ENGINE PERFORMANCE TEST REPORT
MAY 2020

As Defined By

Title 40 Code of Federal Regulations Part 60, Subpart JJJJ & Michigan Renewable Operating Permit No. MI-ROP-N6207-2018 / MI-ROP-P0262-2012

RMCEINC Project #2021-22010

BLUE WATER RENEWABLES, LLC.
SMITHS CREEK, MICHIGAN

TWO (2) INSTALLED LFG-FIRED CATERPILLAR 3520 INTERNAL COMBUSTION ENGINES
(Source ID-Name: EU-ICENGINE1-BWR2 & EU-ICENGINE2-BWR2 (2,233 BHP))

STATE REGISTRATION No.: N6207
RENEWABLE OPERATING PERMIT No: MI-ROP-N6207-2018

Test Date:
FEBRUARY 25TH, 2021

PREPARED FOR:

BLUE WATER RENEWABLES, LLC.

BY:

RMC ENVIRONMENTAL, INC. – CHICAGO REGIONAL OFFICE

N6207_test_20210225_1

REPORT CERTIFICATION

The sampling, analysis, and data collection performed for this report were carried out under my direction and supervision, and I hereby certify that the test report is authentic and accurate, to the best of my knowledge.

Date 3/17/2021 Signature

Rachel Chleborowicz, QSTI
Senior Project Manager
RMC ENVIRONMENTAL, INC.

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1.0 PROJECT INFORMATION

1.1 Facility Information

Name and Address: Blue Water Renewables, LLC.
Smiths Creek Landfill
6779 Smiths Creek Road
Smiths Creek, MI 48074

Contact: Mr. Rob Sanch.
Telephone Number/E-mail: 734-834-4117 / robert.sanch@dteenergy.com

1.2 Testing Firm Information

Name and Address: RMC ENVIRONMENTAL, INC.
9226 North 2nd Street
Machesney Park, Illinois 61115

Contact: Rachel Chleborowicz
Telephone Number: 815-378-6150 Mobile 815-425-1102 Fax
E-Mail Address: RMCE@AirMonitoring.com / RMCEInc@aol.com

1.3 Test Information

Test Requested By: Blue Water Renewables, LLC.
Test Coordinator: Rob Sanch, Blue Water Renewables, LLC.
734-834-4117

Test Objective: Subsequent Performance Testing of Two LFG-Fired Engines in accordance with: Title 40 CFR Part 60, Subpart JJJJ and the Michigan State Operating Permit.

Test Parameters: NOx, CO, VOC & HCl (Fuel Analyses)
Test Methods: EPA Methods 1, 2, 3A, 4, 3A, 7E, 10, 19 and 25A/18

Test Date: **February 25, 2021**

Agency Personnel: Mr. Mark Dziadosz Michigan EGLE, Air Quality Division

Test Personnel: Rachel Chleborowicz RMCEInc
Andrew McDermand RMCEInc

Laboratory Analysis: Saybolt Laboratories (Core Labs) & Analytical Solutions

2.0 SOURCE IDENTIFICATION

Name and Address: Blue Water Renewables
6779 Smiths Creek Road
Smiths Creek, MI 48078

Facility SRN: N6207

Air Permit: MI-ROP-N6207-2018 (Issued to Blue Water Renewables, LLC)
FG-ICENGINES: EU-ICENGINE1-BWR2 & EU-ICENGINE2-BWR2

Sources Tested:

Engine#	Model	Serial Number	Rated Capacity
1	CAT 3520	GZJ00493	2233 bhp / 1600 kW
2	CAT 3520	GZJ00491	2233 bhp / 1600 kW

Fuel: Treated Landfill Gas
Duct Dimensions: Height 12' ID – ~15.5"
Sampling Location: ~ 52" Downstream and ~ 42" Upstream from any flow disturbance

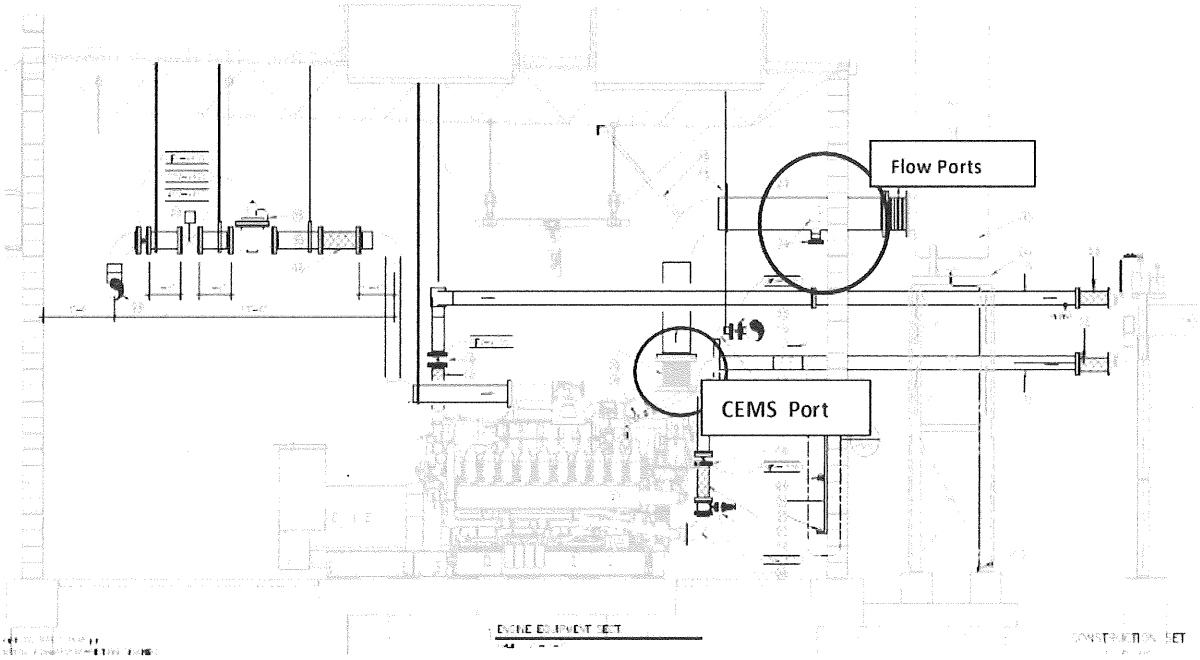
2.1 Facility Description, Process Information, and Emission Source Description

The Blue Water Renewables, LLC. operates a landfill gas-to-energy facility that uses landfill gas (LFG) collected from the Smiths Creek Landfill to generate electric power. The Facility is authorized under MI-ROP-N6207-2018 to operate two (2) landfill gas-fired 2,233 hp internal combustion (IC) engines (EU-ICENGINE1-BWR2 & EU-ICENGINE2-BWR2). LFG delivered to the engine is first routed to a treatment system that processes the collected gas for subsequent use. The pretreatment system includes de-watering and compression of the gas and filtering through a coalescing filter.

The Caterpillar G3520C engine is a four-stroke, lean-burn, reciprocating internal combustion engine fueled by treated LFG. The engine gensets have engine power ratings of 2,233 hp at 100% load, and generator power ratings of 1,600 kW. Testing will be conducted while the units are operated at the maximum normal load of 1,600 kW (+/- 10%).

A schematic of the engine and stack information is provided in **Figure 2.1**. These and all measurements provided before the test team arrived on site were verified.

Figure 2.1-1 – Engine Schematic / Diagram.



Stack Information

	Blue Water Renewables – Engines
Shape of the test plane	Round
Internal diameter	~15"
Reference Flow Sampling Ports (Est. Offset from North)	45° & 135°

An EPA Method 1 data sheet for the engines is included in **Figure 5.1-1**. These and all measurements were verified on-site and are included in the appendices to this report.

3.0 SUMMARY AND DISCUSSION OF RESULTS

Testing of the landfill gas-fired engines was conducted to satisfy the following requirements:

- 40 CFR 60, Subpart JJJJ (New Source Performance Standards for Spark Ignition Internal Combustion Engines), which requires each engine to complete subsequent performance tests every 8,760 hours of engine operation or three (3) years, whichever comes first, to demonstrate ongoing compliance with NOx, CO and VOC emission limits.

The engine performance tests were completed on **February 25, 2021**, within 8,760 hours of the previous tests as detailed in **Table 3-1**.

Table 3-1. Test Dates and Engine Hours

Engine #	Engine SN:	Current Test	
		Test Date	Engine Hours
1	GZJ00493	2/25/2021	77,889
2	GZJ00491	2/25/2021	77,293

Test results and applicable emission limits are summarized in **Table 3-2** and **Table 3-3**. The emission rates are reported as the arithmetic average of all valid test runs conducted on each engine. The data is representative of the emissions from these engines while each was operated at maximum load of 1,600 kW (+/- 10%). Test results demonstrate compliance with Subpart JJJJ and Title V emission limits for NO_x, CO, and VOC.

Table 3-2. Engine Performance Test Results

Parameter	Result[1]	Emission Limit (Specification)
Engine #1 – 2/25/21 SN: GZJ00493		
NOx	0.6 3.0	2.0 g/HP-Hr (40CFR60, Subpart JJJJ) 3.0 lb/Hr (R336.1225)
CO	2.7 13.21	5.0 g/HP-Hr (40CFR60, Subpart JJJJ) 16.3 lb/Hr (R336.1205)
VOC[2]	0.2	1.0 g/HP-Hr (40CFR60, Subpart JJJJ)
Engine #2 – 2/25/21 SN: GZJ00491		
NOx	0.5 2.6	2.0 g/HP-Hr (40CFR60, Subpart JJJJ) 3.0 lb/Hr (R336.1225)
CO	2.2 10.65	5.0 g/HP-Hr (40CFR60, Subpart JJJJ) 16.3 lb/Hr (R336.1205)
VOC[2]	0.2	1.0 g/HP-Hr (40CFR60, Subpart JJJJ)

[1]The procedures and calculations outlined in 40 CFR 60.4244 were followed for this test project.
[2] As Propane

TABLE 3-3. HYDROCHLORIC ACID (HCL) EMISSIONS

Parameter	Result[1]	Emission Limit
Engine #1		
Fuel Chlorine Content Fuel Flow Rate HCl (lb/Hr) Calculated	7.8 ppm 539 scfm 0.02 lb/Hr	 0.51 lb/Hr R336.1225
Engine #2		
Fuel Chlorine Content Fuel Flow Rate HCl (lb/Hr) Calculated	7.3 ppm 517 scfm 0.02 lb/Hr	 0.51 lb/Hr R336.1225

[1]Average HCl content of LFG (7.8/7.3 ppmv) is based on data from the Net Heating Value and Chlorine Analysis Report (March 2021) and the fuel flow rate to the engines obtained during the Performance testing.

Reference test data are enclosed in **Appendices A & B**. The corresponding process data and parameters consisting of electrical production rate (kW), engine fuel flow rate (scfm), engine operating temperatures/pressures and fuel sample analyses are included in **Appendix D**.

4.0 POLLUTANTS AND TEST METHODS

Pollutant Tested:	NO_x	EPA Method 7E – Title 40 CFR 60, Appendix A
	CO	EPA Method 10 – Title 40 CFR 60, Appendix A
	VOC/NMOC	EPA Method 25A/18 – Title 40 CFR, 60 Appendix A

5.0 TEST PROCEDURES

Engine performance testing was conducted in accordance with 40 CFR 60, Subpart JJJJ and the current Operating Permit. The engine performance tests followed the methods and procedures proposed in the test protocol submitted to Michigan Department of Environment, Great Lakes and Energy (EGLE) on **January 15, 2021** and the requirements detailed in the test protocol review letter dated **February 10, 2021**. Testing consisted of three, separate, one-hour test runs for each engine performance test. The engine tests were conducted while each unit operated at maximum capacity of 1,600 kW (+/- 10%). Testing was conducted in accordance with EPA Test Methods 1, 2, 3A, 4, 7E, 10 and 25A/18 defined in Title 40 CFR Part 60, Appendix A as described in the following sections.

The following process data was monitored and recorded at 15-minute intervals during each test and is presented in **Appendix D**:

- Calculated LFG flow to the engine (CFM)
- Engine load (HP) and electrical production rate (kW)
- Oxygen content at engine inlet (%)
- Methane content of the LFG at inlet (%)

Engine output (HP) cannot be measured directly. Therefore, it is calculated based on recorded kW output and a ratio of design HP rating of the engine to kW rating of the generator.

Engine output (HP) = Electricity Output (kW) x Engine HP Rating ÷ Generator kW Rating.
Engine HP = Electricity Output (kW) x 2,233 HP ÷ 1,600 kW

5.1 Sampling Procedures

The test program included the measurement of exhaust gas concentrations of NOx, CO, VOC/NMOC and O_2. RMCEINC used the procedures that conform to the requirements of Title 40 CFR Part 60, Appendix A, Methods 1, 2, 3A, 4, 7E, 10 and 25A/18. Each of the three test runs included a minimum of one hour of continuous flue gas sampling.

Concentration measurements of NOx, CO, VOC/NMOC and O_2, were recorded using the analyzers listed in **Table 5.1-1. Figure 5.1-1** is an EPA Method 1 data sheet for the engines. **Figure 5.1-2** is a schematic of the wet/dry extractive reference measurement gas sampling system used by RMCEINC. All components of the sampling system that contact the sample are stainless steel, glass, or Teflon.

RMCEINC used a standard probe sampling system. The manual sampling probe used was un-heated stainless-steel tubing with a 3-way valve to provide a means of conducting the three-point traverse and calibration checks. The probe assembly was constructed of Type 316 stainless steel. At the Northwest Regional Landfill, the stack temperature is over 800 degrees and the probe was not externally heated due to that excessive heat. A length of heated Teflon tubing, heated to over 450^{O} F, was connected to the probe and to a moisture removal chiller.

Before the moisture removal system, a portion of the wet effluent was diverted to the THC analyzer. This analyzer requires the sample to be unconditioned which allows for the full THC concentration in the sample to be analyzed. In order to obtain VOC / NMOC (Non-Methane Organic Carbon) concentrations, an onsite, inline GC measured the methane concentrations real-time. The methane concentration was then subtracted from the THC concentration to provide an NMOC result.

TABLE 5.1-1 REFERENCE METHOD ANALYZERS

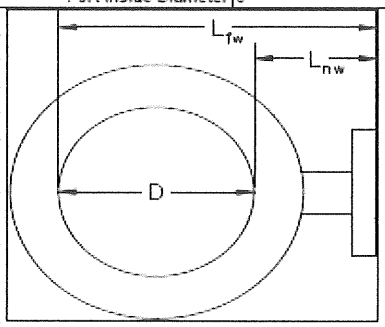
Parameter	Analyzer	Analytical Technique	Instrument Span
NOx	Thermo Environmental Model 42i	Chemiluminescence	0-250 ppm
CO	Thermo Environmental Model 48i	Gas Filter Correlation	0-1000 ppm
VOC	VIG Industries – Model 20/2	Flame Ionization Detection	0-1000 ppm
Methane	VIG Industries - Model 200	Gas Chromatogram	0-3.300 ppm
O_2	Servomex 1440	Paramagnetic	0-21 %

Figure 5.1-1. Engines 1& 2 - Method 1 – Verified

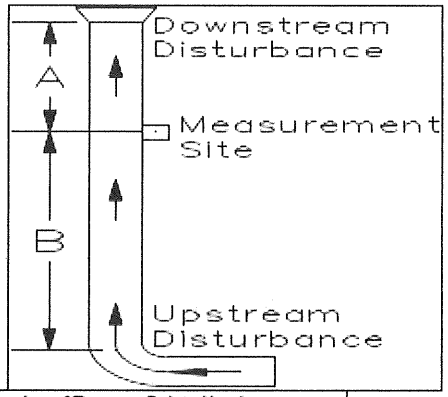
METHOD 1 - SAMPLE AND VELOCITY TRAVERSES FOR CIRCULAR SOURCES

Plant Name	Blue Water Renewables	Date	02/25/21
Sampling Location	Engines 1 & 2	Project #	2021-22010
Operator	AMD	# of Ports Available	2
Stack Type	Circular	# of Ports Used	2
Stack Size	Small	Port Inside Diameter	3

Circular Stack or Duct Diameter			
Distance to Far Wall of Stack	(L_{fw})	28.00	in
Distance to Near Wall of Stack	(L_{nw})	13.00	in
(=Lfw - Lnw) Diameter of Stack	(D)	15.00	in
(=3.14(D/2)^2)) Area of Stack	(A_s)	1.23	ft^2



Distance from Port to Disturbances			
Distance Upstream	(B)	58.00	in
(=B/D) Diameters Upstream	(B_D)	3.87	diameters
Distance Downstream	(A)	64.00	in
(=A/D) Diameters Downstream	(A_D)	4.27	diameters



Number of Traverse Points Required			
Diameters to Flow Disturbance		Minimum Number of[1] Traverse Points	
Up Stream	Down Stream	Particulate Points	Velocity Points
2.00-4.99	0.50-1.24	24	16
5.00-5.99	1.25-1.49	20	16
6.00-6.99	1.50-1.74	16	12
7.00-7.99	1.75-1.99	12	12
>= 8.00	>=2.00	8 or 12[2]	8 or 12[2]
Upstream Spec		24	16
Downstream Spec		8	8
Traverse Pts Required		24	16

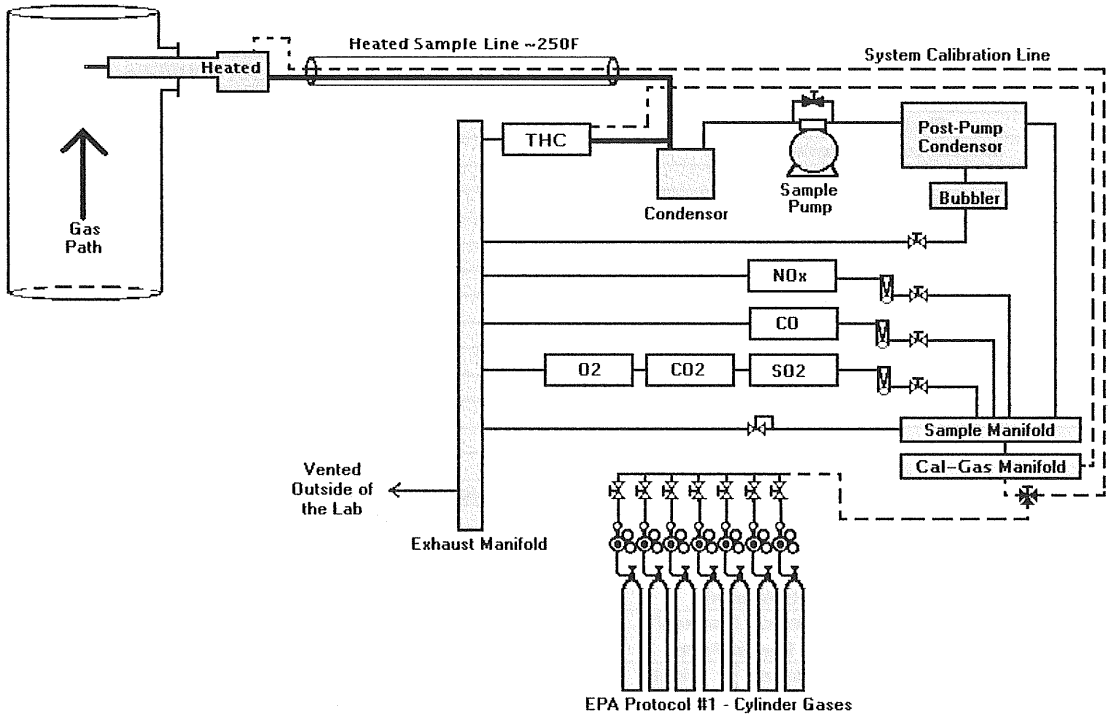
[1] Check Minimum Number of Points for the Upstream and Downstream conditions, then use the largest.
[2] 8 for Circular Stacks 12 to 24 Inches
12 for Circular Stacks over 24 Inches

Number of Traverse Points Used			
2	Ports by	8	Across
16	Pts Used	16	Required
	Particulate	☒	Velocity

Location of Traverse Points in Circular Stacks						
Traverse Point Number	(Fraction of Stack Diameter from Inside Wall to Traverse Point) Number of Traverse Points on a Diameter					
	2	4	6	8	10	12
1	.146	.067	.044	.032	.026	.021
2	.854	.250	.146	.105	.082	.067
3		.750	.296	.194	.146	.118
4		.933	.704	.323	.226	.177
5			.854	.677	.342	.250
6			.956	.806	.658	.356
7				.895	.774	.644
8				.968	.854	.750
9					.918	.823
10					.974	.882
11						.933
12						.979

Traverse Point Locations			
Traverse Point Number	Fraction of Stack Diameter	Distance from Inside Wall	Distance Including Nipple Length
		in	in
1	0.032	4/8	13 4/8
2	0.105	1 5/8	14 5/8
3	0.194	2 7/8	15 7/8
4	0.323	4 7/8	17 7/8
5	0.677	10 1/8	23 1/8
6	0.806	12 1/8	25 1/8
7	0.895	13 3/8	26 3/8
8	0.968	14 4/8	27 4/8
9			
10			
11			
12			

Figure 5.1-2. Reference Method Gas Sampling System Diagram



5.2 Instrumental Analytical Data

RMCEINC performed test runs to measure the flue gas for VOC/NMOC, NO_x and CO in terms of an emission rate (g/HP-Hr). A three-point (zero, mid-range, and high-range) analyzer calibration error check was performed on each reference analyzer before initiating the testing. This check was conducted after final calibration adjustments were made by injecting the calibration gases directly into each gas analyzer and recording the responses on the reference data acquisition system (DAS).

A three-point stratification check was conducted prior to the first test run of each engine. The stratification check was performed at three points on a line passing through the centroidal area of the stack, spaced at approximately 16.7%, 50% and 83.3% of the measurement line. The sample duration was 20 minutes at each check point (which satisfied the requirement to sample a minimum of twice the system response time).

RMCEINC conducted zero and upscale calibration checks both before and after each test run in order to quantify measurement system calibration drift and sampling system bias. Upscale was either the low-, mid- or high-range gas, whichever most closely approximated the flue gas level. During these checks, the calibration gases were introduced into the sampling system through a 3-way valve assembly at the probe outlet so that the calibration gases were analyzed in the same manner as the flue gas samples.

RMCEINC recorded the reference analyzer measurements as 1-minute and 60-minute averages on its DAS. All test run concentration results were determined from the average gas concentrations measured during the run and adjusted based on the zero and upscale sampling system bias check results (Equation 7E-1 presented in Title 40 CFR Part 60, Method 7E, Section 8). The reference VOC/NMOC, CO and NO_x emission values in terms of pounds per hour (lb/Hr) and grams per horsepower-hour (g/HP-Hr) were computed from each test run average of adjusted, dry basis VOC/NMOC, CO, NO_x and percent O_2 using the Title 40 CFR Part 60 Appendix A, Methods 1- 4 and Method 19.

An NO_2 to NO conversion efficiency test was performed before the performance test in accordance with EPA Test Method 7E. Result of the conversion efficiency test are provided in **Appendix C**

The inlet methane and organic chloride (as HCl) concentrations and fuel analyses conducted by Analytical Solutions Laboratories and Saybolt, respectively. This data is presented in **Appendix B and D**, along with the other process parameters collected during the test runs.

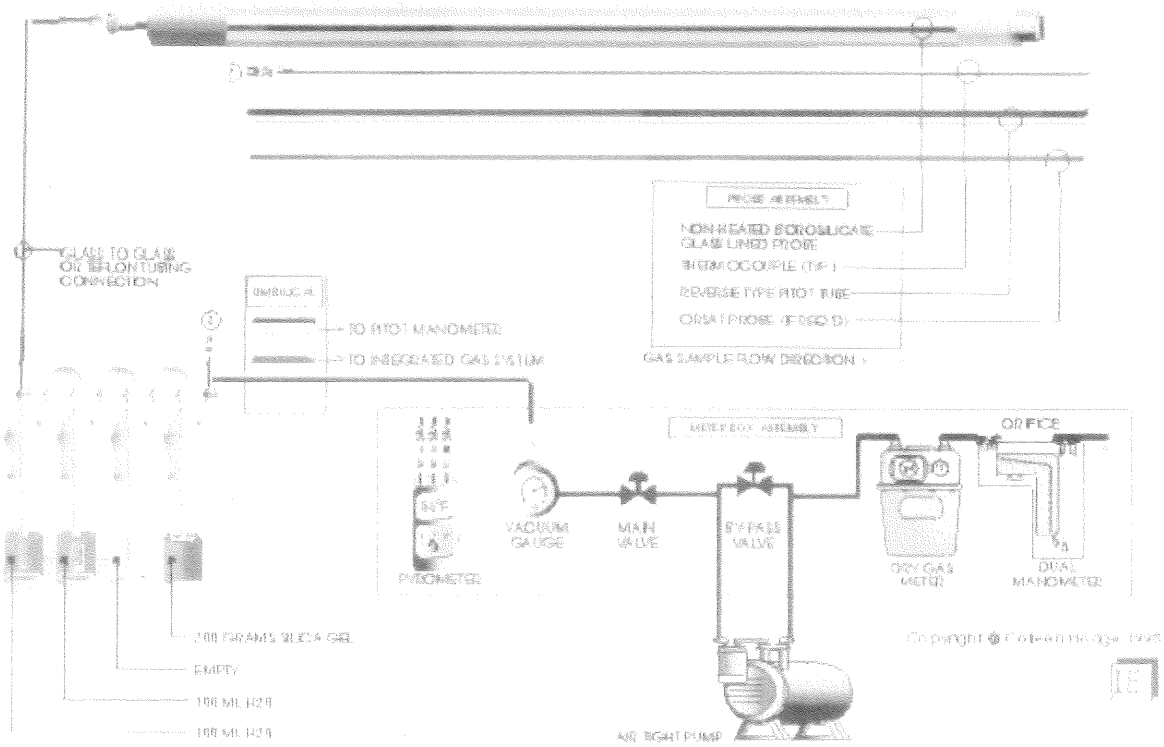
5.3 Volumetric Flow Rates

RMCEINC determined the number and location of the traverse points for volumetric flow rate measurement according to the procedures outlined in EPA Method 1. When determining the location and number of sample points, RMCEINC took into account the number of sample ports, duct configuration, and location of upstream and downstream flow disturbances. **Figure 5.1-1** presents the EPA Method 1 data sheets for the engines. **Figure 5.3-1** is an illustration of the sampling train used for the flowrate and moisture sampling.

The flue gas velocity and volumetric flow rate were determined according to the procedures of EPA Method 2. A Type S pitot tube with a Type K thermocouple was used to measure velocity pressure and stack gas temperature at each sample point. Each Pitot tube conformed to the geometric specifications of EPA Method 2 and was assigned a coefficient of 0.84. An umbilical cord connected the Pitot tube to the digital anemometer or oil manometer and digital temperature readout. RMCEINC leak-checked the Pitot tube prior to and after conducting the flow rate traverses.

RMCEINC determined the flue gas composition and molecular weight using EPA Methods 3A and 4 procedures. Flow rates and moisture content were measured simultaneously with the pollutant test runs. Each moisture run was one (1) hour in duration. Flow rate determination and moisture raw data sheets are included in **Appendix B.**

Figure 5.3-1 – EPA Methods 1-4 Sampling Train Schematic / Diagram



5.4 Fuel Analysis Testing (EPA Method 19)

Gas bombs (small, Sulfinert®-coated, stainless steel pressure vessels) were collected to determine heating value (btu/cf), methane, oxygen, carbon dioxide, nitrogen and sulfur content of the inlet landfill gas. Lab results were used to determine an F-Factor (dscf/MMBtu) for the site. ASTM Method D-6667 was used to determine the sulfur & chlorine content of the fuel. The raw gas analysis data is included in **Appendix B & D.**

6.0 EQUIPMENT CALIBRATION AND QUALITY ASSURANCE

RMCEINC followed the calibration and quality assurance procedures of EPA Methods 1, 2, 3A, 4, 7E, 10, 19 and 25A/18 throughout the test program. The maintenance for our meterboxes, probes, analyzers and a majority of our other test equipment is performed off site by either Clean Air Engineering or Millennium Instruments. These

companies ensure that our equipment is operating correctly and within the specification of the respective methods. All equipment is calibrated in accordance with the EPA Methods and guidelines.

The results of sampling system bias and calibration drift tests for each test run are calculated and presented in the test report. Cylinder gases used during the testing are certified to meet or exceed EPA Protocol 1 requirements. The meter box calibrations, pitot tube inspections, calibration gas certificates of analysis and the analyzer quality assurance checks are included in **Appendix C**.

RMCEINC uses computers throughout the test program. Spreadsheets and software programs are checked in our office for accuracy. Software used by RMCEINC is structured to eliminate human errors in data entry where possible by automating the process. When possible, RMCEINC inputs field data directly into the DAS system and eliminates the hand-written field data sheets. These systems provide an accurate measurement of the raw test data and are not used to modify or change test data in any manner. Equations used in these systems are taken directly from the CFR when possible, and notations are provided if they originated from an alternate source or were customized in any manner.