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Relative Accuracy Test Audit Test Report

Michigan State University
T.B. Simon Power Plant
Combustion Turbine 6
East Lansing, Michigan
February 14, 2017

Report Submittal Date
April 26, 2017

Project No. M170605E

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

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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 Combustion Turbine 6 on February 14, 2017. This report summarizes the results of the test program and test methods.

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

TEST INFORMATION		
Test Location	**Test Date**	**Test Parameters**
Combustion Turbine 6	February 14, 2017	Carbon Monoxide (CO), Oxygen (O_2), and Nitrogen Oxides (NO_x)

The purpose of the test program was to demonstrate the relative accuracies of the Combustion Turbine 6 CO, O_2, and NO_x analyzers during the specified operating condition. The test results from this test program indicate that each CEMS meets the United States Environmental Protection Agency (USEPA) annual performance specification for relative accuracy as published in 40 Code of Federal Regulations Part 60 (40CFR60).

RATA RESULTS					
Test Location	**Date**	**Parameter**	**Units**	**Relative Accuracy Acceptance Criteria**	**Relative Accuracy (RA)**
Combustion Turbine 6	2/14/17	NO_x	lb/mmBtu	≤ 20.0 % of the mean reference value	2.26%
		NO_x	ppmvd	≤ 20.0 % of the mean reference value	4.19%
		O_2	% dry	≤ 20.0 % of the mean reference value	1.07%
		CO	ppmvd	≤ 10.0 % of the mean reference value	2.42%
		CO	lb/mmBtu	≤ 10.0 % of the mean reference value	0.70%

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	CC343413	0.0 ppm	7/11/2024
NO_x	Airgas	CC216539	47.06 ppm	11/7/2019
NO_x	Airgas	CC490411	92.92 ppm	10/31/2024
O_2	Airgas	CC216539	0.0 %	11/7/2019
O_2	Airgas	CC347269	9.082 %	6/13/2024
O_2	Airgas	CC416859	22.19 %	5/14/2023
CO	Airgas	CC347269	0.0 ppm	6/13/2024
CO	Airgas	CC343413	50.31 ppm	7/11/2024
CO	Airgas	CC486880	88.98 ppm	7/7/2024

The identifications of the individuals associated with the test program are 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
Testing Company Personnel		Mr. David Dixon Test Technician

2.0 TEST METHODOLOGY

Emission testing was conducted following the United States Environmental Protection Agency (USEPA) methods specified in 40CFR60, Appendix A in addition the Mostardi Platt Quality Manual. Schematics of the test section diagram and sampling train used are included in Appendix A and B respectively. Calculation nomenclature are included in Appendix C. Copies of analyzer print-outs for each test run are included in Appendix D. CEM data and process data as provided by Michigan State University are included in Appendix E.

The following methodologies were used during the test program:

Method 3A Oxygen (O_2) Determination

Stack gas O_2 concentrations were determined in accordance with USEPA Method 3A. A Servomex analyzer was used to determine the O_2 concentrations in the manner specified in the

Method. The instrument has a paramagnetic detector and the O_2 operates in the nominal range of 0% to 25% with the specific range determined by the high-level calibration gas of 22.19%. High-range calibrations were performed using USEPA Protocol gas. Zero nitrogen (a low ppm pollutant in balance nitrogen calibration gases) was introduced during other instrument calibrations to check instrument zero. High- and a mid-range % O_2 levels in balance nitrogen were also introduced. Zero and mid-range calibrations were performed using USEPA Protocol gas after each test run. Copies of the gas cylinder certifications are found in Appendix G. 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-D 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 100 ppm with the specific range determined by the high-level span calibration gas of 92.92 ppm.

The Model 42i-D High Level is based 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 nitrogen dioxide (NO_2) molecules decay to lower energy states. Specifically,

$$NO+O_3 \rightarrow NO_2+O_2+h\upsilon$$

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 612.6 C. The ambient air sample is drawn into the Model 42i-D High Level through the sample bulkhead. The sample flows through a particulate filter, 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 (NOx mode).

Dry air enters the Model 42i-D High Level through the dry air bulkhead, through a flow sensor, and then through a silent discharge ozonator. The ozonator generates the necessary ozone concentration needed for the chemiluminescent reaction. The ozone reacts with the NO in the ambient air sample to produce electronically excited NO_2 molecules. A photomultiplier tube (PMT) housed in a thermoelectric cooler detects the NO_2 luminescence.

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-D High Level outputs NO, NO_2, and NO_x concentrations to both the front panel display and the analog outputs.

Stack gas was delivered to the analyzer via a Teflon® sampling line, heated to a minimum temperature of 250°F. Excess moisture in the stack gas was removed using a refrigerated condenser. The entire system was calibrated in accordance with the Method, using certified calibration gases introduced at the probe, before and after each test run. This testing met the performance specifications as outlined in the Method.

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

Method 10 Carbon Monoxide (CO) Determination

Stack gas CO concentrations and emission rates were determined in accordance with USEPA Method 16, 40CFR60, Appendix A. A Thermo Scientific Model 48i Gas Filter Correlation Analyzer was used to determine carbon monoxide concentrations, in the manner specified in the Method. The instrument operated in the nominal range of 0 ppm to 100 ppm with the specific range determined by the high-level span calibration gas of 88.98 ppm.

The Model 48i operates on the principle that CO absorbs infrared radiation at a wavelength of 4.6 microns. Because infrared absorption is a non-linear measurement technique, it is necessary to transform the basic analyzer signal into a linear output. The Model 48i uses an internally stored calibration curve to accurately linearize the instrument output over any range up to a concentration of 16,000 ppm. The sample is drawn into the Model 48i 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 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 gas filter acts to produce a reference beam which cannot be further attenuated by CO in the sample cell. The N_2 side of the filter wheel is transparent to the infrared radiation and therefore produces a measurement beam which can be absorbed by CO in the cell. The chopped detector signal is modulated by the alternation between the two gas filters with an, amplitude related to the concentration of CO in the sample cell. Other gases 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. The Model 48i outputs the CO concentration 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 via a Teflon® sampling line, heated to a minimum temperature of 250°F. Excess moisture in the stack gas was removed using a refrigerated condenser. The entire system was calibrated in accordance with the Method, using certified calibration 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 F. Copies of the gas cylinder certifications are found in Appendix G. This testing met the performance specifications as outlined in the Method.

3.0 TEST RESULT SUMMARIES

Client:	Michigan State University	**Location:**	Unit 6 Stack Low Load
Facility:	T.B. Simon Power Plant	**Date:**	2/14/17
Project #:	M170605	**Test Method:**	7E, 3A
Fuel Type:	Natural Gas	**Fuel Factor:**	8710

O2 based NOx lb/mmBtu RATA

CEM Monitor Information

NO_x Monitor/Model:	API 200EM	**NO_x Serial # :**	76421-383 (139)
O2 Monitor/Model:	Servomex 1440D	**O2 Serial # :**	767078-381 (198)

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	50	02/14/17	08:50	09:10	0.038	0.038	0.000	0.000
1	2	50	02/14/17	09:30	09:50	0.037	0.037	0.000	0.000
1	3	50	02/14/17	10:12	10:32	0.038	0.038	0.000	0.000
1	4	50	02/14/17	11:00	11:20	0.037	0.037	0.000	0.000
1	5	50	02/14/17	11:46	12:06	0.037	0.037	0.000	0.000
1	6	50	02/14/17	12:34	12:54	0.038	0.037	0.001	0.000
1	7	50	02/14/17	13:30	13:50	0.038	0.037	0.001	0.000
1	8	50	02/14/17	14:08	14:28	0.038	0.037	0.001	0.000
0	9	50	02/14/17	14:50	15:10	0.039	0.037	0.002	0.000
1	10	50	02/14/17	15:32	15:52	0.038	0.037	0.001	0.000
0	11	50	02/14/17	16:10	16:30	0.040	0.037	0.003	0.000
0	12	50	02/14/17	16:50	17:10	0.039	0.037	0.002	0.000

n	**9**	
t(0.975)	**2.306**	
Mean Reference Method Value	**0.038**	**RM avg**
Mean CEM Value	**0.037**	**CEM avg**
Sum of Differences	**0.004**	**di**
Mean Difference	**0.000**	**d**
Sum of Differences Squared	**0.000**	**di^2**
Standard Deviation	**0.001**	**sd**
Confidence Coefficient 2.5% Error (1-tail)	**0.000**	**cc**
Relative Accuracy	**2.26**	**RA**

Client:	Michigan State University	**Location:**	Unit 6 Stack Low Load
Facility:	T.B. Simon Power Plant	**Date:**	2/14/17
Project #:	M170605	**Test Method:**	7E

NO_x ppmvd RATA

CEM Monitor Information

NO_x Monitor/Model:	API 200EM	**NO_x Serial # :**	76421-383 (139)

1=accept 0=reject	Test Run	KPPH	Test Date	Start Time	End Time	RM NO_x ppmvd	CEM NO_x ppmvd	(RM-CEM) Difference (di)	(RM-CEM) Difference^2 (di^2)
1	1	50	02/14/17	08:50	09:10	10.9	10.7	0.2	0.0
1	2	50	02/14/17	09:30	09:50	10.8	10.6	0.2	0.0
1	3	50	02/14/17	10:12	10:32	10.9	10.8	0.1	0.0
1	4	50	02/14/17	11:00	11:20	10.7	10.5	0.2	0.0
1	5	50	02/14/17	11:46	12:06	10.6	10.3	0.3	0.1
1	6	50	02/14/17	12:34	12:54	10.8	10.5	0.3	0.1
1	7	50	02/14/17	13:30	13:50	10.9	10.3	0.6	0.4
1	8	50	02/14/17	14:08	14:28	11.0	10.5	0.5	0.3
0	9	50	02/14/17	14:50	15:10	11.4	10.5	0.9	0.8
1	10	50	02/14/17	15:32	15:52	10.9	10.4	0.5	0.3
0	11	50	02/14/17	16:10	16:30	11.3	10.3	1.0	1.0
0	12	50	02/14/17	16:50	17:10	11.3	10.3	1.0	1.0

n	9	
t(0.975)	2.306	
Mean Reference Method Value	10.833	**RM avg**
Mean CEM Value	10.511	**CEM avg**
Sum of Differences	2.900	**di**
Mean Difference	0.322	**d**
Sum of Differences Squared	1.170	**di^2**
Standard Deviation	0.172	**sd**
Confidence Coefficient 2.5% Error (1-tail)	0.132	**cc**
Relative Accuracy	4.19	**RA**

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

Location: Unit 6 Stack Low Load
Date: 2/14/17
Test Method: 3A

O_2 % (dry) RATA

CEM Monitor Information

O_2 Monitor/Model: Servomex 1440D | **O_2 Serial # :** 767078-381 (198)

1=accept 0=reject	Test Run	KPPH	Test Date	Start Time	End Time	RM O_2 % (dry)	CEM O_2 % (dry)	(RM-CEM) Difference (di)	(RM-CEM) Difference^2 (di^2)
1	1	50	02/14/17	08:50	09:10	14.6	14.7	-0.1	0.01
1	2	50	02/14/17	09:30	09:50	14.6	14.7	-0.1	0.01
1	3	50	02/14/17	10:12	10:32	14.6	14.7	-0.1	0.01
1	4	50	02/14/17	11:00	11:20	14.6	14.7	-0.1	0.01
1	5	50	02/14/17	11:46	12:06	14.7	14.8	-0.1	0.01
1	6	50	02/14/17	12:34	12:54	14.7	14.7	0.0	0.00
1	7	50	02/14/17	13:30	13:50	14.6	14.8	-0.2	0.04
1	8	50	02/14/17	14:08	14:28	14.6	14.8	-0.2	0.04
0	9	50	02/14/17	14:50	15:10	14.6	14.8	-0.2	0.04
0	10	50	02/14/17	15:32	15:52	14.6	14.8	-0.2	0.04
1	11	50	02/14/17	16:10	16:30	14.7	14.8	-0.1	0.01
0	12	50	02/14/17	16:50	17:10	14.6	14.8	-0.2	0.04

n	9	
t(0.975)	2.306	
Mean Reference Method Value	14.633	RM avg
Mean CEM Value	14.744	CEM avg
Sum of Differences	-1.000	di
Mean Difference	-0.111	d
Sum of Differences Squared	0.140	di^2
Standard Deviation	0.060	sd
Confidence Coefficient 2.5% Error (1-tail)	0.046	cc
Relative Accuracy	1.07	RA

Client: Michigan State University **Location:** Unit 6 Stack Low Load
Facility: T.B. Simon Power Plant **Date:** 2/14/17
Project #: M170605 **Test Method:** 10

CO ppmvd RATA

CEM Monitor Information

CO Monitor/Model:	Teledyne 300E	CO Serial # :	75478-380 (178)

1=accept 0=reject	Test Run	KPPH	Test Date	Start Time	End Time	RM CO ppmvd	CEM CO ppmvd	(RM-CEM) Difference (di)	(RM-CEM) Difference² (di²)
1	1	50	02/14/17	08:50	09:10	32.4	31.7	0.7	0.49
1	2	50	02/14/17	09:30	09:50	33.6	32.8	0.8	0.64
1	3	50	02/14/17	10:12	10:32	32.9	32.1	0.8	0.64
1	4	50	02/14/17	11:00	11:20	33.0	32.5	0.5	0.25
1	5	50	02/14/17	11:46	12:06	33.1	32.4	0.7	0.49
1	6	50	02/14/17	12:34	12:54	32.7	31.9	0.8	0.64
1	7	50	02/14/17	13:30	13:50	32.2	31.6	0.6	0.36
1	8	50	02/14/17	14:08	14:28	32.2	31.5	0.7	0.49
1	9	50	02/14/17	14:50	15:10	32.0	31.2	0.8	0.64
0	10	50	02/14/17	15:32	15:52	32.2	31.2	1.0	1.00
0	11	50	02/14/17	16:10	16:30	31.9	30.8	1.1	1.21
0	12	50	02/14/17	16:50	17:10	32.3	31.2	1.1	1.21

n	9	
t(0.975)	2.306	
Mean Reference Method Value	32.678	RM avg
Mean CEM Value	31.967	CEM avg
Sum of Differences	6.400	di
Mean Difference	0.711	d
Sum of Differences Squared	4.640	di²
Standard Deviation	0.105	sd
Confidence Coefficient 2.5% Error (1-tail)	0.081	cc
Relative Accuracy	2.42	RA

Client:	Michigan State University	**Location:**	Unit 6 Stack Low Load
Facility:	T.B. Simon Power Plant	**Date:**	2/14/17
Project #:	M170605	**Test Method:**	10, 3A
Fuel Type:	Natural Gas	**Fuel Factor:**	8710

O2 based CO lb/mmBtu RATA

CEM Monitor Information

CO Monitor/Model:	Teledyne 300E	**CO Serial # :**	75478-380 (178)
O2 Monitor/Model:	Servomex 1440D	**O2 Serial # :**	767078-381 (198)

1=accept 0=reject	Test Run	KPPH	Test Date	Start Time	End Time	RM CO lb/MMBtu	CEM CO lb/MMBtu	(RM-CEM) Difference (di)	(RM-CEM) Difference^2 (di^2)
1	1	50	02/14/17	08:50	09:10	0.068	0.068	0.000	0.000
0	2	50	02/14/17	09:30	09:50	0.071	0.070	0.001	0.000
1	3	50	02/14/17	10:12	10:32	0.069	0.069	0.000	0.000
1	4	50	02/14/17	11:00	11:20	0.069	0.069	0.000	0.000
1	5	50	02/14/17	11:46	12:06	0.071	0.070	0.001	0.000
1	6	50	02/14/17	12:34	12:54	0.070	0.069	0.001	0.000
1	7	50	02/14/17	13:30	13:50	0.068	0.069	-0.001	0.000
1	8	50	02/14/17	14:08	14:28	0.068	0.068	0.000	0.000
1	9	50	02/14/17	14:50	15:10	0.067	0.068	-0.001	0.000
1	10	50	02/14/17	15:32	15:52	0.068	0.068	0.000	0.000
0	11	50	02/14/17	16:10	16:30	0.068	0.067	0.001	0.000
1	12	50	02/14/17	16:50	17:10	0.068	0.068	0.000	0.000

n	**10**	
t(0.975)	**2.262**	
Mean Reference Method Value	**0.069**	**RM avg**
Mean CEM Value	**0.069**	**CEM avg**
Sum of Differences	**0.000**	**di**
Mean Difference	**0.000**	**d**
Sum of Differences Squared	**0.000**	**di^2**
Standard Deviation	**0.001**	**sd**
Confidence Coefficient 2.5% Error (1-tail)	**0.000**	**cc**
Relative Accuracy	**0.70**	**RA**

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 methods and the Mostardi Platt Quality Manual, as applicable.

MOSTARDI PLATT

____________________________ Program Manager

Stuart L. Burton

____________________________ Quality Assurance

Jeffrey M. Crivlare