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HOT MIX ASPHALT PLANTS KILN DRYER STACK INSTRUMENTAL METHODS TESTING

ASPHALT PLANT "A"
CLAYTON, NORTH CAROLINA

Office of Air Quality Planning and Standards
Clean Air
OAQPS

HOT MIX ASPHALT PLANTS
KILN DRYER STACK
INSTRUMENTAL METHODS TESTING

Asphalt Plant “A”
Clayton, North Carolina

Prepared for

Office of Air Quality Planning and Standards
Emissions, Monitoring and Analysis Division
Emission Measurement Center (MD-19)
Research Triangle Park, North Carolina 27711
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PREFACE

This test report was prepared by Midwest Research Institute (MRI) for the U. S. Environmental Protection Agency (EPA) under EPA Contract No. 68-D-98-027, Work Assignment No. 3-02. Mr. Michael Toney is the Work Assignment Manager (WAM). Mr. Scott Klamm is the MRI Work Assignment Leader (WAL). The field test was performed under EPA Contract No. 68-D2-0165, Work Assignment No. 4-24. A draft report was submitted under EPA Contract No. 68-W6-0048, Work Assignment No. 2-08, Task 2 and a revised draft was submitted under Work Assignment 2-10 of 68-D-98-027. Mr. Toney was also the WAM for the previous work assignments. Dr. Thomas Geyer was the MRI WAL for Work Assignments No. 4-24 and 3-10 and the Task Leader for Task 2. Mr. John Hosenfeld was the MRI WAL for Work Assignment No. 2-08.

This report consists of one volume (360 pages) with six sections and five appendices.

MIDWEST RESEARCH INSTITUTE

Andrew Trenholm
for John Hosenfeld
Program Manager

Approved:

Jeff Shular
Jeff Shular
Director, Environmental Engineering Department

April 2000

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1.0 INTRODUCTION

1.1 BACKGROUND

The Emission Measurement Center (EMC) directed Midwest Research Institute (MRI) to conduct emissions testing at asphalt concrete production plants. This was in response to a test request from the Minerals and Inorganic Chemicals Group of the Emission Standards Division (ESD) and Source Characterization Group of the Emission Monitoring and Analysis Division (EMAD), both in the Office of Air Quality Planning and Standards (OAQPS), U. S. EPA. The test program was done in August 1997 under work assignment 4-24, on EPA Contract No. 68-D2-0165. This draft report was prepared under work assignment 2-08, on EPA Contract No. 68-W6-0048.

The purpose of this project was to perform an emissions test on the inlet and outlet of a baghouse that controls emissions from the counterflow rotary dryer process used at asphalt Plant A in Clayton, NC. Midwest Research Institute used EPA FTIR Draft Method 320[1] and EPA Method 25A. Method 320 is an extractive test method using Fourier Transform infrared (FTIR) spectroscopy. Method 320 uses quantitative analytical procedures described in the EPA FTIR Protocol.[2] Method 25A is an extractive test method using a Flame Ionization Analyzer (FIA). Data will be used to quantify and characterize hazardous air pollutant (HAP) emissions and the performance of the control unit.

1.2 PROJECT SUMMARY

Asphalt paving materials are produced by drying and mixing various amounts of raw (and sometimes recycled) materials in a rotary drum dryer. The product is carried from the dryer by conveyor to heated storage silos before distribution by truck. The dryer emissions are drawn through a baghouse for particulate control before being emitted to atmosphere. Testing was conducted at the inlet and outlet of the baghouse to determine the amount of measurable emissions released.

Four test runs were conducted by MRI at each location over a 3-day period concurrently with manual method testing conducted by Pacific Environmental Services, Inc. (PES). Test Runs 1, 2, and 3 were conducted during production using reclaimed asphalt pavement (RAP). Test Run 4 was conducted during production using non-RAP containing material.

The FTIR samples were collected by alternately sampling the baghouse inlet and stack, using a single instrument. Method 25A testing was continuous at both locations using two analyzers. A summary of the FTIR results for samples collected on a hot/wet basis (i.e., extracted stack gas) direct to the instrument for Runs 1-4 is presented in Table 1-1. FTIR results for samples collected on a cold/dry basis (i.e., stack gas moisture removed with a condenser) for Runs 1-4 are summarized in Table 1-2. Only detected compounds are shown in Tables 1-1 and 1-2. Toluene is shown because some samples were spiked with toluene. The Method 25A results are summarized in Table 1-3. The complete Method 25A results are in Appendix A, and the complete FTIR results are in Appendix B.

The EPA Method 320 uses an extractive sampling procedure. A probe, pump, and heated line are used to transport sample gas from the test port to a gas distribution manifold in a trailer that contains the FTIR equipment. Infrared spectra of a series of samples were recorded and quantitative analysis of the spectra was done after the FTIR data collection was completed. All spectral data and results were saved on computer media. A compact disk containing all FTIR data was provided with the draft report.

The FTIR spectra showed evidence that the emissions included a mixture of aliphatic hydrocarbon compounds. The only HAP's in that classification are 2,2,4-trimethylpentane (isooctane) and hexane. Therefore, in the draft report, the hydrocarbon emissions were primarily represented by "hexane." Since the draft report was submitted, MRI has measured reference spectra of some additional hydrocarbon compounds. The new reference spectra were included in the revised analysis to obtain a better representation of the hydrocarbon emissions.

The EPA Method 25A also uses an extractive sampling procedure, and the same sample transport system was used for both the FTIR and Method 25A testing. Volume concentration data and results obtained from the samples were recorded and saved on computer media and reviewed after the test was completed.

The "wet" results are from spectra of untreated samples. The "condenser" results are from spectra of sample gas that was passed through an ice-temperature chiller to remove moisture from the sample. The condenser results are reported on a dry basis. The condenser, by reducing moisture interference, can aid the analyses of some compounds, but soluble species such as formaldehyde are more accurately measured in the wet samples. Even the concentration of non-soluble species can be reduced by the condenser because vapor pressures are lower at the condenser temperature. Note that the condenser and wet samples cannot be compared directly because they were measured at different times (see Table 3-1).

TABLE 1-1. SUMMARY OF FTIR RESULTS FOR WET SAMPLES AT PLANT A[a]

Untreated (wet) Samples		Run 1		Run 2		Run 3		Run 4	
		Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Toluene	ppm						0.49		
	lb/hr						0.21		
	kg/hr						0.09		
Hexane	ppm		3.22		0.46		2.30		2.00
	lb/hr		1.12		0.20		0.92		0.81
	kg/hr		0.51		0.09		0.42		0.37
Ethylene	ppm	13.6	15.6	3.9	9.5		12.5	11.9	17.6
	lb/hr	1.55	1.77	0.55	1.34		1.62	1.56	2.31
	kg/hr	0.70	0.80	0.25	0.61		0.74	0.71	1.05
Methane	ppm	22.2	20.8	62.9	45.7	23.5	18.1	20.7	22.2
	lb/hr	1.44	1.35	5.04	3.66	1.73	1.34	1.55	1.66
	kg/hr	0.65	0.61	2.28	1.66	0.79	0.61	0.70	0.75
Sulfur Dioxide	ppm	35.5	51.8	9.5	57.1		60.1	52.8	46.5
	lb/hr	9.19	13.42	3.05	18.29		17.77	15.81	13.94
	kg/hr	4.17	6.09	1.38	8.29		8.06	7.16	6.32
Carbon Monoxide	ppm	238.5	226.9	806.8	623.7	49.6	207.5	179.2	225.4
	lb/hr	27.0	25.7	113.0	87.3	6.42	26.8	23.5	29.5
	kg/hr	12.3	11.7	51.2	39.6	2.91	12.2	10.6	13.4
Formaldehyde	ppm	15.5	9.0	1.0	4.7	1.5	13.0		11.4
	lb/hr	1.89	1.10	0.15	0.70	0.21	1.81		1.60
	kg/hr	0.86	0.50	0.07	0.32	0.10	0.82		0.72
Butane	ppm		1.1						
	lb/hr		0.26						
	kg/hr		0.12						
2-Methyl-1-pentene	ppm	0.31			0.66				6.5
	lb/hr	0.106			0.28				2.55
	kg/hr	0.048			0.13				1.16
2-Methyl-2-butene	ppm						0.089		
	lb/hr						0.029		
	kg/hr						0.013		

[a] Blank space indicates a "non-detect."

TABLE 1-2. SUMMARY OF FTIR RESULTS FOR CONDENSER SAMPLES AT PLANT A[a]

Condenser Samples		Run 3		Run 4	
		Inlet	Outlet	Inlet	Outlet
Toluene	ppm		0.28	8.9	12.4
	lb/hr		0.090	3.1	4.34
	kg/hr		0.041	1.4	1.97
Hexane	ppm		2.5		
	lb/hr		0.78		
	kg/hr		0.35		
Ethylene	ppm	12.8	11.0	19.5	21.2
	lb/hr	1.27	1.10	2.08	2.26
	kg/hr	0.58	0.50	0.94	1.02
Methane	ppm	7.4	8.3	10.1	11.4
	lb/hr	0.42	0.47	0.62	0.69
	kg/hr	0.19	0.21	0.28	0.31
Sulfur Dioxide	ppm	49.3	51.5	45.1	35.1
	lb/hr	11.2	11.7	11.0	8.53
	kg/hr	5.06	5.30	4.97	3.87
Carbon Monoxide	ppm	291.4	307.0	311.3	320.3
	lb/hr	28.9	30.5	33.1	34.1
	kg/hr	13.1	13.8	15.0	15.5
Formaldehyde	ppm	9.2	4.1	4.1	5.3
	lb/hr	0.98	0.44	0.46	0.60
	kg/hr	0.44	0.20	0.21	0.27
3-Methylpentane	ppm	1.6	0.11	0.42	0.09
	lb/hr	0.49	0.034	0.14	0.030
	kg/hr	0.22	0.016	0.062	0.013
Isooctane	ppm			0.17	0.0281
	lb/hr			0.08	0.0122
	kg/hr			0.03	0.0055
Butane	ppm	0.79			4.4
	lb/hr	0.16			0.97
	kg/hr	0.074			0.44
2-Methyl-1-pentene	ppm	9.4	3.5	4.1	9.9
	lb/hr	2.8	1.0	1.3	3.2
	kg/hr	1.3	0.47	0.60	1.4
Heptane	ppm			4.3	1.2
	lb/hr			1.6	0.47
	kg/hr			0.73	0.21
1-Pentene	ppm			3.1	0.52
	lb/hr			0.83	0.14
	kg/hr			0.37	0.06
2-Methyl-2-butene	ppm	7.3	1.8	3.3	2.0
	lb/hr	1.84	0.46	0.88	0.53
	kg/hr	0.83	0.21	0.40	0.24

[a] Blank space indicates a "non-detect."

TABLE 1-3. SUMMARY OF HYDROCARBON EMISSIONS RESULTS

Test Data					
Run No. Date	1 19-Aug-98	2 20-Aug-98	3 20-Aug-98	Average[b]	4 21-Aug-98
Baghouse Inlet					
Gaseous Concentrations					
THC Concentration, ppm (wet basis)	66.7	54.0	27.0	49.2	60.1
THC Concentration, ppmc[a] (wet basis)	199.8	162.0	81.0	147.6	180.3
THC Concentration, ppmc (dry basis)	243.4	206.5	105.6	185.2	222.0
Emissions Data					
THC Emission Rate, lb/hr	9.7	9.7	4.5	8.0	10.1
THC Emission Rate, kg/hr	4.4	4.4	2.0	3.6	4.6
Baghouse Outlet (Stack)					
Gaseous Concentrations					
THC Concentration, ppm (wet basis)	47.4	47.7	25.4	40.2	38.1
THC Concentration, ppmc (wet basis)	142.2	143.1	76.2	120.5	114.3
THC Concentration, ppmc (dry basis)	173.2	182.4	99.3	151.7	140.8
Emissions Data					
THC Emission Rate, lb/hr	6.9	8.6	4.2	6.6	6.4
THC Emission Rate, kg/hr	3.1	3.9	1.9	3.0	2.9

[a] ppm is concentration measured as propane; ppmc = ppm as carbon.

[b] Results from Runs 1-3 are averaged because these runs were conducted during production using reclaimed asphalt pavement (RAP). Run 4 was conducted during production using non-RAP material.

1.3 PROJECT PERSONNEL

The EPA test program was administered by the EMC. Some key project personnel are listed in Table 1-4.

TABLE 1-4. PROJECT PERSONNEL

Organization and Title	Name	Phone Number
Plant A Corporation Environmental/ Safety	Phil Adams	(919) 291-5165
Plant A Corporation Plant Manager/Supervisor	George Reeves	(919) 779-9752
U. S. EPA, EMC Work Assignment Manager Work Assignment 4-24 Work Assignment 2-08	Michael L. Toney	(919) 541-5247
U. S. EPA Minerals and Inorganic Chemicals Group	Mary Johnson	(919) 541-5025
MRI Work Assignment Leader Work Assignment	Scott Klamm	(816) 753-7600 Ext 1228
MRI Work Assignment Leader Work Assignment 4-24 Work Assignment 2-10 Task Leader Work Assignment 2-08	Thomas J. Geyer	(919) 851-8181 Ext 3120
MRI Program manager Work Assignment Leader Work Assignment 2-08	John Hosenfeld	(816) 753-7600 Ext 1336

2.0 PROCESS DESCRIPTION AND TEST LOCATIONS

2.1 PROCESS DESCRIPTION

A process description and process data were provided by EC/R Incorporated. The EC/R description and data are attached to this report in Appendix E.

2.2 TEST LOCATIONS

Figures 2-1 and 2-2 are drawings of the baghouse inlet and outlet test locations. Samples from both the baghouse outlet stack and the baghouse inlet were analyzed by FTIR and THC analyzers from the same trailer position.

2.2.1 Baghouse Inlet Duct

The inlet location was a circular duct with a diameter of 48 inches (in.). The testing was conducted in the vertical segment of the duct immediately upstream of where it connects to the baghouse. FTIR and Method 25A testing was conducted in a 4-inch diameter test port that was 36 in. above the baghouse roof. This port was in a plane about 11 in. above the manual testing ports and offset by 45°.

2.2.2 Baghouse Outlet - Stack

The outlet location (stack) was a rectangular duct 49¼ in. wide and 33½ in. deep. The wide face of the duct faces toward the baghouse roof. Six 4-in. ports arrayed in a straight line across the wide side of the duct were used for the manual testing. Another 4-in. port was installed on the short side of the stack, 24 in. below the top to provide access for the FTIR and Method 25A sample probe.

2.3 VOLUMETRIC FLOW

Table 2-1 summarizes the gas composition and flow data provided by PES. PES provided volumetric flow rates, moisture content, gas molecular weight, etc. as part of their manual testing; therefore, MRI did not conduct these tests.

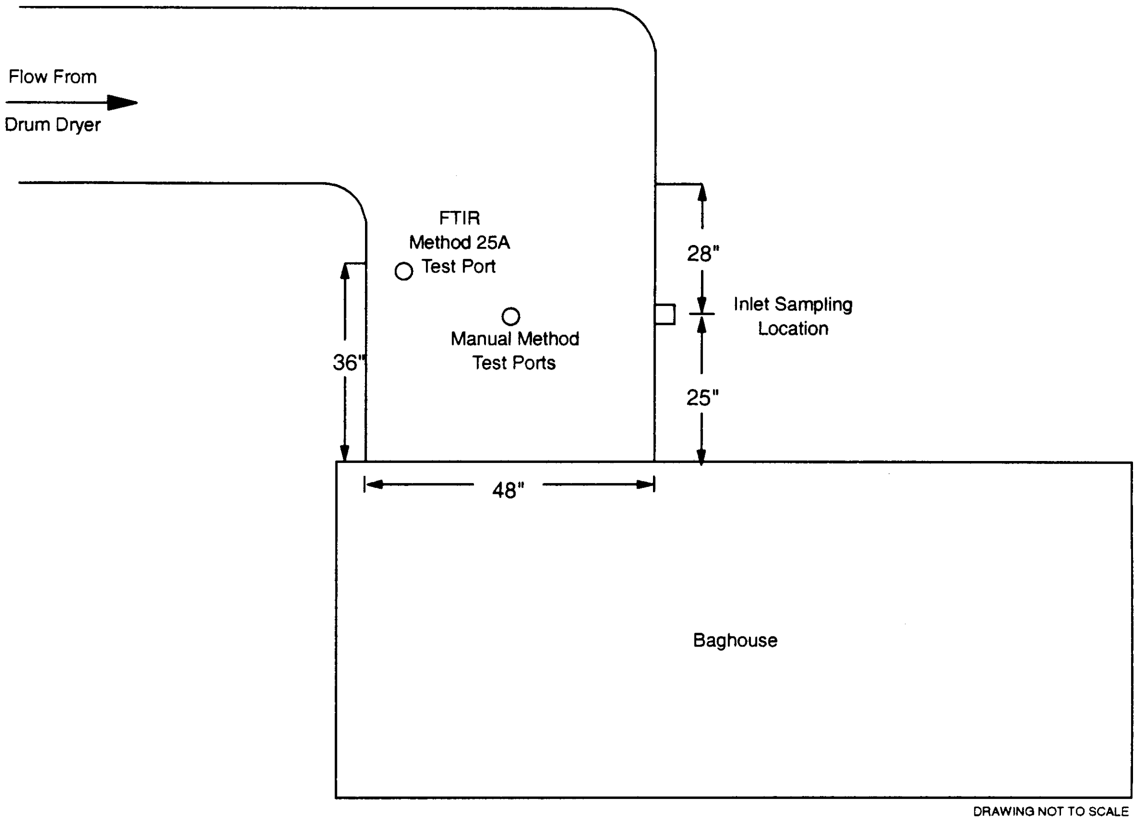


Figure 2-1. Baghouse inlet.

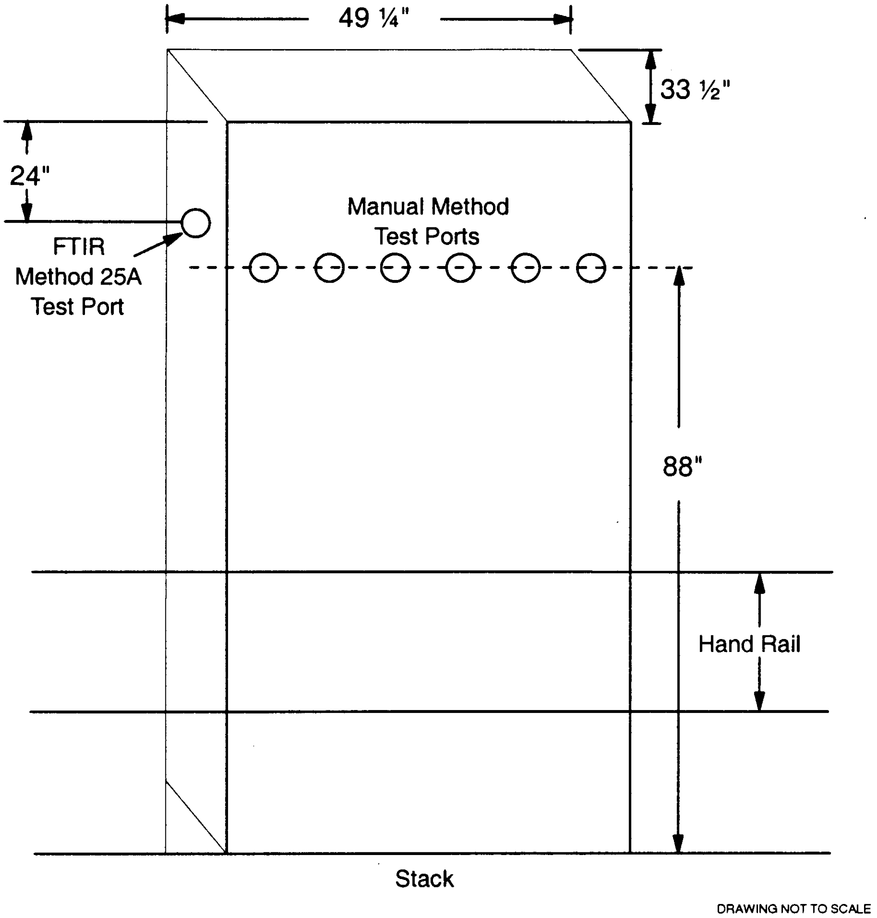


Figure 2-2. Baghouse outlet (stack).

TABLE 2-1. SOURCE GAS COMPOSITION AND FLOW SUMMARY AT PLANT A

Test Data[a]				
Run No.	1	2	3	4
Date	19-Aug-98	20-Aug-98	20-Aug-98	21-Aug-98
Baghouse Outlet (Stack)[b]				
Oxygen, %	13.1	13.1	13.1	10.8
Carbon Dioxide, %	5.3	5.5	5.1	3.2
Moisture Content, %	17.9	21.6	23.3	18.8
Gas Stream Velocity, fps	46	61	55	53
Volumetric Flow Rate, dscfm	21,344	25,198	22,749	24,410

[a] Data in Table 2-1 were provided by Pacific Environmental Services (PES). Raw data are in Appendix A-3.

[b] Manual sampling was terminated at the inlet due to high particulate loading, therefore no gas measurements were made at the inlet. Inlet mass emissions for all Runs were calculated using the velocity and gas composition data measured at the outlet (Section 3.2.6).

3.0 RESULTS

3.1 TEST SCHEDULE

The test program at the Plant A facility was completed from August 19 to August 21, 1997. Table 3-1 summarizes the sampling schedule. A complete record of all Method 25A and FTIR sampling is in Appendices A and B. The FTIR and Method 25A sampling was coordinated with the manual sampling conducted by PES.

TABLE 3-1. PLANT A FTIR AND 25A TEST SCHEDULE[a]

	FTIR				THC (25A)	
	INLET		OUTLET			
Date/Run No.	Wet	Dry	Wet	Dry	Inlet	Outlet
8/19/97 Run 1			754-813 (spike)			900-1005
	834-844 (spike)				927-957	
						1010-1427
	900-913				1017-1024	
			917-1021		1054-1413	
	1026-1038				1428-1501	
	1116-1203					
			1205-1241			
	1243-1307					
			1322-1347			
	1354-1424					
			1433-1438			
8/20/97 Run 2			747-800 (spike)		840-1242	840-1242
	812-817 (spike)					
	834-906					
			912-944			
	950-1030					
			1036-1108			
	1126-1158					
			1205-1239			
8/20/97 Run 3			1341-1401		1307-1725	1307-1656
				1405-1525		1727-1743
		1431-1506				
			1513-1542			
	1549-1617					
				1625-1653		
				1705-1723 (spike)		
		1733-1740 (spike)				

TABLE 3-1. (CONTINUED)

	FTIR				THC (25A)	
	INLET		OUTLET			
Date/Run No.	Wet	Dry	Wet	Dry	Inlet	Outlet
8/21/97 Run 4			732		748-817	
				739-809 (spike)	829-909	812-1158
		817-834 (spike)			938-1158	
			911-939			
	943-1015					
				1028-1059		
		1106-1132				
			1138-1156			

[a] See Tables and plots in Appendices A and B for details of 25A and FTIR sampling times, respectively.

3.2 FIELD TEST PROBLEMS AND CHANGES

Several factors worth noting are discussed below in separate subsections.

3.2.1 High Particulate at the Inlet

A short time into the first test run, the design of the FTIR sample probe and filter was found incapable of handling the high particulate loading at the inlet sampling location. The manual testing at the inlet was stopped because of the high particulate loading at the inlet location. Therefore, no manual gas data were collected by PES at the inlet. The MRI field crew tried several filtering designs before finding a solution that worked over a reasonable period. An additional Balston filter was installed at the probe inlet, offset 90° from the probe and 180° from the gas stream flow. The plugging of the filters and the removal of the probe for redesign caused the loss of all inlet THC data and some FTIR data for these periods. MRI took steps to reduce the loss of inlet data during installation or replacement of the filter.

3.2.2 Method 25A Concentration Spikes

Several times during Run 1 and at the beginning of Run 2, both THC analyzers recorded process spikes when the THC concentration exceeded the analyzers' scale. All of the 1-minute averages that exceeded the scale are included in the run averages. Because the exact concentration was unknown when the instrument scale was exceeded, the 1-minute averages that include these spikes are biased low. Nevertheless, because the number of out-of-range spikes was few and their durations brief, the run average should not be significantly affected. This was discovered during Run 2 and was corrected by recalibrating the analyzers to a higher (0 to 1,000 ppm) range.

3.2.3 Addition of a Fourth Test Run

The EPA decided during the field test to add a fourth run to provide measurements while non-RAP material was being used in the process. Run 4 was performed on August 21.

3.2.4 Method 25A Calibration Checks

The low-level THC calibration error check on the outlet analyzer for Run 4 was 5.2 percent, which exceeds the Method 25A performance limit of less than 5 percent. The error was discovered during MRI's data quality assurance check and was found in the calculation of the difference between the predicted and actual response. The operator used the calibration gas value instead of calculating the predicted response. This approach would have been correct if the instrument zero and span were set to the exact calibration gas values during instrument linearization, but they were not. The calibration errors were recalculated, and all except this one were within the required 5 percent. The oversight in the calibration procedure was brought to the attention of the operator. Since the error is 0.2 percent outside the performance limit, MRI decided that the effect on these data is small, and the data are presented without correction.

3.2.5 Condenser Sampling

Some samples were passed through a moisture condenser before measurement with the FTIR system. This was not mentioned in the Site Specific Test Plan (SSTP), but it was a useful procedure for FTIR analysis because the sample gas contained a relatively high moisture content. The use of the condenser was approved by the EPA observer at the test site. The condenser was used for portions of Runs 3 and 4. Moisture removal was accomplished by passing the sample gas through an impinger immersed in an ice bath just before the FTIR cell. Moisture removal reduces spectral interference in some frequency regions and can improve the analysis of compounds that can pass through the condenser. Analyte spiking was successfully performed through the condenser. Uncertainty results in Section 3.6 show that the quantitation limits are lower for compounds that can pass through a condenser.

3.2.6 Inlet Flow Determination

For all runs, the flow data collected at the stack were used to calculate the inlet mass emission rates. Manual testing at the inlet was discontinued due to high particulate loading, so only limited inlet flow information is available from the first test day. MRI monitored the velocity pressure (ΔP) and temperature at the FTIR sampling point, but these data are not of suitable quality for calculating the volumetric flow rate since they were not collected by the EPA manual method. The use of the outlet flow data to calculate the inlet mass emission rate may give inlet emission rates with a slightly high bias. The outlet flow rate could potentially be higher than at the inlet because the ID fan was located at the base of the stack. This design also can allow dilution air to be pulled into the system if any leaks exist between the inlet sample location and the fan. The hydrocarbon results summarized in Table 1-3 show that the THC outlet concentrations were lower in all of the test runs, which indicates the possibility that air in-leakage across the baghouse occurred.

3.3 METHOD 25A RESULTS

Table 1-3 summarized the Method 25A THC results at both the baghouse inlet and outlet. The emission data are presented in parts per million as carbon (ppmc), pounds per hour as carbon (lb/hr), and kilograms per hour (kg/hr).

The THC emissions for all four runs show high concentration spikes throughout the test periods. The results for Runs 1 and 2 were very similar in the number and duration of the high-concentration spikes. In Run 3 fewer high-concentration THC spikes were seen, apparently because of a burner adjustment, and the Run 3 average THC concentration was half that of Runs 1 and 2 . Run 4, the non-RAP run, displays the highest average emission rate at the inlet. The Run 4 results show fewer spikes, but these are of longer duration than in the previous three runs.

Graphical presentations of outlet results from Runs 2, 3, and 4 are shown in Figure 3-1. The inset in the Run 3 graph shows the 1400-1500 period on an expanded scale. The expanded view shows that the Run 3 variations are qualitatively similar to the variations in Run 2 but smaller in magnitude.

Table 3-2 shows the minimum, maximum, and average THC concentrations for each run. The 1-minute average THC concentrations range from as low as 50.4 ppmc, during Run 3, to as high as 639.9 ppmc, during Run 2. This does not mean that the highest spike was 639.9 ppmc but that the highest 1-minute average was 639.9 ppmc, excluding the first test run because the instrument range was set too low to measure the process spikes. THC emission trends similar to Runs 1, 2, and 3 are what would normally be found at this type of facility.

The complete Method 25A results are included in Appendix A. The concentrations presented were measured by MRI. The mass emissions data, presented in Section 1.2, were calculated using volumetric flow results provided by PES. The pre- and post-run calibrations and QA checks met the Method 25A criteria in all cases except for Run 4 as discussed in Section 3.2. Calibration QA results are included in Appendix A.

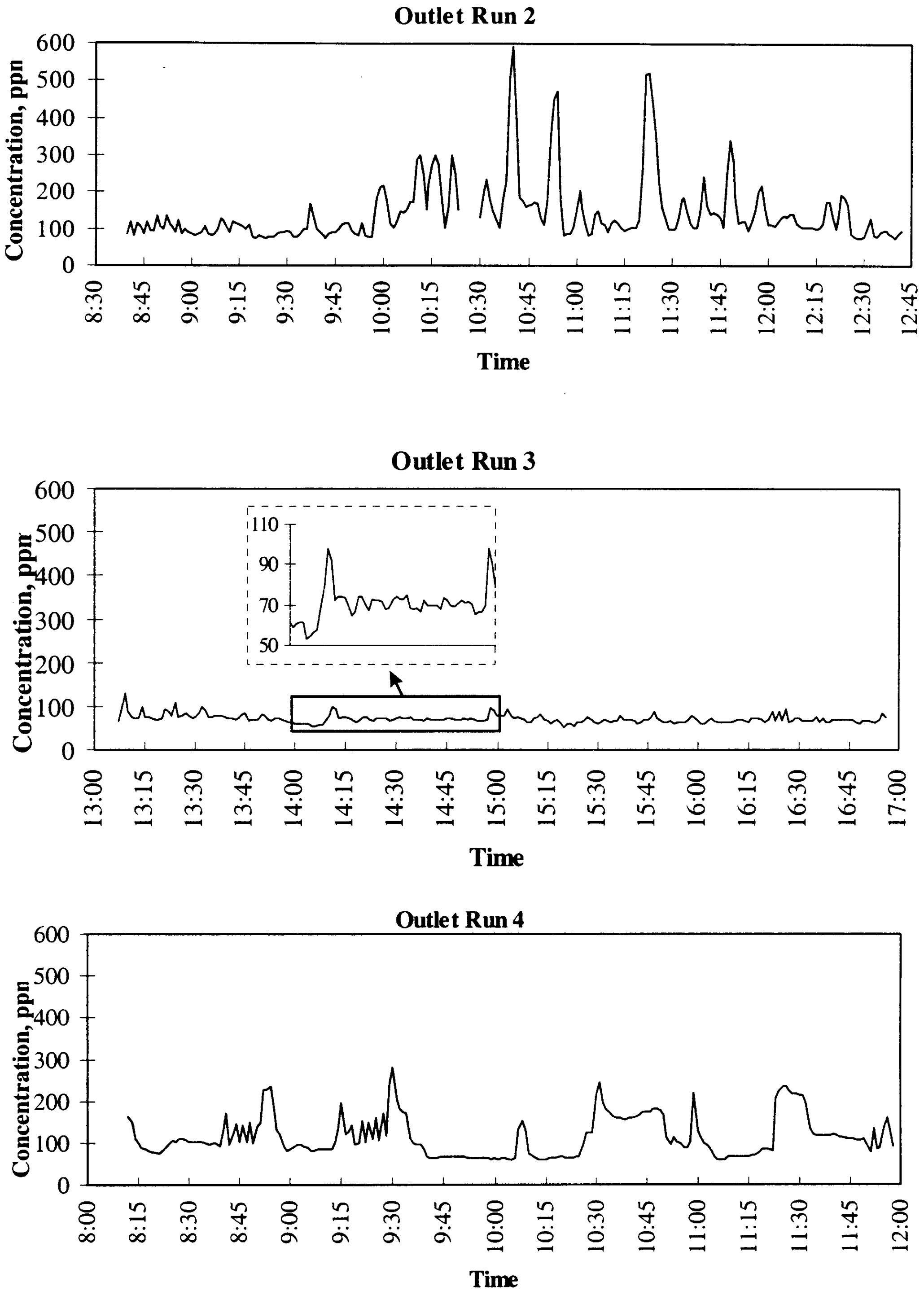


Figure 3-1. THC concentration trend graphs.

TABLE 3-2. MINIMUM AND MAXIMUM THC CONCENTRATIONS[a]

Run No.	Minimum		Maximum		Average	
	ppm	ppmc	ppm	ppmc	ppm	ppmc
Baghouse inlet						
1	42.7	128.1	100.0	300.0[b]	66.7	199.8
2	27.4	82.2	213.1	639.3	54.9	162.0
3	17.9	53.7	83.2	249.6	27.0	81.0
4	31.3	93.9	129.0	387	60.1	180.3
Baghouse stack						
1	25.2	75.6	100.0	300.0[b]	47.4	142.2
2	24.0	72	197.4	592.2	47.7	143.1
3	16.8	50.4	64.0	192	25.4	76.2
4	20.1	60.3	94.0	282	38.1	114.3

[a] ppm is the concentration as propane; ppmc = ppm as carbon

[b] Maximum concentration off scale

3.4 FTIR RESULTS

The two locations were sampled sequentially with the FTIR system. Wet and dry samples were also measured sequentially. Sampling times are shown in Tables B-1 through B-4, and in the accompanying graphs in Appendix B.

A summary of the FTIR results was presented in Tables 1-1 and 1-2. Complete FTIR results at the inlet and outlet are presented in Tables B-1 to B-4 in Appendix B. The infrared spectra showed evidence of water vapor, carbon dioxide (CO_2), CO, methane, formaldehyde, sulfur dioxide (SO_2), toluene, ethylene, and a mixture of aliphatic (non-aromatic) hydrocarbons. The FTIR spectra showed evidence that the emissions included a mixture of aliphatic hydrocarbon compounds. The only HAP's in that classification are 2,2,4-trimethylpentane (isooctane) and hexane. Therefore, the hydrocarbon emissions were primarily represented by "hexane" in the draft report results. Since the draft report was submitted, MRI has measured reference spectra of some additional hydrocarbon compounds. The new reference spectra were included in the revised analysis to obtain a better representation of the hydrocarbon emissions.

A description of the analytical procedures used to prepare the FTIR results is given in Section 4.4. The mass emission rates were calculated using flow data provided by PES. Mass emission calculations for toluene include the results from samples that were not spiked from the toluene cylinder standard.

Some samples in Runs 3 and 4 were measured on a cold/dry basis by passing the gas through a condenser before the FTIR cell. The condenser was used to remove moisture, which was typically above 20 percent by volume. Which compounds can pass through the condenser and be measured in the "dry" samples depends primarily on the vapor pressure and solubility of the compounds in the sample. Analyte spiking was performed through the condenser using the toluene calibration standard. The spike results showed that measurements of toluene (and presumably compounds with similar chemical and physical properties) were unaffected by the condenser. This was consistent with results from an EPA Method 301 validation test at a coal-fired boiler.[4]

Because moisture is removed from the samples and because the calculated uncertainties depend on the residual noise in the spectra, the calculated uncertainties for non-detects are much lower in the dried samples. However, this is significant only for compounds that can pass through the condenser.

3.5 ANALYTE SPIKE RESULTS

A toluene gas standard was used for analyte spiking experiments for quality assurance only. Preferably, a spike standard combines the analyte and the tracer gas in the same cylinder, but the SF_6 and toluene were contained in two separate cylinders. Therefore, the two components (SF_6 and toluene) were quantitatively mixed (in equal proportions) before being introduced into the sample gas stream.

The analyte spike results are presented in Tables 3-3 to 3-6. Samples were spiked with a measured flow of toluene vapor during each run and at each location and through the condenser in runs during which the condenser was used. The SF_6 tracer gas spike was used to determine the spike dilution factor. A description of the spike procedure is given in Section 4.3.1.

In general, the calculated spike recoveries were greater than 130 percent, which is above the range specified by Method 301 for a validation correction factor (between 70 and 130 percent). However, for reasons discussed below, this does not reflect on the accuracy of the emissions results in Tables B-1 to B-4. The residual spectra do not show significant absorbances, indicating that the computer program did not over- or under-subtract analyte reference spectra.

One factor contributing to the (calculated) high spike recoveries relates to the use of the toluene library reference spectra. The toluene spike recoveries and all of the toluene results were obtained using reference spectra in the EPA library. Spectra of the toluene cylinder standard used for spiking were recorded on site during the test. If these spectra are used in the analysis, one obtains results about 40 percent lower (far right column in Tables 3-3 to 3-5) than those obtained using the library reference spectra.

Table 3-7 presents measured band areas of the EPA toluene reference spectra (deresolved to 2 cm^{-1}) and the spectrum of the toluene cylinder standard measured at the Plant A test site. The comparison of the band areas does not agree with the comparison of the concentrations (corrected for path length and temperature). The comparisons differ by nearly 40 percent. This observed difference predicts that, if the spectra of the toluene cylinder standard are used in the analysis rather than the EPA library spectra, then the result would give a toluene concentration that is about 40 percent lower. This in fact happens when the computer program is modified to include the cylinder standard spectra.

A similar disagreement was observed in other field tests using this toluene gas standard, and one possibility is that the certified concentration of the toluene cylinder standard was incorrect. However, this was a recently prepared cylinder with a quoted analytical accuracy of ± 2 percent. This possibility could be evaluated by purchasing several toluene gas standards from different sources and doing a comparison similar to that shown in Table 3-7.

This observation about the toluene library spectra is compound specific, and the information in Table 3-7 does not affect the results for other compounds detected. The deresolved calibration transfer standard (CTS) (ethylene calibration) spectra give a path length result (Section 4.4.1) that is consistent with the observed number of laser passes and the instrument resolution. Additionally, this observation is not related to the deresolution of the spectra because the band areas in the original 0.25 cm^{-1} toluene spectra are nearly equal to the band areas in the deresolved 1 cm^{-1} versions of these spectra.

A discrepancy of this type has the greatest effect on the difference, "spike - unspike," when the unspiked concentration is near zero. This is because two sets of reference spectra that disagree will yield the same answer for a zero concentration but will yield different answers for nonzero concentrations.

A similar disagreement between reference and standard spectra has been observed at least once previously.[5] In that study, which is included in Appendix D, HCl was the analyte. The spike recovery results were not significantly affected because there was a stable unspiked HCl concentration and because both the spiked and unspiked HCl concentrations were large compared with the disagreement between the reference spectra and the spectra of the cylinder standard.

TABLE 3-3. SPIKE RESULTS IN WET SAMPLES COLLECTED AT THE BAGHOUSE INLET

Run	Average Toluene Concentration			Average SF_6 Concentration							% Recovery
	Spike	Unspike	Tol (calc)[a]	Spike	Unspike	SF_6 (calc)[a]	DF[b]	C_{exp}[c]	A[d]	% Recovery	Tol Stan
1	24.1	0.0	24.1	0.541	0.000	0.541	3.7	16.1	8.0	149.7	92.1
	17.4	0.0	17.4	0.329	0.000	0.329	6.1	9.6	7.7	180.2	110.8
2	39.8	0.0	39.8	0.609	0.000	0.609	3.1	19.6	20.2	202.9	124.8

[a] Tol (calc) and SF_6(calc) are equal to the difference between the spiked and unspiked concentrations for toluene and SF_6, respectively.
[b] DF is the dilution factor in equation 4.
[c] C_{exp} is shown in equation 5.
[d] Δ is equal to the difference, Tol(calc) - C_{exp}.

TABLE 3-4. SPIKE RESULTS IN WET SAMPLES AT THE BAGHOUSE OUTLET

Run	Average Toluene Concentration			Average SF_6 Concentration							% Recovery
	Spike	Unspike	Tol (calc)[a]	Spike	Unspike	SF_6 (calc)[a]	DF[b]	C_{exp}[c]	A[d]	% Recovery	Tol Stan
1	21.2	0.0	21.2	0.326	0.000	0.326	6.0	10.1	11.1	209.4	128.8
	17.3	0.0	17.3	0.370	0.000	0.370	5.4	10.9	6.4	159.0	97.8
2	17.1	0.1	17.0	0.170	0.000	0.170	11.3	5.5	11.5	311.4	191.5

[a] Tol (calc) and SF_6(calc) are equal to the difference between the spiked and unspiked concentrations for toluene and SF_6, respectively.
[b] DF is the dilution factor in equation 4.
[c] C_{exp} is shown in equation 5.
[d] Δ is equal to the difference, Tol(calc) - C_{exp}.

TABLE 3-5. SPIKE RESULTS IN CONDENSER SAMPLES AT THE BAGHOUSE INLET

Run	Average Toluene Concentration			Average SF_6 Concentration							
	Spike	Unspike	Tol (calc)[a]	Spike	Unspike	SF_6 (calc)[a]	DF[b]	C_{exp}[c]	D[d]	% Recovery	% Recovery Tol Stan
3	18.0	0.0	18.0	0.328	0.000	0.328	6.0	9.9	8.1	182.39	112.1
4	17.1	5.1	12.0	0.310	0.098	0.213	9.1	6.6	5.4	0.7	111.1

[a] Tol (calc) and SF_6(calc) are equal to the difference between the spiked and unspiked concentrations for toluene and SF_6, respectively.

[b] DF is the dilution factor in equation 4.

[c] C_{exp} is shown in equation 5.

[d] Δ is equal to the difference, Tol(calc) - C_{exp}.

TABLE 3-6. SPIKE RESULTS IN CONDENSER SAMPLES AT THE BAGHOUSE OUTLET

Run	Average Toluene Concentration			Average SF_6 Concentration							
	Spike	Unspike	Tol (calc)[a]	Spike	Unspike	SF_6 (calc)[a]	DF[b]	C_{exp}[c]	D[d]	% Recovery	% Recovery Tol Stan
3	3.3	0.3	3.0	0.607	0.000	0.607	3.2	18.5	14.5	7.18	109.5
4	33.3	11.7	1.6	0.589	0.018	0.572	3.4	18.0	3.6	120.2	73.9

[a] Tol (calc) and SF_6(calc) are equal to the difference between the spiked and unspiked concentrations for toluene and SF_6, respectively.

[b] DF is the dilution factor in equation 4.

[c] C_{exp} is shown in equation 5.

[d] Δ is equal to the difference, Tol(calc) - C_{exp}.

TABLE 3-7. COMPARISON OF EPA REFERENCE SPECTRA TO SPECTRUM OF TOLUENE CYLINDER STANDARD

				Spectra comparison based on band areas		Comparison of spectra based on standard concentrations [a]		
Toluene Spectra	Source	Band Area	Frequency Region (cm^{-1})	Ratio (Ra)	=1/Ra	(ppm-m)/K	Ratio (Rc)	=1/Rc
153a4ara ($2cm^{-1}$)	EPA library	23.4	3160.8 - 2650.1	5.4	0.184	4.94	4.8	0.210
153a4arc ($2cm^{-1}$)	EPA library	4.3		1.0	1.000	1.04	1.0	1.000
1530819a	Plant A	21.9		5.1	0.196	3.18	3.1	0.326

[a] The comparison of the ratio based on concentrations to the ratio based on band area is equal to 61 percent.

4.0 TEST PROCEDURES

The procedures followed in this field test are described in EPA Method 320 for using FTIR spectroscopy to measure HAP's, the EPA Protocol for extractive FTIR testing at industrial point sources, and EPA Method 25A for measuring total gaseous organics. Objectives of the field test were to use the FTIR method to measure emissions from the processes, screen for HAP's in the EPA FTIR reference spectrum library, conduct analyte spiking for quality control measurement, and analyze the spectra for compounds not in the EPA library. Another objective was to monitor the process hydrocarbon emissions using Method 25A. Additionally, manual measurements of gas temperature, gas velocities, moisture, CO_2, and O_2 by PES were used to calculate the mass emissions rates.

The extractive sampling system shown in Figure 4-1 was used to transport sample gas from the test ports to the FTIR instrument and the THC analyzers.

4.1 SAMPLING SYSTEM DESCRIPTION

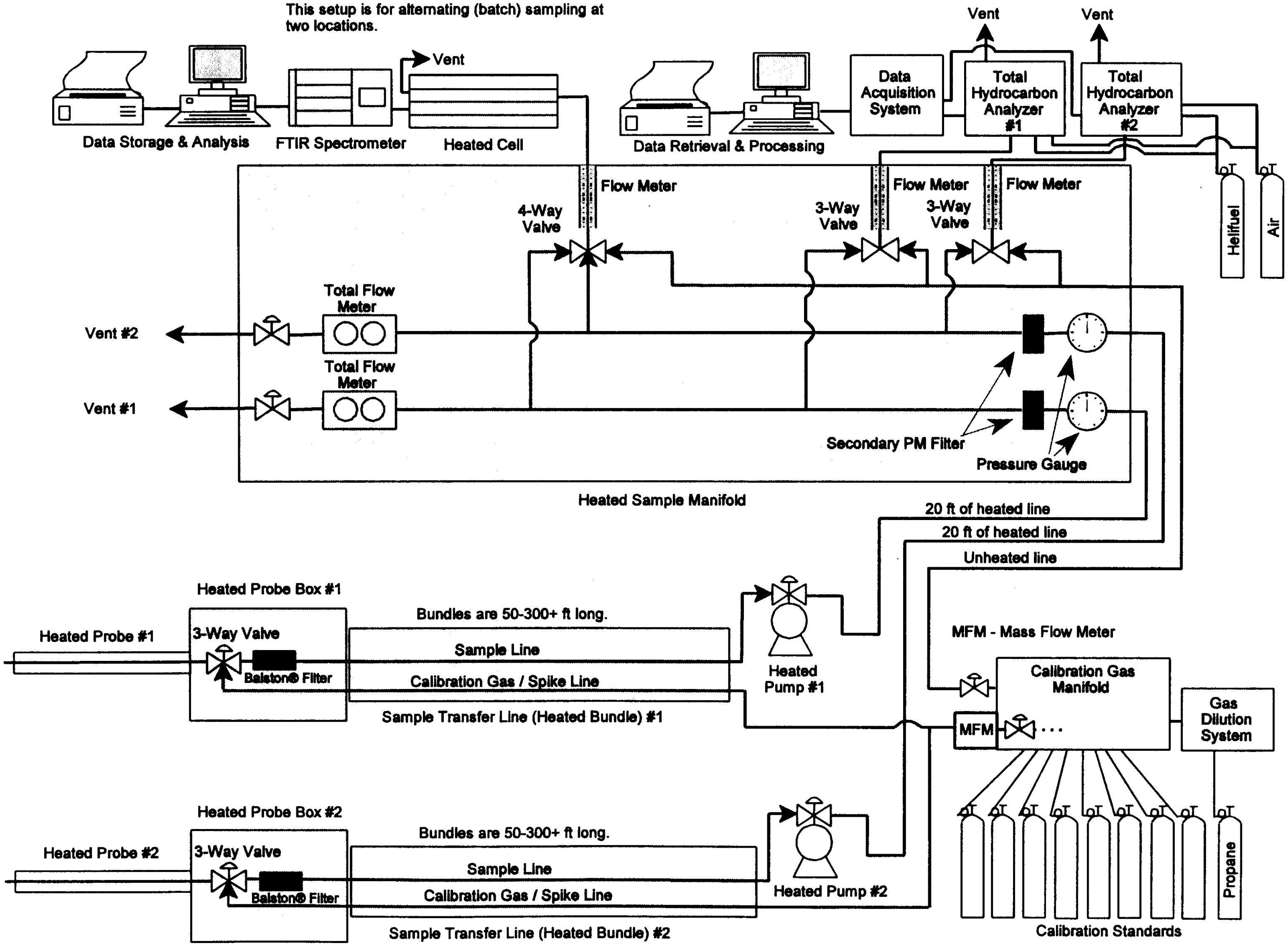
4.1.1 Sample System Components

The sampling system consists of three separate components:

1. Two sample probe assemblies;
2. Two sample lines and pumps; and
3. A gas distribution manifold cart.

All wetted surfaces of the system are made of unreactive materials, Teflon®, stainless steel, or glass and are maintained at temperatures at or above 300°F to prevent condensation.

The sample probe assembly consists of the sample probe, a pre-filter, a primary particulate filter, and an electronically actuated spike valve. The sample probe is a standard heated probe assembly with a pitot tube and thermocouple. The pre-filter is a threaded piece of tubing loaded with glass wool attached to the end of sample probe. The primary filter is a Balston particulate filter with a 99 percent removal efficience at 0.1 μm. The actuated spike valve is controlled by a radio transmitter connected to a switch on the sample manifold cart. All sample probe assembly components are attached to or enclosed in an insulated metal box.



This setup is for alternating (batch) sampling at two locations.

Figure 4-1. Sampling system schematic.

The sample lines are standard heated sample lines with three ⅜ in. Teflon tubes in 10, 25, 50, and 100 foot (ft) lengths. The pumps are heated, single-headed diaphragm pumps manufactured by either KNF Neuberger or Air Dimensions. These pumps can sample at rates up to 20 liters per minute (Lpm) depending on the pressure drop created by the components installed upstream.

The gas distribution manifold was specially constructed for FTIR sampling by MRI. It is built onto a cart that can be operated inside the MRI mobile lab or in an alternate location, if necessary. The manifold consists of a secondary particulate filter, control valves, rotameters, back pressure regulators and gauges, and a mass flow controller. The manifold can control two sample gas stream inputs, eight calibration gases, and has three individual outputs for analyzers. Alsoon the cart are a computer work station and controls for the spike valves and mass flow controller.

4.1.2 Sample Gas Stream Flow

Exhaust gas was withdrawn at both the inlet duct and stack of the strand baghouse through their respective sample probes and transported to the gas distribution manifold. Inside the manifold the gas passed through separate secondary particulate filters. Downstream of the secondary filters, part of each sample gas stream was directed to separate THC analyzers; one to measure the inlet concentration and another to measure the outlet concentration. Part of the remaining sample gas from each stream was either sent to the FTIR instrument for analysis or exhausted with the remaining portion of the gas stream being sampled (i.e., when the inlet sample was analyzed the stack sample was exhausted and vice versa). This was accomplished by rotating the gas selection valves to allow the appropriate sample gas to pass the instrument inlet port. The gas flow to the instruments was regulated by needle valves on rotameters at the manifold outlets.

The FTIR instrument was used to sample each location alternately, while the two THC analyzers were used to sample both locations simultaneously

4.2 FTIR SAMPLING PROCEDURES

Figure 4-1 shows a schematic of the FTIR instrument and connections to the sample distribution manifold.

Sampling was conducted using either the batch or the continuous sampling procedures. All data were collected according to Method 320 sampling procedures, which are described below.

4.2.1 Batch Sampling

In this procedure, the valve on the manifold outlet was turned to divert part of the sample flow to the FTIR cell. A positive flow to the main manifold outlet vent was maintained as the cell was filled to just above ambient pressure. The cell inlet valve was then closed to isolate the sample, the cell outlet valve was open to vent the cell to ambient pressure, the spectrum of the static sample was recorded, and then the cell was evacuated for the next sample.

Batch sampling has the advantage that every sample is an independent sample. The time resolution of the measurements is limited by the interval required to pressurize the cell and record the spectrum. For this test the time resolution was 4 to 5 minutes. All of the spiked samples were collected using this procedure.

4.2.2 Continuous Sampling

The cell was filled as in the batch sampling procedure, but the cell inlet and outlet valves were then opened to keep gas continuously flowing through the cell. The inlet and outlet flows were regulated to keep the sample at ambient pressure. The flow through the cell was maintained at about 5 Lpm (about 0.7 cell volumes per min). The cell volume was about 7 liters (L).

The FTIR instrument was automated to record spectra of the flowing sample about every 2 minutes. The analytical program was revised after the field tests, and the spectra were analyzed to prepare the results reported in Section 3.

This procedure with automated data collection was used for all of the unspiked testing during Runs 2, 3, and 4. Because spectra were collected continuously as the sample flowed through the cell, consecutive samples were mixed. The interval between independent measurements (and the time resolution) depended on the sample flow rate (through the cell), and the cell volume. The following explanation is taken from Performance Specification 15, for continuous operation of FTIR systems: "The Time Constant, TC, is the period for one cell volume to flow through the cell. The TC determines the minimum interval for complete removal of an analyte from the cell volume. It depends on the sampling rate (R_s in Lpm), the cell volume (V_{cell} in L) and the analyte's chemical and physical properties."

$$TC = \frac{V_{cell}}{R_s} \qquad (1)$$

Performance Specification 15 defines 5 * TC as the minimum interval between independent samples. In this test 5 * TC was about 7 minutes.

A stainless steel tube ran from the cell inlet connection point to the front of the cell. The outlet vent was at the back of the cell so that the flowing sample passed through the greatest portion of the cell volume.

4.3 ANALYTE SPIKING

Because no information about possible HAP emissions or flue gas composition was available for this source before the test, validating specific HAP's at this screening test was not planned. MRI conducted spiking for QA purposes using a toluene (121 ppm in air) standard.

4.3.1 Analyte Spiking Procedures

The infrared spectrum is ideally suited for analyzing and evaluating spiked samples because many compounds have distinct infrared spectra.

The reason for analyte spiking is to provide a quality control check that the sampling system can transport the spiked analyte(s) to the instrument and that the quantitative analysis program can measure the analyte in the sample gas matrix. If at least 12 (independent) spiked and 12 (independent) unspiked samples are measured, this procedure can be used to perform a Method 301 validation.[3] No validation was done at this field test.

The spike procedure follows Sections 9.2 and 13 of EPA draft Method 320 in Appendix D. In this procedure a gas standard is measured directly in the cell. This direct measurement is then compared with measurements of the analyte in spiked samples. Ideally, the spike comprises about 1/10 or less of the spiked sample. The actual dilution ratio depends on the sample flow rate and the spike gas flow rate. The expected concentration (C_{exp}, the calculated 100 percent recovery) of the spiked component is determined using a tracer gas, SF_6. The SF_6 concentration in the direct sample divided by the SF_6 concentration in the spiked sample(s) is used as the spike dilution factor (DF). The analyte standard concentration divided by DF gives the "expected" value (100 percent) of the spiked analyte recovery.

In this test the analyte (121 ppm toluene in air) and the tracer gas (4.01 ppm SF_6 in nitrogen) were in separate cylinders. Flows from the two gas standards were passed through separate mass flow meters and then combined into one flow directed up the spike line and introduced into the sample stream at the back of the sampling probe. Because the two gasses were mixed, the concentrations of each component were reduced in the combined spike gas flow. This had to be accounted for in the calculation of the spike dilution factor, DF. For example the SF_6 concentration in the combined spike stream was

$$SF_{6(\text{direct})} = \frac{F_{SF_6}}{F_{\text{toluene}} + F_{SF_6}} * SF_{6(\text{standard})} \tag{2}$$

where:

$SF_{6\ (\text{direct})}$ = the SF_6 in the spike mixture. This is used in place of the cylinder standard concentration.

F_{SF6} and F_{toluene} = the measured flows from the toluene and SF_6 cylinder standards.

$SF_{6\ (\text{standard})}$ = the concentration of the SF_6 cylinder standard.

The toluene concentration in the combined spike flow is calculated in the same way.

$$\text{toluene}_{(\text{direct})} = \frac{F_{\text{toluene}}}{F_{\text{toluene}} + F_{SF_6}} * \text{toluene}_{(\text{standard})} \tag{3}$$

The value, $SF_{6(\text{spike})}$ is compared to the measured SF_6 concentration in the spiked samples to determine the spike dilution factor.

$$DF = \frac{SF_{6(\text{direct})}}{SF_{6(\text{spike})}} \tag{4}$$

where DF is the spike dilution factor in Section 9.2.2 of Method 320 and $SF_{6(\text{direct})}$ is calculated using equation 2.

The calculated 100 percent recovery of the toluene spike is analogous to the expected concentration in Section 9.2.2 of Method 320. In this case:

$$C_{exp} = \frac{\text{toluene}_{(direct)}}{DF} \tag{5}$$

where:

C_{exp} = the expected toluene concentration in the spiked samples (100 percent recovery).

$\text{Toluene}_{(direct)}$ = from equation 3.

DF = from equation 4.

4.3.2 Analysis of Spiked Results

The toluene and SF_6 concentrations used in the evaluation of the spike recoveries in Tables 3-3 through 3-6 were taken directly from the sample analyses reported in Tables B1 through B4. The concentrations in the spiked samples included a contribution from the spike gas and from any analyte present in the flue gas. The component of the toluene concentration attributed to the spike was determined by subtracting the average of the unspiked samples from the measured concentration in each spiked sample (spike-unspike in Tables 3-3 through 3-6). The percent recovery was determined by comparing the differences, spiked - unspiked, to the calculated 100 percent recovery, C_{exp} in Section 4.3.1.

4.4 ANALYTICAL PROCEDURES

Analytical procedures in the EPA FTIR Protocol were followed for this test.[2] A computer program was prepared with reference spectra shown in Table 4-1. The computer program used mathematical techniques based on a K-matrix analysis.[6,7]

Initially, the spectra were reviewed to determined appropriate input for the computer program. Next an analysis was run on all of the sample spectra using all of the reference spectra listed in Table 4-1. Finally, the undetected compounds were removed from the analysis, and the spectra were analyzed again using reference spectra only for the detected compounds. Reference spectra of 2-methyl-2-pentene, 3-methylpentane, butane, 2-methyl-1-pentene, n-heptane, 1-pentene, 2-methyl-2-butene, and n-pentane were included in the analysis to measure the hydrocarbon mixture. These are the recently prepared hydrocarbon reference spectra described in

Sections 1.2 and 3.4. The results from this second analytical run are summarized in Tables 1-1 and 1-2 and reported in Appendix B.

The same program that did the analysis calculated the residual spectra (the difference between the observed and least squares fit absorbance values). Three residuals, one for each of the three analytical regions, were calculated for each sample spectrum. All of the residuals were stored electronically and are included with the electronic copy of the sample data provided with this report. Finally the computer program calculated the standard 1*sigma uncertainty for each analytical result, but the reported uncertainties are equal to 4*sigma.

The concentrations were corrected for differences in absorption path length and temperature between the reference and sample spectra using equation 2.

$$C_{corr} = \left(\frac{L_r}{L_s}\right)\left(\frac{T_s}{T_r}\right) C_{calc} \qquad (6)$$

where:

C_{corr} = concentration, corrected for path length and temperature.

C_{calc} = uncorrected sample concentration.

L_r = cell path length(s) (meters) used in recording the reference spectrum.

$L_{S.}$ = cell path length (meters) used in recording the sample spectra.

T_S = absolute temperature (Kelvin) of the sample gas when confined in the FTIR gas cell.

T_r = absolute temperature(s) (Kelvin) of gas cell used in recording the reference spectra.

The ambient pressure recorded over the three days of the test averaged about 746 mm Hg. Because the sample pressure in the gas cell is equivalent to the ambient pressure, an addition concentration correction factor of about 2 percent was included in the reported concentrations.

The sample path length was estimated by measuring the number of laser passes through the infrared gas cell. These measurements were recorded in the data records. The actual sample path length, L_S was calculated by comparing the sample CTS spectra to CTS (reference) spectra in the EPA FTIR reference spectrum library. The reference CTS spectra, which were recorded with the toluene reference spectra and are included in the EPA library, were used as input for a K-matrix analysis of the CTS spectra collected at the Plant A field test. The calculated average cell path length resulting from this analysis and the variation among the Plant A sample CTS over the 3 days of testing are reported in Section 4.4.1.

4.4.1 Computer Program Input

Table 4-1 presents a summary of the reference spectra input for the computer program used to analyze the sample spectra. Table 4-2 summarizes the program input used to analyze the CTS spectra recorded at the field test. The CTS spectra were analyzed as an independent determination of the cell path length. To analyze the CTS spectra, MRI used 0.25 cm^{-1} spectra "cts0814b" and "cts0814c." These reference CTS spectra were recorded on the same dates as the toluene reference spectra used in the analysis. These spectra were deresolved in the same way as the toluene reference spectra: by using Section K.2.2 of the EPA FTIR protocol. The program analyzed the main two ethylene bands centered near 2,989 and 949 cm^{-1}. Table 4-3 summarizes the results of the CTS analysis. The cell path length from this analysis was used as L_S in equation 2.

4.4.2 EPA Reference Spectra

The toluene spectra used in the MRI analysis were taken from the EPA reference spectrum library (http://www.epa.gov/ttn/emc/ftir/welcome.html). The original sample and background interferograms were truncated to the first 8,192 data points. The new interferograms were then Fourier transformed using Norton-Beer medium apodization and no zero filling. The transformation parameters were chosen to agree with those used to collect the sample absorbance spectra. The new 2 cm^{-1} toluene single beam spectra were combined with their deresolved single beam background spectra and converted to absorbance. This procedure was used to prepare spectral standards for the HAP's and other compounds included in the analysis.

4.5 FTIR SYSTEM

A KVB/Analect Diamond 20 spectrometer was used to collect all of the data in this field test. The gas cell is a heated variable path (D-22H) gas cell from Infrared Analysis, Inc. The path length of the cell was set at 20 laser passes and measured to be about 9.5 meters using the CTS reference and sample spectra. The interior cell walls have been treated with a Teflon® coating to minimize potential analyte losses. A mercury/cadmium/telluride (MCT) liquid nitrogen detector was used. The spectra were recorded at a nominal resolution of 2.0 cm^{-1}.

The optical path length was measured by shining a He/Ne laser through the cell and adjusting the mirror tilt to obtain the desired number of laser spots on the field mirror. Each laser spot indicates two laser passes through the cell. The number of passes was recorded on the field data sheets in Appendix B. The path length in meters was determined by comparing calibration transfer standard (CTS, ethylene in nitrogen) spectra measured in the field to CTS spectra in the EPA reference spectrum library. The procedure for determining the cell path length is described in Section 4.4.

4.6 CONTINUOUS EMISSIONS MONITORING FOR TOTAL HYDROCARBONS (THC)

The guidelines set forth in Method 25A were followed during the sampling at Plant A with two exceptions. Section 7.2 of Method 25A specifies an analyzer drift determination hourly during the test period, this instruction was not followed. Also, Section 7.2 specifies that the mid-level calibration gas is used for the drift determination. For this test program, the high-level calibration gas was used for the drift determination.

There are two reasons the drift determination was not completed as specified. The first reason is because of continuity in the FTIR and THC sampling. With run length exceeding four hours, drift determination as specified would have involved off-line periods of up to 10 minutes each hour for the THC analyzers and possibly for the FTIR instrument. The loss of this time could affect the results if significant process events had occurred during these periods. The second reason is that experience with the analyzers MRI was using show them to be stable over extended periods when they are operated in a climate-controlled environment.

The need to do hourly drift determinations is somewhat diminished when the stability of the analyzer is known and when the possibility that being off-line could affect the representativeness of both the FTIR and THC results.

4.6.1 Total Hydrocarbon Sampling Procedures

The THC sampling was conducted continuously from both locations by using two separate analyzers. The same sample systems used for the FTIR sampling were used for the THC sampling. Sample gas was directed to the analyzers through a separate set of rotameters and control valves. Each test run was conducted from the start to the end of the manual test runs completed by PES. A summary of specific procedures used is given below.

A brief description of each system component follows.

1. THC Analyzer - The THC concentration is measured using a flame ionization detector (FID). MRI used two J.U.M. Model VE-7 analyzers. The THC analyzers were operated on the

zero to 100 ppm range during Run 1 and at the zero to 1,000 ppm range throughout the test period. The fuel for the FID was a mixture of 40 percent hydrogen and 60 percent helium.

2. Data Acquisition System- MRI uses LABTECH notebook (Windows version), which is an integrated system that provides data acquisition, monitoring and control. The system normally writes data to a disk in the background while performing foreground tasks or displaying data in real time. The averaging period set for this test was one minute.

3. Calibration Gases- Calibration gases were prepared from an EPA Protocol 1 cylinder of propane (5278 ppm propane in nitrogen) using an Environics Model 2020 gas dilution system that complies with the requirements of EPA Method 205. High, medium, and low standard gases were generated to perform analyzer calibration checks. The raw data is recorded in ppm as propane, but is converted to an as carbon basis for reporting.

4.6.2 Hydrocarbon Emission Calculations

The hydrocarbon data are presented as THC emissions in Table 1-3. To do this the THC emission data were first converted to an as carbon basis using Equation 7, and then the THC emission rate was calculated using Equation 8.

$$C_c = K C_{meas} \tag{7}$$

where:

C_c = organic concentration as carbon, ppmv.

C_{meas} = organic concentration as measured, ppmv.

K = carbon equivalent correction factor, 3 for propane.

$$E_{THC} = \frac{\frac{C_{Cc}}{(1-B_{ws})} \times MW \times Q_{std} \times 60}{385.3 \times 10^6} \tag{8}$$

where:

E_{THC} = THC mass emission rate, lb/hr.

MW = molecular weight of Carbon, 12 lb/lb-mole.

B_{ws} = moisture fraction in the flue gas stream.

Q_{std} = volumetric flow rate corrected to standard conditions, dscfm.

60 = conversion to hours, min/hr.

385.3 = molar volume, ft^3/mole at standard conditions.

10^6 = conversion for decimal fraction to ppm

TABLE 4-1. PROGRAM INPUT FOR ANALYSIS OF SAMPLE SPECTRA

Compound name	File name	Region No.	ISC [a]	Reference	
				Meters	T (K)
Water	194c1bvj	1,2,3	100 [a]		
Carbon monoxide	co20829a	1	167.1	22	394
Sulfur dioxide	198c1bsc	2	89.5	22	394
Carbon dioxide	193b4a_a	1,2,3	415 [a]		
Formaldehyde	087b4anb	3	100.0	11.25	373
Benzene	015a4ara	3	496.6	3	298
Methane	196c1bsb	3	80.1	22	394
Methyl bromide	106a4asb	2	485.3	3	298
Toluene	153a4arc	3	103.0	3	298
Methyl chloride	107a4asa	3	501.4	3	298
Methyl chloroform	108a4asc	2	98.8	3	298
1,1-dichloroethane	086b4asa	2	499.1	2.25	373
1,3-butadiene	023a4asc	2	98.4	3	298
Carbon tetrachloride	029a4ase	2	20.1	3	298
Chlorobenzene	037a4arc	2	502.9	3	298
Cumene	046a4asc	3	96.3	3	298
Ethyl benzene	077a4arb	3	515.5	3	298
Hexane	095a4asd	3	101.6	3	298
Methylene chloride	117a4asa	2	498.5	3	298
Propionaldehyde	140b4anc	3	99.4	2.25	373
Styrene	147a4asb	2	550.7	3	298
1,1,2,2-tetrachloroethane	150b4asb	2	493.0	2.25	373
p-Xylene	173a4asa	2	488.2	3	298
o-Xylene	171a4asa	3	497.5	3	298
m-Xylene	172a4arh	2	497.8	3	298
Isooctane	165a4asc	3	101.4	3	298
Ethylene	CTS0820b	2	20.1	10.4	394
SF_6	Sf60819a	2	4.01	10.4	394
Ammonia	174a4ast	2	500.0	3	298

Region No.	Upper cm^{-1}	Lower cm^{-1}
1	2,142.0	2,035.6
2	1,275.0	789.3
3	3,160.8	2,650.1

[a] Indicates an arbitrary concentration was used for the interferant.

TABLE 4-2. PROGRAM INPUT FOR ANALYSIS AND CTS SPECTRA AND PATH LENGTH DETERMINATION

Compound name	File name	ASC	ISC	% Difference
Ethylene [a]	cts0814b.spc	1.007	1.014	0.7349
Ethylene	cts0814c.spc	1.007	0.999	0.7350

[a] This spectrum was used in the analysis of the Plant A CTS spectra

TABLE 4-3. RESULTS OF PATH LENGTH DETERMINATION

CTS spectra	Path length calculations		
100 ppm Ethylene	Meters	Delta[a]	% Delta
CTS0819A	10.82	0.22	2.1
CTS0819C	10.39	-0.21	-2.0
CTS0820A	10.42	-0.17	-1.6
CTS0820B	10.58	-0.02	-0.1
CTS0821A	10.71	0.11	1.1
CTS0821B	10.66	0.06	0.6
Average Path Length (M)	10.60		
Standard Deviation	0.166		

[a] The difference between the calculated and average values.

5.0 SUMMARY OF QA/QC PROCEDURES

5.1 SAMPLING AND TEST CONDITIONS

Before the test, sample lines were checked for leaks and cleaned by purging with moist air (250°F). Following this, the lines were checked for contamination using dry nitrogen. This is done by heating the sampling lines to 250°F and purging with dry nitrogen. The FTIR cell was filled with some of the purging nitrogen, and the spectrum of this sample was collected. This single beam spectrum was converted to absorbance using a spectral background of pure nitrogen (99.9 percent) taken directly from a cylinder. The lines were checked again onsite before sampling, after each change of location, and after spiking.

During sampling, spectra of at least 10 different samples were collected during each hour (five at each of two locations).

Each spectrum was assigned a unique file name and written to the hard disk and a backup disk under that file name. Each interferogram was also saved under a file name that identifies it with its corresponding absorbance spectrum. All background spectra and calibration spectra were also stored on disks with their corresponding interferograms.

Notes on each calibration and sample spectrum were recorded on hard copy data sheets. Below are listed some sampling and instrument parameters that were documented in these records.

Sampling Conditions

- Line temperature
- Process conditions
- Sample flow rate
- Ambient pressure
- Time of sample collection

Instrument Configuration

- Cell volume (for continuous measurements)
- Cell temperature
- Cell path length
- Instrument resolution
- Number of scans co-added

- Length of time to measure spectrum
- Time spectrum was collected
- Time and conditions of recorded background spectrum
- Time and conditions of relevant CTS spectra
- Apodization

Hard copy records were also kept of all flue gas measurements, such as sample flow, temperature, moisture, and diluent data.

Effluent was allowed to flow through the entire sampling system for at least 5 minutes before a sampling run started or after changing to a different test location. FTIR spectra were continuously monitored to ensure that there was no deviation in the spectral baseline greater than ±5 percent ($-0.02 \leq$ absorbance $\leq +0.02$). When this condition occurred, sampling was interrupted and a new background spectrum was collected. The run was then resumed until completed or until it was necessary to collect another background spectrum.

5.2 FTIR SPECTRA

For a detailed description of QA/QC procedures relating to data collection and analysis, refer to the "Protocol For Applying FTIR Spectrometry in Emission Testing."[2]

A spectrum of the CTS was recorded at the beginning and end of each test day. A leak check of the FTIR cell was also performed according to the procedures in references 1 and 2. The CTS gas was 100 ppm ethylene in nitrogen. The CTS spectrum provided a check on the operating conditions of the FTIR instrumentation, e.g., spectral resolution and cell path length. Ambient pressure was recorded whenever a CTS spectrum was collected. The CTS spectra were compared to CTS spectra in the EPA library. This comparison is used to quantify differences between the library spectra and the field spectra so library spectra of HAP's can be used in the quantitative analysis.

Two copies of all interferograms, processed backgrounds, sample spectra, and the CTS were stored on separate computer disks. Additional copies of sample and CTS absorbance spectra were also stored for data analysis. Sample absorbance spectra can be regenerated from the raw interferograms, if necessary.

The compact disk enclosed with this report contains one complete copy of all of the FTIR data recorded at the Plant A field test. The data are organized into directories, whose titles identify the contents. The continuous data are in directories identified by the date on which the spectra were recorded. The directory titles "BKG," "CTS," "outlet," and "inlet," identify backgrounds, CTS spectra, and spectra of inlet and outlet samples, respectively. Additional sub-directories "AIF" and "ASF" identify inferograms and absorbance spectra, respectively. All of the sample data are in the Analect Instruments software format. The directories "refs" and "residuals" contain de-resolved reference spectra that were used in the analyses and the residual spectra, respectively. There are three residual spectra for each sample spectrum, one for each analytical region. The information on the enclosed disk with the data records in Appendix A meets the reporting requirements of the EPA FTIR Protocol and Method 320.

To measure HAP's detected in the gas stream MRI used spectra from the EPA library, when available.

5.3 METHOD 25A

5.3.1 Initial Checks

Before starting the first run, the following system checks were performed.

1. Zero and Span check of the analyzer;
2. Analyzer linearity check at intermediate levels; and
3. Response time check of the system.

Calibration criteria for Method 25A is ±5 percent of calibration gas value.

5.3.2 Daily Checks

The following checks were made for each test run.

1. Zero/Span calibration and Linearity checks before each test run; and
2. Final Zero and Span calibration check of the analyzer at the end of each test run.

The difference between initial and final zero and span checks agreed within ±3 percent of the instrument span.

6.0 REFERENCES

1. Test Method 320 (Draft) "Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive Fourier Transform Infrared (FTIR) Spectroscopy," 40 CFR Part 63, Appendix A.

2. "Protocol For the Use of FTIR Spectrometry to Perform Extractive Emissions Testing at Industrial Sources," Revised, EPA Contract No. 68-D2-0165, Work Assignment 3-12, September 1996.

3. "Method 301 - Field Validation of Pollutant Measurement Methods from Various Waste Media," 40 CFR Part 63, Appendix A.

4. Draft Report, "FTIR Method Validation at a Coal-Fired Boiler," EPA Contract No. 68D20163, work assignment 2, July, 1993.

5. "Validation of EPA FTIR Method For Measuring HCl," T. J. Geyer and G. M. Plummer, Air and Waste Management Association, Paper Number 97-MP74.05, 1997.

6. "An Examination of a Least Squares Fit FTIR Spectral Analysis Method," G. M. Plummer and W. K. Reagen, Air and Waste Management Association, Paper Number 96-WA65.03, 1996.

7. "Computer-Assisted Quantitative Infrared Spectroscopy," Gregory L. McClure (ed.), ASTM Special Publication 934 (ASTM), 1987.

8. *Emission Factor Documentation for AP-42 Section 11.1, Hot Mix Asphalt Plants*, U. S. Environmental Protection Agency, Research Triangle Park, NC, Fifth Edition.

APPENDIX A

METHOD 25A AND VOLUMERTRIC FLOW DATA

A-1 METHOD 25A RESULTS

Run 1
Date: 8/19/97
Project No: 3804-24-04-03/4701-08-01
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC Inlet (ppmc)	THC outlet (ppm)	THC Outlet (ppmc)
9:00	THC Off Line	THC Off Line	35.5	106.5
9:01			33.8	101.4
9:02			32.7	98.1
9:03			31.8	95.4
9:04			31.5	94.5
9:05			31.3	93.9
9:06			32.6	97.8
9:07			31.7	95.1
9:08			30.3	90.9
9:09			30.8	92.4
9:10			31.0	93
9:11			30.4	91.2
9:12			30.2	90.6
9:13			30.2	90.6
9:14			29.6	88.8
9:15			28.3	84.9
9:16			28.6	85.8
9:17			28.3	84.9
9:18			27.9	83.7
9:19			28.2	84.6
9:20			28.2	84.6
9:21			28.2	84.6
9:22			27.9	83.7
9:23			28.2	84.6
9:24			28.2	84.6
9:25			30.6	91.8
9:26			29.3	87.9
9:27	50.8		29.3	87.9
9:28	50.7		28.4	85.2
9:29	54.6		28.3	84.9
9:30	59.8		28.3	84.9
9:31	65.6		30.9	92.7
9:32	64.4		31.5	94.5
9:33	59.4		29.0	87
9:34	58.8		29.4	88.2
9:35	55.9		28.1	84.3
9:36			27.5	82.5
9:37			30.1	90.3
9:38	60.6	181.8	30.1	90.3
9:39	55.7	167.1	27.6	82.8
9:40	55.0	165	26.3	78.9
9:41	55.8	167.4	26.8	80.4
9:42	56.7	170.1	26.8	80.4
9:43	63.5	190.5	31.1	93.3
9:44	57.6	172.8	28.3	84.9
9:45	55.7	167.1	27.4	82.2
9:46	54.8	164.4	27.2	81.6
9:47	54.5	163.5	27.2	81.6

Run 1
Date: 8/19/97
Project No: 3804-24-04-03/4701-08-01
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC Inlet (ppmc)	THC outlet (ppm)	THC Outlet (ppmc)
9:48	56.9	170.7	29.0	87
9:49	56.6	169.8	29.2	87.6
9:50	55.7	167.1	28.9	86.7
9:51	55.3	165.9	29.1	87.3
9:52	54.8	164.4	29.0	87
9:53	52.9	158.7	28.4	85.2
9:54	51.0	153	28.1	84.3
9:55	50.6	151.8	28.0	84
9:56	51.6	154.8	29.3	87.9
9:57	52.7	158.1	31.4	94.2
9:58	THC Off Line	THC Off Line	29.1	87.3
9:59			28.5	85.5
10:00			27.9	83.7
10:01			31.1	93.3
10:02			32.2	96.6
10:03			28.9	86.7
10:04			28.3	84.9
10:05			27.2	81.6
10:06			THC Off Line	THC Off Line
10:07				
10:08				
10:09				
10:10			31.3	93.9
10:11			29.4	88.2
10:12			32.3	96.9
10:13			30.0	90
10:14			32.1	96.3
10:15			31.6	94.8
10:16			29.5	88.5
10:17	56.0	168	28.4	85.2
10:18	55.5	166.5	29.5	88.5
10:19	63.6	190.8	35.4	106.2
10:20	61.2	183.6	36.7	110.1
10:21	53.1	159.3	30.1	90.3
10:22	51.8	155.4	28.8	86.4
10:23	59.2	177.6	33.3	99.9
10:24	65.3	195.9	51.8	155.4
10:25	THC Off Line	THC Off Line	26.2	78.6
10:26			31.4	94.2
10:27			25.2	75.6
10:28			26.0	78
10:29			25.7	77.1
10:30			26.8	80.4
10:31			46.8	140.4
10:32			36.9	110.7
10:33			51.8	155.4
10:34			35.6	106.8
10:35			44.4	133.2

Run 1
Date: 8/19/97
Project No: 3804-24-04-03/4701-08-01
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC Inlet (ppmc)	THC outlet (ppm)	THC Outlet (ppmc)
10:36			45.0	135
10:37			37.4	112.2
10:38			40.1	120.3
10:39			37.4	112.2
10:40			31.4	94.2
10:41			29.6	88.8
10:42			30.0	90
10:43			33.1	99.3
10:44			33.9	101.7
10:45			33.4	100.2
10:46			32.0	96
10:47			28.9	86.7
10:48			30.6	91.8
10:49			33.4	100.2
10:50			30.3	90.9
10:51			28.6	85.8
10:52			29.7	89.1
10:53			33.0	99
10:54	49.0	147	30.2	90.6
10:55	47.8	143.4	29.6	88.8
10:56	50.7	152.1	31.9	95.7
10:57	51.2	153.6	33.1	99.3
10:58	48.5	145.5	31.4	94.2
10:59	45.4	136.2	28.6	85.8
11:00	44.6	133.8	27.3	81.9
11:01	46.0	138	27.8	83.4
11:02	53.5	160.5	34.0	102
11:03	45.2	135.6	30.1	90.3
11:04	46.7	140.1	27.8	83.4
11:05	50.3	150.9	31.9	95.7
11:06	50.9	152.7	32.9	98.7
11:07	49.2	147.6	32.8	98.4
11:08	47.0	141	32.8	98.4
11:09	46.9	140.7	29.6	88.8
11:10	44.2	132.6	28.6	85.8
11:11	43.0	129	27.6	82.8
11:12	44.5	133.5	26.1	78.3
11:13	45.6	136.8	29.7	89.1
11:14	43.8	131.4	28.4	85.2
11:15	45.5	136.5	28.4	85.2
11:16	45.0	135	28.6	85.8
11:17	43.9	131.7	28.4	85.2
11:18	42.7	128.1	27.4	82.2
11:19	45.1	135.3	26.9	80.7
11:20	54.6	163.8	34.1	102.3
11:21	60.1	180.3	38.6	115.8
11:22	84.5	253.5	54.0	162
11:23	94.6	283.8	94.5	283.5

Run 1
Date: 8/19/97
Project No: 3804-24-04-03/4701-08-01
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC Inlet (ppmc)	THC outlet (ppm)	THC Outlet (ppmc)
11:24	59.7	179.1	57.8	173.4
11:25	58.2	174.6	41.2	123.6
11:26	80.6	241.8	46.8	140.4
11:27	97.5	292.5	94.3	282.9
11:28	63.8	191.4	64.8	194.4
11:29	53.0	159	40.5	121.5
11:30	78.9	236.7	45.4	136.2
11:31	92.7	278.1	79.3	237.9
11:32	56.2	168.6	56.5	169.5
11:33	65.0	195	38.0	114
11:34	98.9	296.7	72.8	218.4
11:35	82.2	246.6	86.3	258.9
11:36	65.4	196.2	57.2	171.6
11:37	53.8	161.4	36.5	109.5
11:38	85.3	255.9	54.8	164.4
11:39	71.4	214.2	71.3	213.9
11:40	52.6	157.8	39.5	118.5
11:41	82.7	248.1	56.1	168.3
11:42	54.4	163.2	51.9	155.7
11:43	77.5	232.5	57.1	171.3
11:44	54.9	164.7	42.7	128.1
11:45	70.5	211.5	58.9	176.7
11:46	55.1	165.3	38.0	114
11:47	81.0	243	58.6	175.8
11:48	53.6	160.8	47.7	143.1
11:49	75.8	227.4	45.1	135.3
11:50	57.4	172.2	59.1	177.3
11:51	72.4	217.2	40.4	121.2
11:52	74.1	222.3	71.6	214.8
11:53	58.5	175.5	39.9	119.7
11:54	93.3	279.9	76.5	229.5
11:55	49.5	148.5	53.3	159.9
11:56	47.9	143.7	32.3	96.9
11:57	48.9	146.7	34.1	102.3
11:58	46.9	140.7	32.2	96.6
11:59	66.0	198	34.0	102
12:00	97.5	292.5	79.5	238.5
12:01	63.7	191.1	74.5	223.5
12:02	49.5	148.5	35.0	105
12:03	64.5	193.5	41.8	125.4
12:04	83.2	249.6	62.7	188.1
12:05	100.0^	300	99.2^	297.6
12:06	69.2	207.6	70.3	210.9
12:07	49.5	148.5	36.9	110.7
12:08	71.3	213.9	44.0	132
12:09	83.2	249.6	87.2	261.6
12:10	48.5	145.5	36.7	110.1
12:11	84.6	253.8	56.0	168

Run 1
Date: 8/19/97
Project No: 3804-24-04-03/4701-08-01
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC Inlet (ppmc)	THC outlet (ppm)	THC Outlet (ppmc)
12:12	62.5	187.5	61.3	183.9
12:13	86.7	260.1	68.6	205.8
12:14	56.0	168	51.5	154.5
12:15	95.5	286.5	80.8	242.4
12:16	56.5	169.5	51.0	153
12:17	85.5	256.5	68.8	206.4
12:18	74.8	224.4	63.6	190.8
12:19	84.4	253.2	83.8	251.4
12:20	69.0	207	47.3	141.9
12:21	78.6	235.8	81.6	244.8
12:22	57.4	172.2	38.9	116.7
12:23	99.7^	299.1	90.3	270.9
12:24	64.4	193.2	64.7	194.1
12:25	65.6	196.8	43.7	131.1
12:26	98.0	294	89.6	268.8
12:27	100.0^	300	100.0^	300
12:28	93.6	280.8	91.7	275.1
12:29	52.8	158.4	45.0	135
12:30	50.6	151.8	35.2	105.6
12:31	57.6	172.8	40.0	120
12:32	95.2	285.6	80.5	241.5
12:33	99.3^	297.9	100.0^	300
12:34	56.7	170.1	56.5	169.5
12:35	53.1	159.3	37.0	111
12:36	78.2	234.6	66.5	199.5
12:37	51.0	153	41.6	124.8
12:38	71.7	215.1	47.3	141.9
12:39	91.5	274.5	74.5	223.5
12:40	95.4	286.2	96.9	290.7
12:41	63.2	189.6	57.1	171.3
12:42	48.2	144.6	34.7	104.1
12:43	50.3	150.9	33.4	100.2
12:44	91.3	273.9	62.0	186
12:45	99.9^	299.7	91.4	274.2
12:46	97.6	292.8	95.2	285.6
12:47	71.2	213.6	75.4	226.2
12:48	91.2	273.6	79.9	239.7
12:49	61.8	185.4	60.0	180
12:50	88.5	265.5	81.2	243.6
12:51	53.8	161.4	50.4	151.2
12:52	72.1	216.3	44.2	132.6
12:53	86.4	259.2	84.8	254.4
12:54	47.6	142.8	45.1	135.3
12:55	45.2	135.6	31.4	94.2
12:56	53.5	160.5	34.7	104.1
12:57	76.1	228.3	47.3	141.9
12:58	84.4	253.2	98.7	296.1
12:59	55.3	165.9	44.7	134.1

Run 1
Date: 8/19/97
Project No: 3804-24-04-03/4701-08-01
Operator: Gulick

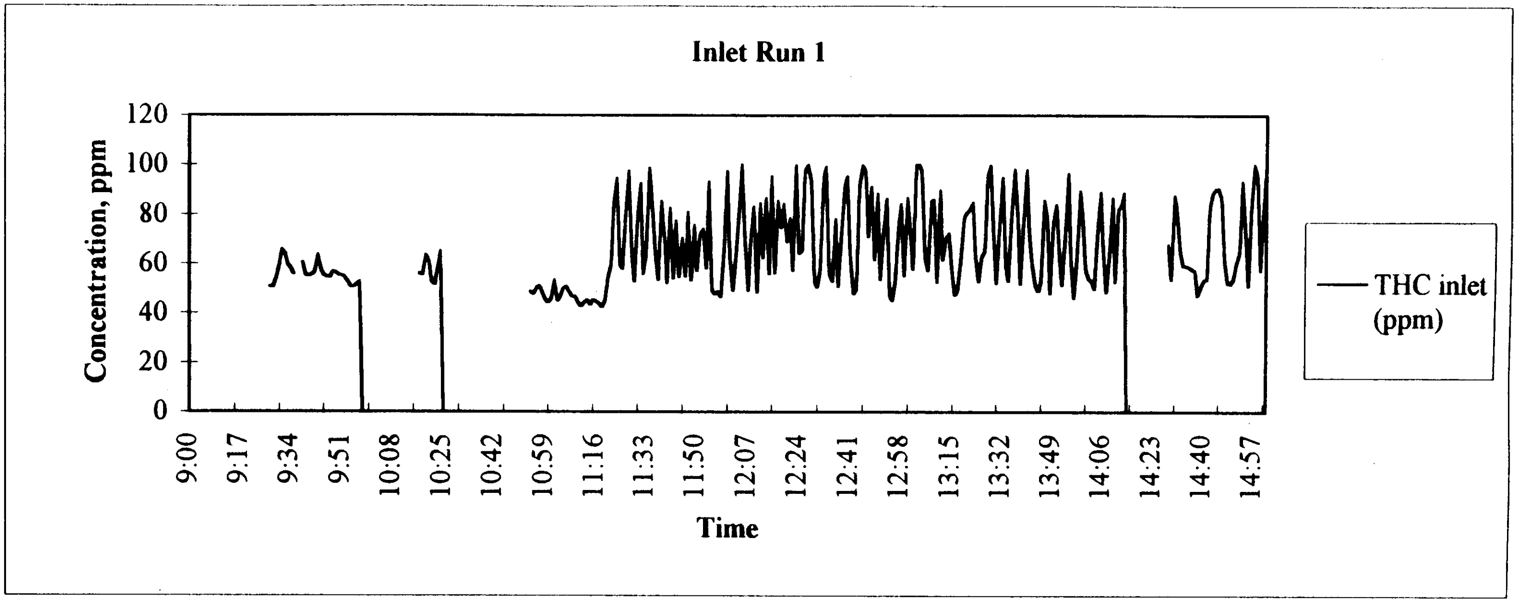
Time (24 hour)	THC inlet (ppm)	THC Inlet (ppmc)	THC outlet (ppm)	THC Outlet (ppmc)
13:00	86.7	260.1	61.8	185.4
13:01	72.2	216.6	79.6	238.8
13:02	57.9	173.7	39.1	117.3
13:03	100.0^	300	78.2	234.6
13:04	100.0^	300	92.0	276
13:05	97.5	292.5	93.9	281.7
13:06	62.6	187.8	69.6	208.8
13:07	57.5	172.5	37.2	111.6
13:08	85.6	256.8	60.7	182.1
13:09	86.2	258.6	91.7	275.1
13:10	52.8	158.4	47.3	141.9
13:11	89.8	269.4	63.4	190.2
13:12	61.8	185.4	75.9	227.7
13:13	70.5	211.5	41.8	125.4
13:14	72.5	217.5	77.9	233.7
13:15	56.5	169.5	44.5	133.5
13:16	47.6	142.8	38.5	115.5
13:17	49.7	149.1	34.2	102.6
13:18	62.0	186	42.2	126.6
13:19	78.9	236.7	64.2	192.6
13:20	80.7	242.1	66.8	200.4
13:21	82.1	246.3	67.2	201.6
13:22	84.7	254.1	90.8	272.4
13:23	63.9	191.7	63.9	191.7
13:24	53.1	159.3	39.1	117.3
13:25	63.0	189	45.9	137.7
13:26	65.8	197.4	51.4	154.2
13:27	96.0	288	80.9	242.7
13:28	99.9^	299.7	100.0^	300
13:29	69.7	209.1	70.0	210
13:30	52.3	156.9	39.7	119.1
13:31	75.4	226.2	51.7	155.1
13:32	95.0	285	90.9	272.7
13:33	60.2	180.6	52.9	158.7
13:34	53.4	160.2	39.6	118.8
13:35	80.5	241.5	56.1	168.3
13:36	98.3	294.9	83.6	250.8
13:37	78.6	235.8	75.1	225.3
13:38	52.1	156.3	40.2	120.6
13:39	77.2	231.6	53.0	159
13:40	97.9	293.7	88.5	265.5
13:41	72.1	216.3	66.8	200.4
13:42	59.5	178.5	45.8	137.4
13:43	51.4	154.2	40.5	121.5
13:44	49.2	147.6	33.5	100.5
13:45	53.0	159	38.3	114.9
13:46	85.7	257.1	64.3	192.9
13:47	77.8	233.4	82.6	247.8

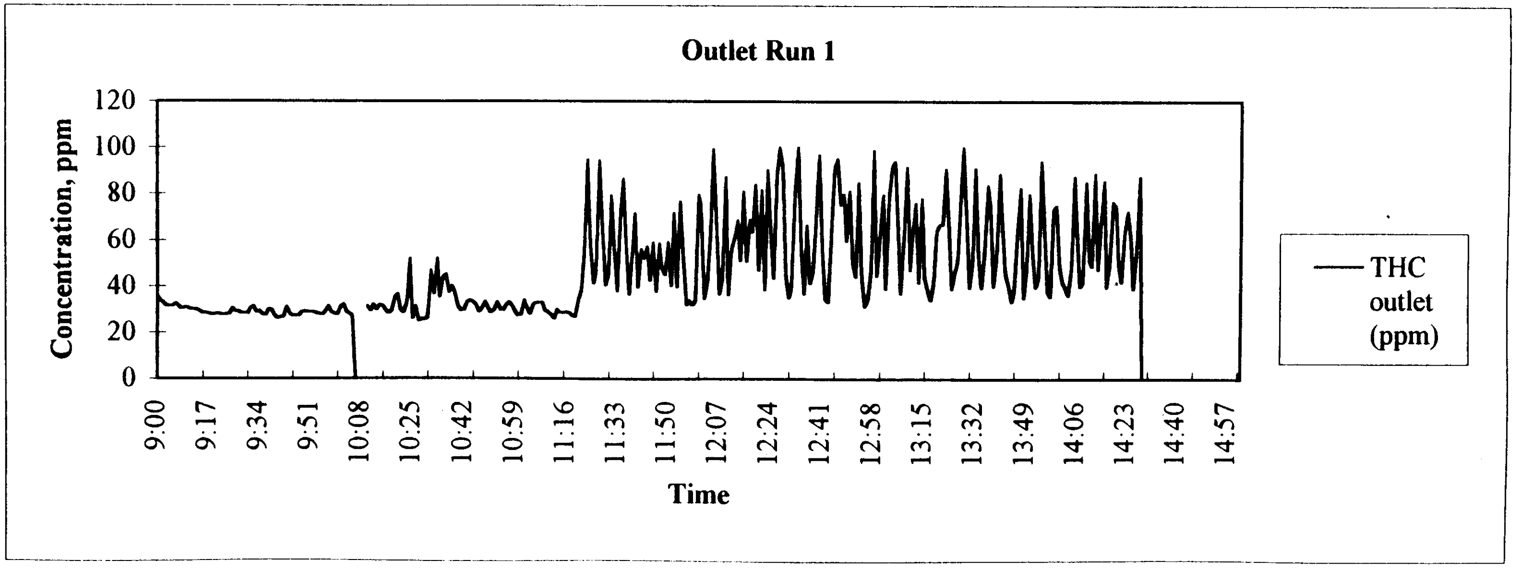
Run 1
Date: 8/19/97
Project No: 3804-24-04-03/4701-08-01
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC Inlet (ppmc)	THC outlet (ppm)	THC Outlet (ppmc)
13:48	48.1	144.3	35.3	105.9
13:49	77.0	231	48.9	146.7
13:50	84.0	252	79.8	239.4
13:51	63.3	189.9	55.3	165.9
13:52	51.4	154.2	39.8	119.4
13:53	72.1	216.3	44.2	132.6
13:54	96.5	289.5	93.9	281.7
13:55	62.3	186.9	65.4	196.2
13:56	46.3	138.9	38.1	114.3
13:57	63.0	189	35.7	107.1
13:58	89.4	268.2	73.6	220.8
13:59	78.9	236.7	74.8	224.4
14:00	57.9	173.7	49.1	147.3
14:01	54.1	162.3	41.7	125.1
14:02	52.9	158.7	39.4	118.2
14:03	49.8	149.4	36.3	108.9
14:04	74.8	224.4	47.1	141.3
14:05	88.9	266.7	87.6	262.8
14:06	65.4	196.2	60.0	180
14:07	48.7	146.1	40.3	120.9
14:08	64.0	192	42.1	126.3
14:09	86.7	260.1	85.0	255
14:10	52.7	158.1	52.1	156.3
14:11	82.3	246.9	48.8	146.4
14:12	83.7	251.1	88.9	266.7
14:13	88.6	265.8	47.6	142.8
14:14	Inlet Spike	Inlet Spike	69.2	207.6
14:15			85.6	256.8
14:16			39.8	119.4
14:17			50.0	150
14:18			76.6	229.8
14:19			74.7	224.1
14:20			50.9	152.7
14:21			42.2	126.6
14:22			64.6	193.8
14:23			72.5	217.5
14:24			60.7	182.1
14:25			39.0	117
14:26			55.6	166.8
14:27			87.5	262.5
14:28	67.7	203.1	Outlet Spike	Outlet Spike
14:29	53.7	161.1		
14:30	87.6	262.8		
14:31	82.0	246		
14:32	65.7	197.1		
14:33	59.2	177.6		
14:34	59.2	177.6		
14:35	58.6	175.8		

Run 1
Date: 8/19/97
Project No: 3804-24-04-03/4701-08-01
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC Inlet (ppmc)	THC outlet (ppm)	THC Outlet (ppmc)
14:36	58.0	174		
14:37	57.2	171.6		
14:38	47.2	141.6		
14:39	50.8	152.4		
14:40	53.5	160.5		
14:41	54.0	162		
14:42	83.0	249		
14:43	89.0	267		
14:44	90.4	271.2		
14:45	90.6	271.8		
14:46	86.6	259.8		
14:47	61.2	183.6		
14:48	52.4	157.2		
14:49	52.1	156.3		
14:50	53.7	161.1		
14:51	60.5	181.5		
14:52	64.8	194.4		
14:53	93.4	280.2		
14:54	73.9	221.7		
14:55	51.3	153.9		
14:56	80.7	242.1		
14:57	100.0^	300		
14:58	95.6	286.8		
14:59	57.4	172.2		
15:00	79.0	237		
15:01	100.0^	300		
Minimum=	42.7	128.1	25.2	75.6
Maximum=	100.0	300	100.0	300
Average=	66.6	199.8	47.4	142.2


Inlet Run 1


Outlet Run 1

Run 2
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppm)	THC outlet (ppmc)
8:40	39.5	118.5	28.8	86.4
8:41	50.1	150.3	40.3	120.9
8:42	35.1	105.3	27.6	82.8
8:43	55.5	166.5	38.0	114
8:44	37.6	112.8	35.0	105
8:45	40.7	122.1	28.5	85.5
8:46	49.7	149.1	40.2	120.6
8:47	38.9	116.7	32.1	96.3
8:48	44.5	133.5	30.9	92.7
8:49	59.1	177.3	45.8	137.4
8:50	41.6	124.8	35.5	106.5
8:51	45.4	136.2	33.0	99
8:52	58.9	176.7	45.6	136.8
8:53	44.7	134.1	37.3	111.9
8:54	43.0	129.0	35.2	105.6
8:55	38.0	114.0	30.3	90.9
8:56	52.1	156.3	41.7	125.1
8:57	35.2	105.6	29.2	87.6
8:58	43.2	129.6	32.8	98.4
8:59	36.2	108.6	30.2	90.6
9:00	35.3	105.9	28.3	84.9
9:01	35.9	107.7	28.0	84
9:02	37.2	111.6	29.1	87.3
9:03	43.2	129.6	30.3	90.9
9:04	39.5	118.5	35.5	106.5
9:05	34.6	103.8	28.5	85.5
9:06	35.0	105.0	27.1	81.3
9:07	35.7	107.1	28.3	84.9
9:08	49.6	148.8	32.7	98.1
9:09	52.2	156.6	42.8	128.4
9:10	51.8	155.4	40.6	121.8
9:11	41.2	123.6	36.1	108.3
9:12	39.6	118.8	30.2	90.6
9:13	53.1	159.3	40.2	120.6
9:14	47.3	141.9	37.9	113.7
9:15	46.5	139.5	36.7	110.1
9:16	46.3	138.9	36.2	108.6
9:17	40.3	120.9	33.2	99.6
9:18	46.9	140.7	36.7	110.1
9:19	29.4	88.2	25.8	77.4
9:20	31.7	95.1	24.0	72
9:21	34.2	102.6	26.9	80.7
9:22	32.6	97.8	26.4	79.2
9:23	32.1	96.3	25.3	75.9
9:24	32.7	98.1	25.7	77.1
9:25	32.4	97.2	25.5	76.5
9:26	33.6	100.8	26.2	78.6
9:27	37.4	112.2	28.9	86.7

Run 2
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppm)	THC outlet (ppmc)
9:28	38.3	114.9	29.9	89.7
9:29	38.9	116.7	30.1	90.3
9:30	40.4	121.2	31.3	93.9
9:31	39.0	117.0	30.8	92.4
9:32	33.2	99.6	26.2	78.6
9:33	33.8	101.4	25.7	77.1
9:34	39.2	117.6	28.8	86.4
9:35	42.8	128.4	33.0	99
9:36	42.6	127.8	33.0	99
9:37	71.5	214.5	55.9	167.7
9:38	46.5	139.5	43.5	130.5
9:39	41.0	123.0	32.4	97.2
9:40	37.6	112.8	29.6	88.8
9:41	33.5	100.5	27.0	81
9:42	31.7	95.1	24.0	72
9:43	37.0	111.0	28.3	84.9
9:44	39.8	119.4	30.3	90.9
9:45	38.8	116.4	30.5	91.5
9:46	42.3	126.9	32.7	98.1
9:47	45.9	137.7	36.8	110.4
9:48	46.7	140.1	38.7	116.1
9:49	44.5	133.5	38.3	114.9
9:50	36.5	109.5	30.9	92.7
9:51	34.6	103.8	28.2	84.6
9:52	35.9	107.7	27.2	81.6
9:53	47.6	142.8	37.7	113.1
9:54	32.9	98.7	26.8	80.4
9:55	33.1	99.3	25.8	77.4
9:56	36.9	110.7	26.3	78.9
9:57	75.4	226.2	51.8	155.4
9:58	75.9	227.7	62.0	186
9:59	84.3	252.9	70.8	212.4
10:00	87.3	261.9	72.6	217.8
10:01	55.9	167.7	58.1	174.3
10:02	42.2	126.6	38.3	114.9
10:03	43.1	129.3	34.3	102.9
10:04	55.8	167.4	40.3	120.9
10:05	58.2	174.6	48.7	146.1
10:06	58.8	176.4	48.6	145.8
10:07	64.9	194.7	50.3	150.9
10:08	67.7	203.1	57.6	172.8
10:09	78.6	235.8	57.9	173.7
10:10	100.0^	300.0	96.3	288.9
10:11	100.0^	300.0	100.0^	300
10:12	69.1	207.3	82.1	246.3
10:13	69.8	209.4	50.7	152.1
10:14	91.7	275.1	72.9	218.7
10:15	99.4^	298.2	90.8	272.4

Run 2
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppm)	THC outlet (ppmc)
10:16	100.0^	300.0	100.0^	300
10:17	86.4	259.2	91.3	273.9
10:18	59.3	177.9	59.1	177.3
10:19	42.9	128.7	34.8	104.4
10:20	80.9	242.7	53.5	160.5
10:21	100.0^	300.0	100.0^	300
10:22	92.4	277.2	83.5	250.5
10:23	49.5	148.5	50.8	152.4
	Range Change			
10:30	50.8	152.4	43.9	131.7
10:31	80.5	241.5	63.6	190.8
10:32	76.4	229.2	77.7	233.1
10:33	63.7	191.1	60.0	180
10:34	51.6	154.8	49.9	149.7
10:35	42.1	126.3	41.5	124.5
10:36	37.9	113.7	34.5	103.5
10:37	73.6	220.8	60.9	182.7
10:38	87.3	261.9	76.6	229.8
10:39	196.9	590.7	168.9	506.7
10:40	213.1	639.3	197.4	592.2
10:41	118.8	356.4	130.9	392.7
10:42	65.2	195.6	62.3	186.9
10:43	63.3	189.9	58.9	176.7
10:44	57.9	173.7	53.8	161.4
10:45	59.5	178.5	54.7	164.1
10:46	59.7	179.1	54.4	163.2
10:47	60.7	182.1	57.0	171
10:48	60.8	182.4	56.5	169.5
10:49	43.4	130.2	43.0	129
10:50	39.4	118.2	36.6	109.8
10:51	74.4	223.2	59.0	177
10:52	134.2	402.6	117.5	352.5
10:53	166.8	500.4	151.1	453.3
10:54	167.0	501.0	157.4	472.2
10:55	44.4	133.2	59.7	179.1
10:56	30.0	90.0	27.4	82.2
10:57	31.7	95.1	28.9	86.7
10:58	31.5	94.5	28.9	86.7
10:59	42.8	128.4	36.1	108.3
11:00	58.5	175.5	52.6	157.8
11:01	75.8	227.4	69.0	207
11:02	53.5	160.5	52.6	157.8
11:03	38.1	114.3	37.7	113.1
11:04	30.2	90.6	28.0	84
11:05	31.3	93.9	28.1	84.3
11:06	53.6	160.8	47.1	141.3
11:07	52.5	157.5	49.1	147.3
11:08	40.4	121.2	38.8	116.4

Run 2
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

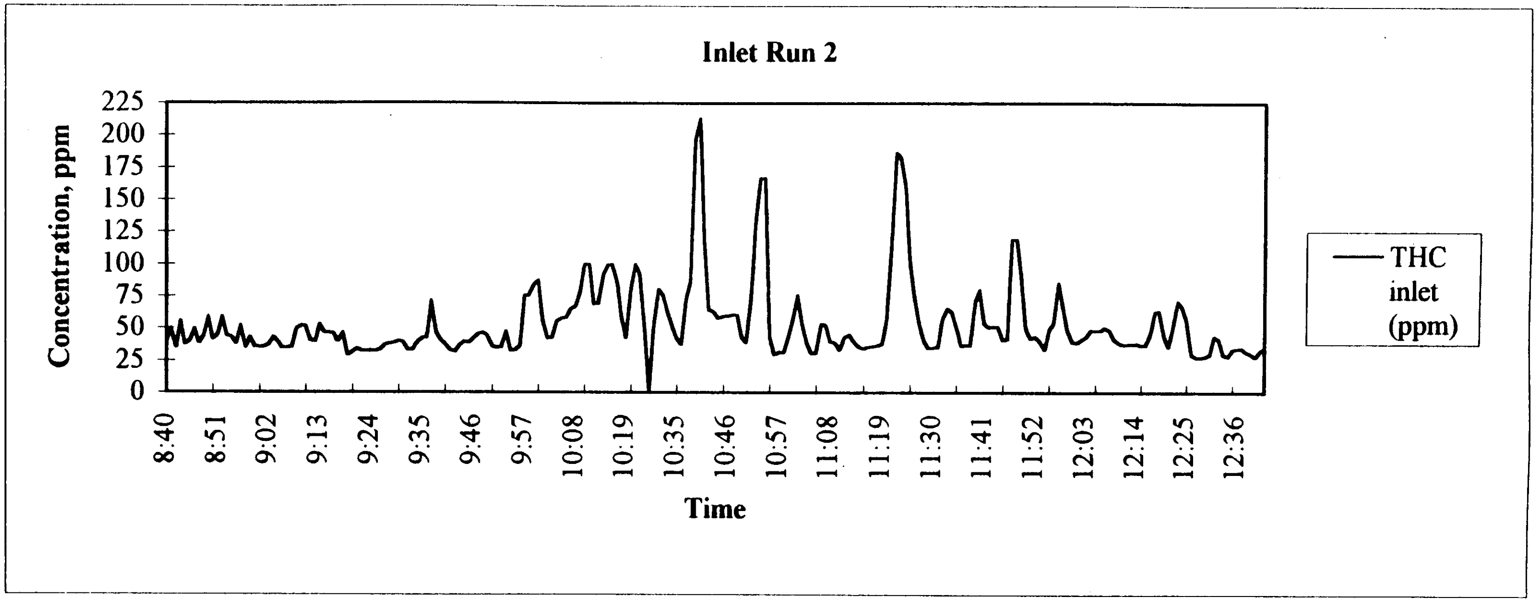
Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppm)	THC outlet (ppmc)
11:09	38.5	115.5	36.8	110.4
11:10	33.4	100.2	30.8	92.4
11:11	43.1	129.3	38.2	114.6
11:12	45.2	135.6	41.6	124.8
11:13	39.8	119.4	38.9	116.7
11:14	36.4	109.2	34.7	104.1
11:15	34.5	103.5	31.9	95.7
11:16	35.7	107.1	32.5	97.5
11:17	36.5	109.5	34.1	102.3
11:18	36.8	110.4	34.0	102
11:19	38.0	114.0	34.9	104.7
11:20	56.2	168.6	41.7	125.1
11:21	117.3	351.9	87.0	261
11:22	186.7	560.1	173.1	519.3
11:23	183.4	550.2	174.3	522.9
11:24	160.7	482.1	148.8	446.4
11:25	101.8	305.4	118.1	354.3
11:26	75.1	225.3	75.1	225.3
11:27	52.7	158.1	51.6	154.8
11:28	40.0	120.0	42.0	126
11:29	34.6	103.8	32.2	96.6
11:30	35.5	106.5	32.9	98.7
11:31	35.3	105.9	32.3	96.9
11:32	57.3	171.9	43.2	129.6
11:33	65.7	197.1	60.2	180.6
11:34	63.0	189.0	61.9	185.7
11:35	51.5	154.5	49.6	148.8
11:36	36.1	108.3	38.0	114
11:37	37.5	112.5	34.2	102.6
11:38	36.7	110.1	34.2	102.6
11:39	71.2	213.6	48.7	146.1
11:40	80.1	240.3	80.8	242.4
11:41	54.1	162.3	55.1	165.3
11:42	50.8	152.4	47.1	141.3
11:43	51.7	155.1	48.3	144.9
11:44	51.2	153.6	47.0	141
11:45	40.6	121.8	43.9	131.7
11:46	42.3	126.9	34.3	102.9
11:47	119.3	357.9	82.6	247.8
11:48	119.0	357.0	113.3	339.9
11:49	89.5	268.5	92.9	278.7
11:50	49.8	149.4	61.1	183.3
11:51	42.1	126.3	38.5	115.5
11:52	43.9	131.7	40.0	120
11:53	40.3	120.9	39.8	119.4
11:54	33.9	101.7	31.1	93.3
11:55	49.1	147.3	39.3	117.9
11:56	54.1	162.3	49.6	148.8

Run 2
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

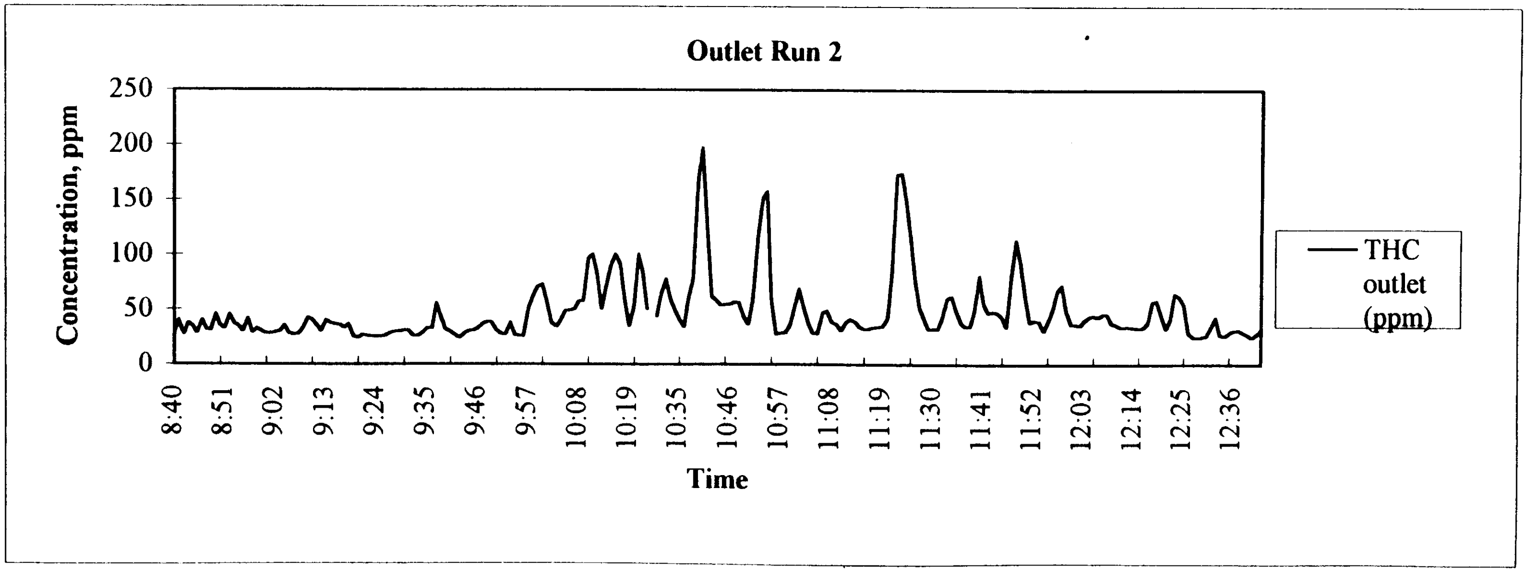
Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppm)	THC outlet (ppmc)
11:57	85.2	255.6	67.2	201.6
11:58	67.2	201.6	72.2	216.6
11:59	48.6	145.8	50.2	150.6
12:00	39.6	118.8	37.1	111.3
12:01	38.9	116.7	36.5	109.5
12:02	41.3	123.9	35.9	107.7
12:03	43.5	130.5	40.0	120
12:04	48.5	145.5	43.8	131.4
12:05	48.3	144.9	45.1	135.3
12:06	48.0	144.0	43.2	129.6
12:07	50.5	151.5	45.9	137.7
12:08	48.9	146.7	45.9	137.7
12:09	41.6	124.8	38.2	114.6
12:10	39.0	117.0	36.0	108
12:11	37.1	111.3	34.0	102
12:12	37.8	113.4	34.3	102.9
12:13	37.9	113.7	34.5	103.5
12:14	38.2	114.6	34.1	102.3
12:15	36.8	110.4	33.4	100.2
12:16	37.5	112.5	33.9	101.7
12:17	46.4	139.2	38.4	115.2
12:18	62.5	187.5	57.0	171
12:19	63.8	191.4	58.0	174
12:20	44.4	133.2	44.1	132.3
12:21	35.7	107.1	32.7	98.1
12:22	50.8	152.4	41.4	124.2
12:23	70.9	212.7	64.1	192.3
12:24	67.2	201.6	61.7	185.1
12:25	56.5	169.5	55.0	165
12:26	29.9	89.7	29.1	87.3
12:27	27.8	83.4	25.5	76.5
12:28	27.4	82.2	24.7	74.1
12:29	28.3	84.9	25.3	75.9
12:30	29.8	89.4	26.5	79.5
12:31	43.6	130.8	34.5	103.5
12:32	41.7	125.1	42.9	128.7
12:33	29.9	89.7	27.5	82.5
12:34	28.3	84.9	25.9	77.7
12:35	33.8	101.4	29.5	88.5
12:36	34.1	102.3	31.0	93
12:37	34.8	104.4	31.7	95.1
12:38	31.8	95.4	29.3	87.9
12:39	30.1	90.3	27.4	82.2
12:40	27.8	83.4	24.8	74.4
12:41	32.7	98.1	28.3	84.9
12:42	35.0	105.0	32.1	96.3
Minimum=	27.4	82.2	24.0	72

Run 2
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppm)	THC outlet (ppmc)
Maximum=	213.1	639.3	197.4	592.2
Average=	54.0	162.0	47.7	143.1



Inlet Run 2



Outlet Run 2

Run 3
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
13:07	29.9	89.7	21.9	65.7
13:08	31.5	94.5	28.8	86.4
13:09	49.1	147.3	43.5	130.5
13:10	26.7	80.1	29.2	87.6
13:11	27.2	81.6	24.8	74.4
13:12	25.4	76.2	23.8	71.4
13:13	30.1	90.3	24.1	72.3
13:14	32.5	97.5	33.0	99
13:15	26.2	78.6	24.7	74.1
13:16	26.1	78.3	25.2	75.6
13:17	24.7	74.1	24.3	72.9
13:18	23.6	70.8	23.0	69
13:19	25.0	75.0	23.4	70.2
13:20	26.2	78.6	24.3	72.9
13:21	35.5	106.5	31.3	93.9
13:22	29.7	89.1	29.2	87.6
13:23	29.3	87.9	25.7	77.1
13:24	38.8	116.4	35.7	107.1
13:25	27.3	81.9	25.3	75.9
13:26	29.8	89.4	26.6	79.8
13:27	30.5	91.5	28.1	84.3
13:28	27.4	82.2	26.1	78.3
13:29	25.9	77.7	23.7	71.1
13:30	27.4	82.2	24.9	74.7
13:31	32.3	96.9	28.3	84.9
13:32	37.8	113.4	33.6	100.8
13:33	31.3	93.9	30.0	90
13:34	26.4	79.2	24.7	74.1
13:35	27.5	82.5	24.7	74.1
13:36	28.4	85.2	25.8	77.4
13:37	28.9	86.7	26.2	78.6
13:38	28.5	85.5	26.3	78.9
13:39	26.8	80.4	25.0	75
13:40	26.6	79.8	24.4	73.2
13:41	25.6	76.8	23.8	71.4
13:42	25.9	77.7	23.6	70.8
13:43	26.7	80.1	24.1	72.3
13:44	30.1	90.3	26.8	80.4
13:45	29.7	89.1	27.8	83.4
13:46	24.2	72.6	22.4	67.2
13:47	24.8	74.4	22.7	68.1
13:48	25.0	75.0	23.1	69.3
13:49	26.6	79.8	23.4	70.2
13:50	30.4	91.2	27.5	82.5
13:51	27.7	83.1	25.7	77.1
13:52	24.7	74.1	23.0	69
13:53	24.3	72.9	22.1	66.3
13:54	26.8	80.4	24.3	72.9

Run 3
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
13:55	26.5	79.5	24.2	72.6
13:56	24.9	74.7	23.0	69
13:57	23.1	69.3	21.9	65.7
13:58	22.5	67.5	20.9	62.7
13:59	22.1	66.3	20.7	62.1
14:00	21.8	65.4	20.5	61.5
14:01	20.9	62.7	19.6	58.8
14:02	21.8	65.4	20.2	60.6
14:03	21.9	65.7	20.5	61.5
14:04	21.8	65.4	20.4	61.2
14:05	18.9	56.7	17.8	53.4
14:06	19.6	58.8	18.1	54.3
14:07	20.4	61.2	18.7	56.1
14:08	20.8	62.4	19.2	57.6
14:09	24.6	73.8	22.5	67.5
14:10	36.8	110.4	26.5	79.5
14:11	29.0	87.0	32.7	98.1
14:12	34.4	103.2	30.7	92.1
14:13	26.1	78.3	24.2	72.6
14:14	27.5	82.5	24.8	74.4
14:15	27.3	81.9	24.8	74.4
14:16	27.1	81.3	24.6	73.8
14:17	24.7	74.1	23.2	69.6
14:18	23.6	70.8	21.5	64.5
14:19	24.6	73.8	22.2	66.6
14:20	28.1	84.3	24.7	74.1
14:21	27.0	81.0	24.8	74.4
14:22	25.4	76.2	23.5	70.5
14:23	24.7	74.1	22.4	67.2
14:24	27.4	82.2	24.3	72.9
14:25	26.5	79.5	24.2	72.6
14:26	26.5	79.5	24.1	72.3
14:27	26.8	80.4	24.0	72
14:28	23.9	71.7	22.6	67.8
14:29	26.2	78.6	22.9	68.7
14:30	26.9	80.7	24.4	73.2
14:31	27.4	82.2	24.7	74.1
14:32	26.6	79.8	24.3	72.9
14:33	27.4	82.2	24.4	73.2
14:34	27.1	81.3	25.0	75
14:35	24.9	74.7	22.8	68.4
14:36	25.0	75.0	22.7	68.1
14:37	25.3	75.9	22.8	68.4
14:38	25.0	75.0	22.3	66.9
14:39	26.6	79.8	24.2	72.6
14:40	25.6	76.8	23.2	69.6
14:41	25.7	77.1	23.2	69.6
14:42	25.7	77.1	23.2	69.6

Run 3
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
14:43	25.8	77.4	23.3	69.9
14:44	24.8	74.4	22.7	68.1
14:45	27.6	82.8	24.6	73.8
14:46	26.3	78.9	24.2	72.6
14:47	25.6	76.8	23.2	69.6
14:48	25.5	76.5	23.1	69.3
14:49	25.9	77.7	23.4	70.2
14:50	26.3	78.9	24.2	72.6
14:51	25.1	75.3	23.6	70.8
14:52	26.0	78.0	23.9	71.7
14:53	24.0	72.0	23.4	70.2
14:54	23.4	70.2	21.7	65.1
14:55	23.9	71.7	22.2	66.6
14:56	23.9	71.7	22.3	66.9
14:57	27.1	81.3	23.3	69.9
14:58	37.2	111.6	32.6	97.8
14:59	32.8	98.4	30.3	90.9
15:00	28.5	85.5	26.2	78.6
15:01	28.8	86.4	26.0	78
15:02	31.7	95.1	26.1	78.3
15:03	32.4	97.2	30.8	92.4
15:04	28.5	85.5	26.1	78.3
15:05	26.3	78.9	24.2	72.6
15:06	28.2	84.6	24.9	74.7
15:07	26.4	79.2	24.1	72.3
15:08	25.2	75.6	23.0	69
15:09	23.2	69.6	21.4	64.2
15:10	23.9	71.7	21.3	63.9
15:11	27.1	81.3	23.7	71.1
15:12	28.6	85.8	25.2	75.6
15:13	29.6	88.8	26.7	80.1
15:14	25.1	75.3	23.4	70.2
15:15	23.3	69.9	22.0	66
15:16	22.1	66.3	20.4	61.2
15:17	24.9	74.7	22.2	66.6
15:18	25.0	75.0	22.9	68.7
15:19	21.7	65.1	20.5	61.5
15:20	17.9	53.7	16.8	50.4
15:21	22.8	68.4	19.6	58.8
15:22	21.0	63.0	20.0	60
15:23	19.7	59.1	17.7	53.1
15:24	22.7	68.1	20.8	62.4
15:25	23.3	69.9	21.5	64.5
15:26	24.5	73.5	22.3	66.9
15:27	27.3	81.9	25.1	75.3
15:28	24.6	73.8	23.5	70.5
15:29	22.7	68.1	21.3	63.9
15:30	21.9	65.7	20.3	60.9

Run 3
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

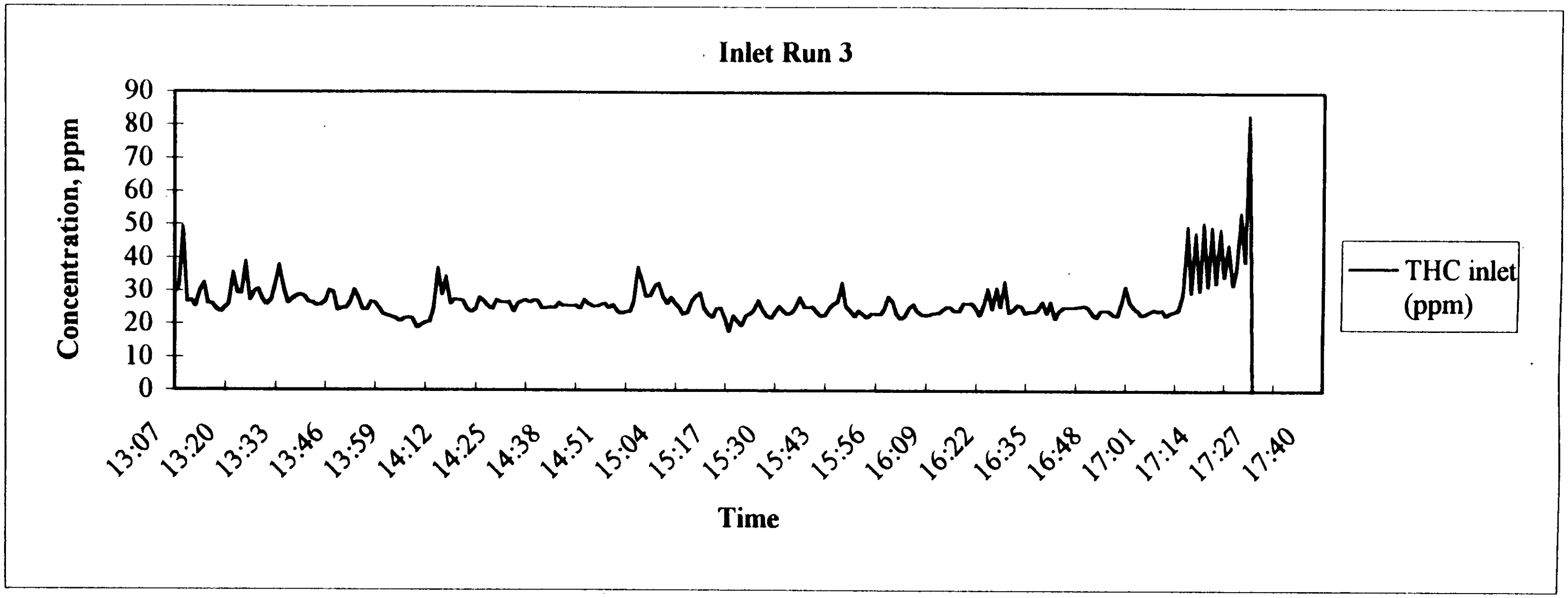
Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
15:31	23.7	71.1	21.3	63.9
15:32	25.6	76.8	23.5	70.5
15:33	24.1	72.3	22.5	67.5
15:34	23.2	69.6	21.5	64.5
15:35	23.7	71.1	21.7	65.1
15:36	25.7	77.1	22.6	67.8
15:37	28.3	84.9	25.9	77.7
15:38	25.5	76.5	23.1	69.3
15:39	25.2	75.6	23.0	69
15:40	25.5	76.5	23.2	69.6
15:41	23.8	71.4	22.3	66.9
15:42	22.5	67.5	20.6	61.8
15:43	23.0	69.0	20.9	62.7
15:44	25.1	75.3	22.7	68.1
15:45	26.2	78.6	23.5	70.5
15:46	26.9	80.7	24.0	72
15:47	32.7	98.1	29.5	88.5
15:48	25.7	77.1	24.1	72.3
15:49	24.2	72.6	22.3	66.9
15:50	22.5	67.5	21.2	63.6
15:51	24.3	72.9	21.6	64.8
15:52	23.1	69.3	21.9	65.7
15:53	22.1	66.3	20.1	60.3
15:54	23.3	69.9	21.5	64.5
15:55	23.3	69.9	21.4	64.2
15:56	23.1	69.3	21.2	63.6
15:57	24.4	73.2	22.1	66.3
15:58	28.5	85.5	25.7	77.1
15:59	27.1	81.3	25.5	76.5
16:00	23.4	70.2	21.7	65.1
16:01	21.8	65.4	20.4	61.2
16:02	22.6	67.8	20.5	61.5
16:03	25.0	75.0	22.1	66.3
16:04	26.2	78.6	23.9	71.7
16:05	24.1	72.3	22.4	67.2
16:06	23.1	69.3	21.3	63.9
16:07	22.8	68.4	21.1	63.3
16:08	23.1	69.3	21.2	63.6
16:09	23.5	70.5	21.1	63.3
16:10	23.5	70.5	21.2	63.6
16:11	24.5	73.5	22.1	66.3
16:12	25.4	76.2	23.0	69
16:13	25.3	75.9	23.1	69.3
16:14	24.0	72.0	21.9	65.7
16:15	24.0	72.0	21.3	63.9
16:16	26.5	79.5	24.0	72
16:17	26.3	78.9	23.8	71.4
16:18	26.6	79.8	24.5	73.5

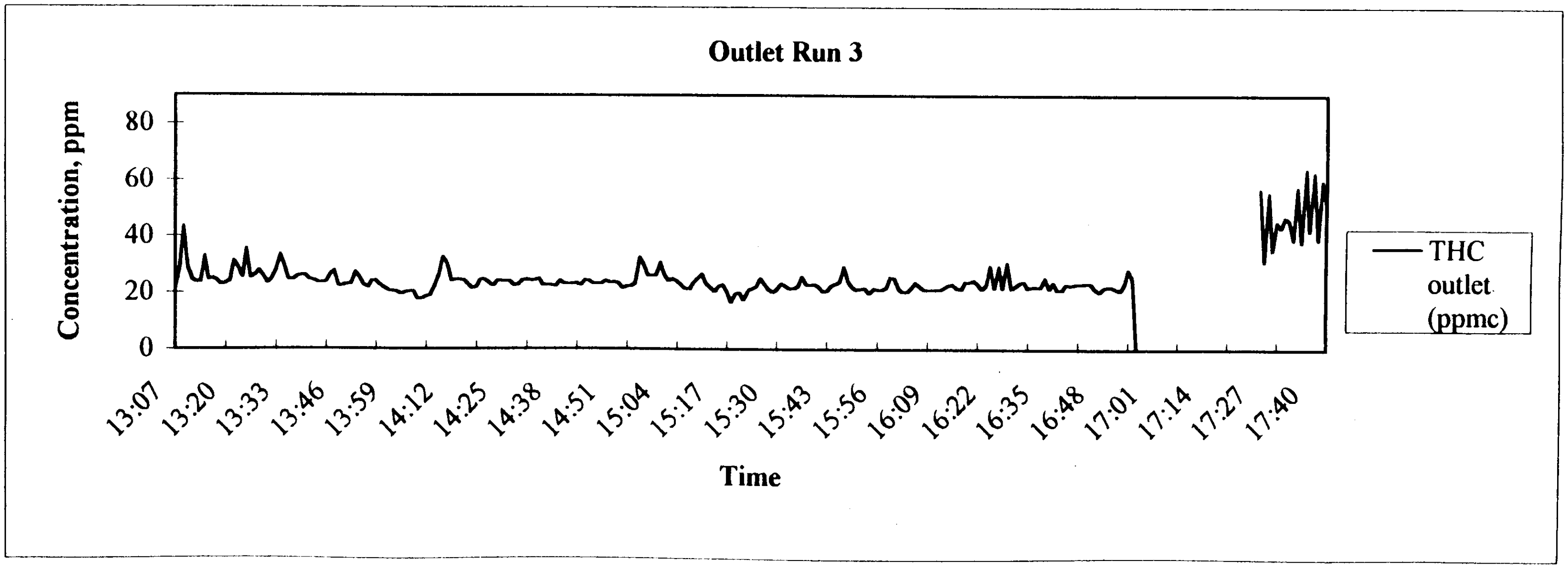
Run 3
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
16:19	25.1	75.3	23.4	70.2
16:20	23.0	69.0	21.4	64.2
16:21	26.5	79.5	22.9	68.7
16:22	30.9	92.7	29.6	88.8
16:23	24.9	74.7	21.8	65.4
16:24	31.2	93.6	29.5	88.5
16:25	25.4	76.2	21.8	65.4
16:26	33.0	99.0	30.8	92.4
16:27	23.6	70.8	21.6	64.8
16:28	24.5	73.5	22.6	67.8
16:29	25.9	77.7	23.7	71.1
16:30	25.7	77.1	24.0	72
16:31	23.5	70.5	21.9	65.7
16:32	24.0	72.0	22.3	66.9
16:33	23.8	71.4	22.2	66.6
16:34	24.9	74.7	22.1	66.3
16:35	27.0	81.0	25.3	75.9
16:36	23.5	70.5	21.6	64.8
16:37	26.9	80.7	23.8	71.4
16:38	22.0	66.0	21.1	63.3
16:39	24.0	72.0	21.2	63.6
16:40	25.2	75.6	23.2	69.6
16:41	25.3	75.9	22.8	68.4
16:42	25.2	75.6	23.1	69.3
16:43	25.5	76.5	23.2	69.6
16:44	25.5	76.5	23.4	70.2
16:45	25.8	77.4	23.5	70.5
16:46	25.2	75.6	23.4	70.2
16:47	23.4	70.2	21.5	64.5
16:48	22.4	67.2	20.6	61.8
16:49	24.3	72.9	21.9	65.7
16:50	24.2	72.6	22.2	66.6
16:51	24.3	72.9	22.3	66.9
16:52	23.2	69.6	21.5	64.5
16:53	22.8	68.4	21.0	63
16:54	26.3	78.9	23.1	69.3
16:55	31.6	94.8	28.4	85.2
16:56	26.8	80.4	25.4	76.2
16:57	25.2	75.6	Outlet Spike	
16:58	24.3	72.9		
16:59	23.0	69.0		
17:00	23.3	69.9		
17:01	24.0	72.0		
17:02	24.6	73.8		
17:03	24.0	72.0		
17:04	24.5	73.5		
17:05	22.8	68.4		
17:06	23.7	71.1		

Run 3
Date: 8/20/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
17:07	24.0	72.0		
17:08	24.6	73.8		
17:09	29.6	88.8		
17:10	49.7	149.1		
17:11	29.9	89.7		
17:12	47.8	143.4		
17:13	30.4	91.2		
17:14	50.9	152.7		
17:15	31.7	95.1		
17:16	49.4	148.2		
17:17	32.6	97.8		
17:18	49.0	147.0		
17:19	34.6	103.8		
17:20	44.1	132.3		
17:21	32.1	96.3		
17:22	37.0	111.0		
17:23	53.9	161.7		
17:24	39.2	117.6		
17:25	83.2	249.6		
17:26	Inlet Spike			
17:27			56.7	170.1
17:28			31.1	93.3
17:29			55.5	166.5
17:30			35.2	105.6
17:31			45.2	135.6
17:32			43.2	129.6
17:33			46.8	140.4
17:34			45.8	137.4
17:35			38.9	116.7
17:36			57.5	172.5
17:37			38.1	114.3
17:38			64.0	192
17:39			42.0	126
17:40			62.5	187.5
17:41			38.9	116.7
17:42			59.6	178.8
17:43			52.3	156.9
Maximum =	17.9	53.7	16.8	50.4
Maximum =	83.2	249.6	64.0	192
Average =	27.0	81.0	25.4	76.2


Inlet Run 3
Concentration, ppm
90
80
70
60
50
40
30
20
10
0
13:07
13:20
13:33
13:46
13:59
14:12
14:25
14:38
14:51
15:04
15:17
15:30
15:43
15:56
16:09
16:22
16:35
16:48
17:01
17:14
17:27
17:40
Time
THC inlet (ppm)


Outlet Run 3
Concentration, ppm
80
60
40
20
0
13:07
13:20
13:33
13:46
13:59
14:12
14:25
14:38
14:51
15:04
15:17
15:30
15:43
15:56
16:09
16:22
16:35
16:48
17:01
17:14
17:27
17:40
Time
THC outlet (ppmc)

Run 4
Date: 8/21/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
7:48	62.8	188.4	Outlet Spike	
7:49	63.3	189.9		
7:50	65.2	195.6		
7:51	65.3	195.9		
7:52	65.4	196.2		
7:53	65.7	197.1		
7:54	65.6	196.8		
7:55	65.9	197.7		
7:56	64.9	194.7		
7:57	65.5	196.5		
7:58	66.5	199.5		
7:59	67.7	203.1		
8:00	67.0	201.0		
8:01	65.8	197.4		
8:02	65.4	196.2		
8:03	74.7	224.1		
8:04	81.0	243.0		
8:05	80.5	241.5		
8:06	83.4	250.2		
8:07	89.5	268.5		
8:08	81.9	245.7		
8:09	89.5	268.5		
8:10	89.9	269.7		
8:11	86.1	258.3		
8:12	80.6	241.8	54.7	164.1
8:13	67.6	202.8	49.6	148.8
8:14	51.2	153.6	36.9	110.7
8:15	45.2	135.6	32.6	97.8
8:16	42.1	126.3	29.8	89.4
8:17	40.2	120.6	28.4	85.2
8:18	Inlet Spike		27.4	82.2
8:19			26.5	79.5
8:20			25.5	76.5
8:21			25.3	75.9
8:22			26.8	80.4
8:23			30.1	90.3
8:24			32.7	98.1
8:25			35.0	105
8:26			34.6	103.8
8:27			36.5	109.5
8:28			36.9	110.7
8:29	85.0	255.0	35.1	105.3
8:30	85.5	256.5	34.7	104.1
8:31	84.8	254.4	34.3	102.9
8:32	84.8	254.4	34.9	104.7
8:33	84.4	253.2	34.6	103.8
8:34	83.8	251.4	34.4	103.2
8:35	82.5	247.5	32.9	98.7

Run 4
Date: 8/21/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
8:36	83.7	251.1	32.4	97.2
8:37	79.6	238.8	33.0	99
8:38	47.2	141.6	33.1	99.3
8:39	45.9	137.7	30.5	91.5
8:40	75.7	227.1	42.2	126.6
8:41	74.4	223.2	57.2	171.6
8:42	43.6	130.8	31.4	94.2
8:43	75.8	227.4	41.3	123.9
8:44	58.5	175.5	48.9	146.7
8:45	67.1	201.3	34.4	103.2
8:46	55.8	167.4	47.5	142.5
8:47	68.5	205.5	34.8	104.4
8:48	58.1	174.3	49.3	147.9
8:49	62.4	187.2	33.2	99.6
8:50	58.0	174.0	46.1	138.3
8:51	95.9	287.7	50.0	150
8:52	113.2	339.6	76.2	228.6
8:53	114.2	342.6	76.0	228
8:54	111.7	335.1	77.6	232.8
8:55	85.7	257.1	62.6	187.8
8:56	62.1	186.3	44.3	132.9
8:57	58.7	176.1	40.7	122.1
8:58	40.8	122.4	30.2	90.6
8:59	41.5	124.5	27.7	83.1
9:00	44.1	132.3	28.6	85.8
9:01	47.4	142.2	30.5	91.5
9:02	49.0	147.0	31.9	95.7
9:03	47.4	142.2	31.8	95.4
9:04	45.2	135.6	30.7	92.1
9:05	42.5	127.5	29.1	87.3
9:06	40.6	121.8	27.8	83.4
9:07	40.0	120.0	26.8	80.4
9:08	42.3	126.9	27.9	83.7
9:09	42.6	127.8	28.4	85.2
9:10			28.4	85.2
9:11			28.0	84
9:12			28.7	86.1
9:13			34.5	103.5
9:14			44.4	133.2
9:15			64.5	193.5
9:16			40.5	121.5
9:17			43.0	129
9:18			47.8	143.4
9:19			31.9	95.7
9:20			33.2	99.6
9:21			50.4	151.2
9:22			33.9	101.7
9:23			49.3	147.9

Run 4
Date: 8/21/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
9:24			37.2	111.6
9:25			53.1	159.3
9:26			35.2	105.6
9:27			56.3	168.9
9:28			38.5	115.5
9:29			79.0	237
9:30			94.0	282
9:31			68.0	204
9:32			60.4	181.2
9:33			58.5	175.5
9:34			56.6	169.8
9:35			36.3	108.9
9:36			33.2	99.6
9:37			31.9	95.7
9:38	48.0	144.0	31.8	95.4
9:39	40.2	120.6	28.5	85.5
9:40	33.3	99.9	21.9	65.7
9:41	32.8	98.4	21.6	64.8
9:42	32.7	98.1	21.4	64.2
9:43	33.5	100.5	21.7	65.1
9:44	34.2	102.6	22.3	66.9
9:45	34.0	102.0	22.0	66
9:46	34.3	102.9	22.4	67.2
9:47	34.1	102.3	22.4	67.2
9:48	34.0	102.0	22.3	66.9
9:49	33.8	101.4	22.2	66.6
9:50	33.5	100.5	22.2	66.6
9:51	33.5	100.5	22.0	66
9:52	33.3	99.9	21.7	65.1
9:53	32.9	98.7	21.6	64.8
9:54	32.4	97.2	21.3	63.9
9:55	32.2	96.6	21.0	63
9:56	32.4	97.2	21.1	63.3
9:57	32.2	96.6	21.0	63
9:58	32.2	96.6	20.9	62.7
9:59	31.8	95.4	20.7	62.1
10:00	31.9	95.7	20.8	62.4
10:01	31.7	95.1	20.6	61.8
10:02	32.0	96.0	20.8	62.4
10:03	31.7	95.1	20.9	62.7
10:04	31.5	94.5	20.5	61.5
10:05	32.1	96.3	20.7	62.1
10:06	34.4	103.2	21.0	63
10:07	76.3	228.9	44.3	132.9
10:08	77.5	232.5	50.4	151.2
10:09	58.4	175.2	44.0	132
10:10	36.8	110.4	24.6	73.8
10:11	34.4	103.2	23.2	69.6

Run 4
Date: 8/21/97
Project No.: 3804-24-04-03
Operator: Gulick

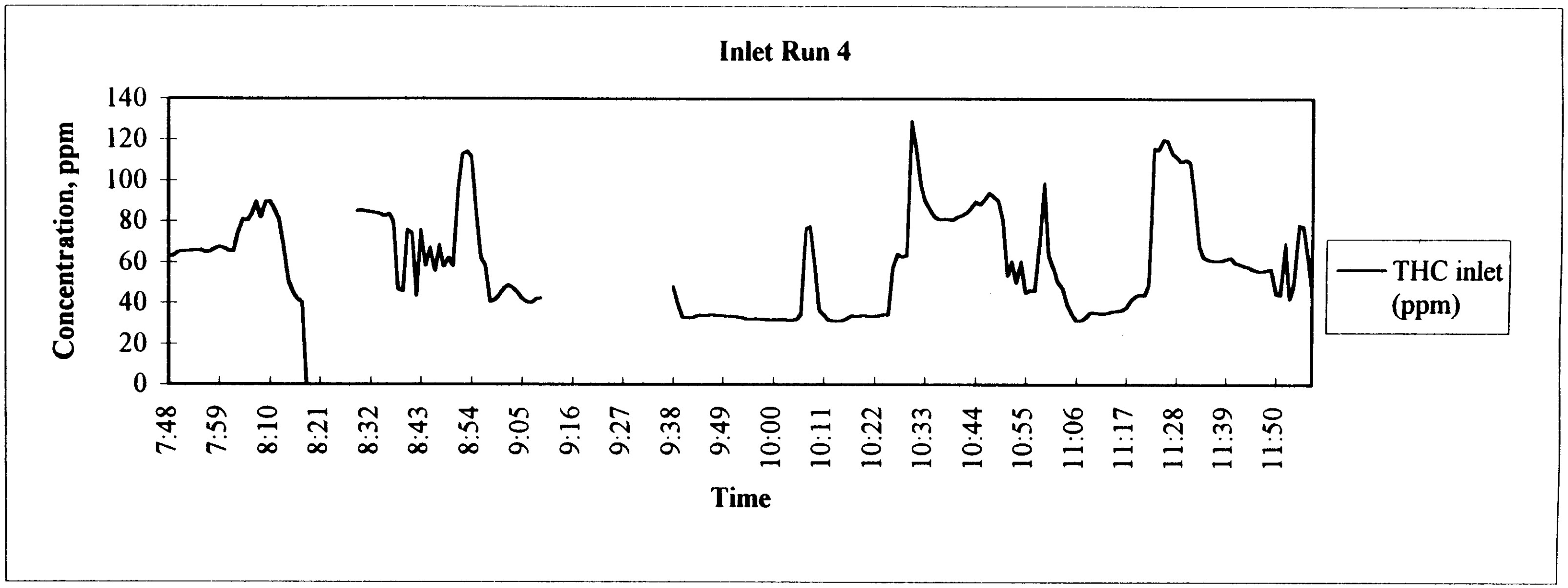
Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
10:12	31.9	95.7	21.0	63
10:13	31.4	94.2	20.6	61.8
10:14	31.3	93.9	20.6	61.8
10:15	31.4	94.2	20.4	61.2
10:16	32.4	97.2	20.8	62.4
10:17	33.8	101.4	21.6	64.8
10:18	33.4	100.2	21.7	65.1
10:19	33.8	101.4	21.9	65.7
10:20	33.8	101.4	22.0	66
10:21	33.4	100.2	21.7	65.1
10:22	33.7	101.1	21.7	65.1
10:23	33.8	101.4	21.7	65.1
10:24	34.4	103.2	22.4	67.2
10:25	34.3	102.9	22.3	66.9
10:26	56.9	170.7	32.0	96
10:27	64.2	192.6	41.7	125.1
10:28	62.6	187.8	40.9	122.7
10:29	63.5	190.5	41.1	123.3
10:30	129.0	387.0	72.7	218.1
10:31	115.1	345.3	81.6	244.8
10:32	98.8	296.4	66.4	199.2
10:33	90.5	271.5	60.3	180.9
10:34	86.2	258.6	57.2	171.6
10:35	82.8	248.4	54.4	163.2
10:36	80.9	242.7	53.0	159
10:37	81.2	243.6	52.8	158.4
10:38	81.4	244.2	52.6	157.8
10:39	80.8	242.4	52.5	157.5
10:40	82.3	246.9	53.2	159.6
10:41	83.2	249.6	53.8	161.4
10:42	84.4	253.2	54.2	162.6
10:43	86.6	259.8	56.0	168
10:44	89.9	269.7	57.7	173.1
10:45	88.3	264.9	57.5	172.5
10:46	91.1	273.3	58.1	174.3
10:47	94.2	282.6	60.9	182.7
10:48	92.4	277.2	60.4	181.2
10:49	90.2	270.6	58.6	175.8
10:50	81.1	243.3	56.1	168.3
10:51	53.4	160.2	37.6	112.8
10:52	60.4	181.2	32.4	97.2
10:53	50.1	150.3	38.4	115.2
10:54	60.6	181.8	34.5	103.5
10:55	45.2	135.6	32.9	98.7
10:56	46.6	139.8	29.3	87.9
10:57	46.1	138.3	29.5	88.5
10:58	71.1	213.3	34.2	102.6
10:59	98.7	296.1	72.8	218.4

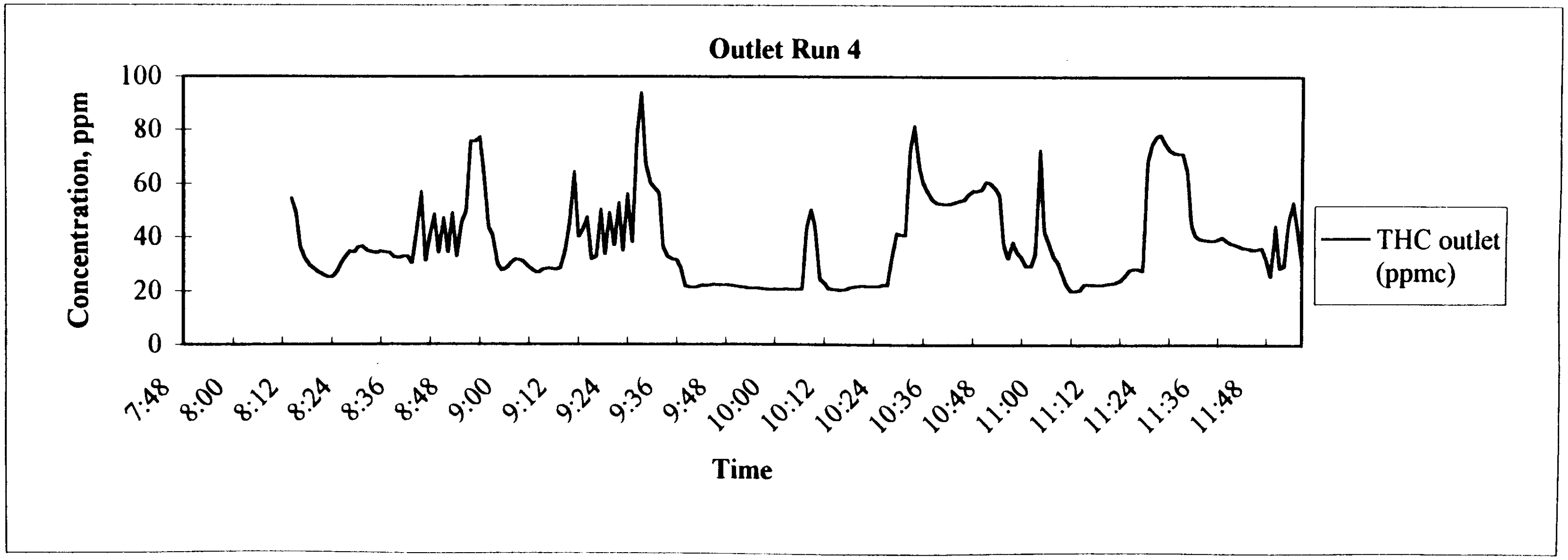
Run 4
Date: 8/21/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
11:00	63.5	190.5	42.8	128.4
11:01	57.1	171.3	37.7	113.1
11:02	50.3	150.9	33.1	99.3
11:03	47.5	142.5	31.0	93
11:04	39.7	119.1	26.9	80.7
11:05	35.1	105.3	22.8	68.4
11:06	31.5	94.5	20.2	60.6
11:07	31.6	94.8	20.1	60.3
11:08	33.0	99.0	20.5	61.5
11:09	35.6	106.8	22.6	67.8
11:10	35.6	106.8	22.6	67.8
11:11	35.1	105.3	22.4	67.2
11:12	34.9	104.7	22.4	67.2
11:13	35.5	106.5	22.5	67.5
11:14	36.1	108.3	22.9	68.7
11:15	36.2	108.6	23.0	69
11:16	36.7	110.1	23.3	69.9
11:17	37.8	113.4	24.0	72
11:18	41.7	125.1	26.0	78
11:19	43.4	130.2	28.0	84
11:20	44.4	133.2	28.4	85.2
11:21	43.6	130.8	28.4	85.2
11:22	49.4	148.2	27.7	83.1
11:23	115.7	347.1	68.6	205.8
11:24	114.8	344.4	75.1	225.3
11:25	120.0	360.0	77.6	232.8
11:26	119.6	358.8	78.4	235.2
11:27	113.8	341.4	75.0	225
11:28	111.6	334.8	72.6	217.8
11:29	109.2	327.6	71.8	215.4
11:30	110.3	330.9	71.3	213.9
11:31	108.9	326.7	71.3	213.9
11:32	91.6	274.8	64.5	193.5
11:33	68.3	204.9	45.2	135.6
11:34	62.7	188.1	40.7	122.1
11:35	61.5	184.5	39.6	118.8
11:36	60.8	182.4	39.4	118.2
11:37	60.8	182.4	39.2	117.6
11:38	60.7	182.1	38.9	116.7
11:39	61.7	185.1	39.6	118.8
11:40	62.3	186.9	40.3	120.9
11:41	59.8	179.4	39.0	117
11:42	59.2	177.6	37.9	113.7
11:43	58.4	175.2	37.6	112.8
11:44	57.8	173.4	36.9	110.7
11:45	56.7	170.1	36.2	108.6
11:46	56.0	168.0	36.2	108.6
11:47	55.7	167.1	35.4	106.2

Run 4
Date: 8/21/97
Project No.: 3804-24-04-03
Operator: Gulick

Time (24 hour)	THC inlet (ppm)	THC inlet (ppmc)	THC outlet (ppmc)	THC outlet (ppm)
11:48	56.1	168.3	35.9	107.7
11:49	56.9	170.7	36.2	108.6
11:50	45.0	135.0	31.6	94.8
11:51	43.9	131.7	25.7	77.1
11:52	69.4	208.2	44.5	133.5
11:53	42.1	126.3	28.8	86.4
11:54	48.7	146.1	29.7	89.1
11:55	78.3	234.9	45.9	137.7
11:56	77.6	232.8	53.3	159.9
11:57	62.5	187.5	42.9	128.7
11:58	45.9	137.7	30.9	92.7
Minimum	31.3	93.9	20.1	60.3
Maximum	129.0	387.0	94.0	282
Average	60.1	180.3	38.1	114.3


Inlet Run 4
Concentration, ppm
140
120
100
80
60
40
20
0
7:48
7:59
8:10
8:21
8:32
8:43
8:54
9:05
9:16
9:27
9:38
9:49
10:00
10:11
10:22
10:33
10:44
10:55
11:06
11:17
11:28
11:39
11:50
Time
THC inlet (ppm)


Outlet Run 4
Concentration, ppm
100
80
60
40
20
0
7:48
8:00
8:12
8:24
8:36
8:48
9:00
9:12
9:24
9:36
9:48
10:00
10:12
10:24
10:36
10:48
11:00
11:12
11:24
11:36
11:48
Time
THC outlet (ppmc)

A-2 METHOD 25A CALIBRATION AND QC CHECK DATA

Calibration Error Determination For 8/19/97

	Cal Gas Value	Predicted Value	Measured Value	Difference as % of Cal Gas	Pass/Fail
THC 1	0.0		0.2	0.2	Pass
Inlet	90.4		91.0	0.7	Pass
	50.4	50.8	49.9	1.8	Pass
	35.2	35.6	34.3	3.5	Pass
THC 2	0.0		0.7	0.7	Pass
Outlet	90.4		91.5	1.2	Pass
	50.4	51.3	50.1	2.4	Pass
	35.2	36.1	34.5	4.3	Pass

Pass Fail Criteria is +/- 5% of Calibration gas.

Calibration Drift Determination For 8/19/97

Zero Drift

	Initial Value	Final Value	Difference as % of Span	Pass/Fail
THC 1 Inlet	0.2	0.2	0.0%	Pass
THC 2 Outlet	0.7	0.0	0.7%	Pass

Instrument Span for THC 1 and THC 2 is 1000 ppm
Pass Fail Criteria is +/- 3% of Span.

Span Drift

	Initial Value	Final Value	Difference as % of Span	Pass/Fail
THC 1 Inlet	91.0	89.1	1.9%	Pass
THC 2 Outlet	91.5	93.1	-1.6%	Pass

Instrument Span for THC 1 and THC 2 is 1000 ppm
Pass Fail Criteria is +/- 3% of Span.

Calibration Error Determination For 8/20/97 (Run 2)

	Cal Gas Value	Predicted Value	Measured Value	Difference as % of Cal Gas	Pass/Fail
THC 1	0.0		-0.1	0.0	Pass
Inlet	898.0		902.0	0.4	Pass
	502.0	504.2	495.0	1.8	Pass
	251.0	252.0	249.0	1.2	Pass
THC 2	0.0		0.5	0.1	Pass
Outlet	898.0		919.0	2.3	Pass
	502.0	514.0	505.0	1.7	Pass
	251.0	257.2	259.0	0.7	Pass

Pass Fail Criteria is +/- 5% of Calibration gas.

Calibration Drift Determination For 8/20/97 (Run 2)

Zero Drift

	Initial Value	Final Value	Difference as % of Span	Pass/Fail
THC 1 Inlet	-0.1	-1.5	0.1%	Pass
THC 2 Outlet	0.5	-0.4	0.1%	Pass

Instrument Span for THC 1 and THC 2 is 1000 ppm
Pass Fail Criteria is +/- 3% of Span.

Span Drift

	Initial Value	Final Value	Difference as % of Span	Pass/Fail
THC 1 Inlet	902.0	906.0	-0.4%	Pass
THC 2 Outlet	919.0	917.0	0.2%	Pass

Instrument Span for THC 1 and THC 2 is 1000 ppm
Pass Fail Criteria is +/- 3% of Span.

Calibration Error Determination For 8/20/97 (Run 3)

	Cal Gas Value	Predicted Value	Measured Value	Difference as % of Cal Gas	Pass/Fail
THC 1	0.0		-1.5	0.2	Pass
Inlet	898.0		906.0	0.9	Pass
	502.0	505.8	512.0	1.2	Pass
	251.0	252.2	252.0	0.1	Pass
THC 2	0.0		-0.4	0.0	Pass
Outlet	898.0		917.0	2.1	Pass
	502.0	512.4	497.0	3.0	Pass
	251.0	256.0	258.0	0.8	Pass

Pass Fail Criteria is +/- 5% of Calibration gas.

Calibration Drift Determination For 8/20/97 (Run 3)

Zero Drift

	Initial Value	Final Value	Difference as % of Span	Pass/Fail
THC 1 Inlet	-1.5	-1.3	0.0%	Pass
THC 2 Outlet	-0.4	0.2	-0.1%	Pass

Instrument Span for THC 1 and THC 2 is 1000 ppm
Pass Fail Criteria is +/- 3% of Span.

Span Drift

	Initial Value	Final Value	Difference as % of Span	Pass/Fail
THC 1 Inlet	906.0	900.0	0.6%	Pass
THC 2 Outlet	917.0	915.0	0.2%	Pass

Instrument Span for THC 1 and THC 2 is 1000 ppm
Pass Fail Criteria is +/- 3% of Span.

Calibration Error Determination For 8/21/97

	Cal Gas Value	Predicted Value	Measured Value	Difference as % of Cal Gas	Pass/Fail
THC 1	0.0		0.3	0.0	Pass
Inlet	898.0		899.0	0.1	Pass
	502.0	502.7	501.0	0.3	Pass
	251.0	251.5	247.0	1.8	Pass
THC 2	0.0		0.5	0.1	Pass
Outlet	898.0		912.0	1.6	Pass
	502.0	510.0	499.0	2.2	Pass
	251.0	255.3	242.0	5.2	Fail
				1.3	

Pass Fail Criteria is +/- 5% of Calibration gas.

Calibration Drift Determination For 8/21/97

Zero Drift

	Initial Value	Final Value	Difference as % of Span	Pass/Fail
THC 1 Inlet	0.3	1.4	-0.1%	Pass
THC 2 Outlet	0.5	1.0	-0.1%	Pass

Instrument Span for THC 1 and THC 2 is 1000 ppm
Pass Fail Criteria is +/- 3% of Span.

Span Drift

	Initial Value	Final Value	Difference as % of Span	Pass/Fail
THC 1 Inlet	899.0	903.0	-0.4%	Pass
THC 2 Outlet	912.0	906.0	0.6%	Pass

Instrument Span for THC 1 and THC 2 is 1000 ppm
Pass Fail Criteria is +/- 3% of Span.

A-3 VOLUMETRIC FLOW DATA

APPENDIX A

METHOD 25A AND VOLUMERTRIC FLOW DATA

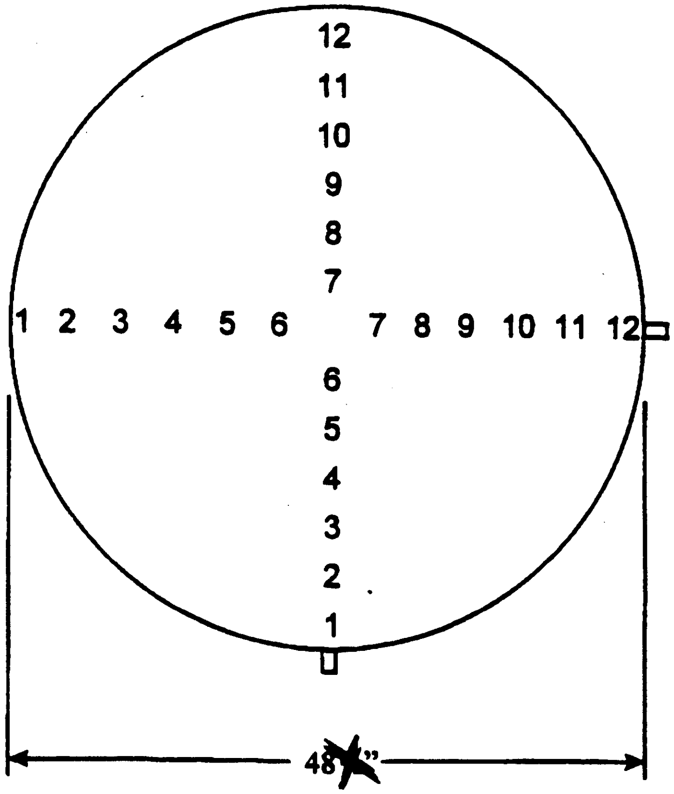
Summary of Stack Gas Parameters and Test Results

US EPA Test Method 23 - PCDD / PCDF
Baghouse Inlet
Page 1 of 6

	RUN NUMBER	***S-M23-I-1***
	RUN DATE	***8/19/97***
	RUN TIME	***0915-1010***
	MEASURED DATA	
γ	Meter Box Correction Factor	1.021
ΔH	Avg Meter Orifice Pressure, in. H_2O	1.93
P_{bar}	Barometric Pressure, inches Hg	29.90
V_m	Sample Volume, ft^3	11.116
T_m	Average Meter Temperature, °F	90
P_{static}	Stack Static Pressure, inches H_2O	-2.5
T_s	Average Stack Temperature, °F	230
V_{lc}	Condensate Collected, ml	84.0
CO_2	Carbon Dioxide content, % by volume	5.3
O_2	Oxygen content, % by volume	13.1
N_2	Nitrogen content, % by volume	81.6
C_p	Pitot Tube Coefficient	0.84
$\Delta p^{1/2}$	Average Square Root Δp, (in. $H_2O)^{1/2}$	0.5927
Θ	Sample Run Duration, minutes	20
D_n	Nozzle Diameter, inches	0.312
	CALCULATED DATA	
A_n	Nozzle Area, ft^2	0.00053
$V_{m(std)}$	Standard Meter Volume, dscf	10.940
$V_{m(std)}$	Standard Meter Volume, dscm	0.310
P_s	Stack Pressure, inches Hg	29.72
B_{ws}	Moisture, % by volume	26.5
$B_{ws(sat)}$	Moisture (at saturation), % by volume	141.2
V_{wstd}	Standard Water Vapor Volume, ft^3	3.954
$1-B_{ws}$	Dry Mole Fraction	0.735
M_d	Molecular Weight (d.b.), lb/lb•mole	29.37
M_s	Molecular Weight (w.b.), lb/lb•mole	26.35
V_s	Stack Gas Velocity, ft/s	39.9
A	Stack Area, ft^2	12.57
Q_a	Stack Gas Volumetric flow, acfm	30,119
Q_s	Stack Gas Volumetric flow, dscfm	16,819
$Q_{s(cmm)}$	Stack Gas Volumetric flow, dscmm	476.3
I	Isokinetic Sampling Ratio, %	77.0

Summary of Stack Gas Parameters and Test Results
US EPA EMC Asphalt Concrete Emissions Testing
US EPA Test Method 29 - Multiple Metals
Baghouse Inlet
Page 1 of 4

	RUN NUMBER	***S-M29-I-1***
	RUN DATE	***8/19/97***
	RUN TIME	***0915-1010***
	MEASURED DATA	
γ	Meter Box Correction Factor	1.016
ΔH	Avg Meter Orifice Pressure, in. H_2O	1.10
P_{bar}	Barometric Pressure, inches Hg	29.90
V_m	Sample Volume, ft^3	10.780
T_m	Average Meter Temperature, °F	92
P_{static}	Stack Static Pressure, inches H_2O	-2.5
T_s	Average Stack Temperature, °F	230
V_{lc}	Condensate Collected, ml	78.8
CO_2	Carbon Dioxide content, % by volume	5.3
O_2	Oxygen content, % by volume	13.1
N_2	Nitrogen content, % by volume	81.6
C_p	Pitot Tube Coefficient	0.84
$\Delta p^{1/2}$	Average Square Root Δp, $(in.\ H_2O)^{1/2}$	0.4682
Θ	Sample Run Duration, minutes	20
D_n	Nozzle Diameter, inches	0.311
	CALCULATED DATA	
A_n	Nozzle Area, ft^2	0.000527
$V_{m(std)\ cf}$	Standard Meter Volume, ft^3	10.491
$V_{m(std)\ cm}$	Standard Meter Volume, m^3	0.297
Q_m	Average Sampling Rate, dscfm	0.525
P_s	Stack Pressure, inches Hg	29.72
B_{ws}	Moisture, % by volume	26.1
$B_{ws(sat)}$	Moisture (at saturation), % by volume	141.2
V_{wstd}	Standard Water Vapor Volume, ft^3	3.709
$1-B_{ws}$	Dry Mole Fraction	0.739
M_d	Molecular Weight (d.b.), lb/lb•mole	29.37
M_s	Molecular Weight (w.b.), lb/lb•mole	26.40
V_s	Stack Gas Velocity, ft/s	31.5
A	Stack Area, ft^2	12.57
Q_a	Stack Gas Volumetric flow, acfm	23,773
$Q_{s\ cfm}$	Stack Gas Volumetric flow, dscfm	13,353
$Q_{s\ cmm}$	Stack Gas Volumetric flow, dscmm	378
I	Isokinetic Sampling Ratio, %	93.6



Section A

Traverse Point Number	Distance from Inside Wall, inches
1	1.02
2	3.25
3	5.72
4	8.58
5	12.1
6	17.3
7	31.2
8	36.4
9	39.9
10	42.8
11	45.3
12	47.5

Figure 3.2 Baghouse Inlet Traverse Point Locations, Garner, North Carolina

Summary of Stack Gas Parameters and Test Results
US EPA EMC Asphalt Concrete Emissions Testing
US EPA Test Method 23 - PCDD / PCDF
Baghouse Outlet
Page 1 of 6

	RUN NUMBER	***S-M23-O-1***	***S-M23-O-2***	***S-M23-O-3***	
	RUN DATE	***8/19/97***	***8/20/97***	***8/20/97***	***Average***
	RUN TIME	***0915-1456***	***0822-1240***	***1405-1730***	
	MEASURED DATA				
γ	Meter Box Correction Factor	0.987	0.987	0.987	0.987
ΔH	Avg Meter Orifice Pressure, in. H_2O	1.29	2.82	2.50	2.20
P_{bar}	Barometric Pressure, inches Hg	29.90	29.80	29.80	30.40
V_m	Sample Volume, ft^3	138.502	199.873	162.107	166.827
T_m	Average Meter Temperature, °F	115	102	109	109
P_{static}	Stack Static Pressure, inches H_2O	-0.22	-0.25	-0.25	-0.24
T_s	Average Stack Temperature, °F	185	223	209	206
V_{lc}	Condensate Collected, ml	601.6	1253.1	912.4	922.4
CO_2	Carbon Dioxide content, % by volume	5.3	5.5	5.1	5.3
O_2	Oxygen content, % by volume	13.1	13.1	13.1	13.1
N_2	Nitrogen content, % by volume	81.6	81.4	81.8	81.6
C_p	Pitot Tube Coefficient	0.84	0.84	0.84	0.84
$\Delta p^{1/2}$	Average Square Root Δp, (in. $H_2O)^{1/2}$	0.6897	0.9039	0.8429	0.8122
Θ	Sample Run Duration, minutes	240	240	200	227
D_n	Nozzle Diameter, inches	0.240	0.251	0.251	0.247
	CALCULATED DATA				
A_n	Nozzle Area, ft^2	0.00031	0.00034	0.00034	0.00033
$V_{m(std)}$	Standard Meter Volume, dscf	125.786	185.768	148.617	153.390
$V_{m(std)}$	Standard Meter Volume, dscm	3.562	5.260	4.208	4.344
P_s	Stack Pressure, inches Hg	29.88	29.78	29.78	29.82
B_{ws}	Moisture, % by volume	18.4	24.1	22.4	21.6
$B_{ws(sat)}$	Moisture (at saturation), % by volume	56.9	NA	93.9	75.4
V_{wstd}	Standard Water Vapor Volume, ft^3	28.317	58.983	42.947	43.416
$1-B_{ws}$	Dry Mole Fraction	0.816	0.759	0.776	0.784
M_d	Molecular Weight (d.b.), lb/lb•mole	29.37	29.40	29.34	29.37
M_s	Molecular Weight (w.b.), lb/lb•mole	27.28	26.66	26.80	26.91
V_s	Stack Gas Velocity, ft/s	44.1	60.2	55.4	53.2
A	Stack Area, ft^2	11.46	11.46	11.46	11.46
Q_a	Stack Gas Volumetric flow, acfm	30,291	41,402	38,097	36,596
Q_s	Stack Gas Volumetric flow, dscfm	20,210	24,166	23,222	22,533
$Q_{s(cmm)}$	Stack Gas Volumetric flow, dscmm	572.3	684.3	657.6	638.1
I	Isokinetic Sampling Ratio, %	94.6	106.8	106.7	102.7

Summary of Stack Gas Parameters and Test Results

US EPA Test Method 23 - PCDD / PCDF
Baghouse Outlet
Page 1 of 6

	RUN NUMBER	***S-M23-O-4***
	RUN DATE	***8/21/97***
	RUN TIME	***0741-1148***
	MEASURED DATA	
γ	Meter Box Correction Factor	0.987
ΔH	Avg Meter Orifice Pressure, in. H_2O	2.37
P_{bar}	Barometric Pressure, inches Hg	29.70
V_m	Sample Volume, ft^3	179.969
T_m	Average Meter Temperature, °F	105
P_{static}	Stack Static Pressure, inches H_2O	-0.25
T_s	Average Stack Temperature, °F	180
V_{lc}	Condensate Collected, ml	819.1
CO_2	Carbon Dioxide content, % by volume	3.2
O_2	Oxygen content, % by volume	10.8
N_2	Nitrogen content, % by volume	86.0
C_p	Pitot Tube Coefficient	0.84
$\Delta p^{1/2}$	Average Square Root Δp, $(in.\ H_2O)^{1/2}$	0.8374
Θ	Sample Run Duration, minutes	240
D_n	Nozzle Diameter, inches	0.251
	CALCULATED DATA	
A_n	Nozzle Area, ft^2	0.00034
$V_{m(std)}$	Standard Meter Volume, dscf	165.621
$V_{m(std)}$	Standard Meter Volume, dscm	4.690
P_s	Stack Pressure, inches Hg	29.68
B_{ws}	Moisture, % by volume	18.9
$B_{ws(sat)}$	Moisture (at saturation), % by volume	51.1
V_{wstd}	Standard Water Vapor Volume, ft^3	38.555
$1-B_{ws}$	Dry Mole Fraction	0.811
M_d	Molecular Weight (d.b.), lb/lb•mole	28.94
M_s	Molecular Weight (w.b.), lb/lb•mole	26.88
V_s	Stack Gas Velocity, ft/s	53.8
A	Stack Area, ft^2	11.46
Q_a	Stack Gas Volumetric flow, acfm	37,027
Q_s	Stack Gas Volumetric flow, dscfm	24,580
$Q_{s(cmm)}$	Stack Gas Volumetric flow, dscmm	696.0
I	Isokinetic Sampling Ratio, %	93.7

Summary of Stack Gas Parameters and Test Results
US EPA EMC Asphalt Concrete Emissions Testing
US EPA Test Method 29 - Multiple Metals
Baghouse Outlet
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	RUN NUMBER	***S-M29-O-1***	***S-M29-O-2***	***S-M29-O-3***	
	RUN DATE	***8/19/97***	***8/20/97***	***8/20/97***	***Average***
	RUN TIME	***0915-1454***	***0822-1240***	***1405-1735***	
	MEASURED DATA				
γ	Meter Box Correction Factor	0.965	0.965	0.965	0.965
ΔH	Avg Meter Orifice Pressure, in. H_2O	1.76	2.57	2.05	2.13
P_{bar}	Barometric Pressure, inches Hg	29.90	29.80	29.80	29.83
V_m	Sample Volume, ft^3	170.576	216.899	159.831	182.435
T_m	Average Meter Temperature, °F	104	96	104	101
P_{static}	Stack Static Pressure, inches H_2O	-0.25	-0.25	-0.25	-0.25
T_s	Average Stack Temperature, °F	179	222	207	203
V_{lc}	Condensate Collected, ml	691.0	993.1	978.8	887.6
CO_2	Carbon Dioxide content, % by volume	5.3	5.5	5.1	5.3
O_2	Oxygen content, % by volume	13.1	13.1	13.1	13.1
N_2	Nitrogen content, % by volume	81.6	81.4	81.8	81.6
C_p	Pitot Tube Coefficient	0.84	0.84	0.84	0.84
$\Delta p^{1/2}$	Average Square Root Δp, (in. $H_2O)^{1/2}$	0.7558	0.9285	0.8233	0.8359
Θ	Sample Run Duration, minutes	240	240	200	227
D_n	Nozzle Diameter, inches	0.251	0.253	0.253	0.252
	CALCULATED DATA				
A_n	Nozzle Area, ft^2	0.000344	0.000349	0.000349	0.000347
$V_{m(std)\,cf}$	Standard Meter Volume, ft^3	154.579	199.270	144.561	166.137
$V_{m(std)\,cm}$	Standard Meter Volume, m^3	4.377	5.643	4.094	4.704
Q_m	Average Sampling Rate, dscfm	0.644	0.830	0.723	0.732
P_s	Stack Pressure, inches Hg	29.88	29.78	29.78	29.81
B_{ws}	Moisture, % by volume	17.4	19.0	24.2	20.2
$B_{ws(sat)}$	Moisture (at saturation), % by volume	49.5	122.4	91.1	87.7
V_{wstd}	Standard Water Vapor Volume, ft^3	32.525	46.745	46.072	41.781
$1-B_{ws}$	Dry Mole Fraction	0.826	0.810	0.758	0.798
M_d	Molecular Weight (d.b.), lb/lb•mole	29.37	29.40	29.34	29.37
M_s	Molecular Weight (w.b.), lb/lb•mole	27.40	27.24	26.60	27.08
V_s	Stack Gas Velocity, ft/s	47.9	61.1	54.3	54.4
A	Stack Area, ft^2	11.46	11.46	11.46	11.46
Q_a	Stack Gas Volumetric flow, acfm	32,964	42,043	37,305	37,437
$Q_{s\,cfm}$	Stack Gas Volumetric flow, dscfm	22,478	26,229	22,276	23,661
$Q_{s\,cmm}$	Stack Gas Volumetric flow, dscmm	637	743	631	670
I	Isokinetic Sampling Ratio, %	95.6	103.9	106.5	102.0

Summary of Stack Gas Parameters and Test Results
US EPA EMC Asphalt Concrete Emissions Testing
US EPA Test Method 29 - Multiple Metals
Baghouse Outlet
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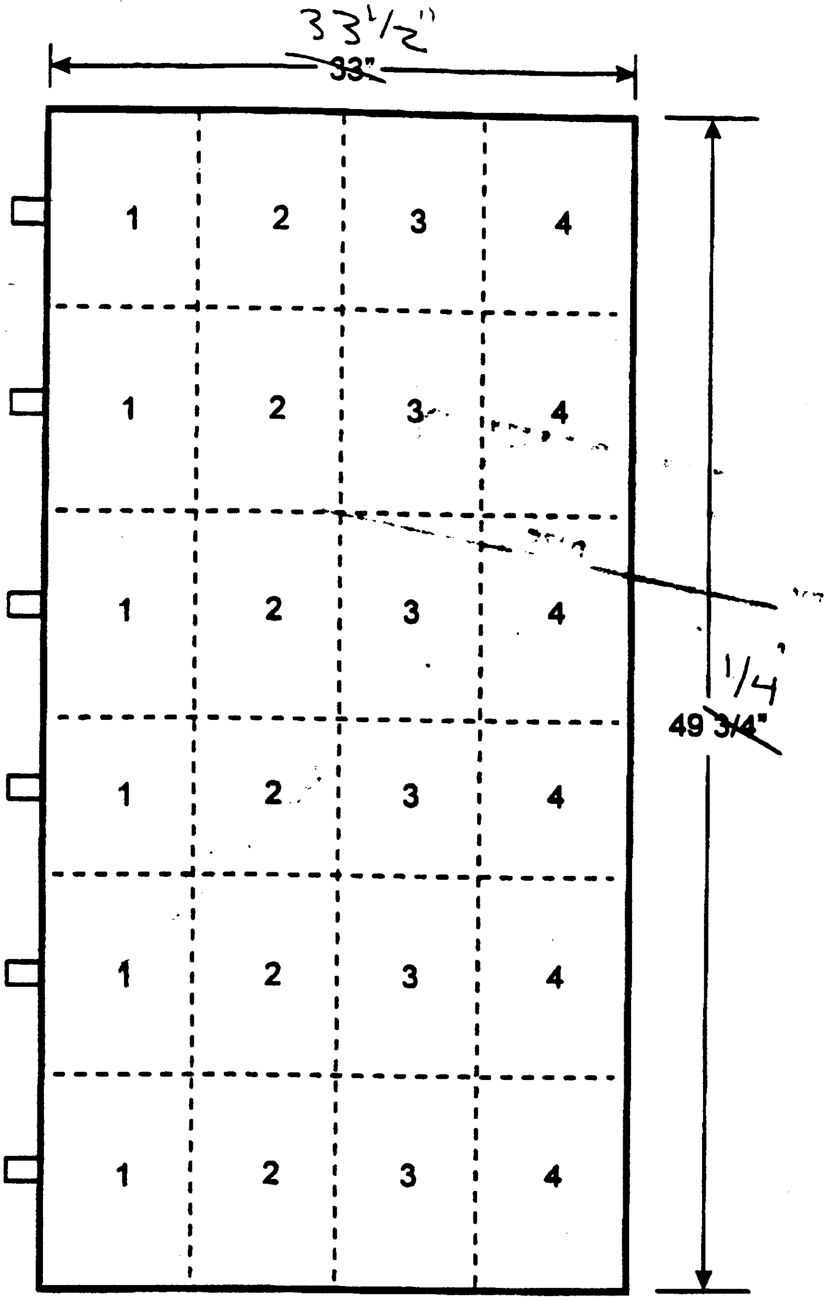
	RUN NUMBER	***S-M29-O-4***
	RUN DATE	***8/21/97***
	RUN TIME	***0741-1153***
	MEASURED DATA	
γ	Meter Box Correction Factor	0.965
ΔH	Avg Meter Orifice Pressure, in. H_2O	2.00
P_{bar}	Barometric Pressure, inches Hg	29.70
V_m	Sample Volume, ft^3	186.221
T_m	Average Meter Temperature, °F	102
P_{static}	Stack Static Pressure, inches H_2O	-0.25
T_s	Average Stack Temperature, °F	180
V_{lc}	Condensate Collected, ml	821.4
CO_2	Carbon Dioxide content, % by volume	3.2
O_2	Oxygen content, % by volume	10.8
N_2	Nitrogen content, % by volume	86.0
C_p	Pitot Tube Coefficient	0.84
$\Delta p^{1/2}$	Average Square Root Δp, (in. $H_2O)^{1/2}$	0.8239
Θ	Sample Run Duration, minutes	240
D_n	Nozzle Diameter, inches	0.253
	CALCULATED DATA	
A_n	Nozzle Area, ft^2	0.000349
$V_{m(std)\,cf}$	Standard Meter Volume, ft^3	168.390
$V_{m(std)\,cm}$	Standard Meter Volume, m^3	4.768
Q_m	Average Sampling Rate, dscfm	0.702
P_s	Stack Pressure, inches Hg	29.68
B_{ws}	Moisture, % by volume	18.7
$B_{ws(sat)}$	Moisture (at saturation), % by volume	51.1
V_{wstd}	Standard Water Vapor Volume, ft^3	38.663
$1\text{-}B_{ws}$	Dry Mole Fraction	0.813
M_d	Molecular Weight (d.b.), lb/lb•mole	28.94
M_s	Molecular Weight (w.b.), lb/lb•mole	26.90
V_s	Stack Gas Velocity, ft/s	53.0
A	Stack Area, ft^2	11.46
Q_a	Stack Gas Volumetric flow, acfm	36,415
$Q_{s\,cfm}$	Stack Gas Volumetric flow, dscfm	24,240
$Q_{s\,cmm}$	Stack Gas Volumetric flow, dscmm	686
I	Isokinetic Sampling Ratio, %	95.0



Section B

Traverse Point Number	Distance from Inside Wall, inches
1	4.13
2	12.4
3	20.6
4	28.9

Figure 3.4 Baghouse Outlet Traverse Point Locations
Garner, North Carolina

APPENDIX B

FTIR DATA

B-1 FTIR RESULTS TABLES

The semi-continuous FTIR analytical results are presented in Tables B-1 to B-4. Table B-1 presents results from the inlet (wet) samples. Table B-2 presents results from the outlet (wet) samples. Tables B-3 and B-4 present results from dry samples collected at the inlet and outlet, respectively.

The concentration results are presented in ppm with estimated uncertainties indicated by the symbol "Δ" in the column heading. Samples that were spiked with toluene and SF_6 are indicated by bold-face type. Refer to the FTIR field data sheets for detailed documentation on each file name and the sampling conditions.

Concentration versus time plots of the FTIR results are presented immediately after Table B-4.

TABLE B-1. FTIR RESULTS OF WET SAMPLES FROM THE PLANT A BAGHOUSE INLET

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/19/97	8:34	**INLSP101**	25.0	7.4		61.6		3.1	0.592	0.059	9.4	5.1	20.9	11.6	80.2	58.0		5.7
	8:39	**INLSP102**	23.2	7.3		60.8		3.0	0.542	0.058	9.2	5.1	22.1	11.4	72.4	56.7		5.6
Run 1	8:44	**INLSP103**	22.9	6.9		57.3		2.9	0.548	0.056	8.6	4.8	19.7	10.9	66.4	53.8		5.3
	9:00	18190001		38.5		185.6		35.6		0.758	25.3	15.3		138.0	198.1	167.5		17.2
	9:02	18190002		39.7		191.8		46.0		0.978	25.7	15.8		178.1	191.4	173.1		17.8
	9:05	18190003		40.1		193.5		45.6		0.969	25.4	15.9		176.5	189.0	174.2		17.9
	9:07	18190004		39.4		189.9		46.1		0.979	25.3	15.6		178.4	186.6	171.1		17.6
	9:09	18190005		39.0		188.4		35.8		0.762	24.9	15.5		138.7	182.6	168.2		17.4
	9:11	18190006		38.7		186.5		35.8		0.761	25.4	15.3		138.7	182.4	167.1	22.1	13.7
	9:13	18190007		38.4		185.2		35.8		0.762	24.9	15.2		138.7	183.3	166.5	23.6	13.6
	10:26	18190040		34.7		167.4	16.3	8.5		0.197	22.5	13.8	75.8	36.2	216.1	155.8		15.5
	10:28	18190041		41.0		197.6		44.7		0.951	24.8	16.2		173.1	234.3	186.4		18.3
	10:30	18190042		40.4		195.0		44.8		0.953	24.5	16.0		173.5	208.7	181.8		18.1
	10:32	18190043		38.3		185.0		35.7		0.760	26.0	15.2		138.4	281.2	176.7		17.1
	10:34	18190044		35.7		172.2	16.7	10.9		0.254	23.6	14.2	72.8	46.5	231.5	159.9		15.9
	10:36	18190045		33.9		163.4	16.3	8.3		0.192	22.0	13.5	68.0	35.3	206.7	150.8		15.1
	10:38	18190046		32.7		157.7	14.7	7.3		0.168	20.9	13.0	64.7	31.0	189.7	144.3		14.6
	11:16	18190047		42.0		202.7		43.7		0.929	28.0	16.7		169.2	267.6	199.2		18.8
	11:18	18190048		42.5		205.1		43.3		0.920	27.9	16.9		167.6	302.0	210.8		19.0
	11:20	18190049		39.8		192.2		44.7		0.951	26.5	15.9		173.1	252.0	187.3		17.8
	11:22	18190050		33.7		162.6	19.1	9.0		0.209	25.8	13.6	55.4	38.3	235.3	152.5	21.9	12.2
	11:24	18190051		32.2		155.3	21.7	7.4		0.172	26.2	13.2	54.2	31.6	254.9	147.7	24.9	11.8
	11:26	18190052		31.2		150.7	20.4	6.7		0.154	25.2	12.8	50.8	28.5	245.4	142.9	23.8	11.4
	11:29	18190053		31.4		151.3	21.1	6.7		0.154	25.5	12.8	52.5	28.5	252.4	143.7	24.7	11.5
	11:31	18190054		31.0		149.4	20.5	6.5		0.150	25.0	12.6	51.8	27.7	249.2	142.6	23.5	11.3
	11:33	18190055		31.4		151.6	19.2	6.8		0.158	24.5	12.7	53.8	29.1	237.7	143.5	22.9	11.4
	11:35	18190056		30.9		149.1	24.0	6.6		0.152	26.4	12.7	50.9	28.0	284.8	145.1	25.8	11.4
	11:37	18190057		31.4		151.6	18.8	6.8		0.157	24.1	12.7	56.1	29.1	236.9	143.5	23.1	11.4
	11:39	18190058		31.4		151.4	20.7	7.2		0.167	24.9	12.7	58.6	30.7	256.1	145.3	24.1	11.4
	11:41	18190059		30.9		149.1	18.8	6.7		0.154	23.4	12.5	58.0	28.4	244.7	142.0	23.0	11.2
	11:44	18190060		31.8		153.2	18.4	7.0		0.161	24.0	12.8	58.0	29.8	234.7	146.6	22.7	11.5
	11:46	18190061		32.9		158.5	18.0	7.9		0.183	24.0	13.2	59.1	33.7	223.9	148.4	21.7	11.8
	11:48	18190062		32.5		156.9	18.9	7.5		0.174	24.5	13.1	59.3	32.1	231.9	147.1	22.1	11.7
	11:50	18190063		32.7		157.6	19.2	7.8		0.180	24.3	13.2	60.3	33.1	233.3	148.1	22.2	11.8
	11:52	18190064		31.2		150.7	19.7	6.9		0.161	24.1	12.6	57.9	29.7	246.3	142.5	22.9	11.3
	11:54	18190065		29.6		142.8	20.9	6.1		0.142	23.8	12.1	50.6	26.2	259.4	138.0	23.7	10.8
	11:56	18190066		27.5		132.7	14.9	5.3		0.121	20.9	11.2	44.5	22.4	211.8	125.4	20.5	10.0
	11:58	18190067		25.0		120.7	12.1	4.8		0.110	18.9	10.2	34.1	20.3	184.8	112.1	17.9	9.1
	12:01	18190068		5.1		24.6	2.5	1.3		0.029	4.6	2.1	10.0	5.4	44.6	20.4	3.4	1.9
	12:03	18190069		17.0		82.1	7.6	3.6		0.084	13.5	7.0	26.5	15.3	139.2	75.8	12.8	6.2
	12:43	18190088		6.9		33.2	3.5	1.7		0.040	6.3	2.9	12.8	7.3	63.8	27.4	5.0	2.6
	12:45	18190089		14.7		71.1	18.9	3.3		0.078	16.3	6.9	22.0	14.2	232.5	74.0	18.1	6.2
	12:48	18190090		24.1		116.2	28.5	4.7		0.108	25.3	11.1	34.0	20.0	347.8	122.4	30.0	9.9
	12:50	18190091		25.0		120.6	22.3	4.8		0.111	22.4	10.8	38.6	20.5	295.3	122.9	26.1	9.6
	12:52	18190092		25.0		120.8	17.7	4.8		0.110	20.6	10.5	39.3	20.4	256.0	118.9	22.8	9.4

TABLE B-1. Continued. Wet Sample Inlet Results.

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/19/97	12:54	18190093		25.3		122.0	18.9	5.0		0.114	21.2	10.6	39.1	21.2	265.4	120.0	22.8	9.5
Run 1	12:56	18190094		23.8		114.7	12.8	4.6		0.105	17.7	9.7	35.6	19.5	208.9	109.5	18.8	8.7
	12:58	18190095		23.9		115.4	22.8	4.6		0.107	22.4	10.4	32.2	19.8	303.8	118.7	23.9	9.3
	13:00	18190096		24.1		116.4	20.4	4.6		0.106	21.4	10.2	35.3	19.7	295.2	116.8	23.0	9.2
	13:02	18190097		25.0		120.4	18.9	4.7		0.107	20.4	10.5	36.1	19.9	268.8	118.8	22.8	9.4
	13:05	18190098		25.1		121.2	26.8	4.8		0.110	24.1	11.0	34.9	20.4	333.9	126.7	26.9	9.8
	13:07	18190099		25.8		124.3	19.0	5.1		0.116	20.9	10.8	37.8	21.6	270.2	123.8	24.2	9.7
	13:54	18190120		23.9		115.2	21.1	4.6		0.106	20.8	10.2	33.4	19.7	293.0	116.3	22.0	9.1
	13:56	18190121		24.5		118.1	16.5	4.9		0.112	18.7	10.2	40.7	20.9	249.8	117.1	20.7	9.1
	13:58	18190122		24.0		115.9	19.1	4.6		0.107	19.7	10.1	37.4	19.8	279.4	117.7	21.4	9.0
	14:00	18190123		24.6		118.8	17.7	5.1		0.118	17.9	9.8	37.4	21.9	267.4	118.4	18.1	8.9
	14:02	18190124		24.7		119.1	13.7	4.8		0.111	17.1	9.9	39.4	20.6	223.8	114.6	16.4	8.9
	14:04	18190125		24.1		116.3	18.3	4.9		0.112	19.7	10.1	35.9	20.8	268.5	116.2	20.0	9.0
	14:06	18190126		24.7		119.1	17.6	4.6		0.106	18.6	10.3	39.0	19.9	265.5	117.3	20.7	9.2
	14:09	18190127		24.1		116.4	18.9	4.7		0.109	19.6	10.1	34.7	20.2	276.0	116.5	20.9	9.1
	14:11	18190128		23.9		115.5	19.2	4.7		0.108	19.8	10.1	35.4	20.0	276.7	115.8	21.4	9.1
	14:17	**INLSP104**		19.4		93.7	13.6	4.3	0.330	0.092	16.1	8.3	29.5	16.8	246.1	93.8	16.8	7.4
	14:24	**INLSP105**		19.5		94.1	14.9	4.4	0.327	0.093	16.6	8.4	30.6	16.8	261.3	95.6	17.7	7.5
		Average --->					13.6				22.2		35.5		238.5		15.5	

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	8:12	**INLSP202**	46.7	12.9		108.0	13.1	4.9	0.616	0.104	18.7	9.0	23.7	18.9	193.6	102.9	16.0	8.1
Run 2	8:17	**INLSP203**	43.1	13.6		114.0	11.3	5.1	0.610	0.108	18.2	9.5	28.4	19.7	176.5	106.1		10.6
	8:34	18200001		41.4		199.6		45.6		0.969	28.2	16.4		176.4	185.2	176.7		18.5
	8:36	18200002		40.3		194.2		36.7		0.779	27.8	16.0		142.0	185.4	170.6		18.0
	8:38	18200003		40.2		194.0		46.1		0.979	29.2	16.0		178.4	211.6	173.5		18.0
	8:40	18200004		40.9		197.5		45.7		0.971	28.8	16.2		176.8	195.8	176.3		18.3
	8:42	18200005		40.5		195.5		45.9		0.977	28.5	16.1		177.8	204.3	175.4		18.1
	8:44	18200006		40.8		196.7		45.7		0.972	28.9	16.2		177.1	206.1	176.1		18.2
	8:46	18200007		39.8		191.8		36.0		0.764	28.7	15.8		139.2	211.6	169.8		17.8
	8:49	18200008		37.7		181.8	17.8	13.0		0.312	27.8	15.0		56.9	216.6	163.0		16.8
	8:51	18200009		37.1		179.1	20.7	11.8		0.276	27.3	14.8	63.6	50.5	214.8	160.4		16.6
	8:53	18200010		37.7		181.7	23.1	12.2		0.284	28.4	15.1	63.8	52.1	230.3	164.3		16.8
	8:55	18200011		38.0		183.5		20.2		0.429	27.4	15.1		78.1	210.5	163.8		17.0
	8:57	18200012		37.9		182.6	16.6	16.3		0.390	27.1	15.1		71.1	208.5	162.6		16.9
	8:59	18200013		37.3		179.8	18.3	12.9		0.300	26.3	14.8	65.6	55.0	196.5	159.4		16.6
8/20/97	9:01	18200014		36.6		176.7	16.8	10.8		0.251	25.6	14.5	65.8	46.0	189.2	156.4		16.4
Run 2	9:04	18200015		35.9		173.3	17.8	9.0		0.208	25.7	14.3	62.5	38.3	198.2	154.1		16.0
	9:06	18200016		36.7		176.9	16.9	9.9		0.230	25.6	14.6	70.2	42.3	191.2	157.3		16.4
	9:50	18200037		41.0		197.9		44.5		0.947	41.6	16.2		172.4	655.7	229.3		18.3
	9:53	18200038		40.1		193.5		45.4		0.966	32.1	15.9		176.0	420.2	195.2		17.9
	9:55	18200039		42.5		205.0		44.0		0.936	30.4	16.8		170.4	309.2	197.0		19.0
	9:57	18200040		44.6		215.0		48.8		1.037	58.6	17.6		188.9	728.8	260.4		19.9
	9:59	18200041		44.9		216.5		48.4		1.029	90.7	17.8		187.4	1202.8	377.8		20.0

TABLE B-1. Continued. Wet Sample Inlet Results.

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
	10:02	18200042		44.1		212.9		48.9		1.040	71.8	17.5		189.4	1002.8	308.7		19.7
8/20/97	10:04	18200043		43.7		210.9		49.3		1.047	51.5	17.3		190.7	776.2	266.5		19.5
Run 2	10:06	18200044		44.6		215.4		48.4		1.029	62.9	17.7		187.4	951.1	311.0		19.9
	10:09	18200045		46.5		224.2		47.3		1.006	73.6	18.4		183.2	1058.6	362.4		20.8
	10:11	18200046		47.7		230.3		46.9		0.997	129.8	18.9		181.6	1702.4	895.7		21.3
	10:13	18200047		47.8		230.6		50.4		1.071	130.9	19.0		195.0	1703.3	895.5		21.3
	10:15	18200048		48.2		232.6		50.1		1.065	112.2	19.1		194.0	1651.9	898.0		21.5
	10:17	18200049		48.7		234.9		48.2		1.024	191.2	19.4		186.5	1894.1	879.7		21.7
	10:19	18200050		43.9		211.7		48.9		1.040	88.9	17.4		189.4	1001.7	305.1		19.6
	10:21	18200051		45.4		219.0		47.8		1.016	114.8	18.0		185.1	1236.2	398.1		20.3
	10:24	18200052		50.8		245.2		49.1		1.044	225.3	20.2		190.1	1967.5	869.2		22.7
	10:26	18200053		46.6		224.7		47.1		1.001	109.3	18.5		182.2	1718.0	783.8		20.8
	10:28	18200054		44.6		214.9		48.3		1.027	68.1	17.6		186.9	988.5	326.5		19.9
	10:30	18200055		44.5		214.6		48.4		1.029	54.8	17.6		187.4	823.1	291.5		19.9
	11:26	18200074		45.9		221.3		50.6		1.076	103.4	18.2		196.0	1654.1	900.7		20.5
	11:29	18200075		43.8		211.4		48.4		1.028	55.6	17.4		187.3	824.8	305.4		19.6
	11:31	18200076		43.2		208.3		43.6		0.926	43.4	17.1		168.6	678.6	269.2		19.3
	11:33	18200077		44.3		213.8		47.9		1.019	70.1	17.6		185.6	1073.3	383.7		19.8
	11:35	18200078		43.8		211.5		47.9		1.018	65.0	17.4		185.3	1016.1	359.6		19.6
	11:37	18200079		43.3		209.0		48.4		1.029	46.0	17.2		187.3	746.1	301.9		19.4
	11:39	18200080		44.4		214.0		47.4		1.008	75.5	17.6		183.5	1034.1	670.2		19.8
	11:41	18200081		44.4		214.1		47.4		1.009	72.7	17.6		183.7	1206.2	728.7		19.8
	11:44	18200082		44.1		212.6		47.5		1.010	64.0	17.5		184.0	988.0	667.8		19.7
	11:46	18200083		43.9		212.0		47.7		1.013	58.8	17.4		184.5	924.7	395.1		19.6
	11:48	18200084		45.4		218.9		46.9		0.997	128.9	18.0		181.6	1780.3	888.8		20.3
	11:50	18200085		44.1		212.7		47.5		1.010	89.8	17.5		184.0	1606.0	905.9		19.7
	11:52	18200086		43.2		208.2		48.2		1.025	56.5	17.1		186.7	929.6	342.6		19.3
	11:54	18200087		43.2		208.5		48.3		1.027	47.0	17.1		187.0	763.5	304.6		19.3
	11:56	18200088		43.5		210.0		47.8		1.016	72.9	17.3		185.0	1149.1	474.8		19.4
	11:58	18200089		42.9		207.0		48.1		1.022	75.7	17.0		186.1	1192.9	474.1		19.2
Average --->							3.9				62.9		9.5		806.8		1.0	

TABLE B-1. Continued. Wet Sample Inlet Results.

Date	Time	File Name	Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
			ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	15:49	18200157		34.0		164.2		35.4		0.752	21.5	13.7		137.0	206.1	168.1		15.2
	15:51	18200158		38.4		185.4		43.8		0.931	23.5	15.4		169.6	272.5	270.7		17.2
Run 3	15:53	18200159		40.1		193.6		43.2		0.918	23.8	16.0		167.2		631.7		17.9
	15:55	18200160		40.6		196.0		43.9		0.934	24.0	16.2		170.1		630.1		18.1
	15:57	18200161		40.0		193.0		43.2		0.919	23.9	16.0		167.3		633.3		17.9
	16:00	18200162		38.7		186.6		43.7		0.929	23.3	15.5		169.2		263.3		17.3
	16:02	18200163		39.7		191.7		43.1		0.917	23.5	15.9		167.0		632.9		17.7
	16:04	18200164		39.4		189.9		43.3		0.920	23.4	15.8		167.6		380.5		17.6
	16:06	18200165		40.5		195.3		43.2		0.918	24.4	16.2		167.3		631.1		18.1
	16:08	18200166		41.6		200.7		48.0		1.021	24.5	16.6		185.9		626.8		18.6
	16:10	18200167		40.5		195.4		48.7		1.036	23.8	16.2		188.7		629.8		18.1
8/20/97	16:12	18200168		39.2		189.1		43.3		0.920	23.0	15.7		167.6		632.8		17.5
Run 3	16:14	18200169		38.5		185.5		43.5		0.925	22.9	15.4		168.5		299.3		17.2
	16:17	18200170		36.7		177.0		44.6		0.949	23.0	14.6		172.7	216.1	212.2	21.5	13.1
Average --->											23.5				49.6		1.5	

Date	Time	File Name	Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
			ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/21/97	9:43	18210016		25.5		122.9	8.9	4.8		0.110	18.3	10.2	51.5	20.5	154.4	112.3		11.4
	9:45	18210017		28.4		137.2	10.5	5.4		0.124	19.9	11.4	52.7	23.2	169.6	124.7		12.7
Run 4	9:47	18210018		29.5		142.3	10.6	5.7		0.130	20.4	11.8	52.7	24.3	172.6	128.3		13.2
	9:49	18210019		30.2		145.5	10.7	5.9		0.135	20.8	12.1	52.5	25.1	168.5	130.3		13.5
	9:52	18210020		30.3		146.1	10.7	5.9		0.135	20.8	12.1	52.4	25.2	164.8	130.2		13.5
	9:54	18210021		30.0		144.8	10.7	5.8		0.133	20.6	12.0	52.6	24.9	166.3	129.2		13.4
	9:56	18210022		29.2		140.6	10.5	5.6		0.129	19.9	11.6	51.4	24.1	166.1	126.3		13.0
	9:58	18210023		28.9		139.3	10.4	5.6		0.127	19.7	11.5	50.8	23.7	168.6	125.6		12.9
	10:00	18210024		28.8		138.8	10.2	5.5		0.126	19.4	11.5	50.2	23.7	171.6	125.6		12.8
	10:02	18210025		28.6		138.0	10.3	5.5		0.126	19.6	11.4	50.5	23.5	171.0	125.2		12.8
	10:04	18210026		28.4		136.9	10.2	5.5		0.125	19.3	11.3	50.3	23.3	169.1	124.0		12.7
	10:06	18210027		29.5		142.1	13.5	5.7		0.129	21.1	11.8	52.3	24.2	200.0	131.0		13.2
	10:09	18210028		32.8		158.1	24.6	7.2		0.165	26.6	13.4	55.4	30.6	284.3	150.4		14.6
8/21/97	10:11	18210029		31.5		152.0	15.7	6.5		0.149	22.7	12.7	58.2	27.8	201.3	138.3		14.1
	10:13	18210030		30.7		148.2	11.7	6.1		0.140	20.9	12.3	56.1	26.1	170.6	133.1		13.7
Run 4	10:15	18210031		30.8		148.7	10.9	6.1		0.139	20.7	12.3	54.7	26.1	168.4	133.4		13.8
Average --->							11.9				20.7		52.8		179.2			

TABLE B-1. Continued. Additional Hydrocarbon Results in Wet Inlet Samples at Plant A

			Butane		2-Methyl-1-pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Uncertainty	ppm	Uncertainty	ppm	Uncertainty
8/19/97	8:34	**INLSP101**		68.8		24.7		17.9
	8:39	**INLSP102**		67.9		24.4		17.7
Run 1	8:44	**INLSP103**		64.0		23.0		16.7
	9:00	18190001		207.4		74.5		54.0
	9:02	18190002		214.3		77.0		55.8
	9:05	18190003		216.2		77.7		56.3
	9:07	18190004		212.2		76.3		55.3
	9:09	18190005		210.5		75.6		54.8
	9:11	18190006		208.4		74.9		54.3
	9:13	18190007		207.0		74.4		53.9
	10:26	18190040		187.1		67.2		48.7
	10:28	18190041		220.8		79.4		57.5
	10:30	18190042		218.0		78.3		56.8
	10:32	18190043		206.7		74.3		53.8
	10:34	18190044		192.4		69.1		50.1
	10:36	18190045		182.6		65.6		47.5
	10:38	18190046		176.2		63.3		45.9
	11:16	18190047		226.5		81.4		59.0
	11:18	18190048		229.2		82.4		59.7
	11:20	18190049		214.7		77.2		55.9
	11:22	18190050		181.7		65.3		47.3
	11:24	18190051		173.5		62.3		45.2
	11:26	18190052		168.4		60.5		43.9
	11:29	18190053		169.0		60.7		44.0
	11:31	18190054		167.0		60.0		43.5
	11:33	18190055		169.4		60.9		44.1
	11:35	18190056		166.7		59.9		43.4
	11:37	18190057		169.4		60.9		44.1
	11:39	18190058		169.1		60.8		44.0
	11:41	18190059		166.6		59.9		43.4
	11:44	18190060		171.2		61.5		44.6
	11:46	18190061		177.1		63.6		46.1
	11:48	18190062		175.4		63.0		45.7
	11:50	18190063		176.1		63.3		45.9
	11:52	18190064		168.4		60.5		43.9
	11:54	18190065		159.6		57.3		41.6
	11:56	18190066		148.3		53.3		38.6
	11:58	18190067		134.9		48.5		35.1
	12:01	18190068		27.5		9.9		7.2
	12:03	18190069		91.7		32.9		23.9
	12:43	18190088		37.1		13.3		9.7
	12:45	18190089		79.4		28.5		20.7
	12:48	18190090		129.8		46.7		33.8
	12:50	18190091		134.8		48.4		35.1
	12:52	18190092		135.0		48.5		35.2
	12:54	18190093		136.3		49.0		35.5
	12:56	18190094		128.1		46.0		33.4
	12:58	18190095		129.0		46.4		33.6
	13:00	18190096		130.1		46.7		33.9
	13:02	18190097		134.5		48.3		35.0
	13:05	18190098		135.5		48.7		35.3
	13:07	18190099		138.9		49.9		36.2
	13:54	18190120		128.7		46.3		33.5
	13:56	18190121		132.0		47.4		34.4
	13:58	18190122		129.5		46.5		33.7
	14:00	18190123		132.7	10.9	3.1		34.6
	14:02	18190124		133.1	8.5	3.1		34.7
	14:04	18190125		130.0		46.7		33.9
	14:06	18190126		133.1		47.8		34.7
	14:09	18190127		130.1		46.7		33.9
	14:11	18190128		129.1		46.4		33.6
	14:17	**INLSP104**		104.6		37.6		27.3
	14:24	**INLSP105**		105.2		37.8		27.4
		Average --->			0.3			

TABLE B-1. Continued. Plant A Wet Sample Inlet Results

Date	Time	File Name	Butane ppm	Butane Uncertainty	2-Methyl-1-pentene ppm	2-Methyl-1-pentene Uncertainty	2-Methyl-2-butene ppm	2-Methyl-2-butene Uncertainty
8/20/97	8:06	**INLSP201**		116.4		41.8		30.3
	8:12	**INLSP202**		120.7		43.4		31.4
Run 2	8:17	**INLSP203**		127.4		45.8		33.2
	8:34	18200001		223.1		80.2		58.1
	8:36	18200002		217.1		78.0		56.5
	8:38	18200003		216.8		77.9		56.5
	8:40	18200004		220.7		79.3		57.5
	8:42	18200005		218.4		78.5		56.9
	8:44	18200006		219.8		79.0		57.2
	8:46	18200007		214.4		77.0		55.8
	8:49	18200008		203.1		73.0		52.9
	8:51	18200009		200.2		71.9		52.1
	8:53	18200010		203.0		73.0		52.9
	8:55	18200011		205.1		73.7		53.4
	8:57	18200012		204.0		73.3		53.1
	8:59	18200013		200.9		72.2		52.3
	9:01	18200014		197.4		70.9		51.4
	9:04	18200015		193.6		69.6		50.4
	9:06	18200016		197.7		71.1		51.5
	9:50	18200037		221.2		79.5		57.6
	9:53	18200038		216.2		77.7		56.3
	9:55	18200039		229.1		82.3		59.7
	9:57	18200040		240.2		86.3		62.6
	9:59	18200041		241.9		86.9		63.0
	10:02	18200042		237.9		85.5		61.9
	10:04	18200043		235.7		84.7		61.4
	10:06	18200044		240.7		86.5		62.7
	10:09	18200045		250.5		90.0		65.2
	10:11	18200046		257.3		92.5		67.0
	10:13	18200047		257.7		92.6		67.1
	10:15	18200048		259.9		93.4		67.7
	10:17	18200049		262.5		94.3		68.4
	10:19	18200050		236.6		85.0		61.6
	10:21	18200051		244.7		87.9		63.7
	10:24	18200052		274.0		98.4		71.3
	10:26	18200053		251.0		90.2		65.4
	10:28	18200054		240.2		86.3		62.5
	10:30	18200055		239.8		86.2		62.5
	11:26	18200074		247.3		88.9		64.4
	11:29	18200075		236.2		84.9		61.5
	11:31	18200076		232.7		83.6		60.6
	11:33	18200077		238.9		85.8		62.2
	11:35	18200078		236.3		84.9		61.6
	11:37	18200079		233.6		83.9		60.8
	11:39	18200080		239.1		85.9		62.3
	11:41	18200081		239.3		86.0		62.3
	11:44	18200082		237.6		85.4		61.9
	11:46	18200083		236.9		85.1		61.7
	11:48	18200084		244.6		87.9		63.7
	11:50	18200085		237.6		85.4		61.9
	11:52	18200086		232.6		83.6		60.6
	11:54	18200087		232.9		83.7		60.7
	11:56	18200088		234.6		84.3		61.1
	11:58	18200089		231.3		83.1		60.3
		Average --->						

TABLE B-1. Continued. Plant A Wet Sample Inlet Results

			Butane		2-Methyl-1-pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Uncertainty	ppm	Uncertainty	ppm	Uncertainty
8/20/97	15:49	18200157		183.5		65.9		47.8
	15:51	18200158		207.2		74.4		54.0
Run 3	15:53	18200159		216.4		77.8		56.4
	15:55	18200160		219.0		78.7		57.0
	15:57	18200161		215.7		77.5		56.2
	16:00	18200162		208.5		74.9		54.3
	16:02	18200163		214.2		77.0		55.8
	16:04	18200164		212.2		76.3		55.3
	16:06	18200165		218.2		78.4		56.8
	16:08	18200166		224.3		80.6		58.4
	16:10	18200167		218.4		78.5		56.9
	16:12	18200168		211.3		75.9		55.0
	16:14	18200169		207.3		74.5		54.0
	16:17	18200170		197.8		71.1		51.5
		Average --->						

			Butane		2-Methyl-1-pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Uncertainty	ppm	Uncertainty	ppm	Uncertainty
8/21/97	9:43	18210016		137.4		49.4		35.8
	9:45	18210017		153.3		55.1		39.9
Run 4	9:47	18210018		159.1		57.2		41.4
	9:49	18210019		162.6		58.4		42.4
	9:52	18210020		163.3		58.7		42.5
	9:54	18210021		161.8		58.1		42.1
	9:56	18210022		157.2		56.5		40.9
	9:58	18210023		155.6		55.9		40.5
	10:00	18210024		155.1		55.7		40.4
	10:02	18210025		154.2		55.4		40.2
	10:04	18210026		152.9		55.0		39.8
	10:06	18210027		158.8		57.1		41.4
	10:09	18210028		176.7		63.5		46.0
	10:11	18210029		169.9		61.0		44.2
	10:13	18210030		165.7		59.5		43.1
	10:15	18210031		166.1		59.7		43.3
		Average --->						

TABLE B-2. FTIR RESULTS OF WET SAMPLES FROM THE PLANT A BAGHOUSE OUTLET

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/19/97	7:54	**WOUAMB01**		2.8		13.6		0.7		0.016	5.6	1.2	4.3	2.8		13.8		1.1
	8:04	**OUTSP001**	**21.7**	**7.9**		67.1	9.9	2.9	**0.324**	**0.061**	19.8	5.5	48.4	11.1	150.9	60.5	9.9	4.9
Run 1	8:09	**OUTSP102**	**21.1**	**7.8**		66.6	10.6	2.8	**0.317**	**0.060**	19.7	5.5	49.1	10.9	154.8	59.9	10.1	4.9
	8:13	**OUTSP103**	**20.8**	**8.2**		69.6	9.5	3.0	**0.336**	**0.064**	20.3	5.7	53.8	11.6	161.6	62.8	9.8	5.1
	9:17	18190009		17.6		85.0	12.9	4.4		0.102	22.5	7.0	70.6	18.6	169.9	75.6		7.9
	9:20	18190010		17.7		85.4	13.0	4.6		0.106	22.5	7.0	72.2	19.5	170.6	76.0		7.9
	9:22	18190011		17.8		85.9	13.1	4.6		0.107	22.8	7.1	73.0	19.7	174.2	76.5		8.0
	9:24	18190012		17.7		85.5	13.2	4.4		0.104	22.5	7.0	71.9	19.0	174.1	76.2		7.9
	9:26	18190013		17.3		83.4	13.6	4.1		0.095	22.2	6.9	68.9	17.5	170.0	74.2		7.7
	9:28	18190014		17.7		85.5	13.5	4.8		0.111	22.9	7.0	73.3	20.4	190.2	76.7		7.9
	9:30	18190015		17.8		85.6	13.5	5.0		0.118	22.8	7.0	76.1	21.6	208.9	77.4		7.9
	9:32	18190016		16.8		81.1	13.9	3.9		0.090	21.7	6.7	67.7	16.6	178.1	72.6		7.5
	9:34	18190017		17.3		83.5	13.5	4.4		0.103	22.2	6.9	70.9	19.0	177.7	74.4		7.7
	9:37	18190018		17.6		85.0	13.5	5.0		0.116	22.7	7.0	73.8	21.2	204.8	77.4		7.9
	9:39	18190019		17.3		83.5	13.5	4.3		0.099	22.2	6.9	69.4	18.2	190.9	74.7		7.7
	9:41	18190020		17.8		85.8	13.1	5.1		0.120	23.0	7.0	75.0	22.0	223.3	78.5		7.9
	9:43	18190021		16.8		80.9	13.3	3.9		0.092	21.3	6.6	67.2	16.8	180.1	72.3		7.5
	9:45	18190022		17.2		82.8	13.0	4.1		0.096	21.8	6.8	69.1	17.7	177.5	74.2		7.7
	9:47	18190023		17.4		83.8	13.1	4.5		0.104	22.1	6.9	71.5	19.1	184.4	75.4		7.8
	9:49	18190024		16.7		80.7	13.3	3.8		0.089	21.3	6.6	67.0	16.4	174.9	72.1		7.5
	9:52	18190025		16.6		79.9	13.2	3.7		0.086	21.0	6.6	66.4	15.8	172.9	71.7		7.4
	9:54	18190026		16.7		80.7	13.0	3.9		0.090	21.0	6.6	68.5	16.6	177.5	72.8		7.5
	9:56	18190027		17.1		82.5	13.2	4.3		0.100	21.4	6.8	70.4	18.3	179.1	73.8		7.6
	9:58	18190028		16.8		81.1	13.6	3.8		0.089	21.3	6.7	68.0	16.4	174.3	72.5		7.5
	10:00	18190029		17.2		82.8	13.2	4.1		0.095	21.6	6.8	71.9	17.4	179.9	74.1		7.7
	10:04	18190030		17.0		82.2	13.4	4.1		0.096	21.3	6.8	71.4	17.6	178.5	74.0		7.6
	10:06	18190031		11.6		3.3	7.6	2.2		0.051	17.7	4.6	53.8	9.3	139.0	50.9	5.4	4.2
	10:09	18190032		8.7		2.5	4.9	1.8		0.041	12.9	3.5	41.4	7.6	110.6	39.0	3.8	3.1
	10:11	18190033		15.1		4.2	11.0	2.9		0.067	20.3	6.0	65.6	12.4	164.5	65.2		6.8
	10:13	18190034		16.5		79.8	13.2	3.7		0.086	20.7	6.6	68.4	15.9	170.9	71.8		7.4
	10:15	18190035		16.6		80.3	13.4	3.8		0.089	20.9	6.6	68.0	16.4	173.9	72.4		7.4
	10:17	18190036		16.8		81.3	13.0	4.0		0.094	21.1	6.7	71.2	17.3	188.1	73.6		7.5
	10:19	18190037		16.4		79.2	13.8	3.6		0.084	21.2	6.5	66.7	15.5	179.6	71.5	9.9	5.8
	10:21	18190038		16.7		80.5	13.3	3.9		0.090	20.8	6.6	69.4	16.5	186.1	72.8		7.4
	12:05	18190070		11.3	6.8	0.8	20.0	2.2		0.051	19.8	4.5	26.1	9.4	276.2	55.7	15.7	4.1
	12:07	18190071		11.8	6.6	0.8	17.9	2.2		0.052	19.4	4.7	32.8	9.6	248.3	56.7	16.6	4.2
	12:09	18190072		11.6	6.0	0.8	16.7	2.2		0.051	18.9	4.6	30.0	9.3	238.8	55.0	15.1	4.1
	12:11	18190073		11.6	5.2	0.8	15.1	2.3		0.052	17.9	4.6	31.6	9.6	229.4	54.3	14.5	4.1
	12:13	18190074		11.8	5.9	0.8	17.2	2.3		0.052	19.4	4.7	33.1	9.7	252.4	56.2	15.2	4.2
	12:16	18190075		12.0	6.2	0.8	17.9	2.3		0.052	19.7	4.8	34.4	9.7	252.4	57.7	16.0	4.3
	12:18	18190076		11.7	6.3	0.8	17.8	2.2		0.052	19.1	4.6	32.0	9.6	249.7	55.8	15.9	4.2
	12:20	18190077		11.2	7.0	0.8	19.0	2.1		0.050	19.1	4.4	28.6	9.2	266.9	54.6	16.0	4.0
	12:22	18190078		11.0	6.6	0.8	17.5	2.1		0.049	18.3	4.4	29.0	9.1	255.6	53.5	15.7	3.9
	12:24	18190079		11.1	7.4	0.8	20.2	2.2		0.050	19.1	4.4	28.4	9.2	282.3	54.9	16.3	4.0
	12:26	18190080		10.9	7.5	0.8	21.0	2.1		0.049	19.4	4.3	27.0	9.1	288.3	54.4	16.3	3.9
	12:28	18190081		11.2	10.3	0.8	26.8	2.2		0.051	21.6	4.4	27.3	9.4	340.5	58.4	19.6	4.0
	12:30	18190082		11.3	5.4	0.8	12.9	2.2		0.051	16.8	4.5	34.4	9.4	209.7	53.0	16.0	4.1
	12:33	18190083		11.0	6.6	0.8	18.2	2.2		0.050	18.6	4.4	29.3	9.3	269.1	54.2	15.9	3.9

TABLE B-2. Continued. Wet Sample Outlet Results.

Date	Time	File Name	Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
			ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
	12:35	18190084		11.5	6.8	0.8	17.7	2.2		0.052	18.8	4.6	33.3	9.5	258.9	55.5	16.8	4.1
	12:37	18190085		11.6	5.6	0.8	15.2	2.2		0.052	17.8	4.6	33.0	9.6	231.1	54.7	15.6	4.1
	12:39	18190086		11.5	5.6	0.8	16.2	2.2		0.051	18.3	4.6	31.0	9.4	242.4	54.8	15.3	4.1
	12:41	18190087		11.7	7.7	0.8	22.0	2.4		0.055	20.1	4.6	32.6	10.1	302.8	57.8	17.7	4.2
	13:22	18190106		11.2	7.1	0.8	21.2	2.2		0.050	19.1	4.5	29.8	9.3	299.3	55.6	15.7	4.0
	13:24	18190107		11.4	6.8	0.8	17.8	2.2		0.051	18.3	4.5	34.4	9.6	268.1	55.3	16.5	4.1
	13:26	18190108		11.4	5.1	0.8	14.3	2.2		0.051	16.4	4.5	33.2	9.4	229.8	53.4	14.5	4.1
	13:28	18190109		11.5	8.5	0.8	24.8	2.3		0.052	20.4	4.5	29.6	9.6	327.5	58.4	17.2	4.1
	13:30	18190110		11.3	6.4	0.8	16.0	2.2		0.050	17.4	4.5	33.9	9.3	260.7	53.5	16.4	4.1
	13:32	18190111		11.2	6.9	0.8	19.3	2.2		0.051	18.5	4.4	30.1	9.4	279.2	55.1	15.8	4.0
	13:34	18190112		11.4	5.2	0.8	13.9	2.2		0.051	16.4	4.5	35.7	9.5	222.0	53.1	14.3	4.1
	13:37	18190113		11.3	7.0	0.8	20.1	2.1		0.049	18.7	4.5	30.6	9.2	289.0	55.8	15.4	4.1
	13:41	18190114		11.2	7.2	0.8	19.6	2.2		0.051	18.5	4.5	28.6	9.5	288.3	55.8	15.6	4.0
	13:43	18190115		11.2	5.0	0.8	13.4	2.1		0.049	15.8	4.5	32.9	9.2	219.2	52.9	14.2	4.0
	13:45	18190116		11.0	4.3	0.8	11.5	2.2		0.050	15.6	4.4	31.7	9.3	198.2	50.7	13.0	3.9
	13:47	18190117		11.2	7.1	0.8	20.0	2.2		0.051	18.1	4.4	30.7	9.4	281.1	55.4	15.2	4.0
	14:33	**OUTSP104**	17.8	5.3	4.1	0.7	10.3	2.1	0.371	0.044	13.0	3.6	26.5	8.1	209.7	43.2	11.7	3.3
	14:38	**OUTSP105**	16.8	5.3	3.3	0.7	8.1	2.1	0.368	0.044	12.3	3.6	26.3	8.0	180.3	41.6	10.1	3.3
		Average --->			3.2		15.6				20.8		51.8		226.9		9.0	

Date	Time	File Name	Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
			ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	7:47	**OUTSP201**	15.3	6.5	4.7	0.8	12.5	2.4	0.160	0.051	18.3	4.4	35.8	9.2	196.2	51.5	15.3	4.0
	7:54	**OUTSP202**	20.2	6.5		53.9	21.6	2.4	0.179	0.051	21.9	4.5	25.4	9.3	269.1	54.9	16.3	4.0
Run 2	8:00	**OUTSP203**	15.8	6.3	6.0	0.8	16.3	2.4	0.172	0.050	19.2	4.3	26.7	9.1	224.4	51.5	13.1	3.9
	9:12	18200019		15.9		76.8	17.2	3.3		0.077	24.0	6.3	62.6	14.2	202.0	69.7	15.4	5.7
	9:14	18200020		16.4		79.2	17.6	3.4		0.079	24.7	6.5	62.4	14.7	203.9	71.6	16.1	5.8
	9:16	18200021		16.6		80.0	18.1	3.6		0.084	24.8	6.6	63.1	15.5	205.7	72.3	16.8	5.9
	9:18	18200022		16.4		79.2	16.6	3.6		0.084	24.5	6.5	60.9	15.6	201.7	71.5	16.3	5.8
	9:21	18200023		17.7		85.4	14.9	4.4		0.103	25.1	7.0	73.2	19.0	195.4	76.5	13.4	6.3
	9:23	18200024		18.7		90.0	15.8	7.2		0.167	25.1	7.4	80.1	30.6	181.3	79.5		8.3
	9:25	18200025		18.9		91.2	15.7	7.3		0.171	26.0	7.5	80.8	31.3	182.9	80.7		8.4
	9:27	18200026		18.0		86.9	15.3	5.2		0.120	24.8	7.1	74.2	22.0	185.1	76.9		8.0
	9:29	18200027		17.2		83.1	15.7	4.2		0.097	24.6	6.8	68.7	17.9	188.1	73.7	11.7	6.1
	9:31	18200028		16.9		81.5	16.0	3.8		0.088	24.2	6.7	67.0	16.3	190.1	72.8	12.0	6.0
	9:33	18200029		15.2		73.3	13.6	3.0		0.068	21.4	6.0	60.5	12.7	183.9	65.9	11.4	5.4
	9:36	18200030		12.5	3.5	0.9	12.6	2.4		0.054	18.1	4.9	36.8	10.1	180.1	55.5	9.2	4.4
	9:38	18200031		14.2		68.7	19.7	2.7		0.062	23.2	5.7	41.3	11.5	236.5	64.1	11.7	5.1
	9:40	18200032		18.3		88.3	18.2	6.3		0.147	26.3	7.2	70.0	26.9	198.1	78.7	12.3	6.5
	9:42	18200033		17.6		85.0	15.2	4.7		0.110	24.1	7.0	74.0	20.2	205.0	76.3		7.9
	9:44	18200034		16.2		78.1	14.5	3.4		0.079	23.1	6.4	63.6	14.6	197.1	70.3	11.5	5.7
	10:36	18200058		18.5		89.2		18.0		0.382	42.0	7.3	72.5	67.5	652.6	104.5		8.3

TABLE B-2. Continued. Wet Sample Outlet Results.

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
	10:38	18200059		19.7		95.0		22.3		0.475	91.7	7.8		83.9	1097.4	146.4		8.8
	10:41	18200060		20.6		99.2	30.0	19.9		0.467	184.0	8.2	97.1	84.8	2023.9	360.8		9.2
	10:43	18200061		19.2		92.6		22.6		0.480	97.3	7.6		84.8	1159.2	148.6		8.6
	10:45	18200062		19.2		92.6		22.6		0.481	65.2	7.6		84.9	958.1	131.0		8.6
	10:47	18200063		18.9		91.3		22.8		0.484	62.7	7.5		85.4	948.9	128.7		8.5
8/20/97	10:49	18200064		18.5		89.4		23.0		0.488	55.8	7.3		86.2	873.4	121.5		8.3
	10:51	18200065		18.8		90.5		22.9		0.486	61.2	7.4		85.8	869.2	121.1		8.4
Run 2	10:53	18200066		19.9		95.9	26.9	20.1		0.473	147.5	7.9	103.1	85.9	1942.2	364.0		8.9
	10:56	18200067		18.6		89.6		23.0		0.489	96.5	7.4		86.3	1020.4	128.6		8.3
	10:58	18200068		18.2		87.8		17.9		0.380	36.5	7.2	73.5	67.1	516.3	95.3		8.1
	11:00	18200069		18.5		89.2		18.2		0.386	42.8	7.3	74.6	68.3	649.6	104.2		8.3
	11:02	18200070		18.4		88.6		19.0		0.403	65.6	7.3	78.5	71.3	963.2	125.1		8.2
	11:04	18200071		17.2		83.1	14.7	5.6		0.130	38.6	6.8	83.1	23.9	629.8	97.2		7.7
	11:06	18200072		17.4		84.0	15.0	5.9		0.136	40.0	6.9	84.5	25.0	647.4	99.0		7.8
	11:08	18200073		17.9		86.5		17.8		0.379	45.5	7.1	77.4	66.9	762.7	109.6		8.0
	12:05	18200092		18.4		88.8		19.5		0.415	48.6	7.3	83.3	73.3	826.8	118.2		8.2
	12:07	18200093		18.6		89.7		20.3		0.431	50.5	7.4	83.2	76.1	847.5	120.4		8.3
	12:09	18200094		18.3		88.3		18.7		0.397	44.0	7.3	80.0	70.2	773.5	114.3		8.2
	12:11	18200095		17.8		85.8		17.9		0.381	37.5	7.0	76.0	67.3	688.5	105.3		7.9
	12:13	18200096		17.9		86.2		17.9		0.380	35.9	7.1	74.6	67.1	655.9	103.2		8.0
	12:16	18200097		18.2		87.8		17.9		0.381	36.3	7.2	75.1	67.4	648.7	105.3		8.1
	12:18	18200098		18.3		88.1		22.9		0.488	51.8	7.2		86.1	850.7	119.5		8.2
	12:20	18200099		18.7		90.2		22.8		0.485	55.5	7.4		85.6	903.7	126.7		8.3
	12:22	18200100		18.7		90.1		22.8		0.485	50.3	7.4		85.7	823.4	120.9		8.3
	12:24	18200101		18.8		90.7		22.7		0.483	70.2	7.5		85.3	1071.2	142.1		8.4
	12:26	18200102		17.5		4.9	15.1	8.3		0.193	40.4	6.9	85.7	35.3	707.5	104.8		7.8
	12:28	18200103		17.1		82.4	13.3	5.4		0.126	27.6	6.8	79.7	23.2	496.2	90.0		7.6
	12:30	18200104		17.2		82.7	13.8	6.1		0.142	33.2	6.8	81.1	26.1	607.0	97.2		7.7
	12:33	18200105		17.4		84.1	14.6	7.2		0.167	36.4	6.9	84.3	30.5	670.3	102.7		7.8
	12:35	18200106		17.4		84.0		17.9		0.381	29.2	6.9	72.1	67.2	536.1	93.9		7.8
	12:37	18200107		17.2		1.2		17.8		0.378	31.8	6.8	73.0	66.8	636.2	101.1		7.7
	12:39	18200108		17.6		84.8		17.8		0.379	28.2	7.0	71.1	67.0	518.7	94.9		7.9
Average --->					0.5		9.5				45.7		57.1		623.7		4.7	

TABLE B-2. Continued. Wet Sample Outlet Results.

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	13:41	OUTUN301		10.1	4.0	0.7	11.1	2.0		0.047	15.7	4.0	50.4	8.7	218.2	48.7	12.4	3.6
	13:49	OUTUN302	4.9	1.8	4.4	0.3	8.8	0.7		0.016	8.2	1.0	23.7	2.9	255.1	26.3	4.9	1.0
Run 3	14:01	OUTUN303	3.9	1.7	4.5	0.2	8.5	0.8		0.018	9.0	1.1	49.6	3.4	297.0	30.5	4.2	1.0
	15:13	18200140		14.4	2.9	1.0	13.3	3.2		0.072	19.0	5.7	59.0	13.5	198.9	65.1	14.4	5.1
	15:15	18200141		14.3	2.7	1.0	13.0	3.2		0.074	18.8	5.7	57.9	13.8	190.9	65.3	14.3	5.1
	15:17	18200142		14.9	2.0	1.0	12.5	3.7		0.084	18.8	5.9	63.4	15.7	188.3	67.9	14.0	5.3
	15:19	18200143		15.4	1.9	1.1	12.8	4.1		0.094	19.5	6.1	64.7	17.4	192.7	70.5	14.1	5.5
	15:21	18200144		15.5	1.3	1.1	11.9	4.1		0.095	19.2	6.2	68.4	17.6	232.2	72.9	13.8	5.5
	15:23	18200145		15.4	1.3	1.1	11.9	4.0		0.091	19.0	6.1	66.6	16.9	202.1	71.0	13.9	5.5
	15:25	18200146		15.9	1.5	1.1	13.0	4.9		0.112	19.8	6.3	65.8	20.7	189.9	73.2	14.0	5.7
	15:28	18200147		15.9	2.1	1.1	13.7	4.5		0.104	19.9	6.3	63.6	19.2	188.1	73.4	14.4	5.7
	15:30	18200148		16.4	1.6	1.1	13.7	6.0		0.140	20.6	6.5	68.4	25.8	213.9	78.1	14.2	5.9
	15:32	18200149		16.4	1.6	1.1	14.2	7.2		0.169	20.4	6.5	69.4	30.8	210.6	77.7	14.3	5.9
	15:34	18200150		15.8	1.8	1.1	13.2	4.8		0.111	19.9	6.3	62.8	20.6	190.4	72.8	14.3	5.7
	15:36	18200151		15.6	2.0	1.1	13.4	5.1		0.118	19.3	6.2	62.0	21.7	186.0	72.7	14.3	5.6
	15:38	18200152		15.1	2.4	1.1	13.5	3.8		0.088	19.4	6.0	58.6	16.4	191.4	69.1	14.5	5.4
	15:40	18200153		15.4	2.1	1.1	13.4	4.1		0.095	19.6	6.1	61.2	17.7	186.3	71.2	14.3	5.5
	15:42	18200154		16.2	1.6	1.1	13.5	5.5		0.128	20.2	6.4	67.0	23.6	202.1	76.2	14.0	5.8
		Average --->	0.5		2.3		12.5				18.1		60.1		207.5		13.0	

TABLE B-2. Continued. Wet Sample Outlet Results.

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/21/97	7:32	OUTUN401		14.4		69.3	27.4	2.7		0.062	27.1	5.7	54.6	11.5	291.7	68.0	19.1	5.2
	9:11	18210001		13.8		66.3	9.5	2.6		0.059	19.5	5.5	42.0	11.1	131.7	58.6		6.1
Run 4	9:13	18210002		14.4		69.7	10.5	2.8		0.063	20.5	5.7	40.8	11.7	136.4	61.1		6.4
	9:15	18210003		15.2		73.3	17.5	3.0		0.068	23.6	6.1	38.2	12.7	208.1	66.6		6.8
	9:17	18210004		15.2		73.1	18.1	2.9		0.067	24.2	6.0	39.3	12.6	215.2	66.7	11.6	5.4
	9:20	18210005		14.6		70.6	15.9	2.8		0.065	22.9	5.8	38.1	12.0	198.2	64.2	11.0	5.2
	9:22	18210006		14.6		70.3	15.7	2.8		0.064	22.8	5.8	38.1	11.9	196.8	63.9	10.4	5.2
	9:24	18210007		15.1		72.9	16.6	3.0		0.068	23.5	6.0	41.3	12.7	202.6	66.1	11.0	5.4
	9:26	18210008		14.8		71.6	17.3	2.9		0.066	23.6	5.9	44.0	12.3	211.2	65.5	12.0	5.3
	9:28	18210009		14.0		67.8	18.3	2.7		0.061	23.1	5.6	43.1	11.4	229.2	63.4	13.1	5.0
	9:30	18210010		13.8		66.7	28.1	2.6		0.061	26.6	5.5	37.3	11.3	307.9	66.1	16.8	5.0
	9:32	18210011		14.2		68.6	27.9	2.7		0.063	26.6	5.7	46.3	11.7	311.4	68.1	19.0	5.1
	9:34	18210012		14.2		68.3	24.3	2.7		0.062	24.9	5.6	49.9	11.6	287.6	66.8	18.2	5.1
	9:37	18210013		13.9	4.6	1.0	16.7	2.6		0.060	21.7	5.5	51.3	11.3	221.1	62.9	14.0	5.0
	9:39	18210014		13.8	3.6	1.0	14.2	2.6		0.060	20.6	5.4	50.7	11.2	197.7	61.4	12.1	4.9
	11:38	18210058		14.1	4.9	1.0	16.7	2.8		0.063	20.5	5.6	51.8	11.8	237.2	64.0	11.9	5.0
	11:40	18210059		14.4	4.9	1.0	17.2	2.9		0.065	20.8	5.7	51.1	12.2	240.3	65.3	12.1	5.1
	11:42	18210060		14.6	4.3	1.0	17.4	2.9		0.067	21.0	5.8	51.7	12.5	240.2	66.2	12.1	5.2
	11:45	18210061		15.0	3.9	1.0	17.4	2.9		0.067	21.4	5.9	52.6	12.6	233.5	67.5	11.8	5.4
	11:47	18210062		14.7	3.7	1.0	17.0	2.9		0.067	21.0	5.8	53.9	12.5	234.7	66.8	11.9	5.3
	11:49	18210063		14.6	3.6	1.0	16.9	2.9		0.066	20.7	5.8	54.3	12.3	236.9	66.0	11.9	5.2
	11:51	18210064		14.1	3.6	1.0	13.6	2.7		0.062	19.0	5.6	51.3	11.6	201.1	62.4	10.6	5.0
	11:54	18210065		13.5	4.7	0.9	13.7	2.6		0.059	18.7	5.3	48.6	11.1	211.6	60.7	10.8	4.8
	11:56	18210066		13.4	6.2	0.9	15.1	2.6		0.059	19.1	5.3	46.4	11.0	226.9	60.9	11.0	4.8
		Average --->			2.0		17.6				22.2		46.5		225.4		11.4	

TABLE B-2. Continued. Additional Hydrocarbon Results of Wet Outlet Samples at Plant A

			Butane		2-Methyl-1-pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ
8/19/97	7:54	**WOUAMB01**		15.2		0.7		0.9
	8:04	**OUTSP001**		16.5		9.6		19.5
Run 1	8:09	**OUTSP102**		16.4		9.6		19.4
	8:13	**OUTSP103**		17.2		10.0		20.3
	9:17	18190009		20.1		11.6		24.7
	9:20	18190010		20.2		11.6		24.9
	9:22	18190011		20.3		11.7		25.0
	9:24	18190012		20.2		11.6		24.9
	9:26	18190013		19.7		11.4		24.3
	9:28	18190014		20.2		11.6		24.9
	9:30	18190015		20.3		11.7		24.9
	9:32	18190016		19.2		11.1		23.6
	9:34	18190017		19.8		11.4		24.3
	9:37	18190018		20.1		11.6		24.7
	9:39	18190019		19.8		11.4		24.3
	9:41	18190020		20.3		11.7		25.0
	9:43	18190021		19.2		11.0		23.5
	9:45	18190022		19.6		11.3		24.1
	9:47	18190023		19.8		11.4		24.4
	9:49	18190024		19.1		11.0		23.5
	9:52	18190025		18.9		10.9		23.3
	9:54	18190026		19.1		11.0		23.5
	9:56	18190027		19.5		11.3		24.0
	9:58	18190028		19.2		11.1		23.6
	10:00	18190029		19.6		11.3		24.1
	10:04	18190030		19.5		11.2		23.9
	10:06	18190031	39.8	2.6		8.6		16.3
	10:09	18190032	31.7	1.9		6.5		12.2
	10:11	18190033		17.8		11.1		21.2
	10:13	18190034		18.9		10.9		23.2
	10:15	18190035		19.0		11.0		23.4
	10:17	18190036		19.2		11.1		23.6
	10:19	18190037		18.8		10.8		23.1
	10:21	18190038		19.1		11.0		23.4
	12:05	18190070		13.3		8.4		15.9
	12:07	18190071		13.8		8.7		16.5
	12:09	18190072		13.6		8.5		16.2
	12:11	18190073		13.6		8.5		16.3
	12:13	18190074		13.9		8.7		16.6
	12:16	18190075		14.1		8.9		16.9
	12:18	18190076		13.7		8.6		16.4
	12:20	18190077		13.1		8.2		15.7
	12:22	18190078		12.9		8.1		15.4
	12:24	18190079		13.0		8.2		15.6
	12:26	18190080		12.8		8.0		15.3
	12:28	18190081		13.2		8.2		15.7
	12:30	18190082		13.3		8.4		15.9
	12:33	18190083		13.0		8.1		15.5
	12:35	18190084		13.5		8.4		16.1
	12:37	18190085		13.6		8.5		16.2
	12:39	18190086		13.5		8.5		16.2
	12:41	18190087		13.7		8.6		16.4
8/19/97	13:22	18190106		13.2		8.3		15.8
	13:24	18190107		13.4		8.4		16.0
Run 1	13:26	18190108		13.4		8.4		16.1
	13:28	18190109		13.5		8.4		16.1
	13:30	18190110		13.3		8.4		15.9
	13:32	18190111		13.1		8.2		15.7
	13:34	18190112		13.4		8.4		16.0
	13:37	18190113		13.3		8.4		15.9
	13:41	18190114		13.2		8.3		15.7

TABLE B-2. Continued. Wet Sample Outlet Results

Date	Time	File Name	Butane ppm	Butane Δ	2-Methyl-1-pentene ppm	2-Methyl-1-pentene Δ	2-Methyl-2-butene ppm	2-Methyl-2-butene Δ
	13:43	18190115		13.2		8.3		15.7
8/19/97	13:45	18190116		13.0		8.1		15.5
	13:47	18190117		13.1		8.2		15.7
Run 1								
	14:33	**OUTSP104**		11.3		6.9		12.8
	14:38	**OUTSP105**		11.2		6.8		12.6
Average --->			1.1					

Date	Time	File Name	Butane ppm	Butane Δ	2-Methyl-1-pentene ppm	2-Methyl-1-pentene Δ	2-Methyl-2-butene ppm	2-Methyl-2-butene Δ
8/20/97	7:47	**OUTSP201**		13.8		8.4		15.7
	7:54	**OUTSP202**		13.3	13.2	1.4		15.7
Run 2	8:00	**OUTSP203**		13.4		8.2		15.2
	9:12	18200019		18.2		10.5		22.3
	9:14	18200020		18.7		10.8		23.0
	9:16	18200021		18.9		10.9		23.3
	9:18	18200022		18.7		10.8		23.0
	9:21	18200023		20.2		11.6		24.9
	9:23	18200024		21.3		12.3		26.2
	9:25	18200025		21.6		12.4		26.5
	9:27	18200026		20.6		11.8		25.3
	9:29	18200027		19.6		11.3		24.2
	9:31	18200028		19.3		11.1		23.7
	9:33	18200029		17.3		10.0		21.3
	9:36	18200030		14.6		9.2		17.5
	9:38	18200031		16.3	9.3	1.8		20.0
	9:40	18200032		20.9		12.0		25.7
	9:42	18200033		20.1		11.6		24.7
	9:44	18200034		18.5		10.6		22.7
	10:36	18200058		21.1		12.1		25.9
	10:38	18200059		22.5		12.9		27.7
	10:41	18200060		19.7		39.8		28.9
	10:43	18200061		24.3		13.7		26.9
	10:45	18200062		21.9		12.6		26.9
	10:47	18200063		21.6		12.4		26.6
	10:49	18200064		21.2		12.2		26.0
	10:51	18200065		21.4		12.3		26.3
	10:53	18200066		19.0		38.5		27.9
	10:56	18200067		23.5		13.3		26.1
	10:58	18200068		20.8		12.0		25.5
	11:00	18200069		21.1		12.1		26.0
	11:02	18200070		21.0		12.1		25.8
	11:04	18200071		19.7		11.3		24.2
	11:06	18200072		19.9		11.5		24.4
	11:08	18200073		20.5		11.8		25.2
	12:05	18200092		21.0		12.1		25.8
	12:07	18200093		21.2		12.2		26.1
	12:09	18200094		20.9		12.0		25.7
	12:11	18200095		20.3		11.7		25.0
	12:13	18200096		20.4		11.8		25.1
	12:16	18200097		20.8		12.0		25.5
8/20/97	12:18	18200098		20.9		12.0		25.6
	12:20	18200099		21.3		12.3		26.2
Run 2	12:22	18200100		21.3		12.3		26.2
	12:24	18200101		21.5		12.4		26.4
	12:26	18200102		20.6		12.9		24.6

TABLE B-2. Continued. Wet Sample Outlet Results

			Butane		2-Methyl-1-pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ
	12:28	18200103		19.5		11.3		24.0
8/20/97	12:30	18200104		19.6		11.3		24.1
	12:33	18200105		19.9		11.5		24.5
Run 2	12:35	18200106		19.9		11.5		24.4
	12:37	18200107		20.3		12.7		24.2
	12:39	18200108		20.1		11.6		24.7
		Average --->			0.7			

			Butane		2-Methyl-1-pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	13:41	**OUTUN301**		11.9		7.5		14.2
	13:49	**OUTUN302**		3.0		1.9	1.6	1.0
Run 3	14:01	**OUTUN303**		3.6		2.2		1.1
	15:13	18200140		16.9		10.6		20.2
	15:15	18200141		16.9		10.6		20.1
	15:17	18200142		17.6		11.0		21.0
	15:19	18200143		18.1		11.4		21.7
	15:21	18200144		18.2		11.4		21.8
	15:23	18200145		18.1		11.4		21.7
	15:25	18200146		18.7		11.7		22.4
	15:28	18200147		18.6		11.7		22.3
	15:30	18200148		19.3		12.1		23.0
	15:32	18200149		19.3		12.1		23.0
	15:34	18200150		18.6		11.7		22.2
	15:36	18200151		18.3		11.5		21.9
	15:38	18200152		17.8		11.2		21.3
	15:40	18200153		18.2		11.4		21.7
	15:42	18200154		19.1		12.0		22.8
		Average --->					0.1	

TABLE B-2. Continued. Wet Sample Outlet Results

			Butane		2-Methyl-1-pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ
8/21/97	7:32	**OUTUN401**		16.6	18.3	1.8		20.2
	9:11	18210001		15.8	8.1	1.7		19.3
Run 4	9:13	18210002		16.5	8.1	1.8		20.3
	9:15	18210003		17.4	11.3	1.9		21.3
	9:17	18210004		17.4	11.4	1.9		21.3
	9:20	18210005		16.8	10.6	1.8		20.5
	9:22	18210006		16.7	10.1	1.8		20.5
	9:24	18210007		17.3	10.3	1.9		21.2
	9:26	18210008		17.0	10.5	1.9		20.8
	9:28	18210009		16.1	11.0	1.8		19.7
	9:30	18210010		15.9	17.4	1.8		19.4
	9:32	18210011		16.3	16.1	1.8		20.0
	9:34	18210012		16.2	12.4	1.8		19.9
	9:37	18210013		16.3		10.2		19.5
	9:39	18210014		16.1		10.1		19.3
	11:38	18210058		16.5		10.4		19.8
	11:40	18210059		16.9		10.6		20.2
	11:42	18210060		17.2		10.8		20.5
	11:45	18210061		17.6		11.0		21.1
	11:47	18210062		17.3		10.9		20.7
	11:49	18210063		17.1		10.7		20.4
	11:51	18210064		16.5		10.4		19.7
	11:54	18210065		15.8		9.9		18.9
	11:56	18210066		15.7		9.8		18.8
		Average --->			6.5			

TABLE B-3. FTIR RESULTS OF DRY SAMPLES FROM THE PLANT A BAGHOUSE INLET

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	14:31	18200121		2.3		11.0	12.8	0.6		0.014	7.5	1.0	52.5	2.6	280.2	29.9	4.4	0.9
	14:34	18200122		2.4		11.5	13.5	0.6		0.015	7.7	1.0	58.1	2.7	279.2	30.5	4.6	1.0
Run 3	14:36	18200123		2.4		11.8	13.1	0.6		0.015	7.6	1.0	59.1	2.8	277.0	30.7	4.6	1.0
	14:38	18200124		2.5		12.0	12.8	0.7		0.015	7.5	1.1	60.5	2.8	276.2	31.1	4.5	1.0
	14:41	18200125		2.5		12.0	13.1	0.7		0.015	7.6	1.1	59.7	2.8	274.6	30.9	4.6	1.0
	14:43	18200126		2.5		11.9	12.9	0.7		0.015	7.4	1.1	58.6	2.8	276.3	30.9	5.3	1.0
	14:45	18200127		2.5		11.9	12.7	0.7		0.015	7.2	1.1	57.3	2.8	276.7	30.8	6.8	1.0
	14:47	18200128		2.5		11.9	12.4	0.6		0.015	7.1	1.1	55.5	2.8	276.8	30.7	8.2	1.0
	14:49	18200129		2.5		12.0	12.1	0.6		0.015	7.0	1.1	54.0	2.7	275.8	30.9	9.6	1.0
	14:51	18200130		2.5		12.0	11.9	0.6		0.015	6.8	1.1	52.1	2.7	276.6	30.7	11.0	1.0
	14:53	18200131		2.5		11.9	11.7	0.6		0.014	6.6	1.1	50.8	2.7	276.8	30.7	12.2	1.0
	14:56	18200132		2.5		12.0	11.5	0.6		0.014	6.7	1.1	48.8	2.7	277.2	30.7	11.4	1.0
	14:58	18200133		2.5		12.0	11.3	0.6		0.015	6.6	1.1	47.9	2.7	277.6	30.7	12.5	1.0
	15:00	18200134		2.5		12.0	11.3	0.6		0.014	6.4	1.1	46.4	2.7	277.1	30.6	13.7	1.0
	15:02	18200135		2.5		12.1	10.9	0.6		0.014	6.4	1.1	45.4	2.7	277.5	30.6	14.7	1.0
	15:04	18200136		2.5		12.1	10.7	0.6		0.014	6.2	1.1	43.2	2.7	276.9	30.7	15.7	1.0
	15:06	18200137		2.5		12.2	10.5	0.6		0.014	6.2	1.1	41.7	2.7	277.3	30.7	16.7	1.0
	17:33	**INLSP301**	**35.9**	1.5		8.2	9.5	0.5	**0.657**	0.010	5.9	0.8	11.0	1.8	218.8	17.7	3.8	0.8
	17:40	**INLSP302**	**36.8**	1.5		8.3	10.9	0.5	**0.659**	0.010	6.3	0.8	13.2	1.8	232.5	18.5	4.1	0.8
		Average --->					12.8				7.4		49.3		291.4		9.2	

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/21/97	8:17	**INLUN401**	4.2	1.4		9.3	9.7	0.6	0.052	0.013	6.4	0.8	49.3	2.3	212.6	27.7	2.1	0.8
	8:28	**INLSP402**	**29.9**	1.2		7.8	6.7	0.5	**0.568**	0.010	5.3	0.7	32.0	1.8	173.3	20.7	1.4	0.7
Run 4	8:34	**INLSP403**	**30.3**	1.4		9.1	8.3	0.5	**0.567**	0.011	5.9	0.7	31.4	2.0	187.2	21.9	1.7	0.8
	11:06	INLUN404		2.9		13.8	13.2	0.8	0.020	0.016	7.4	1.2	58.6	3.0	266.8	32.6	4.5	1.1
	11:13	18210046		2.6		12.5	9.6	0.6		0.014	6.0	1.1	46.1	2.7	224.2	28.4	3.7	1.1
	11:15	18210047		2.6		12.3	9.8	0.6		0.014	6.1	1.1	45.5	2.6	225.7	28.4	3.6	1.1
	11:17	18210048		2.5		12.2	10.1	0.6		0.014	6.1	1.1	45.6	2.6	229.7	28.5	3.6	1.0
	11:19	18210049		2.6		12.3	10.1	0.6		0.014	6.1	1.1	44.9	2.6	228.4	28.3	3.7	1.1
	11:21	18210050		2.6		12.6	10.3	0.6		0.014	6.1	1.2	43.0	2.7	230.1	28.5	3.8	1.1
	11:23	18210051		2.7		12.9	17.3	0.7	0.019	0.016	8.5	1.2	39.0	2.8	289.8	31.5	4.0	1.2
	11:25	18210052	10.8	2.2		13.4	33.5	0.9	0.030	0.018	15.3	1.1	34.3	3.3	400.4	37.2	4.3	1.2
	11:28	18210053	12.7	2.3		13.6	38.0	0.9	0.034	0.019	16.8	1.1	34.2	3.5	426.7	38.6	5.1	1.2
	11:30	18210054	12.4	2.2		13.5	37.3	0.9	0.033	0.019	16.3	1.1	36.3	3.5	425.9	38.3	5.3	1.2
	11:32	18210055	11.7	2.2		13.3	35.7	0.9	0.032	0.019	15.7	1.1	38.4	3.4	418.1	37.7	5.4	1.2
Average --->			8.9				19.5				10.1		45.1		311.3		4.1	

TABLE B-3. Continued. Additional Hydrocarbon Results in Dry Outlet Samples at Plant A

			3-Methylpentane		Isooctane		Butane		2-Methyl-1-pentene		Heptane		1-Pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	14:31	18200121		2.3		0.7		2.9	7.9	0.6		4.7		5.7	4.6	0.8
	14:34	18200122		2.4		0.8		3.1	8.3	0.6		4.9		6.0	5.0	0.9
Run 3	14:36	18200123		2.5		0.8		3.2	8.3	0.6		5.0		6.1	5.0	0.9
	14:38	18200124		0.9		0.8		3.5	8.1	0.6		5.1		6.2	4.9	0.9
	14:41	18200125		2.5		0.8		3.2	8.3	0.6		5.1		6.2	5.0	0.9
	14:43	18200126		0.8		0.8		3.5	8.7	0.6		5.1		6.2	5.4	0.9
	14:45	18200127	0.9	0.8		0.8		3.5	8.1	1.6		5.1		6.2	6.3	0.9
	14:47	18200128	1.2	0.8		0.8		3.5	8.7	1.6		5.1		6.2	7.1	0.9
	14:49	18200129	1.3	0.9		0.8		13.4	9.5	1.6		5.1		6.2	7.7	0.9
	14:51	18200130	1.5	0.9		0.8		3.5	10.0	1.6		5.1		6.2	8.5	0.9
	14:53	18200131	1.8	0.9		0.8		13.3	10.6	1.6		5.1		6.2	9.1	0.9
	14:56	18200132	2.3	1.0		0.8	6.5	3.5	7.2	2.0		5.1		6.2	7.6	0.9
	14:58	18200133	3.3	0.9		0.8		13.4	10.1	1.6		5.1		6.2	8.4	0.9
	15:00	18200134	2.5	1.0		0.8	8.5	3.5	7.7	2.0		5.1		6.2	8.6	0.9
	15:02	18200135	3.7	0.9		0.8		13.5	11.3	1.7		5.2		6.3	9.4	0.9
	15:04	18200136	4.0	0.9		0.8		13.5	11.6	1.7		5.2		6.3	9.9	0.9
	15:06	18200137	4.3	0.9		0.8		13.6	12.1	1.7		5.2		6.3	10.5	0.9
	17:33	**INLSP301**	0.9	0.6		0.5		9.2	5.3	1.2		3.5		4.3	3.9	0.7
	17:40	**INLSP302**	1.0	0.6		0.5		9.3	6.4	1.2		3.5		4.3	4.6	0.7
		Average --->	1.6			0.8	0.8		9.4						7.3	

			3-Methylpentane		Isooctane		Butane		2-Methyl-1-pentene		Heptane		1-Pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/21/97	8:17	**INLUN401**		0.7		0.6		2.6		1.6	6.7	0.1		4.8		0.8
	8:28	**INLSP402**		0.5		0.5		8.8		1.1	4.7	0.1		4.1		0.7
Run 4	8:34	**INLSP403**		0.6		0.6		10.1		1.2	4.6	0.1		4.7		0.8
	11:06	INLUN404		1.0		0.9		4.1	8.3	0.7		5.9		7.1	5.2	1.1
	11:13	18210046	1.1	0.9		0.8		3.7	6.1	1.7		5.3		6.5	5.2	1.0
	11:15	18210047	1.1	0.9		0.8		3.7	6.2	1.7		5.2		6.4	5.3	1.0
	11:17	18210048	1.1	0.9		0.8		3.6	6.3	1.7		5.2		6.3	5.3	1.0
	11:19	18210049	1.1	0.9		0.8		3.7	6.9	1.7		5.2		6.4	6.1	1.0
	11:21	18210050	1.2	0.9		0.8		3.9	7.6	1.8		5.4		6.5	6.9	1.0
	11:23	18210051		1.0		0.8		4.1	12.1	0.7		5.5		6.7	8.3	1.1
	11:25	18210052		2.8	0.5	0.3		14.9		3.6	8.9	0.5	8.9	1.6		1.5
	11:28	18210053		2.8	0.6	0.3		15.2		5.5	9.6	0.5	10.8	1.7		1.4
	11:30	18210054		2.8	0.6	0.3		15.0		5.4	9.6	0.5	10.7	1.7		1.4
	11:32	18210055		2.8	0.5	0.3		5.8		3.6	9.7	0.5	9.9	1.6		1.4
		Average --->	0.4		0.2				4.1		4.3		3.1		3.3	

TABLE B-4. FTIR RESULTS IN DRY SAMPLES FROM THE PLANT A BAGHOUSE OUTLET

			Toluene		Hexane		Ethylene		SF_6		Methane		SO_2		CO		Formaldehyde	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	14:05	18200109		2.6		12.3	8.8	0.6		0.014	7.0	1.1	51.0	2.6	270.5	28.7	2.9	0.9
	14:08	18200110		2.5	3.7	0.2	8.8	0.6		0.014	7.0	1.0	49.6	2.6	247.9	27.0	2.7	0.9
Run 3	14:10	18200111		2.4		11.4	10.1	0.6		0.013	6.9	1.0	43.2	2.4	236.8	24.7	2.9	0.9
	14:12	18200112	6.6	1.9		11.2	12.8	0.6		0.013	8.5	1.0	39.3	2.5	296.8	27.6	5.1	1.0
	14:14	18200113		2.6		12.3	12.1	0.6		0.014	9.5	1.1	48.1	2.7	372.4	32.8	3.9	1.0
	14:16	18200114		2.6		12.5	11.4	0.6		0.014	8.0	1.1	47.8	2.6	281.0	28.4	3.0	1.0
	14:18	18200115		2.6		12.5	10.4	0.6		0.014	7.6	1.1	48.6	2.6	276.5	28.5	3.0	1.0
	14:20	18200116		2.6		12.5	10.9	0.6		0.014	7.7	1.1	48.0	2.6	266.2	27.8	3.0	1.0
	14:22	18200117		2.6		12.5	10.8	0.6		0.014	7.5	1.1	47.8	2.7	266.4	27.9	4.0	1.0
	14:25	18200118		2.6		12.3	11.2	0.6		0.014	7.4	1.1	46.5	2.6	255.0	27.0	4.0	1.0
	16:25	18200174		3.1	5.4	0.2	12.0	0.7		0.016	8.5	1.2	49.1	2.9	295.6	30.6	5.1	1.2
	16:27	18200175		2.7	5.5	0.2	12.0	0.6		0.015	8.2	1.1	52.9	2.7	281.9	29.2	4.2	1.0
	16:29	18200176		2.6		12.7	10.9	0.6		0.014	7.0	1.1	55.6	2.7	265.8	28.4	5.1	1.0
	16:32	18200177		2.6	5.0	0.2	10.1	0.6		0.015	9.3	1.1	58.5	2.7	378.9	33.8	3.9	1.0
	16:34	18200178		2.7	4.5	0.2	9.5	0.6		0.015	11.8	1.1	65.3	2.8	514.9	40.6	3.9	1.0
	16:36	18200179		2.7	5.0	0.2	10.5	0.6		0.015	9.1	1.1	60.3	2.7	366.2	33.1	3.7	1.0
	16:38	18200180		2.6	5.0	0.2	10.4	0.6		0.014	7.9	1.0	56.3	2.7	296.5	29.6	3.6	1.0
	16:40	18200181		2.6	4.9	0.2	10.2	0.6		0.014	7.4	1.0	54.2	2.6	264.1	28.1	3.5	1.0
	16:42	18200182		2.6	5.1	0.2	10.6	0.6		0.014	7.6	1.0	52.7	2.7	252.6	27.7	3.5	1.0
	16:44	18200183		2.6	5.2	0.2	10.7	0.6		0.014	7.5	1.0	51.8	2.7	251.1	27.6	3.5	1.0
	16:46	18200184		2.6	5.1	0.2	10.4	0.6		0.014	7.7	1.0	53.7	2.7	275.5	28.9	3.6	1.0
	16:49	18200185		2.7	4.7	0.2	9.8	0.6		0.015	8.3	1.1	59.3	2.8	336.0	32.3	3.7	1.0
	16:51	18200186		2.7	4.8	0.2	10.1	0.6		0.015	7.9	1.1	60.1	2.8	291.3	30.2	3.7	1.0
	16:53	18200187		2.7	4.7	0.2	9.9	0.6		0.015	8.0	1.1	60.6	2.8	301.3	30.9	3.7	1.0
	17:05	**OUTSP304**	**31.8**	1.8		11.1	5.9	0.6	**0.614**	0.012	5.9	1.0	34.2	2.2	230.2	22.4	4.2	1.0
	17:16	**OUTSP305**	**34.3**	1.7		9.6	10.3	0.5	**0.605**	0.011	6.4	0.9	23.3	2.1	230.7	20.4	4.3	0.9
	17:23	**OUTSP306**	**33.8**	1.7		9.4	9.4	0.5	**0.602**	0.011	6.1	0.9	19.9	2.0	219.3	19.3	4.2	0.9
		Average --->	0.3		2.5		11.0				8.3		51.5		307.0		4.1	

TABLE B-4. Continued. Dry Outlet Samle Results

			Toluene		Hexane		Ethylene		SF_6		Methane		Sulfur Dioxide		Carbon MonoxideFormaldehyde			
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/21/97	7:39	**OUTUN402**	7.5	1.6		10.0	10.5	0.5		0.012	7.3	0.9	38.4	2.3	202.1	25.7	4.6	0.9
	7:54	**OUTSP403**	**32.8**	1.2		7.8	10.5	0.5	**0.589**	0.010	6.6	0.7	23.5	1.8	205.0	22.1	1.2	0.6
Run 4	8:02	**OUTSP404**	**33.1**	1.3		7.9	10.8	0.5	**0.588**	0.010	6.9	0.7	24.3	1.8	211.9	22.3	1.6	0.7
	8:09	**OUTSP405**	**34.0**	1.4		8.4	12.3	0.5	**0.590**	0.011	7.4	0.7	30.8	1.9	222.1	23.8	1.9	0.7
	10:28	OUTUN406		2.6		12.3	12.6	0.6		0.014	7.5	1.1	25.2	2.5	242.3	26.8	3.3	1.0
	10:32	18210032	10.9	2.2		13.4	30.7	0.8	0.025	0.017	14.6	1.1	26.2	3.1	367.8	34.7	4.4	1.2
	10:35	18210033	19.6	2.6		13.7	27.8	0.8	0.025	0.017	14.1	1.4	33.6	3.0	353.4	34.2	6.3	1.4
	10:37	18210034	16.0	2.4		13.5	24.9	0.8	0.023	0.016	13.0	1.3	34.8	2.9	337.2	33.2	7.0	1.3
8/21/97	10:40	18210035	15.1	2.4		13.4	23.8	0.7	0.022	0.016	12.5	1.2	34.5	2.9	330.2	32.7	6.8	1.3
	10:42	18210036	15.0	2.3		13.2	23.6	0.7	0.022	0.016	12.3	1.2	33.7	2.9	329.9	32.5	6.9	1.3
Run 4	10:44	18210037	15.3	2.4		13.3	23.8	0.7	0.021	0.016	12.4	1.2	33.3	2.9	331.1	32.6	6.9	1.3
	10:46	18210038	16.2	2.4		13.5	24.7	0.8	0.023	0.016	12.8	1.3	32.5	2.9	338.2	33.1	7.1	1.3
	10:48	18210039	16.6	2.5		13.7	25.9	0.8	0.023	0.017	13.3	1.3	32.9	3.0	345.5	33.6	7.1	1.3
	10:50	18210040	16.9	2.5		13.7	26.2	0.8	0.024	0.017	13.3	1.3	33.9	3.0	347.5	33.6	7.2	1.3
	10:52	18210041	10.3	2.4		13.5	20.3	0.7	0.020	0.016	10.0	1.3	36.2	2.9	305.8	31.3	6.4	1.3
	10:54	18210042		2.8		13.4	15.0	0.7	0.018	0.015	8.1	1.2	36.9	2.7	266.4	29.3	4.2	1.2
	10:57	18210043		2.8		13.4	13.3	0.6		0.015	7.5	1.2	37.9	2.7	249.4	28.4	4.0	1.1
	10:59	18210044		2.7		13.2	11.7	0.6		0.014	6.9	1.2	32.5	2.6	228.9	26.4	3.7	1.1
		Average --->	12.4				21.2				11.4		35.1		320.3		5.3	

TABLE B-4. Continued. Dry Outlet Sample Results, Additional Hydrocarbon Compounds.

			3-Methylpentane		Isooctane		Butane		2-Methyl-1-pentene		Heptane		1-Pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/20/97	14:05	18200109		2.6		0.8		3.0	5.5	0.6		5.2		6.3	2.1	0.9
	14:08	18200110		2.5		0.8		2.9		1.8		5.1		6.1		0.9
Run 3	14:10	18200111		2.4		0.7		2.8	6.6	0.6		4.8		5.9	2.6	0.8
	14:12	18200112		2.3		0.7		3.0	8.2	0.6		4.8		5.8	3.6	0.9
	14:14	18200113		2.6		0.8		3.3	6.9	0.6		5.2		6.4	3.8	0.9
	14:16	18200114		2.6		0.8		3.1	7.0	0.6		5.3		6.5	3.0	0.9
	14:18	18200115		2.6		0.8		3.1	6.6	0.6		5.3		6.4	2.6	0.9
	14:20	18200116		2.6		0.8		3.1	6.9	0.6		5.3		6.5	2.8	0.9
	14:22	18200117		2.6		0.8		3.3	6.7	0.6		5.4		6.5	4.0	1.0
	14:25	18200118		2.6		0.8		3.3	6.7	0.6		5.3		6.4	3.9	0.9
	16:25	18200174		1.1		1.0		4.1		2.6		6.3		7.7		1.3
	16:27	18200175		1.0		0.8		3.6		2.3		5.5		6.7		1.1
	16:29	18200176		0.9		0.8		3.7	7.0	0.7		5.4		6.6	4.3	1.0
	16:32	18200177		0.9		0.8		3.5		2.3		5.4		6.6		1.1
	16:34	18200178		1.0		0.9		3.6		2.3		5.6		6.8		1.1
	16:36	18200179		0.9		0.8		3.6		2.3		5.5		6.6		1.1
	16:38	18200180		0.9		0.8		3.5		2.2		5.3		6.5		1.1
	16:40	18200181		0.9		0.8		3.4		2.2		5.3		6.4		1.1
	16:42	18200182		0.9		0.8		3.5		2.2		5.3		6.4		1.1
	16:44	18200183		0.9		0.8		3.5		2.2		5.3		6.5		1.1
	16:46	18200184		0.9		0.8		3.5		2.2		5.4		6.5		1.1
	16:49	18200185		1.0		0.8		3.6		2.3		5.5		6.7		1.1
	16:51	18200186		1.0		0.8		3.6		2.3		5.6		6.7		1.1
	16:53	18200187		1.0		0.9		3.7		2.3		5.6		6.8		1.1
	17:05	**OUTSP304**		0.8		0.7		3.2	4.4	0.6		4.7		5.7	2.3	0.9
	17:16	**OUTSP305**	0.9	0.7		0.6		10.8	5.7	1.3		4.1		5.0	3.7	0.8
	17:23	**OUTSP306**	0.9	0.7		0.6		10.5	5.3	1.3		4.0		4.9	3.7	0.8
		Average --->	0.1						3.5						1.8	

TABLE B-4. Continued. Dry Outlet Sample Results, Additional Hydrocarbon Compounds.

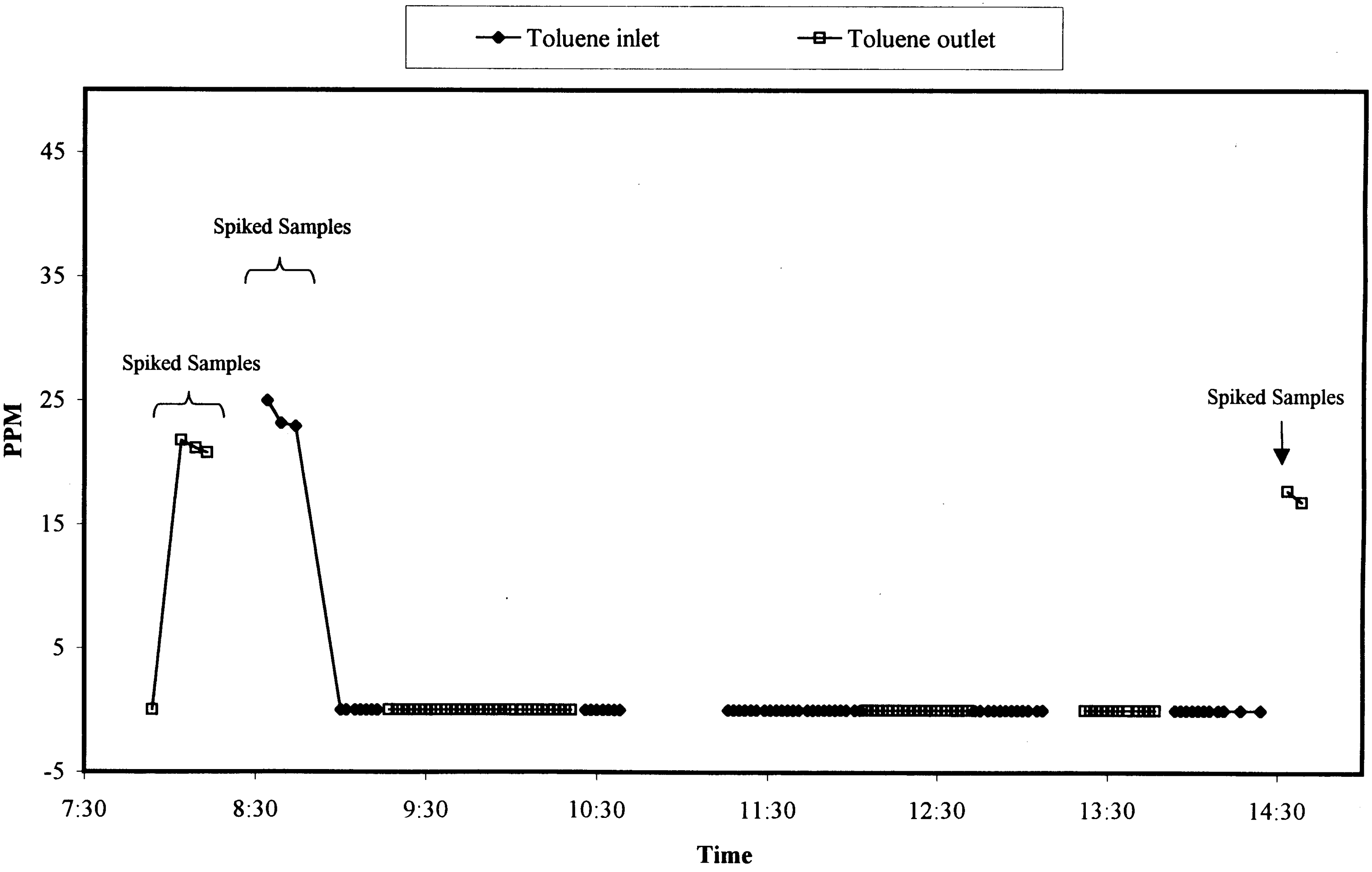
			3-Methylpentane		Isooctane		Butane		2-Methyl-1-pentene		Heptane		1-Pentene		2-Methyl-2-butene	
Date	Time	File Name	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ	ppm	Δ
8/21/97	7:39	**OUTUN402**		2.1		0.7		11.1	8.0	0.3		4.2		5.2		2.9
	7:54	**OUTSP403**	0.9	0.6		0.5		8.8	4.7	1.1		3.3		4.1	2.0	0.6
Run 4	8:02	**OUTSP404**		0.5		0.5		8.8	1.7	0.6	3.5	0.3		4.1		0.7
	8:09	**OUTSP405**		0.6		0.5		9.4	1.4	0.7	4.5	0.3		4.4		0.7
	10:28	OUTUN406		2.6		0.8		3.3	8.1	0.6		5.3		6.4	4.9	1.0
	10:32	18210032		2.8	0.5	0.3		15.0		5.4	7.4	0.5	8.9	1.6		3.9
	10:35	18210033		2.9		0.5	33.7	0.8		5.5		5.8		7.1		4.0
	10:37	18210034		2.8		0.9	5.9	3.8	14.9	2.3		5.8		7.0		3.9
	10:40	18210035		2.8		0.9	5.6	3.8	14.2	2.2		5.7		6.9		3.9
	10:42	18210036		2.7		0.9	5.7	3.7	14.2	2.2		5.6		6.8		3.8
	10:44	18210037		2.8		0.9	5.6	3.8	14.7	2.2		5.7		6.9		3.9
	10:46	18210038		2.8		0.9	5.9	3.9	15.4	2.3		5.8		7.0		3.9
	10:48	18210039		2.9		0.9	6.0	3.9	15.7	2.3		5.9		7.1		4.0
	10:50	18210040		2.9		0.9	6.1	3.9	16.0	2.3		5.8		7.1		4.0
	10:52	18210041		2.8		0.9		3.9	13.4	0.8		5.8		7.0	6.6	1.1
	10:54	18210042		2.8		0.9		3.7	10.2	0.7		5.7		6.9	6.6	1.1
	10:57	18210043		2.8		0.9		3.7	9.3	0.7		5.7		6.9	6.2	1.1
	10:59	18210044		1.0		0.9		4.0	9.0	0.7		5.6		6.8	6.0	1.1
		Average --->	.01		0.3		4.4		9.9		1.2		0.5		2.0	

The graphs on the following pages show concentration-versus-time plots of the FTIR results presented in Tables B-1 to B-4. Each graph presents results from a single Test Run and for a single analyte. Run 1 occurred on 8/19/97, Runs 2 and 3 on 8/20/97 and Run 4 occured on 8/21/97. The run times are indicated on each graph.

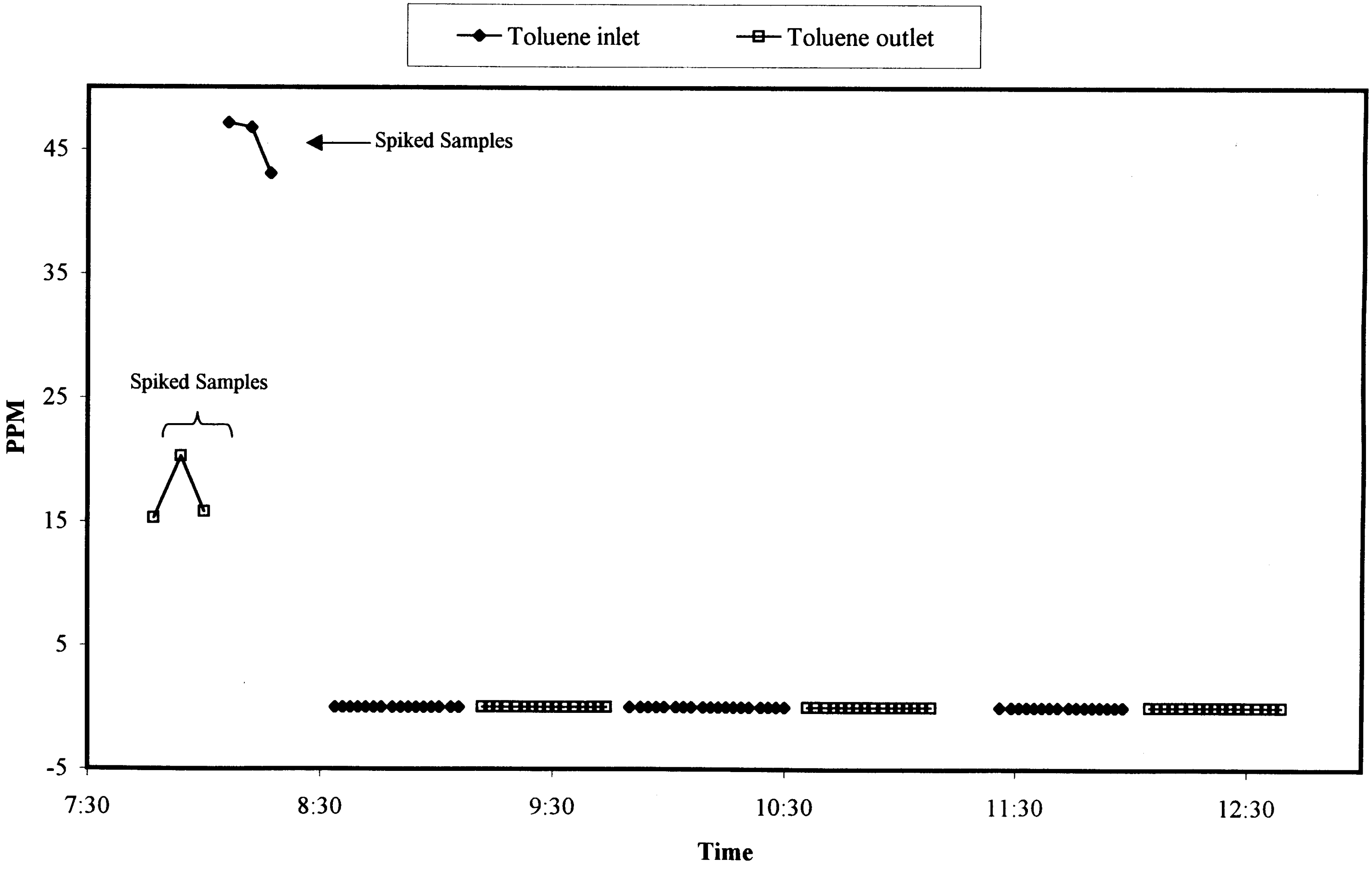
Each result is plotted as a graphical symbol and the results are connected by a solid line. Four different symbols represent the wet and dry inlet results and the wet and dry outlet results. The connecting lines are broken whenever there was a switch between test locations or type of sample treatment (i.e., wet or dry sample). Taken together, the semi-continuous results on each graph show the emission pattern for each analyte for that Run.

The samples spiked with toluene gas standard are indicated on the graph. The spiked results were not included in the toluene run averages, because an unspiked toluene concentration was not detected in the spiked samples.

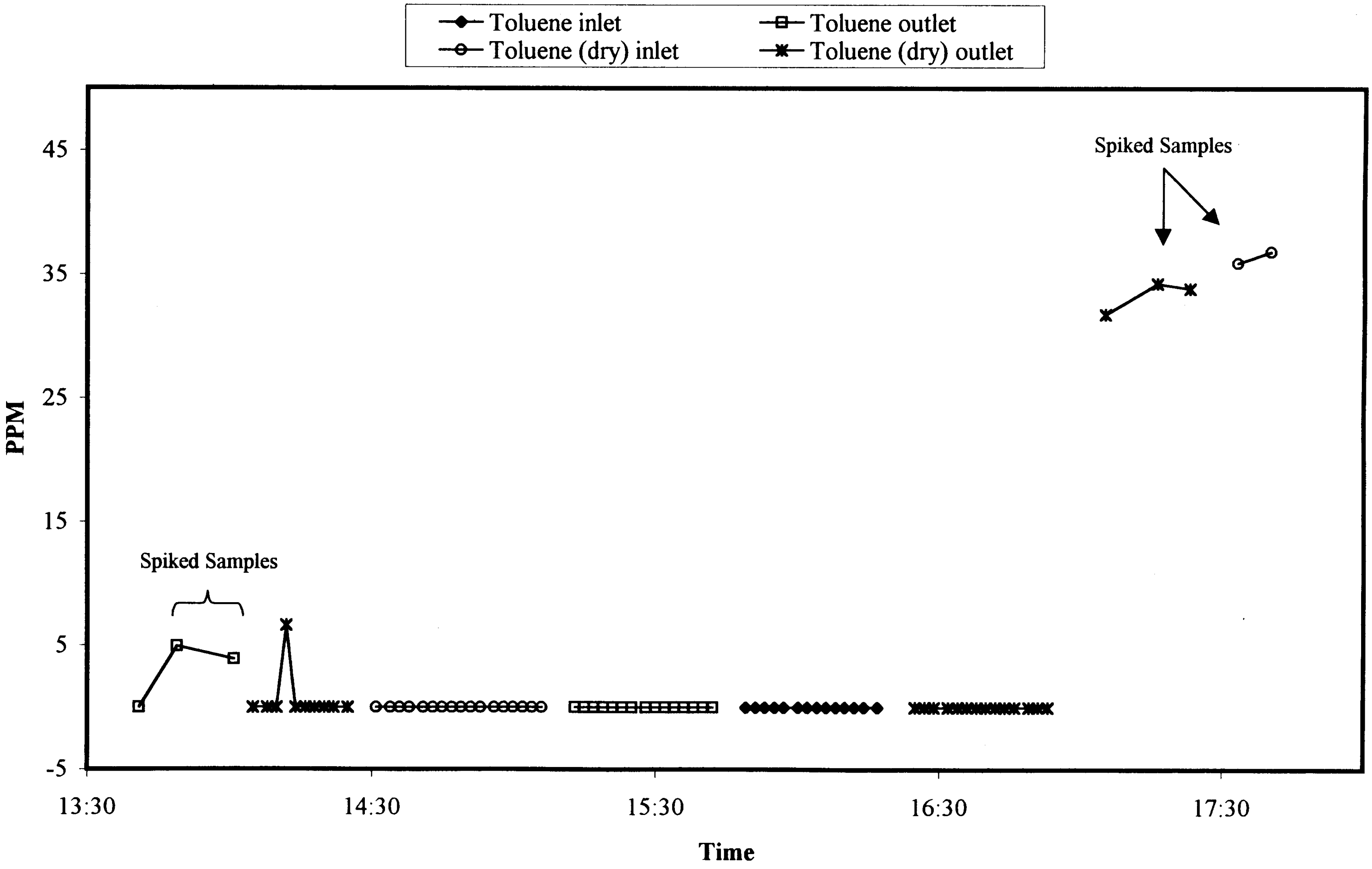
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 1 8/19/97



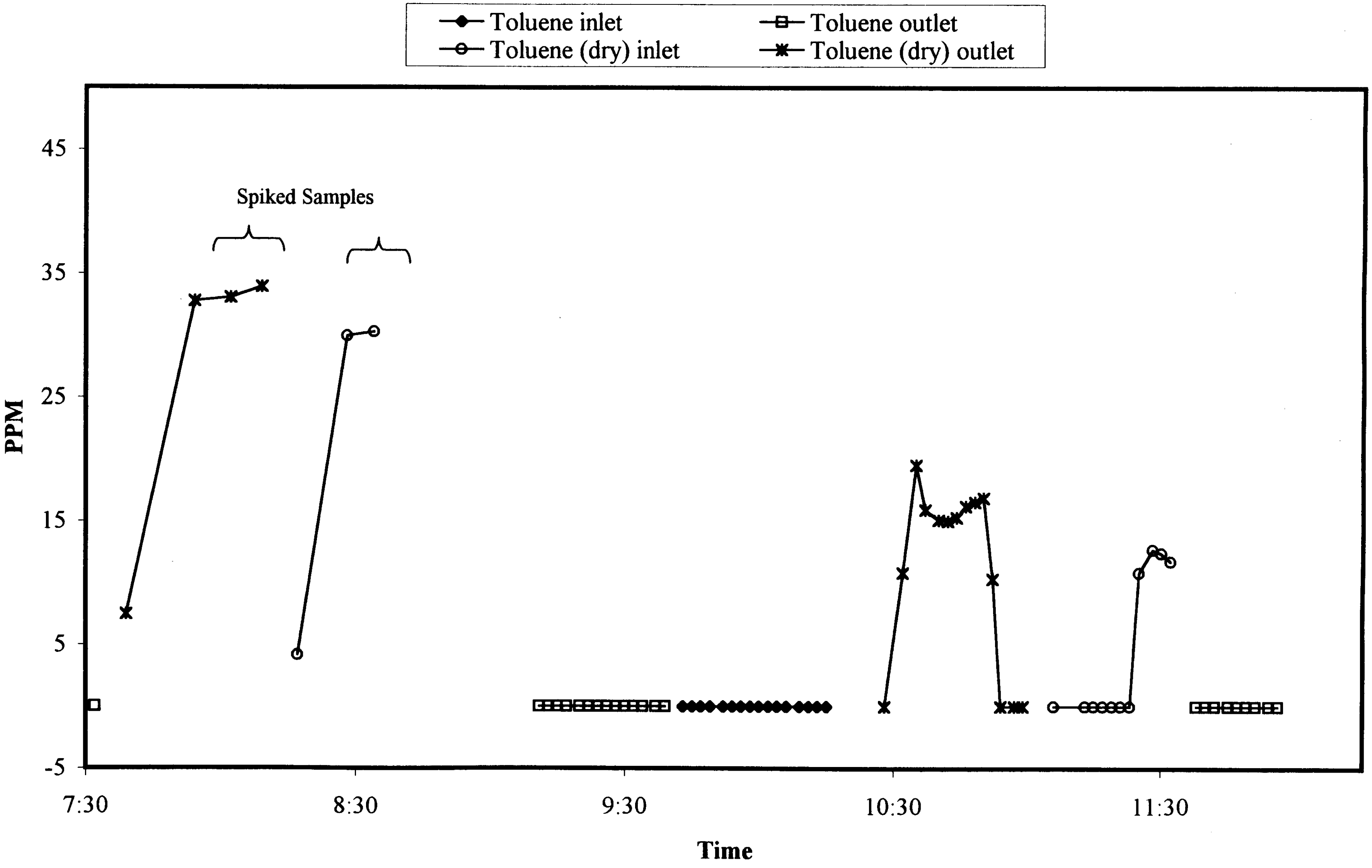
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 2 8/20/97



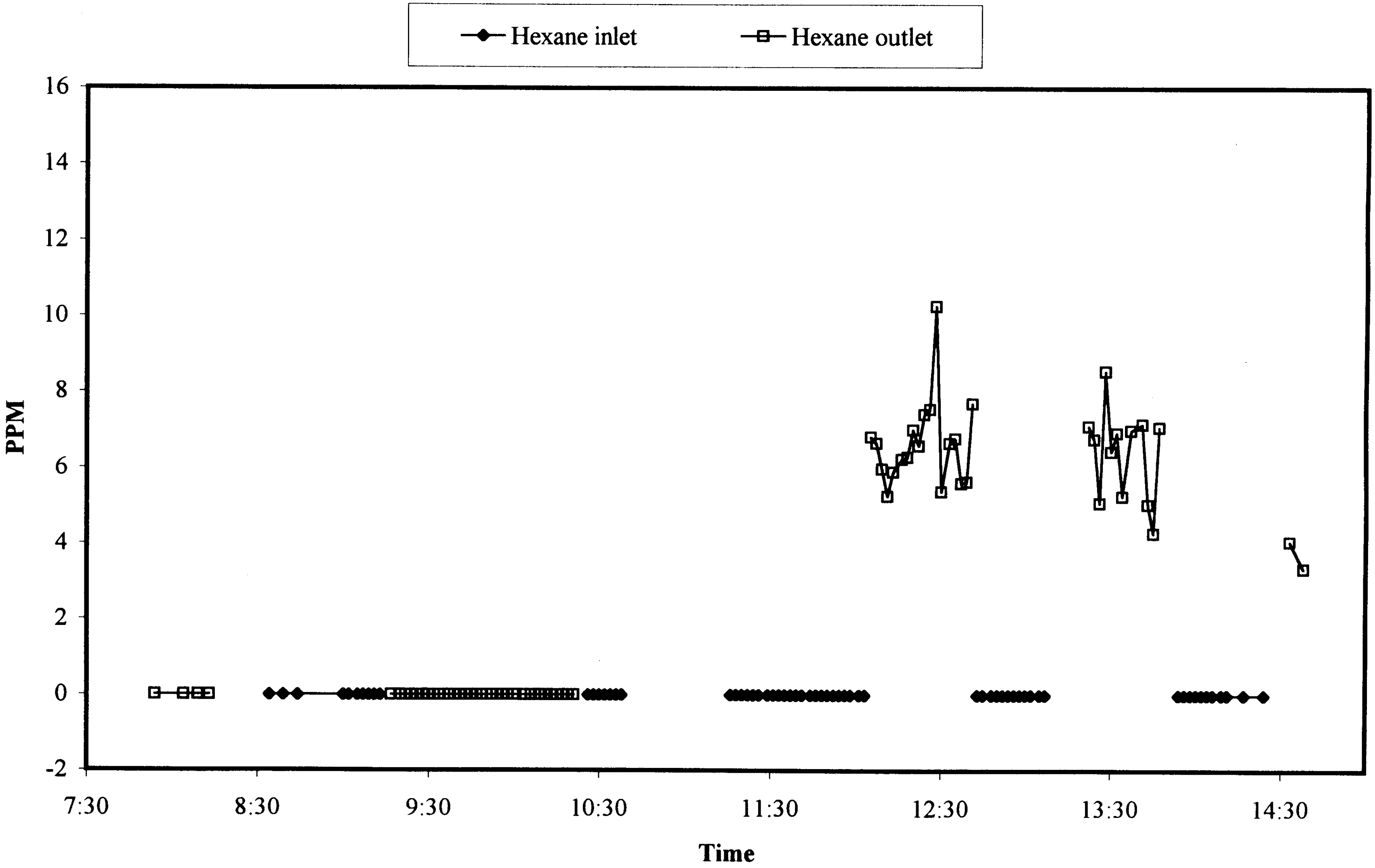
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 3 8/20/97

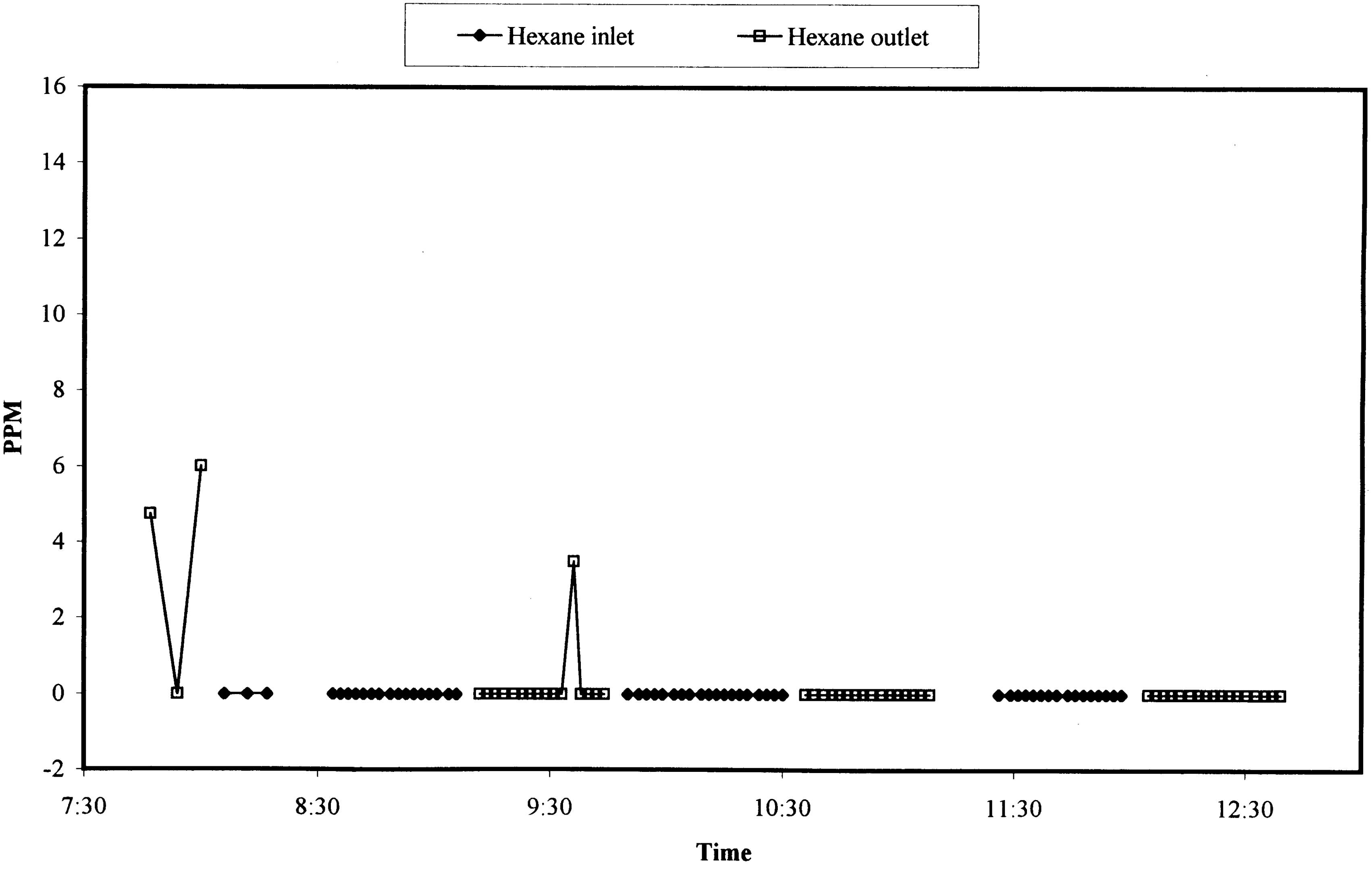


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 4 8/21/97

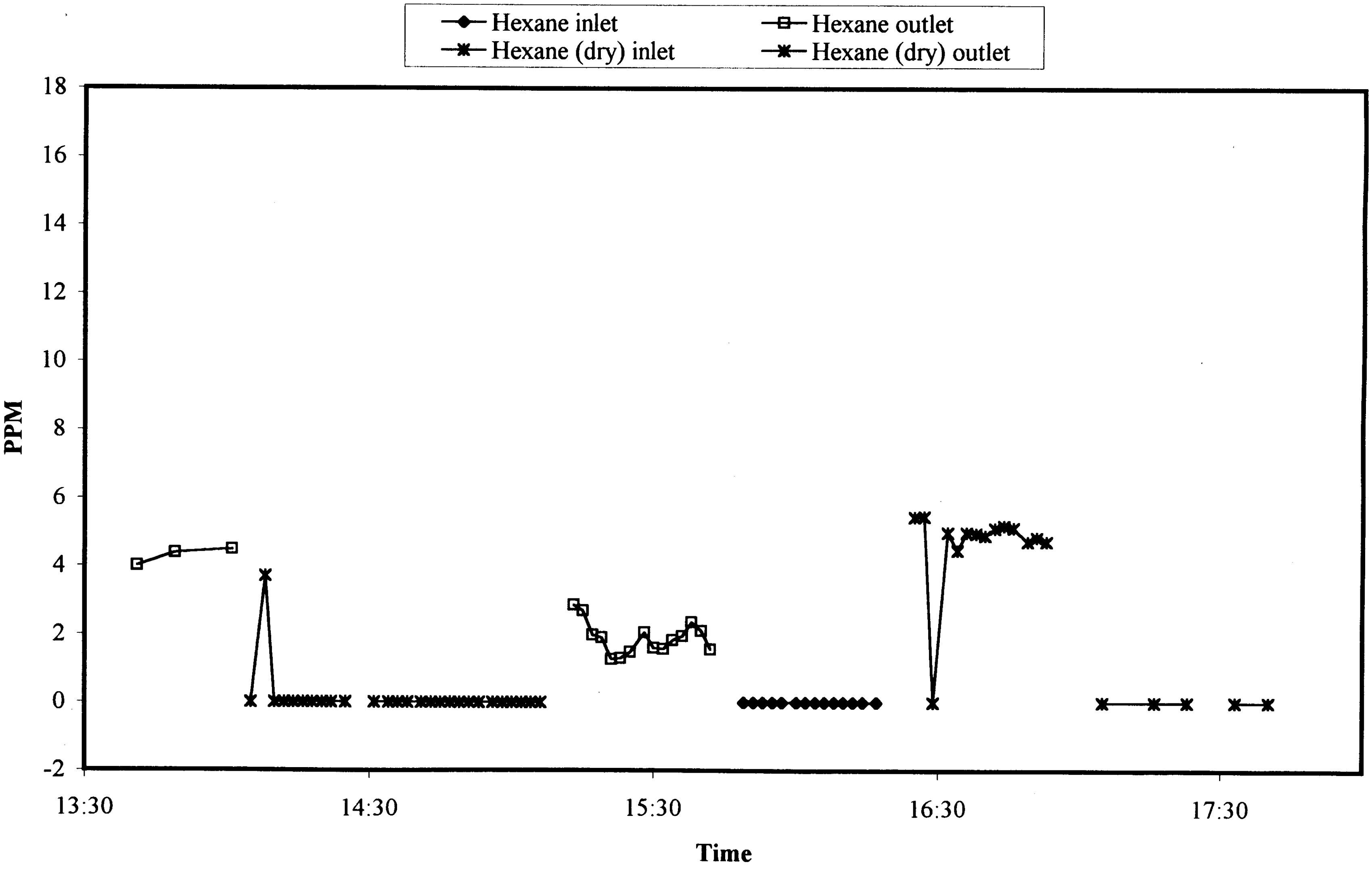


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 1 8/19/97



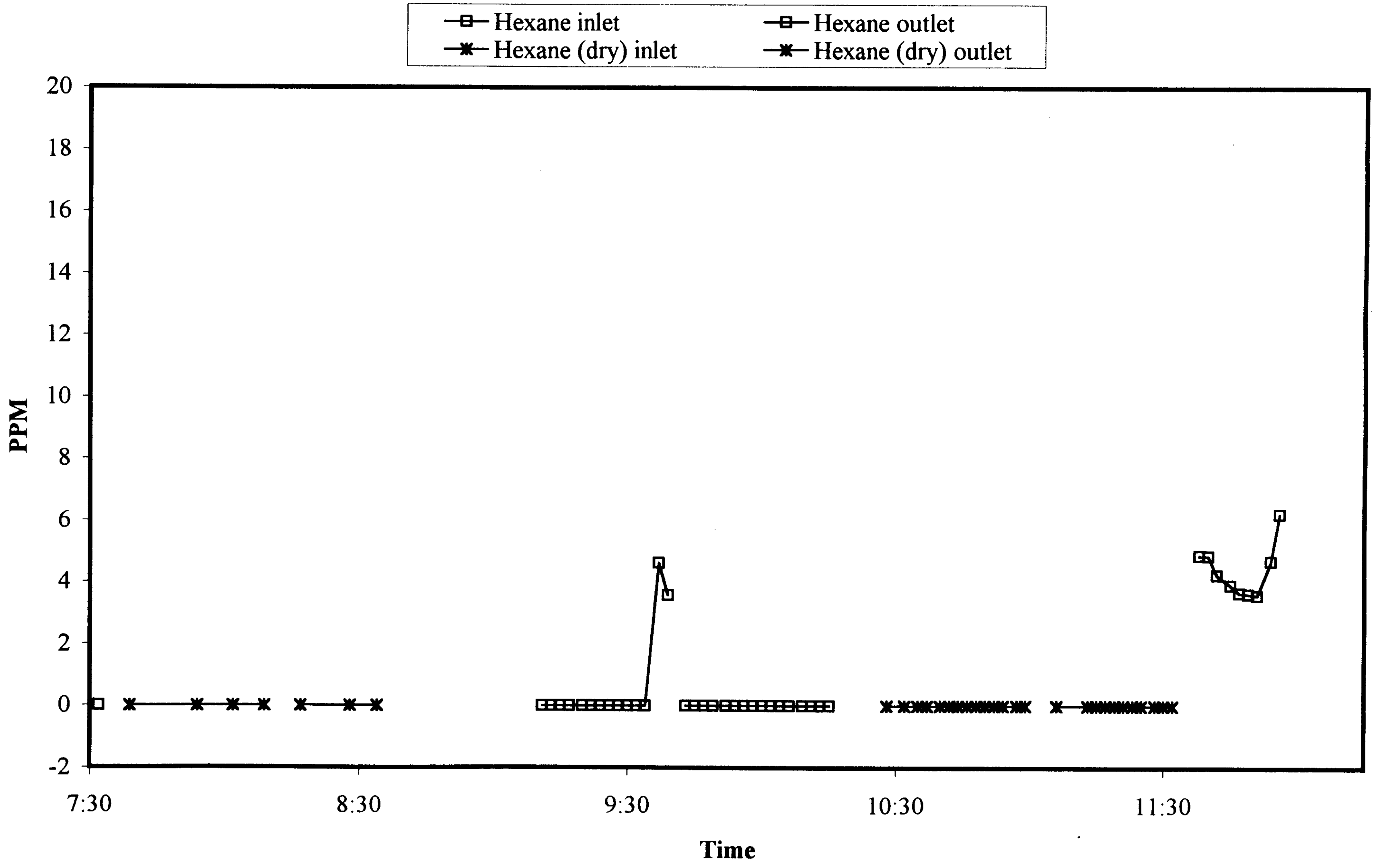


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 2 8/20/97

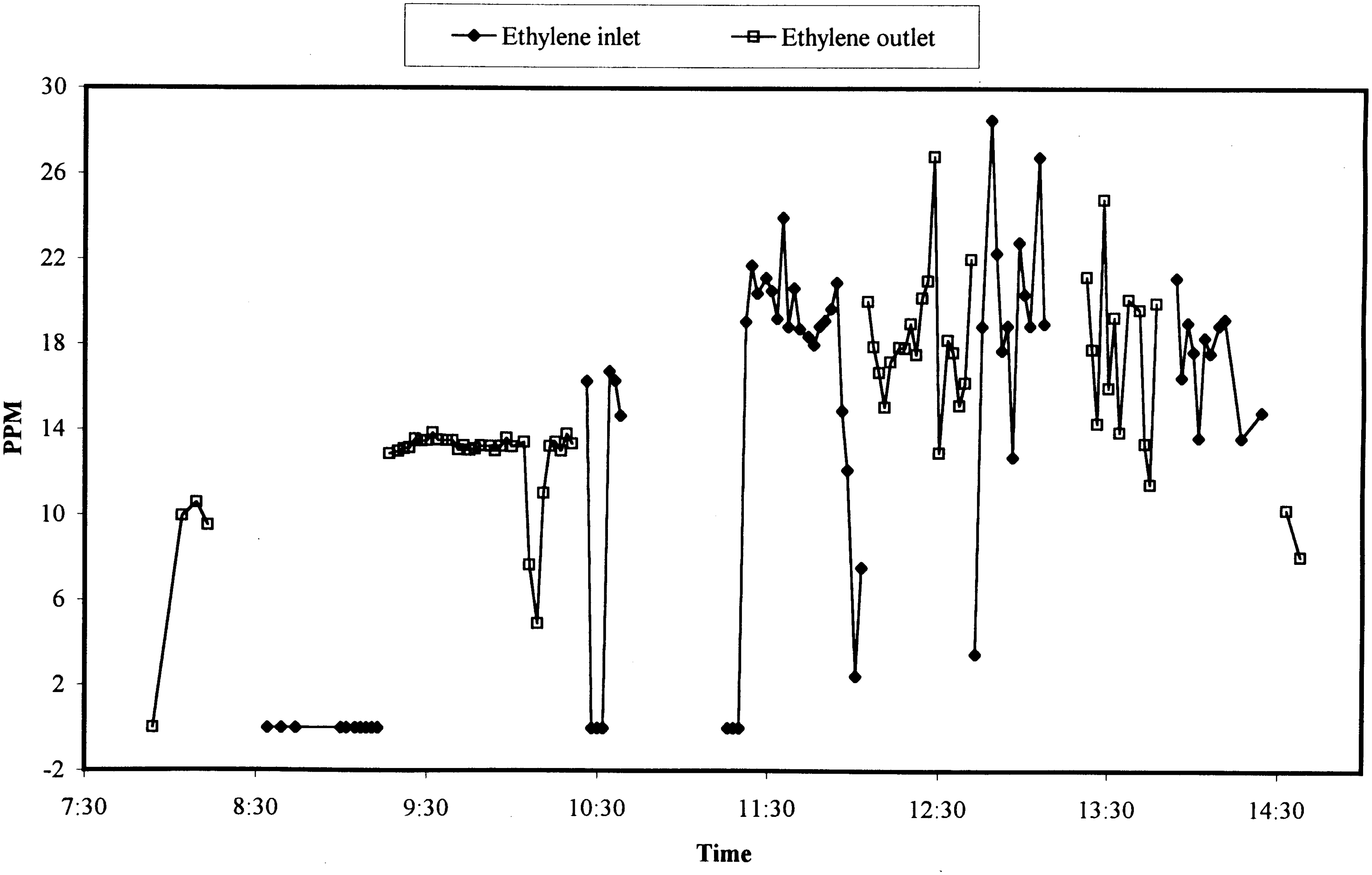


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 3 8/20/97

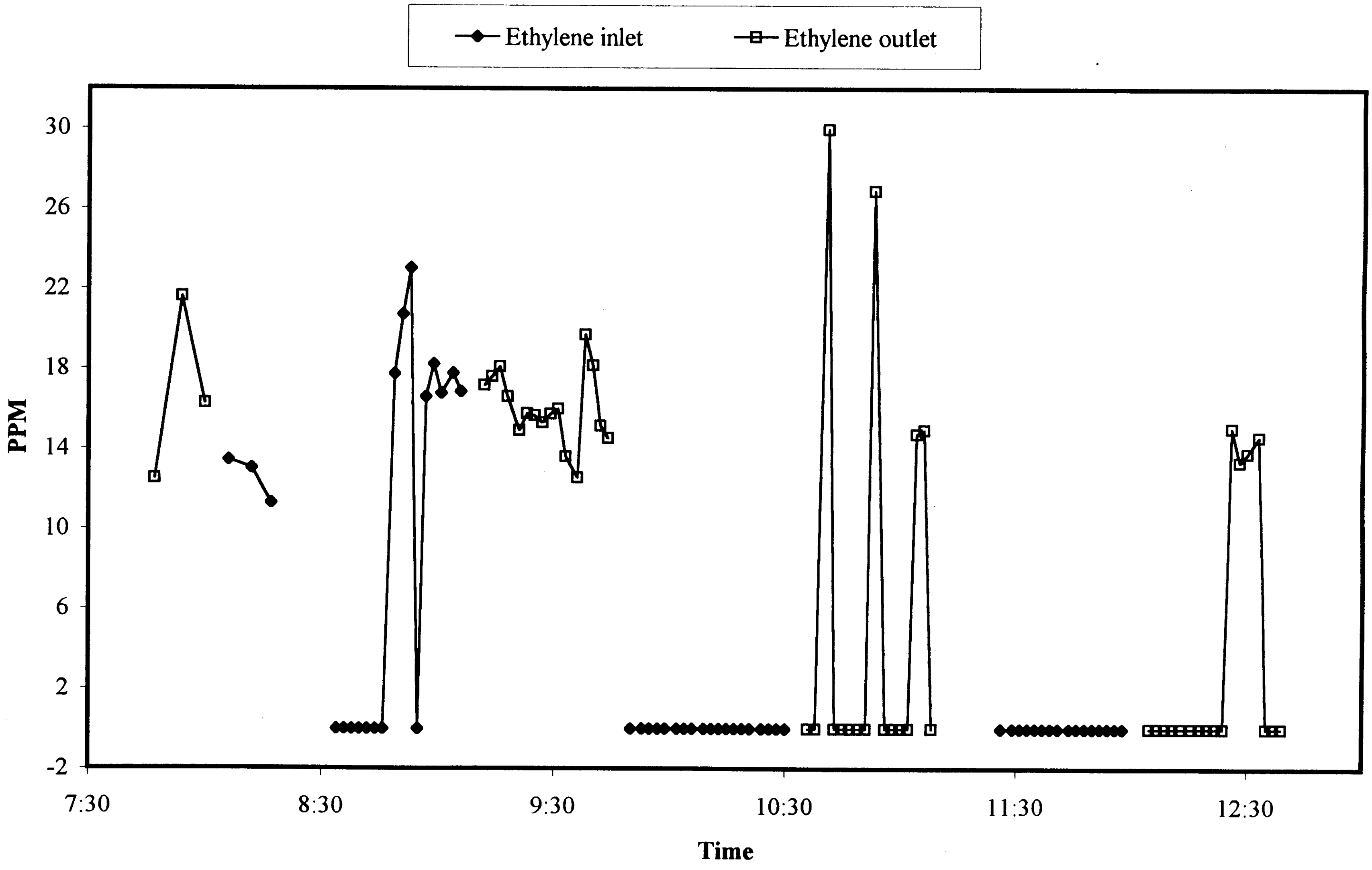
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 4 8/21/97

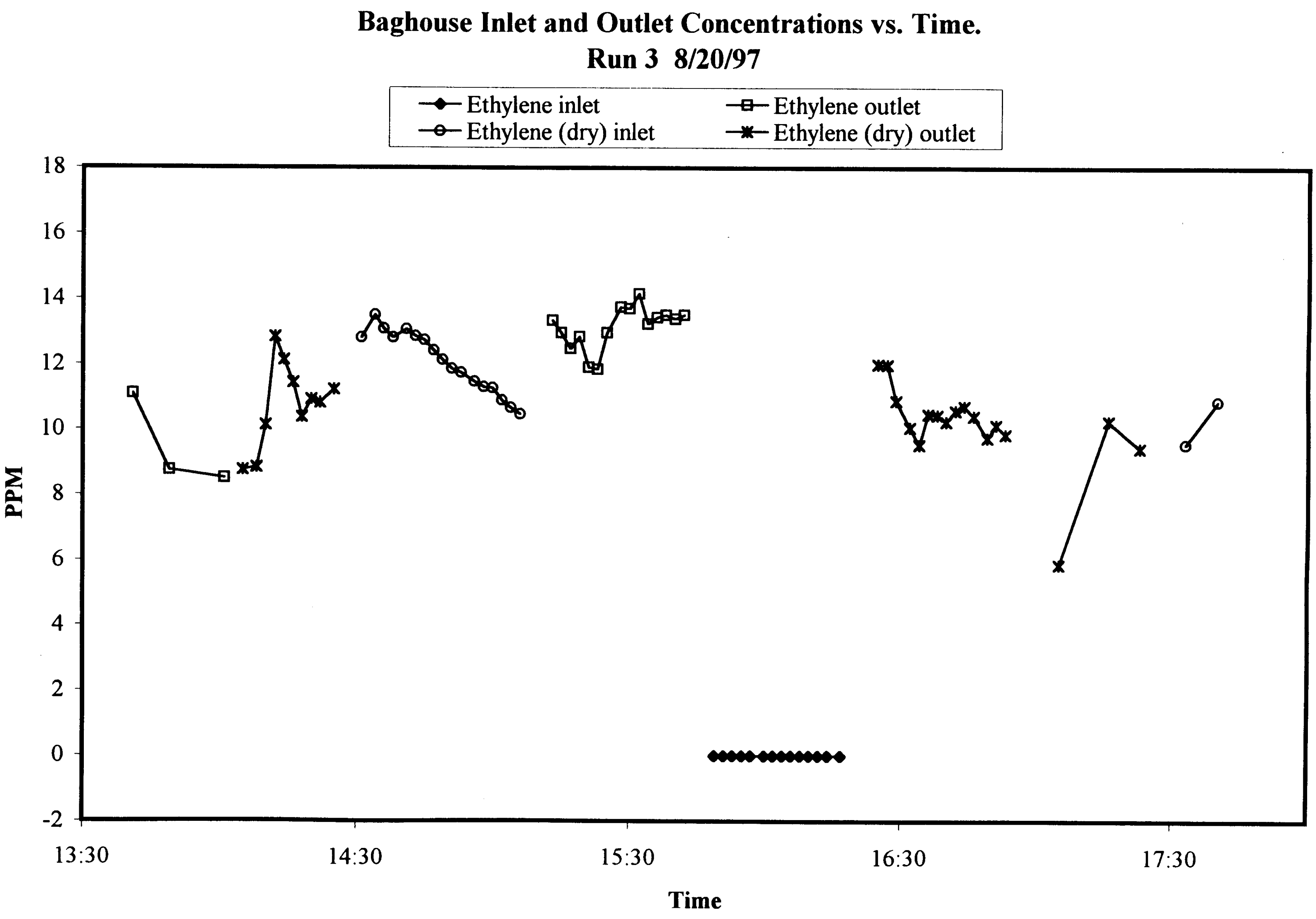


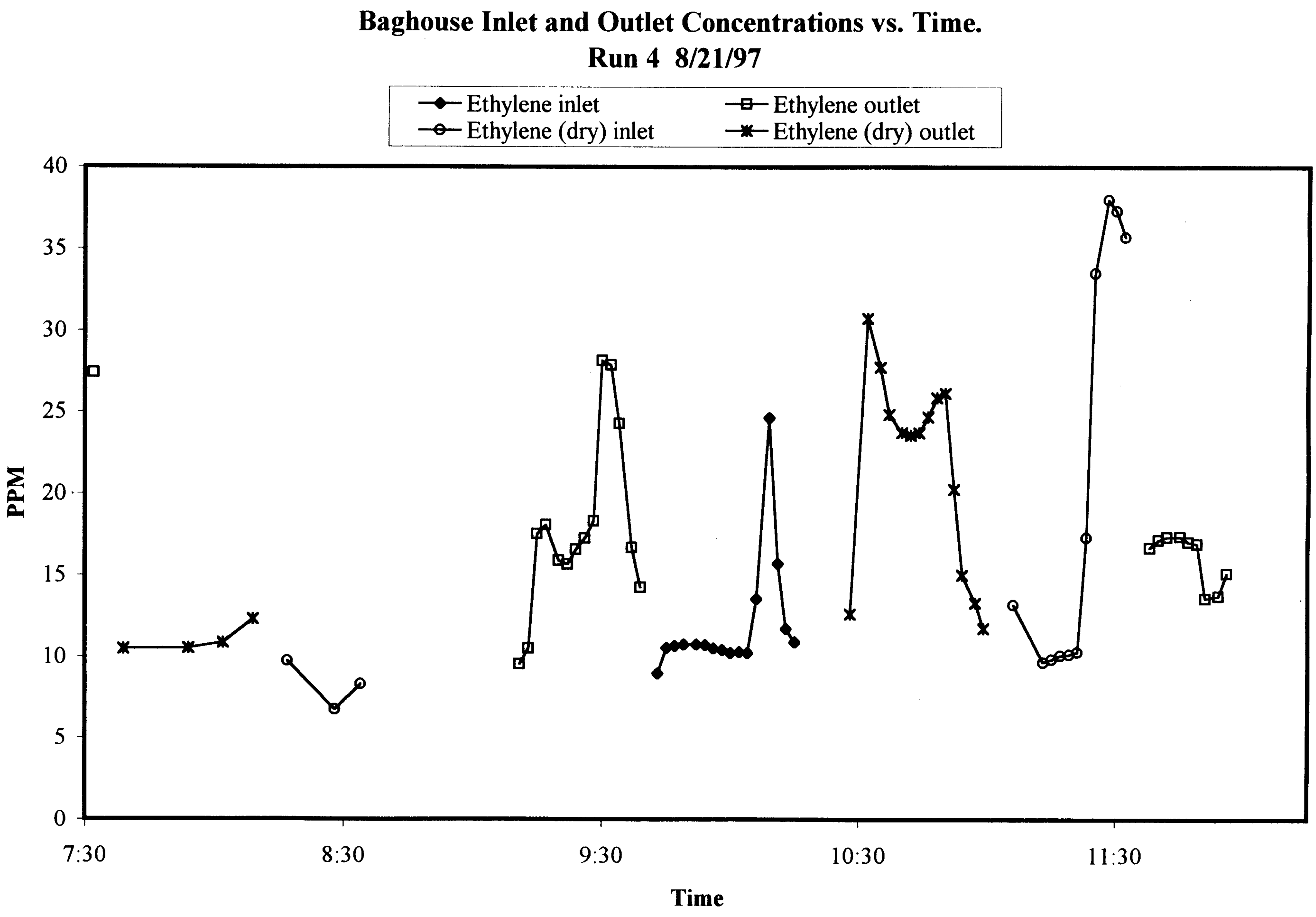
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 1 8/19/97



Baghouse Inlet and Outlet Concentrations vs. Time.
Run 2 8/20/97

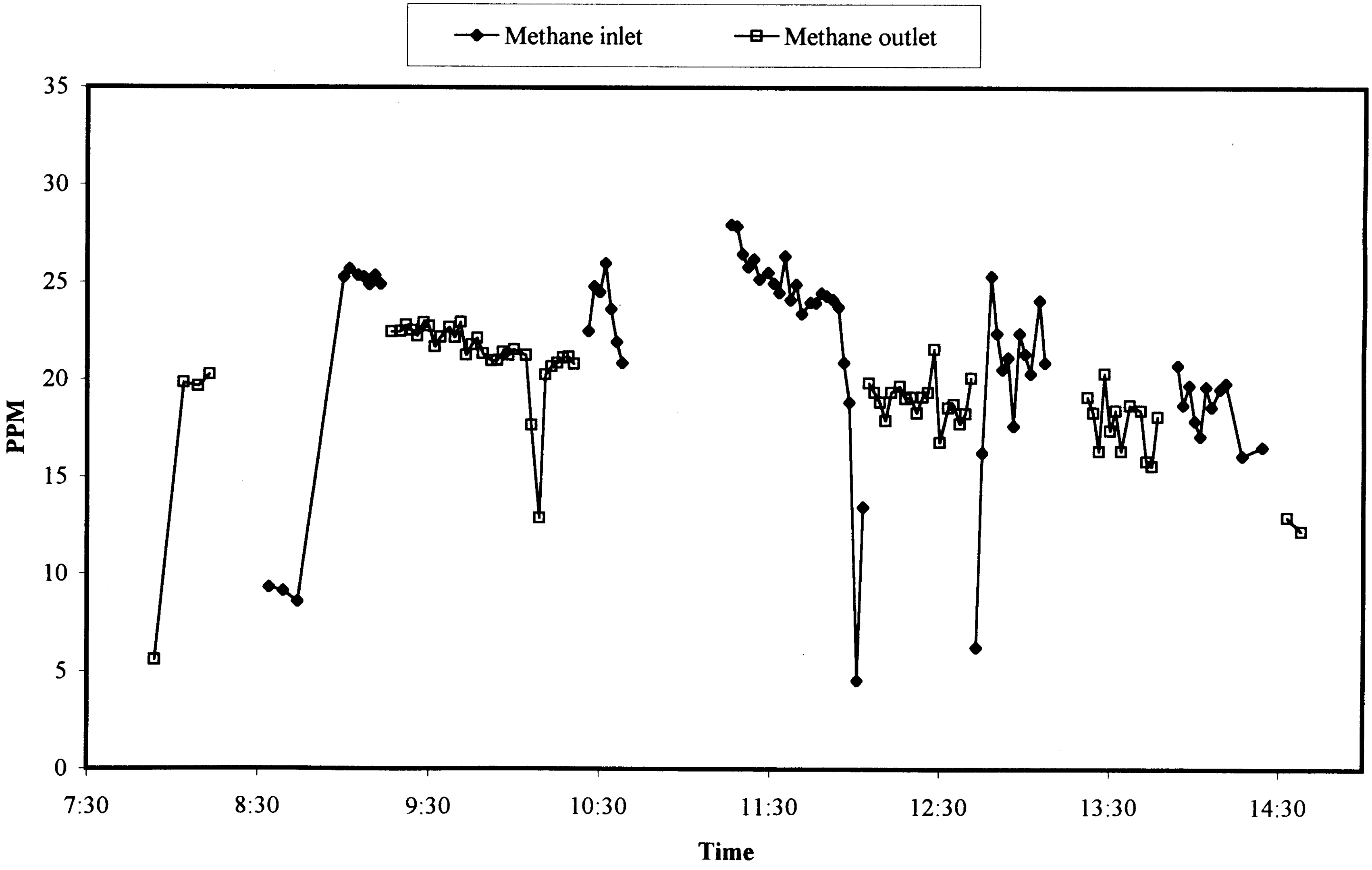


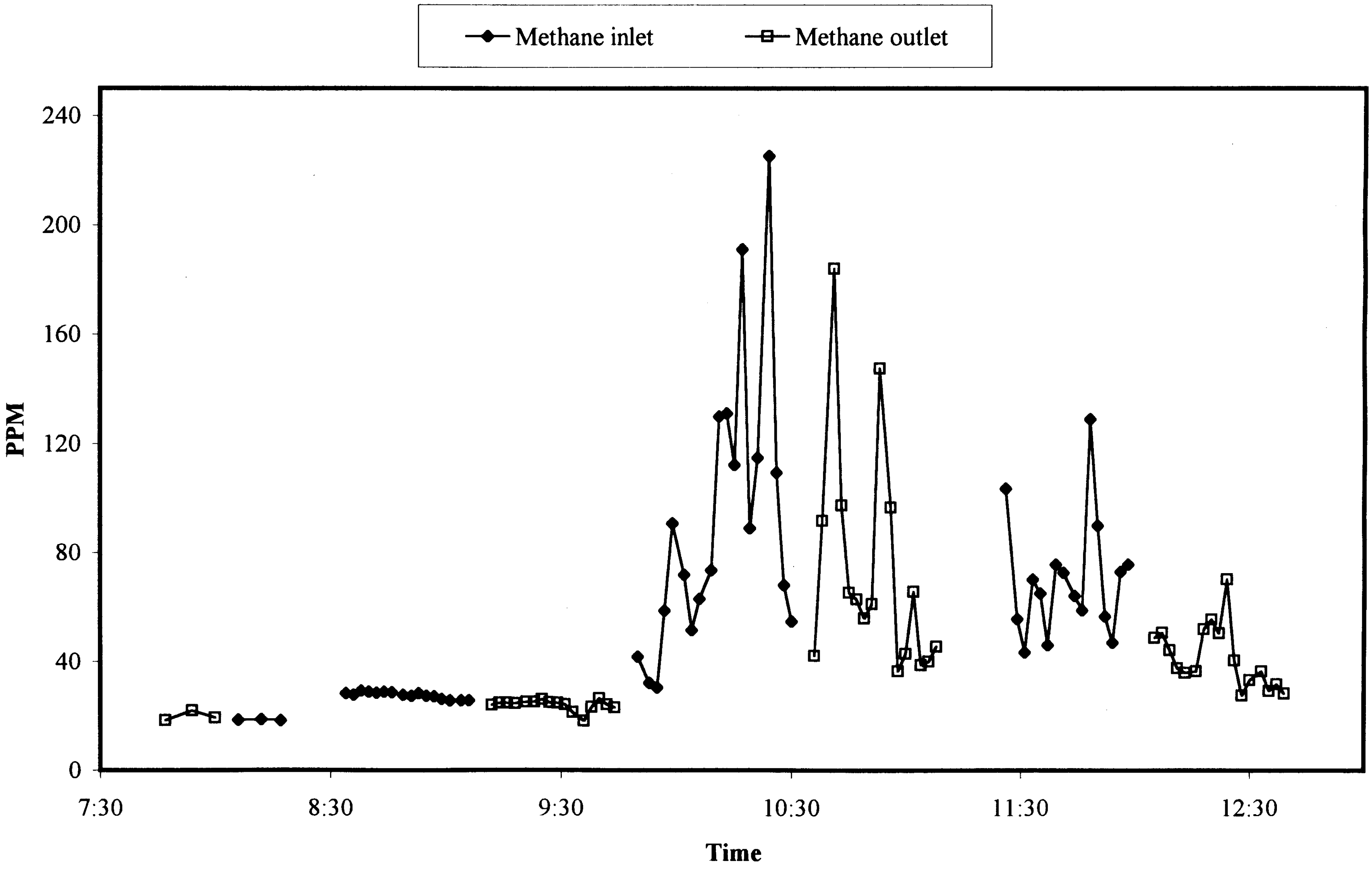

Baghouse Inlet and Outlet Concentrations vs. Time.
Run 3 8/20/97
Ethylene inlet
Ethylene outlet
Ethylene (dry) inlet
Ethylene (dry) outlet
PPM
18
16
14
12
10
8
6
4
2
0
-2
13:30
14:30
15:30
16:30
17:30
Time



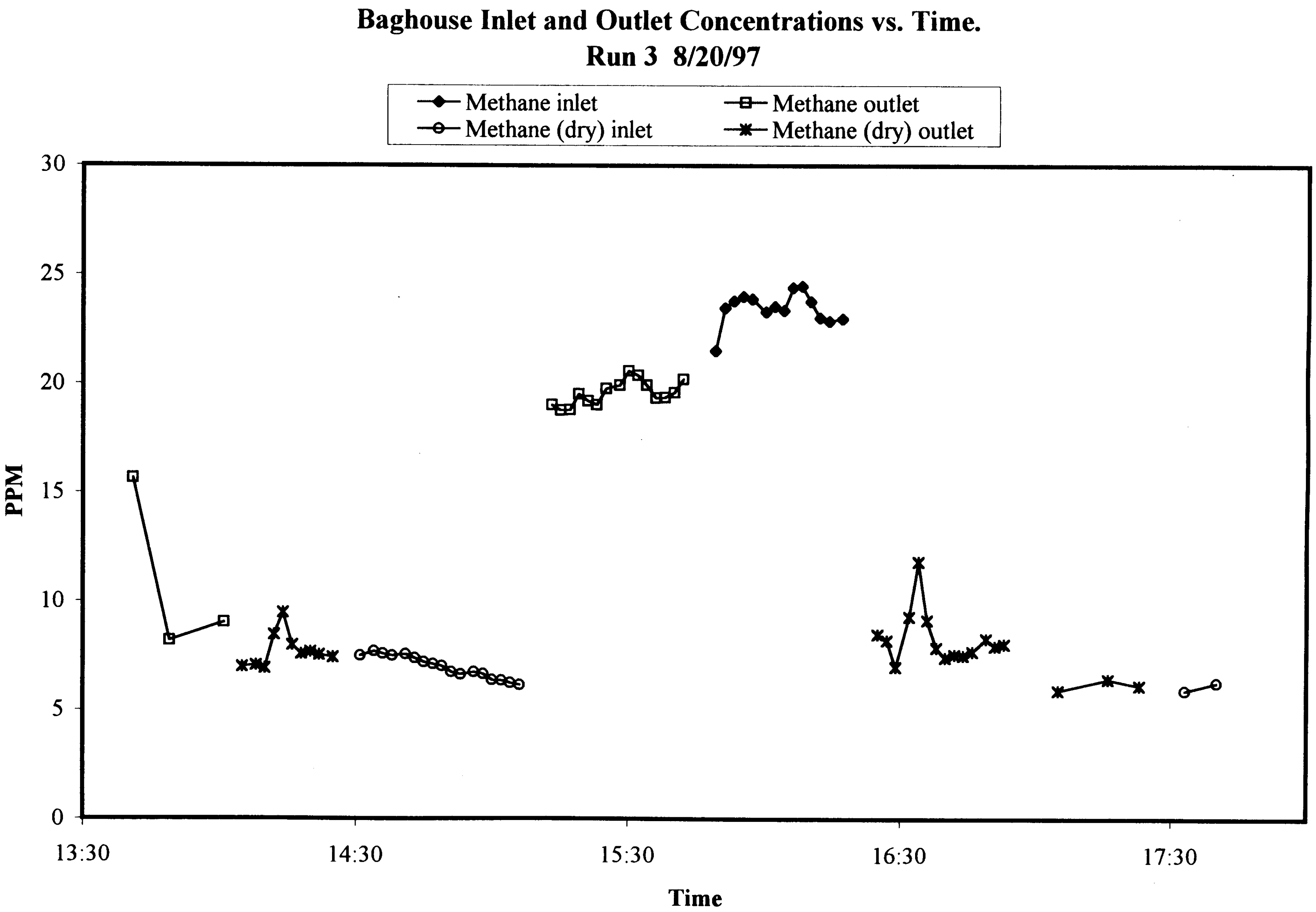
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 4 8/21/97
Ethylene inlet
Ethylene outlet
Ethylene (dry) inlet
Ethylene (dry) outlet
PPM
40
35
30
25
20
15
10
5
0
7:30
8:30
9:30
10:30
11:30
Time

Baghouse Inlet and Outlet Concentrations vs. Time.
Run 1 8/19/97

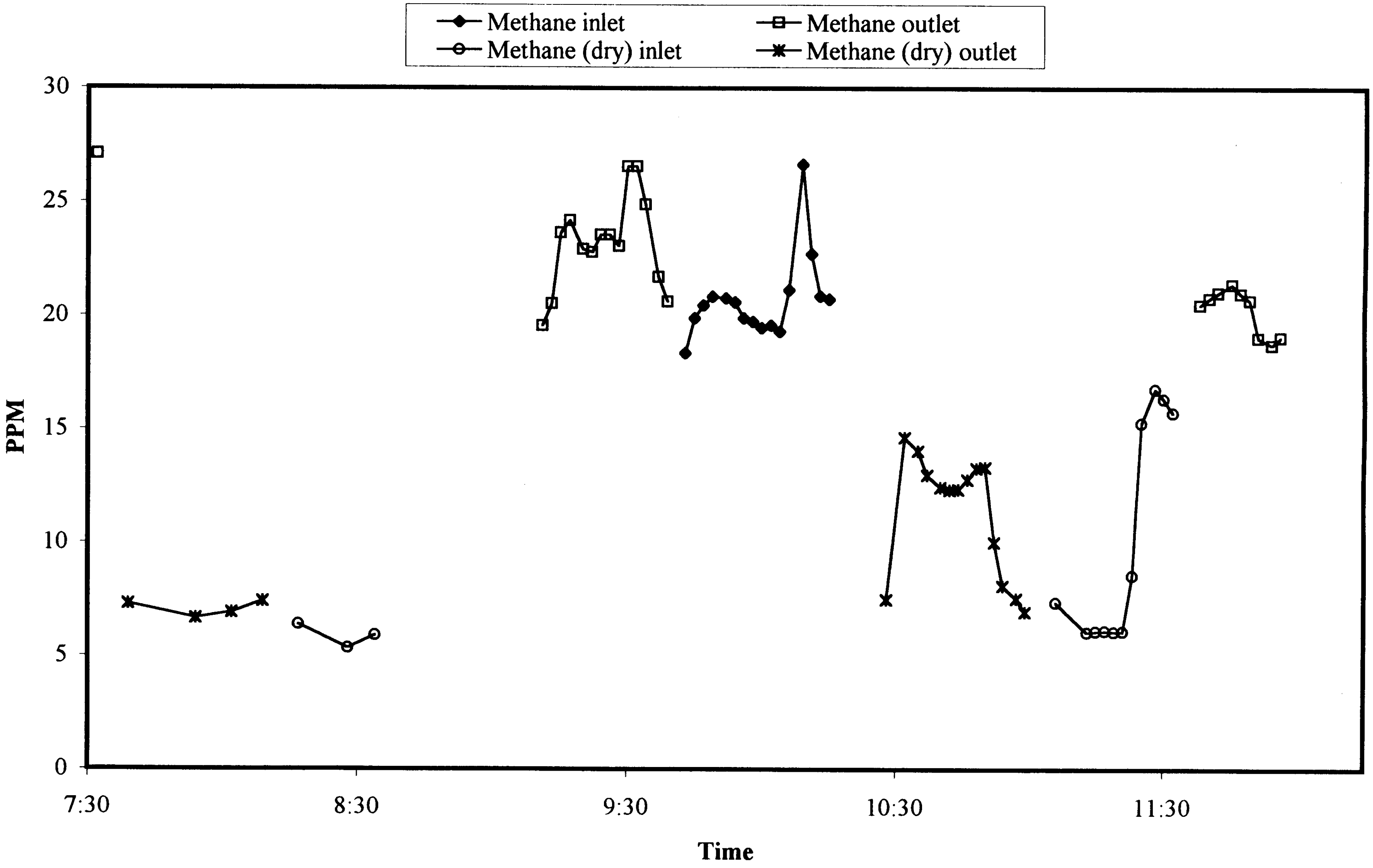


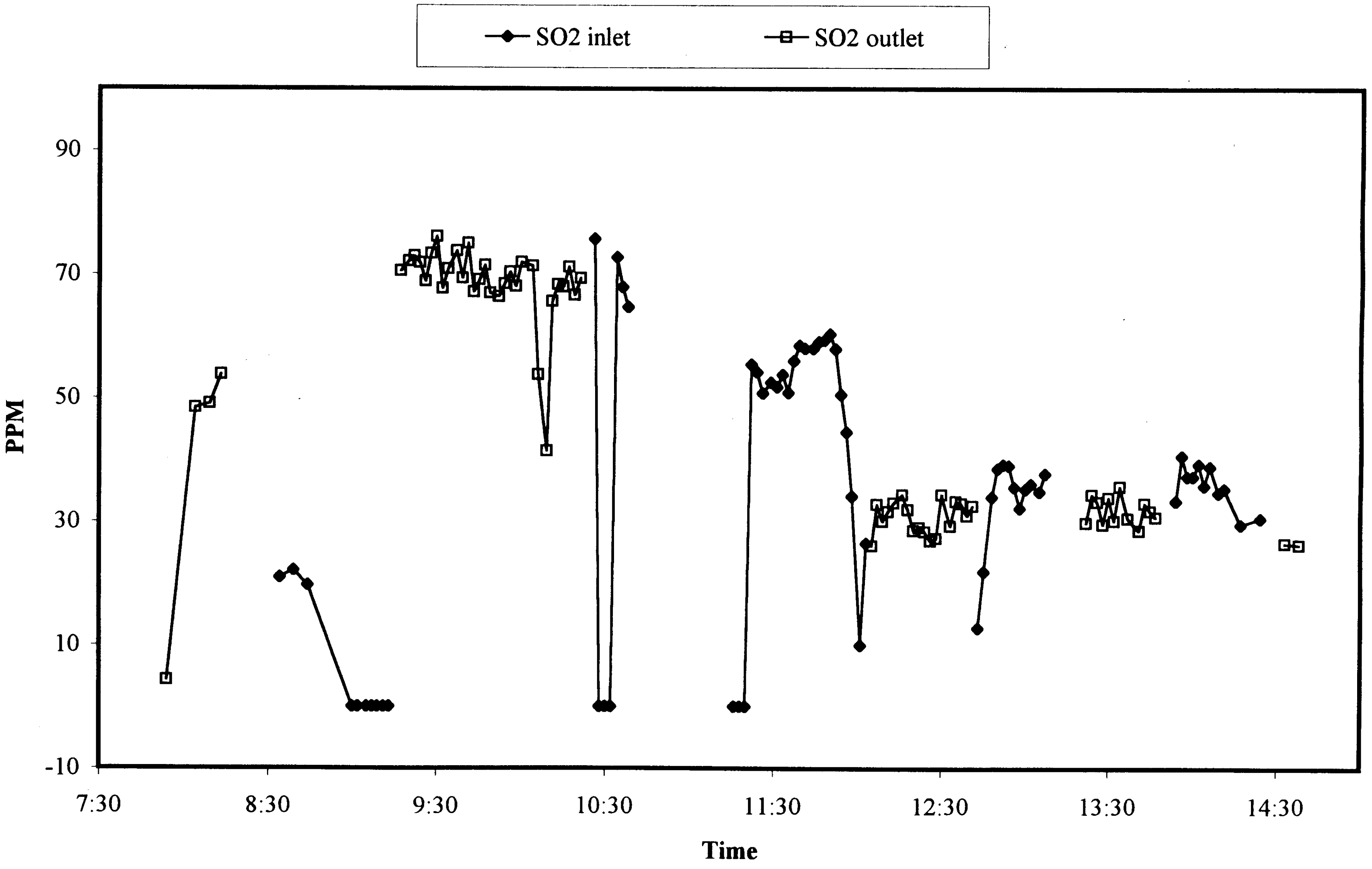


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 2 8/20/97


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 3 8/20/97

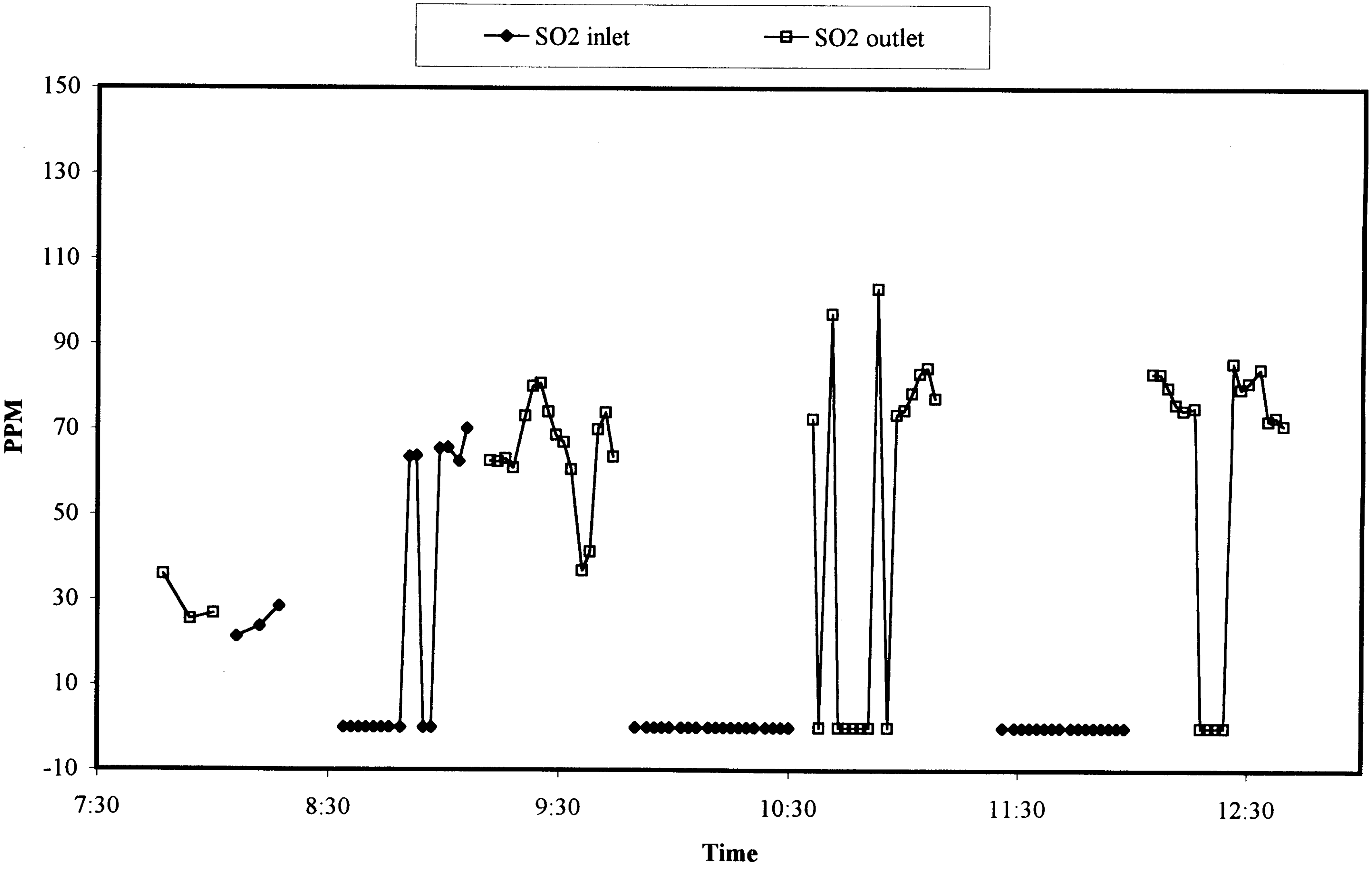
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 4 8/21/97



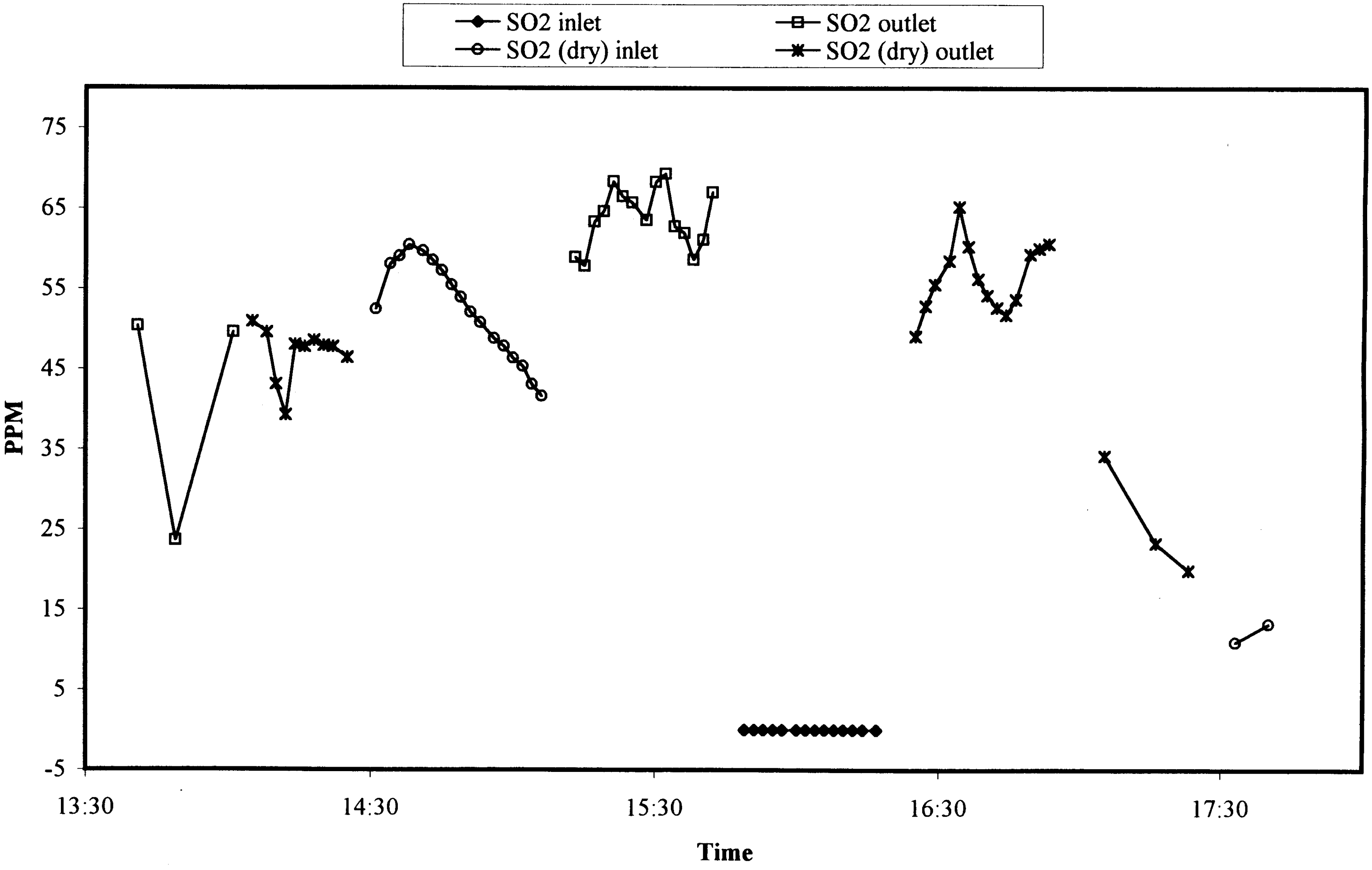


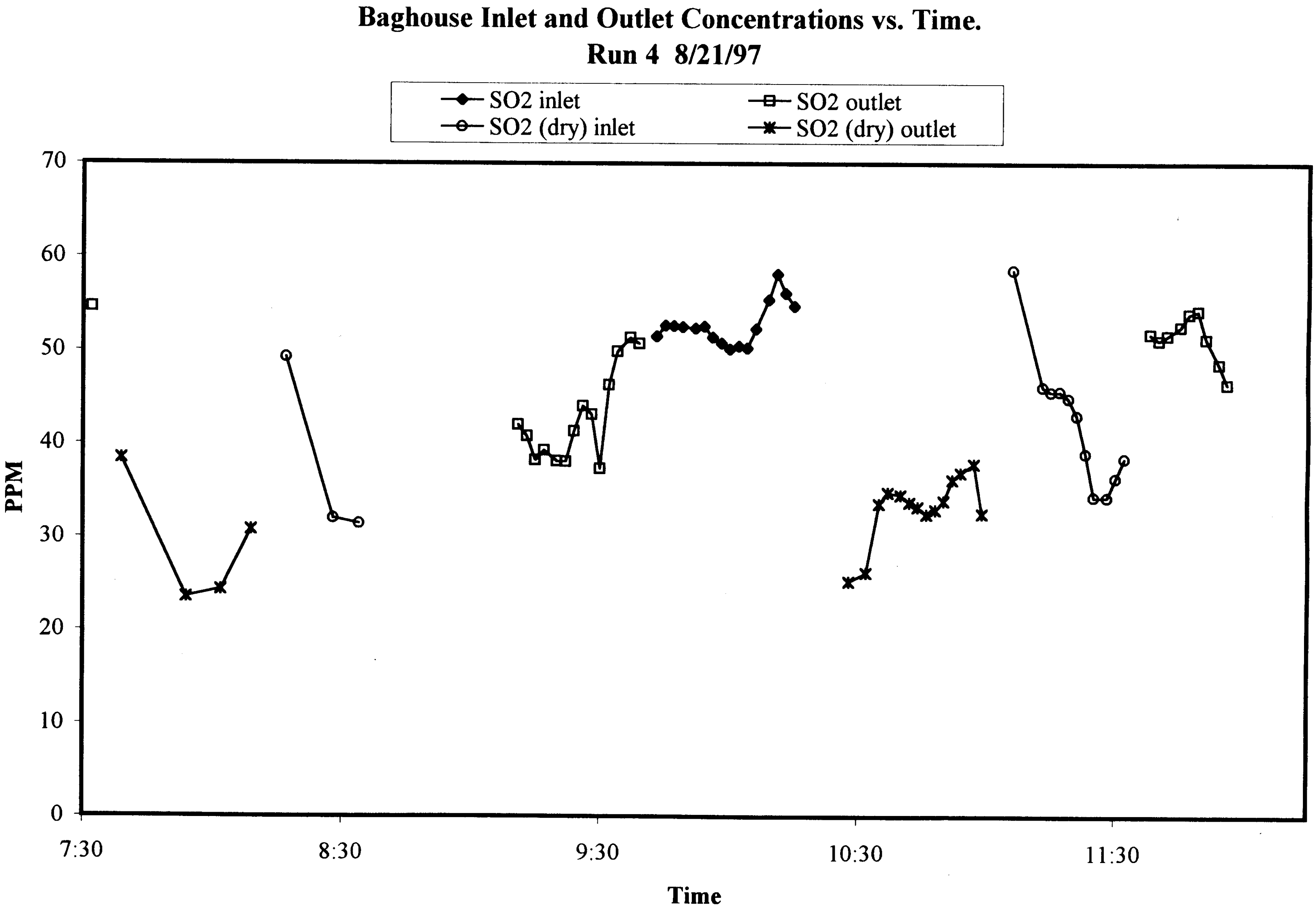
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 1 8/19/97

Baghouse Inlet and Outlet Concentrations vs. Time.
Run 2 8/20/97

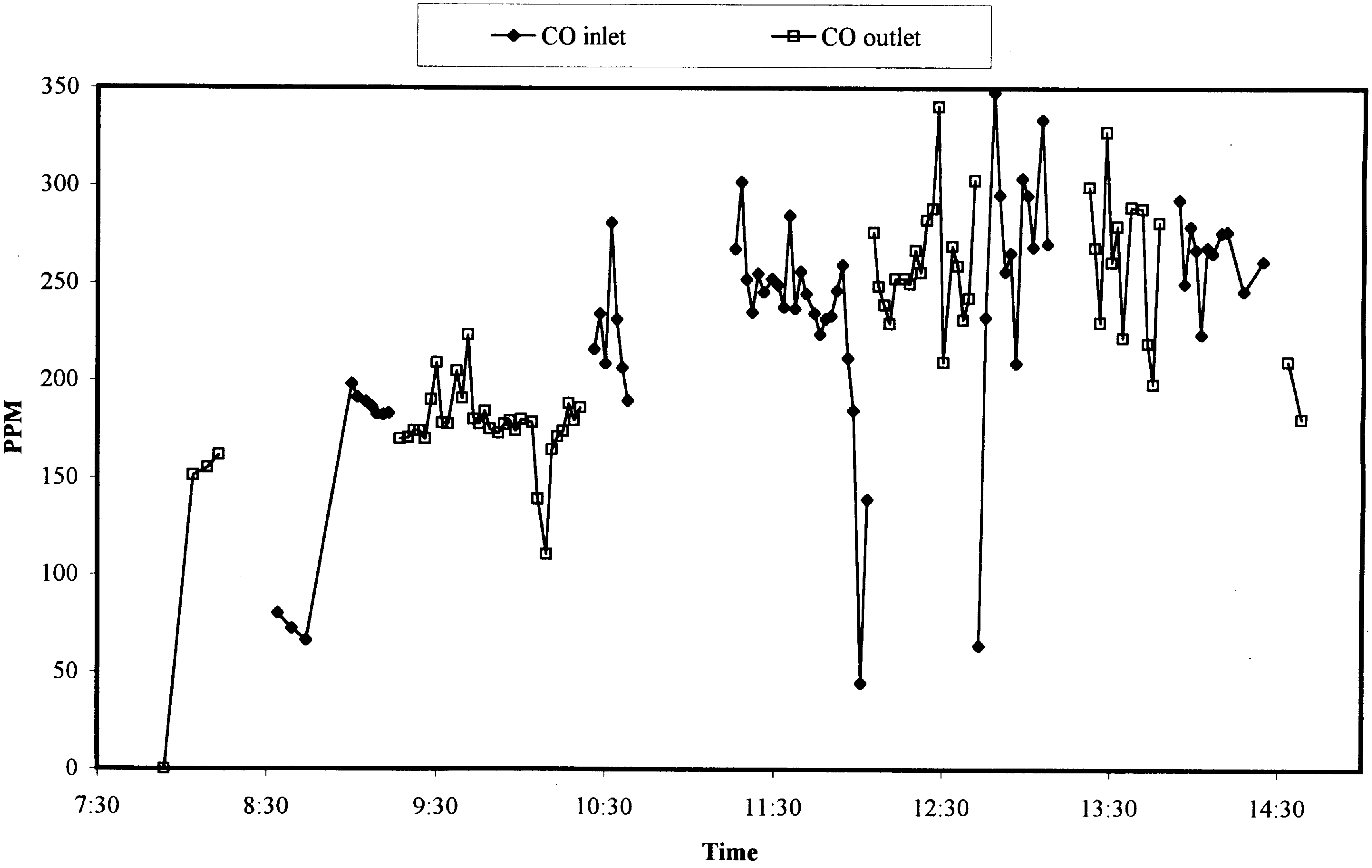


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 3 8/20/97

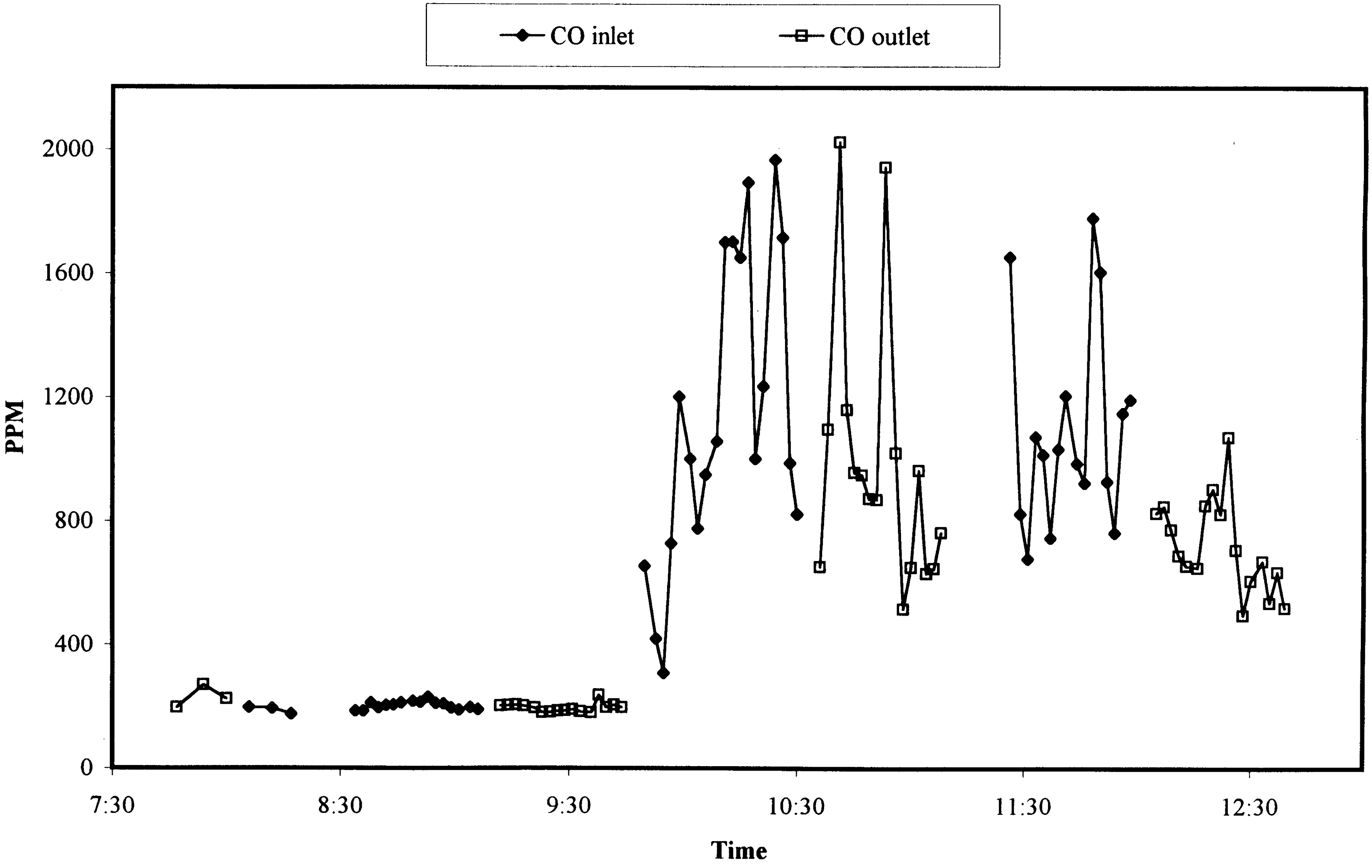



Baghouse Inlet and Outlet Concentrations vs. Time.
Run 4 8/21/97
SO2 inlet
SO2 outlet
SO2 (dry) inlet
SO2 (dry) outlet
70
60
50
40
30
20
10
0
PPM
7:30
8:30
9:30
10:30
11:30
Time

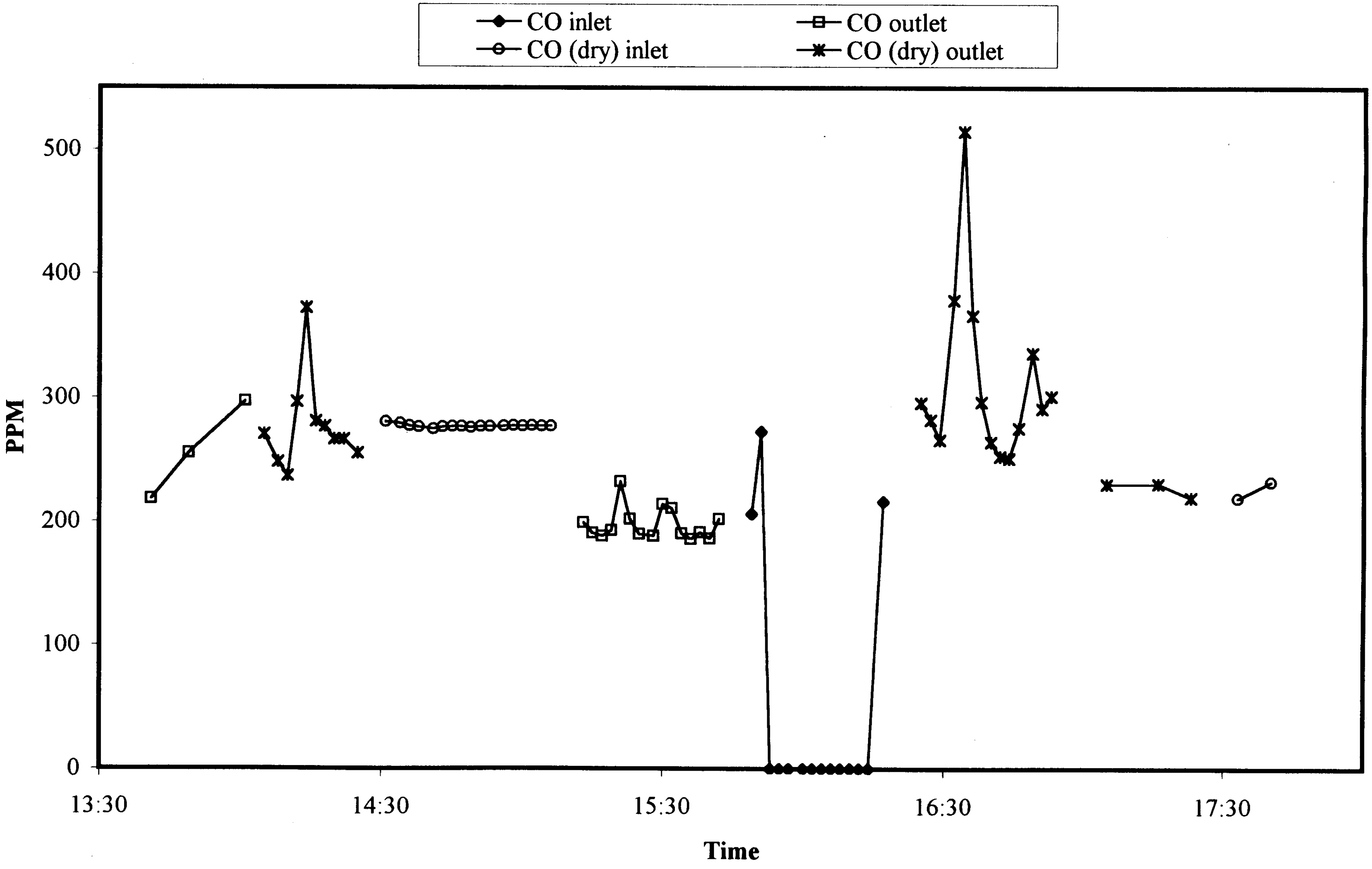
Baghouse Inlet and Outlet Concentrations vs. Time.
Run 1 8/19/97

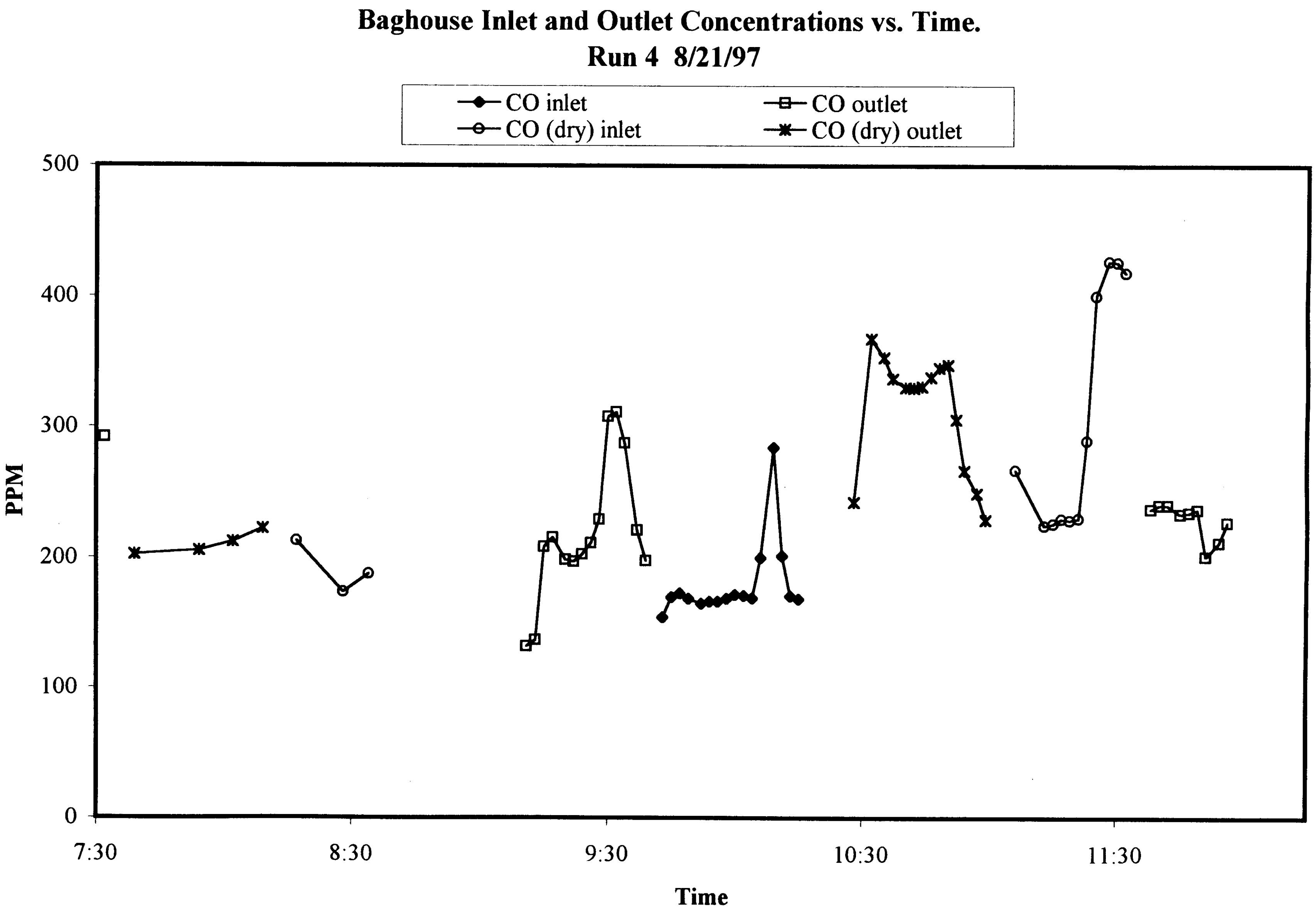


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 2 8/20/97

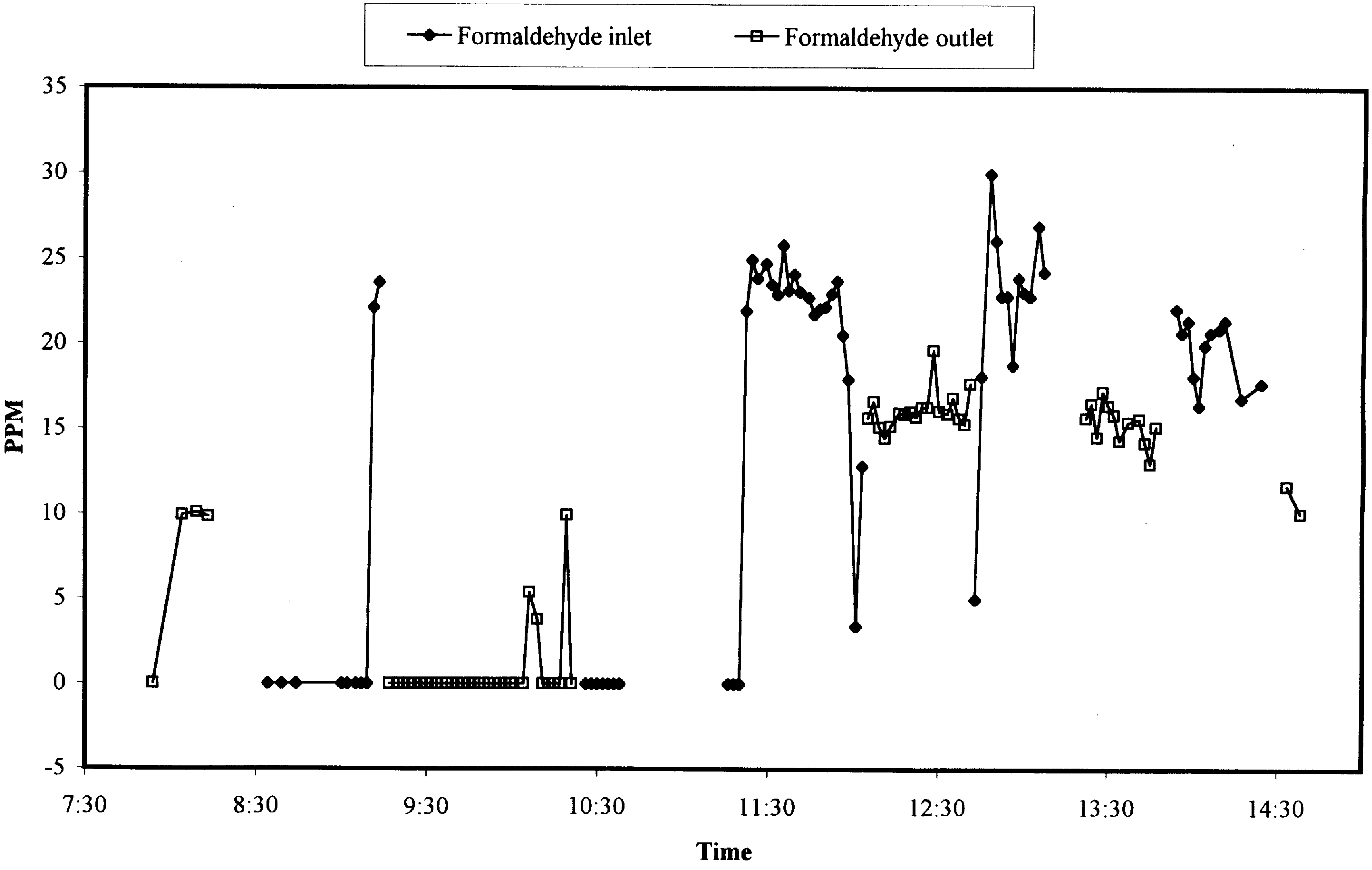


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 3 8/20/97

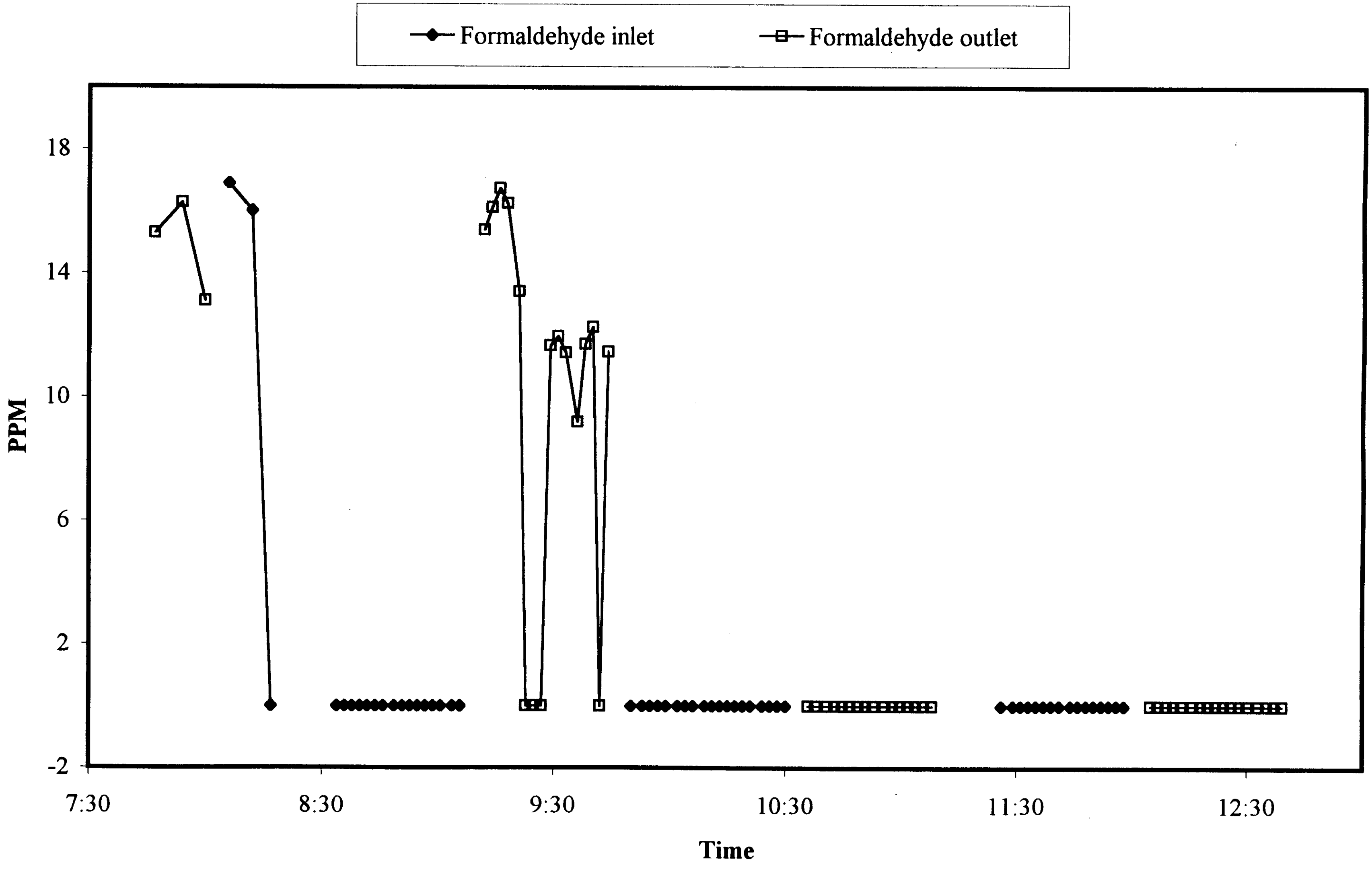


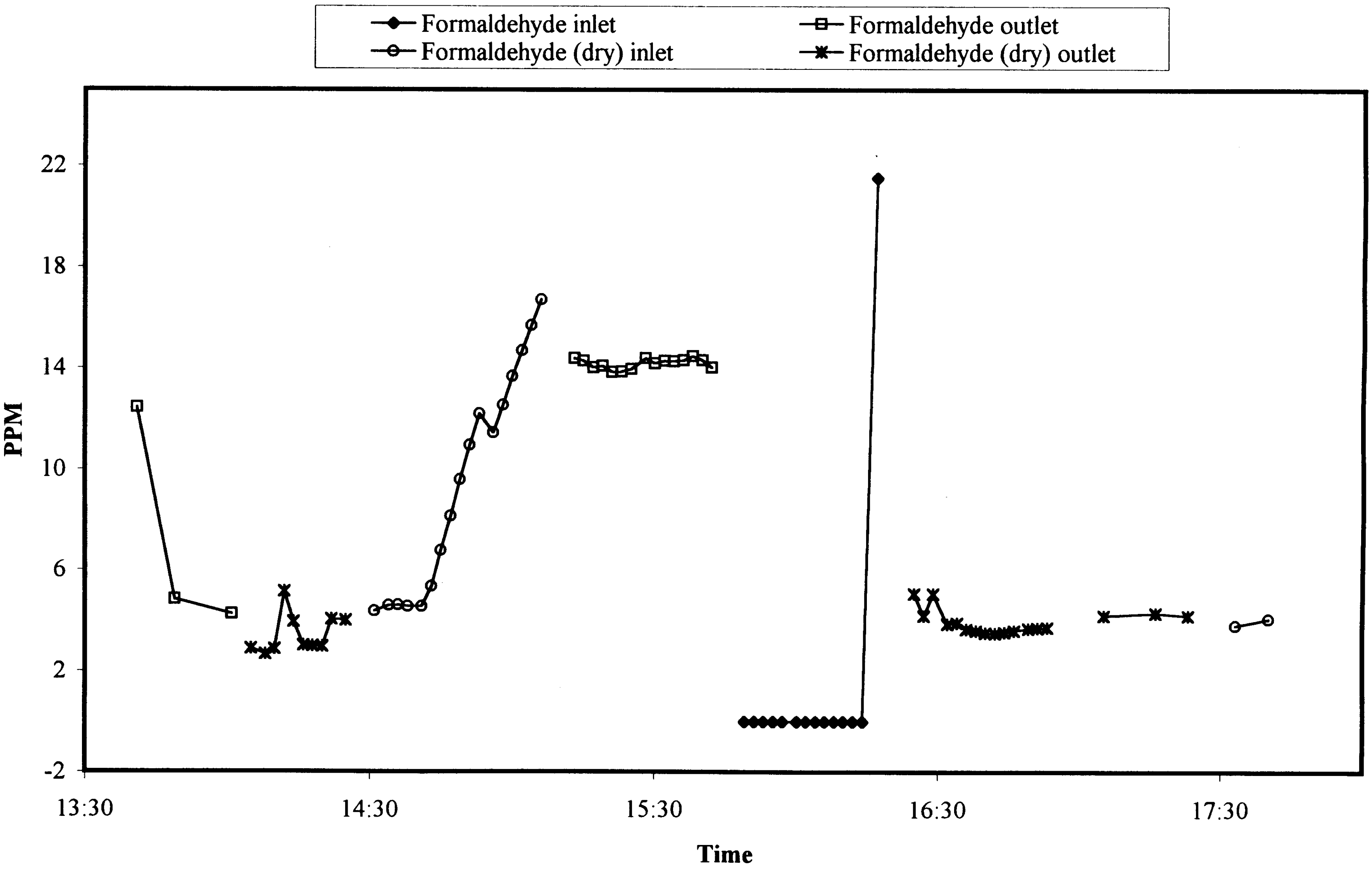

Baghouse Inlet and Outlet Concentrations vs. Time.
Run 4 8/21/97
CO inlet
CO outlet
CO (dry) inlet
CO (dry) outlet
PPM
500
400
300
200
100
0
7:30
8:30
9:30
10:30
11:30
Time

Baghouse Inlet and Outlet Concentrations vs. Time.
Run 1 8/19/97

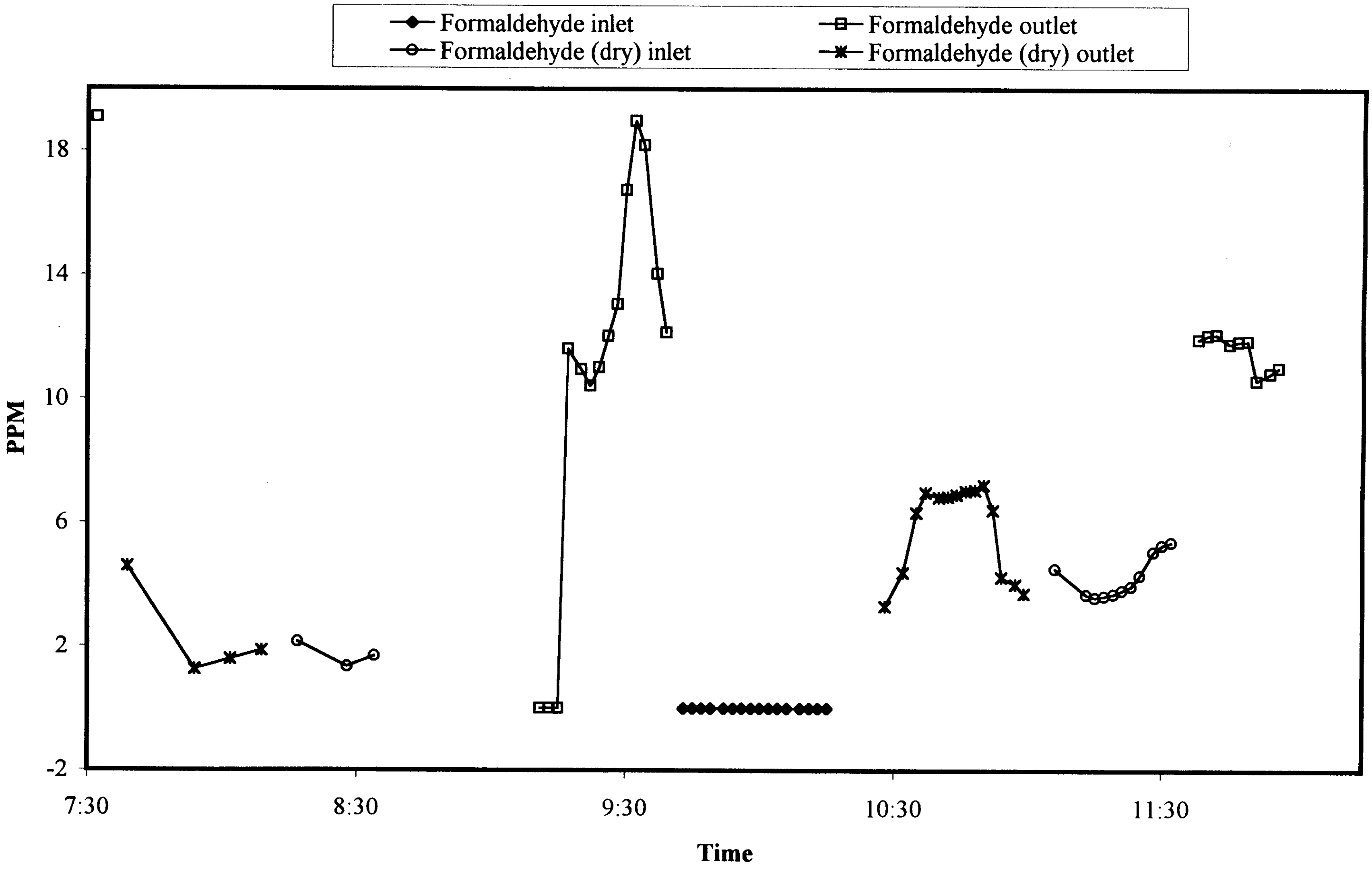


Baghouse Inlet and Outlet Concentrations vs. Time.
Run 2 8/20/97





Baghouse Inlet and Outlet Concentrations vs. Time.
Run 3 8/20/97



Baghouse Inlet and Outlet Concentrations vs. Time.
Run 4 8/21/97

TABLE B-5. PLANT A “METHOD DETECTION LIMIT” ESTIMATES

Compound	**SU**[1]	**MDL**[2] (ppm)
Acetaldehyde	0.13	0.38
Benzene	0.14	0.41
Carbonyl Sulfide	0.00	0.01
Methylchloride	0.37	1.12
Methylchloroform	0.04	0.13
1,1-dichloroethane	0.04	0.11
Toluene	0.33	0.98
1,3-butadiene	0.18	0.53
Methanol	0.05	0.14
Cumene	0.11	0.32
Ethylbenzene	0.31	0.93
Hexane	0.05	0.16
Methylene chloride	0.10	0.30
Propionaldehyde	0.04	0.13
Styrene	0.23	0.69
1,1,2,2-Tetrachloroethane	0.02	0.06
p-Xylene	0.18	0.55
o-Xylene	0.15	0.44
m-Xylene	0.37	1.12
2,2,4-Trimethylpentane	0.02	0.02
Formaldehyde	0.15	0.46

[1] SU = "Statistical Uncertainty" From Proposed ASTM FTIR Method

[2] The "Method Detection Limit" from ASTM FTIR method.

Table B-5 contains results from the “Method Detection Limit” calculation procedure suggested in the September, 1998 version of an FTIR method proposed by the American Society of Testing and Materials (ASTM).

The procedure, briefly, (1) prepares at least 7 spectra with zero analyte concentrations, but with interference absorbance equivalent to the sample spectra, (2) runs the analytical program on these spectra, (3) calculates the standard deviation (“statistical uncertainty,” SU) in the results, and (4) multiplies the SU results by 3 to give the “Method Detection Limit” (MDL)

The spectra in step 1 were prepared in the laboratory as recommended. Seven independent spectra of water vapor (approximately 20 percent), at 124°C, and 753 torr, were measured in a heated cell at a path length of 10 meters. Seven independent spectra of carbon dioxide (CO_2, 20 percent) were also measured using the same instrument conditions. Seven interference spectra were generated by combining pairs of water vapor and CO_2 spectra. The CO_2 concentrations in the interference spectra were higher than in the sample spectra. The interference spectra moisture concentrations were higher than or equivalent to the sample spectra moisture concentrations.

The laboratory moisture and CO_2 spectra were measured at 1.0 cm^{-1}. The spectra were then deresolved to 2.0 cm^{-1} to match the sampling resolution used at the Plant A test. The deresolution procedure followed Appendix K of the EPA FTIR Protocol and involved truncating and Fourier processing the original interferograms.

In step 2 the interference spectra were analyzed using the computer program that was used in the sample analyses. The computer program used reference spectra of moisture and CO_2 that were measured in the laboratory independently of the interference moisture and CO_2 spectra.

The analytical program calculated concentration results for the target analytes in Table B-5. The concentrations were all near zero and the estimated MDL values were determined from the precision of the concentration results for each analyte. The sample results in Tables B-1 to B-4 were prepared using the same computer program, but the program was constrained to measure only the detected analytes.

The calculation of the "SU" value for a single analyte is given in equation B-1.

$$SU = \sqrt{\frac{1}{(n-1)} \sum_{i=1}^{(n-1)} (C_i - C_M)^2} \qquad \text{(B-1)}$$

where;

SU = The "Statistical Uncertainty."
N = The number of spectra analyzed.
C_i = The concentration result from the ith spectrum. In this procedure the absolute value of the results was used in equation B-1.
C_M = The average of the concentration results for all of the spectra.
n = The number of measurements. In this case n = 14.

The values "MDL" reported in Table B-5 are equivalent to 3 * SU for each of the target analytes..

B-2 FTIR FIELD DATA RECORDS

FTIR FIELD DATA FORM

(Background and calibration spectra.)

PROJEC 4701-08-02

BAROMETRIC: ______________

PLANT: A

DATE: 8/19/97

OPERATOR: T.Geyer

SAMPLE TIME	FILE NAME	PATH		NUMBER SCANS	RES (cm-1)	CELL TEMP (F)	PRESSURE	BKG	APOD	NOTES
7:20	BK60819A	20 passes	N2 flowing, Background 2 lpm	500	2	130 C	759.2		NB/med	
7:30	CTS0819A	20 passes	Ethylene 20 ppm	250	2	130 C	762	A	NB/med	
7:38	1530819A	20 passes	Toluene 121 ppm	250	2	130 C	762	A	NB/med	
	SF60819A		SF6 4 ppm	250	2	130 C	762	A	NB/med	
8:30	spike 001		spike flow direct to cell-SF6 0.99 lpm,	250	2	130 C	762	A	NB/med	
			Toluene 0.98 lpm							
10:10			Gulick sending propane to outlet spike							
10:15			Propane spike off							
11:09	BKG0819	20 passes	flowing N2 through cell	500	2	130 C	763 torr		NB/med	
14:47			spike direct to cell SF6 1.05 lpm, Toluene 0.99 lpm					B		
15:00	Spike 002		spike direct to cell SF6 1.04 lpm, Toluene 0.99 lpm							
15:17	CTS0819C		20 ppm ethylene				760.5		B	

FTIR FIELD DATA FORM

(Background and calibration spectra.)

PROJEC 4701-08-02

BAROMETRIC:______________

PLANT: A

DATE: 8/20/97

OPERATOR: T. Geyer

SAMPLE TIME	FILE NAME	PATH		NUMBER SCANS	RES (cm-1)	CELL TEMP (F)	PRESSURE	BKG	APOD	NOTES
			Good leak checks at inlet and outlet							
			Good leak check cell & jumper line							
7:00	BKG0820A	20 passes	N2 flowing through cell	500	2	130 C	756.8		NB/med	
7:10	CTS0820A	20 passes	20 ppm ethylene through cell	250	2	130 C	756.4	A	NB/med	
7:35	BKG0820B	20 passes	N2 through cell - getting a large ice band	250	2	130 C	756.4	A	NB/med	
			Dectector holding aprox. 8 hrs							
13:20	BKG0820C	20 passes	N2 through cell	500	2	130 C	758.4		NB/med	
17:54	Spike 301		spike to cell - SF=1.90 lpm, Tol=1.95 lpm	250	2	130 C	751.2		C	
18:05	CTS0820B		20 ppm ethylene to cell	250	2	130 C	757.3	C	NB/med	

FTIR FIELD DATA FORM

(Background and calibration spectra.)

PROJECT NO. 4701-08-02

BAROMETRIC: ______________

PLANT: A

DATE: 8/21/97

OPERATOR: T. Geyer

SAMPLE TIME	FILE NAME	PATH		NUMBER SCANS	RES (cm-1)	CELL TEMP (F)	PRESSURE	BKG	APOD	NOTES
7:15	BKG0821A	20 passes	N2 flowing through cell	500	2	130 C	752.3		NB/med	
7:25	CTS0821A	20 passes	20 ppm Ethylene through cell	250	2	130 C	752.3	A	NB/med	
8:42 - 8:47	Spike 401		Spike direct to cell --- SF6 = 1.96 lpm, Toluene = 1.9	250	2	130 C	752.3	A	NB/med	
8:57	BKG0821B	20 passes	N2 flowing through cell	500	2	130 C			NB/med	
			All times are approximately 5 minutes fast compared to THC, FTIR computer & manual sampling times							
9:07	N2CON401		N2 through the condenser	250	2	130 C		B	NB/med	
12:16	ICE00401	20 passes	N2 through cell to measure ice band	250	2	130 C	754.4	C	NB/med	
12:22	BKG0821C	20 passes	N2 through cell	500	2	130 C	754.3		NB/med	
12:28	CTS0821B	20 passes	20 ppm ethylene through cell	250	2	130 C	754.3	C	NB/med	
12:43	N2CON402		Nitrogen through the condenser flowing @ 5 lpm	250	2	130 C	755.8	C	NB/med	

FTIR FIELD DATA FORM

(FTIR Sampling Data)

PROJECT NO. 4701-08-02

BAROMETRIC:

PLANT: A

DATE: 8/19/97

OPERATOR: T. Geyer

SAMPLE TIME	FILE NAME	PATH		NUMBER SCANS	RES (cm-1)	CELL TEMP (F)	SPIKED/ UNSPIKED	SAMPLE COND.	SAMPLE FLOW	BKG
7:45	WINAMB01	20 passes	Ambient air through inlet sample line		2	130	U		2 lpm	A
7:58	WOUAMB01	20 passes	Ambient sample from outlet			130	U		2 lpm	A
8:00	OUTSP001		Spike w/toluene & SF6, SF6 flow = 0.99, toluene flow = 0.99			130	S			
8:10	OUTSP102		Spike w/toluene & SF6, SF6 flow = 0.99, toluene flow = 0.99			130	S			
8:17	OUTSP103		Spike w/toluene & SF6, SF6 flow = 0.99, toluene flow = 0.99							
8:25			Took out glass wool plug at inlet to get better flow							
			Spike to inlet, SF6 = 1.06 lpm, Toluene flow = 0.98 lpm,							
			Particulate is restricting and changing inlet flow.							
8:37	INLSP101		SF6 flow became erratic around end of scan							
8:43	INLSP102		SF6 flow = 0.99 lpm, toluene flow = 0.98 lpm			130	S		3 lpm	A
	INLSP103		SF6 flow = 0.99 lpm, toluene flow = 0.98 lpm			130	S		3 lpm	A
9:02			Start sampling at inlet						4 lpm	
9:05	18190001		First spectrum collected at inlet.							
9:10			Started manual run.							
9:12									2 lpm	
9:17	18190007		Last spectrum at inlet							
			Switched to outlet sample.							
9:22	18190009		First outlet spectrum						7 lpm	
9:19			Manual run restarted							
9:50			Putting tip in inlet probe so probe can be pointed away from flow to relieve clogging.							
10:27	18190038		Last outlet spectrum							
10:28			Switched to inlet sample							
	18190040	20 passes	first good inlet spectrum	250	2	130	U		4 lpm	A
			Using elbow on end of probe oriented with the flow							
			Flow is still dropping at the inlet.							
10:45	18190046		Last good inlet spectrum							
11:16			Started filling with inlet							

FTIR FIELD DATA FORM

(FTIR Sampling Data)

PROJECT NO. 4701-08-02

BAROMETRIC:

PLANT: A

DATE: 8/19/97

OPERATOR: T. Geyer

SAMPLE TIME	FILE NAME	PATH		NUMBER SCANS	RES (cm-1)	CELL TEMP (F)	SPIKED/ UNSPIKED	SAMPLE COND.	SAMPLE FLOW	BKG
11:20	18190047	20 passes	Started data collect	250	2	130 C	U		4.5 lpm	B
12:02	18190067		Last good inlet sample. Flow is holding steady.							
12:06			Started filling with outlet sample							
12:10	18190070		First good outlet spectrum							
12:46	18190047		Last good outlet spectrum	250	2	130 C	U		4.5 lpm	B
12:49			Started filling with inlet sample							
12:53	18190090		First good inlet spectrum	250	2	130 C	U		4.5 lpm	B
13:21	18190103		Last good inlet spectrum	250	2	130 C	U		4.5 lpm, good flow	B
13:23			Switched to outlet							
13:25	1819106		First good outlet sample	250	2	130 C	U		5 lpm	B
13:54	1819117		Last good spectrum at outlet	250	2	130 C	U		5 lpm	B
13:56			Started fill at inlet							
13:58	1819120		First good outlet spectrum						5 lpm	B
14:16			Spike on to inlet SF6 at 1.06 lpm, Toluene at 1.00 lpm.							
	18190128		Last good unspiked inlet sample							
14:20	INLSP104		Spiked batch sample - inlet	250	2	130	S		5 lpm	B
14:25-14:30	INLSP105		Spiked batch sample - inlet	250	2	130	S		5 lpm	B
14:32			Spike to outlet							
14:36-14:40	OUTSP104		Spike to outlet location, SF6 at 1.04 lpm,	250	2	130	S		5 lpm	B
			Toluene at 0.98 lpm.							
14:42-14:45	OUTSP105									
1443			SF6 = 1.04 lpm, Toluene = 0.99 lpm							
15:10	CTS0819B		<20 ppm Ethylene direct to cell>		2	130	U		2 lpm	B
			↑Contaminated with propane							
15:18	CTS0819C									
15:15			Good leak check outlet, inlet ~2 lpm leak under vacuum.							

FTIR FIELD DATA FORM

(FTIR Sampling Data)

PROJECT NO. 4701-08-02

BAROMETRIC:

PLANT: A

DATE: 8/20/97

OPERATOR: T. Geyer

SAMPLE TIME	FILE NAME	PATH		NUMBER SCANS	RES (cm-1)	CELL TEMP (F)	SPIKED/ UNSPIKED	SAMPLE COND.	SAMPLE FLOW	BKG
7:45			Spike to outlet						SF6 = 1.95 lpm, toluene = 2.01lpm	
7:49-7:54	OUTSP201		Spike to outlet sample	250	2	130 C	S			B
7:55-8:00	OUTSP202		Spike to outlet sample	250	2	130 C	S			
8:02	OUTSP203		Spike to outlet sample	250	2	130 C	S			
			inlet spike valve was also on spike during above samples							
8:08-8:12	INLSP201		spike to inlet	250	2	130 C	S		SF6 = 1.96 lpm, toluene = 1.99 lpm	
8:13-8:17	INLSP202		spike to inlet	250	2	130 C	S		SF6 = 1.96 lpm, toluene = 1.99 lpm	
8:18-8:23	INLSP203		spike to inlet	250	2	130 C	S		SF6 = 1.96 lpm, toluene = 1.99 lpm	
8:28	Spike201		Spike direct to cell						SF6 = 1.85 lpm, toluene = 1.96 lpm	
8:22			Manual runs started							
8:32			Start sampling at inlet							
8:37	18200001	20 passes	first spectrum	250	2	130 C	U		5 lpm through cell	B
9:12	18200006		Last good inlet spectrum							
			Started outlet sample							
9:20	18200019		first good outlet sample	250	2	130 C	U		4 lpm	B
9:37			Noticed that process conveyor had stopped. But all sampling continues.							
			Received report that process is warming							
9:45			Conveyor moving again							
	18200034		last good outlet spectrum							
9:54			Started inlet sample to cell							
	18200037	20 passes	first good inlet spectrum	250	2	130 C	U		5 lpm	B
10:36	18200055		Last good inlet sample							
10:38			started outlet sample to cell							
10:42	18200058	20 passes	first good sample outlet	250	2	130 C	U		5 lpm	B
11:14	18200073		last good outlet sample	250	2	130 C	U		5 lpm	B
11:19			Started inlet sample to cell							
11:30	18200074		first good inlet spectrum	250	2	130 C	U		4.5 lpm	B
12:04	18200089		Last good inlet spectrum							
12:06			Started outlet sample to cell							
12:09	18200092		First good outlet spectrum	250	2	130 C	U		4.5 lpm	B
12:45	182000108		end of Run #2, last good outlet sample							
13:44	OUTUN301		H/W from outlet	250	2	130 C	U		5 lpm	C
13:49-13:53	OUTUN302		Condensor sample/ outlet	250	2	130 C	U	Cond	4.5 lpm	C

FTIR FIELD DATA FORM

(FTIR Sampling Data)

PROJECT NO. 4701-08-02

BAROMETRIC:

PLANT: A

DATE: 8/20/97

OPERATOR: T. Geyer

SAMPLE TIME	FILE NAME	PATH		NUMBER SCANS	RES (cm-1)	CELL TEMP (F)	SPIKED/ UNSPIKED	SAMPLE COND.	SAMPLE FLOW	BKG
14:05	OUTUN303		Condenser same sample after flow through @ 5 lpm through cell					Cond	755.3 torr	C
14:08			Start continuous collection at outlet					Cond	5 lpm	C
	18200109		First good outlet condenser sample					Cond		
14:30	18200118		Last good outlet condenser sample	250	2	130 C	U	Cond	5 lpm	C
14:36	18200121		first good inlet sample	250	2	130 C	U	Cond	4 lpm	C
15:06	18200137		final outlet sample	250				Cond	4 lpm	
15:19	18200140		first good outlet sample	250	2		U	H/W	4.5 lpm	C
15:19	18200140	20 passes	Outlet first sample	250	2	130 C	U	H/W	5 lpm	C
15:50	18200154		Last outlet sample					H/W		
15:52			Started filling with inlet					H/W		
15:54	18200157		first inlet sample	250	2	130 C	U	H/W	5 lpm	C
15:23	18200170		last inlet sample							
15:28	18200174		first outlet sample	250	2	130 C	U	Cond	5 lpm	
15:58	18200187		last outlet sample	250	2	130 C	U	Cond	5 lpm	
17:01			Started spike to outlet						SF6 flow = 1.99 , toluene = 1.95 lpm	
17:08-17:11	OUTSP304		Spiked outlet through condenser	250	2	130 C		Cond	5 lpm	C
									SF6 flow = 1.95, toluene = 1.93 lpm	
17:20	OUTSP305		Spike spectrum to outlet after spike flow					Cond		
17:26	OUTSP306							Cond		
17:29			Spike on to inlet							
17:36-17:39	INLSP301		Spike to inlet	250	2	130 C	S	Cond	SF6 = 2.00, toluene = 1.93 lpm	
17:44	INLSP302		Spike to inlet through condenser	250	2	130 C	S	Cond	SF6 = 2.00, toluene = 1.93 lpm	C
			End of run #3							

FTIR FIELD DATA FORM

(FTIR Sampling Data)

PROJECT NO. 4701-08-02 **BAROMETRIC:**

PLANT: A **DATE:** 8/21/97 **OPERATOR:** T. Geyer

SAMPLE TIME	FILE NAME	PATH		NUMBER SCANS	RES (cm-1)	CELL TEMP (F)	SPIKED/ UNSPIKED	SAMPLE COND.	SAMPLE FLOW	BKG
7:32-7:36	OUTUN401	20 passes	Outlet	250	2	130 C	U	H/W	5 lpm	A
7:41	OUTUN402		Outlet - Condenser	250	2	130 C	U	Cond	5 lpm	A
7:40			Manual run start							
7:50			Spike on to outlet							
7:55 - 8:00	OUTSP403		Spiked outlet sample	250	2	130 C	S	Cond	F6 = 1.96, toluene = 1.98 lpm (5 lp	A
8:02.- 8:03	OUTSP404		Spiked outlet sample	250	2	130 C	S	Cond	SF6 = 1.95, toluene = 1.97 lpm	
8:10 - 8:15	OUTSP405		Spiked outlet sample	250	2	130 C	S	Cond	SF6 = 1.95, toluene = 1.97 lpm	
			All times are approximately 5 minutes fast relative to the other times (eg. computer,THC,manual)							
8:15			Spike off to outlet							
8:17 - 8:22	INLUN401		Unspiked inlet condenser	250	2	130 C	U	Cond	5 lpm	A
8:24			Spike on to inlet							
8:29 - 8:34	INLSP402		Spiked inlet sample	250	2	130 C	S	Cond	SF6 = 1.96, toluene = 1.97	
8:36	INLSP403		Spiked inlet sample	250	2	130 C	S	Cond	SF6 = 1.96, toluene = 1.97	
			Ethylene is present in samples so will spike with ethylene @ REA							
8:42			Spike off to inlet							
9:10			Start sample from outlet					H/W		
9:14	18210001	20 passes	first outlet sample	250	2	130 C	U	H/W	5 lpm	B
9:45	18210014		last outlet sample	250	2	130 C	U	H/W	5 lpm	B
9:47			Started to fill with inlet sample							
9:52	18210016		first full inlet sample							
10:22	18210031		last inlet sample							
10:30 - 10:35	OUTUN406		Started outlet to cell	250	2	130 C	U	Cond	5 lpm	B
10:33	182100032		first automated outlet spectrum	250	2	130 C	U	Cond	5 lpm	B
11:02	18210044		Last condenser sample outlet	250	2	130 C	U	Cond	5 lpm	B
11:02 - 11:06	INLUN404		Inlet sample	250	2	130 C	U	Cond	4.5 lpm	B
11:14	18210046		Start automated inlet sample	250	2	130 C	U	Cond	4.5 lpm	B
11:39	18210055		last inlet sample	250	2	130 C	U	Cond	4.5 lpm	B
11:40	18210058		Started fill with outlet,	250	2	130 C	U	H/W	5 lpm	B
			first full outlet sample							
12:02	18210066		End of run							
12:16	ICE00401		N2 in cell to measure ice band	250						

Data Sheet: FTIR Background and Calibration Spectra: EPA Work Assignment 4-24

Outlet absorbance Batch Spectra may have copied wrong but interferograms Tom alright 8/26/97

Date	Time	File Name	Path	Location/Notes	#scans	Res (cm-1)	Cell temp (F)	Pressure	BKG	Apod
8/19/97	720 ~~628~~	BK60819A	20 pass	N2 flowing, Background 2lpm	500	2.0	130 C	754.2	-	NB/med
"	730	CTS0819A	20 passes	Ethylene 20 ppm.	250	"	"	762	A	"
"	7:38	TL530819A	20 pass	Toluene 121 ppm						→
		SF60819A		SF6 4 ppm						→
	830	spike 001		spike flow direct-to-cell SF6 0.99 lpm Tol 0.98 lpm						
	~~10:0~~	10:10		Outlet sending propane to outlet spike.						
		10:15		propane spike off.						
	11:09	~~11:09~~ BK60819A	20p	flowing N2 through cell	500	2.0	130C	763 torr	-	NB/med
	1447			Spike direct-to-cell	SF6	1.05 lpm			B	
					Toluene	0.99 lpm				
	1500	spike002		Spike direct-to-cell	SF6	1.08 lpm				
					Toluene	0.99 lpm				
	1517	CTS0819C		20 ppm ethylene.				760.5		B

only the last files copied to the zip disk were there - [illegible]

[illegible]

8/26/97

page 1

Data Sheet: FTIR Samples: EPA Work Assignment 4-24

2.0 through cell

Date	Sample time	File name	Path	Location/Notes	#scans	Res (cm-1)	Cell Temp (F)	Spk/Unsp	Sample Cond.	Sample Flow	BKG
5/9/97	745	WINAMB01	20	ambient air through inlet sample line			130	U	–		A
	758	WOUAMB01	20	ambient sample from outlet			130	U		2 lpm	A
	~~800~~ 8:00	~~OUTS~~ OUTSP001		Spike w/ Toluene & SF6 →				S →		SF6 Flow = 0.99	
										Tol flow = 0.99	
	810	OUTSP102		→							
	817	OUTSP103									
	825	Took out		glass wool plug @ inlet to get better flow.							
	~~835~~	spike to inlet		SF6 flow = 1.06 lpm Toluene flow = 0.98 lpm						particulate is restricting and changing inlet flow.	
	837	inlsp101		SF6 flow became erratic around end of scan							
				{ SF6 flow = 0.99 Tol flow = 0.98							
	8:43	inlsp102					130	S	–	3 lpm	A
		inlsp103		→						3 lpm	A
	9:02			start sampling @ inlet.						4 lpm	
	9:05	18190001		first spectrum collect @ inlet.							
	9:10	started manual Run									
	9:12									2 lpm	
	9:17	18190007		last spectrum @ inlet							
		switched to outlet sample.									
	9:22	18190009		first outlet spectrum						7 lpm	

Data Sheet: FTIR Samples: EPA Work Assignment 4-24 Run 1 page 2

Date	Sample time	File name	Path	Location/Notes	#scans	Res (cm-1)	Cell Temp (F)	Spk/Unsp	Sample Cond.	Sample Flow	BKG
8/19	9:19			Manual Run Restarted							
	9:50			putting tip on inlet probe so probe can be pointed away from flow to relieve clogging.							
	10:27	18190038		last outlet spectrum							
	10:28	18190040	20 path	switched to inlet sample	250	2.0	130	u	–	4 lpm	A
				first good inlet spectrum using elbow on end of probe oriented with the flow.							
				flow is still dripping @ inlet.							
	10:45	18190046		last good inlet spectrum							
	11:16			started filling with inlet							
	11:20	18190047	20P	started data collect	250	2.0 cm-1	130C	u	–	4.5 lpm	B
	12:02	18190067		last good inlet sample flow is holding steady.							
	12:06			started filling with outlet sample.							
	12:10	18190070		first good outlet spectrum							
	12:46	18190047		last good outlet spectrum	250	2.0	130	u	–	4.5 lpm	B
	1249			started filling with inlet sample.							
	1253	18190090		first good inlet spectrum	250	2.0	130	u	–	4.5 lpm	B
	1321	18190103		last good inlet spectrum						→ 4.5 good flow	
	1323			Switched to outlet							
	1325	1819106		first good outlet sample	250	2.0	130	u	–	5 lpm	B
	1354	1819117		last good spectrum @ outlet						→ 5 lpm	B
	1356			started filling inlet							

1358 1819120 first good outlet spectrum 5 lpm B

Data Sheet: FTIR Samples:

EPA Work Assignment 4-

page 3

Date	Sample time	File name	Path	Location/Notes	#scans	Res (cm-1)	Cell Temp (F)	Spk/Unsp	Sample Cond.	Sample Flow	BKG
6/19	1416			Spike on to inlet			SF6 @		1.06 lpm		
		18190128		last good unspiked inlet Sample			Toluene @		1.00 lpm		
								↑			
	1420	inlsp104		spiked batch sample - inlet	250	2.0	130	S	–	5 lpm	B
	1425-1430	inlsp105		"						→	
	1432			spike to outlet							
	1436-1440	outsp104		Spike to outlet location	250	2.0	130	S	–	5 lpm	B
							SF6 @		1.04 lpm		
	1442-1445	outsp105					Toluene @		0.98	lpm	
						1443	SF6		1.04 lpm		
							Toluene		0.99		
Contaminated with propane	1510	CTS0819B		20 ppm ethylene direct to cell.		20	130	u	~	2 lpm	B
	1518	CTS0819C									
	1515			good leak check outlet							
				inlet ~ 2 lpm leak		under vacuum.					

Data Sheet: FTIR Background and Calibration Spectra: EPA Work Assignment 4-24

Date	Time	File Name	Path	Location/Notes	#scans	Res (cm-1)	Cell temp (F)	Pressure	BKG	Apod
8/20/96				Good leak checks at inlet and outlet Good leak check cell & jumper line						
	700	BK608020a	20 passes	N_2 flowing through cell.	500	2.0	130 C	756.8	-	NB med
	710	CTS0820a		20 ppm ethylene through cell.	250	2.0	130 C	756.4	A	NB med
	735	BK608020b		N_2 through cell - getting a large ice band → detector holding ~ 8 hrs						
	1320	BK60820c	20 p	N_2 through cell	500	2.0	130 C	758.4	-	NB/med
	1754	Spike301		Spike to cell	250	2.0	130	751.2		C
							SF_6 = 1.40 lpm			
							Toluene = 1.95 lpm			
	1805	CTS0820b		20 ppm ethylene to cell	250	2.0	130	757.3	C	NB/med

Data Sheet: FTIR Samples: EPA Work Assignment 4-24 Pg 4

Date	Sample time	File name	Path	Location/Notes	#scans	Res (cm-1)	Cell Temp (F)	Spk/Unsp	Sample Cond.	Sample Flow	BKG
8/20/97	745			Spike to outlet						SF6 1.95 lpm	
	749 754	OUTSP201		spike to outlet sample	250	2.0	130 C	S	—	Toluene 2.01 lpm	B
	755 - 800	OUTSP202		"							
	802	OUTSP203		"							
				inlet spike valve was also on spike. during above samples.							
	808-812	INLSP201		spike to inlet	250	2.0	130C	S	-	SF6 - 1.96 lpm	
	813-817	INLSP202		"						Toluene - 1.94 lpm	
	818-823	INLSP203		"							
	828	spike 201		spike direct-to-cell						SF6 - 1.85 Toluene 1.96	
	822			Manual Runs Started.							
	832			Start sampling @ inlet							
	837	18200001	20 purges	first spectrum	250	2.0	130 C	U	-	5 lpm - through cell	B
	912	18200016		last good inlet spectrum							
	920	18200019		started outlet sample first good outlet sample	250	2.0	130 C	U	-	4 lpm "	B
	937			advised that process conveyor had stopped. But all sampling continues Received report that process is [illegible]							
	945			Conveyor moving again.							
		18200034		last good outlet spectrum							

Data Sheet: FTIR Samples: EPA Work Assignment 4-24

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Date	Sample time	File name	Path	Location/Notes	#scans	Res (cm-1)	Cell Temp (F)	Spk/Unsp	Sample Cond	Sample Flow	BKG
3/20/97	959			Started inlet sample to cell							
		18200037	20p	first good inlet spectrum	250	2.0	130 C	u	–	5 lpm	B
	1036	18200055		last good inlet sample.							
	1038			Started outlet sample to cell 250							
	1042	~~18~~18200058	20p	first good sample outlet	250	2.0	130 C	u	–	5 lpm	B
	1114	18200073		last good outlet sample	250	2.0	130 C	u	–	5 lpm	B
	1119			Started inlet sample to cell							
	1130	18200074		first good inlet spectrum	250	2.0	130 C	u	–	4.5 lpm	B
	1204	18200089		last good inlet spectrum							
	1206			started outlet sample to cell							
	1209	18200092		~~las~~ first good outlet spectrum	250	2.0	130 C	u	–	4.5 lpm	B
	1245	18200108		end of Run # 2	last good outlet sample						
	1344	OUTUN301		New pump outlet,	250	2.0	130 C	u	–	5 lpm	C
	1349-1353	OUTUN302		Condenser sample / outlet	250	2.0	130	U	Cond	4.5 lpm	C
755.7 torr	1405	OUTUN303		" same sample	after	flow through	@ 5 lpm		cond. through cell		C
	1408	18200109		Start continuous collect 6 outlet first good outlet condenser sample					Cond ↓	5 lpm	C
	1430	18200118		last good outlet condenser sample	250	2.0	130 C	u	Cond	5 lpm	C
	1436	18200121		first good inlet sample	250	2.0	130 C	u	Cond	4 lpm	C
	1500	18200137		final inlet sample	250				Cond	4 lpm	
	1519	18200140		First good outlet sample	250	2.0	~~130~~	u	–	4.5 lpm	C

Data Sheet: FTIR Samples: EPA Work Assignment 4-24

6

Date	Sample time	File name	Path	Location/Notes	#scans	Res (cm-1)	Cell Temp (F)	Spk/Unsp	Sample Cond.	Sample Flow	BKG
8/20/97	1517	18200140	20m	outlet first Sample	250	2.0	130C	U	H/W	5 lpm	C
	1550	18200154		last outlet sample					H/W		
	1552			started filling w/ inlet					H/W		
	1554	18200157		first inlet sample	250	2.0	130C	u	H/W	5 lpm	C
	1523	18200170		last inlet sample							
	1528	18200174		first outlet sample	250	2.0	130C	u	Cond.	5 lpm	
	1558	18200187		last outlet sample	250	2.0	130C	u	Cond	5 lpm	
	1701			~~SF6~~ started spike to outlet				SF6 flow = 1.99			
	1708 → 1711	OUTSP304		spiked outlet through Condenser	250	[illegible]	130C	Toluene = 1.95	Condenser	5 lpm	C
	~~1716~~	~~On~~						SF6	1.95		
								Toluene	1.93		
	1720 -	OUTSP305		Spike spectrum to outlet after spike flow					Condenser		
	1726	outsp306							"		
	1729			spike on to inlet							
	1736 → 1739	INLSP301		spike to inlet	250	2.0	130C	sp	Condenser		
									SF6 2.00		
end of Run 3	1744 -	INLSP302		spike to inlet through condenser					Toluene 1.93	→	C
		Sp									

Data Sheet: FTIR Samples: EPA Work Assignment 4-24

Date	Sample time	File name	Path	Location/Notes	#scans	Res (cm-1)	Cell Temp (F)	Spk/Unsp	Sample Cond.	Sample Flow	BKG
2/21/97	732-740	OUTUN401	20m	outlet	250	2.0	130 C	U	H/W	5lpm	A
	741-	OUTUN402		outlet - Condenser	"	2.0	130 C	u	Cond	"	A
	740			Manual Run start.							
	750			Spike on to outlet						SF6 1.86 lpm Toluene 1.98 lpm	
	755-800	OUTSP403		spiked outlet sample	250	2.0	130C	Sp	Cond	5lpm	A
	802-808 evacuate ~~805~~	OUTSP404								SF6 = 1.95	lpm
	810-815	OUTSP405								Tol = 1.97	
	~~810~~										
				NOTE: All Times are ~~10~~ ~ 5 minutes fast relative to other times - Computer, THC, Manual.							
	815			Spike off to outlet.							
	817-832	INLUN401		unspiked inlet Condenser	250	2.0	130 C	u	Cond.	5lpm	A
	824-			spike on to inlet							
	829-834	INLSP402		spiked inlet sample	250	2.0	130 C	Sp	Cond.	SF6 = 1.96 Toluene = 1.97	
	836-	INLSP403		spiked inlet sample							
				Ethylene is present in samples so will Spike with Ethylene @ REA.							
	842			spike off to inlet							

Data Sheet: FTIR Background and Calibration Spectra: EPA Work Assignment 4-24

Date	Time	File Name	Path	Location/Notes	#scans	Res (cm-1)	Cell temp (F)	Pressure	BKG	Apod
8/21/97	715	BKG0821A	20p	N_2 flowing through cell	500	2.0	130 C	752.3	—	NB/med
	725	CTS0821A	20p	20 ppm Ethylene through cell	250	"	"	"	A	"
	842-847	Spike 401		Spike direct-to-cell	250	"	"	"	A	"
							SF_6 = 1.96 lpm			
							Toluene = 1.96 lpm			
	857	BKG0821B	20p	N_2 through cell	~~250~~ 500	"	130C	"		NB/med.
				Note: All times are ≈ 5 minutes fast compared to THC, FTIR computer + manual sampling times.						
	9:07	N2CON401		N_2 through the condenser	250	2.0	130C	"	B	NB/med
	1216	ICE004d	20p	N_2 through cell to measure ice Band	250	2.0	130 C	754.4	B	NB/med
	1222	BKG0821C	20 passes	N_2 through cell	500	2.0	130C	754.3	—	NB/med
	1228	CTS0821B	"	20 ppm Ethylene through cell	250	→	→	→	C	"
	1243	N2CON402		Nitrogen through the Condenser flowing @ 5 lpm	250	2.0	130	755.8	C	NB/med

Data Sheet: FTIR Samples: EPA Work Assignment 4-24   Page 8

Date	Sample time	File name	Path	Location/Notes	#scans	Res (cm-1)	Cell Temp (F)	Spk/Unsp	Sample Cond.	Sample Flow Through cell	BKG
8/21/97	910			start sample flow outlet					H/w		
	914	18210001	20 passes	first outlet sample	250	2.0	130 C	u	H/w	5 lpm	B
	9:45	18210014		last outlet Sample	→					→	B
	9:47			started to fill w/ dry inlet sample							
	9:52	18210016		first full inlet Sample							
	10:22	18210031		last inlet Sample							
	1030 - 1035	outlcon406		Started outlet to cell	250	2.0	130C	u	Condenser	5 lpm	B
2 start	1033	182100032		first automated outlet spectrum	250	2.0	130C	u	~~H/w~~ Condenser	5 lpm	B
	1102	18210044		last ~~outlet~~ Condenser sample outlet		→				→	
	1102 - 1106	INLUN404		inlet sample	250	2.0	130 C	u	Condenser	4.5 ~~5~~ lpm	B
	1114	18210046		Start automated inlet Sample	250	2.0	130 C	u	Condenser	4.5 lpm	B
	1139	18210055		last inlet Sample	→					→	
	1140	18210058 →		started fill with outlet					H/w		
				first full outlet sample	250	2.0	130 c	u	H/w	5 lpm	B
	1202	18210066		end of Run							
	1216	ICE00401		N_2 in cell to measure ice Band	250						

B-3 FTIR FLOW AND TEMPERATURE READINGS

FTIR FIELD DATA FORM

PROJECT NO. 3804-24 **PLANT:** ____ **DATE:** 8/21/97 **BAROMETRIC:** 752.6 mm Hg

INLET					
CLOCK TIME	DELTA P IN. H2O	STACK TEMP.	PROBE TEMP.	PROBE BOX TEMP.	
856	.65	215	290	277	
908	.65	196	287	277	
941	0.59	196	286	279	
1010	0.46	176	285	279	
1104	0.42	184	286	279	
1135	0.53	191	288	278	
1150	0.63	201	288	278	

OUTLET					
CLOCK TIME	DELTA P IN. H2O	STACK TEMP.	PROBE TEMP.	PROBE BOX TEMP.	
856		174	276	279	
~~908~~	0.41				
908	0.41	180	276	280	
941	0.47	175	276	279	
1010	0.34	170	278	279	
1104	0.39	179	273	280	
1135	0.39	179	275	279	
1150	0.46	184	277	281	

OPERATOR:

FTIRFORM.XLS

08-08-97

1540 N_2 @ 0.5 lpm through cell
purge to optibus is off

1200 psi
P = 759.7
900 psi @ 6:00

FTIR FIELD DATA FORM

PROJECT NO. 3804-24 **PLANT:**

DATE: 8/20/97 **BAROMETRIC:** 759 torr
29.6 in Hg

INLET filter

CLOCK TIME	DELTA P IN. H2O	STACK TEMP.	PROBE TEMP.	PROBE BOX TEMP.	manifold T
835	0.75	218	286	279	
905	0.78	220	288	273	
952	0.83	251	283	277	
1042	0.86	270	285	279	
1135	0.97	258	283	278	
1235	0.85	251	284	277	265 F
1437	0.69	222	286	280	
1521	0.61	226	283	278	
1744	0.25	165	287	277	

OUTLET

CLOCK TIME	DELTA P IN. H2O	STACK TEMP.	PROBE TEMP.	PROBE BOX TEMP.	
835	0.43	193	278	280	
905	0.49	198	277	280	
952	0.45	215	282	280	
1042	0.69	236	277	278	
1135	0.77	233	281	280	
1235	0.75	231	278	279	
1437	0.43	207	278	280	
1521	0.43	206	281	279	
1744	0.40	167	279	280	

OPERATOR:

probably clogged

FTIR FIELD DATA FORM

PROJECT NO. 3804-24 **PLANT:** _ **DATE:** 8/19/97 **BAROMETRIC:** 759 torr

29.76 in Hg

Power just back on

INLET	Filter				
CLOCK TIME	**DELTA P IN. H2O**	**STACK TEMP.**	**PROBE TEMP.**	**PROBE BOX TEMP.**	
9:10	0.60	233	284	285	
9:48	0.69	231	286	279	
10:22	0.69	233	279	276	Back in stack
11:23	0.70	226	284	276	
12:17	0.45	176	284	279	
14:40	0.52	169	285	280	
14:50	Run	Completed			

OUTLET	Filter				
CLOCK TIME	**DELTA P IN. H2O**	**STACK TEMP.**	**PROBE TEMP.**	**PROBE BOX TEMP.**	
9:10	0.41	206	277	279 F	
9:48	0.41	208	277	279	
10:22	0.42	206	279	280	
11:23	0.40	211	281	279	
12:17	0.33	171	277	280	
14:40	0.33	165	278	281	
~~1520~~					
1520		94	281	282	

Probe [illegible] of [illegible]

OPERATOR:

0600

11 hrs -1600 psi

1900

N2

2500 psi

1 lpm → cell
≤ 1 lpm → purge

4701-08-02-04

B-86

FTIR FIELD DATA FORM

PROJECT NO. 3804-24 **PLANT:** _ **DATE:** 8/18/97 **BAROMETRIC:** 755 mm Hg

INLET

CLOCK TIME	DELTA P IN. H2O	STACK TEMP.	PROBE TEMP.	PROBE BOX TEMP.	
1820	BKG	0818A		20 passes	NB. fled
1825	CTS	0818A		BKG-A	Same settings

OUTLET

CLOCK TIME	DELTA P IN. H2O	STACK TEMP.	PROBE TEMP.	PROBE BOX TEMP.	
2 cm-1 Res		Cell		131 °C	N2 flowing
		500 scans			
250 scans.					

OPERATOR:

C-1 CALIBRATION GAS CERTIFICATES

213-585-2154
FAX# 213-585-0582

LIQUID CARBONIC
CYLINDER GAS PRODUCTS
5700 SOUTH ALAMEDA STREET • LOS ANGELES, CA 90058

CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER ENV. & INDUST. DIST.

P.O NUMBER 80110932 RE:032295-1

REFERENCE STANDARD

COMPONENT		NIST SRM NO.	CYLINDER NO.	CONCENTRATION
PROPANE	GM18	vs 2649	SA 7651	5019 ppm

ANALYZER READINGS

R=REFERENCE STANDARD Z=ZERO GAS C=GAS CANDIDATE

1. COMPONENT PROPANE GM18 ANALYZER MAKE-MODEL-S/N HP 5890 SERIES II S/N 3310A48533

ANALYTICAL PRINCIPLE GC/ FLAME IONIZATION

LAST CALIBRATION DATE 03/28/95

FIRST ANALYSIS DATE 04/07/95

SECOND ANALYSIS DATE

Z	0	R	2607332	C	2744525	CONC.	5283 ppm	Z		R		C		CONC.	
R	2612210	Z	0	C	2745146	CONC.	5274 ppm	R		Z		C		CONC.	
Z	0	C	2737157	R	2602984	CONC.	5278 ppm	Z		C		R		CONC.	

U/M uV-s MEAN TEST ASSAY 5278 ppm U/M uV-s MEAN TEST ASSAY

Values not valid below 150 psig

THIS CYLINDER NO.	SA 8458	CERTIFIED CONCENTRATION	
HAS BEEN CERTIFIED ACCORDING TO SECTION	EPA-600/R93/224	PROPANE	5278 ppm
OF TRACEABILITY PROTOCOL NO.	Rev. 9/93	NITROGEN	BALANCE
PROCEDURE	G1		
CERTIFIED ACCURACY	± 1 % NIST TRACEABLE		
CYLINDER PRESSURE	2000 PSIG		
CERTIFICATION DATE	04/07/95		
EXPIRATION DATE	04/07/98 TERM 36 MONTHS		

ANALYZED BY

CERTIFIED BY JUAN T. YOUNG

213-[illegible]-2154
FAX# 213-[illegible]-0582

LIQUID CARBONIC

CYLINDER GAS PRODUCTS

5700 SOUTH ALAMEDA STREET • LOS ANGELES, CA 90058

CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

CUSTOMER ENV. & INDUST. DIST. **P.O NUMBER** 80110932 RE:032295-1

REFERENCE STANDARD

COMPONENT		NIST SRM NO.	CYLINDER NO.	CONCENTRATION
PROPANE	GMIS	vs 2649	SA 7651	5019 ppm

ANALYZER READINGS

R=REFERENCE STANDARD *Z=ZERO GAS* *C=GAS CANDIDATE*

1. COMPONENT PROPANE GMIS ANALYZER MAKE-MODEL-SN HP 5890 SERIES II S/N 3310A48533
ANALYTICAL PRINCIPLE GC/ FLAME IONIZATION LAST CALIBRATION DATE 03/28/95
FIRST ANALYSIS DATE 04/07/95 SECOND ANALYSIS DATE

Z	0	R	2607332	C	2744525	CONC.	5283 ppm	Z	R	C	CONC.
R	2612210	Z	0	C	2745146	CONC.	5274 ppm	R	Z	C	CONC.
Z	0	C	2737157	R	2602984	CONC.	5278 ppm	Z	C	R	CONC.
U/M	uV-s			MEAN TEST ASSAY			5278 ppm	U/M uV-s			MEAN TEST ASSAY

Values not valid below 150 psig

THIS CYLINDER NO.	SA 8458	CERTIFIED CONCENTRATION	
HAS BEEN CERTIFIED ACCORDING TO SECTION	EPA-600/R93/224	PROPANE	5278 ppm
OF TRACEABILITY PROTOCOL NO.	Rev. 9/93	NITROGEN	BALANCE
PROCEDURE	G1		
CERTIFIED ACCURACY	± 1 % NIST TRACEABLE		
CYLINDER PRESSURE	2000 PSIG		
CERTIFICATION DATE	04/07/95		
EXPIRATION DATE	04/07/98 TERM 36 MONTHS		

ANALYZED BY

CERTIFIED BY JUAN T. YOUNG

Scott Specialty Gases

Shipped From:
6141 EASTON ROAD
PLUMSTEADVILLE PA 18949-0310
Phone: 215-766-8861

PO BOX 310
Fax: 215-766-2070

CERTIFICATE OF ANALYSIS

MIDWEST RESEARCH
TOM GEYER
425 VOLKER BLVD

KANSAS CITY MO 64110

PROJECT #: 01-88514-001
PO#: 029257
ITEM #: 01021951 1AL
DATE: 3/25/97

CYLINDER #: ALM023940
ANALYTICAL ACCURACY: +-1%
FILL PRESSURE: 2000 PSIG
BLEND TYPE : GRAVIMETRIC MASTER GAS

COMPONENT	REQUESTED GAS CONC MOLES		ANALYSIS (MOLES)	
ETHYLENE	20.	PPM	20.01	PPM
NITROGEN		BALANCE		BALANCE

CERTIFIED

ANALYST: G. Kogut
GENYA KOGUT

Scott Specialty Gases

Shipped From: 6141 EASTON ROAD
PLUMSTEADVILLE PA 18949-0310
Phone: 215-766-8861
PO BOX 310
Fax: 215-766-2070

CERTIFICATE OF ANALYSIS

MIDWEST RESEARCH
DAVE ALBURTY, X1525
425 VOLKER BLVD

KANSAS CITY MO 64110

PROJECT #: 01-89796-005
PO#: 029872
ITEM #: 01023912 4AL
DATE: 5/13/97

CYLINDER #: ALM057730
FILL PRESSURE: 2000 PSIG
BLEND TYPE : CERTIFIED MASTER GAS

ANALYTICAL ACCURACY: +/- 2%

COMPONENT	REQUESTED GAS CONC MOLES		ANALYSIS (MOLES)	
TOLUENE	120.	PPM	121.	PPM
AIR		BALANCE		BALANCE

CERTIFIED

ANALYST:
GENYA KOGUT

Scott Specialty Gases

Shipped From: 1290 COMBERMERE STREET
TROY MI 48083
Phone: 248-589-2950
Fax: 248-589-2134

CERTIFICATE OF ANALYSIS

MIDWEST RESEARCH
MELISSA TUCKER; # 026075
425 VOLKER BLVD

KANSAS CITY MO 64110

PROJECT #: 05-97268-002
PO#: 026075
ITEM #: 05023822 4A
DATE: 6/03/96

CYLINDER #: A7853
FILL PRESSURE: 2000 PSI

ANALYTICAL ACCURACY: +/- 2%
PRODUCT EXPIRATION: 6/03/1997

BLEND TYPE : CERTIFIED MASTER GAS

COMPONENT	REQUESTED GAS CONC MOLES	ANALYSIS (MOLES)
SULFUR HEXAFLUORIDE	4. PPM	4.01 PPM
NITROGEN	BALANCE	BALANCE

CERTIFIED MASTER GAS

ANALYST:

Scott Specialty Gases, Inc.

Shipped From:
6141 EASTON ROAD
PLUMSTEADVILLE PA 18949-0310
Phone: 215-766-8861

PO BOX 310
Fax: 215-766-2070

CERTIFICATE OF ANALYSIS

MIDWEST RESEARCH
PO#014952
425 VOLKER BLVD

KANSAS CITY MO 64110

PROJECT #: 01-59176-001
PO#: 014952
ITEM #: 01021912 2AL
DATE: 7/20/94

CYLINDER #: ALM020008

ANALYTICAL ACCURACY: +/-1%

BLEND TYPE : ACUBLEND MASTER GAS

COMPONENT	REQUESTED GAS CONC MOLES		ANALYSIS (MOLES)	
ETHYLENE	100.	PPM	101.	PPM
AIR		BAL		BAL

CERTIFIED

ANALYST: ROBERT K. KUFROVICH

Scott Specialty Gases

Shipped From:
6141 EASTON ROAD
PLUMSTEADVILLE PA 18949-0310
PO BOX 310
Phone: 215-766-8861
Fax: 215-766-2070

CERTIFICATE OF ANALYSIS

MIDWEST RESEARCH

CROSSROADS CORP PARK
5520 DILLARD RD, SUITE 100
CARY NC 27511

PROJECT #: 01-08674-002
PO#: A035678
ITEM #: 01021912 2AL
DATE: 9/22/98

CYLINDER #: ALM020008
ANALYTICAL ACCURACY: +\-2%
FILL PRESSURE: 400 PSIG

BLEND TYPE : ACUBLEND MASTER GAS

COMPONENT	REQUESTED GAS CONC MOLES	ANALYSIS (MOLES)
ETHYLENE	100. PPM	101. PPM
AIR	BALANCE	BALANCE

ANALYST:
GENIA KOGUT

C-2 ENVIRONICS MASS FLOW METER CALIBRATIONS

S/N 2073

ENVIRONICS FLOW CONTROLLER CALIBRATION SHEET

Mf #: 1, Description: AIR , Size: 10000. SCCM, K-factor: 1.0

SERIAL # AW9502156

This flow controller was calibrated using a Sierra Cal Bench(TM), a traceable Primary Flow Standard Calibration System. This calibration is referenced to dry air at a temperature of 32F (__C) and a pressure of 29.92 in.Hg (760Torr).

	Set Flow	True Flow
5 %	500.0 CCM	498.79 CCM
10 %	1000.0 CCM	1009.0 CCM
20 %	2000.0 CCM	2029.8 CCM
30 %	3000.0 CCM	3058.2 CCM
40 %	4000.0 CCM	4088.8 CCM
50 %	5000.0 CCM	5121.9 CCM
60 %	6000.0 CCM	6143.3 CCM
70 %	7000.0 CCM	7178.3 CCM
80 %	8000.0 CCM	8206.3 CCM
90 %	9000.0 CCM	9224.6 CCM
100%	10000. CCM	10252. CCM

Calibration data was last saved on Friday 03 January 97 at 16:22:00

Verified by: Karl Senticany Date: 1 - 3 - 97

ENVIRONICS FLOW CONTROLLER CALIBRATION SHEET

Mf #: 2, Description: AIR , Size: 10000, SCCM, K-factor: 1.0

SERIAL # AW95D2157

This flow controller was calibrated using a Sierra Cal Bench(TM), a traceable Primary Flow Standard Calibration System. This calibration is referenced to dry air at a temperature of 32F (__C) and a pressure of 29.92 in.Hg (760Torr).

	Set Flow	True Flow
5 %	500.0 CCM	510.51 CCM
10 %	1000.0 CCM	1021.4 CCM
20 %	2000.0 CCM	2046.9 CCM
30 %	3000.0 CCM	3074.8 CCM
40 %	4000.0 CCM	4103.8 CCM
50 %	5000.0 CCM	5136.6 CCM
60 %	6000.0 CCM	6156.8 CCM
70 %	7000.0 CCM	7182.5 CCM
80 %	8000.0 CCM	8203.3 CCM
90 %	9000.0 CCM	9219.5 CCM
100%	10000. CCM	10233. CCM

Calibration data was last saved on Friday 03 January 97 at 17:09:00

Verified by: Karl Sentiany Date: 1 - 3 - 97

ENVIRONICS FLOW CONTROLLER CALIBRATION SHEET

Mf #: 3, Description: AIR , Size: 1000.0 SCCM, K-factor: 1.0

SERIAL # AW9502153

This flow controller was calibrated using a Sierra Cal Bench(TM), a traceable Primary Flow Standard Calibration System. This calibration is referenced to dry air at a temperature of 32F (__C) and a pressure of 29.92 in.Hg (760Torr).

	Set Flow	True Flow
5 %	50.0 CCM	50.515 CCM
10 %	100.0 CCM	101.84 CCM
20 %	200.0 CCM	204.84 CCM
30 %	300.0 CCM	306.67 CCM
40 %	400.0 CCM	408.82 CCM
50 %	500.0 CCM	510.43 CCM
60 %	600.0 CCM	611.44 CCM
70 %	700.0 CCM	713.59 CCM
80 %	800.0 CCM	816.61 CCM
90 %	900.0 CCM	918.19 CCM
100%	1000.0 CCM	1021.3 CCM

Calibration data was last saved on Friday 03 January 97 at 17:55:00

Verified by: Karl Sentiany Date: 1 - 3 - 97

ENVIRONICS FLOW CONTROLLER CALIBRATION SHEET

Mf #: 4, Description: AIR , Size: 100.0 SCCM, K-factor: 1.0

SERIAL # AW9612049

This flow controller was calibrated using a Sierra Cal Bench(TM), a traceable Primary Flow Standard Calibration System. This calibration is referenced to dry air at a temperature of 32F (__C) and a pressure of 29.92 in.Hg (760Torr).

	Set Flow	True Flow
5 %	5.0 CCM	5.236 CCM
10 %	10.0 CCM	10.269 CCM
20 %	20.0 CCM	20.434 CCM
30 %	30.0 CCM	30.524 CCM
40 %	40.0 CCM	40.606 CCM
50 %	50.0 CCM	50.636 CCM
60 %	60.0 CCM	60.683 CCM
70 %	70.0 CCM	70.779 CCM
80 %	80.0 CCM	80.917 CCM
90 %	90.0 CCM	91.035 CCM
100%	100.0 CCM	101.12 CCM

Calibration data was last saved on Friday 03 January 97 at 19:11:00

Verified by: Karl Sentivany Date: 1 - 3 - 97

APPENDIX D

TEST METHODS AND HCl VALIDATION PAPER

D-1 EPA METHOD 320

Appendix A of part 63 is amended by adding, in numerical order, Methods 320 and 321 to read as follows:

Appendix A to Part 63-Test Methods

*****

TEST METHOD 320

MEASUREMENT OF VAPOR PHASE ORGANIC AND INORGANIC EMISSIONS BY EXTRACTIVE FOURIER TRANSFORM INFRARED (FTIR) SPECTROSCOPY

1.0 Introduction.

Persons unfamiliar with basic elements of FTIR spectroscopy should not attempt to use this method. This method describes sampling and analytical procedures for extractive emission measurements using Fourier transform infrared (FTIR) spectroscopy. Detailed analytical procedures for interpreting infrared spectra are described in the "Protocol for the Use of Extractive Fourier Transform Infrared (FTIR) Spectrometry in Analyses of Gaseous Emissions from Stationary Sources," hereafter referred to as the "Protocol." Definitions not given in this method are given in appendix A of the Protocol. References to specific sections in the Protocol are made throughout this Method. For additional information refer to references 1 and 2, and other EPA reports, which describe the use of FTIR spectrometry in specific field measurement applications and validation tests. The sampling procedure described here is extractive. Flue gas is extracted through a heated gas transport and handling system. For some sources, sample conditioning systems may be applicable. Some examples are given in this method. Note: sample conditioning systems may be used providing the method validation requirements in Sections 9.2 and 13.0 of this method are met.

1.1 Scope and Applicability.

1.1.1 Analytes. Analytes include hazardous air pollutants (HAPs) for which EPA reference spectra have been developed. Other compounds can also be measured with this method if reference spectra are prepared according to section 4.6 of the protocol.

1.1.2 Applicability. This method applies to the analysis of vapor phase organic or inorganic compounds which absorb energy in the mid-infrared spectral region, about 400 to 4000 cm^{-1} (25 to 2.5 μm). This method is used to determine compound-specific concentrations in a multi-component vapor phase sample, which is contained in a closed-path gas cell. Spectra of samples are collected using double beam infrared absorption spectroscopy. A computer program is used to analyze spectra and report compound concentrations.

1.2 Method Range and Sensitivity. Analytical range and sensitivity depend on the frequency-dependent analyte absorptivity, instrument configuration, data collection parameters, and gas stream composition. Instrument factors include: (a) spectral resolution, (b) interferometer signal averaging time, (c) detector sensitivity and response, and (d) absorption path length.

1.2.1 For any optical configuration the analytical range is between the absorbance values of about .01 (infrared transmittance relative to the background = 0.98) and 1.0 (T = 0.1). (For absorbance > 1.0 the relation between absorbance and concentration may not be linear.)

1.2.2 The concentrations associated with this absorbance range depend primarily on the cell path length and the sample temperature. An analyte absorbance greater than 1.0, can be lowered by decreasing the optical path length. Analyte absorbance increases with a longer path length. Analyte detection also depends on the presence of other species exhibiting absorbance in the same analytical region. Additionally, the estimated lower absorbance (A) limit (A = 0.01) depends on the root mean square deviation (RMSD) noise in the analytical region.

1.2.3 The concentration range of this method is determined by the choice of optical configuration.

1.2.3.1 The absorbance for a given concentration can be decreased by decreasing the path length or by diluting the sample. There is no practical upper limit to the measurement range.

1.2.3.2 The analyte absorbance for a given concentration may be increased by increasing the cell path length or (to some extent) using a higher resolution. Both modifications also cause a corresponding increased absorbance for all compounds in the sample, and a decrease in the signal throughput. For this reason the practical lower detection range (quantitation limit) usually depends on sample characteristics such as moisture content of the gas, the presence of other interferants, and losses in the sampling system.

1.3 Sensitivity. The limit of sensitivity for an optical configuration and integration time is determined using appendix D of the Protocol: Minimum Analyte Uncertainty, (MAU). The MAU depends on the RMSD noise in an analytical region, and on the absorptivity of the analyte in the same region.

1.4 Data Quality. Data quality shall be determined by executing Protocol pre-test procedures in appendices B to H of the protocol and post-test procedures in appendices I and J of the protocol.

1.4.1 Measurement objectives shall be established by the choice of detection limit (DL_i) and analytical uncertainty (AU_i) for each analyte.

1.4.2 An instrumental configuration shall be selected. An estimate of gas composition shall be made based on previous test data, data from a similar source or information gathered in a pre-test site survey. Spectral interferants shall be identified using the selected DL_i and AU_i and band areas from reference spectra and interferant spectra. The baseline noise of the system shall be measured in each analytical region to determine the MAU of the instrument configuration for each analyte and interferant (MIU_i).

1.4.3 Data quality for the application shall be determined, in part, by measuring the RMS (root mean square) noise level in each analytical spectral region (appendix C of the Protocol). The RMS noise is defined as the RMSD of the absorbance values in an analytical region from the mean absorbance value in the region.

1.4.4 The MAU is the minimum analyte concentration for which the AU_i can be maintained; if the measured analyte concentration is less than MAU_i, then data quality are unacceptable.

2.0 Summary of Method.

2.1 Principle. References 4 through 7 provide background material on infrared spectroscopy and quantitative analysis. A summary is given in this section.

2.1.1 Infrared absorption spectroscopy is performed by directing an infrared beam through a sample to a detector. The frequency-dependent infrared absorbance of the sample is measured by comparing this detector signal (single beam spectrum) to a signal obtained without a sample in the beam path (background).

2.1.2 Most molecules absorb infrared radiation and the absorbance occurs in a characteristic and reproducible pattern. The infrared spectrum measures fundamental molecular properties and a compound can be identified from its infrared spectrum alone.

2.1.3 Within constraints, there is a linear relationship between infrared absorption and compound concentration. If this frequency dependent relationship (absorptivity) is known (measured), it can be used to determine compound concentration in a sample mixture.

2.1.4 Absorptivity is measured by preparing, in the laboratory, standard samples of compounds at known concentrations and measuring the FTIR "reference spectra" of these standard samples. These "reference spectra" are then used in sample analysis: (1) compounds are detected by matching sample absorbance bands with bands in reference spectra, and (2) concentrations are measured by comparing sample band intensities with reference band intensities.

2.1.5 This method is self-validating provided that the results meet the performance requirement of the QA spike in sections 8.6.2 and 9.0 of this method, and results from a previous method validation study support the use of this method in the application.

2.2 Sampling and Analysis. In extractive sampling a probe assembly and pump are used to extract gas from the exhaust of the affected source and transport the sample to the FTIR gas cell. Typically, the sampling apparatus is similar to that used for single-component continuous emission monitor (CEM) measurements.

2.2.1 The digitized infrared spectrum of the sample in the FTIR gas cell is measured and stored on a computer. Absorbance band intensities in the spectrum are related to sample concentrations by what is commonly referred to as Beer's Law.

$$A_i = a_i\, b\, c_i \qquad \textbf{(1)}$$

where:

A_i = absorbance at a given frequency of the ith sample component.

a_i = absorption coefficient (absorptivity) of the ith sample component.

b = path length of the cell.

c_i = concentration of the ith sample component.

2.2.2 Analyte spiking is used for quality assurance (QA). In this procedure (section 8.6.2 of this method) an analyte is spiked into the gas stream at the back end of the sample probe. Analyte concentrations in the spiked samples are compared to analyte concentrations in unspiked samples.

Since the concentration of the spike is known, this procedure can be used to determine if the sampling system is removing the spiked analyte(s) from the sample stream.

2.3 Reference Spectra Availability. Reference spectra of over 100 HAPs are available in the EPA FTIR spectral library on the EMTIC (Emission Measurement Technical Information Center) computer bulletin board service and at internet address http://info.arnold.af.mil/epa/welcome.htm. Reference spectra for HAPs, or other analytes, may also be prepared according to section 4.6 of the Protocol.

2.4 Operator Requirements. The FTIR analyst shall be trained in setting up the instrumentation, verifying the instrument is functioning properly, and performing routine maintenance. The analyst must evaluate the initial sample spectra to determine if the sample matrix is consistent with pre-test assumptions and if the instrument configuration is suitable. The analyst must be able to modify the instrument configuration, if necessary.

2.4.1 The spectral analysis shall be supervised by someone familiar with EPA FTIR Protocol procedures.

2.4.2 A technician trained in instrumental test methods is qualified to install and operate the sampling system. This includes installing the probe and heated line assembly, operating the analyte spike system, and performing moisture and flow measurements.

3.0 Definitions.

See appendix A of the Protocol for definitions relating to infrared spectroscopy. Additional definitions are given in sections 3.1 through 3.29.

3.1 Analyte. A compound that this method is used to measure. The term "target analyte" is also used. This method is multi-component and a number of analytes can be targeted for a test.

3.2 Reference Spectrum. Infrared spectrum of an analyte prepared under controlled, documented, and reproducible laboratory conditions according to procedures in section 4.6 of the Protocol. A library of reference spectra is used to measure analytes in gas samples.

3.3 Standard Spectrum. A spectrum that has been prepared from a reference spectrum through a (documented) mathematical operation. A common example is de-resolving of reference spectra to lower-resolution standard spectra (Protocol, appendix K to the addendum of this method). Standard spectra, prepared by approved, and documented, procedures can be used as reference spectra for analysis.

3.4 Concentration. In this method concentration is expressed as a molar concentration, in ppm-meters, or in (ppm-meters)/K, where K is the absolute temperature (Kelvin). The latter units allow the direct comparison of concentrations from systems using different optical configurations or sampling temperatures.

3.5 Interferant. A compound in the sample matrix whose infrared spectrum overlaps with part of an analyte spectrum. The most accurate analyte measurements are achieved when reference spectra of interferants are used in the quantitative analysis with the analyte reference spectra. The presence of an interferant can increase the analytical uncertainty in the measured analyte concentration.

3.6 Gas Cell. A gas containment cell that can be evacuated. It is equipped with the optical components to pass the infrared beam through the sample to the detector. Important cell features include: path length (or range if variable), temperature range, materials of construction, and total gas volume.

3.7 Sampling System. Equipment used to extract the sample from the test location and transport the sample gas to the FTIR analyzer. This includes sample conditioning systems.

3.8 Sample Analysis. The process of interpreting the infrared spectra to obtain sample analyte concentrations. This process is usually automated using a software routine employing a classical least squares (cls), partial least squares (pls), or K- or P- matrix method.

3.9 One hundred percent line. A double beam transmittance spectrum obtained by combining two background single beam spectra. Ideally, this line is equal to 100 percent transmittance (or zero absorbance) at every frequency in the spectrum. Practically, a zero absorbance line is used to measure the baseline noise in the spectrum.

3.10 Background Deviation. A deviation from 100 percent transmittance in any region of the 100 percent line. Deviations greater than ± 5 percent in an analytical region are unacceptable (absorbance of 0.021 to -0.022). Such deviations indicate a change in the instrument throughput relative to the background single beam.

3.11 Batch Sampling. A procedure where spectra of discreet, static samples are collected. The gas cell is filled with sample and the cell is isolated. The spectrum is collected. Finally, the cell is evacuated to prepare for the next sample.

3.12 Continuous Sampling. A procedure where spectra are collected while sample gas is flowing through the cell at a measured rate.

3.13 Sampling resolution. The spectral resolution used to collect sample spectra.

3.14 Truncation. Limiting the number of interferogram data points by deleting points farthest from the center burst (zero path difference, ZPD).

3.15 Zero filling. The addition of points to the interferogram. The position of each added point is interpolated from neighboring real data points. Zero filling adds no information to the interferogram, but affects line shapes in the absorbance spectrum (and possibly analytical results).

3.16 Reference CTS. Calibration Transfer Standard spectra that were collected with reference spectra.

3.17 CTS Standard. CTS spectrum produced by applying a de-resolution procedure to a reference CTS.

3.18 Test CTS. CTS spectra collected at the sampling resolution using the same optical configuration as for sample spectra. Test spectra help verify the resolution, temperature and path length of the FTIR system.

3.19 RMSD. Root Mean Square Difference, defined in EPA FTIR Protocol, appendix A.

3.20 Sensitivity. The noise-limited compound-dependent detection limit for the FTIR system configuration. This is estimated by the MAU. It depends on the RMSD in an analytical region of a zero absorbance line.

3.21 Quantitation Limit. The lower limit of detection for the FTIR system configuration in the sample spectra. This is estimated by mathematically subtracting scaled reference spectra of analytes and interferences from sample spectra, then measuring the RMSD in an analytical region of the subtracted spectrum. Since the noise in subtracted sample spectra may be much greater than in a zero absorbance spectrum, the quantitation limit is generally much higher than the sensitivity. Removing spectral interferences from the sample or improving the spectral subtraction can lower the quantitation limit toward (but not below) the sensitivity.

3.22 Independent Sample. A unique volume of sample gas; there is no mixing of gas between two consecutive independent samples. In continuous sampling two independent samples are separated by at least 5 cell volumes. The interval between independent measurements depends on the cell volume and the sample flow rate (through the cell).

3.23 Measurement. A single spectrum of flue gas contained in the FTIR cell.

3.24 Run. A run consists of a series of measurements. At a minimum a run includes 8 independent measurements spaced over 1 hour.

3.25 Validation. Validation of FTIR measurements is described in sections 13.0 through 13.4 of this method. Validation is used to verify the test procedures for measuring specific analytes at a source. Validation provides proof that the method works under certain test conditions.

3.26 Validation Run. A validation run consists of at least 24 measurements of independent samples. Half of the samples are spiked and half are not spiked. The length of the run is determined by the interval between independent samples.

3.27 Screening. Screening is used when there is little or no available information about a source. The purpose of screening is to determine what analytes are emitted and to obtain information about important sample characteristics such as moisture, temperature, and interferences. Screening results are semi-quantitative (estimated concentrations) or qualitative (identification only). Various optical and sampling configurations may be used. Sample conditioning systems may be evaluated for their effectiveness in removing interferences. It is unnecessary to perform a complete run under any set of sampling conditions. Spiking is not necessary, but spiking can be a useful screening tool for evaluating the sampling system, especially if a reactive or soluble analyte is used for the spike.

3.28 Emissions Test. An FTIR emissions test is performed according specific sampling and analytical procedures. These procedures, for the target analytes and the source, are based on previous screening and validation results. Emission results are quantitative. A QA spike (sections 8.6.2 and 9.2 of this method) is performed under each set of sampling conditions using a representative analyte. Flow, gas temperature and diluent data are recorded concurrently with the FTIR measurements to provide mass emission rates for detected compounds.

3.29 Surrogate. A surrogate is a compound that is used in a QA spike procedure (section 8.6.2 of this method) to represent other compounds. The chemical and physical properties of a surrogate shall be similar to the compounds it is chosen to represent. Under given sampling conditions, usually a single sampling factor is of primary concern for measuring the target analytes: for example, the surrogate spike results can be representative for analytes that are more reactive, more soluble, have a lower absorptivity, or have a lower vapor pressure than the surrogate itself.

4.0 Interferences.

Interferences are divided into two classifications: analytical and sampling.

4.1 Analytical Interferences. An analytical interference is a spectral feature that complicates (in extreme cases may prevent) the analysis of an analyte. Analytical interferences are classified as background or spectral interference.

4.1.1 Background Interference. This results from a change in throughput relative to the single beam background. It is corrected by collecting a new background and proceeding with the test. In severe instances the cause must be identified and corrected. Potential causes include: (1) deposits on reflective surfaces or transmitting windows, (2) changes in detector sensitivity, (3) a change in the infrared source output, or (4) failure in the instrument electronics. In routine sampling throughput may degrade over several hours. Periodically a new background must be collected, but no other corrective action will be required.

4.1.2 Spectral Interference. This results from the presence of interfering compound(s) (interferant) in the sample. Interferant spectral features overlap analyte spectral features. Any compound with an infrared spectrum, including analytes, can potentially be an interferant. The Protocol measures absorbance band overlap in each analytical region to determine if potential interferants shall be classified as known interferants (FTIR Protocol, section 4.9 and appendix B). Water vapor and CO_2 are common spectral interferants. Both of these compounds have strong infrared spectra and are present in many sample matrices at high concentrations relative to analytes. The extent of interference depends on the (1) interferant concentration, (2) analyte concentration, and (3) the degree of band overlap. Choosing an alternate analytical region can minimize or avoid the spectral interference. For example, CO_2 interferes with the analysis of the 670 cm^{-1} benzene band. However, benzene can also be measured near 3000 cm^{-1} (with less sensitivity).

4.2 Sampling System Interferences. These prevent analytes from reaching the instrument. The analyte spike procedure is designed to measure sampling system interference, if any.

4.2.1 Temperature. A temperature that is too low causes condensation of analytes or water vapor. The materials of the sampling system and the FTIR gas cell usually set the upper limit of temperature.

4.2.2 Reactive Species. Anything that reacts with analytes. Some analytes, like formaldehyde, polymerize at lower temperatures.

4.2.3 Materials. Poor choice of material for probe, or sampling line may remove some analytes. For example, HF reacts with glass components.

4.2.4 Moisture. In addition to being a spectral interferant, condensed moisture removes soluble compounds.

5.0 Safety.

The hazards of performing this method are those associated with any stack sampling method and the same precautions shall be followed. Many HAPs are suspected carcinogens or present other serious health risks. Exposure to these compounds should be avoided in all circumstances. For instructions on the safe handling of any particular compound, refer to its material safety data sheet. When using analyte standards, always ensure that gases are properly vented and that the gas handling system is leak free. (Always perform a leak check with the system under maximum vacuum and, again, with the system at greater than ambient pressure.) Refer to section 8.2 of this method for leak check procedures. This method does not address all of the potential safety risks associated with its use. Anyone performing this method must follow safety and health practices consistent with applicable legal requirements and with prudent practice for each application.

6.0 Equipment and Supplies.

Note: Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

The equipment and supplies are based on the schematic of a sampling system shown in Figure 1. Either the batch or continuous sampling procedures may be used with this sampling system. Alternative sampling configurations may also be used, provided that the data quality objectives are met as determined in the post-analysis evaluation. Other equipment or supplies may be necessary, depending on the design of the sampling system or the specific target analytes.

6.1 Sampling Probe. Glass, stainless steel, or other appropriate material of sufficient length and physical integrity to sustain heating, prevent adsorption of analytes, and to transport analytes to the infrared gas cell. Special materials or configurations may be required in some applications. For instance, high stack sample temperatures may require special steel or cooling the probe.

For very high moisture sources it may be desirable to use a dilution probe.

6.2 Particulate Filters. A glass wool plug (optional) inserted at the probe tip (for large particulate removal) and a filter (required) rated for 99 percent removal efficiency at 1-micron (e.g., Balston™) connected at the outlet of the heated probe.

6.3 Sampling Line/Heating System. Heated (sufficient to prevent condensation) stainless steel, polytetrafluoroethane, or other material inert to the analytes.

6.4 Gas Distribution Manifold. A heated manifold allowing the operator to control flows of gas standards and samples directly to the FTIR system or through sample conditioning systems. Usually includes heated flow meter, heated valve for selecting and sending sample to the analyzer, and a by-pass vent. This is typically constructed of stainless steel tubing and fittings, and high-temperature valves.

6.5 Stainless Steel Tubing. Type 316, appropriate diameter (e.g., 3/8 in.) and length for heated connections. Higher grade stainless may be desirable in some applications.

6.6 Calibration/Analyte Spike Assembly. A three way valve assembly (or equivalent) to introduce analyte or surrogate spikes into the sampling system at the outlet of the probe upstream of the out-of-stack particulate filter and the FTIR analytical system.

6.7 Mass Flow Meter (MFM). These are used for measuring analyte spike flow. The MFM shall be calibrated in the range of 0 to 5 L/min and be accurate to ± 2 percent (or better) of the flow meter span.

6.8 Gas Regulators. Appropriate for individual gas standards.

6.9 Polytetrafluoroethane Tubing. Diameter (e.g., 3/8 in.) and length suitable to connect cylinder regulators to gas standard manifold.

6.10 Sample Pump. A leak-free pump (e.g., KNF™), with by-pass valve, capable of producing a sample flow rate of at least 10 L/min through 100 ft of sample line. If the pump is positioned upstream of the distribution manifold and FTIR system, use a heated pump that is constructed from materials non-reactive to the analytes. If the pump is located downstream of the FTIR system, the gas cell sample pressure will be lower than ambient pressure and it must be recorded at regular intervals.

6.11 Gas Sample Manifold. Secondary manifold to control sample flow at the inlet to the FTIR manifold. This is optional, but includes a by-pass vent and heated rotameter.

6.12 Rotameter. A 0 to 20 L/min rotameter. This meter need not be calibrated.

6.13 FTIR Analytical System. Spectrometer and detector, capable of measuring the analytes to the chosen detection limit. The system shall include a personal computer with compatible software allowing automated collection of spectra.

6.14 FTIR Cell Pump. Required for the batch sampling technique, capable of evacuating the FTIR cell volume within 2 minutes. The pumping speed shall allow the operator to obtain 8 sample spectra in 1 hour.

6.15 Absolute Pressure Gauge. Capable of measuring pressure from 0 to 1000 mmHg to within ± 2.5 mmHg (e.g., Baratron™).

6.16 Temperature Gauge. Capable of measuring the cell temperature to within ± 2°C.

6.17 Sample Conditioning. One option is a condenser system, which is used for moisture removal. This can be helpful in the measurement of some analytes. Other sample conditioning procedures may be devised for the removal of moisture or other interfering species.

6.17.1 The analyte spike procedure of section 9.2 of this method, the QA spike procedure of section 8.6.2 of this method, and the validation procedure of section 13 of this method demonstrate whether the sample conditioning affects analyte concentrations. Alternatively, measurements can be made with two parallel FTIR systems; one measuring conditioned sample, the other measuring unconditioned sample.

6.17.2 Another option is sample dilution. The dilution factor measurement must be documented and accounted for in the reported concentrations. An alternative to dilution is to lower the sensitivity of the FTIR system by decreasing the cell path length, or to use a short-path cell in conjunction with a long path cell to measure more than one concentration range.

7.0 Reagents and Standards.

7.1 Analyte(s) and Tracer Gas. Obtain a certified gas cylinder mixture containing all of the analyte(s) at concentrations within ± 2 percent of the emission source levels (expressed in ppm-meter/K). If practical, the analyte standard cylinder shall also contain the tracer gas at a concentration which gives a measurable absorbance at a dilution factor of at least 10:1. Two ppm SF_6 is sufficient for a path length of 22 meters at 250 °F.

7.2 Calibration Transfer Standard(s). Select the calibration transfer standards (CTS) according to section 4.5 of the FTIR Protocol. Obtain a National Institute of Standards and Technology (NIST) traceable gravimetric standard of the CTS (± 2 percent).

7.3 Reference Spectra. Obtain reference spectra for each analyte, interferant, surrogate, CTS, and tracer. If EPA reference spectra are not available, use reference spectra prepared according to procedures in section 4.6 of the EPA FTIR Protocol.

8.0 Sampling and Analysis Procedure.

Three types of testing can be performed: (1) screening, (2) emissions test, and (3) validation. Each is defined in section 3 of this method. Determine the purpose(s) of the FTIR test. Test requirements include: (a) AU_i, DL_i, overall fractional uncertainty, OFU_i, maximum expected concentration ($CMAX_i$), and t_{AN} for each, (b) potential interferants, (c) sampling system factors, e.g., minimum absolute cell pressure, (P_{min}), FTIR cell volume (V_{SS}), estimated sample absorption pathlength, L_S', estimated sample pressure, P_S', T_S', signal integration time (t_{SS}), minimum instrumental linewidth, MIL, fractional error, and (d) analytical regions, e.g., m = 1 to M, lower wavenumber position, FL_m, center wavenumber position, FC_m, and upper wavenumber position, FU_m, plus interferants, upper wavenumber position of the CTS absorption band, FFU_m, lower wavenumber position of the CTS absorption band, FFL_m, wavenumber range FNU to FNL. If necessary, sample and acquire an initial spectrum. From analysis of this preliminary spectrum determine a suitable operational path length. Set up the sampling train as shown in Figure 1 or use an appropriate alternative configuration. Sections 8.1 through 8.11 of this method provide guidance on pre-test calculations in the EPA protocol, sampling and analytical procedures, and post-test protocol calculations.

8.1 Pretest Preparations and Evaluations. Using the procedure in section 4.0 of the FTIR Protocol, determine the optimum sampling system configuration for measuring the target analytes. Use available information to make reasonable assumptions about moisture content and other interferences.

8.1.1 Analytes. Select the required detection limit (DL_i) and the maximum permissible analytical uncertainty (AU_i) for each analyte (labeled from 1 to i). Estimate, if possible, the maximum expected concentration for each analyte, $CMAX_i$. The expected measurement range is fixed by DL_i and $CMAX_i$ for each analyte (i).

8.1.2 Potential Interferants. List the potential interferants. This usually includes water vapor and CO_2, but may also include some analytes and other compounds.

8.1.3. Optical Configuration. Choose an optical configuration that can measure all of the analytes within the absorbance range of .01 to 1.0 (this may require more than one path length). Use Protocol sections 4.3 to 4.8 for guidance in choosing a configuration and measuring CTS.

8.1.4. Fractional Reproducibility Uncertainty (FRU_i). The FRU is determined for each analyte by comparing CTS spectra taken before and after the reference spectra were measured.

The EPA para-xylene reference spectra were collected on 10/31/91 and 11/01/91 with corresponding CTS spectra "cts1031a," and "cts1101b." The CTS spectra are used to estimate the reproducibility (FRU) in the system that was used to collect the references. The FRU must be < AU. Appendix E of the protocol is used to calculate the FRU from CTS spectra. Figure 2 plots results for 0.25 cm^{-1} CTS spectra in EPA reference library: S_3 (cts1101b - cts1031a), and S_4 [(cts1101b + cts1031a)/2]. The RMSD (SRMS) is calculated in the subtracted baseline, S_3, in the corresponding CTS region from 850 to 1065 cm^{-1}. The area (BAV) is calculated in the same region of the averaged CTS spectrum, S_4.

8.1.5 Known Interferants. Use appendix B of the EPA FTIR Protocol.

8.1.6 Calculate the Minimum Analyte Uncertainty, MAU (section 1.3 of this method discusses MAU and protocol appendix D gives the MAU procedure). The MAU for each analyte, i, and each analytical region, m, depends on the RMS noise.

8.1.7 Analytical Program. See FTIR Protocol, section 4.10. Prepare computer program based on the chosen analytical technique. Use as input reference spectra of all target analytes and expected interferants. Reference spectra of additional compounds shall also be included in the program if their presence (even if transient) in the samples is considered possible. The program output shall be in ppm (or ppb) and shall be corrected for differences between the reference path length, L_R, temperature, T_R, and pressure, P_R, and the conditions used for collecting the sample spectra. If sampling is performed at ambient pressure, then any pressure correction is usually small relative to corrections for path length and temperature, and may be neglected.

8.2 Leak-check.

8.2.1 Sampling System. A typical FTIR extractive sampling train is shown in Figure 1. Leak check from the probe tip to pump outlet as follows: Connect a 0- to 250-mL/min rate meter (rotameter or bubble meter) to the outlet of the pump. Close off the inlet to the probe, and record the leak rate. The leak rate shall be ≤ 200 mL/min.

8.2.2 Analytical System Leak check. Leak check the FTIR cell under vacuum and under pressure (greater than ambient). Leak check connecting tubing and inlet manifold under pressure.

8.2.2.1 For the evacuated sample technique, close the valve to the FTIR cell, and evacuate the absorption cell to the minimum absolute pressure P_{min}. Close the valve to the pump, and determine the change in pressure ΔP_v after 2 minutes.

8.2.2.2 For both the evacuated sample and purging techniques, pressurize the system to about 100 mmHg above atmospheric pressure. Isolate the pump and determine the change in pressure ΔP_p after 2 minutes.

8.2.2.3 Measure the barometric pressure, P_b in mmHg.

8.2.2.4 Determine the percent leak volume $\%V_L$ for the signal integration time t_{SS} and for ΔP_{max}, i.e., the larger of ΔP_v or ΔP_p, as follows:

$$\%V_L = 50\, t_{SS} \frac{\Delta P_{max}}{P_{SS}} \quad . \tag{2}$$

where 50 = 100% divided by the leak-check time of 2 minutes.

8.2.2.5 Leak volumes in excess of 4 percent of the FTIR system volume V_{SS} are unacceptable.

8.3 Detector Linearity. Once an optical configuration is chosen, use one of the procedures of sections 8.3.1 through 8.3.3 to verify that the detector response is linear. If the detector response is not linear, decrease the aperture, or attenuate the infrared beam. After a change in the instrument configuration perform a linearity check until it is demonstrated that the detector response is linear.

8.3.1 Vary the power incident on the detector by modifying the aperture setting. Measure the background and CTS at three instrument aperture settings: (1) at the aperture setting to be used in the testing, (2) at one half this aperture and (3) at twice the proposed testing aperture.

Compare the three CTS spectra. CTS band areas shall agree to within the uncertainty of the cylinder standard and the RMSD noise in the system. If test aperture is the maximum aperture, collect CTS spectrum at maximum aperture, then close the aperture to reduce the IR throughput by half. Collect a second background and CTS at the smaller aperture setting and compare the spectra again.

8.3.2 Use neutral density filters to attenuate the infrared beam. Set up the FTIR system as it will be used in the test measurements. Collect a CTS spectrum. Use a neutral density filter to attenuate the infrared beam (either immediately after the source or the interferometer) to approximately 1/2 its original intensity. Collect a second CTS spectrum. Use another filter to attenuate the infrared beam to approximately 1/4 its original intensity. Collect a third background and CTS spectrum. Compare the CTS spectra. CTS band areas shall agree to within the uncertainty of the cylinder standard and the RMSD noise in the system.

8.3.3 Observe the single beam instrument response in a frequency region where the detector response is known to be zero. Verify that the detector response is "flat" and equal to zero in these regions.

8.4 Data Storage Requirements. All field test spectra shall be stored on a computer disk and a second backup copy must stored on a separate disk. The stored information includes sample interferograms, processed absorbance spectra, background interferograms, CTS sample interferograms and CTS absorbance spectra. Additionally, documentation of all sample conditions, instrument settings, and test records must be recorded on hard copy or on computer medium. Table 1 gives a sample presentation of documentation.

8.5 Background Spectrum. Evacuate the gas cell to ≤ 5 mmHg, and fill with dry nitrogen gas to ambient pressure (or purge the cell with 10 volumes of dry nitrogen). Verify that no significant amounts of absorbing species (for example water vapor and CO_2) are present. Collect a background spectrum, using a signal averaging period equal to or greater than the averaging period for the sample spectra. Assign a unique file name to the background spectrum. Store two copies of the background interferogram and processed single-beam spectrum on separate computer disks (one copy is the back-up).

8.5.1 Interference Spectra. If possible, collect spectra of known and suspected major interferences using the same optical system that will be used in the field measurements. This can be done on-site or earlier. A number of gases, e.g. CO_2, SO_2, CO, NH_3, are readily available from cylinder gas suppliers.

8.5.2 Water vapor spectra can be prepared by the following procedure. Fill a sample tube with distilled water. Evacuate above the sample and remove dissolved gasses by alternately freezing and thawing the water while evacuating. Allow water vapor into the FTIR cell, then dilute to atmospheric pressure with nitrogen or dry air. If quantitative water spectra are required, follow the reference spectrum procedure for neat samples (protocol, section 4.6). Often, interference spectra need not be quantitative, but for best results the absorbance must be comparable to the interference absorbance in the sample spectra.

8.6 Pre-Test Calibrations

8.6.1 Calibration Transfer Standard. Evacuate the gas cell to ≤ 5 mmHg absolute pressure, and fill the FTIR cell to atmospheric pressure with the CTS gas. Alternatively, purge the cell with 10 cell volumes of CTS gas. (If purge is used, verify that the CTS concentration in the cell is stable by collecting two spectra 2 minutes apart as the CTS gas continues to flow. If the absorbance in the second spectrum is no greater than in the first, within the uncertainty of the gas standard, then this can be used as the CTS spectrum.) Record the spectrum.

8.6.2 QA Spike. This procedure assumes that the method has been validated for at least some of the target analytes at the source. For emissions testing perform a QA spike. Use a certified standard, if possible, of an analyte, which has been validated at the source. One analyte standard can serve as a QA surrogate for other analytes which are less reactive or less soluble than the standard. Perform the spike procedure of section 9.2 of this method. Record spectra of at least three independent (section 3.22 of this method) spiked samples. Calculate the spiked component of the analyte concentration. If the average spiked concentration is within 0.7 to 1.3 times the expected concentration, then proceed with the testing. If applicable, apply the correction factor from the Method 301 of this appendix validation test (not the result from the QA spike).

8.7 Sampling. If analyte concentrations vary rapidly with time, continuous sampling is preferable using the smallest cell volume, fastest sampling rate and fastest spectra collection rate possible. Continuous sampling requires the least operator intervention even without an automated sampling system. For continuous monitoring at one location over long periods, Continuous sampling is preferred. Batch sampling and continuous static sampling are used for screening and performing test runs of finite duration. Either technique is preferred for sampling several locations in a matter of days. Batch sampling gives reasonably good time resolution and ensures that each spectrum measures a discreet (and unique) sample volume. Continuous static (and continuous) sampling provide a very stable background over long periods. Like batch sampling, continuous static sampling also ensures that each spectrum measures a unique sample volume. It is essential that the leak check procedure under vacuum (section 8.2 of this method) is passed if the batch sampling procedure is used. It is essential that the leak check procedure under positive pressure is passed if the continuous static or continuous sampling procedures are used. The sampling techniques are described in sections 8.7.1 through 8.7.2 of this method.

8.7.1 Batch Sampling. Evacuate the absorbance cell to ≤ 5 mmHg absolute pressure. Fill the cell with exhaust gas to ambient pressure, isolate the cell, and record the spectrum. Before taking the next sample, evacuate the cell until no spectral evidence of sample absorption remains. Repeat this procedure to collect eight spectra of separate samples in 1 hour.

8.7.2 Continuous Static Sampling. Purge the FTIR cell with 10 cell volumes of sample gas. Isolate the cell, collect the spectrum of the static sample and record the pressure. Before measuring the next sample, purge the cell with 10 more cell volumes of sample gas.

8.8 Sampling QA and Reporting.

8.8.1 Sample integration times shall be sufficient to achieve the required signal-to-noise ratio. Obtain an absorbance spectrum by filling the cell with N_2. Measure the RMSD in each analytical region in this absorbance spectrum. Verify that the number of scans used is sufficient to achieve the target MAU.

8.8.2 Assign a unique file name to each spectrum.

8.8.3 Store two copies of sample interferograms and processed spectra on separate computer disks.

8.8.4 For each sample spectrum, document the sampling conditions, the sampling time (while the cell was being filled), the time the spectrum was recorded, the instrumental conditions (path length, temperature, pressure, resolution, signal integration time), and the spectral file name. Keep a hard copy of these data sheets.

8.9 Signal Transmittance. While sampling, monitor the signal transmittance. If signal transmittance (relative to the background) changes by 5 percent or more (absorbance = -.02 to .02) in any analytical spectral region, obtain a new background spectrum.

8.10 Post-test CTS. After the sampling run, record another CTS spectrum.

8.11 Post-test QA.

8.11.1 Inspect the sample spectra immediately after the run to verify that the gas matrix composition was close to the expected (assumed) gas matrix.

8.11.2 Verify that the sampling and instrumental parameters were appropriate for the conditions encountered. For example, if the moisture is much greater than anticipated, it may be necessary to use a shorter path length or dilute the sample.

8.11.3 Compare the pre- and post-test CTS spectra. The peak absorbance in pre- and post-test CTS must be ± 5 percent of the mean value. See appendix E of the FTIR Protocol.

9.0 Quality Control.

Use analyte spiking (sections 8.6.2, 9.2 and 13.0 of this method) to verify that the sampling system can transport the analytes from the probe to the FTIR system.

9.1 Spike Materials. Use a certified standard (accurate to ± 2 percent) of the target analyte, if one can be obtained. If a certified standard cannot be obtained, follow the procedures in section 4.6.2.2 of the FTIR Protocol.

9.2 Spiking Procedure. QA spiking (section 8.6.2 of this method) is a calibration procedure used before testing. QA spiking involves following the spike procedure of sections 9.2.1 through 9.2.3 of this method to obtain at least three spiked samples. The analyte concentrations in the spiked samples shall be compared to the expected spike concentration to verify that the sampling/analytical system is working properly. Usually, when QA spiking is used, the method has already been validated at a similar source for the analyte in question. The QA spike demonstrates that the validated sampling/analytical conditions are being duplicated. If the QA spike fails then the sampling/analytical system shall be repaired before testing proceeds. The method validation procedure (section 13.0 of this method) involves a more extensive use of the analyte spike procedure of sections 9.2.1 through 9.2.3 of this method. Spectra of at least 12 independent spiked and 12 independent unspiked samples are recorded. The concentration results are analyzed statistically to determine if there is a systematic bias in the method for measuring a particular analyte. If there is a systematic bias, within the limits allowed by Method 301 of this appendix, then a correction factor shall be applied to the analytical results. If the systematic bias is greater than the allowed limits, this method is not valid and cannot be used.

9.2.1 Introduce the spike/tracer gas at a constant flow rate of ≤ 10 percent of the total sample flow, when possible. (Note: Use the rotameter at the end of the sampling train to estimate the required spike/tracer gas flow rate.) Use a flow device, e.g., mass flow meter (± 2 percent), to monitor the spike flow rate. Record the spike flow rate every 10 minutes.

9.2.2 Determine the response time (RT) of the system by continuously collecting spectra of the spiked effluent until the spectrum of the spiked component is constant for 5 minutes. The RT is the interval from the first measurement until the spike becomes constant. Wait for twice the duration of the RT, then collect spectra of two independent spiked gas samples. Duplicate analyses of the spiked concentration shall be within 5 percent of the mean of the two measurements.

9.2.3 Calculate the dilution ratio using the tracer gas as follows:

$$DF = \frac{SF_{6(spk)}}{SF_{6(dir)}} \qquad \textbf{(3)}$$

where:

$$CS = DF*Spike_{dir} + Unspike(1-DF) \qquad \textbf{(4)}$$

DF = Dilution factor of the spike gas; this value shall be ≥10.

$SF_{6(dir)}$ = SF_6 (or tracer gas) concentration measured directly in undiluted spike gas.

$SF_{6(spk)}$ = Diluted SF_6 (or tracer gas) concentration measured in a spiked sample.

$Spike_{dir}$ = Concentration of the analyte in the spike standard measured by filling the FTIR cell directly.

CS = Expected concentration of the spiked samples.

Unspike = Native concentration of analytes in unspiked samples

10.0 Calibration and Standardization.

10.1 Signal-to-Noise Ratio (S/N). The RMSD in the noise must be less than one tenth of the minimum analyte peak absorbance in each analytical region. For example if the minimum peak absorbance is 0.01 at the required DL, then RMSD measured over the entire analytical region must be ≤ 0.001.

10.2 Absorbance Path length. Verify the absorbance path length by comparing reference CTS spectra to test CTS spectra. See appendix E of the FTIR Protocol.

10.3 Instrument Resolution. Measure the line width of appropriate test CTS band(s) to verify instrument resolution. Alternatively, compare CTS spectra to a reference CTS spectrum, if available, measured at the nominal resolution.

10.4 Apodization Function. In transforming the sample interferograms to absorbance spectra use the same apodization function that was used in transforming the reference spectra.

10.5 FTIR Cell Volume. Evacuate the cell to ≤ 5 mmHg. Measure the initial absolute temperature (T_i) and absolute pressure (P_i). Connect a wet test meter (or a calibrated dry gas meter), and slowly draw room air into the cell. Measure the meter volume (V_m), meter absolute temperature (T_m), and meter absolute pressure (P_m); and the cell final absolute temperature (T_f) and absolute pressure (P_f). Calculate the FTIR cell volume V_{SS}, including that of the connecting tubing, as follows:

$$V_{SS} = \frac{V_m \dfrac{P_m}{T_m}}{\left[\dfrac{P_f}{T_f} - \dfrac{P_i}{T_i}\right]} \qquad \textbf{(5)}$$

11.0 Data Analysis and Calculations.

Analyte concentrations shall be measured using reference spectra from the EPA FTIR spectral library. When EPA library spectra are not available, the procedures in section 4.6 of the Protocol shall be followed to prepare reference spectra of all the target analytes.

11.1 Spectral De-resolution. Reference spectra can be converted to lower resolution standard spectra (section 3.3

of this method) by truncating the original reference sample and background interferograms. Appendix K of the FTIR Protocol gives specific deresolution procedures. Deresolved spectra shall be transformed using the same apodization function and level of zero filling as the sample spectra. Additionally, pre-test FTIR protocol calculations (e.g., FRU, MAU, FCU) shall be performed using the de-resolved standard spectra.

11.2 Data Analysis. Various analytical programs are available for relating sample absorbance to a concentration standard. Calculated concentrations shall be verified by analyzing residual baselines after mathematically subtracting scaled reference spectra from the sample spectra. A full description of the data analysis and calculations is contained in the FTIR Protocol (sections 4.0, 5.0, 6.0 and appendices). Correct the calculated concentrations in the sample spectra for differences in absorption path length and temperature between the reference and sample spectra using equation 6,

$$C_{corr} = \left(\frac{L_r}{L_s}\right)\left(\frac{T_s}{T_r}\right)\left(\frac{P_r}{P_s}\right) C_{calc} \qquad \textbf{(6)}$$

where:

C_{corr} = Concentration, corrected for path length.

C_{calc} = Concentration, initial calculation (output of the analytical program designed for the compound).

L_r = Reference spectra path length.

L_s = Sample spectra path length.

T_s = Absolute temperature of the sample gas, K.

T_r = Absolute gas temperature of reference spectra, K.

P_s = Sample cell pressure.

P_r = Reference spectrum sample pressure.

12.0 Method Performance.

12.1 Spectral Quality. Refer to the FTIR Protocol appendices for analytical requirements, evaluation of data quality, and analysis of uncertainty.

12.2 Sampling QA/QC. The analyte spike procedure of section 9 of this method, the QA spike of section 8.6.2 of this method, and the validation procedure of section 13 of this method are used to evaluate the performance of the sampling system and to quantify sampling system effects, if any, on the measured concentrations. This method is self-validating provided that the results meet the performance requirement of the QA spike in sections 9.0 and 8.6.2 of this method and results from a previous method validation study support the use of this method in the application. Several factors can contribute to uncertainty in the measurement of spiked samples. Factors which can be controlled to provide better accuracy in the spiking procedure are listed in sections 12.2.1 through 12.2.4 of this method.

12.2.1 Flow meter. An accurate mass flow meter is accurate to ± 1 percent of its span. If a flow of 1 L/min is monitored with such a MFM, which is calibrated in the range of 0-5 L/min, the flow measurement has an uncertainty of 5 percent. This may be improved by re-calibrating the meter at the specific flow rate to be used.

12.2.2 Calibration gas. Usually the calibration standard is certified to within ± 2 percent. With reactive analytes, such as HCl, the certified accuracy in a commercially available standard may be no better than ± 5 percent.

12.2.3 Temperature. Temperature measurements of the cell shall be quite accurate. If practical, it is preferable to measure sample temperature directly, by inserting a thermocouple into the cell chamber instead of monitoring the cell outer wall temperature.

12.2.4 Pressure. Accuracy depends on the accuracy of the barometer, but fluctuations in pressure throughout a day may be as much as 2.5 percent due to weather variations.

13.0 Method Validation Procedure.

This validation procedure, which is based on EPA Method 301 (40 CFR part 63, appendix A), may be used to validate this method for the analytes in a gas matrix. Validation at one source may also apply to another type of source, if it can be shown that the exhaust gas characteristics are similar at both sources.

13.1 Section 5.3 of Method 301 (40 CFR part 63, appendix A), the Analyte Spike procedure, is used with these modifications. The statistical analysis of the results follows section 6.3 of EPA Method 301. Section 3 of this method defines terms that are not defined in Method 301.

13.1.1 The analyte spike is performed dynamically. This means the spike flow is continuous and constant as spiked samples are measured.

13.1.2 The spike gas is introduced at the back of the sample probe.

13.1.3 Spiked effluent is carried through all sampling components downstream of the probe.

13.1.4 A single FTIR system (or more) may be used to collect and analyze spectra (not quadruplicate integrated sampling trains).

13.1.5 All of the validation measurements are performed sequentially in a single "run" (section 3.26 of this method).

13.1.6 The measurements analyzed statistically are each independent (section 3.22 of this method).

13.1.7 A validation data set can consist of more than 12 spiked and 12 unspiked measurements.

13.2 Batch Sampling. The procedure in sections 13.2.1 through 13.2.2 may be used for stable processes. If process emissions are highly variable, the procedure in section

13.2.3 shall be used.

13.2.1 With a single FTIR instrument and sampling system, begin by collecting spectra of two unspiked samples. Introduce the spike flow into the sampling system and allow 10 cell volumes to purge the sampling system and FTIR cell. Collect spectra of two spiked samples. Turn off the spike and allow 10 cell volumes of unspiked sample to purge the FTIR cell. Repeat this procedure until the 24 (or more) samples are collected.

13.2.2 In batch sampling, collect spectra of 24 distinct samples. (Each distinct sample consists of filling the cell to ambient pressure after the cell has been evacuated.)

13.2.3 Alternatively, a separate probe assembly, line, and sample pump can be used for spiked sample. Verify and document that sampling conditions are the same in both the spiked and the unspiked sampling systems. This can be done by wrapping both sample lines in the same heated bundle. Keep the same flow rate in both sample lines. Measure samples in sequence in pairs. After two spiked samples are measured, evacuate the FTIR cell, and turn the manifold valve so that spiked sample flows to the FTIR cell. Allow the connecting line from the manifold to the FTIR cell to purge thoroughly (the time depends on the line length and flow rate). Collect a pair of spiked samples. Repeat the procedure until at least 24 measurements are completed.

13.3 Simultaneous Measurements With Two FTIR Systems. If unspiked effluent concentrations of the target analyte(s) vary significantly with time, it may be desirable to perform synchronized measurements of spiked and unspiked sample. Use two FTIR systems, each with its own cell and sampling system to perform simultaneous spiked and unspiked measurements. The optical configurations shall be similar, if possible. The sampling configurations shall be the same. One sampling system and FTIR analyzer shall be used to measure spiked effluent. The other sampling system and FTIR analyzer shall be used to measure unspiked flue gas. Both systems shall use the same sampling procedure (i.e., batch or continuous).

13.3.1 If batch sampling is used, synchronize the cell evacuation, cell filling, and collection of spectra. Fill both cells at the same rate (in cell volumes per unit time).

13.3.2 If continuous sampling is used, adjust the sample flow through each gas cell so that the same number of cell volumes pass through each cell in a given time (i.e. TC_1 = TC_2).

13.4 Statistical Treatment. The statistical procedure of EPA Method 301 of this appendix, section 6.3 is used to evaluate the bias and precision. For FTIR testing a validation "run" is defined as spectra of 24 independent samples, 12 of which are spiked with the analyte(s) and 12 of which are not spiked.

13.4.1 Bias. Determine the bias (defined by EPA Method 301 of this appendix, section 6.3.2) using equation 7:

$$B = S_m - CS \tag{7}$$

where:

B = Bias at spike level.

S_m = Mean concentration of the analyte spiked samples.

CS = Expected concentration of the spiked samples.

13.4.2 Correction Factor. Use section 6.3.2.2 of Method 301 of this appendix to evaluate the statistical significance of the bias. If it is determined that the bias is significant, then use section 6.3.3 of Method 301 to calculate a correction factor (CF). Analytical results of the test method are multiplied by the correction factor, if $0.7 \leq CF \leq 1.3$. If is determined that the bias is significant and CF > ± 30 percent, then the test method is considered to "not valid."

13.4.3 If measurements do not pass validation, evaluate the sampling system, instrument configuration, and analytical system to determine if improper set-up or a malfunction was the cause. If so, repair the system and repeat the validation.

14.0 Pollution Prevention.

The extracted sample gas is vented outside the enclosure containing the FTIR system and gas manifold after the analysis. In typical method applications the vented sample volume is a small fraction of the source volumetric flow and its composition is identical to that emitted from the source. When analyte spiking is used, spiked pollutants are vented with the extracted sample gas. Approximately 1.6 x 10^{-4} to 3.2 x 10^{-4} lbs of a single HAP may be vented to the atmosphere in a typical validation run of 3 hours. (This assumes a molar mass of 50 to 100 g, spike rate of 1.0 L/min, and a standard concentration of 100 ppm). Minimize emissions by keeping the spike flow off when not in use.

15.0 Waste Management.

Small volumes of laboratory gas standards can be vented through a laboratory hood. Neat samples must be packed and disposed according to applicable regulations. Surplus materials may be returned to supplier for disposal.

16.0 References.

1. "Field Validation Test Using Fourier Transform Infrared (FTIR) Spectrometry To Measure Formaldehyde, Phenol and Methanol at a Wool Fiberglass Production Facility." Draft. U.S. Environmental Protection Agency Report, EPA Contract No. 68D20163, Work Assignment I-32, September 1994.

2. "FTIR Method Validation at a Coal-Fired Boiler".

Prepared for U.S. Environmental Protection Agency, Research Triangle Park, NC. Publication No.: EPA-454/R95-004, NTIS No.: PB95-193199. July, 1993.

3. "Method 301 - Field Validation of Pollutant Measurement Methods from Various Waste Media," **40 CFR part 63, appendix A**.

4. "Molecular Vibrations; The Theory of Infrared and Raman Vibrational Spectra," E. Bright Wilson, J. C. Decius, and P. C. Cross, Dover Publications, Inc., 1980. For a less intensive treatment of molecular rotational-vibrational spectra see, for example, "Physical Chemistry," G. M. Barrow, chapters 12, 13, and 14, McGraw Hill, Inc., 1979.

5. "Fourier Transform Infrared Spectrometry," Peter R. Griffiths and James de Haseth, **Chemical Analysis**, **83**, 16-25,(1986), P. J. Elving, J. D. Winefordner and I. M. Kolthoff (ed.), John Wiley and Sons.

6. "Computer-Assisted Quantitative Infrared Spectroscopy," Gregory L. McClure (ed.), **ASTM Special Publication 934** (ASTM), 1987.

7. "Multivariate Least-Squares Methods Applied to the Quantitative Spectral Analysis of Multicomponent Mixtures," **Applied Spectroscopy**, **39**(10), 73-84, 1985.

Table 1. EXAMPLE PRESENTATION OF SAMPLING DOCUMENTATION.

Sample Time	Spectrum File Name	Background File Name	Sample conditioning	Process condition

Sample Time	Spectrum File	Interferogram	Resolution	Scans	Apodization	Gain	CTS Spectrum

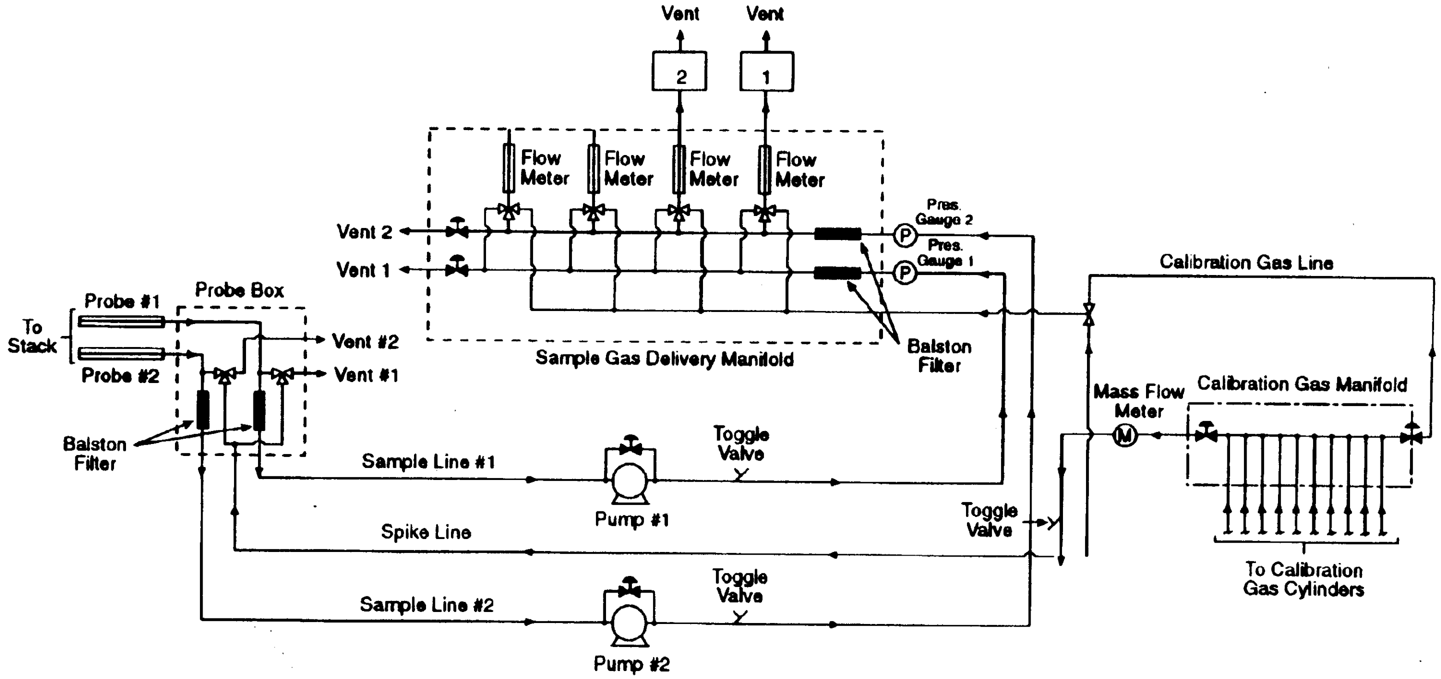

Figure 1. Extractive FTIR sampling system.

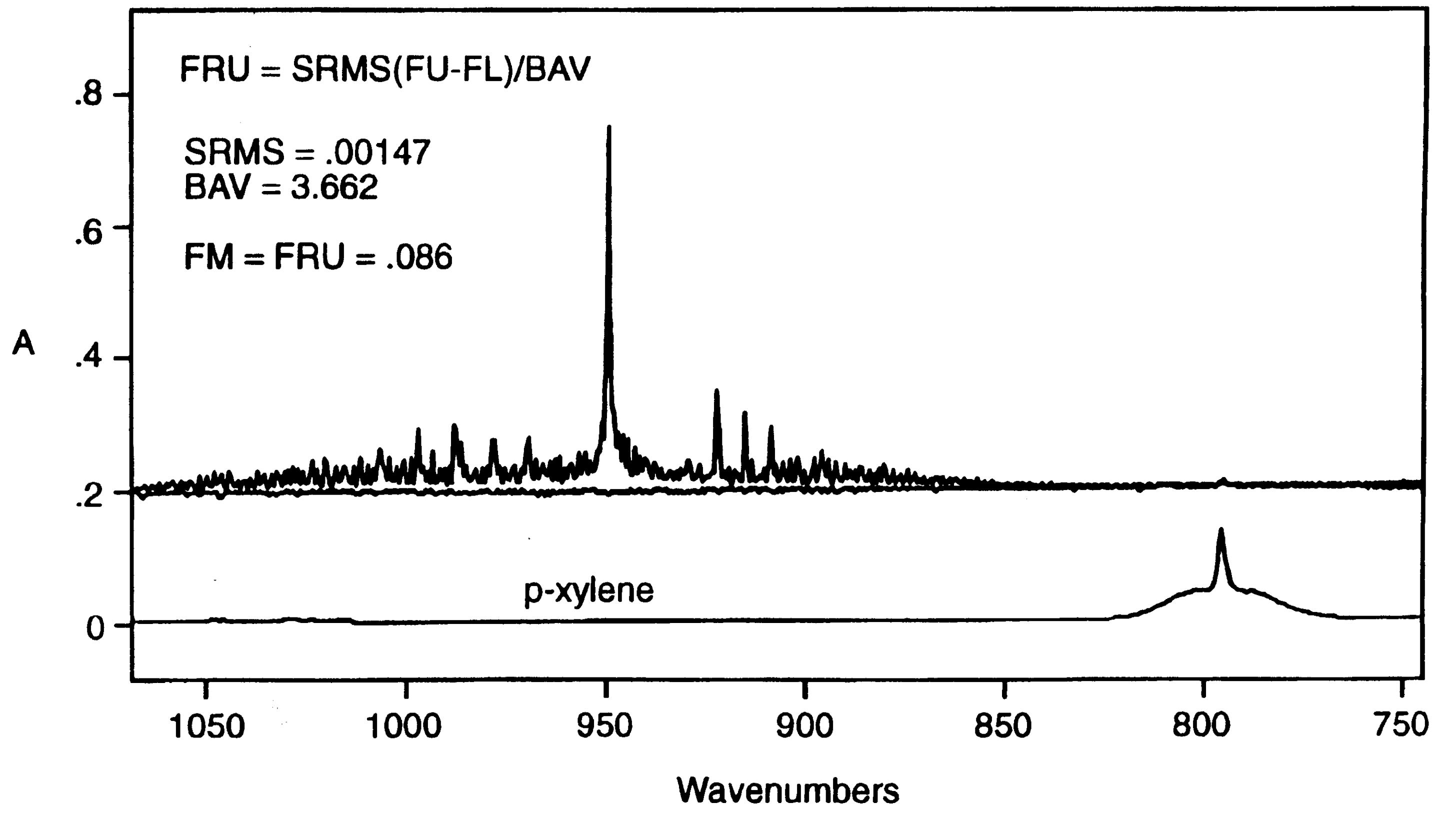

Figure 2. Fractional Reproducibility. Top: average of cts1031a and cts1101b. Bottom: Reference spectrum of p-xylene.

D-2 EPA FTIR PROTOCOL

PROTOCOL FOR THE USE OF EXTRACTIVE FOURIER TRANSFORM INFRARED (FTIR) SPECTROMETRY FOR THE ANALYSES OF GASEOUS EMISSIONS FROM STATIONARY SOURCES

INTRODUCTION

The purpose of this document is to set general guidelines for the use of modern FTIR spectroscopic methods for the analysis of gas samples extracted from the effluent of stationary emission sources. This document outlines techniques for developing and evaluating such methods and sets basic requirements for reporting and quality assurance procedures.

1.0 NOMENCLATURE

1.1 Appendix A lists definitions of the symbols and terms used in this Protocol, many of which have been taken directly from American Society for Testing and Materials (ASTM) publication E 131-90a, entitled "Terminology Relating to Molecular Spectroscopy."

1.2 Except in the case of background spectra or where otherwise noted, the term "spectrum" refers to a double-beam spectrum in units of absorbance vs. wavenumber (cm^{-1}).

1.3 The term "Study" in this document refers to a publication that has been subjected to EPA- or peer-review.

2.0 APPLICABILITY AND ANALYTICAL PRINCIPLE

2.1 Applicability. This Protocol applies to the determination of compound-specific concentrations in single- and multiple-component gas phase samples using double-beam absorption spectroscopy in the mid-infrared band. It does not specifically address other FTIR applications, such as single-beam spectroscopy, analysis of open-path (non-enclosed) samples, and continuous measurement techniques. If multiple spectrometers, absorption cells, or instrumental linewidths are used in such analyses, each distinct operational configuration of the system must be evaluated separately according to this Protocol.

2.2 Analytical Principle.

2.2.1 In the mid-infrared band, most molecules exhibit characteristic gas phase absorption spectra that may be recorded by FTIR systems. Such systems consist of a source of mid-infrared radiation, an interferometer, an enclosed sample cell of known absorption pathlength, an infrared detector, optical elements for the transfer of infrared radiation between components, and gas flow control and measurement components. Adjunct and integral computer systems are used for controlling the instrument, processing the signal, and for performing both Fourier transforms and quantitative analyses of spectral data.

2.2.2 The absorption spectra of pure gases and of mixtures of gases are described by a linear absorbance theory referred to as Beer's Law. Using this law, modern FTIR systems use computerized analytical programs to quantify compounds by comparing the absorption spectra of known (reference) gas samples to the absorption spectrum of the sample gas. Some standard mathematical techniques used for comparisons are classical least squares, inverse least squares, cross-correlation, factor analysis, and partial least squares. Reference A describes several of these techniques, as well as additional techniques, such as differentiation methods, linear baseline corrections, and non-linear absorbance corrections.

3.0 GENERAL PRINCIPLES OF PROTOCOL REQUIREMENTS

The characteristics that distinguish FTIR systems from gas analyzers used in instrumental gas analysis methods (e.g., EPA Methods 6C and 7E) are: (1) Computers are necessary to obtain and analyze data; (2) chemical concentrations can be quantified using previously recorded infrared reference spectra; and (3) analytical assumptions and results, including possible effects of interfering compounds, can be evaluated after the quantitative analysis. The following general principles and requirements of this Protocol are based on these characteristics.

3.1 Verifiability and Reproducibility of Results. Store all data and document data analysis techniques sufficient to allow an independent agent to reproduce the analytical results from the raw interferometric data.

3.2 Transfer of Reference Spectra. To determine whether reference spectra recorded under one set of conditions (e.g., optical bench, instrumental linewidth, absorption pathlength, detector performance, pressure, and temperature) can be used to analyze sample spectra taken under a different set of conditions, quantitatively compare "calibration transfer standards" (CTS) and reference spectra as described in this Protocol. (<u>Note</u>: The CTS may, but need not, include analytes of interest). To effect this, record the absorption spectra of the CTS (a) immediately before and immediately after recording reference spectra and (b) immediately after recording sample spectra.

3.3 Evaluation of FTIR Analyses. The applicability, accuracy, and precision of FTIR measurements are influenced by a number of interrelated factors, which may be divided into two classes:

3.3.1 Sample-Independent Factors. Examples are system configuration and performance (e.g., detector sensitivity and infrared source output), quality and applicability of reference absorption spectra, and type of mathematical analyses of the spectra. These factors define the fundamental limitations of FTIR measurements for a given system configuration. These limitations may be estimated from evaluations of the system before samples are available. For example, the detection limit for the absorbing compound under a given set of conditions may be estimated from the system noise level and the strength of a particular absorption band. Similarly, the accuracy of measurements may be estimated from the analysis of the reference spectra.

3.3.2 Sample-Dependent Factors. Examples are spectral interferants (e.g., water vapor and CO_2) or the overlap of spectral features of different compounds and contamination deposits on reflective surfaces or transmitting windows. To maximize the effectiveness of the mathematical techniques used in spectral analysis, identification of interferants (a standard initial step) and analysis of samples (includes effects of other analytical errors) are necessary. Thus, the Protocol requires post-analysis calculation of measurement concentration uncertainties for the detection of these potential sources of measurement error.

4.0 PRE-TEST PREPARATIONS AND EVALUATIONS

Before testing, demonstrate the suitability of FTIR spectrometry for the desired application according to the procedures of this section.

4.1 Identify Test Requirements. Identify and record the test requirements described below in 4.1.1 through 4.1.5. These values set the desired or required goals of the proposed analysis; the description of methods for determining whether these goals are actually met during the analysis comprises the majority of this Protocol.

4.1.1 Analytes (specific chemical species) of interest. Label the analytes from i = 1 to I.

4.1.2 Analytical uncertainty limit (AU_i). The AU_i is the maximum permissible fractional uncertainty of analysis for the i^{th} analyte concentration, expressed as a fraction of the analyte concentration in the sample.

4.1.3 Required detection limit for each analyte (DL_i, ppm). The detection limit is the lowest concentration of an analyte for which its overall fractional uncertainty (OFU_i) is required to be less than its analytical uncertainty limit (AU_i).

4.1.4 Maximum expected concentration of each analyte ($CMAX_i$, ppm).

4.2 Identify Potential Interferants. Considering the chemistry of the process or results of previous Studies, identify potential interferants, i.e., the major effluent constituents and any relatively minor effluent constituents that possess either strong absorption characteristics or strong structural similarities to any analyte of interest. Label them 1 through N_j, where the subscript "j" pertains to potential interferants. Estimate the concentrations of these compounds in the effluent ($CPOT_j$, ppm).

4.3 Select and Evaluate the Sampling System. Considering the source, e.g., temperature and pressure profiles, moisture content, analyte characteristics, and particulate concentration), select the equipment for extracting gas samples. Recommended are a particulate filter, heating system to maintain sample temperature above the dew point for all sample constituents at all points within the sampling system (including the filter), and sample conditioning system (e.g., coolers, water-permeable membranes that remove water or other compounds from the sample, and dilution devices) to remove spectral interferants or to protect the sampling and analytical components. Determine the minimum absolute sample system pressure (P_{min}, mmHg) and the infrared absorption cell volume (V_{SS}, liter). Select the techniques and/or equipment for the measurement of sample pressures and temperatures.

4.4 Select Spectroscopic System. Select a spectroscopic configuration for the application. Approximate the absorption pathlength (L_S', meter), sample pressure (P_S', kPa), absolute sample temperature T_S', and signal integration period (t_{SS}, seconds) for the analysis. Specify the nominal minimum instrumental linewidth (MIL) of the system. Verify that the fractional error at the approximate values P_S' and T_S' is less than one half the smallest value AU_i (see Section 4.1.2).

4.5 Select Calibration Transfer Standards (CTS's). Select CTS's that meet the criteria listed in Sections 4.5.1, 4.5.2, and 4.5.3.

> Note: It may be necessary to choose preliminary analytical regions (see Section 4.7), identify the minimum analyte linewidths, or estimate the system noise level (see Section 4.12) before selecting the CTS. More than one compound may be needed to meet the criteria; if so, obtain separate cylinders for each compound.

4.5.1 The central wavenumber position of each analytical region lies within 25 percent of the wavenumber position of at least one CTS absorption band.

4.5.2 The absorption bands in 4.5.1 exhibit peak absorbances greater than ten times the value RMS_{EST} (see Section 4.12) but less than 1.5 absorbance units.

4.5.3 At least one absorption CTS band within the operating range of the FTIR instrument has an instrument-independent linewidth no greater than the narrowest analyte absorption band; perform and document measurements or cite Studies to determine analyte and CTS compound linewidths.

4.5.4 For each analytical region, specify the upper and lower wavenumber positions (FFU_m and FFL_m, respectively) that bracket the CTS absorption band or bands for the associated analytical region. Specify the wavenumber range, FNU to FNL, containing the absorption band that meets the criterion of Section 4.5.3.

4.5.5 Associate, whenever possible, a single set of CTS gas cylinders with a set of reference spectra. Replacement CTS gas cylinders shall contain the same compounds at concentrations within 5 percent of that of the original CTS cylinders; the entire absorption spectra (not individual spectral segments) of the replacement gas shall be scaled by a factor between 0.95 and 1.05 to match the original CTS spectra.

4.6 Prepare Reference Spectra.

Note: Reference spectra are available in a permanent soft copy from the EPA spectral library on the EMTIC (Emission Measurement Technical Information Center) computer bulletin board; they may be used if applicable.

4.6.1 Select the reference absorption pathlength (L_R) of the cell.

4.6.2 Obtain or prepare a set of chemical standards for each analyte, potential and known spectral interferants, and CTS. Select the concentrations of the chemical standards to correspond to the top of the desired range.

4.6.2.1 Commercially-Prepared Chemical Standards. Chemical standards for many compounds may be obtained from independent sources, such as a specialty gas manufacturer, chemical company, or commercial laboratory. These standards (accurate to within ±2 percent) shall be prepared according to EPA Protocol 1 (see Reference D) or shall be traceable to NIST standards. Obtain from the supplier an estimate of the stability of the analyte concentration; obtain and follow all the supplier's recommendations for recertifying the analyte concentration.

4.6.2.2 Self-Prepared Chemical Standards. Chemical standards may be prepared as follows: Dilute certified commercially prepared chemical gases or pure analytes with ultra-pure carrier (UPC) grade nitrogen according to the barometric and volumetric techniques generally described in Reference A, Section A4.6.

4.6.3 Record a set of the absorption spectra of the CTS {R1}, then a set of the reference spectra at two or more concentrations in duplicate over the desired range (the top of the range must be less than 10 times that of the bottom), followed by a second set of CTS spectra {R2}. (If self-prepared standards are used, see Section 4.6.5 before disposing of any of the standards.) The maximum accepted standard concentration-pathlength product (ASCPP) for each compound shall be higher than the maximum estimated concentration-pathlength products for both analytes and known interferants in the effluent gas. For each analyte, the minimum ASCPP shall be no greater than ten times the concentration-pathlength product of that analyte at its required detection limit.

4.6.4 Permanently store the background and interferograms in digitized form. Document details of the mathematical process for generating the spectra from these interferograms. Record the sample pressure (P_R), sample temperature (T_R), reference absorption pathlength (L_R), and interferogram signal integration period (t_{SR}). Signal integration periods for the background interferograms shall be $\geq t_{SR}$. Values of P_R, L_R, and t_{SR} shall not deviate by more than ±1 percent from the time of recording {R1} to that of recording {R2}.

4.6.5 If self-prepared chemical standards are employed and spectra of only two concentrations are recorded for one or more compounds, verify the accuracy of the dilution technique by analyzing the prepared standards for those compounds with a secondary (non-FTIR) technique as follows:

4.6.5.1 Record the response of the secondary technique to each of the four standards prepared.

4.6.5.2 Perform a linear regression of the response values (dependant variable) versus the accepted standard concentration (ASC) values (independent variable), with the regression constrained to pass through the zero-response, zero ASC point.

4.6.5.3 Calculate the average fractional difference between the actual response values and the regression-predicted values (those calculated from the regression line using the four ASC values as the independent variable).

4.6.5.4 If the average fractional difference value calculated in Section 4.6.5.3 is larger for any compound than the corresponding AU_i, the dilution technique is not sufficiently accurate and the reference spectra prepared are not valid for the analysis.

4.7 Select Analytical Regions. Using the general considerations in Section 7 of Reference A and the spectral characteristics of the analytes and interferants, select the analytical regions for the application. Label them m = 1 to M. Specify the lower, center and upper wavenumber positions of each analytical region (FL_m, FC_m, and FU_m, respectively). Specify the analytes and interferants which exhibit absorption in each region.

4.8 Determine Fractional Reproducibility Uncertainties. Using Appendix E, calculate the fractional reproducibility uncertainty for each analyte (FRU_i) from a comparison of {R1} and {R2}. If $FRU_i > AU_i$ for any analyte, the reference spectra generated in Section 4.6 are not valid for the application.

4.9 Identify Known Interferants. Using Appendix B, determine which potential interferant affects the analyte concentration determinations. If it does, relabel the potential interferant as "known" interferant, and designate these compounds from k = 1 to K. Appendix B also provides criteria for determining whether the selected analytical regions are suitable.

4.10 Prepare Computerized Analytical Programs.

4.10.1 Choose or devise mathematical techniques (e.g, classical least squares, inverse least squares, cross-correlation, and factor analysis) based on Equation 4 of Reference A that are appropriate for analyzing spectral data by comparison with reference spectra.

4.10.2 Following the general recommendations of Reference A, prepare a computer program or set of programs that analyzes all the analytes and known interferants, based on the selected analytical regions (4.7) and the prepared reference spectra (4.6). Specify the baseline correction technique (e.g., determining the slope and intercept of a linear baseline contribution in each analytical region) for each analytical region, including all relevant wavenumber positions.

4.10.3 Use programs that provide as output [at the reference absorption pathlength (L_R), reference gas temperature (T_R), and reference gas pressure (P_R)] the analyte concentrations, the known interferant concentrations, and the baseline slope and intercept values. If the sample absorption pathlength (L_S), sample gas temperature (T_S) or sample gas pressure (P_S) during the actual sample analyses differ from L_R, T_R, and P_R, use a program or set of programs that applies multiplicative corrections to the derived concentrations to account for these variations, and that provides as output both the corrected and uncorrected values. Include in the report of the analysis (see Section 7.0) the details of any transformations applied to the original reference spectra (e.g., differentiation), in such a fashion that all analytical results may be verified by an independent agent from the reference spectra and data spectra alone.

4.11 Determine the Fractional Calibration Uncertainty. Calculate the fractional calibration uncertainty for each analyte (FCU_i) according to Appendix F, and compare these values to the fractional uncertainty limits (AU_i; see Section 4.1). If $FCU_i > AU_i$), either the reference spectra or analytical programs for that analyte are unsuitable.

4.12 Verify System Configuration Suitability. Using Appendix C, measure or obtain estimates of the noise level (RMS_{EST}, absorbance) of the FTIR system; alternatively, construct the complete spectrometer system and determine the values RMS_{Sm} using Appendix G. Estimate the minimum measurement uncertainty for each analyte (MAU_i, ppm) and known interferant (MIU_k, ppm) using Appendix D. Verify that (a) $MAU_i < (AU_i)(DL_i)$, $FRU_i < AU_i$, and $FCU_i < AU_i$ for each analyte and that (b) the CTS chosen meets the requirements listed in Section 4.5.

5.0 SAMPLING AND ANALYSIS PROCEDURE

5.1 Analysis System Assembly and Leak-Test. Assemble the analysis system. Allow sufficient time for all system components to reach the desired temperature. Then determine the leak-rate (L_R) and leak volume (V_L), where $V_L = L_R\ t_{SS}$. Leak volumes shall be $\leq$4 percent of V_{SS}.

5.2 Verify Instrumental Performance. Measure the noise level of the system in each analytical region using the procedure of Appendix G. If any noise level is higher than that estimated for the system in Section 4.12, repeat the calculations of Appendix D and verify that the requirements of Section 4.12 are met; if they are not, adjust or repair the instrument and repeat this section.

5.3 Determine the Sample Absorption Pathlength. Record a background spectrum. Then, fill the absorption cell with CTS at the pressure P_R and record a set of CTS spectra {R3}. Store the background and unscaled CTS single beam interferograms and spectra. Using Appendix H, calculate the sample absorption pathlength (L_S) for each analytical region. The values L_S shall not differ from the approximated sample pathlength L_S' (see Section 4.4) by more than 5 percent.

5.4 Record Sample Spectrum. Connect the sample line to the source. Either evacuate the absorption cell to an absolute pressure below 5 mmHg before extracting a sample from the effluent stream into the absorption cell, or pump at least ten cell volumes of sample through the cell before obtaining a sample. Record the sample pressure P_S. Generate the absorbance spectrum of the sample. Store the background and sample single beam interferograms, and document the process by which the absorbance spectra are generated from these data. (If necessary, apply the spectral transformations developed in Section 5.6.2). The resulting sample spectrum is referred to below as S_S.

> <u>Note</u>: Multiple sample spectra may be recorded according to the procedures of Section 5.4 before performing Sections 5.5 and 5.6.

5.5 Quantify Analyte Concentrations. Calculate the unscaled analyte concentrations RUA_i and unscaled interferant concentrations RUI_K using the programs developed in Section 4. To correct for pathlength and pressure variations between the reference and sample spectra, calculate the scaling factor $R_{LPS} = (L_R P_R T_S)/(L_S P_S T_R)$. Calculate the final analyte and interferant concentrations $RSA_i = R_{LPS}RUA_i$ and $RSI_k = R_{LPS}RUI_k$.

5.6 **Determine Fractional Analysis Uncertainty.** Fill the absorption cell with CTS at the pressure P_S. Record a set of CTS spectra {R4}. Store the background and CTS single beam interferograms. Using Appendix H, calculate the fractional analysis uncertainty (FAU) for each analytical region. If the FAU indicated for any analytical region is larger than the required accuracy requirements determined in Section 4.1, then comparisons to previously recorded reference spectra are invalid in that analytical region, and the analyst shall perform one or both of the following procedures:

5.6.1 Perform instrumental checks and adjust the instrument to restore its performance to acceptable levels. If adjustments are made, repeat Sections 5.3, 5.4 (except for the recording of a sample spectrum), and 5.5 to demonstrate that acceptable uncertainties are obtained in all analytical regions.

5.6.2 Apply appropriate mathematical transformations (e.g., frequency shifting, zero-filling, apodization, smoothing) to the spectra (or to the interferograms upon which the spectra are based) generated during the performance of the procedures of Section 5.3. Document these transformations and their reproducibility. Do not apply multiplicative scaling of the spectra, or any set of transformations that is mathematically equivalent to multiplicative scaling. Different transformations may be applied to different analytical regions. Frequency shifts shall be smaller than one-half the minimum instrumental linewidth, and must be applied to all spectral data points in an analytical region. The mathematical transformations may be retained for the analysis if they are also applied to the appropriate analytical regions of all sample spectra recorded, and if all original sample spectra are digitally stored. Repeat Sections 5.3, 5.4 (except the recording of a sample spectrum), and 5.5 to demonstrate that these transformations lead to acceptable calculated concentration uncertainties in all analytical regions.

6.0 POST-ANALYSIS EVALUATIONS

Estimate the overall accuracy of the analyses performed in Section 5 as follows:

6.1 Qualitatively Confirm the Assumed Matrix. Examine each analytical region of the sample spectrum for spectral evidence of unexpected or unidentified interferants. If found, identify the interfering compounds (see Reference C for guidance) and add them to the list of known interferants. Repeat the procedures of Section 4 to include the interferants in the uncertainty calculations and analysis procedures. Verify that the MAU and FCU values do not increase beyond acceptable levels for the application requirements. Re-calculate the analyte concentrations (Section 5.5) in the affected analytical regions.

6.2 Quantitatively Evaluate Fractional Model Uncertainty (FMU). Perform the procedures of either Section 6.2.1 or 6.2.2:

6.2.1 Using Appendix I, determine the fractional model error (FMU) for each analyte.

6.2.2 Provide statistically determined uncertainties FMU for each analyte which are equivalent to two standard deviations at the 95% confidence level. Such determinations, if employed, must be based on mathematical examinations of the pertinent sample spectra (not the reference spectra alone). Include in the report of the analysis (see Section 7.0) a complete description of the determination of the concentration uncertainties.

6.3 Estimate Overall Concentration Uncertainty (OCU). Using Appendix J, determine the overall concentration uncertainty (OCU) for each analyte. If the OCU is larger than the required accuracy for any analyte, repeat Sections 4 and 6.

7.0 REPORTING REQUIREMENTS

[Documentation pertaining to virtually all the procedures of Sections 4, 5, and 6 will be required. Software copies of reference spectra and sample spectra will be retained for some minimum time following the actual testing.]

8.0 REFERENCES

A) Standard Practices for General Techniques of Infrared Quantitative Analysis (American Society for Testing and Materials, Designation E 168-88).

B) The Coblentz Society Specifications for Evaluation of Research Quality Analytical Infrared Reference Spectra (Class II); Anal. Chemistry 47, 945A (1975); **Appl. Spectroscopy 444, pp. 211-215, 1990.**

C) Standard Practices for General Techniques for Qualitative Infrared Analysis, American Society for Testing and Materials, Designation E 1252-88.

D) "Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Emissions Monitors (Protocol Number 1)," June 1978, Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods, EPA-600/4-77-027b, August 1977.

APPENDIX A

DEFINITIONS OF TERMS AND SYMBOLS

A.1 Definitions of Terms

absorption band - a contiguous wavenumber region of a spectrum (equivalently, a contiguous set of absorbance spectrum data points) in which the absorbance passes through a maximum or a series of maxima.

absorption pathlength - in a spectrophotometer, the distance, measured in the direction of propagation of the beam of radiant energy, between the surface of the specimen on which the radiant energy is incident and the surface of the specimen from which it is emergent.

analytical region - a contiguous wavenumber region (equivalently, a contiguous set of absorbance spectrum data points) used in the quantitative analysis for one or more analyte.

Note: The quantitative result for a single analyte may be based on data from more than one analytical region.

apodization - modification of the ILS function by multiplying the interferogram by a weighing function whose magnitude varies with retardation.

background spectrum - the single beam spectrum obtained with all system components without sample present.

baseline - any line drawn on an absorption spectrum to establish a reference point that represents a function of the radiant power incident on a sample at a given wavelength.

Beers's law - the direct proportionality of the absorbance of a compound in a homogeneous sample to its concentration.

calibration transfer standard (CTS) gas - a gas standard of a compound used to achieve and/or demonstrate suitable quantitative agreement between sample spectra and the reference spectra; see Section 4.5.1.

compound - a substance possessing a distinct, unique molecular structure.

concentration (c) - the quantity of a compound contained in a unit quantity of sample. The unit "ppm" (number, or mole, basis) is recommended.

concentration-pathlength product - the mathematical product of concentration of the species and absorption pathlength. For reference spectra, this is a known quantity; for sample spectra, it is the quantity directly determined from Beer's law. The units "centimeters-ppm" or "meters-ppm" are recommended.

derivative absorption spectrum - a plot of rate of change of absorbance or of any function of absorbance with respect to wavelength or any function of wavelength.

double beam spectrum - a transmission or absorbance spectrum derived by dividing the sample single beam spectrum by the background spectrum.

Note: The term "double-beam" is used elsewhere to denote a spectrum in which the sample and background interferograms are collected simultaneously along physically distinct absorption paths. Here, the term denotes a spectrum in which the sample and background interferograms are collected at different times along the same absorption path.

fast Fourier transform (FFT) - a method of speeding up the computation of a discrete FT by factoring the data into sparse matrices containing mostly zeros.

flyback - interferometer motion during which no data are recorded.

Fourier transform (FT) - the mathematical process for converting an amplitude-time spectrum to an amplitude-frequency spectrum, or vice versa.

Fourier transform infrared (FTIR) spectrometer - an analytical system that employs a source of mid-infrared radiation, an interferometer, an enclosed sample cell of known absorption pathlength, an infrared detector, optical elements that transfer infrared radiation between components, and a computer system. The time-domain detector response (interferogram) is processed by a Fourier transform to yield a representation of the detector response vs. infrared frequency.

Note: When FTIR spectrometers are interfaced with other instruments, a slash should be used to denote the interface; e.g., GC/FTIR; HPCL/FTIR, and the use of FTIR should be explicit; i.e., FTIR not IR.

frequency, ν - the number of cycles per unit time.

infrared - the portion of the electromagnetic spectrum containing wavelengths from approximately 0.78 to 800 microns.

interferogram, $I(\sigma)$ - record of the modulated component of the interference signal measured as a function of retardation by the detector.

interferometer - device that divides a beam of radiant energy into two or more paths, generate an optical path difference between the beams, and recombines them in order to produce repetitive interference maxima and minima as the optical retardation is varied.

linewidth - the full width at half maximum of an absorption band in units of wavenumbers (cm^{-1}).

mid-infrared - the region of the electromagnetic spectrum from approximately 400 to 5000 cm^{-1}.

pathlength - see "absorption pathlength."

reference spectra - absorption spectra of gases with known chemical compositions, recorded at a known absorption pathlength, which are used in the quantitative analysis of gas samples.

retardation, σ - optical path difference between two beams in an interferometer; also known as "optical path difference" or "optical retardation."

scan - digital representation of the detector output obtained during one complete motion of the interferometer's moving assembly or assemblies.

scaling - application of a multiplicative factor to the absorbance values in a spectrum.

single beam spectrum - Fourier-transformed interferogram, representing the detector response vs. wavenumber.

Note: The term "single-beam" is used elsewhere to denote any spectrum in which the sample and background interferograms are recorded on the same physical absorption path; such usage differentiates such spectra from those generated using interferograms recorded along two physically distinct absorption paths (see "double-beam spectrum" above). Here, the term applies (for example) to the two spectra used directly in the calculation of transmission and absorbance spectra of a sample.

standard reference material - a reference material, the composition or properties of which are certified by a recognized standardizing agency or group.

Note: The equivalent ISO term is "certified reference material."

transmittance, T - the ratio of radiant power transmitted by the sample to the radiant power incident on the sample. Estimated in FTIR spectroscopy by forming the ratio of the single-beam sample and background spectra.

wavenumber, $\bar{v}$ - the number of waves per unit length.

Note: The usual unit of wavenumber is the reciprocal centimeter, cm^{-1}. The wavenumber is the reciprocal of the wavelength, λ, when λ is expressed in centimeters.

zero-filling - the addition of zero-valued points to the end of a measured interferogram.

Note: Performing the FT of a zero-filled interferogram results in correctly interpolated points in the computed spectrum.

A.2 Definitions of Mathematical Symbols

A, absorbance - the logarithm to the base 10 of the reciprocal of the transmittance (T).

$$A = \log_{10}\left(\frac{1}{T}\right) = -\log_{10}T \tag{1}$$

AAI_{im} - band area of the i^{th} analyte in the m^{th} analytical region, at the concentration (CL_i) corresponding to the product of its required detection limit (DL_i) and analytical uncertainty limit (AU_i) .

AAV_{im} - average absorbance of the i^{th} analyte in the m^{th} analytical region, at the concentration (CL_i) corresponding to the product of its required detection limit (DL_i) and analytical uncertainty limit (AU_i) .

ASC, accepted standard concentration - the concentration value assigned to a chemical standard.

ASCPP, accepted standard concentration-pathlength product - for a chemical standard, the product of the ASC and the sample absorption pathlength. The units "centimeters-ppm" or "meters-ppm" are recommended.

AU_i, analytical uncertainty limit - the maximum permissible fractional uncertainty of analysis for the i^{th} analyte concentration, expressed as a fraction of the analyte concentration determined in the analysis.

AVT_m - average estimated total absorbance in the m^{th} analytical region.

$CKWN_k$ - estimated concentration of the k^{th} known interferant.

$CMAX_i$ - estimated maximum concentration of the i^{th} analyte.

$CPOT_j$ - estimated concentration of the j^{th} potential interferant.

DL_i, required detection limit - for the i^{th} analyte, the lowest concentration of the analyte for which its overall fractional uncertainty (OFU_i) is required to be less than the analytical uncertainty limit (AU_i).

FC_m - center wavenumber position of the m^{th} analytical region.

FAU_i, fractional analytical uncertainty - calculated uncertainty in the measured concentration of the i^{th} analyte because of errors in the mathematical comparison of reference and sample spectra.

FCU_i, fractional calibration uncertainty - calculated uncertainty in the measured concentration of the i^{th} analyte because of errors in Beer's law modeling of the reference spectra concentrations.

FFL_m - lower wavenumber position of the CTS absorption band associated with the m^{th} analytical region.

FFU_m - upper wavenumber position of the CTS absorption band associated with the m^{th} analytical region.

FL_m - lower wavenumber position of the m^{th} analytical region.

FMU_i, fractional model uncertainty - calculated uncertainty in the measured concentration of the i^{th} analyte because of errors in the absorption model employed.

FN_L - lower wavenumber position of the CTS spectrum containing an absorption band at least as narrow as the analyte absorption bands.

FN_U - upper wavenumber position of the CTS spectrum containing an absorption band at least as narrow as the analyte absorption bands.

FRU_i, fractional reproducibility uncertainty - calculated uncertainty in the measured concentration of the i^{th} analyte because of errors in the reproducibility of spectra from the FTIR system.

FU_m - upper wavenumber position of the m^{th} analytical region.

IAI_{jm} - band area of the j^{th} potential interferant in the m^{th} analytical region, at its expected concentration ($CPOT_j$).

IAV_{im} - average absorbance of the i^{th} analyte in the m^{th} analytical region, at its expected concentration ($CPOT_j$).

$ISC_{i \text{ or } k}$, indicated standard concentration - the concentration from the computerized analytical program for a single-compound reference spectrum for the i^{th} analyte or k^{th} known interferant.

kPa - kilo-Pascal (see Pascal).

L_s' - estimated sample absorption pathlength.

L_R - reference absorption pathlength.

L_s - actual sample absorption pathlength.

MAU_i - mean of the MAU_{im} over the appropriate analytical regions.

MAU_{im}, minimum analyte uncertainty - the calculated minimum concentration for which the analytical uncertainty limit (AU_i) in the measurement of the i^{th} analyte, based on spectral data in the m^{th} analytical region, can be maintained.

MIU_j - mean of the MIU_{jm} over the appropriate analytical regions.

MIU_{jm}, minimum interferant uncertainty - the calculated minimum concentration for which the analytical uncertainty limit $CPOT_j/20$ in the measurement of the j^{th} interferant, based on spectral data in the m^{th} analytical region, can be maintained.

MIL, minimum instrumental linewidth - the minimum linewidth from the FTIR system, in wavenumbers.

<u>Note</u>: The MIL of a system may be determined by observing an absorption band known (through higher resolution examinations) to be narrower than indicated by the system. The MIL is fundamentally limited by the retardation of the interferometer, but is also affected by other operational parameters (e.g., the choice of apodization).

N_i - number of analytes.

N_j - number of potential interferants.

N_k - number of known interferants.

N_{scan} - the number of scans averaged to obtain an interferogram.

OFU_i - the overall fractional uncertainty in an analyte concentration determined in the analysis ($OFU_i = MAX\{FRU_i, FCU_i, FAU_i, FMU_i\}$).

Pascal (Pa) - metric unit of static pressure, equal to one Newton per square meter; one atmosphere is equal to 101,325 Pa; 1/760 atmosphere (one Torr, or one millimeter Hg) is equal to 133.322 Pa.

P_{min} - minimum pressure of the sampling system during the sampling procedure.

P_s' - estimated sample pressure.

P_R - reference pressure.

P_s - actual sample pressure.

RMS_{sm} - measured noise level of the FTIR system in the m^{th} analytical region.

RMSD, root mean square difference - a measure of accuracy determined by the following equation:

$$\text{RMSD} = \sqrt{\left(\frac{1}{n}\right) \sum_{i=1}^{n} e_i^2} \qquad (2)$$

where:

n = the number of observations for which the accuracy is determined.

e_i = the difference between a measured value of a property and its mean value over the n observations.

Note: The RMSD value "between a set of n contiguous absorbance values (A_i) and the mean of the values" (A_M) is defined as

$$\text{RMSD} = \sqrt{\left(\frac{1}{n}\right) \sum_{i=1}^{n} \left(A_i - A_M\right)^2} \qquad (3)$$

RSA_i - the (calculated) final concentration of the ith analyte.

RSI_k - the (calculated) final concentration of the kth known interferant.

t_{scan}, scan time - time used to acquire a single scan, not including flyback.

t_s, signal integration period - the period of time over which an interferogram is averaged by addition and scaling of individual scans. In terms of the number of scans N_{scan} and scan time t_{scan}, $t_S = N_{scan}t_{scan}$.

t_{sR} - signal integration period used in recording reference spectra.

t_{ss} - signal integration period used in recording sample spectra.

T_R - absolute temperature of gases used in recording reference spectra.

T_s - absolute temperature of sample gas as sample spectra are recorded.

TP, Throughput - manufacturer's estimate of the fraction of the total infrared power transmitted by the absorption cell and transfer optics from the interferometer to the detector.

V_{ss} - volume of the infrared absorption cell, including parts of attached tubing.

W_{ik} - weight used to average over analytical regions k for quantities related to the analyte i; see Appendix D.

Note that some terms are missing, e.g., BAV_m, OCU, $RMSS_n$, SUB_s, SIC_i, SAC_i, S_s

APPENDIX B

IDENTIFYING SPECTRAL INTERFERANTS

B.1 General

B.1.1 Assume a fixed absorption pathlength equal to the value L_s'.

B.1.2 Use band area calculations to compare the relative absorption strengths of the analytes and potential interferants. In the m^{th} analytical region (FL_m to FU_m), use either rectangular or trapezoidal approximations to determine the band areas described below (see Reference A, Sections A.3.1 through A.3.3); document any baseline corrections applied to the spectra.

B.1.3 Use the average total absorbance of the analytes and potential interferants in each analytical region to determine whether the analytical region is suitable for analyte concentration determinations.

> Note: The average absorbance in an analytical region is the band area divided by the width of the analytical region in wavenumbers. The average total absorbance in an analytical region is the sum of the average absorbances of all analytes and potential interferants.

B.2 Calculations

B.2.1 Prepare spectral representations of each analyte at the concentration $CL_i = (DL_i)(AU_i)$, where DL_i is the required detection limit and AU_i is the maximum permissible analytical uncertainty. For the m^{th} analytical region, calculate the band area (AAI_{im}) and average absorbance (AAV_{im}) from these scaled analyte spectra.

B.2.2 Prepare spectral representations of each potential interferant at its expected concentration ($CPOT_j$). For the m^{th} analytical region, calculate the band area (IAI_{jm}) and average absorbance (IAV_{jm}) from these scaled potential interferant spectra.

B.2.3 Repeat the calculation for each analytical region, and record the band area results in matrix form as indicated in Figure B.1.

B.2.4 If the band area of any potential interferant in an analytical region is greater than the one-half the band area of any analyte (i.e., $IAI_{jm} > 0.5\ AAI_{im}$ for any pair ij and any m), classify the potential interferant as known interferant. Label the known interferants k = 1 to K. Record the results in matrix form as indicated in Figure B.2.

B.2.5 Calculate the average total absorbance (AVT_m) for each analytical region and record the values in the last row of the matrix described in Figure B.2. Any analytical region where $AVT_m > 2.0$ is unsuitable.

FIGURE B.1 Presentation of Potential Interferant Calculations

	Analytical Regions 1	. . . .	M
	Analyte Labels		
1	AAI_{11}	. . .	AAI_{1M}
.	.		.
.	.		.
I	AAI_{I1}	. . .	AAI_{IM}
Potential Interferant Labels			
1	IAI_{11}	. . .	IAI_{1M}
.	.		.
.	.		.
J	IAI_{J1}	. . .	IAI_{JM}

FIGURE B.2 Presentation of Known Interferant Calculations

	Analytical Regions 1	. . . .	M
Analyte Labels			
1	AAI_{11}	. . . .	AAI_{1M}
.	.		.
.	.		.
I	AAI_{I1}	. . . .	AAI_{IM}
Known Interferant Labels			
1	IAI_{11}	. . . .	IAI_{1M}
.	.		.
.	.		.
K	IAI_{K1}	. . . .	IAI_{KM}
Total Average Absorbance	AVT_1		AVT_M

APPENDIX C

ESTIMATING NOISE LEVELS

C.1 General

C.1.1 The root-mean-square (RMS) noise level is the standard measure of noise in this Protocol. The RMS noise level of a contiguous segment of a spectrum is defined as the RMS difference (RMSD) between the absorbance values which form the segment and the mean value of that segment (see Appendix A).

C.1.2 The RMS noise value in double-beam absorbance spectra is assumed to be inversely proportional to: (a) the square root of the signal integration period of the sample single beam spectra from which it is formed, and (b) to the total infrared power transmitted through the interferometer and absorption cell.

C.1.3 Practically, the assumption of C.1.2 allow the RMS noise level of a complete system to be estimated from the following four quantities:

(a) RMS_{MAN} - the noise level of the system (in absorbance units), without the absorption cell and transfer optics, <u>under those conditions necessary to yield the specified minimum instrumental linewidth</u>, e.g., Jacquinot stop size.

(b) t_{MAN} - the manufacturer's signal integration time used to determine RMS_{MAN}.

(c) t_{ss} - the signal integration time for the analyses.

(d) TP - the manufacturer's estimate of the fraction of the total infrared power transmitted by the absorption cell and transfer optics from the interferometer to the detector.

C.2 Calculations

C.2.1 Obtain the values of RMS_{MAN}, t_{MAN}, and TP from the manufacturers of the equipment, or determine the noise level by direct measurements with the completely constructed system proposed in Section 4.

C.2.2 Calculate the noise value of the system (RMS_{EST}) as follows:

$$RMS_{EST} = RMS_{MAN} \ TP \sqrt{\frac{t_{ss}}{t_{MAN}}} \qquad (4)$$

APPENDIX D

ESTIMATING MINIMUM CONCENTRATION MEASUREMENT UNCERTAINTIES (MAU and MIU)

D.1 General

Estimate the minimum concentration measurement uncertainties for the i^th analyte (MAU_i) and j^th interferant (MIU_j) based on the spectral data in the m^th analytical region by comparing the analyte band area in the analytical region (AAI_{im}) and estimating or measuring the noise level of the system (RMS_{EST} or RMS_{Sm}).

> Note: For a single analytical region, the MAU or MIU value is the concentration of the analyte or interferant for which the band area is equal to the product of the analytical region width (in wavenumbers) and the noise level of the system (in absorbance units). If data from more than one analytical region is used in the determination of an analyte concentration, the MAU or MIU is the mean of the separate MAU or MIU values calculated for each analytical region.

D.2 Calculations

D.2.1 For each analytical region, set RMS = RMS_{Sm} if measured (Appendix G), or set RMS = RMS_{EST} if estimated (Appendix C).

D.2.2 For each analyte associated with the analytical region, calculate

$$MAU_{im} = (RMS)(DL_i)(AU_i)\frac{(FU_m - FL_m)}{AAI_{im}} \tag{5}$$

D.2.3 If only the m^th analytical region is used to calculate the concentration of the i^th analyte, set $MAU_i = MAU_{im}$.

D.2.4 If a number of analytical regions are used to calculate the concentration of the i^th analyte, set MAU_i equal to the weighted mean of the appropriate MAU_{im} values calculated above; the weight for each term in the mean is equal to the fraction of the total wavenumber range used for the calculation represented by each analytical region. Mathematically, if the set of analytical regions employed is {m'}, then the MAU for each analytical region is

$$MAU_i = \sum_{k \in \{m'\}} W_{ik} \; MAU_{ik} \tag{6}$$

where the weight W_{ik} is defined for each term in the sum as

$$W_{ik} = \left(FM_k - FL_k \right) \left(\sum_{p \in \{m'\}} [FM_p - FL_p] \right)^{-1} \tag{7}$$

D.2.5 Repeat Sections D.2.1 through D.2.4 to calculate the analogous values MIU_j for the interferants $j = 1$ to J. Replace the value $(AU_i)(DL_i)$ in the above equations with $CPOT_j/20$; replace the value AAI_{im} in the above equations with IAI_{jm}.

APPENDIX E

DETERMINING FRACTIONAL REPRODUCIBILITY UNCERTAINTIES (FRU)

E.1 General

To estimate the reproducibility of the spectroscopic results of the system, compare the CTS spectra recorded before and after preparing the reference spectra. Compare the difference between the spectra to their average band area. Perform the calculation for each analytical region on the portions of the CTS spectra associated with that analytical region.

E.2 Calculations

E.2.1 The CTS spectra {R1} consist of N spectra, denoted by S_{1i}, i=1, N. Similarly, the CTS spectra {R2} consist of N spectra, denoted by S_{2i}, i=1, N. Each S_{ki} is the spectrum of a single compound, where i denotes the compound and k denotes the set {Rk} of which S_{ki} is a member. Form the spectra S_3 according to $S_{3i} = S_{2i}-S_{1i}$ for each i. Form the spectra S_4 according to $S_{4i} = [S_{2i}+S_{1i}]/2$ for each i.

E.2.2 Each analytical region m is associated with a portion of the CTS spectra S_{2i} and S_{1i}, for a particular i, with lower and upper wavenumber limits FFL_m and FFU_m, respectively.

E.2.3 For each m and the associated i, calculate the band area of S_{4i} in the wavenumber range FFU_m to FFL_m. Follow the guidelines of Section B.1.2 for this band area calculation. Denote the result by BAV_m.

E.2.4 For each m and the associated i, calculate the RMSD of S_{3i} between the absorbance values and their mean in the wavenumber range FFU_m to FFL_m. Denote the result by $SRMS_m$.

E.2.5 For each analytical region m, calculate the quantity

$$FM_m = SRMS_m(FFU_m-FFL_m)/BAV_m$$

E.2.6 If only the m^{th} analytical region is used to calculate the concentration of the i^{th} analyte, set $FRU_i = FM_m$.

E.2.7 If a number p_i of analytical regions are used to calculate the concentration of the i^{th} analyte, set FRU_i equal to the weighted mean of the appropriate FM_m values calculated above. Mathematically, if the set of analytical regions employed is {m'}, then

$$FRU_i = \sum_{k\in\{m'\}} W_{ik}\, FM_k \tag{8}$$

where the W_{ik} are calculated as described in Appendix D.

APPENDIX F

DETERMINING FRACTIONAL CALIBRATION UNCERTAINTIES (FCU)

F.1 General

F.1.1 The concentrations yielded by the computerized analytical program applied to each single-compound reference spectrum are defined as the indicated standard concentrations (ISC's). The ISC values for a single compound spectrum should ideally equal the accepted standard concentration (ASC) for one analyte or interferant, and should ideally be zero for all other compounds. Variations from these results are caused by errors in the ASC values, variations from the Beer's law (or modified Beer's law) model used to determine the concentrations, and noise in the spectra. When the first two effects dominate, the systematic nature of the errors is often apparent; take steps to correct them.

F.1.2 When the calibration error appears non-systematic, apply the following method to estimate the fractional calibration uncertainty (FCU) for each compound. The FCU is defined as the mean fractional error between the ASC and the ISC for all reference spectra with non-zero ASC for that compound. The FCU for each compound shall be less than the required fractional uncertainty specified in Section 4.1.

F.1.3 The computerized analytical programs shall also be required to yield acceptably low concentrations for compounds with ISC=0 when applied to the reference spectra. The limits chosen in this Protocol are that the ISC of each reference spectrum for each analyte or interferant shall not exceed that compound's minimum measurement uncertainty (MAU or MIU).

F.2 Calculations

F.2.1 Apply each analytical program to each reference spectrum. Prepare a similar table as that in Figure F.1 to present the ISC and ASC values for each analyte and interferant in each reference spectrum. Maintain the order of reference file names and compounds employed in preparing Figure F.1.

F.2.2 For all reference spectra in Figure F.1, verify that the absolute value of the ISC's are less than the compound's MAU (for analytes) or MIU (for interferants).

F.2.3 For each analyte reference spectrum, calculate the quantity (ASC-ISC)/ASC. For each analyte, calculate the mean of these values (the FCU_i for the i^{th} analyte) over all reference spectra. Prepare a similar table as that in Figure F.2 to present the FCU_i and analytical uncertainty limit (AU_i) for each analyte.

FIGURE F.1

Presentation of Accepted Standard Concentrations (ASC's)
and Indicated Standard Concentrations (ISC's)

Compound Name	Reference Spectrum File Name	ASC (ppm)	ISC (ppm)					
			Analytes i=1..............I			Interferants j=1..............J		

FIGURE F.2

Presentation of Fractional Calibration Uncertainties (FCU's)
and Analytical Uncertainties (AU's)

Analyte Name	FCU (%)	AU (%)

APPENDIX G

MEASURING NOISE LEVELS

G.1 General

The root-mean-square (RMS) noise level is the standard measure of noise. The RMS noise level of a contiguous segment of a spectrum is the RMSD between the absorbance values that form the segment and the mean value of the segment (see Appendix A).

G.2 Calculations

G.2.1 Evacuate the absorption cell or fill it with UPC grade nitrogen at approximately one atmosphere total pressure.

G.2.2 Record two single beam spectra of signal integration period t_{ss}.

G.2.3 Form the double beam absorption spectrum from these two single beam spectra, and calculate the noise level RMS_{Sm} in the M analytical regions.

APPENDIX H

DETERMINING SAMPLE ABSORPTION PATHLENGTH (L_S) AND FRACTIONAL ANALYTICAL UNCERTAINTY (FAU)

H.1 General

Reference spectra recorded at absorption pathlength (L_R), gas pressure (P_R), and gas absolute temperature (T_R) may be used to determine analyte concentrations in samples whose spectra are recorded at conditions different from that of the reference spectra, i.e., at absorption pathlength (L_S), absolute temperature (T_S), and pressure (P_S). Appendix H describes the calculations for estimating the fractional uncertainty (FAU) of this practice. It also describes the calculations for determining the sample absorption pathlength from comparison of CTS spectra, and for preparing spectra for further instrumental and procedural checks.

H.1.1 Before sampling, determine the sample absorption pathlength using least squares analysis. Determine the ratio L_S/L_R by comparing the spectral sets {R1} and {R3}, which are recorded using the same CTS at L_S and L_R, and T_S and T_R, but both at P_R.

H.1.2 Determine the fractional analysis uncertainty (FAU) for each analyte by comparing a scaled CTS spectral set, recorded at L_S, T_S, and P_S, to the CTS reference spectra of the same gas, recorded at L_R, T_R, and P_R. Perform the quantitative comparison after recording the sample spectra, based on band areas of the spectra in the CTS absorbance band associated with each analyte.

H.2 Calculations

H.2.1 Absorption Pathlength Determination. Perform and document separate linear baseline corrections to each analytical region in the spectral sets {R1} and {R3}. Form a one-dimensional array $\mathbf{A}_R$ containing the absorbance values from all segments of {R1} that are associated with the analytical regions; the members of the array are A_{Ri}, i = 1, n. Form a similar one-dimensional array $\mathbf{A}_S$ from the absorbance values in the spectral set {R3}; the members of the array are A_{Si}, i = 1, n. Based on the model $\mathbf{A}_S = r\mathbf{A}_R + \mathbf{E}$, determine the least-squares estimate of r', the value of r which minimizes the square error $\mathbf{E}^2$. Calculate the sample absorption pathlength $L_S = r'(T_S/T_R)L_R$.

H.2.2 Fractional Analysis Uncertainty. Perform and document separate linear baseline corrections to each analytical region in the spectral sets {R1} and {R4}. Form the arrays $\mathbf{A}_S$ and $\mathbf{A}_R$ as described in Section H.2.1, using values from {R1} to form $\mathbf{A}_R$, and values from {R4} to form $\mathbf{A}_S$. Calculate the values

$$NRMS_E = \sqrt{\sum_{i=1}^{n}\left[A_{Si} - \left(\frac{T_R}{T_S}\right)\left(\frac{L_S}{L_R}\right)\left(\frac{P_S}{P_R}\right) A_{Ri}\right]^2} \tag{9}$$

and

$$IA_{AV} = \frac{1}{2}\sum_{i=1}^{n}\left|A_{Si} + \left(\frac{T_R}{T_S}\right)\left(\frac{L_S}{L_R}\right)\left(\frac{P_S}{P_R}\right) A_{Ri}\right| \tag{10}$$

The fractional analytical uncertainty is defined as

$$FAU = \frac{NRMS_E}{IA_{AV}} \quad . \tag{11}$$

APPENDIX I

DETERMINING FRACTIONAL MODEL UNCERTAINTIES (FMU)

I.1 General

To prepare analytical programs for FTIR analyses, the sample constituents must first be assumed; the calculations in this appendix, based upon a simulation of the sample spectrum, verify the appropriateness of these assumptions. The simulated spectra consist of the sum of single compound reference spectra scaled to represent their contributions to the sample absorbance spectrum; scaling factors are based on the indicated standard concentrations (ISC) and measured (sample) analyte and interferant concentrations, the sample and reference absorption pathlengths, and the sample and reference gas pressures. No band-shape correction for differences in the temperature of the sample and reference spectra gases is made; such errors are included in the FMU estimate. The actual and simulated sample spectra are quantitatively compared to determine the fractional model uncertainty; this comparison uses the reference spectra band areas and residuals in the difference spectrum formed from the actual and simulated sample spectra.

I.2 Calculations

I.2.1 For each analyte (with scaled concentration RSA_i), select a reference spectrum SA_i with indicated standard concentration ISC_i. Calculate the scaling factors

$$RA_i = \frac{T_R\, L_S\, P_S\, RSA_i}{T_S\, L_R\, P_R\, ISC_i} \qquad (12)$$

and form the spectra SAC_i by scaling each SA_i by the factor RA_i.

I.2.2 For each interferant, select a reference spectrum SI_k with indicated standard concentration ISC_k. Calculate the scaling factors

$$RI_k = \frac{T_R\, L_S\, P_S\, RSI_k}{T_S\, L_R\, P_R\, ISC_k} \qquad (13)$$

and form the spectra SIC_k by scaling each SI_k by the factor RI_k.

I.2.3 For each analytical region, determine by visual inspection which of the spectra SAC_i and SIC_k exhibit absorbance bands within the analytical region. Subtract each spectrum SAC_i and SIC_k exhibiting absorbance from the sample spectrum S_S to form the spectrum SUB_S. To save analysis time and to avoid the introduction of unwanted noise into the subtracted spectrum, it is recommended that the calculation be made (1) only for those spectral data points within the analytical regions, and (2) for each analytical region separately using the original spectrum S_s.

I.2.4 For each analytical region m, calculate the RMSD of SUB_s between the absorbance values and their mean in the region FFU_m to FFL_m. Denote the result by $RMSS_m$.

I.2.5 For each analyte i, calculate the quantity

$$FM_m = \frac{RMSS_m \left(FFU_m - FFL_m \right) AU_i \; DL_i}{AAI_i \; RSA_i} \tag{14}$$

for each analytical region associated with the analyte.

I.2.6 If only the m^{th} analytical region is used to calculate the concentration of the i^{th} analyte, set $FMU_i = FM_m$.

I.2.7 If a number of analytical regions are used to calculate the concentration of the i^{th} analyte, set FM_i equal to the weighted mean of the appropriate FM_m values calculated above. Mathematically, if the set of analytical regions employed is {m'}, then

$$FMU_i = \sum_{k \in \{m'\}} W_{ik} \, FM_k \tag{15}$$

where W_{ik} is calculated as described in Appendix D.

APPENDIX J

DETERMINING OVERALL CONCENTRATION UNCERTAINTIES (OCU)

The calculations in previous sections and appendices estimate the measurement uncertainties for various FTIR measurements. The lowest possible overall concentration uncertainty (OCU) for an analyte is its MAU value, which is an estimate of the absolute concentration uncertainty when spectral noise dominates the measurement error. However, if the product of the largest fractional concentration uncertainty (FRU, FCU, FAU, or FMU) and the measured concentration of an analyte exceeds the MAU for the analyte, then the OCU is this product. In mathematical terms, set $OFU_i = MAX\{FRU_i, FCU_i, FAU_i, FMU_i\}$ and $OCU_i = MAX\{RSA_i * OFU_i, MAU_i\}$.

APPENDIX K

SPECTRAL DE-RESOLUTION PROCEDURES

K.1 General.

High resolution reference spectra can be converted into lower resolution standard spectra for use in quantitative analysis of sample spectra. This is accomplished by truncating the number of data points in the original reference sample and background interferograms.

De-resolved spectra must meet the following requirements to be used in quantitative analysis.

(a) The resolution must match the instrument sampling resolution. This is verified by comparing a de-resolved CTS spectrum to a CTS spectrum measured on the sampling instrument.

(b) The Fourier transformation of truncated interferograms (and their conversion to absorbance spectra) is performed using the same apodization function (and other mathematical corrections) used in converting the sample interferograms into absorbance spectra.

K.2 Procedures

This section details three alternative procedures using two different commercially available software packages. A similar procedures using another software packages is acceptable if it is based on truncation of the original reference interferograms and the results are verified by Section K.3.

K.2.1 KVB/Analect Software Procedure - The following example converts a 0.25 cm^{-1} 100 ppm ethylene spectrum (cts0305a) to 1 cm^{-1} resolution. The 0.25 cm^{-1} CTS spectrum was collected during the EPA reference spectrum program on March 5, 1992. The original data (in this example) are in KVB/Analect FX-70 format.

(i) **decomp cts0305a.aif,0305dres,1,16384,1**

"decomp" converts cts0305a to an ASCII file with name 0305dres. The resulting ASCII interferogram file is truncated to 16384 data points. Convert background interferogram (bkg0305a.aif) to ASCII in the same way.

(ii) **compose 0305dres,0305dres.aif,1**

"Compose" transforms truncated interferograms back to spectral format.

(iii) **IG2SP 0305dres.aif,0305dres.dsf,3,1,low cm^{-1},high cm^{-1}**

"IG2SP" converts interferogram to a single beam spectrum using Norton-Beer medium apodization, 3, and no zero filling, 1.

De-resolved interferograms should be transformed using the same apodization and zero filling that will be used to collect sample spectra. Choose the desired low and high frequencies, in cm^{-1}. Transform the background interferogram in the same way.

(iv) **DVDR 0305dres.dsf,bkg0305a.dsf,0305dres.dlf**

"DVDR" ratios the transformed sample spectrum against the background.

(v) **ABSB 0305dres.dlf,0305dres.dlf**

"ABSB" converts the spectrum to absorbance.

The resolution of the resulting spectrum should be verified by comparison to a CTS spectrum collected at the nominal resolution. Refer to Section K.3.

K.2.2 Alternate KVB/Analect Procedure -- In either DOS (FX-70) or Windows version (FX-80) use the "Extract" command directly on the interferogram.

(i) **EXTRACT CTS0305a.aif,0305dres.aif,1,16384**

"Extract" truncates the interferogram to data points from to 16384 (or number of data points for desired nominal resolution). Truncate background interferogram in the same way.

(ii) Complete steps (iii) to (v) in Section K.2.1.

K.2.3 Grams™ Software Procedure - Grams™ is a software package that displays and manipulates spectra from a variety of instrument manufacturers. This procedure assumes familiarity with basic functions of Grams™.

This procedure is specifically for using Grams to truncate and transform reference interferograms that have been imported into Grams from the KVB/Analect format. Table K-1 shows data files and parameter values that are used in the following procedure.

The choice of all parameters in the ICOMPUTE.AB call of step 3 below should be fixed to the shown values, with the exception of the "Apodization" parameter. This parameter should be set (for both background and sample single beam conversions) to the type of apodization function chosen for the de-resolved spectral library.

TABLE K-1. GRAMS DATA FILES AND DE-RESOLUTION PARAMETERS.

Desired Nominal Spectral Resolution (cm^{-1})	**Data File Name**	**Parameter "N" Value**
0.25	Z00250.sav	65537
0.50	Z00500.sav	32769
1.0	Z01000.sav	16385
2.0	Z02000.sav	8193

(i) **Import** using "File/Import" the desired *.aif file. Clear all open data slots.

(ii) **Open** the resulting *.spc interferogram as file #1.

(iii) **Xflip** - *If the x-axis is increasing from left to right, and the ZPD burst appears near the left end of the trace, omit this step.*

In the "Arithmetic/Calc" menu item input box, type the text below. Perform the calculation by clicking on "OK" (once only), and, when the calculation is complete, click the "Continue" button to proceed to step (iv). Note the comment in step (iii) regarding the trace orientation.

```
xflip:#s=#s(#0,#N)+50
```

(iv) **Run ICOMPUTE.AB** from "Arithmetic/Do Program" menu. Ignore the "subscripting error," if it occurs.

The following menu choices should be made before execution of the program (refer to Table K-1 for the correct choice of "**N**":)

First: **N** Last: **0** Type: **Single Beam**
Zero Fill: **None** Apodization: **(as desired)**
Phasing: **User**
Points: **1024** Interpolation: **Linear** Phase: **Calculate**

(v) As in step (iii), in the "**Arithmetic/Calc**" menu item enter and then run the following commands (refer to Table 1 for appropriate "**FILE**," which may be in a directory other than "c:\mdgrams.")

```
setffp 7898.8805, 0 : loadspc "c:\mdgrams\ FILE" : #2=#s+#2
```

(vi) Use "**Page Up**" to activate file #2, and then use the "**File/Save As**" menu item with an appropriate file name to save the result.

K.3 Verification of New Resolution

K.3.1 Obtain interferograms of reference sample and background spectra. Truncate interferograms and convert to absorbance spectra of desired nominal resolution.

K.3.2 Document the apodization function, the level of zero filling, the number of data points, and the nominal resolution of the resulting de-resolved absorbance spectra. Use the identical apodization and level of zero filling when collecting sample spectra.

K.3.3 Perform the same de-resolution procedure on CTS interferograms that correspond with the reference spectra (reference CTS) to obtain de-resolved CTS standard spectra (CTS standards). Collect CTS spectra using the sampling resolution and the FTIR system to be used for the field measurements (test CTS). If practical, use the same pathlength, temperature, and standard concentration that were used for the reference CTS. Verify, by the following procedure that CTS linewidths and intensities are the same for the CTS standards and the test CTS.

K.3.4 After applying necessary temperature and pathlength corrections (document these corrections), subtract the CTS standard from the test CTS spectrum. Measure the RMSD in the resulting subtracted spectrum in the analytical region(s) of the CTS band(s). Use the following equation to compare this RMSD to the test CTS band area. The ratio in equation 7 must be no greater than 5 percent (0.05).

$$\frac{RMSS_i \times n(FFU_i - FFL_i)}{A_{CTS\text{-}test}} \leq .05 \qquad \textbf{(16)}$$

RMSS=RMSD in the i^{th} analytical region in subtracted result, test CTS minus CTS standard.

n=number of data points per cm^{-1}. Exclude zero filled points.

FFU_i &=The upper and lower limits (cm^{-1}), respectively, of the FFL_i analytical region.

$A_{test\text{-}CTS}$=band area in the i^{th} analytical region of the test CTS.

D-3 EPA METHOD 25A

METHOD 25A-DETERMINATION OF TOTAL GASEOUS ORGANIC CONCENTRATION USING A FLAME IONIZATION ANALYZER

1. Applicability and Principle

1.1 Applicability. This method applies to the measurement of total gaseous organic concentration of vapors consisting primarily of alkanes, alkenes, and/or arenes (aromatic hydrocarbons). The concentration is expressed in terms of propane (or other appropriate organic calibration gas) or in terms of carbon.

1.2 Principle. A gas sample is extracted from the source through a heated sample line, if necessary, and glass fiber filter to a flame ionization analyzer (FIA). Results are reported as volume concentration equivalents of the calibration gas or as carbon equivalents.

2. Definitions

2.1 Measurement Systems. The total equipment required for the determination of the gas concentration. The system consists of the following major subsystems:

2.1.1 Sample Interface. That portion of the system that is used for one or more of the following: sample acquisition, sample transportation, sample conditioning, or protection of the analyzer from the effects of the stack effluent.

2.1.2 Organic Analyzer. That portion of the system that senses organic concentration and generates an output proportional to the gas concentration.

2.2 Span Value. The upper limit of a gas concentration measurement range that is specified for affected source categories in the applicable part of the regulations. The span value is established in the applicable regulation and is usually 1.5 to 2.5 times the applicable emission limit. If no span value is provided, use a span value equivalent to 1.5 to 2.5 times the expected concentration. For convenience, the span value should correspond to 100 percent of the recorder scale.

2.3 Calibration Gas. A known concentration of a gas in an appropriate diluent gas.

2.4 Zero Drift. The difference in the measurement system response to a zero level calibration gas before and after a stated period of operation during which no unscheduled maintenance, repair, or adjustment took place.

2.5 Calibration drift. The difference in the measurement system response to a midlevel calibration gas before and after a stated period of operation during which no unscheduled maintenance, repair or adjustment took place.

2.6 Response Time. The time interval from a step change in pollutant concentration at the inlet to the emission measurement system to the time at which 95 percent of the corresponding final value is reached as displayed on the recorder.

2.7 Calibration Error. The difference between the gas concentration indicated by the measurement system and the known concentration of the calibration gas.

3. Apparatus.

A schematic of an acceptable measurement system is shown in Figure 25A-1. The essential components of the measurement system are described below:

3.1 Organic Concentration Analyzer. A flame ionization analyzer (FIA) capable of meeting or exceeding the specifications in this method.

3.2 Sample Probe. Stainless steel, or equivalent, three-hole rake type. Sample holes shall be 4 mm in diameter or smaller and located at 16.7, 50, and 83.3 percent of the equivalent stack diameter. Alternatively, a single opening probe may be used so that a gas sample is collected from the centrally located 10 percent area of the stack cross-section.

3.3 Sample Line. Stainless steel or Teflon * tubing to transport the sample gas to the analyzer. The sample line should be heated, if necessary, to prevent condensation in the line.

3.4 Calibration Valve Assembly. A three way valve assembly to direct the zero and calibration gases to the analyzers is recommended. Other methods, such as quick-connect lines, to route calibration gas to the analyzers are applicable.

3.5 Particulate Filter. An in-stack or an out-of-stack glass fiber filter is recommended if exhaust gas particulate loading is significant. An out-of-stack filter should be heated to prevent any condensation.

* Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

3.6 Recorder. A strip-chart recorder, analog computer, or digital recorder for recording measurement data. The minimum data recording requirement is one measurement value per minute, Note: This method is often applied in highly explosive areas. Caution and care should be exercised in choice of equipment and installation.

4. Calibration and Other Gases.

Gases used for calibrations, fuel, and combustion air (if required) are contained in compressed gas cylinders. Preparation of calibration gases shall be done according to the procedure in Protocol No. 1, listed in Citation 2 of Bibliography. Additionally, the manufacturer of the cylinder should provide a recommended shelf life for each calibration gas cylinder over which the concentration does not change more than ±2 percent from the certified value. For calibration gas values not generally available (i.e., organics between 1 and 10 percent by volume), alternative methods for preparing calibration gas mixtures, such as dilution systems, may be used with prior approval of the Administrator.

Calibration gases usually consist of propane in air or nitrogen and are determined in terms of the span value. Organic compounds other than propane can be used following the above guidelines and making the appropriate corrections for response factor.

4.1 Fuel. A 40 percent H_2/60 percent N_2 gas mixture is recommended to avoid an oxygen synergism effect that reportedly occurs when oxygen concentration varies significantly from a mean value.

4.2 Zero Gas. High purity air with less than 0.1 parts per million by volume (ppmv) of organic material (propane or carbon equivalent) or less than 0.1 percent of the span value, whichever is greater.

4.3 Low-level Calibration Gas. An organic calibration gas with a concentration equivalent to 25 to 35 percent of the applicable span value.

4.4 Mid-level Calibration Gas. An organic calibration gas with a concentration equivalent to 45 to 55 percent of the applicable span value.

4.5 High-level Calibration Gas. An organic calibration gas with a concentration equivalent to 80 to 90 percent of the applicable span value.

5. Measurement System Performance Specifications

5.1 Zero Drift. Less than ±3 percent of the span value.

5.2 Calibration Drift. Less than ±3 percent of span value.

5.3 Calibration Error. Less than ±5 percent of the calibration gas value.

6. Pretest Preparations

6.1 Selection of Sampling Site. The location of the sampling site is generally specified by the applicable regulation or purpose of the test; i.e., exhaust stack, inlet line, etc. The sample port shall be located at least 1.5 meters or 2 equivalent diameters upstream of the gas discharge to the atmosphere.

6.2 Location of Sample Probe. Install the sample probe so that the probe is centrally located in the stack, pipe, or duct and is sealed tightly at the stack port connection.

6.3 Measurement System Preparation. Prior to the emission test, assemble the measurement system following the manufacturer's written instructions in preparing the sample interface and the organic analyzer. Make the system operable.

FIA equipment can be calibrated for almost any range of total organics concentrations. For high concentrations of organics (>1.0 percent by volume as propane) modifications to most commonly available analyzers are necessary. One accepted method of equipment modification is to decrease the size of the sample to the analyzer through the use of a smaller diameter sample capillary. Direct and continuous measurement of organic concentration is a necessary consideration when determining any modification design.

6.4 Calibration Error Test. Immediately prior to the test series, (within 2 hours of the start of the test) introduce zero gas and high-level calibration gas at the calibration valve assembly. Adjust the analyzer output to the appropriate levels, if necessary. Calculate the predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level responses. Then introduce low-level and mid-level calibration gases successively to the measurement system. Record the analyzer responses for low-level and mid-level calibration gases and determine the differences between the measurement system responses and the predicted responses. These differences must be less than 5 percent of the respective calibration gas value. If not, the measurement system is not acceptable and must be replaced or repaired prior to testing. No adjustments to the measurement system shall be conducted after the calibration and before the drift check (Section 7.3). If adjustments are necessary before the completion of the test series, perform the drift checks prior to the required adjustments and repeat the calibration following the adjustments. If multiple electronic ranges are to be used, each additional range must be checked with a mid-level calibration gas to verify the multiplication factor.

6.5 Response Time Test. Introduce Zero gas into the measurement system at the calibration valve assembly. When the system output has stabilized, switch quickly to the high-level calibration gas. Record the time from the concentration change to the measurement system response equivalent to 95 percent of the step change. Repeat the test three times and average the results.

7. Emission Measurement Test Procedure

7.1 Organic Measurement. Begin sampling at the start of the test period, recording time and any required process information as appropriate. In particular, note on the recording chart periods of process interruption or cyclic operation.

7.2 Drift Determination. Immediately following the completion of the test period and hourly during the test period, reintroduce the zero and mid-level calibration gases, one at a time, to the measurement system at the calibration valve assembly. (Make no adjustments to the measurement system until after both the zero and calibration drift checks are made.) Record the analyzer response. If the drift values exceed the specified limits, invalidate the test results preceding the check and repeat the test following corrections to the measurement system. Alternatively, recalibrate the test measurement system as in Section 6.4 and report the results using both sets of calibration data (i.e., data determined prior to the test period and data determined following the test period).

8. Organic Concentration calculations

Determine the average organic concentration in terms of ppmv as propane or other calibration gas. The average shall be determined by the integration of the output recording over the period specified in the applicable regulation. If results are required in terms of ppmv as carbon, adjust measured concentrations using Equation 25A-1.

$$C_C = KC_{meas} \qquad \text{Eq. 25A-1}$$

Where:

C_c = Organic concentration as carbon, ppmv.

C_{meas} = Organic concentration as measured, ppmv.

K = Carbon equivalent correction factor.

K = 2 for ethane.

K = 3 for propane.

K = 4 for butane.

K = Appropriate response factor for other organic calibration gases.

9. Bibliography

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2. Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors (Protocol No. 1). U.S. Environmental Protection Agency,

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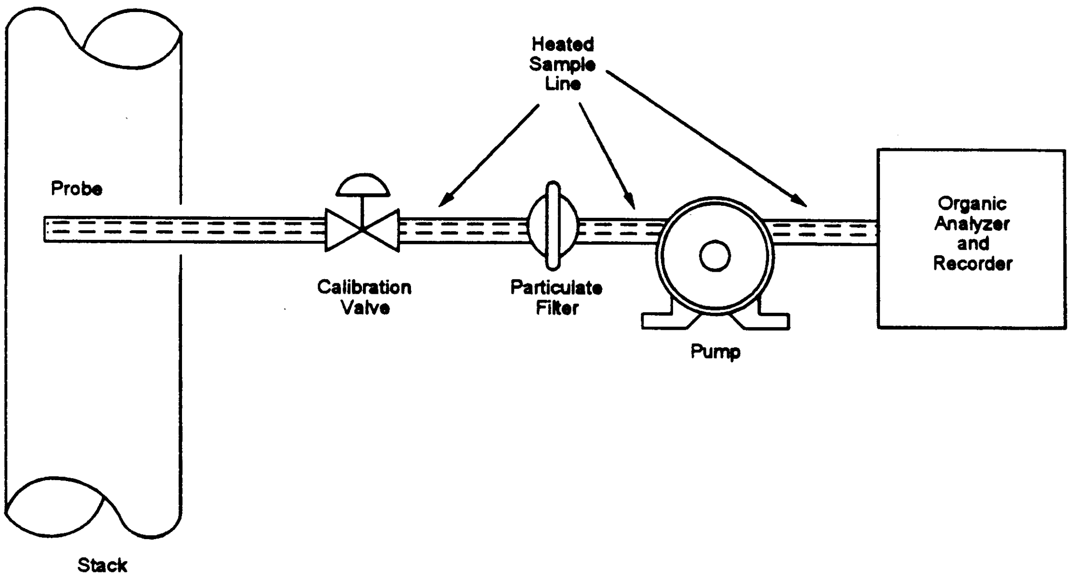

Figure 25A-1. Organic Concentration Measurement System.

D-4 EPA DRAFT METHOD 205

EMISSION MEASUREMENT TECHNICAL INFORMATION CENTER
TEST METHOD

DRAFT--DO NOT CITE OR QUOTE

The EPA proposes to amend Title 40, Chapter I, Part 51 of the Code of Federal Regulations as follows:

1. The authority citation for Part 51 continues to read as follows: Authority: Section 110 of the Clean Air Act as amended. 42 U.S.C. 7410.

2. Appendix M, Table of Contents is amended by adding an entry to read as follows:

Method 205--Verification of Gas Dilution Systems for Field Instrument Calibrations

3. By adding Method 205 to read as follows:

Method 205 - Verification of Gas Dilution Systems for Field Instrument Calibrations

1. INTRODUCTION

1.1 Applicability. A gas dilution system can provide known values of calibration gases through controlled dilution of high-level calibration gases with an appropriate dilution gas. The instrumental test methods in 40 CFR Part 60 -- e.g., Methods 3A, 6C, 7E, 10, 15, 16, 20, 25A and 25B -- require on-site, multi-point calibration using gases of known concentrations. A gas dilution system that produces known low-level calibration gases from high-level calibration gases, with a degree of confidence similar to that for Protocol[1] gases, may be used for compliance tests in lieu of multiple calibration gases when the gas dilution system is demonstrated to meet the requirements of this method. The Administrator may also use a gas dilution system in order to produce a wide range of Cylinder Gas Audit concentrations when conducting performance specifications according to Appendix F, 40 CFR Part 60. As long as the acceptance criteria of this method are met, this method is applicable to gas dilution systems using any type of dilution technology, not solely the ones mentioned in this method.

1.2 Principle. The gas dilution system shall be evaluated on one analyzer once during each field test. A precalibrated analyzer is chosen, at the discretion of the source owner or operator, to demonstrate that the gas dilution system produces predictable gas concentrations spanning a range of concentrations. After meeting the requirements of this method, the remaining analyzers may be calibrated with the dilution system in accordance to the requirements of the applicable method for the duration of the field test. In Methods 15 and 16, 40 CFR Part 60, Appendix A, reactive compounds may be lost in the gas dilution system. Also, in Methods 25A and 25B, 40 CFR Part 60, Appendix A, calibration with target compounds other than propane is allowed. In these cases, a laboratory evaluation is required once per year in order to assure the Administrator that the system will dilute these reactive gases without significant loss. **Note:** The laboratory evaluation is required only if the source owner or operator plans to utilize the dilution system to prepare gases mentioned above as being reactive.

2. SPECIFICATIONS

2.1 Gas Dilution System. The gas dilution system shall produce calibration gases whose measured values are within ±2 percent of the predicted values. The predicted values are calculated based on the certified concentration of the supply gas (Protocol gases, when available, are recommended for their accuracy) and the gas flow rates (or dilution ratios) through the gas dilution system.

injection shall differ by more than ±2 percent from the average instrument response for that dilution. **3.2.5** For each level of dilution, calculate the difference between the average concentration output recorded by the analyzer and the predicted concentration calculated in Section 3.2.2. The average concentration output from the analyzer shall be within ±2 percent of the predicted value.

3.2.6 Introduce the mid-level supply gas directly into the analyzer, bypassing the gas dilution system. Repeat the procedure twice more, for a total of three mid-level supply gas injections. Calculate the average analyzer output concentration for the mid-level supply gas. The difference between the certified concentration of the mid-level supply gas and the average instrument response shall be within ±2 percent.

3.3 If the gas dilution system meets the criteria listed in Section 3.2, the gas dilution system may be used throughout that field test. If the gas dilution system fails any of the criteria listed in Section 3.2, and the tester corrects the problem with the gas dilution system, the procedure in Section 3.2 must be repeated in its entirety and all the criteria in Section 3.2 must be met in order for the gas dilution system to be utilized in the test.

4. REFERENCES

1. "EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards," EPA-600/R93/224, Revised September 1993.

D-5 HCl VALIDATION PAPER

For Presentation at the Air & Waste Management Association's 90th Annual Meeting & Exhibition, June 8-13, 1997, Toronto, Ontario, Canada

97-MP74.05

Validation of EPA FTIR Method For Measuring HCl

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Introduction

In 1997 EPA is preparing to publish a sampling method (Draft Method 320)[1] based on the use of Fourier transform infrared (FTIR) spectroscopy to measure emissions of hazardous air pollutants (HAPs). This method establishes sampling procedures for measuring HAPs and employs analytical procedures in the EPA FTIR Protocol.[2]

In 1996 EPA conducted a field test at a source with HCl emissions. The test goal was to use the FTIR Draft Method 320 to measure vapor phase pollutants at this source. Measurements were conducted on the inlet and outlet of a control device. Hydrogen chloride (HCl) was a target pollutant for this source and, for this reason, some samples were spiked from a cylinder containing a standard concentration of 103 ppm HCl. Results of HCl measurements are presented along with a Method 301[3] statistical analysis of spiked and unspiked samples, and a comparison of results obtained using EPA reference spectra and results obtained using spectra of the HCl gas standard to measure the sample concentrations.

Experimental

The source tested in this project was a coal burning process with a relatively low moisture content (3 to 4% by volume). Flue gas temperatures were between 400 and 500°F. The principal components of the gas stream were water vapor, CO_2, SO_2, and NO.

Sampling System

The sampling system is depicted in Figure 1. The sample was extracted through a 4-ft long, 0.5-in diameter stainless steel probe. Sample was transported through heated 3/8-in Teflon line using a KNF Neuberger heated head sample pump (Model NO35 ST.11I). A Balston particulate filter (holder Model Number 30-25, filter element Model Number 100-25-BH, 99 percent removal efficiency at 0.1 µm) was connected in-line at the outlet of the sample probe. The sample line was heat wrapped and insulated. Temperature controllers were used to monitor and regulate the sample line temperature at about 350° F. The stainless steel manifold contained 3/8-in tubing, rotameters and 4-way valves to monitor and control the sample flow to the FTIR gas cell. The manifold temperature was maintained between 300 to 310°F.

The FTIR system included an Analect instruments Model RFX-40 interferometer equipped with a broad band MCT detector. Samples were contained in an Infrared Analysis Model D22H variable path gas cell. The cell temperature was maintained at 250°F.

Sampling Procedure

A series of discreet batch samples was collected by filling the cell above ambient pressure and closing the inlet valve to isolate the sample. An outlet valve was briefly opened to vent the sample to ambient pressure. The spectrum of the static sample was recorded. Then the cell was evacuated for the next sample. Each spectrum consisted of 50 co-added scans. The minimum time between consecutive samples was about 2 minutes. Inlet and outlet runs were conducted at the same time: the two location were sampled alternately with the one FTIR system. The minimum time between consecutive measurements was about 3 to 5 minutes.

Path Length Determinations

Two path lengths were used in this test. The cell was adjusted to 40 beam passes for the first two test runs and reduced to 20 beam passes for a third test run. The number of beam passes was measured by shining a He/Ne laser through the optical path and observing the number of laser spots on the field mirror. The path lengths in meters were determined by comparing CTS EPA reference spectra to the CTS spectra collected at each path length.

Absorption path lengths were determined from a comparison of the field test CTS spectra and EPA library CTS spectra of ethylene (C_2H_4) . For high temperature spectra, the EPA library interferograms cts0115a.aif and bkg0115a.aif were de-resolved to the appropriate spectral resolution (either 1 or 2 cm^{-1}) according to the procedures of reference 2 (Appendix K). The same procedure was used to generate low-temperature spectra from the original interferometric data in the EPA library files cts0829a.aif and bkg0829a.aif. The resulting files were used in least squares fits to the appropriate field CTS spectra (see reference 2, Appendix H) in two regions (the FP, or "fingerprint" region from 790 to 1139 cm^{-1} and the CH, or "CH-stretch region" from 2760 to 3326 cm^{-1}). The fit results for each region, test, and set of test sampling conditions were averaged. They and their average uncertainties are presented in Table 1. The CH values were used in analytical region 4 where HCl was measured.

Analyte Spiking

Draft Method 320[1] contains a procedure for spiking the flue gas with one or more of the target analytes. The spike procedure closely follows Section 6.3 of reference 3. The primary purpose of analyte spiking is to provide a quality assurance check on the sampling system to determine if analyte losses occur in transport to the analyzer. A second purpose is to test the analytical program to verify that the analyte(s) can be measured in the sample matrix. If at least 12 (independent) spiked and 12 (independent) unspiked samples are measured then a Method 301 statistical analysis can be performed on the results to "validate" the method.

Figure 1 shows the sampling configuration used for the analyte spike. This procedure is described in detail elsewhere[1]. In this test, a measured flow of the gas standard was preheated to the sample line temperature before being introduced into the extracted flue gas at the back of the probe. The spiked sample then passed through all of the sample components to the gas cell where the spectrum was recorded. A series of unspiked samples was measured, the spike was turned on and then a complete series of spiked samples was measured. The spike then was turned off to make additional unspiked measurements. Ideally, the spike comprises 1/10 or less of the sample mixture. The dilution is estimated by comparing the spike flow to the total flow, but the actual dilution is determined measuring a tracer (SF_6) concentration in the spiked samples and comparing that to tracer concentration in the undiluted gas standard.[1]

Usually the tracer is spiked with the analyte standard. In this test the SF_6 standard and HCl standard were contained in separate cylinders so the SF_6 was spiked first, then the HCl was spiked, and finally the SF_6 was spiked again. The total sample flow stayed constant during the entire sampling period. The spike flow was also held constant to insure that the dilution ratio was the same when the SF_6 was spiked as when the HCl was spiked.

Quantitative Analysis

FTIR analysis is performed in two steps: (1) collecting spectra of samples, and (2) analyzing the spectra to determine concentrations of detected compounds. The quantitative analysis step usually is performed with an automated program that relates sample absorbance intensities to absorbance intensities at known concentrations in reference spectra.[2] The Protocol[2] describes procedures for preparing reference spectra and Method 320[1] requires the analyst to use reference spectra prepared with the Protocol procedures. To date, the only existing set of reference spectra for HCl and most Clean Air Act HAPs is in the EPA FTIR spectral library (http://info.arnold.af.mil/epa/welcome.htm).

The Calibration Transfer Standard[2] is the key requirement in using reference spectra for quantitative analysis. CTS spectra help the analyst characterize differences in resolution, path length, temperature, and sample pressure between the instrument system used to collect reference spectra and the system used to collect the sample spectra. Table 1 illustrates how the CTS spectra were used to determine the optical path lengths for the system used in this test. The HCl reference spectra were de-resolved in the same way as the CTS reference spectra before they were used in the quantitative analysis.

References 4 through 8 comprise a thorough description of one technique for analyzing FTIR absorbance spectra. Two different analytical routines were used in this study. The first was prepared by Rho Squared using the programming language ARRAY BASIC™ (GRAMS,™ Version 3.02, Galactic Industries Corporation, Salem, New Hampshire). The "classical least squares" (CLS) or "K-Matrix" technique and the associated computer program "4FIT" are described in Reference 9. The terminology and basic analytical approach employed in this work are described in the "EPA FTIR Protocol" (Reference 2). The second routine used the K-matrix analytical program "Multicomp" version 6.0 (Analect Instruments).

The two analyses were performed independently by different analysts and then compared without modification.

Reference Spectra

The program "4FIT" used as input EPA FTIR library spectra of HCl de-resolved to 1 cm^{-1} and normalized for absolute temperature, concentration, and absorption path length. The resulting files were averaged to provide a "reduced absorptivity" (see Reference 9), which was stored in the spectral file 097.alf and employed in all subsequent HCl analyses. The HCl analysis was applied to the de-resolved EPA library HCl spectra to determine the fractional calibration uncertainty (FCU), which is presented in Table 2.

During the test MRI recorded spectra of samples taken directly from an HCl cylinder standard (103 ppm HCl in nitrogen, ± 5% accuracy from Scott Specialty Gases). Four independent HCl "calibration" spectra were measured at each of the two instrument configurations used to collect the data presented in Figures 2 and 3. The Fractional Calibration Uncertainty for each set of four spectra and the analytical region for the "Multicomp" analysis is presented in Table 2.

Even though the two sets of results are identified by the program names "4FIT" and "Mulitcomp," it is important to note that the "Multicomp" results were reproduced by the program "4FIT" when the HCl calibration spectra were used as input for "4FIT." Therefore, any differences in the analyses are not attributable to the programs, but to the use of different input spectra.

Results

HCl Concentrations

Table 3 summarizes results from the three test runs at the two locations. The agreement between the "4FIT" and the "Multicomp" analyses is very good except for the third run. This run was conducted after the path length had been decreased from 40 to 20 laser passes.

The two comparisons plotted in Figures 2 and 3 are indicated in Table 3. The Run 2 outlet results (Figure 2) are typical of those obtained for the Run 2 inlet results recorded on the same day and the Run 1 inlet and outlet results recorded a day earlier. The close agreement was typical also for two data sets collected at another field test in one test run. For 3 of the 6 data sets presented in Table 3, the results obtained with program "4FIT," using de-resolved EPA library reference spectra and the CTS-derived absorption path lengths, are nearly identical (within the 4 σ uncertainty) to those obtained using "Multicomp," which employed the field HCl calibration standard spectra without an explicit absorption path length determination. The average percent difference of the Run 2 inlet results was slightly higher than the 4σ uncertainty, but this percent difference corresponded to an average difference of 1.7 ppm. The error bars in Figures 2 and 3 correspond to the 4σ statistical uncertainties in the "4FIT" HCl concentrations.

Method 301 Analysis

Tables 4 and 5 present the results of the method 301 statistical analysis of the spiked and unspiked "4FIT" and "Multicomp" Run 3 outlet results, respectively. Note that the nearly constant difference of about 19 percent in the two analyses has almost no effect on the Method 301 statistical analyses, which indicate no significant bias in the HCl measurements. This is because the statistical treatment analyzes differences between spiked and unspiked measurements and compares the differences to an expected value of the spike. Since the same offset is apparent in the "Multicomp" analysis of both the spiked and unspiked results, the calculated bias is not affected.

This is another indication that the difference in the "4FIT" and "Multicomp" run 3 results is not due to a measurement or analytical error. It is likely due either to an anomaly in the Run 3 path length determination for the CH stretch region or to an error associated with using the HCl "calibration spectra as input for the "Multicomp" program. As stated above, the "4FIT" program reproduced the "Multicomp" results when using the HCl "calibration" spectra as input.

Discussion

The uncertainties for the four data sets in Runs 1 and 2 are approximately equal to the small differences between the "4FIT" and "Multicomp" results. The excellent agreement of the two analyses is noteworthy for several reasons. HCl is notoriously difficult both in terms of sampling and data analysis, due (respectively) to the compound's high chemical reactivity and the details of the infrared spectrum which make the analysis susceptible to instrument resolution errors. The results also provide a direct comparison between two fundamentally different analytical approaches, one relying on *in situ* calibration of the instrument using actual calibration gas standards, and the other using the calibration transfer concept.

This comparison is somewhat clouded by the results depicted in Figure 3, which show the HCl concentration determined during Run 3 at the outlet. These are also typical of the results for another data set recorded on the same day at the inlet. Unlike the Runs 1 and 2 data, the Run 3 data indicate a statistically meaningful difference of approximately 18% between the "4FIT" and "Multicomp" results. We stress that this difference is **not** attributable to errors in the computer programs, which produced reliable results in these and many independent test cases. Rather, the difference seems be related to an anomaly in the absorption path length determinations presented in Table 1. Note that the CTS-derived absorption path length for (nominally) 20 passes, corresponding to the Run 3 data, are 10.2 meters 14.3 meters for the CH-stretch and "fingerprint" (FP) analytical regions. The difference between the CH and FP results is much larger for this particular day of testing than on the other two test days, represented in the table by the 16- and 40- pass results. (It is also anomalous with respect to results obtained using the same instrument in another field test completed within nine days of the testing addressed here.) Moreover, were the average of the CH and FP region values (12.2 meters) used for the HCl concentration values rather than the CH region value of 10.2 meters, the level of agreement between the two sets of analytical results for the Run 3 data would be comparable to that of the Run 1 and 2 data discussed immediately above.

We have attempted to determine the cause of this difference by considering of a number of possible operational and instrumental problems. However, no single systematic effect seems sufficient. Because consistent path length determinations were carried out both before and after the HCl measurements in question, a sudden change in instrument performance must be ruled out. Gas pressure and dilution effects cannot cause the type of wavenumber-dependent effects observed in the CTS spectra; subsequent laboratory measurements of C_2H_4 indicated that temperature variations, like pressure and dilution effects, would lead to path length errors in the same direction for the CH and FP regions. Because the same EPA CTS ethylene spectra were used in all the path length determinations and led to excellent statistical results in all cases, potential data processing errors in the deresoluton procedure are also insufficient to explain the anomalous results. However, we note that the observed 18% discrepancy still allows high confidence in the data and the infrared technique, and the discrepancy is obvious mainly because of the overall high quality of the data set and statistical results.

Conclusions

The evaluation presented in this paper demonstrates that the EPA FTIR Protocol analytical procedures based on the use of laboratory reference spectra to determine analyte concentrations in sample spectra give excellent, and verifiable, results. This is true even for HCl, which is difficult to sample, and even when the reference spectra are deresolved to match the sample spectra.

Two independent analyses using different programs and different spectral input data were performed on 6 FTIR data sets collected at a site with HCl emissions. The alternate analyses produced nearly identical results in 4 of the data sets. In two of the data sets the agreement was also good, but the average discrepancy of about 18 percent between results produced by the alternate analyses was larger than the average measurement uncertainty of about 5.5 percent. A preliminary evaluation of this discrepancy has not determined the exact cause, but it is probably attributable to an anomaly in the measurement of the absorption path length for the one test run.

These results also demonstrate the need for careful instrument performance checks and preparation of library reference spectra. Strict QA/QC standard procedures are required to produce accurate measurements. The Method 301 validation results showed no significant bias in the FTIR measurements of HCl at this test, but the validation procedure cannot reveal a constant offset "error" that is applied equally to both spiked and unspiked samples.

Acknowledgments

The field test discussed in this paper was funded by the Emission Measurement Center of the United States Environmental Protection Agency.

References

1) Draft Method 320, "Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive Fourier Transform Infrared (FTIR) Spectroscopy," EPA Contract No. 68-D2-0165, Work Assignment 3-08, July, 1996.

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9. G. M. Plummer and W. K. Reagen, "An Examination of a Least Squares Fit FTIR Spectral Analysis Method," Air and Waste Management Association, Paper Number 96-WA65.03, Nashville, 1996.

10. T. J. Geyer, "Method 301 Validation of Fourier Transform Infrared (FTIR) spectroscopy For Measuring Formaldehyde and Carbonyl Sulfide," Air and Waste Management Association, Paper Number. 96-RA110.03, Nashville, 1996.

Table 1. Pathlength Determination Results.

	CTS Conditions		CH region		FP region	
	# Passes	Temp (K)	Result (m)	% uncert.	Result (m)	% uncert.
	16	293	6.5	2.9	6.7	1.3
	20	293	11.0	2.6	11.3	1.6
Run 3 (Figure 3)	20	393	10.2	2.5	14.3	2.2
	40	293	19.2	5.5	20.0	1.8
Run2 (Figure 2)	40	393	20.2	2.6	23.4	1.6

Table 2. Fractional Calibration Uncertainties (FCU in Reference 2) For the Two Quantitative Analyses.

Compound	FCU (%)	Analytical Region (cm^{-1})
HCl "4fit"	4.6	2747 - 2848
HCl "Mcomp"		2569 - 2871
Run 2 *	1.05	
Run 3 *	3.14	

* Spectra of four samples from the cylinder standard (103 ppm HCl in nitrogen) were used in the "Mcomp" analysis. The spectra were measured at the same instrument configuration used in each run.

Table 3. Summary of results comparisons in 4 runs (8 data sets).

Data Set	Average "4FIT" Results		Average "Multicomp" Result		
	HCl ppm	% 4 * σ [1]	HCl ppm	% Difference [2]	No. of Results [3]
Run 1 Inlet	43.3	3.9	42.1	2.9	36
Run 1 Outlet	34.5	4.1	32.9	4.4	30
Run 2 Inlet	14.8	7.7	13.1	11.8 [4]	16
Run 2 Outlet (Figure 2)	48.0	4.5	46.4	3.2	33
Run 3 Inlet	62.5	5.6	50.9	18.6	41
Run 3 Outlet (Figure 3)	58.0	5.5	47.3	18.4	52

1 - Average percent uncertainty in the 4FIT results.

2 - Equals (4FIT-Multicomp)/4FIT.

3 - Equals the number of spectra included in the average. Results from condenser and ambient air samples were not included in the averages.

4 - Flow restriction during this run may have caused HCl losses resulting in lower measured concentrations for this run. An average difference of 1.7 ppm corresponded to a relatively large percent difference of 11.8 % on the smaller average concentration for this run.

Table 4. Method 301 statistical analysis of "4FIT" HCl results in Figure 3.

	Unspiked			Spiked		
	HCl ppm	d_i	$(d_i)^2$	HCl ppm	d_i	$(d_i)^2$
Run Average =	57.18 *	9.68	52.561	62.14 *	4.74	25.784
Statistical Results	SD =	2.093		SD =	1.466	
	F =	0.491		SD_{pooled} =	1.807	
	RSD=	3.7				
	Bias =	**-0.088**		**Exp Conc =**	**5.05**	
	t =	**0.12**		**CF =**	**1.02**	

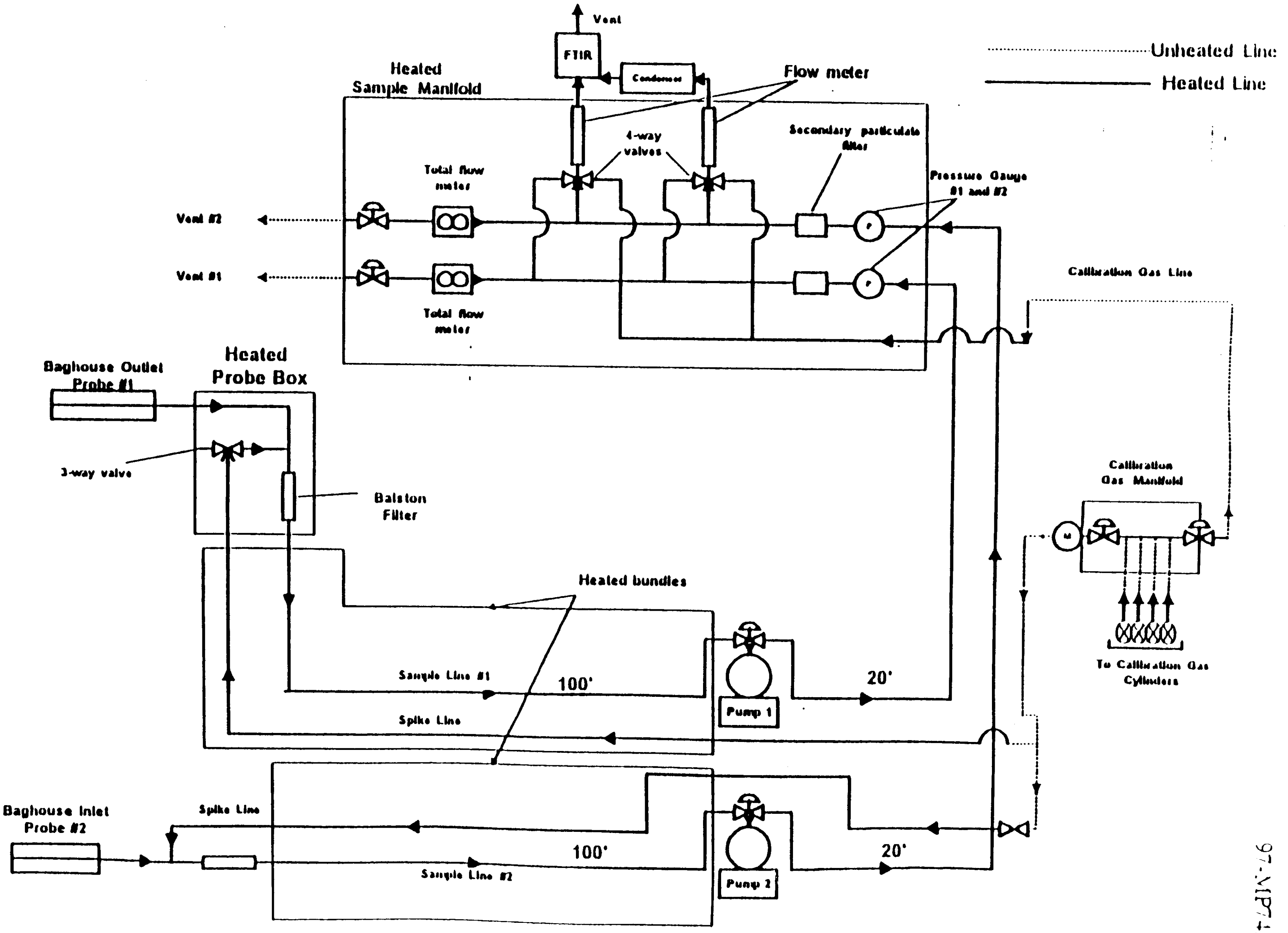
* Represents the average result in 12 unspiked or spiked samples. Statistical variables are described in Section 6.3 of EPA Method 301.[3] Procedure for determining spiked dilution factor and expected concentration, Exp Conc, is described in reference 10.

Table 5. Summary of Method 301 statistical analysis of "Multicomp" results in Figure 3.

	Unspiked			Spiked		
	HCl ppm	d_I	$(d_i)^2$	HCl ppm	d_i	$(d_i)^2$
Run Average =	45.88 *	8.62	34.242	50.86 *	3.51	21.496
Statistical Results	SD =	1.689		SD =	1.338	
	F =	0.628		SD_{pooled} =	1.524	
	RSD=	3.7				
	Bias =	**-0.070**		**Exp Conc =**	**5.05**	
	t =	**0.11**		**CF =**	**1.01**	

* Represents the average result in 12 unspiked or spiked samples. Statistical variables are described in Section 6.3 of EPA Method 301.[3] Procedure for determining spiked dilution factor and expected concentration, Exp Conc, is described in reference 10.

Figure 1. Extractive sampling system.



APPENDIX E

PROCESS DESCRIPTION

This process description was prepared by EC/R Incorporated and was provided to MRI by the Emission Measurement Center. The process description was included in this report without review by MRI.

PROCESS DESCRIPTION FOR CLAYTON FACILITY

Facility Description

The Construction Asphalt Concrete Production Facility in Clayton, North Carolina, has been in operation since 1989. It is a counter flow, continuous drum mix process. The dryer/mixer is an ASTEC double-barrel drum, a variation of the drum mixer, with a rated capacity of 400 tons per hour. The plant has the capability of producing up to 15 asphalt mix types, with or without the use of reclaimed asphalt pavement (RAP).

Asphalt concrete, called "hot mix asphalt"(HMA) by the industry, is a mixture of well-graded, high quality virgin aggregate that is heated and mixed with liquid asphalt cement to produce paving material. The characteristics of the asphalt concrete are determined by the relative amounts and types of aggregate (and RAP) used. In the asphalt reclamation process, old asphalt pavement is removed from the road surface, transported to the plant, and crushed and screened to the appropriate size for further processing.

In the counter flow continuous double-barrel drum mix process, virgin aggregate of various sizes is fed to the drum by cold feed controls in proportions dictated by the final mix specifications. Aggregate is delivered by conveyor belt to the inner drum, entering at the opposite end as the burner (hence, the descriptor "counter" flow). The aggregate moves towards the burner within the inner drum and is dried. The hot aggregate falls to the outer drum through holes at the burner end of the inner drum. As the hot aggregate moves along the outer drum, liquid asphalt cement and conditioner (if used) are added. The liquid asphalt cement and conditioner are delivered to the drum mixer by a variable flow pump that is electronically linked to the aggregate feed weigh scales. Recycled dust from the control system and RAP (if used) are also added into the outer drum. The resulting asphalt concrete mixture is discharged from the outer drum and conveyed to storage silos for delivery to trucks.

There are five cold storage bins and three hot mix storage silos at Clayton facility. The hot mix storage silo capacity is 200 tons each, for a total of 600 tons. There are three screens for aggregate sizing and one 52,000 gallon (130 ton) heated asphalt cement storage vessel. The plant uses virgin and recycled No.2 fuel oil, supplied by Noble Oil Services, Inc., for all its process fuel needs. (Recycled fuel assay report is attached). Virgin fuel oil is used during extremely cold weather and/or if there is a fuel-related problem with the burner. Therefore, virgin fuel is usually only used during the winter months (January/February). The amount of energy needed from the fuel for the asphalt production process is 225,600 BTU per ton of asphalt produced. The hot gas contact time with the aggregate is approximately 1 minute, and the process time from the beginning of the drum to the coater is approximately 6 minutes.

Clayton facility uses an asphalt cement (AC) called AC-20, obtained from Citgo of Wilmington, North Carolina. An anti-strip conditioner, called Perma-Tac (from Arr-Maz), is sometimes used; antistrip is required for all NC DOT jobs. (Conditioner MSDS is attached). For particulate matter (PM) control, the facility uses a fabric filter. The fabric filter is an ASTEC Pulse-Jet, equipped with 1024 14-ounce Nomex bags; it is operated with an air-to-cloth ratio of 5.54 feet per minute. The process gas exits the drum and coater and proceeds into the fabric filter, where it is exhausted through a stack. As mentioned above, the dust collected by the PM control devices is recycled to process.

<u>Source Tests</u>

EPA source tests were performed at Clayton facility on August 19, 20, and 21, 1997. The source testing took place at the inlet and outlet of the fabric filter. Data were taken at 15-minute intervals during the entire "test period," i.e. the time period when at least one manual and both instrumental tests were running. According to plant personnel, the plant was operating under normal conditions during the tests.

Four tests were performed during the three-day test period. (Two test runs were performed on August 20: one in the morning and one in the afternoon). The average asphalt concrete production rates during the four test runs were 171, 276, 240, and 185 tons per hour (tph), respectively, corresponding to total production of 735, 1,187, 840, and 778 tons. During the first three test runs (August 19, August 20 a.m., and August 20 p.m.), a surface asphalt coating that included RAP was produced; during the fourth test run (August 21), a surface coating (accounting for 75 percent of the total asphalt concrete produced) and a binder coating (accounting for 25 percent of total production) were produced, both without RAP. Recycled No. 2 fuel oil was used for fuel in the production process during the tests. Conditioner was used during the four test runs at a rate of 0.25 percent of the asphalt cement used, for a total of 186, 302, 220, and 200 pounds, respectively, during the four test runs. No visible emissions were observed by EC/R Inc. personnel during the source tests.

Table 1 that follows summarizes the operating conditions observed during the EPA source test periods at Clayton facility. Tables 2 and 3 describe the asphalt mixes produced and the fuel used, respectively, during the tests. Table 4 describes the specifics of plant operation during the tests. Appendix A shows all the data recorded during the tests, along with the results of statistical analyses.

TABLE 1. PLANT OPERATING CONDITIONS DURING SOURCE TESTS, AUGUST 19, 20, AND 21, 1997

	Test Run / Test Date			
Process Data	**Run 1 08/19/97**	**Run 2 08/20/97 (a.m.)**	**Run 3 08/20/97 (p.m.)**	**Run 4 08/21/97**
Product Type(s)[a]	surface mix, with RAP (BCSC, Type RDS)	surface mix, with RAP (BCSC, Type RDS)	surface mix, with RAP (BCSC, Type RDS)	surface mix, no RAP (BCSC, Type HDS); and binder (BCBC, Type H)
Asphalt Concrete				
Production Rate, tph				
Average[b]	171	276	240	185
Range	146-254	223-302	152-254	150-204
Total Produced, tons	735	1,187	840	778
Mix Temperature, °F				
Average[b]	305	312	310	308
Range	295-315	303-346	299-322	271-351
Raw Material (Virgin Aggregate)				
Use Rate, tph				
Average[b]	145	236	205	176
Range	126-213	191-255	138-215	142-194
Total Used, tons	622	1,013	718	740

TABLE 1. (continued)

Process Data	Test Run / Test Date			
	Run 1 08/19/97	Run 2 08/20/97 (a.m.)	Run 3 08/20/97 (p.m.)	Run 4 08/21/97
RAP				none
Use rate, tph				
Average[b]	18	28	24	
Range	13-27	21-32	17-27	
Total Used, tons	76	119	85	
Asphalt Cement				
Use rate, tph				
Average[b]	8.7	14.0	12.3	9.2
Range	7.5-12.6	11.4-15.5	7.8-13.0	7.8-10.6
Total Used, tons	37	60	43	39
Conditioner (lb)[c]	186	302	216	200
Fabric Filter Operation[b]				
Temperature, °F				
Inlet	193	255	232	201
Outlet	170	214	195	175
Pressure Drop, inches water				
Average[b]	1.8	3.3	2.5	1.9
Range	1.5 - 2.9	2.1-4.0	1.8-2.9	1.8-2.0
Fuel				
Use Rate,[d] gph	214	410	334	280
Total Used, gal	920	1,762	1,168	1,117

TABLE 1. (continued)

Process Data	Test Run / Test Date			
	Run 1 08/19/97	Run 2 08/20/97 (a.m.)	Run 3 08/20/97 (p.m.)	Run 4 08/21/97
Visible Emissions	none	none	none	none

[a] BCSC, Type HDS = bituminous concrete, surface coarse, type high density surface
BCSC, Type RDS = bituminous concrete, surface coarse, type high density surface with RAP
BCBC, Type H = bituminous concrete, binder coarse (type H)

See Table 2 for more detail on product specifications.

[b] As a straight average of the 15-minute interval data shown in Appendix A.

[c] The amount of conditioner used was calculated as 0.25 percent of the asphalt cement.

[d] Fuel use rate was calculated from the total fuel used during the time interval.

TABLE 2. ASPHALT MIX SPECIFICATIONS

Product	Material	Amount
Surface Coating (BCSC, Type HDS)	78-M	50% aggregate
	screenings	30% aggregate
	sand	20% aggregate
	asphalt cement	5.2% mix
	conditioner	0.25% cement
Surface Coating, with RAP (BCSC, Type RDS)	78-M	43% aggregate
	dry screenings	27% aggregate
	natural sand	20% aggregate
	RAP	10% aggregate
	asphalt cement total	5.1% mix
	additional	4.6% mix
	from RAP	0.5% mix
	conditioner	0.25% cement
Binder (BCBC, Type H)	78-M	16% aggregate
	#67	46% aggregate
	screenings	20% aggregate
	sand	18% aggregate
	asphalt cement	4.5% mix
	conditioner	0.25% cement

TABLE 3. FUEL SPECIFICATIONS

Fuel Type	Characteristics		Descriptor(s)
Oil	flash point	150°F	recycled no. 2 diesel fuel
	lead	28 mg/kg	
	sulfur	3590 mg/kg (0.36%)	

TABLE 4. SPECIFICS OF PLANT OPERATION DURING EPA SOURCE TESTS

Parameter	Test Run / Test Date			
	Run 1 08/19/97	Run 2 08/20/97 (a.m.)	Run 3 08/20/97 (p.m.)	Run 4 08/21/97
Test Period	0915-1456	0822-1240	1405-1735	0741-1153
Plant Shut Downs[a] (with approximate duration)	none	0930(4 min)	none	none
Plant Production Rate Change(s)	1115-1145: mix rate slowed from nominally 250 to 200 tph 1200-1500: mix rate slowed from nominally 200 to 150 tph	0945-1245: mix rate increased from nominally 225 to 300 tph	1715-1745: mix rate decreased from nominally 250 to 150 tph	1030-1200: mix rate increased from nominally 180 to 200 tph
Product Changes	none	none	none	0730-0815, 0900-0915, 1015-1155: HDS produced (600 tons) 0830-0900, 0915-1000, 1155-1200: binder produced 195 tons)

[a] Shutdown occured because the RAP feed went down.

Appendix A: Process Data

Test Run 1
Test Date: August 19, 1997
Total Test Time: 4.3 hrs

Time	Event	Product Type	Asphalt Concrete Production		Asphalt Temp.	Aggregate Use		RAP Use		Asphalt Cement Use		Calculated Conditioner Use	
			Rate (TPH)	Total (tons)	(oF)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)
0915	*	RDS	250		315	213		26		12.5		0.03	
1100		RDS	254		304	211		27		12.6		0.03	
1115	*	RDS	202		295	171		22		10.2		0.03	
1130		RDS	202		311	170		21		10.0		0.03	
1145		RDS	200		304	168		21		10.0		0.03	
1200	*	RDS	150		299	127		15		7.8		0.02	
1215		RDS	152		306	126		16		7.5		0.02	
1230		RDS	149		306	127		16		7.7		0.02	
1245		RDS	150		300	127		15		7.7		0.02	
1300		RDS	152		300	128		16		7.6		0.02	
1315		RDS	150		300	127		16		7.8		0.02	
1330		RDS	150		310	128		15		7.6		0.02	
1345		RDS	149		301	127		15		7.7		0.02	
1415		RDS	147		313	127		13		7.6		0.02	
1430		RDS	146		307	127		15		7.5		0.02	
1445		RDS	150		305	128		15		7.7		0.02	
1456		RDS	151		304	129		15		7.7		0.02	
Total**				735			622		76		37		0.093
Mean			171		305	145		18		8.7		0.02	
St. Dev			35		5	29		4		1.7		0.004	
Min			146		295	126		13		7.5		0.02	
Max			254		315	213		27		12.6		0.03	

* See Table 4 for a description of these events.

** Because running total data were not available, the run totals were calculated from the average of the TPH data multiplied by the total run time.

Appendix A: Process Data

Test Run 1
Test Date: August 19, 1997
Total Test Time: 4.3 hrs

			Fabric Filter			Fuel Use		
Time	Event	Product Type	Inlet Temp. (oF)	Outlet Temp. (oF)	Pressure Drop (in. H2O)	Rate (GPM)	Total (gal)	Visible Emissions
0915	*	RDS	245	200	2.9	5	80	none
1100		RDS	240	200	2.5	5	1693	none
1115	*	RDS	220	195	2.5	5	1817	none
1130		RDS	205	185	2.0	5	1855	none
1145		RDS	205	180	2.0	3	1911	none
1200	*	RDS	180	170	1.8	3	1994	none
1215		RDS	175	160	1.5	3	2036	none
1230		RDS	185	160	1.5	3	2092	none
1245		RDS	180	160	1.8	3	2136	none
1300		RDS	180	160	1.5	3	2192	none
1315		RDS	185	160	1.5	3	2234	none
1330		RDS	185	160	1.5	3	2274	none
1345		RDS	182	160	1.7	3	2336	none
1415		RDS	180	160	1.5	3	2388	none
1430		RDS	180	160	1.5	3	2441	none
1445		RDS	180	160	1.5	3	2489	none
1456		RDS	170	160	1.5	3	2533	none
Total**							920	
Mean			193	170	1.8	3.5		
St. Dev			22	15	0.4	0.9		
Min			170	160	1.5	3.0		
Max			245	200	2.9	5.3		

* See Table 4 for a description of these events.

** Because running total data were not available, the run totals were calculated from the average of the TPH data multiplied by the total run time.

Appendix A: Process Data

Test Run 2
Test Date: August 20, 1997 a.m.
Total Test Time: 4.3 hrs

			Asphalt Concrete Production		Asphalt	Aggregate Use		RAP Use		Asphalt Cement Use		Calculated Conditioner Use	
Time	Event	Product Type	Rate (TPH)	Total (tons)	Temp. (oF)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)
0822		RDS	225		306	192		21		11.5		0.03	
0845		RDS	226		304	191		24		11.5		0.03	
0900		RDS	223		316	192		22		11.5		0.03	
0915		RDS	225		306	191		23		11.4		0.03	
0930	*	RDS	223		346	214		24		11.5		0.03	
0945	*	RDS	249		308	213		25		12.7		0.03	
0100		RDS	298		312	254		30		15.3		0.04	
1015		RDS	299		314	254		30		15.5		0.04	
1030		RDS	301		308	255		30		15.3		0.04	
1045		RDS	300		314	254		31		15.2		0.04	
1100		RDS	300		303	255		26		15		0.04	
1115		RDS	301		314	253		32		15		0.04	
1130		RDS	302		309	255		31		15		0.04	
1145		RDS	300		311	255		31		15.4		0.04	
1200		RDS	300		317	254		30		15.3		0.04	
1215		RDS	300		307	252		31		15		0.04	
1230		RDS	298		313	255		29		15		0.04	
1240		RDS	299		310	253		30		15		0.04	
Total**				1,187			1,013		119		60		0.151
Mean			276		312	236		28		14.0		0.04	
St. Dev			34		9	27		4		1.7		0.00	
Min			223		303	191		21		11.4		0.03	
Max			302		346	255		32		15.5		0.04	

* See Table 4 for a description of these events.

** Because running total data were not available, the run totals were calculated from the average of the TPH data multiplied by the total run time.

Appendix A: Process Data

Test Run 2
Test Date: August 20, 1997 a.m.
Total Test Time: 4.3 hrs

Time	Event	Product Type	Fabric Filter			Fuel Use		Visible Emissions
			Inlet Temp. (oF)	Outlet Temp. (oF)	Pressure Drop (in. H2O)	Rate (GPM)	Total (gal)	
0822		RDS	230	185	2.1	5	324	none
0845		RDS	230	192	2.6	5	427	none
0900		RDS	230	190	2.8	5	512	none
0915		RDS	235	197	2.8	5	592	none
0930	*	RDS	195	200	2.1	3	704	none
0945	*	RDS	260	205	2.8	7	760	none
0100		RDS	270	215	3.2	7	869	none
1015		RDS	270	225	3.1	7	984	none
1030		RDS	270	230	3.8	7	1118	none
1045		RDS	271	228	3.6	7	1200	none
1100		RDS	269	225	3.5	7	1335	none
1115		RDS	262	220	3.8	7	1440	none
1130		RDS	270	225	4.0	7	1539	none
1145		RDS	270	225	3.8	8	1663	none
1200		RDS	270	230	3.5	7	1757	none
1215		RDS	265	225	3.9	7	1881	none
1230		RDS	268	220	3.8	7	1993	none
1240		RDS	260	220	3.8	6	2086	none
Total**							1,762	
Mean			255	214	3.3	6.3		
St. Dev			21	15	0.6	1.2		
Min			195	185	2.1	3.0		
Max			271	230	4.0	8.0		

* See Table 4 for a description of these events.

** Because running total data were not available, the run totals were calculated from the average of the TPH data multiplied by the total run time.

Appendix A: Process Data

Test Run 3
Test Date: August 20, 1997 p.m.
Total Test Time: 3.5 hrs

Time	Event	Product Type	Asphalt Concrete Production		Asphalt Temp. (oF)	Aggregate Use		RAP Use		Asphalt Cement Use		Calculated Conditioner Use	
			Rate (TPH)	Total (tons)		Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)
1405		RDS	250		309	214		25		12.6		0.03	
1415		RDS	251		303	211		27		13.0		0.03	
1430		RDS	251		312	212		27		13.0		0.03	
1445		RDS	252		311	212		26		13.0		0.03	
1500		RDS	245		305	212		25		12.8		0.03	
1515		RDS	245		320	212		22		12.5		0.03	
1530		RDS	254		310	215		26		12.8		0.03	
1545		RDS	250		307	213		25		12.9		0.03	
1600		RDS	249		307	211		24		13.0		0.03	
1615		RDS	247		322	215		23		12.7		0.03	
1630		RDS	252		312	214		25		12.6		0.03	
1645		RDS	250		316	213		24		12.8		0.03	
1700		RDS	249		315	213		25		12.8		0.03	
1715	*	RDS	205		307	172		24		10.5		0.03	
1735		RDS	152		299	138		17		7.8		0.02	
Total**				840			718		85		43		0.108
Mean			240		310	205		24		12.3		0.03	
St. Dev			26		6	21		2		1.3		0.003	
Min			152		299	138		17		7.8		0.02	
Max			254		322	215		27		13.0		0.03	

* See Table 4 for a description of these events.

** Because running total data were not available, the run totals were calculated from the average of the TPH data multiplied by the total run time.

Appendix A: Process Data

Test Run 3
Test Date: August 20, 1997 p.m.
Total Test Time: 3.5 hrs

			Fabric Filter			Fuel Use		
Time	Event	Product Type	Inlet Temp. (oF)	Outlet Temp. (oF)	Pressure Drop (in. H2O)	Rate (GPM)	Total (gal)	Visible Emissions
1405		RDS	240	200	2.8	6	2560	none
1415		RDS	238	200	2.9	5	2630	none
1430		RDS	232	200	2.5	5	2731	none
1445		RDS	235	195	2.5	5	2823	none
1500		RDS	230	195	2.5	5	2873	none
1515		RDS	240	195	2.8	6	2992	none
1530		RDS	235	195	2.5	6	3071	none
1545		RDS	240	195	2.5	5	3162	none
1600		RDS	245	200	2.5	6	3248	none
1615		RDS	235	200	2.5	5	3333	none
1630		RDS	240	200	2.5	6	3415	none
1645		RDS	240	200	2.5	6	3488	none
1700		RDS	240	200	2.5	6	3602	none
1715	*	RDS	210	190	2.0	5	3656	none
1735		RDS	180	165	1.8	3	3728	none
Total**							1,168	
Mean			232	195	2.5	5.3		
St. Dev			16	9	0.3	0.8		
Min			180	165	1.8	3.0		
Max			245	200	2.9	6.0		

* See Table 4 for a description of these events.

** Because running total data were not available, the run totals were calculated from the average of the TPH data multiplied by the total run time.

Appendix A: Process Data

Test Run 4
Test Date: August 21, 1997
Total Test Time: 4.2 hrs

Time	Event	Product Type	Asphalt Concrete Production		Asphalt Temp. (oF)	Aggregate Use		RAP Use		Asphalt Cement Use		Calculated Conditioner Use	
			Rate (TPH)	Total (tons)		Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)	Rate (TPH)	Total (tons)
0741		HDS	150		315	142		0		7.8		0.02	
0745		HDS	179		306	169		0		9.2		0.02	
0800		HDS	177		302	169		0		9.2		0.02	
0815		HDS	177		335	168		0		9.3		0.02	
0830		Binder	178		300	171		0		8.1		0.02	
0845		Binder	179		300	171		0		8.2		0.02	
0900		HDS	184		351	174		0		9.0		0.02	
0915		Binder	179		283	167		0		9.1		0.02	
0930		Binder	181		297	172		0		8.5		0.02	
0945		Binder	178		319	172		0		8.0		0.02	
1000		Binder	177		320	171		0		7.8		0.02	
1015		HDS	176		350	167		0		9.3		0.02	
1030	*	HDS	200		271	191		0		10.4		0.03	
1045		HDS	200		303	190		0		10.6		0.03	
1100		HDS	200		282	189		0		10.4		0.03	
1115		HDS	200		310	190		0		10.5		0.03	
1130		HDS	200		289	191		0		10.3		0.03	
1145		HDS	200		318	189		0		10.6		0.03	
1153		Binder/ HDS	204		297	194		0		8.9		0.02	
Total**				778			740		0		39		0.10
Mean			185		308	176		0		9.2		0.02	
St. Dev			13		21	13		0		1.0		0.00	
Min			150		271	142		0		7.8		0.02	
Max			204		351	194		0		10.6		0.03	

* See Table 4 for a description of these events.

** Because running total data were not available, the run totals were calculated from the average of the TPH data multiplied by the total run time.

Appendix A: Process Data

Test Run 4
Test Date: August 21, 1997
Total Test Time: 4.2 hrs

Time	Event	Product Type	Fabric Filter			Fuel Use		Visible Emissions
			Inlet Temp. (oF)	Outlet Temp. (oF)	Pressure Drop (in. H2O)	Rate (GPM)	Total (gal)	
0741		HDS	195	168	2.0	5	146	none
0745		HDS	203	178	2.0	4	216	none
0800		HDS	203	177	2.0	4	288	none
0815		HDS	205	178	2.0	4	363	none
0830		Binder	195	170	2.0	4	440	none
0845		Binder	200	170	2.0	3	474	none
0900		HDS	210	180	2.0	4	560	none
0915		Binder	200	180	1.8	3	626	none
0930		Binder	195	170	2.0	4	669	none
0945		Binder	195	175	1.9	4	743	none
1000		Binder	190	168	1.9	4	812	none
1015		HDS	192	170	1.8	4	871	none
1030		HDS	205	170	1.9	5	932	none
1045	*	HDS	210	180	2.0	5	1004	none
1100		HDS	205	175	1.9	5	1063	none
1115		HDS	200	180	1.8	4	1133	none
1130		HDS	205	175	1.9	4	1208	none
1145		HDS	210	180	2.0	5	1285	none
1153		Binder/ HDS	210	180	1.9	4	1323	none
Total**							1,177	
Mean			201	175	1.9	4.2		
St. Dev			6	5	0.1	0.6		
Min			190	168	1.8	3.0		
Max			210	180	2.0	5.0		

* See Table 4 for a description of these events.

** Because running total data were not available, the run totals were calculated from the average of the TPH data multiplied by the total run time.

SPECIALIZED ASSAYS ENVIRONMENTAL
2960 Foster Creighton Drive
Nashville, Tennessee 37204

ANALYTICAL REPORT

** Original report and a copy of the chain of custody will follow by mail.

NOBLE OIL CO. 7680
ATTN: LARRY PRICE
5617 CLYDE RHYNE DRIVE
SANFORD, NC 27330

Lab Number: 97-A065425

Sample ID: 861-625 OIL

Project:

Project Name:

Sampler:

State Certification: 387

Date Collected: 7/25/97

Time Collected:

Date Received: 8/ 7/97

Time Received: 9:00

Sample Type: Oil

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
METALS										
Arsenic	ND	mg/kg	1.0	1.0	1	8/11/97	14:29	R.Street	6010A	2146
Cadmium	ND	mg/kg	1.0	1.0	1	8/11/97	14:29	R.Street	6010A	2146
Chromium	ND	mg/kg	1.0	1.0	1	8/11/97	14:29	R.Street	6010A	2146
Lead	28.0	mg/kg	1.0	1.0	1	8/11/97	14:29	R.Street	6010A	2146
Nickel	ND	mg/kg	1.0	1.0	1	8/11/97	14:29	R.Street	6010A	2146
GENERAL CHEMISTRY PARAMETERS										
Chlorine in Oil	464.	mg/kg	10.0	10.0	1	8/12/97	15:50	K.Witte	9076	2568
Ash	0.57	%		0.01	1	8/9/97	14:17	A Hardison	D482	2433
Flash Point, Closed Cup	FLASHED AT 150F					8/14/97	9:22	D. Hoover	1010	3465
Sulfur	3590	mg/kg	100.	5.00	20	8/14/97	12:37	G. Baun	ASTMD808	6920

ND = Not detected at the report limit.

Flash point/Ignitability reported to the nearest 10 deg F.

Report Approved By: ____________________ Report Date: 8/14/97

Theodore J. Duello, Ph.D., Q.A. Officer
Michael H. Dunn, M.S., Technical Director
Danny B. Hale, M.S., Laboratory Director

MATERIAL SAFETY DATA SHEET

Manufacturer
ARR-MAZ PRODUCTS, L.P.
621 Snively Avenue
Winter Haven, Fl 33880
Emergency Phone Number
941-293-7884

PRODUCT INFORMATION

Trade Name:	AD-here LOF 65-00	
Chemical Family:	Amines	
Composition:	Modified Fatty Amidoamine	
HMIS RATING:	Health Hazard	2 Moderate
	Flammability Hazard	1 Slight
	Reactivity Hazard	0 Minimal
D.O.T. Shipping Classification:	Not regulated	

PHYSICAL DATA

Boiling Point (°F):	> 500°F
Solubility in Water:	Slight
Vapor Pressure (mmHg at 25°C):	< 1
Vapor Density (Air = 1):	> 1
Appearance:	Dark brown liquid
Odor:	Mild
Specific Gravity (at 77°F):	0.96 - 0.98

FIRE EXPLOSION

Flash Point PM Closed Cup °F:	>300 °F
Extinguishing Media:	CO2, foam, or dry chemical
Special Fire Fighting Procedures:	Wear NIOSH/MSHA approved self-contained breathing equipment and protective clothing.

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