2009 Report

Landfill Gas-to-Energy Engine Testing
Waste Management Disposal Services of Maine, Inc.

Prepared for

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TRC Project No. 168156.0000.0000
September 2009

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1.0 INTRODUCTION

Waste Management Disposal Services of Maine, Inc. (WMDSM) has retained TRC Environmental Corporation (TRC) of South Portland, Maine to perform landfill gas (LFG) engine emissions testing at the Crossroads Landfill in Norridgewock, Maine. The purpose of this program is to demonstrate compliance with the Maine DEP license #A-816-77-1-A, Amendment #1 issued July 11, 2008.

WMDSM has recently installed two engine generator units as part of a landfill gas-to-energy (LFGTE) project. TRC was contracted to perform triplicate 60-minute tests for emissions of particulate matter (PM), oxides of nitrogen (NO_x) and carbon monoxide (CO) at each of the two Caterpillar G3520C engines.

All testing took place on September 3, 2009. **Table 1-1** presents the applicable contact information for this program.

Table 1-1
Contact Information

WMDSM, Norridgewock	Mr. Sherwood McKenney	(207) 634-2714 x-223
Maine DEP, Augusta	Mr. Bob Hartley, P.E.	(207) 287-7644
TRC Test Coordinator	Mr. Kirk Laakso	(860) 298-9692
TRC Project Manager	Mr. Edward Bennett	(207) 772-3333 x-12

Table 1-2 presents the applicable emissions limits for each engine.

Table 1-2
Emissions Limits for Engine #1 and #2

PM	0.05 lb/MMBtu 0.85 lb/hr
NO_x	0.6 g/bhp-hr
CO	4.2 g/bhp-hr

The summary of results is presented in Section 2.0 of this report. Section 3.0 provides a description of the pertinent source and associated control equipment. Section 4.0 describes the sampling and analytical methodologies that were utilized and Section 5.0 outlines TRC's quality assurance procedures.

2.0 SUMMARY OF RESULTS

TRC conducted triplicate 60-minute tests for emissions of PM, NO_x and CO at the exhaust sample locations for engine #1 and #2. Testing was conducted in accordance with EPA Method 5, 7E and 10 as presented in Chapter 40 of the Code of Federal Regulations, Part 60 (40CFR60), Appendix A. All results demonstrated compliance with WMDSM's air license requirements.

Table 2-1 presents the results from Engine #1.

Table 2-1
Engine #1 Emissions Results

Test #:	1	2	3	Average	Limit
Date:	9/3/09	9/3/09	9/3/09	--	--
Time:	0730-0838	0850-1000	1002-1108	--	--
PM (lb/MMBtu):	0.003	0.002	0.002	0.002	0.05
PM (lb/hr):	0.02	0.01	0.01	0.01	0.85
CO (g/bhp-hr):	2.7	2.7	2.7	2.7	4.2
NO_x (g/bhp-hr):	0.5	0.5	0.5	0.5	0.6

Table 2-2 presents the results from Engine #2.

Table 2-2
Engine #2 Emissions Results

Test #:	1	2	3	Average	Limit
Date:	9/3/09	9/3/09	9/3/09	--	--
Time:	1133-1240	1245-1352	1358-1506	--	--
PM (lb/MMBtu):	0.002	0.002	0.002	0.002	0.05
PM (lb/hr):	0.01	0.02	0.02	0.02	0.85
CO (g/bhp-hr):	2.6	2.8	2.8	2.7	4.2
NO_x (g/bhp-hr):	0.4	0.4	0.4	0.4	0.6

3.0 PROCESS DESCRIPTION

The Landfill Gas to Energy facility was recently constructed and became fully operational on March 9, 2009. The facility diverts landfill gas from the Phase 8/9 and 11/12 flares to two internal combustion reciprocating engine generator units. The Phase 8, 9, 11, and 12 Secure Landfills were designed to accept special waste, Construction Demolition Debris, and MSW. In addition, over 1 million cubic yards of relocated waste was removed from the previously existing MSW Landfill and placed within Phase 8. Phase 8 is currently active and is approximately 50 acres in size with a design capacity of approximately 4.5 million cubic yards.

The Phase 8, 9, 11, and 12 landfills are equipped with an active landfill gas collection and control system. As waste is placed into the active areas, horizontal gas collector pipes are placed within the waste at select intervals, based on the radius of influence of the individual collector pipes, in order to convey the gas to the two reciprocating engine generator units. In addition, extraction wells are installed at locations that are at or approaching final waste grades.

Engines #1 and #2 are each Caterpillar G3520C 1,600 KW engine-generator units that are rated for 17.6 MMBtu/hr while firing landfill gas comprised of approximately 50% methane. Flares #1 and #3 are used as backup landfill gas control devices, or to operate simultaneously with the engines as necessary. Each engine is rated at 80.4% efficiency.

Heat input (MMBtu/hr) is determined by the facility's ABB Total Flow model NGC8203 gas analyzer. The unit was calibrated at start up (3-9-09). On 8-20-09 the analyzer was set-up to calibrate weekly.

3.1 Process Monitoring

During testing, WMDSM recorded landfill gas flow rate, header pipe pressure, power output (KW), heat input (MMBtu/hr) and gas composition using facility monitoring equipment. Process data was recorded electronically in 15-minute intervals.

3.2 Sample Location

Sample ports were installed just prior to sampling. During testing, TRC accessed the sample ports by a boom-lift that was provided by WMDSM. **Figure 3-1** presents a recent photograph of the two engine stacks.

All sampling took place in each engine's 16-inch internal diameter exhaust stack. Each stack has approximately 12-feet of straight run between the top of the stack and the silencer. Two sample ports were used for isokinetic sampling, each with a 6-inch long/4-inch ID port sleeve spaced 90-degrees apart. The ports were positioned 30-inches upstream from the top of the stack and 114-inches downstream from the silencer exhaust. **Figure 3-2** presents a schematic of these sample locations with calculated traverse points.

An additional sample port was installed for single point CEMS monitoring. This single port was positioned approximately 16-inches upstream from the inlet of the silencer.

Figure 3-1
Photograph of Engine Stacks

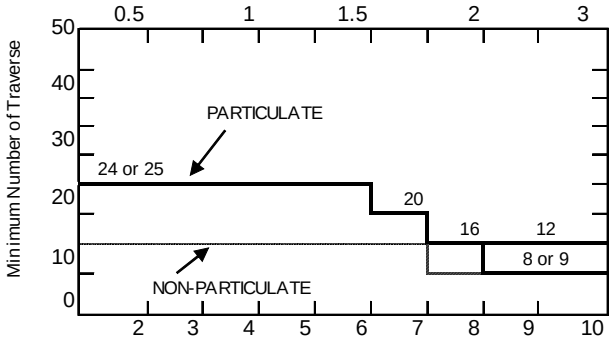
Figure 3-2

TRC Environmental Corporation
EPA Method 1 Data Sheet

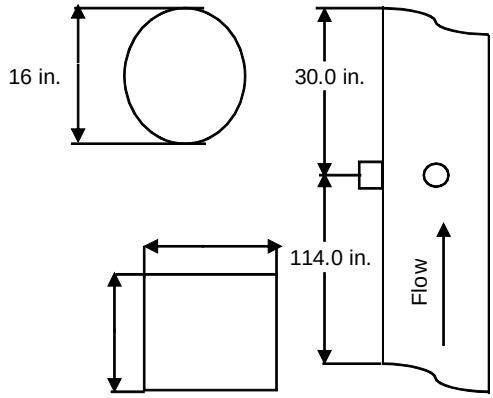
Firm	WMDSM-Norridgewock	Total Traverse Points Required	16
Location	Engine #1 & 2 Stacks	Number of Ports	2
Diameters Upstream	1.9	Points Per Port	8
Diameters Downstream	7.1	Traverse (Horizontal or Vertical)	horizontal
Nipple Size (in.)	6		

Minimum Number of Traverse Points For Particulate and Non-Particulate Traverses

Duct Diameters Upstream From Flow Disturbance



Duct Diameters Down Stream From Flow Disturbance



Cross-Sectional Layout For Rectangular Stacks Total	
Total Traverse Points	Matrix
9	3x3
12	4x3
16	4x4
20	5x4
25	5x5

Point Number On a Diameter	(Percent of Stack Diameter from Inside Wall to Traverse Point) (No. of Traverse Points on a Dia.) 4	6	8	10	12
1	6.7	4.4	3.2	2.6	2.1
2	25.0	14.6	10.5	8.2	6.7
3	75.0	29.6	19.4	14.6	11.8
4	93.3	70.4	32.3	22.6	17.7
5		85.4	67.7	34.2	25.0
6		95.6	80.6	65.8	35.6
7			89.5	77.4	64.4
8			96.8	85.4	75.0
9				91.8	82.3
10				97.4	88.2
11					93.3
12					97.9

Traverse Point Location

Point Number	Distance From Wall	Nipple Size	Total Distance
1	0.5	6.0	6.5
2	1.7	6.0	7.7
3	3.1	6.0	9.1
4	5.2	6.0	11.2
5	10.8	6.0	16.8
6	12.9	6.0	18.9
7	14.3	6.0	20.3
8	15.5	6.0	21.5
9			
10			
11			
12			

4.0 SAMPLING AND ANALYTICAL METHODS

TRC conducted triplicate 60-minute tests for emissions of PM, NO_x and CO for engines #1 and #2 as detailed in the following sub-sections.

4.1 Equipment Calibration

TRC follows a program of positive actions to prevent the failure of equipment or pertinent instruments during use. This preventative maintenance and regular calibration helps to ensure accurate measurements from field and laboratory instruments.

4.1.1 Equipment for EPA Method 5

All equipment that is scheduled for field use is cleaned and inspected prior to use. Once the equipment has gone through the cleaning and inspection process it is then calibrated. Following calibration, the equipment is packed and stored to ensure its integrity until use in the field.

Calibration of the equipment required for this program was conducted in accordance with the procedures outlined in EPA documents entitled "*Quality Assurance Handbook for Air Pollution Measurement Systems; Volume III - Stationary Source Specific Methods*" (EPA-600/4-77-027b) and 40CFR60 Appendix A.

- Pitot tubes (QA Handbook, Vol. III, Section 3.1.2, pp. 1-13) - measured for appropriate spacing and dimensions or calibrated in a wind tunnel. Rejection criteria given on the calibration sheet. Post-test check - inspect for damage.
- Thermocouples (QA Handbook, Vol. III, Section 3.4.2, pp. 12-18) - verified at water boiling and freezing points.
- Dry gas meters (EPA 40 CFR Part 60, Method 5, Section 5.3) - calibrated against a series of critical orifices. Acceptance criteria - pretest $Y_i = Y = \pm 0.02$; post test $Y = \pm 0.05\ Y_i$.
- Probe Nozzles (QA Handbook, Vol. III. Section 3.4.2, pp.19) - average of three ID measurements of nozzle; difference between high and low $\leq$ 0.004 in. Recalibrate, reshape and sharpen when nozzle becomes nicked dented or corroded.
- Field Barometer (QA Handbook, Vol. III, Section 3.4.2, pp. 18-19) - compared against a mercury-in-glass barometer or Airport Station BP and corrected for elevation. Acceptance criteria - $\pm$ 0.02 in. Hg; post-test check - same.

4.1.2 Continuous Emissions Monitoring (CEM) Equipment

Instrument calibrations with zero and upscale gases are performed prior to initiation of testing to demonstrate compliance with measurement system performance specifications. Calibration gas is introduced to the measurement system in accordance with the appropriate EPA Method for each parameter to be measured. Calibrations using a zero and one upscale gas concentration are performed both prior to and following each run. This is accomplished by directing calibration gas through the sample line and conditioning system. These procedures allow for determination

of initial and final system calibration error, as well as system drift. Calibration gases used are EPA Protocol 1, traceable to the National Institute of Standards and Technology (NIST). The measurement system will meet all performance specifications as stated in 40CFR60 Appendix A, for Methods 3A and 7E.

NO_2 to NO Conversion Efficiency

While on-site, the NO_2 to NO converter was checked with a certified NO_2 calibration standard.

4.2 EPA Methods 1 and 2 for Velocity Measurements and Cyclonic Flow

This procedure is referred to as the nulling technique. An S-type pitot tube connected to an inclined manometer is used in this method. The pitot tube is positioned at each traverse point so that the face openings of the pitot tube are perpendicular to the stack cross-sectional plane. The velocity pressure (ΔP) measurement is noted. If the ΔP reading is not zero, the pitot tube is rotated clockwise or counter clockwise until the ΔP reading became zero. This angle is then measured with a leveled protractor and reported to the nearest degree. After this null technique is applied at each traverse point, the average of the cyclonic angles is calculated. This average must be less than 20° to be deemed acceptable to test.

Velocity traverses are conducted with an S-type pitot assembly in accordance with EPA Reference Methods 1 and 2. An S-type pitot tube with an attached inclined manometer is used to measure the exhaust velocities of the sampling location. An attached Type-K thermocouple with remote digital display is used to determine the flue gas temperature. The required number of velocity measurement points has been determined following EPA Method 1 and are presented in section 2 of this test plan.

4.3 Particulate Test Procedures

Testing for emissions of particulate matter (PM) is conducted in strict accordance with EPA method 5 as presented in 40CFR60.

4.3.1 Sample Collection

Particulate sampling is performed isokinetically in accordance with EPA Method 5. This sampling train is presented in **Figure 4-1** and consists of a nozzle, a probe, a filter, a flexible umbilical line, four impingers, a vacuum pump, a dry-gas meter, and an orifice flow meter. A stainless steel nozzle is attached to a glass-lined probe, which is heated to 248°F ± 25°F to prevent condensation of moisture. Whatman EPM 2000 filter media are supported in a 3½-inch glass filter holder. The filter assembly is enclosed in a heated box to maintain temperatures at 248°F ± 25°F. A thermocouple located inside the back half of the filter holder monitors the gas stream temperature and verifies that the temperature is kept within the appropriate range. An ice bath containing four impingers is attached to the back end of the filter via flexible tubing.

The first two impingers each contain 100 milliliters (ml) of distilled, deionized water (DDH_2O), the third is empty, and the fourth contains silica gel to remove any remaining moisture. The

entire impinger train is weighed before and after each test run for determination of moisture gain. Flexible tubing, a vacuum gauge, a needle valve, a leakless vacuum pump, a bypass valve, a dry-gas meter, a calibrated orifice, and an inclined manometer complete the sampling train. The stack velocity pressure is measured using an S-type pitot tube and inclined manometer. The stack temperature is monitored by a thermocouple attached to the pitot and connected to a potentiometer.

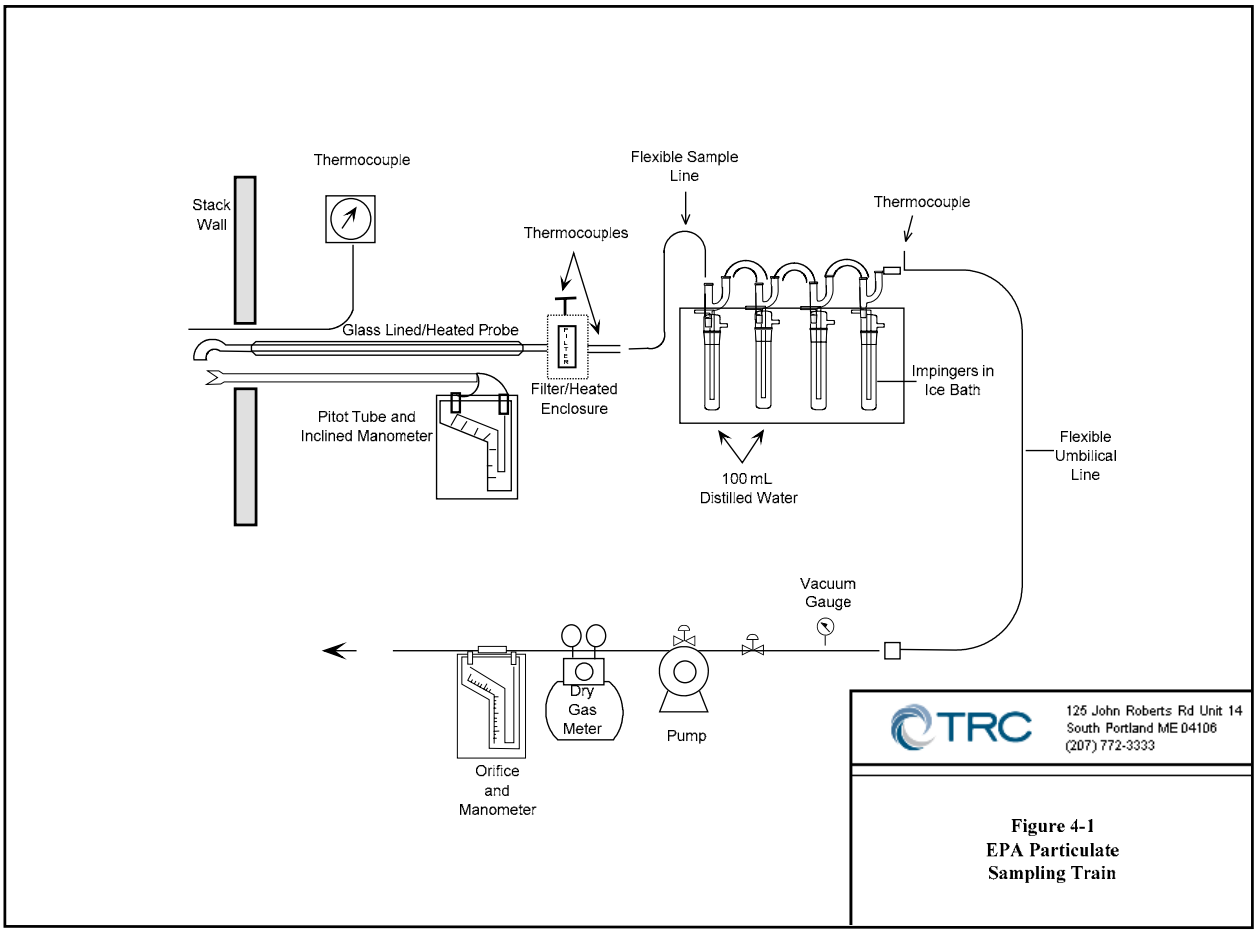


Figure 4-1
EPA Particulate Sampling Train

4.3.2 Sample Recovery

Samples are recovered at the end of each test and placed in appropriate containers as follows:

Container No. 1: The 3½-inch filter is removed from its holder, placed in a petri dish, sealed and labeled.

Container No. 2: The probe, nozzle, and front half of the filter holder are brushed and rinsed three times with acetone. The wash is deposited into a 250-ml sample jar and labeled.

All samples are placed in shockproof containers for transport to TRC's gravimetric laboratory located in South Portland, Maine.

4.3.3 Sample Analysis

Sample analyses are performed at TRC's gravimetric laboratory in South Portland, Maine in accordance with EPA Method 5, as follows:

Container No. 1: The glass fiber filter is desiccated for at least 24 hours and weighed to a constant weight to determine PM mass. This is reported to the nearest 0.1 milligram (mg).

Container No. 2: The acetone wash is evaporated, weighed to a constant weight, and reported to the nearest 0.1 mg.

A computer program developed by TRC is used to calculate mass emission rates. The program is also used to calculate the stack moisture (%), molecular weight of the stack gas, and the percent isokinetics.

4.4 Continuous Emissions Monitoring

TRC conducted continuous emissions monitoring for oxygen and carbon dioxide (EPA Method 3A), oxides of nitrogen (EPA Method 7E) and carbon monoxide (EPA Method 10). The CEMS consists of three subsystems: sample collection/conditioning, sample analysis, and data acquisition. Sample collection/conditioning is designed to deliver a representative sample of the gas stream to the sample analysis subsystem. Since the stream must be clean and dry for the O_2, CO_2, NO_x and CO analyzers, a filter and non-contact moisture condenser are used for particulate and moisture removal.

The sample line is heat traced to eliminate condensation of water vapor prior to the condenser. The data acquisition subsystem consists of a digital data logger designed to receive and log instrument signals (raw voltages) at user defined intervals. A schematic of the CEM system is presented in **Figure 4-2**.

Prior to insertion of the probe into the sampling location, the system is leak checked by the following procedure:

a. Plug probe
b. Observe that flow in rotameter reaches zero LPM
c. Observe vacuum
d. Confirm that sample vacuum during sampling does not exceed vacuum attained during leak check

The sampling train starts with a stainless-steel sampling probe. The sample stream is drawn through a glass fiber filter which is heated to prevent moisture condensation, Teflon^R sample line, and a sample conditioner to remove the moisture and particulate from the gas stream. The sample is then drawn through Teflon^R tubing by a leak-free Teflon^R double diaphragm pump to a stainless-steel sample manifold with and atmospheric by-pass rotameter. The O_2, CO, and NO_x analyzers each draw sample gas from this manifold. All CEM sampling was conducted from a single centrally located sample point within each stack.

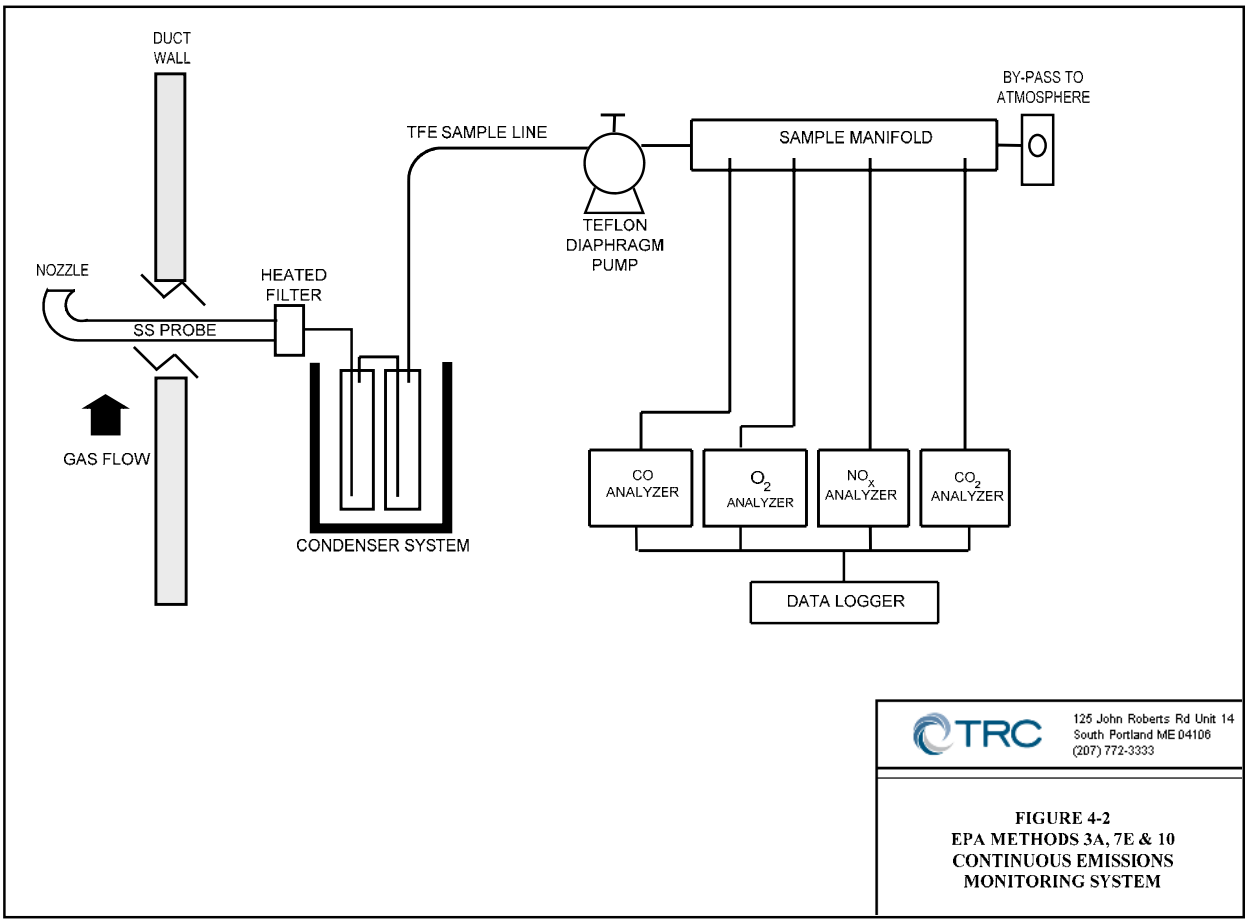


FIGURE 4-2
EPA METHODS 3A, 7E & 10
CONTINUOUS EMISSIONS
MONITORING SYSTEM

4.5 Calculations

Heat input (MMBtu/hr) was provided by the facility for each test. PM emissions expressed in terms of lb/MMBtu are calculated by dividing the mass-emission rate by the facility provided heat input as follows:

$$\left(lb/MMBtu\right) = \frac{\left(lb/hr\right)}{\left(MMBtu/hr\right)}$$

NO_x and CO emissions reported in terms of g/b-hp-hr are calculated as follows:

$$\left(g/b-hp-hr\right) = \left(lb/hr\right)\left(\frac{454g}{lb}\right)\left(\frac{1}{b-hp}\right)$$

Where:

$$\left(b-hp\right) = KW\left(\frac{1hp}{0.7457KW}\right)\left(Efficiency\right)$$

Where: Efficiency = 0.804

5.0 QUALITY ASSURANCE

5.1 Overview

TRC Environmental Corporation is fully committed to an effective Quality Assurance/Quality Control (QA/QC) Program whose objective is the delivery of a quality product. For much of TRC's work, that product is data resulting from field measurements, sampling and analysis activities, engineering assessments, and the analysis of gathered data for planning purposes. The Quality Assurance Program works to provide complete, precise, accurate, representative data in a timely manner for each project, considering both the project's needs and budget constraints.

This section highlights the specific QA/QC procedures followed for this Test Program.

5.2 Field Quality Control Summary

5.2.1 Calibration Procedures

Calibration of the field sampling equipment is performed prior to the field sampling effort. Copies of the calibration sheets are submitted to the field team leader to take onsite and for the project file. Calibrations are performed as described in the EPA publications "*Quality Assurance Handbook for Air Pollution Measurement Systems; Volume III - Stationary Source Specific Methods*" (EPA-600/4-77-027b) and EPA 40CFR60, Appendix A. Equipment to be calibrated includes the sample metering system, nozzles, barometers, thermocouples, and pitot tubes. All calibration forms were available for review at the test program.

5.2.2 Equipment Leak Checks

Prior to sampling, each sampling train is leak checked according to the procedures outlined in EPA Reference Method 5. During the course of a test run, a leak check is conducted before and after every test, or if replacement of a component becomes necessary. Final leak checks are performed to ensure that no leaks developed in the train during the course of the test run. All leakage rates, if any found, are recorded on the appropriate field data sheet.

5.2.3 Cyclonic Flow Check

The absence of cyclonic flow within each sampling location is verified as outlined in Section 4.2 of this report.

5.2.4 Calibration Gases

All calibration gases used to conduct instrument calibrations are prepared in accordance with EPA Protocol 1, or are traceable to NIST.

5.2.5 Instrument Calibrations

All instrument calibrations meet the performance criteria defined in 40CFR60, Appendix A. Any test not meeting these criteria is considered questionable and the test run repeated.

5.3 Data Reduction, Validation, and Reporting

Specific QC measures are used to ensure the generation of reliable data from sampling activities. Proper collection and organization of accurate information followed by clear and concise reporting of the data is a primary goal in all projects.

5.3.1 Field Data Reduction

The Field Team Leader and at least one other field crew member review the field data collected in the field. Errors or discrepancies are noted in the field book.

5.3.2 Data Validation

TRC's supervisory and QC personnel use validation methods and criteria appropriate to the type of data and the purpose of the measurement. Records of all data are maintained, including that judged to be an "outlying" or spurious value. The persons validating the data have sufficient knowledge of the technical work to identify questionable values.

Field sampling data are validated by the Field Team Leader and/or the QC Coordinator based on their review of the adherence to an approved sampling protocol and written sample collection procedure.

The following criteria are used to evaluate the field sampling data:

- Use of approved test procedures;
- Proper operation of the process being tested;
- Use of properly operating and calibrated equipment;
- Leak checks conducted before and after tests;
- Use of reagents conforming to QC specified criteria;
- Proper chain-of-custody maintained.