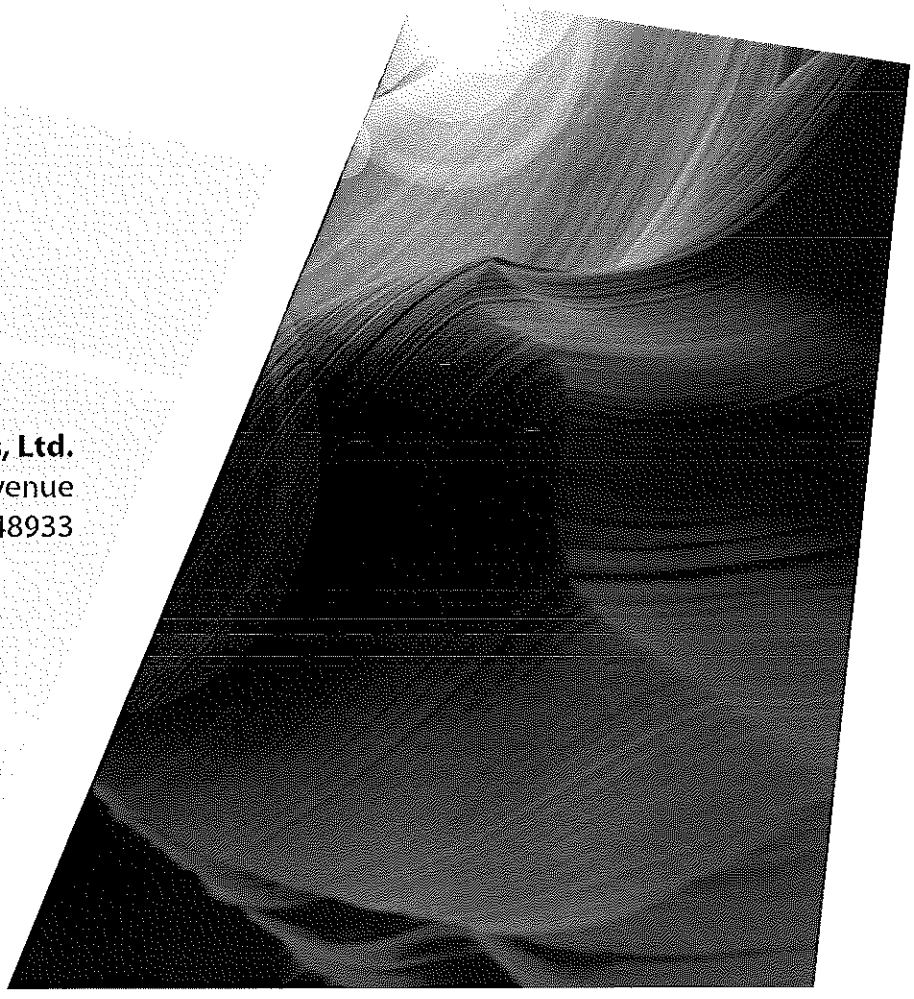
Report

Emissions Testing
EUTURBINE1 and EUTURBINE2
REO Town Combined Heat & Power Plant
Test Dates: July 23 – August 1, 2013

Lansing Board of Water and Light
Lansing, Michigan

NTH Project No. 73-120004-60
October 3, 2013



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1.0 INTRODUCTION

NTH Consultants, Ltd. (NTH) was retained by Lansing Board of Water and Light (BWL) to conduct emissions testing for carbon monoxide (CO), particulate matter (PM), and fine particulate matter ($PM_{10}/PM_{2.5}$) on two (2) natural gas-fired combustion turbines identified as EUTURBINE1 and EUTURBINE2 in Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) No. MI-ROP-B2647-2012. The CO testing was performed at three (3) load levels (60%, 80%, and 100%) and serves as the "summer season" test. The turbines are located at the REO Town Combined Heat and Power (CHP) plant located in Lansing, Michigan.

1.1 Purpose of Test

The testing was performed to demonstrate compliance with the emission limits for CO, PM, PM_{10}, and $PM_{2.5}$ pursuant to the requirements contained in MI-ROP-B2647-2012.

1.2 Test Date

The testing was performed on July 23 through August 1, 2013.

1.3 Project Contact Information

Location	Address	Contact
Test Facility	REO Town CHP Plant Lansing Board of Water and Light 1201 S. Washington Avenue Lansing, Michigan 48910	Ms. Angie Goodman 517-702-7059 ame1@LBWL.com
Test Company Representative	NTH Consultants, Ltd. 1430 Monroe Avenue NW, Suite 180 Grand Rapids, Michigan 49505	Mr. Graziano Gozzi, QSTI 616-451-6262 ggozzi@nthconsultants.com
State Representative	Michigan Department of Environmental Quality 525 W. Allegan, Constitution Hall, 4th Floor N Lansing, Michigan 48909	Mr. Tom Gasloli 517-335-4861 gaslolit@michigan.gov

This test program was performed by Messrs. Graziano Gozzi, Kyle Daneff, and Tyler Hanna of NTH. Messrs. Scott McQuiston, Justin Hill, Roberto Hodge and Ms. Angie Goodman of BWL coordinated the test events. Messrs. Tom Gasloli, Nathaniel Hude, Dave Patterson, and Karen Kajiya-Mills of MDEQ observed the test event.

1.4 Summary of Results

Triplicate 60-minute test runs were performed for CO at three load levels (60%, 80%, and 100%) at the exhaust locations of EUTURBINE1 and EUTURBINE2. CO concentrations were reported in parts per million by volume on a dry basis (ppmvd). The concentration was then converted to pounds per hour (lb/hr). Triplicate 120-minute test runs were performed for PM, PM_{10}, and $PM_{2.5}$. Particulate testing was performed at 100% load.

The comprehensive CO field data compiled during the test runs is located in Appendix E. Handwritten field data for all testing is contained in Appendix F, and results and calculations are contained in Appendix B. Additionally, analytical results for particulate matter are contained in Appendix D. The average of the test results are shown in Tables 1-1 and 1-2 below. Detailed results are presented in Tables 1-6 at the end of this report.

Table 1-1. EUTURBINE1 Emissions Test Results

Pollutant	Load	Measured Emissions	Permit Limit(s)
CO	60%	22.6 ppmv dry[1] 13.1 lb/hr2	100 ppmv dry[1] 48.2 lb/hr[2]
CO	80%	31.8 ppmv dry[1] 27.9 lb/hr[2]	50 ppmv dry[1] 48.2 lb/hr[2]
CO	100%	12.6 ppmv dry[1] 10.5 lb/hr[2]	50 ppmv dry[1] 48.2 lb/hr[2]
PM	100%	0.5 lb/hr[2]	2.0 lb/hr[2]
$PM_{2.5}$	100%	1.2 lb/hr[2]	5.0 lb/hr[2]
PM_{10}	100%	1.2 lb/hr[2]	5.0 lb/hr[2]

[1] ppmv dry: parts per million, dry volume basis, at 15% oxygen

[2] lb/hr: pound of pollutant per hour

Table 1-2. EUTURBINE2 Emissions Test Results

Pollutant	Load	Measured Emissions	Permit Limit(s)
CO	60%	47.2 ppmv dry[1] 28.6 lb/hr[2]	100 ppmv dry[1] 48.2 lb/hr[2]
CO	80%	46.1 ppmv dry[1] 36.6 lb/hr[2]	50 ppmv dry[1] 48.2 lb/hr[2]
CO	100%	12.4 ppmv dry[1] 10.4 lb/hr[2]	50 ppmv dry[1] 48.2 lb/hr[2]
PM	100%	0.45 lb/hr[2]	2.0 lb/hr[2]
$PM_{2.5}$	100%	1.0 lb/hr[2]	5.0 lb/hr[2]
PM_{10}	100%	1.0 lb/hr[2]	5.0 lb/hr[2]

[1] ppmv dry: parts per million, dry volume basis, at 15% oxygen

[2] lb/hr: pound of pollutant per hour

2.0 PROCESS DESCRIPTION

REO Town CHP is a combined-cycle, cogeneration facility consisting of two (2) natural gas-fired combustion turbines (EUTURBINE1 and EUTURBINE2), two (2) heat recovery steam generators (HRSGs) with duct burners (EUHRSG1 and EUHRSG2), a steam turbine, a natural gas-fired auxiliary boiler (EUAUXBOILER), a four cell mechanical draft cooling tower (EUCOOLTWR), an emergency engine (EUNGENGINE), and other miscellaneous ancillary equipment. The turbines are equipped with HRSGs to produce steam from the turbine exhaust gas for use as process steam, or to power a steam turbine generator to produce electric power. The HRSGs are equipped with duct burners to provide supplemental heat for steam production. The auxiliary boiler serves as backup when a combustion turbine/HRSG is out of service and/or during periods of peak demand. The emergency engine will be used for emergency purposes.

3.0 REFERENCE METHODS AND PROCEDURES

The following U.S. EPA Reference Test Methods were performed for the emissions testing:

- **Method 1:** Sample and Velocity Traverses for Stationary Sources
- **Method 2:** Determination of Stack Gas Velocity and Volumetric flow rate (Type S Pitot tube)
- **Method 3A:** Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)
- **Method 4:** Determination of Moisture Content in Stack Gases
- **Method 5:** Determination of Particulate Matter Emissions from Stationary Sources
- **Method 10:** Determination of Carbon Monoxide Emissions from Stationary Sources
- **Method 202:** Dry Impinger Method for Determining Condensable Particulate Emissions from Stationary Sources

3.1 Traverse Points

The number of traverse points for exhaust gas velocity and cyclonic air flow was determined in accordance with U.S. EPA Method 1. The cross-sectional inside diameter of the stack was measured, and based upon these values and availability of access ports, traverse points were selected for measuring the exhaust gas velocity, pressure, temperature and sampling. A schematic depicting traverse point locations are shown in Figure 1.

3.2 Velocity and Temperature

The exhaust gas velocity and temperature measurements were conducted in accordance with U.S. EPA Reference Method 2. The exhaust stack differential pressure (delta P) was measured during each test run using an S-type Pitot tube connected to an appropriately sized inclined water column manometer at each pre-determined traverse point described in Section 3.1 above. Temperatures were recorded in conjunction with delta P determinations using a chromel/alumel "Type K" thermocouple and a temperature indicator.

3.3 Molecular Weight

The exhaust gas composition was determined using U.S. EPA Reference Method 3A. The oxygen and carbon dioxide concentrations were used to determine exhaust gas composition and molecular weight.

3.4 Moisture

The exhaust gas moisture content was determined for each combustion turbine using U.S. EPA Reference Method 4. Exhaust gas was passed through a series of four impingers; the first two containing water, the third empty, and the fourth containing silica gel. The impingers were immersed in an ice bath to assure condensation of the exhaust gas stream moisture. The amount of water vapor collected was measured gravimetrically and used to calculate the moisture concentration (as %) in the exhaust gas.

3.5 Particulate Matter

Particulate matter (PM) samples were withdrawn isokinetically from each outlet following the guidelines of U.S. EPA Method 5. The sampling train for the Method 5 testing consisted of a nozzle, a heated probe, a heated 83 mm glass fiber filter, five (5) chilled impingers, and a metering console. The particulate samples were collected in the nozzle, and filters. At the conclusion of each test run, the filter was removed from the filter holder, visually inspected and placed into a separate petri dish, with the front half of the filter holder rinsed with acetone into a separate sample bottle. An acetone blank was collected during the times that the PM testing occurred.

At the laboratory, U.S. EPA Method 5 analytical procedures were used to analyze the samples for PM at the outlet. The acetone rinses were evaporated and desiccated to dryness, and the residue weighed to determine the amount of PM collected. The filters were also desiccated to remove the uncombined water and then weighed to determine the amount of PM collected. A diagram of the Method 5 sampling apparatus is appended in Figure 2.

3.6 Carbon Monoxide

The CO concentrations were measured at three (3) load levels: 60%, 80%, and 100% using a non-dispersive infrared analyzer (NDIR) following the guidelines of U.S. EPA Reference Method 10. The analyzer was calibrated at a minimum of three points: zero gas, mid-level gas (40-60 percent of calibration span), and high-level gas (90 – 100 percent of span) for the testing.

The setup of the trailer and stack is shown in Figure 3.

3.7 Data Acquisition System

Information and data from each analog instrument signal output was collected with a STRATA® data acquisition system (DAS). Calibration error, drift and bias corrections were calculated automatically. All gathered data was linked to spreadsheets that support dynamic data exchange (i.e. Microsoft™ Excel) for quick data reduction and report generation.

3.8 Condensable Particulate Matter

The condensable particulate matter concentrations were measured using U.S. EPA Reference Method 202. The exhaust gas was extracted from the sample stream isokinetically through a heated glass lined probe, a glass coil type condenser, a dropout impinger and a modified Greenburg-Smith impinger with an open tube tip, a condensable particulate matter filter holder containing a Teflon$_c$ membrane filter, one impinger containing 100 mL of water and one impinger containing silica gel for moisture collection. All glassware used in the Method 202 sampling train was cleaned prior to testing according to method specifications. During the testing, the condensable particulate matter filter temperatures were monitored and maintained at the method appropriate temperatures through the use of a recirculation pump attached to the condenser, and chilled water surrounded the impinger apparatus. Figure 4 shows the Method 202 apparatus.

4.0 QUALITY ASSURANCE

Each promulgated U.S. EPA reference method described above is accompanied by a statement indicating that to obtain reliable results, persons using these methods should have a thorough knowledge of the techniques associated with each. To that end, NTH attempts to minimize any factors in the field which could increase error by implementing a quality assurance program into every testing activity segment.

The pitot tubes and thermocouples used to measure the exhaust gas during this test program were calibrated according to the procedures outlined in the *Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III, Stationary Source-Specific Methods,* Method 2, *Type S Pitot Tube Inspection,* and Calibration Procedure 2E *Temperature Sensor.*

U.S. EPA Protocol No. 1 gas standards were used to calibrate the CO, O_2, and CO_2 analyzers during the test program. These gases are certified according to the *U.S. EPA Traceability Protocol for Assay & Certification of Gaseous Calibration Standards; Procedure G-1; September, 1997*, and are certified to have a total relative uncertainty of ±1 percent.

The DAS software in use during the testing is programmed to the specifications described in the applicable U.S. EPA Method in use during the test, and operates based on each pre-programmed analyzer span value.

5.0 DISCUSSION OF RESULTS

Operations at the EUTURBINE1 and EUTURBINE2 appeared normal with no apparent problems. It should be noted that during testing of EUTURBINE1 at 80% load and EUTURBINE2 at 60% and 100% loads, the HRSG's were engaged causing a reduction in stack temperatures. However, duct firing did not occur so there should be no impact to the emissions.

During testing on EUTURBINE1 at 80% load, a stack temperature thermocouple malfunction was discovered. It was corrected, the stack was re-traversed and temperatures found to be consistent with HRSG operations. Testing continued without interruption.

Test results are tabulated and can be found in Tables 1-6 at the end of this section. Laboratory sample analysis data can be found in Appendix D. Process data was collected by BWL and can be found in Appendix C. QA/QC information is contained in Appendix G.

TABLES

Table 1

Lansing BWL

EUTURBINE1 60% Load

Summary of CO Emissions

July 30, 2013

Run No.	1	2	3	Average
Test Date	July 30, 2013	July 30, 2013	July 30, 2013	
Run Time	0850-0950	1005-1105	1119-1219	
Volumetric Flow Rates				
Actual Cubic Feet per Minute:	405,872	415,461	410,751	410,695
Standard Cubic Feet per Minute:	160,338	160,874	158,813	160,009
Dry Standard Cubic Feet per Minute:	151,170	152,238	147,864	150,424
Fixed Gases				
Oxygen, % by volume, dry:	15.67	15.70	15.75	15.71
Carbon dioxide, % by volume, dry:	2.96	2.98	2.94	2.96
Moisture, % by volume:	5.72	5.37	6.89	5.99
Run No.	1	2	3	Average
Concentration (ppmv corrected to 15% O_2)				
Carbon Monoxide:	23.09	22.79	21.94	22.61
Emission Rate, (lb/hr):				
Carbon Monoxide:	13.51	13.36	12.37	13.08

ppmv = parts per million by volume, dry, corrected to 15% oxygen
lb/hr = pounds per hour

Table 2

Lansing BWL

EUTURBINE1 80% Load

Summary of CO Emissions

July 26, 2013

Run No.	1	2	3	Average
Test Date	July 26, 2013	July 26, 2013	July 26, 2013	
Run Time	1344-1444	1507-1605	1621-1721	
Volumetric Flow Rates				
Actual Cubic Feet per Minute:	306,513	362,574	386,944	352,010
Standard Cubic Feet per Minute:	269,447	232,584	195,705	232,579
Dry Standard Cubic Feet per Minute:	254,620	219,478	183,486	219,195
Fixed Gases				
Oxygen, % by volume, dry:	15.43	15.45	15.46	15.45
Carbon dioxide, % by volume, dry:	3.08	3.06	3.07	3.07
Moisture, % by volume:	5.50	5.64	6.24	5.79
Run No.	**1**	**2**	**3**	**Average**
Concentration (ppmv corrected to 15% O_2)				
Carbon Monoxide:	29.15	32.92	33.20	31.76
Emission Rate, (lb/hr):				
Carbon Monoxide:	30.08	29.17	24.54	27.93

ppmv = parts per million by volume, dry, corrected to 15% oxygen
lb/hr = pounds per hour

Table 3

Lansing BWL

EUTURBINE1 100% Load

Summary of CO, PM, $PM_{2.5}$, and PM_{10} Emissions

July 30-31, 2013

Run No.	1	2	3	Average
Test Date	July 30, 2013	July 30, 2013	July 31, 2013	
PM Run Time	1250-1505	1545-1750	0815-1025	
CO Run Time	1335-1434	1556-1655	1915-1016	
Volumetric Flow Rates				
Actual Cubic Feet per Minute:	548,471	548,345	574,842	557,219
Standard Cubic Feet per Minute:	211,099	211,023	223,474	215,199
Dry Standard Cubic Feet per Minute:	197,129	197,345	207,426	200,633
Fixed Gases				
Oxygen, % by volume, dry:	15.35	15.37	15.30	15.34
Carbon dioxide, % by volume, dry:	3.20	3.20	3.18	3.19
Moisture, % by volume:	6.62	6.48	7.18	6.76

Run No.	1	2	3	Average
Emission Rate, (lb/hr):				
Filterable Particulate Matter (PM):	0.43	0.60	0.38	0.47
Condensable Particulate Matter (CPM):	0.71	0.70	0.87	0.76
Fine Particulate Matter ($PM_{2.5}$):	1.14	1.30	1.26	1.23
Fine Particulate Matter (PM_{10}):	1.14	1.30	1.26	1.23
Concentration (ppmv corrected to 15% O_2)				
Carbon Monoxide:	9.44	9.68	18.75	12.62
Emission Rate, (lb/hr):				
Carbon Monoxide:	7.64	7.82	16.13	10.53

ppmv = parts per million by volume, dry, corrected to 15% oxygen
lb/hr = pounds per hour

Table 4

Lansing BWL

EUTURBINE2 60% Load

Summary of CO Emissions

July 31, 2013

Run No.	1	2	3	Average
Test Date	July 31, 2013	July 31, 2013	July 31, 2013	
Run Time	1235-1335	1349-1449	1512-1612	
Volumetric Flow Rates				
Actual Cubic Feet per Minute:	433,305	330,252	301,908	355,155
Standard Cubic Feet per Minute:	175,046	173,351	169,994	172,797
Dry Standard Cubic Feet per Minute:	165,050	159,939	155,249	160,079
Fixed Gases				
Oxygen, % by volume, dry:	15.80	15.83	15.76	15.80
Carbon dioxide, % by volume, dry:	2.92	2.88	2.90	2.90
Moisture, % by volume:	5.71	7.74	8.67	7.37
Run No.	1	2	3	Average
Concentration (ppmv corrected to 15% O_2)				
Carbon Monoxide:	48.30	49.81	43.38	47.16
Emission Rate, (lb/hr):				
Carbon Monoxide:	30.12	29.92	25.62	28.56

ppmv = parts per million by volume, dry, corrected to 15% oxygen
lb/hr = pounds per hour

Table 5

Lansing BWL

EUTURBINE2 80% Load

Summary of CO Emissions

July 23, 2013

Run No.	1	2	3	Average
Test Date	July 23, 2013	July 23, 2013	July 23, 2013	
Run Time	1315-1415	1430-1530	1545-1645	
Volumetric Flow Rates				
Actual Cubic Feet per Minute:	573,655	558,260	557,058	562,991
Standard Cubic Feet per Minute:	217,217	211,769	211,418	213,468
Dry Standard Cubic Feet per Minute:	193,047	196,568	193,398	194,338
Fixed Gases				
Oxygen, % by volume, dry:	15.39	15.41	15.37	15.39
Carbon dioxide, % by volume, dry:	3.05	3.05	3.07	3.06
Moisture, % by volume:	11.13	7.18	8.52	8.94

Run No.	1	2	3	Average
Concentration (ppmv corrected to 15% O_2)				
Carbon Monoxide:	50.41	46.89	41.06	46.12
Emission Rate, (lb/hr):				
Carbon Monoxide:	39.68	37.45	32.51	36.55

ppmv = parts per million by volume, dry, corrected to 15% oxygen
lb/hr = pounds per hour

Table 6

Lansing BWL

EUTURBINE2 100% Load

Summary of CO, PM, $PM_{2.5}$, and PM_{10} Emissions

August 1, 2013

Run No.	1	2	3	Average
Test Date	August 1, 2013	August 1, 2013	August 1, 2013	
PM Run Time	0840-1055	1130-1535	1555-1810	
CO Run Time	0914-1014	1200-1449	1615-1717	
Volumetric Flow Rates				
Actual Cubic Feet per Minute:	591,509	516,707	572,973	560,397
Standard Cubic Feet per Minute:	226,600	228,723	225,764	227,029
Dry Standard Cubic Feet per Minute:	210,345	212,685	210,539	211,190
Fixed Gases				
Oxygen, % by volume, dry:	15.30	15.83	15.36	15.50
Carbon dioxide, % by volume, dry:	3.27	2.97	3.20	3.15
Moisture, % by volume:	7.17	7.01	6.74	6.98
Run No.	**1**	**2**	**3**	**Average**
Emission Rate, (lb/hr):				
Filterable Particulate Matter (PM):	0.49	0.49	0.35	0.45
Condensable Particulate Matter (CPM):	0.84	0.81	0.00	0.55
Fine Particulate Matter ($PM_{2.5}$):	1.34	1.31	0.35	1.00
Fine Particulate Matter (PM_{10}):	1.34	1.31	0.35	1.00
Concentration (ppmv corrected to 15% O_2)				
Carbon Monoxide:	11.76	13.46	11.85	12.35
Emission Rate, (lb/hr):				
Carbon Monoxide:	10.25	10.75	10.23	10.41

ppmv = parts per million by volume, dry, corrected to 15% oxygen
lb/hr = pounds per hour

FIGURES

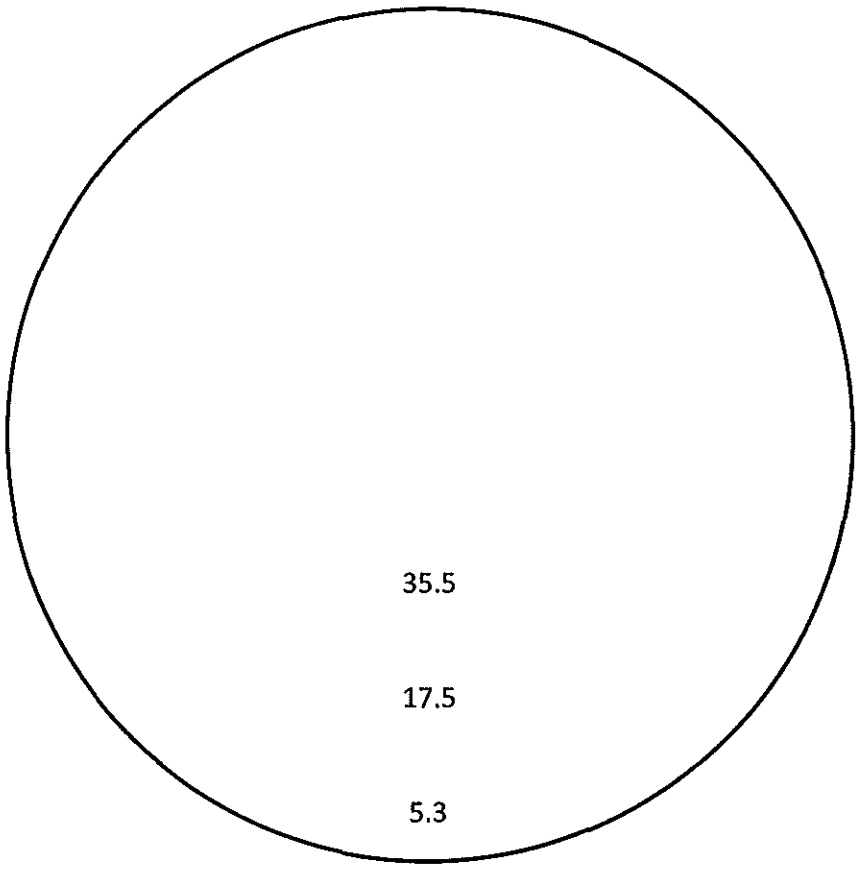
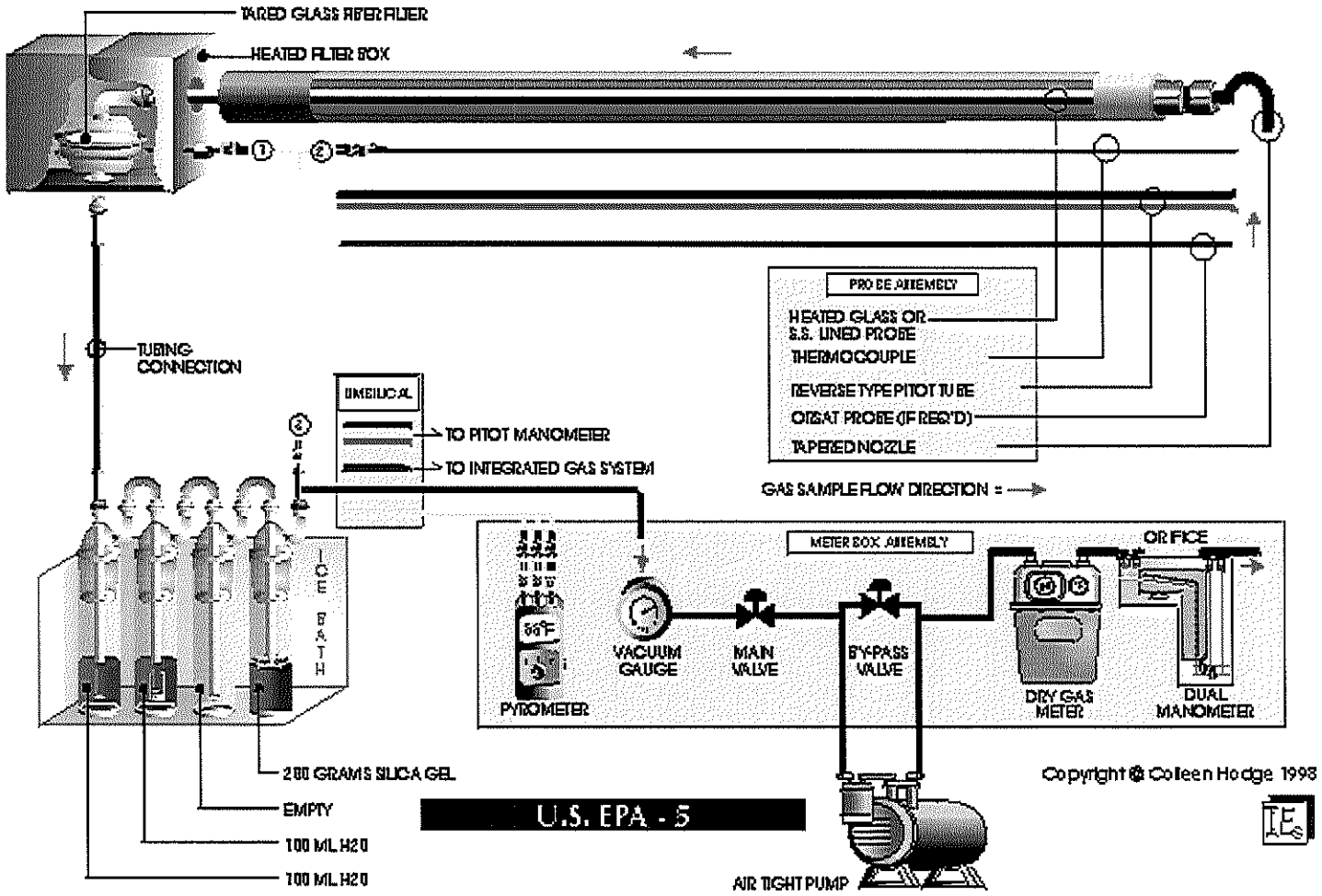


Figure 1. Stack Point Locations

Lansing BWL REO Town EUTURBINE1 and EUTURBINE2

Figure 2. U.S. EPA Method 5



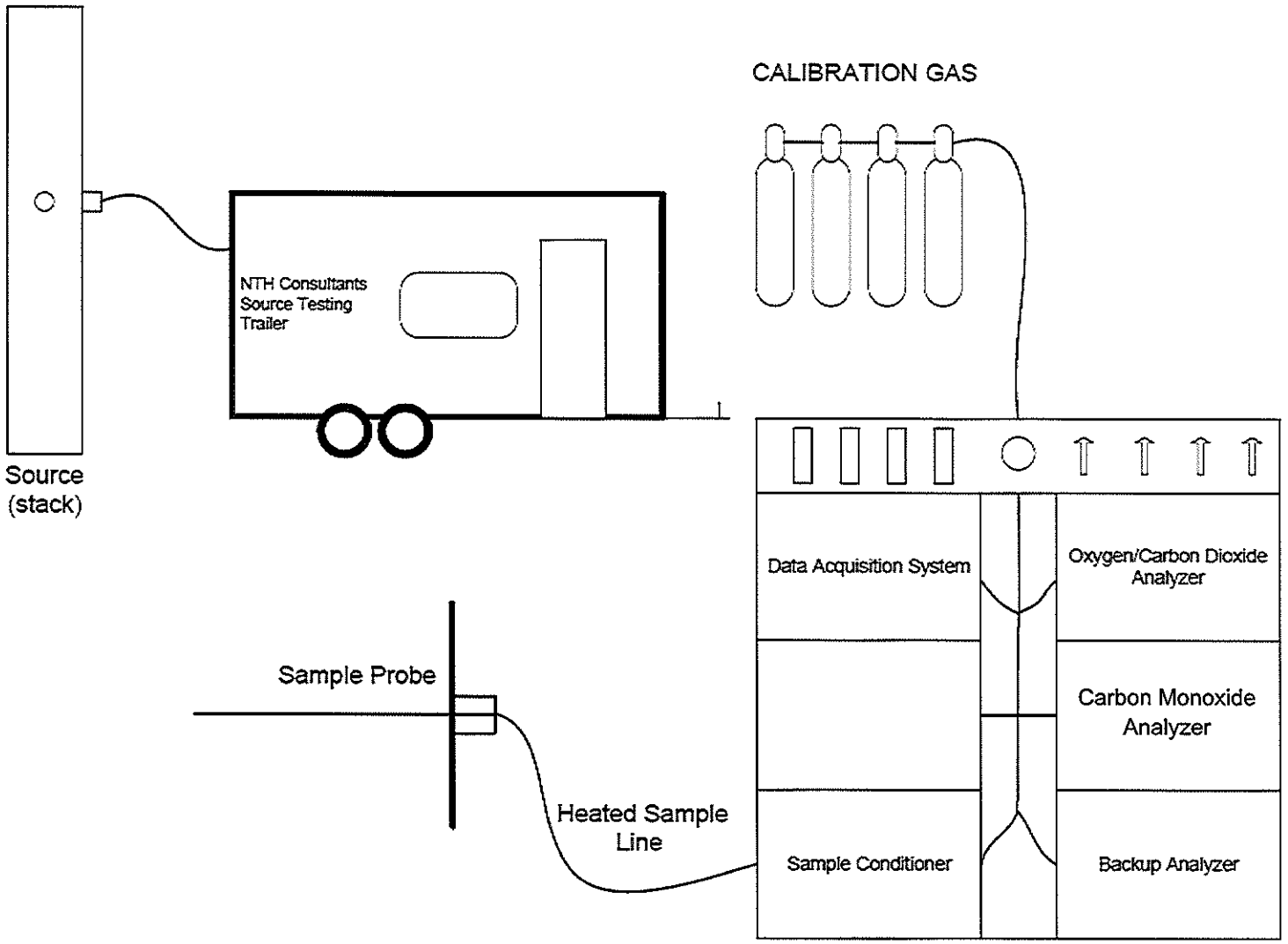


Figure No. 3
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Gas Composition/Volatile Organic
Compound Analyzers

Figure 4. U.S. EPA Method 202