CISWI Annual Compliance Testing

DDP Specialty Electronic Materials US, Inc., Midland, MI
EU95-S1 Tar Incinerator
1130 Building Specialty Monomers/DVB THROX

MI-ROP-A4033-2017b

June 5-7, 2019

1. Introduction

1.1 Summary of Test Program

AECOM Technical Services Inc. (AECOM) was contracted by DDP Specialty Electronic Materials US, Inc. (DuPont) in Midland, Michigan, Specialty Monomers (Spec Mono) Plant to conduct performance testing on their site Tar Incinerator (EU95) during the week of June 3rd, 2019. The performance testing consisted of measurements for nitrogen oxides (NO_X), carbon monoxide (CO), sulfur dioxide (SO_2), filterable particulate matter (PM), polychlorinated dibenzodioxins and dibenzofurans (D/F) (total mass basis and TEQ basis), hydrogen chloride (HCl) and metals, specifically lead (Pb), cadmium (Cd), and mercury (Hg). The following sections present the regulatory background, objectives, description, and schedule of the testing program.

Table 7 of the CISWI Guidelines Rule (40 CFR 60 Subpart DDDD) requires that observations for fugitive ash be conducted during performance testing. The Tar Incinerator does not create ash or have an ash handling system; therefore, in an email dated June 28, 2018 from Kathy Brewer of the Department of Environment, Great Lakes, and Energy (EGLE), formerly Michigan Department of Environmental Quality (MDEQ), – Air Quality Division, the agency agreed this condition is not applicable to the unit. Instead a qualitative visual observation of the unit was completed to confirm there were no fugitive emissions.

The results of testing are presented in Table 1-1. Details supporting these data are presented in the balance of this report.

Table 1-1 Emission Testing Results

Sample Type	Test Method	Sampling Time (min/run)	Allowable Emission Rate	Actual Emission Rate[1]
PM	EPA Method 5	160 min	110 mg/dscm @ 7% O_2	<3.9 mg/dscm @ 7% O_2
SO_2	EPA Method 6C	60 min	720 ppmv @ 7% O_2	0.5 ppmv @ 7% O_2
NO_X	EPA Method 7E	60 min	76 ppmv @ 7% O_2	54 ppmv @ 7% O_2
CO	EPA Method 10	60 min	35 ppmv @ 7% O_2	0.0 ppmv @ 7% O_2
D/F	EPA Method 23	256 min	2.9 ng/dscm @ 7% O_2 (total) - or - 0.32 ng/dscm @7% O_2 (TEQ)	<0.019 ng/dscm @ 7% O_2 (total) - or - <0.0017 ng/dscm @7% O_2 (TEQ)
HCl	EPA Method 26A	160 min	14 ppmv @ 7% O_2	<0.058 ppmv @ 7% O_2
Cd	EPA Method 29	160 min	0.023 mg/dscm @ 7% O_2	<0.0001 mg/dscm @ 7% O_2
Pb	EPA Method 29	160 min	0.096 mg/dscm @ 7% O_2	<0.002 mg/dscm @ 7% O_2
Hg	EPA Method 29	160 min	0.0024 mg/dscm @ 7% O_2	<0.0004 mg/dscm @ 7% O_2

[1]Results shown with a "<" refer to results below the lab reporting limit (RDL).

1.2   Regulatory Background

On March 21, 2011, in parallel with publication of the Boiler National Emission Standard for Hazardous Air Pollutants (NESHAP) rules and the Non-Hazardous Secondary Material (NHSM) rule, EPA promulgated the final updates to the New Source Performance Standards (NSPS) and Emission Guidelines (EG) for Existing CISWI Units, collectively referred to as the "2011 CISWI Rules." The 2011 CISWI Rules impact any facility that owns an emission unit that "combusts, or has combusted in the preceding six months, any solid waste as that term is defined in 40 CFR Part 241.2." The CISWI rules were then reconsidered and amended in 2013. The final version of the CISWI Rules/Guidelines were published in the Federal Register on February 7, 2013. The final rule is titled: <u>Subpart DDDD—Emissions Guidelines and Compliance Times for Commercial and Industrial Solid Waste Incineration Units.</u> EGLE then promulgated the state rules on January 2, 2019: Rule R 336.1974 Emissions Standards for Existing Commercial and Industrial Solid Waste Incinerators.

The requirements of that testing is outlined in 40 CFR 60.2690, as referenced by Michigan Rule R 336.1974(9)(e). Per Section 60.2720(a)(3) of the Federal CISWI rule as referenced by Michigan Rule R 336.1974(9)(g), DuPont intends to reduce the frequency of testing to a triennial frequency, for the following constituents, due to a successful completion of this test: hydrogen chloride, mercury, carbon monoxide, sulfur dioxide, cadmium, lead, dioxins/furans, particulate matter and fugitive ash. Successful completion of the test is a test result at a level equal to or less than 75% of the applicable emission limit in both this test and the initial July 2018 performance test. Therefore, the 2020 performance test will include measurements for only nitrogen oxides (NO_x). The next performance test to include the entire list of constituents will be 2022.

This test protocol addresses the compliance test.

Responsible Groups	• DDP Specialty Electronic Materials US, Inc. (DuPont) • Department of Environment, Great Lakes, and Energy (EGLE) • Environmental Protection Agency (EPA)
Applicable Regulations	• MI-ROP-A4033 • 40 CFR Part 60 Commercial and Industrial Solid Waste Incineration Units NSPS (Subpart DDDD) • Michigan Air Quality Division Part 9, Rule 336.1974"
Industry/Plant	• Specialty Monomers, 1130 Building
Plant Location	• DuPont Michigan Operations in Midland, Michigan 48640
Unit Initial Start-up	• 1990
Air Pollution Control Equipment	• N/A
Emission Points	• EU-95 Tar Incinerator (EU95-S1)
Pollutants/Diluent Measure	• Particulate Matter (PM) • Sulfur Dioxide (SO_2) • Nitrogen Oxides (NO_x) • Carbon Monoxide (CO) • Polychlorinated Dibenzodioxins (PCDDs) • Polychlorinated Dibenzofurans (PCDFs) • Hydrogen Chloride (HCl) • Lead/Cadmium/Mercury (Pb/Cd/Hg) • Oxygen (O_2)
Test Dates	• June 5-7, 2019

1.3 Key Personnel

The key personnel coordinating this test program are:

- Cody Lindemulder provided support as the Process Focal Point. The Process Focal Point is responsible for coordinating the plant operation during the test and ensuring the unit is operating at the agreed upon conditions in the test plan. They also serve as the key contact for collecting any process data required and providing all technical support related to process operation.

- Sara Bennett and Colleen Rosenbrock provided support as the Environmental Focal Points for this test. The Environmental Focal Points are responsible for ensuring that all regulatory requirements and citations are reviewed and considered for the testing.

- Daniel J. Nuñez served as the Test Plan Coordinator. The Test Plan Coordinator is responsible for the overall leadership of the sampling program. They also develop the overall testing plan and determine the correct sample methods.

- Eugene Youngerman provided support as a technical reviewer of the test data.

- James Edmister served as the Sample Team Leader. The Sample Team Leader is responsible for ensuring the data generated meets the quality assurance objectives of the plan. Kyle Kennedy, Randy Reinke and Matthew Newland also assisted as sampling technicians.

2. Plant and Sampling Location Descriptions

2.1 Facility Description

DuPont operates a tar incinerator (EU95-S1) at its Midland, Michigan chemical manufacturing facility. EU95-S1 is a boiler that produces steam from the heat input of natural gas and process tars. The process tars contain distillation heavies from the 1130 building process and process aids from the distillation process. The boiler is rated for 48 MMBtu/hr while the burner is rated for 15 MMBtu/hr. EU95-S1 must meet the requirements of the Commercial and Industrial Solid Waste Incineration (CISWI) rule promulgated under 40 CFR Part 60 Subpart DDDD, as referenced by Michigan Rule R 336.1974, and is regulated as an Energy Recovery Unit under the rule.

2.2 Performance Test Operations

The Performance Test was conducted at one operating condition to demonstrate the system performance with respect to the emission standards listed in this test report. During each test run plant process data was monitored and stack gas emissions were measured. The following sections briefly summarize the activities associated with the performance test.

2.2.1 Unit Process Data

Process monitoring information pertinent to establishing that the unit is operating at normal conditions was recorded during the test by the EU-95 Tar Incinerator data acquisition system. One-minute average data was obtained from the process control system for each operating parameter specified in the test plan for each test run. For each operating parameter, an average value was calculated for each test run.

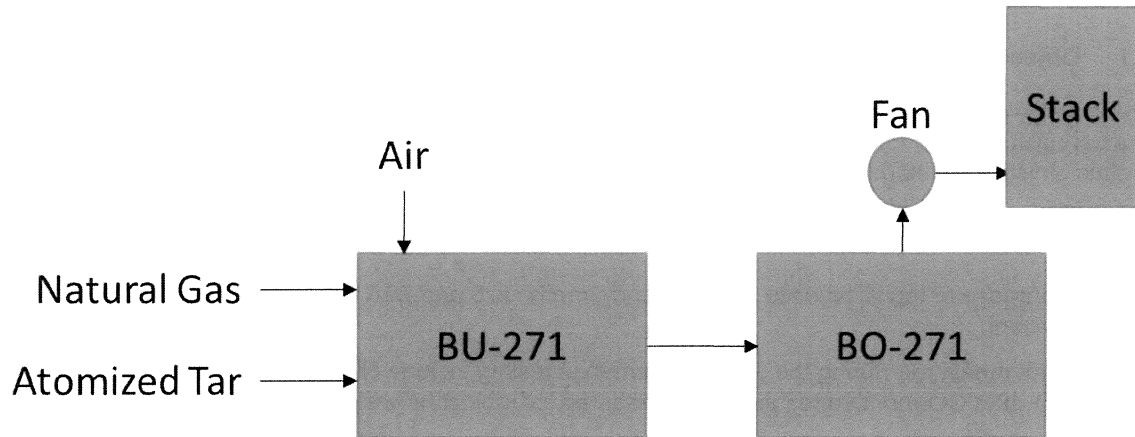**Figure 1 EU95 Tar Incinerator Process Schematic**

Table 2-1 Manufacturer's Name and Model Number

Equipment	Manufacturer	Model Number
BU-271	Bloom	S-1610-022
BO-271	Johnston	509 Series

3. Summary and Discussion of Test Plan

3.1 Objectives and Test Matrix

The primary objective of this testing is to demonstrate compliance with the requirements of 40 CFR 60 Subpart DDDD. The Performance Testing of the Incinerator Stack NO_X, CO, SO_2, PM, D/F, HCl and metals emissions was performed in strict accordance with the procedures specified in 40 CFR 60, Appendix A. This test report describes the instrumental and manual procedures performed on the Incinerator Stack located within the DuPont Specialty Monomers Plant.

(For the purpose of logistical ease and efficiency, methods 5 and 26A were combined for the PM/HCl determination).

Parameters measured during the June Performance testing include NO_X, CO, SO_2, PM, D/F, HCl and metals. O_2 and CO_2 concentrations were measured for molecular weight and excess air correction.

Table 3-1 presents the parameters test methods and the emission limits.

Table 3-1 Test Matrix and Objectives

Parameter	Test Method	Regulation	Emission Limit
O_2/CO_2	EPA Method 3A	40 CFR 60, Subpart DDDD	N/A
PM	EPA Method 5	40 CFR 60, Subpart DDDD	110 mg/dscm @ 7% O_2
SO_2	EPA Method 6C	40 CFR 60, Subpart DDDD	720 ppmv @ 7% O_2
NO_X	EPA Method 7E	40 CFR 60, Subpart DDDD	76 ppmv @ 7% O_2
CO	EPA Method 10	40 CFR 60, Subpart DDDD	35 ppmv @ 7% O_2
D/F	EPA Method 23	40 CFR 60, Subpart DDDD	2.9 ng/dscm @ 7% O_2 (total) - or - 0.32 ng/dscm @7% O_2 (TEQ)
HCl	EPA Method 26A	40 CFR 60, Subpart DDDD	14 ppmv @ 7% O_2
Cd	EPA Method 29	40 CFR 60, Subpart DDDD	0.023 mg/dscm @ 7% O_2
Pb	EPA Method 29	40 CFR 60, Subpart DDDD	0.096 mg/dscm @ 7% O_2
Hg	EPA Method 29	40 CFR 60, Subpart DDDD	0.0024 mg/dscm @ 7% O_2

The compliance test was conducted on June 5-7, 2019 under normal process operating conditions. The emission testing of the Incinerator Stack consisted of three (3) test runs each for NO_X, CO, SO_2, PM, D/F, HCl and metals.

3.2 Process Operating Rates

As required by the regulation and EGLE guidance, all sampling was completed at normal operating conditions.

The normal operating rates were determined by reviewing the process data from the previous six months of operation and deciding the typical operating range of the unit. The average values do not include calibration data, startup data, shutdown data, malfunction data, and data obtained not burning waste.

Parameter	Normal Operating Rate	Operating Rate During Testing
Heat Input (MMBtu/hr)	4-13	~7.92
Tars Feed Rate (lb/hr)	180-420	~416
Natural Gas Feed Rate (scfh)	1450-9000	~864
O_2 in Vent Stack (%)	9-15	~10.7

The minimum natural gas set point on the Throx was changed during turnaround in April from 25 scfm to 15 scfm (~900 scfh). This change in operating rate did not get updated in the test plan before it was submitted. There is no effect on the results in the test report because CISWI results are characterized as hourly averages in concentration per dry volume corrected to 7% Oxygen and the volume is calculated for the report from stack velocity directly measured during testing.

Table 3-2 Testing Run Data (PM/HCl)

	Run 1	Run 2	Run 3	Average
Run Date	5-Jun-19	7-Jun-19	7-Jun-19	
Run Times	14:30-18:40	0820-11:13	16:30-19:20	
Stack Gas Wet flow (acf/hr)	448,876	450,062	465,043	454,660
Stack Gas Wet Flow Std. Cond. (scf/hr)	286,433	290,035	299,833	292,100
Stack Gas Dry Flow Std. Cond. (dscf/hr)	258,019	263,089	273,784	265,964
Volume Collected (dscf)	42.284	42.697	45.070	43.350
Stack Gas O_2 (%)	12.5	12.4	12.7	
HCl				
Mass Found (µg)	<74.6	<65.7	<58.0	<66.10
Concentration (mg/dscf)	<0.0018	<0.0015	<0.0013	<0.0015
Concentration (ppmdv)	<0.041	<0.036	<0.030	<0.036
Concentration (ppmdv @ 7%O_2)	<0.066	<0.058	<0.051	<0.058
PM				
Mass Found (mg)				
Total	<5.50	<1.90	<1.4	
Loading (mg/dscm)	<4.6	<1.5	<1.1	<2.4
Loading (mg/dscm) @7% O_2	<7.4	<2.5	<1.8	<3.9

Table 3-3 Testing Run Data (Cd/Pb/Hg)

	Run 1	Run 2	Run 3	Average
Run Date	6/5/2019	6/7/2019	6/7/2019	
Run Times	14:30-18:40	0820-11:30	16:30-19:20	
Stack Gas Wet flow (acf/hr)	449,427	442,031	435,771	452,409
Stack Gas Wet Flow Std. Cond. (scf/hr)	305,023	284,028	278,828	289,293
Stack Gas Dry Flow Std. Cond. (dscf/hr)	272,733	257,688	255,432	261,951
Volume Gas Collected (dscf)	86.930	81.455	80.484	82.956
Stack Gas O_2 (%)	12.5	12.4	12.7	
Mass Found (µg)				
Cadmium (Cd)	<0.15	<0.14	<0.14	
Lead (Pb)	3.15	3.66	3.06	
Mercury (Hg)	<0.76	<0.45	<0.46	
Concentration (µg/dscm)				
Cadmium (Cd)	<0.062	<0.061	<0.062	<0.062
Lead (Pb)	1.28	1.58	1.34	1.40
Mercury (Hg)	<0.31	<0.19	<0.20	<0.23
Concentration (µg/dscm @ 7%O_2)				
Cadmium (Cd)	<0.10	<0.10	<0.10	<0.10
Lead (Pb)	2.11	2.60	2.28	2.33
Mercury (Hg)	<0.31	<0.32	<0.34	<0.39
Concentration (mg/dscm @ 7%O_2)				
Cadmium (Cd)	<0.0001	<0.0001	<0.0001	<0.0001
Lead (Pb)	0.00211	0.0026	0.00228	0.00233
Mercury (Hg)	<0.0005	<0.00032	<0.00034	<0.00039

Table 3-4 Testing Run Data (D/F)

	TEF	Run 1	Run 2	Run 3	Average
Run Date		6/5/2019	6/6/2019	6/7/2019	
Run Times		09:30-13:59	08:15-12:38	11:40-16:02	
Stack Gas Wet flow (cf/hr)		427,194	443,113	426,988	432,431
Stack Gas Wet Flow Std. Cond. (scf/hr)		270,723	283,053	274,075	275,950
Stack Gas Dry Flow Std. Cond. (dscf/hr)		245,388	259,594	252,045	252,342
Volume Gas Collected (dscf)		143.083	151.340	146.369	146.930
Stack Gas O_2 (%)		11.53	12.60	12.65	
Dioxin/Furan (D/F)					
Mass Found (pg)					
2,3,7,8-TCDD	1	<1.02	2.63*	2.14*	
1,2,3,7,8-PeCDD	0.5	<1.42	<0.932	<1.33	
1,2,3,4,7,8-HxCDD	0.1	<1.69	<1.59	<1.79	
1,2,3,6,7,8-HxCDD	0.1	<1.59	<1.5	<1.68	
1,2,3,7,8,9-HxCDD	0.1	<1.65	<1.56	<1.75	
1,2,3,4,6,7,8-HpCDD	0.01	6.54	3.87	3.29	
OCDD	0.001	37.3	13*	11.9*	
2,3,7,8-TCDF	0.1	<1.35	<1.32	<1.47	
1,2,3,7,8-PeCDF	0.05	<1.53	<1.17	<1.09	
2,3,4,7,8-PeCDF	0.5	<1.59	<1.22	<1.13	
1,2,3,4,7,8-HxCDF	0.1	<1.01	<1.01	<0.837	
1,2,3,6,7,8-HxCDF	0.1	<0.998	<0.883	<0.729	
1,2,3,7,8,9-HxCDF	0.1	<1.31	<1.16	<0.956	
2,3,4,6,7,8-HxCDF	0.1	<1.18	<1.04	<0.861	
1,2,3,4,6,7,8-HpCDF	0.01	6.26	<0.624	<0.924	
1,2,3,4,7,8,9-HpCDF	0.01	<0.727	<0.719	<1.07	
OCDF	0.001	7.63	2.75	<2.52	
Total D/F		<75	<37	<35	
Total TEQ		<3.9	<4.8	<4.5	
Concentration (ng/dscm)					
Total D/F [1]		<0.00053	<0.00024	<0.00024	<0.0003
Total TEQ [1]		<0.0001	<0.0011	<0.0011	<0.0011
Concentration (ng/dscm @ 7% O_2)					
Total D/F [1]		<0.0276	<0.0144	<0.0144	<0.0188
Total TEQ [1]		<0.0014	<0.0019	<0.0018	<0.0017

[1]Results calculated using EDL ("<") and EMPC ("*") as full values

Table 3-5 Testing Run Data (NO$_x$, CO and SO$_2$)

	Run 1	Run 2	Run 3	Average
Run Date	6/5/2019	6/5/2019	6/5/2019	
Run Times	13:00-14:00	14:01-15:01	15:02-16:02	
Stack Gas O$_2$ (%)	12.39	12.41	12.44	
Nitrogen Oxides				
ppmdv	32.9	33.2	33.5	33.2
ppmdv @7% O$_2$	53.82	54.38	55.13	54.44
Carbon Monoxides				
ppmdv	0.0	0.0	0.0	0.0
ppmdv @7% O$_2$	0.0	0.0	0.0	0.0
Sulfur Dioxide				
ppmdv	0.4	0.3	0.3	0.3
ppmdv @7% O$_2$	0.6	0.48	0.41	0.50

4.   Sampling and Analytical Procedures

4.1   Sample Time

The duration of each test run for instrumental methods (NOx, CO and SO$_2$) test runs was sixty (60) minutes. For "wet-method" isokinetic methods (PM, D/F, HCl and metals) test runs times are shown below:

- PM/HCl: 160 minutes
- D/F: 256 minutes
- Pb/Cd/Hg: 160 minutes

4.2   Sample Test Runs

Three (3) sample test runs were performed for each method.

4.3   Sample Port Location

The stack is approximately 40-ft high with and inside diameter of 35 inches at the elevation of the sampling points. The sampling ports are approximately 64 -in downstream from the closest disturbance (stack breach) and 108 -in upstream from the next nearest disturbance (stack exit). The number of sampling points at this port location will be determined in accordance with EPA Method 1. Figure 2 and Figure 3 present schematics of the sampling points and location.

4.4   Isokinetic Sampling Methods

4.4.1   EPA Methods 2, 3A and 4 (Flow Rate, Gas Composition, and Moisture)

Concurrent with the performance of all isokinetic sampling trains, measurements were made to determine stack gas flow rate by EPA Method 2, gas composition by EPA Method 3A, and moisture by EPA Method 4.

4.4.2 EPA Methods 5/26A (Particulate Matter and Hydrogen Chloride)

For logistical ease and efficiency, methods 5 and 26A were combined for the PM/HCl determination. According to these methods, gas is withdrawn from the duct using a gooseneck nozzle. S-type pitot differential pressure is monitored to determine the isokinetic sampling rate.

The particulate matter is filtered from the gas sample. The particulate matter is determined in the rinse of the probe and nozzle, and on the filter, gravimetrically for determination of front-half particulate matter. Back-half particulate matter was not collected as only filterable PM is regulated in the rule.

From the heated filter, sample gas enters the series of impingers which are charged with absorbing solutions in accordance with EPA Method 26A. The first two impingers contain a solution of 1N H_2SO_4. The third and fourth impingers contain a solution of 1N NaOH. The fifth and final impinger contains a desiccant to dry the sample gas before metering. A pump and dry gas meter are used to control and monitor the sample gas flow rate.

The impingers were recovered and rinsed in to separate containers and analyzed in accordance with the requirements of Method 26A.

An example of the sampling "train" is shown in Figure 5.

4.4.3 EPA Methods 23 (PCDDs/PCDFs)

The stack gas was sampled for determination of dioxins and furans using a sampling train meeting the requirements of EPA Method 23. According to this method, gas is withdrawn from the duct isokinetically, utilizing a gooseneck nozzle of proper size. S-type pitot differential pressure is monitored to determine the isokinetic sampling rate.

Particulate matter is filtered from the gas sample, which then enters a sorbent module (water-cooled condenser and jacketed XAD-2 resin trap. Following the resin trap, the sample gas passes through a series of impingers to dry the gas before it enters the control console. Sample fractions were recovered in separate containers, to simplify shipping logistics, and later combined in the analytical laboratory and extracted to provide a single sample for analysis in accordance with the requirements of Method 23.

An example of the sampling "train" is shown in Figure 6.

4.4.4   EPA Methods 29 (Metals)

The stack gas was sampled for determination of metals (Pb/Cd/Hg) using a sampling train meeting the requirements of EPA Method 29. According to this method, gas is withdrawn from the duct isokinetically, utilizing a gooseneck nozzle of proper size. S-type pitot differential pressure is monitored to determine the isokinetic sampling rate.

Particulate matter is filtered from the gas sample. From the heated filter, sample gas enters the series of impingers which are charged with absorbing solutions in accordance with EPA Method 29. The first two impingers contain a solution of 5%HNO_3 and 10% H_2O_2. The third impinger is empty. The fourth and fifth impingers contain a solution of 4% $KMnO_4$ and 10% H_2SO_4. The sixth and final impinger contains a desiccant to dry the sample gas before metering. A pump and dry gas meter are used to control and monitor the sample gas flow rate. The impingers are recovered and rinsed in to separate containers and analyzed in accordance with the requirements of Method 29.

An example of the sampling "train" is shown in Figure 7.

4.5   Instrumental Methods

Emission gas was withdrawn from the Incinerator Stack and transported to the AECOM CEMS located at ground level. A stainless-steel sampling probe was inserted into the stack and used to collect sample gas. A heated Teflon sample line was used to transport the sample gas from the sampling probe to the CEMS. At the mobile laboratory, stack exhaust gas was dried using a condenser and routed to the individual analyzers for analysis on a dry basis. Data were collected using a dedicated data acquisition system. The system stores the data as fifteen-second averages.

Each analyzer was calibrated before testing using gas standards as specified by EPA Methods 6C, 7E, 3A and 10. Only EPA Protocol gases or certified pure zero nitrogen and air gases were used for calibration.

Method compliance is ensured by performing:

- Calibration error (challenging the calibrated instrument at three levels)
- System drift (challenging the overall system at two levels)
- System response testing
- Stratification check demonstrating lack of stratification and allowing sample gas to be collected from a single point.
- Calibration drift (repeating system bias after testing)

A schematic of the instrumental sampling system is shown in Figure 4.

The following instruments were used:

- EPA Method 3A (O_2/CO_2) - Teledyne model 300M; paramagnetic
- EPA Method 6C (SO_2) - Western Research Series 921; non-dispersive ultraviolet light analyzer.
- EPA Method 7E (NO_X) - TECO Model 42; chemiluminescent NO detector.
  EPA Method 10 (CO) - Teledyne Model 300M; gas filter correlation (GFC) infrared.

Figure 2 Sample Points
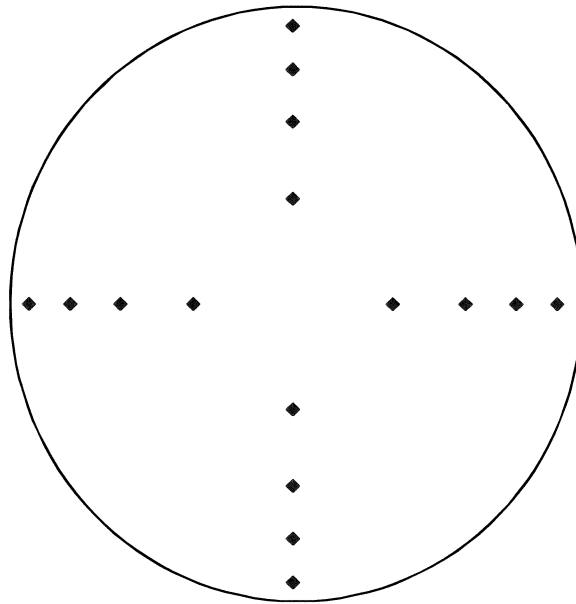
Stack Diameter 2.9 feet

Point	Percentage of Diameter	Distance from Wall (feet)
1	3.2	0.09
2	10.5	0.31
3	19.4	0.57
4	32.3	0.94
5	67.7	1.97
6	80.6	2.35
7	89.5	2.61
8	96.8	2.82

Figure 3 Sample Location

Stack Exit

Downstream Disturbance
Stack exit

Distance A
108 inches

Port

Port

Distance B
64 inches

Flow

Upstream Disturbance
Stack inlet

Inlet
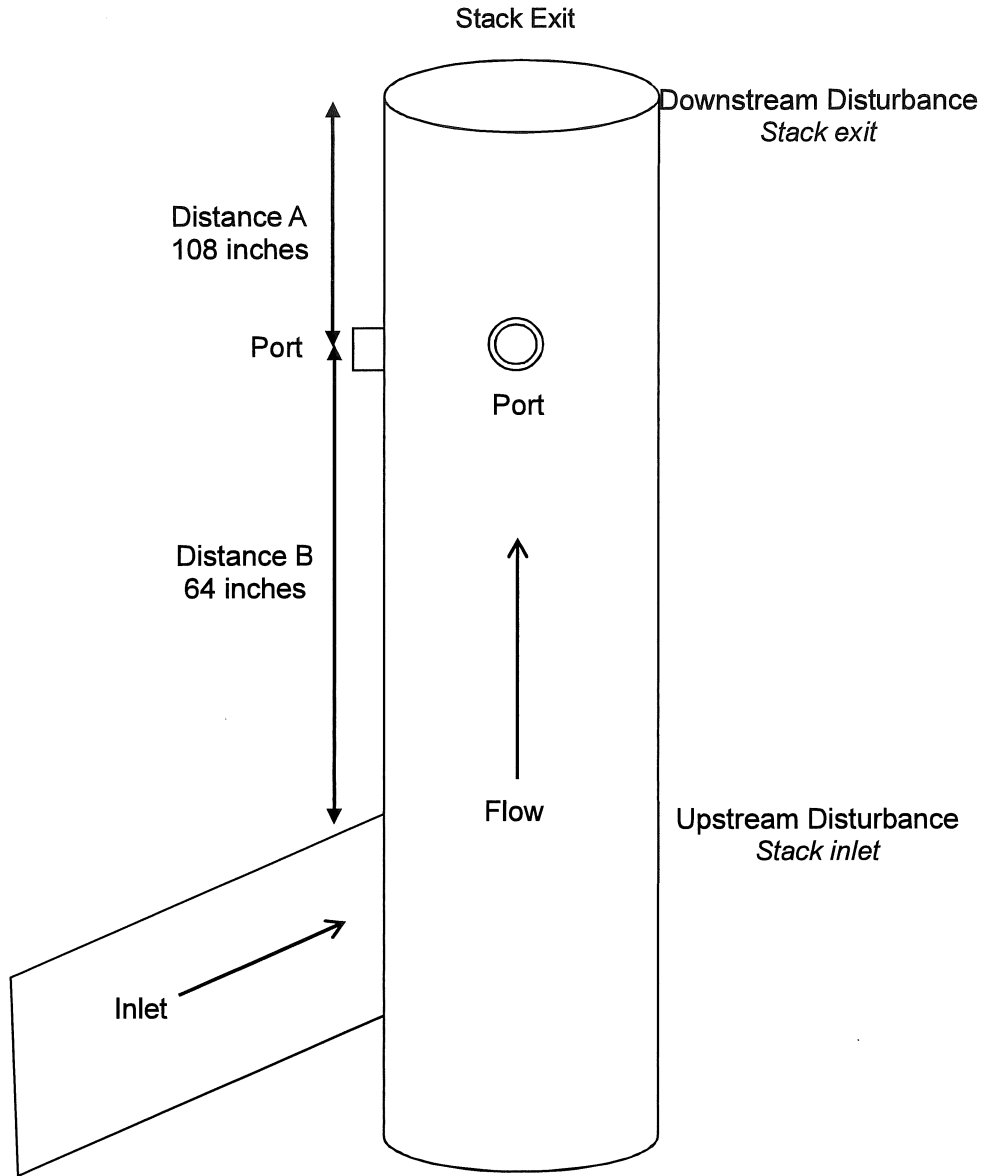
Figure 4 Schematic of AECOM CEM System
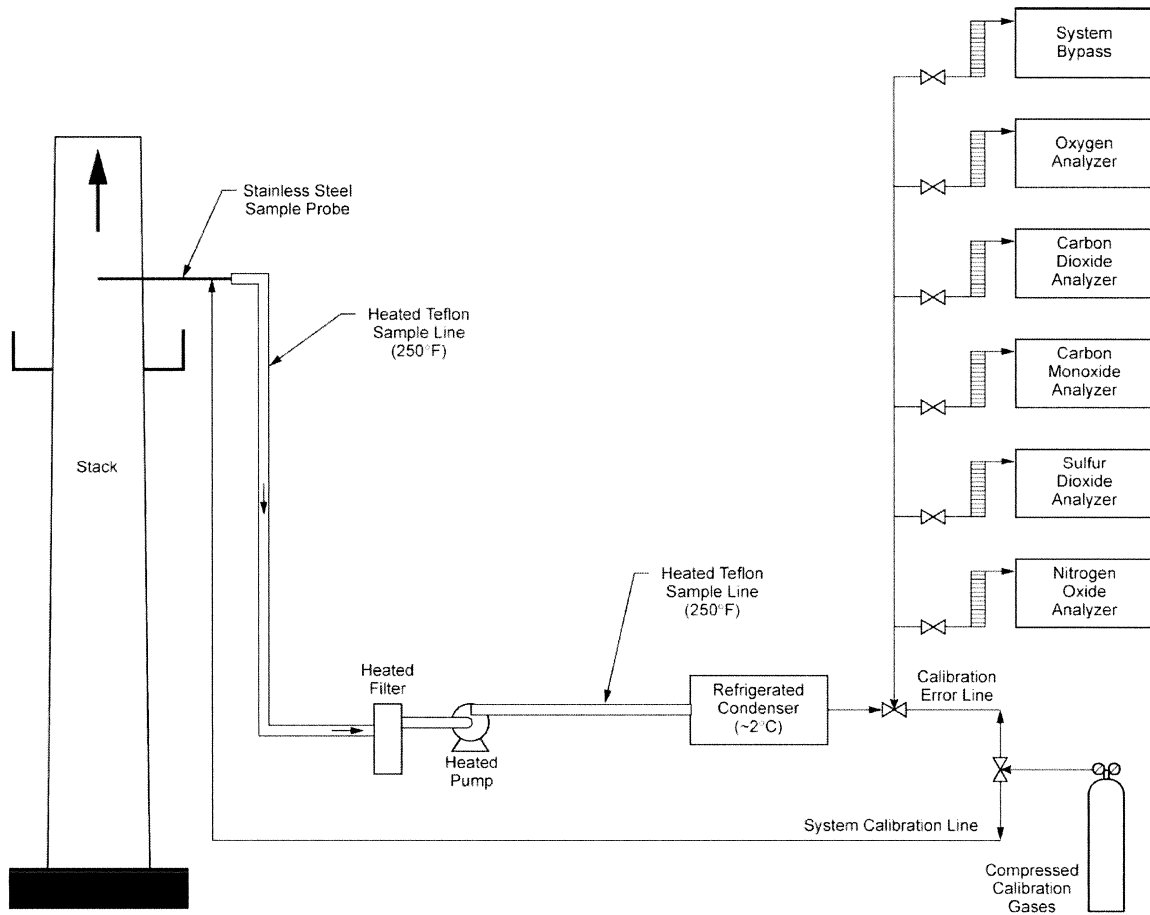
Figure 5 Schematic of Method 5/26A Sample Train
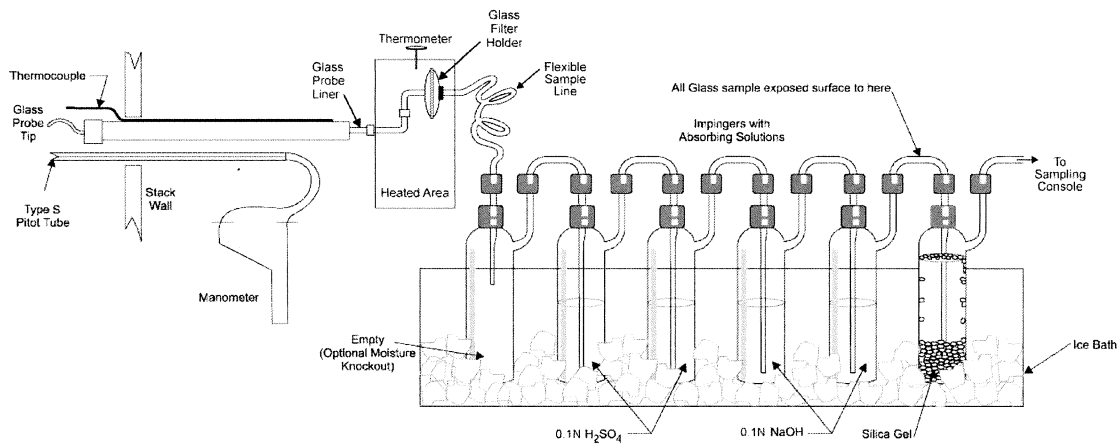
Figure 6 Schematic of Method 23 Sample Train
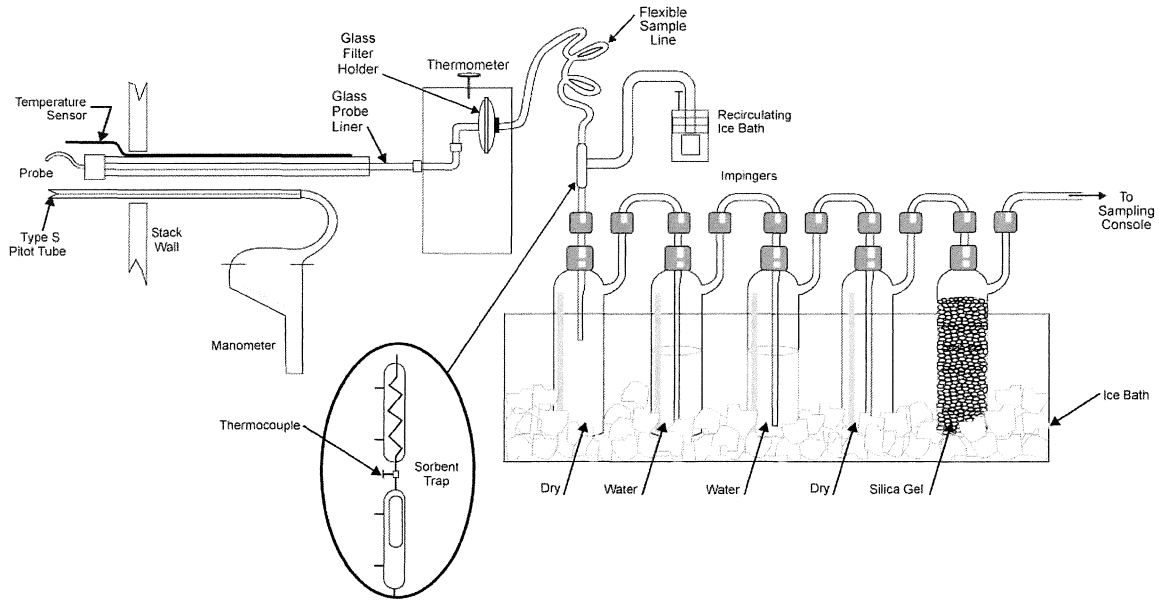
Figure 7 Schematic of Method 29 Sample Train
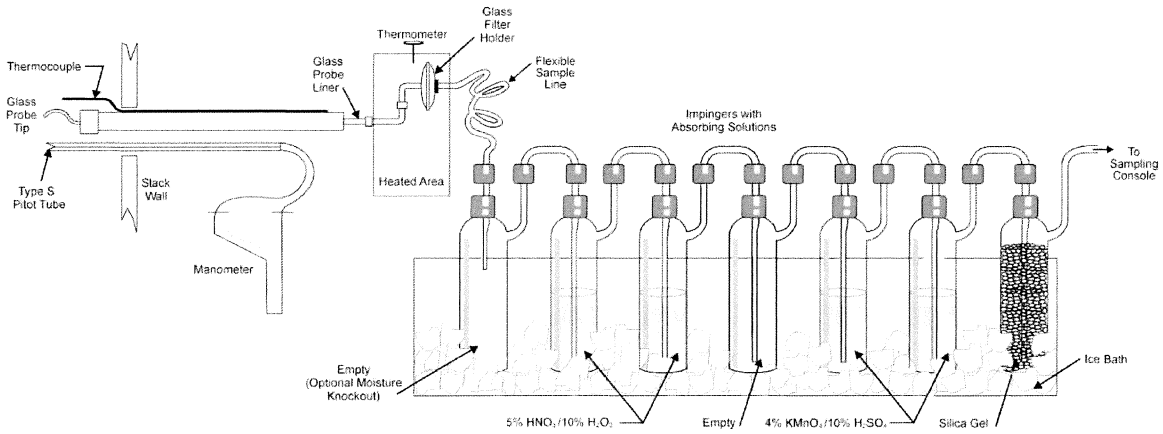
5. Calculation Examples

Stack Gas Velocity & Volumetric Rates (EPA M2)

The velocity and volumetric flow rate of the stack gas are calculated using the following equations:

$$V_S = K_P C_P \left(\sqrt{\Delta p}\right)_{AVG} \sqrt{\frac{T_{S(AVG)}}{P_S M_S}}$$

$$Q_W = V_S A_S (60 \ sec/min)$$

$$Q_{SW} = Q_W \left(\frac{528 \ °R}{T_S}\right) \left(\frac{P_S}{29.92" \ Hg}\right)$$

$$Q_{SD} = Q_{SW}(DGF)$$

Where: V_S = Stack gas velocity (ft/sec)

K_P = Pitot Tube Constant, $85.49 \ \frac{ft}{sec} \sqrt{\frac{(lb/lb \ mol)(" \ Hg)}{(°R)("H_2O)}}$

C_P = Pitot Tube Coefficient, 0.84 (dimensionless)

Δp = Velocity Head of Stack Gas, ("H₂O)

T_S = Stack Temperature (°R)

P_S = Absolute Stack Pressure ("Hg)

M_S = Molecular weight of stack gas, wet basis (lb/lb-mole)

Q_W = Stack Gas Wet Volumetric Flow at Stack Conditions (ft³/min)

Q_{SW} = Stack Gas Wet Volumetric Flow at Standard Conditions (ft³/min)

A_S = Stack Area (ft²)

Q_{SD} = Stack Gas Flow @ Std. Conditions, dry basis (dscf/min)

DGF = Dry Gas Fraction

VOLUMETRIC FLOW EXAMPLE CALCULATION (M5/26A RUN 1)

$$V_S = \left(85.49 \ \frac{ft}{sec} \sqrt{\frac{(lb/lb \ mol)(" \ Hg)}{(°R)("H_2O)}}\right)(0.84)(0.27 \ "H_2O) \sqrt{\frac{821.5 \ °R}{(29.97 \ " \ Hg)(28.37 \ lb/lb \ mol)}} = \underline{18.88 \ ft/sec}$$

$$Q_W = \left(\frac{18.88 \ ft}{sec}\right)\left(\frac{6.61 ft^2}{1}\right)\left(\frac{60 \ sec}{min}\right)\left(\frac{60 \ min}{1 \ hr}\right) = \underline{4.48 \ x \ 10^5 \ acfh}$$

$$Q_{WS} = \left(\frac{4.48 \ x \ 10^5 \ acf}{hr}\right)\left(\frac{528 \ °R}{821 \ °R}\right)\left(\frac{29.71 \ " \ Hg}{29.92" \ Hg}\right) = \underline{2.86 \ x \ 10^5 \ scfh}$$

$$Q_{SD} = (2.86 \ x \ 10^5 \ scfh)(0.91) = \underline{2.58 \ x \ 10^5 \ dscfh}$$

Analyzer Calibration Error Calculations

The calibration error test consisted of challenging each reference monitor at three measurement points against known calibration gas values. Calibration error for the reference is calculated using the following equation:

$$CE_{RM} = \frac{|Analyzer\ Response - Calibration\ Gas\ Value|}{Span\ of\ Analzyer} \times 100$$

Reference O_2 Calibration Error Example (Run 1)

$$CE_{RM} = \frac{|(0.0\ \%) - (0.07\ \%)|}{(19.72\ \%)} \times 100 = \underline{0.4\ \%}$$

$$CE_{RM} = \frac{|(19.69\ \%) - (19.72\ \%)|}{(19.72\ \%)} \times 100 = \underline{0.2\ \%}$$

$$CE_{RM} = \frac{|(9.92\ \%) - (9.89\ \%)|}{(19.72\ \%)} \times 100 = \underline{0.1\ \%}$$

System Calibration Bias Calculations

The system bias calibration test consisted of challenging the reference sample system at two measurement points against the local calibration values. Calibration bias calculations for the reference sample system are calculated using the following equation:

$$CB_{RM} = \frac{System\ Calibration\ Response - Analzyer\ Calibration\ Response}{Span\ of\ Analzyer} \times 100$$

Reference O$_2$ Initial System Bias Example (Run 1)

$$CB_{RM} = \frac{|(0.08\%) - (0.07\ \%)|}{(19.72\ \%)} \times 100 = \underline{0.1\ \%}$$

$$CB_{RM} = \frac{|(9.75\ \%) - (9.92\ \%)|}{(19.72\ \%)} \times 100 = \underline{-0.9\ \%}$$

Calibration Drift Calculations

The calibration drift tests were conducted at the beginning and end of each run. Analyzer maintenance, repair or adjustment could not be completed until the system calibration response was recorded. Calibration drift for the reference is calculated using the following equation:

$$CD_{RM} = \frac{|Final\ System\ Cal\ Response - Initial\ System\ Cal\ Response|}{Span\ of\ Analzyer} \times 100$$

Reference O$_2$ Calibration Drift Run #1 Example

$$CD_{RM} = \frac{|(-0.8\ \%) - (0.9\ \%)|}{(19.72\ \%)} \times 100 = \underline{0.1\ \%}$$

$$CD_{RM} = \frac{|(9.75\ \%) - (9.77\ \%)|}{(19.72\ \%)} \times 100 = \underline{-0.8\ \%}$$

System Calibration Drift Correction

The gas concentrations are corrected for the system calibration bias. The concentrations are calculated using the following equations:

$$C_{Gas} = (\overline{C} - C_O)\left(\frac{C_{MA}}{C_M - C_O}\right)$$

where: C_{Gas} = Effluent Concentration, dry ppm or %
      $\overline{C}$ = Average Analyzer Concentration, ppm or %
      C_O = Average Initial and Final System Calibration
          Responses for Zero Gas, ppm or %
      C_M = Average Initial and Final System Calibration
          Responses for Upscale Calibration Gas, ppm or %
      C_{MA} = Actual Concentration of Upscale Calibration Gas, ppm or %

O$_2$ System Calibration Drift Correction for Run #1 Example

$$C_{Gas} = (12.21\ \% - 0.09\ \%)\left(\frac{9.89\ \%}{9.76\ \% - 0.09\ \%}\right) = \underline{12.39\ \%}$$

PCDD/PCDF Total Toxicity Equivalents Rate Example Calculation

Toxic Equivalents, or TEQs, are used to report the toxicity-weighted masses of mixtures of dioxins. The TEQ method of dioxin reporting is more meaningful than simply reporting the total number of grams of a mixture of variously toxic compounds because the TEQ method offers toxicity information about the mixture.

Within the TEQ method, each dioxin compound is assigned a Toxic Equivalency Factor, or TEF (see the table below). This factor denotes a given dioxin compound's toxicity relative to 2,3,7,8-TCDD, which is assigned the maximum toxicity designation of one. Other dioxin compounds are given equal or lower numbers, with each number roughly proportional to its toxicity relative to that of 2,3,7,8-TCDD. Developed by the World Health Organization, TEFs are used extensively by scientists and governments around the world. The EPA uses units of grams-TEQ to report emissions of dioxins from known sources to the open environment in its Inventory of Sources of Dioxin in the United States.

To obtain the number of grams-TEQ of a dioxin mixture, one simply multiplies the mass of each compound in the mixture by its TEF and then totals them.

Analyte	Toxicity Equivalent Factor
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	0.5
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.001
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.001

2,3,7,8-TCDD Correction for Run #1 Example

$$2,3,7,8 - TCDD_{TEQCor} = (< 1.02\,pg)\big(1_{TEQFactor}\big) = \underline{< 1.02\,pg}$$

Total Toxicity Equivalents Conversion

All PCDD/PCDF are summed to provide a "Total Toxicity Equivalent". This total "TEQ" is converted from picograms to nanograms. The emission value in nanograms is then adjusted based on a sample flow rate at 7% oxygen.

$$Total\ TEQ = \left(\frac{concentration\ pg}{1}\right)\left(\frac{1\ ng}{1000\ pg}\right)\left(\frac{1}{sample\ volume\ dscm}\right)$$

$$TEQ_{Corr} = TEQ \times \left(\frac{11.36\ \%}{20.9\% - Corrected\ Raw\ O2\ Value}\right)$$

Emission Concentration Example Run#1

$$Total\ TEQ = \left(\frac{<3.9\ pg}{1}\right)\left(\frac{1\ ng}{1000\ pg}\right)\left(\frac{1}{143.083\ dscf}\right)\left(\frac{1\ dscf}{0.028317\ dscm}\right) = \underline{<0.0097\ ng/dscm}$$

$$TEQ_{Corr} = <0.0097\ ng/dscm \times \left(\frac{20.9\% - 7\ \%}{20.9\% - 11.36\%}\right) = \underline{<0.0014\ ng/dscm\ @\ 7\%O_2}$$

6. Field test Data

Analytical Results of Particulate Matter in Stack Gas

	Run 1	Run 2	Run 3	Average
Date	5-Jun-19	7-Jun-19	7-Jun-19	
Time	14:30-18:40	08:20-11:13	16:30-19:20	
Volume Collected (dscf)	42.284	42.697	45.070	
Flow Rate (dscfm)	4,303	4,387	4,566	
Oxygen Concentration (%)	12.29	12.40	12.70	
Particulate Matter Found (mg)				
Filter	<0.5	<0.5	<0.5	
Probe and Nozzle Rinse	4.96	1.37	0.86	
Front Half Total	5.50	1.90	1.40	
Full Train Total	<5.5	<1.9	<1.4	
Stack Gas Loading - Front Half Only				
Particulate Matter (mg/dscf)	<0.13	<0.044	<0.030	<0.068
Particulate Matter (mg/dscm)	<4.6	<1.5	<1.1	<2.4
Particulate Matter (mg/dscm, corrected to 7% O_2)	<7.4	<2.5	<1.8	<3.9
Stack Gas Loading - Full Train				
Particulate Matter (mg/dscf)	<0.13	<0.044	<0.030	<0.068
Particulate Matter (mg/dscm)	<4.6	<1.5	<1.1	<2.4
Particulate Matter (mg/dscm, corrected to 7% O_2)	<7.4	<2.5	<1.8	<3.9
Emission Standard (mg/dscm @ 7% O_2)				110
Mass Emission Rate (lb/hr)				
Front Half Only	<0.073	<0.025	<0.018	<0.039
Full Train	<0.073	<0.025	<0.018	<0.039

Analytical Results of HCl and Cl$_2$ in Stack Gas

	Run 1	Run 2	Run 3	
Date	6/5/2019	6/7/2019	6/7/2019	
Time	14:30-18:40	08:20-11:13	16:30-19:20	
Volume (dscf)	42.284	42.697	45.070	
Flow Rate (dscfm)	4,303	4,387	4,566	
Oxygen (%)	12.29	12.40	12.70	
Mass Found (ug)				
Hydrogen chloride	<74.6	<65.7	<58	
Concentration (mg/dscf)				
Hydrogen chloride	<0.0018	<0.0015	<0.0013	<0.0015
Concentration (chloride equivalents ppmvd)				
Hydrogen chloride	<0.041	<0.036	<0.030	<0.036
Total	<0.041	<0.036	<0.030	<0.036
Concentration (Chloride equivalents, ppmvd, corrected to 7% O$_2$)				
Total	<0.066	<0.058	<0.051	<0.058
Emission Standard (chloride equivalents, ppmvd, corrected to 7% O$_2$)				14
Mass Emission Rate (lb/hr)				
HCl Emissions Rate (lbs/hr)	<0.0010	<0.00089	<0.00078	<0.00089

Analytical Results of PCDDs/PCDFs in Stack Gas

		Run 1	Run 2	Run 3
Date		5-Jun-19	6-Jun-19	7-Jun-19
Time		09:30-13:59	08:15-12:38	11:40-16:02
Volume (dscf)		143.083	151.340	146.369
Flow Rate (dscfm)		4089.805253	4326.56382	4200.748527
Oxygen Concentration (%)		11.52713265	12.59648524	12.64870094
Analyte	**Toxicity Equivalent Factor**	**Mass Found (pg)**		
2,3,7,8-TCDD	1	<1.02	2.63*	2.14*
1,2,3,7,8-PeCDD	0.5	<1.42	<0.932	<1.33
1,2,3,4,7,8-HxCDD	0.1	<1.69	<1.59	<1.79
1,2,3,6,7,8-HxCDD	0.1	<1.59	<1.5	<1.68
1,2,3,7,8,9-HxCDD	0.1	<1.65	<1.56	<1.75
1,2,3,4,6,7,8-HpCDD	0.01	6.54	3.87	3.29
OCDD	0.001	37.3	13*	11.9*
2,3,7,8-TCDF	0.1	<1.35	<1.32	<1.47
1,2,3,7,8-PeCDF	0.05	<1.53	<1.17	<1.09
2,3,4,7,8-PeCDF	0.5	<1.59	<1.22	<1.13
1,2,3,4,7,8-HxCDF	0.1	1.55*	<1.01	<0.837
1,2,3,6,7,8-HxCDF	0.1	<0.998	<0.883	<0.729
1,2,3,7,8,9-HxCDF	0.1	<1.31	<1.16	<0.956
2,3,4,6,7,8-HxCDF	0.1	<1.18	<1.04	<0.861
1,2,3,4,6,7,8-HpCDF	0.01	6.26	<0.624	<0.924
1,2,3,4,7,8,9-HpCDF	0.01	<0.727	<0.719	<1.07
OCDF	0.001	7.63	2.75	<2.52
Total Toxicity Equivalents		0.173	0.0415	0.0329
Concentration (ng TEQ/dscf)		0.00000121	0.000000274	0.000000225
Concentration (ng TEQ/dscm)		0.0000427	0.00000967	0.00000794
Concentration (ng TEQ/dscm @ 7% O_2)		0.0000633	0.0000162	0.0000134
Average Concentration (ng TEQ/dscm @ 7% O_2)		0.0000310		
Total Toxicity Equivalents		<3.9	<4.8	<4.5
Concentration (ng TEQ/dscf)		<0.000027	<0.000032	<0.000031
Concentration (ng TEQ/dscm)		<0.00097	<0.0011	<0.0011
Concentration (ng TEQ/dscm @ 7% O_2)		<0.0014	<0.0019	<0.0018
Average Concentration (ng TEQ/dscm @ 7% O_2)		<0.0017		
Emission Standard (ng TEQ/dscm @ 7% O_2)		0.32		

Analytical Results of Metals in Stack Gas

	Run 1	Run 2	Run 3	Average
Date	6/5/2019	6/7/2019	6/7/2019	
Time	14:30-18:40	08:20-11:13	16:30-19:20	
Volume Collected (dscf)	87.076	81.455	80.484	
Stack Gas Flow Rate (dscfm)	4,546	4,295	4,257	
Oxygen Concentration (%)	12.5	12.4	12.7	
Mass Found (µg)				
Cadmium	<0.15	<0.14	<0.14	
Lead	3.15	3.66	3.06	
Mercury	<0.76	<0.45	<0.46	
Stack Gas Concentration (µg/dscf)				
Cadmium	<0.0018	<0.0017	<0.0018	<0.0017
Lead	0.0362	0.0449	0.0380	0.0397
Mercury	<0.0088	<0.0055	<0.0057	<0.0066
Stack Gas Concentration (µg/dscm)				
Cadmium	<0.062	<0.061	<0.062	<0.062
Lead	1.28	1.58	1.34	1.40
Mercury	<0.31	<0.19	<0.20	<0.23
Stack Gas Concentration (µg/dscm, 7% O2)				
Cadmium	<0.10	<0.10	<0.11	<0.10
Lead	2.11	2.60	2.28	2.33
Mercury	<0.51	<0.32	<0.34	<0.39
Stack Gas Concentration (mg/dscm, 7% O2)				
Cadmium	<0.0001	<0.0001	<0.00011	<0.0001
Lead	0.00211	0.0026	0.00228	0.00233
Mercury	<0.00051	<0.00032	<0.00034	<0.00039