BTEC Inc.

CO, NOx, and VOC Emissions Test Report

Prepared for:

General Motors LLC Orion Assembly

Lake Orion, MI

GM Orion Assembly Plant
4555 Giddings Road
Lake Orion, MI 48359

Project No. 049AS-452593
October 12, 2018

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

EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC), a subsidiary of Montrose Air Quality Services (MAQS), was retained by General Motors (GM) to evaluate nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compound (VOC) emission rates from five engines at the GM facility located in Lake Orion, Michigan. The emissions test program was conducted on August 28-30, 2018.

Testing of Engines 1, 2, 3, 4, and 5 consisted of triplicate 60-minute test runs. The emissions test program was required by MDEQ Air Quality Division Renewable Operating Permit (ROP) No. MI-ROP-B7227-2015b. The results of the emission test program are summarized by Table I.

Table I
Overall Emission Summary
Test Date: August 28-30, 2018

Source	Pollutant	Average Emission Rate	Emission Limit
Engine 1	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.47 g/hp-hr	2.0 g/hp-hr
	CO	2.26 g/hp-hr	3.5 g/hp-hr
Engine 2	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.42 g/hp-hr	2.0 g/hp-hr
	CO	2.14 g/hp-hr	3.5 g/hp-hr
Engine 3	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.48 g/hp-hr	2.0 g/hp-hr
	CO	2.30 g/hp-hr	3.5 g/hp-hr
Engine 4	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.49 g/hp-hr	2.0 g/hp-hr
	CO	2.17 g/hp-hr	3.5 g/hp-hr
Engine 5	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.50 g/hp-hr	2.0 g/hp-hr
	CO	2.22 g/hp-hr	3.5 g/hp-hr

1. Introduction

BT Environmental Consulting, Inc. (BTEC), a subsidiary of Montrose Air Quality Services (MAQS), was retained by General Motors (GM) to evaluate nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compound (VOC) emission rates from five engines at the GM facility located in Lake Orion, Michigan. The emissions test program was conducted on August 28-30, 2018. The purpose of this report is to document the results of the test program.

AQD has published a guidance document entitled "Format for Submittal of Source Emission Test Plans and Reports" (March 2018). The following is a summary of the emissions test program and results in the format suggested by the aforementioned document.

1.a Identification, Location, and Dates of Test

Sampling and analysis for the emission test program was conducted on August 28-30, 2018 at the GM facility located in Lake Orion, Michigan. The test program included evaluation of VOC, NOx, and CO emissions from Engines 1, 2, 3, 4, and 5.

1.b Purpose of Testing

AQD issued Renewable Operating Permit No. MI-ROP-B7227-2015b FGENGINES Section I. This permit limits emissions from each engine as summarized by Table 1.

Table 1
Emission Limitations
GM Orion

Facility	VOC Emission Limit	NOx Emission Limit	CO Emission Limit
GM Orion	1.0 g/hp-hr	2.0 g/hp-hr	3.5 g/hp-hr

1.c Source Description

Each engine generator is rated at 1600 kW electrical output (2242 hp). The total combined maximum electrical output will be 8000 kW or 8 MW. The maximum heat input capacity for each engine is approximately 15 MMBtu/hr. The heat capacity of landfill gas is estimated at 500 btu/scf.

GM's Orion Assembly Plant is located near two nonhazardous solid waste landfills and has access to the landfill gas. The engine generators are specifically designed to burn the landfill gas.

The combined exhaust from all five engine generators vents through the existing powerhouse stack located at the plant.

1.d Test Program Contacts

The contact for the source and test report is:

Mr. Robert Fenn
Environmental Engineer
General Motors LLC
Orion Assembly
4555 Giddings
Lake Orion, MI 48359
248 941 5353

Ms. Jessica Jeffery
Sr. Environmental Engineer
General Motors LLC
VEC East
30400 Van Dyke Ave.
Warren, MI 48093-2368
313 215 8203

Mr. Tom Caltrider
Sr. Environmental Engineer
General Motors LLC
VEC East
30400 Van Dyke Ave.
Warren, MI 48093-2368
248 255 7663

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

Table 2
Test Personnel

Name and Title	Affiliation	Telephone
Mr. Matt Young Client Project Manager	BTEC 4949 Fernlee Royal Oak, MI 48073	(586) 744-9133
Mr. Mason Sakshaug Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Ms. Regina Hines	MDEQ Air Quality Division	(313) 418-0895

RECEIVED
OCT 30 2018
AIR QUALITY DIVISION

2. Summary of Results

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

2.a Operating Data

The kilowatt output of each engine was monitored and recorded every =10 minutes for the duration of each test. The landfill gas usage was also recorded for the duration of the test.

2.b Applicable Permit

The applicable permit for this emissions test program is Renewable Operating Permit (ROP) No. MI-ROP-B7227-2015b.

2.c Results

The overall results of the emission test program are summarized by Table 3 (see Section 5.a). VOC emissions from each engine were below the limit of 1.0 g/hp-hr. NOx emissions from each engine were below the limit of 2.0 g/hp-hr. CO emissions from each engine were also below the limit of 3.5 g/hp-hr.

3. Source Description

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

3.a Process Description

See section 1.C.

3.b Process Flow Diagram

Due to the simplicity of the landfill gas engine, a process flow diagram is not necessary.

3.c Raw and Finished Materials

The engine generator burns landfill gas and generates electrical output.

3.d Process Capacity

Each engine generator is rated at 1600 kW electrical output (2242 hp). The total combined maximum electrical output will be 8000 kW or 8 MW. The maximum heat input capacity for each engine is approximately 15 MMBtu/hr. The heat capacity of landfill gas is estimated at 500 btu/scf.

3.e Process Instrumentation

The process was tested under normal operating conditions for time period in which the generators were operating. During the testing, the generators were run at 100% +/- 10% of maximum production as required by 40 CFR 60, Subpart JJJ.

4. Sampling and Analytical Procedures

Sections 4.a through 4.d provide a summary of the sampling and analytical procedures used.

4.a Sampling Train and Field Procedures

The NOx and CO content of the gas stream was measured using a Thermo Model 42i NOx gas analyzer and a TECO 48 CO gas analyzer. The exhaust gas O_2 and CO_2 content was also measured a Servomex 4100 O_2/CO_2 gas analyzer. The gas stream was drawn through a stainless-steel probe with a heated in-line filter to remove any particulate, a heated Teflon® sample line, through a refrigerated Teflon® sample conditioner to remove the moisture from the sample before it enters the analyzers. Data was recorded on a PC equipped with data acquisition software. Recorded NOx, CO, O_2 and CO_2 concentrations were averaged and reported for the duration of each 60-minute test (as drift corrected per Method 7E).

Volatile Organic compound (VOC) concentrations were measured according to 40 CFR 60, Appendix A, Method 25A. A sample of the gas stream was drawn through a stainless steel probe with an in-line 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 IOtech® data acquisition software. BTEC used a JUM Model 109A Methane/Non-Methane THC hydrocarbon analyzer to determine the VOC concentration.

The JUM Model 109A analyzer utilizes two flame ionization detectors (FIDs) in order to report the average ppmv for total hydrocarbons (THC), as propane, as well as the average ppmv for methane (as methane). Upon entry, the analyzer splits the gas stream. One FID ionizes all of the hydrocarbons in the gas stream sample into carbon, which is then detected as a concentration of total hydrocarbons. Using an analog signal, specifically voltage, the concentration of THC is then sent to the data acquisition system (DAS), where recordings are taken at 4-second intervals to produce an average based on the overall duration of the test. This average is then used to determine the average ppmv for THC reported as the calibration gas, propane, in equivalent units.

The second FID reports methane only. The sample enters a chamber containing a catalyst that destroys all of the hydrocarbons present in the gas stream other than methane. As with the THC sample, the methane gas concentration is sent to the DAS and recorded. The methane concentration, reported as methane, can then be converted to methane, reported as

propane, by dividing the measured methane concentration by the analyzer's response factor.

The analyzer's response factor is obtained by introducing a methane calibration gas to the calibrated J.U.M. 109A. The response of the analyzer's THC FID to the methane calibration gas, in ppmv as propane, is divided by the Methane analyzer's response to the methane calibration gas, in ppmv as methane.

For analyzer calibrations, calibration gases were mixed to desired concentrations using an Environics Series 4040 Computerized Gas Dilution System. The Series 4040 consists 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 State's 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.

Measurement of exhaust gas velocity, molecular weight, and moisture content was conducted using the following reference test methods codified at Title 40, Part 60, Appendix A of the Code of Federal Regulations (40 CFR 60, Appendix A):

- Method 1 - *"Location of the Sampling Site and Sampling Points"*
- Method 2 - *"Determination of Stack Gas Velocity and Volumetric Flowrate"*
- Method 4 - *"Determination of Moisture Content in Stack Gases"*

Stack gas velocity traverses were conducted in accordance with the procedures outlined in Method 1 and Method 2. S-type pitot tubes with thermocouple assemblies, calibrated in accordance with Method 2, Section 4.1.1, were used to measure exhaust gas velocity pressures (using a manometer) and temperatures during testing. The s-type pitot tube dimensions outlined in Sections 2-6 through 2-8 were within specified limits, therefore, a baseline pitot tube coefficient of 0.84 (dimensionless) was assigned.

Cyclonic flow checks were performed at the sampling location. The existence of cyclonic flow is determined by measuring the flow angle at each sample point. The flow angle is the angle between the direction of flow and the axis of the stack. If the average of the absolute values of the flow angles is greater than 20 degrees, cyclonic flow exists. The null angle was determined to be less than 10 degrees at each sampling point.

Exhaust gas moisture content was evaluated using Method 4. Exhaust gas was extracted as part of the moisture sampling and passed through (i) two impingers, each with 100 ml deionized water, (ii) an empty impinger, and (iii) an impinger filled with silica gel. Exhaust gas moisture content was then determined gravimetrically.

Sampling and Analysis Procedures

The emissions test program will utilize 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 Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)"
- Method 10 - "Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)"
- Method 25A - "Determination of Total Gaseous Organic Concentration Using A Flame Ionization Analyzer"
- Method 205 - "Verification of Gas Dilution Systems for Field Instrument Calibrations""

Each exhaust duct was traversed as required by 40 CFR 60, Subpart JJJJ.

4.b Recovery and Analytical Procedures

This test program did not include laboratory samples, consequently, sample recovery and analysis is not applicable to this test program.

4.c Sampling Ports

A diagram of the stack showing sampling ports in relation to upstream and downstream disturbances is included as Figure 4.

4.d Traverse Points

A diagram of the stack indicating traverse point locations and stack dimensions is included as Figure 4.

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 3. Detailed results for the emissions test program are summarized by Tables 4-8.

Table 3
Overall Emission Summary
Test Date: August 28-30, 2018

Source	Pollutant	Average Emission Rate	Emission Limit
Engine 1	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.47 g/hp-hr	2.0 g/hp-hr
	CO	2.26 g/hp-hr	3.5 g/hp-hr
Engine 2	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.42 g/hp-hr	2.0 g/hp-hr
	CO	2.14 g/hp-hr	3.5 g/hp-hr
Engine 3	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.48 g/hp-hr	2.0 g/hp-hr
	CO	2.30 g/hp-hr	3.5 g/hp-hr
Engine 4	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.49 g/hp-hr	2.0 g/hp-hr
	CO	2.17 g/hp-hr	3.5 g/hp-hr
Engine 5	VOC	0.0 g/hp-hr	1.0 g/hp-hr
	NOx	0.50 g/hp-hr	2.0 g/hp-hr
	CO	2.22 g/hp-hr	3.5 g/hp-hr

5.b Discussion of Results

The overall results of the emission test program are summarized by Table 3 (see Section 5.a). VOC emissions from each engine were below the limit of 1.0 g/hp-hr. NOx emissions from each engine were below the limit of 2.0 g/hp-hr. CO emissions from each engine were also below the limit of 3.5 g/hp-hr.

5.c Sampling Procedure Variations

There were no sampling variations used during the emission compliance test program.

5.d Process or Control Device Upsets

No upset conditions occurred during testing.

5.e Control Device Maintenance

There was no control equipment maintenance performed during the emissions test program.

5.f Re-Test

The emissions test program was not a re-test.

5.g Audit Sample Analyses

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

5.h Calibration Sheets

Relevant equipment calibration documents are provided in Appendix B.

5.i Sample Calculations

Sample calculations are provided in Appendix C.

5.j Field Data Sheets

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

5.k Laboratory Data

There are no laboratory results for this test program. Raw CEM and Production data is provided electronically in Appendix D.

BTEC Inc.

MEASUREMENT UNCERTAINTY STATEMENT

Both qualitative and quantitative factors contribute to field measurement uncertainty and should be taken into consideration when interpreting the results contained within this report. Whenever possible, Montrose Air Quality Services, LLC, (MAQS) personnel reduce the impact of these uncertainty factors through the use of approved and validated test methods. In addition, MAQS personnel perform routine instrument and equipment calibrations and ensure that the calibration standards, instruments, and equipment used during test events meet, at a minimum, test method specifications as well as the specifications of our Quality Manual and ASTM D 7036-04. The limitations of the various methods, instruments, equipment, and materials utilized during this test have been reasonably considered, but the ultimate impact of the cumulative uncertainty of this project is not fully identified within the results of this report.

Limitations

All testing performed was done in conformance to the ASTM D7036-04 standard. The information and opinions rendered in this report are exclusively for use by GM. BTEC will not distribute or publish this report without GM's consent except as required by law or court order. BTEC accepts responsibility for the competent performance of its duties in executing the assignment and preparing reports in accordance with the normal standards of the profession, but disclaims any responsibility for consequential damages.

This report was prepared by: _____
Matt Young
Client Project Manager

This report was reviewed by: _____
Brandon Chase
QA/QC Manager

Table 4
Engine 1
NOx, CO, and VOC Emission Rates
GM Orion
Lake Orion
BTEC Project No. 049AS-452593
Sampling Dates: 8/28/2018

KW	1593	1588	1589	
Parameter	**Run 1**	**Run 2**	**Run 3**	**Average**
Test Run Date	8/28/2018	8/28/2018	8/28/2018	
Test Run Time	9:00-10:00	10:25-11:25	11:50-12:50	
Outlet Flowrate (dscfm)	4,471	4,468	4,461	**4,467**
Outlet Flowrate (scfm)	5,151	5,078	5,134	**5,121**
bhp	2,232	2,225	2,227	
Oxygen Concentration (%)	8	8	8	**7.8**
Oxygen Concentration (%, drift corrected as per USEPA 7E)	7.6	7.5	7.6	**7.6**
Carbon Dioxide Concentration (%)	11.3	11.4	11.4	**11.4**
Carbon Dioxide Concentration (%, drift corrected as per USEPA 7E)	11.6	11.6	11.6	**11.6**
Outlet Oxides of Nitrogen Concentration (ppmv)	71.6	73.0	74.0	**72.9**
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	72.2	72.1	73.4	**72.6**
NOx Emission Rate (lb/hr)	**2.3**	**2.3**	**2.4**	**2.3**
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	**2.3**	**2.3**	**2.3**	**2.3**
Outlet Carbon Monoxide Concentration (ppmv)	558.1	563.2	567.4	**562.9**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	566.4	572.6	577.4	**572.1**
CO Emission Rate (lb/hr)	**10.8**	**10.9**	**11.0**	**10.9**
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**11.0**	**11.1**	**11.2**	**11.1**
Outlet VOC Concentration (ppmv as propane)	474.4	489.0	489.7	**484.3**
Outlet Methane Concentration (ppmv as methane)	1206.1	1424.1	1392.2	**1340.8**
Outlet VOC Concentration (ppmv, corrected as per USEPA 7E)	473.1	489.4	494.2	**485.6**
Outlet Methane Concentration (ppmv, corrected as per USEPA 7E)	1189.3	1392.5	1348.4	**1310.1**
Outlet VOC Concentration (ppmv propane, -Methane) *	0.0	0.0	0.0	**0.0**
Outlet VOC Concentration (ppmv propane, -Methane, corrected as per USEPA 7E) *	0.0	0.0	0.0	**0.0**
VOC Emission Rate as Propane (lb/hr) (-Methane) *	**0.0**	**0.0**	**0.0**	**0.0**
VOC Emission Rate as Propane(lb/hr) (-Methane) (corrected as per USEPA 7E) *	**0.0**	**0.0**	**0.0**	**0.0**
NOX (g/bhp-hr)	0.47	0.47	0.48	**0.47**
CO (g/bhp-hr)	2.24	2.27	2.28	**2.26**
VOC (g/bhp-hr) *	0.00	0.00	0.00	**0.00**

O_2 Correction			
Co	0.15	0.14	0.11
Cma	9.9	9.9	9.9
Cm	10.18	10.14	10.06

CO_2 Correction			
Co	0.11	0.11	0.13
Cma	9.95	9.95	9.95
Cm	9.75	9.77	9.81

NOx Correction			
Co	1.22	2.07	1.32
Cma	49.9	49.9	49.9
Cm	49.88	51.15	50.70

CO Correction			
Co	1.37	1.70	1.70
Cma	399.5	399.5	399.5
Cm	394.04	393.48	393.09

VOC Correction			
Co	1.19	1.89	1.82
Cma	750	750	750
Cm	751.42	748.33	742.20

Methane Correction			
Co	0.85	1.63	2.60
Cma	1295	1295	1295
Cm	1313.18	1324.50	1337.20

*; VOC concentrations are negative after methane subtraction is performed and have been replaced with zero for calculations.

scfm = 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
MW = molecular weight (CO = 28.01, NOx = 46.01, SO_2 = 64.05, C_3H_8 = 44.10, carbon = 12.01)
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 **2.3**
Response factor obtained from introducing propane into methane analyzer:

Co= Average of initial and final zero gases
Cma=Actual concentration of the calibration gas
Cm= Average of initial and final calibration gases
$C_c = KC_{meas}$
where Cc = Concentration as Carbon (ppmv), K= Carbon equivalent correction factor (3 for Propane)
and C_{meas} = concentration as measured (as propane)
[1]emission rate calculated on dry basis
[2]emission rate calculated on wet basis

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
$Conc_{@15\%-O2} = Conc * (20.9 - 15)/(20.9 - \%O_2)$

Table 5
Engine 2
NOx, CO, and VOC Emission Rates
GM Orion
Lake Orion
BTEC Project No. 049AS-452593
Sampling Dates: 8/28/2018

KW	1595	1595	1587	
Parameter	**Run 1**	**Run 2**	**Run 3**	**Average**
Test Run Date	8/28/2018	8/28/2018	8/28/2018	
Test Run Time	13:25-14:25	14:42-15:42	16:02-17:02	
Outlet Flowrate (dscfm)	4,346	4,403	4,421	**4,390**
Outlet Flowrate (scfm)	5,071	5,091	5,105	**5,089**
bhp	2,235	2,235	2,224	
Oxygen Concentration (%)	8	8	8	**7.7**
Oxygen Concentration (%, drift corrected as per USEPA 7E)	7.44	7.54	8.05	**7.7**
Carbon Dioxide Concentration (%)	11.5	11.6	11.1	**11.4**
Carbon Dioxide Concentration (%, drift corrected as per USEPA 7E)	11.71	11.68	11.15	**11.5**
Outlet Oxides of Nitrogen Concentration (ppmv)	67.1	66.8	63.6	**65.8**
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	66.7	67.5	65.7	**66.7**
NOx Emission Rate (lb/hr)	**2.1**	**2.1**	**2.0**	**2.1**
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	**2.1**	**2.1**	**2.1**	**2.1**
Outlet Carbon Monoxide Concentration (ppmv)	547.0	547.3	525.3	**539.9**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	557.7	558.5	535.3	**550.5**
CO Emission Rate (lb/hr)	**10.3**	**10.5**	**10.1**	**10.3**
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**10.5**	**10.7**	**10.3**	**10.5**
Outlet VOC Concentration (ppmv as propane)	490.0	482.5	460.7	**477.7**
Outlet Methane Concentration (ppmv as methane)	1340.3	1414.2	1390.7	**1381.8**
Outlet VOC Concentration (ppmv, corrected as per USEPA 7E)	494.5	489.5	473.2	**485.7**
Outlet Methane Concentration (ppmv, corrected as per USEPA 7E)	1324.2	1405.1	1373.2	**1367.5**
Outlet VOC Concentration (ppmv propane, -Methane) *	0.0	0.0	0.0	**0.0**
Outlet VOC Concentration (ppmv propane, -Methane, corrected as per USEPA 7E) *	0.0	0.0	0.0	**0.0**
VOC Emission Rate as Propane (lb/hr) (-Methane) *	**0.0**	**0.0**	**0.0**	**0.0**
VOC Emission Rate as Propane(lb/hr) (-Methane) (corrected as per USEPA 7E) *	**0.0**	**0.0**	**0.0**	**0.0**
NOX (g/bhp-hr)	0.42	0.43	0.42	**0.42**
CO (g/bhp-hr)	2.14	2.17	2.10	**2.14**
VOC (g/bhp-hr) *	0.00	0.00	0.00	**0.00**

O_2 Correction			
Co	0.08	0.04	0.00
Cma	9.9	9.9	9.9
Cm	10.02	9.90	9.72

CO_2 Correction			
Co	0.15	0.18	0.23
Cma	9.95	9.95	9.95
Cm	9.82	9.87	9.97

NOx Correction			
Co	1.10	1.29	0.81
Cma	49.9	49.9	49.9
Cm	50.44	49.72	48.47

CO Correction			
Co	1.56	1.70	1.83
Cma	399.5	399.5	399.5
Cm	392.25	392.02	392.50

VOC Correction			
Co	1.95	2.13	2.15
Cma	750	750	750
Cm	742.21	738.04	728.93

Methane Correction			
Co	1.70	0.31	0.05
Cma	1295	1295	1295
Cm	1310.76	1303.39	1311.50

*: VOC concentrations are negative after methane subtraction is performed and have been replaced with zero for calculations.

scfm = 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
MW = molecular weight (CO = 28.01, NOx = 46.01, SO_2 = 64.05, C_3H_8 = 44.10, carbon = 12.01)
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
Response factor obtained from introducing propane into methane analyzer: **2.3**

Co= Average of initial and final zero gases
Cma=Actual concentration of the calibration gas
Cm= Average of initial and final calibration gases
$C_c = KC_{prop}$
where Cc = Concentration as Carbon (ppmv), K= Carbon equivalent correction factor (3 for Propane)
and C_{prop} = concentration as measured (as propane)
[1]emission rate calculated on dry basis
[2]emission rate calculated on wet basis

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
$Conc_{@15\%O2} = Conc * (20.9 - 15)/(20.9 - \%O_2)$

Rev. 2.0
5/8/2012 BC

Table 6
Engine 3
NOx, CO, and VOC Emission Rates
GM Orion
Lake Orion
BTEC Project No. 049AS-452593
Sampling Dates: 8/29/2018

KW	1582	1584	1591	
Parameter	**Run 1**	**Run 2**	**Run 3**	**Average**
Test Run Date	8/29/2018	8/29/2018	8/29/2018	
Test Run Time	8:30-9:30	10:00-11:10	11:45-12:45	
Outlet Flowrate (dscfm)	4,355	4,357	4,333	**4,348**
Outlet Flowrate (scfm)	5,082	5,072	5,044	**5,066**
bhp	2,217	2,220	2,229	
Oxygen Concentration (%)	8	8	7	**7.5**
Oxygen Concentration (%, drift corrected as per USEPA 7E)	7.43	7.44	7.35	**7.4**
Carbon Dioxide Concentration (%)	12.1	12.1	12.2	**12.1**
Carbon Dioxide Concentration (%, drift corrected as per USEPA 7E)	11.75	11.70	11.87	**11.8**
Outlet Oxides of Nitrogen Concentration (ppmv)	76.2	75.5	74.4	**75.4**
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	76.3	76.6	76.5	**76.5**
NOx Emission Rate (lb/hr)	**2.4**	**2.3**	**2.3**	**2.3**
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	**2.4**	**2.4**	**2.4**	**2.4**
Outlet Carbon Monoxide Concentration (ppmv)	581.0	581.2	590.7	**584.3**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	592.4	592.5	602.9	**595.9**
CO Emission Rate (lb/hr)	**11.0**	**11.0**	**11.1**	**11.0**
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**11.2**	**11.2**	**11.4**	**11.3**
Outlet VOC Concentration (ppmv as propane)	468.1	464.4	465.9	**466.2**
Outlet Methane Concentration (ppmv as methane)	1202.9	1312.3	1353.8	**1289.7**
Outlet VOC Concentration (ppmv, corrected as per USEPA 7E)	470.1	469.5	476.5	**472.0**
Outlet Methane Concentration (ppmv, corrected as per USEPA 7E)	1195.7	1311.9	1347.3	**1285.0**
Outlet VOC Concentration (ppmv propane, -Methane) *	0.0	0.0	0.0	**0.0**
Outlet VOC Concentration (ppmv propane, -Methane, corrected as per USEPA 7E) *	0.0	0.0	0.0	**0.0**
VOC Emission Rate as Propane (lb/hr) (-Methane) *	**0.0**	**0.0**	**0.0**	**0.0**
VOC Emission Rate as Propane(lb/hr) (-Methane) (corrected as per USEPA 7E) *	**0.0**	**0.0**	**0.0**	**0.0**
NOX (g/bhp-hr)	0.49	0.49	0.48	**0.48**
CO (g/bhp-hr)	2.29	2.29	2.31	**2.30**
VOC (g/bhp-hr) *	0.00	0.00	0.00	**0.00**

O_2 Correction			
Co	0.12	0.09	0.06
Cma	9.9	9.9	9.9
Cm	10.08	10.02	9.94

CO_2 Correction			
Co	0.13	0.15	0.17
Cma	9.95	9.95	9.95
Cm	10.23	10.32	10.29

NOx Correction			
Co	0.82	1.04	0.49
Cma	49.9	49.9	49.9
Cm	50.11	49.53	48.71

CO Correction			
Co	1.47	1.30	1.51
Cma	399.5	399.5	399.5
Cm	392.25	392.26	391.92

VOC Correction			
Co	0.28	0.93	1.34
Cma	599	599	599
Cm	596.41	592.30	585.29

Methane Correction			
Co	1.76	2.36	3.92
Cma	995	995	995
Cm	1001.27	995.87	1000.81

*: VOC concentrations are negative after methane subtraction is performed and have been replaced with zero for calculations.

scfm = 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
MW = molecular weight (CO = 28.01, NOx = 46.01, SO_2 = 64.05, C_3H_8 = 44.10, carbon = 12.01)
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 **2.3**
Response factor obtained from introducing propane into methane analyzer.

Co= Average of initial and final zero gases
Cma=Actual concentration of the calibration gas
Cm= Average of initial and final calibration gases
C_c=KC_{meas}
where Cc = Concentration as Carbon (ppmv), K= Carbon equivalent correction factor (3 for Propane)
and C_{meas} = concentration as measured (as propane)
[1]emission rate calculated on dry basis
[2]emission rate calculated on wet basis

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
$Conc_{@15\%O2}$ = Conc * (20.9 -15)/(20.9 - $\%O_2$)

Table 7
Engine 4
NOx, CO, and VOC Emission Rates
GM Orion
Lake Orion
BTEC Project No. 049AS-452593
Sampling Dates: 8/29/2018

KW	1594	1598	1598	
Parameter	**Run 1**	**Run 2**	**Run 3**	**Average**
Test Run Date	8/29/2018	8/29/2018	8/29/2018	
Test Run Time	13:20-14:20	14:40-15:40	16:03-17:03	
Outlet Flowrate (dscfm)	4,372	4,389	4,478	**4,413**
Outlet Flowrate (scfm)	5,078	5,079	5,072	**5,076**
bhp	2,234	2,239	2,239	
Oxygen Concentration (%)	7	7	8	**7.5**
Oxygen Concentration (%, drift corrected as per USEPA 7E)	7.33	7.42	8.00	**7.6**
Carbon Dioxide Concentration (%)	12.3	12.3	11.8	**12.1**
Carbon Dioxide Concentration (%, drift corrected as per USEPA 7E)	11.93	11.86	11.39	**11.7**
Outlet Oxides of Nitrogen Concentration (ppmv)	74.1	74.4	69.5	**72.6**
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	77.1	78.8	74.9	**76.9**
NOx Emission Rate (lb/hr)	**2.3**	**2.3**	**2.2**	**2.3**
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	**2.4**	**2.5**	**2.4**	**2.4**
Outlet Carbon Monoxide Concentration (ppmv)	554.3	552.8	523.8	**543.6**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	566.1	566.4	540.1	**557.5**
CO Emission Rate (lb/hr)	**10.5**	**10.5**	**10.2**	**10.4**
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**10.8**	**10.8**	**10.5**	**10.7**
Outlet VOC Concentration (ppmv as propane)	488.0	482.5	476.7	**482.4**
Outlet Methane Concentration (ppmv as methane)	1430.5	1446.2	1398.6	**1425.1**
Outlet VOC Concentration (ppmv, corrected as per USEPA 7E)	514.5	514.1	499.7	**509.4**
Outlet Methane Concentration (ppmv, corrected as per USEPA 7E)	1422.8	1442.1	1406.1	**1423.7**
Outlet VOC Concentration (ppmv propane, -Methane) *	0.0	0.0	0.0	**0.0**
Outlet VOC Concentration (ppmv propane, -Methane, corrected as per USEPA 7E) *	0.0	0.0	0.0	**0.0**
VOC Emission Rate as Propane (lb/hr) (-Methane) *	**0.0**	**0.0**	**0.0**	**0.0**
VOC Emission Rate as Propane(lb/hr) (-Methane) (corrected as per USEPA 7E) *	**0.0**	**0.0**	**0.0**	**0.0**
NOX (g/bhp-hr)	0.49	0.50	0.49	**0.49**
CO (g/bhp-hr)	2.18	2.19	2.13	**2.17**
VOC (g/bhp-hr) *	0.00	0.00	0.00	**0.00**

O_2 Correction			
Co	0.02	0.01	0.01
Cma	9.9	9.9	9.9
Cm	9.86	9.75	9.65

CO_2 Correction			
Co	0.20	0.22	0.23
Cma	9.95	9.95	9.95
Cm	10.31	10.36	10.30

NOx Correction			
Co	1.00	1.55	0.98
Cma	49.9	49.9	49.9
Cm	48.32	47.71	46.61

CO Correction			
Co	2.69	2.53	2.03
Cma	399.5	399.5	399.5
Cm	391.93	390.66	387.98

VOC Correction			
Co	1.85	1.96	2.11
Cma	599	599	599
Cm	567.75	561.89	571.02

Methane Correction			
Co	4.88	3.78	4.14
Cma	995	995	995
Cm	1001.83	999.01	990.88

*: VOC concentrations are negative after methane subtraction is performed and have been replaced with zero for calculations.

scfm = 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
MW = molecular weight (CO = 28.01, NOx = 46.01, SO_2 = 64.05, C_3H_8 = 44.10, carbon = 12.011)
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 **2.3**
Response factor obtained from introducing propane into methane analyzer:

Co= Average of initial and final zero gases
Cma=Actual concentration of the calibration gas
Cm= Average of initial and final calibration gases
C_c=KC_{meas}
where Cc = Concentration as Carbon (ppmv), K= Carbon equivalent correction factor (3 for Propane)
and C_{meas} = concentration as measured (as propane)
[1]emission rate calculated on dry basis
[2]emission rate calculated on wet basis

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
$Conc_{@15\%O2}$ = Conc * (20.9 -15)/(20.9 - $\%O_2$)

Rev. 2.0
5/8/2012 BC

Table 8
Engine 5
NOx, CO, and VOC Emission Rates
GM Orion
Lake Orion
BTEC Project No. 049AS-452593
Sampling Dates: 8/30/2018

KW	1602	1594	1589	
Parameter	**Run 1**	**Run 2**	**Run 3**	**Average**
Test Run Date	8/30/2018	8/30/2018	8/30/2018	
Test Run Time	7:45-8:45	9:05-10:05	10:25-11:25	
Outlet Flowrate (dscfm)	4,420	4,440	4,473	**4,444**
Outlet Flowrate (scfm)	5,127	5,127	5,129	**5,128**
bhp	2,245	2,234	2,227	
Oxygen Concentration (%)	8	8	8	**7.6**
Oxygen Concentration (%, drift corrected as per USEPA 7E)	7.57	7.52	7.52	**7.5**
Carbon Dioxide Concentration (%)	12.0	12.0	12.0	**12.0**
Carbon Dioxide Concentration (%, drift corrected as per USEPA 7E)	11.66	11.65	11.64	**11.7**
Outlet Oxides of Nitrogen Concentration (ppmv)	74.8	75.9	76.5	**75.7**
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	76.4	78.1	79.2	**77.9**
NOx Emission Rate (lb/hr)	**2.4**	**2.4**	**2.4**	**2.4**
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	**2.4**	**2.5**	**2.5**	**2.5**
Outlet Carbon Monoxide Concentration (ppmv)	573.9	576.8	577.0	**575.9**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	562.2	566.8	567.3	**565.4**
CO Emission Rate (lb/hr)	**11.0**	**11.1**	**11.2**	**11.1**
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**10.8**	**10.9**	**11.0**	**10.9**
Outlet VOC Concentration (ppmv as propane)	455.0	504.0	492.6	**483.9**
Outlet Methane Concentration (ppmv as methane)	1223.0	1289.5	1303.2	**1271.9**
Outlet VOC Concentration (ppmv, corrected as per USEPA 7E)	463.2	501.9	489.7	**484.9**
Outlet Methane Concentration (ppmv, corrected as per USEPA 7E)	1233.8	1336.1	1350.3	**1306.7**
Outlet VOC Concentration (ppmv propane, -Methane) *	0.0	0.0	0.0	**0.0**
Outlet VOC Concentration (ppmv propane, -Methane, corrected as per USEPA 7E) *	0.0	0.0	0.0	**0.0**
VOC Emission Rate as Propane (lb/hr) (-Methane) *	**0.0**	**0.0**	**0.0**	**0.0**
VOC Emission Rate as Propane(lb/hr) (-Methane) (corrected as per USEPA 7E) *	**0.0**	**0.0**	**0.0**	**0.0**
NOX (g/bhp-hr)	0.49	0.50	0.51	**0.50**
CO (g/bhp-hr)	2.18	2.22	2.25	**2.22**
VOC (g/bhp-hr) *	0.00	0.00	0.00	**0.00**

O_2 Correction			
Co	0.07	0.05	0.05
Cma	9.9	9.9	9.9
Cm	10.02	10.02	9.97

CO_2 Correction			
Co	0.10	0.11	0.13
Cma	9.95	9.95	9.95
Cm	10.23	10.28	10.31

NOx Correction			
Co	1.29	1.41	0.87
Cma	49.9	49.9	49.9
Cm	49.26	49.00	48.52

CO Correction			
Co	1.85	1.93	1.06
Cma	399.5	399.5	399.5
Cm	408.31	407.16	406.63

VOC Correction			
Co	0.82	1.32	1.27
Cma	599	599	599
Cm	588.15	601.24	602.24

Methane Correction			
Co	2.53	2.60	2.11
Cma	995	995	995
Cm	986.76	960.96	960.85

*: VOC concentrations are negative after methane subtraction is performed and have been replaced with zero for calculations.

scfm = 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
MW = molecular weight (CO = 28.01, NOx = 46.01, SO_2 = 64.05, C_3H_8 = 44.10, carbon = 12.01)
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
Response factor obtained from introducing propane into methane analyzer: 2.35

Co= Average of initial and final zero gases
Cma=Actual concentration of the calibration gas
Cm= Average of initial and final calibration gases
$C_c = KC_{mea}$
where Cc = Concentration as Carbon (ppmv), K= Carbon equivalent correction factor (3 for Propane)
and C_{mea} = concentration as measured (as propane)
[1]emission rate calculated on dry basis
[2]emission rate calculated on wet basis

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
$Conc_{@15\%O2}$ = Conc * (20.9 -15)/(20.9 - $\%O_2$)

BTEC Inc.

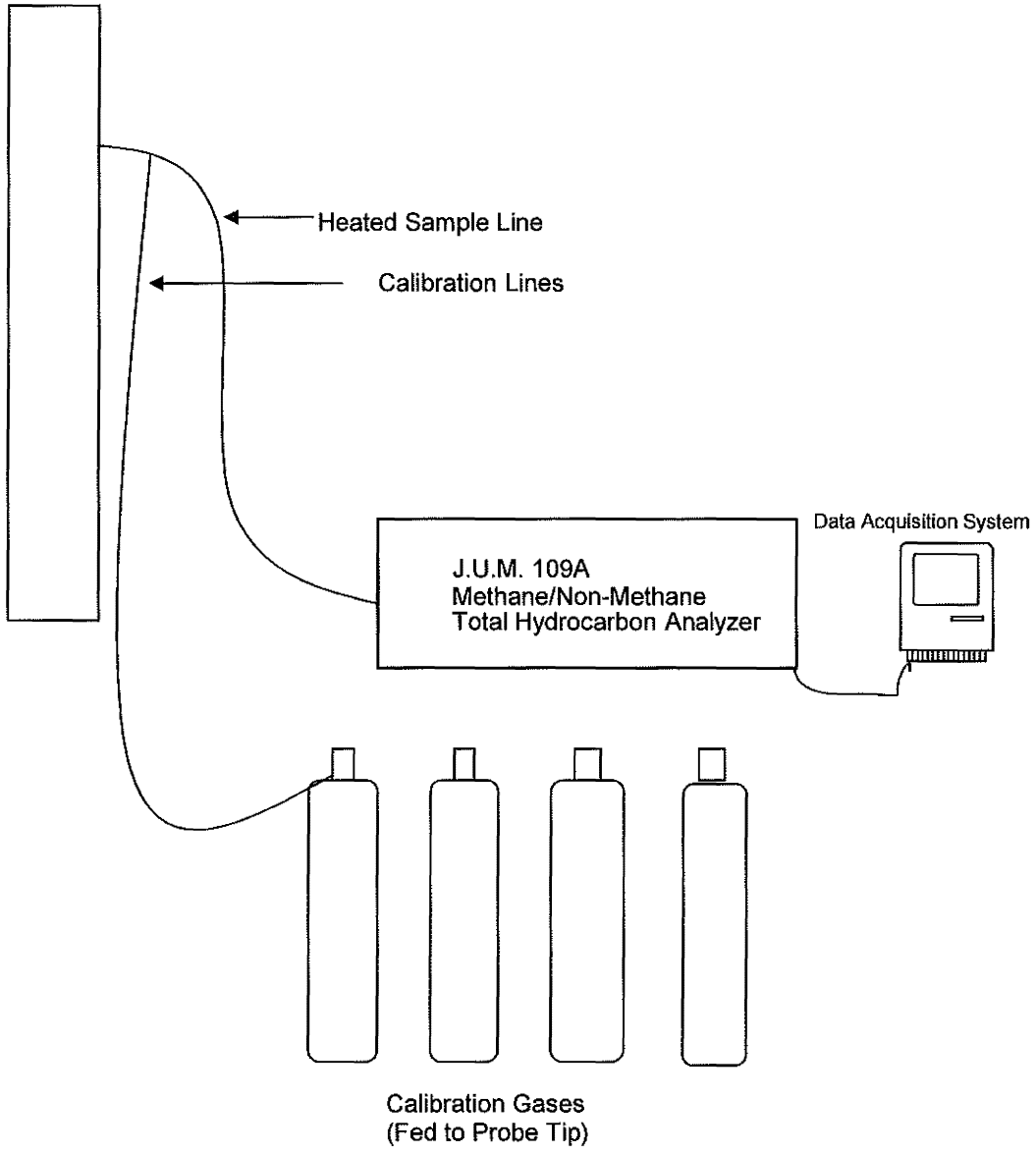


Figure 2

Site:	Sampling Dates:	
USEPA Method 25A General Motors LLC Lake Orion, Michigan	August 28-30, 2018	BT Environmental Consulting, Inc. 4949 Fernlee Avenue Royal Oak, Michigan 48073

BTEC Inc.

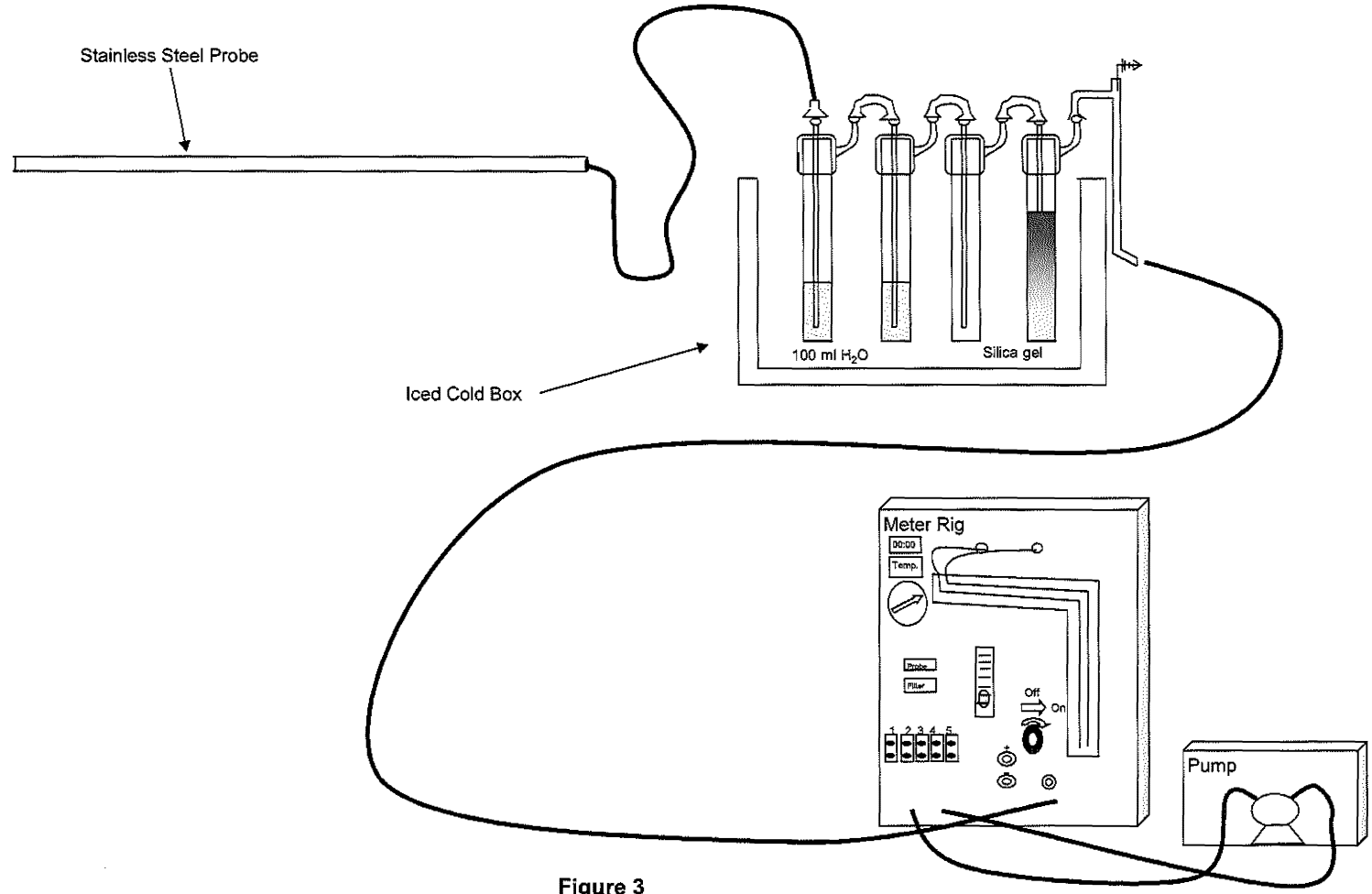


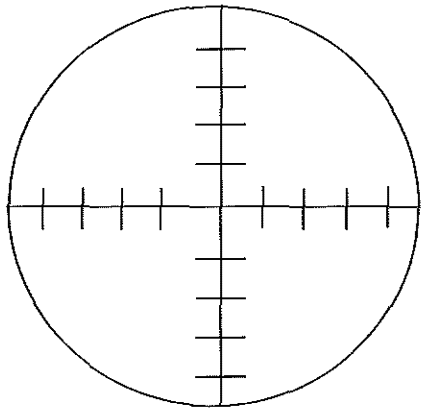
Figure 3

Site:	Sampling Dates:	
USEPA Method 4 General Motors LLC Lake Orion, Michigan	August 28-30, 2018	BT Environmental Consulting, Inc. 4949 Fernlee Avenue Royal Oak, Michigan 48073

BTEC Inc.

diameter = 15.5"

Points	Distance "
1	0.5
2	1.6
3	2.9
4	4.8
5	10.2
6	12.1
7	13.4
8	14.5



Not to Scale

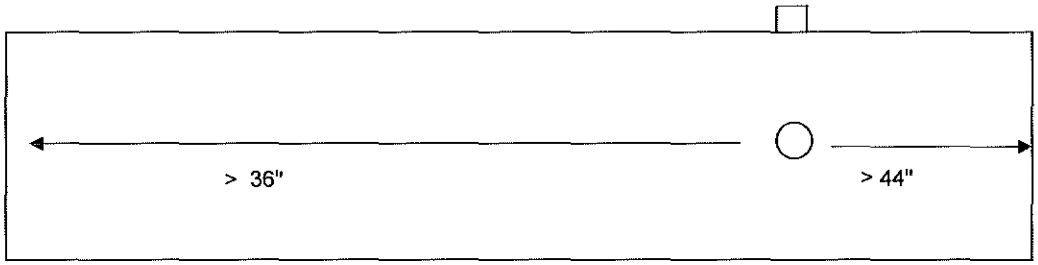


Figure No. 4

Site: **Engines 1, 2, 3, 4, and 5** **GM Orion** **Lake Orion, Michigan**	**Sampling Date:** **August 28-30, 2018**	**BT Environmental Consulting, Inc.** **4949 Fernlee** **Royal Oak, Michigan**