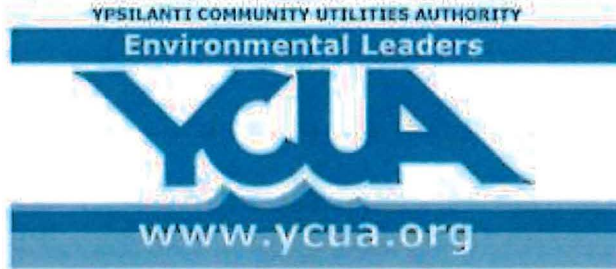




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**Fluidized Bed Sewage
Sludge Incinerator
(FBSSI)
Ypsilanti, Michigan**

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**AIR EMISSIONS
TEST PROTOCOL**

40 CFR PART 60, SUBPART M MMM

GamAir Project No.: 825-2209
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1.0 INTRODUCTION

1.1 Summary of Test Program

Gammie Air Monitoring, LLC (GamAir) was retained by Ypsilanti Community Utilities Authority (YCUA) to perform an air emissions compliance test program on one fluidized bed sewage sludge incinerator (FBSSI). Michigan Department of Environment, Great Lakes, & Energy (EGLE) has identified this source as State Registration No.: B6237 & Permit No.: MI-ROP-B6237-2020.

The purpose of this emission measurement test program is to quantify the controlled emissions of oxides of nitrogen (NO_x), carbon monoxide (CO), filterable particulate matter (FPM), hydrogen chloride (HCl), dioxins/furans (D/F), total polychlorinated biphenyls (PCB), mercury (Hg), cadmium (Cd), lead (Pb), and mercury (Hg). The applicable United States Environmental Protection Agency (EPA)/ EGLE emission limits are presented below in Table 1-1:

Table 1-1		
PARAMETER	MASS LIMIT	CONCENTRATION LIMIT
NO _x	-	150 ^a
CO	-	64 ^a
FPM	18 ^b 0.35 ^c	-
HCl	0.8 ^c	0.51 ^a
D/F	1.2 ^d 0.1 ^e	- -
PCB	1.2E-06 ^e	-
Cd	0.0016 ^b 8.5E-03 ^c	85 ^f
Pb	0.0074 ^b	-
Hg	0.037 ^b 6.9E-04 ^c 3200 ^g	3.7 ^f

^a - ppmvd @ 7% O₂

^b - mg/dscm @ 7% O₂

^c - lb/ton of sludge

^g - g/24-hr

^d - ng/dscm @ 7% O₂ total mass basis

^e - ng/dscm @ 7% O₂ toxic equivalency basis

^f - PTI Limit mg/kg dry sludge

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Compliance emission tests were performed on the parameters listed above. The tests were conducted in accordance with the conditions and monitoring requirements for compliance testing as set forth with the EGLE guidelines for source emission testing. Compliance tests were conducted in accordance with USEPA Methods 1-5, 7E, 10, 23, 26A and 29 as published in Title 40, Code of Federal Regulations, Part 60 (40CFR60). Representatives from YCUA and GamAir were responsible for coordinating the testing with EGLE. YCUA personnel was responsible for collecting all process data, biosolids samples and the analysis of the biosolids. Gammie Air Monitoring, LLC (GamAir) is responsible for collecting all air emission samples and the respective analysis of those samples.

Section 2.0 of this report presents a description of each source and the sampling locations. Section 3.0 summarizes the test results. Sampling and analysis methodologies utilized are presented in Section 4.0. Quality assurance procedures specific to this test program are described in Section 5.0.

1.2 Test Program Organization

Table 1-2 lists the individuals responsible for the organization of this test program.

Table 1-2		
NAME	AFFILIATION	CONTACT INFORMATION
Sree Mullapudi	YCUA	(734) 484-4600 smullapudi@ycua.org
Jeremy Brown	EGLE	(586) 753-3745 brownj9@michigan.gov
Judd F. Gammie	GamAir	(860) 757-3340 judd@gamair.com
Clayton Johnson	BV Labs	(905) 817-5700 ext. 7065769 clayton.johnson@bureauveritas.com

2.0 SOURCE DESCRIPTION

2.1 Process and Air Pollution Control Description

YCUA operates a fluidized bed biosolids incinerator (FBI) which is rated at 6,300 pounds per hour (3.15 tons per hour) of biosolids. During emissions testing the FBI operated at least 85% of the maximum capacity rating (MCR) which equates $\geq 5,355$ pounds per hour.

Air emissions from the FBI are controlled by a venturi/impingement tray scrubber operating at an overall scrubber pressure drop range of 30"-40" inches of water column (in. w.c.). Total water injection to the venturi scrubber is approximately 325 gallons per minute (gpm); the water injection rate to the impingement tray is 577.4 gpm. Following the scrubber is a wet electrostatic precipitator (WESP) followed by a granular activated carbon (GAC) filter.

2.3 Process Monitoring

During the test program the incinerator operated at an optimized feed rate. The process parameters to be monitored during each test consisted of the following:

- Hourly sludge tonnage input
- Sludge moisture content (%)
- Bed combustion temperatures
- Incinerator oxygen content (% wet)
- Scrubber water flowrates
- Scrubber system pressure drop
- Granular Activated Carbon Pressure Drop
- Temperature Differential between GAC inlet and WESP outlet
- WESP secondary voltage
- WESP secondary amperage

Table 2-1 summarizes the operational process parameters monitored during testing. Copies of YCUA's process monitoring can be found in Appendix D.

Table 2-1
Summary of Process Data
Compliance Test Program
Ypsilanti Community Utilities Authority
Fluidized Bed Incinerator
13 December 2022
Ypsilanti, Michigan

Method/Component	Units	Run 1 09:15-10:41	Run 2 11:05-12:31	Run 3 13:03-14:27	Run 4 15:00-16:24	Run 5 16:36-18:00	Average
Biosolids Feed Rate	dry pounds/hour	4679	5380	4936	5605	5462	5469
Percent Blended Solids	%	1.66	1.72	1.60	1.81	1.76	1.71
Fluidized Bed Temperature	°F	1336	1340	1338	1339	1341	1339
Free Board Temperature	°F	1709	1705	1718	1696	1705	1707
Venturi Water Flow	gallon/minute	340	340	341	342	344	341
Venturi Pressure Drop	inches w.c.	32.2	32.6	32.5	32.1	32.7	32.4
Tray Scrubber Water Flow	gallon/minute	549	549	547	548	546	548
Tray Scrubber Pressure Drop	inches w.c.	11.5	11.5	11.6	11.4	11.5	11.5
GAC Pressure Drop	inches w.c.	5.4	5.5	5.5	5.4	5.3	5.4
WESP Secondary Voltage	kV	37.8	41.5	38.5	41.0	37.3	39.2
WESP Amperage	mA	25.4	17.8	14.8	22.5	22.0	20.5
Temperature Diff. GAC inlet WESP outlet	°F	37.0	35.3	34.0	33.3	37.0	35.3
YCUA - Carbon Monoxide @ 7% Oxygen	ppmvd	4.4	4.5	10.0	8.1	3.7	6.1
YCUA - Sulfur Dioxide	ppmvd	4.6	8.4	9.1	6.6	8.7	7.5
Oxygen	%	4.95	5.94	4.98	4.89	6.00	5.35

2.4 Outlet Flue Gas Sampling Locations

Outlet flue gas sampling for the FBSSI occurred in a vertical section of the 41.5-inch inside diameter steel stack downstream of the pollution control devices. Two test ports were located 90 degrees apart in a straight section of exhaust stack. The sample ports were located 173-inches (4.17 duct diameters) downstream and 293-inches (7.06 duct diameters) upstream from the nearest flow disturbances. In accordance with EPA Method 1, twelve traverse points (6 per port) were used for volumetric flow sampling. Both test ports were used for the velocity traverses, FPM, HCl, PCB, D/F, and multiple metals isokinetic sampling. Each port was sampled at 6 points for a total of 12 sampling points. A cyclonic flow check was performed prior to the start of compliance testing. All measurements were field verified for accuracy. An EPA Method 1 data sheet identifying the individual traverse locations can be found in the Appendix. Table 4-1 presents the individual traverse points.

Traverse Point	Percent of Stack Diameter	Distance from Stack Wall (inches)
1	0.044	1.9
2	0.146	6.0
3	0.296	12.2
4	0.704	29.2
5	0.854	35.5
6	0.956	43.6

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4.1 Continuous Emissions Monitoring Sampling Location

Continuous emissions monitoring (CEM) sampling occurs in a separate port near the isokinetic sampling ports. CEM sampling took place through a single port. Prior to the start of the CEM sampling a three-point stratification check was performed. The individual traverse point locations are shown below, and ductwork schematic are in the Appendix.

Traverse Point	Percent of Stack Diameter	Distance from Stack Wall (inches)
1	0.167	6.93
2	0.500	20.75
3	0.833	34.57

3.0 SUMMARY AND DISCUSSION OF RESULTS

3.1 Objectives

The purpose of this test program was to measure air emissions from the FBSSI exhaust. Three emissions test runs were conducted for each parameter, with the average result of the three test runs reported. Table 3-1 lists the parameters that were measured along with their respective USEPA test method and sample time for each run for the FBSSI. Emissions testing was conducted in accordance with EPA approved test procedures to be used at the stack sampling location. The specific objectives for the FBSSI compliance testing were:

- Measure volumetric flowrates from the exhaust stack in accordance with EPA Methods 1 & 2.
- Measure O₂/CO₂ emissions from the FBSSI exhaust stack in accordance with EPA Method 3A.
- Measure the moisture from the FSSBI exhaust stack in accordance with EPA Method 4.
- Measure FPM emissions from the FBSSI exhaust stack in accordance with EPA Method 5.
- Measure NO_x emissions from the FBSSI exhaust stack in accordance with EPA Method 7E.
- Measure CO emissions from the FBSSI exhaust stack in accordance with EPA Method 10.
- Measure total PCBs and D/F emissions from the FBSSI exhaust stack in accordance with EPA Method 23.
- Measure HCl emissions from the FBSSI exhaust stack in accordance with EPA Method 26A.
- Measure multiple metals from the exhaust stack in accordance with EPA Method 29.

3.2 Test Matrix

Table 3-1 presents the sampling and analytical matrix used at the outlet stack for the FBSSI's sampling location.

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**Table 3-1
Test Matrix
Air Emissions Compliance Test Program
YCUA
Fluidized Bed Sewage Sludge Incinerator
Ypsilanti, Michigan**

Parameter	EPA Test Methods	Sample Times	Analytical Laboratory	Number of Runs
Volumetric Flowrates	Methods 1-2	84 min.	GamAir	9
O ₂ /CO ₂	Method 3A	84 min.	GamAir	3
NO _x	Method 7E	84 min.	GamAir	3
CO	Method 10	84 min.	GamAir	3
FPM	Method 5	84 min.	BV Labs	3
HCl	Method 26A	84 min.	BV Labs	3
PCB & D/F	Method 23	84 min.	BV Labs	3
Multiple Metals ¹	Method 29	84 min.	BV Labs	3

¹ – cadmium (Cd), lead (Pb), & mercury (Hg)

3.3 Summary of Results

Table 3-2 details the results from emission testing.

Table 3-2
Summary of Gaseous Emissions Data
EPA Subpart M Test Program
YCUA
Fluidized Bed Sewage Sludge Incinerator
Ypsilanti, Michigan
13 December 2022

PARAMETER	UNITS	3 RUN AVERAGE	EPA/ EGLE LIMIT	PERCENT OF LIMIT	PASS/FAIL
NO _x	ppmvd @ 7% O ₂	36.34	150	24.2%	Pass
CO	ppmvd @ 7% O ₂	8.96	64	14.0%	Pass
FPM	ppmvd @ 7% O ₂	8.91E-01	18	5.0%	Pass
	lb/dry ton of sludge	0.020	0.35	5.6%	Pass
HCl	ppmvd @ 7% O ₂	2.50E-01	0.51	49.1%	Pass
	lb/dry ton of sludge	8.47E-03	0.8	1.1%	Pass
D/F	ng/dscm @ 7% O ₂ ¹	1.43E-01	1.2	11.9%	Pass
	ng/dscm @ 7% O ₂ ²	4.28E-03	0.1	4.3%	Pass
PCB	lb/dry ton of sludge	6.80E-08	1.20E-06	5.7%	Pass
Cd	mg/dscm @ 7% O ₂	2.78E-04	0.0016	17.4%	Pass
	lb/dry ton of sludge	1.55E-05	8.50E-03	0.2%	Pass
	mg/kg dry sludge	4.1	85	4.8%	Pass
Pb	mg/dscm @ 7% O ₂	5.25E-04	0.0074	7.1%	Pass
Hg	mg/dscm @ 7% O ₂	8.51E-03	0.037	23.0%	Pass
	lb/dry ton of sludge	1.90E-04	6.90E-04	27.6%	Pass
	gram/ 24-hr	5.26	3200	0.2%	Pass
	mg/kg dry sludge	0.28	3.7	7.6%	Pass

ppmvd @ 7% O₂ – parts per million volume dry corrected to 7% O₂

lb/dry ton of sludge – pounds per dry ton of sludge

ng/dscm @ 7% O₂¹ - ng/dscm @ 7% O₂ total mass basis

ng/dscm @ 7% O₂² - ng/dscm @ 7% O₂ toxic equivalency basis

mg/kg dry sludge – milligram per kilogram of dry sludge

4.0 SAMPLING AND ANALYTICAL METHODOLOGY

The following EPA test methods will be utilized during this emissions test program:

EPA Method 1	Sample and velocity traverses for stationary sources
EPA Method 2	Determination of stack gas velocity and volumetric flow rate (type S Pitot tube)
EPA Method 3A	Determination of oxygen and carbon dioxide concentrations in emissions from stationary sources (instrumental analyzer procedure)
EPA Method 4	Determination of moisture content in stack gases
EPA Method 5	Determination of particulate emissions from stationary sources
EPA Method 7E	Determination of oxides of nitrogen emissions from stationary sources (instrumental analyzer procedure)
EPA Method 23	Determination of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) emissions from stationary sources
EPA Method 26A	Determination of hydrogen chloride emissions from stationary sources
EPA Method 29	Determination of metals emissions from stationary sources

The following sections describe the sampling and analytical procedures used during the emissions testing. All tests were performed in triplicate unless otherwise noted. All sampling and analytical procedures followed those outlined in 40CFR60, Appendix A.

4.1 Volumetric Flow Rate Tests

The volumetric flowrate of the exhaust gases, at the scrubber outlet test location was determined using EPA Methods 1-4. In accordance with EPA Method 1 twenty-four traverse points were utilized for flue gas velocity measurements. The locations of the traverse points, as determined by EPA Method 1, are showed in Appendix A. Flue gas velocity measurements were taken at each traverse point during each test run using an S-type Pitot tube and an inclined water manometer in accordance with EPA Method 2. Stack temperature measurements were taken at each traverse point using a Type-K thermocouple and digital temperature readout. The stack static pressure was also measured during each test run using the Pitot tube and manometer setup. Pitot tube leak checks were performed before and after each test run in accordance with EPA Method 2.

The molecular weight of the outlet exhaust gas was determined by measuring the oxygen (O₂) and carbon dioxide (CO₂) concentrations using an oxygen and carbon dioxide analyzer as described in EPA Method 3A. Carbon dioxide and oxygen concentrations were determined from integrated gaseous samples collected during each of the test using the sample train described in EPA Method 3A. The flue gas moisture content was determined from the moisture catch of the sampling train during the emissions testing in accordance with EPA Method 4. Each individual impinger was weighed before and after each test. All exterior moisture present on post-test impingers was thoroughly dried before any weight measurement. A minimum sample volume of 1 dry cubic meter was collected during each of the metals, hydrogen chloride and particulate matter tests and a minimum sample volume of 3 dry cubic meters was collected during the three dioxin and furan runs. The moisture content of the flue gas was calculated as the ratio of the moisture catch corrected to standard conditions to the sum of the dry sample volume and the moisture catch, both corrected to

standard conditions.

4.2 Hydrogen Chloride and Particulate Matter Tests

The hydrogen chloride (HCl) and particulate matter (PM) emissions were sampled and analyzed in accordance with EPA Methods 5 and 26A. Three 84-minute tests were performed for compliance determination of the FBSSI. This sampling train is shown in Appendix A. The Method 5/26A sampling train consisted of a Pyrex® glass nozzle, a heated glass lined sample probe, a heated Teflon filter (tared), a set of four tared glass impingers connected in series in an ice bath, a control module consisting of a leak free sampling pump, a calibrated critical orifice, an inclined manometer, and a calibrated dry gas meter.

The first two impingers each contained 100 ml of 0.1 N sulfuric acid (H₂SO₄) while the third impinger contained 100 ml of sodium hydroxide (NaOH). The fourth impinger contained a known quantity of silica gel. The sampling train glassware was cleaned prior to testing with soap and water and rinsed thoroughly with water. The sample probe and oven box were maintained at a temperature of 250 to 273°F during sampling to prevent moisture condensation. The impinger outlet temperature was maintained below 68°F during sampling by adding ice to the cold box. A vacuum line was connected from the outlet of the fourth impinger to the control module.

Before each test, the sampling train was leak checked to ensure no leakage greater than 0.02 cubic feet per minute at 10" Hg vacuum. The probe was then placed in the stack and stack gas is withdrawn isokinetically for an equal period of time at each traverse point with a sampling rate not exceeding 1.0 cfm.

The velocity differential pressure, critical orifice differential pressure, dry gas meter volume, dry gas meter outlet temperatures, probe temperature, stack temperature, oven box temperature, impinger outlet temperature, and sample vacuum were recorded at each traverse point during sampling. At the end of each test, the sampling train was leak checked to ensure no leakage greater than 0.02 cubic feet per minute at the highest recorded test vacuum.

Sample recovery consisted of rinsing the nozzle, probe, and filter holder front half three times with acetone. These acetone rinses were collected in Container 2. The tared Teflon filter was recovered in a clean laboratory area and placed in Container 1. Both the acetone and filter were desiccated and weighed (constant weight) in accordance with EPA Method 5. The contents of the four impingers were measured gravimetrically for moisture gain then transferred to sample Container 3. Impingers 1 and 2 and their connecting glassware were then rinsed with deionized distilled (DI) water twice. These rinses were added to Container 3. The third impinger contents were discarded. The sample containers were sealed and the liquid levels marked. The HCl samples were shipped to a contract laboratory for analysis. The HCl analysis was performed by ion chromatography as described in EPA Method 26A.

4.3 Multiple Metals Tests

Multiple metals (beryllium, cadmium, mercury, and lead) were sampled and analyzed in accordance with EPA Method 29. These metals tests were performed in triplicate on the FBSSI at the exhaust stack location during 84-minute test runs. A schematic of the multiple metals sampling train is shown in Appendix A. The following is a description of the metals sampling train and the procedures to be used to quantify multiple metals during the test.

program. The multiple-metals sampling train consisted of a glass nozzle, a heated glass lined probe, a quartz filter/holder in a heated box, a set of six glass impingers connected in series, a control module consisting of a leak free sampling pump, a calibrated critical orifice, an inclined manometer, and a calibrated dry gas meter. A Teflon fitting connected the nozzle to the probe liner. All of the sampling train glassware was cleaned and soaked in nitric acid according to the procedure described in EPA Method 29 prior to testing. The sample probe and oven box were maintained at a temperature of 248±25°F during sampling to prevent moisture condensation. The first and second impingers each contained 100 ml of 5% nitric acid/10% hydrogen peroxide (5% HNO_3 /10% H_2O_2). The third impinger was empty. The fourth and fifth impingers contained 100 ml of 4% potassium permanganate/10% sulfuric acid (4% KMnO_4 /10% H_2SO_4). The acidic permanganate solution was prepared fresh on-site daily. The sixth impinger contained a known quantity of silica gel. The second impinger was a Greenburg-Smith impinger with a standard tip, while the other impingers had modified tips. The temperature at the outlet of the sixth impinger was maintained below 68°F during sampling by adding ice to the water bath. A vacuum line connected the outlet of the sixth impinger to the control module.

Before each test and after test run, the sampling train was leak checked to ensure no leakage greater than 0.02 cubic feet per minute at 15" Hg vacuum. The probe was then placed in the stack and stack gas was withdrawn isokinetically for an equal period of time at each traverse point. The velocity differential pressure, critical orifice differential pressure, dry gas meter volume, dry gas meter inlet and outlet temperatures, probe temperature, stack temperature, oven box temperature, impinger outlet temperature, and sample vacuum were recorded at each traverse point during sampling. Before port changes and at the completion of each test, the sampling train was leak checked to ensure no leakage greater than 0.02 cubic feet per minute at the highest recorded test vacuum. After the post-test leak check, the sampling train was disassembled, all open ends were sealed, and the sampling train components were moved to the cleanup area for recovery. The recovery procedure for the multiple-metals sampling train is described as follows. The filter was carefully removed from the filter holder with Teflon coated forceps and placed in a labeled plastic Petri dish (Container 1). Any particulate matter or filter fragments that adhere to the filter holder gasket were transferred to the Petri dish using a dry, acid cleaned nylon bristle brush. The Petri dish was then sealed for transport to the laboratory.

The nozzle, probe liner, and filter holder front half were then rinsed and brushed thoroughly with 100 ml of 0.1 N nitric acid (HNO_3) using a Teflon coated brush. These rinses were collected in a labeled glass sample jar (Container 3). The sample jars were sealed, and the liquid level marked. The nozzle, probe liner, and filter holder front half were then rinsed with deionized water followed by acetone. These rinses were discarded. The moisture gain in the first two impingers was measured gravimetrically and their contents were transferred to a labeled glass sample jar (Container 4). The first two impingers, the filter support, the back half of the filter holder, and the connecting glassware between the back half of the filter holder and the second impinger were then rinsed with 100 ml of 0.1 N HNO_3 . These rinses were combined with the impinger contents, and the sample jar were sealed and the liquid level marked.

The moisture gain in the third impinger was measured gravimetrically and its contents were transferred to a labeled glass sample jar (Container 5A). This impinger was then rinsed with

100 ml of 0.1 N HNO₃. The rinses were combined with the impinger contents and the sample jar were sealed and the liquid level marked.

The moisture gain in the permanganate impingers was measured gravimetrically and the contents were transferred to a labeled glass sample jar (Container 5B). The impinger and connecting glassware were then rinsed with 100 ml of fresh 4%KMnO₄/10%H₂SO₄ followed by a rinse with 100 ml of deionized water. The permanganate and deionized water rinses were combined with the impinger contents and the sample jar was sealed and the liquid level marked. This sample jar was not completely filled and was vented to relieve excess pressure. If any visible permanganate deposits remain after the water rinses, the permanganate impinger was rinsed with a total of 25 ml of 8N HCl. The walls and stem of the permanganate impingers were rinsed and collected in a labeled sample jar containing 200 ml of deionized water (Container 5C). The sample jar was then sealed and the liquid level marked. The silica gel impinger was weighed for moisture gain. The silica gel was then returned to its original storage container to be dried for reuse. The following is a list of the sample recovery containers.

- Container 1 filter was removed from filter holder and stored in sealed Petri dish
- Container 2 not used in this procedure, used for FPM procedure
- Container 3 nozzle, sample probe, and front half of filter housing were brushed and rinsed three times with 100 ml of 0.1N HNO₃ and save
- Container 4 measured contents of impingers 1 and 2 and save; filter support, back half of filter housing were rinsed three times with 100 ml of 0.1N HNO₃ and saved
- Container 5A measured contents of impinger 3 then rinsed three times with 100 ml of 0.1N HNO₃ and saved
- Container 5B measured contents of impingers 4&5 then rinsed three times with 100 ml of acidified KMnO₄ and 100 ml of deionized distilled water and saved
- Container 5C rinsed impingers 4&5 with 25 ml of 8N HCl solution followed by 100 ml of deionized distilled water and saved
- Container 6 weighed contents of impinger 6 for moisture gain
- Container 7 not used in this procedure
- Container 8A 0.1N HNO₃ reagent blank (300 ml)
- Container 8B deionized distilled water blank (100 ml)
- Container 9 HNO₃/H₂O₂ reagent blank (200 ml)
- Container 10 acidified KMnO₄ reagent blank (100 ml)
- Container 11 8N HCl reagent blank (200 ml)
- Container 12 filter blanks (3)

One unused filter and aliquots of each of the impinger and rinse solutions, in the volumes specified in Method 29, were collected and submitted with the field samples as reagent blanks. Where applicable metals results were reagent blank corrected. Front half and back half fractions were combined before analysis. Containers 1 through 4 were digested in concentrated acid before being analyzed for the target metals (except mercury) by inductively coupled plasma-mass spectrometry (ICP/MS). The mercury analysis (Containers 5A, B, and C) were conducted on each of the sample fractions following digestion with acid and permanganate by cold vapor atomic absorption spectroscopy (CVAAS). All collected reagent blanks were analyzed using the same methodologies as the collected samples.

4.4 Dioxins/ Furans and PCB Tests

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) and Polychlorinated biphenyls (PCB) sampling were conducted in accordance with EPA Method 23. Three PCDD/PCDF/PCB tests were performed on the FBSSI with each test being 84-minutes in duration. The Method 23 sampling train is shown in Appendix A. The following is a description of the sampling train and the procedures used to quantify PCDD, PCDF, and PCB.

The sampling train consists of precleaned acid soaked, DI water soaked, and tap water rinsed glassware, a Pyrex® glass button hook nozzle, a heated glass lined sample probe, a heated filter in a glass filter holder, a water cooled glass coil condenser, an water cooled adsorbent module (spiked pre-weighed XAD-2 trap), a set of four glass impingers connected in series in an ice bath, and a control module consisting of a leak free sampling pump, a calibrated critical orifice, an inclined manometer, and a calibrated dry gas meter. A Teflon fitting connects the nozzle to the probe liner. The probe and oven box were maintained at a temperature of 248±25°F during sampling to prevent moisture condensation. The first impinger was empty with the next two impingers each containing 100 ml of deionized water. The fourth impinger contained a known quantity of silica gel. The second impinger used a standard Greenburg-Smith tip, while the other impingers had modified straight tips. The glass components of the sampling train including the adsorbent module were cleaned in strict accordance with the procedures of EPA Method 23. Silicone grease was not used on any GamAir sampling trains. The adsorbent traps were loaded with XAD resin by the subcontracted analytical laboratory prior to being shipped to the test site. The fourth impinger outlet temperature was maintained below 68°F during sampling by adding ice. The coil condenser was cooled by circulating water to and from the cold box using a peristaltic pump. The adsorbent module was also maintained at a temperature less than 68°F during sampling.

Before each test the sampling train was leak checked to ensure no leakage greater than 0.02 cubic feet per minute at 10" Hg vacuum. The probe was placed in the stack and stack gas is withdrawn isokinetically for an equal period of time at each traverse point. The velocity differential pressure, critical orifice differential pressure, dry gas meter volume, dry gas meter outlet temperatures, probe temperature, stack temperature, oven box temperature, impinger outlet temperature, and sample vacuum were recorded at each traverse point during sampling. At the completion of each test, the sampling train is leak checked to ensure no leakage greater than 0.02 cubic feet per minute at the highest recorded test vacuum.

The sample recovery and analysis procedures were as follows. The filter was carefully removed from the filter holder with PTFE forceps and placed in a labeled glass sample container (Container 1). Any particulate matter or filter fragments, which adheres to the filter holder gasket, were placed into Container 1. The adsorbent module (Container 1A) was post weighed, wrapped in Teflon tape and hexane rinsed aluminum foil and stored on ice for transport to the analytical laboratory. The nozzle, probe liner, filter holder front half, Teflon frit, and filter holder back half were rinsed three times each with acetone and collected in Container 2, then three times with toluene and collected in Container 3. The connecting glassware and the coil condenser were rinsed three times with acetone and collected in Container 2, then soaked with three separate rinses of toluene for 5 minutes each and collected in Container 3. After all toluene rinses and soaks, one rinse of acetone was performed to remove any residual toluene left in the glassware and collected in Container 2.

Contents of the first three impingers and the distilled deionized water rinses of the impingers and connecting glassware were collected in Container 4. The first three impingers and connecting glassware were then rinsed with acetone and collected in Container 2, then rinsed with toluene and collected in Container 3. All sample containers were sealed and the liquid level marked.

The moisture gain was determined by gravimetrically weighing the XAD module and the first three impingers prior to their recovery. The silica gel impinger was also weighed for moisture gain. The collected samples were submitted to BV Labs for analysis. The solvent rinses (acetone and toluene), filters and XAD resins were extracted prior to analysis. The PCDD's and PCDF's were separated by high resolution gas chromatography (HRGC) and measured by high resolution mass spectrometry (HRMS).

The collected samples were submitted to a Bureau Veritas Labs for analysis. The solvent rinses (acetone and toluene), filters and XAD resins were extracted prior to analysis. D/F analysis were performed in accordance with EPA Method 8290. PCB analysis was performed in accordance with EPA Method 1668A. PCB was separated by high resolution gas chromatography (HRGC) and measured by high resolution mass spectrometry (HRMS). Total PCB consisted of the 10 homolog group (mono to deca) and were reported as the sum of that group. Non-detect isomers were reported at the detection limit identified in the laboratory report.

4.6 Biosolids Tests

During the course of each test run (84-minute sampling duration) four biosolids grab samples were collected (half hour prior to run, start of run, middle of run, and end of run) into a 250-milliliter sample jar. Each composite sample were thoroughly mixed and then refrigerated until analysis. Each sample was analyzed for total solids content in accordance with Standard Method 2540B. A total of three biosolids samples were analyzed for the three PCDD/PCDF/metals tests, three biosolids samples were analyzed for the three HCl/FPM tests. The percent solids and the average wet biosolids feed rate, for each 84-minute test run, were used in calculating the dry tons per hour feed rate for that particular test run. YCUA was responsible for the percent solids analyses.

4.7 Continuous Emission Monitoring Tests (CEMS)

O₂, CO₂, NO_x, and CO were measured with a properly calibrated, transportable, continuous emissions monitoring system (CEMS). Sampling occurred at the vertical exhaust stack locations. A daily instrument calibration check and individual test run system calibration check was performed on each analyzer in accordance with EPA Methods 3A, 7E, and 10. A schematic diagram of the CEM sampling train is shown in Appendix A. Triplicate 60-minute test runs for CO₂, O₂, NO_x, and CO were performed with the data recorded electronically in one-minute averages. The average concentration over the 60-minute test period constituted a single test run. The CEM measurement system consisted of heated probe, in stack filter, calibration valve, heated Teflon transfer sample line, moisture removal system, leakless vacuum pump, Teflon transport line, sample gas manifold (w/ bypass vent), individual flow control valve for each specific analyzer. Instrument calibrations were performed with NIST certified compressed gas mixtures of O₂, CO₂, NO_x, and CO with a nitrogen balance. A three-point analyzer calibration error (<2%) check was conducted, prior to testing, by injecting the

calibration gases directly into the gas analyzers and recording the responses. Zero and upscale calibration checks were conducted both before and after each test run in order to quantify measurement system calibration drift (<3%) and sampling system bias (<5%). During these checks, the calibration gases were introduced into the sampling system at the probe outlet so that the calibration gases were analyzed in the same manner as the flue gas samples. Drift is the difference between the pre- and post-test run calibration check responses. Sampling system bias is the difference between the test run calibration check responses (direct analyzer calibration) and the initial calibration error responses (direct analyzer calibration) to the zero and upscale calibration gases. Analyzer outputs were recorded continuously with a PC driven data acquisition system (DAS). One-minute averages were produced for each gas component. The following continuous emission monitors, or their equivalent were used on this program. The analyzer manufacturer and instrument operating ranges for each pollutant can be found below in Table 4-1:

Table 4-1 Continuous Emissions Monitoring Instrumentation Operating Ranges			
Parameter	Manufacturer	Model Number	Measurement Range
O ₂	Teledyne API	T200H	0-20.96 %
CO ₂	Teledyne API	T300M	0-18.02%
NO _x	Teledyne API	T200H	0-246.1 ppm
CO	Teledyne API	T300M	0-226.6ppm

A Teledyne API (API) Model 200EH chemiluminescent NO/NO_x monitor was used to measure oxides of nitrogen (NO_x) and houses an oxygen sensor. The instrument operation is based on the principal of the chemiluminescent reaction of nitric oxide (NO) and ozone. Light emission results when electronically excited nitrogen dioxide (NO₂) molecules revert to their ground state. To measure NO concentrations, the gas sample to be analyzed, is blended with ozone (O₃) in the instrument's reaction chamber. The resulting chemiluminescence is monitored through an optical filter by a highly sensitive photomultiplier tube (PMT) positioned at one end of the reaction chamber. The filter/photomultiplier combination responds to light in a narrow wavelength band unique to this chemiluminescent reaction (detailed below) the filter assists in eliminates interferences in this wavelength:



To measure NO_x concentrations (NO plus NO₂), the sample gas flow is diverted through an NO₂ - to - NO converter. The chemiluminescent response in the reaction chamber to the converter effluent is linearly proportional to the NO_x concentration entering the converter (sample gas). The system is operated in the NO_x mode during all phases of the program. The oxygen portion of this instrument uses the paramagnetic principle, whereby the magnetic susceptibility of the gas volume is measured by the force acting on a nonmagnetic test body

suspended in a magnetic field. The force is converted to an output current proportional to the O₂ concentration.

A Teledyne API (API) Model T300M CO₂ analyzer was located in the same housing as the CO monitor and used to measure concentrations of CO₂. The instrument operates on the principle of absorption of filtered infrared frequencies by the molecular bonds of the target gas molecules in the sample cell. This analyzer utilizes dual-in-line reference and sample detectors to measure the attenuation of the infrared energy, which is proportional to the concentration of the CO₂ present. The raw signals from the two detectors are subtracted, and the difference then linearized and amplified prior to electronic output from the analyzer. The signal generated is an analog voltage linearly proportional to the carbon dioxide concentration in the gas stream. The CO portion of this instrument is a nondispersive infrared gas analyzer. The analyzer contains an infrared detector that uses the signal nondispersive beam technique with alternate modulations of the sample and reference cells. Radiation absorbed by CO in the sample cell results in a capacitance change in the detector, which is proportional to the CO concentration. The CO analyzer does not require a CO₂ scrubber based on the gas correlation filter technology.

5.0 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

5.1 QC Procedures

Specific quality control (QC) procedures will be followed to ensure the continuous production of useful and valid data throughout the course of this test program. The QC checks and procedures described in this section represent an integral part of the overall sampling and analytical scheme. Strict adherence to prescribed procedures is quite often the most applicable QC check. A discussion of both the sampling and analytical QC checks that will be utilized during this program is presented below.

5.1.1 Equipment Inspection and Maintenance

Each item of field test equipment purchased by GamAir is assigned a unique, permanent identification number. An effective preventative maintenance program is necessary to ensure data quality. Each item of equipment that is returned from the field is inspected before it is returned to storage. During the course of these inspections, items are cleaned, repaired, reconditioned, and recalibrated where necessary. Each item of equipment transported to the field for this test program is inspected again before being packed to detect equipment problems, which may originate during periods of storage. This minimizes lost time on the job site due to equipment failure. Occasional equipment failure in the field is unavoidable despite the most rigorous inspection and maintenance procedures. For this reason, GamAir routinely transports to the job site replacement equipment for all critical sampling train components.

5.1.2 Equipment Calibration

New equipment for which calibration is required are calibrated before initial field use. Equipment whose calibration status may change with use or time is inspected in the field before testing begins and again upon return from each field use. When an item of equipment is found to be out of calibration, it is repaired and recalibrated or retired from service. All equipment is periodically recalibrated in full, regardless of the outcome of these regular inspections. Calibrations are conducted in a manner and at a frequency, which meets or exceeds USEPA specifications. GamAir follows the calibration procedures outlined in the EPA Methods, and those recommended within the Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III (EPA-600/R-94/-038c, September 1994). When these methods are inapplicable, GamAir uses methods such as those prescribed by the American Society for Testing and Materials (ASTM). Data obtained during calibrations are recorded on standardized forms, which are checked for completeness and accuracy by GamAir. Data reduction and subsequent calculations are performed using GamAir computer facilities. Calculations are checked at least twice for accuracy. Copies of calibration forms are included in the test report.

Emissions sampling equipment requiring calibration includes Pitot tubes, pressure gauges, thermometers, dry gas meters, and barometers. The following sections elaborate on the calibration procedures followed by GamAir for these items of equipment.

Pitot Tubes. All Type S Pitot tubes used by GamAir, whether separate or attached to a sampling probe are constructed in-house. Each new Pitot is calibrated in accordance with the geometry standards contained in EPA Method 2. A Type S Pitot tube, constructed and positioned according to these standards, will have a coefficient of 0.84 ± 0.02 . This

coefficient should not change as long as the Pitot tube is not damaged. Each Pitot tube is inspected visually upon being returned from the field. If a cursory inspection indicates damage or raises doubt that the Pitot remains in accordance with EPA geometry standards, the Pitot tube is refurbished as needed and recalibrated.

Differential Pressure Gauges. Some meter consoles used by GamAir are equipped with 10-inch water column (W.C.) inclined-vertical manometers. Fluid manometers do not require calibration other than leak checks. Manometers are leak checked in the field prior to each test series, and again upon return from the field.

Impinger Thermometer. Prior to the start of testing, the thermometer used to monitor the temperature of the gas leaving the last impinger is compared with a mercury-in-glass thermometer, which meets ASTM specifications. The impinger thermometer is adjusted if necessary until it agrees within 2°F of the reference thermometer. If the thermometer is not adjustable, it is labeled with a correction factor.

Dry Gas Meter Thermometer. The thermometer used to measure the temperature of the metered gas sample is checked prior to each field trip against an ASTM mercury-in-glass thermometer. The dry gas meter thermometer is acceptable if the values agree within $\pm 5^\circ\text{F}$. Thermometers not meeting this requirement are adjusted or labeled with a correction factor.

Flue Gas Temperature Sensor. All thermocouples employed by GamAir for the measurement of flue gas temperatures are calibrated upon receipt. Initial calibrations are performed at three points (ice bath, boiling water, and hot oil). An ASTM mercury-in-glass thermometer is used as a reference. The thermocouple is acceptable if the agreement is within ± 1.5 percent (absolute) at each of the three calibration points.

Prior to the start of testing, an on-site reading of the flue gas thermocouple-potentiometer combination is compared with an ASTM mercury-in-glass reference thermometer. If the two agree within ± 1.5 (absolute), the thermocouple and potentiometer are considered to be in proper working order for the test series.

After each field use, the thermocouple-potentiometer system is compared with an ASTM mercury-in-glass reference thermometer at a temperature within ± 10 percent of the average absolute flue gas temperature. If the absolute temperatures agree within ± 1.5 percent, the temperature data are considered valid.

Dry Gas Meter and Orifice. Two procedures are used to calibrate the dry gas meter and orifice simultaneously. The full calibration is a complete laboratory procedure used to obtain the calibration factor of the dry gas meter. Full calibrations are performed over a wide range of orifice settings. A simpler procedure, the post test calibration, is designed to check whether the calibration factor has changed. Post test calibrations are performed after each field test series at an intermediate orifice setting (based on the test data) and at the maximum vacuum reached during the test. GamAir uses, as a transfer standard, a dry gas meter that is calibrated annually against a spirometer. During the annual calibration, triplicate calibration runs are performed at seven flow rates ranging from 0.25 to 1.40 cfm.

Dry Gas Meter. Each metering system receives a full calibration at the time of purchase and a post test calibration after each field use. If the calibration factor, Y, deviates by less than 5 percent from the initial value, the test data are acceptable. If Y deviates by more than 5 percent, the meter is recalibrated, and the meter coefficient (initial or recalibrated) yielding

the lowest sample volume for the test runs is used. EPA Method 5B requires another full calibration any time the post test calibration check indicates that Y has changed by more than 5 percent. GamAir recalibrates the dry gas meter when Y is found to be outside the range of 0.97 to 1.03.

Orifice. An orifice calibration factor is calculated for each flow setting during a full calibration. If the range of values does not vary by more than 0.15 inches H₂O (over the range of 0.5 to 3.0 inches H₂O), the arithmetic average of the values obtained during the calibration is used.

Barometer. Each field barometer is adjusted before each test series to agree within ± 0.1 inches of a reference aneroid barometer. The reference barometer is checked weekly against the station pressure value (corrected for elevation difference) reported by the National Weather Service station at Bradley International Airport, approximately 8.0 miles from GamAir office location.

5.1.3 Sampling Quality Control Procedures

The following pretest QC checks will be conducted:

- All sampling equipment will be thoroughly checked to ensure clean and operable components.
- Equipment will be inspected for possible damage from shipment.
- The oil manometer or Magnehelic gauge used to measure pressure across the Type S Pitot tube will be leveled and zeroed.
- The number and location of the sampling traverse points will be checked before taking measurements.
- The temperature measurement system will be visually checked for damage and operability by measuring the ambient temperature prior to each traverse.

In addition to the general QC procedures listed above, QC procedures specific to each sampling method will also be incorporated into the sampling scheme. These method specific procedures are discussed below.

Preformatted data sheets will also act as QC check lists. Copies of data sheets to be used on this program are contained in the Appendix.

Sampling Train QC Checks. The following QC procedures will be emphasized:

Prior to Start of Tests:

- Keep all cleaned glassware and sample train components sealed until train assembly.
- Assemble the sampling trains in an environment free from uncontrolled dust.
- Visually inspect each sampling train for proper assembly.
- Perform pretest calculations to determine the proper sampling nozzle size.

Prior to Testing Each Day:

- Visually inspect the sampling nozzle.
- Visually inspect the Type S Pitot tube.
- Leak check each leg of the Type S Pitot tube.
- Leak check the entire sampling train.

During Testing Each Day:

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- Readings of temperature and differential pressure will be taken at each traverse point.
- All sampling data and calculations will be recorded on preformatted data sheets.
- All calibration data forms will be reviewed for completeness and accuracy.
- Any unusual occurrences will be noted during each run on the appropriate data form.
- The project manager will review sampling data sheets daily during testing.
- Properly maintain the roll and pitch axis of the Type S Pitot tube and the sampling nozzle.
- Leak check the train before and after any move from one sampling port to another during a run or if a filter change takes place.
- Conduct additional leak checks if the sampling time exceeds four hours.
- Maintain the probe, filter, and impingers at the proper temperature.
- Maintain ice in the ice bath at all times.
- Make proper readings of the dry gas meter, delta P and delta H, temperature, and pump vacuum during sampling at each traverse point.

After Testing Each Day

- Visually inspect the sampling nozzle.
- Visually inspect the Type S Pitot tube.
- Leak check each leg of the Type S Pitot tube.
- Leak check the entire sampling train.

5.1.4 Quality Control for Volumetric Air Flow Rate Determinations

Flue Gas Velocity. Data required to determine the flue gas velocity will be collected using the methodology specified in EPA Method 2. Quality control procedures are:

- Visually inspect the Type S Pitot tube before and after sampling.
- Leak check both legs of the Pitot tube before and after sampling.
- Check the number and location of the sampling traverse points before taking measurements.

Flue Gas Molecular Weight. The flue gas is deemed ambient as there is no combustion.

Quality control will focus on the following procedures:

- The sampling system will be leak checked before and after each test day.
- Calibration gases will be introduced at the sample probe exit before and after each test run.

Moisture Content. The moisture content of the gas stream will be determined using the technique specified in EPA Method 4. The following QC checks will be performed:

- The thermocouple used is calibrated before field use.

Table 5-1		
Quality Control Samples		
EPA Test Method	Criteria	QC Limits
Methods 1-2		
Pitot Tube Leak Check	Stable for 30 seconds	TBD
Methods 3A, 7E & 10		
Analyzer Calibration Error	Less than 2% of the span	TBD
Sampling System Bias	Less than 5% of span	TBD
Zero Drift	Less than 3% of span	TBD
Calibration Drift	Less than 3% of span	TBD
EPA Methods 5, 23, 26A, 29	Sampling rate	90 to 110 percent
EPA Method 23		
Internal Standards Recoveries	Percent recovery	40 to 130 percent and 25 to 130 percent
Surrogates	Percent recovery	70 to 130 percent
EPA Method 26		
Method Blank	Concentration of analytes	Below detection limit
Spiked Blank	Percent recovery	90 to 110 percent
Reagent Blank	One per test program	Report as analyzed
Matrix Spike	Percent recovery	80 to 120 percent
EPA Method 29		
Method Blank	Concentration of analytes	Below detection limit
Reagent Blank	One per test program	Report as analyzed
Duplicate Analysis	Relative percent difference	20% of average
Matrix Spikes (MS, MSD 1 each)	Percent recovery	80-120% recovery
Matrix Spikes (MS, MSD 1 each)	Percent recovery	80-120% recovery

5.1.5 Calculations Quality Control Procedures

Calculations for determining flow rates, moisture contents, and gaseous concentrations are made using a spreadsheet developed by GamAir. This spreadsheet utilizes the calculation procedures and equations specified in EPA Methods 2, 4, and 7E. The spreadsheet has been successfully used for numerous test efforts and has been validated by independent performance audits. Sample calculations are performed by the spreadsheet and a definition of terms will be provided in the final report. Data will be transported to the spreadsheet directly from the field data sheets.

5.2 QA/QC Checks of Data Reduction

The project manager will run an independent check (using a validated computer program) of the calculations with predetermined data before the field test. This will ensure that calculations done in the field are accurate. The project manager will also conduct a spot check on-site to assure that data are being recorded accurately. After the test, the QA/QC manager will check the data input to assure that the raw data have been transferred to the computer accurately.