BTEC Inc.

# Emergency Generator Engine Emissions Test Report



*Prepared for:*

## Western Michigan University

Kalamazoo, Michigan

Engine Location: Western Michigan University
Sangren Hall
1093 West Michigan Avenue
Kalamazoo, Michigan

Project No. 15-4731.00
January 11, 2016

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

## EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by Western Michigan University (WMU) to evaluate emission rates from an emergency generator set located outside Sangren Hall (Sangren). Sangren is located at 1903 West Michigan Avenue in Kalamazoo, Michigan. The generator set is a Gaseous Fuel Generator Set Model GTA50 CC Engine Series manufactured by Cummins.

Testing consisted of triplicate 60-minute test runs. The generator set is owned and operated by WMU and is included in Renewable Operating Permit No. MI-ROP-K2131-2015a as EU-138-EMERGEN-01. The emissions testing is required by the Standards of Performance for Stationary Spark Ignition Internal Combustion Engines codified at Title 40, Part 60, Subpart JJJJ of the Code of Federal Regulations (40 CFR 60, Subpart JJJJ). Emission limitations included in Subpart JJJJ that are applicable to this generator set are summarized in Table I in addition to test program summary results.



**Table I**
**Western Michigan University**
**Sangren Hall Emergency Generator**
**Compliance Test Program Results Summary**

| Source | Pollutant | Test Result (ppmvd @15%/$O_2$) | Emission Limitation (ppmvd @15%/$O_2$) |
|---|---|---|---|
| GTA50 CC Generator Set | NOx | 15 | 160 |
| | CO | 65 | 540 |
| | VOC | 0 | 86 |

Note: The measured total hydrocarbon concentration, minus methane, was negative and, therefore, is reported as zero.

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### APPENDIX

## 1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by Western Michigan University (WMU) to evaluate emission rates from an emergency generator set located outside Sangren Hall (Sangren). Sangren is located at 1903 West Michigan Avenue in Kalamazoo, Michigan. The generator set is a Gaseous Fuel Generator Set Model GTA50 CC Engine Series manufactured by Cummins.

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, see Appendix A). The following is a summary of the emissions test program and results in the format outlined by the AQD document.

### 1.a Identification, Location, and Dates of Test

Field-sampling for this emission test program was conducted on November 19, 2015 at 1903 West Michigan Avenue in Kalamazoo, Michigan. The purpose of this report is to document the results of the emissions test program.

### 1.b Purpose of Testing

The generator set is owned and operated by WMU and is included in Renewable Operating Permit No. MI-ROP-K2131-2015a as EU-138-EMERGEN-01. The emissions testing is required by the Standards of Performance for Stationary Spark Ignition Internal Combustion Engines codified at Title 40, Part 60, Subpart JJJJ of the Code of Federal Regulations (40 CFR 60, Subpart JJJJ). Emission limitations included in Subpart JJJJ that are applicable to this generator set are summarized by Table 2 (see Section 2.d).

The purpose of the testing was to quantify emission levels of oxides of nitrogen (NOx), CO, and VOC (as propane). In addition, the concentrations of oxygen ($O_2$) and methane ($CH_4$) in the engine exhaust were measured during the emissions test program.

### 1.c Test Program Contact

The contacts for the test program are:

Mr. George Jarvis
Power Plant Director
Western Michigan University
1903 West Michigan Avenue
Kalamazoo, Michigan 49008
(269) 387-8548

Mark Weiss
Director of Environmental Health and Safety
Western Michigan University
1903 W. Michigan Ave
Kalamazoo MI 49008-5485
(269) 387-5588

Ms. Lori Myott
Project Manager
NTH Consultants, Ltd.
608 South Washington Avenue
Lansing, Michigan 48933
(517) 242-2692

### 1.d 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 |
|---|---|---|
| Mr. George Jarvis<br>Power Plant Director<br>Western Michigan University | Western Michigan University<br>1903 West Michigan Avenue<br>Kalamazoo, Michigan 49008 | (269) 387-8548 |
| Ms. Rhiana Dornbos<br>Sr. Staff Engineer | NTH Consultants, Ltd.<br>608 S. Washington Ave.<br>Lansing, Michigan 48823 | (517) 702-2953 |
| Mr. Barry Boulianne<br>Senior Project Manager | BTEC<br>4949 Fernlee Avenue<br>Royal Oak, MI 48073 | (248) 548-8072 |
| Mr. Steve Smith<br>Project Manager | BTEC<br>4949 Fernlee Avenue<br>Royal Oak, MI 48073 | (248) 548-8070 |
| Ms. Monica Brothers<br>Environmental Quality Analyst | MDEQ<br>Air Quality Division<br>Kalamazoo District Office | (269) 567-3552 |
| Mr. Dale Turton<br>Environmental Quality Analyst | MDEQ<br>Air Quality Division<br>Kalamazoo District Office | (269) 567-3554 |

## 2. Summary of Results

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

### 2.a Operating Data

The generator set was run prior to testing to ensure proper internal temperature could be reached for the onboard non-selective catalytic reduction (NSCR) system and to adjust the fuel/air mix ratio for optimal emissions control system performance. As specified by 40 CFR 60.4244(a), emissions testing was conducted with the engine operating within 10 percent of 100 percent peak load. The power generation rate during the emissions test program was approximately 598 kW. Operating data is provided in Appendix F.

### 2.b Applicable Permit

The generator set is owned and operated by WMU and is included in Renewable Operating Permit No. MI-ROP-K2131-2015a as EU-138-EMERGEN-01. The emissions testing is required by the Standards of Performance for Stationary Spark Ignition Internal Combustion Engines codified at Title 40, Part 60, Subpart JJJJ of the Code of Federal Regulations (40 CFR 60, Subpart JJJJ).

### 2.c Results

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

### 2.d Emission Regulation Comparison

Emission limitations for the Sangren Hall emergency generator set are summarized by Table 2.

**Table 2**
**Emission Limitations for Emergency Generators Greater Than 130 hp**

| Pollutant | Emission Limitation (ppmv@15% $O_2$) | Emission Limitation (g/bhp-hr) |
|---|---|---|
| NOx | 160 | 2.0 |
| CO | 540 | 4.0 |
| VOC | 86 | 1.0 |

Note: Emission Limitations are expressed in two separate units. Either set of emission limitations can be used to demonstrate compliance with 40 CFR 60, Subpart JJJJ. Emissions were determined in terms of concentration (ppmvd@15% $O_2$).

As summarized by Table 3 (Section 5.a), the emissions test result for each pollutant was less than the corresponding emission limitation.

## 3. Source Description

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

### 3.a Process Description

The emission unit is a natural gas-fired emergency generator set manufactured by Cummins. The generator set (Model GTA50 CC) is rated for a maximum of 600 kW at a gross engine power output of 1,035 bhp.

### 3.b Raw and Finished Materials

The only raw material supplied to the generator set is natural gas.

### 3.c Process Capacity

The only raw material supplied to the generator set is natural gas. The generator is rated for 600 kW.

### 3.d Process Instrumentation

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

## 4. Sampling and Analytical Procedures

Sections 4.a through 4.d provide a summary of the sampling and analytical procedures used to verify emissions from the emergency generator.

### 4.a Sampling Train and Field Procedures

Sampling and analysis procedures followed the methodologies of the following emissions 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"* will be used to evaluate the $O_2$ content of the engine exhaust
- Method 7E - *"Determination of Nitrogen Oxides Emissions from Stationary Sources"* will be used to measure NOx concentrations in the exhaust gas
- Method 10 - *"Determination of Carbon Monoxide Emissions from Stationary Sources"* will be used to measure CO concentrations in the exhaust gas
- Method 25A - *"Determination of Total Gaseous Organic Concentration Using Flame Ionization Analyzer"* will be used to measure VOC concentrations in the exhaust gas

The $O_2$ content and the CO content were measured using a Teledyne 300E $CO/O_2$ gas analyzer. The NOx content of the gas stream was measured using a TECO Model 42C NOx 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 analyzers. Data was recorded at 4-second intervals on a PC equipped with data acquisition software. A schematic drawing of the Methods 3A, 7E, and 10 sampling train is provided as Figure 1.

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 data acquisition software. BTEC will use 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. A schematic drawing of the Method 25A sampling train is provided as Figure 2.

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.

All analyzers were calibrated in accordance with the procedures of Methods 3A, 7E, 10, and 25A.

### 4.b Recovery and Analytical Procedures

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

### 4.c Sampling Ports

All sampling took place at the engine exhaust ducts. The entire run time was spent in one of two exhaust ducts, with the sampling probe being switched between ducts at the halfway point of the test run (based on time, not sample volume). Readings from approximately three minutes of time required for switchover were removed from the BTEC analysis averages.

### 4.d Traverse Points

The exhaust ducts are 8.25 inches in diameter. The left exhaust duct[1] was traversed at three points across the duct for a total of 10 minutes each during each emissions test run. The right exhaust duct was sampled at a single point for thirty minutes during each emissions test run.

[1] The left duct is the duct on the left if facing the exhaust end of the generator.

## 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 3.

**Table 3**
**Western Michigan University**
**Sangren Hall Emergency Generator**
**Compliance Test Program Results Summary**

| Source | Pollutant | Test Result (ppmvd @15%/$O_2$) | Emission Limitation (ppmvd @15%/$O_2$) |
|---|---|---|---|
| GTA50 CC Generator Set | NOx | 15 | 160 |
| | CO | 65 | 540 |
| | VOC | 0 | 86 |

Note: The measured total hydrocarbon concentration, minus methane, was negative and, therefore, is reported as zero.

### 5.b Discussion of Results

Emission limitations are summarized by Table 2 (see Section 1.b). The results of the emissions test program are summarized by Table 3 (see Section 5.a). Detailed emissions test results are summarized by Tables 4, 5, and 6.

### 5.c Sampling Procedure Variations

No sampling procedure variations occurred during testing. It should be noted that, for portions of the first test run, outlet oxygen concentrations were elevated and nitrogen concentrations were slightly reduced. While the exact cause is unknown, it appears that the probe may have been sampling a small amount of ambient air during portions of the test run. However, it is clear that the emission rates from the engine were well below emission limitations during the entire emissions test program.

### 5.d Process or Control Device Upsets

No upset conditions occurred during testing.

### 5.e Control Device Maintenance

Preventative and corrective maintenance is performed per manufacturer recommendations.

### 5.f Audit Sample Analyses

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

### 5.g Calibration Sheets

All relevant equipment calibration documents are provided as Appendix B.

### 5.h Sample Calculations

Sample calculations are provided in Appendix C.

### 5.i Field Data Sheets

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

### 5.j Laboratory Data

All analysis was done live through the use of online Analyzers and as such there is no laboratory data. Raw analyzer data is provided in Appendix E.

**Table 4**
**Sangren Hall Emergency Generator Engine NOx, VOC, and CO Emission Rates - Generator Left Exhaust**
**Western Michigan University**
**Kalamazoo, Michigan**
**BTEC Project No. 14-4731.00**
**Sampling Date: 11/19/15**

| Parameter | Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|
| Test Run Date | 11/19/2015 | 11/19/2015 | 11/19/2015 | |
| Test Run Time | 8:49 - 9:19 | 10:17 - 10:47 | 11:41 - 12:11 | |
| Outlet Oxygen Concentration (%) | 0.4 | 0.3 | 0.3 | 0.32 |
| Outlet $O_2$ Concentration (ppmv, corrected as per USEPA 7E) | 0.0 | 0.0 | 0.0 | 0.01 |
| Outlet Oxides of Nitrogen Concentration (ppmv) | 40.41 | 54.78 | 63.36 | 52.85 |
| Outlet NOx Concentration (ppmv, corrected as per USEPA 7E) | 40.71 | 55.51 | 63.98 | 53.40 |
| **NOx Emission Rate (ppmvd@15% $O_2$)** | 11.5 | 15.7 | 18.0 | **15.1** |
| Outlet Carbon Monoxide Concentration (ppmv) | 211.79 | 255.81 | 243.86 | 237.15 |
| Outlet CO Concentration (ppmv, corrected as per USEPA 7E) | 207.84 | 253.67 | 238.03 | 233.18 |
| **CO Emission Rate (ppmvd@15% $O_2$)** | 58.8 | 71.7 | 67.1 | **65.85** |
| Outlet VOC Concentration (ppmv as propane) | 88.04 | 93.91 | 85.69 | 89.21 |
| Outlet Methane Concentration (ppmv as methane) | 210.33 | 230.09 | 216.81 | 219.08 |
| Outlet VOC Concentration (ppmv, corrected as per USEPA 7E) | 88.93 | 95.35 | 85.79 | 90.02 |
| Outlet Methane Concentration (ppmv, corrected as per USEPA 7E) | 211.24 | 233.50 | 218.56 | 221.10 |
| Outlet VOC Concentration (ppmv as Propane -Methane) | -2.1 | -5.3 | -8.4 | -5.3 |
| Exhaust Gas Mositure Content (% v/v) | 11.5 | 16.3 | 15.0 | 14.3 |
| Outlet VOC Concentration (ppmvd as Propane -Methane) | -2.4 | -6.3 | -9.9 | -6.2 |
| **VOC Emission Rate (ppmvd@15% $O_2$)** | -0.7 | -1.8 | -2.8 | **-1.8** |

response factor = 2.32

| O2 Correction | | | |
|---|---|---|---|
| Co | 0.32 | 0.30 | 0.32 |
| Cma | 10 | 10 | 10 |
| Cm | 10.01 | 10.09 | 10.15 |

| NOx Correction | | | |
|---|---|---|---|
| Co | 0.17 | 0.17 | 0.27 |
| Cma | 49.8 | 49.8 | 49.8 |
| Cm | 49 | 49 | 49.38 |

| CO Correction | | | |
|---|---|---|---|
| Co | 10.25 | 10.59 | 10.98 |
| Cma | 398 | 398 | 398 |
| Cm | 396 | 395 | 400 |

| VOC Correction | | | |
|---|---|---|---|
| Co | 0.57 | 0.72 | 0.02 |
| Cma | 248.8 | 248.8 | 248.8 |
| Cm | 245 | 244 | 248 |

| CH4 Correction | | | |
|---|---|---|---|
| Co | 0.61 | 0.68 | 0.31 |
| Cma | 448.2 | 448.2 | 448.2 |
| Cm | 446 | 441 | 444 |

ppmv = parts per million on a volume-to-volume basis
Co= Average of initial and final zero gases
Cma=Actual concentration of the calibration gas
Cm= Average of initial and final calibration gases

*Left Exhaust means the exhaust on the left side if facing the back of the generator set (i.e., the side closer to the exhaust pipes)

**Table 5**
**Sangren Hall Emergency Generator Engine NOx, VOC, and CO Emission Rates - Generator Right Exhaust**
**Western Michigan University**
**Kalamazoo, Michigan**
**BTEC Project No. 14-4731.00**
**Sampling Date: 11/19/15**

| Parameter | Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|
| Test Run Date | 11/19/2015 | 11/19/2015 | 11/19/2015 | |
| Test Run Time | 9:22 - 9:52 | 10:51 - 11:21 | 12:14 - 12:44 | |
| Outlet Oxygen Concentration (%) | 1.7 | 0.3 | 0.3 | 0.78 |
| Outlet $O_2$ Concentration (ppmv, corrected as per USEPA 7E) | 1.5 | 0.0 | 0.0 | 0.49 |
| Outlet Oxides of Nitrogen Concentration (ppmv) | 26.87 | 63.11 | 56.29 | 48.76 |
| Outlet NOx Concentration (ppmv, corrected as per USEPA 7E) | 27.01 | 63.97 | 56.81 | 49.27 |
| **NOx Emission Rate (ppmvd@15% $O_2$)** | 8.2 | 18.0 | 16.0 | **14.1** |
| Outlet Carbon Monoxide Concentration (ppmv) | 200.43 | 223.98 | 262.50 | 228.97 |
| Outlet CO Concentration (ppmv, corrected as per USEPA 7E) | 196.13 | 220.74 | 257.08 | 224.65 |
| **CO Emission Rate (ppmvd@15% $O_2$)** | 59.5 | 62.2 | 72.6 | **64.80** |
| Outlet VOC Concentration (ppmv as propane) | 86.70 | 77.35 | 89.19 | 84.41 |
| Outlet Methane Concentration (ppmv as methane) | 207.95 | 184.88 | 213.50 | 202.11 |
| Outlet VOC Concentration (ppmv, corrected as per USEPA 7E) | 87.57 | 78.40 | 89.30 | 85.09 |
| Outlet Methane Concentration (ppmv, corrected as per USEPA 7E) | 208.85 | 187.49 | 215.22 | 203.85 |
| Outlet VOC Concentration (ppmv as Propane -Methane) | -2.4 | -2.4 | -3.5 | -2.8 |
| Exhaust Gas Mositure Content (% v/v) | 11.5 | 16.3 | 15.0 | 14.3 |
| Outlet VOC Concentration (ppmvd as Propane -Methane) | -2.8 | -2.9 | -4.1 | -3.2 |
| **VOC Emission Rate (ppmvd@15% $O_2$)** | -0.8 | -0.8 | -1.2 | **-0.9** |

response factor = 2.32

| O2 Correction | | | |
|---|---|---|---|
| Co | 0.32 | 0.30 | 0.32 |
| Cma | 10 | 10 | 10 |
| Cm | 10.01 | 10.09 | 10.15 |

| NOx Correction | | | |
|---|---|---|---|
| Co | 0.17 | 0.17 | 0.27 |
| Cma | 49.8 | 49.8 | 49.8 |
| Cm | 49 | 49 | 49 |

| CO Correction | | | |
|---|---|---|---|
| Co | 10.25 | 10.59 | 10.98 |
| Cma | 398 | 398 | 398 |
| Cm | 396 | 395 | 400 |

| VOC Correction | | | |
|---|---|---|---|
| Co | 0.57 | 0.72 | 0.02 |
| Cma | 248.8 | 248.8 | 248.8 |
| Cm | 245 | 244 | 248 |

| CH4 Correction | | | |
|---|---|---|---|
| Co | 0.61 | 0.68 | 0.31 |
| Cma | 448.2 | 448.2 | 448.2 |
| Cm | 446 | 441 | 444 |

ppmv = parts per million on a volume-to-volume basis
Co= Average of initial and final zero gases
Cma=Actual concentration of the calibration gas
Cm= Average of initial and final calibration gases

*Right Exhaust means the exhaust on the right side if facing the back of the generator set (i.e., the side closer to the exhaust pipes)

**Table 6**
**Sangren Hall Emergency Generator Engine NOx, VOC, and CO Emission Rates**
**Western Michigan University**
**Kalamazoo, Michigan**
**BTEC Project No. 14-4731.00**
**Sampling Date: 11/19/15**

| Parameter | Run 1 | Run 2 | Run 3 | Average |
|---|---|---|---|---|
| Test Run Date | 11/19/2015 | 11/19/2015 | 11/19/2015 | |
| Test Run Time | 8:49 - 9:52 | 10:17 - 11:21 | 11:41 - 12:44 | |
| **NOx Emission Rate (ppmvd@15% $O_2$)** | 9.9 | 16.9 | 17.0 | **14.6** |
| **CO Emission Rate (ppmvd@15% $O_2$)** | 59.1 | 67.0 | 69.9 | **65.3** |
| **VOC Emission Rate (ppmvd@15% $O_2$)** | -0.8 | -1.3 | -2.0 | **-1.3** |

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

# FIGURES

BTEC Inc.

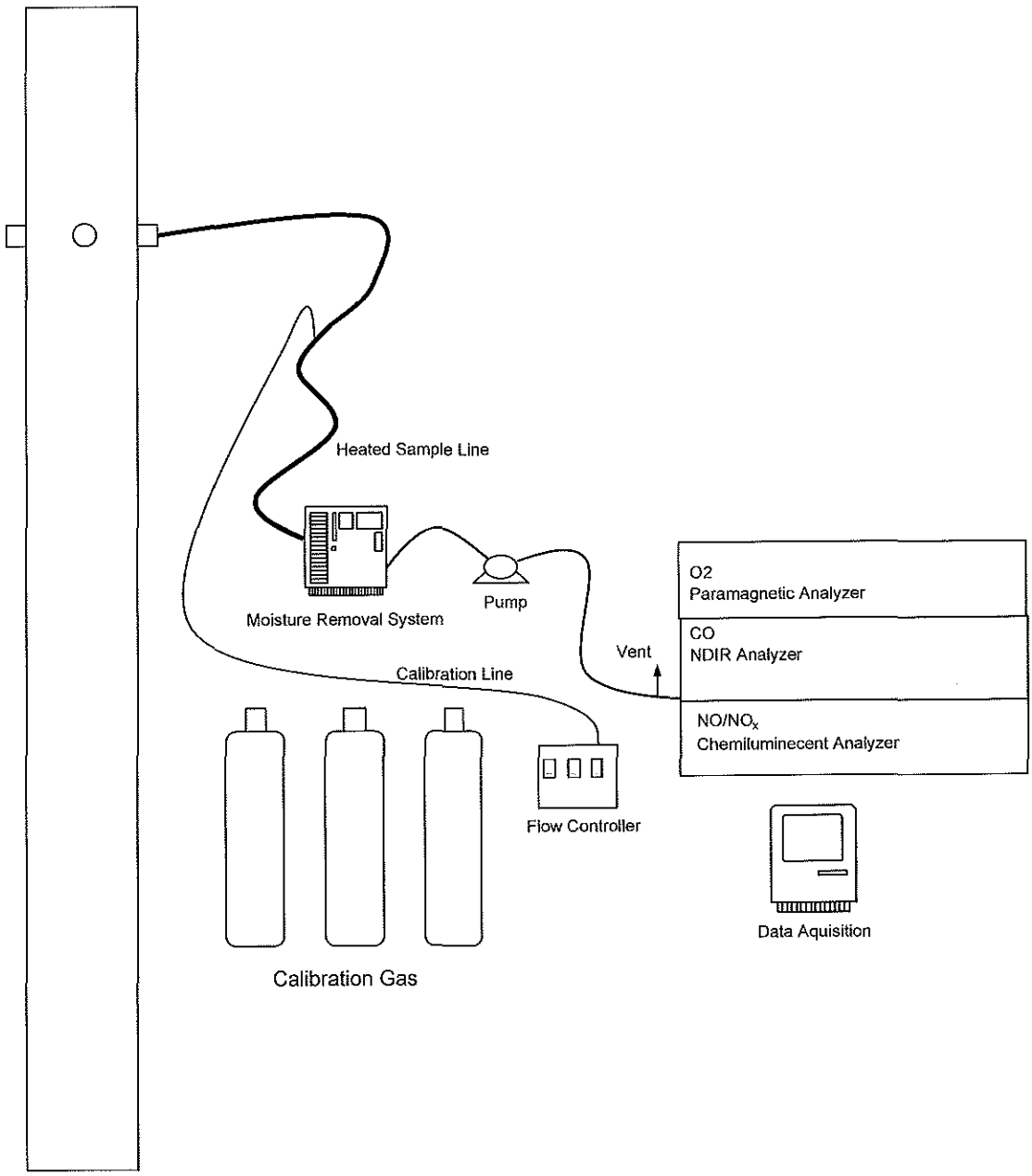


**Figure 1**

| Site: | Sampling Date: | |
|---|---|---|
| USEPA Method 3A/7E/10<br>Western Michigan University<br>Sangren Hall Emergency Generator Test | November 19, 2015 | BT Environmental Consulting Inc.<br>4949 Fernlee Avenue<br>Royal Oak, MI 48073 |

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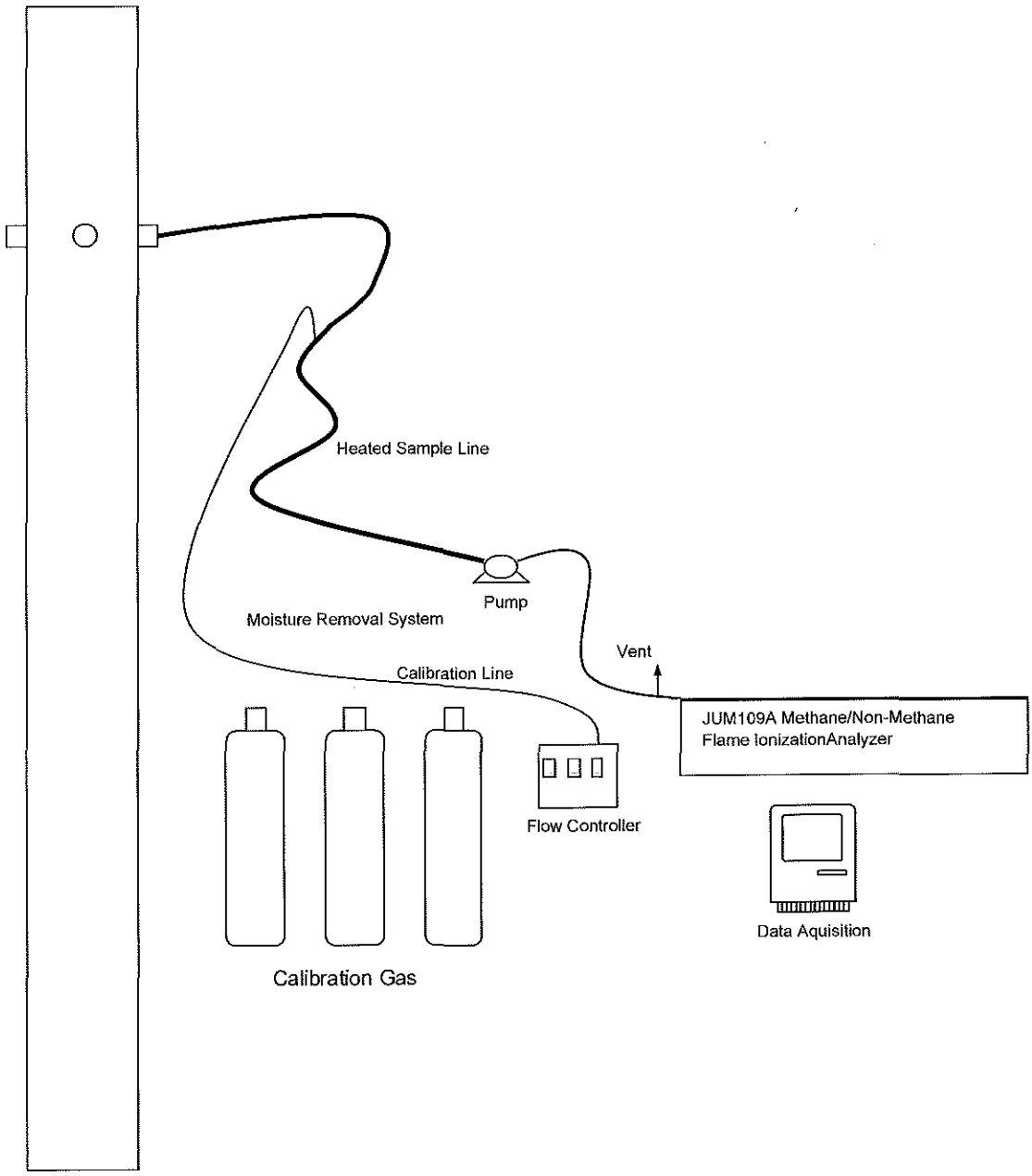


**Figure 2**

| Site: | Sampling Date: | |
|---|---|---|
| USEPA Method 25A<br>Western Michigan University<br>Sangren Hall Emergency Generator Test | November 19, 2015 | BT Environmental Consulting Inc.<br>4949 Fernlee Avenue<br>Royal Oak, MI 48073 |