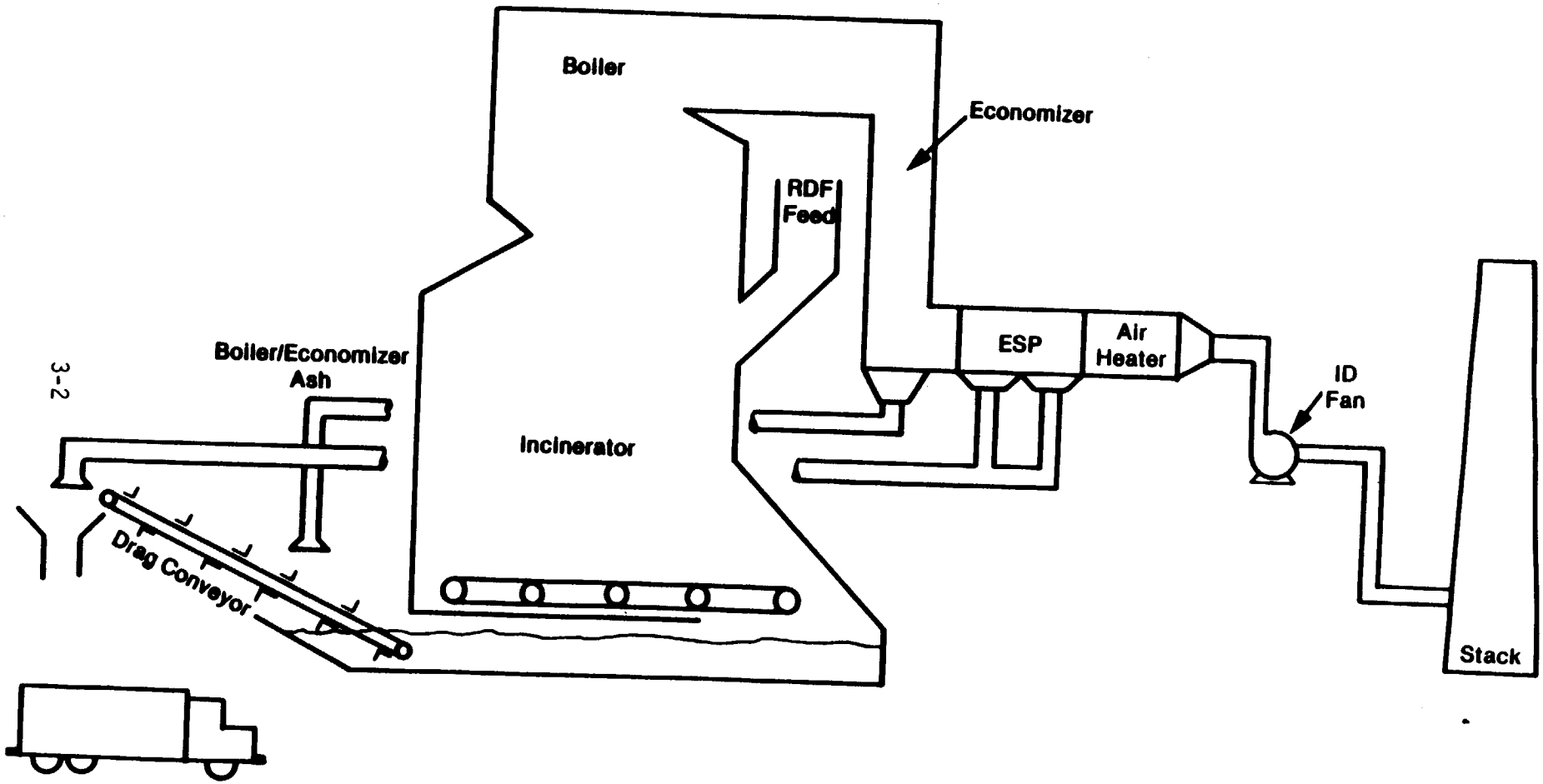


Figure 3-1. Schematic diagram of the RFA facility.

4.0 SAMPLING LOCATIONS AND ANALYTICAL PROCEDURES

The sampling methods and analytical procedures used at this site are summarized in Table 4-1. A brief description of these methods and the sampling locations are included in this section.

4.1 Sampling Locations

The sampling locations for the flue gas samples and ash samples are discussed in this section. The sampling locations are shown on the process flow diagram presented in Figure 4-1.

4.1.1 Flue Gas Sampling Locations

The flue gas was sampled at the outlet of the induced draft (ID) fan. The sampling location, port locations, and dimensions of the duct are shown in Figure 4-2. Scaffolding was constructed in order to gain access to this sampling location. The average flue gas temperature and moisture at this location were 402^{o}F and 12.3 percent by volume, respectively.

Two 4-inch ports are located 90^{o} apart on a 9-foot diameter circular, horizontal duct. The sampling ports are located 18 feet (2 equivalent diameters) downstream of a bend in the duct and 9 feet (1 equivalent diameter) upstream of a disturbance. In accordance with EPA Method 1, 24 sampling points were used; twelve points on each diameter. The traverse point layout used during sampling is shown in Figure 4-3.

The presence of cyclonic flow at the flue gas sampling location was a concern. Straightening veins are located at the bend which precedes the sample ports. The flow was checked for cyclonic conditions according to EPA Method 1 twice before sampling began. The average angle from the zeroed position for the two runs was 13.3 degrees. The original data sheets are located in Appendix D. The maximum average angle for which flow is not considered cyclonic is 10 degrees according to EPA Method 1. The Massachusetts DEQE observer approved sampling at the conditions which were present.

4.1.2 Ash Sampling Locations

The ESP ash samples were collected from the screw conveyor which transports the ash from the hoppers to the total ash discharge point. The ESP

TABLE 4-1. SUMMARY OF SAMPLING METHODS AND ANALYTICAL PROCEDURES

Parameter	Sampling Method	Analytical Procedure
Dioxin/furans	ASME Environmental Standards Workshop Protocol (December 1984 draft)	High resolution GC/MS
Volumetric flowrate	EPA Method 2	Radian computer program
Molecular weight (O_2, CO_2, N_2)	EPA Method 3	Orsat Analysis
Moisture	EPA Method 4	Gravimetric, analytical balance

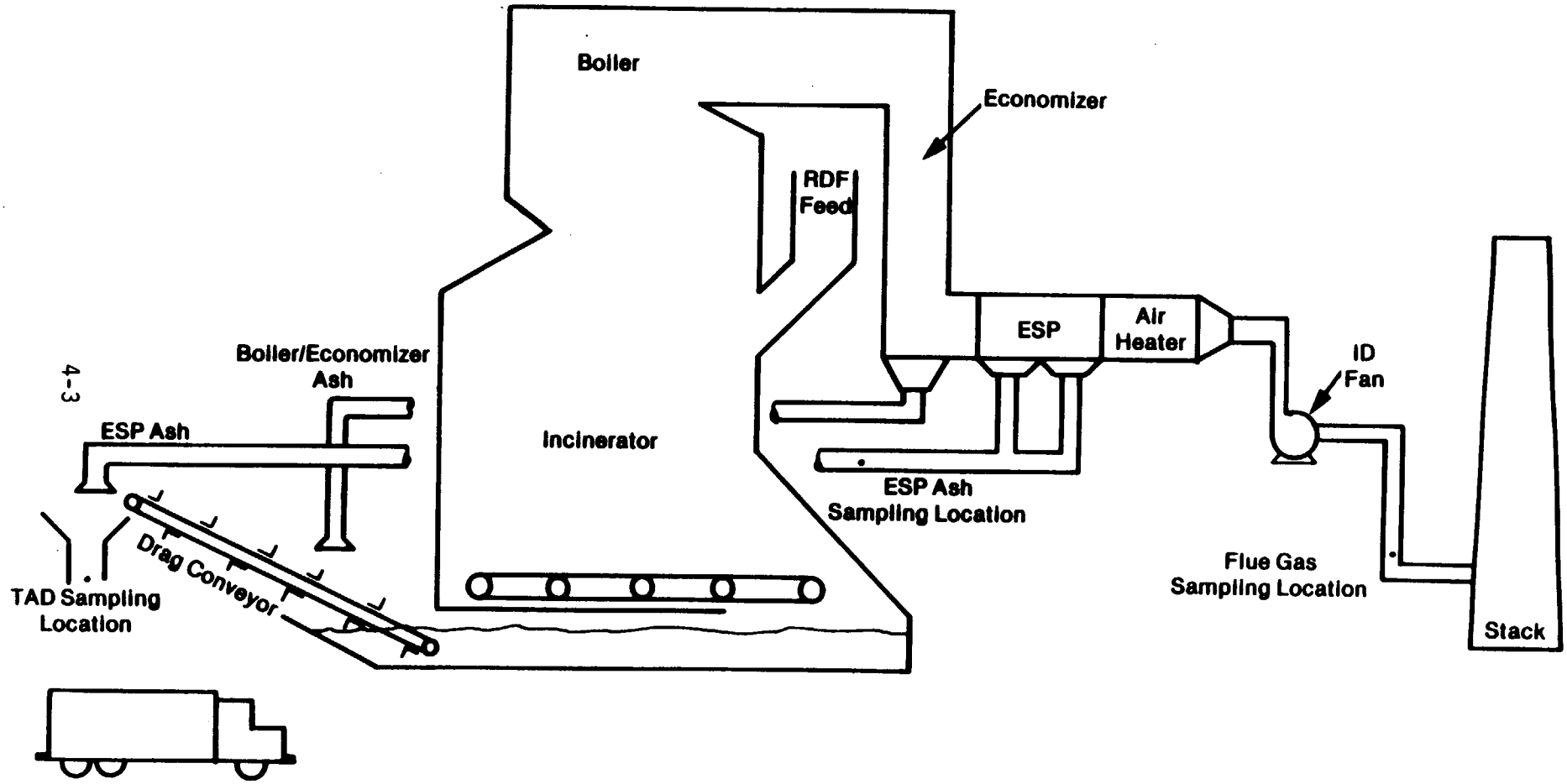


Figure 4-1. Sampling locations at the RFA facility.

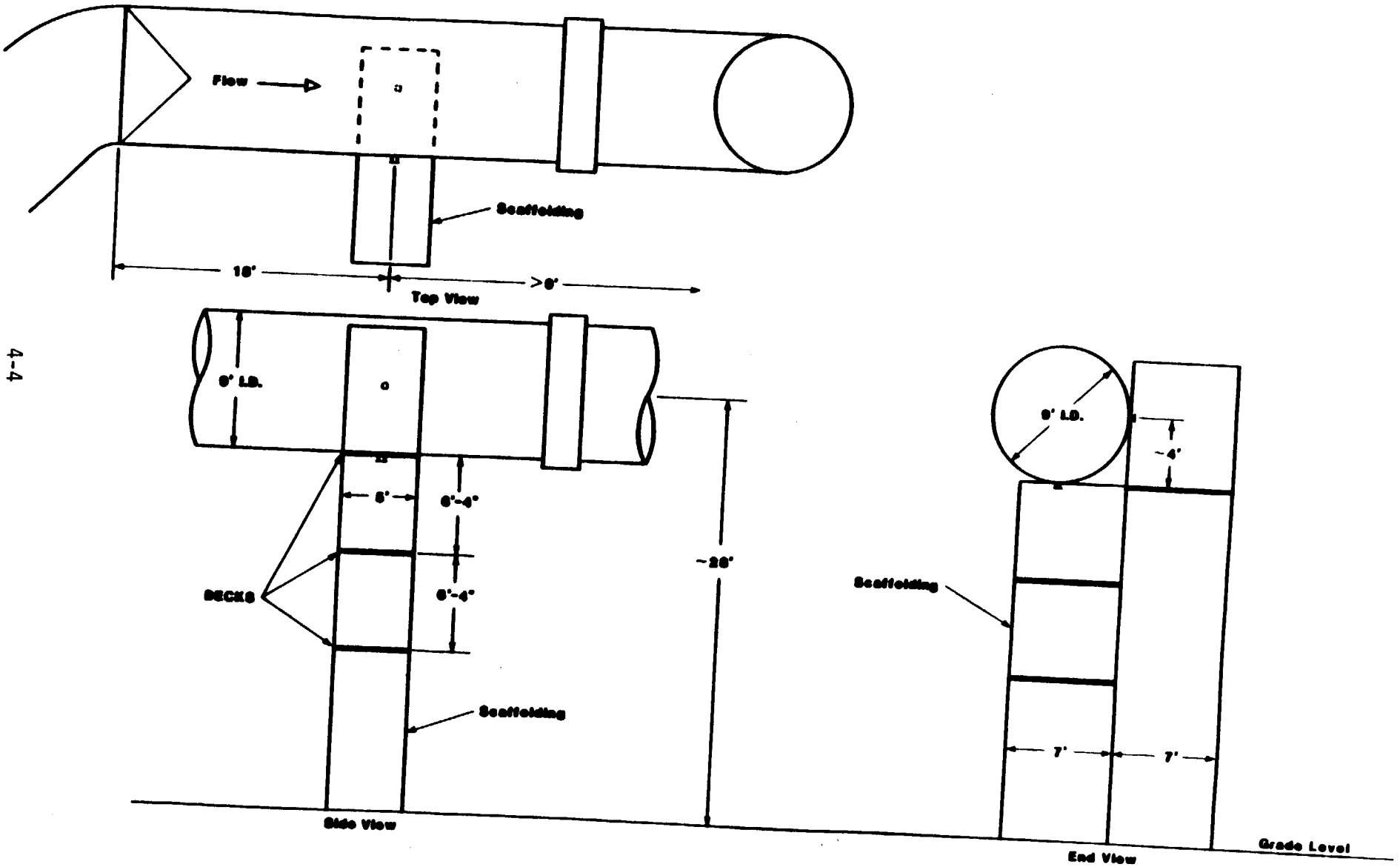
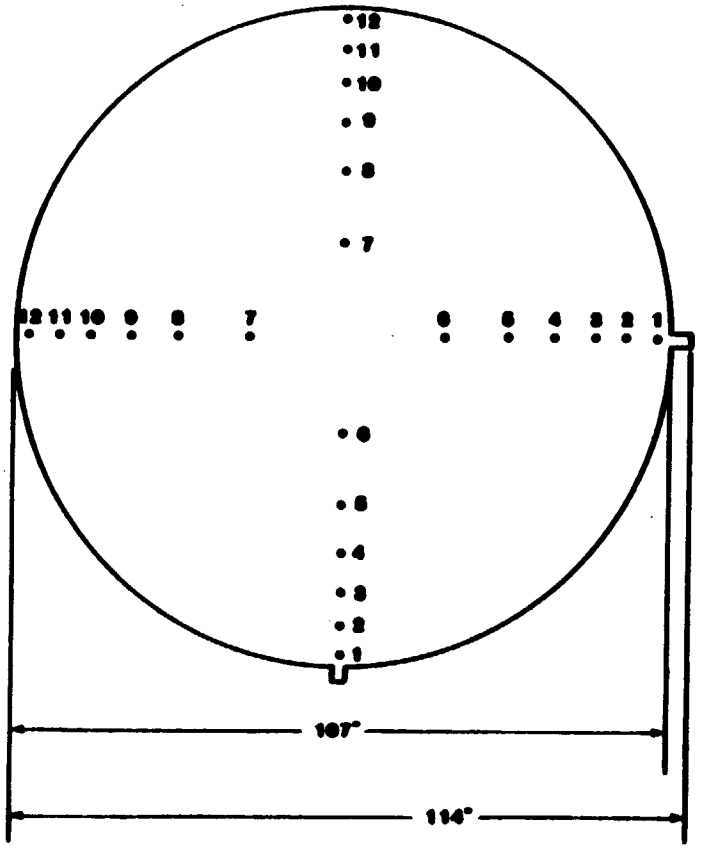


Figure 4-2. Flue gas sampling location at the RFA Facility.



Distance from outer edge of nipple

Point	Distance (in.)
1	9
2	14
3	20
4	26
5	34
6	45
7	76
8	87
9	95
10	101
11	107
12	112

Figure 4-3. Traverse Point Layout for the RFA Facility.

ash sample was taken from a point immediately prior to the ESP ash being water quenched. A schematic diagram of the ESP ash sampling location is shown in Figure 4-4. The total ash discharge samples were collected at the chute where the combined economizer ash, boiler bottom ash and the ESP ash are discharged to the dump truck. A bucket was used to get a representative cross-section of the ash sample as it fell from the chute. A schematic diagram of the total ash discharge handling system is shown in Figure 4-5.

4.2 SAMPLING AND ANALYTICAL PROCEDURES

4.2.1 Flue Gas Dioxin/Furan Determination

Gas sampling and analysis for PCDD/PCDF were conducted according to the latest draft of the Environmental Standards Workshop (sponsored by EPA and ASME) chlorinated organic compound sampling protocol with several modifications. This protocol is included in Appendix A.

The sampling method is a modified version of EPA Method 5 that includes a solid sorbent module for trapping vapor phase organics. Radian has modified the protocol to include: 1) the use of a horizontal condenser, and 2) the use of methylene chloride for final recovery of dioxins. These deviations have been approved by both EPA and New York DEC and have been used in the Tier 4 program conducted for U.S. EPA and a joint test on the Westchester facility which involved New York DEC and the EPA's Office of Solid Waste. The horizontal condenser lowers the profile of the train and reduces breakage. The XAD trap following the condenser is maintained in a vertical position. No problems of channeling have been noted. In one of the Tier 4 test series, a backup XAD trap was used to determine if any breakthrough was occurring. None was found. Methylene chloride has been shown to be a better solvent for hepta- and octa- dioxins and is an acceptable solvent for EPA, New York DEC and Environment Canada Dioxin tests.

Each sample was collected for a total of 192 minutes. The sampling train was leak checked before and after sampling was conducted at each port. After sampling, the filters and resin traps were removed from the train and sealed. The contents of the impingers and acetone and methylene chloride rinses of the train glassware were recovered into pre-cleaned amber glass bottles. The field data and sample recovery sheets are included in Appendix C.

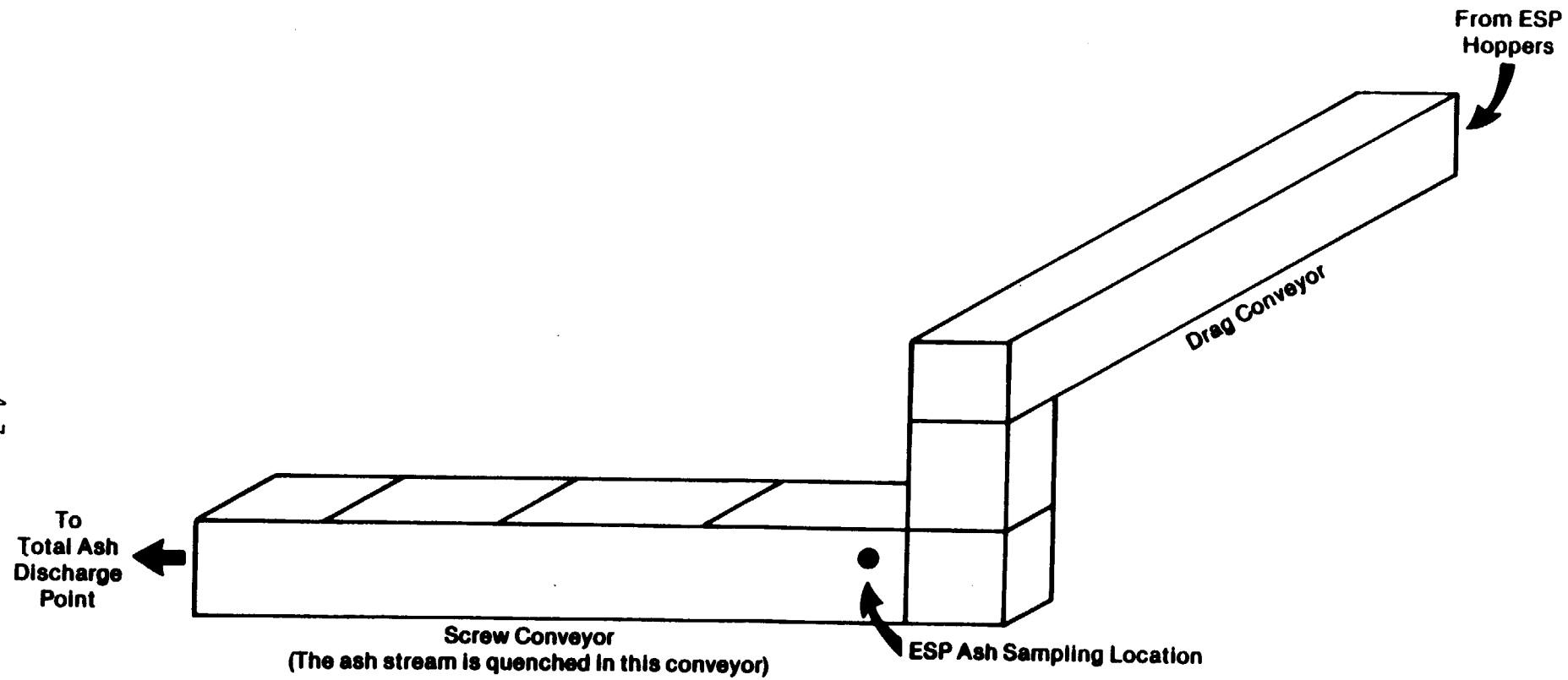


Figure 4-4. ESP ash sampling location at the RFA facility.

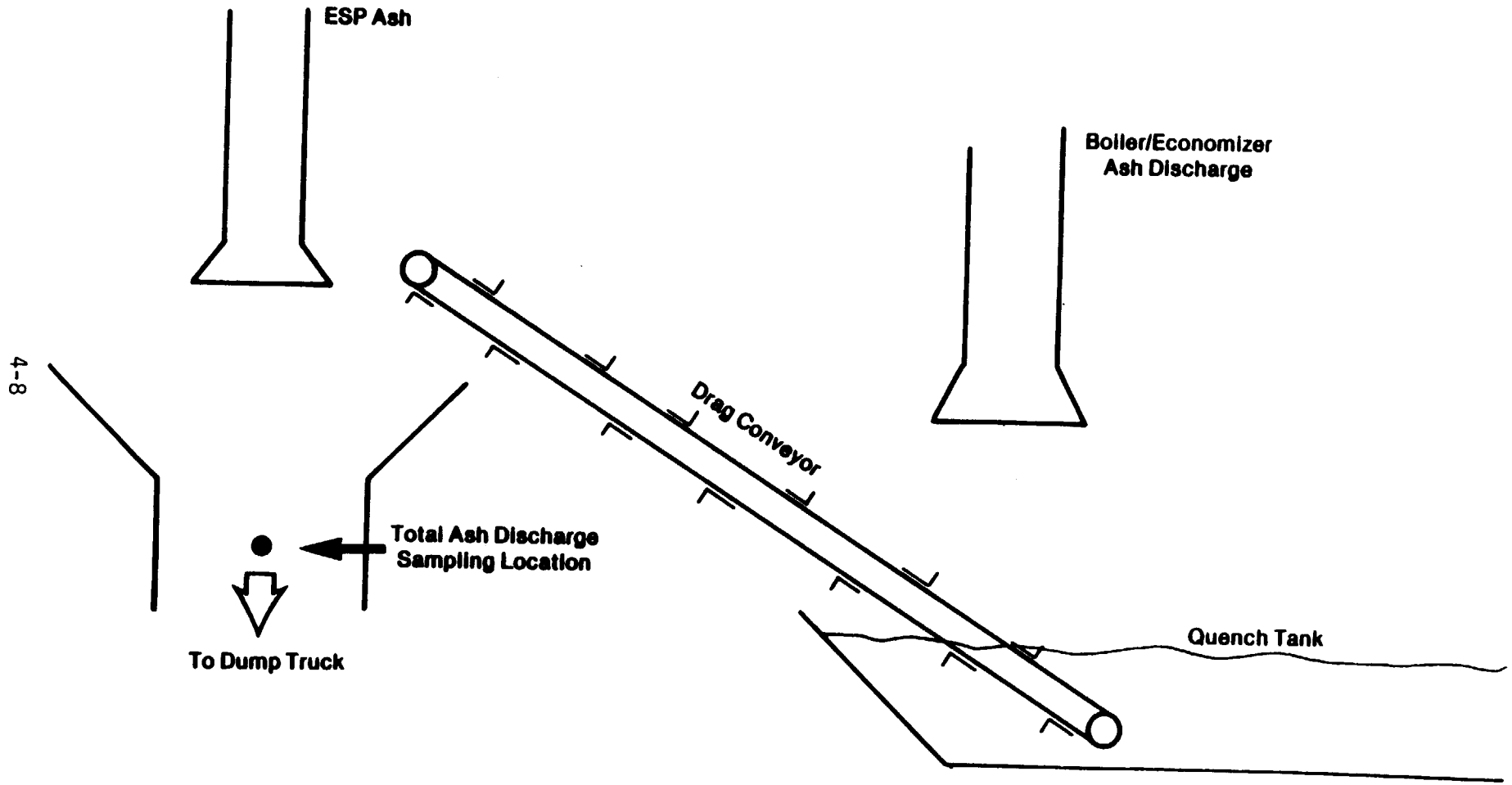


Figure 4-5. Total ash discharge sampling location.

The dioxin/furan analyses were performed by Triangle Laboratories, Research Triangle Park, North Carolina, according to ASME/EPA procedures.[1] During sample preparation, the sample components are extracted, combined and concentrated according to the scheme in Figure 4-6. The samples are analyzed by gas chromatography followed by high resolution mass spectrometry (GC/MS). Internal standards and isotopically labelled spikes are used to tune and calibrate the GC/MS system.

4.2.2 Volumetric Flowrate, Molecular Weight and Moisture

Volumetric flowrate was measured according to EPA Method 2. A type K thermocouple and S-type pitot tube were used to measure flue gas temperature and velocity, respectively. The average flue gas moisture content was determined by measuring the amount of condensate that collected in the sampling train impingers according to EPA Method 4. The molecular weight of the flue gas was determined from an integrated bag sample collected according to the technique described in EPA Method 3. An Orsat analyzer was used to determine the CO_2 and O_2 concentration of the sample. Nitrogen was determined by difference.

4.2.3 Ash Sampling

The ash collecting methods used for this project followed ASTM D 2234-82 procedures as closely as possible. Two (2) ash streams were sampled for dioxin/furan analysis during each test run: ESP ash and total plant ash discharge (a combination of furnace bottom ash, boiler/economizer fly ash and ESP dust).

For the total ash discharge, a flow diagram of the sampling procedure used is presented in Figure 4-7. No standard protocol was available. However, ASTM D2234-82, collection of a gross sample of coal, was used for guidance in terms of sampling method, frequency, and size.

The number of grab samples of ash required to represent a statistically relevant average of the ash over the sampling period cannot be determined at this time since an estimate of the variance in the parameter of concern in the bulk lot is needed. The coal sampling procedures in D 2234 are based on some estimate of the variance of the ash content of the coal. However, a grab sample of total ash discharge was collected every 15 minutes throughout the test period, starting 45 minutes after the flue gas sampling begins. This lag

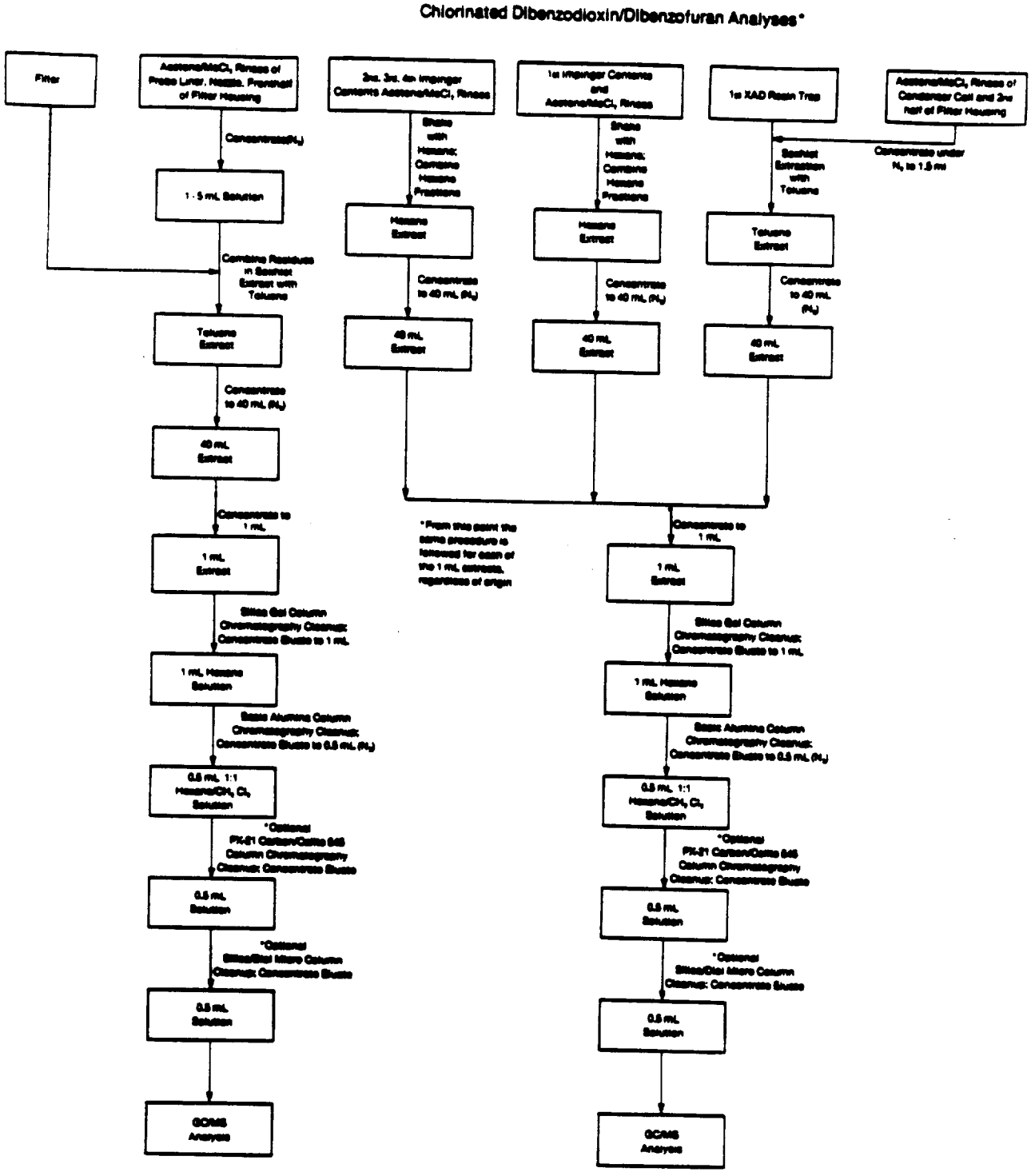


Figure 4-6. Dioxin/Furan analysis methodology.

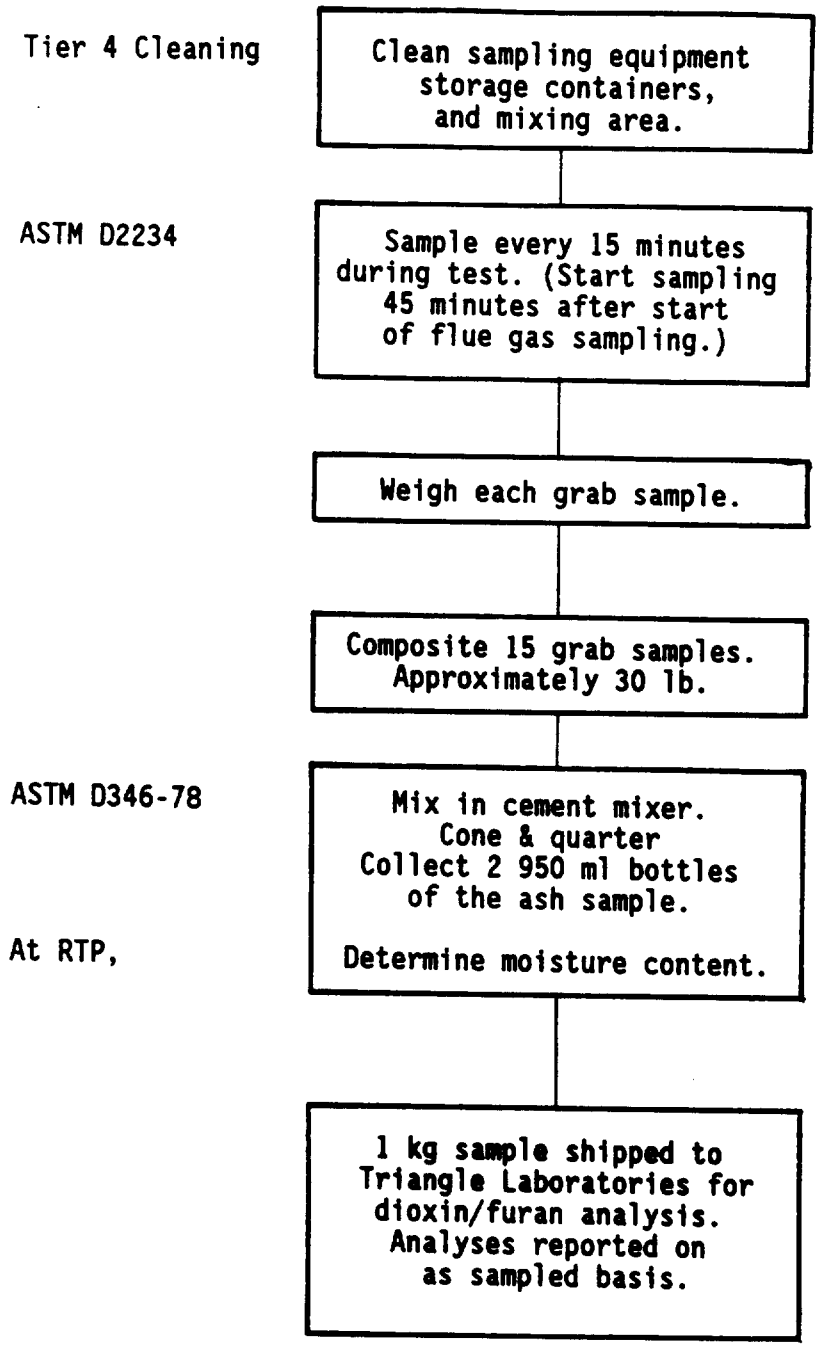


Figure 4-7. Ash sampling scheme for total ash discharge.

in the start time of ash sampling was because of the grate holdup time for the bottom ash, and allowed closer correlation of the ash results to the flue gas results.

ASTM D 2234 does not require that all grabs be of the same size, volume or weight, just that a minimum number and size of sample be taken. Sampling was conducted using a bucket attached to a rope. A representative cross-section was collected from the ash discharge chute which is immediately above the dump truck. Each grab sample was weighed and held for compositing. Hand-sorting of the ash was not necessary.

Approximately 30 pounds of total ash discharge was collected over the sample period. The composite sample was mixed in a cement mixer before a 5 pound composite sample was collected which was returned to the Radian RTP laboratories. At RTP one aliquot was analyzed for moisture and one was sent to Triangle Labs for dioxin/furan analysis. The moisture content of the samples is reported on an as-received basis.

ESP samples were taken from an intermediate transfer point on the screw conveyor prior to combination with the other ash streams. The samples were collected every 30 minutes starting 45 minutes after the start of flue gas sampling. Approximately 4 pounds of ESP ash was collected during each test run which was composited and an aliquot placed in a 950 mL amber glass bottle.

One kg of each type of ash is sufficient for laboratory extraction and analysis. (Ten grams maximum per extraction.) The analytical results are reported as mass of dioxin/furans detected per mass of sample analyzed.

5.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

This section summarizes results of Quality Assurance and Quality Control (QA/QC) activities for sampling and analytical activities for Refuse Fuels Associates (RFA) in Lawrence, Massachusetts. Manual gas sampling methods are considered in Section 5.1. Analytical QA/QC results are reported in Section 5.2. The Site Specific Test Plan describes the QA/QC activities that took place in greater detail.

5.1 MANUAL GAS SAMPLING

Quality Assurance and Quality Control (QA/QC) activities for the manual sampling methods centered around (1) equipment calibration, (2) glassware cleaning, (3) procedural QC checks, and (4) sample custody procedures. Key activities and QC results in each of these areas are discussed in this section. Also discussed are problems encountered that may have affected data quality.

5.1.1 Equipment Calibration and Glassware Preparation

Pre-test calibrations or inspections were conducted on pitot tubes, sampling nozzles, temperature sensors and analytical balances. Both pre-test and post-test calibrations were performed on the dry gas meters. All of the field test equipment met the calibration criteria specified in the Quality Assurance Project Plan. Differences in the pre-test and post- test dry gas meter calibrations were less than 1 percent.

Precleaning procedures were used for all MM5 dioxin/furan and TOCL sample train glassware and sample containers. The cleaning procedure outlined in Table 5-1 was implemented to minimize the potential for sample contamination with substances that could interfere with the dioxin/furan analysis. To determine dioxin/furan background levels in the glassware a blank MM5 dioxin/furan train that had been pre-cleaned using the procedure in Table 5-1 (i.e., proof train blank) was recovered according to the usual MM5 dioxin procedures. The rinses and other train components of the proof train blank (i.e., filter XAD trap, and impinger solution) were submitted to Triangle Laboratories for dioxin/furan analysis. To minimize the potential for

TABLE 5-1. MM5 DIOXIN GLASSWARE CLEANING PROCEDURE

NOTE: USE DISPOSABLE GLOVES AND ADEQUATE VENTILATION

1. Soak all glassware in hot soapy water (Alconox^R)
2. H_2O rinse (X3)[a].
3. Distilled/deionized H_2O rinse (X3).
4. Bake at 450°F for 2 hours.[b]
5. Acetone rinse (X3), (pesticide grade).
6. Methylene chloride rinse (X3), (pesticide grade).
7. Cap glassware with clean glass plugs or $MeCl_2$ rinsed aluminum foil.

[a](X3) = three times.

[b]Step (4) was not used for probe liners and non-glass components of the train that could not withstand 450°F (i.e., teflon coated filter frits and seals). The probe liners are too large for the baking ovens.

contamination in the field, all sample train glassware was capped with rinsed foil prior to use. To determine the field recovery efficiency, a blank MM5 dioxin/furan train that had been used and field-recovered at least once at Lawrence (i.e., field recovery train blank) was also recovered and submitted for analysis. Analytical results for the MM5 proof train blanks and the field recovery train blanks are presented in Section 5.2.1.3.

5.1.2 Procedural QC Activities/Manual Gas Sampling

Procedural QC activities during the manual gas sampling for dioxin/furan focused on:

- visual equipment inspections,
- utilization of sample train blanks,
- ensuring the proper location and number of traverse points,
- conducting pre-test and post-test sample train leak checks,
- maintaining proper temperatures at the filter housing, sorbent trap and impinger train,
- maintaining isokinetic sampling rates, and
- recording all data on preformatted field data sheets.

Unusual circumstances that occurred while carrying out the procedural QC activities were also noted.

Results of the average isokinetics calculations and leak checks for the six MM5 dioxin test runs are shown in Table 5-2. The QA objective of 100 ±10 percent was met for all test runs. Initial, final, and port change leak checks for the MM5 sample trains achieved the QA objectives for all test runs [leakage rate $\leq$ 0.02 ft^3/min or 4% of the average sampling rate (whichever is less)].

5.1.3 Sample Custody

Sample custody procedures used during this program emphasized documentation of the collected samples and the use of chain-of-custody records for samples transported to the laboratory for analysis. Steps taken to identify and document samples collected included labeling each sample with a unique code and logging each individual sample in a master logbook. All samples shipped to Triangle Laboratories were also logged on chain-of-custody records that were signed by the field sample custodian upon shipment and also signed upon receipt at the laboratory. Each sample container lid was

TABLE 5-2. ISOKINETICS AND LEAK CHECK RESULTS

Run Number	Isokinetics (Percent)	Met QC Objective?[a]	Leak Check[b]
MM5 Dioxin Tests[c]			
01	98.1	Yes	Good
02	98.6	Yes	Good
03	99.9	Yes	Good

[a]The QC objective for isokinetics is 100 ± 10 percent.

[b]The QC objective for leak checks is a leak-free train or leakage rate less than or equal to 0.02 cfm or less than 4% of the average sampling rate (whichever is less).

individually sealed to ensure that samples were not tampered with. No evidence of loss of sample integrity was reported for samples collected at this site.

5.2 LABORATORY ANALYSES

QA/QC activities were carried out for dioxin/furan analyses performed on RFA samples. The dioxin/furan analyses of MM5 train samples (performed by Triangle Laboratories) are discussed in Section 5.2.1.

5.2.1 Dioxin/Furan Analyses

Analytical recoveries of labeled surrogate compounds spiked onto MM5 train samples, prior to extraction are reported in Section 5.2.1.1. Sample blank data are reported in Section 5.2.1.2.

5.2.1.1 Surrogate Recoveries of the Test Samples. Table 5-3 presents the analytical recovery data reported by Triangle Laboratories for three isotopically labeled surrogate compounds spiked onto the MM5 train and quality control samples. Samples were spiked with the surrogates shown in Table 5-3. In general, the data show excellent surrogate recoveries, with values ranging from 87-125 percent, excluding those recoveries that were flagged for interferences or column saturation. Table 5-4 presents the analytical recovery data for internal standards. The surrogate recovery efficiencies are used to estimate the recovery efficiency of the target compound since they cannot be measured directly.

5.2.1.2 Sample Blanks. Table 5-5 summarizes the analytical results reported by Triangle for internal laboratory blanks, proof blank MM5 train samples, field recovery blank MM5 train samples, and reagent blanks. Insignificant quantities of target dioxin and furan species were found in all of the blank quality control samples.

5.2.2 Duplicate Analyses

A duplicate injection was performed with MM5, Run 03 front half sample. The results are presented in Table 5-6. The purpose of the duplicate injection was to evaluate the reproducibility (precision) of the analytical methodology. The average absolute relative error for duplicate pairs was 8.7 percent, well within the acceptance criteria of $\pm$ 10 percent. Thus, the analytical system was shown to be in control during analysis of the RFA samples.

TABLE 5-3. PERCENT SURROGATE RECOVERIES FOR RFA DIOXIN/FURAN ANALYSES

Sample Type	^{13}C-$_{12}$TCDF	$^{37}Cl_4$-TCDD	$^{13}C_{12}$-HxCDF
	FH/BH	FH/BH	FH/BH
MM5 Samples			
Run 01	115/101	118/101	92/90
Run 02	111/89	114/91	101/96
Run 03	103/91	107/92	115/87
Run 03 (Duplicate)	107/a	105/a	124/a
ESP Ash Samples			
Run 01	94	100	185[b]
Run 02	108	117	278[c]
Run 04	104	116	186[c]
Total Ash Discharge			
Run 01	109	125	138[c]
Run 02	113	119	139[c]
Run 03	102[b]	101	176[c]
Quality Control Samples			
Field Blank	97/90	104/97	95/93
Analytical Method Blank	106	109	103
Soxhlet Blank	111	116	99
Proof Blank			
Probe Rinse	93	100	92
Coil Rinse	94	100	91
Condenser Rinse	85	89	75
Impinger Rinse	86	94	83

[a]Only the front half was analyzed in duplicate.

[b]Above the calibration range, experienced interferences.

[c]Experienced interferences.

TABLE 5-4. PERCENT INTERNAL STANDARD RECOVERIES FOR RFA DIOXIN/FURAN ANALYSES

Sample Type	2378-$^{13}C_{12}$-TCDD	$^{13}C_{12}$-PCDD	$^{13}C_{12}$-HxCDD	$^{13}C_{12}$-HpCDD	$^{13}C_{12}$-OCDD
	FH/BH	FH/BH	FH/BH	FH/BH	FH/BH
MM5 Samples					
Run 01	83/92	99/106	98/111	95/132	61/124
Run 02	94/91	105/82	120/79	152/97	147/86
Run 03	91/103	78/96	71/92	76/116	89/114
Run 03 (Duplicate)	96/a	104/a	99/a	104/a	80/a
ESP Ash Samples					
Run 01	88	73	68	70[b]	57
Run 02	96	113	98	0.05[b]	0.03[b]
Run 03	65	65	71	88	71
Total Ash Discharge					
Run 01	96	117	100	130	113
Run 02	99	117	105	157	76
Run 03	101	89	80	92	92
Quality Control Samples					
Field Blank	91/91	79/82	71/75	82/82	72/80
Analytical Method Blank	101	99	87	97	77
Soxhlet Blank	99	112	107	109	101
Proof Blank					
Probe Rinse	92	74	67	67	52
Coil Rinse	86	70	68	65	58
Condenser Rinse	82	63	63	59	51
Impinger Rinse	90	74	72	70	66

[a]Only the front half was analyzed in duplicate.
[b]Above the calibration range, experienced interferences.
[c]Experienced interferences.

TABLE 5-5 ANALYTICAL RESULTS FOR RFA QUALITY CONTROL SAMPLES[a]

Compound	Flue Gas Quality Control Samples			
	Laboratory Method Blank	Proof Blank MM5 Train	Field Blank MM5 Train	Soxhlet Blank
Dioxins				
Mono-CDD	ND	ND	ND	ND
Di-CDD	ND	ND	ND	ND
Tri-CDD	ND	ND	ND	ND
2378-TCDD	ND	ND	ND	ND
Other TCDD	ND	ND	ND	ND
12378 PCDD	ND	ND	ND	ND
Other PCDD	ND	ND	ND	ND
123478 HxCDD	ND	ND	ND	ND
123678 HxCDD	ND	ND	ND	ND
123789 HxCDD	ND	ND	ND	ND
Other HxCDD	ND	ND	ND	ND
Hepta-CCD	ND	ND	1.95	ND
Octa-CDD	ND	ND	5.45	ND
Total PCCD	ND	ND	8.46	ND
			15.68	ND
Furans				
Mono-CDF	ND	ND	ND	ND
Di-CDF	ND	ND	ND	ND
Tri-CDF	ND	ND	ND	ND
2378 TCDF	ND	ND	ND	ND
Other TCDF	ND	ND	ND	ND
12378 PCDF	ND	ND	ND	ND
23478 PCDF	ND	ND	ND	ND
Other PCDF	ND	ND	ND	ND
123478 HxCDF	ND	ND	0.15	ND
123678 HxCDF	ND	ND	0.53	ND
123789 HxCDF	ND	ND	0.22	0.04
Other HxCDF	ND	ND	ND	ND
Hepta-CDF	ND	ND	0.65	0.01
Octa-CDF	ND	ND	2.06	0.16
Total PCDF	ND	ND	0.80	ND
			4.41	0.21

[a]All values reported in nanograms (10^{-9} g) per sample.
ND = Not detected.

TABLE 5-6. RESULTS OF DUPLICATE ANALYSIS OF RFA MM5 SAMPLE, RUN 03, FRONT HALF

Homologue	Run #1	Run #2	Absolute Percent Difference
Dioxins			
Mono-CDD	ND	ND	0.00
Di-CDD	1.30	1.06	22.6
Tri-CDD	10.93	8.22	33.0
2378-TCDD	2.58	2.60	0.77
Other TCDD	33.47	31.44	6.5
12378 PCDD	10.23	9.47	8.0
Other PCDD	58.53	66.28	11.7
123478 HxCDD	16.82	16.21	3.8
123678 HxCDD	18.08	17.62	2.6
123789 HxCDD	37.87	37.73	0.38
Other HxCDD	160.60	156.29	2.8
Hepta-CDD	349.94	350.6	0.20
Octa-CDD	362.94	353.27	2.7
Total PCDD	1063.29	1050.79	1.2
Furans			
Mono-CDF	0.13	ND	--
Di-CDF	ND	ND	0.00
Tri-CDF	75.70	65.47	15.6
2378 TCDF	22.09	21.36	3.4
Other TCDF	102.05	92.19	10.7
12378 PCDF	9.15	7.32	0.04
23478 PCDF	18.42	14.85	0.04
Other PCDF	53.32	42.87	0.38
123478 HxCDF	46.51	44.00	0.03
123678 HxXCDF	20.25	19.18	0.01
123789 HxCDF	ND	ND	0.00
Other HxCDF	115.82	107.90	0.11
Hepta-CDF	206.42	193.80	0.14
Octa-CDF	40.65	36.93	0.06
Total PCDF	710.51	645.89	0.60

[a]All values reported in nanograms (10^{-9}g) per gram of sample.
ND = not detected.

6.0 REFERENCES

1. Environmental Standards Workshop, Sponsored by the American Society of Mechanical Engineers, U.S. Department of Energy and U.S. Environmental Protection Agency, December 31, 1984.

2. Procedures for Estimating Risks Associated with Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans (CDD and CDF). (Prepared by the U.S. Environmental Protection Agency, Washington, DC.) April 1986.

APPENDIX A

Environmental Standards Workshop Protocol
December, 1984
Draft

APPENDIX B.1

Example Calculations and Terminology

RADIAN SOURCE TEST
EPA METHODS 2-5
DEFINITION OF TERMS

PARAMETER	DEFINITION
Tt(min.)	TOTAL SAMPLING TIME
Dn(in.)	SAMPLING NOZZLE DIAMETER
Ps(in.H2O)	ABSOLUTE STACK STATIC GAS PRESSURE
Vm(cu.ft.)	ABSOLUTE VOLUME OF GAS SAMPLE MEASURED BY DGM
Vw(gm.)	TOTAL STACK MOISTURE COLLECTED
Pm(in.H2O)	AVERAGE STATIC PRESSURE OF DGM
Tm(F)	AVERAGE TEMPERATURE OF DGM
Pb(in.Hg.)	BAROMETRIC PRESSURE
% CO2	CARBON DIOXIDE CONTENT OF STACK GAS
% O2	OXYGEN CONTENT OF STACK GAS
% N2	NITROGEN CONTENT OF STACK GAS
SQR(DELPS)	AVE. SQ. ROOT OF S-PITOT DIFF. PRESSURE-TEMP. PRODUCTS
As(sq.in.)	CROSS-SECTIONAL AREA OF STACK(DUCT)
Ts(F)	TEMPERATURE OF STACK
Vm(dscf)	STANDARD VOLUME OF GAS SAMPLED ,Vm(std),AS DRY STD. CF
Vm(dscm)	STANDARD VOLUME OF GAS SAMPLED,Vm(std),AS DRY STD. CM
Vw gas(scf)	VOLUME OF WATER VAPOR IN GAS SAMPLE,STD
% moisture	WATER VAPOR COMPOSITION OF STACK GAS
Md	PROPORTION, BY VOLUME,OF DRY GAS IN GAS SAMPLE
MWd	MOLECULAR WEIGHT OF STACK GAS,DRY BASIS LB/LB-MOLE
MW	MOLECULAR WEIGHT OF STACK GAS,WET BASIC LB/LB-MOLE
Vs(fpm)	AVERAGE STACK GAS VELOCITY
Flow(acfm)	AVERAGE STACK GAS FLOW RATE(ACTUAL STACK COND.)
Flow(acmm)	AVERAGE STACK GAS FLOW RATE(ACTUAL STACK COND.)
Flow(dscfm)	AVERAGE STACK GAS VOLUMETRIC FLOW RATE(DRY BASIS)
Flow(dscmm)	AVERAGE STACK GAS VOLUMETRIC FLOW RATE(DRY BASIS)
% I	PERCENT ISOKINETIC
% EA	PERCENT EXCESS AIR IN STACK GAS
DGM	DRY GAS METER
Y	DRY GAS METER CORRECTION FACTOR
Pg	STACK STATIC GAS PRESSURE
Cp	PITOT COEFFICIENT
dH	ORIFICE PLATE DIFF. PRESS. VALUE
dP	PITOT DIFF. PRESS. VALUE
*** EPA STANDARD CONDITIONS	Temperature = 68 deg-F (528 deg-R) Pressure = 29.92 in. Hg.

SAMPLE CALCULATION
PAGE TWO

5) Average Molecular Weight of DRY stack gas :

MWd = (.44 x %CO2) + (.32 x %O2) + (.28 x %N2)

MWd = (.44 x 9.7) + (.32 x 10.4) + (.28 x 78.9) = 29.688

6) Average Molecular Weight of wet stack gas :

MW = MWd x Md + 18(1 - Md)

MW = 29.688 x .8812872 + 18(1 - .8812872) = 28.30048

7) Stack gas velocity in feet-per-minute (fpm) at stack conditions :

Vs = KpxCp x [SQRT (dP)](ave) x SQRT [Ts (avg)] x SQRT [1/(PsxMW)] x 60se

Vs = 85.49 x .84 x 60 x 20.48185 x SQRT[1/(30.28883 X 28.30048)]

Vs = 3014.235 FPM

8) Average stack gas dry volumetric flow rate (DSCFM) :

$$Qsd = \frac{Vs \times As \times Md \times T(std) \times Ps}{144 \text{ cu.in./cu.ft.} \times (Ts + 460) \times P(std)}$$

$$Qsd = \frac{3014.235 \times 9160.905 \times .8812872 \times 528 \times 30.28883}{144 \times 856.1875 \times 29.92}$$

Qsd = 105500.9 dscfm

APPENDIX B.2

Method 5 Calculations for Dioxin/Furan Train

RADIAN SOURCE TEST
EPA METHODS 2-5
FINAL RESULTS

PLANT : RFA
PLANT SITE : LAWRENCE , MA
SAMPLING LOCATION : ESP OUTLET
TEST # : ONE
DATE : 9/17/96
TEST PERIOD : 0900-1334

PARAMETER	RESULT
Vm(dscf)	102.2253
Vm(dscm)	2.895021
Vw gas(scf)	13.77016
Vw gas (scm)	.3899709
% moisture	11.87129
Md	.8812872
MWd	29.688
MW	28.30048
Vs(fpm)	3014.235
Vs (mpm)	918.9739
Flow(acfm)	191757.8
Flow(acmm)	5430.579
Flow(dscfm)	105500.9
Flow(dscmm)	2987.786
% I	98.12344
% EA	99.71619

Program Revision: 1.

RADIAN SOURCE TEST
EPA METHOD 2-5
(RAW DATA)

PLANT	: RFA
PLANT SITE	: LAWRENCE , MA
SAMPLING LOCATION	: ESP OUTLET
TEST #	: TWO
DATE	: 9/17/96
TEST PERIOD	: 1422-1848

PARAMETER	VALUE
Sampling time (min.)	192
Barometric Pressure (in.Hg)	30.28
Sampling nozzle diameter (in.)	.245
Meter Volume (cu.ft.)	102.479
Meter Pressure (in.H2O)	.9079591
Meter Temperature (F)	90.44898
Stack dimension (sq.in.)	9160.905
Stack Static Pressure (in.H2O)	.12
Stack Moisture Collected (gm)	299.3
Absolute stack pressure(in Hg)	30.28883
Average stack temperature (F)	408.449
Percent CO2	9.899999
Percent O2	10.1
Percent N2	80
Delps Subroutine result	20.32236
DGM Factor	.9985
Pitot Constant	.84

RADIAN SOURCE TEST
EPA METHOD 2-5
(RAW DATA)

PLANT	: RFA
PLANT SITE	: LAWRENCE , MA
SAMPLING LOCATION	: ESP OUTLET
TEST #	: THREE
DATE	: 9/18/86
TEST PERIOD	: 0918-1351

PARAMETER	VALUE
Sampling time (min.)	192
Barometric Pressure (in.Hg)	30.31
Sampling nozzle diameter (in.)	.245
Meter Volume (cu.ft.)	106.469
Meter Pressure (in.H2O)	.9391666
Meter Temperature (F)	94.65625
Stack dimension (sq.in.)	9160.905
Stack Static Pressure (in.H2O)	.12
Stack Moisture Collected (gm)	310.2
Absolute stack pressure(in Hg)	30.31882
Average stack temperature (F)	403.375
Percent CO2	9.600001
Percent O2	10.5
Percent N2	79.9
Delps Subroutine result	20.57342
DGM Factor	.9985
Pitot Constant	.84

APPENDIX C.1

MM5 Field Data Sheets

RADIAN CORPORATION

MODIFIED METHOD 5 DATA

PLANT RFA
DATE 9/17/86
SAMPLING LOCATION ESP outlet
SAMPLE TYPE MM5
RUN NUMBER 1
OPERATOR fcg
AMBIENT TEMPERATURE 54°C
BAROMETRIC PRESSURE 30.28
STATIC PRESSURE (P_s) -1.2
FILTER NUMBER (s)
MINIMUM SAMPLE VOLUME 90 cf
INITIAL LEAK CHECK .018 @ 15"

PROBE LENGTH AND TYPE 10' glass
NOZZLE I.D. .245
ASSUMED MOISTURE, % 12
SAMPLE BOX NUMBER 1
METER BOX NUMBER 4
METER Δ HP 1.76
C FACTOR NA
PROBE HEATER SETTING 1002
HEATER BOX SETTING 250°
REFERENCE Δp NA
DRY/GAS METER FACTOR (Y) .9985
FINAL LEAK CHECK

SCHEMATIC OF TRAVERSE POINT LAYOUT
READ AND RECORD ALL DATA EVERY 4 MINUTES

Traverse Point Number	Sampling Time Min.	Clock Time (24-hr Clock)	Gas Meter Reading (V_m), ft^3	Velocity Head (ΔP), in. H_2O	Stack T, in °F	Orifice Pressure Differential (ΔH, in. H_2O)		Temperature (°F) °C (Circle One)								Pump Vacuum in. Hg
									Filter				Dry Gas Meter			
						Desired	Actual	Probe	Skin	Out	Recirc. Water	Absorbent Trap	Inlet (T_m in)	Outlet (T_m out)	Impinger Exit	
		0900	948.486													
A-12	4	04	950.4	.38	385	.72	.72	410	281	—	—	44	59	59	55	4
12	8	08	952.2	.38	386	.72	.72	411	278	—	—	43	66	62	56	6
11	12	12	954.1	.38	386	.72	.72	398	271	—	—	46	77	67	57	6
11	16	16	955.9	.38	392	.72	.72	395	268	—	—	46	80	68	57	6
10	20	20	957.8	.40	388	.76	.76	389	251	—	—	48	86	67	59	6
10	24	24	959.8	.40	391	.76	.76	376	281	—	—	46	87	65	57	6
9	28	28	961.8	.44	384	.84	.84	360	246	—	—	45	88	66	54	7
9	32	32	963.9	.44	388	.84	.84	321	235	—	—	45	89	66	55	7
8	36	36	965.8	.42	388	.80	.80	278	240	—	—	45	91	67	56	7
8	40	40	967.9	.45	389	.85	.85	231	231	—	—	45	91	68	56	7
7	44	44	970.0	.45	388	.85	.85	248	247	—	—	45	92	69	56	7
7	48	48	972.1	.49	396	.93	.93	271	267	—	—	45	93	70	57	7
6	52	52	974.2	.45	393	.85	.85	275	269	—	—	46	95	71	57	7
6	56	56	976.3	.45	396	.85	.85	282	269	—	—	46	94	72	57	7
5	60	1000	978.6	.54	395	1.03	1.03	271	281	—	—	46	95	72	57	8

COMMENTS

RT-1 Run # 1 -111/16 leak rate .007 2 of 2

Traverse Point Number	Sampling Time Min.	Clock Time (24-hr Clock)	Gas Meter Reading (V_m), ft^3	Velocity Head (ΔP_s), in. H_2O	Stack T in °F	Orifice Pressure Differential (ΔH, in. H_2O) Desired	Actual	Temperature °F (Circle One) Probe	Filter Stack	Filter Out	Recirc. Water	Absorbent Trap	Dry Gas Meter Inlet (T_m in)	Dry Gas Meter Outlet (T_m out)	Impinger Exit	Pump Vacuum in. Hg
		1136	2,034													
B-12	100	40	4.5	.56	399	1.06	1.06	353	235	—	—	57	72	67	60	9 *
12	104	1144	6.8	.56	399	1.06	1.06	373	257	—	—	58	79	68	59	9 *
	104	1144	6.8			Stopped to fix broken t/c wire in probe										* fixed problem
11	108	48	9.1	.50	400	.95	.95	381	276	—	—	58	89	68	61	8 *
11	112	52	12.0	.52	400	.99	.99	380	269	—	—	58	90	69	61	8 *
10	116	56	14.2	.54	401	1.03	1.03	379	258			53	93	70	58	*
10	120	1200	15.862	.97	401	.90	.90	366	256	—	—	51	97	72	60	7 *
		1224	15.862			Stopped to Fix broken t/c wire in probe										
9	120	1228	18.1	.46	402	.87	.87	222	226	—	—	53	85	75	61	7
9	124	1232	20.2	.47	400	.90	.90	249	224	—	—	52	95	77	61	7
8	128	1234	22.3	.45	400	.86	.86	234	228			53	98	78	60	7
8	132	1238	23.6	.46	402	.87	.87	290	230			52	100	78	60	7
7	136	1242	25.5	.43	401	.83	.83	225	258	—	—	52	101	79	60	7
7	140	1246	27.55	.46	401	.87	.87	236	278	—	—	52	102	80	59	7
6	144	1250	29.84	.41	405	.76	.76	294	298	—	—	53	103	80	60	7
6	148	54	31.47	.38	402	.72	.72	298	261	—	—	53	101	81	60	7
5	152	58	33.45	.40	404	.76	.76	300	260	—	—	53	101	81	60	7
5	156	1302	35.42	.41	406	.76	.76	246	295	—	—	53	101	82	59	7
4	160	06	37.3	.39	402	.72	.72	249	279	—	—	54	101	82	60	7
4	164	10	39.5	.48	405	.91	.91	252	271	—	—	54	102	82	60	8
3	168	14	41.7	.50	406	.95	.95	256	261	—	—	54	104	82	61	8
3	172	18	44.0	.50	403	.95	.95	242	274	—	—	54	104	83	60	8
2	176	22	46.3	.52	404	.99	.99	244	270	—	—	54	104	82	59	8
2	180	26	48.6	.52	402	.99	.99	250	272	—	—	53	106	83	60	8
1	188	30	50.9	.50	405	.95	.95	261	272	—	—	56	110	84	61	8
1	192	1334	53.094	.50	404	.95	.95	263	271	—	—	55	111	85	61	8

COMMENTS * these values were done again after the T/C wire was fixed.

Final leak rate .007

MOISTURE RECOVERY FORM FOR METHODS 4, 5, 6

Plant Refuse Fuels — Sample Identification Code: RFA-0917-MM5-01

Date 9/17/86

Trap #10

Sampling location outlet

Sample type MM5

Run number RFA-0917-MM5-01

Sample box number 2

Clean-up person GDS

Solvent rinses Acetone / MeCl2

Impinger Number	Impinger Solution	Amount of Solution (g)	Impinger Tip Configuration	Impinger Weight (grams) Final	Initial	Weight Gain
1	Empty	0	cut off stem	718.5	459.88	258.72
2	HPLC WATER	100.45	STD	576.1	574.05	2.05
3	HPLC Water	100.37	STD	533.7	533.33	.43
4	Empty	0	STD	463.9	461.25	2.65
5	Silica Gel	254.64	STD	748.8	720.6	28.2
6						
7						

Total Weight Gain (grams) 292.05

RADIAN CORPORATION

MODIFIED METHOD 5 DATA

PLANT BFA
DATE 9/17/86
SAMPLING LOCATION ESP outlet
SAMPLE TYPE mm5
RUN NUMBER 2
OPERATOR Jeg
AMBIENT TEMPERATURE 66
BAROMETRIC PRESSURE 30.28
STATIC PRESSURE (P_s) +1.2
FILTER NUMBER (s) 2
MINIMUM SAMPLE VOLUME 90 cf
INITIAL LEAK CHECK .008 @ 15"

PROBE LENGTH AND TYPE 10' glass
NOZZLE I.D. .245
ASSUMED MOISTURE, % 12
SAMPLE BOX NUMBER 2
METER BOX NUMBER 4
METER Δ H@ 1.76
C FACTOR N/A
PROBE HEATER SETTING 1007.
HEATER BOX SETTING 250°
REFERENCE Δp N/A
DRY/GAS METER FACTOR (Y) .9985
FINAL LEAK CHECK

SCHEMATIC OF TRAVERSE POINT LAYOUT
READ AND RECORD ALL DATA EVERY 4 MINUTES

Traverse Point Number	Sampling Time Min.	Clock Time (24-hr Clock)	53.751 Gas Meter Reading (V_m), ft^3	Velocity Head (ΔP_s), in. H_2O	Stack T, in °F	Orifice Pressure Differential (ΔH, in. H_2O)		Temperature °F/°C (Circle One)								Pump Vacuum in. Hg
									Filter				Dry Gas Meter			
						Desired	Actual	Probe	Skin	Out	Recirc. Water	Absorbent Trap	Inlet (T_m in)	Outlet (T_m out)	Impinger Exit	
		1422	~~53.556~~													
A-12	4	26	55.6	.40	406	.76	.76	332	250	~	—	58	74	74	53	4
12	8	30	57.5	.38	406	.72	.72	395	256	—	—	52	80	75	48	6
11	12	34	59.4	.40	404	.76	.76	428	261	—	—	57	86	75	47	6
11	16	38	61.4	.40	407	.76	.76	412	243	—	—	56	91	75	46	6
10	20	42	63.5	.47	409	.89	.89	409	256	—	—	57	93	76	52	7
10	24	46	65.6	.47	408	.89	.89	402	243	—	—	55	97	76	49	7
9	28	50	67.7	.42	409	.80	.80	399	252	—	—	57	100	77	49	7
9	32	54	69.7	.42	409	.80	.80	403	241	—	—	60	102	79	47	7
8	36	58	72.0	.47	410	.89	.89	398	248	—	—	59	102	80	46	7
8	40	1502	74.0	.47	411	.89	.89	395	245	—	—	59	103	81	47	7
7	44	06	76.1	.46	409	.87	.87	395	237	—	—	58	104	81	52	7
7	45	1507	76.488	.46	409	.87	.87	344	239	—	—	57	104	82	49	7
					stopped to clean plant grating											

COMMENTS

fig

K+A Run #2 9/17/86 leak rate .007 @ 1" Sheet 2 of 2

Traverse Point Number	Sampling Time Min. 96	Clock Time (24-hr Clock)	Gas Meter Reading (V_m), ft^3	Velocity Head (ΔP), in. H_2O	Stack T in °F	Orifice Pressure Differential (dH, in. H_2O)		Temperature °F/°C (Circle One)								Pump Vacuum in. Hg
									Filter				Dry Gas Meter			
						Desired	Actual	Probe	Skin	Out	Recirc. Water	Absorbent Trap	Inlet (T_m in)	Outlet (T_m out)	Impinger Exit	
		1714	106.793													
B-12	100	1718	108.8	.42	405	.80	.80	255	223	—	—	64	81	79	55	8
12	104	1722	111.3	.48	404	.91	.91	365	240	—	—	67	91	80	52	9
11	108	1726	113.4	.47	405	.90	.90	394	265	—	—	57	99	80	52	7
11	112	1730	115.6	.48	404	.91	.91	401	268	—	—	55	100	80	53	7
10	116	1734	117.8	.47	406	.90	.90	407	274	—	—	57	102	81	54	7
10	120	1738	119.9	.48	406	.91	.91	449	286	—	—	58	103	81	53	7
9	124	42	122.0	.48	405	.91	.91	462	281	—	—	57	104	82	54	7
9	128	46	124.2	.48	404	.91	.91	438	271	—	—	58	104	82	53	7
8	132	50	126.4	.46	406	.87	.87	416	269	—	—	58	106	83	55	7
8	136	54	128.5	.46	405	.87	.87	410	259	—	—	59	106	84	56	7
7	140	58	130.6	.44	405	.84	.84	404	258	—	—	60	106	84	56	7
7	144	1802	132.6	.44	407	.84	.84	343	253	—	—	60	107	85	56	7
6	148	06	134.5	.36	405	.68	.68	330	250	—	—	60	107	85	56	6
6	152	10	136.4	.36	406	.68	.68	269	246	—	—	61	107	86	56	6
5	156	14	138.5	.46	407	.87	.87	272	248	—	—	61	108	86	56	7
5	160	18	140.6	.46	410	.87	.87	280	257	—	—	61	109	87	56	7
4	164	22	142.6	.40	408	.76	.76	272	257	—	—	61	110	88	55	7
4	168	24	144.6	.40	407	.76	.76	269	258	—	—	61	109	88	55	7
3	172	28	145.6	.44	409	.84	.84	261	258	—	—	62	109	89	56	7
3	176	32	147.8	.46	410	.87	.87	262	261	—	—	62	110	89	56	7
2	180	36	149.9	.46	408	.87	.87	262	263	—	—	62	111	89	55	7
2	184	40	152.1	.48	408	.91	.91	260	260	—	—	62	111	90	55	7
1	188	44	154.3	.48	408	.91	.91	257	264	—	—	63	113	90	55	7
1	192	1848	156.488	.48	408	.91	.91	258	264	—	—	64	114	90	54	7
						Final leak rate .008 @ 10"										

COMMENTS

MOISTURE RECOVERY FORM FOR METHODS 4, 5, 6

Plant Refuse Fuels

Sample Identification Code: RFA-0917-MM5-02

Date 9/17/86

TRAP # 4

Sampling location ESP outlet

Sample type MM5

Run number RFA-0917-MM5-02

Sample box number —

Clean-up person GD H

Solvent rinses Acetone/MeCl2

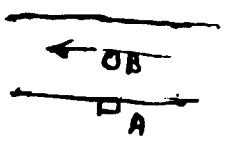
Impinger Number	Impinger Solution	Amount of Solution (g)	Impinger Tip Configuration	Impinger Weight (grams) Final	Initial	Weight Gain
1	Empty	0	cut off stem	706.9	442.36	264.54
2	HPLC water	101.48	STD	543.12	535.86	7.26
3	HPLC water	101.15	STD	555.50	554.40	1.10
4	empty	0	STD	519.7	517.68	2.02
5	Silica Gel	258.8	STD	771.0	746.6	24.4
6						
7						

Total Weight Gain (grams) 299.3

RADIAN CORPORATION

MODIFIED METHOD 5 DATA

PLANT RFA
DATE 9/18/86
SAMPLING LOCATION ESP outlet
SAMPLE TYPE MMS
RUN NUMBER 3
OPERATOR Jlg
AMBIENT TEMPERATURE 49
BAROMETRIC PRESSURE 30.31
STATIC PRESSURE (P_s) +.12
FILTER NUMBER (s) 3
MINIMUM SAMPLE VOLUME 90 cf
INITIAL LEAK CHECK .018 @ 15"



A-vertical
B-horizontal

PROBE LENGTH AND TYPE 10' 9/955
NOZZLE I.D. .245
ASSUMED MOISTURE, % 12
SAMPLE BOX NUMBER 3
METER BOX NUMBER 4
METER Δ H@ 1.76
C FACTOR NA
PROBE HEATER SETTING 100%
HEATER BOX SETTING 250°
REFERENCE Δp NA
DRY/GAS METER FACTOR (Y) .9985
FINAL LEAK CHECK

SCHEMATIC OF TRAVERSE POINT LAYOUT
READ AND RECORD ALL DATA EVERY 4 MINUTES

Traverse Point Number	Sampling Time Min.	Clock Time (24-hr Clock)	158.624 Gas Meter Reading (V_m), ft^3	Velocity Head (ΔP_s), in. H_2O	Stack T in °F	Orifice Pressure Differential (ΔH, in. H_2O)		Temperature (°F) °C (Circle One)								Pump Vacuum in. Hg
									Filter				Dry Gas Meter			
						Desired	Actual	Probe	Skin	Out	Recirc. Water	Absorbent Trap	Inlet (T_m in)	Outlet (T_m out)	Impinger Exit	
		0918	~~158.622~~													
A-12	4	22	160.585	.44	401	.84	.84	282	238	—	—	50	65	60	56	6
					Stopped to clean grating											
		0954	160.585													
A-12	8	58	162.7	.44	405	.84	.84	312	241	—	—	49	63	63	56	10
11	12	1002	164.7	.42	403	.76	.76	409	245	—	—	45	71	63	57	9
11	16	06	166.8	.45	405	.89	.89	381	230	—	—	46	79	64	57	10
10	20	10	168.9	.48	405	.91	.91	359	252	—	—	47	86	64	58	10
10	24	14	171.1	.48	403	.91	.91	347	234	—	—	47	92	66	58	10
9	28	18	173.3	.48	405	.91	.91	353	251	—	—	47	96	68	59	10
9	32	22	175.4	.48	405	.91	.91	327	233	—	—	48	99	70	59	10
8	36	26	177.6	.47	403	.89	.89	344	253	—	—	49	101	72	60	10
8	40	30	179.7	.47	404	.89	.89	279	230	—	—	49	102	74	60	10
7	44	34	182.0	.54	403	1.03	1.03	249	248	—	—	50	104	75	61	11
7	48	38	184.3	.54	404	1.03	1.03	231	231	—	—	50	107	77	61	11
6	52	42	186.5	.46	401	.87	.87	230	257	—	—	51	109	79	61	10

COMMENTS

7/18/86 leak rate .010 @ 16 Sheet 2 of 2

Traverse Point Number	Sampling Time Min.	Clock Time (24-hr Clock)	Gas Meter Reading (V_m), ft^3	Velocity Head (ΔP_s), in. H_2O	Stack T in °F	Orifice Pressure Differential (ΔH), in. H_2O		Temperature °F/°C (Circle One)					Dry Gas Meter			Pump Vacuum in. Hg
									Filter							
						Desired	Actual	Probe	Skin	Out	Recirc. Water	Absorbent Trap	Inlet (T_m in)	Outlet (T_m out)	Impinger Exit	
		1215	214.298													
B-12	100	19	216.4	.42	400	.80	.80	221	244	—	—	55	81	81	68	10
12	104	23	218.4	.42	401	.80	.80	210	265	—	—	53	92	81	67	10
11	108	27	220.5	.42	400	.80	.80	225	274	—	—	52	97	81	68	10
11	112	31	222.5	.42	401	.80	.80	330	268	—	—	52	102	82	67	10
10	116	35	224.6	.46	403	.87	.87	363	277	—	—	53	105	83	68	10
10	120	39	226.7	.46	403	.87	.87	391	268	—	—	53	107	84	69	10
9	124	43	228.8	.42	402	.80	.80	368	281	—	—	51	109	85	68	10
9	128	47	230.9	.45	401	.86	.86	409	273	—	—	53	110	86	67	10
8	132	51	233.1	.47	404	.89	.89	408	268	—	—	52	182	87	66	10
8	136	55	235.3	.47	403	.89	.89	394	268	—	—	52	114	88	67	10
7	140	59	237.5	.47	403	.89	.89	397	265	—	—	53	114	89	66	10
7	144	1303	239.6	.47	402	.89	.89	349	262	—	—	54	116	90	68	10
6	148	07	241.7	.42	406	.80	.80	299	258	—	—	55	115	92	65	10
6	152	11	243.8	.42	406	.80	.80	289	255	—	—	54	115	92	66	10
5	156	15	245.9	.46	403	.87	.87	287	252	—	—	56	116	93	68	10
5	160	19	248.1	.42	406	.80	.80	260	250	—	—	57	116	93	68	10
4	164	23	250.2	.48	405	.91	.91	264	245	—	—	56	116	94	68	10
4	168	27	252.3	.48	405	.91	.91	242	244	—	—	58	116	95	69	10
3	172	31	254.5	.48	407	.91	.91	237	242	—	—	59	117	95	67	10
3	176	35	256.8	.48	407	.91	.91	237	241	—	—	59	118	95	68	10
2	180	39	259.1	.52	407	.99	.99	237	238	—	—	61	118	96	69	11
2	184	43	261.56	.52	406	.99	.99	233	240	—	—	62	119	96	68	11
1	188	47	263.74	.52	408	.99	.99	228	238	—	—	62	118	97	69	11
1	192	51	265.85	.45	406	.85	.85	228	240	—	—	62	117	97	69	11
			END of TEST													

COMMENTS FINAL LEAK .010 @ 15" Hg

MOISTURE RECOVERY FORM FOR METHODS 4, 5, 6

Plant Refuse Fuels

Sample Identification Code: RFA-0918-MM5-TRAP #9

Date 9/18/86

Sampling location ESP outlet

Sample type MM5

Run number RFA-0918-MM5-03

Sample box number —

Clean-up person GOH

Solvent rinses Acetone/MeCl2

Impinger Number	Impinger Solution	Amount of Solution (g)	Impinger Tip Configuration	Impinger Weight (grams) Final	Initial	Weight Gain
1	Empty	0	cut off stem	733.1	460.4	
2	HPLC water	102.7	STD	580.7	577.4	
3	HPLC water	102.01	STD	535.2	534.4	
4	Empty	0	STD	464.2	461.2	
5	SelicaGel	254.05	STD	750.3	719.9	
6						
7						

Total Weight Gain (grams) _____

APPENDIX C.2

Total Ash Discharge Field Data Sheets

PROCESS SAMPLE FIELD DATA

Plant RFA

Process Sample Total Ash

Sampling Location Ash Conveyor

Date	Run No.	Time (military)	Composite Number	Sample Weight	Container Weight	Comments
9/17/86	01	0945	1	1.516	4 16	
		0959	2	2	6	
		1014	3	1	7	
		1029	4	2	9	
		10:44	5	2	11	
		11:00	6	1	12	
		11:16	7	1.5	13.5	
		11:30	8	1.5	15	
		~~11~~ 11:44	9	1.	16	
		11:59	10	2	18	
		12:15	11	2	20	
		12:30	12	2	4	
		12:44	13	2.5	6,5	
		12:59	14	6	12.5	
		13:29	~~14~~ 15	2	14.5	No sample at 13:15 - belt stopped to change ash truck

PROCESS SAMPLE FIELD DATA

Plant RFA

Process Sample Total Ash

Sampling Location Ash Conveyor

Date	Run No.	Time (military)	Composite Number	Sample Weight	Container Weight	Comments
9/18/86	03	1030	1	2	4	
		1045	2	2	6	
		1100	3	3	9	
		1115	4	1	10	
		1129	5	1	11	
		1145	6	1	12	
		1202	7	1.5	13.5	
		1215	8	2.5	16	
		1231	9	2.0	18	
		1245	10	4	6	
		1300	11	2	8	
		1316	12	2	10	
		1330	13	1	11	
		1346	14	1	12	
		1359	15	2	14	

APPENDIX C.3

ESP Ash Sampling Field Data Sheets

PROCESS SAMPLE FIELD DATA

Plant RFA

Process Sample ESP Ash

Sampling Location Screw Conveyor

Date	Run No.	Time (military)	Composite Number	Sample Weight	Comments
9/17/84	01	1001	1		
		1030	2		
		1102	3		
		1132	4		
		1201	5		
		1232	6		
		1302	7		
		1331	8		

PROCESS SAMPLE FIELD DATA

Plant RFA

Process Sample ESP Ash

Sampling Location Screw Conveyor

Date	Run No.	Time (military)	Composite Number	Sample Weight	Comments
7/18/86	03	1032	1		
		1102			
		1131			
		1204			
		1233			
		1302			
		1332			

APPENDIX C.4

Orsat Analyses

ORSAT DATA SHEET

Location Refuse Fuels Comments RFA-0917-M3-01

Date 9/17/96

Time [illegible]

Operator GDH

Sorbing Reagents: 40% KOH (CO_2) Pyrogallol (O_2) None (CO)

Replicate Number	Original Volume Reading 1	(CO_2) Reading 2 (ml)	(CO_2) Volume (2-1) (ml)	(O_2) Reading 3 (ml)	(O_2) Volume (3-2) (ml)	(CO) Reading 4 (ml)	(CO) Volume (4-3) (ml)
(1)	0	96	9.6	20.6	10.6		
(2)	0		9.8	20.2	10.4		
(3)	0		9.7	20.2	10.5		

Averaged Results: % CO_2 9.7 % O_2 10.4

% CO N/A % N_2 78.9

Dry Molecular Weight, MW (dry) =

$= 0.44 \frac{9.7}{(\% CO_2)} + 0.32 \frac{10.4}{(\% O_2)} + 0.28 \frac{78.9}{(\% CO + \% N_2)}$

$= \_\_\_\_ + \_\_\_\_ + \_\_\_\_$

$= 29.69$ g/mole

ORSAT DATA SHEET

M3

Location Refuse Fuels Comments RFA-0918-~~M3~~S-03

Date 9/18/86

Time

Operator GDH

Sorbing Reagents: 40% KOH (CO_2) Pyrogallol (O_2) NONE (CO)

Replicate Number	Original Volume Reading 1	(CO_2) Reading 2 (ml)	(CO_2) Volume (2-1) (ml)	(O_2) Reading 3 (ml)	(O_2) Volume (3-2) (ml)	(CO) Reading 4 (ml)	(CO) Volume (4-3) (ml)
①	0	9.4	9.4	20.0	10.6		
②	0	9.4	9.4	20.0	10.6		
③	0	9.8	9.8	20.8	10.4		

Averaged Results: % CO_2 9.6 % O_2 10.5

% CO ____ % N_2 79.9

Dry Molecular Weight, MW (dry) =

$= 0.44 \frac{9.6}{(\% CO_2)} + 0.32 \frac{10.5}{(\% O_2)} + 0.28 \frac{79.9}{(\% CO + \% N_2)}$

$= \_\_\_\_ + \_\_\_\_ + \_\_\_\_$

$= 29.96$ g/mole

APPENDIX D

Preliminiary Sampling Measurements and Calculations

RADIAN CORPORATION

PRELIMINARY VELOCITY TRAVERSE

PLANT RFA
DATE 2/15/86
LOCATION OUTLET DUCT
STACK I.D. 9 FT.
BAROMETRIC PRESSURE, in. Hg
STACK GAUGE PRESSURE, in. H_2O 0.12
OPERATORS FLG / MAP

SCHEMATIC OF TRAVERSE POINT LAYOUT

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F	CYCLONIC FLOW CHECK (°)	TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
B-1	.52	399	+23			
2	.57	400	+18			
3	.53	399	+17			
4	.48	399	+17			
5	.42	399	+13			
6	.43	398	+11			
7	.53	396	-5			
8	.56	395	-8			
9	.59	394	-11			
10	.61	393	-18			
11	.60	393	-17			
12	.56	392	-23			
A 1			-22			
2			-16			
3			-14			
4			-10			
5			-8			
6			0			
7			+4			
8			+12			
9			+13			
10			+16			
11			+18			
12						
AVERAGE	.533	596.4	13.4	AVERAGE		

EPA (Dur) 233
4/72

CALCULATIONS

(1) $V.P. = S.V.P. - \left[(3.67 \times 10^{-4}) \cdot (P_s) \cdot (T_d - T_w) \cdot \left[1 + \left(\frac{T_w - 32}{1571}\right)\right]\right]$

_____ = _____ $- \left[(\quad) \cdot (\quad) \cdot (\quad) \cdot \left[1 + \left(\frac{\quad}{1571}\right)\right]\right.$

(2) $B_{ws} = \frac{V.P.}{P_s}$ = _____

(3) $M_d = \left((0.44) \cdot (\%\ CO_2)\right) + \left((0.32) \cdot (\%\ O_2)\right) + \left((0.28) \cdot (\%\ CO + \%\ N_2)\right)$

29.96 = $\left((0.44) \cdot (9.6)\right) + \left((0.32) \cdot (10.5)\right) + \left((0.28) \cdot (0 + 79.9)\right)$

(4) $M_s = \left[\left(M_d\right) \cdot \left(1 - B_{ws}\right)\right] + \left[(18) \times (B_{ws})\right]$

28.52 = $\left[(29.96) \cdot (.89)\right] + \left[(18) \cdot (.12)\right]$

(5) $\Delta H = K \sqrt{\Delta P}$

$\left(\frac{29.96}{28.52}\right)\left(\frac{29.93}{29.92}\right)\left(\frac{531}{864}\right)$

$K = (846.72) \cdot (D_n^4) \cdot (\Delta H@) \cdot (C_p^2) \cdot (1-B_{ws})^2 \cdot \left(\frac{M_d}{M_s}\right) \cdot \left(\frac{P_s}{P_m}\right) \cdot \left(\frac{T_m\ ^\circ R}{T_s\ ^\circ R}\right)$

_____ = (846.72) . ( ) . (1.76) . (.7056) . (.7744). ( ) . (____)(____)

~~2.064~~

(6) $\%\ I = \frac{(T_s\ ^\circ R) \cdot (\text{GAS VOL. S.T.P.}) \cdot (P_{std}) \cdot (100)}{(T_{std}\ ^\circ R) \cdot (V_s\ \text{ft./sec.}) \cdot (P_s) \cdot (\text{Sampling Time Min.})\ (60)\ (A_n)\ (1-B_{ws}$

_____ % = $\frac{(1\ ^\circ R) \cdot (2\ \text{stp}) \cdot (29.92) \cdot (100)}{(528^\circ R) \cdot (3\ \text{ft/sec.}) \cdot (4\ \text{"Hg}) \cdot (5\ \text{Min.}) \cdot (60\ \frac{\text{Sec.}}{\text{Min.}}) \cdot (6\ \text{ft}$

RUN # 2 K = 1.93 D = 0.246

RUN # 1 K = 1.89 D = 0.245

APPENDIX E

Incinerator Operating Data

Shift: A/C

Refuse Fuels Daily Log Sheet - RDF Boiler

Date: 9/17/86

	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15
	~~6:00~~	~~7:00~~	~~8:00~~	~~9:00~~	~~10:00~~	~~11:00~~	~~12:00~~	~~1:00~~	~~2:00~~	~~3:00~~	~~4:00~~	~~5:00~~
FEEDWATER TEMP			231	228	230	232	230	230	230	230	230	230
AIR HEATER GAS OUT #1			345	348	349	349	349	350	350	355	354	355
AIR HEATER GAS OUT #2			327	335	330	330	329	330	330	335	335	337
AIR HEATER AIR INLET			84	85	85	86	86	88	88	89	89	88
AIR HEATER GAS OUTLET #1			330	341	341	333	333	333	337	333	333	335
AIR HEATER GAS OUTLET #2			361	360	363	364	365	365	365	370	370	370
CONDUCTIVITY			990	980	950	960	1000	1010	1000	1000	1000	1000
STEAM PRESSURE (PSIG)			645	650	650	650	640	650	640	640	640	650
BRN FF (#/hr x 100)			—	—	—	—	—	—	—	—	—	—
BRN FF (#/hr x 1000)			43000	43000	44000	43000	43000	43000	43000	43,000	44,000	44,000
SF (#/hr x 1000)			220000	220000	217000	218000	208000	210000	220000	218,000	216,000	220,000
FW FLOW (#hr x 1000)			220000	235000	220000	230000	215000	218000	220000	220,000	235,000	235,000
DRUM LEVEL INLET			N	N	N	N	N	N	N	N	N	N
RDF DEMAND %			56%	48%	53%	48%	60%	48%	60%	50	49	54
UG A/F (#/hr x 1000)			55%	55%	55%	55%	55%	55%	55%	57	55	57
OF A/F (#/hr x 1000)			150+	150+	150+	150+	150+	150+	150+	150+	150+	150+
OXYGEN A %			9.9%	9.6%	9.7%	10%	10.6%	8.8%	10.2%	10	9	9.8
OXYGEN B %			7.2%	6.4%	6.4%	7.0%	8.0%	7.6%	7.9%	8.2	8	7.5
FEEDWATER (PSIG)			1000	1000	1010	980	1020	1040	1000	1050	980	980
SH OUTLET TEMP			522	525	530	530	525	530	535	539	538	537
FINAL STEAM TEMP			697	700	702	701	693	703	706	705	697	704
FUEL OIL FLOW			778954	778954	778954	778954	778954	778954	778954	778954	778954	778954
STEAM FLOW			605177	605283	605283	605339	605346	605436	605446	605547	605602	605612
FEEDWATER FLOW			751370	751420	751470	751533	751589	751640	751703	751756	751812	751864
BOILER EXIT GAS TEMP			818	816	815	828	805	822	840	847	840	845
ECON EXIT GAS TEMP			529	531	530	531	528	535	540	539	538	545
AIR HEATER GAS INLET			503	505	504	504	505	505	510	511	511	515
AIR HEATER GAS INLET			800	810	811	811	798	804	824	822	822	830
			790	805	796	783		783	800	801	800	805

TEST # 8 and 3 Page 1 of 4

Shift: C

Refuse Fuels Daily Log Sheet - RDF Boiler

Date : 9/17/86

	2100	2:15	2:30	2:45	3:00	3:15	3:20	3:35	4:00	4:15	4:30	4:45
	~~6:00~~	~~7:00~~	~~8:00~~	~~9:00~~	~~10:00~~	~~11:00~~	~~12:00~~	~~1:00~~	~~2:00~~	~~3:00~~	~~4:00~~	~~5:00~~
FEEDWATER TEMP	230	230	230	230	233				230	230	230	230
AIR HEATER GAS OUT #1	360	355	357	360	363				385	370	365	365
AIR HEATER GAS OUT #2	345	340	340	342	344				360	350	345	345
AIR HEATER AIR INLET	95	95	95	94	95				95	95	95	95
AIR HEATER GAS OUTLET #1	345	345	345	346	350				365	355	350	350
AIR HEATER GAS OUTLET #2	375	375	375	378	380				400	390	385	380
CONDUCTIVITY	950	1000	980	1000	980				950	950	950	1000
STEAM PRESSURE (PSIG)	650	640	640	630	640				640	630	640	650
BRN FF (#/hr x 100)	—	—	—	—	—				—	—	—	—
BRN FF (#/hr x 1000)	43000	43,000	42000	42000	42000				42,000	43000	40,000	45,000
SF (#/hr x 1000)	210,000	210,000	212000	220000	208000				200,000	195,000	210,000	220,000
FW FLOW (#hr x 1000)	215,000	235,000	220000	235000	220000				200,000	210,000	225000	235,000
DRUM LEVEL INLET	N	N	N	N	N.				N	N	N	N
RDF DEMAND %	52%	52%	62%	60%	57%				60%	56%	50%	48%
UG A/F (#/hr x 1000)	58%	58%	57%	56%	56%				57%	57%	54%	53%
OF A/F (#/hr x 1000)	150+	150+	150+	150+	150+				150+	150+	150+	150+
OXYGEN A %	9.0%	9.2%	9.2%	9.1%	9.0%				10.8%	10.%	9.6%	9.4%
OXYGEN B %	7.8%	7.2%	7.2%	6.4%	4.4%				7.2%	7.6%	6.6%	6.2%
FEEDWATER (PSIG)	1040	1020	1000	1000	1000				1040	1020	1000	1020
SH OUTLET TEMP	535	535	525	580	590				530	520	530	535
FINAL STEAM TEMP	705	698	699	691	696				696	689	694	701
FUEL OIL FLOW	778954	778954	778954	778954	778954				778954	778954	778954	778954
STEAM FLOW	606251	606297	606354	606407	606462				606679	606709	606773	606814
FEEDWATER FLOW	752487	752536	752545	752648	752706				752929	752964	753031	753075
BOILER EXIT GAS TEMP	850	840	837	838	860				826	810	830	830
ECON EXIT GAS TEMP	550	540	540	550	540				550	535	540	545
AIR HEATER GAS INLET	520	520	518	520	514				530	525	520	520
AIR HEATER GAS INLET 25	830	825	820	~~808~~ 820	790				805	795	825	835
9	820	800	805	808	850				810	800	805	815
60	[illegible]	55	56	[illegible]	48				51	54	52	59

GRATE PROBLEMS

Test # 2 [illegible] page 3/4

Shift: C 73 85

Refuse Fuels Daily Log Sheet - RDF Boiler

TEST

Date: 9-18-86

	~~12:15~~ ~~7:00~~	~~12:30~~ ~~8:00~~	~~1:45~~ ~~9:00~~ ~~9:30~~	~~5:00~~ ~~5:00~~	~~10:00~~ ~~10:00~~	~~10:15~~ ~~11:00~~	~~10:30~~ ~~12:00~~	~~10:45~~ ~~1:00~~	~~11:00~~ ~~2:00~~	~~11:15~~ ~~3:00~~	12:15 ~~4:00~~	12:20 ~~5:00~~
FEEDWATER TEMP					230	230	230	230	230	230	230	230
AIR HEATER GAS OUT #1					365	355	355	357	360	366	360	358
AIR HEATER GAS OUT #2					335	336	335	340	340	340	340	340
AIR HEATER AIR INLET					85	86	86	90	90	91	95	97
AIR HEATER GAS OUTLET #1					335	[illegible]	337	340	340	342	345	345
AIR HEATER GAS OUTLET #2					370	370	370	372	372	375	375	375
CONDUCTIVITY					1.25	[illegible]	1.25	1.25	1.25	1.25	1.25	1.25
STEAM PRESSURE (PSIG)					590	590	590	595	570	590	595	570
BRN FF (#/hr x 100)					-	-	-	-	-	-	-	-
BRN FF (#/hr x 1000)					415.000	415.000	418.000	415.000	415.000	415.000	415.000	415.000
SF (#/hr x 1000)					210.000	212.000	207.000	220.000	210.000	210.000	205.000	220.000
FW FLOW (#hr x 1000)					210.000	225.000	210.000	220.000	220.000	220.000	220.000	225.000
DRUM LEVEL INLET					N	N	N	N	N	N	N	N
RDF DEMAND %					58	49	60	48	58	28	54	66
UG A/F (#/hr x 1000)					55	55	55	55	55	55	55	55
OF A/F (#/hr x 1000)					150#	150#	150#	150	150	150	150#	150#
OXYGEN A %					7%	8%	7.0	6.8	7.2	6.8	8.0	6.4
OXYGEN B %					10½	10.8	10.2	10.2	9.2	9.2	8.9	9.2
FEEDWATER (PSIG)					1100#	1100#	1100	1100	1100	1100	1100	1100
SH OUTLET TEMP					540	540	535	540	540	520	530	520
FINAL STEAM TEMP					695	705	697	709	697	694	695	701
FUEL OIL FLOW					778954	778954	773954	778954	778954	778954	778954	778954
STEAM FLOW					610280	610282	610275	610433	610432	610536	610735	610209
FEEDWATER FLOW					756705	756739	756807	756864	756932	756781	757735	[illegible]
BOILER EXIT GAS TEMP 26					825	830	835	820	811	820	820	820
ECON EXIT GAS TEMP					545	545	545	550	540	545	545	540
AIR HEATER GAS INLET					520	520	520	520	520	520	515	515
AIR HEATER GAS INLET 25					805	830	825	825	820	810	820	815
							900	795	800	820	818	830

TEST 04 pm 1 of 2

APPENDIX F

Triangle Labs Dioxin/Furan Analytical Report

TRIANGLE LABS

DATE : 10/30/86
TLI# : 8601181
OBJECTIVE: ANALYSIS OF ASH AND MM-5 TRAIN SAMPLES FOR THE PRESENCE OF MONO-OCTA CHLORO-DIBENZODIOXINS AND FURANS

METHOD. A method based on the ASME protocol was used for extraction of the ash samples and the modified method 5 train. Front half and back half were analyzed separately. Twenty nanograms of internal standards and surrogate standards were added to each sample, except 13C-OCDD which was added at 40 ngs. For the ash samples this gave approximately 2 ng/g (4 ng/g for 13C-OCDD). The weight of each ash sample is given on the enclosed analyst worksheet. The results for the MM-5 trains and ash samples are enclosed.

The data enclosed indicates that the samples were highly contaminated, and some of the results are beyond the calibration range. The highest amounts used in the initial calibration were 20 ng for the mono through tetra isomers, 100 ng for the penta through hepta isomers and 200 ng for 13C12-OCDD. The results may give a reasonble approximation at twice the calibration amount, but beyond that the numbers should be considered lower limits.

Dorothy Bertino, Ph.D.
Quality Control Officer

Triangle Laboratories, Inc.
4915F Prospectus Drive
Research Triangle Park, NC 27713
919-544-5729

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861875
DATE	10/22/86	SAMPLE ID	RADIAN BLANK (SOX)
		CONCAL #	M1861874
FRACT. INJ.	0.05	TLI #	8601181

NAME	AMT (ng)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.005	1.000	
TOTAL DCDD	ND	0	0.007	1.000	
TOTAL TRICDD	ND	0	0.007	1.000	
2378-TCDD	ND		0.039	10.000	25.23
TOTAL TCDD	ND	0	0.174	2.731	
12378-PCDD	ND		0.008	1.000	0.00
TOTAL PCDD	ND	0	0.008	1.000	
123478-HxCDD	ND		0.013	1.000	0.00
123678-HxCDD	ND		0.014	1.000	0.00
123789-HxCDD	ND		0.016	1.000	0.00
TOTAL HxCDD	ND	0	1.258	3.034	
1234678-HpCDD	ND		0.471	0.952	42.29
TOTAL HpCDD	ND	0	0.690	1.449	
OCDD	ND		0.475	0.268	0.00
TOTAL MCDF	ND	0	0.004	1.000	
TOTAL DCDF	ND	0	0.003	1.000	
TOTAL TRICDF	ND	0	0.006	1.000	
2378-TCDF	ND		0.005	1.000	0.00
TOTAL TCDF	ND	0	0.122	0.755	
12378-PCDF	ND		0.047	0.500	30.05
23478-PCDF	ND		0.007	1.000	0.00
TOTAL PCDF	ND	0	0.058	0.500	
123478-HxCDF	ND		0.007	1.000	0.00
123678-HxCDF	0.04			1.222	34.55
234678-HxCDF	ND		0.009	1.000	0.00
123789-HxCDF	ND		0.010	1.000	0.00
TOTAL HxCDF	0.05	1		1.222	
1234678-HpCDF	0.14			0.926	41.04
1234789-HpCDF	ND		0.019	1.000	0.00
TOTAL HpCDF	0.16	1		0.926	
OCDF	ND		0.031	1.000	0.00

SURROGATE RESULTS SUMMARY

NAME	AMT (ng)	% RECOVERY	RATIO	RT
13C12-TCDF	22.28	111.40	0.769	24.42
37Cl TCDD	23.22	116.09		25.23
13C12-HxCDF	19.88	99.40	1.227	34.46

INTERNAL STANDARDS RECOVERY RESULTS

NAME	AMT (ng)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	19.88	99.42	0.773	25.23
13C12-PCDD	22.36	111.80	0.639	31.22
13C12-HxCDD	21.42	107.11	1.225	35.59
13C12-HpCDD	21.90	109.48	1.052	42.30
13C12-OCDD	40.25	100.63	0.902	48.03

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861886
DATE	10/28/86	SAMPLE ID	MM5-01 FH #1
		CONCAL #	M1861884
FRACT. INJ.	0.05	TLI #	8601181

NAME	AMT (ng)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.003	1.000	
TOTAL DCDD	6.39	3		1.575	
TOTAL TRICDD	26.09	4		1.036	
2378-TCDD	6.20			0.695	25.20
TOTAL TCDD	86.09	12		0.741	
12378-PCDD	19.58			0.581	31.20
TOTAL PCDD	158.17	12		0.584	
123478-HxCDD	30.31			1.254	35.49
123678-HxCDD	37.44			1.265	35.56
123789-HxCDD	71.68			1.263	36.24
TOTAL HxCDD	456.48	7		1.260	
1234678-HpCDD	358.13			1.001	42.37
TOTAL HpCDD	798.28	2		0.996	
OCDD	1041.31			0.869	48.10
TOTAL MCDF	0.31	1		3.511	
TOTAL DCDF	22.61	2		1.332	
TOTAL TRICDF	203.19	9		0.995	
2378-TCDF	55.31			0.749	24.43
TOTAL TCDF	258.45	9		0.746	
12378-PCDF	16.43			0.652	30.03
23478-PCDF	33.50			0.605	30.54
TOTAL PCDF	162.23	10		0.585	
123478-HxCDF	88.05			1.248	34.44
123678-HxCDF	34.94			1.248	34.54
234678-HxCDF	47.66			1.257	35.39
123789-HxCDF	4.26			1.122	36.53
TOTAL HxCDF	293.36	10		1.245	
1234678-HpCDF	318.81			0.972	41.11
1234789-HpCDF	12.83			0.958	43.13
TOTAL HpCDF	459.99	4		0.972	
OCDF	95.48			0.912	48.23

SURROGATE RESULTS SUMMARY

NAME	AMT (ng)	% RECOVERY	RATIO	RT
13C12-TCDF	23.13	115.67	0.751	24.39
37Cl-TCDD	23.52	117.58		25.20
13C12-HxCDF	18.31	91.56	1.167	34.45

INTERNAL STANDARDS RECOVERY RESULTS

NAME	AMT (ng)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	16.66	83.29	0.776	25.19
13C12-PCDD	19.85	99.23	0.608	31.19
13C12-HxCDD	19.61	98.05	1.230	35.55
13C12-HpCDD	18.92	94.60	1.043	42.37
13C12-OCDD	24.33	60.82	0.856	48.09

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861890
DATE	10/20/86	SAMPLE ID	MM5-02 BH #4
		CONCAL #	M1861888
FRACT. INJ.	0.05	TLI #	8601181

NAME	AMT (ng)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.006	1.000	
TOTAL DCDD	8.47	5		1.450	
TOTAL TRICDD	42.27	6		0.963	
2378-TCDD	6.33			0.704	25.18
TOTAL TCDD	110.10	12		0.780	
12378-PCDD	22.13			0.580	31.17
TOTAL PCDD	158.52	11		0.574	
123478-HxCDD	25.21			1.227	35.45
123678-HxCDD	28.77			1.256	35.53
123789-HxCDD	51.37			1.201	36.21
TOTAL HxCDD	361.63	7		1.250	
1234678-HpCDD	159.53			0.985	42.33
TOTAL HpCDD	363.33	2		0.984	
OCDD	265.36			0.830	48.06
TOTAL MCDF	ND	0	0.004	1.000	
TOTAL DCDF	17.74	4		1.587	
TOTAL TRICDF	227.06	9		0.939	
2378-TCDF	52.87			0.735	24.40
TOTAL TCDF	272.76	10		0.734	
12378-PCDF	18.79			0.610	30.00
23478-PCDF	36.64			0.658	30.52
TOTAL PCDF	188.28	10		0.627	
123478-HxCDF	74.49			1.254	34.41
123678-HxCDF	34.92			1.267	34.50
234678-HxCDF	34.12			1.241	35.36
123789-HxCDF	ND		0.010	1.000	0.00
TOTAL HxCDF	259.45	9		1.252	
1234678-HpCDF	194.11			0.985	41.07
1234789-HpCDF	7.09			0.986	43.10
TOTAL HpCDF	269.23	4		0.983	
OCDF	29.60			0.905	48.18

SURROGATE RESULTS SUMMARY

NAME	AMT (ng)	% RECOVERY	RATIO	RT
13C12-TCDF	17.79	88.96	0.794	24.37
37Cl-TCDD	18.26	91.29		25.17
13C12-HxCDF	19.28	96.42	1.147	34.41

INTERNAL STANDARDS RECOVERY RESULTS

NAME	AMT (ng)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	18.02	90.09	0.800	25.17
13C12-PCDD	16.47	82.35	0.629	31.16
13C12-HxCDD	15.77	78.86	1.236	35.52
13C12-HpCDD	19.40	96.99	1.012	42.33
13C12-OCDD	34.31	85.78	0.871	48.05

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861910
DATE	10/29/86	SAMPLE ID	MM5-03 FH #5
		CONCAL #	M1861906
FRACT. INJ.	0.05	TLI #	8601181

NAME	AMT (ng)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.006	1.000	
TOTAL DCDD	3.08	1		1.790	
TOTAL TRICDD	23.91	4		1.072	
2378-TCDD	7.58			0.792	25.20
TOTAL TCDD	99.07	12		0.791	
12378-PCDD	27.57			0.615	31.19
TOTAL PCDD	220.45	13		0.621	
123478-HxCDD	47.17			1.258	35.48
123678-HxCDD	51.26			1.262	35.55
123789-HxCDD	109.78			1.240	36.23
TOTAL HxCDD	663.00	7		1.250	
1234678-HpCDD	474.73			1.015	42.38
TOTAL HpCDD	1020.25	2		1.014	
OCDD	1028.00			0.879	48.13
TOTAL MCDF	ND	0	0.957	2.398	
TOTAL DCDF	ND	0	52.515	11.357	
TOTAL TRICDF	190.52	9		0.976	
2378-TCDF	62.17			0.747	24.42
TOTAL TCDF	330.45	13		0.748	
12378-PCDF	21.31			0.615	30.02
23478-PCDF	43.22			0.618	30.54
TOTAL PCDF	189.27	8		0.623	
123478-HxCDF	128.05			1.232	34.44
123678-HxCDF	55.82			1.243	34.53
234678-HxCDF	63.69			1.232	35.39
123789-HxCDF	ND		0.016	1.000	0.00
TOTAL HxCDF	497.85	10		1.238	
1234678-HpCDF	393.41			0.985	41.11
1234789-HpCDF	18.88			0.997	43.13
TOTAL HpCDF	563.96	4		0.988	
OCDF	107.46			0.902	48.23

SURROGATE RESULTS SUMMARY

NAME	AMT (ng)	% RECOVERY	RATIO	RT
13C12-TCDF	21.35	106.76	0.778	24.39
37Cl-TCDD	21.05	105.26		25.20
13C12-HxCDF	24.82	124.11	0.956	34.45

INTERNAL STANDARDS RECOVERY RESULTS

NAME	AMT (ng)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	19.15	95.76	0.786	25.19
13C12-PCDD	20.77	103.84	0.618	31.18
13C12-HxCDD	19.80	98.99	1.262	35.55
13C12-HpCDD	20.73	103.67	1.042	42.37
13C12-OCDD	31.99	79.99	0.910	48.12

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861893
DATE	10/24/86	SAMPLE ID	MM5 FIELD BLANK #7
		CONCAL #	M1861888
FRACT. INJ.	0.05	TLI #	8601181

NAME	AMT (ng)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.006	1.000	
TOTAL DCDD	ND	0	0.008	1.000	
TOTAL TRICDD	ND	0	0.011	1.000	
2378-TCDD	ND		0.151	0.030	25.15
TOTAL TCDD	ND	0	0.838	0.811	
12378-PCDD	ND		0.216	0.027	31.13
TOTAL PCDD	ND	0	0.426	1.027	
123478-HxCDD	ND		0.017	1.000	0.00
123678-HxCDD	ND		0.365	46.500	35.50
123789-HxCDD	ND		0.700	0.014	36.20
TOTAL HxCDD	1.95	3		1.345	
1234678-HpCDD	2.67			0.968	42.30
TOTAL HpCDD	5.45	2		0.952	
OCDD	8.46			0.845	48.00
TOTAL MCDF	ND	0	0.005	1.000	
TOTAL DCDF	ND	0	0.004	1.000	
TOTAL TRICDF	ND	0	1.305	1.400	
2378-TCDF	ND		0.657	0.569	24.37
TOTAL TCDF	ND	0	1.328	0.598	
12378-PCDF	ND		0.006	1.000	0.00
23478-PCDF	ND		0.009	1.000	0.00
TOTAL PCDF	0.15	1		0.675	
123478-HxCDF	0.53			1.188	34.38
123678-HxCDF	0.22			1.343	34.48
234678-HxCDF	0.27			1.008	35.33
123789-HxCDF	ND		0.013	1.000	0.00
TOTAL HxCDF	1.67	4		1.235	
1234678-HpCDF	1.81			0.948	41.03
1234789-HpCDF	ND		0.017	1.000	0.00
TOTAL HpCDF	2.06	1		0.948	
OCDF	0.30			1.008	48.15

SURROGATE RESULTS SUMMARY

NAME	AMT (ng)	% RECOVERY	RATIO	RT
13C12-TCDF	19.93	99.65	0.783	24.34
37Cl-TCDD	20.78	103.91		25.15
13C12-HxCDF	18.93	94.65	1.255	34.38

INTERNAL STANDARDS RECOVERY RESULTS

NAME	AMT (ng)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	18.20	90.98	0.797	25.14
13C12-PCDD	15.72	78.59	0.634	31.14
13C12-HxCDD	14.11	70.55	1.229	35.49
13C12-HpCDD	16.49	82.47	1.038	42.30
13C12-OCDD	28.88	72.20	0.884	48.01

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861895
DATE	10/21/86	SAMPLE ID	RFA-3 #9
		CONCAL #	M1861888
FRACT. INJ.	0.05	TLI #	8601181

NAME	AMT (ng)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.009	1.000	
TOTAL DCDD	ND	0	0.012	1.000	
TOTAL TRICDD	ND	0	0.016	1.000	
2378-TCDD	ND		0.013	1.000	0.00
TOTAL TCDD	ND	0	0.337	1.667	
12378-PCDD	ND		0.018	1.000	0.00
TOTAL PCDD	ND	0	0.018	1.000	
123478-HxCDD	ND		0.027	1.000	0.00
123678-HxCDD	ND		0.024	1.000	0.00
123789-HxCDD	ND		0.030	1.000	0.00
TOTAL HxCDD	ND	0	0.027	1.000	
1234678-HpCDD	ND		0.040	1.000	0.00
TOTAL HpCDD	ND	0	0.040	1.000	
OCDD	ND		0.071	1.000	0.00
TOTAL MCDF	ND	0	0.007	1.000	
TOTAL DCDF	ND	0	0.007	1.000	
TOTAL TRICDF	ND	0	0.012	1.000	
2378-TCDF	ND		0.009	1.000	0.00
TOTAL TCDF	ND	0	0.246	0.316	
12378-PCDF	ND		0.010	1.000	0.00
23478-PCDF	ND		0.015	1.000	0.00
TOTAL PCDF	ND	0	0.012	1.000	
123478-HxCDF	ND		0.013	1.000	0.00
123678-HxCDF	ND		0.014	1.000	0.00
234678-HxCDF	ND		0.018	1.000	0.00
123789-HxCDF	ND		0.020	1.000	0.00
TOTAL HxCDF	ND	0	0.016	1.000	
1234678-HpCDF	ND		0.024	1.000	0.00
1234789-HpCDF	ND		0.032	1.000	0.00
TOTAL HpCDF	ND	0	0.028	1.000	
OCDF	ND		0.064	1.000	0.00

SURROGATE RESULTS SUMMARY

NAME	AMT (ng)	% RECOVERY	RATIO	RT
13C12-TCDF	18.57	92.84	0.780	24.32
37Cl-TCDD	19.94	99.69		25.13
13C12-HxCDF	18.31	91.56	1.220	34.36

INTERNAL STANDARDS RECOVERY RESULTS

NAME	AMT (ng)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	18.35	91.74	0.776	25.12
13C12-PCDD	14.78	73.91	0.603	31.12
13C12-HxCDD	13.44	67.19	1.201	35.47
13C12-HpCDD	13.34	66.71	0.997	42.27
13C12-OCDD	20.87	52.18	0.850	47.59

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861897
DATE	10/21/86	SAMPLE ID	RFA-5 #11
		CONCAL #	M1861888
FRACT. INJ.	0.05	TLI #	8601181

NAME	AMT (ng)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.009	1.000	
TOTAL DCDD	ND	0	0.013	1.000	
TOTAL TRICDD	ND	0	0.016	1.000	
2378-TCDD	ND		0.013	1.000	0.00
TOTAL TCDD	ND	0	0.013	1.000	
12378-PCDD	ND		0.019	1.000	0.00
TOTAL PCDD	ND	0	0.019	1.000	
123478-HxCDD	ND		0.026	1.000	0.00
123678-HxCDD	ND		0.024	1.000	0.00
123789-HxCDD	ND		0.030	1.000	0.00
TOTAL HxCDD	ND	0	0.026	1.000	
1234678-HpCDD	ND		0.042	1.000	0.00
TOTAL HpCDD	ND	0	0.042	1.000	
OCDD	ND		0.068	1.000	0.00
TOTAL MCDF	ND	0	0.007	1.000	
TOTAL DCDF	ND	0	0.007	1.000	
TOTAL TRICDF	ND	0	0.013	1.000	
2378-TCDF	ND		0.010	1.000	0.00
TOTAL TCDF	ND	0	0.010	1.000	
12378-PCDF	ND		0.010	1.000	0.00
23478-PCDF	ND		0.016	1.000	0.00
TOTAL PCDF	ND	0	0.013	1.000	
123478-HxCDF	ND		0.013	1.000	0.00
123678-HxCDF	ND		0.013	1.000	0.00
234678-HxCDF	ND		0.017	1.000	0.00
123789-HxCDF	ND		0.020	1.000	0.00
TOTAL HxCDF	ND	0	0.015	1.000	
1234678-HpCDF	ND		0.025	1.000	0.00
1234789-HpCDF	ND		0.033	1.000	0.00
TOTAL HpCDF	ND	0	0.029	1.000	
OCDF	ND		0.060	1.000	0.00

SURROGATE RESULTS SUMMARY

NAME	AMT (ng)	% RECOVERY	RATIO	RT
13C12-TCDF	17.08	85.42	0.755	24.33
37Cl-TCDD	17.86	89.31		25.14
13C12-HxCDF	15.05	75.25	1.268	34.38

INTERNAL STANDARDS RECOVERY RESULTS

NAME	AMT (ng)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	16.49	82.45	0.764	25.13
13C12-PCDD	12.66	63.30	0.626	31.13
13C12-HxCDD	12.68	63.41	1.337	35.48
13C12-HpCDD	11.85	59.26	1.049	42.30
13C12-OCDD	20.30	50.75	0.933	48.00

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861899
DATE	10/20/86	SAMPLE ID	FRA-22 #13
		CONCAL #	M1861888
FRACT. INJ.	0.05	TLI #	8601181

NAME	CONC(ng/g)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.001	1.000	
TOTAL DCDD	2.52	5		1.467	
TOTAL TRICDD	10.22	5		1.062	
2378-TCDD	1.35			0.767	25.16
TOTAL TCDD	22.15	13		0.774	
12378-PCDD	7.56			0.588	31.15
TOTAL PCDD	51.37	12		0.609	
123478-HxCDD	22.04			1.257	35.45
123678-HxCDD	22.63			1.240	35.53
123789-HxCDD	51.55			1.234	36.21
TOTAL HxCDD	287.95	7		1.240	
1234678-HpCDD	447.19			0.996	42.40
TOTAL HpCDD	833.33	2		0.994	
OCDD ①	1423.38			0.927	48.26
TOTAL MCDF	ND	0	0.001	1.000	
TOTAL DCDF	ND	0	0.001	1.000	
TOTAL TRICDF	32.39	9		0.989	
2378-TCDF	9.02			0.733	24.38
TOTAL TCDF	51.39	13		0.739	
12378-PCDF	1.84			0.596	29.52
23478-PCDF	9.91			0.611	30.51
TOTAL PCDF	50.42	10		0.611	
123478-HxCDF	38.10			1.231	34.42
123678-HxCDF	14.68			1.236	34.51
234678-HxCDF	20.57			1.230	35.36
123789-HxCDF	2.41			1.209	36.49
TOTAL HxCDF	173.12	10		1.227	
1234678-HpCDF	193.96			0.981	41.10
1234789-HpCDF	10.38			0.961	43.11
TOTAL HpCDF	289.86	4		0.983	
OCDF	152.27			0.897	48.30

SURROGATE RESULTS SUMMARY

NAME	CONC(ng/g)	% RECOVERY	RATIO	RT
13C12-TCDF	1.87	93.72	0.767	24.35
37Cl-TCDD	1.99	100.11		25.16
13C12-HxCDF ②	3.67	184.63	0.574	34.42

INTERNAL STANDARDS RECOVERY RESULTS

NAME	CONC(ng/g)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	1.75	87.84	0.803	25.15
13C12-PCDD	1.45	72.74	0.620	31.15
13C12-HxCDD	1.35	67.91	1.209	35.52
13C12-HpCDD ②	1.39	70.09	0.512	42.38
13C12-OCDD	2.27	57.00	0.718	48.28

① above the calibration range ② interference

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861903
DATE	10/28/86	SAMPLE ID	RFA-38 #15
SAMPLE WT	10.1	CONCAL #	M1861901
FRACT. INJ.	0.05	TLI #	8601181

NAME	CONC(ng/g)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.001	1.000	
TOTAL DCDD	4.88	5		1.437	
TOTAL TRICDD	19.40	5		0.994	
2378-TCDD	6.58			0.781	25.15
TOTAL TCDD	85.52	13		0.791	
12378-PCDD	28.78			0.598	31.15
TOTAL PCDD	164.06	11		0.608	
123478-HxCDD	68.10			1.265	35.47
123678-HxCDD	77.88			1.267	35.55
123789-HxCDD	200.85			1.260	36.24
TOTAL HxCDD	955.05	7		1.255	
1234678-HpCDD	1789.81 C			0.995	42.42
TOTAL HpCDD	3309.68 C	2		0.996	
OCDD	3177.59 C			0.752	48.39
TOTAL MCDF	0.01	1		2.879	
TOTAL DCDF	4.81	3		1.546	
TOTAL TRICDF	50.74	10		0.990	
2378-TCDF	ND		0.002	1.000	0.00
TOTAL TCDF	148.45	16		0.756	
12378-PCDF	11.14			0.613	29.59
23478-PCDF	24.20			0.603	30.51
TOTAL PCDF	123.80	10		0.610	
123478-HxCDF	109.35			1.233	34.45
123678-HxCDF	57.02			1.242	34.53
234678-HxCDF	55.21			1.240	35.37
123789-HxCDF	5.77			1.325	36.50
TOTAL HxCDF	502.26	10		1.219	
1234678-HpCDF	477.92			0.965	41.17
1234789-HpCDF	43.12			0.973	43.15
TOTAL HpCDF	1020.46 C	4		0.967	
OCDF	437.88			0.896	48.42

SURROGATE RESULTS SUMMARY

NAME	CONC(ng/g)	% RECOVERY	RATIO	RT
13C12-TCDF	2.07	104.33	0.797	24.34
37Cl-TCDD	2.29	115.81		25.15
13C12-HxCDF I	3.69	186.49	0.664	34.46

INTERNAL STANDARDS RECOVERY RESULTS

NAME	CONC(ng/g)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	1.99	100.68	0.762	25.14
13C12-PCDD	2.29	115.55	0.619	31.14
13C12-HxCDD	1.90	96.08	1.221	35.54
13C12-HpCDD	1.34	67.68	0.951	42.43
13C12-OCDD E	2.25	56.92	1.000	48.37

C-beyond Calibra
I-interference; E-estimated (interference); Range

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861905
DATE	10/24/86	SAMPLE ID	RFA-41 #17
SAMPLE WT	10.5	CONCAL #	M1861901
FRACT. INJ.	0.05	TLI #	8601181

NAME	CONC(ng/g)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.001	1.000	
TOTAL DCDD	1.53	2		1.460	
TOTAL TRICDD	9.24	5		0.993	
2378-TCDD	2.78			0.804	25.14
TOTAL TCDD	34.07	13		0.791	
12378-PCDD	8.98			0.597	31.13
TOTAL PCDD	50.01	11		0.599	
123478-HxCDD	16.38			1.248	35.42
123678-HxCDD	18.52			1.244	35.51
123789-HxCDD	44.75			1.269	36.19
TOTAL HxCDD	217.07	7		1.263	
1234678-HpCDD	214.72			1.017	42.36
TOTAL HpCDD	402.29	2		1.015	
OCDD	1498.65			0.911	48.22
TOTAL MCDF	ND	0	0.001	1.000	
TOTAL DCDF I	ND	0	0.260	0.002	
TOTAL TRICDF	10.22	10		0.985	
2378-TCDF	4.89			0.756	24.36
TOTAL TCDF	34.60	15		0.762	
12378-PCDF	2.95			0.600	29.56
23478-PCDF	5.34			0.618	30.49
TOTAL PCDF	26.51	9		0.622	
123478-HxCDF	23.18			1.240	34.39
123678-HxCDF	11.21			1.249	34.48
234678-HxCDF	11.53			1.215	35.33
123789-HxCDF	ND		0.003	1.000	0.00
TOTAL HxCDF	104.12	8		1.241	
1234678-HpCDF	113.00			0.985	41.08
1234789-HpCDF	4.33			0.915	43.08
TOTAL HpCDF	151.48	4		0.982	
OCDF	116.42			0.911	48.24

SURROGATE RESULTS SUMMARY

NAME	CONC(ng/g)	% RECOVERY	RATIO	RT
13C12-TCDF	2.15	113.02	0.770	24.34
37Cl-TCDD	2.27	119.29		25.14
13C12-HxCDF I	2.65	139.35	0.970	34.39

INTERNAL STANDARDS RECOVERY RESULTS

NAME	CONC(ng/g)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	1.88	98.51	0.803	25.13
13C12-PCDD	2.22	116.50	0.622	31.13
13C12-HxCDD	2.00	104.95	1.252	35.49
13C12-HpCDD	2.98	156.67	1.104	42.36
13C12-OCDD	2.89	75.77	0.909	48.21

I - interference

TRIANGLE LABORATORIES, INC.
MONO - OCTA CHLORO DIOXIN/FURAN ANALYSIS

ANALYST	DB	FILE NAME	M1861908
DATE	10/21/86	SAMPLE ID	TLI BLANK #19
		CONCAL #	M1361906
FRACT. INJ.	0.05	TLI #	8601181

NAME	AMT (ng)	NUMBER	DL	RATIO	RT
TOTAL MCDD	ND	0	0.008	1.000	
TOTAL DCDD	ND	0	0.012	1.000	
TOTAL TRICDD	ND	0	0.017	1.000	
2378-TCDD	ND		0.017	1.000	0.00
TOTAL TCDD	ND	0	0.017	1.000	
12378-PCDD	ND		0.020	1.000	0.00
TOTAL PCDD	ND	0	0.020	1.000	
123478-HxCDD	ND		0.034	1.000	0.00
123678-HxCDD	ND		0.033	1.000	0.00
123789-HxCDD	ND		0.039	1.000	0.00
TOTAL HxCDD	ND	0	0.035	1.000	
1234678-HpCDD	ND		0.037	1.000	0.00
TOTAL HpCDD	ND	0	0.037	1.000	
OCDD	ND		0.065	1.000	0.00
TOTAL MCDF	ND	0	0.006	1.000	
TOTAL DCDF	ND	0	0.009	1.000	
TOTAL TRICDF	ND	0	0.013	1.000	
2378-TCDF	ND		0.012	1.000	0.00
TOTAL TCDF	ND	0	0.012	1.000	
12378-PCDF	ND		0.010	1.000	0.00
23478-PCDF	ND		0.015	1.000	0.00
TOTAL PCDF	ND	0	0.012	1.000	
123478-HxCDF	ND		0.017	1.000	0.00
123678-HxCDF	ND		0.017	1.000	0.00
234678-HxCDF	ND		0.022	1.000	0.00
123789-HxCDF	ND		0.025	1.000	0.00
TOTAL HxCDF	ND	0	0.020	1.000	
1234678-HpCDF	ND		0.021	1.000	0.00
1234789-HpCDF	ND		0.029	1.000	0.00
TOTAL HpCDF	ND	0	0.024	1.000	
OCDF	ND		0.057	1.000	0.00

SURROGATE RESULTS SUMMARY

NAME	AMT (ng)	% RECOVERY	RATIO	RT
13C12-TCDF	21.13	105.66	0.797	24.36
37Cl-TCDD	21.79	108.97		25.17
13C12-HxCDF	20.65	103.27	1.305	34.41

INTERNAL STANDARDS RECOVERY RESULTS

NAME	AMT (ng)	% RECOVERY	RATIO	RT
2378-13C12-TCDD	20.12	100.58	0.750	25.16
13C12-PCDD	19.83	99.17	0.670	31.16
13C12-HxCDD	17.38	86.90	1.285	35.53
13C12-HpCDD	19.44	97.21	1.016	42.33
13C12-OCDD	30.92	77.29	0.946	48.05

APPENDIX G

Radian/RTP Total Ash Discharge Moisture Analytical Report

RADIAN LABORATORIES (RTP, N.C.)

TOTAL ASH DISCHARGE MOISTURE ANALYSIS

Radian ID	13747	13748	13749
Field ID	RFA-23	RFA-39	RFA-31
Reported Total Wt., g	1827.2	1901.5	2001.0
(Sample Wt, g)	(1435.0)	(1506.5)	(1607.9)
Condition	Good	Leaky	Leaky
Experimental Total Wt., g	1826.7	1842.0	1996.6
, g	-0.5	-59.5	-4.4
Wt. Filtered, g	383.2	236.7	Not filtered
Liquid Phase Recovered	18.6	27.4	NA
Wt. before drying, g	1801.7	1810.4	1996.6
Liquid phase evaporated at 135°C, g			
-- Overnight	278.1	295.8	282.9
-- End of 10-3-86	12.2	9.5	31.7
-- Total	290.3	305.3	314.7
Final Results			
Percent Moisture	21.5	22.1	19.6

APPENDIX H

Calibration Data

Date: 9/8/86 Operator Initials: flg

Pitot Tube I.D. No.: 10-2 Length: 10

Pitot tube assembly level? ✓ yes _____ no

Pitot tube openings damaged? _____ yes (explain below) ✓ no

Quick connects attached, leak free? ✓ yes _____ no

α_1 = _____° α_2 = _____°

β_1 = _____° β_2 = _____°

γ = _____°, θ = _____°, A = _____ cm (in.)

z = A sin γ = _____ cm (in.);

w = A sin θ = _____ cm (in.);

P_A = _____ cm (in.);

P_b = _____ cm (in.);

D_t = _____ cm (in.)

Acceptance Criteria:

α_1 and $\alpha_2 < 10°$ _____ yes _____ no

β_1 and $\beta_2 < 5°$ _____ yes _____ no

$z < 0.32$ cm (1/8 in.) _____ yes _____ no

$w < 0.08$ cm (1/32 in.) _____ yes _____ no

P_A and P_b, $1.05\ D_t < P < 1.50\ D_t$ _____ yes _____ no

D_t, 0.48 cm (3/16 in) $\leq D_t \leq$ 0.95 cm (3/8 in) _____ yes _____ no

Pitot Tube Acceptable? ✓ yes _____ no

Comments: no physical damage

Figure 5-1. Pitot tube inspection sheet.

Date: 9/8/86 Operator Initials: klg

Pitot Tube I.D. No.: 10-3 Length: 10'

Pitot tube assembly level? ✓ yes _____ no

Pitot tube openings damaged? _____ yes (explain below) ✓ no

Quick connects attached, leak free? ✓ yes _____ no

α_1 = _____° α_2 = _____°

β_1 = _____° β_2 = _____°

γ = _____°, θ = _____°, A = _____ cm (in.)

z = A sin γ = _____ cm (in.);

w = A sin θ = _____ cm (in.);

P_A = _____ cm (in.);

P_B = _____ cm (in.);

D_t = _____ cm (in.)

Acceptance Criteria:

α_1 and $\alpha_2 < 10°$	_____ yes	_____ no
β_1 and $\beta_2 < 5°$	_____ yes	_____ no
z < 0.32 cm (1/8 in.)	_____ yes	_____ no
w < 0.08 cm (1/32 in.)	_____ yes	_____ no
P_A and P_B, 1.05 $D_t < P < 1.50\ D_t$	_____ yes	_____ no
D_t, 0.48 cm (3/16 in) $\leq D_t \leq$ 0.95 cm (3/8 in)	_____ yes	_____ no

Pitot Tube Acceptable? ✓ yes _____ no

Comments: no physical damage

Figure 5-1. Pitot tube inspection sheet.

Saugus Retest Post-cal

DRY GAS METER CALIBRATION DATA

(English Units) Pretest Post Test X

Calibration Meter # 6837014 Y = .9989

Date 9/3/86

Barometric Pressure, Bp = 29.82

Meter Box # 4

Dry Gas Meter # 4

Vacuum = 5"

Orifice Manometer Setting ΔH in. H_2O	Manometer Pressure Cal. Meter ΔHw	Gas Volume Calibration Meter Vw ft³	Gas Volume Dry Gas Meter Vd ft³	Temperature: Calibration Meter In	Out	Temperature: Dry Gas Meter In	Out	Time θ Min. .00	Y	
.85	-.03	final 102.639	final 26.503	initial 74	74	initial 83	75			
		initial 97.547	initial 21.250	mid.		mid.				
		total 5.092	total 5.203	final 74	74	final 94	77		.9908	
				ave. 74		ave. 83.3				
.85	-.03	final 7.772	final 31.787	initial 73	74	initial 94	77			
		initial 2.639	initial 26.503	mid.		mid.				
		total 5.133	total 5.284	final 73	74	final 102	80		.9953	
				ave. 73.5		ave. 88.3				
.85	-.03	final 12.875	final 32.051	initial 73	74	initial 102	80			
		initial 7.772	initial 31.787	mid.		mid.				
		total 5.103	total 5.264	final 73	74	final 103	82		.9996	
				ave. 73.5		ave. 91.8				
		final	final	initial		initial				
		initial	initial	mid.		mid.				
		total	total	final		final				

ΔHθ AVE .9952

$$\frac{V_w}{V_d}\left(P_b - \frac{\Delta H}{13.6}\right)\frac{(t_d + 460)}{(t_w + 460)}$$

$$\frac{0.0317\ \Delta H}{P_b}\cdot\frac{t_d + 460}{V_w}\left[\frac{t_w + 460\ \theta}{V_w}\right]^2$$

ΔH	
.85	$\frac{5.092 \times 29.82 \times 543 \times .9989}{5.203 \times 29.88 \times 534} = .9908$
.85	$\frac{5.133 \times 29.82 \times 548.3 \times .9989}{5.284 \times 29.88 \times 533.5} = .9953$
.85	$\frac{5.103 \times 29.82 \times 551.8 \times .9989}{5.264 \times 29.88 \times 533.5} = .9996$

Meter leak check front ✓ back ✓

Pitot leak check ✓

Electrical check ✓

Calibrating technician [illegible]

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • (312) 953 9300

IVISION MANAGER
ER

PLEASE ADDRESS ALL CORRESPONDENCE TO
1627 EAST 25th ST., CLEVELAND, OH 44114
OFFICE TEL. (216) 241-0971

bcock & Wilcox
82 Strausser St. NW
rth Canton, OH 44720

January 24, 1985

Sample identification
by Babcock & Wilcox

ample
l to us RDF

ken at xxxxx

ken by Submitted

mpled xxxxx

ceived 12/27/84

IDENT: Test #4 1300 Hours
12/21/84
P.O. NO: 073991FL
RELEASE: 016

Analysis report no. 81-7838

ULTIMATE ANALYSIS

	As Received	Dry
% Moisture	19.93	xxxxx
% Carbon	37.85	47.27
% Hydrogen	5.09	6.36
% Nitrogen	0.35	0.44
% Chlorine	0.37	0.46
% Sulfur	0.24	0.30
% Ash	10.99	13.73
% Oxygen (diff.)	25.18	31.44
	100.00 %	100.00 %

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Joseph Moratosky
Manager, Cleveland Laboratory

atermarked
tection

Charter Mem

RFA - Post test

DRY GAS METER CALIBRATION DATA

(English Units) Pretest Post Test

Calibration Meter # 6837014 Y = .9989

Date 10/6/86

Barometric Pressure, Bp = 29.67

Meter Box # 4

Dry Gas Meter # 4

Vacuum = -

Orifice Manometer Setting ΔH in. H_2O	Manometer Pressure Cal. Meter ΔHw	Gas Volume Calibration Meter, Vw ft³	Gas Volume Dry Gas Meter, Vd ft³	Temperature: Calibration Meter In	Out	Dry Gas Meter In	Out	Time θ Min. .00	Y	ΔH
.95	-.02	final 29.518	final 75.002	initial 74	73	initial 80	74			
		initial 24.221	initial 69.616	mid.		mid.				
		total 5.297	total 5.386	final 74	74	final 92	76		.9924	
				ave. 73.8		ave. 80.5		9:30.7		
.95	-.02	final 34.523	final 80.152	initial 74	74	initial 92	76			
		initial 29.518	initial 75.002	mid.		mid.				
		total 5.055	total 5.150	final 74	74	final 98	78		1.0001	
				ave. 74		ave. 86		9:05.8		
.95	-.02	final 39.683	final 85.380	initial 74	74	initial 96	78			
		initial 34.573	initial 80.152	mid.		mid.				
		total 5.11	total 5.228	final 74	73	final 101	80		1.0014	
				ave. 73.8		ave. 88.8		9:13.3		
		final	final	initial		initial				
		initial	initial	mid.		mid.				
		total	total	final		final				
								AVE	.9986	

$$\frac{V_w}{V_d}\left(P_b - \frac{\Delta H}{13.6}\right)\frac{(t_d + 460)}{(T_w + 460)}$$

$$\frac{0.0317\ \Delta H}{P_b}\cdot\frac{t_d + 460}{V_w}\left[\frac{T_w + 460\ \theta}{V_w}\right]^2$$

ΔH	
.95	$\frac{5.297 \times 29.67 \times 540.5 \times .9989}{5.386 \times 29.74 \times 533.8} = .9924$
.95	$\frac{5.055 \times 29.67 \times 546 \times .9989}{5.15 \times 29.74 \times 534} = 1.0001$
.95	$\frac{5.111 \times 29.67 \times 548.8 \times .9989}{5.228 \times 29.74 \times 533.8} = 1.0014$

Meter leak check front ✓ back ✓

Pitot leak check ✓

Electrical check ✓

Calibrating technician [illegible]

APPENDIX I

Sample Shipment Letters

RADIAN
CORPORATION

9/23, 1986

Triangle Laboratories, Inc.
Post Office Box 13485
Research Triangle Park, NC 27709

Attention: Ron Hass

Subject: Dioxin/Furan Analysis Instructions

Dear Sir:

The objective of this letter is to clarify instructions for individual dioxin/furan samples collected by Radian at Refuse Fuel Associates. The sample shipment consists of 2 boxes containing 34 samples. The samples include three sets of MM5 train samples, one set of MM5 field blanks, one set of MM5 laboratory proof blanks, three ESP ash samples and three combined ash samples.

RFA has requested front half and back half analysis of the dioxin/furan samples. The MM5 dioxin/furan sampling trains are recovered as six components. The six components are (1) the probe rinses and front half of the filter housing rinses (acetone and methylene chloride), (2) filterable solids from the gas stream collected on filter paper, (3) the XAD module, (4) the back half of the filter housing and coil condenser rinses (acetone and methylene chloride), and (5) the condensate from the first condenser and rinses (water, acetone and methylene chloride) and (6) the impinger solutions of the last three condensers with rinses (water, acetone and methylene chloride). Each component should be extracted separately. The XAD module and the condensate and impinger solution samples which contain water will need to be extracted by 11 01 86 (14 days from the end of the test). The front half is defined as components (1) and (2) and the back half as components (3), (4), (5) and (6). The results of the analyses for each test run should be described as front half, back half and total of each dioxin/furan species. Each sample will need to be analyzed for the dioxin/furan species listed in Table 1. In addition, one duplicate analyses will be required. A duplicate analysis should be done for one of the front half samples from the MM5 trains. The individual samples are listed on the following pages.

Radian Run # MM5-03
(Total of 6 train components)

Front Half	RFA-34		(1) Front Half/Probe Rinse (PR)
	RFA-32		(2) Filter (F)
Back Half	RFA-33		(3) XAD Module (SM)
	RFA-35		(4) Back Half/Coil Rinse (CR)
	RFA-36		(5) Condensate (CD)
	RFA-37		(6) Impinger Solution (IM)

MM5 FIELD BLANK

Radian Run # FIELD BLANK
(Total of 6 train components)

	Radian #	Container	Fraction
Front Half	RFA-12		(1) Front Half/Probe Rinse (PR)
	RFA-10		(2) Filter (F)
Back Half	RFA-11		(3) XAD Module (SM)
	RFA-13		(4) Back Half/Coil Rinse (CR)
	RFA-14		(5) Condensate (CD)
	RFA-15		(6) Impinger Solution (IM)

TABLE 1. LIST OF CHLORINATED ORGANIC COMPOUNDS FOR ANALYSIS

1.	Total Trichlorinated dibenzo dioxins (TrCDD)
2.	2,3,7,8 Tetrachloro dibenzo-p-dioxin (2,3,7,8 TCC)
3.	Total Tetrachlorinated dibenzo dioxins (TCDD)
4.	1,2,3,7,8, Pentachloro dibenzo dioxin (1,2,3,7,8 PeCDD)
5.	Total Pentachlorinated dibenzo dioxins (PeCDD)
6.	1,2,3,4,7,8, Hexachloro dibenzo dioxin (1,2,3,4,7,8, HxCDD)
7.	1,2,3,6,7,8 Hexachloro dibenzo dioxin (1,2,3,6,7,8, HxCDD)
8.	1,2,3,7,8,9 Hexachloro dibenzo dioxin (1,2,3,7,8,9, HxCDD)
9.	Total Hexachlorinated dibenzo dioxins (HxCDD)
10.	Total Heptachlorinated dibenzo dioxins (HpCDD)
11.	Total Octachlorinated dibenzo dioxins (OCDD)
12.	Total Trichlorinated dibenzo furans (TrCDF)
13.	2,3,7,8 Tetrachloro dibenzo furans (2,3,7,8 TCDF)
14.	Total Tetrachlorinated dibenzo furans (TCDF)
15.	1,2,3,7,8 Pentachloro dibenzo furan (1,2,3,7,8, PeCDF)
16.	2,3,4,7,8 Pentachloro dibenzo furan (2,3,4,7,8, PeCDF)
17.	Total Pentachlorinated dibenzo furans (PeCDF)
18.	1,2,3,4,7,8 Hexachloro dibenzo furan (1,2,3,4,7,8, HxCDF)
19.	1,2,3,7,8,9 Hexachloro dibenzo furan (1,2,3,7,8,9, HcCDF)
20.	2,3,4,6,7,8 Hexachloro dibenzo furan (2,3,4,6,7,8 HxCDF)
21.	Total Hexachlorinated dibenzo furans (HxCDF)
22.	Total Heptachlorinated dibenzo furans (HpCDF)
23.	Total Octachlorinated dibenzo furans (OCDF)
24.	Monochlorinated dibenzo dioxin (MCDD)
25.	Total dichlorinated dibenzo dioxins (DCDD)
26.	Monochlorinated dibenzo furan (MCDF)
27.	Total dichlorinated dibenzo furan (DCDF)

APPENDIX J

Ultimate and Proximate Analysis of a Representative RDF Sample

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • (312) 953-9300

LAKES DIVISION MANAGER
D. L. MEIER

PLEASE ADDRESS ALL CORRESPONDENCE TO
1627 EAST 25th ST., CLEVELAND, OH 44114
OFFICE TEL. (216) 241-0971

Babcock & Wilcox
4282 Strausser St. NW
North Canton, OH 44720

January 24, 1985

Sample identification
by Babcock & Wilcox

IDENT: Test #4 0900 Hours 12/21/84
P.O. NO: 073991FL
RELEASE: 016

Kind of sample reported to us: RDF
Sample taken at: xxxxx
Sample taken by: Submitted
Date sampled: xxxxx
Date received: 12/27/84

Analysis report no. 81-7836

ULTIMATE ANALYSIS

	As Received	Dry
% Moisture	21.83	xxxxx
% Carbon	38.98	49.87
% Hydrogen	5.03	6.43
% Nitrogen	1.32	1.69
% Chlorine	1.40	1.79
% Sulfur	0.30	0.38
% Ash	9.72	12.44
% Oxygen (diff.)	21.42	27.40
	100.00 %	100.00 %

CC

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Joseph D. Brantovsky

Manager, Cleveland Laboratory

inal Copy Watermarked
or Your Protection

Charter Mem

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • (312) 953 9300

IVISION MANAGER
ER

PLEASE ADDRESS ALL CORRESPONDENCE TO
1627 EAST 25th ST., CLEVELAND, OH 44114
OFFICE TEL. (216) 241-0971

bcock & Wilcox
82 Strausser St. NW
rth Canton, OH 44720

January 24, 1985

Sample identification
by Babcock & Wilcox

ample
l to us RDF

ken at xxxxx

ken by Submitted

mpled xxxxx

ceived 12/27/84

IDENT: Test #4 1300 Hours
12/21/84
P.O. NO: 073991FL
RELEASE: 016

Analysis report no. 81-7838

ULTIMATE ANALYSIS

	As Received	Dry
% Moisture	19.93	xxxxx
% Carbon	37.85	47.27
% Hydrogen	5.09	6.36
% Nitrogen	0.35	0.44
% Chlorine	0.37	0.46
% Sulfur	0.24	0.30
% Ash	10.99	13.73
% Oxygen (diff.)	25.18	31.44
	100.00 %	100.00 %

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Joseph Moratosky
Manager, Cleveland Laboratory

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Charter Mem

Babcock & Wilcox

EFFICIENCY TEST

12/13/84

AVERAGE FUEL ANALYSIS* AS RECEIVED

HHV	6837 BTU/LB
H_2O	23.94%
C	37.32%
H	5.16%
N	0.34%
Cl	0.52%
S	0.29%
Ash	8.4%
O_2	24.03%

* Average of nine (9) hourly composite samples

EXHIBIT B

Ultimate analysis by weight (based on actual field test data)

Elements	% of Average	Elements	% of Range
Ash	12.00	Ash	9.0 - 18.00
S	.3	S	.25- .45
H	5.1	H	4.50- 5.5
C	37.0	C	37.00- 40.00
Cl	0.4	Cl	0.25- 1.25
H_2O	22.0	H_2O	18.00- 27.00
N_2	0.4	N_2	0.35- 0.50
O_2	22.8	O_2	21.00- 26.00

EXHIBIT D

RDF Composition:

Heating Value	5,000 - 7,500 BTU
Ash	20% Maximum
Moisture	10% - 35%
Ferrous	0.5% Average

Note: Please delete aluminum and other nonferrous metal.