mostardi platt

Relative Accuracy Test Audit
Test Report

Michigan State University
T.B. Simon Power Plant
Unit 3 Outlet Duct
East Lansing, Michigan
February 24 and 27, 2017

Report Submittal Date
April 26, 2017

Project No. M170605C

888 Industrial Drive
Elmhurst, Illinois 60126
630-993-2100

1.0 EXECUTIVE SUMMARY

MOSTARDI PLATT conducted a Continuous Emissions Monitoring System (CEMS) Relative Accuracy Test Audit (RATA) test program for Michigan State University at the T.B. Simon Power Plant in East Lansing, Michigan, on the Unit 3 Outlet Duct on February 24 and 27, 2017. This report summarizes the results of the test program and test methods used in accordance with the Mostardi Platt Protocol M170605 Rev. 2 dated February 2, 2017. Mostardi Platt is a self-certified air emissions testing body (AETB). A copy of Mostardi Platt's self-certification can be found in Appendix A.

The test location, test dates, and test parameters are summarized below.

TEST INFORMATION		
Test Location	**Test Dates**	**Test Parameters**
Unit 3 Outlet Duct	February 24 and 27, 2017	Carbon Dioxide (CO_2), Nitrogen Oxides (NO_x), and Volumetric Flow

The purpose of the test program was to demonstrate the relative accuracies of the Unit 3 Outlet Duct CO_2, NO_x, and volumetric flow analyzers during the specified operating conditions. The test results from this test program indicate that each CEMS component meets the United States Environmental Protection Agency (USEPA) annual performance specification for relative accuracy as published in 40 Code of Federal Regulations Part 75 (40CFR75).

RATA RESULTS						
Test Location	**Date**	**Parameter**	**Units**	**Relative Accuracy Acceptance Criteria**	**Relative Accuracy (RA)**	**Bias Adjustment Factor (BAF)**
Unit 3 Outlet Duct	2/24/17	NO_x	lb/mmBtu	≤ 7.5 % of the mean reference value	2.44%	1.000
		CO_2	% wet	≤ 7.5 % of the mean reference value	2.99%	N/A
	2/27/17	Volumetric Flow – Low (Normal) Load	scfh	≤ 7.5% of the mean reference value	0.79%	1.000
		Volumetric Flow – Mid Load	scfh	≤ 7.5% of the mean reference value	4.26%	1.000

The gas cylinders used to perform the RATA are summarized below.

GAS CYLINDER INFORMATION				
Parameter	**Gas Vendor**	**Cylinder Serial Number**	**Cylinder Value**	**Expiration Date**
NO_x	Airgas	CC135830	0.0 ppm	9/21/2024
NO_x	Airgas	CC490411	92.92 ppm	10/31/2024
NO_x	Airgas	CC417164	181.0 ppm	10/21/2024
CO_2	Airgas	CC490411	0.00 %	10/31/2024
CO_2	Airgas	CC135830	10.20 %	9/21/2024
CO_2	Airgas	EB0075821	19.70 %	2/1/2024

No deviations, additions, or exclusions from the test protocol, test methods, the Mostardi Platt Quality Manual, or the ASTM D7036-12 occurred. The specific test conditions encountered did not interfere with the collection of the data.

The identification of individuals associated with the test program is summarized below.

TEST PERSONNEL INFORMATION		
Location	**Address**	**Contact**
Test Facility	Michigan State University 354 Service Rd East Lansing, MI 48824	Mr. Rick Johnson Electrical Engineer (517) 884-7108 (phone) rjohnson@ipf.msu.edu
Testing Company Supervisor	Mostardi Platt 888 Industrial Drive Elmhurst, Illinois 60126	Mr. Stuart L. Burton Senior Project Manager 630-993-2100 (phone) sburton@mp-mail.com QI Group V (certified on 2/1/13)
Testing Company Personnel		Mr. Benjamin Garcia Test Engineer QI Group V (certified on 3/4/16)
		Mr. David Dixon Test Technician
		Mr. Eric Karberg Test Technician

Copies of the QI certifications for test personnel are included in Appendix B.

2.0 TEST METHODOLOGY

Emission testing was conducted following the United States Environmental Protection Agency (USEPA) methods specified in 40CFR75, 40 Code of Federal Regulations (40CFR60) Appendix A, and ASTM E337-02 in addition to the Mostardi Platt Quality Manual and the Mostardi Platt test protocol. Schematics of the test section diagrams and sampling trains used are included in Appendix C and D respectively. Calculation and nomenclature are included in Appendix E.

Copies of analyzer print-outs for each test run are included in Appendix F. CEM data and process data as provided by Michigan State University are included in Appendix G.

The following methodologies were used during the test program:

Method 1 Sample and Velocity Traverse Determination

Test measurement points were selected in accordance with USEPA Method 1, 40CFR60, Appendix A. The characteristics of the measurement location are summarized below.

TEST POINT INFORMATION AT Unit 3 Outlet Duct								
Stack Dimensions (Feet)	Equivalent Diameter (Feet)	Stack Area (Square Feet)	No. of Ports	Port Length (Inches)	Upstream Diameters	Downstream Diameters	Test Parameter	Number of Sampling Points
4.5 by 17.5	7.159	78.75	6	17.0	0.5	2	Volumetric Flow	24

Method 2 Volumetric Flow Rate Determination

Gas velocity was measured following USEPA Method 2, 40CFR60, Appendix A, for purposes of calculating stack gas volumetric flow rate. A 9.0 foot long S-type pitot tube, 0-10 inch differential pressure gauge, and K-type thermocouple and temperature readout were used to determine gas velocity at each sample point. All of the equipment used was calibrated in accordance with the specifications of the Method. Copies of field data sheets are included in Appendix H. Calibration data are presented in Appendix I. This testing met the performance specifications as outlined in the Method.

Method 3A Oxygen (O_2)/Carbon Dioxide (CO_2) Determination

Stack gas molecular weight was determined in accordance with USEPA Method 3, 40CFR60, Appendix A, during each volumetric flow rate determination. An ECOM analyzer was used to determine stack gas O_2 and CO_2 content and, by difference, nitrogen content. Calibration data are presented in Appendix I. Gas cylinder certifications are included in Appendix J. This testing met the performance specifications as outlined in the Method.

Method 3A Carbon Dioxide (CO_2) Determination

Stack gas CO_2 concentrations were determined in accordance with USEPA Method 3A, 40CFR60, Appendix A. A Thermo Scientific Model 41C Gas Filter Correlation Carbon Dioxide Analyzer was used to determine carbon dioxide concentrations in the manner specified in the Method. The instrument has a nondispersive infrared-based detector and operated in the nominal range of 0% to 20% with the specific range determined by the high-level span calibration gas of 19.70%.

The Model 41C High Level is based on the principle that CO_2 absorbs infrared radiation. Because infrared absorption is a non-linear measurement technique, it is necessary for the instrument electronics to transform the basic analyzer signal into a linear output. The analyzer uses an exact calibration curve to accurately linearize the instrument output over any range up to a concentration of 2000 ppm.

The sample is drawn into the analyzer through the sample bulkhead. The sample flows through the optical bench. Radiation from an infrared source is chopped and then passed through a gas filter alternating between CO_2 and N_2. The radiation then passes through a narrow bandpass

interference filter and enters the optical bench where absorption by the sample gas occurs. The infrared radiation then exits the optical bench and falls on an infrared detector.

The CO_2 side of the filter wheel acts to produce a reference beam which cannot be further attenuated by CO_2 in the sample cell. The N_2 side of the filter wheel is transparent to the infrared radiation and therefore produces a measure beam which can be absorbed by CO_2 in the cell. The rotating gas filter wheel causes the detector signal to be modulated. The amplitude of the detector signal is directly proportional to the concentration of CO_2 in the sample cell. Gases other than CO_2 do not cause modulation of the detector signal since they absorb the reference and measure beams equally. Thus the GFC system responds specifically to CO_2. The Model 41C High Level outputs the CO_2 concentration to the front panel display and the analog outputs.

Stack gas was delivered to the analyzer through an EPM in-situ dilution sampling system. Stack gas concentrations were diluted at a nominal 100:1 ratio utilizing purified dilution air. The entire system was calibrated in accordance with the Method, using USEPA Protocol gases introduced at the probe, before and after each test run.

A list of calibration gases used and the results of all calibration and other required quality assurance checks are found in Appendix I. Copies of the gas cylinder certifications are found in Appendix J. This testing met the performance specifications as outlined in the Method.

Method 4 Moisture Determination

USEPA Method 4, 40CFR60, Appendix A, was utilized to determine water (H_2O) content of the exhaust gas. 100 milliliters (ml) of water were added to each of the first two impingers, the third impinger was left empty, and the fourth impinger was charged with approximately 200 grams of silica gel. The impingers were placed in an ice bath to maintain the sampled gas passed through the silica gel impinger outlet below 68°F in order to increase the accuracy of the sampled dry gas volume measurement. The water volumes of the impinger train were measured and the silica gel was weighed before and after each test run to determine the mass of moisture condensed.

Each sample was extracted through a heated stainless-steel probe and filter assembly at a constant sample rate of approximately 0.75 cubic feet per minute, which was maintained throughout the course of the test run. Approximately, 21 dry standard cubic feet (dscf) were sampled for each, moisture run. After each run, a leak check of the sampling train was performed at a vacuum greater than the sampling vacuum to determine if any leakage had occurred during sampling. Following the leak check, the impingers were removed from the ice bath, water levels were measured, and the silica gel weight was recorded.

All of the equipment used was calibrated in accordance with the specifications of the Method. Copies of field data sheets are included in Appendix H. Calibration data is presented in Appendix I. This testing met the performance specifications as outlined in the Method.

Method 7E Nitrogen Oxides (NO_x) Determination

Stack gas NO_x concentrations and emission rates were determined in accordance with USEPA Method 7E, 40CFR60, Appendix A. A Thermo Scientific Model 42i Chemiluminescence Nitrogen Oxides Analyzer was used to determine nitrogen oxides concentrations, in the manner specified in the Method. The instrument operated in the nominal range of 0 ppm to 200 ppm with the specific range determined by the high-level span calibration gas of 181.0 ppm.

The Model 42i operates on the principle that nitric oxide (NO) and ozone (O_3) react to produce a characteristic luminescence with an intensity linearly proportional to the NO concentration. Infrared light emission results when electronically excited NO_2 molecules decay to lower energy states. Specifically,

$$NO+O_3 \rightarrow NO_2+O_2+hv$$

Nitrogen dioxide (NO_2) must first be transformed into NO before it can be measured using the chemiluminescent reaction. NO_2 is converted to NO by a molybdenum NO_2-to-NO converter heated to about 340 °C. The flue gas sample is drawn into the Model 42*i* through the sample bulkhead. The sample flows through a capillary, and then to the mode solenoid valve. The solenoid valve routes the sample either straight to the reaction chamber (NO mode) or through the NO_2-to-NO converter and then to the reaction chamber (NO_x mode). A flow sensor prior to the reaction chamber measures the sample flow. Dry air enters the Model 42*i* through the dry air bulkhead, passes through a flow switch, and then through a silent discharge ozonator. The ozonator generates the ozone needed for the chemiluminescent reaction. At the reaction chamber, the ozone reacts with the NO in the sample to produce excited NO_2 molecules. A photomultiplier tube (PMT) housed in a thermoelectric cooler detects the luminescence generated during this reaction. From the reaction chamber, the exhaust travels through the ozone (O_3) converter to the pump, and is released through the vent.

The NO and NO_x concentrations calculated in the NO and NO_x modes are stored in memory. The difference between the concentrations is used to calculate the NO_2 concentration. The Model 42i outputs NO, NO_2, and NO_x concentrations to the front panel display, the analog outputs, and also makes the data available over the serial or ethernet connection.

Stack gas was delivered to the analyzer through an EPM in-situ dilution sampling system. Stack gas concentrations were diluted at a nominal 100:1 ratio utilizing purified dilution air. The entire system was calibrated in accordance with the Method, using USEPA Protocol gases introduced at the probe, before and after each test run.

A list of calibration gases used and the results of all calibration and other required quality assurance checks are found in Appendix I. Copies of the gas cylinder certifications are found in Appendix J. The NO_2 to NO converter test can be found in Appendix K. This testing met the performance specifications as outlined in the Method.

3.0 TEST RESULT SUMMARIES

Client: Michigan State University
Facility: T.B. Simon Power Plant
Project #: M170605
Fuel Type: Natural Gas

Location: Unit 3 Outlet Duct Low Load
Date: 2/24/17
Test Method: 7E, 3A
Fuel Factor: 1040

NO_x lb/mmBtu RATA

CEM Monitor Information

NO_x Monitor/Model:	TECO 42CHL	**NO_x Serial # :**	42CHL-74905-378
CO_2 Monitor/Model:	TECO 41 CHL	**CO_2 Serial # :**	420107041

1=accept 0=reject	Test Run	KPPH	Test Date	Start Time	End Time	RM NO_x lb/mmBtu	CEM NO_x lb/mmBtu	(RM-CEM) Difference (di)	(RM-CEM) Difference^2 (di^2)
1	1	157.6	02/24/17	06:48	07:08	0.130	0.131	-0.001	0.000
1	2	157.8	02/24/17	07:24	07:44	0.128	0.131	-0.003	0.000
1	3	157.7	02/24/17	07:55	08:15	0.128	0.131	-0.003	0.000
0	4	157.5	02/24/17	08:26	08:46	0.128	0.132	-0.004	0.000
1	5	157.9	02/24/17	09:00	09:20	0.128	0.131	-0.003	0.000
1	6	158.1	02/24/17	09:35	09:55	0.128	0.130	-0.002	0.000
1	7	157.1	02/24/17	10:09	10:29	0.127	0.130	-0.003	0.000
1	8	157.4	02/24/17	10:39	10:59	0.127	0.129	-0.002	0.000
1	9	158.2	02/24/17	11:11	11:31	0.126	0.129	-0.003	0.000
1	10	157.7	02/24/17	11:45	12:05	0.126	0.129	-0.003	0.000
0	11	157.2	02/24/17	12:18	12:38	0.125	0.129	-0.004	0.000
0	12	157.2	02/24/17	12:51	13:11	0.125	0.128	-0.003	0.000

n	**9**	
t(0.025)	**2.306**	
Mean Reference Method Value	**0.128**	**RM avg**
Mean CEM Value	**0.130**	**CEM avg**
Sum of Differences	**-0.023**	**di**
Mean Difference	**-0.003**	**d**
Sum of Differences Squared	**0.000**	**di^2**
Standard Deviation	**0.001**	**sd**
Confidence Coefficient 2.5% Error (1-tail)	**0.001**	**cc**
Relative Accuracy	**2.44**	**RA**
Bias Adjustment Factor	**1.000**	**BAF**

Client: Michigan State University
Facility: T.B. Simon Power Plant
Project #: M170605

Location: Unit 3 Outlet Duct Low Load
Date: 2/24/17
Test Method: 3A

CO_2 % (wet) RATA

CEM Monitor Information

CO2 Monitor/Model:				TECO 41 CHL		**CO2 Serial # :**		420107041	
1=accept 0=reject	**Test Run**	**KPPH**	**Test Date**	**Start Time**	**End Time**	**RM CO_2 % (wet)**	**CEM CO_2 % (wet)**	**(RM-CEM) Difference (di)**	**(RM-CEM) Difference^2 (di^2)**
1	1	157.6	02/24/17	06:48	07:08	6.1	6.0	0.1	0.01
1	2	157.8	02/24/17	07:24	07:44	6.2	6.0	0.2	0.04
1	3	157.7	02/24/17	07:55	08:15	6.2	6.0	0.2	0.04
1	4	157.5	02/24/17	08:26	08:46	6.2	6.0	0.2	0.04
1	5	157.9	02/24/17	09:00	09:20	6.2	6.1	0.1	0.01
1	6	158.1	02/24/17	09:35	09:55	6.2	6.1	0.1	0.01
1	7	157.1	02/24/17	10:09	10:29	6.2	6.1	0.1	0.01
1	8	157.4	02/24/17	10:39	10:59	6.2	6.1	0.1	0.01
1	9	158.2	02/24/17	11:11	11:31	6.2	6.0	0.2	0.04
0	10	157.7	02/24/17	11:45	12:05	6.2	6.0	0.2	0.04
0	11	157.2	02/24/17	12:18	12:38	6.2	6.0	0.2	0.04
0	12	157.2	02/24/17	12:51	13:11	6.2	6.0	0.2	0.04

n	**9**	
t(0.025)	**2.306**	
Mean Reference Method Value	**6.189**	**RM avg**
Mean CEM Value	**6.044**	**CEM avg**
Sum of Differences	**1.300**	**di**
Mean Difference	**0.144**	**d**
Sum of Differences Squared	**0.210**	**di^2**
Standard Deviation	**0.053**	**sd**
Confidence Coefficient 2.5% Error (1-tail)	**0.041**	**cc**
Relative Accuracy	**2.99**	**RA**

Client: Michigan State University					**Test Location:** Unit 3 Outlet Duct			
Facility: T.B. Simon Power Plant					**Test Date:** 2/27/2017			
Project #: M170605					**Test Method:** 2			
					CEM Monitor Information			
Volumetric Flow RATA - Low (Normal) Load								
Flow Monitor/Model:			OFC 2000		**Flow Serial # :**		0250048	
1=accept 0=reject	**Test Run**	**Test Date**	**Start Time**	**End Time**	**Reference Method Flow SCFH**	**CEM Flow SCFH**	**(RM-CEM) Difference (di)**	**(RM-CEM) Difference ^{2} (di^2)**
1	1	02/27/17	20:10	20:20	4,098,000	4,026,000	72,000	5,184,000,000
1	2	02/27/17	20:30	20:40	4,075,000	4,080,000	-5,000	25,000,000
1	3	02/27/17	20:43	20:55	4,086,000	4,083,000	3,000	9,000,000
1	4	02/27/17	21:04	21:15	4,076,000	4,107,000	-31,000	961,000,000
1	5	02/27/17	21:18	21:30	4,066,000	4,082,000	-16,000	256,000,000
1	6	02/27/17	21:33	21:45	4,056,000	4,072,000	-16,000	256,000,000
1	7	02/27/17	21:53	22:05	4,110,000	4,099,000	11,000	121,000,000
1	8	02/27/17	22:10	22:20	4,070,000	4,126,000	-56,000	3,136,000,000
0	9	02/27/17	22:24	22:35	4,020,000	4,105,000	-85,000	7,225,000,000
1	10	02/27/17	22:37	22:47	4,093,000	4,104,000	-11,000	121,000,000
				n	**9**			
				t(0.025)	**2.306**			
				Mean Reference Method Value	**4081111.111**		**RM avg**	
				Mean CEM Value	**4086555.556**		**CEM avg**	
				Sum of Differences	**-49000.000**		**di**	
				Mean Difference	**-5444.444**		**d**	
				Sum of Differences Squared	**10069000000.000**		**di^2**	
				Standard Deviation	**35003.968**		**sd**	
				Confidence Coefficient 2.5% Error (1-tail)	**26906.383**		**cc**	
				Relative Accuracy	**0.79**		**RA**	
				Bias Adjustment Factor	**1.000**		**BAF**	

Client: Michigan State University					**Test Location:** Unit 3 Outlet Duct			
Facility: T.B. Simon Power Plant					**Test Date:** 2/27/2017			
Project #: M170605					**Test Method:** 2			
					CEM Monitor Information			
Volumetric Flow RATA - Mid Load								
Flow Monitor/Model:		OFC 2000			**Flow Serial # :**		0250048	
1=accept 0=reject	**Test Run**	**Test Date**	**Start Time**	**End Time**	**Reference Method Flow SCFH**	**CEM Flow SCFH**	**(RM-CEM) Difference (di)**	**(RM-CEM) Difference ^{2} (di^2)**
0	1	02/27/17	14:00	14:20	4,870,000	5,430,000	-560,000	313,600,000,000
0	2	02/27/17	14:25	14:40	4,903,000	5,439,000	-536,000	287,296,000,000
0	3	02/27/17	14:55	15:10	5,002,000	5,441,000	-439,000	192,721,000,000
1	4	02/27/17	15:57	16:11	5,133,000	5,455,000	-322,000	103,684,000,000
1	5	02/27/17	16:35	16:50	5,174,000	5,440,000	-266,000	70,756,000,000
1	6	02/27/17	16:55	17:10	5,253,000	5,443,000	-190,000	36,100,000,000
1	7	02/27/17	17:25	17:40	5,351,000	5,475,000	-124,000	15,376,000,000
1	8	02/27/17	17:43	17:58	5,304,000	5,455,000	-151,000	22,801,000,000
1	9	02/27/17	18:05	18:15	5,345,000	5,459,000	-114,000	12,996,000,000
1	10	02/27/17	18:17	18:27	5,314,000	5,450,000	-136,000	18,496,000,000
1	11	02/27/17	18:30	18:40	5,430,000	5,463,000	-33,000	1,089,000,000
1	12	02/27/17	18:44	18:56	5,422,000	5,459,000	-37,000	1,369,000,000
				n	**9**			
				t(0.025)	**2.306**			
				Mean Reference Method Value	**5302888.889**		**RM avg**	
				Mean CEM Value	**5455444.444**		**CEM avg**	
				Sum of Differences	**-1373000.000**		**di**	
				Mean Difference	**-152555.556**		**d**	
				Sum of Differences Squared	**282667000000.000**		**di^2**	
				Standard Deviation	**95661.004**		**sd**	
				Confidence Coefficient 2.5% Error (1-tail)	**73531.425**		**cc**	
				Relative Accuracy	**4.26**		**RA**	
				Bias Adjustment Factor	**1.000**		**BAF**	

4.0 CERTIFICATION

MOSTARDI PLATT is pleased to have been of service to Michigan State University. If you have any questions regarding this test report, please do not hesitate to contact us at 630-993-2100.

CERTIFICATION

As the program manager, I hereby certify that this test report represents a true and accurate summary of emissions test results and the methodologies employed to obtain those results. The test program was performed in accordance with the test protocol, test methods, the Mostardi Platt Quality Manual, and the ASTM D7036-12, as applicable.

MOSTARDI PLATT

Program Manager

Stuart L. Burton

Quality Assurance

Jeffrey M. Crivlare