BTEC Inc.

CO Capture Efficiency Emissions Test Summary Report

Prepared for:

General Motors LLC

Pontiac, Michigan

GM Global Propulsion Systems
895 Joslyn Road
Pontiac, Michigan
Test Date: May 10, 2017

Project No. 17-5011.01
June 21, 2017

BT Environmental Consulting, Inc.
4949 Fernlee Avenue
Royal Oak, Michigan 48073
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EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by General Motors LLC (GM) to conduct a compliance carbon monoxide (CO) capture efficiency (CE) test on one representative engine test cell in Wing 3 at the GM Propulsions Systems facility in Pontiac, Michigan. The CO CE test program was conducted on May 10, 2017.

The purpose of the CE test program was to evaluate the CO capture efficiency of the engine test cell operations exhausting through five representative emission points, identified as follows:

(1) D301 Test Cell Engine Exhaust;
(2) AHU Supply*;
(3) AHU Exhaust;
(4) Scavenge Air Supply*;
(5) Scavenge Air Exhaust.

** AHU Supply and Scavenge Air Supply streams were tested to quantify the effects of ambient CO on the CE.*

The CE is presented two ways: The first is using the AHU and Scavenge Air exhaust numbers only and not subtracting the supply CO numbers, the second is subtracting the supply CO from the exhaust before calculating the CE. The below is a summary of the CE test results:

TEST RUN	CE Result (%) (using exhaust only numbers)	CE Result (%) (supply subtracted from exhaust – accounts for effects of ambient CO)
1	99.33	99.65
2	99.58	99.75
3	99.67	99.93
Avg.	99.53	99.78

Tables 2 and 3 summarize the overall results of the emissions test program.

1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by General Motors LLC (GM) to conduct a compliance carbon monoxide (CO) capture efficiency (CE) test on one representative engine test cell in Wing 3 at the GM Propulsions Systems facility in Pontiac, Michigan. The CO CE test program was conducted on May 10, 2017.

The purpose of the CE test program was to evaluate the CO capture efficiency (CE) of the engine test cell operations exhausting through five representative emission points, identified as follows:

(1) D301 Test Cell Engine Exhaust;
(2) AHU Supply*;
(3) AHU Exhaust;
(4) Scavenge Air Supply*;
(5) Scavenge Air Exhaust.

** AHU Supply and Scavenge Air Supply streams were tested to quantify the effects of ambient CO and CE.*

The purpose of this document is to present the results of the CE compliance 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

The engine test cell was evaluated for CO CE using Methods 1, 2, 3, 4, 10, and 19 codified at Title 40, Part 60, Appendix A, of the Code of Federal Regulations (40 CFR 60, Appendix A). The engine test cells are located at the General Motors Propulsions Systems facility in Pontiac, Michigan. The CO CE testing was conducted on May 10, 2017.

1.b Purpose of Testing

The objective of the test program was to determine the overall capture efficiency (CE) of carbon monoxide (CO) from the test cell operations.

1.c Source 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. The testing was conducted based on representative operating conditions which evaluated the CE of a single Wing 3 test cell, out of the eleven firing cells in this Wing.

Engine selection was selected based on historical operating data, on the most frequent family of engines tested, and a common automated development test program. Wing 3 is configured to only run development test programs in the test cells.

Exhaust gases from the test cell is diverted to a main exhaust header which leads to the inlet of the site's four (4) regenerative thermal oxidizers (RTOs). RTOs 1 and 2 share one common inlet feed; similarly, RTOs 3 and 4 share common ductwork which leads to the inlet of these RTOs. Each RTO has individual exhaust stacks.

1.d Test Program Contact

The contact for information regarding the test program as well as the test report is as follows:

Ms. Lisa M. Parks
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Ms. Bethany Gunnels
Environmental Engineer
General Motors LLC
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General Motors LLC
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850 Glenwood Ave

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(586) 709-2737

Mr. Barry P. Boulianne
Senior Project Manager
BT Environmental Consulting, Inc.
4949 Fernlee Avenue
Royal Oak, MI 48073
(313) 449-2361

1.e Test Personnel

Names and affiliations for personnel who were present during the testing program are provided in 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 Propulsions Systems 850 Glenwood Mail Code: 483-710-106 Pontiac, Michigan 48340	(248) 520-2396
Mr. Michael Richards Manager - Global Laboratory Systems	General Motors LLC Pontiac Propulsions Systems 850 Glenwood Mail Code: 483-710-106 Pontiac, Michigan 48340	(586) 709-2737
Mr. Matt Young Project Manager	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Steve Smith Project Manager	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Mike Nummer Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Jake Zott Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070

Mr. Tom Maza	MDEQ Air Quality Division	(313) 456-4709
Mr. Mark Dziadosz	MDEQ Air Quality Division	(586) 753-3745
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

Test Cell D301 was operating a 2.0L turbocharged in-line four (4) cylinder engine running through a typical development test. The three emission test runs were each 180 minutes in duration. Test cell engine operating data for the emissions test program is included in Appendix D.

2.b Applicable Permit

The engine test cells are covered by MI-ROP-B4032-2014d.

2.c Results

The overall results of the CO CE test program are summarized in Tables 2-3. Detailed flowrate and CO concentration test results are included in Appendix A.

2.d Emission Regulation Comparison

The site is operated under permit MI-ROP-B4032-2014d which includes 11 firing test cells in the Wing 3 test cell operations. The test cells are controlled by four natural gas-fired regenerative thermal oxidizers (RTOs) and the following permit conditions FG-TESTCELLMACT apply:

- Limits CO or THC to 20 ppmvd or 96 percent reduction in emissions

The objective of the test program was to determine the overall capture efficiency (CE) of carbon monoxide (CO) from the test cell operations.

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. The testing was conducted based on representative operating conditions which evaluated the CE of a single Wing 3 test cell, out of the eleven firing cells in this Wing. Engine selection was selected based on historical operating data, on the most frequent family of engines tested, and a common automated development test program. Wing 3 is configured to only run development test programs in the test cells.

Exhaust gases from the test cells are diverted to a main exhaust header which leads to the inlet of the site's four (4) regenerative thermal oxidizers (RTOs). RTOs 1 and 2 share one common inlet feed; similarly, RTOs 3 and 4 share common ductwork which leads to the inlet of these RTOs. 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 necessary.

3.c Raw and Finished Materials

The relevant raw material included in this emissions test program was gasoline. Engine fuel flowrate data is included in Appendix D. A sample of the gasoline was collected and submitted for ultimate analysis as well as heating value and density. The results of this analysis are included in Appendix E.

3.d Process Capacity

FG-TESTCELLMACT limits CO or THC to 20 ppmvd or 96 percent reduction in emissions. Each RTO is rated at 27,000 scfm.

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 procedures used to evaluate CO emission rates at the seven sampling points.

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 Flowrate"
- 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"
- Method 19 - "Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates"

Stack gas velocity traverses were conducted in accordance with the procedures outlined in Method 1 and Method 2C. Standard pitot tubes with thermocouple assemblies, calibrated in accordance with Method 2, Section 10.2, were used to measure exhaust gas velocity pressures (using a manometer) and temperatures during testing. The standard pitot tube dimensions outlined in Figure 2-5 were within specified limits, therefore, a baseline pitot tube coefficient of 0.99 (dimensionless) was assigned.

Molecular weight determinations were evaluated according to USEPA Method 3, "Gas Analysis for the Determination of Dry Molecular Weight." The equipment used for this evaluation consisted of a one-way squeeze bulb with connecting tubing and a set of Fyrite® combustion gas analyzers. Carbon dioxide and oxygen content were analyzed using the Fyrite® procedure.

Exhaust gas moisture content was evaluated using the wet bulb/dry bulb.

The CO content of the exhaust gas was evaluated according to procedures outlined in 40 CFR 60, Appendix A, Method 10, *"Determination of Carbon Monoxide Emissions from Stationary Sources."* 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 electronic sample conditioner to remove the moisture from the sample before it entered the CO analyzer. Data was recorded on a PC equipped with PDaqview® data acquisition software.

An emission rate (lb/mmBTU) was calculated by determining an F-factor for the engine exhaust. The F-factor was determined by sending a fuel sample used by GM during the testing, to Paragon Labs in Livonia Michigan. The analytical results were applied to equation 19-13 found in Method 19, which yielded an F-factor of 9,078. The F-factor was then applied to equation 19-1 from Method 19 to yield an engine exhaust CO emission rate.

4.b Recovery and Analytical Procedures

A sample of the fuel used during the CE testing was collected and sent to Paragon Labs in Livonia, Michigan to determine the gross heating value (BTU/lb) of the fuel.

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 1-4.

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 in Tables 2 and 3. Detailed flowrate and CO concentration results are included in Appendix A and Appendix B. Field Data and Field Notes are available in Appendix A. Analyzer raw data is provided in electronic form in Appendix D.

5.b Discussion of Results

The objective of the test program was to determine the overall capture efficiency (CE) of carbon monoxide (CO) from the test cell operations.

The CO concentrations in the AHU Supply and Scavenge Air Supply air streams were measured due to the extremely low CO concentrations expected in the AHU Exhaust and Scavenge Air Exhaust streams. The intent of sampling the AHU Supply and Scavenge Air Supply was to quantify ambient CO concentrations. The presence of ambient CO in the supply air streams was expected to affect the overall CE calculation due to its relative impact on the CO concentration in the exhaust streams.

The effects of ambient CO on the CE calculation are not explicitly addressed in the Engine Test MACT rule (40 CFR 63. Subpart PPPPP). Therefore, CE results are presented in Tables 2 and 3 calculated both with and without the effects of ambient CO.

5.c Sampling Procedure Variations

There were no sampling procedure variations.

5.d Process or Control Device Upsets

No upset conditions occurred during testing.

5.e Control Device Maintenance

The emissions test program did not include the evaluation of control device performance.

5.f Re-Test Changes

The CO emissions 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

Included in Appendix B are certificates of analysis for the calibration gases used in this CE test program and calibration data for the gas dilution system used in this CE test program.

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

Fuel analytical results are summarized in Appendix E.

Table 2
Overall Results Summary
GM Pontiac Powertrain
Wing 3 Test Cell CO Capture Efficiency Testing (Not including ambient CO in supply)
Test Dates: May 10, 2017

Test Run	Run Date	Run Time	Wing 3 Room Air Exhaust Gas Flowrate (dscfm)	Scavenge Air Exhaust Gas Flowrate (dscfm)	Wing 3 Room Air CO Concentration (ppmvd)	Scavenge Air CO Concentration (ppmvd)	Wing 3 Room Air CO Emission Rate (lbs/hr)	Scavenge Air CO Emission Rate (lbs/hr)	Engine Test Cell CO Emission Rate (lbs/hr)	Overall CE (%)
1	5/10/2017	7:50-10:50	7,169	1,282	0.26	0.51	0.008	0.003	1.62	99.33
2	5/10/2017	11:20-14:20	4,895	1,323	0.16	0.61	0.003	0.004	1.66	99.58
3	5/10/2017	14:48-17:48	4,853	1,326	0.18	0.28	0.004	0.002	1.66	99.67
										99.53

*Engine Test Cell Parameters			
Run	Average Engine Fuel Flowrate (g/s)	Average Engine Exhaust O2 Content (% v/v)	Average Engine Exhaust CO Concentration (ppmvd)
1	1.88	0.6	8321.2
2	1.87	0.6	8535.8
3	1.87	0.6	8571.6

Table 3
Overall Results Summary
GM Pontiac Powertrain
Wing 3 Test Cell CO Capture Efficiency Testing (Accounting for ambient CO - Supply subtracted from exhaust)
Test Dates: May 10, 2017

Test Run	Run Date	Run Time	Wing 3 Room Air Exhaust Gas Flowrate (dscfm)	Scavenge Air Exhaust Gas Flowrate (dscfm)	Wing 3 Room Air CO Concentration (ppmvd)	Scavenge Air CO Concentration (ppmvd)	Wing 3 Room Air CO Emission Rate (lbs/hr)	Scavenge Air CO Emission Rate (lbs/hr)	Engine Test Cell CO Emission Rate (lbs/hr)	Overall CE (%)
1	5/10/2017	7:50-10:50	7,169	1,282	0.26	0.51	0.0038	0.0019	1.62	99.65
2	5/10/2017	11:20-14:20	4,895	1,323	0.16	0.61	0.0015	0.0028	1.66	99.75
3	5/10/2017	14:48-17:48	4,853	1,326	0.18	0.28	0.0004	0.0008	1.66	99.93
										99.78

*Engine Test Cell Parameters			
Run	Average Engine Fuel Flowrate (g/s)	Average Engine Exhaust O2 Content (% v/v)	Average Engine Exhaust CO Concentration (ppmvd)
1	1.88	0.6	8321.2
2	1.87	0.6	8535.8
3	1.87	0.6	8571.6

Run 1

SOURCE	CO CONCENTRATION	FLOWRATE	CO LBS/HR	CO LBS/HR (Exhaust Minus Supply)
AHU Exhaust	0.26	7168.9	0.0081	0.003788839
AHU Supply	0.24	4146.14	0.0043	
Scavenge Exhaust	0.51	1281.8	0.0029	0.001860274
Scavenge Supply	0.2	1135.64	0.0010	

Run 2

SOURCE	CO CONCENTRATION	FLOWRATE	CO LBS/HR	LBS/HR MINUS INLET
AHU Exhaust	0.16	4894.73	0.0034	0.001460456
AHU Supply	0.21	2134.53	0.0020	
Scavenge Exhaust	0.61	1322.61	0.0035	0.002767244
Scavenge Supply	0.15	1148.13	0.0008	

Run 3

SOURCE	CO CONCENTRATION	FLOWRATE	CO LBS/HR	LBS/HR MINUS INLET
AHU Exhaust	0.18	4852.99	0.0038	0.00037603
AHU Supply	0.26	3028.11	0.0034	
Scavenge Exhaust	0.28	1326.36	0.0016	0.000769301
Scavenge Supply	0.16	1218.55	0.0009	

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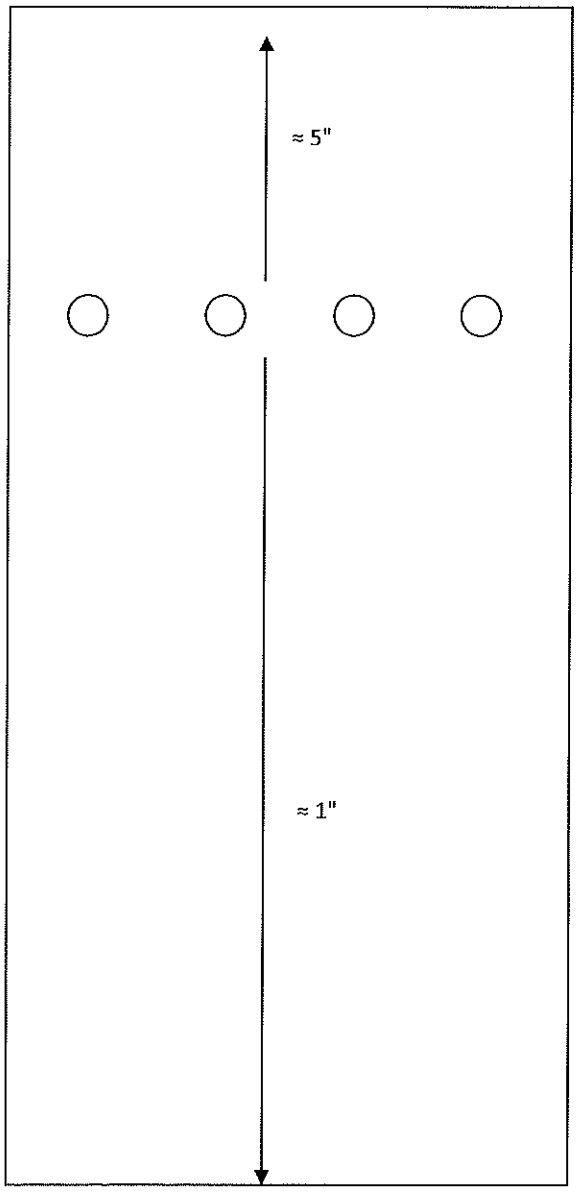
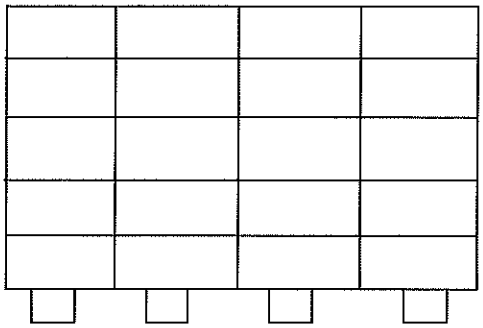
Stack Dimensions:

Depth:	36	inches
Width:	36	inches





Not to Scale

Points	Distance "
1	3
2	9
3	15
4	21
5	27
6	33

Figure No. 1

Site: **AHU Exhaust** **GM Pontiac Dyno** **Pontiac, Michigan**	**Sampling Date:** **May 10, 2017**	**BT Environmental Consulting, Inc.** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**

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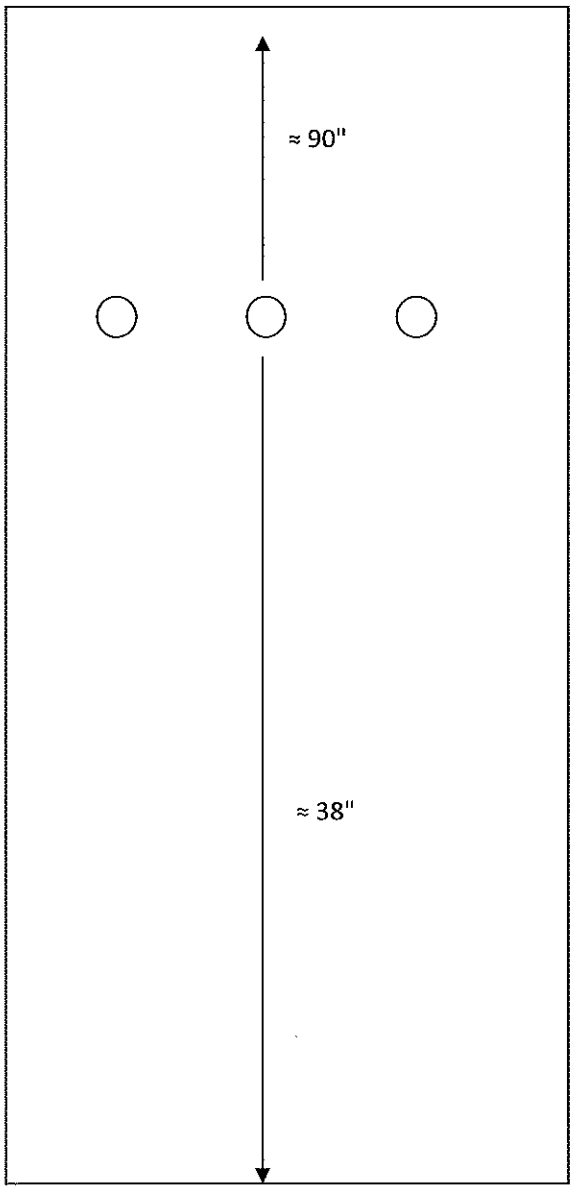
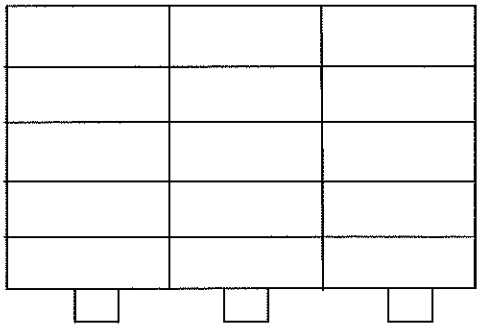
Stack Dimensions:

Depth:	10	inches
Width:	16	inches





Not to Scale

Points	Distance "
1	0.6
2	1.9
3	3.1
4	4.4
5	5.6
6	6.9
7	8.1
8	9.4

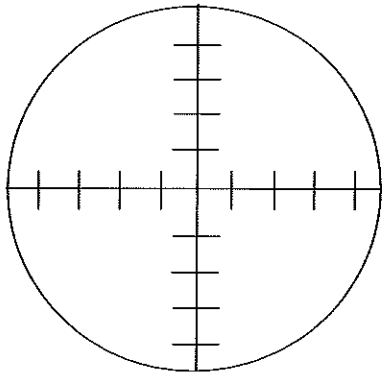
Figure No. 2

Site: **Scavenge Air Exhaust** **GM Pontiac Dyno** **Pontiac, Michigan**	**Sampling Date:** **May 10, 2017**	**BT Environmental Consulting, Inc.** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**

BTEC Inc.

diameter = 12 inches

Points	Distance "
1	0.4
2	1.3
3	2.3
4	3.9
5	8.1
6	9.7
7	10.7
8	11.6



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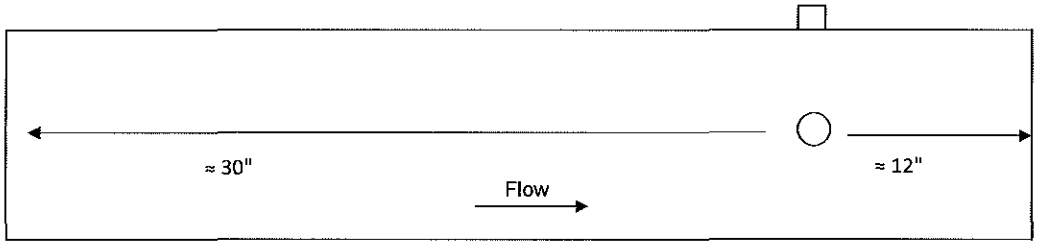


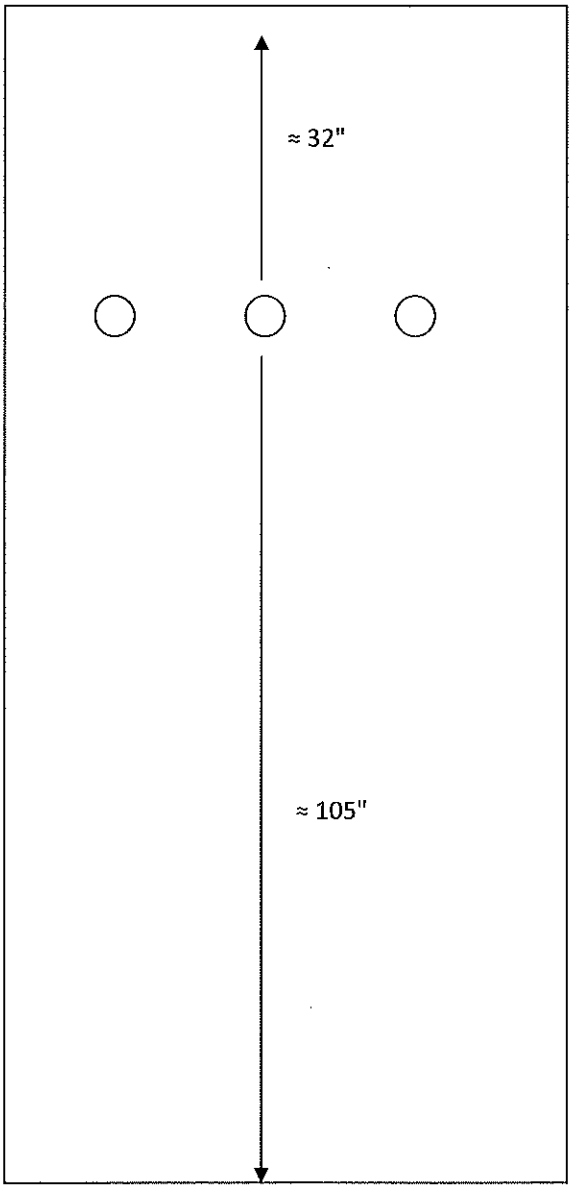
Figure No. 3

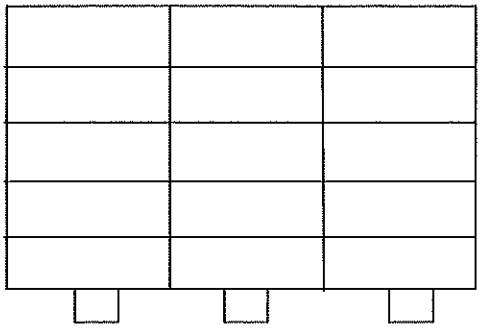
Site:	Sampling Date:	
Scavenge Air Supply GM Pontiac Pontiac, Michigan	May 10, 2017	BT Environmental Consulting, Inc. 4949 Fernlee Avenue Royal Oak, Michigan 48073

BTEC Inc.

Stack Dimensions:

Depth:	66	inches
Width:	16	inches





Not to Scale

Points	Distance "
1	5.5
2	16.5
3	27.5
4	38.5
5	49.5
6	60.5

Figure No. 4

Site: **AHU Supply** **GM Pontiac** **Pontiac, Michigan**	**Sampling Date:** **May 10, 2017**	**BT Environmental Consulting, Inc.** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**

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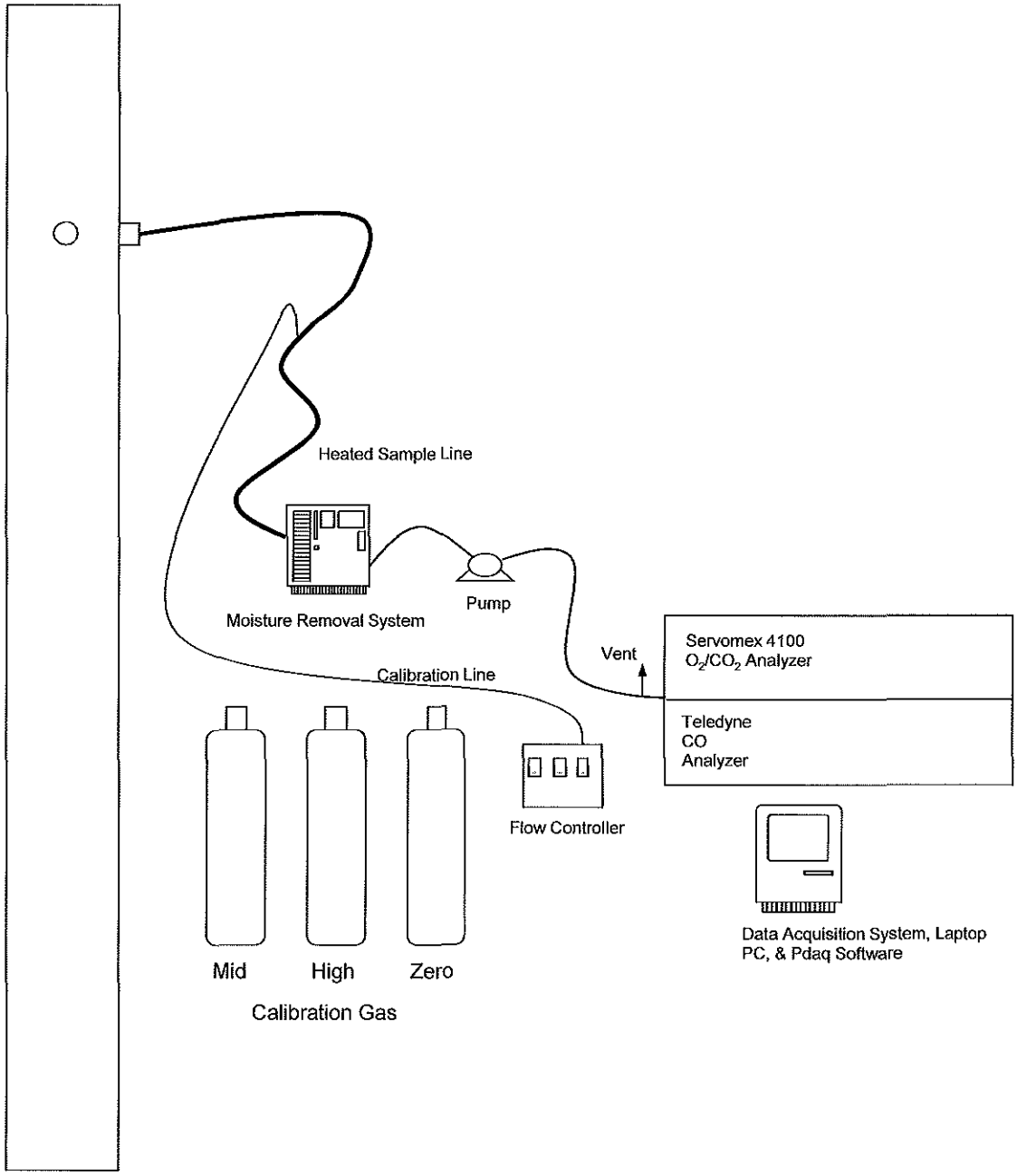

Figure No. 5

Site:	Sampling Date:	
USEPA Method 3A and 10 GM Pontiac Pontiac, Michigan	May 10, 2017	BT Environmental Consulting Inc. 4949 Fernlee Avenue Royal Oak, MI 48073