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Project Summary

Municipal Waste Combustion Multipollutant Study, Emission Test Report, Maine Energy Recovery Company Refuse Derived Fuel Facility, Biddeford, Maine

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This report describes results of an emission test of a new municipal solid waste combustor that burns refuse-derived fuel and is equipped with a lime spray dryer/fabric filter (SD/FF) emission control system. The facility tested is operated by the Maine Energy Recovery Company and is located in Biddeford, Maine.

Control efficiency of the SD/FF emission control system was measured for polychlorinated dibenzodioxins (PCDD), polychlorinated dibenzofurans (PCDF), particulate matter (PM), cadmium (Cd), chromium (Cr), arsenic (As), lead (Pb), mercury (Hg), sulfur dioxide (SO_2), and hydrogen chloride (HCl). Additional continuous monitoring was conducted at various locations for oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and total hydrocarbons (THC). Process samples were also collected and analyzed for metals and selected physical properties.

Average emissions of total PCDD were 290 ng/dscm* (uncontrolled) and 1.3 ng/dscm (controlled). Total PCDF emissions were 590 ng/dscm (uncontrolled) and 2.9 ng/dscm (controlled). The control efficiency was about 99.5% for both dioxins and furans. All of the above results are corrected to 12% CO_2. The 17 specific PCDD/PCDF isomers, as well as the tetra through octa chlorinated total congeners, showed no significant change in distribution across the control device.

Uncontrolled particulate emissions averaged 7,400 mg/dscm, and controlled particulates averaged 33 mg/dscm (corrected to 12% CO_2) for an average particulate control efficiency of 99.5%.

Metals emissions (uncontrolled) varied from 500 μg/dscm for As and Hg to 30,000 μg/dscm for Pb. Controlled metals emissions varied from 6 μg/dscm for As and Cr to 160 μg/dscm for Pb. Metals control efficiencies varied from 98.2% for Hg to 99.8% for Cr. The process ash sample results were in general agreement with the con-centrations measured in the stack samples.

The continuous monitoring results and process data logging indicated that the combustion process was never under optimum operating conditions. There were frequent problems with feeder conveyors during all three test runs. CO concentrations averaged 70 ppm, with some short duration excursions above 200 ppm.

The automatic SD/FF control system was not operating during these tests; therefore, the lime slurry and dilution water feed rates were set at constant values for these tests. During the first test, the molar stoichiometric lime-to-1/2 HCl + SO_2 ratio was 1.7, which resulted in an SO_2 removal efficiency of 66% and an HCl removal efficiency of 98%. During the early stages of the second test, the lime feed rate was doubled to give a stoichiometric ratio of 3.4. During the third test the stoichiometric ratio was 3.9

(*) To convert to nonmetric units, use the conversion factors at the end of this Summary.

and removal efficiencies were improved to 90% for SO_2 and 99.4% for HCl.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

As part of the U.S. Environmental Protection Agency (EPA) efforts to develop and support new source performance standards (NSPS) for municipal waste combustors, (MWCs), EPA is sponsoring test projects at several new MWC facilities. These test projects include measurements to determine the emission levels and collection efficiency of criteria pollutants, acid gases, heavy metals, and semivolatile organic compounds.

Prior to EPA's decision to develop NSPS for MWCs, Midwest Research Institute under contract to EPA, compiled the available data base for the pollutants of interest (i.e., criteria pollutants, acid gases, metals, and semivolatile organic compounds). The emission data base was reviewed to determine the information gaps in achievable emission levels. Virtually no information was available on the control of the pollutants of interest from new MWC facilities that fired refuse-derived fuel (RDF). The Maine Energy Recovery Company (MERC) located in Biddeford, Maine, was identified as the first new RDF-firing MWC with dry scrubbing and a high efficiency particulate collector to come on-line in the U.S. in the 1980s. To take advantage of the first opportunity to fill this information gap, EPA entered into a cooperative agreement with KTI Holdings, Inc. (the owner/operator of MERC) to measure emissions for the pollutants of interest. This report summarizes the measurement procedures and the results of the MERC test project.

Facility Operations

The MERC plant (Figure 1) is an RDF-fired facility with an operational capacity of 454 Mg/d of municipal waste and wood chips. The test program data presented in this report are for RDF-fired conditions alone. The wood chips and, to a lesser extent, fuel oil and natural gas, are supplements to accommodate fluctuations in refuse volume and energy content of the boiler fuel. The two identical combustion systems consist of a Detroit Stoker RDF spreader stoker and a Babcock & Wilcox Controlled Combustion Zone boiler, each rated at 158,200 MJ/h .

Municipal waste is received in packer trucks and transfer trailers and is off-loaded onto the floor of the tipping floor building. Noncombustibles and potentially explosive or hazardous items are sorted and removed by visual inspection and bucket loader, magnetic separation, and screening. The "cleaned" refuse is shredded into a nominal 10-cm sized RDF.

Each boiler is a balanced-draft (employing both forced and induced draft fans) waterwall power boiler with a superheater, economizer, and air preheater. The stoker is a traveling grate located at the bottom of the furnace. Fuel from metered feeders is admitted above the grate at the front of the boiler. A single auxiliary burner (natural gas or No. 2 fuel oil) is on the right furnace sidewall, directly above the primary fuel combustion zone. It is used for start-up, shutdown, and during periods when load stabilization is required.

Combustion air for the solid fuels is introduced into the furnace as undergrate and overfire air. The boiler configuration and location of the overfire airports are designed to promote mixing and complete burnout of organic material injected into the furnace. Medium pressure superheated steam is delivered from the boilers to a steam turbine which powers an electric generator.

Combustion gases from each boiler pass through a cyclone, a lime spray dryer, and a fabric filter baghouse. The exhaust from both baghouses vents to the atmosphere through a common 74-m stack.

The acid gas scrubber is a reaction vessel where slurry of slaked lime is sprayed into the flue gas, which contains particulate matter, acid gases, and other pollutants in gaseous and aerosol form. The slurry water is evaporated by the flue gas heat, and the acid gases react with the slaked lime. Particulates, postreaction compounds, and excess sorbent likely serve as nucleation points for absorption and agglomeration of semivolatile organics and trace metals. A baghouse then collects the particulate from the gas stream. The excess sorbent in the bag filter cake provides a second stage reaction site for further acid gas removal.

The ash system removes residue from the stoker discharge, generating bank hopper, air heater hopper, mechanical dust collector (cyclone) hopper, spray absorber hopper, and baghouse module hoppers.

All of the hopper discharges are through rotary seal valves. This ensures a positive seal and prevents boiler gases from entering the ash conveyors and air from entering the hoppers and boilers.

Test Conditions

Three tests were run from December 9 through December 12, 1987. The facility burned 100% RDF at full load conditions during all three tests.

Intermittent process problems occurred during all three tests and were primarily related to RDF conveyor feeder malfunctions. During test runs 1 and 3 the problems were severe enough to end the test early. In both runs, the sampling teams had completed at least 65% of the test period, and the partial tests were judged to be acceptable by EPA personnel on site.

The automatic SD/FF control system was not operated during this test project. During run 1, the molar lime-to-1/2 HCl + SO_2 ratio was 1.7. During the early stages of run 2, the lime feed rate was doubled, resulting in a stoichiometric ratio of 3.4. During run 3, the lime feed rate resulted in an average stoichiometric ratio of 3.9.

The facility records process data on selected process measurements every 4 minutes. A summary of average operating values for key parameters recorded during each run is presented in Table 1.

Sampling and Analysis Summary

Sampling locations used during the test program are depicted in Figure 1. Free stream process conditions measured immediately upstream of the spray dryer are referred to as "uncontrolled" emissions. Free stream process conditions measured downstream of the fabric filter baghouse are referred to as "controlled" emissions. Conditions between the spray dryer and baghouse are called "midpoint" conditions. Table 2 shows the complete test matrix including all sampling locations and activities. The basic sampling program included:

1. Sampling for PCDD, PCDF, PM, Cd, Cr, As, Pb, Hg, O_2, and CO at the spray dryer inlet.
2. Continuous emission monitoring of O_2, CO, CO_2, SO_2, HCl, and THC at the spray dryer inlet.
3. Continuous monitoring of HCl, C and CO_2 at the baghouse inlet.
4. Sampling for PCDD, PCDF, PM, Cd, Cr, As, Pb, Hg, O_2, and CO at the baghouse outlet.
5. Continuous monitoring of HCl, CO_2, SO_2, NO_x, and O_2 at the baghouse outlet.

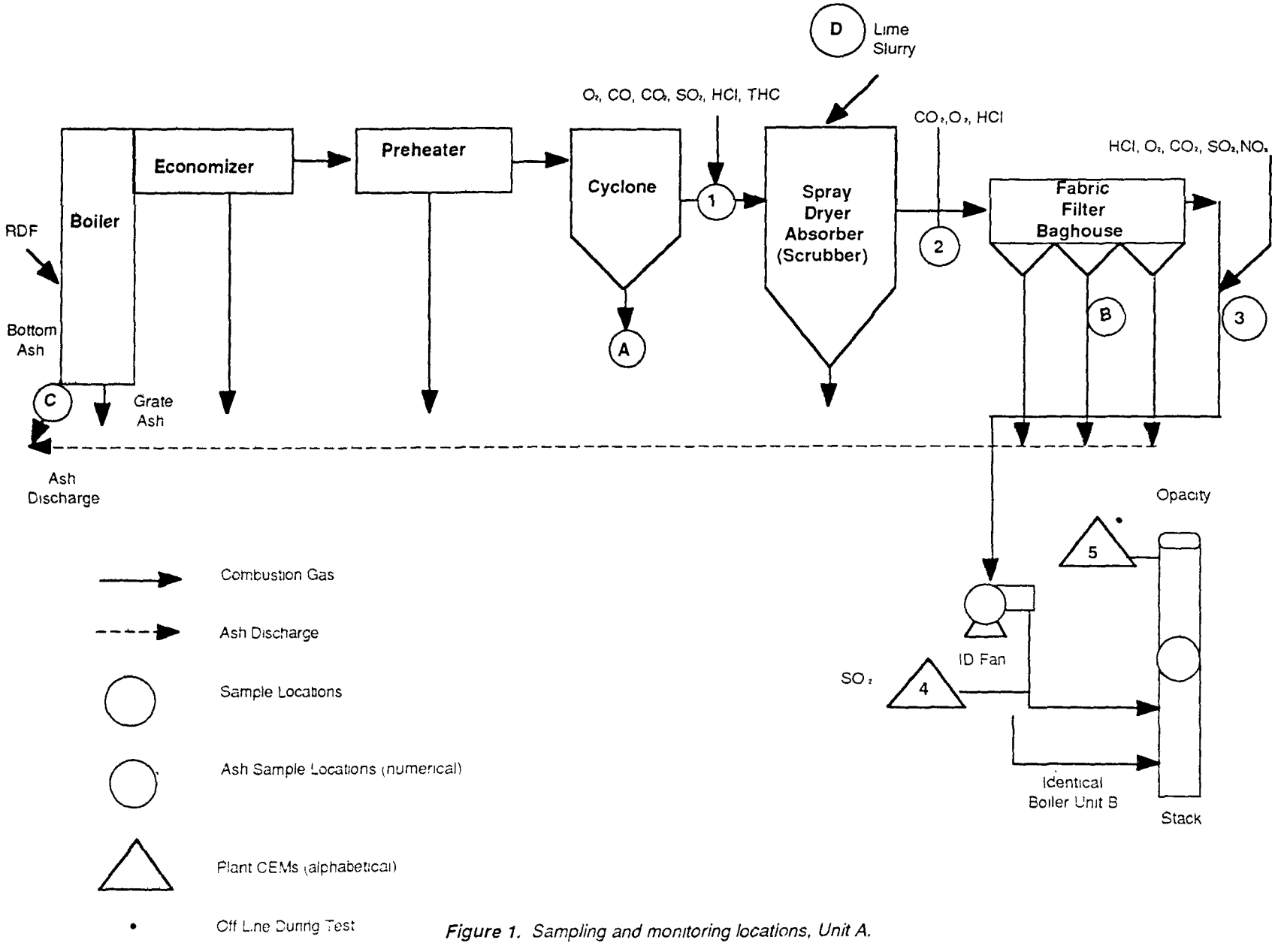

Figure 1. Sampling and monitoring locations, Unit A.

Table 1. Key Operating Parameters During the MERC Test Program in Biddeford, Maine

	Run 1 12-09-87	Run 2 12-10-87	Run 3 12-12-87	Average
Superheater steam				
Flow rate (1,000 lb/h)	106	109	108	108
Pressure (psig)	663	676	671	670
Outlet temperature (°F)	746	751	748	748
Combustion air				
Total airflow rate (1,000 lb/h)	124	123	134	127
Undergrate airflow rate (1,000lb/h)[a]	53	50	63	55
Overfire airflow rate(1,000 lb/h)	71	73	70	71
Overfire air distribution (%)[b]	57	59	52	56
Undergrate air pressure (in. H_2O)	-0.23	-0.86	-0.26	-0.45
Overfire air fan pressure (in. H_2O)	25.3	25.6	25.0	25.3
Air heater inlet air temperature (°F)	127	66	118	104
Air heater outlet air temperature (°F)	381	368	385	378
Excess oxygen (% by volume, wet)				
Left side	5.59	5.77	5.78	5.71
Right side	7.91	8.13	8.02	8.02
Heat release (10^6 Btu/h)				
Total (RDF + auxiliary fuel)	150	153	151	151
RDF only	150	153	150	151
Flue gas temperatures (°F)				
Economizer inlet	779	788	801	789
Economizer outlet/air heater inlet	515	523	532	523
Air heater outlet	374	363	383	373
Spray dryer inlet	374	364	384	374
Spray dryer outlet/fabric filter inlet	277	278	279	278
Fabric filter outlet	268	268	268	268
Gas differential pressures (in. H_2O)				
Undergrate to furnace	0.46	0.34	0.44	0.41
Dust collector (cyclone)	3.02	3.07	3.37	3.15
Spray dryer	4.24	4.84	5.17	4.75
Fabric filter	7.16	7.89	8.22	7.75
Flue gas pressures (in. H_2O)				
Spray dryer inlet	-7.20	-7.25	-7.39	-7.28
Spray dryer outlet	-11.5	-13.1	-13.4	-12.7
I. D. fan suction	-18.7	-21.0	-21.7	-20.5
Lime slurry feed rate (gpm)	2.91	6.70	7.80	5.80
Dilution water feed rate (gpm)	6.95	3.39	4.89	5.07
Total lime slurry and water feed rate (gpm)	9.86	10.1	12.7	10.9

[a] Undergrate airflow rate was calculated as the difference between the total airflow rate and overfire airflow rate.

[b] Overfire air distribution was calculated as the overfire airflow rate divided by the total airflow rate.

Table 2. Sampling and Analysis Parameters and Methods

Sampling location[a]	Sample type	Sampling frequency/duration for each run	Sampling method	Sample size	Analytical parameters	Preparation method[b]	Analytical method[b]
1-Spray dryer inlet	Combustion gas	Continuous 4 h	MM5-P/M[c]	≥ 120 ft³	Particulate	Desiccation	Gravimetric (EPA M5)
					Metals[d]	Acid digestion	ICAP/AAS[e]
			MM5-SVO[f]	≥ 140 ft³	PCDD/PCDF[g]	Solvent extraction	IRGC/MS[h]
			M3	~ 30 L	CO_2, O_2	N/A	Orsat
			CEMS (MRI)	N/A	CO_2, CO	Gas conditioning	NDIR analyzer
					O_2		Paramagnetic
					SO_2		Electrochemical
					THC		Heated FID (Beckman 402)
			CEMS (Entropy)[i]		HCl		IR gas filter correlation
2-Spray dryer outlet	Combustion gas	Continuous 4 h	CEMS (MRI)	N/A	CO_2	Gas conditioning	NDIR analyzer
					O_2		Polarographic analyzer
			CEMS (Entropy)[i]		HCl		Specific ion electrode
3-Fabric filter outlet	Combustion gas	Continuous 4 h	MM5-P/M[c]	≥ 120 ft³	Particulate	Desiccation	Gravimetric (EPA M5) ICAP/AAS[e]
					Metals[d]	Acid digestion	
			MM5-SVO[f]	≥ 140 ft³	PCDD/PCDF[g]	Solvent extraction	HRGC/MS[h]
			M3	~ 30 L	CO_2, O_2	N/A	Orsat
			CEMS (MRI)	N/A	CO_2	N/A	NDIR analyzer
					O_2		Polarographic analyzer
					NO_x		Chemilumine-scence
					SO_2		Electrochemical
			CEMS (Entropy)[i]		HCl		IR gas filter correlation
RDF		Run 1--one shovelful per grab. Three grabs total. Runs 2 and 3--19 L pail-fuls per grab from the ram feed. Three grabs per run.		Fiber drum		N/A	Archived

(Continued)

Table 2. (continued)

Sampling location[a]	Sample type	Sampling frequency/duration for each run	Sampling method	Sample size	Analytical parameters	Preparation method[b]	Analytical method[b]
A-Cyclone ash discharge	Fly ash	Two grab samples every 30 min. composited into two separate samples each run	Scoop (S007)	1 kg	Metals[d] % Combustibles % Carbon	Acid digestion N/A N/A	ICAP/AAS[e] ASTM E830 ASTM E777
B-Fabric filter (baghouse)	Fly ash/spray dryer residue	One grab sample every 60 min. composited and split into four jars for each run	Scoop (S007)	1 kg	Metals[d] % Combustibles % Carbon Resistivity K factor	Acid digestion N/A N/A N/A N/A	ICAP/AAS[e] ASTM E830 ASTM E777 IEEE 548-1984 N/A
C-Bottom ash discharge	Bottom ash	Two grab samples every 30 min. composited into two separate samples each run	Scoop (S007)	1 kg	Metals[d] % Combustibles % Carbon	Acid digestion N/A N/A	ICAP/AAS[e] ASTM E830 ASTM E777
D-Spray dryer inlet	Lime slurry	One grab sample every hour composited into one sample for entire test	Tap (S004)	100 mL per grab	Metals[d]	Acid digestion	ICAP/AAS[e]

[a] Numbers or letters refer to Figure 1.

[b] Sample preparation and analytical methods are described in detail in the Appendix of the Project Quality Assurance Work Plan referencing SW-846 methods and draft metals protocols.

[c] Modified Method 5 train for particulates and metals.

[d] Target metals are cadmium, total chromium, mercury, lead, and arsenic.

[e] Inductively coupled argon plasma atomic emission spectroscopy and graphite furnace atomic absorption spectrometry.

[f] Modified Method 5 train for semivolatile organics.

[g] PCDD/PCDF includes all tetra through octa dioxins and furans, all 2,3,7,8-substituted isomers, and to the extent possible, 1,2,3,4,8,-PeCDF and 1,2,3,4,7,9-HxCDF.

[h] High resolution gas chromatography/mass spectroscopy.

[i] Entropy Environmentalists Inc., is conducting the HCl monitoring under separate contract.

Results and Discussion

PCDD/PCDF Emissions

Table 3 summarizes the controlled and uncontrolled emissions of PCDD and PCDF. The PCDF fraction was about twice as large as the PCDD for both controlled and uncontrolled emissions. There was no significant variation among the three runs. The average total PCDD/PCDF combustor emission rate for the three runs was 877 ng/dscm (corrected to 12% CO_2), measured at the inlet to the spray dryer. The average total PCDD/PCDF emission rate downstream of the baghouse was 4.3 ng/dscm at 12% CO_2. This represents an average emission control rate of 99.5%.

The uncontrolled samples had separate analyses for the front and back halves of the sampling train. The back half fractions showed concentrations near detection limits indicating that the PCDD/PCDF emissions are associated with the particulate matter at the control device inlet.

All 17 dioxin and furan isomers for which analyses were conducted were well above detection limits in the uncontrolled samples. For the controlled samples, all 17 isomers were detected in the completed test run, and most were also detected in the partial runs. Distributions of these isomers did not change significantly across the control devices.

The EPA 2,3,7,8-PCDD toxic equivalencies were calculated for both uncontrolled and controlled emissions. Due to lower equivalent toxicity for furans, the total toxicity is similar for the dioxin and furan emissions. 2,3,7,8-TCDD itself accounts for about 10% (uncontrolled) to 20% (controlled) of total toxicity.

Particulate Emissions

Particulate mass loading was determined by gravimetric analysis of the filter, cyclone, and front half acetone rinses of the metals train. After reaching constant weight, these fractions were digested for metals analysis. Particulate results were blank corrected as specified in EPA Method 5 Uncontrolled emissions averaged 7,400 mg/dscm, and controlled emissions averaged 33 mg/dscm, for an average control efficiency of 99.5 % for the three runs.

Metals Emissions

Table 4 summarizes the emission data for selected hazardous metals (As, Cd, Cr, Pb, and Hg). Pb emissions dominate, with an average of 27 mg/dscm (uncontrolled) and 0.15 mg/dscm (controlled). The control efficiency varies from 98 % for Cd to 99.8 percent for Cr, which is in general agreement with the relative volatilities of the metals.

The ratio of the selected metals to total particulate mass shows little change across the control devices. The ratio for Cr decreased by about a factor of 2. The other ratios increased by between 1.5 (Pb) and 3 (As and Hg).

Process Sample Characteristics

Table 5 shows the characteristics of the process samples collected. The selected metals are absent in the lime slurry except for about 4 µg/g of As. Cd was not detected in the bottom ash, and the other metals were present at levels of a few hundred micrograms per gram. Lead accounted for about half of the total. At the cyclone ash hopper (immediately upstream of the uncontrolled emissions test location) and in the baghouse ash hopper, Pb dominated the data, as it had in the uncontrolled emissions measurements. As, Cd, and Pb are more concentrated in both cyclone and baghouse ash than in the uncontrolled emissions samples. Uncontrolled Cr emissions fall between the concentrations found in the same two ash samples.

ACID Gases

Table 6 summarizes the results of the CEM measurements for SO_2, HCl, and NO_x. The acid gas results are difficult to assess because the process was on manual control instead of the design automatic system. The changed lime feedrate during run 2 is reflected in increased SO_2 and HCl control efficiencies during runs 2 and 3.

Calculated molar ratios of actual lime to stoichiometric lime for1/2 HCl +SO_2 increased from 1.7 for run 1 to 3.9 for run 3. Since the peak concentrations of HCl and SO_2 are about twice the averages, the lime feedrate for run 1 was too low to neutralize the acid gases during periods of peak furnace emissions.

Other Gases

Table 7 summarizes the results of CEM measurements for O_2, CO_2, CO, and THC. The O_2 and CO_2 results indicate that no significant leakage, dilution, or reaction of CO_2 occurred across the control devices. The CO_2 analyzer at the spray dryer outlet shows fewer excursions than the other analyzers because of slower response time for this instrument.

Average CO emissions for runs 1, 2, and 3 were 62.8, 68.5, and 89.9 ppm, respectively. The THC monitor was only operational during run 3. THC emissions at the spray dryer inlet averaged 1.1 ppm during this test. CO emissions, which are used as an indicator of combustion conditions, exhibited short transients which occasionally exceeded 200 ppm. One transient exceeded 700 ppm. The facility was experiencing problems with the conveyor which supplies RDF to the combustor, and these transient CO conditions are most likely due to sudden changes in the amount or properties of RDF being fed to the boiler.

Quality Assurance

Several QA checks were performed as part of the sampling and analysis program as specified in the project QA plan. These results are discussed below. An internal data audit revealed no significant problems. External systems audit of field and laboratory operations were conducted by Research Triangle Institute and EPA. Both QA reports gave acceptable ratings for the project.

PCDD/PCDF Analyses

The primary QA/QC checks used for monitoring the PCDD/PCDF analyses were method internal standard surrogate recoveries, relative response factors, sampling train blanks, duplicate analyses, and audit samples.

Recovery of the ^{13}C-PCDD/PCDF surrogates was consistently around the lower limit of 50 %. No reason for the low results was found. The impact of the low recoveries should be minimal because the spiked performance audit samples showed good recovery efficiency.

The relative response factors for 38 isomers and homologs were monitored daily with never more than 1 of the 38 factors in any of the calibration samples exceeding the ±20 % criterion.

The blank samples analyzed included one initial proof rinse, a field blank train, and a posttest blank from the control device outlet. Varying levels near the detection limits were found for Tetra and Octa - CDD. No blank correction was used because the blank levels detected were all less than 10% of any stack sample.

The sample from run 1 outlet was analyzed by duplicate injection. All compounds detected above 0.08 ng total showed a relative difference of less than 12%.

Four spiked unknown samples were prepared and analyzed with the field samples. The homolog totals showed recoveries between 70 and 104% with surrogate recoveries similar to those found in the field samples.

Table 3. Selected Process Conditions and PCDD/PCDF Emissions for MERC

	Run 1 (12-09-87)			Run 2 (12-10-87)			Run 3 (12-12-87)			Average		
	Uncontrolled	Controlled	Control efficiency (%)	Uncontrolled	Controlled	Control efficiency (%)	Uncontrolled	Controlled	Control efficiency (%)	Uncontrolled	Controlled	Control efficiency (%)
Flue Gas Characteristics												
Flow rate (dscfm)	38,300	39,200	-	40,500	41,100	-	41,000	42,500	-	39,900	40,900	-
Temperature (°F)	371	270	-	362	269	-	381	272	-	371	270	-
Moisture (% by volume)	14.3	15.3	-	14.4	13.5	-	16.0	17.0	-	14.9	15.3	-
CO_2 (% by volume)	10.9	10.9	-	11.0	10.9	-	11.3	11.3	-	11.1	11.0	-
O_2 (% by volume)	8.6	8.6	-	8.5	8.6	-	8.2	8.2	-	8.4	8.5	-
Process Operations												
Steam load (10^3 lb/h)	106	106	-	109	109	-	108	108	-	108	108	-
PCDD Results												
Total PCDD (ng/dscm)	217	1.25	99.42	259	1.45	99.44	323	0.972	99.70	266	1.22	99.54
Total PCDD (corrected to 12% CO_2, ng/dscm)	239	1.38	99.42	282	1.59	99.44	342	1.03	99.70	288	1.33	99.54
PCDF Results												
Total PCDF (ng/dscm)	540	2.67	99.50	514	3.14	99.38	580	2.23	99.62	545	2.68	99.51
Total PCDF (corrected to 12% CO_2, ng/dscm)	594	2.94	99.50	560	3.45	99.38	615	2.36	99.62	590	2.92	99.50

(continued)

Table 3. (continued)

	Run 1 (12-09-87)			Run 2 (12-10-87)			Run 3 (12-12-87)			Average		
	Uncontrolled	Controlled	Control efficiency (%)	Uncontrolled	Controlled	Control efficiency (%)	Uncontrolled	Controlled	Control efficiency (%)	Uncontrolled	Controlled	Control efficiency (%)
PCDD/PCDF Results												
Total PCDD/PCDF (ng/dscm)	757	3.93	99.48	772	4.58	99.40	903	3.20	99.64	811	3.90	99.52
Total PCDD/PCDF (corrected to 12% CO_2, ng/dscm)	833	4.32	99.48	842	5.04	99.40	957	3.39	99.64	877	4.25	99.51
2,3,7,8-TCDD toxic equivalent (ng/dscm at 12% CO_2)[a]	11.4	0.066	99.42	12.9	0.087	99.33	13.6	0.058	99.57	12.6	0.071	99.44
Emission Rates (ug/h)												
Total PCDD	14,000	83.3	-	17,800	101	-	22,500	70.2	-	18,100	84.8	-
Total PCDF	35,200	178	-	35,400	219	-	40,400	161	-	37,000	186	-
Total PCDD/PCDF	49,200	261	-	53,200	320	-	62,900	231	-	55,100	271	-

[a] USEPA. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of PCDDs/PCDFs. EPA-625/3-87/012.

Table 4. Particulate Matter and Specific Metals Mass Emission Rates(Normalized to 12% CO_2)

Metal	Run 1 µg/dscm	Run 1 g/h	Run 2 µg/dscm	Run 2 g/h	Run 3 µg/dscm	Run 3 g/h	Average µg/dscm	Average g/h
				Uncontrolled				
Particulate matter	7,410[c]	474[d]	6,540[c]	428[d]	8,099[c]	550[d]	7,350[c]	484[d]
Arsenic	462	33	513	36	511	37	495	35
Cadmium	990	70	1,030	73	1,230	89	1,080	77
Chromium	2,300	162	2,600	185	3,110	225	2,670	191
Lead	25,700	1,810	26,700	1,900	27,400	1,980	26,600	1,900
Mercury	481	34	315	22	341	24	379	27
				Controlled				
Particulate matter	21.9[c]	1.34[d]	32.6[c]	2.10[d]	44.5[c]	3.15[d]	33.0	2.20
Arsenic	7.53[b]	0.509[b]	6.79[b]	0.483[b]	4.78[b]	0.361[b]	6.37	0.451
Cadmium	11.7[b]	0.791[b]	10.2[b]	0.726[b]	14.8[b]	1.12[b]	12.2	0.879
Chromium	5.75[b]	0.389[b]	5.73[b]	0.408[b]	6.47[b]	0.488[b]	5.98	0.428
Lead	142	9.60	151	10.7	172	13.0	155	11.1
Mercury	< 2.03[a]	< 0.137[a]	6.00[b]	0.427[b]	7.77[b]	0.586[b]	6.89	0.506

	Removal Efficiency			
	Run 1	Run2	Run 3	Average
Particulate matter	99.71	99.50	99.45	99.55
Arsenic	98.5	98.7	99.1	98.7
Cadmium	98.8	99.0	98.8	98.9
Chromium	99.7	99.8	99.8	99.8
Lead	99.4	99.4	99.4	99.4
Mercury	< 99.6[a]	98.1	97.7	98.2

[a] Some fractions below detection limit. Reported value is maximum possible.

[b] All fractions below detection limit. Not included in averages.

[c] Milligrams per dry standard cubic meters.

[d] Kilograms per hour.

Table 5. Process Characteristics

	Run 1	Run 2	Run 3	Average
Cyclone as				
As,µg/g	32.2	32.7	38.9	34.6
Cd,µg/g	30.7	35.2	38.1	34.7
Cr, µg/g	383	438	424	415
Pb,µg/g	2,100	2,090	2,070	2,087
Hg,µg/g	15.3	5.00	13.4	11.2
Carbon, %	1.06	0.89	1.60	1.18
Ash, %	98.3	98.3	95.8	97.5
Baghouse ash				
As,µg/g	47.6	47.2	53.6	49.5
Cd, µg/g	129	80.1	77.4	95.5
Cr, µg/g	152	159	167	159
Pb, µg/g	2,770	1,290	2,130	2,063
Hg, µg/g	80.2	34.0	29.4	47.9
Carbon, %	5.48	2.62	3.67	3.93
Ash, %	89.1	96.0	90.2	91.8
Bottom ash				
As,µg/g	7.24	14.0	[b]	10.6
Cd, µg/g	< 1.50[a]	2.73	[b]	2.73
Cr, µg/g	169	312	[b]	241
Pb, µg/g	417	585	[b]	501
Hg, µg/g	0.0640	1.22	[b]	0.64
Carbon, %	1.30	1.11		1.20
Ash, %	75.2	75.5		75.3
Lime slurry				
As, µg/g	4.25	2.20	4.19	3.55
Cd, µg/g	< 0.226[a]	< 0.231[a]	< 0.199[a]	< 0.219
Cr,µg/g	< 0.943[a]	< 0.960[a]	< 0.830[a]	< 0.911
Pb, µg/g	< 5.78[a]	< 5.88[a]	< 5.09[a]	< 5.58
Hg, µg/g	< 0.224[a]	< 0.216[a]	0.419	< 0.286
CaO, %	11.8	9.58	12.3	11.2
Solids, %	20.6	18.3	22.1	20.4
Specific gravity	1.13	1.12	1.14	1.13

[a] Some fractions below detection limit. Reported value is maximum.

[b] Bottom ash was not collected during run 3.

Table 6. CEM Data Summary --Acid Gases

		Average (ppm)	RSD [a] %
Run 1			
SO_2	Dryer inlet	83.2	16.1
	Baghouse outlet	28.4	43.3
	Removal efficiency	66.0	-
HCl	Dryer inlet	478	NA[d]
	Dryer outlet	63	NA
	Baghouse outlet	9	NA
	Removal efficiency	98.2	-
NO_x	Baghouse outlet	203	8.72
Run 2[b]			
SO_2	Dryer inlet	76.9	11.3
	Baghouse outlet	21.2	45.6
	Removal efficiency	72.3	-
HCl	Dryer inlet	566	NA
	Dryer outlet	8	NA
	Baghouse outlet	4	NA
	Removal efficiency	99.3	-
NO_x	Baghouse outlet	206	8.25
Run 3			
SO_2	Dryer inlet	115	20.3
	Baghouse outlet	12.0	18.6
	Removal efficiency	89.6	-
HCl	Dryer inlet	540	NA
	Dryer outlet [c]	1	NA
	Baghouse outlet	3	NA
	Removal efficiency	99.4	-
NO_x	Baghouse outlet	210	8.76
Average of 3 runs			
SO_2	Dryer inlet	91.8	-
	Baghouse outlet	20.5	-
	Removal efficiency	76.0	-
HCl	Dryer inlet	528	-
	Dryer outlet	24	-
	Baghouse outlet	5	-
	Removal efficiency	99	-
NO_x	Baghouse outlet	206	-

[a] RSD (relative standard deviation) = (100 x standard deviation)÷ mean.
[b] Spray dryer lime slurry flow rate was increased by 100% at about 13:45 during run 2.
[c] HCl results at the dryer outlet are questionable for run 3.
[d] NA = Data is not available for HCl, which is contained in a separate report.

TABLE 7. CEM Data Summary --Other Gases

		Average	RSD [a] (%)
Run 1[b]			
O_2, %	Dryer inlet	7.9	14.8
	Dryer outlet	7.4	14.9
	Baghouse outlet	8.0	14.3
CO_2, %	Dryer inlet	11.6	8.45
	Dryer outlet	11.5	6.78
	Baghouse outlet	11.6	8.71
CO, ppm	Dryer inlet	62.8	36.1
Run 2[b]			
O_2, %	Dryer inlet	8.5	10.6
	Dryer outlet	7.9	13.7
	Baghouse outlet	8.4	12.4
CO_2, %	Dryer inlet	11.2	7.29
	Dryer outlet	11.7	2.82
	Baghouse outlet	11.1	8.47
CO, ppm	Dryer inlet	68.5	17.3
Run 3[b]			
O_2, %	Dryer inlet	8.4	13.3
	Dryer outlet	7.8	15.5
	Baghouse outlet	8.6	15.4
CO_2, %	Dryer inlet	11.2	12.0
	Dryer outlet	11.7	3.42
	Baghouse outlet	11.3	10.8
CO, ppm	Dryer inlet	89.9	55.9
THC[a], ppm	Dryer inlet	1.14	86.0

[a] RSD (relative standard deviation) = (100 x standard deviation)÷mean.

[b] The total hydrocarbon analyzer was not functioning properly for runs 1 and 2 and had span drift during run 3.

MM5 Sampling Equipment

The sampling trains for both PCDD/PCDF and particulates/metals met all requirements for nozzle dimensions, meter factor, temperature, barometer, and pitot tube calibration. All samples were collected at 90 to 110 % isokinetic. One train, run 3 outlet PCDD/PCDF, failed its leak check for the final 30 min because of accidental jarring of the probe, but was accepted as usable after the moisture data were reviewed. The moisture data and overall data were consistent with the other two runs.

Metals Analyses

The results of the nine duplicate sample analyses showed acceptable agreement. Instrument calibration drift met the QA plan objectives. Only Hg was found consistently in the blank samples. It was found in the front half rinse at an average of about 8 µg, which was the only blank correction used for metals. One of the four EPA metals audit samples showed Cr at 135% of the true value. Analysis of a second EPA sample at twice the concentration showed close agreement with its true value. Further analyses of these EPA samples showed little change in relative accuracy values.

Continuous Emission Monitoring

The three sets of analyzers used passed all leak checks. Comparisons of the working standard cylinders against EPA Protocol 1 cylinders showed no significant errors. Only the SO_2 monitor located at the spray dryer inlet failed to meet the analyzer drift criteria of 10%. The drift was probably caused by poisoning of the sensor and changed suddenly instead of being a gradual drift. Only the test data before the first sudden change each day are reported, and only the initial calibration data for each day areused to calculate results.

Conclusions and Recommendations

Based on the results obtained during this project, the following conclusions are drawn:

- Removal efficiency across the spray dryer/fabric filter was about 99.5% for dioxins, furans, and particulates.
- The PCDF levels were about twice as large at the PCDD levels for both controlled and uncontrolled emission values.
- No significant change occurred across the control devices for the molar distributions of the tetra- through octa-CDF and CDD.
- Metals (As, Cd, Cr, Pb, and Hg) removal efficiencies varied from 98.2% for Hg to 99.8% for Cr.
- Concentrations of the five selected metals measured in the ash samples were in general agreement with those found in the stack samples.
- Removal efficiency for SO_2 varied from 66% in run 1 to 90% in run 3, in direct relation to the amount of slaked lime fed to the spray dry adsorber.
- Control efficiency for HCl varied from 98% in run 1 to 99% in run 3.
- No air dilution or absorption of CO_2 occurred across the control devices.

The following recommendations are suggested for further study of this type of facility:

- Data should be obtained for the performance of the automatic lime control system.
- The effect of combustion conditions on the emission of PCDD/PCDF, CO, NO_x, and other pollutants should be investigated.

Conversion Factors

Metric units are used in this Summary. Readers more familiar with nonmetric units may use the following conversion factors:

Multiply Nonmetric	By	To obtain Metric
Btu/h	1.05488	MJ/h
°F	5/9 (°F-32)	°C
ft	0.3048	m
ft^3/min	28316.8	cm^3/min
gal.	3.785	liter
gr/dscf	2288	mg/dscm
in.	2.54	cm
in. H_2O	0.0394	mm H_2O
lb/h	0.4536	kg/h
tons/day	0.907	mg/day

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The complete report, entitled "Municipal Waste Combustion Multipollutant Study, Emission Test Report, Maine Energy Recovery Company Refuse Derived Fuel Facility, Biddeford , Maine" (Set Order No. PB90-228 826/AS; Cost: $116.00 cost subject to change)
"Volume I. Summary of Results,"(Order No. PB 90-228 834; Cost: $23.00, subject to change).
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"Volume III. Appendices G- N," (Order No. PB 90-228 859; Cost: $60.00, subject to change).
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