

VOC, CO, and NOx, Emissions Test Report

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AIR QUALITY DIV.

Prepared for:

North American Natural Resources, Inc.

Southeast Berrien, Michigan

Southeast Berrien Generation 1520 Mayflower Road Buchanan, Michigan 49107

> Project No. 15-4758.00 December 29, 2015

BT Environmental Consulting, Inc. 4949 Fernlee Avenue Royal Oak, Michigan 48073 (248) 548-8070



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EXECUTIVE SUMMARY

AIR QUALITY DIVISION

BT Environmental Consulting, Inc. (BTEC) was retained by North American Natural Resources (NANR) to evaluate oxides of nitrogen (NOx), carbon monoxide (CO), and volatile organic compounds (VOC) emission rates from three reciprocating engines located at the North American Natural Resources (NANR) Southeast Berrien Generating Station in Southeast Berrien, Michigan. Field sampling for this emission test program was conducted on November 5, 2015. The purpose of this report is to document the results of the emissions compliance test program.

Testing consisted of triplicate 60-minute test runs on three engines at the facility. The emissions test program was required Michigan Renewable Operating Permit No. MI-ROP-N5432-2011. The results of the emission test program are summarized by Table E-I.

Table E-INorth American Natural Resources – Southeast Berrien FacilityLandfill Gas-Fired Reciprocating Engines 1, 2, and 3Compliance Test Program Results Summary

Source	Pollutant	Test Result	Emission Limitation	
Destructions	NOx	0.36 g/bhp-hr	0.62 g/bhp-hr	
Engine 1	СО	2.27 g/bhp-hr	2.8 g/bhp-hr	
Engine i	VOC	0.0 g/bhp-hr*	1.0 g/bhp-hr	
	NOx	0.25 g/bhp-hr	0.62 g/bhp-hr	
Engine 2	СО	2.46 g/bhp-hr	2.8 g/bhp-hr	
	VOC	0.0 g/bhp-hr *	1.0 g/bhp-hr	
	NOx	0.30 g/bhp-hr	0.62 g/bhp-hr	
Finding 3	СО	2.37 g/bhp-hr	2.8 g/bhp-hr	
Lingine J	VOC	0.36 g/bhp-hr 2.27 g/bhp-hr 0.0 g/bhp-hr* 0.25 g/bhp-hr 2.46 g/bhp-hr 0.0 g/bhp-hr 2.30 g/bhp-hr 2.37 g/bhp-hr 0.0 g/bhp-hr	1.0 g/bhp-hr	

* All VOC emissions were determined to be Methane (CH₄)

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1. Introduction



BT Environmental Consulting, Inc. (BTEC) was retained by North American Natural Resources (NANR) to evaluate oxides of nitrogen (NOx), carbon monoxide (CO), and polatileorganic compounds (VOC) emission rates from three reciprocating engines located at the North American Natural Resources (NANR) Southeast Berrien Generating Station in Southeast Berrien, Michigan. Field sampling for this emission test program was conducted on November 5, 2015. The purpose of this report is to document the results of the emissions compliance test program.

The Air Quality Division (AQD) of Michigan's Department of Natural Resources and Environment has published a guidance document entitled "Format for Submittal of Source Emission Test Plans and Reports" (December 2013, see Appendix A). The following is a summary of the emissions test program and results in the format outlined by the AQD document.

1.a Identification, Location, and Dates of Test

Field sampling for this emission test program was conducted on November 5, 2015 at the North American Natural Resources Southeast Berrien Landfill facility in Southeast Berrien, Michigan. The purpose of this report is to document the results of the emissions determined during compliance test program.

The emission test program included the evaluation of oxides of nitrogen (NOx), carbon monoxide (CO), and non-methane volatile organic compounds (VOC) emissions from three landfill gas-fired reciprocating engines.

1.b Purpose of Testing

Michigan Renewable Operating Permit (ROP) No. MI-ROP-N5432-2011 includes the emission limitations listed in Table 1. The purpose of the testing was to quantify NOx, CO, and VOC emission rates in terms of g/bhp-hr. These emission rates will be utilized to demonstrate compliance with ROP No. MI-ROP-N5432-2011 as well as the requirements of Title 40, Part 60, Subpart JJJJ of the Code of Federal Regulations (40 CFR 60, Subpart JJJJ).

1.c Source Description

The Southeast Berrien facility includes three (*Caterpillar 3520*) landfill gas-fired, sparkignition, lean-burn reciprocating engines. Each reciprocating engine produces approximately 2,000 kilowatts (kW) at 2250 bhp. Normal operation of the engine includes operation at constant speed near 100% load conditions.



1.d Test Program Contact

The contact for the source and test plan is:

Mr. Richard Spranger Environmental Manager North American Natural Resources 4516 Rathburn Rd. Birch Run, Michigan 48415 (517) 719-1322

1.e Testing Personnel

Names and affiliations for personnel who were present during the testing program are summarized by Table 2.

2. Summary of Results

Sections 2.a through 2.d summarize the results of the emissions compliance test program.

2.a Operating Data

Inlet gas flowrate, exhaust temperature, methane content, and generator power load (kW) were monitored during the testing.

2.b Applicable Permit

The applicable permit for this emissions test program is MI-ROP-N5432-2011.

2.c Results

The overall results of the emissions compliance test program are summarized by Table 3.

2.d Emission Regulation Comparison

Emission limitations for NANR are summarized by Table 1.

3. Source Description

Sections 3.a through 3.e provide a detailed description of the process.

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3.a Process Description

Landfill gas is compressed, filtered, and chilled to 50 degrees Fahrenheit. Gas enters the main header where flowrate, temperature, and methane content are measured. The engines burn the landfill gas to produce electricity. As methane content fluctuates throughout the day, the engines gas jets are adjusted to minimize emissions.

3.b Raw and Finished Materials

The raw material supplied to the engine includes landfill gas. The finished material is electricity.

3.c Process Capacity

The Engines produce approximately 1,600 kW at an inlet pressure of 225 kPa. If the landfill gas methane content changes, the inlet pressure changes and the operators adjust the engine's fuel ratio to bring up boost (kPa) to maintain an average of 9% oxygen in the engine exhaust. Each engine is rated at 2,250 bhp.

3.d Process Instrumentation

Engines performance is determined by methane input and kW output.

4. Sampling and Analytical Procedures

Sections 4.a through 4.d provide a summary of the sampling and analytical procedures used to verify emission rates from the engines.

4.a Sampling Train and Field Procedures

Sampling and analysis procedures utilized the following test methods codified at Title 40, Part 60, Appendix A of the Code of Federal Regulations (40 CFR 60, Appendix A):

•	Method 1 -	"Sample and Velocity Traverses for Stationary Sources"
•	Method 2 -	"Determination of Stack Gas Velocity and Volumetric Flowrate"
•	Method 3A -	"Determination of Molecular Weight of Dry Stack Gas"
•	Method 4 -	"Determination of Moisture Content in Stack Gases"
•	Method 7E -	"Determination of Nitrogen Oxide Emissions from Stationary Sources"
•	Method 10 -	"Determination of Carbon Monoxide Emissions from Stationary Sources"

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Method 25A - "Determination of total gaseous organic concentration using a flame ionization analyzer"

The NO_x content of the exhaust gas was measured using a TECO 42hi NO_x gas analyzer and the O₂, CO, & CO₂ content was measured using M&C and Teledyne analyzers. A sample of the gas stream was drawn through an insulated stainless-steel probe with an inline glass fiber filter to remove any particulate, a heated Teflon[®] sample line, and through a Universal Analyzers 3080PV electronic sample conditioner to remove the moisture from the sample before it entered the analyzer. Data was recorded at 4-second intervals on a PC equipped with data acquisition software.

A USEPA Method 7E NO2 to NO conversion efficiency test was performed on November 5, 2015. The results are presented in Appendix C.

The VOC content of the exhaust was measured using a J.U.M. Model 109A analyzer. A sample of the gas stream was drawn through an insulated stainless-steel probe with an inline glass fiber filter to remove any particulate and a heated Teflon[®] sample line to prevent the condensation of any moisture from the sample before it enters the analyzer. Data was recorded at 4-second intervals on a PC equipped with data acquisition software.

For analyzer calibrations, calibration gases were mixed to desired concentrations using an Environics Series 4040 Computerized Gas Dilution System. The Series 4040 consisting of a single chassis with four mass flow controllers. The mass flow controllers are factory-calibrated using a primary flow standard traceable to the United States' National Institute of Standards and Technology (NIST). Each flow controller utilizes an 11 point calibration table with linear interpolation, to increase accuracy and reduce flow controller nonlinearity. Schematic drawings of the flow traverse points, continuous emission systems, and the moisture sampling train are provided as Figures 1 through 4.

USEPA Method 205 Verification of Gas Dilution Systems for Field Instrument Calibrations was performed. The results of this verification can be found in Appendix C.

4.b Recovery and Analytical Procedures

Recovery and analytical procedures were described in Section 4.a.

4.c Sampling Ports

Sampling port locations met the minimum criteria of Method 1.

5. Test Results and Discussion

Sections 5.a through 5.k provide a summary of the test results.



5.a Results Tabulation

The results of the emissions test program are summarized by Table 3. Detailed data for each test run can be found in Tables 4, 5, and 6.

5.b Discussion of Results

Emission limitations for the Michigan ROP No. MI-ROP-N5432-2011 are summarized by Table 1. The results of the emissions test program are summarized by Table 3.

5.c Sampling Procedure Variations

No sampling procedure variations were employed during this emissions test program.

5.d Process or Control Device Upsets

No process upset condition occurred during the emissions test program.

5.e Control Device Maintenance

No control device maintenance was performed.

5.f Audit Sample Analyses

No audit samples were collected as part of the test program.

5.g Calibration Sheets

All relevant equipment calibration documents are provided in Appendix C.

5.h Sample Calculations

Sample calculations are provided in Appendix D.

5.i Field Data Sheets

Field documents relevant to the emissions test program are presented in Appendix B.

5.j Laboratory Data

There are no laboratory results for this test program. Analyzer raw data files are provided in Appendix E.

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ROP No. MI-ROP-N5432-2011 Emission Limitations			
Pollutant	Emission Limitation	Emission Limitation Units	
NOx	0.62	g/bhp-hr	
CO	2.8	g/bhp-hr	
VOC	1.0	g/bhp-hr	

Table 1



Name and Title	Affiliation	Telephone
Mr. Richard Spranger Environmental Manager	North American Natural Resources - Zeeland, Michigan	(269) 362-5546
Mr. Matt Young Project Manager	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Steve Smith Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Dave Trehan Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070

Table 2 Test Personnel

 Table 3

 North American Natural Resources – Southeast Berrien Facility

 Landfill Gas-Fired Reciprocating Engines 1, 2, and 3

 Compliance Test Program Results Summary

Source	Pollutant	Test Result	Emission Limitation
	NOx	0.36 g/bhp-hr	0.62 g/bhp-hr
Finding 1	СО	2.27 g/bhp-hr	2.8 g/bhp-hr
	VOC	0.0 g/bhp-hr*	1.0 g/bhp-hr
Designed	NOx	0.25 g/bhp-hr	0.62 g/bhp-hr
Engine 2	CO	2.46 g/bhp-hr	2.8 g/bhp-hr
Eligine 2	VOC	tant Test Result vx 0.36 g/bhp-hr 0 2.27 g/bhp-hr C 0.0 g/bhp-hr* vx 0.25 g/bhp-hr 0 2.46 g/bhp-hr C 0.0 g/bhp-hr C 0.30 g/bhp-hr O 2.46 g/bhp-hr C 0.30 g/bhp-hr C 0.30 g/bhp-hr C 0.30 g/bhp-hr C 0.30 g/bhp-hr C 0.0 g/bhp-hr	1.0 g/bhp-hr
Reciprocating	NOx	0.30 g/bhp-hr	0.62 g/bhp-hr
	СО	2.37 g/bhp-hr	2.8 g/bhp-hr
Engine 5	VOC	0.0 g/bhp-hr *	1.0 g/bhp-hr

* All VOC emissions were determined to be Methane (CH₄)

Table 4 Engine 1 NOx, VOC, and CO Emission Rates North American Natural Resources Southeast Berrien, MI BTEC Project No. 15-4758.00 Sampling Date: 11/5/2015

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	11/5/2015	11/5/2015	11/5/2015	
Test Run Time	9:20-10:20	10:50-11:50	12:10-13:10	
Outlet Flowrate (dscfm)	4,514	4,456	4,463	4,478
Outlet Flowrate (scfm)	5,171	5,104	5,083	5,119
bhp	2,250	2,250	2,250	
Outlet Oxides of Nitrogen Concentration (ppmv)	55.67	47.15	57,53	53.45
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	57.07	49.25	60.31	55.54
NOx Emission Rate (lb/hr)	1.8	1.5	1.8	1.7
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	1.8	1.6	1.9	1.8
Outlet Carbon Monavide Concentration (namy)	568.08	533.35	561 75	555 73
Outlet CO Concentration (opmy, corrected as per USEPA 7E)	587.01	556.60	588.06	577 22
CO Emission Bate (lb/hr)	11.1	10.3	10.9	10.8
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	11.5	10.8	11.4	11.2
Outlet VOC Concentration (nomy as propage)	579 11	571.53	585 31	578.65
Outlet Methane Concentration (ppmv as methane)	1361.23	1357.72	1398.63	1372.53
Outlet VOC Concentration (ppmv, corrected as per USEPA 7E)	580.05	586.95	598.86	588.62
Outlet Methane Concentration (ppmv, corrected as per USEPA 7E)	1381.48	1391,25	1399.47	1390.73
Outlet VOC Concentration (ppmv as Propane -Methane)*	0.0	0.0	0.0	0.0
Outlet Methane Concentration (ppmv as Propane -Methane, corrected as per USEPA 7E)*	0.0	0,0	0.0	0.0
VOC Emission Rate as Propane (lb/hr)	0.0	0,0	0.0	0.0
VOC Emission Rate as Propane(lb/hr) (corrected as per USEPA 7E)	0.0	0.0	0.0	0.0
NOX (g/bhp-hr)	0.37	0.32	0,39	0.36
CO (g/bhp-hr)	2.32	2.17	2.30	2.27
VOC (g/bhp-hr)	0,00	0.00	0.00	0.00

VOC Correction			
Co	-0.45	0.31	0.07
Cma	499	499	499
Cm	498.13	485.94	487.72

Methane Correction			
C٥	-0.37	1.29	2.28
Cma	1493	1493	1493
Cm	1471.15	1456.93	1491.96

*: Methane subtraction resulted in a negative value, which has been replaced with zero.

response factor = 2.25

sofm = standard cubic feet per minute

dscfm = dry standard cubic feet per minute

ppmv = parts per million on a volume-to-volume basis

ib/hr = pounds per hour

$$\begin{split} MW &= molecular \mbox{ weight (CO} = 28.01, \mbox{ NOx} = 46.01, \mbox{ C_3H_g} = 44.10) \\ 24.14 &= molar \mbox{ volume of air at standard conditions (70°F, 29.92° Hg)} \end{split}$$

35.31 = ft³ per m³

453600 = mg per lb

g/bhp-hr = grams per brake horse power hour

Equations

lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453.600 * scfm * 60 for VOC lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453.600 * dcfm * 60

Table 5 Engine 2 NOx, VOC, and CO Emission Rates North American Natural Resources Southeast Berrien, MI BTEC Project No. 15-4758.00 Sampling Date: 11/5/2015

	Kun I	Kun Z	Run 3	Average
Test Run Date	11/5/2015	11/5/2015	11/5/2015	
Test Run Time	13:45-14:45	15:12-16:12	16:35-17:35	
Outlet Flowrate (dscfm)	4.304	4,534	4,494	4,444
Outlet Flowrate (scfm)	4.886	5.044	5.023	4.984
bhp	2,250	2,250	2,250	-,
Outlet Oxides of Nitrogen Concentration (onmy)	37.96	36.42	35.82	36 73
Outlet NOx Concentration (pnuv, corrected as per LISEPA 7E)	39.49	37.99	37.51	38 33
NOx Emission Rate (lb/hr)	12	1.2	11	12
NOx Emission Rate (lb/br) (corrected as per USEPA 7E)	1.2	1.2	1.2	1.2
Outlet Cathon Monovide Concentration (npmy)	606 91	607 50	602 37	605.59
Outlet CO Concentration (nomy, corrected as per LISEPA 7E)	632.59	634.13	629.52	632.08
CO Emission Rate (lh/hr)	11.4	12.0	11.8	11.7
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	11.8	12.5	12.3	12.2
Outlet VOC Concentration (ppmv as propane)	766.13	786.35	772.20	774.89
Outlet Methane Concentration (ppmv as methane)	1803.89	1859.09	1822,54	1828.51
Outlet VOC Concentration (ppmv, corrected as per USEPA 7E)	785.71	816.98	789.29	797.33
Outlet Methane Concentration (ppmv, corrected as per USEPA 7E)	1822.38	1919.90	1869.17	1870.48
Outlet VOC Concentration (ppmv as Propane -Methane) *	0.0	0.0	0.0	0.0
Outlet Methane Concentration (ppmv as Propane -Methane, corrected as per USEPA 7E	0.0	0.0	0.0	0.0
VOC Emission Rate as Propane (Ib/hr)	0.0	0.0	0.0	0.0
VOC Emission Rate as Propane(lb/hr) (corrected as per USEPA 7E)	0.0	0.0	0.0	0.0
NOX (g/bhn-hr)	0.24	0.25	0.24	0.25
CO (g/hhp-hr)	2 39	2.52	7.48	2.46
VOC (g/bhn-hr)	0.00	0.00	0.00	0.00

VOC Correction			
	_		
Co	-0.34	-0.40	0.12
Ста	499	499	499
Cm	486,44	480.14	488.24

Methane	Correction		
Co	3.10	2.81	3.04
Cma	1493	1493	1493
Cm	1478.41	1446,34	1456.37

*: Methane subtraction resulted in a negative value, which has been replaced with zero.

response factor = 2.25

sofm = standard cubic feet per minute

dscfm = dry standard cubic feet per minute

ppmv = parts per million on a volume-to-volume basis

lb/hr = pounds per hour

$$\label{eq:MW} \begin{split} MW &= molecular \mbox{ weight (CO = 28.01, NOx = 46.01, C_3H_8 = 44.10)} \\ 24.14 &= molar \mbox{ volume of air at standard conditions (70°F, 29.92" Hg)} \end{split}$$

 $35.31 = ft^3 per m^3$

453600 = mg per lb g/bhp-hr = grams per brake horse power hour

Equations

lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453.600 * scfm * 60 for VOC lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453.600 * dcfm * 60

Table 6 Engine 3 NOx, VOC, and CO Emission Rates North American Natural Resources Southeast Berrien, MI BTEC Project No. 15-4758.00 Sampling Date: 11/5/2015

Parameter	Run í	Run 2	Run 3	Average
Test Run Date	11/5/2015	11/5/2015	11/5/2015	
Test Run Time	17:55-18:10	19:39-20:39	20:55-21:55	1
	18:22-19:07			1
Outlet Flowrate (dscfm)	4,524	4,513	4,583	4,540
Outlet Flowrate (scfm)	5,248	5,223	5,226	5,232
bhp	2,250	2,250	2,250	
Outlet Oxides of Nitrogen Concentration (ppmv)	46.6	43.2	41.0	43.6
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	48.8	44.9	42.2	45.3
NOx Emission Rate (lb/hr)	1.5	1.4	1.3	1.4
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	1.6	1.4	1.4	1,5
Custo Cabas Manavida Cancantation (mmm)	574 0	567.0	570 Å	571.4
Outlet Carbon Monoxide Concentration (ppinv)	574.0	500.7	506.5	505.9
CO Emission Rets (Ib/hu)	11 3	11.1	390,3	373.0
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	11.8	11.6	11.9	11.8
Outlet VOC Concentration (news as pronane)	475.9	477.2	472.9	475.3
Outlet Methane Concentration (ppmy as methane)	1125.4	1149.3	1141.6	1138.7
Outlet VOC Concentration (ppmv, corrected as per USEPA 7E)	474.8	478.3	483.5	478.8
Outlet Methane Concentration (ppmy, corrected as per USEPA 7E)	1153.4	1163.6	1150.5	1155.8
Outlet VOC Concentration (ppmv as Propane -Methane) *	0.0	0.0	0.0	0.0
Outlet Methane Concentration (ppmy as Propane -Methane, corrected as per USEPA 7E)	0.0	0.0	0.0	0.0
VOC Emission Rate as Propane (lb/hr)	0.0	0.0	0.0	0.0
VOC Emission Rate as Propane(lb/hr) (corrected as per USEPA 7E)	0.0	0.0	0.0	0.0
NOX (g/bhp-hr)	0.32	0.29	0.28	0.30
CO (g/bhp-hr)	2.38	2.34	2.40	2.37
VOC (g/bhp-hr)	0.00	0.00	0.00	0.00

VOC Correction			
Co	0.22	-0.55	-0.96
Cma	499	499	499
Cm	500.12	497.88	488,11

Methane	Correction		
Co	3.51	3.15	2,84
Cma	1493	1493	1493
Cm	1455.74	1473,66	1480.53

*: Methane subtraction resulted in a negative value, which has been replaced with zero.

response factor = 2.25

sofm = standard cubic feet per minute

dsefin = dry standard cubic feet per minute

ppmv = parts per million on a volume-to-volume basis

lb/hr = pounds per hour

MW = molecular weight (CO = 28.01, NOx = 46.01, $C_3H_8 = 44.10$)

24.14 = molar volume of air at standard conditions (70°F. 29.92" Hg)

 $35.31 = ft^3 per m^3$

453600 = mg per lb

g/bhp-hr = grams per brake horse power hour

Equations

lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453.600 * scfm * 60 for VOC lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453.600 * dcfm * 60