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The Dow Chemical Company, Michigan Operations

CISWI Compliance Testing
1130 Building Specialty Monomers, EU95-S1 Tar Incinerator

MI-ROP-A4033

September 14, 2018

Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
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Distribution List

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1. Introduction

1.1 Summary of Test Program

AECOM Technical Services Inc. (AECOM) was contracted by Dow Chemical (Dow) in Midland Michigan, Specialty Monomers (Spec Mono) Plant to conduct Performance testing on their Tar Incinerator (EU95) during the week of July 16th, 2018. The performance testing consisted of measurements for nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO₂), 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 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	144 and 160 min	110 mg/dscm @ 7% O ₂	10.8 mg/dscm @ 7% O ₂
SO ₂	EPA Method 6C	60 min	720 ppmv @ 7% O ₂	0.01 ppmv @ 7% O ₂
NO _x	EPA Method 7E	60 min	76 ppmv @ 7% O ₂	62 ppmv @ 7% O ₂
CO	EPA Method 10	60 min	35 ppmv @ 7% O ₂	<0.1 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)	0.116 ng/dscm @ 7% O ₂ (total) - or - 0.0067 ng/dscm @ 7% O ₂ (TEQ)
HCl	EPA Method 26A	144 and 160 min	14 ppmv @ 7% O ₂	0.34 ppmv @ 7% O ₂
Cd	EPA Method 29	144 and 160 min	0.023 mg/dscm @ 7% O ₂	<0.0005 mg/dscm @ 7% O ₂
Pb	EPA Method 29	144 and 160 min	0.096 mg/dscm @ 7% O ₂	<0.0022 mg/dscm @ 7% O ₂
Hg	EPA Method 29	144 and 160 min	0.0024 mg/dscm @ 7% O ₂	<0.00051 mg/dscm @ 7% O ₂

¹Results 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: Subpart DDDD—Emissions Guidelines and Compliance Times for Commercial and Industrial Solid Waste Incineration Units.

In accordance with the requirements of 40 CFR 60 Subpart DDDD, each affected unit must conduct an annual performance test. The requirements of that testing is outlined in 40 CFR 60.2690 and in tables 2 or 6-9, depending on the specific mechanism by the unit is affected.

The following table summarizes the pertinent data for this compliance test:

Responsible Groups	<ul style="list-style-type: none"> • The Dow Chemical Company • Michigan Department of Environmental Quality (MDEQ) • Environmental Protection Agency (EPA)
Applicable Regulations	<ul style="list-style-type: none"> • MI-ROP-A4033 • 40 CFR Part 60 Commercial and Industrial Solid Waste Incineration Units MACT (Subpart DDDD)
Industry/Plant	<ul style="list-style-type: none"> • Specialty Monomers, 1130 Building
Plant Location	<ul style="list-style-type: none"> • The Dow Chemical Company Midland, Michigan 48667
Unit Initial Start-up	<ul style="list-style-type: none"> • 1989
Air Pollution Control Equipment	<ul style="list-style-type: none"> • N/A
Emission Points	<ul style="list-style-type: none"> • EU-95 Tar Incinerator (EU95-S1)
Pollutants/Diluent Measure	<ul style="list-style-type: none"> • Particulate Matter (PM) • Sulfur Dioxide (SO₂) • Nitrogen Oxides (NO_x) • Carbon Monoxide (CO) • Polychlorinated Dibenzodioxins (PCDDs) • Polychlorinated Dibenzofurans (PCDFs) • Hydrogen Chloride (HCl) • Lead/Cadmium/Mercury (Pb/Cd/Hg) • Oxygen (O₂)
Test Dates	<ul style="list-style-type: none"> • July 19-21, 2018

1.3 Key Personnel

The key personnel coordinating this test program were:

- Cody Lindemulder, Laura Allington and Katie Frankowski provided support as the Process Focal Point(s). 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.
- Jennifer Kraut, Colleen Rosenbrock and Michelle Kendall provided support as the Environmental Focal Points for this test. The Environmental Focal Point is 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.
- Daniel J Nuñez 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, Matthew Newland and James Edmister also assisted as sampling technicians.

2. Plant and Sampling Location Descriptions

2.1 Facility Description

The Dow Chemical Company (DOW) 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, 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 Table 3-1. During each test run CMS parameters were monitored and stack gas emissions were measured. The following sections briefly summarize these 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 hourly average value was calculated for each test run.

Figure 1 EU95 Tar Incinerator Process Schematic

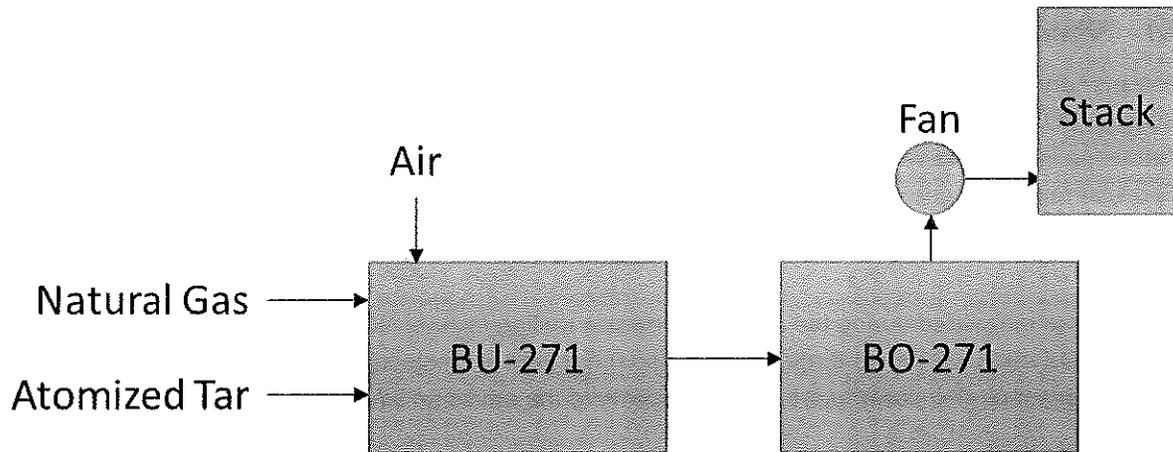


Table 2-1 Manufacturer's Name and Model Number

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 was to demonstrate compliance with the requirements of 40 CFR 60 Subpart DDDD. The performance testing of the Incinerator Stack NOX, CO, SO₂, PM, D/F, HCl and metals emissions was performed in 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 Dow Chemical Specialty Monomers Plant.

Parameters measured during the July performance testing include NOX, CO, SO₂, PM, D/F, HCl and metals. O₂ and CO₂ concentrations were also 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 July 19-21, 2018 under normal process operating conditions. The emission testing of the Incinerator Stack consisted of three (3) test runs each for NO_x, CO, SO₂, PM, D/F, HCl and metals.

3.2 Process Operating Rates

As required by the regulation and MDEQ guidance, all sampling is to be 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
Tars Feed Rate (lb/hr)	180-420	230-285
Natural Gas Feed Rate (scfh)	2095-4834**	2100-2500
O ₂ in Vent Stack (%)	9-15	12-14

**3900 – 9000 scfh natural gas feed rate proposed in the test plan.

It was identified after the performance test that the natural gas flowmeters were scaled incorrectly. The corrected natural gas flow rates from the testing are represented in the table above. The effect of correcting the natural gas flow is a change to the operating range of the natural gas flow from what was originally stated in the test plan. This change is reflected in the table above for both the normal operating rate and the operating rate during the test.

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

	Run 1	Run 2	Run 3	Average
Run Date	7/19/2018	7/20/2018	7/21/2018	
Run Times	08:45-11:40	08:31-11:31	07:45-11:00	
Stack Gas Wet Flow (cf/hr)	555,751	535,696	564,850	552,099
Stack Gas Wet Flow Std. Cond. (scf/hr)	345,968	331,362	348,071	341,800
Stack Gas Dry Flow Std. Cond. (dscf/hr)	318,301	306,493	319,858	314,884
Volume Gas Collected (dscf)	72.092	81.064	80.504	77.887
Stack Gas O ₂ (%)	13.79	13.64	13.54	
HCl				
Mass Found (µg)	45.7	31.1	104	45.7
Concentration (mg/dscf)	0.000634	0.000384	0.00129	0.000770
Concentration (ppmdv)	0.0148	0.00894	0.0301	0.0179
Concentration (ppmdv @ 7%O ₂)	0.0287	0.0170	0.0565	0.0341
PM				
Mass Found (mg)				
Probe and Nozzle Rinse	0.06	0.08	0.05	
Filter	11.21	14.05	11.83	
Total	11.3	14.1	11.9	
Loading (mg/dscm)	5.52	6.16	5.21	5.63
Loading (mg/dscm) @ 7% O ₂)	10.8	11.8	9.85	10.8

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

	Run 1	Run 2	Run 3	Average
Run Date	7/19/2018	7/20/2018	7/21/2018	
Run Times	08:46-11:41	08:30-11:30	07:46-11:01	
Stack Gas Wet Flow (cf/hr)	567,694	536,632	554,275	552,867
Stack Gas Wet Flow Std. Cond. (scf/hr)	353,826	335,222	348,797	345,948
Stack Gas Dry Flow Std. Cond. (dscf/hr)	323,115	307,402	320,048	316,855
Volume Gas Collected (dscf)	70.441	76.428	83.197	70.441
Stack Gas O ₂ (%)	13.79	13.64	13.54	
Mass Found (µg)				
Cadmium (Cd)	1.15	0.281	<0.16	
Lead (Pb)	2.89	2.84	<1.5	
Mercury (Hg)	<0.49	<0.73	<0.53	
Concentration (ug/dscm)				
Cadmium (Cd)	0.578	0.130	<0.067	<0.26
Lead (Pb)	1.45	1.31	<0.65	<1.1
Mercury (Hg)	<0.24	<0.34	<0.23	<0.27
Concentration (mg/dscm @ 7%O ₂)				
Cadmium (Cd)	0.00113	0.000249	<0.00013	<0.0005
Lead (Pb)	0.00283	0.00251	<0.0012	<0.0022
Mercury (Hg)	<0.00048	<0.00064	<0.00042	<0.00051

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

	TEF	Run 1	Run 2	Run 3	Average
Run Date		7/19/2018	7/20/2018	7/21/2018	
Run Times		13:00-17:33	12:30-16:58	11:50-16:18	
Stack Gas Wet Flow (cf/hr)		511,655	521,609	529,741	521,002
Stack Gas Wet Flow Std. Cond. (scf/hr)		318,302	321,501	326,862	322,222
Stack Gas Dry Flow Std. Cond. (dscf/hr)		296,627	298,681	301,846	299,052
Volume Gas Collected (dscf)		119.630	145.830	147.919	137.793
Stack Gas O ₂ (%)		13.79	13.64	13.54	
Dioxin/Furan (D/F)					
Mass Found (pg)					
2,3,7,8-TCDD	1	<3.42	<8.39	<2.58	
1,2,3,7,8-PeCDD	0.5	<4.11	<3.19	<4.27	
1,2,3,4,7,8-HxCDD	0.1	<5.78	<3.06	<3.82	
1,2,3,6,7,8-HxCDD	0.1	<5.46	<2.89	<3.61	
1,2,3,7,8,9-HxCDD	0.1	<5.47	<2.89	<3.62	
1,2,3,4,6,7,8-HpCDD	0.01	12.8	<8.95	13.1	
OCDD	0.001	59.1	44.8	63.9	
2,3,7,8-TCDF	0.1	<3.99	<3.41	<2.42	
1,2,3,7,8-PeCDF	0.05	<5.52	<4.78	<3.31	
2,3,4,7,8-PeCDF	0.5	<5.66	<4.90	6.29	
1,2,3,4,7,8-HxCDF	0.1	<2.73	6.93	<6.87	
1,2,3,6,7,8-HxCDF	0.1	<2.42	5.76	7.85	
1,2,3,7,8,9-HxCDF	0.1	<3.09	<2.81	<2.73	
2,3,4,6,7,8-HxCDF	0.1	<2.72	<2.47	<5.48	
1,2,3,4,6,7,8-HpCDF	0.01	24.0	26.3	49.2	
1,2,3,4,7,8,9-HpCDF	0.01	<3.45	<4.00	10.1	
OCDF	0.001	50.3	40.1	109	
Total D/F		<200	<176	<298	
Total TEQ		<12.3	<16.2	<12.6	
Concentration (ng/dscm)					
Total D/F ¹		<0.059	<0.043	<0.071	
Total TEQ ¹		<0.0036	<0.0039	<0.0030	
Concentration (ng/dscm @ 7% O ₂)					
Total D/F		<0.116	<0.081	<0.131	<0.116
Total TEQ		<0.0071	<0.0075	<0.0055	<0.0067

¹Total developed by summing all "not-detects"

Table 3-5 Testing Run Data (NO_x, CO and SO₂)

	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Average
Run Date	7/19/2018	7/19/2018	7/19/2018	7/19/2018	7/19/2018	7/19/2018	
Run Times	0845-0945	0946-1046	1047-1147	1357-1457	1512-1612	1613-1713	
Stack Gas O ₂ (%)	13.81	13.79	13.76	13.82	13.81	13.76	
Nitrogen Oxides ¹							
ppmdv	--	--	--	31.8	32.7	32.7	31.8
ppmdv @7% O ₂	--	--	--	62.54	64.15	64.60	62.54
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	0.03	0.09	0.0	--	--	--	0.04
ppmdv @7% O ₂	0.06	0.18	0.0	--	--	-	0.08

¹The NO_x analyzer failed the post-run bias check following Run 3, therefore it was re-calibrated and additional test runs were performed.

4. Sampling and Analytical Procedures

4.1 Sample Time

The duration of each test run for instrumental methods (NO_x, CO and SO₂) test runs was sixty (60) minutes in duration. For "wet-method" isokinetic methods (PM, D/F, HCl and metals) test runs times are shown below:

- PM/HCl: 144 minutes (Run 1) and 160 minutes (Runs 2 and 3)
- D/F: 256 minutes
- Pb/Cd/Hg: 144 minutes (Run 1) and 160 minutes (Runs 2 and 3)

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 an inside diameter of 35 inches at the elevation of the sampling points. The sampling ports are approximately 64 inches downstream from the closest disturbance (stack breach) and 108 inches upstream from the next nearest disturbance (stack exit). The number of sampling points at this port location was 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 the purpose of 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 H₂SO₄. 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% HNO₃ and 10% H₂O₂. The third impinger is empty. The fourth and fifth impingers contain a solution of 4% KMnO₄ and 10% H₂SO₄. 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.

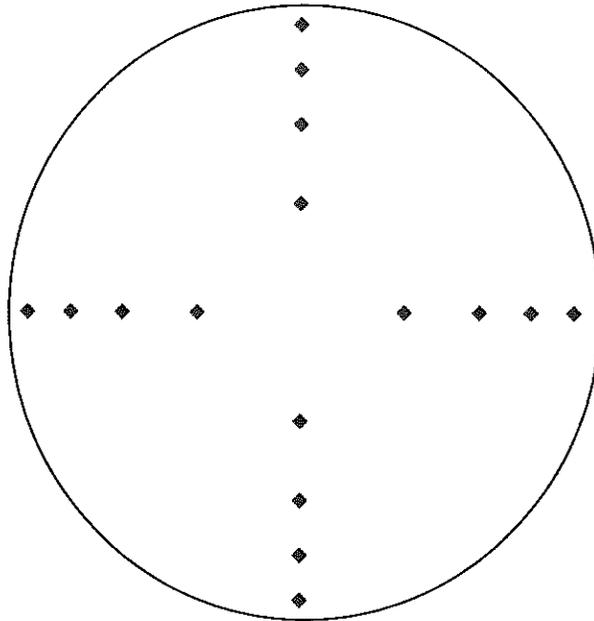
Method compliance is ensured by performing:

- 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 (O₂/CO₂) - Teledyne model 300M; paramagnetic
- EPA Method 6C (SO₂) - 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.

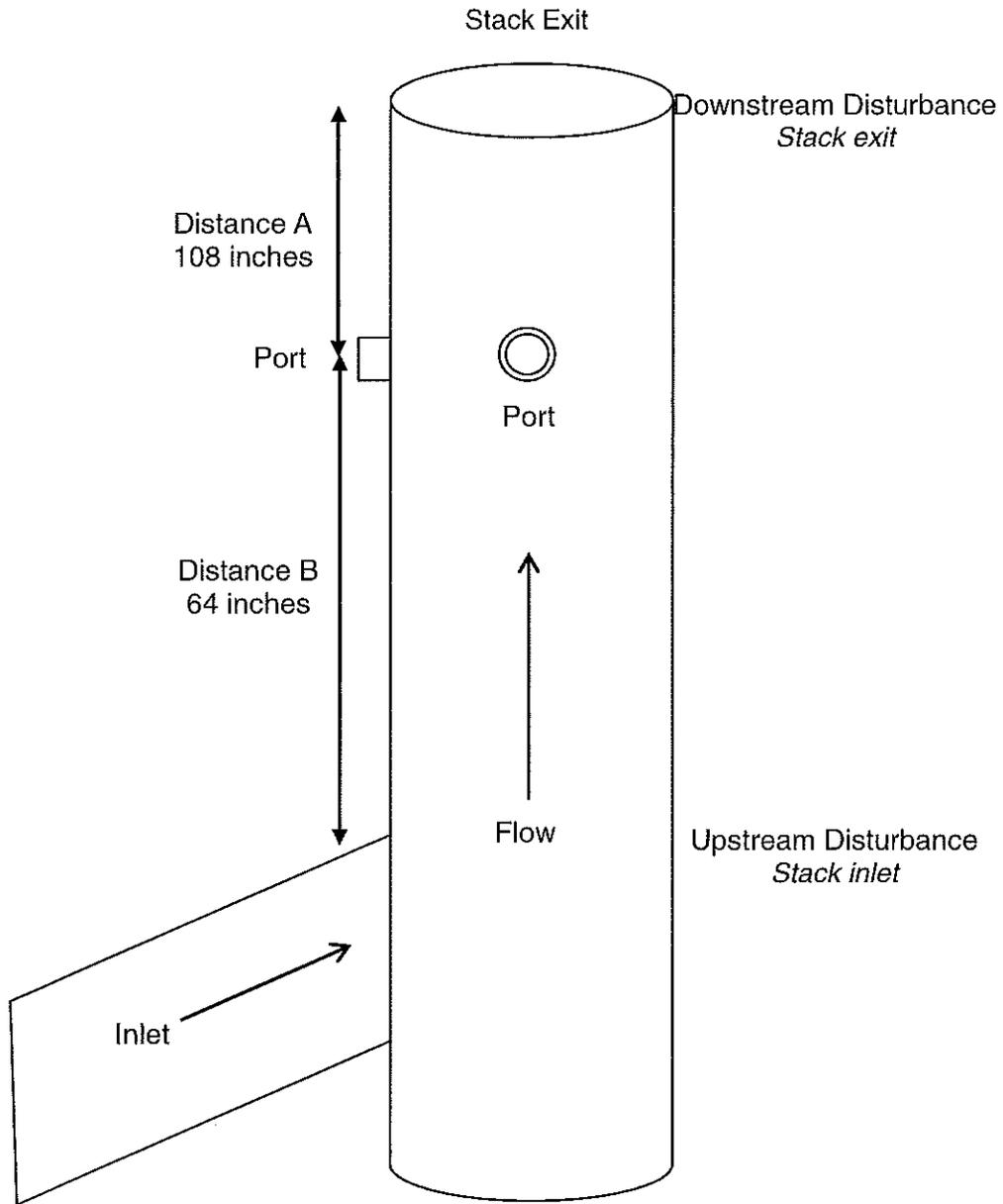
Figure 2 Sample Points



Stack Diameter 2.9 feet

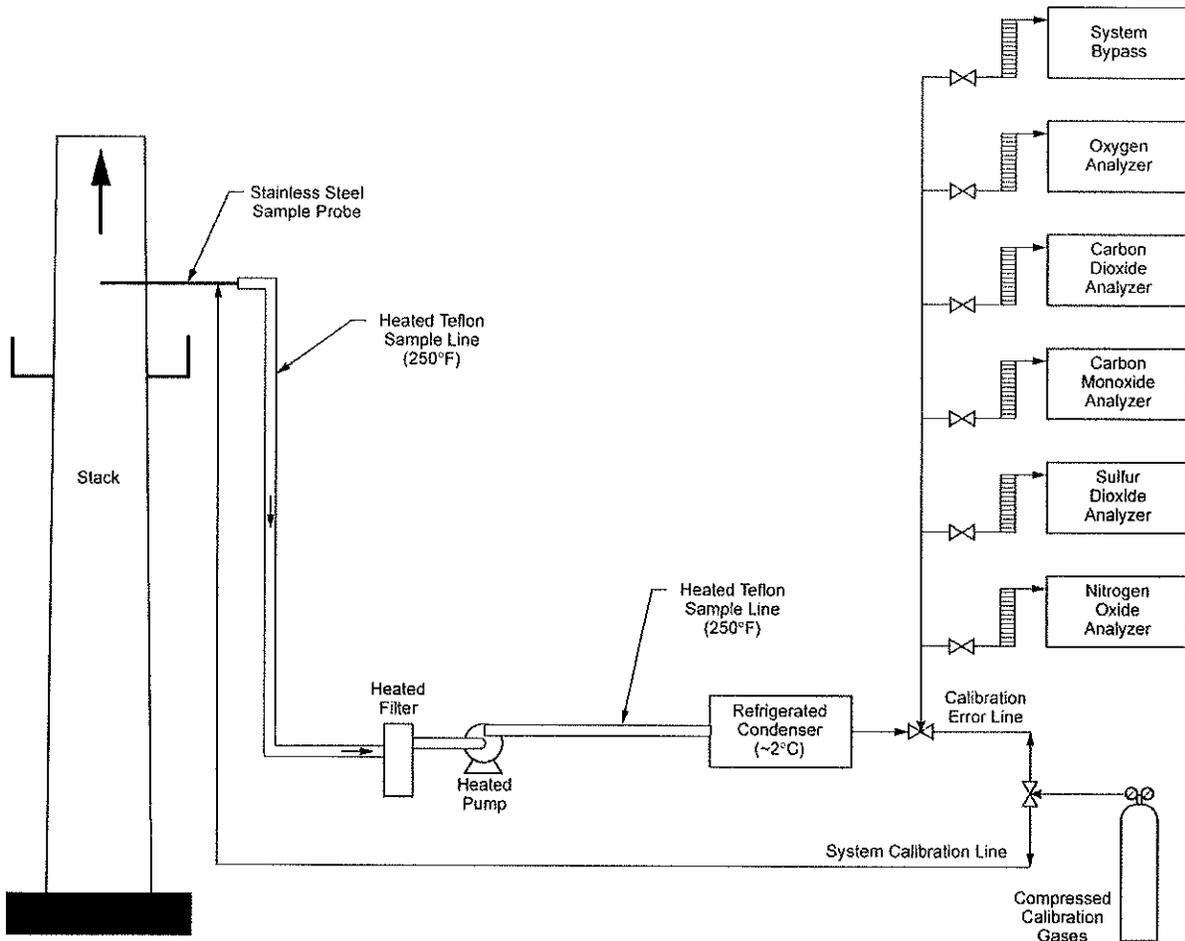
Point	Percentage of Diameter	Distance from Wall (feet)
1	3.2	0.09
2	10.5	0.31
3	19.4	0.57
4	32.3	0.94
5	67.7	1.97
6	80.6	2.35
7	89.5	2.61
8	96.8	2.82

Figure 3 Sample Location



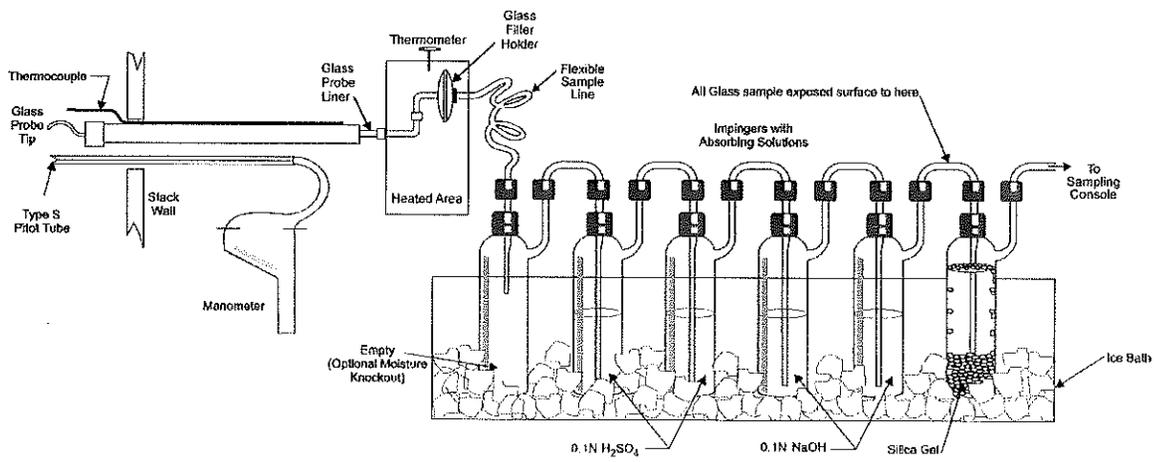
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Figure 4 Schematic of AECOM CEM System



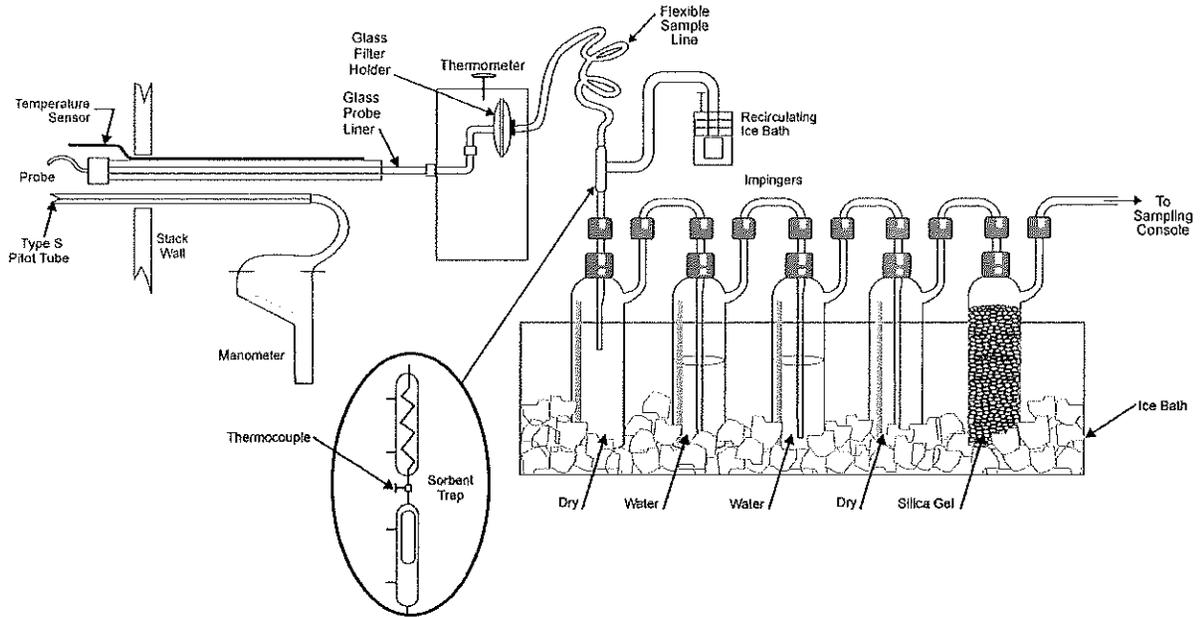
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Figure 5 Schematic of Method 5/26A Sample Train



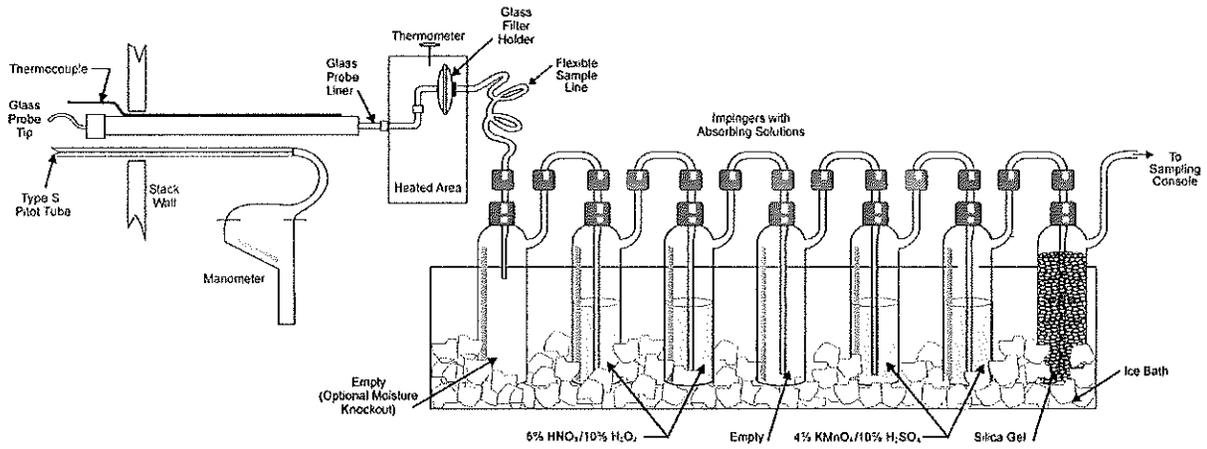
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Figure 6 Schematic of Method 23 Sample Train



AV/Graphic/Figures_testing/SV010.a_L_Oct_2014

Figure 7 Schematic of Method 29 Sample Train



AV/Graphic/Figures_testing/fig_11_1_07.a_L_Oct_2014

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:

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

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

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

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

Where: V_S	= Stack gas velocity (ft/sec)
K_P	= Pitot Tube Constant, $85.49 \frac{ft}{sec} \sqrt{\frac{(lb/lb \text{ mol})(\text{" Hg})}{(\text{ }^\circ R)(\text{" H}_2\text{O})}}$
C_P	= Pitot Tube Coefficient, 0.84 (dimensionless)
Δp	= Velocity Head of Stack Gas, ("H ₂ O)
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 (ft ³ /min)
Q_{SW}	= Stack Gas Wet Volumetric Flow at Standard Conditions (ft ³ /min)
A_S	= Stack Area (ft ²)
Q_{SD}	= Stack Gas Flow @ Std. Conditions, dry basis (dscf/min)
DGF	= Dry Gas Fraction

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

$$V_S = \left(85.49 \frac{ft}{sec} \sqrt{\frac{(lb/lb \text{ mol})(\text{" Hg})}{(\text{ }^\circ R)(\text{" H}_2\text{O})}} \right) (0.84)(0.33 \text{ " H}_2\text{O}) \sqrt{\frac{834 \text{ }^\circ R}{(29.43 \text{ " Hg})(28.4 \text{ lb/lb mol})}} = \underline{23.37 \text{ ft/sec}}$$

$$Q_W = \left(\frac{23.37 \text{ ft}}{sec} \right) \left(\frac{6.61 \text{ ft}^2}{1} \right) \left(\frac{60 \text{ sec}}{min} \right) \left(\frac{60 \text{ min}}{1 \text{ hr}} \right) = \underline{5.56 \times 10^5 \text{ acfh}}$$

$$Q_{WS} = \left(\frac{5.56 \times 10^5 \text{ acf}}{hr} \right) \left(\frac{528 \text{ }^\circ R}{834 \text{ }^\circ R} \right) \left(\frac{29.43 \text{ " Hg}}{29.92 \text{ " Hg}} \right) = \underline{3.46 \times 10^5 \text{ scfh}}$$

$$Q_{SD} = (3.46 \times 10^5 \text{ scfh})(0.92) = \underline{3.18 \times 10^5 \text{ dscfh}}$$

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:

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

Reference O₂ Calibration Error Example (Run 1)

$$CE_{RM} = \frac{|(0.0\%) - (-0.11\%)|}{(19.94\%)} \times 100 = \underline{0.6\%}$$

$$CE_{RM} = \frac{|(19.91\%) - (19.94\%)|}{(19.94\%)} \times 100 = \underline{0.2\%}$$

$$CE_{RM} = \frac{|(9.95\%) - (9.98\%)|}{(19.94\%)} \times 100 = \underline{0.2\%}$$

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:

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

Reference O₂ Initial System Bias Example (Run 1)

$$CB_{RM} = \frac{|(0.0\%) - (-0.11\%)|}{(19.94\%)} \times 100 = \underline{0.6\%}$$

$$CB_{RM} = \frac{|(9.95\%) - (9.88\%)|}{(19.94\%)} \times 100 = \underline{-0.4\%}$$

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:

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

Reference O₂ Calibration Drift Run #1 Example

$$CD_{RM} = \frac{|(0.0\%) - (0.0\%)|}{(19.94\%)} \times 100 = \underline{0.0\%}$$

$$CD_{RM} = \frac{|(9.66\%) - (9.88\%)|}{(19.94\%)} \times 100 = \underline{-1.1\%}$$

System Calibration Drift Correction

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

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

- where:
- C_{Gas} = Effluent Concentration, dry ppm or %
 - \bar{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 %

O₂ System Calibration Drift Correction for Run #1 Example

$$C_{Gas} = (13.51 \% - 0.0 \%) \left(\frac{9.98 \%}{9.77 \% - 0.0 \%} \right) = \underline{13.81 \%}$$

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

$$2,3,7,8 - TCDD_{TEQCor} = (< 3.42 \text{ pg})(1_{TEQFactor}) = < 3.42 \text{ pg}$$

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.

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

$$TEQ_{corr} = TEQ \times \left(\frac{13.9\ \%}{20.9\ \% - Corrected\ Raw\ O_2\ Value} \right)$$

Emission Concentration Example Run#1

$$Total\ TEQ = \left(\frac{< 12.3\ pg}{1} \right) \left(\frac{1\ ng}{1000\ pg} \right) \left(\frac{1}{119.630\ dscf} \right) \left(\frac{1\ dscf}{0.028317\ dscm} \right) = < 0.0036\ ng/dscm$$

$$TEQ_{corr} = < 0.0036\ ng/dscm \times \left(\frac{13.9\ \%}{20.9\ \% - 13.8\ \%} \right) = < 0.0071\ ng/dscm$$

6. Field test Data

Analytical Results of Particulate Matter in Stack Gas

	Run 1	Run 2	Run 3	Average
Date	19-Jul-18	20-Jul-18	21-Jul-18	
Time	08:45-11:40	08:31-11:31	07:45-11:00	
Volume Collected (dscf)	72.092	81.064	80.504	
Flow Rate (dscfm)	5,305	5,523	5,801	
Oxygen Concentration (%)	13.79	13.64	13.54	
Particulate Matter Found (mg)				
Filter	0.06	0.08	0.05	
Probe and Nozzle Rinse	11.21	14.05	11.83	
Front Half Total	11.3	14.1	11.9	
Full Train Total	11.3	14.1	11.9	
Stack Gas Loading - Front Half Only				
Particulate Matter (mg/dscf)	0.156	0.174	0.148	0.159
Particulate Matter (mg/dscm)	5.52	6.16	5.21	5.63
Particulate Matter (mg/dscm, corrected to 7% O ₂)	10.8	11.8	9.85	10.8
Stack Gas Loading - Full Train				
Particulate Matter (mg/dscf)	0.156	0.174	0.148	0.159
Particulate Matter (mg/dscm)	5.52	6.16	5.21	5.63
Particulate Matter (mg/dscm @ 7% O ₂)	10.8	11.8	9.85	10.8
Emission Standard (mg/dscm @ 7% O₂)				110
Mass Emission Rate (lb/hr)				
Front Half Only	0.110	0.127	0.113	0.117
Full Train	0.110	0.127	0.113	0.117

Analytical Results of HCl and Cl₂ in Stack Gas

	Run 1	Run 2	Run 3	Average
Date	7/19/2018	7/20/2018	7/21/2018	
Time	08:45-11:40	08:31-11:31	07:45-11:00	
Volume (dscf)	72.092	81.064	80.504	
Flow Rate (dscfm)	5,305	5,523	5,801	
Oxygen (%)	13.79	13.64	13.54	
Total Heat Input from Waste (mmBTU/hr)	0.0	0.0	0.0	
Mass Found (ug)				
Hydrogen chloride	45.7	31.1	104	
Chlorine	123	89.2	97.4	
Concentration (mg/dscf)				
Hydrogen chloride	0.000634	0.000384	0.00129	0.000770
Chlorine	0.00171	0.00110	0.00121	0.00134
Concentration (chloride equivalents ppmvd)				
Hydrogen chloride	0.0148	0.00894	0.0301	0.0179
Chlorine	0.0409	0.0264	0.0290	0.0321
Total	0.0556	0.0353	0.0591	0.0500
Concentration (Chloride equivalents, ppmvd, corrected to 7% O₂)				
Total	0.108	0.0672	0.111	0.0954
Emission Standard (chloride equivalents, ppmvd, corrected to 7% O₂)				
14				
Mass Emission Rate (lb/hr)				
HCl Emissions Rate (lbs/hr)	0.000445	0.000280	0.000991	0.000572
Cl Emissions Rate (lbs/hr)	0.00120	0.000804	0.000928	0.000977
Total Emissions Rate (lbs/hr) (as chlorine)	0.00163	0.00108	0.00189	0.00153

Analytical Results of Metals in Stack Gas

	Run 1	Run 2	Run 3	Average
Date	7/19/2018	7/20/2018	7/21/2018	
Time	08:46-11:41	08:30-11:30	07:46-11:01	
Volume Collected (dscf)	70.441	76.428	83.197	
Stack Gas Flow Rate (dscfm)	5,897	5,587	5,813	
Oxygen Concentration (%)	13.8	13.6	13.4	
Mass Found (µg)				
Cadmium	1.15	0.281	<0.16	
Lead	2.89	2.84	<1.5	
Mercury	<0.49	<0.73	<0.53	
Stack Gas Concentration (µg/dscf)				
Cadmium	0.0164	0.00368	<0.0019	<0.0073
Lead	0.0410	0.0372	<0.019	<0.032
Mercury	<0.0069	<0.0095	<0.0064	<0.0076
Stack Gas Concentration (µg/dscm)				
Cadmium	0.578	0.130	<0.067	<0.26
Lead	1.45	1.31	<0.65	<1.1
Mercury	<0.24	<0.34	<0.23	<0.27
Stack Gas Concentration (µg/dscm, 7% O₂)				
Cadmium	1.13	0.249	<0.13	<0.50
Lead	2.83	2.51	<1.2	<2.2
Mercury	<0.48	<0.64	<0.42	<0.51
Stack Gas Concentration (mg/dscm, 7% O₂)				
Cadmium	0.00113	0.000249	<0.00013	<0.0005
Lead	0.00283	0.00251	<0.0012	<0.0022
Mercury	<0.00048	<0.00064	<0.00042	<0.00051

D/F Stack Conc.

Analytical Results of PCDDs/PCDFs in Stack Gas

	Run 1	Run 2	Run 3	
Date	19-Jul-18	20-Jul-18	21-Jul-18	
Time	13:00-17:33	12:30-16:58	11:50-16:18	
Volume (dscf)	119.6296079	145.82977	147.9192744	
Flow Rate (dscfm)	5305.036494	5358.347348	5447.704681	
Oxygen Concentration (%)	13.82894557	13.61587164	13.32054957	
Analyte	Toxicity Equivalent Factor	Mass Found (pg)		
2,3,7,8-TCDD	1	<3.42	<8.39	<2.58
1,2,3,7,8-PeCDD	0.5	<4.11	<3.19	<4.27
1,2,3,4,7,8-HxCDD	0.1	<5.78	<3.06	<3.82
1,2,3,6,7,8-HxCDD	0.1	<5.46	<2.89	<3.61
1,2,3,7,8,9-HxCDD	0.1	<5.47	<2.89	<3.62
1,2,3,4,6,7,8-HpCDD	0.01	12.8	<8.95	13.1
OCDD	0.001	59.1	44.8	63.9
2,3,7,8-TCDF	0.1	<3.99	<3.41	<2.42
1,2,3,7,8-PeCDF	0.05	<5.52	<4.78	<3.31
2,3,4,7,8-PeCDF	0.5	<5.66	<4.90	6.29
1,2,3,4,7,8-HxCDF	0.1	<2.73	6.93	<6.87
1,2,3,6,7,8-HxCDF	0.1	<2.42	5.76	7.85
1,2,3,7,8,9-HxCDF	0.1	<3.09	<2.81	<2.73
2,3,4,6,7,8-HxCDF	0.1	<2.72	<2.47	<5.48
1,2,3,4,6,7,8-HpCDF	0.01	24.0	26.3	49.2
1,2,3,4,7,8,9-HpCDF	0.01	<3.45	<4.00	10.1
OCDF	0.001	50.3	40.1	109
Total Toxicity Equivalents		0.477	1.62	4.83
Concentration (ng TEQ/dscf)		0.00000399	0.0000111	0.0000326
Concentration (ng TEQ/dscm)		0.000141	0.000392	0.00115
Concentration (ng TEQ/dscm @ 7% O₂)		0.000277	0.000747	0.00211
Average Concentration (ng TEQ/dscm @ 7% O₂)		0.00105		
Total Toxicity Equivalents		12.3	16.2	12.6
Concentration (ng TEQ/dscf)		0.000102	0.000111	0.0000849
Concentration (ng TEQ/dscm)		0.00362	0.00392	0.00300
Concentration (ng TEQ/dscm @ 7% O₂)		0.00711	0.00747	0.00550
Average Concentration (ng TEQ/dscm @ 7% O₂)		0.00670		
Emission Standard (ng TEQ/dscm @ 7% O₂)		0.32		

Emission Summary Table
1130 Spec Mono CIS/WI Pre-Test
1130 Spec Mono
Throx

Run Identification	1	2	3	4	5	6	Average
Run Date	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	
Time	0845-0945	0946-1046	1047-1147	1357-1457	1512-1612	1613-1713	
<u>Exhaust Gas Conditions</u>							
<u>Oxygen</u>							
% (dry volume)	13.81	13.79	13.76	13.82	13.81	13.86	13.80
<u>Carbon Dioxide</u>							
% (dry volume)	5.00	5.01	4.99	5.03	5.11	5.10	5.01
<u>Nitrogen Oxides</u>							
ppmdv				31.8	32.7	32.7	31.8
ppmdv @7% O ₂	--	--	--	62.54	64.15	64.60	62.54
<u>Carbon Monoxide</u>							
ppmdv	-0.1	0.0	-0.1				-0.1
ppmdv @7% O ₂	-0.14	-0.10	-0.25	--	--	--	-0.16
<u>Sulfur Dioxide</u>							
ppmdv	0.03	0.09	-0.10				0.01
ppmdv @7% O ₂	0.06	0.18	-0.20	--	--	--	0.01