Report of...

Emission Sampling

Performed for...

FERRIS STATE UNIVERSITY

Big Rapids, Michigan

On the...

Turbine & No. 2 Boiler (Duct Burner)

October 15-16, 2013

Project #: 290.02

By...

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Grand Rapids, MI

Performed for

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TABLE OF CONTENTS

Appendices

I. INTRODUCTION

Network Environmental, Inc. was retained by Ferris State University of Big Rapids, Michigan, to perform emission sampling on their Gas Fired Turbine and Duct Burner (Boiler No. 2). The purpose of the sampling was to meet the testing requirements of Michigan Department of Environmental Quality (MDEQ) – Air Quality Division Permit To Install No. 254-07.

The following is a list of the testing conducted:

Operating Condition	Compound(s) Sampled
Turbine/Duct Burner @ 90-100% of Peak Load	Oxides of Nitrogen (NO_x) & Carbon Monoxide (CO),
Turbine Only @ 90-100% of Peak Load	NO_x & CO
Turbine Only @ 75% of Peak Load	NO_x
Turbine Only @ 50% of Peak Load	NO_x
Turbine Only @ 25% of Peak Load	NO_x
(1) The sampling was conducted with the turbine firing on natural gas.	

Three (3) samples, for the compounds tested, were collected at each of the operating conditions. Each sample at the 90-100% Peak Load conditions was sixty (60) minutes in duration. Each sample at the 75%, 50% and 25% Peak Load conditions was thirty (30) minutes in duration.

The following reference test methods were employed to conduct the sampling:

- Oxides of Nitrogen (NO_x) – U.S. EPA Method 7E
- Carbon Monoxide (CO) – U.S. EPA Method 10
- Exhaust Gas Parameters – U.S. EPA Methods 1 through 4

The sampling was performed over the period of October 15-16, 2013 by R. Scott Cargill, Richard D. Eerdmans and David D. Engelhardt of Network Environmental, Inc.. Assisting with the sampling were Mr. Roger Bula of Ferris State University and the operating staff of the power house facility. Mr. Jeremy Howe and Mr. Steve LaChance of the MDEQ – Air Quality Division were present to observe the sampling and source operation.

II.1 TABLE 1 (Page 1 of 3)
OXIDES OF NITROGEN (NO_x) EMISSION RESULTS
FERRIS STATE UNIVERSITY
BIG RAPIDS, MICHIGAN

Source	Sample	Date	Time	Air Flow Rate DSCFM (1)	NO_x Concentration PPM Actual (2)	Oxygen % (3)	NO_x Concentration PPM @15%O_2 (4)	NO_x Mass Rate Lbs/Hr (5)
Turbine/ Duct Burner 100%	4	10/15/13	14:59-15:59	12,269	125.4	3.1	41.57	10.95
	5	10/15/13	16:19-17:19	12,269	120.9	3.2	40.30	10.56
	6	10/15/13	17:32-18:32	12,269	116.5	3.3	39.05	10.17
	Average			**12,269**	**120.9**	**3.2**	**40.31**	**10.56**
Turbine Only 100%	1	10/15/13	10:30-11:30	13,448	58.4	16.2	73.31	5.59
	2	10/15/13	11:46-12:46	13,448	57.6	16.2	72.31	5.51
	3	10/15/13	13:01-14:01	13,448	57.1	16.2	71.68	5.46
	Average			**13,448**	**57.7**	**16.2**	**72.43**	**5.52**

(1) DSCFM = Dry Standard Cubic Feet Per Minute (Standard Temperature & Pressure = 68 °F & 29.92 in. Hg)
(2) PPM Actual = Parts Per Million (v/v) On A Dry Basis At The Actual Exhaust Oxygen
(3) % = Percent O_2 On A Dry Basis
(4) PPM @ 15% O_2 = Parts Per Million (v/v) On a Dry Basis Corrected To 15% Oxygen
(5) Lbs/Hr = Pounds of NO_x Per Hour

II.1 TABLE 1 (Page 2 of 3)
OXIDES OF NITROGEN (NO_x) EMISSION RESULTS
FERRIS STATE UNIVERSITY
BIG RAPIDS, MICHIGAN

Source	Sample	Date	Time	Air Flow Rate DSCFM (1)	NO_x Concentration PPM Actual (2)	Oxygen % (3)	NO_x Concentration PPM @15%O_2 (4)	NO_x Mass Rate Lbs/Hr (5)
Turbine Only 75%	7	10/16/13	09:16-09:46	14,083	44.3	16.9	65.34	4.44
	8	10/16/13	10:01-10:31	14,083	44.2	16.9	65.20	4.43
	9	10/16/13	10:43-11:13	14,083	44.0	16.9	64.90	4.41
	Average			14,083	**44.2**	16.9	**65.15**	**4.43**
Turbine Only 50%	10	10/16/13	11:35-12:05	13,798	32.0	17.7	59.00	3.14
	11	10/16/13	12:17-12:47	13,798	32.1	17.7	59.18	3.15
	12	10/16/13	12:59-13:29	13,798	32.0	17.7	59.00	3.14
	Average			13,798	**32.0**	17.7	**59.06**	**3.14**

(1) DSCFM = Dry Standard Cubic Feet Per Minute (Standard Temperature & Pressure = 68 °F & 29.92 in. Hg)
(2) PPM Actual = Parts Per Million (v/v) On A Dry Basis At The Actual Exhaust Oxygen
(3) % = Percent O_2 On A Dry Basis
(4) PPM @ 15% O_2 = Parts Per Million (v/v) On a Dry Basis Corrected To 15% Oxygen
(5) Lbs/Hr = Pounds of NO_x Per Hour

II.1 TABLE 1 (Page 3 of 3)
OXIDES OF NITROGEN (NO_x) EMISSION RESULTS
FERRIS STATE UNIVERSITY
BIG RAPIDS, MICHIGAN

Source	Sample	Date	Time	Air Flow Rate DSCFM (1)	NO_x Concentration PPM Actual (2)	Oxygen % (3)	NO_x Concentration PPM @15%O_2 (4)	NO_x Mass Rate Lbs/Hr (5)
Turbine Only 25%	13	10/16/13	13:41-14:11	14,003	23.4	18.3	53.10	2.33
	14	10/16/13	14:20-14:50	14,003	23.7	18.3	53.78	2.36
	15	10/16/13	14:59-15:29	14,003	23.7	18.3	53.78	2.36
	Average			14,003	**23.6**	18.3	**53.55**	**2.35**

(1) DSCFM = Dry Standard Cubic Feet Per Minute (Standard Temperature & Pressure = 68 °F & 29.92 in. Hg)
(2) PPM Actual = Parts Per Million (v/v) On A Dry Basis At The Actual Exhaust Oxygen
(3) % = Percent O_2 On A Dry Basis
(4) PPM @ 15% O_2 = Parts Per Million (v/v) On a Dry Basis Corrected To 15% Oxygen
(5) Lbs/Hr = Pounds of NO_x Per Hour

II.2 TABLE 2
CARBON MONOXIDE (CO) EMISSION RESULTS
FERRIS STATE UNIVERSITY
BIG RAPIDS, MICHIGAN

Source	Sample	Date	Time	Air Flow Rate DSCFM (1)	CO Concentration PPM Actual (2)	Oxygen % (3)	CO Concentration PPM @15%O_2 (4)	CO Mass Rate Lbs/Hr (5)
Turbine/ Duct Burner 100%	4	10/15/13	14:59-15:59	12,269	0.4	3.1	0.13	0.021
	5	10/15/13	16:19-17:19	12,269	0.4	3.2	0.13	0.021
	6	10/15/13	17:32-18:32	12,269	0.4	3.3	0.13	0.021
	Average			**12,269**	**0.4**	**3.2**	**0.13**	**0.021**
Turbine Only 100%	1	10/15/13	10:30-11:30	13,448	4.3	16.2	5.40	0.25
	2	10/15/13	11:46-12:46	13,448	4.3	16.2	5.40	0.25
	3	10/15/13	13:01-14:01	13,448	4.3	16.2	5.40	0.25
	Average			**13,448**	**4.3**	**16.2**	**5.40**	**0.25**

(1) DSCFM = Dry Standard Cubic Feet Per Minute (Standard Temperature & Pressure = 68 °F & 29.92 in. Hg)
(2) PPM Actual = Parts Per Million (v/v) On A Dry Basis At The Actual Exhaust Oxygen
(3) % = Percent O_2 On A Dry Basis
(4) PPM @ 15% O_2 = Parts Per Million (v/v) On a Dry Basis Corrected To 15% Oxygen
(5) Lbs/Hr = Pounds of CO Per Hour

III. DISCUSSION OF RESULTS

The results of the emission sampling are summarized in Tables 1 through 2 (Sections II.1 through II.2). The results are presented as follows:

III.1 NO_x

Table 1 – Oxides of Nitrogen (NO_x) Emission Results Summary

- Source
- Sample
- Date
- Time
- Air Flow Rate (DSCFM) – Dry Standard Cubic Feet Per Minute (STP = 68 °F & 29.92 In. Hg)
- NO_x Concentration (PPM Actual) – Parts Per Million (v/v) on a Dry Basis at Actual Exhaust Oxygen
- Oxygen Concentration (%) – Percent O_2 On a Dry Basis
- NO_x Concentration (PPM @ 15 % O_2) – Parts Per Million (v/v) On a Dry Basis Corrected to 15% O_2
- NO_x Mass Emission Rate (Lbs/Hr) – Pounds of NO_x Per Hour

All the NO_x raw sample data was calibration corrected using Equation 7E-5 from U.S. EPA Method 7E.

III.2 CO

Table 2 – Carbon Monoxide (CO) Emission Results Summary

- Source
- Sample
- Date
- Time
- Air Flow Rate (DSCFM) – Dry Standard Cubic Feet Per Minute (STP = 68 °F & 29.92 In. Hg)
- CO Concentration (PPM Actual) – Parts Per Million (v/v) on a Dry Basis at Actual Exhaust Oxygen
- Oxygen Concentration (%) – Percent O_2 On a Dry Basis
- CO Concentration (PPM @ 15 % O_2) – Parts Per Million (v/v) On a Dry Basis Corrected to 15% O_2
- CO Mass Emission Rate (Lbs/Hr) – Pounds of CO Per Hour

All the CO raw sample data was calibration corrected using Equation 7E-5 from U.S. EPA Method 7E.

III.3 Emission Limits

MDEQ – Air Quality Division Permit To Install No. 254-07 has established the following emission limits for this source:

Operating Condition	Compound(s) Sampled
Turbine/Duct Burner	NO_x: 42 PPM@15%O_2 & 10.64 Lbs/Hr & CO: 24 PPM@15%O_2 & 3.74 Lbs/Hr
Turbine Only	NO_x: 65 PPM@15%O_2 & 6.15 Lbs/Hr & CO: 18 PPM@15%O_2 & 1.04 Lbs/Hr
Duct Burner	NO_x: 4.49 Lbs/Hr & CO: 2.7 Lbs/Hr
(1) The limits are with the turbine firing on natural gas.	

IV. SOURCE DESCRIPTION

The source sampled is a co-generation system consisting of a 1130 KW gas turbine, and a boiler (duct burner) rated at 50,000 pounds of steam per hour and a heat input of 45 MBTU per hour. The unit was natural gas fired during the sampling.

Source operating data during the testing can be found in Appendix G.

V. SAMPLING AND ANALYTICAL PROTOCOL

The sampling was conducted on the 36 inch I.D. exhaust stack at a location approximately 7 duct diameters downstream and greater than 7 duct diameters upstream from the nearest disturbances. There are 2 sample ports on the stack.

A preliminary gas stratification test was conducted for the source in accordance with U.S. EPA Method 7E. The results of this test showed that no stratification existed, so one (1) sampling point was used for the gas (NO_x & CO) sampling. The stratification test results can be found in Appendix A.

V.1 Oxides of Nitrogen – The NO_x sampling was conducted in accordance with U.S. EPA Reference Method 7E. A Thermo Environmental Model 42H gas analyzer was used to monitor the exhaust. A heated teflon sample line was used to transport the exhaust gases to a gas conditioner to remove moisture and reduce the temperature. From the gas conditioner stack gases were passed to the analyzer. The analyzer produces instantaneous readouts of the NO_x concentrations (PPM).

The analyzer was calibrated by direct injection prior to the testing. A span gas of 170.3 PPM was used to establish the initial instrument calibration. Calibration gases of 99.46 PPM and 54.84 PPM were used to determine the calibration error of the analyzer. A direct injection of 45.04 PPM nitrogen dioxide (NO_2) was performed to show the conversion efficiency of the monitor. The conversion efficiency was 93.20% and can be found in Appendix A. The sampling system (from the back of the stack probe to the analyzer) was injected using the 54.84 PPM gas to determine the system bias. After each sample, a system zero and system injection of 54.84 PPM were performed to establish system drift and system bias during the test period. All calibration gases were EPA Protocol 1 Certified.

The analyzer was calibrated to the output of the data acquisition system (DAS) used to collect the data from the exhaust. The analyzer averages were corrected for calibration error and drift using formula EQ.7E-5 from 40 CFR Part 60, Appendix A, Method 7E. A diagram of the sampling train is shown in Figure 1.

V.2 Carbon Monoxide – The CO sampling was conducted in accordance with U.S. EPA Reference Method 10. A Thermo Environmental Model 48 gas analyzer was used to monitor the exhaust. A heated teflon sample line was used to transport the exhaust gases to a gas conditioner to remove moisture and reduce the temperature. From the gas conditioner stack gases were passed to the analyzer. The analyzer produces instantaneous readouts of the CO concentrations (PPM).

The analyzer was calibrated by direct injection prior to the testing. A span gas of 92.97 PPM was used to establish the initial instrument calibration. A Calibration gas of 51.06 PPM was used to determine the calibration error of the analyzer. The sampling system (from the back of the stack probe to the analyzer) was injected using 51.06 PPM gas to determine the system bias. After each sample, a system zero and system injection of 51.06 PPM were performed to establish system drift and system bias during the test period. All calibration gases were EPA Protocol 1 Certified.

The analyzer was calibrated to the output of the data acquisition system (DAS) used to collect the data from the exhaust. The analyzer averages were corrected for calibration error and drift using formula EQ.7E-5 from 40 CFR Part 60, Appendix A, Method 7E. A diagram of the sampling train is shown in Figure 1.

V.3 Oxygen & Carbon Dioxide – The O_2 & CO_2 sampling was conducted in accordance with U.S. EPA Reference Method 3A. Servomex Model 1400M portable stack gas analyzers were used to monitor the exhaust. A heated teflon sample line was used to transport the exhaust gases to a gas conditioner to remove moisture and reduce the temperature. From the gas conditioner stack gases were passed to the analyzers. The analyzers produce instantaneous readouts of the O_2 & CO_2 concentrations (%).

The analyzers were calibrated by direct injection prior to the testing. Span gases of 20.9% (ambient air) and 20.33% CO_2 were used to establish the initial instrument calibrations. Calibration gases of 12.11% O_2/6.019% CO_2 and 6.038% O_2/12.21% CO_2 were used to determine the calibration error of the analyzers. The sampling system (from the back of the stack probe to the analyzers) was injected using the 12.11% O_2/6.019% CO_2 gas to determine the system bias. After each sample, a system zero and system injection of 12.11% O_2/6.019% CO_2 were performed to establish system drift and system bias during the test period. All calibration gases were EPA Protocol 1 Certified.

The analyzers were calibrated to the output of the data acquisition system (DAS) used to collect the data from the exhaust. The analyzer averages were corrected for calibration error and drift using formula EQ.7E-5 from 40 CFR Part 60, Appendix A, Method 7E. A diagram of the sampling train is shown in Figure 1.

V.4 Exhaust Gas Parameters – The exhaust gas parameters (air flow rate, temperature, moisture and density) were determined in conjunction with the other sampling by employing U.S. EPA Methods 1 through 4.

One (1) velocity traverse and one (1) moisture sample were collected during each operating condition. All the quality assurance and quality control procedures listed in the methods were incorporated in the sampling and analysis.

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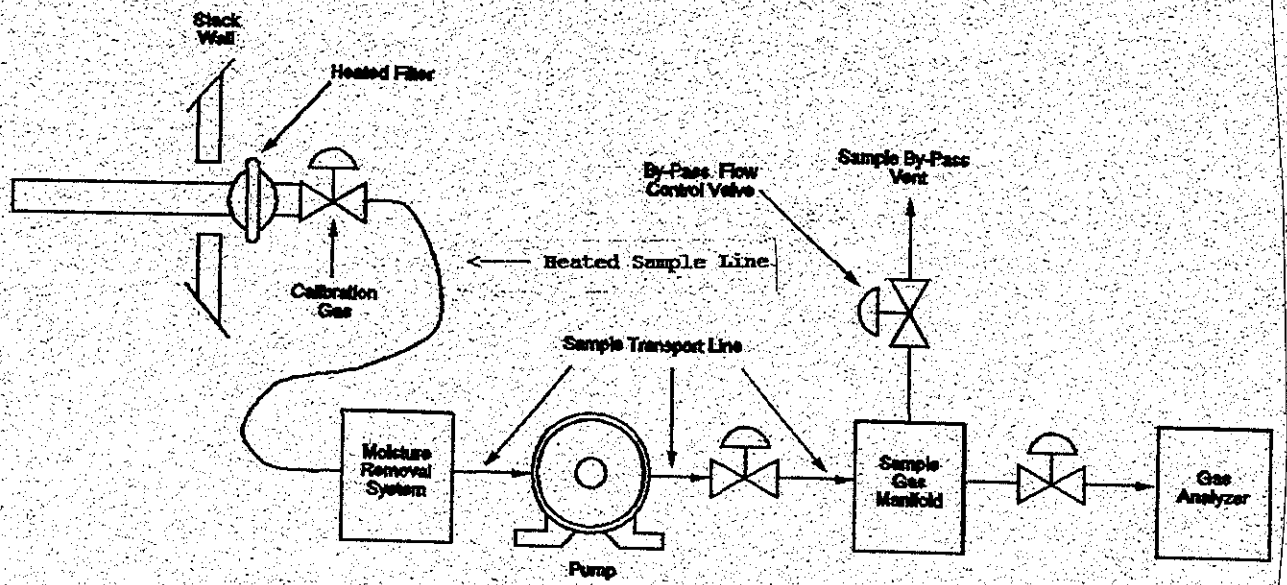

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Figure 1

NO_x, CO, O_2 & CO_2 Sampling Train