# Report

## *Emissions Testing*
## *EUNGENGINE*
## *REO Town Combined Heat & Power Plant*
## *Test Date: July 29, 2013*

**Lansing Board of Water and Light**
**Lansing, Michigan**

**NTH Project No. 73-120004-60**
**September 18, 2013**

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ACEC MEMBER


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## 1.0 INTRODUCTION

NTH Consultants, Ltd. (NTH) was retained by Lansing Board of Water and Light (BWL) to conduct emissions testing for nitrogen oxides ($NO_x$), carbon monoxide (CO), particulate matter (PM), fine and coarse particulate matter ($PM_{10}$/$PM_{2.5}$), and volatile organic compounds (VOC) on a single natural gas-fired spark ignition reciprocating internal combustion engine (RICE) identified as EUNGENGINE in Michigan Department of Environmental Quality Permit to Install (PTI) No. 149-10B. EUNGENGINE is located at the REO Town Combined Heat and Power (CHP) plant located in Lansing, Michigan.

### 1.1 Purpose of Test

The testing was performed to demonstrate compliance with the emission standards for $NO_x$, CO, PM, $PM_{10}$, $PM_{2.5}$, and VOC pursuant to the requirements contained in PTI No. 149-10B. In addition, the testing was performed to demonstrate initial compliance with the emissions standards for $NO_x$, CO, and VOC pursuant to Subpart JJJJ to 40 CFR Part 60. Specifically, EUNGENGINE has not been certified by the manufacturer; therefore, an initial performance test is required.

### 1.2 Test Date

The testing was performed on July 29, 2013.

### 1.3 Project Contact Information

| Location | Address | Contact |
|---|---|---|
| Test Facility | REO Town CHP Plant<br>Lansing Board of Water and Light<br>1201 S. Washington Avenue<br>Lansing, Michigan 48910 | Ms. Angie Goodman<br>517-702-7059<br>ame1@lbwl.com |
| Test Company Representative | NTH Consultants, Ltd.<br>1430 Monroe Avenue NW, Suite 180<br>Grand Rapids, Michigan 49505 | Mr. Graziano Gozzi, QSTI<br>616-451-6262<br>ggozzi@nthconsultants.com |
| State Representative | Michigan Department of Environmental Quality<br>525 W. Allegan, Constitution Hall, 4th Floor N.<br>Lansing, Michigan 48909 | Mr. Tom Gasloli<br>517-335-4861<br>gaslolit@michigan.gov |

This test program was performed by Messrs. Graziano Gozzi, Kyle Daneff, and Tyler Hanna of NTH. Mr. Scott McQuiston and Ms. Angie Goodman of BWL coordinated the test events. Mr. Tom Gasloli of MDEQ observed the test event.

### 1.4 Summary of Results

Triplicate 60-minute test runs were performed for $NO_x$, CO, and VOC at the exhaust location of EUNGENGINE. $NO_x$ and CO concentrations were reported in parts per million by volume dry (ppmvd) and VOC concentrations in ppmv. The concentrations were then converted to grams per horsepower hour (g/hp-hr). Triplicate 120-minute test runs were performed for PM, $PM_{10}$, and $PM_{2.5}$. Testing was performed at maximum engine standby capacity of 1,345 kilowatts (kW) or approximately 1,803 horsepower (hp). The conversion to horsepower is shown below:

$$\text{Engine horsepower} = 1{,}345\ kW \times \frac{1.34\ hp}{kW} = 1{,}803\ hp$$

The comprehensive CO, $NO_x$, and VOC field data compiled during the test runs is located in Appendix E. Handwritten field data is contained in Appendix F, and results and calculations are contained in Appendix B. Additionally, laboratory data is contained in Appendix D. The average of the test results are shown in Table 1-1 below. Detailed results are presented in Tables 1 and 2 at the end of this report.

**Table 1-1. EUNGENGINE Emissions Test Results**

| Pollutant | Average Emissions | Permit Limit |
|---|---|---|
| $NO_x$ | 0.94 g/hp-hr | 0.5 g/hp-hr |
| CO | 2.21 g/hp-hr | 2.5 g/hp-hr |
| VOC | 0.90 g/hp-hr | 0.81 g/hp-hr |
| PM | 0.05 lb/hr | 0.12 lb/hr |
| $PM_{2.5}$ | 0.21 lb/hr | 0.13 lb/hr |
| $PM_{10}$ | 0.21 lb/hr | 0.13 lb/hr |

## 2.0 PROCESS DESCRIPTION

REO Town CHP is a combined-cycle, cogeneration facility consisting of two (2) natural gas-fired turbines (EUTURBINE1 and EUTURBINE2), two (2) heat recovery steam generators (HRSGs) with duct burners (EUHRSG1 and EUHRSG2), a steam turbine, a natural gas-fired auxiliary boiler (EUAUXBOILER), a four cell mechanical draft cooling tower (EUCOOLTWR), an emergency engine (EUNGENGINE), and other miscellaneous ancillary equipment. The turbines are equipped with HRSGs to produce steam from the turbine exhaust gas for use as process steam, or to power a steam turbine generator to produce electric power. The HRSGs are equipped with duct burners to provide supplemental heat for steam production. The auxiliary boiler serves as backup when a combustion turbine/HRSG is out of service and/or during periods of peak demand. The emergency engine will be used for emergency purposes.

## 3.0 REFERENCE METHODS AND PROCEDURES

The following U.S. EPA Reference Test Methods were performed for the emissions testing:

- **Method 1:** Sample and Velocity Traverses for Stationary Sources
- **Method 2:** Determination of Stack Gas Velocity and Volumetric flow rate (Type S Pitot tube)
- **Method 3A:** Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)
- **Method 4:** Determination of Moisture Content in Stack Gases
- **Method 5:** Determination of Particulate Matter Emissions from Stationary Sources
- **Method 7E:** Determination of Nitrogen Oxides Emissions from Stationary Sources
- **Method 10:** Determination of Carbon Monoxide Emissions from Stationary Sources
- **Method 25A:** Determination of Total Gaseous Organic Concentrations using a Flame Ionization Analyzer
- **Method 202:** Dry Impinger Method for Determining Condensable Particulate Emissions from Stationary Sources

## 3.1 Traverse Points

The number of traverse points for exhaust gas velocity and cyclonic air flow was determined in accordance with U.S. EPA Method 1. The cross-sectional inside diameter of the stack was measured, and based upon these values and availability of access ports, twelve (12) traverse points were selected for measuring the exhaust gas velocity, pressure, temperature and sampling. A schematic depicting traverse point locations are shown in Figure 1.

## 3.2 Velocity and Temperature

The exhaust gas velocity and temperature measurements were collected in accordance with U.S. EPA Reference Method 2. The exhaust stack differential pressure (delta P) was measured during each test run using an S-type Pitot tube connected to an appropriately sized inclined water column manometer at each pre-determined traverse point described in Section 3.1 above. Temperatures were recorded in conjunction with delta P determinations using a chromel/alumel "Type K" thermocouple and a temperature indicator.

## 3.3 Molecular Weight

The exhaust gas composition was determined using U.S. EPA Reference Method 3A. The oxygen and carbon dioxide concentrations were used to determine exhaust gas composition and molecular weight.

## 3.4 Moisture

The exhaust gas moisture content was determined for the engine using U.S. EPA Reference Method 4, as part of the U.S. EPA Method 5/202 sample apparatus. Exhaust gas was passed through a series of four impingers; the first two containing water, the third empty, and the fourth containing silica gel. The impingers were immersed in an ice bath to assure condensation of the flue gas stream moisture. The amount of water vapor collected was measured gravimetrically and used to calculate the moisture concentration (as %) in the exhaust gas.

## 3.5 Particulate Matter

Particulate matter (PM) samples were withdrawn isokinetically from the outlet following the guidelines of U.S. EPA Method 5. The sampling train for the Method 5 testing consisted of a nozzle, a heated probe, a heated 83 mm glass fiber filter, five (5) chilled impingers, and a metering console. The particulate samples were collected in the nozzle, and filters. At the conclusion of each test run, the filter was removed from the filter holder, visually inspected and placed into a separate petri dish, with the front half of the filter holder rinsed with acetone into a separate sample bottle. An acetone blank was collected during the times that the PM testing occurred.

At the laboratory, U.S. EPA Method 5 analytical procedures were used to analyze the samples for PM at the outlet. The acetone rinses were evaporated and desiccated to dryness, and the residue weighed to determine the amount of PM collected. The filters were also desiccated to remove the uncombined water and then weighed to determine the amount of PM collected. A diagram of the Method 5 sampling apparatus is appended in Figure 2.

### 3.6 Carbon Monoxide

The CO concentrations were measured using a non-dispersive infrared analyzer (NDIR) following the guidelines of U.S. EPA Reference Method 10. The analyzer was calibrated at a minimum of three points: zero gas, mid-level gas (40-60 percent of calibration span), and high-level gas (90 – 100 percent of span) for the testing.

### 3.7 Nitrogen Oxides

A chemiluminescence analyzer was used to measure concentrations of nitrogen oxides in the dry sample gas following the guidelines of U.S. EPA Method 7E. The analyzer measures the concentration of $NO_x$ by converting $NO_2$ to NO and then measuring the light emitted by the reaction of NO with ozone. The $NO_x$ sampling system was calibrated at three points: zero gas, mid-level gas (40-60 percent of span), and high range (90 – 100 percent of span) for the testing.

### 3.8 Volatile Organic Compounds

A Flame Ionization Analyzer (FIA) was used to measure concentrations of Volatile Organic Compounds in the sample gas following the guidelines of U.S. EPA Method 25A. The analyzer was calibrated at a minimum of four points: zero gas, low-level gas (25 – 30 percent of calibration span), mid-level gas (45 – 55 percent of calibration span), and high-level gas (90 – 100 percent of span) for the testing.

The total concentration of VOC is expressed in terms of propane utilizing the FIA. However, a large amount of methane is present in natural gas, and must be accounted for and subtracted from the total measured VOC concentration. Therefore, methane concentrations in the exhaust gas were determined by the analytical laboratory from a gas sample collected for each run. The result is then converted to propane, and subtracted from the total amount of VOC concentration measured for each test run.

The setup of the trailer and stack is shown in Figure 3.

### 3.9 Data Acquisition System

Information and data from each analog instrument signal output was collected with a STRATA® data acquisition system (DAS). Calibration error, drift and bias corrections were calculated automatically. All gathered data was linked to spreadsheets that support dynamic data exchange (i.e. Microsoft™ Excel) for quick data reduction and report generation.

### 3.10 Condensable Particulate Matter

The condensable particulate matter concentrations were determined by U.S. EPA Reference Method 202. The exhaust gases were extracted from the sample stream isokinetically through a heated glass lined probe, a glass coil type condenser, a dropout impinger and a modified Greenburg-Smith impinger with an open tube tip, a condensable particulate matter filter holder containing a Teflonc membrane filter, one impinger containing 100 mL of water and one impinger containing silica gel for moisture collection. All glassware used in the Method 202 sampling train was cleaned prior to testing according to method specifications. During the testing, the condensable particulate matter filter temperatures were monitored and maintained at the method appropriate temperatures through the use of a recirculation pump attached to the condenser, and chilled water surrounded the impinger apparatus. Figure 4 shows the Method 202 apparatus.

## 4.0 QUALITY ASSURANCE

Each promulgated U.S. EPA reference method described above is accompanied by a statement indicating that to obtain reliable results, persons using these methods should have a thorough knowledge of the techniques associated with each. To that end, NTH attempts to minimize any factors in the field that could increase error by implementing a quality assurance program into every testing activity segment.

The pitot tubes and thermocouples used to measure the exhaust gas during this test program were calibrated according to the procedures outlined in the *Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III, Stationary Source-Specific Methods,* Method 2, *Type S Pitot Tube Inspection,* and Calibration Procedure 2E *Temperature Sensor.*

U.S. EPA Protocol No. 1 gas standards were used to calibrate the $NO_x$, CO, VOC, $O_2$, and $CO_2$ analyzers during the test program. These gases are certified according to the *U.S. EPA Traceability Protocol for Assay & Certification of Gaseous Calibration Standards; Procedure G-1; September, 1997,* and are certified to have a total relative uncertainty of ±1 percent.

The DAS software in use during the testing is programmed to the specifications described in the applicable U.S. EPA Method in use during the test, and operates based on each pre-programmed analyzer span value.

## 5.0 DISCUSSION OF RESULTS

Operations at the EUNGENGINE appeared normal with no apparent problems. Note that engine warm-up did not occur prior to Run 1. Test results are tabulated and can be found in Tables 1 and 2 at the end of this section. Laboratory sample analysis data can be found in Appendix D. Process data was collected by BWL and can be found in Appendix C. QA/QC information in contained in Appendix G.

# TABLES

### Table 1

### Lansing BWL

### EUNGENGINE

### Summary of Particulate Matter Emissions - PM, $PM_{10}$, and $PM_{2.5}$

### July 29, 2013

| Run No. | 1 | 2 | 3 | Average |
|---|---|---|---|---|
| Run Time | 1055-1344 | 1424-1627 | 1710-1915 | |
| Process Conditions | | | | |
| Horsepower: | 1,803 | 1,803 | 1,803 | |
| Volumetric Flow Rates | | | | |
| Actual Cubic Feet Minute: | 10,854 | 10,743 | 11,161 | 10,919 |
| Standard Cubic Feet Minute: | 4,590 | 4,583 | 4,729 | 4,634 |
| Dry Standard Cubic Feet Minute: | 4,003 | 4,012 | 4,150 | 4,055 |
| Fixed Gases | | | | |
| Oxygen, % by volume, dry: | 8.86 | 8.86 | 8.92 | 8.88 |
| Carbon dioxide, % by volume, dry: | 4.03 | 4.01 | 4.30 | 4.12 |
| Moisture, % by volume: | 12.79 | 12.45 | 12.25 | 12.50 |
| Run No. | 1 | 2 | 3 | Average |
| **Emission Rate, (lb/hr):** | | | | |
| Filterable Particulate Matter (PM): | 0.07 | 0.05 | 0.03 | 0.05 |
| Condensable Particulate Matter (CPM): | 0.36 | 0.08 | 0.05 | 0.16 |
| Fine Particulate Matter ($PM_{2.5}$): | 0.43 | 0.12 | 0.09 | 0.21 |
| Coarse Particulate Matter ($PM_{10}$): | 0.43 | 0.12 | 0.09 | 0.21 |

lb/hr = pounds per hour

## Table 2

## Lansing BWL

## EUNGENGINE

## Summary of $NO_x$, CO, and VOC Emissions

## July 29, 2013

| Run No. | 1 | 2 | 3 | Average |
|---|---|---|---|---|
| Run Time | 1055-1344 | 1424-1627 | 1710-1915 | |
| Process Conditions | | | | |
| Horsepower: | 1,803 | 1,803 | 1,803 | |
| Volumetric Flow Rates | | | | |
| Actual Cubic Feet Minute: | 10,854 | 10,743 | 11,161 | 10,919 |
| Standard Cubic Feet Minute: | 4,590 | 4,583 | 4,729 | 4,634 |
| Dry Standard Cubic Feet Minute: | 4,003 | 4,012 | 4,150 | 4,055 |
| Fixed Gases | | | | |
| Oxygen, % by volume, dry: | 8.86 | 8.86 | 8.92 | 8.88 |
| Carbon dioxide, % by volume, dry: | 4.03 | 4.01 | 4.30 | 4.12 |
| Moisture, % by volume: | 12.79 | 12.45 | 12.25 | 12.50 |

| Run No. | 1 | 2 | 3 | Average |
|---|---|---|---|---|
| **Emission Rate, (g/hp-hr):** | | | | |
| Nitrogen Oxide: | 0.92 | 0.94 | 0.96 | 0.94 |
| Carbon Monoxide: | 2.19 | 2.19 | 2.26 | 2.21 |
| Volatile Organic Compounds (as propane): | 0.97 | 1.01 | 0.71 | 0.90 |

g/hp-hr = grams per horsepower-hour

# FIGURES

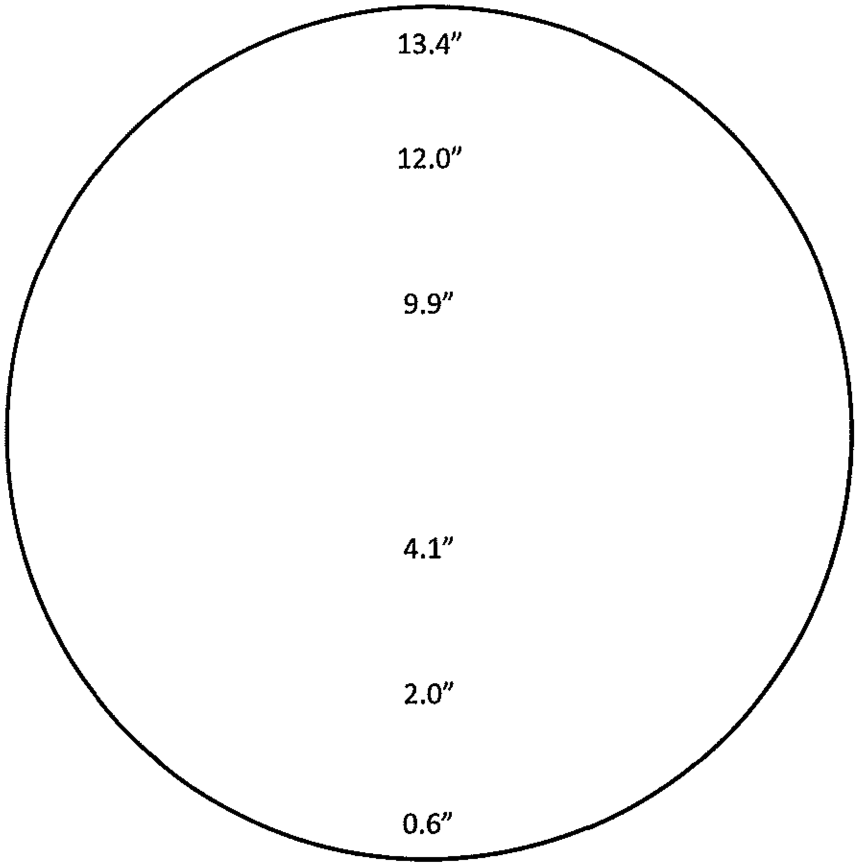
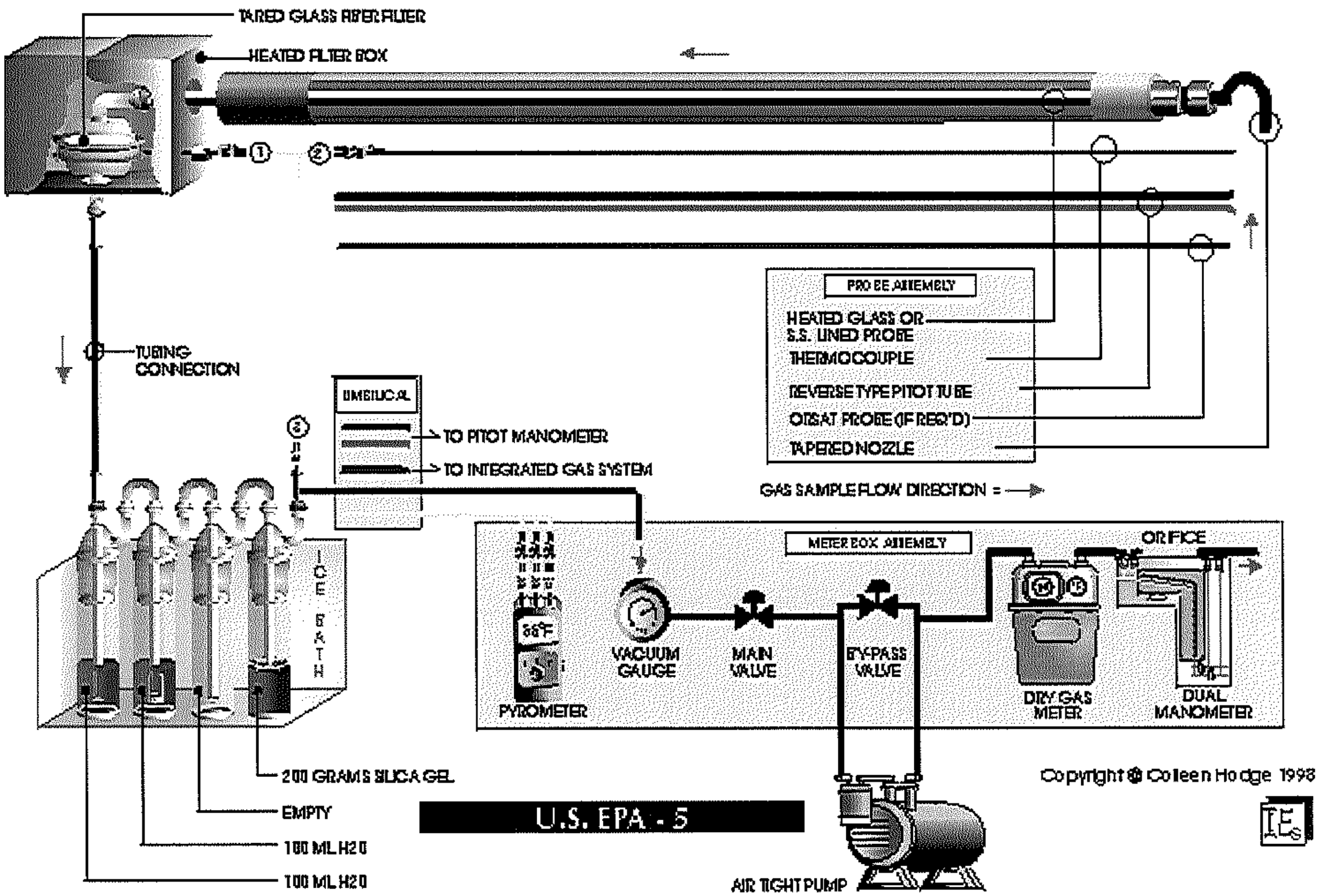



**Figure 1. Stack Point Locations**

**Lansing BWL REO Town EUNGENGINE**

Figure 2. U.S. EPA Method 5



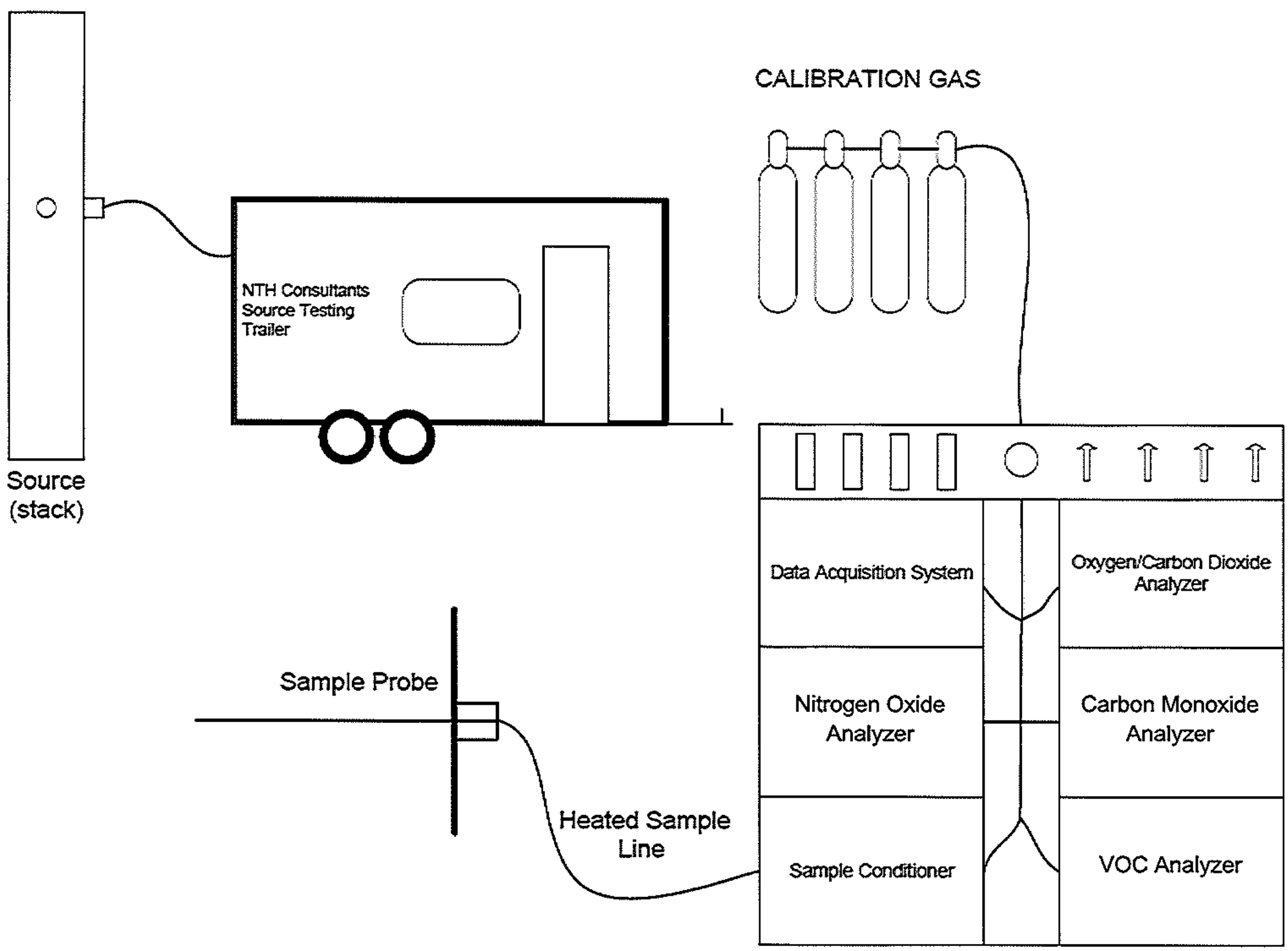



Figure No. 3
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Gas Composition/Volatile Organic
Compound Analyzers

Figure 4.  U.S. EPA Method 202