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Formaldehyde and VOC Emissions from a General Electric LM6000 Combustion Turbine with SCR and CO Catalysts

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Technical Update, February 2006

EPRI Project Manager

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TRC Environmental

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PRODUCT DESCRIPTION

This report summarizes measurements to characterize trace organic emissions from New York Power Authority's Harlem River Unit 1 - a simple-cycle, natural gas-fired General Electric (GE) LM6000 combustion turbine, and employing selective catalytic reduction (SCR) and carbon monoxide (CO) catalyst.

Results & Findings

Formaldehyde emissions were higher during the low load and winter tests. Formaldehyde emission concentrations during the winter averaged 46 $\mu g/m^3$ (37 ppb) at high load and 151 $\mu g/m^3$ (121 ppb) at low load. The summer test showed lower formaldehyde emissions compared to the winter tests and also showed a similar pattern of higher formaldehyde emissions at low load. Warm weather formaldehyde concentration averaged 7.9 $\mu g/m^3$ (6.3 ppb) at high load and 41 $\mu g/m^3$ (33 ppb) at low load. Carbon monoxide was also elevated during the low load testing, indicating that incomplete combustion may have been a factor in formaldehyde emissions at low load.

Most volatile organic compounds (VOCs) were below or marginally above the detection limits. The one exception was benzene, which was detected at significant concentrations during both the winter and summer tests. Decreasing levels of benzene emissions were detected. For example, the benzene emission concentrations over the four high load winter tests started at 155 $\mu g/m^3$ (48 ppb) during the first test, decreased each subsequent run, and measured 9.8 $\mu g/m^3$ (3 ppb) during the fourth test – all of which occurred in less than three hours. During the low load winter tests conducted on the following day, benzene was either below detection limit or detected just above the detection limit, with the highest benzene concentration being 0.8 $\mu g/m^3$ (0.3 ppb). There were no obvious measures of either sampling or laboratory contamination, as the trip and field blanks were benzene-free. Lastly, the results were not indicative of gasoline contamination where toluene and xylenes would have also been detected at similar levels.

Challenges & Objectives

The objectives of this study are:

- Characterize aldehyde and VOC emissions from "utility-size" state-of-the-art combustion turbines.
- Evaluate the impact of seasonal effects (ambient temperature) and operating load.

The most significant challenges are the complexity of the trace organic measurements at low ppb levels.

Applications, Values & Use

The results would assist in permitting new combustion turbines, as well as to support reporting estimated emissions for Toxics Release Inventory (TRI).

EPRI Perspective

These results summarize formaldehyde and VOC emission measurements from a simple cycle combustion turbine operating at several operating loads and during summer and winter conditions. The formaldehyde results indicated higher emission concentrations during lower load operation as well as winter operating conditions. The VOCs were generally not detected, with the exception of benzene. Decreasing levels of benzene emissions were detected, and it is unclear whether the measurements are representative of real operating conditions, a sampling/analytical issue, and/or outside contamination. Previous EPRI measurements at a Siemens-Westinghouse 501F gas-fired combustion turbine with SCR and CO catalysts indicated similar results for formaldehyde, but generally not detected values for the VOCs, although benzene was detected during start-up (EPRI 1005408).

Additional trace organic measurements are planned to characterize other combustion turbine designs.

Approach

Measurements were conducted in the winter as well as the summer to evaluate the impact of ambient temperature. Measurements were conducted at full load, as well as a reduced load in order to evaluate the impact of operating load. Investigators measured formaldehyde using EPA SW-846 Method 0011 and 8315a. The VOCs were measured using the volatile organic sampling train (VOST) in accordance with EPA SW-846 Method 0300. Flue gas measurements were conducted at only the stack.

Keywords

Air toxics, formaldehyde, combustion turbines

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1.0 INTRODUCTION

TRC Environmental Corporation (TRC) was retained by the Electric Power Research Institute (EPRI) to perform a volatile organic compound (VOC) air emission measurement project on a simple cycle gas turbine generator firing natural gas. The emissions test was conducted on a General Electric LM6000 combustion turbine generator (CTG) operated by the New York Power Authority (NYPA) at the Harlem River site in The Bronx. The LM6000 turbine has a nominal capacity of 48 megawatts and a heat input of approximately 400 MMBtu/hr at 59 degrees F. The project included testing at maximum and partial turbine loads and was repeated during winter and summer weather. Both winter and summer weather emission tests were conducted according to the following test matrix.

Parameter	**Sampling Method**	**Analytical Method**	**Test Duration (minutes)**	**Number of Tests at Each Operating Load**
Aldehydes and Ketones	SW-846 0011	SW-846 8315a	64	3
VOC (non-water soluable compounds)	SW-846 0030	SW-846 8260	40	4

Target compounds included aldehydes and ketones measured according to EPA SW-846 Method 0011 and 8315a. Samples are collected in dinitrophenylhydrazine (DNPH) solution, which forms a derivative with aldehydes and ketones. The DNPH is extracted in methylene chloride, and the extract is analyzed by high pressure liquid chromatography (HPLC) for multiple compounds.

Target compounds also included non-water soluble volatile organic compounds (VOC) measured according to EPA SW-846 Method 0030 and 8260. The Method 0030 samples are collected on sorbent tubes (Tenax® and charcoal), which are thermally desorbed and analyzed by gas chromatography/mass spectrometry (GC/MS) according to Method 8260. The target compound list included 70 compounds.

The tests were conducted on the stack of the Harlem River Plant Unit 1. Cold weather testing was conducted on December 14-15, 2004 and warm weather testing was conducted on July

13-14, 2005. The GE LM6000 turbine generators are used by NYPA for peak demand power generation and during the winter the generators are typically fired in the late afternoon. The winter tests were conducted between 3:20 and 8:00 PM with ambient temperature in the range of 20 to 25^{o} F. During the summer the generators are typically fired in the early afternoon and the July tests were conducted between noon and 5:00 pm with the ambient temperature in the range of 73 to 81^{o} F.

Sampling was conducted by TRC staff including Jim Canora, Kirk Laakso and Robert Mennillo. Method 0011 laboratory analyses were conducted by Enthalpy Analytical in Raleigh, NC, and Method 0030 VOC analyses were conducted by Air Toxics, Inc in Folsom, CA. Michael Stockstad of NYPA coordinated testing with the plant operation.

The test results are presented and discussed in Section 2 of this report followed by a brief discussion of the process in Section 3. Section 4 presents a description of sampling and analytical methods and Section 5 presents a discussion of measurement quality assurance. Copies of sampling data, sampling calibration forms, process data, and analytical data summaries are included in the appendices.

2.0 SUMMARY AND DISCUSSION OF RESULTS

Test results are summarized in Tables 2-1 and 2-2 for the winter and summer tests. Only 5 compounds (formaldehyde, acetaldehyde, acetone, benzene and toluene) were detected in at least two samples and these compounds are the only compounds included in Tables 2-1 and 2-1. Detection limits for other target compounds are presented in Appendices A – D. In summary, the test program showed increased formaldehyde emissions at low load and at cold weather operations.

Emissions are presented in micrograms per standard cubic meter ($\mu g/m^3$), parts per billion volume (ppbv) and pounds per million Btu (lb/MMBtu). The lb/MMBtu emissions were calculated using the natural gas dry fuel factor (F_d= 8,710 dscf/MMBtu) provided in EPA Method 19. Winter high load tests were conducted on December 14, 2004 with an average power output of 47.95 megawatts and winter low load tests were conducted on the following day with an average power output of 36.88 megawatts. Summer high load tests were conducted on July 13, 2005 with an average power output of 47.76 megawatts and summer low load tests were conducted on the following day with an average power output of 38.02 megawatts.

2.1 Aldehyde and Ketone Emissions – SW-846 Method 0011

Tests showed that formaldehyde emissions were higher during low load and winter weather. Formaldehyde emission concentration during the winter averaged 46.4 $\mu g/m^3$ at high load and 151 $\mu g/m^3$ at low load; concentration was approximately 3 times higher during low load. The summer test showed lower formaldehyde emissions compared to the winter tests and also showed a similar pattern of higher formaldehyde emissions at low load. Warm weather formaldehyde concentration averaged 7.9 $\mu g/m^3$ at high load and 40.7 $\mu g/m^3$ at low load. Carbon monoxide concentration, measured by the plant CEMS, was also elevated during the low load testing, indicating that incomplete combustion may have been a factor in formaldehyde emissions at low load.

2.2 VOC Emissions – SW-846 Method 0030

The cold weather test results showed that most target compounds were below, or marginally above, the detection limits. The one exception was benzene, which was detected at significant concentrations during the high load winter tests. Benzene emission concentrations rapidly decreased over the four high load winter tests, starting at 155 $\mu g/m^3$ during the first test and decreasing to 9.75

µg/m^3 during the fourth test. During the low load winter tests conducted on the following day, benzene was either below detection limit or marginally detectable; the highest benzene concentration during the low load winter test was 0.84 µg/m^3. There was no indication of sampling or laboratory contamination, as trip and field blanks were benzene free and the results were not indicative of gasoline contamination where toluene and xylenes would have also been detected at similar levels.

The warm weather test results also showed that most target compounds were below, or marginally above, the detection limits. However, benzene was again detected in decreasing concentrations similar to the cold weather high load test; the warm weather high load benzene emissions decreased from 60.0 to 6.0 µg/m^3 and the low load decreased from 65.6 to 1.2. As with the winter tests there was no evidence of sampling or laboratory contamination and no indication of gasoline contamination.

Possible explanations for the benzene emissions include benzene in the compressor condensate entering the turbine exhaust through the catalyst inlet dilution air fans. The condensate consists of an oil/water mixture and analyses of the condensate shows significant benzene concentration. The condensate is stored in tanks located near the dilution air fan intake and there is the potential for tank vapors to be injected into the turbine exhaust prior to the catalyst. Benzene emissions as a function of test time to turbine start up were also investigated and the data showed no correlation. Cold weather testing was initiated within 1 hour of a cold turbine start up on both test days and the first day showed high benzene emissions and the second day showed low benzene emissions. Warm weather testing was initiated within 1 hour of start up on the low load day and 6 hours after start up on the high load day, and benzene emissions were similar on both days.

In summary, decreasing levels of benzene emissions were detected and the data indicates the emissions were a transient condition. A possible source of the benzene is the dilution air fans and benzene vapors from condensate storage tanks. There was no correlation with the benzene emissions and the time between testing and turbine start up. There was no evidence of sampling and analytical benzene contamination; however, there is the possibility of an unusual sampling train contamination that only occurred when the sampling system was exposed to high temperature stack gas.

TABLE 2-1
SIMPLE CYCLE GAS TURBINE
COLD WEATHER VOC EMISSIONS TEST SUMMARY

NYPA - HARLEM RIVER UNIT 1

Date	December 14, 2004						December 15, 2005				
Load	High Load (48.0 MW)						Low Load (36.9 MW)				
Test No.	1	2	3	4	Average		1	2	3	4	Average
CEMS Data											
CO (ppm @ 15% O_2)	1.1	1.1	1.1		1.1		2.5	1.9	1.9		2.1
NH_3 (ppm @ 15% O_2)	7.2	7.2	7.4		7.3		7.2	7.0	6.6		6.9
NOx (ppm @ 15% O_2)	2.3	2.3	2.4		2.3		2.2	2.0	2.2		2.1
O_2 (%)	15.1	15.1	15.2		15.1		16.0	15.9	16.0		16.0
Emission Conc (ug/dscm)											
formaldehyde	59.0	49.2	31.0		46.4		165	141	146		151
acetaldehyde	15.3	9.4	10.2		11.6		9.2	28.1	9.4		15.6
acetone	ND	ND	ND		ND		84.2	10.9	69.2		54.8
benzene	155	69.5	18.4	9.8	63.3		0.6	0.84	ND	ND	<0.6
toluene	6.04	2.52	ND	ND	<2.4		ND	ND	ND	ND	ND
Emission Conc (ppbv)											
formaldehyde	47.3	39.4	24.9		37.2		132	113	117		121
acetaldehyde	8.4	5.1	5.6		6.3		5.0	15.3	5.1		8.5
acetone	ND	ND	ND		ND		34.9	4.5	28.7		22.7
benzene	47.8	21.4	5.7	3.0	19.5		0.2	0.3	ND	ND	<0.2
toluene	1.6	0.7	ND	ND	0.6		ND	ND	ND	ND	ND
Emission Rate (lb/mmBtu)											
formaldehyde	1.2E-04	9.6E-05	6.2E-05		9.1E-05		3.8E-04	3.2E-04	3.4E-04		3.5E-04
acetaldehyde	3.0E-05	1.8E-05	2.0E-05		2.3E-05		2.1E-05	6.4E-05	2.2E-05		3.6E-05
acetone	ND	ND	ND		ND		2.0E-04	2.5E-05	1.6E-04		1.3E-04
benzene	3.8E-04	1.7E-04	4.4E-05	2.4E-05	1.5E-04		1.5E-06	2.0E-06	ND	ND	<1.4E-06
toluene	1.5E-05	6.1E-06	ND	ND	<5.7E-06		ND	ND	ND	ND	ND

ND = non-detected

ug/dscm = micrograms per dry standard cubic meter at 68 °F and 29.92 in Hg

< = detection limit based on averages of detected quantities and detection limits

TABLE 2-2
SIMPLE CYCLE GAS TURBINE
WARM WEATHER VOC EMISSIONS TEST SUMMARY

NYPA - HARLEM RIVER UNIT 1

Date	July 13, 2005						July 14, 2005				
Load	High Load (47.8 MW)						Low Load (38.0 MW)				
Test No.	1	2	3	4	Average		1	2	3	4	Average
CEMS Data											
CO (ppm @ 15% O_2)	1.2	1.2	1.2		1.2		3.6	3.6	3.6		3.6
NH_3 (ppm @ 15% O_2)	3.2	3.3	2.9		3.1		1.3	1.1	1.1		1.2
NOx (ppm @ 15% O_2)	1.9	1.8	1.9		1.9		1.9	1.9	1.9		1.9
O_2 (%)	15.0	15.0	15.0		15.0		15.7	15.7	15.6		15.7
Emission Conc (ug/dscm)											
formaldehyde	12.8	5	5.9		7.9		37.4	41.8	43		40.7
acetaldehyde	ND	ND	ND		ND		ND	ND	ND		ND
acetone	9.5	6.8	18.5	6.0	11.6		14.2	4.8	23.6		14.2
benzene	60.0	23.5	11.1	6.0	25.1		65.6	13.8	1.7	1.2	20.6
toluene	1.6	0.9	ND	ND	<0.9		2.1	1.1	ND	ND	<1.0
Emission Conc (ppbv)											
formaldehyde	10.3	4.0	4.7		6.3		30	34	34		33
acetaldehyde	ND	ND	ND		ND		ND	ND	ND		ND
acetone	3.9	2.8	7.7		4.8		5.9	2.0	9.8		5.9
benzene	18.5	7.2	3.4		7.7		20.2	4.3	ND		6.4
toluene	0.4	0.2	ND		0.2		ND	ND	ND		ND
Emission Rate (lb/mmBtu)											
formaldehyde	2.5E-05	9.9E-06	1.2E-05		1.6E-05		8.3E-05	9.5E-05	1.0E-04		9.3E-05
acetaldehyde	ND	ND	ND		ND		ND	ND	ND		ND
acetone	1.9E-05	1.3E-05	3.5E-05	1.1E-05	2.3E-05		3.2E-05	1.1E-05	5.5E-05		3.2E-05
benzene	1.2E-04	4.6E-05	2.7E-05	1.1E-05	5.2E-05		1.6E-04	3.3E-05	4.2E-06	3.0E-06	5.0E-05
toluene	3.2E-06	1.8E-06	ND	ND	<1.8E-06		5.0E-06	2.6E-06	ND	ND	<2.5E-06

ND = non-detected
ug/dscm = micrograms per dry standard cubic meter at 68 ^{o}F and 29.92 in Hg
< = detection limit based on averages of detected quantities and detection limits

3.0 PROCESS INFORMATION

3.1 Process Description

New York Power Authority (NYPA) operates ten identical LM-6000 gas turbines, which fire only natural gas. The turbines are located at six separate sites. There are a total of four sites that operate dual units and two sites that operate a single unit. The dual unit sites are Harlem River, Hell Gate, Gowanus and Vernon Blvd. and the single units are Kent and Pouch Terminal. The net capacity for all units is 47 MW. The dual units are restricted to 79.9 MW combined output.

Each gas turbine operates as a simple cycle unit, employing a spray inter-cooling system to optimize power output. Each plant is equipped with Selective Catalytic Reduction (SCR) units for control of oxides of nitrogen and catalytic oxidation units (CO catalyst) for the control of carbon monoxide attached to each combustion turbine. Dilution air fans are used to inject ambient air prior to the catalyst bed to control gas temperature at the catalyst.

3.2 Process Monitoring

The gas turbine stacks are equipped with dedicated continuous emission monitoring systems (CEMS). The CEMS are dry extractive design, and measure stack concentrations of NOx, CO, O_2, and NH_3 on a dry basis. Power output, gas flow rate, and other process operating parameters are also monitored and recorded. Process data and emissions data recorded during the emissions test are included in Appendices E and F.

4.0 SAMPLING AND ANALYTICAL METHODS

Sampling was conducted from four ports in the 150-inch diameter stack. The ports were located 50 feet (4 diameters) downstream of the breeching entrance and greater than 25 feet (2 diameters) upstream of the stack exit. The stack schematic and sampling point locations are presented in Figure 4-1.

4.1 Volatile Organic Compounds

The concentrations of volatile organic compounds were determined using the volatile organic sampling train (VOST) in accordance with EPA SW-846 Method 0030. Four samples were collected during each operating load for a total of 8 samples. One field blank and one trip blank were also collected. Sampling duration was 40 minutes per test.

4.1.1 Sample Collection

A 20-liter (nominal) sample of exhaust gas was collected at a flow rate of approximately 0.5 liter per minute (lpm). A schematic of the sampling train is shown in Figure 4-2. The sampling train includes a heated (250° F ± 25° F) glass-lined probe followed by a glass 3-way valve, and a condenser chilled to 20 °C. A Tenax® cartridge follows the first condenser which is followed by a second condenser and a second sorbent cartridge containing a 3:1 mix of Tenax® and activated charcoal.

Each pair of sorbent cartridges (Tenax® and Tenax®/charcoal) were desorbed and analyzed together. The field blank and trip blank cartridge pairs were also desorbed and analyzed togather. There was approximately 2 milliliters of condensate from each set of four samples and the condensates were collected in a 40 milliliter vials which were filled to "zero headspace" with purified water. The two condensate samples were analyzed with a purge and trap concentrator for the Method 8260 compounds and no compounds were detected.

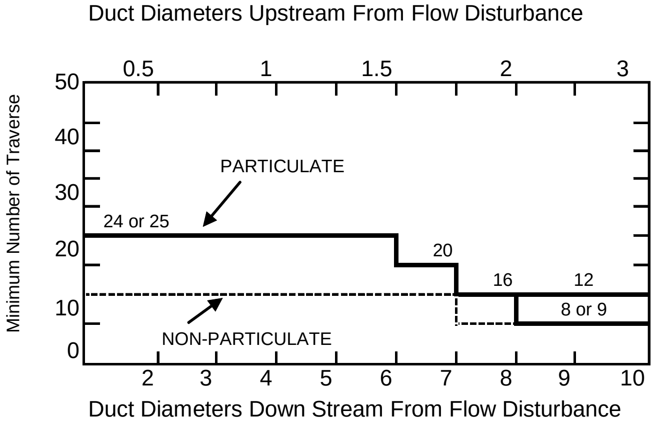
Figure 4-1

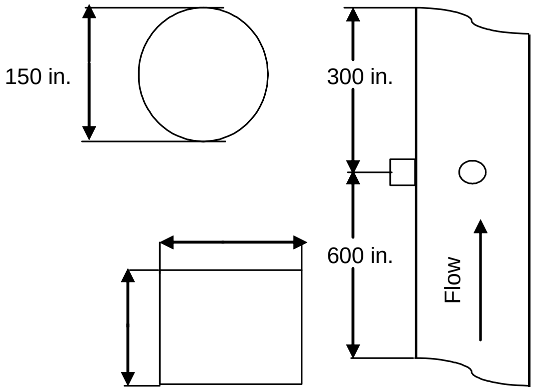
TRC Environmental Corporation
EPA Method 1 Data Sheet

Firm NYPA Harlem River
Location Unit 1 Stack
Diameters Upstream 2.0
Diameters Downstream 4.0
Nipple Size (in.) 6

Total Traverse Points Required 16
Number of Ports 2
Points Per Port 8
Traverse (Horizontal or Vertical) Horizontal

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





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	c	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	4.8	6.0	10.8
2	15.8	6.0	21.8
3	29.1	6.0	35.1
4	48.5	6.0	54.5
5	101.6	6.0	107.6
6	120.9	6.0	126.9
7	134.3	6.0	140.3
8	145.2	6.0	151.2
9			
10			
11			
12			

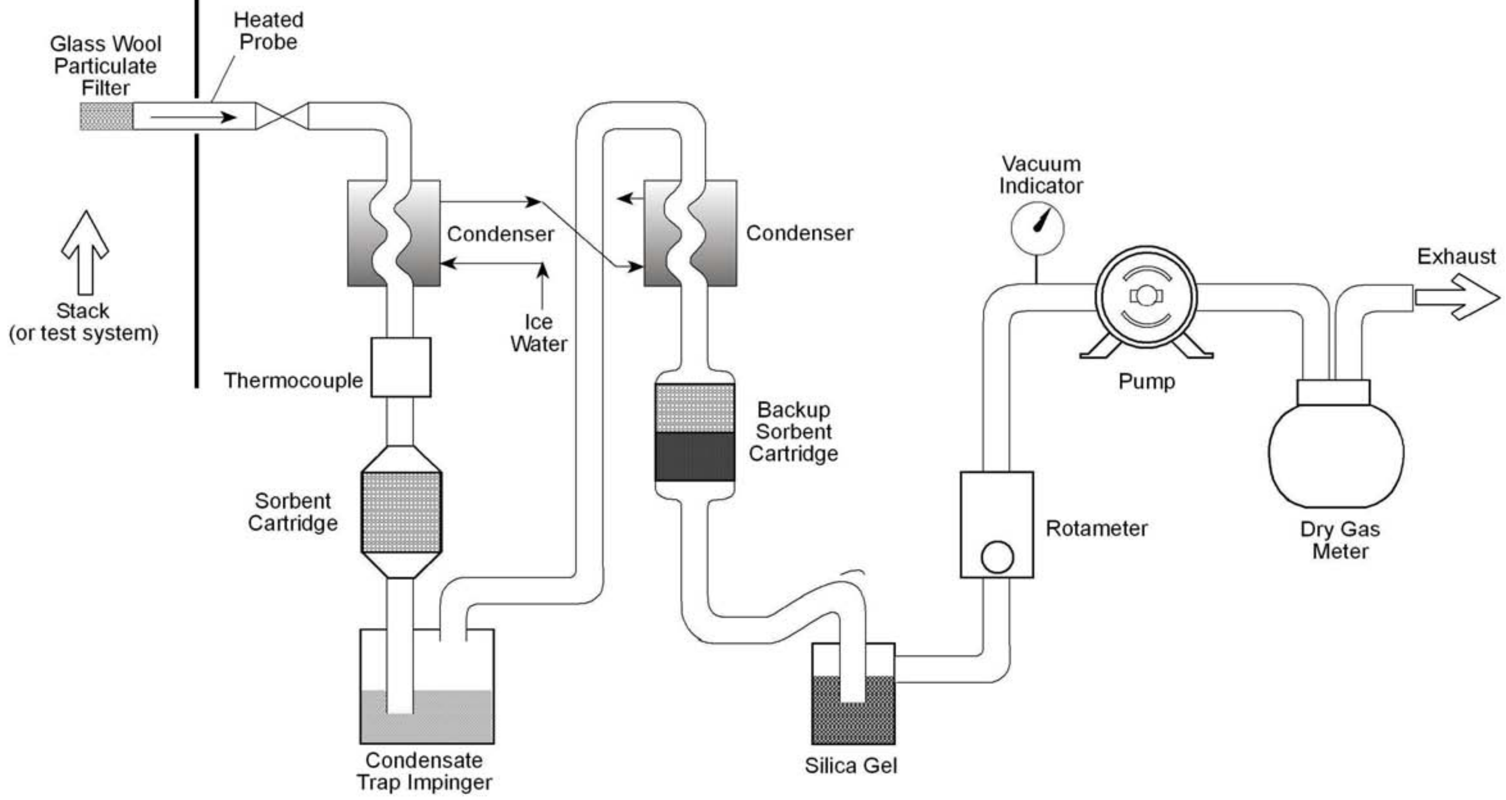


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FIGURE 4-2

SCHEMATIC OF VOLATILE ORGANIC SAMPLING TRAIN (VOST)

4.1.2 Sample Recovery

At the completion of each test run, the sample cartridges were sealed with Swagelok fittings and stored on ice until shipment for analysis. Test data was recorded on appropriate field data sheets.

4.1.3 Sample Analysis

Sample analysis was performed by Air Toxics, Inc according to Methods 0030 and 8260. The contents of the paired sorbent cartridges were spiked with an internal standard and thermally desorbed for 11 minutes at 180° C with organic-free nitrogen gas, bubbled through 5 ml of organic-free water, and trapped on an analytical absorbent trap. After the 11-minute desorption, the analytical absorbent trap was rapidly heated to 180° C with the carrier gas flow reversed so that the effluent flow from the analytical trap was directed into the GC/MS. The volatile compounds were separated by temperature-programmed gas chromatography and detected by low-resolution mass spectrometry. The concentrations of volatile compounds were based on calibration runs performed with standards containing the target compounds.

One additional compound was added to the target compound list for this project; this was 1,4-dioxane. The additional compound was quantified as a tentatively identified compound (TIC) using an internal standard calibration and recovery factor.

4.2 Aldehydes and Ketones – SW-846 Method 0011

Emissions measurements for formaldehyde, acetaldehyde, acetone, acrolein, and 16 additional compounds were conducted in accordance with EPA SW-846 Method 0011 and 8315a.

4.2.1 Sample Collection

The sampling train, as shown in Figure 4-3, consisted of a glass nozzle, heated glass-lined probe, four full-size impingers, a vacuum pump, dry gas meter, and calibrated orifice. The first and second impingers were each charged with 100 ml of DNPH solution. The third impinger was empty and the fourth impinger contained 200g of indicating silica gel to capture any remaining moisture. Prior to sampling, the entire impinger train was weighed to the nearest 0.5 gram. A programmable

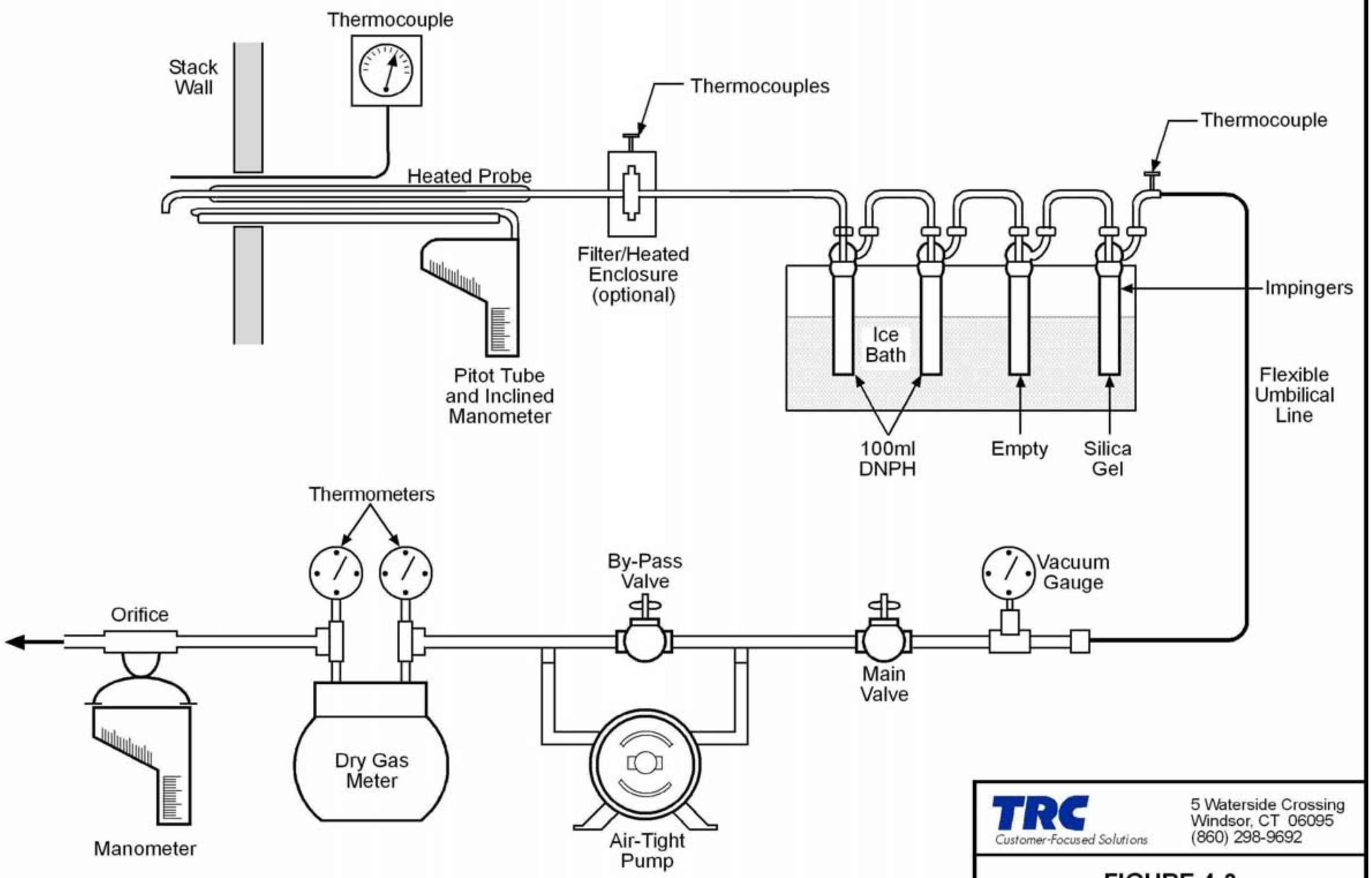

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FIGURE 4-3

**SOLID WASTE METHOD 0011
SAMPLING TRAIN SCHEMATIC**

m-0011. fh9

calculator was used to quickly determine the orifice pressure drop required for the measured pitot velocity pressure and stack temperature in order to maintain isokinetic sampling conditions. Sampling flow was adjusted by means of the bypass valve.

4.2.2 Sample Recovery

At the completion of each test the impinger train was weighed to the nearest gram to determine moisture gain. The following sample fractions were collected:

Container No. 1:	The nozzle and probe were brushed and rinsed in triplicate with methylene chloride and HPLC water. The rinses were deposited into a glass sample container. The jar was marked, labeled, and sealed with a Teflon-lined lid.
Container No. 2:	The contents of the first three impingers were deposited into a 500 ml glass sample jar. The impingers were rinsed in triplicate with methylene chloride and HPLC grade water and the washes deposited into the same jar. The jar was marked, labeled, and sealed with a Teflon-lined lid.

4.2.3 Sample Analysis

The collected liquid samples were submitted for formaldehyde analysis by HPLC according to SW-846 Method 0011.

5.0 QUALITY ASSURANCE

The Project Manager was responsible for developing data of the highest quality. The following discussions present the standard TRC QC procedures for source test emissions. These discussions are organized into sampling, analytical, and reporting procedures.

5.1 Sample Collection

The TRC quality assurance (QA) program for source testing is designed to ensure that emission measurement work is performed by qualified people using proper equipment and following written procedures in order to provide accurate, defensible data. The program is based upon the EPA *Quality Assurance Handbook for Air Pollution Measurement Systems*, Volume III (EPA-600/4-77-0276).

Sampling and measurement equipment, including continuous analyzers, recorders, pitot tubes, dry meters, orifice meters, thermocouples, probes, nozzles, and any other pertinent apparatus, are uniquely identified, undergo preventive maintenance, and are calibrated before and after each field effort, following written procedures and acceptance criteria. Most calibrations are performed with standards traceable to the National Institute for Science and Technology (NIST). These standards include wet test meters, standard pitot tubes, and NIST Standard Reference Materials. Records of all calibration data are maintained in TRC files.

During field tests, sampling performance and progress were continually evaluated, and deviations from sampling method criteria were reported to the Field Team Leader who then determined the validity of the test run. All field data were recorded on prepared data sheets. Field Team Leaders maintained a written log describing the events of each day. Field samples, including field blanks, were transported from the field in shockproof, secure containers. Sample integrity was controlled through the use of prepared data sheets, positive sample identification, and chain-of-custody forms.

5.2 Sample Analysis

In the TRC and subcontract laboratories, all QC samples including field blank samples, reagent and filter blanks, and any audit samples were analyzed with the actual test samples. Each laboratory maintains a continuous QC program to monitor instrument response and analyst proficiency and to ensure the precision and accuracy of all analytical results. These programs have been developed in consultation with EPA, NIOSH, and various state departments of health.

Each subcontract laboratory has its own standard internal QA program and was directed by the Project Leaders to conduct additional project specific QC procedures. The laboratory conducted the specified laboratory QC procedures in addition to their internal procedures.

The following quality control procedures were used during this program:

> *Field Blanks* - For each set of samples taken, a field blank was also collected. Field blanks were collected and analyzed for both VOST and Method 0011 samples. The analysis showed that the VOST field blank was clean demonstrating that field procedures were conducted properly. The Method 0011 field blanks contained small amounts of acetone and cyclohexanone and the results were used to blank correct samples. During the warm weather test the Method 0011 blank contained low levels of formaldehyde and the sample results were also blank corrected.
>
> *Method Blanks* - To ensure that no contamination occurs during the laboratory work-up, the laboratories processed a method blank with all analytical runs. These blanks indicated no contamination from analytical procedures.
>
> *Spiked Samples* - All VOST cartridges were spiked with known quantities of target compound isotopes prior to sampling to determine the percent recovery and to indicate the overall accuracy. VOST cartridge pairs were spiked with three surrogate isotopes prior to analysis to determine the percent recovery and recoveries were within method specifications. A Method 0011 field spike was also conducted and the formaldehyde recovery was within method specification.

5.3 Reporting

All calculations were performed using an Excel spreadsheet developed by TRC. The final results were checked by a senior-level project scientist.

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