BTEC Inc.

NOx and CO Emissions Test Summary Report

Prepared for:

Federal-Mogul Powertrain, Inc.

Federal-Mogul Powertrain, Inc.
47001 Port Street
Plymouth, Michigan 48170

Project No. 14-4537.00
June 27, 2014

BT Environmental Consulting, Inc.
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EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by Federal-Mogul Powertrain Plymouth Technical Center (Federal-Mogul) to measure nitrogen oxides (NOx) and carbon monoxide (CO) emission rates from the engine test cell exhaust stacks (FG-ALLCELLS) at the Federal-Mogul facility located in Plymouth, Michigan. The facility operates under Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) No. MIROP-N6327-2009a. The ROP requires that testing be performed to determine NOx and CO emission rates from a representative number of test cells. For the purposes of this test event, a representative number of test cells include the following:

- A medium-size gasoline engine during developmental testing, operating without the air injection control system (AICS); and
- A medium-size gasoline engine during durability testing, operating with the air injection control system.

This represents the engines and mode of operation that result in the worst-case emissions for the type of dynamometer engine testing that Federal-Mogul typically performs.

The emissions test program was conducted on May 13, 2014. The results of the emission test program are summarized by Table I.

Table I
Test Cell 2 Overall Emission Summary
Test Date: May 13, 2014

Condition	Pollutant	Emission Rate (lb/hr)	Emission Rate (lb/lb of fuel)
Durability with AICS	NOx	0.55	0.0048
	CO	8.75	0.08
Developmental without AICS	NOx	0.36	0.0244
	CO	1.68	0.11

1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by Federal-Mogul Powertrain Plymouth Technical Center (Federal-Mogul) to measure nitrogen oxides (NOx) and carbon monoxide (CO) emission rates from the engine test cell exhaust stacks (FG-ALLCELLS) at the Federal-Mogul facility located in Plymouth, Michigan. The facility operates under Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) No. MIROP-N6327-2009a. The ROP requires that testing be performed to determine NOx and CO emission rates from a representative number of test cells. For the purposes of this test event, a representative number of test cells include the following:

- A medium-size gasoline engine during developmental testing, operating without the air injection control system (AICS); and
- A medium-size gasoline engine during durability testing, operating with the air injection control system.

This represents the engines and mode of operation that result in the worst-case emissions for the type of dynamometer engine testing that Federal-Mogul typically performs.

The emissions test program was conducted on May 13, 2014. 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" (December 2013). 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

Federal-Mogul Powertrain, Inc. in Plymouth, Michigan tests engines and engine components in dynamometer cells. The facility is located in a light industrial area near M-14 and Beck Road.

Sampling and analysis for the emission test program was conducted on May 13, 2014.

1.b Purpose of Testing

Permit No. MIROP-N6327-2009a limits emissions from FG-ALLCELLS as summarized by Table 1.

Table 1
FG-ALLCELLS Emission Limitations

Pollutant	Emission Limit	Time Period
CO	223.3 tons per year	12 Month Rolling Time Period
NOx	62.1 tons per year	12 Month Rolling Time Period

1.c Source Description

Federal- Mogul Powertrain, Inc. is currently permitted to operate 16 engine test cells. Fifteen (15) of the test cells can be used to conduct testing on gasoline or diesel engines, but typically 12-13 are used for gasoline engine testing. One (1) cell is used to test small engines. The engines are connected to a dynamometer that simulates a vehicle load on the engine. The tests include durability, deep thermal shock, and developmental cycles. Each is designed to test specific components, or overall performance, of an engine.

Emissions are controlled by an Air Injection Control System (AICS), which is required to be operated when gasoline is used as fuel and during durability and deep thermal shock testing. No controls are required for diesel fuel engine testing or during developmental testing.

1.d Test Program Contacts

The contact for the source and test report is:

Terry Walter
Manager of Testing & Administration
Federal-Mogul Powertrain, Inc.
47001 Port Street
Plymouth, Michigan 48170
(734) 254-8291

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. Terry Walter Manager of Testing & Administration	Federal-Mogul Powertrain, Inc. 47001 Port Street Plymouth, Michigan 48170	(734) 254-8291
Ms. Lori Myott Vice President	NTH Consultants, Ltd. 608 S. Washington Ave. Lansing, Michigan 48823	(517) 702-2957
Mr. Barry Boulianne Senior Project Manager	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8072
Mr. Todd Wessel Senior Project Manager	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(616) 885-4013
Mr. Kenny Felder Environmental Technician	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070
Mr. Mark Dziadosz Environmental Quality Analyst	MDEQ Air Quality Division	(313) 753-3745

2. Summary of Results

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

2.a Operating Data

Process data monitored during the emissions test program includes AICS Air injection rate, air-to-fuel ratio, temperature before air injection, temperature after air injection, and fuel flow. Process data is included in Appendix D.

2.b Applicable Permit

The applicable permit for this emissions test program is MDEQ ROP No. MI-ROP-N6327-2009a.

2.c Results

The overall results of the emission test program are summarized by Table 3 (see Section 5.a).

3. Source Description

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

3.a Process Description

Federal- Mogul Powertrain, Inc. is currently permitted to operate 16 engine test cells. Fifteen (15) of the test cells can be used to conduct testing on gasoline or diesel engines, but typically 12-13 are used for gasoline engine testing. One (1) cell is used to test small engines. The engines are connected to a dynamometer that simulates a vehicle load on the engine. The tests include durability, deep thermal shock, and developmental cycles. Each is designed to test specific components, or overall performance, of an engine.

Emissions are controlled by an Air Injection Control System (AICS), which is required to be operated when gasoline is used as fuel and during durability and deep thermal shock testing. No controls are required for diesel fuel engine testing or during developmental testing.

Federal-Mogul installed an Air Injection Control System (AICS) in 2004 to control CO and VOC emissions from the test cells. The AICS works by injecting a measured stream of air into the exhaust gas, which is hotter than the auto ignition point of CO, causing the CO to oxidize in the exhaust pipe.

The air injection rate (scfm) and temperature before and after air injection are monitored to ensure proper destruction. The air injection rate is dependent on the type of test being performed (durability or deep thermal shock). The minimum rates for each test are defined in the ROP. The exhaust temperature must reach 1,100°F to oxidize CO; exhaust temperatures using the AICS usually exceed 1,400°F. The AICS is used with durability and deep thermal shock testing for gasoline engines, but is not used with diesel or small engines or during developmental testing. The facility also operates an Automatic Data Acquisition System, which monitors all operating parameters of the test cells on a continuous basis. These parameters include fuel usage, exhaust temperature, and air injection rate.

3.b Process Flow Diagram

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

3.c Raw and Finished Materials

The raw material used by the process is gasoline.

3.d Process Capacity

Federal Mogul tests various sized gasoline engines and small diesel engines. The dynamometers are sized up to 600 horsepower (hp); however engines are typically in the 100-400 hp range.

3.e Process Instrumentation

Process data monitored during the emissions test program includes AICS Air injection rate, air-to-fuel ratio, temperature before air injection, temperature after air injection, and fuel flow. Process 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 used.

4.a Sampling Train and Field Procedures

NOx content was measured using a Teledyne Model T-200H NOx gas analyzer, the CO content was measured using a Teledyne Model 300EM CO gas analyzer, and the O_2 content was measured using a M&C Products PMA 100-L O_2 gas analyzer. 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 enters the analyzer. Data was recorded at 4-second intervals on a PC equipped with data acquisition software.

For analyzer calibrations, calibration gases were mixed to desired concentrations using an Environics Series 4040 Computerized Gas Dilution System. The Series 4040 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. A schematic of the sampling train is provided as Figure 1.

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

- Method 3A, *"Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources"*, was used to measure the O_2 and CO_2 concentration of the exhaust gas.

- Method 7E, *"Determination of Nitrogen Oxide Emissions from Stationary Sources"*, was used to measure the NOx concentration of the exhaust gas.

- Method 10, *"Determination of Carbon Monoxide Emissions from Stationary Sources"*, was used to measure the CO concentration of the exhaust gas.

- Method 19, *"Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates"*, was used to calculate the exhaust gas flowrates.

The accuracy of the gas dilution system was verified using the procedures detailed by Method 205 and the NOx converter efficiency was verified as specified by Method 7E.

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.

Fuel was collected by Federal-Mogul and analyzed by Paragon Laboratories. Laboratory analytical results for the gasoline are available in Appendix E.

4.c Sampling Ports

Engine exhaust gas was extracted from the exhaust pipe with the probe tip located at the centroid of the 6-inch diameter pipe.

4.d Traverse Points

Engine exhaust gas was extracted from the exhaust pipe with the probe tip located at the centroid of the 6-inch diameter pipe.

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 and 5.

Table 3
Test Cell 2 Overall Emission Summary
Test Date: May 13, 2014

Condition	Pollutant	Emission Rate (lb/hr)	Emission Rate (lb/lb of fuel)
Durability with AICS	NOx	0.55	0.0048
	CO	8.75	0.08
Developmental without AICS	NOx	0.36	0.0244
	CO	1.68	0.11

5.b Discussion of Results

This test event provides emission rates for a representative number of test cells under various operating conditions at Federal-Mogul. Based on the derived emission factors (lb pollutant/lb fuel) for these conditions, and assuming maximum allowable fuel flow over an entire year (2,630,750 lb/year) to all cells, the maximum actual annual emission rates for NOx and CO would not exceed permitted limits for FG-ALLCELLS, as shown in the table below. These annual emission estimates, based on actual, representative worst-case testing and maximum gasoline usage, demonstrate that Federal-Mogul is in compliance with NOx and CO permit limits.

Pollutant	Worst-case Emission Factor[2] (without AICS) [lb pollutant/lb fuel]	Maximum Actual Annual Emissions [tpy][1]	Permit Limit [tpy]
NO_x	0.0244	32.1	62.1
CO	0.11	144.7	223.3

[1] Based on maximum allowable fuel flow of 2,630,750 lbs gasoline per year
[2] Worst-case emission factor from this test event, based on a "representative" number of test cells and a medium-sized engine.

5.c Sampling Procedure Variations

Sampling for CO was performed using two analyzers. One analyzer was calibrated in the 0-10,000 ppm range (CO low), and the second analyzer was calibrated in the 0-10% range (CO Hi). Portions of each test were above the 10,000 upper range of the CO low analyzer, and therefore the CO Hi data has been used for all calculations. Raw CEM data for each analyzer is included on the CD in Appendix D.

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

Laboratory analytical results for this test program are included as Appendix E.
Raw CEM data is provided electronically in Appendix D.

Tables

Table 4
NOx and CO Emission Rates (Durability with AICS)
Federal Mogul
Plymouth, Michigan
BTEC Project No. 14-4537
Sampling Dates: May 13, 2014

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	5/13/2014	5/13/2014	5/13/2014	
Test Run Time	9:38-10:38	10:55-11:55	12:18-13:18	
Fuel Flow (lb/hr)	115	114	114	
F_d (dscf/10^6 Btu)	9,045	9,045	9,045	
Gross Heating Value (BTU/lb)	19,323	19,323	19,323	
Fuel Flow (MMBtu/hr)	2.22	2.20	2.20	
Oxygen Concentration (%)	0.29	0.16	0.01	**0.15**
Oxygen Concentration (%, drift corrected as per USEPA 7E)	0.04	0.02	**0.00**	**0.02**
Carbon Dioxide Concentration (%)	15.54	15.64	15.78	**15.65**
Carbon Dioxide Concentration (%, drift corrected as per USEPA 7E)	15.73	16.06	15.82	**15.87**
Outlet Oxides of Nitrogen Concentration (ppmv)	209.29	241.60	239.53	230.14
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	208.45	241.42	239.57	229.81
Outlet NOx Concentration (lb/scf, corrected as per USEPA 7E)	0.000025	0.000029	0.000029	0.000027
NOx Emission Rate (lb/MMBtu)	0.23	0.26	0.26	0.25
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	**0.50**	**0.57**	**0.57**	**0.55**
NOx Emission Rate (lb/lb fuel) (corrected as per USEPA 7E)	**0.0044**	**0.0050**	**0.0050**	**0.0048**
Outlet Carbon Monoxide Concentration (%)	0.81	0.39	0.80	0.67
Outlet CO Concentration (%, corrected as per USEPA 7E)	0.79	0.27	0.75	0.60
Outlet CO Concentration (lb/scf, corrected as per USEPA 7E)	0.000572	0.000195	0.000543	0.000437
CO Emission Rate (lb/MMBtu)	5.18	1.77	4.91	3.95
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**11.52**	**3.90**	**10.82**	**8.75**
CO Emission Rate (lb/lb fuel) (corrected as per USEPA 7E)	**0.10**	**0.03**	**0.09**	**0.08**

Note: Run 3 drift corrected oxygen value was -0.03. Zero has been substituted for calculations.

ppmv = parts per million on a volume-to-volume basis
lb/hr = pounds per hour
MW = molecular weight (CO = 28.01, NOx = 46.01, O_2 = 16, CO_2 = 44.10, N_2 = 28)
24.14 = molar volume of air at standard conditions (70F, 29.92" Hg)
35.31 = ft^3 per m^3
453600 = mg per lb
386.9 = ft^3 per lb-mol
10^6 = Btu per MMBtu
10,000 = ppm per %

Equations
lb/scf = ppm * Conversion factor
NOx conversion factor is given by Table 19-1 of Method 19 as $1.194x10^{-7}$
CO conversion factor is derived as MW * (1 mol / 24.14 L) *(m^3 / 35.31 ft^3) * (1 lb / 453.6 g) *(1000 L / m^3) * (1 part/ 10^6parts), = $7.24x10^{-8}$
Fuel Flow (MMBtu/hr) = Fuel Flow (lb/hr) * Gross Heating Value (Btu/lb) * $1/10^6$
Pollutant (lb/hr) = C_d*F_d*20.9/(20.9-%O_2) - Equation 19-1, Where C_d is pollutant concentration (lb/scf)
lb/lb fuel = lb/hr / Fuel Flow

Table 5
NOx and CO Emission Rates (Developmental without AICS)
Federal Mogul
Plymouth, Michigan
BTEC Project No. 14-4537
Sampling Dates: May 13, 2014

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	5/13/2014	5/13/2014	5/13/2014	
Test Run Time	13:46-14:46	15:19-16:19	16:49-17:49	
Fuel Flow (lb/hr)	14.57	14.78	14.73	
F_d (dscf/10^6 Btu)	9,045	9,045	9,045	
Gross Heating Value (BTU/lb)	19,323	19,323	19,323	
Fuel Flow (MMBtu/hr)	0.28	0.29	0.28	
Oxygen Concentration (%)	1.45	1.61	1.92	**1.66**
Oxygen Concentration (%, drift corrected as per USEPA 7E)	1.48	1.50	1.60	**1.53**
Carbon Dioxide Concentration (%)	14.43	14.39	14.18	**14.33**
Carbon Dioxide Concentration (%, drift corrected as per USEPA 7E)	14.08	14.33	14.48	**14.30**
Outlet Oxides of Nitrogen Concentration (ppmv)	1184.14	1099.17	999.88	1094.40
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	1188.41	1095.72	973.43	1085.85
Outlet NOx Concentration (lb/scf, corrected as per USEPA 7E)	0.000142	0.000131	0.000116	0.000130
NOx Emission Rate (lb/MMBtu)	1.38	1.27	1.14	1.26
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	**0.39**	**0.36**	**0.32**	**0.36**
NOx Emission Rate (lb/lb fuel) (corrected as per USEPA 7E)	**0.0267**	**0.0246**	**0.0220**	**0.0244**
Outlet Carbon Monoxide Concentration (%)	1.28	0.69	0.79	0.92
Outlet CO Concentration (%, corrected as per USEPA 7E)	1.33	0.52	0.67	0.84
Outlet CO Concentration (lb/scf, corrected as per USEPA 7E)	0.000963	0.000376	0.000485	0.000608
CO Emission Rate (lb/MMBtu)	9.37	3.67	4.75	5.93
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**2.64**	**1.05**	**1.35**	**1.68**
CO Emission Rate (lb/lb fuel) (corrected as per USEPA 7E)	**0.18**	**0.07**	**0.09**	**0.11**

ppmv = parts per million on a volume-to-volume basis
lb/hr = pounds per hour
MW = molecular weight (CO = 28.01, NOx = 46.01, O_2 = 16, CO_2 = 44.10, N_2 = 28)
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
386.9 = ft^3 per lb-mol
10^6 = Btu per MMBtu
10,000 = ppm per %

Equations
lb/scf = ppm * Conversion factor
NOx conversion factor is given by Table 19-1 of Method 19 as 1.194×10^{-7}
CO conversion factor is derived as MW * (1 mol / 24.14 L) *(m^3 / 35.31 ft^3) * (1 lb / 453.6 g) *(1000 L / m^3) * (1 part/ 10^6parts), = 7.24×10^{-8}
Fuel Flow (MMBtu/hr) = Fuel Flow (lb/hr) * Gross Heating Value (Btu/lb) * $1/10^6$
Pollutant (lb/hr) = $C_d * F_d * 20.9/(20.9-\%O_2)$ - Equation 19-1, Where C_d is pollutant concentration (lb/scf)
lb/lb fuel = lb/hr / Fuel Flow

Figures

BTEC Inc.

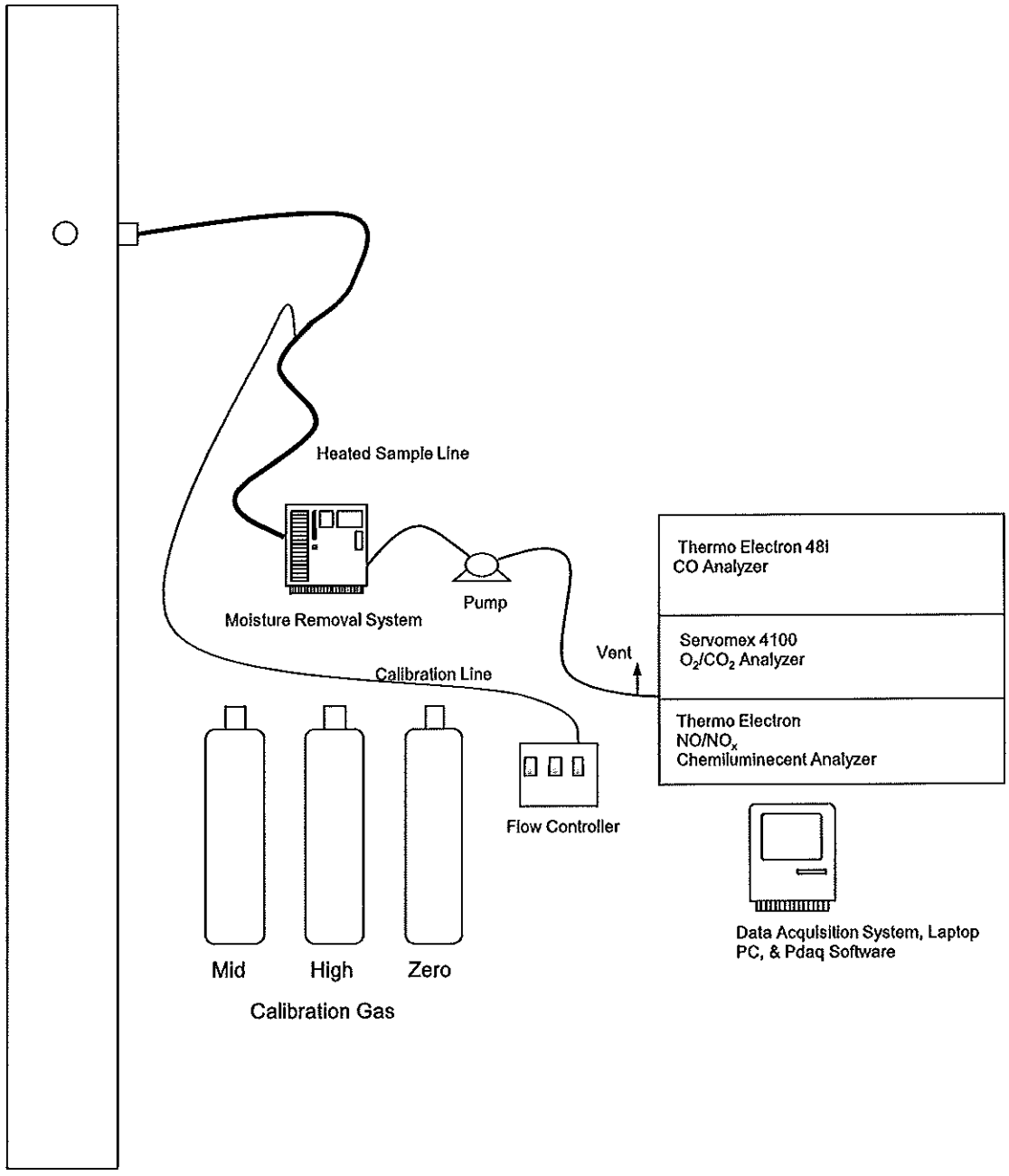

Figure No. 1

Site:	Sampling Date:	
USEPA Method 3A, 7E, and 10 Federal-Mogul Plymouth, Michigan	May 13, 2014	BT Environmental Consulting Inc. 4949 Fernlee Avenue Royal Oak, MI 48073