NE NORTHERN ENGINEERING

Incorporated 2006

Thirty-Seven Corneau Way, South Windsor, Connecticut, 06074

860-528-7652

November 5, 2017

Dr. Yongtian He
Environmental Engineer
Environmental Management Division
Directorate of Public Works
US Military Academy
667 Ruger Road
West Point, NY 10996

Re: Compliance Test Report
Cummins Diesel Generator Sets
NEI Project No. 16017wpmaGenSets

Dr. He:

Enclosed please find the "Compliance Test Report, Tier 4 Cummins Diesel Generator Sets Package, U. S. Army Garrison, West Point, New York" dated November 5th, 2017.

This report details the results of the Compliance Test Program that was performed on two (2) 2.0 MW Cummins Model No. DQKAE (Spec F) generator sets operating at three (3) load conditions. Testing was performed during the month of October 2017.

If you have any questions or require additional information, please do not hesitate to call the Northern Engineering, Inc. office.

Sincerely yours,

Northern Engineering, Inc.

James Davis
Project Engineer

16017wpmaGenSet Test Rpt

Enclosure

C: Jillian Martin, USACE, Project Manager

NE NORTHERN ENGINEERING

Incorporated 2006

Thirty-Seven Corneau Way, South Windsor, Connecticut, 06074

860-528-7652

Compliance Test Report
Emissions Test Program
Cummins Diesel Generator Sets
U. S. Army Garrison
West Point, New York

Prepared for:

U. S. Army Corps of Engineers
USACE NY District
667A Ruger Road
West Point, NY 10996
Ms. Jillian Martin
917-790-8122

Prepared by:

Northern Engineering, Inc.

NEI Project No. 16017wpmaGenSet

November 5, 2017

TABLE OF CONTENTS

SECTION		PAGE
1.0	INTRODUCTION	2
1.1	Summary of Test Program	2
1.2	Test Program Organization	2
2.0	SOURCE DESCRIPTION	3
2.1	Cummins 2 MW Model DQKAE (Spec F) Generator Sets	3
2.2	Allowable Emission Limits	3
2.3	Process Information	3
3.0	OBJECTIVES AND TEST MATRIX	4
4.0	DESCRIPTION OF SAMPLING LOCATIONS	6
5.0	SAMPLING AND ANALYTICAL PROCEDURES	7
5.1	Continuous Emission Monitoring	7
5.2	Exhaust Volumetric Flow Determination	9
5.4	Exhaust Gas Molecular Weight Determinations	9
5.5	Exhaust Gas Moisture Determination	9
6.0	QA/QC ACTIVITIES	11
6.1	QC Procedure/QA Audits	11
6.2	Sample Identification and Custody	11
6.3	QA/QC Checks of Data Reduction	12
7.0	REPORTING AND DATA REDUCTION	13
7.1	Summary Tables	13
8.0	DISCUSSION OF EXCESS TSP EMISSIONS	21
8.1	Excess TSP Emissions	21

APPENDICES

Appendix A – CEM Summary of Test Results
Appendix B – EPA Method 2, 3, and 4 Data Summary
Appendix C – Summary of TSP Emissions
Appendix D – Calculation Examples
Appendix E – Field Data Sheets
Appendix F – Reference Method Printouts
Appendix G – Process Data
Appendix H – Gas Cylinders Certificates
Appendix I – Schematic Diagram of Reference Method CEM System
Appendix J – Schematic Diagram of Sampling Locations
Appendix K – Schematic Diagram of Moisture Sampling Train
Appendix L – NOx Converter Efficiency Test

1.0 INTRODUCTION

1.1 Summary of Test Program

Northern Engineering, Inc. (NEI) was retained by U.S. Army Garrison – West Point (WPMA) in conjunction with the M. Scher Company to conduct the emissions compliance test program on two (2) newly installed 2.0 MW Cummins Model no. DQKAE (Spec F) Generators, Serial Number L160134320 (Generator #1), Serial Number K160119884 (Generator #2) (Diesel Generator Sets) located near Building #706, U. S. Army Garrison in West Point, New York. The test program was conducted in accordance with the State of New York – Department of Environmental Conservation's (NYSDEC) Permit to Operate, the applicable sub sections of 40*CFR*63 MACT, and 40*CFR*60 Appendices A & B.

Test parameters were measured at the generators outlet sampling locations consisting of oxides of nitrogen (NO_x, expressed as NO_2), carbon monoxide (CO), total hydrocarbons (THC) (outlet only), particulate matter (PM)(outlet only), carbon dioxide (CO_2), oxygen (O_2), volumetric flowrates (outlet only), and moisture. Compliance testing consisted of three (3) one-hour test runs at each of three (3) electrical loads, namely, 50%, 75% and 90 - 100% maximum load (kW), however, particulate matter was only measured during the 90 - 100% of maximum load (kW).

1.2 Test Program Organization

The following represents the test program organization including the names and telephone numbers of responsible individuals:

Mr. Yongtian (Tom) He	WPMA	845-938-4463
Mr. Karl Weed	WPMA	845-938-2116
Mr. Brandon Dengler	WPMA	845-938-0396
Ms. Jillian Martin	USACE	917-790-8122
Mr. James Davis	NEI	860-528-7652
Mr. Terry Thomasson	NEI	860-528-7652
Mr. David Kowaleski	NEI	860-528-7652
Mr. Willard Whiteman	M. Scher	518-462-5544

2.0 SOURCE DESCRIPTION

2.1 Cummins 2 MW Model DQKAE (Spec F) Generator Sets

WPMA installed two (2) Cummins 2MW Model DQKAE (Spec F) diesel generator sets (Serial Number L160134320 Gen. #1 and K160119884 Gen. #2). Each generator has a rated electrical output of approximately 2000 kW and 1800 kW prime. Each engine is equipped with an H+H Selective Maximum Catalytic Reduction System (SCR) (Serial Number's 313727 and 313728). The engines are each rated at 2,000 kW (2,680 horsepower) limited duty, with a maximum permitted fuel-firing rate of 124.1 gal/hr of diesel fuel. The maximum gross heat input is 19.44 million Btu per hour (MMBtu/hr). The minimum exhaust gas flowrate is 10,057 actual cubic feet per minute (acfm), and the stack exit temperature is approximately 765 degrees Fahrenheit (^{o}F).

The SCR system is equipped with a Selective Catalyst/Diesel Particulate Filter (DPF), specifically "DCL SCRonF" for reduction of NOx, and Particulate Matter. The SCR System has a design removal efficiency of 80% - 90% at a temperature of 400^{0}C and 90% - 92% at a temperature of 475^{0}C for NO_x, and 85-95% Particulate Matter – by mass.

2.2 Allowable Emission Limits

The allowable emission limits for the parameters tested for the engine are as follows:

Pollutants	Units	Limit
NOX	g/kW-hr	0.67
CO	g/kW-hr	3.5
THC	g/kW-hr	0.19
Particulate (PM)	g/kW-HR	0.03

The above limits may be subject to a 90% "Catalytic Reduction" rule.

2.3 Process Information

The SCR System is equipped with a Urea Pump Station and each catalyst section is provided with an inlet and outlet temperature sensor and a Delta P (pressure) Monitor.

Electrical power is measured by the Generator Control Systems. Fuel Flow is calculated by the EMV (Engine Computer) and displayed at the Engine Control Panel.

During each test run, fuel flow, catalyst temperatures, ammonia injection rate, percent load, and pressure drops across the catalyst were recorded manually by plant personnel on log sheets. These "Process Log Sheets" can be found in Appendix G.

3.0 OBJECTIVES AND TEST MATRIX

The purpose of the test program was to determine air emission rates for the generators identified in Section 2.0. The specific parameters tested were as follows:

- Measure continuous outlet stack emissions for O_2/CO_2, NO_X, CO, and VOC in accordance with EPA Methods 3A, 7E, 10, and 25A (40*CFR*60, Appendix A - Reference Methods), respectively.
- Determine volumetric flow rates using EPA Methods 1-4 calculations and measure exhaust moisture in accordance with EPA Method 4.

Table 3-1 presents the sampling and analytical matrix for Generator #1

Table 3-1
Test Matrix
Cummins 2MW Diesel Engine Generator # 1
U. S. Army Garrison
West Point, New York

Test Location	Pollutant/ Species	Sampling Method	Load (kW)*	No. of Tests	No. of Runs per Test	Sampling Time/Run (min.)	Analytical Lab
Exhaust Stack of Gen. #1	O_2/CO_2	M3A	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	NO_x	M7E	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	CO	M10	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	VOC (as THC)	M25A	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	Flows	M2	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	Moisture	M4	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	Particulate	M5	2,000	1	3	60	NEI

M3A = EPA Method 3A–Determination of Oxygen & Carbon Dioxide Concentrations in Emissions from Stationary Sources
M7E = EPA Method 7E-Determination of Nitrogen Oxides Emissions from Stationary Sources.
M10 = EPA Method 10-Determination of Carbon Monoxide Emissions from Stationary Sources.
M25A = EPA Method 25A for total hydrocarbons (THC)-Determination of Total Gaseous Organic Emissions as Carbon
M4 = EPA Method 4-Determination of Moisture Content in Stack Gases
M2 = EPA Method 2-Determination of Stack Gas Velocity and Volumetric Flow Rate
M5 = EPA Method 5-Determination of Particulate Matter Emissions from Stationary Sources.
*100% Load must be between 1,800 and 2,000 kW to receive an EPA 2,000 kW rating. If 1,800 kilowatts cannot be obtained during the test, the generator will be limited to the actual kilowatts generated.

Table 3-2 presents the sampling and analytical matrix for Generator #2

Table 3-2
Test Matrix
Cummins 2MW Diesel Engine Generator # 2
U. S. Army Garrison
West Point, New York

Test Location	Pollutant/ Species	Sampling Method	Load (kW)*	No. of Tests	No. of Runs per Test	Sampling Time/Run (min.)	Analytical Lab
Exhaust Stack of Gen. #2	O_2/CO_2	M3A	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	NO_x	M7E	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	CO	M10	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	VOC (as THC)	M25A	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	Flows	M2	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	Moisture	M4	1,000 1,500 2,000	1 1 1	3 3 3	60 60 60	NEI
	Particulate	M5	2,000	1	3	60	NEI

M3A = EPA Method 3A–Determination of Oxygen & Carbon Dioxide Concentrations in Emissions from Stationary Sources
M7E = EPA Method 7E-Determination of Nitrogen Oxides Emissions from Stationary Sources.
M10 = EPA Method 10-Determination of Carbon Monoxide Emissions from Stationary Sources.
M25A = EPA Method 25A for total hydrocarbons (THC)-Determination of Total Gaseous Organic Emissions as Carbon
M4 = EPA Method 4-Determination of Moisture Content in Stack Gases
M2 = EPA Method 2-Determination of Stack Gas Velocity and Volumetric Flow Rate
M207M5 = EPA Method 5-Determination of Particulate Matter Emissions from Stationary Sources.
*100% Load must be between 1,800 and 2,000 kW to receive an EPA 2,000 kW rating. If 1,800 kilowatts cannot e obtained during the test, the generator will be limited to the actual kilowatts generated.

4.0 DESCRIPTION OF SAMPLING LOCATIONS

Please refer to Appendix I for a schematic of the sampling locations. The schematic shows the ¾" test ports for the CEM (NOx) and the 3" EPA test ports for the Particulate. All ports were mounted in a seven (7) foot section of a 24" diameter temporary stack extension installed specifically for this test program. Method 1 – 5 support "monorails" were provided.

5.0 SAMPLING AND ANALYTICAL PROCEDURES

5.1 Continuous Emission Monitoring

Continuous emissions monitoring (CEM) tests were conducted at the stack exhaust location for O_2/CO_2, NO_x, CO, and THC using EPA Reference Methods 3A, 7E, 10, and 25A, respectively. A schematic of the reference method (RM) CEM system can be found in Appendix I.

The CEMS draws sample gas in through a stainless steel probe with a heated (250^0F) out of stack filtration system. The gas sample is drawn through the probe and filter(s) by a heated Teflon-lined diaphragm vacuum pump. From the pump, the sample is sent through a heated Teflon sample line. At the end of the sample line, the extracted sample gas is split into two, with one portion going through a condenser to remove moisture, into a manifold, which supplies the O_2, CO_2, NO_x, and CO analyzers, and the second portion going to the THC analyzer in a hot, wet state. Analyzer outputs were recorded by a PC based Data Acquisition System (DAS) at ten (10) second intervals.

Three 60-minute CEM test runs were performed with the engine at three load conditions, namely 50%, 75% and 90 - 100% of full load conditions ($\geq$90%) with a zero and mid-range calibration check between each test run. In addition, a full range calibration and linearity check were performed on each RM analyzer at the beginning of each test day. Emissions were reported in pounds per hour (lb/hr), grams per horsepower hour (g/hp-hr), and grams per kilowatt hour (g/kW-hr). Oxygen and CO_2 are reported in percent (%) by volume.

All field data reporting and calculations were conducted in accordance with the guidelines presented in EPA Reference Methods 3A, 7E, 10 and 25A. The field data sheets can be found in Appendix E.

5.1.1 Instrumentation

The O_2 instrument was a Servomex Model 1440 analyzer, which measures O_2 concentration by means of the paramagnetic susceptibility of the sample gas using a proven magneto-type measuring cell. Oxygen molecules are attracted more strongly by the magnetic field than are molecules of other gases, and their concentrations can thereby be measured. The O_2 analyzer was operated on a 0-25% range.

The CO_2 instrument was a Servomex 1440 analyzer, which measures CO_2 concentration by means of non-dispersive infrared radiation (NDIR). The percentage of infrared radiation absorbed is proportional to the concentration of CO_2 in the gas stream. The CO_2 range was 0-20%.

The NO_X instrument was a TECO Model 42 NO/NO_x analyzer. This instrument utilizes the principle of chemiluminescence, whereby NO in the sample gas reacts with ozone (O_3) at a specific wavelength to produce NO_2. The NO_2 is then disassociated by a converter to produce NO, which is the combination of the original NO and the disassociated NO_2 in the sample stream. This total NO is proportional to the original NO_x (NO and NO_2) concentration. Based on expected source emissions, the NO_x analyzer range was set to 0-100 parts per million (ppm).

The CO analyzer was a TECO Model 48 analyzer, which measures CO concentration by Gas Filter Correlation (GFC) spectroscopy. GFC spectroscopy is based upon comparison of the detailed structure of the absorption spectrum of the measured gas to that of the other gases also present in the sample being analyzed. Infrared radiation is chopped and then passed through a gas filter alternating between CO (reference cell) and nitrogen (sample cell) by rotation of a filter wheel. The radiation then passes through a narrow band-pass filter and a multiple optical pass cell where absorption by the sample gas occurs. Based on expected source emissions, the analyzer range was 0-200 parts per million (ppm).

The THC analyzer was a Rosemount Model 402, which utilizes a flame ionization detector (FID) for measuring THC in the gas stream on a hot, wet basis. The sensor is a burner in which a regulated flow of sample gas passes through a flame sustained by the regulated flow of air and fuel. Within the flame, a complex ionization of the hydrocarbons in the sample stream occurs which allows for their detection and measurement. Based on expected source emissions, the THC analyzer was operated on the 0-100 parts per million (ppm as propane) range.

5.1.2 Analyzer Calibrations

Analyzer calibrations were performed daily. Certified EPA Protocol compressed span gases of O_2, CO_2, NO, CO, and propane (C_3H_8) were used as the calibration standards. Hydrocarbon free (HCF) zero air was used as the zero gas. For the field tests, the analyzers were calibrated and linearized at the required three or four points along their measurement ranges at the beginning of each test day with the Protocol gases. The system bias and drift tests were conducted with appropriate mid-range gases. These system calibrations were repeated after each test run. The gases passed through all components of the sampling system except the sampling probe. The calibration gas concentrations were based on the specific methodologies and expected source emissions, and had the following concentrations:

Constituent	High-Level	Mid-Level	Low-Level	Zero
O_2	20.96%	11.06%	----	HCF
CO_2	17.76%	11.08%	----	HCF
NO	96.60 ppm	50.41 ppm	----	HCF
CO	181.50 ppm	97.71 ppm	54.84 ppm	HCF
C_3H_8	84.58 ppm	49.86 ppm	29.93 ppm	HCF

The Cylinder Gas Certificates can be found in Appendix H.

5.1.3 Data Reduction

The system calibrations were performed to document any instrument drift. Using Equation 6C-1 (*40CFR60*, Appendix A), the ppm and percent values were corrected to account for the zero and span values and any instrument drift as follows:

$$C_{gas} = (C - C_o) \times \frac{C_{ma}}{C_m - C_o},$$

where C_{gas} = pollutant concentration (ppm or %)

C = average pollutant reading (ppm or %)

C_o = average zero reading (ppm or %)

C_m = average span reading (ppm or %)

C_{ma} = span gas concentration (ppm or %).

The corrected ppm and % averages were used to calculate emission rates in the appropriate standard units.

The hydrocarbon analyzers were calibrated using propane standards and sample concentrations were reported in parts per million by volume (ppmv). The THC measurements were calculated in terms of ppmv as Carbon using Equation 25A-1:

$$C_c = KC_{meas},$$

where C_c = the THC concentration in ppmv as Carbon,

C_{meas} = the THC concentration as measured in ppmv as propane,

K = the response factor for the calibration gas being used (propane = 3).

The final THC test results are expressed in terms of pounds per hour (lb/hr), grams per horsepower – hour (g/hp-hr) and grams per kilowatt hour (g/kW-hr). All field data sheets can be found in Appendix E.

5.2 Exhaust Volumetric Flow Determination

Volumetric flow for each run was calculated using data manually acquired from the Engine Controls (EMU). EPA Method 2, 3A and 4, and the EPA published fuel F Factor, were used to calculate both dry standard cubic feet per hour and wet standard cubic feet per hour.

Units of flow are expressed as dry standard cubic feet per minute and actual cubic feet per minute.

5.4 Exhaust Gas Molecular Weight Determinations

The composition of the gas stream at each engine exhaust location was analyzed for oxygen and carbon dioxide in accordance with EPA Method 3A. Triplicate one-hour samples were obtained. The stack gas molecular weight was calculated from the above analysis.

5.5 Exhaust Gas Moisture Determination

The stack gas moisture content at the engine exhaust location was measured in accordance with EPA Method 4. Triplicate moisture tests were performed simultaneously with each CEM test run.

5.5 Exhaust Gas Moisture Determination

The stack gas moisture content at the engine exhaust location was measured in accordance with EPA Method 4. Triplicate moisture tests were performed simultaneously with each CEM test run. The gas sample was extracted from a single central point along the cross-section of the exhaust duct, at a constant rate (a minimum of thirty cubic feet of stack gas was be sampled). The sample stream moisture was determined volumetrically and gravimetrically. The measured stack gas moisture was used to correct actual sampling conditions to dry standard conditions. The moisture sampling train is shown in Appendix J. Exhaust gas temperature was continuously monitored during the testing using a Type K Thermocouple.

6.0 QA/QC ACTIVITIES

6.1 QC Procedure/QA Audits

NEI maintains specific laboratory facilities dedicated to maintenance and calibration of source sampling equipment used in performing EPA and other reference method source tests. These facilities include all equipment and standards necessary for equipment calibration using the procedures outlined in the *Quality Assurance Handbook for Air Pollution Measurement Systems Volume III, Stationary Source Specific Methods* (EPA 600/R-94/038c).

The checkout and calibration of the source sampling equipment is performed prior to and at the completion of each project. Referenced calibration procedures are strictly followed and the results properly documented and retained. The following calibrated equipment was used during the test program:

- Type-S Pitot Tubes
- Type-K Thermocouples
- Dry Gas Meters
- Continuous Gas Analyzers
- Certified EPA Protocol Gases

Calculations for determining flow rates, moisture contents, isokinetics, particulate and gaseous concentrations, where applicable, are made using a computer program developed by the QA/QC Engineer at NEI. This program utilizes the calculation procedures and equations specified in EPA Methods 2, 4, 7E, 6C, 10, 25A and 5. The program has been successfully used for numerous test efforts and has been validated by independent performance audits. Sample calculations are performed by the software program and a definition of terms are can be found in Appendix D. Data is input to the software directly from the field data sheets.

Quality control for the various organic and inorganic analytical procedures is established using field blanks, method blanks, trip blanks, surrogate spiking, and internal standards for quantitation. Where applicable, percent recoveries are calculated and determined.

6.2 Sample Identification and Custody

Sample custody procedures for this program are based on EPA recommended procedures. The project manager is responsible for ensuring that proper custody and documentation procedures were followed for the field sampling and field analytical efforts. The project manager is assisted by key sampling personnel involved in sample recovery.

All sampling data, including information regarding sampling times, locations, and any specific considerations associated with sample acquisition are recorded in black ink on pre-formatted data sheets. A master sample logbook is used to document all sample collection activities. The project manager is responsible for reviewing the logbook on a daily basis and ensuring that entries are complete and up to date.

Following sample collection, all samples are given a unique alphanumeric sample identification code. Sample labels and integrity seals are completed and affixed to the sample container. The samples are stored in a secure area until shipment. The sample volumes are determined and recorded and the liquid levels on each bottle are marked. All samples are packed and shipped according to Department of Transportation (DOT) guidelines. As the samples are packed for shipment to the appropriate laboratories, chain-of-custody forms are completed for each shipment box, these forms are enclosed in each respective box.

A daily activity log is maintained by the project manager. This is an informal log used to record various types of information, such as minor problems which may have arose, sketches of sampling locations, names and phone numbers of contacts.

6.3 QA/QC Checks of Data Reduction

The QA/QC Engineer ran an independent check (using a validated computer program) of the calculations with predetermined data before the field test. This ensures that calculations done in the field are accurate. The QA/QC Engineer also conducted a spot check on-site to assure that data are being recorded accurately. After the test, the QA/QC Engineer checked the data input to assure that the raw data had been transferred to the computer accurately.

7.0 Reporting and Data Reduction

7.1 Summary Tables

Table 7-1 shows the Summary of Data for Generator # 1 – 1800 kW:

Table 7-1
Summary of Emission Data
Cummins 2MW Diesel Engine Generator # 1
1800 kW
U. S. Army Garrison
West Point, New York

Method/Component	Units	Run 1	Run 2	Run 3	Avg.
	Date:	10/03/17	10/03/17	10/03/17	
	Time:	1136-1238	1320-1442	1507-1625	
Method 2 – Flowrate	acfm	13566	14001	13894	13820
	dscfm	5474	5607	5518	5533
Method 4 - Moisture	%	8.09	7.74	8.21	8.01
Method 3A – O_2	%	10.50	10.80	10.80	10.70
CO_2	%	7.30	7.00	7.40	7.23
Method 7E - NO_x	lb/hr	2.17	2.07	2.04	2.09
	g/hp-hr	0.41	0.39	0.38	0.39
	g/kW-hr	0.5463	0.5199	0.5116	0.5259
Method 10 - CO	lb/hr	0.0286	0.0245	0.0361	0.0297
	g/hp-hr	0.0054	0.0046	0.0068	0.0056
	g/kW-hr	0.0072	0.0061	0.0091	0.0075
Method 25A - THC	lb/hr	0.1481	0.1454	0.0798	0.1244
	g/hp-hr	0.0278	0.0272	0.0149	0.0233
	g/kW-hr	0.0372	0.0365	0.0200	0.0313
Method 5 – Particulate	g/kW-hr	0.0428	0.0405	0.0537	0.0457
Fuel Flow Rate	gal/hr	113.76	113.62	114.19	113.86
Generator Output	kW	1804	1805	1805	1805
Ammonia Injection Rate	lb/hr	31.36	32.08	31.97	31.80
Catalyst Temperature	^0F	800	806	805	804
Catalyst Delta P	$"H_2O$	20.42	20.48	20.37	20.42

Table 7-2 shows the Summary of Data for Generator # 1 – 1500 kW:

Table 7-2
Summary of Emission Data
Cummins 2MW Diesel Engine Generator # 1
1500 kW
U. S. Army Garrison
West Point, New York

Method/Component	Units	Run 1	Run 2	Run 3	Avg.
	Date:	10/04/17	10/04/17	10/04/17	
	Time:	944-1056	1115-1218	1237-1338	
Method 2 – Flowrate	acfm	12187	10459	12122	11589
	dscfm	5136	4369	4996	4834
Method 4 - Moisture	%	7.47	6.55	6.49	6.84
Method 3A – O_2	%	11.90	11.60	11.50	11.67
CO_2	%	6.80	6.80	6.90	6.83
Method 7E - NO_x	lb/hr	2.13	1.85	2.09	2.03
	g/hp-hr	0.53	0.46	0.52	0.50
	g/kW-hr	0.7071	0.6140	0.6962	0.6712
Method 10 - CO	lb/hr	0.0784	0.0267	0.0414	0.0488
	g/hp-hr	0.0194	0.0066	0.0102	0.0121
	g/kW-hr	0.0260	0.0088	0.0137	0.0162
Method 25A - THC	lb/hr	0.0249	0.0201	0.0320	0.0257
	g/hp-hr	0.0062	0.0050	0.0079	0.0063
	g/kW-hr	0.0082	0.0067	0.0106	0.0085
Fuel Flow Rate	gal/hr	15.31	15.40	15.51	15.41
Generator Output	kW	1369	1369	1369	1369
Ammonia Injection Rate	lb/hr	92.23	92.70	92.90	92.61
Catalyst Temperature	^0F	766	773	781	773
Catalyst Delta P	$"H_2O$	17.48	17.80	17.90	17.72

Table 7-3 shows the Summary of Data for Generator # 1 – 1000 kW:

Table 7-3
Summary of Emission Data
Cummins 2MW Diesel Engine Generator # 1
1000 kW
U. S. Army Garrison
West Point, New York

Method/Component	Units	Run 1	Run 2	Run 3	Avg.
	Date:	10/11/17	10/11/17	10/11/17	
	Time:	1009-1110	1128-1231	1245-1346	
Method 2 – Flowrate	acfm	9970	9883	10317	10057
	dscfm	4070	4017	4203	4097
Method 4 - Moisture	%	6.81	6.85	6.69	6.78
Method 3A – O_2	%	12.42	12.62	12.35	12.46
CO_2	%	6.39	6.40	6.49	6.43
Method 7E - NO_x	lb/hr	1.77	1.74	1.82	1.78
	g/hp-hr	0.52	0.51	0.53	0.52
	g/kW-hr	0.6975	0.6870	0.7163	0.7003
Method 10 - CO	lb/hr	0.311	0.0443	0.0511	0.0422
	g/hp-hr	0.0091	0.0130	0.0150	0.0124
	g/kW-hr	0.0123	0.0175	0.0202	0.0166
Method 25A - THC	lb/hr	0.0218	0.0266	0.0450	0.0311
	g/hp-hr	0.0064	0.0078	0.0132	0.0092
	g/kW-hr	0.0086	0.0105	0.0177	0.0123
Fuel Flow Rate	gal/hr	77.36	77.06	77.10	77.20
Generator Output	kW	1150	1150	1150	1150
Ammonia Injection Rate	lb/hr	8.99	9.06	9.23	9.09
Catalyst Temperature	^0F	759	769	775	767
Catalyst Delta P	$"H_2O$	15.70	16.34	16.70	16.24

Table 7-4 shows the Summary of Data for Generator # 2 – 1800 kW:

Table 7-4
Summary of Emission Data
Cummins 2MW Diesel Engine Generator # 2
1800 kW
U. S. Army Garrison
West Point, New York

Method/Component	Units	Run 1	Run 2	Run 3	Avg.
	Date:	10/05/17	10/05/17	10/05/17	
	Time:	843-943	957-1059	1116-1247	
Method 2 – Flowrate	acfm	14675	14753	14834	14754
	dscfm	5579	5647	5606	5611
Method 4 – Moisture	%	10.24	8.91	9.46	9.54
Method 3A – O_2	%	10.66	10.53	10.40	10.53
CO_2	%	7.57	7.76	7.70	7.68
Method 7E – NO_x	lb/hr	2.53	2.59	2.47	2.53
	g/hp-hr	0.47	0.48	0.46	0.47
	g/kW-hr	0.6328	0.6498	0.6178	0.6335
Method 10 – CO	lb/hr	0.0419	0.0468	0.0479	0.0455
	g/hp-hr	0.0078	0.0087	0.0089	0.0085
	g/kW-hr	0.0105	0.0117	0.0120	0.0114
Method 25A – THC	lb/hr	0.0767	0.0584	0.0764	0.0705
	g/hp-hr	0.0143	0.0109	0.0143	0.0132
	g/kW-hr	0.0192	0.0146	0.0191	0.0177
Method 5 – Particulate	g/kW-hr	0.0449	0.0424	0.0199	0.0358
Fuel Flow Rate	gal/hr	115.62	115.0	116.4	115.6
Generator Output	kW	1811	1811	1811	1811
Ammonia Injection Rate	lb/hr	30.32	30.82	29.97	30.37
Catalyst Temperature	^0F	816	827	836	826
Catalyst Delta P	"H_2O	17.28	17.42	17.40	17.36

Table 7-5 shows the Summary of Data for Generator # 2 – 1500 kW:

Table 7-5
Summary of Emission Data
Cummins 2MW Diesel Engine Generator # 2
1500 kW
U. S. Army Garrison
West Point, New York

Method/Component	Units	Run 1	Run 2	Run 3	Avg.
	Date:	10/04/17	10/04/17	10/04/17	
	Time:	1500-1559	1623-1722	1737-1837	
Method 2 – Flowrate	acfm	13423	13261	13686	13457
	dscfm	5412	5378	5307	5366
Method 4 - Moisture	%	6.29	7.51	7.38	7.06
Method 3A – O_2	%	10.90	10.80	11.00	10.90
CO_2	%	7.15	7.15	7.09	7.11
Method 7E - NO_x	lb/hr	2.29	2.34	2.37	2.33
	g/hp-hr	0.48	0.49	0.50	0.49
	g/kW-hr	0.6485	0.6619	0.6715	0.6607
Method 10 - CO	lb/hr	0.0283	0.0399	0.0671	0.0451
	g/hp-hr	0.0060	0.0084	0.0142	0.0095
	g/kW-hr	0.0080	0.0113	0.0190	0.0128
Method 25A - THC	lb/hr	0.0324	0.0446	0.0418	0.0396
	g/hp-hr	0.0068	0.0094	0.0088	0.0084
	g/kW-hr	0.0092	0.0126	0.0118	0.0112
Fuel Flow Rate	gal/hr	99.5	99.39	99.5	99.46
Generator Output	kW	1600	1600	1600	1600
Ammonia Injection Rate	lb/hr	19.93	20.20	19.29	19.81
Catalyst Temperature	^0F	762	801	801	788
Catalyst Delta P	"H_2O	14.96	15.10	15.10	15.05

Table 7-6 shows the Summary of Data for Generator # 2 – 1000 kW:

Table 7-6
Summary of Emission Data
Cummins 2MW Diesel Engine Generator # 2
1000 kW
U. S. Army Garrison
West Point, New York

Method/Component	Units	Run 1	Run 2	Run 3	Avg.
	Date:	10/05/17	10/05/17	10/05/17	
	Time:	1306-1406	1431-1533	1555-1659	
Method 2 – Flowrate	acfm	11470	11589	11494	11518
	dscfm	4077	4024	4230	4110
Method 4 - Moisture	%	7.22	7.36	7.70	7.43
Method 3A – O_2	%	11.83	11.58	11.63	11.68
CO_2	%	6.63	6.61	6.67	6.64
Method 7E - NO_x	lb/hr	1.76	1.80	1.92	1.82
	g/hp-hr	0.50	0.51	0.55	0.52
	g/kW-hr	0.6714	0.6863	0.7323	0.6967
Method 10 - CO	lb/hr	0.0475	0.0709	0.0808	0.0664
	g/hp-hr	0.0135	0.0202	0.0230	0.0189
	g/kW-hr	0.0181	0.0271	0.0308	0.0253
Method 25A - THC	lb/hr	0.0308	0.0692	0.0497	0.0499
	g/hp-hr	0.0088	0.0197	0.0141	0.0142
	g/kW-hr	0.0118	0.0264	0.0190	0.0190
Fuel Flow Rate	gal/hr	77.02	76.65	77.00	76.89
Generator Output	kW	1188	1188	1188	1188
Ammonia Injection Rate	lb/hr	9.88	9.86	9.65	9.79
Catalyst Temperature	^0F	793	791	792	792
Catalyst Delta P	" H_2O	13.1	13.3	13.4	13.3

Table 7-7 shows the Summary of Weighted Emissions Data for Generator # 1:

Table 7-7 Summary of Weighted Emissions Data Cummins 2MW Diesel Engine, Generator #1 U. S. Army Garrison West Point, New York				
Oxides of Nitrogen				
Load Designation	**Range**	**Test Results**	**Allowable run time (as a percentage of total run time)**	**Weighting Factor**
Units	kW	grams/kW-Hr	%	
Max.	1800 to 2000	0.5259	100	0.500
Mid.	1500 to 1600	0.6712	30	0.300
Low	1000 to 1200	0.7003	20	0.200
Weighted Emission Results NOx , (Grams Per kW-hr)				**0.6324**
Carbon Monoxide				
Max.	1800 to 2000	0.0075	100	0.500
Mid.	1500 to 1600	0.0162	30	0.300
Low	1000 to 1200	0.0166	20	0.200
Weighted Emission Results CO, (Grams Per kW-hr)				**0.01343**
Total HydroCarbons (as carbon)				
Max.	1800 to 2000	0.0313	100	0.500
Mid.	1500 to 1600	0.0085	30	0.300
Low	1000 to 1200	0.0123	20	0.200
Weighted Emission Results THC, (Grams Per kW-hr)				**0.0173**
Total Particulate expressed as PM-2.5				
Max.	1800 to 2000	0.0457	100	0.500
Mid.	1500 to 1600	0.0457	30	0.300
Low	1000 to 1200	0.0457	20	0.200
Weighted Emission Results TSP, (Grams Per kW-Hr)				**0.0457**

Table 7-8 shows the Summary of Weighted Emissions Data for Generator # 2:

Table 7-8 Summary of Weighted Emissions Data Cummins 2MW Diesel Engine, Generator #2 U. S. Army Garrison West Point, New York				
Oxides of Nitrogen				
Load Designation	**Range**	**Test Results**	**Allowable run time (as a percentage of total run time)**	**Weighting Factor**
Units	kW	grams/kW-Hr	%	
Max.	1800 to 2000	0.6335	100	0.500
Mid.	1500 to 1600	0.6607	30	0.300
Low	1000 to 1200	0.6967	20	0.200
Weighted Emission Results NOx , (Grams Per kW-hr)				**0.6636**
Carbon Monoxide				
Max.	1800 to 2000	0.0114	100	0.500
Mid.	1500 to 1600	0.0128	30	0.300
Low	1000 to 1200	0.0253	20	0.200
Weighted Emission Results CO, (Grams Per kW-hr)				**0.0165**
Total HydroCarbons (as carbon)				
Max.	1800 to 2000	0.0177	100	0.500
Mid.	1500 to 1600	0.0112	30	0.300
Low	1000 to 1200	0.0190	20	0.200
Weighted Emission Results THC, (Grams Per kW-hr)				**0.0159**
Total Particulate expressed as PM-2.5				
Max.	1800 to 2000	0.0358	100	0.500
Mid.	1500 to 1600	0.0358	30	0.300
Low	1000 to 1200	0.0358	20	0.200
Weighted Emission Results TSP, (Grams Per kW-Hr)				**0.0358**

8.0 Discussion of Excess TSP Emissions

8.1 Excess TSP Emissions

A very faint (orange/yellow) tint was noticed on the M-5 Filter Quartz Paper, however, these filters showed zero weight gain.

Due to high temperatures of the exhaust gas, EPA Method 5 was chosen in lieu of an "In Stack Filter" method.

All weight gain was acquired by the nozzle and probe washes. NEI attributes most, to all, of this gain to condensation of ammonium sulfate on the relatively cold (250^{0}F) probe liner and filter housing front half. NEI noted that the front half "dried residual" was soluble in distilled water.

Please refer to Appendix C of this report for the "Summary of TSP Emissions".

APPENDIX A

CEM Summary of Test Results

CEM Tests Summary of Results
USMA - West Point, NY - Lot AAA
Generator #1 - 1800 kW

TEST:	CEM - 1	CEM - 2	CEM - 3	AVERAGE
DATE:	10/3/2017	10/3/2017	10/3/2017	
TIME:	1136-1238	1320-1442	1507-1625	
INPUTS				
O_2 Concentration (%), dry	10.50	10.80	10.80	10.70
CO_2 Concentration (%), dry	7.30	7.00	7.40	7.23
NO_x Concentration (ppm), dry	55.40	51.50	51.50	52.80
CO Concentration (ppm), dry	1.20	1.00	1.50	1.23
THC Conc. (ppm), wet, as C	13.30	12.80	7.10	11.07
Ambient Barometric Press ("Hg)	30.60	30.60	30.50	30.57
Moisture Content (%)	8.09	7.74	8.21	8.01
Volumetric Flowrate (dscfm)	5474	5607	5518	5533
Kilowatt Output	1804	1805	1805	1805
Fuel Analysis				
% Carbon				
% Hydrogen				
% Nitrogen				
% Sulfur				
% Oxygen				
Gross Calorific Value, (Btu/lb)				
F-factor, (dscf/MMBtu), M19	9190	9190	9190	9190
OUTPUTS				
F_d, (dscf/MMBtu) fuel analysis				
Break-horsepower-hour	2419.2	2420.5	2420.5	2420.1
NO_x (ppm@15%O_2)	31.4	30.1	30.1	30.5
NO_x (g/dscf)	3.00E-03	2.79E-03	2.79E-03	2.86E-03
NO_x (g/hr)	9.85E+02	9.38E+02	9.23E+02	9.49E+02
NO_x (g/Hp-hr)	0.41	0.39	0.38	0.39
NO_x (lb/hr)	2.17	2.07	2.04	2.09
NO_x (lb/MMBtu)	0.1222	0.1170	0.1170	0.1187
NOx (g/kW-hr)	0.5463	0.5199	0.5116	0.5259
CO (ppm@15%O_2)	0.68	0.58	0.88	0.71
CO (g/dscf)	3.96E-05	3.30E-05	4.95E-05	4.07E-05
CO (g/hr)	1.30E+01	1.11E+01	1.64E+01	1.35E+01
CO (g/BHp-hr)	0.0054	0.0046	0.0068	0.0056
CO (lb/hr)	0.0286	0.0245	0.0361	0.0297
CO (lb/MMBtu)	0.0016	0.0014	0.0021	0.0017
CO (g/kW-hr)	0.0072	0.0061	0.0091	0.0075
THC (ppm, as C, dry)	14.5	13.9	7.7	12.0
THC (ppm@15%O_2)	8.2	8.1	4.5	6.9
THC (g/dscf)	2.04E-04	1.96E-04	1.09E-04	1.70E-04
THC (g/hr)	6.72E+01	6.59E+01	3.62E+01	5.64E+01
THC (g/BHp-hr)	0.0278	0.0272	0.0149	0.0233
THC (lb/hr)	0.1481	0.1454	0.0798	0.1244
THC (lb/MMBtu)	0.0083	0.0082	0.0046	0.0070
THC (g/kW-hr)	0.0372	0.0365	0.0200	0.0313

CEM Tests Summary of Results
USMA - West Point, NY - Lot AAA
Generator #1 - 1369 kW

TEST:	CEM - 1	CEM - 2	CEM - 3	AVERAGE
DATE:	10/4/2017	10/4/2017	10/4/2017	
TIME:	944-1056	1115-1218	1237-1338	
INPUTS				
O_2 Concentration (%), dry	11.90	11.60	11.50	11.67
CO_2 Concentration (%), dry	6.80	6.80	6.90	6.83
NO_x Concentration (ppm), dry	58.00	59.20	58.40	58.53
CO Concentration (ppm), dry	3.50	1.40	1.90	2.27
THC Conc. (ppm), wet, as C	2.40	2.30	3.20	2.63
Ambient Barometric Press ("Hg)	30.40	30.40	30.30	30.37
Moisture Content (%)	7.47	6.55	6.49	6.84
Volumetric Flowrate (dscfm)	5136	4369	4996	4834
Kilowatt Output	1369	1369	1369	1369
Fuel Analysis				
% Carbon				
% Hydrogen				
% Nitrogen				
% Sulfur				
% Oxygen				
Gross Calorific Value, (Btu/lb)				
F-factor, (dscf/MMBtu), M19	9190	9190	9190	9190
OUTPUTS				
F_d, (dscf/MMBtu) fuel analysis				
Break-horsepower-hour	1835.8	1835.8	1835.8	1835.8
NO_x (ppm@15%O_2)	38.0	37.6	36.7	37.4
NO_x (g/dscf)	3.14E-03	3.21E-03	3.16E-03	3.17E-03
NO_x (g/hr)	9.68E+02	8.41E+02	9.48E+02	9.19E+02
NO_x (g/BHp-hr)	0.53	0.46	0.52	0.50
NO_x (lb/hr)	2.13	1.85	2.09	2.03
NO_x (lb/MMBtu)	0.1478	0.1460	0.1425	0.1454
NO_x (g/kW-hr)	0.7071	0.6140	0.6926	0.6712
CO (ppm@15%O_2)	2.29	0.89	1.19	1.46
CO (g/dscf)	1.15E-04	4.62E-05	6.26E-05	7.47E-05
CO (g/hr)	3.56E+01	1.21E+01	1.88E+01	2.21E+01
CO (g/BHp-hr)	0.0194	0.0066	0.0102	0.0121
CO (lb/hr)	0.0784	0.0267	0.0414	0.0488
CO (lb/MMBtu)	0.0054	0.0021	0.0028	0.0035
CO (g/kW-hr)	0.0260	0.0088	0.0137	0.0162
THC (ppm, as C, dry)	2.6	2.5	3.4	2.8
THC (ppm@15%O_2)	1.7	1.6	2.1	1.8
THC (g/dscf)	3.66E-05	3.48E-05	4.84E-05	3.99E-05
THC (g/hr)	1.13E+01	9.12E+00	1.45E+01	1.16E+01
THC (g/BHp-hr)	0.0062	0.0050	0.0079	0.0063
THC (lb/hr)	0.0249	0.0201	0.0320	0.0257
THC (lb/MMBtu)	0.0017	0.0016	0.0022	0.0018
THC (g/kW-hr)	0.0082	0.0067	0.0106	0.0085

CEM Tests Summary of Results
USMA - West Point, NY - Lot AAA
Generator # 1 - 1150 kW

TEST:	CEM - 1	CEM - 2	CEM - 3	AVERAGE
DATE:	10/11/2017	10/11/2017	10/11/2017	
TIME:	1009-1110	1128-1231	1245-1346	
INPUTS				
O_2 Concentration (%), dry	12.42	12.62	12.35	12.46
CO_2 Concentration (%), dry	6.39	6.40	6.49	6.43
NO_x Concentration (ppm), dry	60.65	60.52	60.31	60.49
CO Concentration (ppm), dry	1.75	2.53	2.79	2.36
THC Conc. (ppm), wet, as C	2.67	3.30	5.34	3.77
Ambient Barometric Press ("Hg)	30.10	30.10	30.10	30.10
Moisture Content (%)	6.81	6.85	6.69	6.78
Volumetric Flowrate (dscfm)	4070	4017	4203	4097
Kilowatt Output	1150	1150	1150	1150
Fuel Analysis				
% Carbon				
% Hydrogen				
% Nitrogen				
% Sulfur				
% Oxygen				
Gross Calorific Value, (Btu/lb)				
F-factor, (dscf/MMBtu), M19	9190	9190	9190	9190
OUTPUTS				
F_d, (dscf/MMBtu) fuel analysis				
Break-horsepower-hour	1542.2	1542.2	1542.2	1542.2
NO_x (ppm@15%O_2)	42.2	43.1	41.6	42.3
NO_x (g/dscf)	3.28E-03	3.28E-03	3.27E-03	3.28E-03
NO_x (g/hr)	8.02E+02	7.90E+02	8.24E+02	8.05E+02
NO_x (g/Hp-hr)	0.52	0.51	0.53	0.52
NO_x (lb/hr)	1.77	1.74	1.82	1.78
NO_x (lb/MMBtu)	0.1640	0.1676	0.1618	0.1645
NO_x (g/kW-hr)	0.6975	0.6870	0.7163	0.7003
CO (ppm@15%O_2)	1.22	1.80	1.93	1.65
CO (g/dscf)	5.77E-05	8.34E-05	9.20E-05	7.77E-05
CO (g/hr)	1.41E+01	2.01E+01	2.32E+01	1.91E+01
CO (g/BHp-hr)	0.0091	0.0130	0.0150	0.0124
CO (lb/hr)	0.0311	0.0443	0.0511	0.0422
CO (lb/MMBtu)	0.0029	0.0043	0.0046	0.0039
CO (g/kW-hr)	0.0123	0.0175	0.0202	0.0166
THC (ppm, as C, dry)	2.9	3.5	5.7	4.0
THC (ppm@15%O_2)	2.0	2.5	3.9	2.8
THC (g/dscf)	4.05E-05	5.01E-05	8.09E-05	5.71E-05
THC (g/hr)	9.89E+00	1.21E+01	2.04E+01	1.41E+01
THC (g/BHp-hr)	0.0064	0.0078	0.0132	0.0092
THC (lb/hr)	0.0218	0.0266	0.0450	0.0311
THC (lb/MMBtu)	0.0020	0.0026	0.0040	0.0029
THC (g/kW-hr)	0.0086	0.0105	0.0177	0.0123

CEM Tests Summary of Results
USMA - West Point, NY - Lot AAA
Generator # 2 - 1811 kW

TEST:	CEM - 1	CEM - 2	CEM - 3	AVERAGE
DATE:	10/5/2017	10/5/2017	10/5/2017	
TIME:	843-943	957-1059	1116-1247	
INPUTS				
O_2 Concentration (%), dry	10.66	10.53	10.40	10.53
CO_2 Concentration (%), dry	7.57	7.76	7.70	7.68
NO_x Concentration (ppm), dry	63.21	64.13	61.41	62.92
CO Concentration (ppm), dry	1.72	1.90	1.96	1.86
THC Conc. (ppm), wet, as C	6.60	5.04	6.60	6.08
Ambient Barometric Press ("Hg)	30.10	30.10	30.10	30.10
Moisture Content (%)	10.24	8.91	9.46	9.54
Volumetric Flowrate (dscfm)	5579	5647	5606	5611
Kilowatt Output	1811	1811	1811	1811
Fuel Analysis				
% Carbon				
% Hydrogen				
% Nitrogen				
% Sulfur				
% Oxygen				
Gross Calorific Value, (Btu/lb)				
F-factor, (dscf/MMBtu), M19	9190	9190	9190	9190
OUTPUTS				
F_d, (dscf/MMBtu) fuel analysis				
Break-horsepower-hour	2428.6	2428.6	2428.6	2428.6
NO_x (ppm@15%O_2)	36.4	36.5	34.5	35.8
NO_x (g/dscf)	3.42E-03	3.47E-03	3.33E-03	3.41E-03
NO_x (g/hr)	1.15E+03	1.18E+03	1.12E+03	1.15E+03
NO_x (g/BHp-hr)	0.47	0.48	0.46	0.47
NO_x (lb/hr)	2.53	2.59	2.47	2.53
NO_x (lb/MMBtu)	0.1416	0.1418	0.1341	0.1392
NO_x (g/kW-hr)	0.6328	0.6498	0.6178	0.6335
CO (ppm@15%O_2)	0.99	1.08	1.10	1.06
CO (g/dscf)	5.67E-05	6.26E-05	6.46E-05	6.13E-05
CO (g/hr)	1.90E+01	2.12E+01	2.17E+01	2.06E+01
CO (g/BHp-hr)	0.0078	0.0087	0.0089	0.0085
CO (lb/hr)	0.0419	0.0468	0.0479	0.0455
CO (lb/MMBtu)	0.0023	0.0026	0.0026	0.0025
CO (g/kW-hr)	0.0105	0.0117	0.0120	0.0114
THC (ppm, as C, dry)	7.4	5.5	7.3	6.7
THC (ppm@15%O_2)	4.2	3.1	4.1	3.8
THC (g/dscf)	1.04E-04	7.82E-05	1.03E-04	9.50E-05
THC (g/hr)	3.48E+01	2.65E+01	3.46E+01	3.20E+01
THC (g/BHp-hr)	0.0143	0.0109	0.0143	0.0132
THC (lb/hr)	0.0767	0.0584	0.0764	0.0705
THC (lb/MMBtu)	0.0043	0.0032	0.0042	0.0039
THC (g/kW-hr)	0.0192	0.0146	0.0191	0.0177

CEM Tests Summary of Results
USMA - West Point, NY - Lot AAA
Generator # 2 - 1600 kW

TEST:	CEM - 1	CEM - 2	CEM - 3	AVERAGE
DATE:	10/4/2017	10/4/2017	10/4/2017	
TIME:	1500-1559	1623-1722	1737-1837	
INPUTS				
O_2 Concentration (%), dry	10.90	10.80	11.00	10.90
CO_2 Concentration (%), dry	7.10	7.15	7.09	7.11
NO_x Concentration (ppm), dry	59.00	60.60	62.30	60.63
CO Concentration (ppm), dry	1.20	1.70	2.90	1.93
THC Conc. (ppm), wet, as C	3.00	4.10	3.90	3.67
Ambient Barometric Press ("Hg)	30.20	30.20	30.20	30.20
Moisture Content (%)	6.29	7.51	7.38	7.06
Volumetric Flowrate (dscfm)	5412	5378	5307	5366
Kilowatt Output	1600	1600	1600	1600
Fuel Analysis				
% Carbon				
% Hydrogen				
% Nitrogen				
% Sulfur				
% Oxygen				
Gross Calorific Value, (Btu/lb)				
F-factor, (dscf/MMBtu), M19	9190	9190	9190	9190
OUTPUTS				
F_d, (dscf/MMBtu) fuel analysis				
Break-horsepower-hour	2145.6	2145.6	2145.6	2145.6
NO_x (ppm@15%O_2)	34.8	35.4	37.1	35.8
NO_x (g/dscf)	3.20E-03	3.28E-03	3.37E-03	3.28E-03
NO_x (g/hr)	1.04E+03	1.06E+03	1.07E+03	1.06E+03
NO_x (g/BHp-hr)	0.48	0.49	0.50	0.49
NO_x (lb/hr)	2.29	2.34	2.37	2.33
NO_x (lb/MMBtu)	0.1353	0.1376	0.1443	0.1391
NO_x (g/kW-hr)	0.6485	0.6619	0.6715	0.6607
CO (ppm@15%O_2)	0.71	0.99	1.73	1.14
CO (g/dscf)	3.96E-05	5.60E-05	9.56E-05	6.37E-05
CO (g/hr)	1.28E+01	1.81E+01	3.04E+01	2.05E+01
CO (g/BHp-hr)	0.0060	0.0084	0.0142	0.0095
CO (lb/hr)	0.0283	0.0399	0.0671	0.0451
CO (lb/MMBtu)	0.0017	0.0023	0.0041	0.0027
CO (g/kW-hr)	0.0080	0.0113	0.0190	0.0128
THC (ppm, as C, dry)	3.20	4.43	4.21	3.95
THC (ppm@15%O_2)	1.89	2.59	2.51	2.33
THC (g/dscf)	4.52E-05	6.26E-05	5.95E-05	5.58E-05
THC (g/hr)	1.47E+01	2.02E+01	1.89E+01	1.79E+01
THC (g/BHp-hr)	0.0068	0.0094	0.0088	0.0084
THC (lb/hr)	0.0324	0.0446	0.0418	0.0396
THC (lb/MMBtu)	0.0019	0.0026	0.0025	0.0024
THC (g/kW-hr)	0.0092	0.0126	0.0118	0.0112

CEM Tests Summary of Results
USMA - West Point, NY - Lot AAA
Generator # 2 - 1188 kW

TEST:	CEM - 1	CEM - 2	CEM - 3	AVERAGE
DATE:	10/5/2017	10/5/2017	10/5/2017	
TIME:	1306-1406	1431-1533	1555-1659	
INPUTS				
O_2 Concentration (%), dry	11.83	11.58	11.63	11.68
CO_2 Concentration (%), dry	6.63	6.61	6.67	6.64
NO_x Concentration (ppm), dry	60.20	62.35	63.29	61.95
CO Concentration (ppm), dry	2.67	4.04	4.38	3.70
THC Conc. (ppm), wet, as C	3.75	8.52	5.80	6.02
Ambient Barometric Press ("Hg)	30.10	30.10	30.10	30.10
Moisture Content (%)	7.22	7.36	7.70	7.43
Volumetric Flowrate (dscfm)	4077	4024	4230	4110
Kilowatt Output	1188	1188	1188	1188
Fuel Analysis				
% Carbon				
% Hydrogen				
% Nitrogen				
% Sulfur				
% Oxygen				
Gross Calorific Value, (Btu/lb)				
F-factor, (dscf/MMBtu), M19	9190	9190	9190	9190
OUTPUTS				
F_d, (dscf/MMBtu) fuel analysis				
Break-horsepower-hour	1593.1	1593.1	1593.1	1593.1
NO_x (ppm@15%O_2)	39.16	39.47	40.28	39.64
NO_x (g/dscf)	3.26E-03	3.38E-03	3.43E-03	3.36E-03
NO_x (g/hr)	7.98E+02	8.15E+02	8.70E+02	8.28E+02
NO_x (g/BHp-hr)	0.50	0.51	0.55	0.52
NO_x (lb/hr)	1.76	1.80	1.92	1.82
NO_x (lb/MMBtu)	0.1522	0.1534	0.1566	0.1541
NO_x (g/kW-hr)	0.6714	0.6863	0.7323	0.6967
CO (ppm@15%O_2)	1.74	2.56	2.79	2.36
CO (g/dscf)	8.80E-05	1.33E-04	1.44E-04	1.22E-04
CO (g/hr)	2.15E+01	3.22E+01	3.66E+01	3.01E+01
CO (g/BHp-hr)	0.0135	0.0202	0.0230	0.0189
CO (lb/hr)	0.0475	0.0709	0.0808	0.0664
CO (lb/MMBtu)	0.0041	0.0061	0.0066	0.0056
CO (g/kW-hr)	0.0181	0.0271	0.0308	0.0253
THC (ppm, as C, dry)	4.04	9.20	6.28	6.51
THC (ppm@15%O_2)	2.63	5.82	4.00	4.15
THC (g/dscf)	5.71E-05	1.30E-04	8.88E-05	9.19E-05
THC (g/hr)	1.40E+01	3.14E+01	2.25E+01	2.26E+01
THC (g/BHp-hr)	0.0088	0.0197	0.0141	0.0142
THC (lb/hr)	0.0308	0.0692	0.0497	0.0499
THC (lb/MMBtu)	0.0027	0.0059	0.0041	0.0042
THC (g/kW-hr)	0.0118	0.0264	0.0190	0.0190

APPENDIX B

EPA Method 2, 3, and 4 Data Summary

EPA Method 2, 3, and 4 Data Summary
Lot AAA - USMA - West Point, NY
2.0 MW Cummins Generator #1 Model No. DQKAE (Spec F) Serial No. L160134320
Load - 1800 kW

RUN NO.:	M2-1/M4-1	M2-2/M4-2	M2-3/M4-3	Average
DATE:	10/3/2017	10/3/2017	10/3/2017	
TIME:	1120-1220	1315-1425	1517-1623	
INPUTS				
Pbar, ("Hg)	30.60	30.60	30.50	30.57
Stack Area, (ft^2)	3.14	3.14	3.14	3.14
Total Time, (minutes)	60	70	66	65
Calibration Factor	1.0085	1.0085	1.0085	1.0085
Pitot Coefficienct	0.84	0.84	0.84	0.84
Square Root Delta P, ("H_2O)	0.8465	0.8689	0.8609	0.8588
Delta H, ("H_2O)	0.8727	0.9450	0.9250	0.9142
Meter Temp., (^oF)	71	74	73	73
Static Press., ("H_2O)	1.000	1.000	1.000	1.000
Stack Temp., (^oF)	773	787	787	782
Meter Volume, (ft^3)	31.420	38.045	36.037	35.167
Total H_2O Vapor, (ml)	60.4	69.3	69.9	66.5
CO_2 in Stack Gas, (%)	7.3	7.0	7.4	7.2
O_2 in Stack Gas, (%)	10.5	10.8	10.8	10.7
CO in Stack Gas, (%)	0.0	0.0	0.0	0.0
N_2 in Stack Gas, (%)	82.2	82.2	81.8	82.1
OUTPUTS				
Meter Volume Standard, (ft^3)	32.29	38.89	36.78	35.99
H_2O in Stack Gas, (%)	8.09	7.74	8.21	8.01
Stack Gas Molecular Weight	28.65	28.66	28.66	28.66
Excess Air, (%)	93.7	99.1	100.0	97.6
Stack Gas Velocity, (fpm)	4320.24	4459.07	4424.90	4401.40
Gas Flowrate, (acfm)	13566	14001	13894	13820
STP Flowrate, (dscfm)	5473	5607	5518	5533

NE NORTHERN ENGINEERING

EPA Method 2, 3, and 4 Data Summary
Lot AAA - USMA - West Point, NY
2.0 MW Cummins Generator #1 Model No. DQKAE (Spec F) Serial No. L160134320
1369 kW

RUN NO.:	M2-1/M4-1	M2-2/M4-2	M2-3/M4-3	Average
DATE:	10/4/2017	10/4/2017	10/4/2017	
TIME:	0945-1048	1122-1222	1250-1342	
INPUTS				
Pbar, ("Hg)	30.40	30.40	30.30	30.37
Stack Area, (ft^2)	3.14	3.14	3.14	3.14
Total Time, (minutes)	63	60	58	60
Calibration Factor	1.0085	1.0085	1.0085	1.0085
Pitot Coefficienct	0.84	0.84	0.84	0.84
Square Root Delta P, ("H_2O)	0.7752	0.6603	0.7602	0.7319
Delta H, ("H_2O)	2.00	2.00	2.00	2.00
Meter Temp., (^oF)	65	71	74	70
Static Press., ("H_2O)	1.000	1.000	1.000	1.000
Stack Temp., (^oF)	721	743	756	740
Meter Volume, (ft^3)	50.984	48.310	42.660	47.318
Total H_2O Vapor, (ml)	90.5	73.7	63.8	76.0
CO_2 in Stack Gas, (%)	6.8	6.8	6.9	6.8
O_2 in Stack Gas, (%)	11.9	11.6	11.5	11.7
CO in Stack Gas, (%)	0.0	0.0	0.0	0.0
N_2 in Stack Gas, (%)	81.4	81.5	81.6	81.5
OUTPUTS				
Meter Volume Standard, (ft^3)	52.79	49.48	43.27	48.51
H_2O in Stack Gas, (%)	7.47	6.55	6.49	6.84
Stack Gas Molecular Weight	28.70	28.80	28.82	28.77
Excess Air, (%)	123.6	117.5	115.0	118.7
Stack Gas Velocity, (fpm)	3881.10	3330.77	3860.45	3690.78
Gas Flowrate, (acfm)	12187	10459	12122	11589
STP Flowrate, (dscfm)	5136	4369	4996	4834

NE NORTHERN ENGINEERING

EPA Method 2, 3, and 4 Data Summary
Lot AAA - USMA - West Point, NY
2.0 MW Cummins Generator #1 Model No. DQKAE (Spec F) Serial No. L160134320
1150 kW

RUN NO.:	M2-1/M4-1	M2-2/M4-2	M2-3/M4-3	Average
DATE:	10/11/2017	10/11/2017	10/11/2017	
TIME:	1010-1110	1120-1220	1224-1347	
INPUTS				
Pbar, ("Hg)	30.10	30.10	30.10	30.10
Stack Area, (ft^2)	3.14	3.14	3.14	3.14
Total Time, (minutes)	60	60	83	68
Calibration Factor	1.0085	1.0085	1.0085	1.0085
Pitot Coefficienct	0.84	0.84	0.84	0.84
Square Root Delta P, ("H_2O)	0.6224	0.6158	0.6433	0.6272
Delta H, ("H_2O)	2.00	2.00	2.00	2.00
Meter Temp., (^oF)	72	77	80	76
Static Press., ("H_2O)	1.000	1.000	1.000	1.000
Stack Temp., (^oF)	755	760	760	758
Meter Volume, (ft^3)	48.576	49.798	68.877	55.750
Total H_2O Vapor, (ml)	76.4	77.9	104.6	86.3
CO_2 in Stack Gas, (%)	6.4	6.4	6.5	6.4
O_2 in Stack Gas, (%)	12.4	12.6	12.3	12.5
CO in Stack Gas, (%)	0.0	0.0	0.0	0.0
N_2 in Stack Gas, (%)	81.2	81.0	81.2	81.1
OUTPUTS				
Meter Volume Standard, (ft^3)	49.18	49.89	68.72	55.93
H_2O in Stack Gas, (%)	6.81	6.85	6.69	6.78
Stack Gas Molecular Weight	28.74	28.74	28.76	28.75
Excess Air, (%)	137.9	144.0	136.0	139.3
Stack Gas Velocity, (fpm)	3175.06	3147.58	3285.63	3202.76
Gas Flowrate, (acfm)	9970	9883	10317	10057
STP Flowrate, (dscfm)	4070	4017	4203	4097

NE NORTHERN ENGINEERING

EPA Method 2, 3, and 4 Data Summary
Lot AAA - USMA - West Point, NY
2.0 MW Cummins Generator #2 Model No. DQKAE (Spec F) Serial No. K160119884
1811 kW

RUN NO.:	M5-1	M5-2	M5-3	Average
DATE:	10/5/2017	10/5/2017	10/5/2017	
TIME:	0845-0945	1015-1115	1144-1244	
INPUTS				
Pbar, ("Hg)	30.10	30.10	30.10	30.10
Stack Area, (ft^2)	3.14	3.14	3.14	3.14
Total Time, (minutes)	60	60	60	60
Calibration Factor	1.0085	1.0085	1.0085	1.0085
Pitot Coefficienct	0.84	0.84	0.84	0.84
Square Root Delta P, ("H_2O)	0.8963	0.9003	0.9010	0.8992
Delta H, ("H_2O)	1.017	1.027	1.019	1.021
Meter Temp., (^oF)	69	79	84	78
Static Press., ("H_2O)	1.000	1.000	1.000	1.000
Stack Temp., (^oF)	797	807	816	807
Meter Volume, (ft^3)	34.728	35.449	35.335	35.171
Total H_2O Vapor, (ml)	85.4	73.4	77.4	78.7
CO_2 in Stack Gas, (%)	7.6	7.8	7.7	7.7
O_2 in Stack Gas, (%)	10.7	10.5	10.4	10.5
CO in Stack Gas, (%)	0.0	0.0	0.0	0.0
N_2 in Stack Gas, (%)	81.8	81.7	81.9	81.8
OUTPUTS				
Meter Volume Standard, (ft^3)	35.23	35.31	34.85	35.13
H_2O in Stack Gas, (%)	10.24	8.91	9.46	9.54
Stack Gas Molecular Weight	28.45	28.62	28.55	28.54
Excess Air, (%)	97.6	95.4	92.8	95.3
Stack Gas Velocity, (fpm)	4673.49	4698.33	4724.32	4698.71
Gas Flowrate, (acfm)	14675	14753	14834	14754
STP Flowrate, (dscfm)	5580	5647	5606	5611

NE NORTHERN ENGINEERING

EPA Method 2, 3, and 4 Data Summary
Lot AAA - USMA - West Point, NY
2.0 MW Cummins Generator #2 Model No. DQKAE (Spec F) Serial No. K160119884
1600 kW

RUN NO.:	M2-1/M4-1	M2-2/M4-2	M2-3/M4-3	Average
DATE:	10/4/2017	10/4/2017	10/4/2017	
TIME:	1515-1604	1609-1709	1717-1817	
INPUTS				
Pbar, ("Hg)	30.20	30.20	30.20	30.20
Stack Area, (ft^2)	3.14	3.14	3.14	3.14
Total Time, (minutes)	49	60	60	56
Calibration Factor	1.0085	1.0085	1.0085	1.0085
Pitot Coefficienct	0.84	0.84	0.84	0.84
Square Root Delta P, ("H_2O)	0.8482	0.8373	0.8596	0.8484
Delta H, ("H_2O)	2.00	2.00	2.00	2.00
Meter Temp., (^oF)	78	79	78	78
Static Press., ("H_2O)	1.000	1.000	1.000	1.000
Stack Temp., (^oF)	735	731	744	737
Meter Volume, (ft^3)	38.708	49.240	49.335	45.761
Total H_2O Vapor, (ml)	55.4	85.2	83.9	74.8
CO_2 in Stack Gas, (%)	7.1	7.1	7.1	7.1
O_2 in Stack Gas, (%)	10.9	10.8	11.0	10.9
CO in Stack Gas, (%)	0.0	0.0	0.0	0.0
N_2 in Stack Gas, (%)	81.9	82.0	81.9	82.0
OUTPUTS				
Meter Volume Standard, (ft^3)	38.83	49.39	49.56	45.92
H_2O in Stack Gas, (%)	6.29	7.51	7.38	7.06
Stack Gas Molecular Weight	28.85	28.71	28.72	28.76
Excess Air, (%)	102.4	100.3	102.7	101.8
Stack Gas Velocity, (fpm)	4274.72	4223.32	4358.52	4285.52
Gas Flowrate, (acfm)	13423	13261	13686	13457
STP Flowrate, (dscfm)	5623	5502	5624	5583

NE NORTHERN ENGINEERING

EPA Method 2, 3, and 4 Data Summary
Lot AAA - USMA - West Point, NY
2.0 MW Cummins Generator #2 Model No. DQKAE (Spec F) Serial No. K160119884
1188 kW

RUN NO.:	M2-1/M4-1	M2-2/M4-2	M2-3/M4-3	Average
DATE:	10/5/2017	10/5/2017	10/5/2017	
TIME:	1342-1444	1446-1536	1540-1630	
INPUTS				
Pbar, ("Hg)	30.10	30.10	30.10	30.10
Stack Area, (ft^2)	3.14	3.14	3.14	3.14
Total Time, (minutes)	62	50	50	54
Calibration Factor	1.0085	1.0085	1.0085	1.0085
Pitot Coefficienct	0.84	0.84	0.84	0.84
Square Root Delta P, ("H_2O)	0.7117	0.7178	0.7116	0.7137
Delta H, ("H_2O)	2.00	2.00	2.00	2.00
Meter Temp., (^oF)	86	88	87	87
Static Press., ("H_2O)	1.000	1.000	1.000	1.000
Stack Temp., (^oF)	769	772	772	771
Meter Volume, (ft^3)	50.933	41.216	42.212	44.787
Total H_2O Vapor, (ml)	83.0	68.3	73.7	75.0
CO_2 in Stack Gas, (%)	6.6	6.6	6.7	6.6
O_2 in Stack Gas, (%)	11.8	11.6	11.6	11.7
CO in Stack Gas, (%)	0.0	0.0	0.0	0.0
N_2 in Stack Gas, (%)	81.5	81.8	81.7	81.7
OUTPUTS				
Meter Volume Standard, (ft^3)	50.24	40.49	41.57	44.10
H_2O in Stack Gas, (%)	7.22	7.36	7.70	7.42
Stack Gas Molecular Weight	28.70	28.67	28.64	28.67
Excess Air, (%)	122.0	115.5	117.0	118.2
Stack Gas Velocity, (fpm)	3653.00	3690.65	3660.62	3668.09
Gas Flowrate, (acfm)	11470	11589	11494	11518
STP Flowrate, (dscfm)	4611	4640	4585	4612

NE NORTHERN ENGINEERING

APPENDIX C

Summary of TSP Emissions

Summary of TSP Emissions

TEST SITE: USMA - West Point, NY Lot AAA
TEST LOCATION: Generator #1

RUN NO.:	M5-1	M5-2	M5-3	AVERAGE
DATE:	10/3/2017	10/3/2017	10/3/2017	
TIME:	1120-1220	1315-1425	1517-1623	
PBAR, (in. Hg)	30.60	30.60	30.50	30.57
STACK AREA, (ft^2)	3.14	3.14	3.14	3.140
NOZZLE DIA., (in.)	0.250	0.250	0.250	0.250
TOTAL TIME, (minutes)	60	70	66	65
CALIBRATION FACTOR	1.0085	1.0085	1.0085	1.01
PITOT COEFFICIENT	0.84	0.84	0.84	0.84
SQ.RT.DELTA P, (in. H_2O)	0.8465	0.8689	0.8609	0.8588
DELTA H, (in. H_2O)	0.8727	0.9450	0.9250	0.9142
METER TEMP., (Degree F)	71.0	74.0	73.0	72.7
STATIC PRESS., (in. H_2O)	1.00	1.00	1.00	1.00
STACK TEMP., (Degree F)	773.0	787.0	787.0	782.3
METER VOLUME, (cu.ft.)	31.420	38.045	36.037	35.167
TOTAL H_2O VAPOR, (ml)	60.4	69.3	69.9	66.5
KILOWATT (kW)	1804	1805	1805	1805
CO_2 IN STACK GAS, (%)	7.30	7.00	7.40	7.23
O_2 IN STACK GAS, (%)	10.50	10.80	10.80	10.70
CO IN STACK GAS, (%)	0.00	0.00	0.00	0.00
N_2 IN STACK GAS, (%)	82.20	82.20	81.80	82.07
TOTAL PART. CATCH, (mg)	7.59	8.45	10.78	8.94
HYDROGEN IN FUEL, (%)				
CARBON IN FUEL, (%)				
SULFUR IN FUEL, (%)				
NITROGEN IN FUEL, (%)				
OXYGEN IN FUEL, (%)				
GCV, (Btu/lb)				
F-FACTOR, (dscf/MMBtu)	9190	9190	9190	9190.00
METER VOL. STD, (cu.ft.)	32.29	38.89	36.78	35.99
H_2O IN STACK GAS, (%)	8.09	7.74	8.21	8.01
STACK GAS MOLECULAR WT	28.65	28.66	28.66	28.66
EXCESS AIR, (%)	93.7	99.1	100.0	97.6
STACK GAS VEL., (fpm)	4320.24	4459.07	4424.90	4401.40
GAS FLOWRATE, (acfm)	13566	14001	13894	13820
STP FLOWRATE, (dscfm)	5473	5607	5518	5533
ISOKINETIC, (%)	90.6	91.3	93.1	91.7
PART. CONC., (ug/acm)	3.3511E+03	3.0750E+03	4.1128E+03	3.51E+03
PART. CONC., (gr/acf)	1.4633E-03	1.3428E-03	1.7959E-03	1.53E-03
PART. CONC., (gr/dscf)	3.6267E-03	3.3528E-03	4.5222E-03	3.83E-03
PART. CONC., (gr/dscf@7%O_2)	4.85E-03	4.61E-03	6.22E-03	5.23E-03
CONC., (gr/dscf@12%CO_2)	5.9618E-03	5.7477E-03	7.3333E-03	6.35E-03
CONC, (gr/dscf@50%EA)	4.68E-03	4.45E-03	6.03E-03	5.06E-03
EMISSION RATE, (lb/hr)	0.1701	0.1611	0.2139	1.82E-01
F-FACTOR, (dscf/MMBtu)	9190	9190	9190	9190
EMISSIONS, (lb/MMBtu)	9.5714E-03	9.1114E-03	1.2289E-02	1.03E-02
EMISSIONS, (g/kW-hr)	0.0428	0.0405	0.0537	0.0457

NE NORTHERN ENGINEERING

Summary of TSP Emissions

TEST SITE: USMA - West Point, NY - Lot AAA
TEST LOCATION: Generator #2

RUN NO.:	M5-1	M5-2	M5-3	AVERAGE
DATE:	10/5/2017	10/5/2017	10/5/2017	
TIME:	0845-0945	1015-1115	1144-1244	
PBAR, (in. Hg)	30.10	30.10	30.10	30.10
STACK AREA, (ft^2)	3.14	3.14	3.14	3.140
NOZZLE DIA., (in.)	0.250	0.250	0.250	0.250
TOTAL TIME, (minutes)	60	60	60	60
CALIBRATION FACTOR	1.0085	1.0085	1.0085	1.01
PITOT COEFFICIENT	0.84	0.84	0.84	0.84
SQ.RT.DELTA P, (in. H_2O)	0.8963	0.9003	0.9010	0.8992
DELTA H, (in. H_2O)	1.017	1.0267	1.0187	1.02
METER TEMP., (Degree F)	69.4	79.2	84.4	77.7
STATIC PRESS., (in. H_2O)	1.00	1.00	1.00	1.00
STACK TEMP., (Degree F)	797.0	807.0	815.6	806.5
METER VOLUME, (cu.ft.)	34.728	35.449	35.335	35.171
TOTAL H_2O VAPOR, (ml)	85.4	73.4	77.4	78.7
KILOWATT (kW)	1811	1811	1811	1811
CO_2 IN STACK GAS, (%)	7.57	7.76	7.70	7.68
O_2 IN STACK GAS, (%)	10.66	10.53	10.40	10.53
CO IN STACK GAS, (%)	0.00	0.00	0.00	0.00
N_2 IN STACK GAS, (%)	81.77	81.71	81.90	81.79
TOTAL PART. CATCH, (mg)	8.567	8.010	3.737	6.771
HYDROGEN IN FUEL, (%)				
CARBON IN FUEL, (%)				
SULFUR IN FUEL, (%)				
NITROGEN IN FUEL, (%)				
OXYGEN IN FUEL, (%)				
GCV, (Btu/lb)				
F-FACTOR, (dscf/MMBtu)	9190	9190	9190	9190.00
METER VOL. STD, (cu.ft.)	35.23	35.31	34.85	35.13
H_2O IN STACK GAS, (%)	10.24	8.91	9.46	9.54
STACK GAS MOLECULAR WT	28.45	28.62	28.55	28.54
EXCESS AIR, (%)	97.6	95.4	92.7	95.2
STACK GAS VEL., (fpm)	4673.54	4698.39	4724.38	4698.77
GAS FLOWRATE, (acfm)	14675	14753	14835	14754
STP FLOWRATE, (dscfm)	5580	5647	5606	5611
ISOKINETIC, (%)	97.0	96.0	95.5	96.2
PART. CONC., (ug/acm)	3.2673E+03	3.0688E+03	1.4318E+03	2.59E+03
PART. CONC., (gr/acf)	1.4267E-03	1.3400E-03	6.2523E-04	1.13E-03
PART. CONC., (gr/dscf)	3.7524E-03	3.5006E-03	1.6544E-03	2.97E-03
PART. CONC., (gr/dscf@7%O_2)	5.09E-03	4.69E-03	2.19E-03	3.99E-03
CONC., (gr/dscf@12%CO_2)	0.005948287	5.4133E-03	2.5782E-03	4.65E-03
CONC, (gr/dscf@50%EA)	4.94E-03	4.56E-03	2.13E-03	3.88E-03
EMISSION RATE, (lb/hr)	0.1795	0.1694	0.0795	0.1428
F-FACTOR, (dscf/MMBtu)	9190	9190	9190	9190
EMISSIONS, (lb/MMBtu)	1.0058E-02	9.2652E-03	4.3245E-03	7.88E-03
EMISSIONS (g/kW-hr)	0.0449	0.0424	0.0199	0.0358

NE NORTHERN ENGINEERING

APPENDIX D

Calculation Examples

EXAMPLE CALCULATIONS

1. grams per dry standard cubic meter, (g/dscm)

$$= \frac{\text{ppmv} \times \text{MW}}{22.414\ \text{l/g-mole} \times 1\text{E-3}\ m^3/\text{l} \times (293.15^\circ\text{K}/273.15^\circ\text{K})} \times (1/1\text{E6 ppm})$$

2. grams per dry standard cubic foot, (g/dscf)

$$= \frac{\text{ppmv} \times \text{MW}}{22.414\ \text{l/g-mole} \times 3.531\text{E-2}\ ft^3/\text{l} \times (528.27^\circ\text{R}/492.27^\circ\text{R})} \times (1/1\text{E6 ppm})$$

3. grams per hour, (g/hr)

$$= \text{g/dscf} \times \text{dscfm} \times 60$$

4. grams per Break-Horsepower-Hour, (g/BHp-hr)

$$= \frac{\text{g/hr}}{\text{BHp-hr}} = \frac{\text{g/hr}}{\text{kW} \times 1.341}$$

where, ppmv = parts per million by volume
MW = molecular weight in grams per gram-mole (g/g-mole)
l/g-mole = liters per gram-mole
ft^3/l = cubic feet per liter
$^\circ K$ = degrees Kelvin
$^\circ R$ = degrees Rankine

5. Conversion Factor (for the calculation of pounds per dry standard cubic feet)

$$= \frac{2.205\text{E-3 lb/g} \times 1.00\text{E-06}}{22.414\ \text{l/g-mole} \times 3.531\text{E-2 cf/l} \times (528.27^\circ\text{R}/492.27^\circ\text{R})}$$

where, lb/g = pounds per gram
l/g-mole = liters per gram-mole
cf/l = cubic feet per liter
$^\circ R$ = degrees Rankine
MW = molecular weight in grams per gram-mole (g/g-mole)

6. pounds per dry standard cubic feet, (lb/dscf)

$$= \text{ppm} \times \text{MW} \times 2.596\text{E-09}$$

7. pounds per hour, (lb/hr)

$$= \text{lb/dscf} \times \text{dscfm} \times 60$$

8. F-Factor, F_d, (dscf/MMBtu)

$$= \frac{10^6 \times (3.64\ \%H + 1.53\ \%C + 0.57\ \%S + 0.14\ \%N - 0.46\ \%O)}{GCV}$$

9. pounds per million Btu, (lb/MMBtu)

$$= \text{lb/dscf} \times F_d \times \frac{20.9}{20.9 - \%O_2}$$

NE NORTHERN ENGINEERING

EXAMPLE CALCULATIONS

Location:	Generator #1
Run No.:	M5-1
Date:	10/3/2017
Time:	1120-1220

INPUTS			EMISSION CALCULATION SYMBOLS
P bar	30.60	"	Barometric pressure, "Hg
As	3.14	"	Cross sectional area of duct, square feet
Dn	0.25	"	Nozzle Diameter, inches
Ttot	60	-	Total sampling time, minutes
Y	1.0085	-	Dry gas meter calibration factor
Cp	0.84	-	Pitot tube coefficient, dimensionless
DP avg	0.8465	-	Average square root of velocity head, sqrt("H_2O)
DH avg	0.8727	-	Average orifice pressure drop, "H_2O)
Tm avg	71	-	Average dry gas meter temperature, degrees F
Ps avg	1	-	Average duct static pressure, "H_2O)
Ts avg	773	-	Average Stack Temperature, degrees F
Vm tot	31.42	-	Total meter sample volume, cubic feet
Vi Vs	60.4	-	Total volume of liquid collected
%CO2	7.3	-	Percent CO_2 by volume (dry basis), %
%O2	10.5	-	Percent O_2 by volume (dry basis), %
%CO	0.0	-	Percent CO by volume (dry basis), %
%N2	82.2	-	Percent N_2 by volume (dry basis), %
Mn	7.59	-	Total particulate collected, mg

Fuel Input			
%H	0	-	Percent by weight of hydrogen in fuel
%C	0	-	Percent by weight of carbon in fuel
%S	0.00	-	Percent by weight of sulfur in fuel
%N	0.00	-	Percent by weight of nitrogen in fuel
%O	0.00	-	Percent by weight of oxygen in fuel
GCV	0	-	Gross calorific value of fuel, Btu/lb

Tstd	68	-	-Standard Temperature, degrees F
Pstd	29.92	-	-Standard Pressure, "Hg
Lp		-	-Final Leak Rate of Sampling Train, cfm
La		-	-Allowable Leak Rate of Sampling Train, cfm

1. Volume of Sample Measured By Dry Gas Meter, Corrected to Standard Conditions (Vm std)

$$= \text{Vm total} \times Y \times \frac{Tstd + 460}{Tm\ avg + 460} \times \frac{Pbar + DHavg/13.6}{P\ std}$$

$$= 31.42 \times 1.0085 \times \frac{68 + 460}{71 + 460} \times \frac{30.6 + 0.873/13.6}{29.92}$$

Vmstd = 32.29 dscf

2. Moisture Content of Duct Gas (%H2O)

$$= \frac{0.04707 \times (Vi + Vsg)}{Vm\ std + 0.04707 \times (Vi + Vsg)}$$

$$= \frac{0.04707 \times 60.4}{32.291714 + 0.04707 \times 60.4}$$

%H2O = 8.1 %

3. Molecular Weight of Stack Gas (MWs)

$$= [(0.44 \times \%CO2) + (0.28 \times \%CO) + (0.28 \times \%N2) + (0.32 \times \%O2)] \times \left(1 - \frac{\%H2O}{100}\right) + (0.18 \times \%H2O)$$

$$= [(0.44 \times 7.3) + (0.28 \times 0.0) + (0.28 \times 82.2) + (0.32 \times 10.5)] \times \left(1 - \frac{8.0}{100}\right) + (0.18 \times 8.0)$$

MWs = 28.65 lb/lb mole

4. Average Duct Gas Density (Dst)

$$= 0.0458 \times MWs \times \frac{Pbar + (Ps\ avg / 13.6)}{Ts\ avg + 460}$$

$$= 0.0458 \times 28.6503 \times \frac{30.6 + (1 / 13.6)}{773 + 460}$$

Dst = 0.033 lbs / cubic feet

5. Excess Air (EA)

$$= \frac{100 \times \%O2 - (0.5 \times \%CO)}{0.264 \times \%N2 - (\%O2 - (0.5 \times \%CO))}$$

$$= \frac{100 \times 10.5 - (0.5 \times 0)}{0.264 \times 82.2 - (10.5 - (0.5 \times 0))}$$

EA = 94 %

6. Average Duct Velocity (Vs)

$$= 5129.4 \times Cp \times DP\ avg \times SQRT\left\{\frac{Ts\ avg + 460}{(P\ bar + Ps\ avg / 13.6) \times MW}\right\}$$

$$= 5129.4 \times 0.84 \times 0.847 \times SQRT\left\{\frac{773 + 460}{(30.6 + 1 / 13.6) \times 28.65}\right\}$$

Vs = 4320 ft/min

7. Duct Volumetric Flow Rate, (Q)

$$= Vs \times As$$

$$= 4320.2384 \times 3.14$$

Q = 13566 acfm

8. Duct Volumetric Flow Rate, Corrected to Dry Standard Conditions, (Qstd)

$$= Q \times \left(1 - \frac{\%H2O}{100}\right) \times \frac{Tstd + 460}{Ts\ avg + 460} \times \frac{P\ bar + Ps\ avg / 13.6}{P\ std}$$

$$= 13565.549 \times \left(1 - \frac{8.09179}{100}\right) \times \frac{68 + 460}{773 + 460} \times \frac{30.6 + 1 / 13.6}{29.92}$$

Qstd = 5473 dscfm

9. Isokinetic Factor, (I)

$$= \frac{5.67 \times (Ts\ avg + 460) \times Vm\ std}{(P\ bar + \frac{Ps\ avg}{13.6}) \times Vs \times T\ tot \times (1 - \frac{\%H2O}{100}) \times (\frac{Dn^2 \times 0.785}{144})}$$

$$= \frac{5.67 \times (773 + 460) \times 32.29}{(30.6 + \frac{1}{13.6}) \times 4320.24 \times 60 \times (1 - \frac{8.092}{100}) \times (\frac{0.063 \times 0.785}{144})}$$

I = 90.6 %

10. Actual Particulate Concentration, grains/acf, (C)

$$= \frac{0.01543 \times Mn \times (Tstd + 460) \times (P\ bar + \frac{Ps\ avg}{13.6} \times (1 - \frac{\%H2O}{100}))}{Vm\ std \times Ts\ avg + 460) \times P\ std}$$

$$0.01543 \times 7.59 \times (68 + 460) \times (30.6 + \frac{1}{} \times (1 - \frac{8.092}{}))$$

NE NORTHERN ENGINEERING

$$= \frac{}{32.2917 \times (773 + 460) \times \frac{13.6}{29.92}} \quad 100$$

Cs = 1.46E-03 grains/acf

10a. Actual Particulate Concentration based on stack conditions, ug/acm. (Cd)

$$= \frac{1000 \times Mn \times (Tstd + 460) \times (P\,bar + \frac{Ps\,avg}{13.6}) \times (1 - \frac{\%H2O}{100})}{0.02832 \times Vm\,std \times (Ts\,avg + 460) \times P\,std}$$

$$= \frac{1000 \times 7.59 \times (68 + 460) \times (30.6 + \frac{1}{13.6}) \times (1 - \frac{8.092}{100})}{0.02832 \times 32.2917 \times (773 + 460) \times 29.92}$$

Cd = 3348.8 ug/acm

11. Particulate Concentration, Corrected to Dry Standard Conditions. (Cs)

$$= 0.01543 \times \frac{Mn}{Vm\,std}$$

$$= 0.01543 \times \frac{7.59}{32.2917}$$

Cs = 3.63E-03 gr/dscf

12. Particulate Emission Rate, (ER)

$$= 0.008571 \times Cs \times Qstd$$

$$= 0.008571 \times 0.004 \times 5473.49$$

ER = 0.1701 lbs/hr

13. F - Factor (F)

$$= \frac{(1 \times 10^6) \times \{(3.64 \times \%H) + (1.53 \times \%C) + (0.57 \times \%S) + (0.14 \times \%N) - (0.46 \times \%O)\}}{GCV}$$

$$= \frac{(1 \times 10^6) \times \{(3.64 \times 0) + (1.53 \times 0.00) + (0.57 \times 0.00) + (0.14 \times 0.00) - (0.46 \times 0.00)\}}{0}$$

F = #DIV/0! dscf/MM BTU

14. Particulate Emission. (E)

$$= 0.0001429 \times Cs \times F \times \left(\frac{20.9}{20.9 - \%O2}\right)$$

$$= 0.0001429 \times 0.00363 \times \#DIV/0! \times \left(\frac{20.9}{20.9 - 10.5}\right)$$

E = #DIV/0! lb/MM BTU

15. Particulate Concentration Corrected to Dry Standard Conditions and 12% CO2. (Cs @12%CO2)

$$= Cs \times \frac{12}{\%CO2}$$

$$= 0.004 \times \frac{12}{7.3}$$

Cs @ 12%CO2 0.006 grains/dscf @ 12% CO2

16. Particulate Concentration Corrected to Dry Standard Conditions and 7% O2, (Cs @7%O2)

$$= Cs \times \frac{20.9 - 7}{20.9 - \%d20d}$$

NE NORTHERN ENGINEERING

$$0.004 \times \frac{20.9 - 7}{20.9 - 10.5}$$

Cs @7%O2 = 0.005 grains/dscf @ 7% O2

17. Correction for Excessive Leak Rate, (Vmc total)

if Lp > La use Vmc total in place of Vm total in all subsequent equations.

Lp - Final leak rate of sampling train, cfm

Vm tot - (Lp - La) x T tot

31.42 - (0 - 0) x 60

Vmc tot = 31.42 cubic feet

EXAMPLE CALCULATIONS

Analyzer Calibration Error Calculations:

EPA Method 6C:

$$\frac{\text{Cylinder Value} - \text{Analyzer Response}}{\text{Span}} \times 100$$

EPA Method 25A:

Multiplication Factor Calculation, Mf:

$$Mf = \frac{Cm - Co}{Cma}$$

Cma = Span Gas Conc
Cm = Cal response
Co = Zero response

Calibration Error Calculation, Cerr:

$$Cerr = \frac{(\text{Cal Response} - \text{Zero}) - \text{Predicted Response}}{\text{Cal Gas Concentration}} \times 100$$

System Calibration Error Calculations:

System Bias:

$$\frac{\text{System Response} - \text{Analyzer Response}}{\text{Span}} \times 100$$

System Drift:

$$\frac{\text{Initial Response} - \text{Final Response}}{\text{Span}} \times 100$$

Adjusted Concentrations:

M6C Adjusted Conc., Cgas: (Avg Conc. - Avg Zero) x $\frac{\text{Cal. Gas Conc.}}{\text{Avg Upscale} - \text{Avg Zero}}$

M25A Adjusted Conc., Cgas: (Avg Conc. - Avg Zero)

Concentration as Carbon, ppmC: Cgas x Cal Gas K-Factor
(Propane K-factor = 3)

NE NORTHERN ENGINEERING