BTEC Inc.

Carbon Monoxide Destruction Efficiency Test Report

Prepared for:

General Motors LLC

Pontiac, Michigan

GM Global Propulsion Systems
895 Joslyn Road
Pontiac, Michigan 48340
Test Dates: May 16-17, 2017

Project No. 17-5010.00
June 21, 2017

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

EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by General Motors LLC (GM) to conduct a compliance carbon monoxide (CO) destruction efficiency (DE) test program of the four (4) Regenerative Thermal Oxidizers (RTOs) at the GM facility in Pontiac, Michigan. The test program was conducted on May 16 and 17, 2017.

Table I summarizes the overall results of the emissions test program.

Table I
Overall Emissions Test Results Summary

Source	CO Destruction Efficiency
RTO 1	99.0%
RTO 2	98.6%
RTO 3	98.1%
RTO 4	98.2%

1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by General Motors LLC (GM) to conduct a compliance carbon monoxide (CO) destruction efficiency (DE) test program of four (4) Regenerative Thermal Oxidizers at the GM facility in Pontiac, Michigan. The test program was conducted on May 16 and 17, 2017. Capture efficiency was tested at an earlier date and those results will be submitted under separate cover.

This report presents the results of the DE test program. The Air Quality Division (AQD) of Michigan's Department of Environmental Quality has published a guidance document entitled "Format for Submittal of Source Emission Test Plans and Reports" (December 2013). The following is a summary of the emissions report in the format suggested by the AQD test report format guide.

1.a Identification, Location, and Dates of Test

RTOs 1 through 4 were evaluated for CO DE using Methods 1, 2, 3, 4, and 10 codified at Title 40, Part 60, Appendix A, of the Code of Federal Regulations (40 CFR 60, Appendix A). The RTOs are located at the General Motors Global Propulsion Systems facility in Pontiac, Michigan. The emission testing was conducted on May 16 and 17, 2017.

1.b Purpose of Testing

The objective of the emissions test program was to evaluate the CO DE of each of the four RTOs.

1.c Source Description

The General Motors Global Propulsion Systems engine test cell facility was built, in part, to test internal combustion engines for research and development purposes using a wide variety of fuels and test protocols, many mandated by the U.S. EPA. The engines at the facility are fueled by unleaded gasoline, leaded gasoline, diesel, and other fuels. A complete list of all fuels is included in Appendix D. A variety of test cycles are used depending on the test program and type of engine.

Exhaust gases from the test cells are diverted to a main exhaust header which leads to the inlet of the RTOs. RTOs 1 and 2 share one common inlet feed, and RTOs 3 and 4 similarly share common ductwork. Each RTO has an individual exhaust stack.

1.d Test Program Contact

The contacts for information regarding the test program as well as the test report are as follows:

Ms. Lisa Parks
Staff Environmental Engineer
General Motors LLC
Global Environmental Compliance and Sustainability Group
30200 Mound Road
Mail Code: 480-111-1N
Warren, Michigan 48092-2029
(248) 410-2591

Mr. Tom Caltrider
Staff Environmental Engineer
General Motors LLC
Global Environmental Compliance and Sustainability Group
30400 Mound Road
WTC Mfg. B Bldg.
Mail Code: 480-109-MB1
Warren, Michigan 48092-2029
(248) 255-7663

Ms. Bethany Gunnels
Environmental Engineer
General Motors LLC
Pontiac Global Propulsion Systems
850 Glenwood
Mail Code: 483-710-106
Pontiac, Michigan 48340
(248) 520-2396

Mr. Michael Richards
General Motors LLC
Manager – Global Laboratory Systems
850 Glenwood Ave
Mail Code: 483-710-106
Pontiac, Michigan 48340
(586) 709-2737

Mr. Matt Young
Senior Project Manager
BT Environmental Consulting, Inc.
4949 Fernlee Avenue
Royal Oak, MI 48073
(586) 744-9133

1.e Test Personnel

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

Table 1
Test Personnel

Name and Title	Affiliation	Telephone
Ms. Lisa Parks Staff Environmental Engineer	General Motors LLC Global Environmental Compliance and Sustainability Group 30200 Mound Road Warren, Michigan 48090	(248) 410-2591
Ms. Bethany Gunnels Environmental Engineer	General Motors LLC Pontiac Global Propulsion Systems 850 Glenwood Mail Code: 483-710-106 Pontiac, Michigan 48340	(248) 520-2396
Mr. Tom Caltrider Staff Environmental Engineer	General Motors LLC Global Environmental Compliance and Sustainability Group 30200 Mound Road Warren, Michigan 48090	(248) 255-7663
Mr. Michael Richards Manager – Global Laboratory Systems	General Motors LLC Pontiac Global Propulsion Systems 850 Glenwood Mail Code: 483-710-106 Pontiac, Michigan 48340	
Mr. Matt Young Senior Project Manager	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(586) 744-9133
Mr. Mike Nummer Environmental Technician	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070

Mr. Jake Zott Environmental Technician	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070
Mr. Tom Maza	MDEQ Air Quality Division	(313) 456-4709
Mr. Sam Liveson	MDEQ Air Quality Division	(586) 753-3749

2. Summary of Results

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

2.a Operating Data

Operating data is included in Appendix D.

2.b Applicable Permit

The applicable permit is AQD Permit No. MI-ROP-B4032-2014d.

2.c Results

The overall results of the test program are summarized by Table 2. Detailed test results are included as Tables 3 through 6.

Table 2
Overall Emissions Test Results Summary

Source	CO Destruction Efficiency
RTO 1	99.0%
RTO 2	98.6%
RTO 3	98.1%
RTO 4	98.2%

3. Source Description

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

3.a Process Description

The General Motors engine test cell facility was built, in part, to test internal combustion engines for research and development purposes using a wide variety of fuels and test

protocols. Unleaded gasoline, leaded gasoline, diesel, and other fuels are used in the engine test facilities. A complete list of all fuels is included in Appendix D. A variety of test cycles are used depending on the test program and type of engine.

Exhaust gases from the test cells are diverted to a main exhaust header which leads to the inlet of the RTOs. RTOs 1 and 2 share one common inlet feed and RTOs 3 and 4 similarly share common ductwork Each RTO has individual exhaust stacks.

3.b Process Flow Diagram

Due to the simplicity of the engine dynamometer process flow, a process flow diagram is not provided.

3.c Raw and Finished Materials

There are no "raw materials" in this process. Engine fuel flow usage data is included in Appendix D.

3.d Process Capacity

Test cells in Wings 1 & 2 (FG-TESTCELLS) have an equivalent fuel consumption limited to 7,280 MMBtu per calendar day, and 520,000 MMBtu per 12-month rolling time period as determined at the end of each calendar month. Test cells in Wing 3 (FG-3RDWING&DTCS) have a combined spark-ignited fuel consumption limited to 23,312 MMBtu per 12-month rolling time period as determined at the end of each calendar month. MMbtu is used as a surrogate for fuel consumption.

Each RTO is rated at 27,000 scfm and is designed to destroy VOC at greater than 96% destruction efficiency as calculated by mass.

3.e Process Instrumentation

Engine operating data is included in Appendix D.

4. Sampling and Analytical Procedures

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

4.a Sampling Train and Field Procedures

Measurement of exhaust gas velocity, molecular weight, and moisture content was conducted using the following reference test methods codified at 40 CFR 60, Appendix A:

- Method 1 - "Sample and Velocity Traverses for Stationary Sources"
- Method 2 - "Determination of Stack Gas Velocity and Volumetric Flow Rate"

- Method 3 - "Determination of Molecular Weight of Dry Stack Gas"(Fyrite)
- Method 4 - "Determination of Moisture Content in Stack Gases"
- Method 10 - "Determination of Carbon Monoxide Emissions from Stationary Sources"

Stack gas velocity traverses were conducted in accordance with the procedures outlined in Methods 1 and 2. An S-type pitot tube with a thermocouple assembly, calibrated in accordance with Method 2, Section 4.1.1, was used to measure exhaust gas velocity pressures (using a manometer) and temperatures at each traverse location. The S-type pitot tube dimensions were within specified limits, therefore, a baseline pitot tube coefficient of 0.84 (dimensionless) was assigned.

A cyclonic flow check was performed at each 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. Both sampling locations, on each TO, were evaluated for cyclonic flow and deemed acceptable for flow rate measurement.

Exhaust gas molecular weight was determined according to Method 3. The equipment used for the Method 3 evaluation consisted of a one-way squeeze bulb with connecting tubing and a set of Fyrite® combustion gas analyzers. CO_2 and O_2 content was analyzed using the Fyrite® procedure.

Exhaust gas was extracted as part of the moisture sampling train. Exhaust gas moisture content was determined gravimetrically.

The CO content of the gas stream was measured using a TECO 48 CO gas analyzers. 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 a Universal Analyzers 3080PV electronic sample conditioner was used to remove the moisture from the sample before it entered the analyzer. Data was recorded at 4-second intervals on a PC equipped with a data acquisition system.

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.

4.b Recovery and Analytical Procedures

Recovery and analytical procedures are described in the previous section.

4.c Sampling Ports

Sampling port locations met the minimum criteria of Method 1.

4.d Traverse Points

Exhaust duct traverse point locations are summarized by Figures 1 and 2.

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 2. Detailed results are summarized by Tables 3 through 6.

5.b Discussion of Results

The emissions test program was conducted for the purpose of evaluating CO DE.

5.c Sampling Procedure Variations

The inlet sampling location on RTO 1 and RTO 2 was not suitable for flow rate measurements, and therefore only concentration measurements were performed at those locations. BTEC assumed that the ratio of inlet to outlet flow rates for RTO 1 and RTO 2 is the same as for RTO 3 and RTO 4. The average ratio was 87.24%. The RTO 1 and RTO 2 inlet flow rates were calculated using this assumption.

5.d Process or Control Device Upsets

No upset conditions occurred during testing.

5.e Control Device Maintenance

Each RTO undergoes monthly and quarterly preventative maintenance tasks which include inspection of poppet valve seals and cylinders, insulation, burner and combustion blower system, thermocouple checks, hydraulic system, etc. Some parts may require lubrication. System temperature and pressures are observed.

5.f Re-Test Changes

The test program was not a Re-Test.

5.g Audit Sample Analyses

Audit samples were not relevant for this emissions test program.

5.h Calibration Sheets

Calibration sheets are included in Appendix B.

5.i Sample Calculations

Sample calculations are provided as Appendix C.

5.j Field Data Sheets

Copies of field data sheets and relevant field notes are provided in Appendix A.

5.k Laboratory Data

There are no laboratory results for this test program.

Table 3
RTO 1 CO Destruction Efficiency Results Summary
General Motors Pontiac
Pontiac, Michigan
BTEC Project No. 17-5010.00
Sampling Dates: May 17, 2017

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	5/17/2017	5/17/2017	5/17/2017	
Test Run Time	13:10	14:30	15:50	
Inlet Flowrate (dscfm)	15,279	15,251	16,416	**15,649**
Outlet Flowrate (dscfm)	17,514	17,481	18,816	**17,937**
Inlet Carbon Monoxide Concentration (ppmv)	2,120.79	1,058.92	2,202.44	**1,794.05**
Inlet CO Concentration (ppmv, corrected as per USEPA 7E)	2,333.81	1,173.30	2,448.09	**1,985.07**
CO Inlet Emission Rate (lb/hr)	**140.85**	**70.20**	**157.15**	**122.73**
CO Inlet Emission Rate (lb/hr) (corrected as per USEPA 7E)	**155.00**	**77.78**	**174.68**	**135.82**
Outlet Carbon Monoxide Concentration (ppmv)	16.07	7.31	16.54	**13.31**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	20.42	11.66	20.66	**17.58**
CO Outlet Emission Rate (lb/hr)	**1.22**	**0.56**	**1.35**	**1.04**
CO Outlet Emission Rate (lb/hr) (corrected as per USEPA 7E)	**1.55**	**0.89**	**1.69**	**1.38**
CO Destruction Efficiency (%) (corrected as per USEPA 7E)	**99.0%**	**98.9%**	**99.0%**	**99.0%**

*Inlet Flows calculated as 87.24% of the Outlet. Ratio obtained from testing RTO 3 and 4.

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)
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

Equations
lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453,600 * ***dcfm*** * 60
DE = (mass in - mass out) / mass in

Table 4
RTO 2 CO Destruction Efficiency Results Summary
General Motors Pontiac
Pontiac, Michigan
BTEC Project No. 17-5010.00
Sampling Dates: May 17, 2017

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	5/17/2017	5/17/2017	5/17/2017	
Test Run Time	9:05	10:30	11:50	
Inlet Flowrate (dscfm)	15,149	15,287	15,398	**15,278**
Outlet Flowrate (dscfm)	17,364	17,523	17,650	**17,513**
Inlet Carbon Monoxide Concentration (ppmv)	1,689.39	1,927.40	1,845.71	**1,820.83**
Inlet CO Concentration (ppmv, corrected as per USEPA 7E)	1,776.79	2,026.97	1,923.00	**1,908.92**
CO Inlet Emission Rate (lb/hr)	**111.24**	**128.07**	**123.54**	**120.95**
CO Inlet Emission Rate (lb/hr) (corrected as per USEPA 7E)	**117.00**	**134.69**	**128.71**	**126.80**
Outlet Carbon Monoxide Concentration (ppmv)	14.28	20.15	20.98	**18.47**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	18.99	24.84	25.45	**23.09**
CO Outlet Emission Rate (lb/hr)	**1.08**	**1.53**	**1.61**	**1.41**
CO Outlet Emission Rate (lb/hr) (corrected as per USEPA 7E)	**1.43**	**1.89**	**1.95**	**1.76**
CO Destruction Efficiency (%) (corrected as per USEPA 7E)	**98.8%**	**98.6%**	**98.5%**	**98.6%**

*Inlet Flows calculated as 87.24% of the Outlet. Ratio obtained from testing RTO 3 and 4.

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)
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

Equations
lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453,600 * ***dcfm*** * 60
DE = (mass in - mass out) / mass in

Table 5
RTO 3 CO Destruction Efficiency Results Summary
General Motors Pontiac
Pontiac, Michigan
BTEC Project No. 17-5010.00
Sampling Dates: May 16, 2017

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	5/16/2017	5/16/2017	5/16/2017	
Test Run Time	15:30	16:50	18:10	
Inlet Flowrate (dscfm)	15,840	15,650	14,554	**15,348**
Outlet Flowrate (dscfm)	17,744	18,422	17,445	**17,870**
Inlet Carbon Monoxide Concentration (ppmv)	793.27	1,140.88	708.12	**880.76**
Inlet CO Concentration (ppmv, corrected as per USEPA 7E)	879.79	1,269.47	791.95	**980.40**
CO Inlet Emission Rate (lb/hr)	**54.62**	**77.61**	**44.80**	**59.01**
CO Inlet Emission Rate (lb/hr) (corrected as per USEPA 7E)	**60.57**	**86.36**	**50.10**	**65.68**
Outlet Carbon Monoxide Concentration (ppmv)	11.48	17.51	11.25	**13.41**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	13.99	19.76	13.58	**15.78**
CO Outlet Emission Rate (lb/hr)	**0.89**	**1.40**	**0.85**	**1.05**
CO Outlet Emission Rate (lb/hr) (corrected as per USEPA 7E)	**1.08**	**1.58**	**1.03**	**1.23**
CO Destruction Efficiency (%) (corrected as per USEPA 7E)	**98.2%**	**98.2%**	**97.9%**	**98.1%**

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)
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

Equations
lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453,600 * ***dcfm*** * 60
DE = (mass in - mass out) / mass in

Table 6
RTO 4 CO Destruction Efficiency Results Summary
General Motors Pontiac
Pontiac, Michigan
BTEC Project No. 17-5010.00
Sampling Dates: May 16, 2017

Parameter	Run 2	Run 3	Run 4	Average
Test Run Date	5/16/2017	5/16/2017	5/16/2017	
Test Run Time	11:20	12:45	14:05	
Inlet Flowrate (dscfm)	16,083	15,587	15,598	**15,756**
Outlet Flowrate (dscfm)	17,862	17,953	17,537	**17,784**
Inlet Carbon Monoxide Concentration (ppmv)	1,488.94	1,157.93	1,097.97	**1,248.28**
Inlet CO Concentration (ppmv, corrected as per USEPA 7E)	1,610.40	1,269.69	1,213.73	**1,364.61**
CO Inlet Emission Rate (lb/hr)	**104.09**	**78.45**	**74.44**	**85.66**
CO Inlet Emission Rate (lb/hr) (corrected as per USEPA 7E)	**112.58**	**86.02**	**82.29**	**93.63**
Outlet Carbon Monoxide Concentration (ppmv)	27.62	22.57	22.55	**24.25**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	24.16	19.37	21.16	**21.56**
CO Outlet Emission Rate (lb/hr)	**2.14**	**1.76**	**1.72**	**1.87**
CO Outlet Emission Rate (lb/hr) (corrected as per USEPA 7E)	**1.88**	**1.51**	**1.61**	**1.67**
CO Destruction Efficiency (%) (corrected as per USEPA 7E)	**98.3%**	**98.2%**	**98.0%**	**98.2%**

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)
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

Equations
lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453,600 * ***dcfm*** * 60
DE = (mass in - mass out) / mass in

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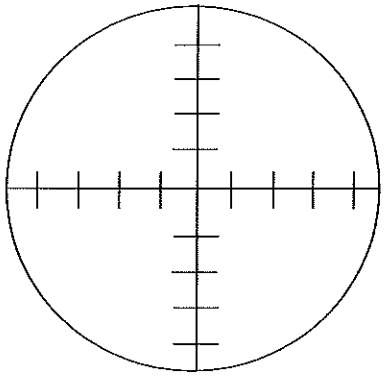
diameter = 31 inches

Points	Distance "
1	1.0
2	3.3
3	6.0
4	10.0
5	21.0
6	25.0
7	27.7
8	30.0



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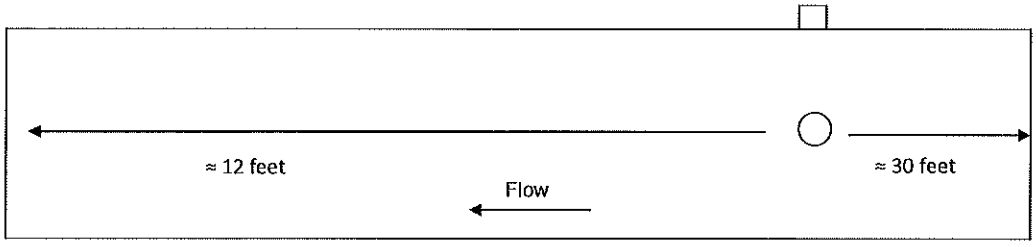


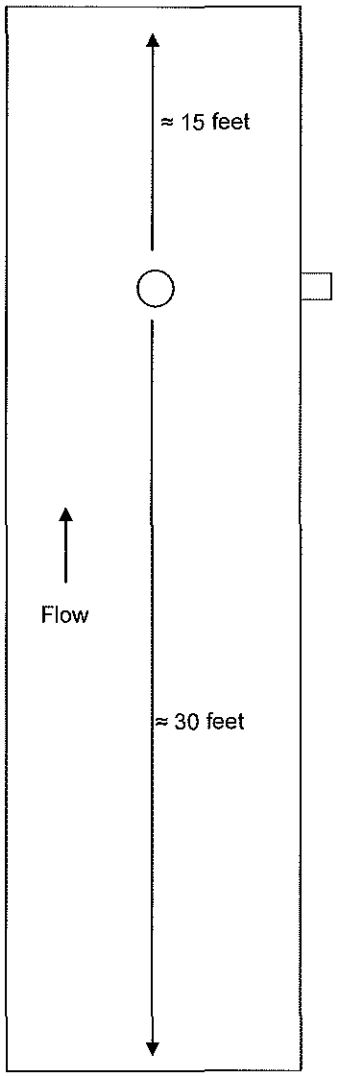
All RTOs are identical in dimensions.

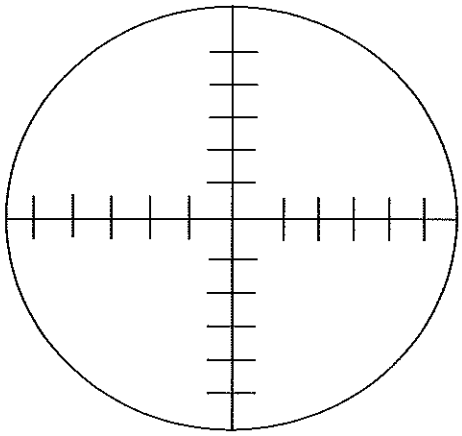
Figure No. 1

Site: **RTO 3,4 Inlet** **GM Pontiac Powertrain** **Pontiac, Michigan**	**Sampling Date:** **May 16-17, 2017**	**BT Environmental Consulting, Inc.** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**

BTEC Inc.

diameter = 43.5 inches





Not to Scale

Points	Distance "
1	1.1
2	3.6
3	6.4
4	9.8
5	14.9
6	28.6
7	33.7
8	37.1
9	39.9
10	42.4

All RTOs are identical in dimensions.

Figure No. 2

Site: **RTO 1,2,3,4 Exhaust** **GM Pontiac Powertrain** **Pontiac, Michigan**	**Sampling Date:** **May 16-17, 2017**

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Royal Oak, Michigan 48073

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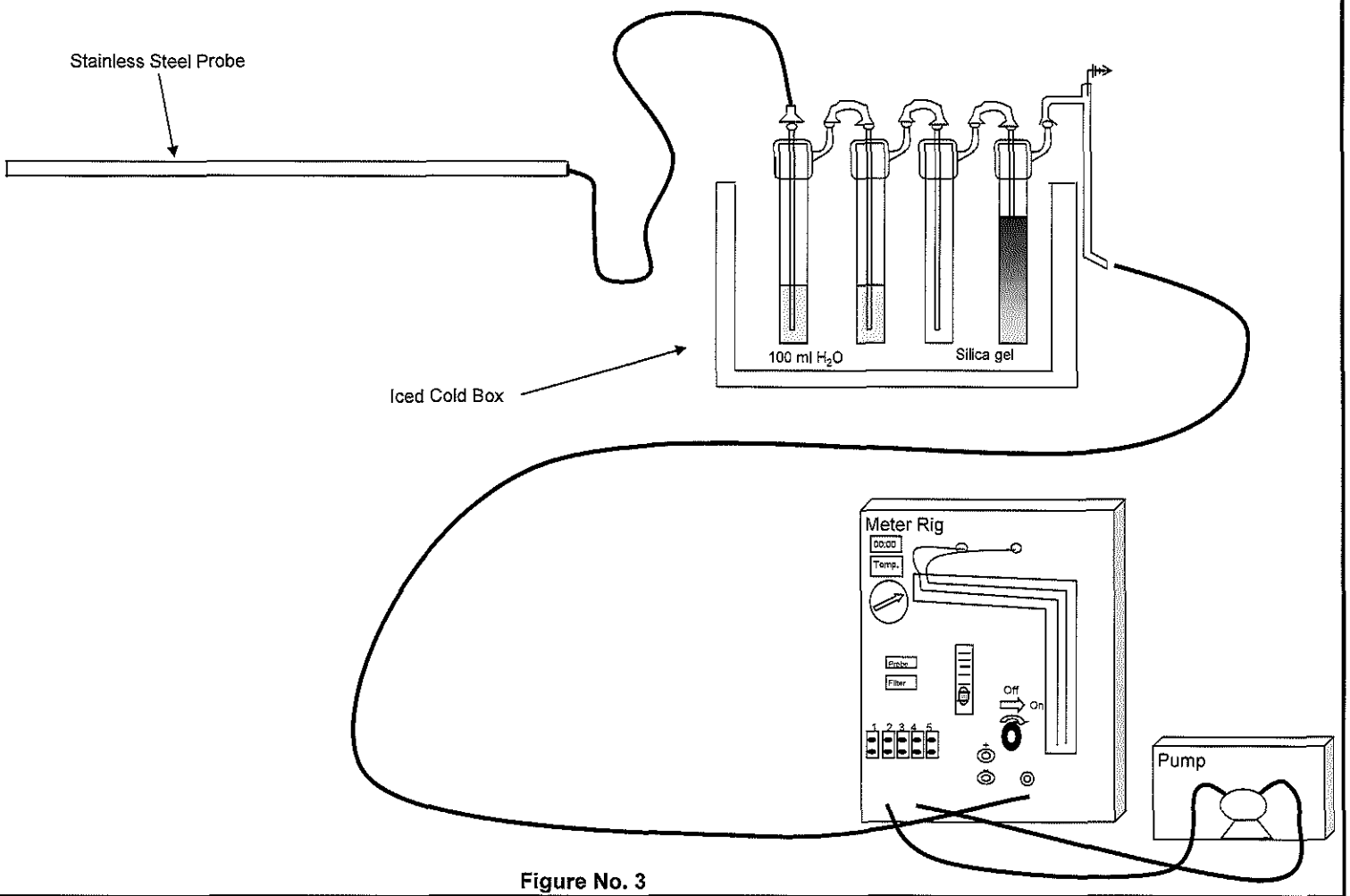

Figure No. 3

Site: USEPA Method 4 GM Pontiac Powertrain Pontiac, Michigan	Sampling Date: May 16-17, 2017	BT Environmental Consulting, Inc. 4949 Fernlee Avenue Royal Oak, Michigan

BTEC Inc.

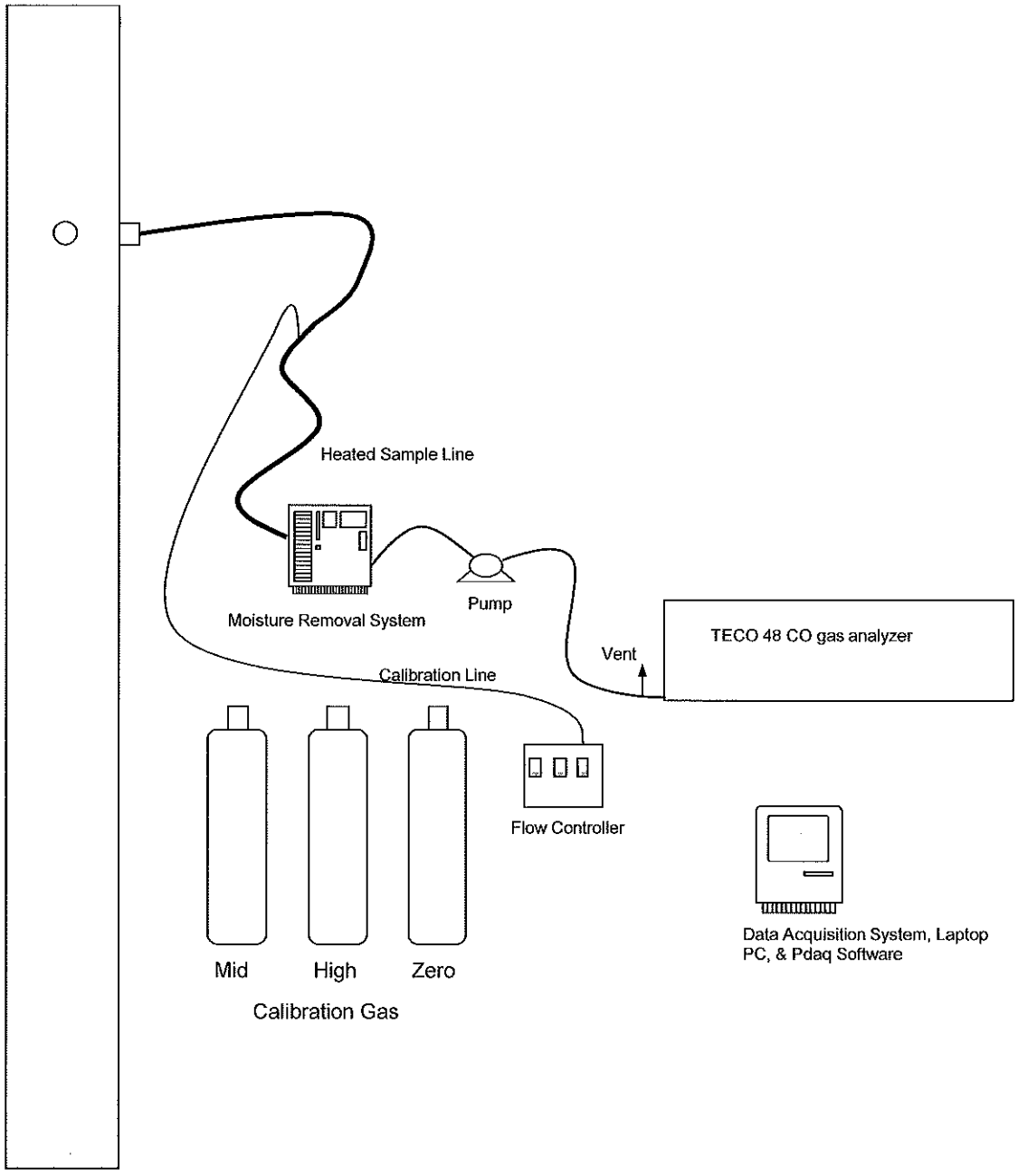

Figure No. 4

Site: **USEPA Method 10** **GM Pontiac Powertrain** **Pontiac, Michigan**	**Sampling Date:** **May 16-17, 2017**	**BT Environmental Consulting Inc.** **4949 Fernlee Avenue** **Royal Oak, MI 48073**