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MICHIGAN PUBLIC POWER AGENCY – KALKASKA CT#1
KALKASKA, MICHIGAN
EMISSIONS TEST REPORT

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REV. NO.	REV. DATE	ORIGINATOR NAME/INITIAL	REVIEWER NAME/INITIAL	APPROVER NAME/INITIAL	DESCRIPTION
0	6/5/17	JLH	GWJ	JLH	Initial Issue
1	6/16/17	JLH	GWJ	JLH	Revised per Comments
2	6/19/17	JLH	GWJ	JLH	Revised per Comments
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4	10/24/17	JLH	GWJ	JLH	Revised per Comments
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Approved for Issue

	Name	Signature	Date
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EXECUTIVE SUMMARY

Emissions testing was conducted at the Michigan Public Power Agency (MPPA) Kalkaska CT#1 Facility located at 1750 Prough Road SW, Kalkaska, MI on May 10, 2017 by McHale Emissions Measurement Services (EMS) for MPPA. Testing was performed in general accordance with the Emissions Test Protocol dated May 3, 2017; a copy may be found in Appendix D.

The goal of the test program was to evaluate and re-establish the baseline correlation curve for emissions of nitrogen oxides (NO_x) at four (4) load levels pursuant to the Renewable Operating Permit (ROP) #MI-ROP-N7113-2016 and compare NO_x concentrations corrected to 15% oxygen to the permit limit of 25 ppmvd. Operating parameters indicative of NO_x formation were also measured during the testing.

Test Run 1 at 70% load (as seen in the test data log) was invalidated due to a traverse of the stack not being done, all other runs were traversed. For the purpose of reporting, the runs are referred to as runs 1, 2 and 3, which correspond to runs 2, 3 and 4 as seen in the raw data test log.

Results for the emissions testing can be seen below in Table E-1.

Table E-1: Emissions Testing Results for CT #1A & B

Load (%)	CT #1A Load (MW)	CT #1B Load (MW)	Unit 1A NOx ppmvd @ 15% O2	Unit 1B NOx ppmvd @ 15% O2	Emissions Limit (ppmvd) @15% O2	Pass
100	25.8	27.5	20.4	20.9	25	yes
90	24.0	25.6	20.5	22.1	25	yes
80	22.9	24.1	20.2	22.4	25	yes
70	20.4	21.6	20.1	21.5	25	yes

Section 2.0 of this document provides a brief description of the process, the sampling locations and the facility. Section 3.0 presents the emissions testing results. Section 4.0 outlines the procedures and test methods used. Section 5.0 discusses the quality assurance/quality control measures followed during sampling and analysis. Sample data sheets and calculations are contained in the appendices to this document.

The above results show successful satisfaction of the Test Goals. Further description and explanation of the particular details of the testing program and results are provided in this document.

1.0 INTRODUCTION

1.1 TEST DESCRIPTION

Emissions testing was conducted at the Michigan Public Power Agency (MPPA) Kalkaska CT#1 Facility located at 1750 Prough Road SW, Kalkaska, MI on May 10, 2017 by McHale Emissions Measurement Services (EMS) for MPPA. Testing was performed in general accordance with the Emissions Test Protocol dated May 3, 2017, a copy may be found in Appendix D, and pursuant to Renewable Operating Permit (ROP) #MI-ROP-N7113-2016.

NO_x emission rates were evaluated on the exhaust of one Pratt and Whitney Power Systems FT8 Twin Pac gas turbine fired on natural gas, which is comprised of two engines and power turbines connected to a single generator package. The emissions were measured on both of the engines stacks simultaneously at four operating load levels and were used to determine and revise the baseline correlation curve for NO_x and determine appropriate ranges for the following operating parameters:

- Pipeline natural gas flow rate
- Water injection flow rate
- Water to fuel ratio
- Heat input

The testing was conducted at approximately 100%, 90%, 80%, and 70% of maximum available load, as determined by heat input to the unit.

In addition to measuring the NO_x and O_2 concentrations, the following operating parameters were collected during the test, which are indicative of NO_x formation:

- Turbine megawatt output
- Pipeline natural gas flow rate
- Water injection flow rate
- Water to fuel ratio
- Heat input
- Inlet gas temperature
- Volumetric flow
- Exhaust gas temperature

The test methods which were used by McHale EMS for this test program are listed briefly below:

- EPA Method 1: Sample and Velocity Traverses for Stationary Sources

- EPA Method 3A: Continuous determination of oxygen content in the flue gas. A paramagnetic analyzer or fuel cell analyzer is used for O_2 determination.
- EPA Method 7E: Determination of Nitrogen Oxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

All procedures and quality control guidelines specified in the appropriate EPA methods, 40CFR75 Appendix E and the EPA Quality Assurance Handbook for Air Pollution Measurement Systems - Volume III were strictly followed during the test program. All test runs were a minimum of twenty five (25) minutes in duration, and conducted in triplicate for each load condition.

1.2 REPORT ORGANIZATION

Section 2.0 of the report provides a brief description of the process and the sampling location. Section 3.0 presents the summary of test results. Section 4.0 outlines the test procedures and methods used, and section 5.0 discusses the quality assurance /quality control measures followed during the sampling and analysis. Data summaries and sample calculations, field data sheets, analytical data, quality assurance data, operating data and a list of project participants are included in the appendices to this document.

2.0 PROCESS DESCRIPTION AND SAMPLING LOCATION

The Kalkaska CT #1Facility is an electric generating station that includes one Pratt & Whitney Model FT-8 TwinPac unit. The TwinPac consists of two combustion turbines coupled to a single electric generator. The combustion turbines include a compressor, combustor, and turbine and have a nominal load capacity of 25 MW each, with a nominal combined electrical capacity of 50 MW. Because of this configuration where the two turbines run a single generator, the testing of both turbines exhaust was conducted simultaneously in order for the unit to be operating at base load. Exhaust gases from each turbine are discharged into the atmosphere through separate stacks.

2.1 SAMPLING LOCATION

All testing was conducted at the turbines' exhaust stacks. Each stack has a diameter of 114", a height of 272" from the turbines' exhaust, four (4) test ports 90 degrees from one another located 212" from the turbines' exhaust, and a total height of 60' from the ground. A schematic of the stack configuration is provided in Appendix D as part of the Test Protocol.

3.0 EMISSION TEST RESULTS

Emission testing at the Kalkaska CT# 1 Facility was conducted on May 10, 2017. Testing was performed at the following load conditions while the unit was run on natural gas:

- 100% Load (53.3 MW)
- 90% Load (49.6 MW)
- 80% Load (47.0 MW)
- 70% Load (42.0 MW)

Maximum (Base) load operation for combustion turbines is affected by the ambient temperature at the time of the tests. The partial load condition percentages are based, to the extent practicable, on the base load achieved.

The testing was conducted to demonstrate compliance with the NO_x emissions limits contained in ROP #MI-ROP-N7113-2016. The tests at the three reduced loads were conducted to collect data combined with the base load results to develop a correlation curve for NO_x to use for estimating emissions as required in 40CFR75, Appendix E.

Calibration drift and bias checks for the instrumental methods were conducted between each test run. All data were corrected for the pre-and post-test bias/drift results. Three gaseous (O_2 and NO_x) test runs were conducted at each condition with a minimum test time of 25 minutes per run. EPA Method 3A was used for oxygen and Method 7E/20 for nitrogen oxides.

The test results for the four load conditions are presented in Tables 3-1 and 3-2. The average results for the baseline correlation curve showing the correlation of NO_x emissions in lb/MMBtu to the units' heat input are provided in Figures 3-1 and 3-2 below.

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Table 3-1 Summary of Predictive Emissions Monitoring Curve Data & 40CFR75, Appendix E Test Results
MPPA Kalkaska
Kalkaska, MI
Unit 1-A

Percent Load	Unit Load (MW)	Fuel Flow lb/hr	Gross Heat Input (MMBtu/hr)	NOx Emission Rate (lb/MMBtu)	NOx Conc at 15% O2 ppmvd	NOx Emission Rate lb/hr	Water Inj. Ratio lb/lb	Water Flow lb/hr	Exhaust Gas Temp. (deg F)	Inlet Gas Temp. (deg F)
Base	25.8	11,522	268.4	0.075	20.4	20.2	0.9	10936	1327	53
90%	24.0	10,857	252.9	0.075	20.5	19.1	0.9	10255	1326	67
80%	22.9	10,443	243.3	0.074	20.2	18.1	0.9	9518	1300	63
70%	20.4	9,424	219.6	0.074	20.1	16.3	0.8	7362	1212	46

Figure 3-1. MPPA Kalkaska Plant NOx - 40CFR75, Appendix E Curve Unit 1-A

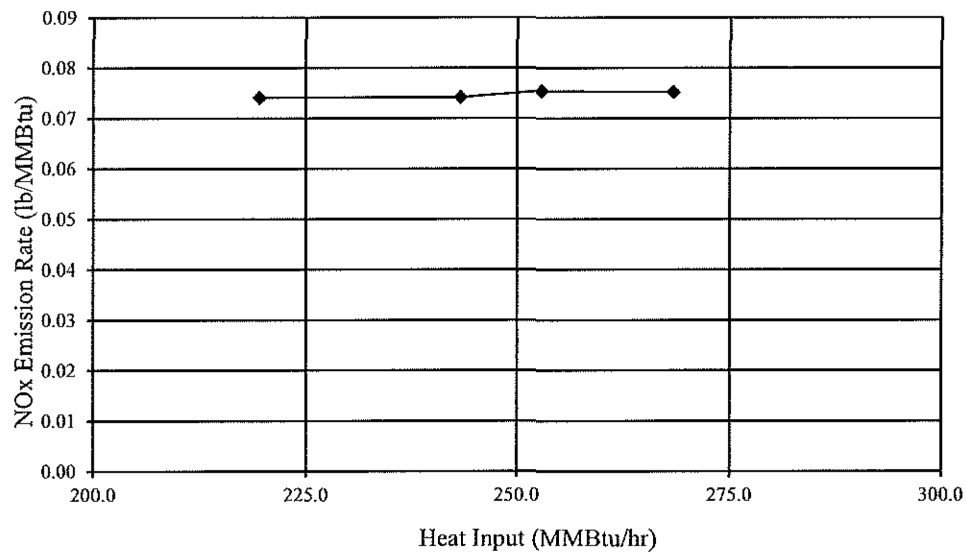
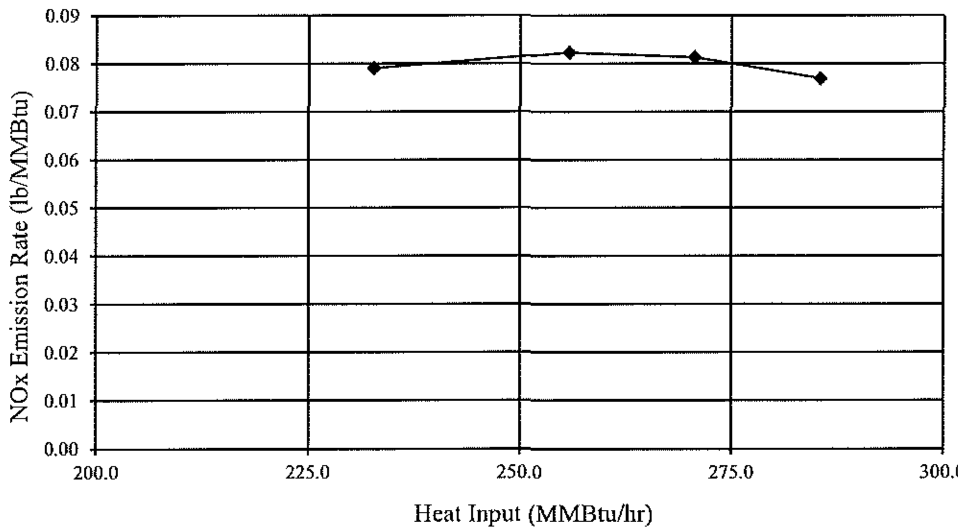


Table 3-2 Summary of Predictive Emissions Monitoring Curve Data & 40CFR75, Appendix E Test Results
MPPA Kalkaska
Kalkaska, MI
Unit 1-B

Percent Load	Unit Load (MW)	Fuel Flow lb/hr	Gross Heat Input (MMBtu/hr)	NOx Emission Rate (lb/MMBtu)	NOx Conc at 15% O2 ppmvd	NOx Emission Rate lb/hr	Water Inj. Ratio lb/lb	Water Flow lb/hr	Exhaust Gas Temp. (deg F)	Inlet Gas Temp. (deg F)
Base	27.5	12,251	285.4	0.077	20.9	22.0	1.1	13440	1325	56
90%	25.6	11,613	270.5	0.081	22.1	22.0	1.1	12737	1327	68
80%	24.1	10,979	255.8	0.082	22.4	21.1	1.1	11712	1291	65
70%	21.6	9,989	232.7	0.079	21.5	18.4	1.0	9814	1206	39

Figure 3-2. MPPA Kalkaska Plant NOx - 40CFR75, Appendix E Curve Unit 1B



4.0 EPA TEST PROCEDURES

4.1 INSTRUMENTAL REFERENCE METHODS

Stack gas emissions of oxides of nitrogen (NO_X) is measured using continuous instrumental techniques. Diluent oxygen concentration is also measured using continuous instrumental techniques. These tests are performed in accordance with EPA Methods 3A for oxygen and 7E for NO_x as outlined in Title 40, Part 60, Appendix A of the Code of Federal Regulations. Copies of all on-line instrumental reference method data collected during the testing are included in the final report. Calibration records are also given with the data. Flue gas sample is withdrawn from the stack at a constant rate via heated stainless steel sample probe.

The sample probe is equipped with an additional stainless steel line to enable probe tip calibrations. The probe is of sufficient length to allow traversing across the duct as required by the performance specifications and the applicable test methods. Extracted sample is passed from the probe through a filter and a heated Teflon sample line to the moisture removal system.

The moisture removal system (gas conditioner) is designed for minimal contact between condensate and sample gas in order to prevent any reaction between the moisture and the measured pollutants. All components of the sampling and gas conditioning system are fabricated from borosilicate glass, Teflon, or stainless steel. The gas conditioning system consists of a continuously downward Teflon condenser coil (to prevent bubbling) and two glass knockout condenser traps.

Moisture is continuously removed from the traps by an external peristaltic pump. The gas conditioning system is cooled in an ice water bath to facilitate complete moisture removal. Dry gas sample from the gas conditioner is transported to the instrument trailer via an unheated 1/4-inch O.D. Teflon tube to a Teflon-lined diaphragm pump, which delivers positive pressure sample to the instrument system. Flow control valves are used to deliver the gas sample at a regulated positive pressure to the reference method analytical instruments through a Teflon and stainless steel manifold delivery network. Flow and pressure to all monitors is held constant by monitoring sample and bypass rotameters. A diagram of the instrumental reference method sampling and analysis system used for the test program is given in Figure 4-1.

The sampling system is leak checked by passing known calibration gas standards up through a calibration line to the end of the probe. The gas standards are then pulled back through the sampling probe at stack pressure and subsequently through the entire sampling system to the instrument system. An oxygen analyzer response of less than or equal to 0.5% V to a zero oxygen standard is considered an acceptable leak check.

Analyzer calibration error is calculated by the difference between the known calibration gas concentration and the concentration exhibited by the analyzer. Bias checks are performed by comparing calibration responses through the entire sampling system to those exhibited at the analyzer. EPA Protocol #1, NIST traceable standard calibration gases are used to calibrate the analyzers.

Acceptable system performance checks do not exceed +/-2% calibration error, +/-5% system bias check, +/-3% zero drift, and +/- 3% upscale span drift.

Instrument response time is found by alternating zero nitrogen and upscale span gases through the bias check line and recording the upscale and downscale time. The response time of the CEM sampling system is performed to determine the length of time for the CEM's to respond to changes in the stack gas exhaust stream. Known, Protocol 1 reference gases and zero nitrogen are passed through the heated sample line, sample conditioning system and the manifold delivery network to the continuous emission monitors.

4.2 DATA ACQUISITION

The data acquisition system (DAS) for the CEM analyzers consists of a Microlink 751 with a USB interface and a Data Acquisition program. The data are stored on disk as well as on a printed hardcopy for each run. The system has 16-bit analog to digital conversion resolution (1 in 64,000) and a scan rate of approximately 1200 readings per minute. Data is averaged and reported by the DAS on a 30 second basis. The averaging time may be changed if desired. The system is capable of displaying the on line results in measured units and corrected to 15% O_2 as well as in lb/MMBtu. Averages are generated immediately at the end of each test run.

4.3 REFERENCE METHOD ANALYZER PRINCIPLES OF OPERATION

4.3.1 METHOD 3A: OXYGEN ANALYSIS

Flue gas sample is continuously analyzed for oxygen by a CAI Model 600 paramagnetic instrument. The analyzer uses electron paramagnetic resonance to detect the presence of oxygen molecules. Unlike most substances, oxygen has a triplet electron ground state, which leaves one electron unpaired, making it a paramagnetic molecule. This electron may have one of two quantum spin states (ms = +/- 2). By applying an alternating electromagnetic field of the proper frequency, the analyzer induces resonance between the two spin quantum states. In effect, the O2 analyzer measures the electromagnetic energy absorbed by O2 molecules at the resonant frequency.

4.3.2 METHOD 7E AND 20: OXIDES OF NITROGEN ANALYSIS

An API Model 200AH instrument is used to analyze NOx. The principle of operation of this instrument is a chemiluminescent reaction in which ozone (O_3)

reacts with nitric oxide (NO) to form oxygen (O_2) and nitrogen dioxide (NO_2). During this reaction, a photon with a specific ultraviolet wavelength is emitted which is detected by a photomultiplier tube. The instrument is capable of analyzing total oxides of nitrogen (NO + NO_2) by thermally converting NO_2 to NO in a separate reaction chamber prior to the photomultiplier tube, if desired. The analyzer is operated in the NOx mode during sampling. A converter efficiency test is performed on the analyzer to demonstrate sufficient conversion.

5.0 QUALITY ASSURANCE /QUALITY CONTROL

Strict Quality Assurance/Quality Control (QA/QC) measures were observed for all sampling and analysis performed during the emissions test program. The McHale EMS QA/QC program is designed to provide the highest quality data in terms of the accuracy and precision of the measurements as well as the completeness, representativeness and comparability of the results.

Accuracy is the degree to which a measurement agrees to the true value or to an accepted reference value. Precision is the degree of reproducibility (or agreement) of a set of individual measurements of an identical property.

The objective of the overall QA/QC program is to provide guidelines in terms of accuracy and precision that can be used to assess the uncertainty in the results, and to substantiate the data in terms of the use of accepted procedures. Quality Control can be defined as the use of operational techniques and activities that sustain good quality data. Adherence to accepted sampling and analytical methods and procedures (and specifically noting any aberrations or exceptions to these procedures) is an example of quality control. Quality Assurance includes all those planned and systematic activities necessary to ensure that the accuracy and precision of the results meets the needs of the testing program.

The QA program includes the activities planned by routine operators and analysts to provide an assessment of test data precision (and accuracy). Examples of implementation of QA measures include routine calibration checks to assess the bias and drift of an analyzer after each test run. The measurement system bias is an indicator of the accuracy of the system and the drift is an indication of the precision of the measurements.

The quality assurance/quality control measures for sampling and analysis included in the following documents were strictly followed during the emissions test program, except as noted below and elsewhere in this document. The procedures are incorporated by reference into the quality assurance program for this effort as they apply to the collection, analysis, and calculation of pollutant concentrations and mass emission rates from the test locations:

The Code of Federal Regulations, Title 40, Part 60, Appendix A., EPA Methods 1, 2, 3A, 7E and 19. The Quality Assurance Handbook for Air Pollution

Measurement Systems - Volume III - Stationary Source Specific Methods (EPA-600/4-77-027b) Sections 3.0-3.4.

5.1 CALIBRATION AND DRIFT SPECIFICATIONS

At the beginning of each test day, the EPA Reference Method 3A and 7E equipment is calibrated, and adjusted as required, on a two-point basis. EPA Protocol #1, NIST traceable standard calibration gases are used to calibrate the analyzers. Subsequently, additional calibration standards are introduced to the analyzers to check the linearity of the instrument response. If the linearity of the instrument is within +/-2% of span of the calibration standard value, the calibration is accepted. (Note that span is defined as the value of the high level calibration gas). Otherwise, corrective maintenance is performed, and the instrument is re-calibrated. During this time, bias checks are also performed by introducing calibration standards directly to the instrument manifold and through the entire sampling system and comparing the results.

Calibration checks are performed through the entire sampling system at the conclusion of each test run to determine calibration drift and any change in sample system bias. Introducing a mid-range or high-range gas through the sampling system and back to the analyzers assesses sampling system bias. The maximum allowable bias is 5% of the value the analyzer read for the same gas when introduced to the total sampling system as a percent of the span.

Sampling system drift checks are subsequently performed at the conclusion of each test run. The criterion for drift is +/- 3% of span. All calibration gases are EPA Protocol 1, NIST traceable standards with a rated accuracy of +/- 1%. Calibration gas analysis certificates are included in the appendices.

5.2 NO_x CONVERTER EFFICENCY CHECK

An NO_2 to NO converter efficiency test was performed as prescribed in EPA Method 7E and 20. The procedure used for testing the converter efficiency is given below:

- Fill a leak-free Tedlar bag approximately half full with an NO in N_2 blend.
- Fill the remainder of the bag with 0.1 UHP grade air.
- Immediately attach the NO/Air mixture to the inlet of the NO_x monitor.
- Allow the monitor to sample the gas in the bag for 30 minutes.

As the O_2 and NO in the bag are exposed to each other a reaction occurs which changes the NO to NO_2. Attenuation in response over time of greater than two percent absolute indicates that the converter efficiency is unacceptable. The converter efficiency was found to meet the requirements.

5.3 ANALYZER RESPONSE TIME

Instrument response time is found by alternating zero nitrogen and upscale span gases through the bias check line and recording the upscale and down scale time for a 95% response. The response time test of the instrumental sampling system is performed to determine the length of time for the reference method system to respond to changes in the stack gas exhaust stream. Known, Protocol 1 reference gases and zero gases nitrogen are passed through the heated sample line, sample conditioning system and the manifold delivery network to the continuous emission monitors.

5.4 ANALYZER SYSTEM LEAK CHECK

Since all calibrations are performed through the entire sampling system, leak-checks are incorporated in each calibration. The criterion used for this test is an oxygen response to a zero gas of less than 0.5% O_2. Leak checks are also incorporated into the zero and span drift checks at the end of each run since the calibration gas is passed through the entire sampling system for each posttest drift check. In addition, McHale conducts a bag leak check prior to initial sampling. The bag leak is performed by filling a tedlar bag with nitrogen (0% O_2) and connecting it to the end of the sampling system probe. A 0.5% O_2 response indicates that the analyzer system is leak free.

5.5 STRATIFICATION TEST

A traverse of the stack was conducted during each run on both stacks and both ports on each stack. Six points were used on each axis of the traverse.