



Landfill Gas Engine VOC, CO, NOx and Formaldehyde Emissions Test Report

Prepared for:

Zeeland Farm Services, Inc.

Zeeland, Michigan

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Source Address:

Zeeland Farm Services, Inc.
2525 84th Avenue
Zeeland, Michigan 49464

Project No. 13-4434.00
November 13, 2013

BT Environmental Consulting, Inc.
4949 Fernlee Avenue
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EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by the Zeeland Farm Services, Inc. (ZFS) to evaluate volatile organic compounds (VOC), carbon monoxide (CO), nitrogen oxides (NO_x), and formaldehyde (CH₂O) concentrations and emission rates from two landfill gas-fired engines (Engines 1 and 2) at the ZFS facility located in Zeeland, Michigan. Triplicate 60-minute emission test runs were conducted for each parameter on September 17, 2013. Table E-I summarizes the results of the emissions test program.

Table E-I
Zeeland Farm Services
Engines 1 and 2
Test Program Results Summary

Source	Pollutant	Test Result (lbs/MMBtu)
Engine 1	NO _x	0.23
	CO	1.13
	VOC	0.20
	Formaldehyde	0.17
Engine 2	NO _x	0.19
	CO	0.94
	VOC	0.16
	Formaldehyde	0.14

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Appendix E	Example Calculations
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1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by the Zeeland Farm Services, Inc. (ZFS) to evaluate volatile organic compounds (VOC), carbon monoxide (CO), nitrogen oxides (NO_x), and formaldehyde (CH₂O) concentrations and emission rates from two landfill gas-fired engines (Engines 1 and 2) at the ZFS facility located in Zeeland, Michigan.

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" (February 2008, 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 September 17, 2013 at 2525 84th Avenue in Zeeland, Michigan. The purpose of this report is to document the results of the emissions determined during the compliance test program.

1.b Purpose of Testing

The landfill gas engines are included in Permit No. MI-ROP-M4204-2012a. Testing for CO, NO_x, VOC, and formaldehyde were being performed in accordance with MDEQ requirements.

1.c Test Program Contact

The contact for the test program is:

Ms. Bridgette Rillema, P.E.
Environmental Manager
Zeeland Farm Services, Inc.
2525 84th Ave
Zeeland, Michigan 49464
(616) 879-1711



1.d Test Personnel

Names and affiliations for personnel who were present during the testing program are summarized by Table 1.

2. Summary of Results

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

2.a Operating Data

Operating data for the emissions test program is included in Appendix B.

2.b Applicable Permit

The landfill gas engines are included in Permit No. MI-ROP-M4204-2012a.

2.c Results

The overall results of the emissions compliance test program are summarized by Table 2.

3. Source Description

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

3.a Process Description

The emission units are Caterpillar Model 3520C landfill gas engines. The engines are regulated by the power output of the generator as well as by landfill gas pressure and landfill gas heating value. In addition, the engine is regulated by air/fuel ratio.

3.b Raw and Finished Materials

The raw material is landfill gas and the finished material is electric power.

3.c Process Capacity

At 100% load, the engine is rated for 2,242 bhp and a generator power output of 1,600 kW.

3.d Process Instrumentation

The engine is equipped with controls to adjust the fuel-air ratio of the engine intake manifold.

4. Sampling and Analytical Procedures

Sections 4.a through 4.d provide a summary of the sampling and analytical procedures used to verify emissions from the landfill gas engines.

4.a Sampling Train and Field Procedures

Sampling and analysis procedures followed the methodologies of the following emission test methods codified at Title 40, Part 60, Appendix A of the Code of Federal Regulations (40 CFR 60, Appendix A) and 40 CFR 63, Appendix A:

- Method 3A - *"Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources"*
- Method 320 - *"Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive Fourier Transform Infrared Spectroscopy"*

The O₂ content was measured using a M&C Products PMA 100-L O₂ gas analyzer (or equivalent) and the CO₂ content was measured using a CAI 600 Series CO₂ gas analyzer (or equivalent). A sample of the gas stream was drawn through an insulated stainless-steel probe with an in-line glass fiber filter to remove any particulate, a heated Teflon[®] sample line, and through an electronic sample conditioner to remove the moisture from the sample before it entered the analyzers. Data was recorded at 4-second intervals on a PC equipped with data acquisition software.

Exhaust gas CO, NO, NO₂, CH₂O formaldehyde, CH₄, C₂H₆ (ethane), C₂H₄ (ethylene), C₃H₈ (propane) and total aliphatic hydrocarbons (as hexane) concentrations were measured by Fourier Transform Infrared (FTIR) spectroscopy. Emissions from the engine were continually purged through the sampling system and FTIR. The sample gas was extracted from the engine exhaust using a heated stainless steel probe, maintained at 191°C. A heated filter box (191°C) connected the probe to the filter assembly to a heated transfer line. A 0.1 μ glass filter will used for particulate matter removal. A heated diaphragm pump was used to pull the sample from the engine. The sampling rate was 8 to 10 liters per minute.

The heated transfer line, held at 191°C, connected the probe/filter assembly to the FTIR. The FTIR was be equipped with a temperature-controlled, 5.11 meter multipass gas cell maintained at 191°C.

FTIR data was collected using an MKS MultiGas 2030 FTIR spectrometer. All data was collected at 0.5cm⁻¹ resolution. Each sample spectrum was derived from the co-addition of 60 scans, with a new data point generated every one minute.

FTIR sampling and analysis was conducted by Prism Analytical Technologies, Inc. (PATI) of Mount Pleasant, Michigan. A copy of PATI's test summary report is included as



Appendix C. Figure 1 presents a diagram of the O₂ monitoring system and Figure 2 presents a diagram of the FTIR monitoring system.

4.b Recovery and Analytical Procedures

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

4.c Sampling Ports

All sampling took place at the engine exhaust ducts.

4.d Traverse Points

The generator sets came pre-installed with one exhaust duct that is 13.5 inches in diameter.

5. Test Results and Discussion

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

5.a Results Tabulation

The overall results of the emissions test program are summarized by Table 2. Detailed test run emission test results are summarized by Tables 3 and 4.

5.b Discussion of Results

As summarized by Table 2, both engines were operating in excess of their emission limitations for both CO and NOx.

5.c Sampling Procedure Variations

No sampling procedure variations occurred during testing.

5.d Process or Control Device Upsets

Engine 1 shut down approximately 30 minutes into Run 2. Upon inspection, it was found that the high temperature of the engine oil caused the engine to run improperly. After a period of time running improperly, the engine automatically shutdown to protect itself. Once the oil temperature cooled off. Engine 1 was restarted. When it was determined that the engine was running normally, a new Run was conducted.

5.e Control Device Maintenance

No control device maintenance was performed during the testing.

5.f Audit Sample Analyses

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

5.g Calibration Sheets

Relevant equipment calibration documents are provided in Appendix D.

5.h Sample Calculations

Sample calculations are provided in Appendix E.



5.i Field Data Sheets

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

5.j Laboratory Data

All analysis was done live through the use of online Analyzers and as such there is no laboratory data. Raw analyzer data as well as the FTIR test report provided by Prism Analytical Technologies are provided in Appendix C.

TABLES

Table 1
Test Personnel

Name and Title	Affiliation	Telephone
Ms. Bridgette Rillema Environmental Manager	Zeeland Farm Services 2525 84 th Avenue Zeeland, Michigan 49464	(616) 879-1711
Mr. Nathan Hude Technical Programs Unit	MDEQ Technical Programs Unit Air Quality Division	(517) 335-3082
Mr. Ken Lievens Project Manager	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070
Mr. Paul Draper Environmental Technician	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070

Table 2
Zeeland Farm Services
Engines 1 and 2
Test Program Results Summary

Source	Pollutant	Test Result (lbs/MMBtu)
Engine 1	NOx	0.23
	CO	1.13
	VOC	0.20
	Formaldehyde	0.17
Engine 2	NOx	0.19
	CO	0.94
	VOC	0.16
	Formaldehyde	0.14

Table 3
Engine 1 NOx, CO, VOC, and Formaldehyde Emission Rates
ZFS
Zeeeland, MI
BTEC Project No. 13-4434.00
Sampling Date: 9-17-13

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	9/17/2013	9/17/2013	9/17/2013	
Test Run Time	12:52-13:52	15:05-16:05	16:17-17:17	
Landfill Gas Inlet Flowrate (scfm)	554	546	542	
Landfill Gas Methane Content (% v/v)	52.8	53.1	53.2	
Landfill Gas Heat Input Rate (MMBtu/hr)	17.74	17.59	17.49	
Engine Exhaust O ₂ Content (%)	8.62	8.60	8.40	8.54
Engine Exhaust H ₂ O Content (%)	11.6	11.7	11.9	11.7
Engine Operating Load (hp)	1,997	2,006	1,996	2,000
Outlet Flowrate (scfm)	5,448	5,495	5,498	5,481
Outlet Oxides of Nitrogen Concentration (ppmv)	97.6	105.9	101.0	101.5
Outlet Carbon Monoxide Concentration (ppmv)	764.1	761.8	964.1	830.0
Outlet Formaldehyde Concentration (ppmv)	115.4	116.2	118.9	116.8
Outlet Methanol Concentration (ppmv)	2.6	2.5	2.7	2.6
Outlet Formic Acid Concentration (ppmv)	2.4	2.6	2.7	2.6
Outlet Ethylene Concentration (ppmv)	18.1	17.9	17.9	18.0
Outlet Oxides of Nitrogen Emission Rate (lbs/hr)	3.8	4.2	4.0	4.0
Outlet Carbon Monoxide Emission Rate (lbs/hr)	18.1	18.3	23.1	19.8
Outlet Formaldehyde Emission Rate (lbs/hr)	2.9	3.0	3.1	3.0
Outlet Methanol Emission Rate (lbs/hr)	0.1	0.1	0.1	0.1
Outlet Formic Acid Emission Rate (lbs/hr)	0.1	0.1	0.1	0.1
Outlet Ethylene Emission Rate (lbs/hr)	0.4	0.4	0.4	0.4
Outlet Total VOC Emission Rate (lbs/hr)	3.5	3.6	3.7	3.6
Outlet Oxides of Nitrogen Emission Rate (lbs/MMBtu)	0.21	0.24	0.23	0.23
Outlet Carbon Monoxide Emission Rate (lbs/MMBtu)	1.02	1.04	1.32	1.13
Outlet Formaldehyde Emission Rate (lbs/MMBtu)	0.17	0.17	0.17	0.17
Outlet Methanol Emission Rate (lbs/MMBtu)	0.00	0.00	0.00	0.00
Outlet Formic Acid Emission Rate (lbs/MMBtu)	0.01	0.01	0.01	0.01
Outlet Ethylene Emission Rate (lbs/MMBtu)	0.02	0.02	0.02	0.02
Outlet Total VOC Emission Rate (lbs/MMBtu)	0.20	0.20	0.21	0.20
Outlet Oxides of Nitrogen Emission Rate (g/hp-hr)	0.86	0.94	0.90	0.90
Outlet Total VOC Emission Rate (g/hp-hr)	0.80	0.81	0.83	0.82
Outlet Carbon Monoxide Emission Rate (g/hp-hr)	4.12	4.13	5.25	4.50
Outlet Oxides of Nitrogen Emission Rate (ppmvd @ 15% O ₂)	58.43	63.40	59.51	60.45
Outlet Total VOC Emission Rate (ppmvd @ 15% O ₂)	82.91	83.34	83.79	83.35
Outlet Carbon Monoxide Emission Rate (ppmvd @ 15% O ₂)	457.42	456.09	568.09	493.87

scfm = standard cubic feet per minute
ppmv = parts per million on a volume-to-volume basis
lb/hr = pounds per hour

Table 4
Engine 2 NOx, CO, VOC, and Formaldehyde Emission Rates
ZFS
Zeeland, MI
BTEC Project No. 13-4434.00
Sampling Date: 9-17-13

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	9/17/2013	9/17/2013	9/17/2013	
Test Run Time	8:32-9:32	9:50-10:50	11:02-12:02	
Landfill Gas Inlet Flowrate (scfm)	589	594	589	
Landfill Gas Methane Content (% v/v)	52.2	52.2	52.4	
Landfill Gas Heat Input Rate (MMBtu/hr)	18.65	18.81	18.72	
Engine Exhaust O ₂ Content (%)	7.78	8.07	7.74	7.86
Engine Exhaust H ₂ O Content (%)	11.9	12.1	12.0	12.0
Engine Operating Load (hp)	2,066	2,067	2,067	2,067
Outlet Flowrate (scfm)	5,047	5,140	5,190	5,126
Outlet Oxides of Nitrogen Concentration (ppmv)	95.4	96.7	99.1	97.1
Outlet Carbon Monoxide Concentration (ppmv)	774.7	793.2	797.2	788.4
Outlet Formaldehyde Concentration (ppmv)	105.5	107.8	106.7	106.7
Outlet Methanol Concentration (ppmv)	2.6	2.4	2.4	2.5
Outlet Formic Acid Concentration (ppmv)	2.3	2.6	2.6	2.5
Outlet Ethylene Concentration (ppmv)	15.8	15.9	15.9	15.9
Outlet Oxides of Nitrogen Emission Rate (lbs/hr)	3.4	3.6	3.7	3.6
Outlet Carbon Monoxide Emission Rate (lbs/hr)	17.0	17.8	18.0	17.6
Outlet Formaldehyde Emission Rate (lbs/hr)	2.5	2.6	2.6	2.6
Outlet Methanol Emission Rate (lbs/hr)	0.1	0.1	0.1	0.1
Outlet Formic Acid Emission Rate (lbs/hr)	0.1	0.1	0.1	0.1
Outlet Ethylene Emission Rate (lbs/hr)	0.3	0.4	0.4	0.4
Outlet Total VOC Emission Rate (lbs/hr)	3.0	3.1	3.1	3.1
Outlet Oxides of Nitrogen Emission Rate (lbs/MMBtu)	0.18	0.19	0.20	0.19
Outlet Carbon Monoxide Emission Rate (lbs/MMBtu)	0.91	0.94	0.96	0.94
Outlet Formaldehyde Emission Rate (lbs/MMBtu)	0.13	0.14	0.14	0.14
Outlet Methanol Emission Rate (lbs/MMBtu)	0.00	0.00	0.00	0.00
Outlet Formic Acid Emission Rate (lbs/MMBtu)	0.00	0.01	0.01	0.00
Outlet Ethylene Emission Rate (lbs/MMBtu)	0.02	0.02	0.02	0.02
Outlet Total VOC Emission Rate (lbs/MMBtu)	0.16	0.17	0.17	0.16
Outlet Oxides of Nitrogen Emission Rate (g/hp-hr)	0.76	0.78	0.81	0.78
Outlet Total VOC Emission Rate (g/hp-hr)	0.66	0.68	0.68	0.67
Outlet Carbon Monoxide Emission Rate (g/hp-hr)	3.74	3.90	3.96	3.87
Outlet Oxides of Nitrogen Emission Rate (ppmvd @ 15% O ₂)	52.94	55.39	54.89	54.40
Outlet Total VOC Emission Rate (ppmvd @ 15% O ₂)	70.05	73.71	70.68	71.47
Outlet Carbon Monoxide Emission Rate (ppmvd @ 15% O ₂)	429.87	454.31	441.56	441.91

scfm = standard cubic feet per minute

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

lb/hr = pounds per hour

FIGURES

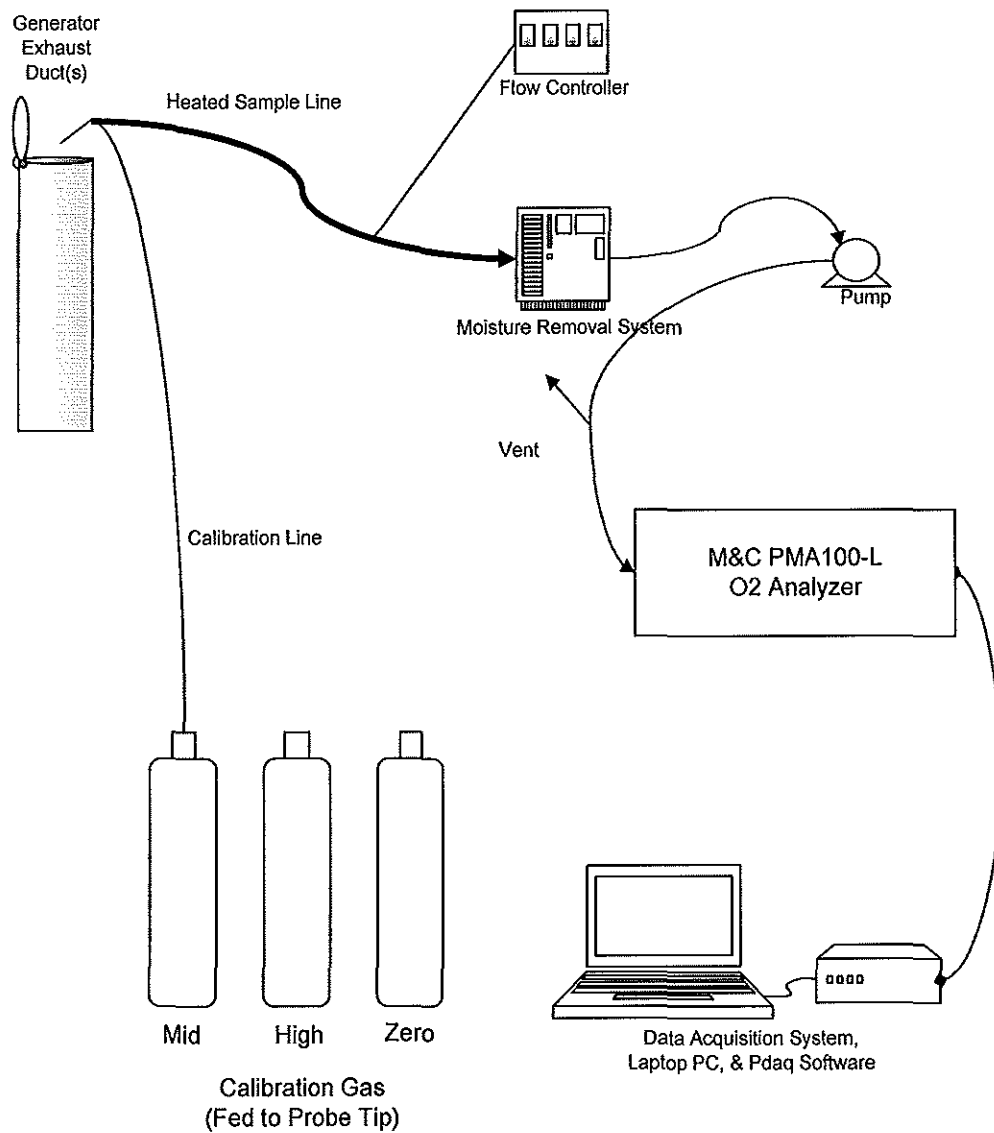


Figure 1
USEPA Method 3A

Site:
Engines 1 and 2
Zeeland Farm Services
Zeeland, MI

Sampling Date:
September 17, 2013

BT Environmental Consulting Inc.
4949 Fernlee Avenue
Royal Oak, MI 48073

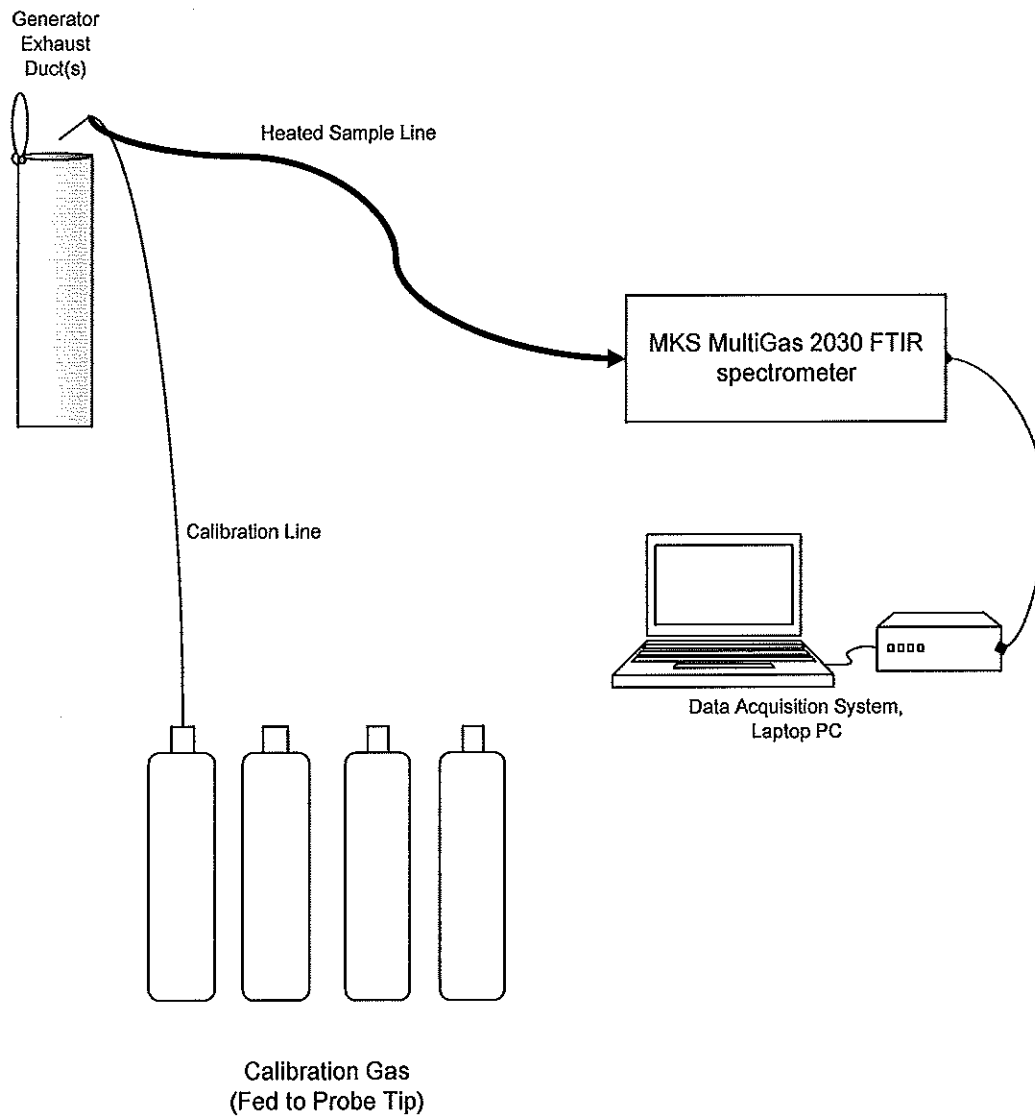


Figure 2
USEPA Method 320

Site:
Engines 1 and 2
Zeeland Farm Services
Zeeland, MI

Sampling Date:
September 17, 2013

BT Environmental Consulting Inc.
4949 Fernlee Avenue
Royal Oak, MI 48073